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Michel Köhler

The Sustainable Infrastructure Pension

Exploring the potential of pension systems to finance sustainable energy development

EUROPA-UNIVERSITÄT FLENSBURG

DOCTORAL THESIS

The Sustainable Infrastructure Pension
-
Exploring the potential of pension systems to finance sustainable energy development

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Dedicated to the next generation, for Liz and Piet!

Executive Summary

Limiting global warming to well below 2°C, as the international community committed itself to in the context of the Paris Agreement, requires massive reductions of anthropogenic greenhouse gas (GHG) emissions. In this context, the energy sector represents a major source of GHG emissions. Without its transition and decarbonization the climate targets will fail. Additionally, about 1 billion people still lack electricity access to date. In the context of the United Nations Sustainable Development Goals (SDGs), countries adopted the goal to achieve "affordable and clean energy for all" by 2030. Both objectives require substantial investments into sustainable energy that comprise of e.g. renewable power capacity, storage and transmission systems, energy efficiency measures or electric mobility for which massive private finance flows are indispensable.

At the same time, pension schemes are under reform pressure due to demographic changes and fiscal impacts. Privately managed, asset-backed retirement schemes have been increasingly implemented as envisaged solution worldwide during the last decades. However, these schemes struggle to provide intended results such as generating sufficient pension income levels while relieving state budgets and younger generations. Due to macroeconomic impacts resulting from the 2008 global financial crisis, returns from traditional capital market products have decreased significantly. Thus, pension managers seek for innovative investment opportunities providing higher returns.

This thesis explores whether and how the capital requirements for energy transitions and the financial volumes stemming from asset-backed pension systems can be matched in a Sustainable Infrastructure Pension (SIP) concept for sustainable energy financing. To assess design elements, applicability, impact and capital mobilization potential of the SIP, the thesis formulates four research hypotheses:

(1) *Sustainable energy development faces funding challenges.*

(2) *Pension systems do not considerably invest in sustainable energy elements.*

(3) *Under appropriate conditions, capital-based pension systems can cover the investment needs of sustainable energy infrastructure in developed and developing countries.*

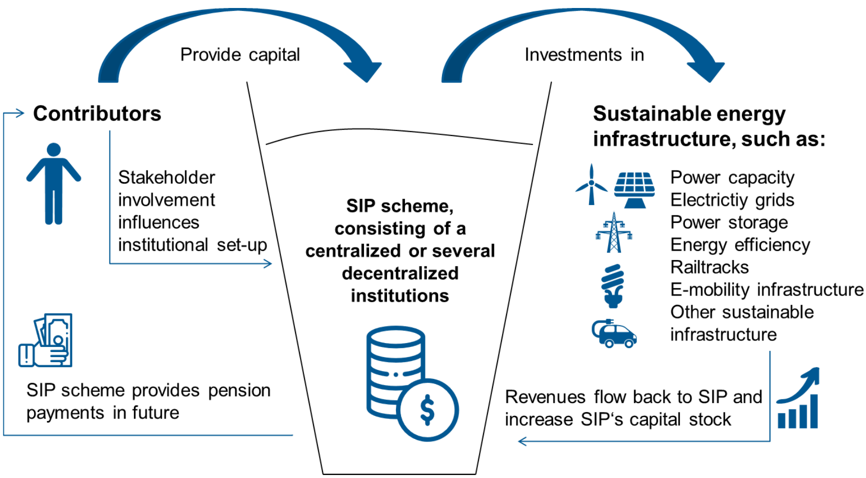
(4) *Large-scale pension investments for transformative infrastructure benefit both the sustainability of pension systems as well as the transition of the energy sector.*

There are various studies assessing the investment needs for the implementation of sustainable energy supply systems that are consistent with the Paris Agreement and SDG goals. Global estimates range from USD 2.8 to 4.4 trillion annually until 2050. Compared to the current annual energy supply system investments of about USD 1.8 billion, this represents a significant increase of required energy infrastructure funding. As some countries likely mobilize sufficient investment capital and others fail to do so, the thesis' findings do not support a generalization of the *first hypothesis* on a global level to date. While the precise future financing gap is not transparently quantified by literature, studies recurrently emphasize the need to mobilize private capital at large scale in order to address upcoming investments. In this context, literature cites Sovereign Wealth Funds (SWFs), insurers or pension funds recurrently as required solution for financing future energy investments. With different risk-revenue expectations than traditional energy investors, they could play an important role for reducing capital costs in developed countries as well as addressing the shortage of financial resources in developing countries. Although, the main share of capital expenditure for energy infrastructure is sourced by banks and channelled via loans or bonds to balance sheets of project developers, utilities, specialized companies or households that finally invest in energy transformation equipment so far. Institutional investors including pension funds do hardly play any role, representing approximately 0.5% to 1% of the total investment as political, regulatory and internal capacity constraints hinder them to engage in energy transformation investments. At the same time, they remain unaffected by constraints other investors have, such as short-term liquidity requirements or limitations for direct, long-term project finance. This advantageous position for certain investments allows institutional investors to generate premiums for e.g. long-term horizons, illiquidity or higher transaction costs that are typical for many energy infrastructure investments. Slightly growing energy infrastructure engagement from pension funds and insurances can be observed in markets with rather mature legal and regulatory frameworks as a response to the low-interest rate environment in which they currently operate. Summing up, institutional investors are in a pivotal position for financing energy transition infrastructure and their current activities indicate that pension capital will increasingly flow into energy transition assets in the future, partly disproving the *second hypothesis* for the moment.

By today, specialized SIP institutions do not exist, neither does theoretical research on SIP approaches. While a variety of literature discusses institutional or SWF investments in sustainable energy assets, scientific literature about intended combinations of pension schemes and sustainable energy investments is almost unavailable to date. An assessment of existing SWFs as well as public or private pension funds in the context of this thesis provides helpful experiences about objectives, institutional set-up and internal procedures that enable energy infrastructure investments.

Although the findings suggest that a standardized SIP design for various country contexts does not exist, there are several core elements shared by all potential SIP approaches. Figure 1 illustrates schematically the basic operation of the SIP scheme.

Figure 1: Schematic illustration of the SIP scheme



Source: Own illustration

Inflowing pension contributions are provided by active labour force members, the SIP institutions identify, assess and prioritize suitable investments. The SIP infrastructure assets sell generated goods and services such as electricity or generate usage fees from e.g. power transmission. Revenues from operation and relieved capital from past investments flow back to the fund and enable further investments. Thus, the SIP scheme aggregates an asset portfolio over time. As soon as the first contributors retire, the fund provides parts of its resources to these members as pension benefit payments. An assessment of the key elements required for the successful operation of a SIP scheme suggests direct project finance debt as most suitable financing instrument for SIP investments from a risk-revenue perspective. An independent, sovereign institutional set-up with a transparent disclosure and investment policy including appropriate investment criteria and stakeholder involvement is required for creating sufficient public legitimacy for SIP reforms. Further SIP design elements require the choice between different options that reflect the respective country context. The thesis' findings indicate that a preferable SIP system is based on public, centralized institutions with strong internal capacities and mandatory coverage of large parts of the work force that provides defined benefits.

Finally, without appropriate framework conditions in the pension and energy supply sector, a SIP scheme will not be able to successfully operate. Particularly stable, transparent and predictable market conditions based on appropriate regulation and economic incentive mechanisms reflecting the countries energy strategy and targets are important. Also, a pipeline consisting of mature, bankable sustainable energy asstes represents a prerequisite for identifying sufficient SIP investment opportunities.

Since energy transitions and pension system designs are highly context and country specific, the discussed SIP concepts are explored in case studies of two countries with diverse characteristics. While Germany is a highly industrialized country with several mature pension scheme pillars and an ongoing energy transition, the Seychelles represent a Small Island Developing State with one centralized pension fund but incomplete pension coverage and a predominantly fossil fuel-based energy supply system.

Guided by the four hypotheses, the thesis aims to assess whether a SIP system can mobilize capital for sustainable energy investments at large-scale and how it affects retirement schemes and energy transitions. Hereby, the applied methodology comprises of an assessment of the existing pension systems' suitability to allocate resources towards sustainable energy assets, a quantitative evaluation of the capital mobilization potential, a qualitative analysis of positive and negative implications of a SIP engagement and a discussion of a concrete set of policy adjustments required for establishing an appropriate SIP option for the specific country-context.

For the German case, four scenarios with increasing ambition are simulated by a quantitative cash-flow model. While the Business as Usual (BAU) scenario and a scenario assuming additional regulation of the existing pension schemes can cover 6% to 31% of the total energy transition investment needs of about EUR 1,150 billion by the target year 2050, the two simulated specific SIP institutions can provide more capital than required.

For the Seychelles, the findings show insolvency of the pension scheme in the long-run, regardless of energy infrastructure investments. A stabilized system assuming an increase of the contribution rate by 20% can theoretically cover 30% of the cumulated energy transition investment needs of about USD 580 million until the target year with 100% renewable energy supply by 2035 (see results in Table 1). In case the SIP scheme focuses on direct equity investments, additional co-finance debt could be mobilized to cover larger shares of the energy transition investment needs. Thus, the case study results confirm the general validity of the *third hypothesis* but also emphasize country-specificity and the role of policy interventions to achieve full coverage of investment needs.

Table 1: Comparison of case studies scenario results, all in billion USD2018

	Germany				Seychelles	
	BAU scenario	Regulatory scenario	Voluntary SIP-Fund	Mandatory SIP-Fund	SeyRES 100 scenario (unadjusted)	SeyRES 100 scenario (adjusted*)
Target year	2050				2035	
Cumulated energy trans. investment needs until target year	1,360[1]				0.58	
Total pension scheme asset volume in target year	1,650	1,800	2,700	2,125	0.16	0.4
Total pension scheme energy asset volume in target year	80	425	2,700	2,125	0.06	0.17
Coverage of energy transition investment needs in target year	6%	31%	200%	156%	0%	30%

Source: Rounded results of models "SIP simulation_Germany" and "SIP simulation_Seychelles"; *contribution rate adjusted by +20%

[1] All EUR values are translated to USD based on the average 2018 currency exchange rate by OECD (2019)

The qualitative exploration of SIP scheme impacts finds significant positive implications. With regards to distributional effects, SIP schemes can increase the profitability, stability and sustainability of the pension system or reduce energy costs as benefits can be shared between the pension system shareholders, it's members and the users of the energy infrastructure outputs. Furthermore, the SIP can increase energy security, reduce resistance against energy infrastructure implementation, democratize the asset ownership structure, enhance environmental benefits and lead to inter- and intra-generational energy justice. Since literally the majority of the population would own their energy infrastructure under an encompassing SIP scheme, long-term identification with the energy transition could be achieved, and associated short-term burdens would rather become acceptable.

However, the analysis also reveals potential negative implications of a SIP scheme. Among these are distributional conflicts between reduced energy costs and pension payments or energy market dominance due to the potential size and influence of centralized SIP institutions. Crowding out of finance in other important sectors is a sensitive issue as it can lead to higher costs of corporate or state financing and potentially interfere with competing development objectives, as identified for real estate development in the Seychelles case. A broad coverage of workforce and future pensioners is the key element to maximize distributional, acceptance, democratization and energy justice benefits while minimizing risks. Though, large SIP schemes with broad coverage likely also experience reduced political feasibility. Resistance against SIP reforms can be particularly expected in countries with several existing pension providers operating in multi-pillar pension schemes that would face market share losses. With regards to institutional capability, most existing institutions are not ready for large-scale SIP engagement as they lack experience, knowledge and internal capacity.

Summing up, the thesis' results cannot entirely confirm the *fourth hypothesis*. It finds significant positive implications generated by SIP schemes but also identifies negative impacts that can be partly addressed by consideration of an appropriate country- and context-specific SIP design.

With the scientific exploration of the SIP approach, this thesis formulates an innovative and alternative option for addressing the increasing energy transition investment needs while sustaining capital-based pension schemes. The analyses of the hypotheses demonstrates that retirement schemes barely participate in sustainable infrastructure financing, despite a favourable match of investment characteristics. According to the ambitious case study scenario results, the SIP capital mobilization potential can cover the most or full energy transition investment needs, subject to appropriate regulatory and economic frameworks. Qualitatively, this thesis analysis SIP impacts on economic, distributional and environmental objectives as well as the institutional and political feasibility and identifies predominantly positive effects.

With these findings, the thesis expands literature on the interrelations and beneficial correlation of capital-based pension schemes and energy transition investments. It assesses the four hypotheses qualitatively and quantitatively by means of different research methods, including literature reviews and cash-flow simulations in the context of a background assessment and two case studies. However, the methodology also shows some limitations with regards to the scope of the spreadsheet model, pension capital data availability and the generalization of mobilization potential and SIP implications beyond the case study countries. Future work should therefore extend the scope of assessed and evaluated details to increase the scientific understanding of the approach, its practical likelihood of application and maximization of its positive results. An in-depth assessment of operational, legal and regulatory SIP design features with their high dependency on country specific laws and legal frameworks would further enhance the understanding of a precise SIP set-up. Research on the development of SIP-appropriate investment pipelines could facilitate the operation of potential SIP schemes. An application in other country contexts with deviating characteristics such as Least Developed Countries (LDCs) or emerging economies could explore an additional scope for applicability. Finally, further research on the impacts of a changing institutional investment environment due to the COVID-19 pandemic and the energy market distortions in the year 2022 is recommended.

Concluding, the thesis' findings suggest the SIP approach as a promising solution to finance energy transitions, stabilize retirement schemes and support the achievement of the climate goals and SDGs, subject to appropriate design features and reflection of the local context. Policy-makers from industrialized and developing states are encouraged to apply the thesis' methodology to evaluate whether and how a SIP scheme could be realized in a way that maximizes benefits in their respective countries.

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Abbreviations

AnlV	Anlageverordnung
Basel	Basel Committee on Banking Supervision
BAU	Business as Usual
CEO	Chief Executive Officer
CO_2	Carbon Dioxide
CPI	Climate Policy Initiative
CSES	Centre for Sustainable Energy Systems Flensburg
DB	Defined Benefit
DC	Defined Contribution
ESG	Environmental, Social and Governance
ESMAP	Energy Sector Management Program
ET	Energy Transition
EU	European Union
EUR	Euro
GBP	Great British Pound
GCF	Green Climate Fund
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIB	Green Investment Bank
GPFG	Government Pension Fund Global
GPFN	Government Pension Fund Norway
GWh	Gigawatt hour
IEA	International Energy Agency
ILO	International Labour Organization
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
KfW	Kreditanstalt für Wideraufbau
LDC	Least Developed Country
LGD	Loss Given Default
MEECC	Seychelles Ministry of Environment, Energy and Climate Change

MRV	Monitoring, Reporting and Verification
MW	Megawatt
NGO	Non-Governmental Organisation
O&M	Operation and Maintenance
OECD	Organisation for Economic Development
PAYG	Pay-As-You-Go
PFAV	Pensionsfonds-Aufsichtsverordnung
PF	Direct Project Finance
PPA	Power Purchase Agreement
PUC	Seychelles Public Utilities Corporation
PV	Photovoltaic
SCR	Seychelles Rupee
SDG	United Nations Sustainable Development Goal
SeyRES 100	Seychelles 100% Renewable Energies Strategy
SIDS	Small Island Developing State
SIP	Sustainable Infrastructure Pension
SME	Small- and Medium Enterprise
SPF	Seychelles Pension Fund
SPV	Special-Purpose Vehicle
SWF	sovereign wealth funds
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
VAG	Versicherungsaufsichtsgesetz
WBGU	German Advisory Board on Global Change

1. Problem Statement

Since the signature of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, it is internationally acknowledged that significant mitigation of Greenhouse Gas (GHG) emissions will be required to avoid massive economic and human loss due to climate change impacts in future (compare UN, 1992). By the end of 2015, the international community has adopted the Paris Agreement to "limit global warming to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (UN, 2015, Article 2). In this context, large-scale deployment of technical GHG mitigation measures will be required to achieve the agreed targets. Hereby particularly the energy sector with its subsectors electricity and heat production plays a crucial role, being responsible for more than a third of anthropogenic GHG emissions globally (compare IPCC, 2014, p. 9). Projections of the Intergovernmental Panel on Climate Change (IPCC) indicate a doubling to tripling of GHG emissions until 2050. Thus, it recommends decarbonizing particularly electricity generation as cost-effective mitigation strategy in achieving low-stabilization levels (IPCC, 2014, p. 554ff and 564).

Apart from the need to transform existing energy supply systems, many people still lack adequate access to energy, particularly electricity. Energy access is characterized as "golden thread" by the International Energy Agency (IEA, 2017a, p. 3), connecting economic growth, human development and environmental sustainability. To achieve universal access to affordable, reliable and modern energy services until 2030, the international community has adopted the Sustainable Development Goal (SDG) 7. It specifies targets and indicators for energy access and particularly emphasizes that renewable energies shall contribute a significant share (compare UN, 2018, p. 22ff). Despite a successful decrease of the number of people without electricity access from 1.7 billion in the year 2000 to 1.1 billion in 2016, the IEA expects still about 675 million people lacking access by 2030 (IEA, 2017a, p. 3). Furthermore, the share of renewable energies in final energy consumption only increased modestly to 17.5% in 2015. Thus, the UN criticises international progress and pace as insufficient to meet the SDG energy targets for 2030 (compare UN, 2018, p. 22). The reason for slow progress is that many developing but also industrialized countries struggle with the implementation of sustainable energy infrastructure. Significant barriers are institutional and human capacity constraints, an unequal distribution of energy supply assets and costs among different economic and population groups, the resilience of the implemented systems, a lack of communication and acceptance among impacted stakeholders and in many cases the sourcing of appropriate funding (compare IPCC, 2014, pp. 552–553).

Various studies quantify energy related mitigation investment needs for achieving a 2°C compatible pathway. For instance, the IPCC (2014, p. 552), IRENA (2018, p. 41f) or the IEA (2012, p. 1) assume additional investments in the range of USD 600 billion to USD 1.1 trillion per year until 2050 (compare also chapter 3.1 for a detailed analysis). To achieve universal access to electricity by 2030, the IEA estimates additional investment needs of USD 52 billion per year (see IEA, 2017a, p. 5). One major concern in the political and scientific debate on energy transitions are the funding sources to address these identified additional investment needs. Many experts argue that private capital has to cover the main share of the overall volume. In its report to the UN General Secretary, the High-level Advisory Group for Climate Finance emphasizes that "international private investment flows are essential for the transition to a low-carbon and climate-resilient future" (UN, 2010, p. 6). Buchner et al. (2017, p. 6f) reveal that private finance provides already today the lion's share of mitigation related finance, particularly in the energy sector.

Considering the additional investment needs for sustainable energy transitions and access in the upcoming decades, it is required to mobilize significantly higher volumes of private finance. REN 21 emphasizes "now that renewables are becoming economically competitive and investors are increasingly recognizing their value, key to further development will be the design of effective financing tools to overcome initial investment costs" (REN21 2014, p.103). As a potential solution for overcoming the funding gap with private capital, institutional investors are well placed. According to IRENA (2018, p. 67), REN 21 (REN21, 2014, p. 103) or Ernst and Young (2014, p. 3ff), they could benefit from the characteristics of energy supply funding as it matches their investment objectives. However, less than 1% of their resources are invested directly in long-term infrastructure projects to date (compare Buchner et al., 2017, p. 7; Corfee-Morlot and Kennedy, 2012, p. 52).

Implementing social protection systems for all, including elderly people, is one particular SDG target (SDG target 1.3). The International Labour Organization (ILO, 2017, p. 75ff) finds that despite pension systems are the most widespread form of social protection globally, only about 68% of the world's population is covered by retirement schemes in

2016. The authors highlight that particularly low-income countries lack pension schemes for the majority of their population. For instance, only about 23% of the Sub-Saharan African or 24% of the South-Asian people receive pension benefits. It is likely that many developing countries expand the coverage of pension schemes during the upcoming decades.

By today, the majority of countries relies on contribution schemes or a mix of contributory and non-contributory approaches. About 35% of the global labour force contributes capital to a pension insurance scheme that is either directly redistributed or invested as pension savings. However, recent demographic and fiscal consolidation trends reduced the adequacy of pension levels in many high and middle-income countries (compare chapter 3.4 for detailed analysis). Due to changing socio-economic and health patterns such as declining fertility rates, improved medical systems and wealth levels and therefore increasing average live ages, these societies face a growing proportion of retired people compared to the actively working population. This poses pressure on traditional direct benefit pension systems that are often financed through pay-as-you-go schemes based on the redistribution of employees' income (compare Pallares-Miralles et al., 2012, pp. 12–14). As response, increasingly fully-funded, direct contribution pension saving schemes have been introduced since the 1990s to relieve fiscal pressure from tax-financed systems or reduce costs of labour to increase international competitiveness (ILO, 2017, p. 94). Despite state subsidies that support these usually privately managed schemes, it is contentious whether these systems provide sufficient security and return for future pensioners to guarantee adequate pension levels among the retired population. In particular the risks of asset value and return fluctuations at capital-markets, such as observed during the recent financial crisis at the end of the 2000s highlight the need to scientifically discuss options for improving such capital-based systems in a sustainable manner.

To address the outlined challenges of pension schemes and achieve an accelerated decarbonization of energy supply simultaneously, this thesis explores chances and barriers of introducing Sustainable Infrastructure Pension (SIP) systems. It analyses whether and how such systems can cover required sustainable energy infrastructure investments in both developed and developing country contexts. Moreover, it assesses the impact on both the performance and stability of pension schemes as well as the implementation characteristics of sustainable energy developments.

While various literature on infrastructure investments by institutional investors exist, only a few authors discuss centralized state funds explicitly targeting climate mitigation finance including transformative energy infrastructure. An intentionally planned combination of capital-based pension schemes and large-scale sustainable energy development has been rarely discussed in literature and not been assessed scientifically yet (also compare the literature reviews in chapter 3.2.4 and chapter 4.1).

In order to scientifically evaluate the design elements, applicability, impact and potential of the SIP concept for sustainable energy financing, the thesis formulates the following four research hypotheses:

- *Sustainable energy development faces funding challenges.*
- *Pension systems do not considerably invest in sustainable energy elements.*
- *Under appropriate conditions, capital-based pension systems can cover the investment needs of sustainable energy infrastructure in developed and developing countries.*
- *Large-scale pension investments for transformative infrastructure benefit both the sustainability of pension systems as well as the transition of the energy sector.*

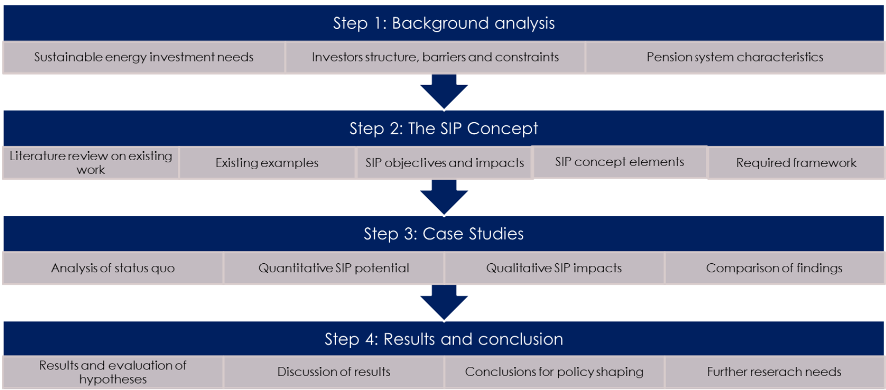
Due to the long review process, this thesis reflects the situation of early 2020 and does therefore not consider impacts resulting from:

- the Covid 19 pandemic and its influence on global fiscal and economic developments (see for instance IMF, 2022, chapter 2; World Bank, 2022, chapter 1 and 2);
- the energy crisis and natural gas shortage as a result of the sanctions against Russia (compare IEA, 2022, chapter 2.2);
- the inflation as a result of the energy crisis (see World Bank, 2022, chapter 1).

2. Methodology

This thesis applies a methodology consisting of four interlinked steps that analyse the four hypotheses qualitatively based on literature reviews and quantitatively based on publicly available data. It covers the theoretical background and outlines common characteristics, key elements and optional choices for potential SIP systems (see Figure 2). Since energy transitions and pension system designs are highly context and country specific (compare for instance IRENA, 2018, p. 28ff; Pallares-Miralles et al., 2012, p. 55ff), an assessment of these hypotheses on a theoretical basis only would lead to scientifically insufficient results. Thus, the thesis explores the applicability of the discussed SIP concepts in case studies of two countries with diverse characteristics. This allows to explore a linkage of pension systems and sustainable energy developments both theoretically and practically.

Figure 2: Illustration of the methodological steps for the dissertation



Source: Own illustration

The applied approach reflects the hypotheses from different perspectives and describes key outcomes qualitatively and quantitatively, leading to a solid result to verify or discard the hypotheses, derive generalized findings and conclusions for shaping policies as well as identify further research needs.

The chapters of this thesis address the four methodological steps in the following way:

Chapter 3 represents a background analysis based on literature reviews. On the one hand, global energy transition investment needs are evaluated and the provided capital to address these needs is summarized. A detailed assessment of different investor characteristics is conducted, and the individual investor type's share of the total investments is derived. On the other hand, the status quo, structure and challenges of pension systems worldwide are summarized. General approaches and barriers for pension systems' infrastructure investments, particularly into energy transition elements, are described. Based on this assessment, the thesis evaluates the investment gap that can be filled with SIP systems. A literature review explores existing scientific work on sustainable infrastructure financing by pension systems and assesses the operation of existing pension funds that include features and characteristics applicable for the SIP concept.

Chapter 4 explores existing literature and institutions that reflect an intended combination of pension schemes and energy infrastructure investments. A qualitative discussion analyses positive and negative impacts of SIP schemes on sustainable energy development as well as on pension systems and their members. The chapter further describes common elements and optional design parameters of potential SIP concepts. Required framework conditions for implementation are summarized.

Chapter 5 and 6 simulate the application of the SIP concept in two country case studies with diverse characteristics. The thesis attempts to provide a quantitative simulation that reveals the potential of SIP concepts in the specific country context as well as highlights the constraints and barriers that might hinder an application of pension capital for energy transition investments. A detailed overview of the sub-methodology for the case study assessments is given in chapter 2.1 below. Chapter 7 compares the results of the two case studies and the literature review findings to reveal generalities and deviations.

Chapter 8 synthesizes the results from the background analysis and practical assessments. It summarizes whether the hypotheses have been supported or falsified and interprets the outcomes. Finally, a conclusion in chapter 0 sums up the key results of the thesis, discusses the applicability and limitations of the methodology, identifies further research needs for future work and derives recommendations for shaping policies.

2.1. Case study methodology

As the case studies represent a prominent and complex step of the overarching methodology to evaluate the practical relevance and country-specificity of the SIP concept, this section defines additional sub-methodological steps how to derive the required qualitative and quantitative information. Hereby the main objectives are to assess (compare also Seychelles Case Study in Annex I by Köhler, 2020a, p. 2):

- *whether the existing institutions managing pension capital are already investing in sustainable energy assets and whether they are eligible and suitable for such investments,*
- *what reforms, alternative options or innovative institutions could unlock additional volumes for sustainable energy investments,*
- *what volume of sustainable energy investment needs could be matched by pension capital resources over the energy transition implementation period, and*
- *what benefits and drawbacks can be expected by increased investments of private pension capital in sustainable energy assets.*

General approach

For achieving the defined objectives, the following four step methodology as illustrated in Figure 3 is applied:

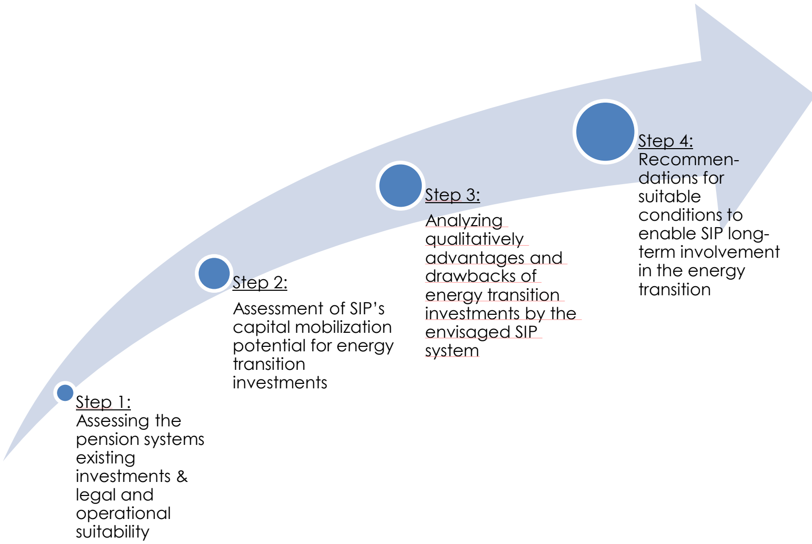
First, the current investment portfolio of the existing capital-based pension systems is analysed to identify potential energy transition investments. Further, the general suitability and eligibility of investments according to the existing legal and institutional structure, including the consideration of regulated investment guidelines, are analysed. "Gaps and limitations are highlighted and solutions to address those are derived.

Second, a spread-sheet model simulates quantitatively the long-term potential for energy transition engagement" (Köhler, 2020, p. 2). So far it is unclear what SIP capital volumes can be leveraged for investments in the energy transformation until 2050. Since typically policy makers, governments or steering committees manage and streamline transformational processes, it is of key importance that these institutions are provided with sufficient information of available domestic funding sources.

Third, advantages and disadvantages of a SIP engagement in financing the energy transition are discussed qualitatively. This assessment builds on the theoretical discussion in chapter 4.3 and reflects country-specific characteristics.

Finally, recommendations are given how suitable conditions for a SIP engagement can be realized, what limitations are given and what actions are required from involved actors such as the pension system operator, pension insurers or the Government.

Figure 3: Illustration of the methodological steps for the SIP case studies



Source: Own illustration

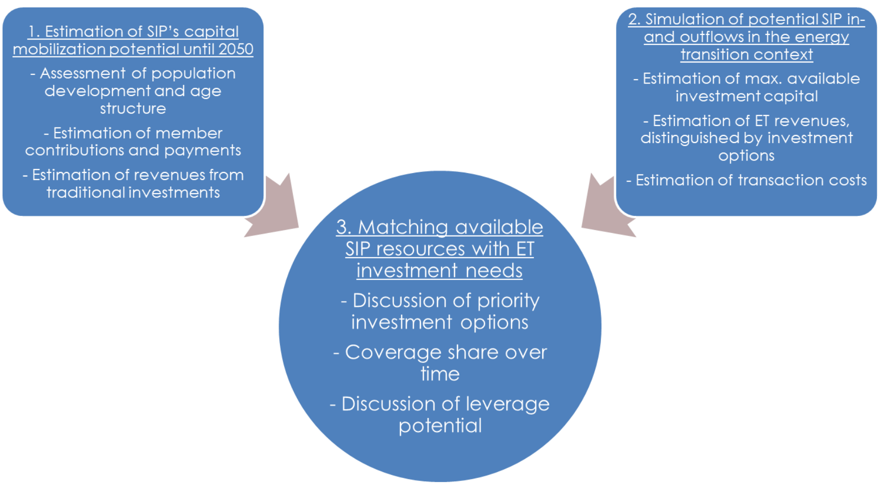
Approach for quantifying the SIP potential

Cichon and Latulippe (1998, p. 7ff) describe objectives and basic approaches for quantitative modelling of pension systems in the context of a OECD publication. They highlight that "major financial redistribution systems which are designed to have a profound impact on the income and hence on the wellbeing of individuals and households require financial analyses both under the status quo and in a context of reforms. Models – limited as they are – are the main quantitative planning tool available to social protection planners, governors, managers and administrators" (Cichon and Latulippe, 1998, p. 20). In the authors' context, such models shall be particularly applied to assess the financial viability of pension schemes in the long-term. Furthermore, they should be used to examine the financial impact of alternative options in order to assist policy makers in reforms. A highly important element is the equilibrium describing how the different values of lifetime benefits provided by the scheme and the value of contributions and other inflows have to be balanced. To guarantee long-term operation of a scheme, adjustments of e.g. contribution rates or benefit levels might be necessary. This can be simulated by a sensitivity analysis.

For operationalizing such models, the authors define demographic and macroeconomic assumptions with long time perspectives as key inputs for pension models. Hereby they specify information on covered population, salary development, existing scheme assets, annual cash flows of investment income and related interest rates as required information. The pension projections shall be performed on an annual cohort methodology that differentiates the population according to age cohorts that are gradually replaced with succeeding cohorts over time. Following this argumentation, a suitable methodology for the quantitative assessment of SIP's long-term potential in energy transition investments mainly relies on demographic parameters and financial in- and outflows. Such an approach has also been applied by the European Union to project the performance of the German pension systems until 2060 (EC, 2009, pp. 46–54).

As described in the case study methodology in Annex I, "for assessing financial in- and outflows of the assessed pension schemes in the context of this thesis, a combined approach of the above-mentioned elements and cash-flow analysis stemming from financial statements is interpreted as suitable, particularly due to its focus on viability and liquidity" (Köhler, 2020, p. 2). According to Brycz and Pauka (2012, p. 5), "the cash-flow statement provides information about the cash efficiency of operating, investing and financing activities as well as liquidity and solvency of the institution itself" (Köhler, 2020, p. 2). It reports all transactions that have an impact on the cash account, including cash inflows from operating activities, investments or financing activities as well as cash outflows for operating activities, investments or financing activities. Ueli (2004, pp. 2–3) describes cash flow projections for defined benefit pension funds, i.e. pension insurances with predefined levels of pension payments. He also highlights the need of reassembling results from population modelling, salary modelling and adds the requirement of a savings model that describes the accumulation process of contributions and interest proceeds. "From the perspective of energy transition investments, the application of non-levelized cash-flows for any given point of time in the future is also deemed appropriate by several long-term energy scenario developers (compare e.g. IEA/IRENA, 2017, p. 62; Singer et al., 2011, p. 193f)" (Köhler, 2020, p. 2). They stress that for assessing the profitability of investments, a levelized cost approach considering future present values of capital would be more feasible but for the macro-economic view of energy scenario developments over time, the cash-flow approach is suitable. "Taking these findings into account, the quantification model applied in the context of this thesis builds on the demographic, macroeconomic and cash-flow specific elements described above" (Köhler, 2020, p. 2). It combines them in a way that allows to address the research question of how the volume of energy transition investment needs could be matched by pension capital resources over the energy transition implementation period. The detailed methodological steps and considered inflow and outflow elements are summarized in Figure 4 and Figure 5.

Figure 4: Methodological steps to assess maximum SIP investment potential of energy transition (ET) elements



Source: Own illustration

First, a profound analysis of the SIP system's investment possibilities depends on the ability to mobilize capital over the next decades. This is subject to several parameters around population growth and demographic structure. The number of newborn, immigrants as well as emigrants and mortality rates lay ground for an assessment of the age structure including estimation of adolescences, workforce and retirees per year until 2050. Also, existing investment revenues determine the maximum potential for mobilizing energy transition funds. A combination of these elements allows to simulate a SIP cash-flow forecast over the next decades.

Second, the model estimates the SIP system's potential investment capital for the energy transition including future revenues and reflows that can be reinvested. Such revenues are distinguished by pre-defined investment options, also related transaction costs are taken into account. A comprehensive quantitative simulation presents the span of theoretically available annual capital until 2050, a complementary sensitivity analysis highlights the crucial parameters that might impact the accuracy of the long-term forecast.

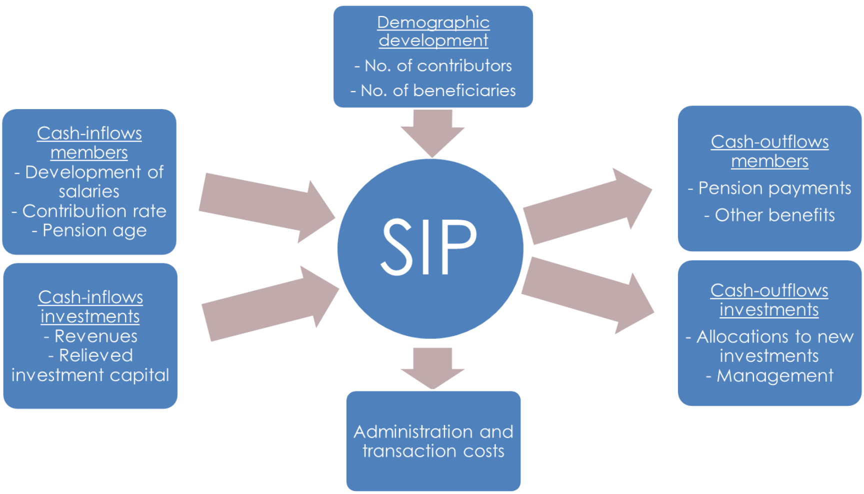
Based on the results of the first and second sub-step, a matching with the long-term energy transition investment needs is conducted. The results are demonstrated over the energy transition implementation period until 2050. The matching considers suitable investment opportunities such as renewable energy capacity, transmission and distribution grids, power storage facilities, e-mobility infrastructure and energy efficiency measures foreseen to be implemented within the timeframe. As key investment characteristics such as project lifetime, amortization periods, revenues, default risks or investment volume can be very different for the potential investment opportunities it will be important to have a distinguished overview. Hereby the comparison of these investment characteristics with existing investment policies or regulations as well as the discussed investment criteria discussed in chapter 4.5.2 allows prioritization of potential investment opportunities.

Furthermore, the third step includes a discussion of additional leverage potential if particularly equity investments are undertaken by the SIP system. A range of additionally mobilized co-financing due to SIP activities demonstrates the potential for energy transition financing beyond SIP's own resources.

The quantitative estimation of the SIP's potential for mobilizing private capital from its members requires a suitable approach for determining the systems capability. As discussed, the cash-flow analysis is appropriate to determine the sustainability of an economic institution. Hereby the internal profit of the institution and individual tax considerations are not considered as purely the liquidity of in- vs outflows are simulated. This however is interpreted as an appropriate approach for the case study assessments as the objective is to derive the mobilization potential from a macro-economic perspective rather than a micro-economic or profitability assessment level.

The applied cash-flow analysis depends on several in- and outflow parameters. Hereby the population's demographic development as well as cash inflows and outflows of the fund represent elements with highest impact on the cash-flow development (compare Figure 5). An analysis of SIP systems' inflows can be separated by mandatory or voluntary contributions on the on hand and investment income on the other hand. "The latter can be separately expressed by interest on typical assets such as government bonds, bills and bank accounts, dividends from stock equity or rental income from real estate values" (Köhler, 2020, p. 2). Additionally, relieved capital from debt investments with maturity frequently flow back on SIP's virtual balance sheet and require reinvestment. The SIP system's cash-outflows are mainly consisting of benefit payments for retirees and capital allocation to new investments. Further, the SIP system operations inherit transaction costs for administrative purposes or asset management expenses.

Figure 5: Elements influencing SIP systems' future cash-flow as considered in the simulation models of the case studies



Source: Own illustration, based on Köhler (2020a, p.3)

To operationalize the SIP model, several basic equations are applied. They are identical for all assessed scenarios in the two case studies. As the underlying pension schemes vary, related parameters are described within the respective chapters 5.3 and 6.2.

<u>SIP mobilization potential for sustainable energy investment capital</u>

$$SIP_{MOB} = \sum_{i}^{n} INV_{TOT} - INV_{TRA}$$

Where:

i Start year of modelling, currently year 2020 across all scenarios

n Final year of modelling, currently year 2050 across all scenarios

INV_{TOT} Total available investment capital, in EUR_{2018} or USD_{2018}

INV_{TRA} Traditional investment allocation, in EUR_{2018} or USD_{2018}

Total available investment capital

$$INV_{TOT} = SIP_{IN} - SIP_{OUT}$$

Where:

SIP_{IN} Cash-inflows to the SIP scheme, in EUR_{2018} or USD_{2018}

SIP_{OUT} Cash-outflows from the SIP scheme, in EUR_{2018} or USD_{2018}

Cash-inflows

$$SIP_{IN} = PEN_C + SG + INV_{REF} + INV_{REV}$$

$$PEN_C = POP_E \times SIP_{MC} \times INC_{POP} \times CON$$

Where:

PEN_C Pension contributions, in EUR_{2018} or USD_{2018}

SG Supplementary grants by the state (if applicable), in EUR_{2018} or USD_{2018}

INV_{REF} Reflows from relieved investments, in EUR_{2018} or USD_{2018}

INV_{REV} Revenues from investments, in EUR_{2018} or USD_{2018}

POP_E Total employed population

SIP_{MC} Share of employed population with SIP-membership, in %

INC_{POP} Average employment income of population, in EUR_{2018} or USD_{2018}

CON Average SIP contribution share of total employment income, in %

Cash-outflows

$$SIP_{OUT} = PEN_P + AC$$

$$PEN_P = POP_R \times SIP_{MR} \times \frac{\sum_i^y CON_{RC} \times (1 + RR)^y}{PEN_T}$$

$$AC = AC_M + AC_{EM}$$

Where:

PEN_P	Pension and other benefit payments, in EUR_{2018} or USD_{2018}
AC	Administrative costs, in EUR_{2018} or USD_{2018}
POP_R	Total retired population
SIP_{MR}	Share of retired population with SIP-membership, in %
CON_{RC}	Pension contribution of the respective cohort in year i till y, in EUR_{2018} or USD_{2018}
PEN_T	Average pension payment duration, in years
RR	Effective rate of return on individual capital stock, in %
y	Number of years of contribution
AC_M	Administrative costs for member account mgmt, in EUR_{2018} or USD_{2018}
AC_{EM}	Administrative costs for SIP equity asset mgmt, in EUR_{2018} or USD_{2018}

2.2. Selection of case study countries

To derive different findings from a practical application of the SIP concept that allow comparison and generalization (see also chapter 7), case studies are conducted in two diverse countries. Thereby, the thesis reveals the potential of SIP concepts in different specific country contexts and highlights the respective constraints and barriers that might hinder a SIP implementation. Germany and the Seychelles are selected as case study countries due to well established contacts and working relationships. Long-lasting exchange with responsible politicians from the Ministries of Energy and institutions from the pension scheme landscape allowed to gain valuable insights and perspectives that benefitted the analysis in the scope of the case studies. Personal work relationships also allowed to gather a broad set of energy and pension scheme related data. Those aspects improved the qualitative and quantitative results of this thesis. Moreover, the two countries show highly distinct characteristics that allow for the generalization of results up to a certain extent (compare synthesis in chapter 8). Germany and the Seychelles differ as follows (for a detailed discussion of the aspects compare the respective chapters 5 and 6):

- Regarding the level of economic development, Germany represents a highly industrialized country and is the fourth largest economy worldwide, whereas the Seychelles as a Small Island Developing State (SIDS) are among the 20 smallest economies globally (see World Bank, 2018a).
- Geographically, Germany is a large country in the middle of Europe while the Seychelles are a remotely located SIDS surrounded by the Indian Ocean. This characteristic also impacts the respective economic possibilities and the vulnerability to external economic and environmental effects.
- While Germany is currently in the process of transforming the energy supply system based on a comparably mature legal, regulatory and economic framework, the Seychelles rely almost entirely on fossil-fuels.
- From the perspective of pension systems, Germany has a diversified pension scheme with full coverage in place while the Seychelles provide a centralized but incomplete pension system covering only about half of the retirees with income-replacing pensions to date.
- Germany represents a comparably transparent governance system with good data availability due to a high level of capacity and resources within the responsible institutions while data availability and transparency are limited on the Seychelles due to resource and capacity constraints. However good personal contact through an established working relationship with Seychelles institutions resolved this latter challenge in the context of this thesis.
- Finally, both countries share basic characteristics with other states. Germany shares its basic facets with many industrialized countries while characteristics similar to the Seychelles can be found on many of the 38 SIDS and 20 SIDS-like territories (compare UN, 2019). This indicates that the case study results can serve to generalize findings beyond the case study countries and potentially allow replication of elements in comparable contexts.

3. Background Analysis

The background analysis represents the basis for the succeeding methodological steps, including the case studies. Based on a literature review, it first describes the general investment needs for sustainable energy infrastructure development until 2050 and assesses the existing investor structure. Further it describes barriers for investment in infrastructure assets faced by institutional investors such as pension funds. Finally, the background analysis assesses the status quo of pension system worldwide and explores recent developments and challenges.

3.1. Global sustainable energy investment needs

In the light of the Paris Agreement and the SDG objectives described in chapter 1, literature reveals substantial energy infrastructure investment needs until the year 2050. By 2016, the total global investments in energy infrastructure were estimated to amount for USD 1.7 trillion (see IEA, 2017b, p. 3), up from between USD 1.076 and USD 1.35 trillion in 2010 (IPCC, 2014, p. 552). Power investments dominated with about USD 0.72 trillion in 2016, followed by upstream oil and gas investments with about USD 0.68 trillion and energy efficiency investments with USD 0.23 trillion.

In order to achieve the objectives of the Paris Agreement mentioned above, future finance flows will have to be “consistent with a pathway towards low greenhouse gas emissions and climate-resilient development” (UN, 2015, Article 2). Different studies estimate total and incremental investments for pursuing a 2°C compatible pathway in the energy supply and demand sector until the year 2050 (compare summary in Table 2 below). For instance, the IPCC (2014, p. 552) summarizes estimations of additional investment needs for the energy supply and demand sector of about USD 0.8 trillion per year until 2050. According to the most recent IEA estimation, additional investments of USD 0.6 trillion annually will be required for a 66% probability to stay below 2°C until 2050, on top of USD 2.8 trillion in a reference scenario reflecting current policies (compare IEA/IRENA, 2017, p. 8). Hereby renewable energies on the supply side and efficiency and mobility on the demand side require the main share of total investments. IRENA (2018, p. 41f) expects cumulative investments of USD 120 trillion in the energy supply and demand sector until 2050 of which about USD 27 trillion are specifically required for achieving the 2°C target. This translates in investment needs in the reference scenario of about USD 2.65 trillion per year and an annual incremental investment need of about USD 0.77 trillion, particularly for energy efficiency and renewable energy investments.

Other studies have estimated global investment needs for 100% renewable energy supply scenarios by 2050, emphasizing substantial environmental and economic benefits but also highlighting significant funding requirements, particularly in the beginning of the energy transition process. Singer at al. (2011, p. 73) expect that "global capital expenditure will need to continue to grow for the next 25 years to around USD 4.5 trillion[2] a year but will not rise above 2 per cent of global GDP." The authors also demonstrate the sector specific, additional investments that are dominated by investments in buildings and transport until 2035, afterwards renewable heat and fuels require most capital expenditures. According to Ram et al. (2017, p. 54), the power supply sector only would require about USD 1 trillion[3] annually until 2025 then slowly decreasing to about USD 0.66 trillion by 2050 in order to achieve 100% renewable power supply. The incremental share of these investment needs remains unclear. Teske et al. (2019, p. 23f) estimate USD 1.36 trillion of annual investments for renewable power generation under a 2°C scenario and USD 1.42 trillion per year under a 1.5°C scenario. For the baseline with 5°C temperature increase they find significantly lower capital needs of ~USD 0.6 trillion compared to the other studies that reflect at least some existing policies. Additionally, Teske et al. assume annual investment needs of USD 0.37 trillion (2°C), USD 0.34 trillion (1.5°C) and 0.08 (5°C) respectively for renewable heating capacity, particularly heat pumps and solar collectors.

To achieve universal access to electricity by 2030, the IEA estimates additional investment needs of USD 52 billion per year, representing more than twice the level mobilized under the current policy outlook (see IEA, 2017a, p. 5).

[2] Value given in EUR. Calculated with OECD USD exchange rate from 2005 (OECD, 2019)

Table 2: Comparison of key study results assessing annual, global energy investment requirements for different scenarios, all in trillion USD

Source	Energy investment in reference scenario	Incremental investments for 100% REN by 2050	Incremental investments for 2°C compatible scenario	100% power access by 2030
(IPCC, 2014) (USD_{2010})			0.8	
(IEA/IRENA, 2017) **(USD_{2016})**	2.8		0.6	
IRENA 2018 (USD_{2015})	2.66		0.77	
(IEA, 2017a) **(USD_{2016})**	0.009 (energy access only)			0.052
(Teske et al., 2019) **(USD_{2019})**	0.6		1.14	
Singer et al. 2011 (WWF) (USD_{2005})	1.8 to 4.4			

Source: Own table based on reviewed literature sources

Summarizing the most recent study results as presented in Table 2, it can be expected that the average annual investment needs until 2050 that consider current policies in place will be about USD 1 trillion higher than in 2016. For a high likelihood of achieving the Paris Agreement objective, the results indicate an additional average investment need of about USD 0.8 trillion per year. Thus, the total global capital expenditure requirements sum up to about USD 3.3 to USD 3.6 trillion annually. For achieving the SDG goal of universal electricity access, another USD 0.05 trillion per year will be required until 2030.

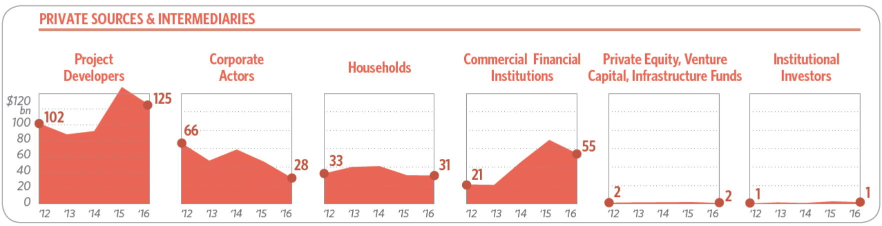
What all assessed studies highlight, is the necessity for early action to avoid stranded assets and achieve the climate GHG reduction targets (compare e.g. IEA/IRENA, 2017, p. 143; Singer et al., 2011, p. 72f; Teske et al., 2019, p. 472). This emphasizes the need to mobilize large volumes of capital as soon as possible thus all studies refer to innovative approaches that unlock additional, currently untapped capital (compare e.g. Fulton and Capalino, 2014, p. 4ff; IPCC, 2014, p. 552; IRENA, 2018, p. 67).

3.2. Assessment of current investments and investors-structure

When discussing options for addressing the above-described energy infrastructure investment needs with an increased speed, a key element are the sources of funding. While infrastructure will be ultimately financed by users and/or taxpayers, it is initially funded by either public institutions through development banks, public finance institutions, governments and governmental corporations or the private sector through corporate or project finance.

Buchner et al. (2017, p. 10) assessed for the Climate Policy Initiative (CPI) that private finance provides the main share of mitigation related finance with about USD 250 billion in 2016. Hereby project developers[4] including utilities, that plan and implement activities, dominate the structure of funding sources, providing USD 125 billion in 2016, followed by corporate actors, households and commercial financial institutions (compare Figure 6). However, project developers mainly rely on balance sheet financing[5] through bank loans that are not separately listed by Buchner et al. Households and corporate actors also require underlying finance sources, mainly commercial or public banks. Private equity funds and institutional investors do hardly participate at all according to the CPI study.

Figure 6: Sources and intermediaries of private climate finance in 2016



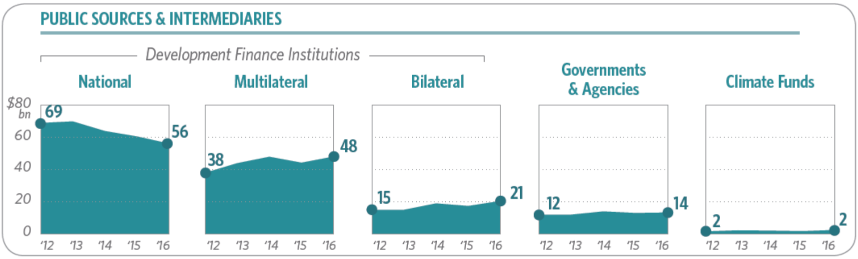
Source: (Buchner et al., 2017, p. 7)

[4] CPI includes in the category "project developers" dedicated energy project developers, engineering, procurement and construction (EPC) contractors, utilities and independent power producers.

[5] Balance sheet financing describes the traditional form of corporate financing. Hereby a corporation can apply debt or equity instruments, typically it borrows loans from banks, issues corporate bonds or attracts listed or unlisted equity investments. Main characteristic is that these funds are not provided for a specific project activity but flow on the balance sheet of the corporation that also serves as liability (compare taxonomy in Della Croce et al., 2015, p. 14ff).

With regard to public investors, mainly national and multilateral development finance institutions provide resources for mitigation activities. About USD 100 billion or 71% have been invested in the energy and transportation sector, including energy efficiency measures, renewable energies, sustainable transport and transmission and distribution in 2016 (compare Buchner et al., 2017, p. 11) (see Figure 7).

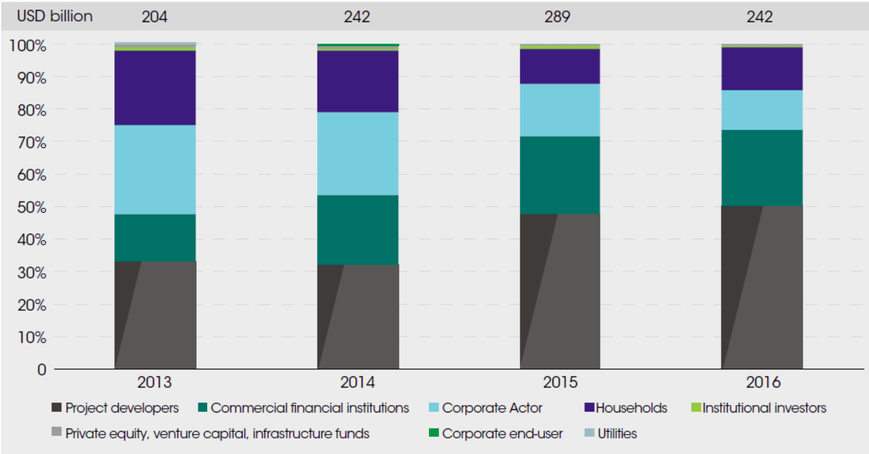
Figure 7: Sources and intermediaries of public climate finance in 2016



Source: (Buchner et al., 2017, p. 4)

Studies by the International Renewable Energy Agency and International Energy Agency support the CPI findings. According to IRENA, private investors provided more than 90% of the total renewable energy investment of USD 263 billion in 2016 (Buchner et al., 2018, p. 12f). Hereby project developers provided about 50% of the private resources, commercial financial institutions 23%, households 16%, corporate actors 14% while private utilities played a rather marginal role and institutional investors only contributed less than 1% (see Figure 8). The split between equity and debt financing is almost balanced, debt accounted for about 55%.

Figure 8: Development of private investment in renewable energies by source, from 2013 to 2016



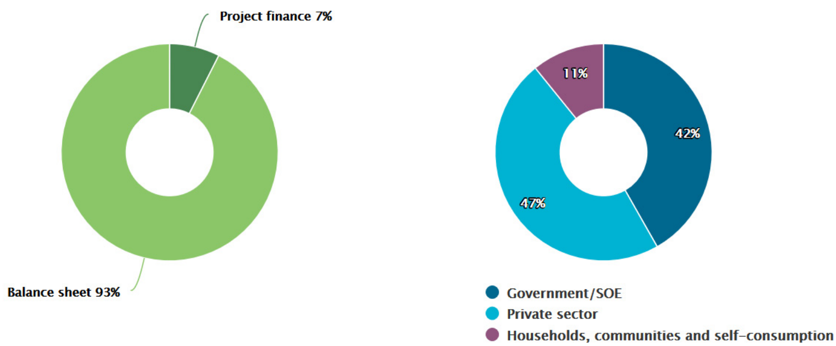
Source: (Buchner et al., 2018, p. 31)

An assessment of Mazzucato and Semeniuk (2018, pp. 12–15) reveals a more important role of institutional investors in large renewable power capacity investments. The authors explored the source of all global investment flows to renewable electricity assets larger than 1 MW capacity between the years 2004 and 2014, based on data from Bloomberg New Energy Finance. Their findings highlight the important role of public and commercial banks that provided about 27% or USD 326 billion as well as private and state utilities that provided 30% or USD 362 billion during the given 10 years. Hereby particularly public utilities provided significant funding volumes which explains the discrepancy to the IRENA findings focusing entirely on private investments. Institutional investors including private equity firms and pension funds were responsible for about 7% or USD 84 billion, translating in an average annual volume of about USD 8 billion. However, it is not clear whether the definition of institutional investors reflects a consistent set of institutions comparable to the IRENA and CPI approach.

An IEA analysis covers all trends in global energy investments, including fossil-fuel and renewable energies (compare International Energy Agency, 2017, p. 3ff). While the total global energy investments were around USD 1.7 trillion, the power sector became the largest recipient with USD 718 billion or a 43% share. IEA states USD 297 billion of investments in renewable energy capacity, a slightly higher value than estimated by IRENA. Allocations to renewables for transport and heat add an additional USD 20 billion. Spending on power storage and networks increased to an "all-time high" of USD 277 billion. Energy efficiency investments across transport, buildings, household appliances and industry sectors amounted to USD 231 billion in 2016. The UNFCCC's Biennial Assessment backs the IEA numbers as potential upper bound of estimations while it highlights that the CPI mitigation numbers are likely understating the actual financial flows (compare SCF, 2016, p. 54). The fact that a universal definition for energy efficiency or sustainable transport does not exist creates uncertainty regarding the underlying data.

According to IEA 2017, more than 40% of the investments origin from state owned enterprises, about 47% come from the private sector (compare
Figure 9). Regarding the individual sources, IEA highlights the role of balance sheets of investors. More than 90% of the total investments is based on these balance sheets, the remaining share is direct project financing. However, it is important to consider that not all balance sheet resources are originating from earnings of the respective investor but rather depend on general bank loans.

Figure 9: Finance sources of USD 1.7 trillion investments in energy assets in 2016



Source: (IEA, 2017b)

Summing up, the big picture of global energy related, sustainable finance or climate finance is prone to uncertainties regarding definitions and scopes as well as challenges regarding quantitative data availability. Nevertheless, one can derive a range of funding flows based on the existing research and estimations. Hereby investments in renewable power capacity as well as power grids and storage facilities dominate the financial flows. Energy efficiency investments also represent a significant volume, renewables for heating and transport play a minor role. In terms of investor structure, a comparably precise estimation can only be given for renewable capacity investments. These are dominated by balance sheet allocations from mainly private and public project developers and commercial financial institutions. Households, corporate actors and institutional investors only play a minor role. Moreover, it has to be considered that this picture might be misleading in terms of primary origin of the financial resources. As the balance sheets of the given actors are mainly funded by loans and corporate bonds and only to a minor share by equity investments or historical and current revenues and earnings, the most important but indirect provider of resources for financing the energy transition remain commercial and public banks. Taking only into account the investors that identify appropriate investment opportunities and take the final investment decisions for energy infrastructure, the current investor's structure consists mainly of utilities, commercial banks and institutional investors. In its advisory report for the 2017 G20 summit, the OECD (2017a, p. 266ff) describes some of the individual characteristics of infrastructure funding through these investors:

3.2.1. Banks

Banks remain the key source of providing finance for energy infrastructure. The OECD estimates that they provide about 80% of all sustainable infrastructure finance, mainly in terms of project or balance sheet debt (OECD, 2017a, p. 267). Therefore, capital provided by utilities, project developers or households is often indirectly based on bank loans. Besides commercial banks, also public-owned institutions and development banks are relevant for providing resources, particularly in low- and middle-income countries. As loans are flexible products that can be paired with various other project finance instruments and structures, banks can engage in different constellations, including private and public shareholders. In these cases of loan lending, banks are however not involved in the selection of specific project activities. With regards to international, large infrastructure corporate financing, banks typically form syndicates consisting of several debt providers. This structure allows the most competent bank to lead the syndicate thus reduces risks, particularly the risk of government holdup (see also chapter 3.3.1). Syndicated loan volumes for infrastructure investments have increased since 2010, topping USD 1 trillion in 2015 (compare OECD, 2017a, p. 268). Banks are also a crucial source for small-scale investments. In the energy-efficiency and micro-scale renewables sector they are typically the key source of debt funding.

3.2.2. Utilities

Controlling substantial financial volumes over their balance sheets, utilities traditionally provide an important share of investments in power generation, transmission and distribution. During the recent decade they were forced to adjust their business models and strategies due to additional regulation, decentralization, disentanglement and liberalization. The changing competition in many power markets pose significant challenges on traditional utilities with limited capabilities and interest to adapt (see OECD, 2017a, p. 266). For instance, the traditional utilities in the German power market have lost significant market shares due to their inability to adjust their business models to modern, renewable energy supply systems (compare chapter 5.1.3).

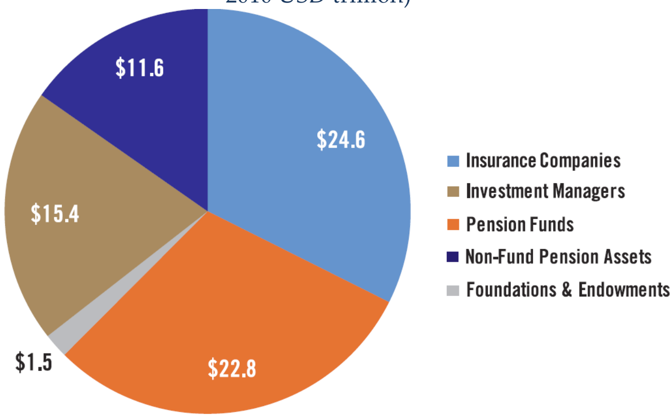
3.2.3. Corporations

Large corporations in developed countries such as Amazon, Google, Microsoft, Facebook, Norsk Hydro or Wal-Mart increasingly seek to decarbonize their operation or benefit from renewable energy revenues. While the competitive cost of electricity is a major reason for the investments, also marketing motivation with regard to the corporation's clients foster this development. Corporations financed activities particularly through direct equity investments, Power Purchase Agreements (PPAs) and partnership models. By 2016, about sixty-five global corporations have committed to 100% renewable energies, over 5 GW of renewable capacities have been realized in 2015 (see OECD, 2017a, p. 267).

3.2.4. Institutional Investors

Institutional investors i.e. pension funds, public pension reserve funds, investment managers, mutual funds and insurance companies invest their members' contributions today to provide protection through products like life insurance or pension payments in the future. According to the Sawant (2010, p. 10ff) and OECD (2017a, p. 270ff), institutional investors located in OECD countries held more than 83 trillion USD in assets while the OECD member states combined' Gross Domestic Product per anno (GDP/a) was USD 46 trillion in 2012. As further described in chapter 3.4.1, pension fund assets exceed the countries' GDP, e.g. in the Netherlands, Australia, Iceland or Switzerland (compare Inderst and Della Croce, 2013, p. 8; Sawant, 2010, p. 23). Fulton and Capalino support this number estimating the value of assets managed by institutional investors to about USD 76 trillion in 2010. Insurance companies and pension funds are responsible for about two thirds of this volume (compare Figure 10).

Figure 10: Asset value managed by institutional investors in the OECD in 2010 (in 2010 USD trillion)



Source: Fulton and Capalino (2014, p. 4)

With regard to these numbers, Nelson and Pierpont highlight that these investors are not a homogenous group but characterized by variation in investment objectives, policies, target markets and assets, regulation and their ability to engage in long-term investments (Nelson and Pierpont, 2013, p. 6). Thus, they estimate that only about USD 45 trillion of these assets meet the traditional definition of an institutional investor providing long-term capital for long-term obligations. Apart from these limitations, the volume demonstrates the economic importance and power of institutional investors. Due to the downturn of the financial markets in 2008 and the following years, institutional investors were incentivized to identify alternative investment opportunities besides traditional financial market products such as government bonds or stocks. Thus, these investors have increasingly invested in "hedge funds, private equity, real estate, infrastructure and commodities to diversify their portfolios" (OECD, 2013a).

As a potential solution for addressing the energy infrastructure funding needs identified in chapter 3.1, institutional investors might be well placed. Particularly pension funds and life insurers offering long-term fixed guarantees without requirements regarding short-term liquidity seek to match such liabilities with long-term assets. Therefore, they seem to be suited as financiers for long-term infrastructure, for instance in the field of large-scale renewable energy deployment and flanking activities such as transmission grids. However, the OECD has revealed in an international survey that institutional investors like pension funds allocate only minor shares of their resources under management to infrastructure activities (OECD, 2018, p. 41f). 49 large pension funds from Europe, Australia, North America and Latin America reported that 3.6% or about USD 91 billion was allocated to equity or debt investments with relation to infrastructure by the end of 2015. Moreover, sustainable investments within these infrastructure allocations represent only a minor share. According to OECD (2016a, p. 152), out of 26 pension and reserve funds that reported infrastructure allocations, only 9 communicated investments into renewable energies. This matches with CPI's estimation of USD 1 billion of institutional investors' direct allocation to renewable energy related assets in 2016, representing less than 0.5 % of private climate finance and about 0.3% of total investments in this sector (see Buchner et al., 2017, p. 7f). Nelson and Pierpont (2013) apply a comprehensive methodology to account for the theoretical maximum potential of existing institutional funds flowing into renewable energies as well as the annual volume that could be available within the current context of regulation and policy frameworks. There estimation of available annual flows from existing institutional investors within the OECD until 2035 amount to about USD 56 billion of equity and USD 83 billion of project debt, translating into an annual average of about USD 7 billion (compare Nelson and Pierpont, 2013, pp. 65–71).

Summing up, experts identified the need of large volumes of institutional investor capital for mitigation and energy transition activities, but investors seem reluctant to provide the required quantities. The following chapter attempts to explain why institutional investors hesitate from strong engagement in sustainable infrastructure.

3.3. Barriers and constraints for institutional investors to engage in infrastructure

Infrastructure investments by institutional investors are characterized by specific challenges and barriers that help to understand the cautious investment behaviour analysed in the previous section. In this context Kemfert and Schäfer (2012, p. 5) stress that investors tend to overstate energy infrastructure risks hindering the implementation of projects in the energy sector. Thus, the following section specifically focuses on the discussion of typical infrastructure investment risks but also assesses regulatory barriers and capacity constraints. Finally, the chapter sketches potential solutions and derives implications for the SIP context.

3.3.1. Risks

Szado (2014, p. 50) describes typical risks for infrastructure projects consisting of "construction risk, operational risk, business risk, interest rate risk, refinancing risk, legal risk, regulatory risk, environmental risk, political and taxation risk, and social risks. At the fund level, the risks include concentration risk, illiquidity risk, valuation risk, and governance risk". In OECD (2017a, p. 285f), these risks are clustered according to the three main categories "political and regulatory", "macroeconomic and business" and "technical" risks. For the different phases of the investment several risks occur per category (compare Table 3). While technical risks have typically minor impact on investment performance (compare analysis of Standard & Poors project finance downgrades by Sawant, 2010, p. 116f), the most important political, regulatory, macroeconomic and business risks are described in more detail in the following section.

Table 3: Infrastructure investment risks, separated over project lifecycle; green shaded risks are linked to climate change risks

Risk Categories	Development Phase	Construction Phase	Operation Phase	Termination Phase
Political and regulatory	Environmental review, land acquisition	Cancellation of permits	Change in tariff regulation	Contract duration
	Rise in pre-construction costs (longer permitting process)	Contract renegotiation		Decommission
				Asset transfer
			Currency convertibility	
	Change in taxation			
	Social acceptance			
	Change in regulatory or legal environment			
	Changes in climate change policy and support schemes			
	Enforceability of contracts, collateral and security			
Macroeconomic and business	Prefunding	Default of counterparty		
	Financing availability		Refinancing risk	
			Liquidity	
			Volatility of demand/market risk	
			Liability risks - compensation from victims of climate change	
	Inflation			
	Real interest rates			
	Exchange rate fluctuation			
	Long pay-back period for climate change mitigation investment			
Technical	Governance of the project			Termination value different from expected / stranded assets
	Environmental			
	Project feasibility and inclusion in investments plan*	Reliability of forecasts for construction costs and delivery time	Qualitative deficit of the physical structure/ service	
	Archaeological			
	Obsolescence			
	Force Majeure			

Source: (OECD, 2017a, p. 286)

Political and regulatory risks

Governments are involved in infrastructure operation through "regulators, input suppliers, output buyers and as direct suppliers of security and legal environments" (Sawant, 2010, p. 124) thus they can change political and economic frameworks. This phenomenon might directly affect infrastructure investors' assets in various ways and is broadly called sovereign or governmental holdup (see e.g. Bitsch, 2012, p. 164). Particularly in the infrastructure sector, that usually provides basic goods to the population in monopoly-like contexts, investments and the provision of services are politically sensitive. According to analysis by Standard and Poor's, counterparty and sovereign holdup risks are responsible for more than half of the project finance debt downgrades between 2000 and 2010 (Sawant, 2010, p. 116).

Generally, Sawant (2010, p. 122f) distinguishes between several acts of direct discrimination including actions by the host government against the assets. Among these are:

- Expropriation: A rare case is the nationalization of infrastructure assets. Governments have hardly applied outright expropriation of assets during the last decades. Usually, it requires a breach of contract and can be sued by courts – if the legal system works independently. It can be expected that it would create public relation problems for the Government and potentially diplomatic protection measures in case of foreign investors.
- Creeping expropriation: Governments can try to profit from the stable revenues of infrastructure assets through changes in taxing, duties on outputs, fees, levies or royalties (compare also examples in Table 3). It differs from breach of contract or direct expropriation as regulatory adjustments by the host government are perceived as legitimate sovereign right. Thus, creeping expropriation is not easily identified, and countermeasures are difficult.
- Inconvertibility: The currency exchange rates can have significant impact on economic activities. Currencies in developing countries particularly can fluctuate heavily. If the project finance debt is in an external currency, for instance US dollars, the project's viability can be on risk if the local currency devaluates. Further, there might be limitation of currency exchange in countries if capital controls are in place. Blocking currency flows has been reduced in recent years due to globalization of capital markets but still exists. For some developing country markets, typical hedging options provided by the financial market such as forwards, options or currency swaps might not be available.

Political factors without discrimination, also called "force majeure" are events of political or social behaviour, not directly steered by the host-government. This can include war, civil war, revolutions, terrorism, chemical or nuclear catastrophes or other tremendous political and social events (see Della Croce et al., 2015, p. 61ff).

Macroeconomic and business risks

Institutional investors require to maintain liquidity across their investment portfolios (see e.g. Underhill, 2010, p. 166). They need to ensure that there are enough cash resources available to meet their obligations and liabilities at any time. Regarding liquidity characteristics, "the most liquid assets are cash, followed by publicly traded stocks and bonds" (Nelson and Pierpont, 2013, p. 31). Non-market traded shares of companies, real estate or investment-funds with long payback-periods are less liquid. The least liquid assets comprise of direct investments with long lock-in timeframes, including both debt and equity investments in e.g. direct venture, strategic public equity and infrastructure activities. Limited opportunities to sell these assets as well as comparably high transaction costs as well as special risks lead to high illiquidity.

Infrastructure assets generate cash flows over long-time periods, as the lifetime of infrastructure is lengthy, e.g. 60 years for transmission lines or 30 years for roads or sewage treatment (compare Sawant, 2010, p. 44). This poses a risk as the investor has to rely on stable investment environments and faces reduced liquidity. Kemfert and Schäfer (2012, p. 11) highlight that private equity firms typically have an "investment horizon of five to ten years maximum" to repay their shareholders. This limits the direct engagement in long-term equity financing. Being a crucial success factor, investment managers might act cautious, some generally avoid illiquid investments. Illiquidity means that there are not sufficient buyers for an asset one wants to sell, offering reasonable price levels. Thus pension funds often limit or prohibit direct investments in project activities, reducing potential of harnessing additional returns for long-term, illiquid investment opportunities while complicating infrastructure engagement (compare Nelson and Pierpont, 2013, p. 38). The Allianz Insurance (2015, pp. 3–5) explicitly highlights the liquidity risk as a premium reward for investors. "Senior infrastructure debt as an illiquid alternative to other more traditional fixed income instruments has both diversification and yield benefits but is illiquid and requires a buy-and-hold mentality". This actually suggests that long-term investors are well positioned to exploit illiquidity risk premiums but "many participants will require external ratings of underlying projects and will require investment grade assets. Not all infrastructure debt portfolios will conform to these requirements […]" thus "ironically long-term investors […] maintain credit quality and dampen portfolio volatility" (Allianz, 2015, p. 6). According to the World Economic Forum, only about USD 700 billion equalizing 1% of assets held by institutional investors are allocated towards direct investments, that are usually characterised by long-term timeframes (see Wyman, 2014, p. 22). In this context, the typical financial regulation limits activities by requiring mark-to-market accounting. This means that also illiquid assets have to be evaluated according to their market value even though there might be no or a highly limited market for such assets only. This implicates uncertainties and costs for constant estimation of current market values of the infrastructure assets that are not associated with liquid assets such as stocks or traded bonds (compare Dichtl, 2018, p. 136f).

Pension funds are exposed to additional, specific business risks comprising of investments that do not earn sufficient returns in capital-based schemes, the risk of devaluation and "members living longer than benefits are planned for" (Sawant, 2010, p. 40ff). If the estimated market value of the Pension Funds' assets falls below the value of its estimated liabilities, a funding gap exists. According to the author, this has happened in 2002/2003 during the dot.com bubble burst, in 2008/2009 during the collapse of equity values and during 2010/2011 when government bonds defaulted. These risks that are highly relevant for a sustainable operation of potential SIP schemes are further discussed in chapter 4.3.2 and 4.5.1.

3.3.2. Regulatory barriers

Regulators impose requirements for some investor groups that directly impact the ability and attractiveness to invest in infrastructure assets. Some of the key regulations relevant for insurers, banks and institutional investors that also impact the availability of capital for sustainable energy development and a potential SIP scheme operation are outlined in the following section.

Solvency II

After the global financial crisis of 2007/2008, regulators introduced new approaches to mitigate financial risks of investments. For instance, all EU based insurance and reinsurance companies need to comply with Solvency II regulation. It is a risk-based approach posing capital requirements for various asset classes (see EIOPA, 2018). According to predefined calculations, specific shares of capital have to be guaranteed on the balance sheet of the insurer. The riskier an investment is, the more capital has to be reserved in order to cover expected worst-case losses over a year. In 2017, the European Commission adopted an amended regulation that reduces the investment capital charges for infrastructure corporate assets by 25% thus increasing the attractiveness of respective investments. To qualify as infrastructure corporation that falls under the adjusted capital requirements, criteria such as the geographical location within the EU, a predictability and diversification of revenues and a historical performance or investment grade quality of BBB or higher have to be fulfilled (see Beltran et al., 2017, pp. 2–5). According to the insurance industry, these new rules better reflect the risk profile of infrastructure and advantage the cost of capital for respective investments and they warn to impose further regulatory burden on long-term engagement (compare e.g. GDV, 2018a, p. 11; Kleine and Krautbauer, 2012, p. 22; Parkes et al., 2015, p. 9). Taking these experiences into account, a balanced and appropriate regulation can be interpreted as a precondition for enhanced action of particularly domestic insurers as discussed in required framework conditions of chapter 4.6, the SIP design options of chapter 4.4.2 and for the German context in chapter 5.4.

Basel II and III

As with Solvency II for the insurance sector, regulators also introduced international rules for the banking sector, commonly referred to as Basel Committee on Banking Supervision (Basel) II and III (compare BIS, 2017). This regulatory system groups bank assets in different categories and weights them according to their credit default risk. For instance, cash reserves are weighted with a risk of 0% while most corporate debts are weighted with a risk of 100%. This risk weight is translated into required minimum capital ratios that the respective banks have to keep on their balance sheet in order to withstand credit defaults (see Ma, 2016, pp. 109–111). In the context of energy infrastructure investments, particularly project finance provided by banks is relevant. According to Basel II, project finance is a subcategory of wholesale lending groups (compare Sawant, 2010, p. 187). Basel II requires banks to appreciate the risks of individual activities instead of bundling risks on average basis. Contrary to Basel I where banks had to back up project finance loans with an average 8% equity on their balance sheets, Basel II requires an evaluation and coverage of default probabilities for each loan individually (see Elbing and Liebchen in von Hirschhausen, Christian; Beckers, Thorsten; Mitusch, 2004, p. 70f). Under Basel II the project finance credit volume is weighted as per individual risk thus being individually lower or, mostly higher per specific asset than the 8% from Basel I. For determining the risk, the probability of default, as well as loss given default and exposure at default are applied. This combination describes the estimated loss in case of default in relation to the remaining loan and the loan’s maturity. Hereby banks can conduct internal estimations which are particularly beneficial in a specialized field like infrastructure investments. Basel III further strengthens the stability of banks as a response to the impacts of the financial turmoil 2008/2009. It regulates the quality of capital backing project finance, imposes an additional capital buffer of 2.5%, reduces the maximum leverage ratio and increases the requirement of liquid assets in the portfolio (compare Ma, 2016, p. 112ff). According to Ma, these new regulations help to increase systemic stability in times of financial turmoil but at the same time they strongly discourage banks to provide long-term, direct project finance loans. This in turn incentivizes project developers to increasingly issue project bonds that are particularly attractive for institutional investors. Also, direct project financing loans from institutional investors can substitute the contracting bank sector. The author labels this phenomenon as "shadow banking".

3.3.3. Capacity constraints

Besides the outlined external limitations and barriers preventing institutional investors to enhance their activities in infrastructure financing, also internal characteristics restrain them. According to Laboul and Della Croce (2014, p. 36f), investors lack transparent accounting standards that provide information about costs and revenues as well as reliable data on historical performance of infrastructure assets. In contrast to traditional asset managers for e.g. government bonds or stocks, the institutions mainly do not have internal expert teams to evaluate and monitor the risk of infrastructure projects. As they are not familiar with new business fields, and have limited internal experience and capabilities, they might sign incomplete contracts with their counterparts such as suppliers, operators or customers. Incomplete means that the contract does not include all eventualities that might occur in future. Thus, renegotiation might be required, likely leading to reduced revenues. Sawant (2010, p. 99) describes this as potential holdups with partners or clients leading to the biggest transaction costs in infrastructure investments. At the same time, intuitional investors are cautious to outsource evaluations and operational management to specialized providers like fund-managers that invest resources on their behalf as it has happened before the financial crisis. A critical mass of approved project loans would be required before it is attractive for the institutional investor to hire own expert staff (compare Ma, 2016, p. 125).

Besides the internal capacity constraints of institutional investors, also project developers do not provide appropriate conditions for unlocking enhanced capital allocation to infrastructure. According to Beltran et al. (2017, p. 6), the lack of a visible project pipeline limits investments as most institutional investors are not able to identify sufficient opportunities internally. Also many financial vehicles structured by energy project developers do not match the requirements of institutional investors, particularly the risk/return profiles many pension funds are looking for, are not met. (compare Della Croce et al., 2011, p. 23). The importance of sufficient internal capacity and the limitations of capacity constraints are also visible in the analysis of existing institutions in chapter 4.2 and further reflected in the description of SIP design elements in chapter 4.4.2.

3.3.4. Solutions for overcoming the barriers

To address the above described key risks and barriers, Sawant (2010, p. 135ff) suggests some specific risk mitigation strategies and tools.

Political and regulatory risks and barriers

For political and regulatory issues, the alignment with government objectives helps to sustain the project and reduce the risk for government holdup. E.g. contributions to poverty reduction, employment generation, technology transfer or the reliable provision of services are typical objectives of governments. Hereby, pension funds seem to have a "strong ability to influence their governments and seek diplomatic protection" (Sawant, 2010, p. 124).

Local community support and strong local partners can also be successful strategies to mitigate sovereign holdup risks. Besides federal engagement also exchanges with and involvement of local stakeholders is very important to reduce resistance in the population. Local partners such as financial institutions are well suited as the host government will likely not expropriate domestic firms. However politically influential, local partners can also "become liabilities if they fall out of power" (Sawant, 2010, p. 137). Customers and society are particularly sensitive towards price increases for basic services as typically provided by infrastructure. Fair and reasonable revenues instead of a maximization of profits can help to avoid sovereign holdup. An output price that matches the Government and populations' expectation can be determined by analysing prices for comparable services in the country or region or by assessing the costs as share of consumers' total average income. Also surveys among customers can serve to determine a fair and reasonable output price.

Besides these direct interaction with the host government and affected communities, the purchase of political risk insurance can hedge the risk of political holdups. Investors are compensated e.g. for expropriation, breach of contract or inconvertibility. Also, insurances for riots, revolution or devaluation in the context of force majeure events exists. Many political risk insurances are offered by Multilateral Development Banks e.g. the Multilateral Investment Guarantee Agency (MIGA) from World Bank or the US State managed Overseas Private Investment Corporation (OPIC).

Finally, a suitable capital structure can use leverage as a tool to mitigate the probability for holdups before occurrence and enhances favourable post-investment renegotiations. Debt represents here the threat of bankruptcy leading to a default of the project to the disadvantage of the counterparty. It thus shields wealth away from external counterparts such as suppliers and reduces the risk of a holdup. Suitable investment vehicles and capital structures for SIP activities are further discussed in chapter 4.5.1.

Macroeconomic and business risks

With regards to unmatched revenue expectations, Singer et al. (2011, p. 73) state that the current financial system is not suited for long-term investments as investors expect a return within a couple of years. To overcome this constrain, there exists a range of ideas how to promote private investments by applying mainly economic policy incentives and risk management instruments. These include e.g. insurances or guarantees as well as "income-enhancing mechanisms, such as feed-in tariffs, tradable certificates, tax incentives, clean energy subsidies" (Buchner et al., 2013, p. 9). To unlock the potential of institutional investors, there is also the option of creating innovative partnerships. Hereby an experienced commercial bank or utility acts as leading institution, providing a debt and/or equity portion and due diligence as well as monitoring capabilities. The institutional investors can serve as project sponsor, also providing debt while building on the experience of the bank or utility. An own skillset of monitoring and due diligence capabilities is not required. This approach can eliminate a barrier for greenfield investments through minimized construction risks (compare OECD, 2017a, p. 270).

To address over-exposure of the investments to a single sector, portfolio diversification is a recurring element of risk mitigation in literature. For instance, Nelson and Pierpont (2013, p. 36) highlight the practice of institutional investors to manage risks by balancing the target ranges for different asset classes. This shall avoid over exposure to particular risks of a single sector, theme or trend. Portfolio diversification approaches are also reported by existing institutions such as the assessed public and private investors in chapter 4.2 or the SPF's investment guidelines, outlined in Annex I, section 3.1.3.

Capacity constraints

Regarding the lack of internal capacity and shortcomings of decision-making characteristics, Della Croce et al. (2011, p. 61ff) suggest to improve the institutional investor's governance structures. Increasing the scale and size of investors such as pension funds represents a key option to enable the specialization of staff and the development of internal expertise for engaging in direct infrastructure project investments. For smaller institutions, pooling resources for joint investments might be a feasible option to address the barrier of in-house capacity constraints. Finally decision-making processes within the investment institutions need to be adapted to incentivize sustainable infrastructure engagement. This can be achieved through regulatory requirements or through internal changes that benefit long-term, strategic investment considering environmental and social governance. Several existing examples for successfully developing internal capacity and governance structures from Canadian, Australian, and German institutions are presented in chapter 4.2.1.

The discussed solutions to address the political, regulatory, business-related and capacity risks and barriers directly feed into the design elements of the SIP scheme presented in chapter 4.5. Hereby investment strategies that generate predictable revenues, procedures to minimize risks and transaction costs, an appropriate institutional set up and a feasible governance structure are reflected.

3.4. Analysis of pension systems globally

By today, many industrialized countries, emerging economies but also developing countries are characterized by an aging society. While globally there were only 200 million people over age 60 in 1950, the World Bank expects over 2 billion by 2050 (Pallares-Miralles et al., 2012, p. 12). Thus "concerns about the challenges posed by aging populations have moved to the forefront of the public policy debate in many countries" (Chand and Jaeger, 1996, p. 1).

In most traditional societies family members or communities take care of their elderly individuals. With modernization of societies, increased mobilization and urbanization lead to weakened family and community ties creating economic challenges for the elderly. Individuals might try to continue working in advanced age or save properties in form of real estate, livestock or other valuable assets. However fluctuating prices, diseases and injuries, exclusion from labour markets, misfortune, theft or force majeure like natural disasters or wars jeopardize a successful outcome of such individualized approaches (compare Schwarz, 2006, p. 1). Thus, social security for the elderly in form of public and private pension systems represents a key cornerstone of ensuring income security and avoidance of poverty in the old age. Pension schemes therefore play a pivotal role in many domestic and international political contexts. Consequently they are for instance covered under SDG 1 and their implementation guaranteeing a basic level of income and health service are endorsed by the G20 and the UN (see ILO, 2014, p. 15).

3.4.1. Classification and status quo of pension schemes

There are different approaches how to classify pension schemes. Generally, literature distinguishes on the one hand between different "pillars" that fulfil different social security objectives. These pillars can form pension frameworks in various combinations. On the other hand, pension schemes can be categorized according to the underlying operative principles and funding mechanisms.

With regards to the pillar categorization, the World Bank introduced a system of five elements that is mainly referred to in this context (see Pallares-Miralles et al., 2012, p. 36ff; Wagstaff and Farrand, 2016, p. 8):

- A non-contributory scheme providing basic security, regardless of contribution history, forms the "zero pillar". In many cases, these schemes can only provide a minimum pension to avoid seniors being confronted with high poverty levels.
- A mandatory-earnings based "first pillar" with the objective of replacing the earnings of covered members in the old age. Most of these systems are based on a pay-as-you-go (PAYG) basis, where contributions from current employees cover the pensions of today's retirees.
- A "second pillar" comprising of a mandatory individual saving scheme that is usually managed by private insurance companies. They are "explicitly organized as specialized pension savings schemes rather than general contractual savings vehicles such as bank accounts, mutual funds or life insurance policies that may

also be used by individuals for retirement related savings" (Pallares-Miralles et al., 2012, p. 39).

- A complementary, voluntary "third pillar" based on individual savings that can comprise elements from the second pillar as well as general contractual saving mechanisms, and
- A non-financial "fourth pillar" that provides access to informal support such as health or housing.

This pillar categorization is applied in various combinations and nomenclatures however a framework consisting of at least one basic security pillar, one mandatory-earnings pillar and one individual saving pillar tends to be accepted taxonomy by different institutions and actors (compare e.g. Holzmann, 2012, p. 13ff; ILO, 2017, p. 78; OECD, 2013b, p. 8; Schwarz, 2006) or geographical backgrounds (see for instance German Case Study in chapter 5.2). Thus, in the context of this thesis the following terminology will be applied:

- First pillar schemes are providing basic security without individual contributions,
- Second pillar schemes are based on publicly managed, mandatory-earning based contributions and replace a certain level of the earnings during old age,
- Third pillar schemes are mandatory or voluntary private account pension saving schemes that can be either publicly or privately managed.

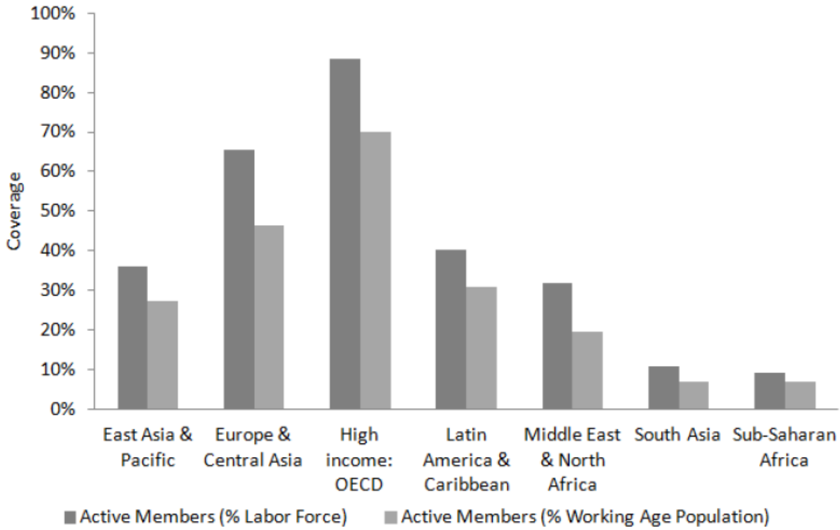
Regarding the underlying operational mechanisms, literature defines traditionally the basic form of funding and the benefit promise. Regarding the financing, schemes can be either contributory, meaning that members finance the system through regular contributions or the scheme can be non-contributory thus directly state funded (ILO, 2017, p. 77). With regards to the provided payment, the system is either based on a defined benefit (DB) provision that is usually steered by legislation according to a formula describing what benefit is provided due to criteria such as contribution time or level of contributions. Many of these schemes are organized on PAYG basis, describing that the current contributors generate the pensions of current pensioners and rely on an intergenerational contract specifying that they will also profit from the contributions of the future labour force. Some of the DB schemes combine member inflows with parallel asset portfolio accumulation, particularly in the initial period where contributions exceed benefit payments (compare as illustrative example the Seychelles Pension Fund in Annex

I, section 3.1.2). The alternative system is based on defined contribution (DC), that specifies the contribution volume per month or year that is usually aggregated in individual capital accounts. The level of benefit at pension age is often subject to the returns that are generated from the contributed capital. This system is obviously only operative with fully-funded schemes (compare e.g. Holzmann, 2012, p. 1f; Pallares-Miralles et al., 2012, p. 34ff; Schwarz, 2006, pp. 4–14). In this system the member can often decide on the level of risk and the main risk of poor investment performance lies with the contributor, not the fund. Contrary, DB plans have distinct contributions and benefits, allowing the fund to obtain a potential premium but leaving the risk of underperformance exclusively to the pension fund. These differences have strong implications on investment strategies, liquidity and risk (compare Sawant, 2010, p. 23).

The qualitative and quantitative discussion and interpretation of advantages and shortcomings of the described systems on the global level is dominated mainly by three multilateral institutions with different foci and interest – the World Bank, the OECD and the ILO. While the World Bank started to intensively promote the substitution of public DB systems through privately managed, fully-funded DC schemes after the collapse of the socialist Governments at the beginning of the 1990s (see Holzmann, 2012, p. 2) , the ILO rejects that individuals shall bear most of the financial risks in DC schemes and therefore supports a strengthening of rather solidarity based public schemes and a reversion of privatized retirement systems (see ILO, 2017, p. 93ff). The OECD has a focus on the assessment of characteristics of capital-based pension schemes in its member states and thus tends to engage in systems compatible with the third pillar and the World Bank approach (see e.g. Cichon and Latulippe, 1998; Della Croce and Yermo, 2013; OECD, 2017b, 2017c, 2013b). This contentious interpretation of successful pension schemes is also reflected in the quantitative information and assessments these three institutions provide.

A World Bank survey among 176 countries shows a highly diverse coverage of current labour force by pension schemes. While about 90% of all high-income OECD labour force is covered by some form of pension scheme whereas only 10% of the labour force in South Asia or Sub-Saharan Africa benefits from retirement system coverage (see Figure 11).

Figure 11: Average pension system coverage by region



Source: Pallares-Miralles et al. 2012, p.81

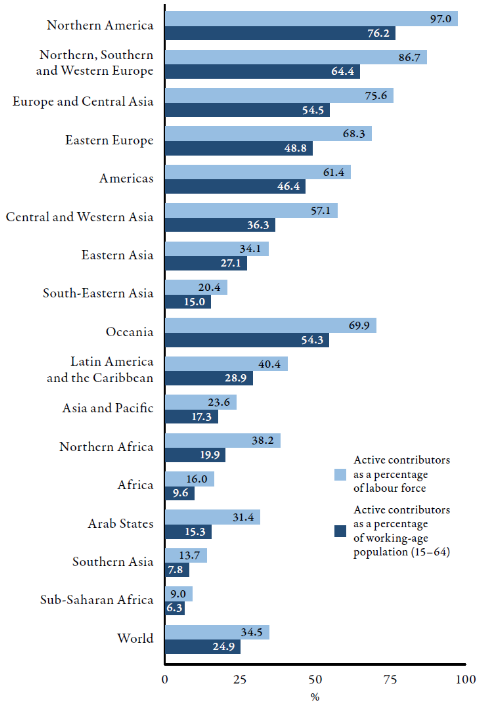
With regards to the characteristics of the pension schemes, about two third of the identified mandatory schemes are DB systems and 15% are DC systems, 6% have a tax financed first pillars only. About half of the schemes operate on an PAYG basis without direct state funding, the other half is either partially or fully capitalized. 80% of all systems are publicly managed while one fifth is privately managed.

Regarding the distribution according to the pillar categorization, the majority have a second, earnings-replacement pillar in place. Some countries have pillar one only and a few others only third pillars based on capitalized private savings (compare Pallares-Miralles et al., 2012, pp. 35–40).

The ILO does not apply the pillar categorization and relies instead of a presentation of contributory and non-contributory schemes. It reveals that 186 of 192 countries provide periodic cash benefits, often through a combination of schemes. However, many current pensioners worldwide do not have a legal right to income security yet and are dependent on the respective Government and its social programmes.

The predominant form of pension system design is featuring contributory and non-contributory schemes together. This is also reflected in the legal coverage of current workforce that builds up claims for income in the old age. Worldwide, about 40% are covered by mandatory and about 18% by voluntary contributory schemes. Non-contributory schemes cover about 25% of the workforce. The Arab States and Sub-Saharan Africa have the lowest rates of coverage (see ILO, 2017, pp. 77–78). About 35% of the global labor force contributes to pensions schemes, the shares are very different across world regions. While in North America and the EU a broad majority contributes, only 5 to 15% are providing resources in Africa and South Asia (see Figure 12).

Figure 12: Contributor coverage to retirement systems by world region

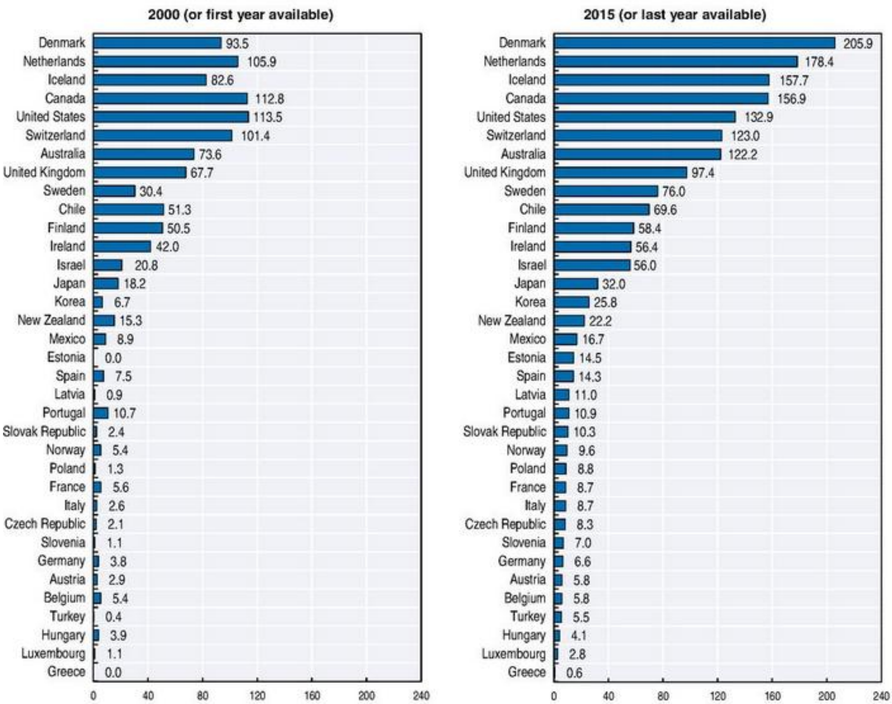


Source: ILO 2017, p.80

The OECD observes retirement schemes specifically in its member countries. In many reports, the organization explores the development of asset-backed schemes. In its most recent Pension Outlook, the OECD provides an overview of a strong growth of accumulated assets in private funded pension arrangements in correlation to the member countries' GDP. Figure 13 shows that individual savings grew by more than 100% in several smaller states like Denmark, Iceland or Sweden between the year 2000 and 2015. The overall nominal volume of these assets amount to USD 13.1 trillion in DB schemes and USD 7.9 trillion in DC schemes in 2015 (compare OECD, 2016b, p. 21).

This observation is broadly supported in literature. "In the industrial countries, public schemes for providing for the retired are predominantly of a PAYG type, whose coverage is typically comprehensive, but which are frequently supplemented by funded schemes, mostly operated by the private sector" (Chand and Jaeger, 1996, p. 1). Hereby the "role of private pensions in the provision of retirement income has grown significantly in the past two decades, reflecting efforts by many countries to trim down unsustainable pay-as-you-go benefits" (Tapia, 2008, p. 1).

Figure 13: Total OECD countries pension assets as % of GDP, 2000-2015



Source: OECD 2016, p.19

In this context, pension funds represent a sub-sector of institutional investors. They are fragmented into a diverse landscape of some bigger funds and a broad variety of smaller funds. About 20% of the pension fund assets within the OECD are held by about 20 funds with asset volumes larger than USD 20 billion while the majority of more than two thirds of assets is managed by funds with total volumes below USD 35 billion. The respective asset allocation is dominated by equity investments with more than 40%, fixed income including e.g. debt or bonds represents 33% and alternative assets make up 26% (compare Nelson and Pierpont, 2013, p. 8).

3.4.2. Pressure on retirement schemes and reform dynamics

Literature cites a number of challenges that pension schemes face. Among these are demographic, labor market and fiscal parameters such as declining fertility rates, improved health systems and wealth levels and therefore increasing average live ages but also public budget constraints or competing spending priorities and poor macroeconomic performances (see for instance Bloom and McKinnon, 2013, p. 2). Some of these challenges predominantly impact existing schemes in high-income countries, others are particularly relevant for low-income countries currently implementing pension systems.

What almost all societies face, are demographic changes in form of increased longevity and average age of population. For middle- and high-income countries, this leads to a growing proportion of elderly compared to the active working population. PAYG scheme maintenance in aging societies can become complex, as it either requires constant increases of payments from fewer contributors to higher numbers of retirees or a decrease of benefit levels jeopardizing adequate income levels of pensioners (compare for instance the German case study in chapter 5.2). Sustaining the benefit level based on rising contributions can lead to intergenerational tensions and disadvantages for the competitiveness of the economy. One answer is the increase of the statutory pension age and policies to keep elderly in the labor market (compare Holzmann, 2012, p. 8). Financial support from the state budgets can be a solution to stabilize contributions in PAYG systems without reducing benefit levels. This approach is only possible for countries that do not apply fiscal consolidation measures and reduce spending though. A shift from PAYG to fully funded, privatized systems as identified by OECD is another alternative option, applied by many countries. This approach of addressing fiscal pensions scheme deficits has been promoted by the World Bank since the beginning of the 1990s (compare e.g. Andrews, 2006, pp. 3–4). Contrary to the described demographic challenges for developed countries and emerging economies, the ratio of working aged population to elderly is expected to increase until mid of the century in low and lower-middle income states providing a chance for building sustainable pension schemes (compare Bloom and McKinnon, 2013, p. 8).

The implications of the financial crisis on pension schemes are threefold. First, it increased the indebtedness of many countries and pressed for reduced public spending. This minimized options for stabilizing public pension schemes. Second it temporarily reduced the value of assets held by fully funded pension funds and insurers. Many of them recovered until 2018. Third, the reaction of central banks to recover and stabilize economies and inflation rates led to very low interest rates for many financial market products including government bonds (compare e.g. OECD, 2016a, p. 112ff; Wyman, 2014, p. 12). The OECD highlights low and falling interest rates of capital market products as key risk for the assets and liabilities of fully funded pension schemes. This has impacts either on the solvency of DB asset-backed pension plans or the reliability of DC pensions. In both cases, the solvency, reliability and sustainability of the schemes have been jeopardized and many institutions still struggle to provide the promised benefits (see OECD, 2016b, p. 28). The authors revealed that many recent legislative reforms focused on closing DB arrangements and encourage savings in DC plans. This in turn shifts the financial risk from the provider to the recipient of the pension payments. ILO (2017, p. 88ff) supports this findings, stating that most public retirement systems provide declining benefits in future. Inadequate adjustments to inflation and reforms in the context of austerity measures and fiscal consolidation are highlighted as main reasons.

To address these challenges, many industrialized and developing countries started the implementation of retirement system reforms (compare e.g. OECD, 2017b, p. 16ff, 2013b, p. 3ff). According to Schwarz (2006, p. 16ff), pension reforms can be clustered in four categories:

- Parametric reforms continue the application of pension schemes in place but adjust key parameters. These parameters include for instance contribution rates, wages that are subject to contributions, the accrual rate determining the level of benefit per year, the postretirement indexation of pensions, the level of minimum pensions or eligibility conditions comprising of the statutory retirement age or the years of contributions required before receiving a pension.

- Systemic reforms change the underlying scheme, e.g. from DB to DC. This happened during the past two decades. Such reforms can resolve the fiscal challenges of social systems or allow smoothed consumption among individuals. But they also inherit the threat of losing the safety net for protecting members against capital market fluctuations or insufficient benefit payments. Other systemic reforms include a change of the financing system, e.g. from PAYG to non-contributory, tax-financed schemes.
- Regulatory reforms can include adjustments of investment guidelines leading potentially to fairer treatment of contributors with less financial knowledge on the pension scheme members side. On the capital market side, regulatory reforms can steer the allocation of resources towards specific asset classes.
- Administrative reforms aim on the simplification or unification of multiple systems in order to improve and streamline the operation. Such reforms may benefit the fiscal structure due to reduced transaction and management costs. Further it can improve the service and transparency while reducing the risk of embezzlement and corruption. However, some stakeholders participating in a fragmented system may lose individual benefits and poverty levels might increase temporarily.

3.4.3. The specific situation of developing countries

While developed countries discuss reform steps, many developing countries do not have any system in place for large parts of their population. "Worldwide, the most dramatic aging is projected to take place in low and middle-income countries. Traditional family-based care for the elderly has broken down in many developing countries without adequate formal mechanisms to take its place" (Pallares-Miralles et al., 2012, p. 12). The ILO highlights that in lower-income countries only a minority of the labour force is employed with formal contracts. This in turn challenges a widespread coverage of population by retirement systems. Thus the authors posit that effective coverage "seems to be strongly associated with a countries income level, although it is in fact labour market structures, law enforcement and governance that actually exert the critical influence" (ILO, 2017, p. 80). Also ensuring gender equality remains a challenge. Women coverage under contributory systems is lower than for men as women tend to spend more lifetime for childbearing and childcaring instead of participating in the labour force. "Providing economic security for the elderly may well be the single biggest social and economic challenge facing developing Asia in the 21st century" (Park and Estrada, 2013, p. 2) as well as many developing countries in Africa or Latin America.

Developing country-oriented economists like Max Neef reflect social security as an important development objective. In Neef's (1992, p. 85ff) taxonomy of Human Scale Development that addresses the satisfaction of basic human needs he posits social security as key element of protection. Furthermore, he stresses the need to restructure the financial and banking system in order to stimulate community saving and circulate surpluses among the people that create them. This emphasizes the need for developing countries to implement social systems for the elderly with strong involvement of the population, both in terms of security and financial benefits.

With regards to an appropriate design of pension schemes in developing countries, Bloom and McKinnon (2013, p. 13) suggest that policymakers discuss reforms beyond the existing frameworks, take into account the formal and informal sectors of employment and reflect the capabilities of the countries respective financial institutions. In this context, Schwarz (2006, p. 3 and 15) defines poverty reduction and consumption smoothing as the two key objectives of pension systems. It is up to the societal priority of the respective countries to prefer or focus on one of these purposes. Many countries also apply different instruments to achieve both objectives.

Summarizing the global status quo of pension schemes and reforms that have been implemented, three key findings are particularly relevant for the SIP system discussion:

First, about one third of the elderly are not covered by any pension support, particularly in South Asia and Africa. About one third of pensioners that receives benefits depend on non-sustainable government programmes without having a long-lasting legal right for income security.

Second, the remaining third contributes resources to either DB or DC schemes thus building up claims for future pensions, that inherit legal coverage as well as usually higher benefit payments than non-contributory systems.

Third, there is a trend from solidarity based PAYG frameworks towards asset-backed, fully funded schemes that invest large volumes of private property in financial market assets. Pension schemes of several OECD countries hold assets that are higher than the respective GDPs. Associated risks are transferred to the scheme members and the 2008/2009 financial crisis proofed that they have to bear losses as DC systems provide reduced benefit levels after asset returns underperformed.

3.5. Summary from the SIP perspective

On the one hand, chapter 3 had the objective to identify the gap for future sustainable energy investment needs and assess the role of pension funds for energy infrastructure financing. On the other hand, the chapter's purpose was to reveal the global status of retirement systems and the role of capital allocation within the pension fund landscape. The most important findings from the perspective of a potential SIP system include:

- While the current investments into energy infrastructure stand at about USD 1.8 trillion per year, a global development and transformation of the energy system compatible with the Paris Agreement and the SDGs will require about USD 2.8 to 4.4 trillion annually until 2050.
- While a significant financing gap for energy infrastructure in developed countries is currently not observed, developing countries lack sufficient resources to successfully prolong a low-carbon development pathway. Despite solid studies on future energy transition investment needs, a precise future financing gap is not transparently quantified by literature. In order to address upcoming investments, studies recurrently emphasize the need to mobilize private capital at large scale.
- So far, the main share of capital expenditure for energy infrastructure is sourced by banks and channelled via loans or bonds to balance sheets of project developers, utilities, specialized companies or households that finally invest in energy transformation equipment. Institutional investors including pension funds do hardly play any role, representing approximately 0.5% to 1% of the total investment.
- Institutional investors could reduce costs of finance in developed countries and address the shortage of resources in developing countries. Literature cites

sovereign wealth funds, insurers or pension funds recurrently as required solution for financing future energy investments.

- There are various barriers that hinder institutional investors to engage in energy transformation investments. Pension funds have specific, unique barriers but also remain unaffected by constraints other investors have, moving them into an advantageous position for certain investments.
- Many pension funds can harvest premiums for specialized investment characteristics they are able to bear such as long-term horizons, illiquidity or higher transaction costs. This premium value can be theoretically shared between the pension system shareholders, it's members and the buyers of the energy transition outputs such as renewable power, transmitted power or energy efficiency benefits (compare also the discussion of distributional impacts by potential SIP schemes in chapter 4.3.1).
- Pension schemes in higher income countries are under reform pressure due to demographic and fiscal impacts. Pension systems in lower income countries do not cover sufficiently the population and will be further expanded.
- Asset-backed retirement schemes are increasingly implemented and partly substitute existing public systems. Due to macroeconomic impacts resulting from the financial crisis in 2007-2009, return expectations from traditional capital market products have decreased significantly. Thus, pension managers seek for innovative investment opportunities providing higher returns.

4. The Sustainable Infrastructure Pension (SIP) Concept

This chapter discusses the basic elements of the SIP concept. It reviews existing literature elaborating on pension schemes that explicitly finance sustainable energy investments, describes existing examples and approaches of respective private and public institutional investors, describes the main elements of a SIP scheme, outlines required design features, qualitatively discusses potential impacts of SIP on retirees, society, pension scheme performance and energy transitions and sketches required regulatory and economic frameworks to enable investments. This work represents the theoretical and conceptual base for conducting the case studies in the later chapters.

4.1. Existing work on linking pension systems and sustainable energy investments

As reflected in chapter 3.2.4, there exist various literature assessments on infrastructure investments by institutional investors. They focus on investment volumes (Buchner et al., 2017; Della Croce and Yermo, 2013; IEA, 2017b; Woetzel et al., 2016), individual characteristics and challenges (compare for instance Inderst and Della Croce, 2013; OECD, 2013a), economic benefits for investors (Allianz, 2015; Beltran et al., 2017; EY, 2014; Liesch et al., 2017) or solutions and strategies to address barriers (Bitsch, 2012; Fulton and Capalino, 2014; Laboul and Dell Croce, 2014; Sawant, 2010; Underhill, 2010). Some authors explore particular investments in sustainable infrastructure including energy assets (Buchner et al., 2017) or renewable energies (Buchner et al., 2018; Dichtl, 2018; IRENA, 2016; Nelson and Pierpont, 2013; Varadarajan et al., 2017). All these publications analyse existing institutional investors and partly discuss how to scale-up their funding, often in a sound scientific way. But they do not explicitly reflect an intended combination of a pension scheme and sustainable energy development.

Contrary to the literature landscape reflecting institutional investors and infrastructure financing, there are some authors and institutions dealing with centralized state funds explicitly targeting climate mitigation finance including transformative energy infrastructure. They however emphasize sovereign wealth funds (SWFs) that are funded by currently not existing carbon taxes or fees (WBGU, 2016, p. 26ff). Bönke and Harnack (2017, p. 19f) suggest additional government debt or shifted government subsidies as capital inflows for the creation of transformative infrastructure state funds. These approaches discuss the implications on society and the institutional set-up comprehensively but remain vague on the details of financing and investments. A linkage of infrastructure with pensions is not discussed.

Finally, there is rare literature discussing a planned combination of capital-based pension schemes and large-scale sustainable energy development towards 100% renewables. Two of the few examples comprise of Flämig (2016) discussing a Climate Protection Pension for Germany and Corbell et al. (2018) matching the allocation of annual Australian pension contributions with a 100% renewable energy transition in Australia. Both concepts are further explored in the following, Flämig's approach is additionally reflected in option 4 of the German case study (compare chapter 5.4.4). Flämig (2016, p. 120 and 122) suggests a "strategy for the century" that builds on an ecological-social market economy with broad participation, described as "Agenda 2100". It consists of several sub-goals addressing a sustainable transformation of the society. Among these are the realization of 100% renewable energy supply, resource- and energy efficiency gains across all sectors, cradle to cradle concepts, smart infrastructure, decentralization and a broad participation of the society (compare Flämig, 2016, p. 141). In this context he suggests as key financing tool an additional, fourth pillar mandatory pension scheme that introduces an additional 2 percent payment by the employed population as well as workforce that are not insured yet, summing up to the whole employed work force of about 45 million people. The funds shall be invested for climate protection as well as ecologically and economically reasonable assets. The federal state should guarantee the saved capital. Pension payments can start after 45 contribution years or when the eligible retirement age is reached. It shall be paid out through a fixed amount calculated by the saved capital plus interest divided by the average life expectancy at pension start. In case of premature death before statutory retirement age, the relatives receive the saved capital. The minimal interest rate shall be above comparable products.

The investments have to focus on "intelligent supply by renewable energies (heat, power, mobility), resource and energy efficiency programs, preventive climate protection and adaptation measures as well as structures and technologies that are required as sustainable basis" (Flämig, 2016, p. 99). This includes applications in housing, supply and culture or industry and services. Hereby concepts like green economy, blue economy or common welfare economy shall be implemented in decentralized units targeting mainly small and medium enterprises (SMEs). According to Flämig (2016, p. 238), the mid-term prioritization of investments are 40% energy transformation, 20% sustainable infrastructure with smart technologies, 20% resource efficiency and recycling structures, 10% blue economy and 10% climate change adaptation. This prioritization should be publicly discussed and adjusted over time.

The operationalization requires an allocation mechanism that invests the funds to Small and Medium Enterprises (SMEs) in Germany. The author suggests the Fund to be managed by the German Pension Insurance (Rentenversicherung Bund) which would be responsible for the account administration of the insured population, the Kreditanstalt für Wideraufbau (KfW) responsible for the overall allocation and on the ground disbursement through Sparkassen and Raiffeisenbanken. Hereby Flämig expects the KfW to provide the allocation framework based on specialized funds targeting the different elements of the transformation. The contributors shall have the right to allocate annually their funding to the different KfW funds that also lead to different interest rates. The KfW would be responsible to transparently inform about the economic success of the different funds and specific projects. Flämig expects that this would lead to higher transaction costs for all involved stakeholders but at the same time increases acceptance among the impacted part of the population. Regarding the financial instrument, the author foresees the application of mezzanine funding for SMEs that are facing limitations of bank credit supply due to the Basel III regulation (compare also chapter 3.2.1). Mezzanine capital is a specialized form of equity that is associated with lower risks but also lower return rates than traditional equity. It does not allow direct influence on the enterprise operations and has a predefined maturity. From a macroeconomic point of view, Flämig stresses the advantage that the increased, mezzanine-strengthened equity of many SMEs would allow them to better attract debt thus strengthen the SME sector overall. To decrease risk of default, he suggests state guarantees for all default cases. There is no quantitative estimation what additional federal resources would be required to cover this element.

Flämig also discusses the aspect of additional burden through the climate protection pension. He refers that this might lead to additional cost and rationalizing pressure on enterprises and employees but justifies this additional pension payments through elaborating on pressing needs. Instead of consuming resources, Germany requires investments into its social, environmental and ecological future while future costs of climate change will increase with higher proportions. The aging population requires new retirement systems. Financing climate protection through an ecological-social generation treaty is more robust than fragile financing through taxes and fees. The investment shall be resilient and sustainable through on ground disbursement to SMEs by local banks. Thus, he concludes that a mandatory two percent increase of the social insurance levy is reasonable for both employees and employers.

However, the challenge how KfW and local banks will be able to identify suitable SMEs to invest up to EUR 40 billion annually is not further addressed. It is not described how the financial structures for using mezzanine finance will be set up. The concept lacks clarity whether it foresees balance sheet funding of SMEs or whether it flows into project-based finance. A focus on equity-like mezzanine would not allow to realize equity advantages such as transparency and control while at the same time neglecting the positive aspects debt funding could offer for the overall approach such as reduced risk mitigation potential, tax-shielding benefits and cash-flow stability (compare also discussion in chapter 4.5.1). The broad distribution of assets might diminish the potential of the overall, centralized idea to avoid government holdup as the variety of elements cannot be properly controlled and addressed by the KfW's and local banks' management. Summing up, the suggested approach is highly ambitious in terms of political innovation but will likely lead to significant transaction costs and inherit a high potential for default, covered by state guarantees. This in turn decreases returns and likely imposes political resistance against taking up unquantifiable taxpayer risks. Summing up, the publication provides mainly a comprehensive justification why countries might engage in realizing a SIP scheme and what implications on society are associated with such approach. These elements are further discussed in chapter 4.3.

Corbell et al. (2018, pp. 6–17) describe the investment needs for Australia's energy transition until 2050 and compare them to the total pension contributions provided to the countries' capital-based DC schemes. They quantify the share of contributions required for covering the 100% investments with three assumed rates of returns on provided capital. However, the authors do not transparently disclose their calculations, neither they discuss any further implications on society, pension schemes or energy transition. Thus, the result is rather a matchmaking of expected pension payment versus energy infrastructure investments than a scientific assessment.

Concluding, the variety of literature on institutional or SWF investments in renewables as well as the two SIP-like examples demonstrate that the idea of investing pension contributions in sustainable infrastructure development in an intended and coordinated manner is increasingly reflected around the globe. Scientific literature analysing the requirements, advantages and challenges that intended combinations of pension schemes and sustainable energy investments comprise are unavailable to date.

4.2. Analysis of exemplary investment institutions

For financing energy infrastructure in a SIP context, theoretically public or private institutions and sources are available. They are characterized by diverse facets and facing different challenges and barriers. The following section assesses prominent private and public systems and funds that engage in infrastructure financing, including transformational energy supply elements. The results are applied to discuss SIP objectives, the SIP concept and SIP elements in the precedent chapters.

According to the investment data provider IPE, both private and public entities are among the institutions owning the largest volumes of infrastructure assets. As shown in Table 4, these institutions include SWFs, insurances and pension managers. Canadian institutions dominate the landscape with five entities in the top 10.

Table 4: Ranking of the 10 largest infrastructure investors, by asset value

Name	Country	Asset value in USD billion	Ownership	Origin of funding
China Investment Corporation	China	52.9	Public	Non-commodity
Abu Dhabi Investment Authority	UAE – Abu Dhabi	24.8	Public	Oil
Canada Pension Plan Investment Board	Canada	22.4	Public	Pensions
Allianz	Germany	18.6	Private	Insurance
National Pension Service	Canada	16.6	Public	Pensions
Ontario Teachers' Pension Plan	Canada	14.9	Public	Pensions
APG	Netherlands	13.7	Public	Pensions
Ontario Municipal Employees Retirement System (OMERS)	Canada	13.6	Public	Pensions
Caisse de depot et placement du Québec (CDPQ)	Canada	12.9	Public	Pensions

Legal & General Investment Management	UK	11.8	Private	Pensions

Source: Own table based on (IPE Research, 2018). Status 10/2018

While this ranking indicates that mainly public entities invest in infrastructure assets, there are also numerous private equity managers that raise private and public capital from different investors and manage it in pooled funds that engage in infrastructure financing. Despite many of those entities do not possess directly the infrastructure assets they manage, their applied methods, procedures and approaches can serve as helpful guidance for deriving SIP relevant design elements.

Thus, the following two sections further analyse illustrative examples from the private and public sector that provide additional information about best practice approaches and design features for successful infrastructure investments in general and sustainable energy engagement in particular.

4.2.1. Analysis of private infrastructure investment activities

Specialized private firms like railroad operators or utilities that invest in their specific infrastructure base have a long history. But financial-market raised, large-scale private equity or debt investment in infrastructure assets is a rather new phenomenon. According to PwC (2017), the first wave of private infrastructure investments mid of the 2000s was organized in professionally managed funds. Based on strong asset management capabilities, these funds invested indirectly in listed and directly in unlisted long-term infrastructure assets. Acquisitions have been realized mainly from governmental or corporate vendors. Table 5 shows the 10 largest managers of equity investments in infrastructure, demonstrating a strong Anglo-Saxon representation of institutions.

Table 5: Ranking of 10 largest equity infrastructure investment managers

Name	Country	Asset value in USD billion
Macquire Infrastructure and Real Assets	Australia	86.7
Brookfield Asset Management	Canada	69.3
M&G Investments	UK	55.1
Global Infrastructure Partners	USA	37.8
IFM Investors	Australia	32.2
The Carlyle Group	USA	21.2

DWS	Germany	17.9
BlackRock	USA	16.0
Energy Capital Partners	USA	15.7
EIG Global Energy Partners	USA	14.8

Source: Own table based on (IPE Research, 2018). Status 08/2018

Private pension funds, insurance companies and investment funds have entered the market since the financial crisis in 2008/2009. They bring capital with lower costs and longer investment horizons but also inherit limited capabilities and therefore appetite for risk-reduced minority stakes. Particularly the risks and challenges of greenfield project investments "are typically beyond the remit of many specialist investors" (PwC, 2017, p. 15). Privately managed infrastructure investments are part of the current scientific discussion as well as the operative business of financial service providers. Bitsch (2012) explores the role of infrastructure funds in financing projects and the importance for private investors. He particularly assesses empirically whether privately managed infrastructure investments are characterized by specific facets, taking into account not only listed but also unlisted infrastructure funds. Key result of Bitsch's research is that there is a heterogenous environment of infrastructure investments, ranging from indirect to direct and listed to unlisted assets (compare Bitsch, 2012, p. 169).

However, the existing investment opportunities for private actors are limited as core infrastructure tasks are public responsibilities in many countries and new infrastructure fields often lack sufficient regulation to stimulate private investments. One opportunity for interested private actors is privatization of existing, public infrastructure. Promotors of infrastructure privatization typically stipulate efficiency gains associated with private operation (compare Kessides, 2005, p. 82f; or Martimort and Straub, 2007, p. 6). One the one hand, they are postulated to stem from increased competition. To avoid a monopolistic or oligopolistic market environment, the government has to ensure a variety of actors in the infrastructure sectors. Related competition might lead to higher revenues for the contributors of a potential SIP scheme and/or lower costs of capital for infrastructure investments (compare also the discussion of distributional impacts in chapter 4.3.1). On the other hand, innovative investments identified by the private actors could lead to new energy infrastructure solutions or additional co-benefits. That competition and a variety of market actors can generate innovative solutions for GHG mitigation project types was shown by new project types identified in the context of the international market mechanism under the Kyoto Protocol, the Clean Development Mechanism (compare Ruthner et al., 2011, p. 13f). With regards to efficiency gains, PwC (2017, p. 11ff) provides a number of selected examples aiming to demonstrate positive impacts of infrastructure privatization. For instance, the authors state that private power distribution owners in Australia operate their assets cheaper than public ones, opening space for increased profits as well as lower tariffs. Privatized UK electricity suppliers reduced outages and supply interruptions. Significantly reduced water leakage in the UK due to private investments allowed the regulator to decrease water tariffs. Private capital investments led to the treatment of almost 100% of Chile's wastewater in 2015, instead of 21% only in 2000. Broad literature reviews by Birdsall and Nellis (2003, p. 5f) or Martimort and Straub (2007, p. 6) support these findings highlighting improvements in operating performance and quality, reductions in distributional losses in the water and electricity sector, high profit margins for the new shareholders and no significant impacts on welfare, output and coverage. Further the authors state that privatization led to improved fiscal stability of the state budgets and was in most case beneficial for the new asset owners.

Despite these rather positive evaluations of infrastructure privatization, public discontent with privatization has grown significantly. For instance Kessides (2005, p. 8) shows that the percentage of population in 15 Latin American countries disapproving privatization has grown from less than 50% at the end of the 1980s to 70%-90% in 2002. A variety of literature tries to explain this development by discussing the shortcomings and negative implications of privatized infrastructure. Particularly price increases for costumers and a reduction of employed labour was observed in the context of privatized infrastructure (compare Birdsall and Nellis, 2003, p. 6ff; or Martimort and Straub, 2007, p. 6). Apart from macroeconomic impacts also fatal accidents in privatized infrastructure led to resistance and renationalization of the systems in some cases. For instance, four railway accidents with dozens of deaths and hundreds of injured people in the UK between 1997 and 2002 resulted from underinvestment in privately operated rail tracks (Bowman, 2015, p. 5). Schreiner (2018) assumes an intended and coordinated privatization effort of infrastructure and pension schemes in some countries. He argues that public debt limitations lead to an intended reduced ability of public funding requiring private capital for infrastructure investment. A privatization of pension systems provides this capital.

Concluding, literature provides no clear evidence for or against privatized infrastructure but highlights the need of well-structured regulation (Kessides, 2005, p. 85f) and suggests to emphasize equity benefits instead of strong efficiency gains in the short-run (Birdsall and Nellis, 2003, p. 13).

Regarding private, institutional investments in new infrastructure assets, Inderst and Della Croce (2013, pp. 9–54) highlight Australia and Canada as exemplary frontrunners. In Australia, PPP models have been adopted since the early 1990s, creating one of the biggest privatized infrastructure markets worldwide. At the same time, the introduction of a compulsory occupational DC pension system covering more than 70% of the work force aggregated approximately USD 1.4 trillion of asset value by 2012 (compare also chapters 3.4.1 and 4.1). This decentralized scheme is predominantly managed by privately managed pension funds. Even though the DC system allows easy switching of members thus requiring liquidity, the authors estimate that about 5-6% of their investments are in rather illiquid infrastructure, representing one of the highest shares globally. The pension funds traditionally outsource their investment activities to about 10 to 20 external fund managers that mainly apply unlisted equity funds. Key Australian managers represent Macquire, IFM, Hastings and Babcock & Brown (compare also Table 5). Geographically, the focus shifted from domestic investments towards international activities. Australian pension funds have the longest experience with infrastructure investments globally.

Inderst and Della Croce (2013, p. 25ff) state that pure privatization is not popular in Canada but institutional investors are an important source of project finance bond markets. At the same time, Canadian pension funds hold assets with a volume of approximately USD 1.1 trillion representing about 65% of the national GDP. About 60% of the assets are held by public institutions while about 40% are possessed by private insurers and private pension funds. The market is diverse with more than 5,000 corporate pension schemes, predominately designed as DB systems. Some of them are mandatory for specific parts of the labour force, others are voluntary. As analysed in chapter 3.4.2, DB schemes are increasingly underfunded which is also the case for many Canadian systems, most of them have negative cash contribution flows. Infrastructure constitutes about 5% of the total asset portfolio which is a comparably high value, the assets are located in Canada and abroad. Particularly larger pension plans substantially invested in infrastructure assets, the so called "Canadian model" of direct investments in infrastructure through unlisted funds has attracted global attention (compare Inderst and

Della Croce, 2013, p. 31). Hereby, the pension funds take leading roles in the direct investments and provide the required expertise and skilled staff in-house. The authors identified the DB characteristic with long-term planning abilities, the large size of the funds, the strong governance models with independent Boards and the internal capabilities as key success factors. Private and public Canadian pension funds are characterized as the most experienced infrastructure investors globally with a focus on internally managed, direct investments. According to Nelson and Pierpont (2013, p. 26), also Dutch private pension funds are increasingly capable for direct infrastructure investment activities including sustainable energy assets. Designated pension providers that are regulated by the Dutch Central Bank manage about USD 350 billion of assets. Due to pooled pension provisions, the funds have been able to create "larger and more sophisticated investment teams than elsewhere".

A prominent example of a private institutional investor represents the Allianz insurance. On the one hand it is one of the biggest owners of infrastructure (compare Table 4 above), on the other hand it is active in the promotion of low-carbon infrastructure investments. Allianz provides comparably transparent information on their low-carbon investment activities and internal procedures. According to their own information they started to divest coal assets in 2015 and increased their renewable energy assets to a total of EUR 5.6 billion by the end of 2017 (see Juretzek, 2018, p. 34). Beneficial characteristics of renewable energy assets are predictable, long-term cash yields, large and growing investment opportunities and no correlation with capital markets thus leading to portfolio diversification. As financial instrument, the Allianz prefers equity without external leverage of additional debt resources. Geographically, they focus on the EU (see Allianz Capital Partners, 2019). An in-house renewable energy asset management team with experience in project development, financing, construction and operation as well as the integration of Environmental, Social and Governance (ESG) standards into internal processes enabled direct equity investments. In cooperation with the NGO Germanwatch, Allianz publishes rankings of low-carbon investment needs and investment framework attractiveness of the G20 states (see Liesch et al., 2018).

Apart from the discussion whether privately operated infrastructure is generally beneficial for the majority of the population, global examples show that large private institutional investors are increasingly active in the field of infrastructure investments including sustainable energy. Pension funds and insurances from higher income countries started to build internal expertise and try to pool investments that allow direct engagement.

4.2.2. Selected examples of public systems and funds

Since the first publicly managed institutional investors built up internal staff for infrastructure investments in Canada in the 1990s, many other public Sovereign Wealth Funds (SWFs), public pension funds or specially created funds engaged in infrastructure financing or considered to do so (see Bitsch, 2012, p. 160f). Also, smaller sovereign development funds in various countries engage partly in energy transition financing. For instance, the Ireland Strategic Investment Fund manages about EUR 8 billion of public service pensions until at least 2055, "investing in sectors of strategic significance to the future of the Irish economy" (ISIF, 2019). Among the investments are more than EUR 250 million in renewable energy assets.

Three examples of public institutions, that disclose manifold information and provide valuable experience for the discussion of the SIP scheme, are analysed subsequently. Two of them are among the 10 largest SWFs globally (see Table 6), the Government Pension Fund Global in Norway and Temasek Holdings in Singapore. Additionally, the UK Green Investment Bank is reflected as it is one of the first public institutional investors specifically created to promote an energy transition.

Table 6: Ranking of the 10 largest Sovereign Wealth Funds, by asset value

Country	SWF Name	Asset value in USD billion	Inception year	Resource origin
Norway	Government Pension Fund Global	1,058	1990	Oil
China	China Investment Corporation	941	2007	Non-commodity
UAE – Abu Dhabi	Abu Dhabi Investment Authority	683	1976	Oil

Kuwait	Kuwait Investment Authority	592	1953	Oil
China – Hong Kong	Hong Kong Monetary Authority	523	1993	Non-commodity
Saudi Arabia	SAMA Foreign Holdings	516	1952	Oil
China	SAFE Investment Corporation	441	1997	Non-commodity
Singapore	GoS Investment Corporation	390	1981	Non-commodity
Singapore	Temasek Holdings	375	1974	Non-commodity
Saudi Arabia	Public Investment Fund	360	2008	Oil

Source: Own table based on SWFI (2018). Status 12/2018

Norwegian Government Pension Fund

By end of 2018, the Norwegian Government Pension Fund that comprises of a Global (GPFG) and a Norwegian (GPFN) section, manages the largest volume of financial assets worldwide. It owns about 1.4% of listed companies' stocks worldwide and about 2.4% of listed European companies' stocks and has the objective to enable a long-term government spending of Norwegian petroleum revenues and management of the national insurance system savings (see Norges Bank, 2018). Thus, it ensures sound management of wealth to intergenerational benefit. GPFG is managed by Norges Bank Investment Management, a part of the Norwegian Central Bank and GPFN is operated by Folketrygdfondet, the National Insurance Scheme Fund. While the GPFN has a comparably small asset volume of about USD 15 billion and invests in Norwegian and Nordic companies' stocks only, the GPFG has a volume of about USD 1,000 billion and is funded by oil revenues. GPFG invests mainly in international equity through stock markets, debt markets and up to 5% in real estate. The annual return rate across the portfolio averages at about 5.5% between 1998 and 2016 (compare Norwegian Ministry of Finance, 2017, p. 9ff).

The Funds investment strategy aims to profit from investments that offer risk premiums over long time horizons. Its operation is characterized by s diverse range of the investments, a responsible investment practice, cost-effectiveness and a clear governance structure. The main objective of the management framework is to achieve maximum possible return with a moderate risk level while guaranteeing transparency and ethical awareness. For the latter, the government created a framework for responsible management with a council for ethics that excluded about 125 international enterprises due to human rights violation, severe ecological damage, corruption and production of nuclear weapons systems. Since 2016, the Fund added new climate change exclusion criteria. One reflects unacceptable volumes of GHG emissions in operation which is not yet implemented. The second criterion targets on mining companies and energy producers that derive 30% or more of their revenues or base 30% of their operations on thermal coal. This led to the additional exclusion of 59 companies in 2016 (compare Norwegian Ministry of Finance, 2017, p. 95ff). Moreover, Norges Bank stresses that it promotes international principles and standards and exercises ownership rights through voting and engagement with companies. "Corporate governance, environmental and social considerations are integrated in the investment process and in risk management" and in all decisions "transparency is a prerequisite for securing widespread confidence in the management of Norway's saving in the GPFG" (Norwegian Ministry of Finance, 2017, p. 17).

In 2018, the government and parliament rejected an approach to allow unlisted, direct infrastructure investments. Based on a Norges Banks and McKinsey assessment the Ministry of Finance concludes that on the one hand structural advantages such as the size or the low liquidity needs eventually prioritizing long-term infrastructure engagement in a hypothetical, isolated scenario above listed investments. On the other hand, it is stated that direct infrastructure projects are highly complex, return expectations are uncertain and highly depend on the respective managers capabilities (see Nahem and Lindvag, 2018, pp. 2–4; Norwegian Ministry of Finance, 2017, p. 63ff). Particularly the importance of infrastructure to local communities and the resulting exposure to political, regulatory and reputational risks is emphasized. Also, the small market for unlisted infrastructure challenges liquification of assets. Due to the existing staff number, internal expertise, investment structure and risk management it is expected that significant adjustments and upgrades would be required. Thus, administrative and transaction costs would increase while liquidity would decrease. However, renewable energy investments might be handled differently. As Sanzillo et al. (2017, p. 35) evaluates particularly renewables as infrastructure with comparably high revenues and lower risk, there is the discussion to allow Norges investments in stocks of utilities engaged with renewables under the current investment mandate and further options for engagement in unlisted renewable energy opportunities in the future (see Fixsen, 2018). In this context, recruitment of specialized staff and co-investment partnerships are suggested as prerequisites.

Despite the size of the fund making it an illustrative example of managing people's resources in a prudent way, there are mainly three other elements that are relevant for the SIP discussion. First the fund sets standards in terms of transparency as it provides detailed information about investments, operations, and governance. Second, the political consensus backing the fund's objectives and operation highlights the advantage of cross-party support. As being managed by the independent Norwegian Central Bank, politicians have not interfered in day-to-day business of the fund however society is strongly influencing the underlying investment framework. The strong ethical investment guidelines excluded assets with relation to weapons or human rights violations from the beginning. Furthermore, the fund was the first large SWF that decided to divest GHG intensive assets, influencing the climate finance debate significantly and giving an example of "making financial flows consistent" with Article 2 of the Paris Agreement. Third however, the fund is not an example of unlisted, direct infrastructure investment. After long debates, the government has decided to not allow direct project financing at this time. Particularly the risk of government holdup coupled with transparency, regulatory and reputational challenges that the fund and its managers expect, are the decisive elements for rejecting such engagement (compare chapter 3.3.1).

Temasek Holdings Singapore

After independence from Great Britain, the Government of Singapore owned various small and large businesses and enterprises, including an airline, a shipping company, and a zoo. In 1974 it decided to focus on macroeconomics and outsource the management of the individual enterprises worth USD 354 million to a public investment company called Temasek Holdings. With its sole shareholder, the Singapore Ministry of Finance, it is classified as one of the oldest and largest Sovereign Wealth Funds globally. By March 2018, Temasek's net portfolio value grew to USD 308 billion, multiplying the original asset value by 870 times. About one quarter of the managed resources are invested in Singapore, 50% in Asia and the remaining share in the rest of the world. Infrastructure in a broader sense, including transportation, industrials, energy, and resources accounted for about one quarter of the total asset value. Unlisted assets including direct project finance are making up about one third of the total portfolio. Temasek achieved a shareholder return of 15% since its inception in 1974 while recent average returns were fluctuating between 5% and 12%. Up to 50% of the annual dividends of ~USD 8 billion in average per year are transferred to the Singapore state budget while the remaining share builds future reserves (compare Temasek Holding, 2018, pp. 5–35). According to Temasek (2018, p. 41), the organisation is committed towards "ecosperity", twinning prosperity with ecology. The organization refers to all 17 SDGs, highlighting sustainability, intergenerational interest and long-term focus of its investments. Cummine (2014) highlights the importance of Temasek for Singapore's past development. It acted as an establisher of start-ups and investor in strategic infrastructure sectors like transportation, utilities, electricity generation or telecommunication that have been privatized by the Singaporean Government during the 1990s. From the early 2000s onwards, the Singapore's prime minister's wife took over responsibility of Temasek, shifting the focus from domestic engagement only towards global activities. According to Cummine, formally neither the president nor the government of Singapore can influence Temasek's investment decisions, nonetheless the institution was and will be an important provider of basic services to the Singapore population. Summing up, Temasek serves as an illustrative example how a SWF can be succesfully involved in direct, unlisted large-scale investments within its own country. Also, the reflection of climate change and SDGs in its investment decisions is an interesting experience for the SIP concept.

Green Investment Bank UK

Around the year 2008, it became evident that the UK will not be able to achieve its international and domestic climate change goals leading to a decarbonization of economy and an energy transition that faced barriers and market failures creating a significant investment gap of up to two thirds of the required capital (see Bundock et al., 2011, p. 5). In order to address this shortcoming, a broad campaign mainly led by the think tank E3G and the NGO Friends of the Earth led to the proposal of a Green Investment Bank (GIB) supported by many NGO's, unions, business and financial institutions. The idea finally received cross-party political support and all leading parties had the establishment of GIB in their 2010 election programmes. Following the elections, the winning Conservative-Liberal coalition government initiated a commission to explore the design of the GIB.

Finally, the Bank was legally established in 2012 (compare Holmes, 2013). Its main objective was to support the government achieving its climate change goals through provision of resources for green infrastructure assets and support UK's energy transition. This was to be achieved through leveraging private capital by offering attractive risk-return ratios of the underlying assets. It was decided that GIB shall be established as an independent financial institution in form of a public company, giving it "sufficient freedom to pursue its objectives and intentionally constrain its investment activities" (UK NAO, 2017, p. 6ff). Competent staff specialized on energy and waste financing was recruited, to allow a rapid and sustainable start of financing activities. The number of employees reached about 120 by 2017. To comply with EU state aid principles, GIB was required to invest in-line with key principles, including an encouragement of others to invest, avoidance of crowding out other investors and invest on terms acceptable to commercial investors. As initial capitalization, the government agreed to provide up to GBP 3 billion until 2015. Borrowing of capital from the financial market was not allowed by the government, restraining the financial capacities of GIB significantly. This limitation was criticised by media and environmental groups as unambitious jeopardizing the paramount goals of GIB. The governmental reaction pointed to the fiscal deficits the UK budget faced at this time, highlighting a need to limit additional debt from state organizations (compare e.g. Carrington, 2012; Harrabin, 2011). Thus, the financial structure of GIB ended up rather as a fund than a bank.

By March 2017, GIB committed almost GBP 3.5 billion of own resources to about 100 offshore wind, energy efficiency, waste and bioenergy projects, leveraging about GBP 8.5 billion of private co-finance (compare UK GIB, 2017, p. 6). The National Auditor Organisation (NAO) evaluating governmental financial activities assessed GIB's effectiveness from 2013 to 2017. It concluded that GIB developed a sound economic basis, became operational quickly, established strong capabilities and expertise in financing green infrastructure and stimulated significant investments by addressing market failures in some sectors like offshore wind. GIB's internal procedures and investment strategy was perceived as successful, building on different financial instruments. More than 50% of the capital was allocated as direct equity, one quarter as direct debt and the remaining share as equity or debt investments in specialized funds. The portfolio return, calculated on a cash-flow basis, fluctuates between 8% and 10%. With regards to environmental effectiveness, NAO estimates reduction of about 8 million tCO_2e until 2022, representing about 16.5% of the total UK GHG emission reductions.

In 2015, the government announced that it considers the sale of GIB to private ownership with the objective of delivering money for the taxpayer and remove GIB from the public sector balance sheet to reduce government debt while guaranteeing GIB's involvement to a sustainable economy (compare UK NAO, 2017, p. 30f). In 2017, a two-round sales process was completed with the decision to sell 100% of the shares to the private Australian infrastructure financier Macquire. The final purchase price payed by Macquire represents a taxpayer premium of about GBP 126 million, the institution was relabelled as Green Investment Group. As a private entity it has now the advantage of theoretically being able to borrow and lend resources without contributing to UK deficit increases. However, this privatization was criticised by NAO as non-transparent, lacking clear criteria to show that all identified market failures have been successfully addressed. Further it claims potentially higher purchase income for the taxpayers at a later point of time. The lengthy sale process and the uncertainty of the future shareholder led to the loss of key GIB staff jeopardizing operational capabilities. Finally, the long-term sustainability of GIB activities in the UK is without legal obligation thus remains to be "seen over time" for NAO (2017, p. 46). Environmental NGOs like, political opposition parties such as the Liberal Democrats and media reacted with harsher criticism, describing the deal as a "disaster", "politically dubious" and "environmentally irresponsible" (compare Kollewe, 2018). Particularly the absence of specific or legally binding commitments for future investments might negatively impact UK's decarbonization strategy (see Pratley, 2018).

4.3.SIP objectives and impacts

Besides the potential to overcome a share of the funding gap discussed in chapter 3.1, the SIP engagement in energy transition financing is likely to have additional impacts on the energy transformation, the pension schemes and society in general. These categories are building on IPCC's (2014, p. 235ff) suggestion of four policy objective categories for evaluating climate related policies. They are clustered according to Köhler 2020a (see Annex I) and reflect:

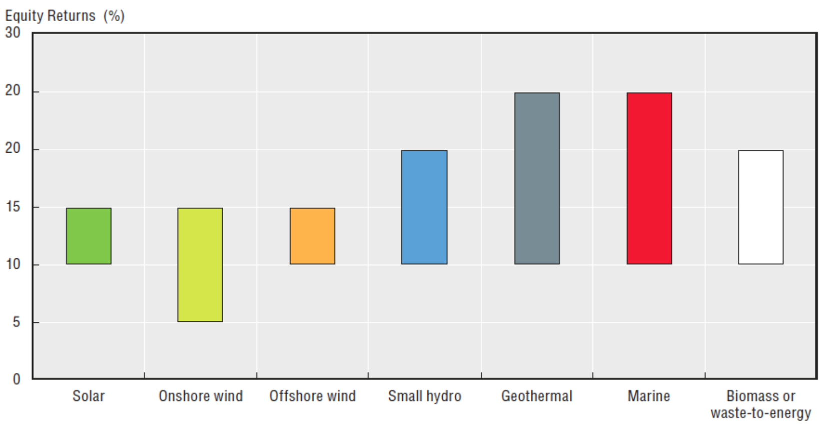
- an economic objective including efficiency, effectiveness and transaction costs;
- distributional objectives including acceptance, fairness and equity,
- environmental objectives, and
- the institutional and political feasibility.

As reflected in the case study chapters 5.5 and section 3.3. of Annex I, all assessed impacts are highly context and country specific, especially regarding differences of developing and developed countries. Nevertheless, the basic elements are discussed in a generalized way in the following. Based on the findings, subsequently a list of potential investment criteria for the SIP and a general description of required design features is derived.

4.3.1. Investment revenues and distributional impacts

Investment revenues and associated distributional impacts on the economy are crucial elements for a successful operation of potential SIP schemes. Regarding efficiency, there is a strong indication, that an increased SIP engagement in energy transition infrastructure generates higher rates of return than traditional investment alternatives in the current low interest-rate environment. This is likely for both direct and indirect investments. With regards to direct project investment, an OECD (2017a, p. 285) survey revealed that investors within OECD expect in average about 10-15% returns on equity for renewable energies investments. For marine and geothermal activities, the survey describes return demands of up to 25% (see Figure 14), only onshore wind seems to be acceptable with returns below 10%.

Figure 14: Investors equity return expectations, for renewable energy finance (in %)



Source: (OECD, 2017a, p. 285)

Kleine and Krautbauer (2012, p. 7) provide expected revenues per development level of infrastructure assets in European countries. They assume 11-16% of expected annual rate of revenue for new greenfield infrastructure during planning phase, 10-14% for mature greenfield in planning stage, 9-13% for greenfield under construction, 7-11% for shares or debt to mature and regulated utilities and 6-10% for operative activities already creating cash-flows without market risk. A PricewaterhouseCoopers survey (PwC, 2017, p. 6ff) explored characteristics of private infrastructure investments since 2000. It revealed that average return expectations of the interviewed infrastructure funds decreased from 14.0% in 2004 to 10.6% in 2016. Particularly new entrants in the infrastructure investment market bring lower return requirements, smaller interest in stakes while building up their internal capabilities. Sanzillo et al. (2017, p. 21) show average rate of returns on unlisted infrastructure fund investments of about 10%. The fluctuation between 5% and 12.5% is lower than for other unlisted asset classes. Besides an evaluation of indices, the authors confirm their findings with four case studies of infrastructure asset management companies that also include renewable power generation in Europe, North America and South America into their portfolio.

Fleischer et al. in Underhill (2010, p. 82ff) analyse the revenue performance of Master Limited Partnerships (MLPs) in the US energy infrastructure. They control about USD 250 billion of assets including transmission, processing and storage of natural gas, crude oil and refined petroleum products and have a comparatively strong performance of about 14% annual return between the year 2000 and 2008. Related assets are characterized by low deviations and a low correlation to other asset classes, mainly due to the relatively inelastic demand and almost monopolistic market environments. Since MLPs are publicly traded at major stock exchanges, they also offer liquidity and flexibility.

With regards to non-direct project finance, there are plentiful literature assessments of listed stock indices that partly allow a characterisation of sustainable infrastructure asset returns. For instance Underhill (2010, p. 168ff) analyses historical performance of listed infrastructure stocks. He posits the long-term annual yields of traditional stocks with 4.37%, bonds with 4.29% while listed infrastructure stocks experienced 5.15%. Ohri et al. (2016, p. 60f) as well as the Carbon Disclosure Project (2017, p. 21) demonstrate that sustainable and low GHG intensive stock investments outperform conventional indices like STOXX Global 1800 or MSCI All Country World Index by up to 30% over five years while the fluctuation is with up to 0.35% only marginally higher. The

GHG emission intensity of the stocks was 10% to 90% lower than the conventional indices. Summing up, indirect investments direct investments are likely competitive and on a comparable level than other opportunities in the post financial-crisis low interest-rate environment. Direct investments provide significantly higher revenues than traditional alternatives but also come with additional risks and requirements (compare also discussion in chapter 4.5.1).

Considering that the SIP financed energy infrastructure is located in the same country as the SIP scheme and its members, the regulatory frameworks for domestic energy infrastructure can be adjusted in the future. This offers a potential to guarantee the resilience of a SIP system dependent on energy infrastructure revenues under unforeseen constellations. Thus, potential adjustments of e.g. user fees or feed-in-tariffs can represent higher revenues or an additional financial safeguard for the contributors in the long-run. However, from a macroeconomic point of view, institutional investors might also be capable to provide financial resources more cost effectively as they can offer lower interest rates, longer time horizons or varied risk/return expectations (compare also the assessment of institutional investors' characteristics in chapter 3.2.4 and the discussion by Nelson and Pierpont (2013, p. 4)). This in turn, can decrease electricity prices benefitting private users as well as business sectors, particularly the energy intensive industry. Thus, for the application of SIP schemes two distribution challenges are expected. They are particularly relevant if the SIP covers a minor share of the population only:

- First, politics and regulators have to balance the benefits of the investment returns. According to OECD/IEA (2017, p. 32), one key motivation of recent policy reforms is to ensure "adequate, reliable and safe electricity services at reasonable prices, while sharing system costs and benefits among stakeholders". Thus, on the one hand, SIP clients could likely receive higher revenues on their contributions and finally higher pension payments compared to the current system. On the other hand, the whole population and business sector could likely benefit from lower power prices. This trade-off between lowering consumer prices for all versus higher pensions for SIP members only needs careful consideration.
- Second, future politicians might misuse the SIP scheme for benefitting partial voter groups by increasing revenues from energy assets through ex-post regulatory reforms. This would pose burden on all power consumers while only the SIP

members profit. Also, the contrary approach is thinkable, lowering energy prices on the cost of SIP members.

Both distributional impacts will be of higher relevance, the lower the coverage rate of the SIP scheme across the population is. However, even with a 100% coverage of labour force, the current pensioners without membership in the SIP scheme would be affected by the described conflict of interests.

Another macro-economic, distributional challenge discussed by IRENA (2018, p. 62) is the crowding out of capital from other sectors of the economy taken for the additional investment needs of the energy transition. IRENA's global analysis assumes that about 50% of net additional investment will be drained from other sectors until 2050. According to the authors, resources stemming from commercial banks do not lead to crowding out of investment in other sectors as the money is newly created within the existing macroeconomic conditions and regulations. However, non-bank investors such as pension funds mainly operate by reallocating the existing stock of credit as well as new contributions. The envisaged SIP scheme would fall into the category of non-bank investors. As discussed in chapter 3.2.4, institutional investment is mainly allocated to listed equity stocks and fixed-income debt in form of corporate and government bonds. While a drainage of funds from stocks leads to a reduced stock market price with limited economic impact, a decline in bond acquisition might increase debt costs for states and enterprises. Two elements are relevant in this context. First, depending on the institutional set-up not all SIP schemes will drain money from existing investments but rather allocate new contributions differently. Second, required annual investments for the energy transition represent only a comparably small volume of assets under management of institutional investors. Thus, the argument is valid and the impact exists, although the micro-economic impact for economic sectors beside energy are expected to be marginal. However, in certain country contexts a redistribution of capital by a SIP scheme might create distributional competition with other development objectives (see Seychelles case in chapter section 3.3.1 of Annex I).

4.3.2. Investment risks

Energy infrastructure investments face a set of typical risks that can be mitigated or intensified through a SIP scheme. The following section discusses SIP influence on key risks analysed in chapter 3.3.1, namely government holdup, investment default and insufficient capacity. Additionally, macro-economic risks that could appear due to the introduction of SIP schemes are considered.

Referring to the literature review, government holdup constitutes the most important risk for many infrastructure investments (compare investment risks in chapter 3.3.1 or the evaluation by the Norwegian Pension Fund in chapter 4.2.2). It particularly affects investments in markets where the investor lacks knowledge, reputation or influence. This usually appears outside the home market and is more complex in countries with weak legal frameworks. As the envisaged SIP scheme would strongly or even exclusively focus on the country of its members, there is a high likelihood that government holdup risks can be effectively hedged. Solid knowledge about the home market is considered as prerequisite for successful operation and the reputation should be positive under consideration that the SIP institution is well managed (compare also required SIP elements discussed in chapter 4.5 below). With regards to the SIP influence on key risks, the size and importance of the SIP scheme likely determines its possibilities. If the SIP scheme is publicly managed, there is a higher likelihood that the government does not violate the interests of state institutions. Many SIP scheme members would decrease the likelihood for negative government interference as voters could penalise such activities during elections. This characteristic is also given for privately managed SIP schemes.

Political and public concerns around energy security in the context of liberalized and globalized energy markets represent an additional facet of government holdup in recent years. Bridge et al. (2018, p. 4ff) explore intersections between energy infrastructure and political economies of national development, highlighting that energy security is increasingly scaled as national concern. The authors cite cases from Israel’s offshore gas infrastructure or Turkey’s hydropower development based on extreme legislative measures beyond normal politics or a nationalization of energy infrastructure in Bolivia, Ecuador or Venezuela as symbols to emphasize the faith of nation. Also, the potential impairment of critical infrastructure through purchases by foreign investors led to an increase of imposing acquisition restrictions based on existing laws as the prohibition of wind farm sale in the USA in 2016 (The White House, 2018) or the passing of new bills or tools that allow such state interference (compare e.g. EU Parliament (2018) or the German case study in chapter 5.5.2). A SIP scheme could address this concern of reduced energy security through acquisition of critical infrastructure by controlling large parts of the energy infrastructure asset portfolio. Therefore, it can be expected that the risk of government holdup in different facets can be effectively mitigated by the introduction of SIP systems that focus on their domestic home market.

Investment default is a serious threat for asset-backed retirement systems. A loss of retirement savings would undermine the legitimacy of the pension system, jeopardizing public support and acceptance. According to literature, default of pension scheme investments occurs predominately due to unbalanced asset portfolios (compare chapter 3.3.1). As SIP schemes focus on energy infrastructure only, their investment portfolio diversification is significantly limited compared to traditional set-ups of asset-backed pension funds or SWFs thus resulting theoretically in increased default risk. Despite the low diversification of assets, the special SIP structure provides also advantages with regards to long-term sustainability and investment default mitigation. Being rather independent from fiscal and financial market developments, energy infrastructure generates revenues as long as demand exists. Even significant inflation rate increases, or a significant devaluation of the currency value could be subsisted, as for instance electricity tariffs can be readjusted (compare also chapter 4.3.1). Thus, SIP members are expected to possess comparably resilient assets, potentially outbalancing the risk of insufficient portfolio diversification.

With regards to the average performance of the investments, that indirectly also influence the resilience of the overall portfolio, it is unclear how a pure sustainable infrastructure focus would perform compared to the existing globalized, listed equity and listed debt investment portfolios. The challenges of traditional investments resulting from the aftermath of the financial crisis indicate, that particularly direct, unlisted infrastructure investments lead to higher rate of returns. Whether existing asset classes are more profitable in the long run remains unclear as data on SIP scheme performance over long timeframes is not available yet.

As revealed by the literature review in chapter 3.3.3, capacity constraints represent a major barrier for infrastructure engagement. All identified risks and challenges associated with infrastructure implementation can only be adequately addressed if the relevant institutions have sufficient experience, know-how and capacity. This requires either large institutions that are able to build up such capacity internally as it has happened in existing institutions with regards to real estate investments. In this context, the Norwegian Pension Fund or the Seychelles Case Study represent illustrative examples (compare chapter 4.2.2 and chapter 6). Alternatively, the investors rely on external support that however likely increases transaction costs due to remuneration of intermediaries and experts. The development of internal capacity depends on the characteristics and the operational design of potential SIP schemes. Particularly if the SIP is set up as a centralized SIP institution, sustainable investments based on internal capacity are rather likely (compare discussion of SIP characteristics in the subsequent chapter 4.4).

Finally, the introduction of a large-scale SIP scheme comes with systemic risks that are absent in the current investor's and capital-based pension system structure. First, the monopolistic characteristic of a SIP scheme that is investing large volumes of money could increase the operational costs and purchase prices for energy infrastructure. Due to decreased competition, providers and operators of energy infrastructure might attempt to harness windfall profits. This risk might also intensify with the desired design feature of transparency. As more details about the available resources and operational procedures of the SIP scheme are disclosed, the risk of excessive prices for the purchase of SIP assets increases. Second, an innovative institution managing large volumes of funding can be exposed to a risk of fraud and corruption. Particularly publicly managed institutions that are active in the energy sector are historically prone to embezzlement of resources. Grasso (2017, p. 244ff) analyses that such institutions show increased tendencies of corruption. Its geopolitical and domestic importance, the massive volumes of money allowing energy related corporations to obtain "an unfair advantage in the political marketplace", their ability to arrange complex schemes to deceive the public observers and prosecuting authorities as well as the associated environmental risks and related regulations make the energy sector vulnerable to corruptive activities. In this context, state-owned or public entities located in emerging economies with weaker public institutions face the highest risk for embezzlement. Grasso specifically names institutions like Gazprom from Russia, PetroChina from China, Petrobras from Brazil as well as the fossil-fuel rich countries of Iraq, Iran, Venezuela, Mexico and Nigeria. That the phenomenon of corruption does not exclusively apply to fossil-fuel based energy systems but also to renewables has been revealed by Gennaioli and Tavoni (2016, p. 25f). They show statistically that favourable subsidies for wind energy development in Italy leads to higher experience of corruptive activities in regions with weak institutions. Thus, these studies show for different energy carriers and geographical regions that a more developed legal framework and stable regulatory institutions lower the observed corruption risk. From a SIP perspective, this aspect is particularly relevant regarding the institutional set-up and the governance structure as well as a surrounding framework that requires solid fiduciary standards and provides reliable supervision of the SIP's activities. As the SIP concept might be highly relevant for emerging economies and developing countries, a mitigation of corruption risks needs thorough consideration.

4.3.3. Acceptance

Acceptance of energy transition infrastructure can be a key barrier for a rapid implementation (compare also chapter 1 and 0). While individual resistance and solutions are highly country specific, there are general recommendations how to address acceptance challenges in the context of energy transitions. The IPCC (2014, p. 187f) determines public support or opposition towards new activities primarily by the perceived risks of the applied technology, the communication between project developer and local population, transparency as well as the perception of economic costs and benefits. Di Nucci and Brunnengräber (2017, p. 13ff) describe the impact of compensation on siting resistance in the extreme case of a nuclear waste disposal site. They state that compensations can support offsetting real or perceived discrepancies, if there are imbalances between collective benefits and regional or local costs or burdens. According to the authors, economic incentives represent a useful tool for addressing acceptance problems in standard economic theory. In empirical literature the authors find also contradictory conclusions highlighting that pure monetary compensation can lead to a "bribe effect", making financial incentives unappealing if the planned projects are perceived as undesirable. Thus, the societal importance and paramount distributional justice likely plays a similar significant role.

Moreover, Flämig (2016, p. 13f) stresses emotional aspects of a pension scheme providing resources for building a more sustainable future. In his view, the scheme can contribute to the mobilization of the population towards a universal strategy of sustainable transformation through e.g. intellectual convincement, motivation beyond the cognitive level, securing constant engagement, balance between voluntary and obligatory subsidiarity, leading to a strengthened bottom-up process. Further the concept can contribute to a large-scale understanding of the transformation and an increased effectiveness of the transformational instruments building on the performance of citizen' initiatives. Flämig also emphasizes the approaches' practical social structure that opens components of the "human soul" towards a sustainable transformation through desire for social and emotional security in retirement age, the desire for a healthy environment, an intact environment for children and grandchildren, to participate in the set-up of a stable future, to invest into reasonable and identifiable projects, fair and solid interest on capital, contributing to climate and environmental protection but also being part of a value-sharing community. Thus, such a pension system can promote an increasing acceptance and thoughts on sustainable development among broad parts of the population and economy.

In response to the outlined challenges of resistance, the coverage of large parts of the population through a SIP scheme could enable broad economic participation, ownership and emotional identification. Subject to key design features such as transparency, communication and integrity, the SIP approach could likely increase acceptance and help to address existing energy transition implementation barriers in the context of population resistance.

4.3.4. Democratization

Democratized energy infrastructure assets can be a decisive success factor for a successful implementation of energy transitions. As described in chapter 1, chapter 4.3.3 above and the German case study in chapter 5.5.4., a broad ownership of infrastructure reduces barriers and enhances the speed of implementation. A SIP scheme could further increase acceptance of energy transition infrastructure deployment. Instead of typical shareholders such as stockholders, banks and institutional investors that usually provide private equity and debt capital for project realization, it is literally the majority of the population that owns their energy infrastructure. Hereby the threshold for participation is crucial. For instance, Hall et al. (2018, p. 776) describe minimum amounts of GBP 25,000 to participate in the UK energy transition through institutional investors as limitation for a “democratic financing” scheme.

But democratization goes beyond pure economic motivation. A continuous democratization of energy transition assets through jointly realizing future-oriented infrastructure can increase a common understanding and identification with the aims and objectives of the whole transformation. According to Flämig (2016, p. 149ff), a consequential and continuous societal demand for change is essential, if the transformational change shall be successful. This demand can be initiated with the provision of “practice-oriented, multi-dimensional” elements such as a pension scheme that is linked to the solution for the problem of climate change. Participation and democratization are key elements to encourage the population for accepting the societal and fundamental change. The SIP scheme can provide a basis for enhanced democratization, subject to its population coverage and design features. In case, the SIP scheme competes with other actors, it has to be reflected that locally emerged funding and ownership structures that represent already democratic participation might be jeopardized.

4.3.5. Energy justice and energy finance

Hall et al. (2018, p. 773ff) investigate justice principles at the interface between energy transitions and finance. Hereby the authors describe energy justice as a condition in which benefits and costs of energy services are fairly disseminated, enabled by representative and impartial energy decision-making. They outline 6 key principles that contribute to just energy finance: "affordability, good governance, due process, intra-generational equity, spatial equity, and financial resilience" (Hall et al., 2018, p. 772). Energy policy that seeks to mobilize capital at that scale should take into account all these six principles. For operationalizing energy justice, Hall et al. suggest alternative finance frameworks, that attempt to achieve additional outcomes beyond the calculus of risk revenue ratios. While affordability is discussed in the context of revenues and effectiveness in chapter 4.3.1 and financial resilience is reflected in the chapter 4.3.2 on risks, the SIP impact on the other elements is explored in the following.

"Good governance" refers to frameworks in which the investments take place. Hereby the legal background, the governmental institutions and their integrity as well as the investors with their individual track-record influence the quality of paramount governance. This principle has direct influence on political feasibility and acceptance as well as the required framework conditions (see chapter 4.5.2 below).

"Due process" refers to procedures that enable engagement and accountability of stakeholders. In this context, transparency of impacts, performance, revenues and profits of project activities in combination with stakeholder involvement and active participation in decision-making are described as required features by Hall et al. (2018, p. 776). Whether a SIP scheme fulfils these requirements depends on the institutional set-up, the disclosure policy and the participation options for its members (compare also discussion of design features in chapter 4.4 below).

Inter-generational equity refers to a conflict of interest among population shares with different ages. While the current generation covers the main share of the energy transition through higher energy supply costs, it will mainly be the next generations that profit from mitigated climate change impacts, lower dependency on fossil-fuel imports and lower energy costs. This intergenerational conflict, that the energy transition poses upon the population, lies "at the heart of transition governance" (Laes et al., 2014, p. 15). Theoretically it can be addressed by economic participation of the population through SIP schemes. With increased pension payments based on revenues generated by sustainable energy infrastructure assets, the financial benefits of the transformation could be shared more equally.

Spatial equity highlights rootedness of project activities in specific local frameworks. A stronger distribution of financial interest among the community where the activity takes place, is perceived as a key justice element by the local population. Hall et al. demonstrate the image of "foreign" investors using profits in their home-country to relief customers as asymmetric flows of finance finally building resistance against the project activities. A SIP scheme could help to address the spatial equity justice principle through communication of benefit distribution and incorporation of local population's interests.

4.3.6. Environmental impacts

Large-scale infrastructure activities have significant impacts on the environment. There are various mature regulations, requirements and tools that mitigate such impacts or guarantee compensation. Furthermore, respective activities also replace or substitute existing or avoid possible infrastructure with higher or lower environmental impacts.

As the SIP explicitly targets sustainable energy infrastructure, it is likely that it provides environmental benefits such as reduced GHG emissions or avoided air pollutants compared to a baseline scenario. Lower costs of capital due to SIP investments can also have direct impact for the implementation of decarbonizing capital-intensive technologies. Hirth and Steckel (2016, p. 6f) demonstrate that besides carbon pricing reduced capital costs are an important factor for emission reductions in the power sector. This result is particularly relevant for developing countries that usually tend to have less access to capital and higher capital costs.

However, sustainable infrastructure can also have severe environmental impacts, particularly at the local level. As extreme examples, carbon capture and storage and nuclear power are sometimes classified as sustainable energy. But also wind parks or biomass production can jeopardize environmental conditions. Therefore, the achievement of the environmental objectives associated with a SIP scheme depend on the definition of sustainable energy infrastructure in the related investment criteria (see also chapter 4.4.1) and the operational procedures that identify environmentally sound activities and mitigate negative environmental impacts.

4.3.7. Political feasibility

Contrary to the other SIP impacts assessed, political feasibility is not an outcome or result that can be achieved through the implementation of a SIP scheme but rather a prerequisite. According to the IPCC (2014, p. 237) political feasibility depends on the administrative burden associated with the envisaged policy and the likelihood of being adopted and implemented. The administrative burden reflects the human and financial costs of developing and implementing the required institutional framework and achieving the targeted policy objectives. The likelihood of gaining political acceptance considers the "key design features that can generate or reduce resistance among political parties" (IPCC, 2014, p. 237). This process may be influenced by powerful interest groups such as business associations or labour unions. A generalization of political feasibility success factors is difficult as it is highly dependent on the culture, political system and socio-economic conditions in the respective countries. Hall et al. (2018, p. 774f) for instance highlight that different countries show varieties of political perceptions of the financial system that in turn lead to the prioritization of diversified funding instruments and strategies. They assess for instance the UK as a liberal market economy with highly developed capital markets targeting on short term profit maximization and strong and capable institutional investors. Contrary they describe Germany as a coordinated, ordoliberal market economy with a distinct set of stable regulatory and financing institutions like community owned banks focusing rather on long-term investments. The authors specify that a distinct, best-suited funding system cannot be generalized. It rather has to be analysed in the specific country contexts how the political and economic model can be best applied to mobilize investment capital and guarantee energy justice. The IPCC stresses in this context that "policies will be more feasible if the benefits can be used to buy the support of a winning coalition" (IPCC, 2014, p. 238). This also applies for a SIP scheme that has to adapt to the local circumstances and design its institutional set-up, investment priorities and benefit sharing processes in a way that a majority of stakeholders and relevant interest groups profit. Successful examples of broad public and political party backing for comparable institutions to a SIP scheme are the creation of the Norwegian Pension Fund and the UK Green Investment Bank described in chapter 4.2. Possible SIP designs and their context specific impact on political feasibility are evaluated individually for the two Case Studies.

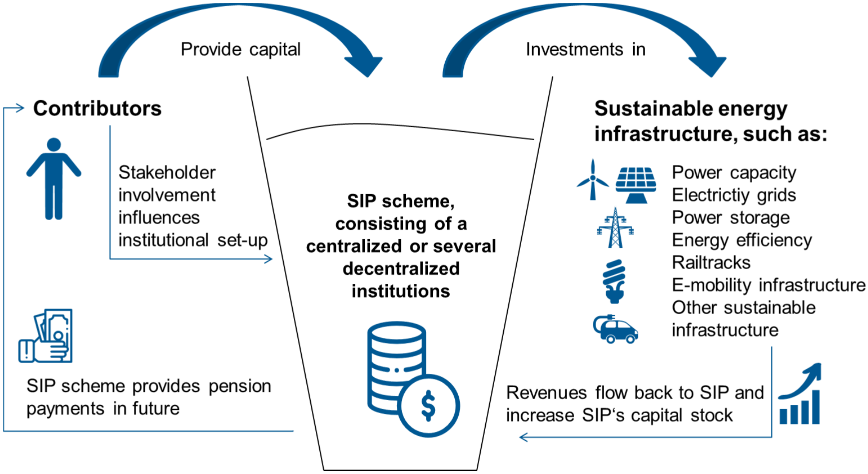
4.4. Discussion of the basic SIP concept

Referring to the third hypothesis "*under appropriate conditions, capital-based pension systems can cover the investment needs of energy transitions in developed and developing countries*", this chapter attempts to sketch basic SIP concept features. It builds on the analysis of barriers for energy infrastructure investments in chapter 3.3, the pension systems in chapter 3.4 and the discussed objectives and impacts from chapter 4.3. The results are further applied in the context of the case studies and support the elaboration of generalized conclusions in chapter 7. As many parameters and design features are context and country-specific, there exists not one universal SIP scheme. It has rather some identical "core characteristics" while other elements are optional.

4.4.1. Core characteristics of SIP schemes

What potential SIP schemes have in common is that pension contributions are invested in sustainable energy infrastructure. The general design of the scheme is based on the third pension system pillar that relies on individual private capital stocks (compare chapter 3.4.1). Its core operation relies on pension contributions to a capital-based scheme which invests in sustainable infrastructure. Figure 15 illustrates schematically the basic operation of the SIP scheme. The pension capital flowing into the SIP scheme is provided by labour force members. The SIP institution(s) identify, assess and prioritize suitable investments according to regulated investment guidelines. Contracts with the respective project developers or partner entities are signed and investment capital is provided.

Figure 15: Schematic illustration of the SIP scheme



Source: Own illustration

Appropriate investment vehicles and economic instruments such as equity, debt or mezzanine finance are applied for different kinds of activities (compare analysis of appropriate investment approaches in chapter 4.5.1). The SIP infrastructure assets sell produced goods such as electricity or generate usage fees such as power transmission grids. Over time, revenues from operation and relieved capital from past investments flow back to the fund and enable further investments. Thus, the SIP scheme aggregates an asset portfolio over time. As soon as the first contributors retire, the fund provides parts of its resources to these members as pension payments. High transparency, disclosure and supervision standards for the SIP scheme are a key prerequisite to guarantee long-lasting public backing for the new concept. It can be operationalized through an appropriate Monitoring, Reporting and Verification (MRV) system that transparently tracks and evaluates contributions, investments, pension provisions and impacts reflecting the investment criteria (see further discussion in chapter 4.5.3).

4.4.2. Optional elements of SIP schemes

Besides common characteristics, the potential institutional designs of SIP schemes include optional elements that are selected according to the country-specific context. Based on design factors identified by Inderst and Della Croce (2013, p. 7ff) as well as the previous analysis of existing pension schemes and institutional investors in chapter 3.4 and 4.2, the following options are described:

- Direct Contribution (DC) versus Direct Benefit (DB): Capital-based pension systems vary according to the level of benefit payments. Either the payments depend on the individually, contributed capital (DC) or they are predefined by politics and management of the respective system (DB). As discussed in chapter 3.4.1 this choice has important implications. While the contributors bear the risk of unsuccessful investments in DC schemes, DB systems transfer this risk to the scheme itself. This can increase intergenerational justice and improve the social impact in DB schemes. However, it can also lead to unsustainable operation in the long run if policy makers and scheme managers do not carefully balance contributions and benefit payments (for further discussion of these impacts see also chapter 7.2). Despite the experience from private pension funds showing that DB schemes are theoretically better suited for long-term direct infrastructure investments, the Australian example also demonstrates significant engagement from DC financed institutions that seem to manage liquidity constraints successfully (compare chapter 4.2.1).
- Voluntary versus mandatory: The second optional choice with significant impact on the size and coverage of a SIP scheme is the legal obligation for membership. Voluntary schemes do not cover all labour force members and have to canvass for clients. Economic incentives and subsidies from the state can help to increase the number of voluntary members (compare for instance the German third pillar pension systems in chapter 5.2). Mandatory systems lead to a broad coverage of labour force members and are often characterized by significant qualitative distribution and democratization benefits. Mandatory membership further facilitates the SIP scheme to cover high volumes of the energy transition investment needs. But an introduction of mandatory schemes also faces political challenges (compare qualitative discussion of German SIP options in chapter 5.5 and the discussion of political feasibility in chapter 4.3.7).

- Public versus private: Regarding administration of the SIP scheme, both a private system and a publicly managed institution is possible. This choice influences for instance envisaged profit margins, transaction and management costs, reputation or the ability to attract skilled staff. The analysis in chapter 4.2 shows that both options have realized successful investments in the sustainable infrastructure sector.
- Diverse versus centralized: Globally, third pillar pension systems exist in diverse, decentralized or centralized structures. While centralized schemes are almost exclusively operated by public institutions to avoid a monopolistic private market, decentralized systems often consist of various private actors. However also public institutions can operate in a diverse environment, as for instance demonstrated by the different public pension funds in Canada (compare chapter 4.2) or the various public occupation pension institutions in Germany (compare chapter 0).
- New versus existing: The SIP can build on existing institution(s) or require the establishment of new organizations. This element depends on other selected design options such as diverse/centralized or public/private and is highly country-specific as each society has a different set of institutions in place. Existing actors tend to accelerate the implementation of a SIP scheme as they are familiar with attracting and investing large volumes of pension contributions. Their operation would require adjustment to the new set of investment criteria that additional regulations and the policy framework needs to monitor, evaluate, steer and adapt.
- Internal versus external management: Finally, the SIP institution(s) need to either build internal capacities for managing the investments or externalize management responsibilities. Nelson and Pierpont (2013, p. 34) assessed that a minimum size of the total institution's portfolio of about USD 40 to USD 50 billion is required to justify an internal, direct infrastructure investment team. However, the analysis of private and public pension institutions in Canada and Australia as well as the UK GIB represent existing examples of entities with smaller size that still apply internal infrastructure investment teams.

4.5. Elements of the SIP concept

This chapter discusses the key elements that are required to operationalize a SIP scheme. It builds on the defined objectives and impacts as described in the previous chapter 4.3.

They reflect the requirements to address the identified challenges of energy transitions and pension systems as well as the demands of policy makers, society and members to their potential SIP system. As energy supply infrastructure, pension schemes, economies and cultural backgrounds are varying across the globe, a universally applicable SIP scheme blueprint does not exist. Nonetheless there are elements that all potential SIP concepts include. Some of them allow for different design options and approaches comprising of individual advantages and disadvantages.

Both literature reviewed in chapter 3 (for instance Bitsch, 2012, p. 45ff; Inderst, 2010, p. 74f; Nelson and Pierpont, 2013, p. 41ff; OECD, 2015, p. 35ff) and the analysed exemplary institutions in chapter 4.2 share predominantly four elements that are required for a successful operation of investors engaging in markets with high relevance for large parts of the population, such as infrastructure. They comprise of investment strategies that generate maximized revenues, procedures to minimize risks and transaction costs, an appropriate institutional set up and governance structure and a decent level of transparency and democratic control. The latter is particularly relevant for publicly managed institutions.

4.5.1. Investment strategies and vehicles

Infrastructure investments can be undertaken in various ways. According to Sawant (2010, p. 50), investment approaches are typically clustered according to the dimensions of equity versus debt lending as well as indirect versus direct involvement (compare also Figure 16). In the context of indirect equity engagement, firms typically invest in stocks of infrastructure companies or equity-based infrastructure indexes, consisting of various stocks. Indirect debt lending can happen through investments in infrastructure debt funds or infrastructure bonds. These indirect engagements are also framed as investments in corporations as they are not flowing in a distinct project. A direct investment can be realized via equity ownership in a specialized project firm, alternatively project debt or bonds associated with a distinct project activity or project firm are also possible.

Figure 16: Dimensions of infrastructure investments

	Equity	Debt
Indirect investment	Infrastructure indexes	
	Infrastructure equity funds	Infrastructure debt funds
	Stocks of infrastructure firms	Infrastructure bonds
Direct investment	Individual project sponsoring	Lenders to individual projects

Source: Own illustration based on Sawant (2010, p. 50)

Since these various dimensions and options of financing impede a streamlined understanding of suitable approaches particularly for sustainable energy asset investments, Nelson and Pierpont's (2013, pp. 13–15) suggestion to classify the potential investment options according to the three channels direct project financing, indirect corporate balance sheet financing and capital pool approaches is reflected in the following. While this classification is not the only possible approach of clustering sustainable energy investments, several OECD (Della Croce et al., 2015, p. 14ff; OECD, 2015, p. 51ff) assessments that mapped various financing taxonomies, approaches and channels conclude with a similar distinction. Table 7 clusters existing financing instruments along the three financing channels and adds hybrid asset categories that comprise of equity and debt elements. They are also defined as mezzanine finance instruments. Since the three financing channels as well as the underlying instruments have different implications on return, risk and internal expertise requirements of the investor institution, their main characteristics are discussed in the subsequent part.

Table 7: Taxonomy of instruments and vehicles for infrastructure financing

Modes		Infrastructure Finance Instruments		Market Vehicles
Asset Category	**Instrument**	**Infrastructure Project**	**Corporate Balance Sheet / Other Entities**	**Capital Pool**
Fixed Income	**Bonds**	Project Bonds	Corporate Bonds, Green Bonds	Bond Indices, Bond Funds, ETFs
		Municipal, Sub-sovereign bonds		
		Green Bonds, Sukuk	Subordinated Bonds	
	Loans	Direct/Co-Investment lending to Infrastructure project, Syndicated Project Loans	Direct/Co-investment lending to infrastructure corporate	Debt Funds (GPs)
			Syndicated Loans, Securitized Loans (ABS), CLOs	Loan Indices, Loan Funds
Mixed	**Hybrid**	Subordinated Loans/Bonds, Mezzanine Finance	Subordinated Bonds, Convertible Bonds, Preferred Stock	Mezzanine Debt Funds (GPs), Hybrid Debt Funds
Equity	**Listed**	YieldCos	Listed infrastructure & utilities stocks, Closed-end Funds, REITs, IITs, MLPs	Listed Infrastructure Equity Funds, Indices, trusts, ETFs
	Unlisted	Direct/Co-Investment in infrastructure project equity, PPP	Direct/Co-Investment in infrastructure corporate equity	Unlisted Infrastructure Funds

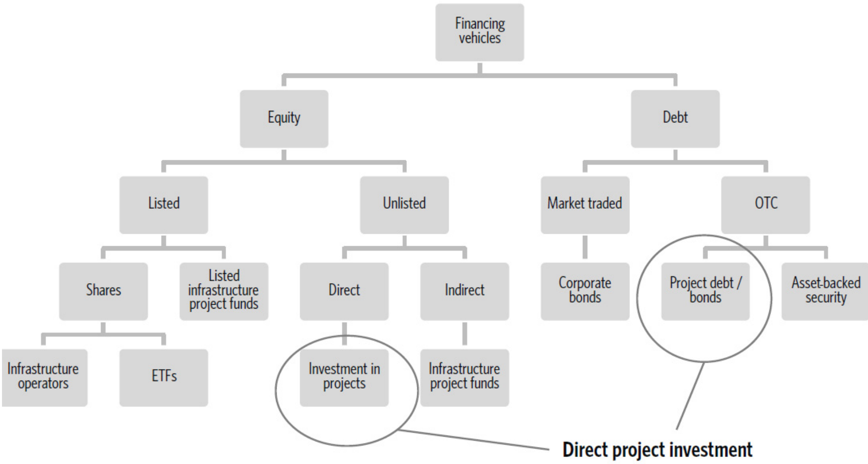
Source: Della Croce et al. (2015, p. 15)

Direct project financing

Direct project-finance (PF) describes the establishment of a specific financial structure for a particular project activity, also called special-purpose vehicle (SPV). Figure 17 describes the location of direct project financing in the landscape of available financing instruments for infrastructure activities. Typically, different shareholder groups are involved. So-called "sponsors" provide unlisted equity and lenders provide non-market traded debt capital. The latter comes mainly in form of loans or project bonds.

In this context, increasingly innovative financial products such as Green Bonds as a sub-form of infrastructure bonds with sustainable characteristics or YieldCos, coming from yield and company, allow new approaches to attract investors (compare Dichtl, 2018, p. 239f). A YieldCo consists of a portfolio of single activities and is placed as an own entity at a stock exchange. In the context of this placement a due diligence according to the financial regulation of the stock marketplace is conducted, providing required information to the potential investors. Such approaches help bundling and aggregating single activities into larger portfolios that can be easier assessed by investors. They usually focus on selling shares of already operational activities without building or realization risks. Consequently, the rate of return is lower than investing directly into the underlying activities.

Figure 17: Financing vehicles for infrastructure investments



Source: Nelson and Pierpont (2013, p. 62)

Generally, the main advantage of PF is that financial distress of the involved firms does not affect the viability of the project-finance activity vice versa. In contrast, for corporate financed activities the overall capital in the balance sheet of the corporation represents liability for repayments to debt providers while corporate defaults would also lead to default of the project activity. Thus, PF does not adversely affect the balance-sheets of involved firms in case of default. However, PF includes higher transaction costs, as typically a large number of contracts has to be fixed before implementation. Sawant (2010, p. 148) states that for a typical infrastructure project about 40 contracts between suppliers, buyers, contractors, lenders, operators, managers, employees and governments have to be signed before implementation can start. This tends to increase transaction costs that are estimated to constitute between 3% and 12%, depending on the legal environment. Hereby costs for technical studies seem to be lower than costs for dealing with the host government. Particularly smaller investors struggle with the relatively high transaction costs of direct PF.

Furthermore, lenders try to fence their debt for assets with contractual arrangements. For accepting a nonrecourse status, meaning that they cannot look at the balance sheet of the sponsors, they demand higher interest rates (compare Sawant, 2010, p. 152). Single activity SPVs eliminate the risk of asset substitution while losing the benefit of coinsurance of having several varying cash flows that stabilize debt repayments. With regards to transaction costs, tailored SPVs for specific activities reduce information asymmetry between equity owners and lenders and therefore the need for due diligence. Lenders are usually organized in syndicates, including large bilateral or multilateral institutions such as multilateral or domestic development banks, global lending banks, insurers or pension funds. A major drawback of direct investments is the illiquidity of the assets. Particularly smaller investors with unpredictable liabilities face challenges when shifting larger portions of portfolio into long-term, illiquid assets.

Corporate level investments

Financing balance sheets of companies implementing infrastructure activities is the traditional approach of non-public finance (Della Croce et al., 2015, p. 18f). Through issuance of shares on the stock market or borrowing funds from capital markets respective companies leverage capital and finance their diversified portfolio.

Hereby, investments in corporations directly or indirectly strengthen the balance sheet of the respective firms. Thus, investments in energy transition elements can only be achieved indirectly and without direct control of the investor. If equity shares are acquired, a significant portion of the value lies in the future prospects instead of the current assets of the firm. Therefore, the investor requires internal or external expertise to evaluate the value of current and future assets, management, skills and experience. Expected cash-flows are dependent on the dividend policy of the corporation, the general corporate strategy of e.g. sustainability in the sense of the objective of the investor as well as the market risk of fluctuating prices for shares or bonds.

Generally, most pension funds face comparably few constraints of investing in corporate energy transition elements as they are usually publicly traded. Thus, such investments do not limit liquidity and research is available for market traded corporate shares or bonds. According to Nelson and Pierpont (2013, p. 14f) the limiting factor is sector diversification, that avoids being overly exposed to a single economic or political development. As long as energy transition elements are comparably attractive to other corporate assets, it will be limiting the portfolio allocation of pension funds.

Pooled investment vehicles

Such vehicles can obtain advantages of both indirect and direct investments, particularly expertise, size and liquidity. There is a broad variety of options, ranging from indirect, indexed sustainable infrastructure equity or debt to pooled direct investments. According to Sawant (2010, p. 51), the most important equity infrastructure indexes that exist since the beginning of the 2000s include the S&P Global Infrastructure Index, Macquarie Global Infrastructure Index and the Credit Suisse First Boston Emerging Markets Infrastructure Index. An assessment by Sawant demonstrates that equity infrastructure indexes inherit comparably high volatility as well as high returns. Additionally, there is a high correlation with the broad equity and stock market indexes and underlying business cycles.

Laboul and Della Croce (2014, p. 34) define the debt fund model as facilitated access to the infrastructure market for fixed income investments. In this model, the investor provides funding to a resource pool managed by an external asset manager, providing the expertise and skills that smaller pension funds might not have. Thus, institutional investors without a dedicated internal team to invest in assets can participate. As debt markets are a comparably new instrument, the market size and experience is limited. So far, private asset managers initiated debt markets for infrastructure activities. Among those are for instance BlackRock. It established a European infrastructure debt platform with a focus on Germany, France, the UK and Benelux countries in 2012, La Banque Postale Asset Management, Amundi or Macquarie managing projects based in the UK and Northern Europe (compare Laboul and Dell Croce, 2014, p. 35). If the pooled fund shares are traded over an exchange, the option allows for liquidity. In case direct investment is included, the size of the fund can decrease risk due to portfolio diversification. Therefore, pooled investment funds could allow nearly all institutions to directly invest into energy transition elements, unlocking significant additional capital of up to USD 270 billion of equity and USD 290 billion of debt in OECD countries (see Nelson and Pierpont, 2013, pp. 14–18). However, transaction costs associated with the funds might be high, as the teams and expertise can be expensive.

Conclusion: Beneficial investment approaches for SIP schemes

Referring to the key dimensional variances of infrastructure investments, equity versus debt, direct versus indirect and listed versus unlisted engagement, literature and practice give indications for SIP scheme preferences.

Infrastructure activities have generally high shares of debt. According to literature assessments (Della Croce et al., 2015, p. 16f; Sawant, 2010, p. 153ff), debt instruments comprise in average 70 to 80 percent of the total investment. This is due to the benefits high leverage provides for infrastructure investments. The mitigation of holdup risks, shielding taxes and sovereign interest through reduced profit reporting, ex-ante definition of cash flows, monitoring of the management and increasing ex-post negotiation power of sponsors are evident advantages of high debt ratios. It can also reveal creeping expropriation and has the potential to "activate the reputation effect" (Sawant, 2010, p. 154), as it counters already small shortfalls of cash flows due to governmental activities or other counterpart holdups with the threat of default. With respect to financing means provided from the private sector to infrastructure investments, Saha et al. (2018, p. 14) confirm this split of equity and debt. According to their analysis of more than USD 24.6 billion of private investments provided to more than 100 infrastructure projects in the first half of 2018, 20% of the volume comprised of mainly private equity, 78% of debt and 2% of subsidies. They find that international and domestic debt constituted about half of the total debt each. Due to its focus on long-term, predictable cash-flows with low variety, SIP schemes preferences particularly correspond with the characteristics of debt (compare for instance Kleine and Krautbauer, 2012, p. 10ff). Most public and private institutions analysed in chapter 4.2 also strongly focus on debt investments, particularly corporate and government bonds.

Equity investments have the advantage of stronger profiting from the project's or company's success and they bring management and control rights and responsibilities. The disadvantage is the exposure to the asset-specific risk as there are usually no securities in case of default (compare Della Croce et al., 2015, p. 17f). Low liquidity of unlisted equity as well as unpredictable cash-flows and return rates of particularly direct PF equity investments do often not match the requirements of pension investors.

With regards to the characteristics of listed and unlisted investments, Bitsch (2012) describes that unlisted infrastructure has a higher performance than non-infrastructure however he does not find evidence for more stable cash flows. Returns were not linked to inflation but probably influenced by the regulatory framework. In contrast, listed infrastructure provides relatively stable cash flows. Transparent financial, governance and regulatory environments lead to better valuation of listed infrastructure. He concludes that institutional investors with limited capabilities to construct diversified portfolios face lower risk when investing into infrastructure funds rather than companies.

Historically, institutional investors including pension funds focused mainly on indirect financing through corporate bonds representing debt investments or stocks representing equity investments. This is also confirmed through the behaviour of most public and private institutions analysed in chapter 4.2. For instance, the Norwegian Pension Fund Global recently rejected the proposal to allow direct project financing. Nevertheless, pressured by the low-interest environment, institutional investors increasingly engage in direct project financing. Temasek or the UK GIB provide significant volumes of direct PF. Theoretically, the determination to apply direct PF or corporate finance is mainly dependent on the likelihood of default and the financial loss given default (LGD). If LGD is low, the asset retains most of its value also under default. This is a typical characteristic for most infrastructure activities. For direct PF, a low LGD is a necessary condition while both low and high probability of default can be acceptable. Sawant (2010, p. 150ff) argues that debt investments with an increased probability of default might rather be suited for corporate financing with a broad balance sheet backing the repayments of debt. Bitsch (2012, pp. 169–171) highlights that directly investing into infrastructure assets provides most favourable characteristics however due to lack of capacity and know-how, high fix-costs and investment volumes, this approach is feasible only for a few large institutional investors. According to Dichtl (2018, p. 48f), large-scale energy infrastructure financing is hardly possible through corporate funding as the financial volumes are restrictively high, the payback periods exceedingly long and determents of related cashflows too complex. This is particularly due to the Basel III regulation that significantly impacts the attractiveness of large volume debt provisions from banks (compare also discussion in chapter 3.3).

An assessment of energy project finance in different geographical markets by OECD/IEA (2017, p. 34) broadly confirms the results of the discussion. For SIP relevant assets such as electricity networks, they revealed corporate or state-owned enterprise balance sheet investments as typical and suitable approach. For utility scale renewable power capacity projects, the authors analysed both direct project investments and corporate balance sheet financing as preferred funding means. For energy efficiency, particularly small-scale building refurbishment, direct PF is not suitable but aggregated asset-backed securities or green bonds are discussed as suitable solution. This shows that no fit-for-all solutions exist. Instead SIP schemes in different markets and with different investment opportunities have to identify and apply suited investment strategies and vehicles. The analysis shows that there is a broad variety of mature as well as some innovative, new instruments available that can be applied by potential SIP schemes. A discussion of potential practical applications on the country level is conducted in the case studies (compare chapter 5.4 and section 3.2.2 of Annex I).

4.5.2. Institutional structure and operational procedures

The SIP concept can be realized through either the establishment of a new institution or the integration into an existing institution. In both cases it is required to reflect best-practice approaches for successful institutional set-ups, governance and operational procedures internally applied by the institution. There are attempts to streamline international standards for public institutional investors. For instance, Al-Hassan et al. (2013, p. 3ff) reflect the "Generally Accepted Principles and Practices of the International Working Group of SWFs" and stipulates recommendations for institutional frameworks and good governance. They distinguish between the legal and institutional set-up, the operational investment management in day-to-day business and transparency aspects including disclosure of information.

With regards to the institutional set-up, one has to distinguish between a public and a private institution. Regarding a public institution, Bönke and Harnack (2017, p. 21f) refer to the Norwegian Pension Fund Global as blueprint. As described in chapter 4.2.2 its legal framing is based on sovereign wealth outside direct control of the government. Its operation is controlled by the independent Norwegian Central Bank. Thus, its resources are not available for other governmental activities, representing secured assets for its members. An independent "Council on Ethics" consisting for instance of politicians, civil servants, lawyers, entrepreneurs, scientists, journalists or NGO members supervises the fund and adjusts the allocation targets and investment criteria (compare Etikkradet, 2018, p. 6; Norwegian Ministry of Finance, 2017, p. 97f). This allows to reflect perspectives from different interest groups and political views as well as to adapt to new economic or ecological developments. Al-Hassan et al. (2013, pp. 27–28) also stress the need for a well-defined institutional structure that builds on decision making hierarchies limiting risks and ensuring integrity with regards to the overarching objectives. For private institutions, there are regulations in place that would require adjustment according to the objectives a SIP should achieve. To implement elements of the impact and objective discussion in chapter 4.4, an approach that includes different political parties and interest groups comparable to an ethical committee described above could be appropriate.

Regarding necessary operational procedures for a SIP scheme, literature discusses key elements. For instance Underhill (2010, p. 173f) describes a typical establishment of an infrastructure management process for institutional investors like pension funds. It consists of several steps that are required to implement a framework that allows portfolio and investment managers to allocate funds according to standardized procedures. This procedure of creating and applying investment policies has been transparently conducted by large public institutions such as the Norwegian Pension Fund, UK GIB (compare chapter 4.2.2) or the Green Climate Fund (GCF) under the UNFCCC.

A first step consists of the development of a policy guideline that guarantees consistency with the envisaged objectives and impacts as discussed in chapter 4.3. This includes guidance on investment criteria, allocation targets, return expectations, investment vehicles and associated risk management systems that are applied to identify and prioritize potential investment activities (compare Al-hassan et al., 2013, p. 17ff). Within the operational process of the investor, multiple dimensions of risk management are crucial to avoid poor investment performance. Underhill (2010, p. 174) stresses that flexibility, control and responsiveness have shown to be key parameters for successfully managing large capital portfolios. Hereby it will be important for the portfolio managers and a potential investment committee to build on a set of quantifiable parameters that can be monitored and evaluated. Identifying all related risks and recording them in a risk register is a helpful and typical procedure. Among these risks can typically be credit risk, currency risk, political risk, labour risk, regulatory risk, construction risk, market risk, environmental risk, climate risk, liquidity risk and financial risk associated with leveraged debt (compare also the discussion of infrastructure investment risks in chapter 3.3.1). With regards to investments' lifetimes and liquidity constraints, SIP schemes are likely long-term oriented. This characteristic has to be reflected in the decision-making structures of the institution to avoid short-term oriented incentives for the management staff (see Sharma, 2015, pp. 4–6). Compared to other investors that do not share such a long-term focus the institution can generate a return premium (compare Allianz, 2015, p. 4).

Particularly relevant for achieving economically and environmentally sustainable impacts under a SIP scheme is the definition of appropriate investment criteria. They should include parameters that are beneficial for SIP members and energy transition activities while reflecting a fair balance between ambition, return and risk. A suggested criterion based on approaches from the GCF Investment Framework and the UK GIB Investment Policy is sustainable impact potential. Only activities that provide sustainable impact, for instance contribute to the mitigation of GHG emissions or activities that are indirectly required as an enabling framework infrastructure, such as power grids, are eligible in the exemplary frameworks (compare for instance GCF, 2014, p. 5 Investment Criterion 1; or UK GIB, 2016, pp. 1–5). The divestment strategy of the Norwegian Pension Fund that limits eligible investments according to the GHG emissions of the respective economic activity of underlying companies (compare chapter 4.2) or recently announced divestment targets of Multilateral Development Banks like the World Bank (World Bank, 2017) serve as additional illustrative examples how such an investment criteria can be operationalized. Also, private institutions like the Allianz Insurance, AXA Insurance or the Dutch ING DiBa bank published targets for limitation of GHG intensive investments (Reuters, 2017).

As not all sustainable infrastructure activities are suffering from underinvestment, financial additionality might be an additional criterion in some SIP contexts. It represents the financial need for long-term funding that has not been enabled by other support schemes (compare for instance GCF Investment Criterion 6). Sustainable socioeconomic or environmental co-benefits of the infrastructure investments are considered by some public funds with objectives beyond risk-revenue optimization. Such benefits could be positively considered when prioritizing the investment options. These might include employment effects or health benefits (compare for instance GCF Investment Criterion 5).

Finally, the geographical scope for eligible investments under the SIP scheme has to be defined. Some authors argue that focusing on one preferred country only leads to macroeconomic inefficiencies, poses substantial stability risks to the domestic economy and increases the risk of corruption and embezzlement (compare discussion of distributional impacts in chapter 4.3.1). The Norwegian GPFG is an example of strongly limiting investments in its "home country" in order to refrain currency exchange rate increases. However, the discussion of associated benefits in a SIP context in chapter 4.3.1 shows the advantage of explicitly focusing on domestic investments. Temasek, as analysed in chapter 4.2.2, is a blueprint example of a SWF strongly and successfully investing in domestic infrastructure. Benefits for and synergies with the surrounding economic area, e.g. the neighbouring countries or an economic area like the European Union, should be taken into account. For instance, Temasek also engaged successfully in Asian neighbouring countries (Cummine, 2014; Temasek Holding, 2018).

The second step of Underhill's' (2010, p. 173f) suggested approach deals with the establishment of procedures for the institutions day-to-day business. Investment and portfolio managers apply the elaborated policy or investment guideline and defined investment criteria to decide on concrete investments. For unlisted infrastructure, the process of identifying appropriate investment opportunities can be a "daunting challenge for institutional investors of any size" (Underhill, 2010, p. 177). It requires exploration, due diligence, valuation, judgement and a skill set to identify and transact suitable infrastructure assets. Across literature and practical experiences (for instance Al-hassan et al., 2013, p. 28; or Nelson and Pierpont, 2013, p. 41, or experiences from UK GIB and Norway GPFG in chapter 4.2.3), many experts stress the importance of competent staff and asset management skills for successful operation and achieve risk-revenue targets while preserving the institution's integrity.

Listed infrastructure equities are an alternative for investors to facilitate due diligence and performance assessments. This approach also provides the ability to adjust the portfolio over time and offers liquidity as the assets can be traded in the market. However, if additional SIP criteria as described above are applied in the allocation process, likely further assessments or standards will be required. The debate around standardized "Green Bonds" or an EU taxonomy for sustainable investments has the potential to facilitate the operationalization also for smaller investors that are not able to conduct all evaluations internally (compare Climate Bonds Initiative, 2019; EC, 2018; The Climate Bonds Initiative, 2015).

Finally, the third step addresses the time after the investment has taken place. Portfolio monitoring to evaluate performance and changing risks over time allow comparison to the pre-defined benchmarks, objectives and goals. It is important to identify problems in an early stage to take action. The monitoring systems for unlisted and listed infrastructure assets are different. While unlisted infrastructure typically reports on a quarterly basis, the challenge is to address problems that occur in between these reporting frequencies. For listed infrastructure there is daily information available about market value and returns. For both approaches, listed and unlisted, the ability of a portfolio manager or investment committee “to act on a judicious manner will help the program perform according to stated objectives” (Underhill, 2010, p. 179).

4.5.3. Transparency and democratic control

The legitimacy of legal reforms, particularly in existential social sectors like pension schemes, relies on the existence of broad-based public support. According to Bloom and McKinnon (2013, p. 3) creating such support depends on the development of “shared values, trust and mutual expectations”. This includes a transparent process of political mediation and social dialogue to allow the reflection of various stakeholder opinions. As both a large-scale implementation of sustainable energy infrastructure and pension system reforms require population backing, proposing SIP schemes will be particularly scrutinized by voters and interest groups. If a reform creates decreasing market shares or profits for existing actors within the pension provider or energy supply landscape, it might generate substantial resistance. This emphasizes the need for high transparency standards and stakeholder involvement. Establishing a process that defines the objectives, legal frameworks and institutional set-up in a concise manner, as for instance the Norwegian GPFG has realized, would increase political feasibility and acceptance. According to Al-Hassan et al. (2013, p. 27), informing the general public about the institutions’ characteristics, investment guidance and associated risks increases resilience in phases of market or capital reflow volatilities.

With regards to transparency and reporting, for instance the Linaburg-Maduell transparency index represents current best-practice standards. It comprises of ten indicators including historical performance data, annual independent validation of activities or an explanation of ethical investment guidance (compare Bönke and Harnack, 2017, p. 19). Also the OECD (2015, p. 123) stresses appropriate transparency and reporting standards that facilitate the investor to fulfill is fiduciary duties towards its members. Al-Hassan et al. (2013, p. 25ff) discuss disclosure and transparency requirements for SWFs. They stress the importance of transparency and disclosure needs to avoid corruption or mismanagement, build public trust in asset safety and improve the institutions’ management. Through open communication with members, stakeholders and civil society, legitimacy of the institution can be increased, and reputational risks decreased. Minimum communication activities comprise of educational seminars, media engagement, publication of annual reports including financial statements and maintaining a webpage with up-to-date information on activities and performance.

4.6.Required framework conditions

A potential SIP scheme needs a suitable environment to operate in. Literature and institutions analysing infrastructure investment strategies highlight the need for appropriate framework conditions as necessary precondition. Parkes et al. (2015, p. 3ff) describe principles of holistic policy frameworks for capital market infrastructure investments from the perspective of the asset manager BlackRock. They highlight the need for political, regulatory, legal, tax and economic stability for long-term engagements over decades. Further they stress transparency of infrastructure data, project pipelines and procurement processes as a requirement for investors to adequately assess revenues and risks. As potential solutions the authors suggest to first develop funding structures that better align interests of investors and public authorities. Second they discuss options for stable, long-term regulatory investment environments building on coordinated decision-making processes between different regulatory institutions, reduced barriers and regulations for investors and the potential of pooling and de-risking investments (compare for instance the EFSI mechanism described in chapter 3.3.4). This approach of applying risk-mitigation instruments, reducing transaction costs through streamlined processes and, if applicable, establishing specialized facilities that leverage funds from different investors or provide technical expertise is also proposed by IRENA (2016, pp. 119–128).

Mooren et al. (2017, p. 8ff) apply a methodology to rank countries according to their relative attraction to infrastructure investors in the long-run. They reflect 24 indicators clustered in five main categories including the economic environment, business environment, risk, existing infrastructure characteristics and financial environment. Indicators of dynamism of the national economies are given high weightings. Despite emphasizing macro-economic parameters such as GDP growth or population growth in a stronger way than Parkes et al. and adding qualitative infrastructure data, the authors basically reflect legal and regulatory environment, investor protection, political stability, implemented financial incentive mechanisms or financial services in a similar way.

Also multilateral organizations like the OECD (2015, p. 122ff) postulate preconditions for sustainable energy investments by institutional investors. The authors highlight the need for a stable macroeconomic environment, responsible fiscal management, strong financial market and a suitable system of channeling public and private savings towards long-term investments. Further they emphasize the requirement of a favorable business environment consisting of "predictable, stable, transparent, fair and reliable business regulation and supervision and administrative and procurement procedures" (OECD, 2015, p. 123).

IRENA (2016, p. 13f) suggests that policies must lead to stable, transparent and predictable market conditions while being flexible for adaptation in changing circumstances. The authors have elaborated framework recommendations for government and financers that, if addressed, help to scale up renewable energy investment (IRENA, 2016, p. 119ff):

- Investors require a solid pipeline of projects for identifying and evaluating activities that best match their investment guidelines. Support of project development from initiation to full investment maturity through capacity building, dedicated grants and networking platforms address this need.
- Access to affordable financing means is a precondition for investments. While the SIP itself addresses this requirement, there might be the need to leverage additional finance for covering the full sustainable energy investment needs. IRENA highlights specifically the role of local financial institutions in renewable energy finance.
- An acceptable level of risk is required to attract private investors. Besides stable regulatory environments, IRENA suggest instruments that particularly focus on developing countries with the aim to reduce off-taker risk and emerging market currency risk.

The World Bank driven Energy Sector Management Program (ESMAP) assesses regulatory frameworks for renewables in most countries worldwide. Hereby ESMAP applies the tool "Regulatory Indicators for Sustainable Energy" (RISE), consisting of 7 main indicators with various sub-criteria to evaluate and score country conditions (see ESMAP, 2018, p. 101ff). The main indicators comprise of:

(1) Legal framework for renewable energy, analyzing primary legislation and legal private ownership;

(2) Planning for renewable energy expansion, evaluating renewable energy targets and plans for different sectors such as power generation, heating and cooling or transport as well as available resource data and siting;
(3) Incentives and regulatory support for renewable energy, assessing financial and regulatory support, grid access;
(4) Attributes of financial and regulatory incentives, such as auctions or feed-in tariffs;
(5) Network connection and use, analyzing connection and cost allocation, network pricing or renewable grid integration;
(6) Counterparty risk, evaluating credit worthiness, payment risk mitigation or utility transparency and monitoring;
(7) Carbon pricing and monitoring, assessing whether there are carbon pricing mechanisms in place or a MRV system for the sector exists.

Table 8 shows an aggregation of the above discussed framework elements that are required for institutional investments and a translation into the SIP scheme context. It briefly describes the framework conditions and gives examples of successful realization. The case studies refer to this table and evaluate the respective country-specific framework conditions in the chapters 5.2.6 and .

Table 8: Summary of required framework conditions for SIP concept implementation

Framework condition	Description
General political and legal framework	This condition describes the general stability and reliability of the political and legal system. This implicitly demonstrates the likelihood of government holdup. It further indicates whether public resistance against infrastructure investments by the pension scheme or against energy related investments can be expected. For assessing the political and legal framework of the country, the “Ease of Doing Business Index” by the World Bank (2018b) and the “Corruption Perception Index” by Transparency International (2019) are suitable publicly available indicators
Legal and regulatory framework for institutional investors	This condition refers to the eligibility of infrastructure investments under the regulatory framework for institutional investors, particularly pension funds and insurances.
Legal and regulatory	This condition refers to the security and stability of the regulatory framework regarding energy transition activities. It also highlights gaps of regulation that

framework for energy transition	need to be addressed by politics in future. It is for instance evaluated under RISE indicators 1-4.
Priorities of investors	This criterion describes the priorities and interests of existing institutional investors in the respective country. It is particularly relevant in case the SIP scheme is integrated into existing institutions.
Experience and capacity of investors	This element describes the experience and capacity of institutional investors to conduct energy infrastructure investments. It is particularly relevant in case the SIP scheme is integrated into existing institutions.
Project pipeline	This criterion describes the availability of a pipeline consisting of mature, bankable investment opportunities that can be evaluated by investors with their traditional tools and methodologies. Further the availability of pooled investments or distinct facilities that bundle projects and funding is reflected.
Potential to leverage debt	This element describes the availability and quality of a financial market environment beyond the SIP. It considers for instance banks or public financial institutions that could provide debt capital to envisaged SIP activities.

Source: Own compilation of required framework conditions based on analysis in chapter 4.6.

4.7. Summary from the SIP perspective

Chapter 4 provides the theoretical and conceptual base for conducting the case studies below. It assesses existing literature elaborating on pension schemes that explicitly finance sustainable energy investments, derives lessons for the SIP approach from existing examples and approaches of private and public institutional institutions, discusses potential impacts of SIP on retirees, society, pension scheme performance and energy transition and describes the main elements and requirements of a SIP scheme. From the perspective of the SIP system, the most important findings of this chapter include:

- While a variety of literature on institutional or SWF investments in sustainable energy assets exists, scientific literature about intended combinations of pension schemes and sustainable energy investments is almost unavailable to date.
- The largest investments in infrastructure assets are coming from public institutions, mainly SWFs and pension funds. Frontrunners have been Canadian and Australian institutions that mainly source their capital from DB or DC pension schemes. Private institutional investors are also increasingly active in the field of infrastructure investments including sustainable energy.

- The assessed private Allianz SE and the public institutions Norwegian GPFG, Temasek Holdings and UK GIB provide helpful experiences about objectives, institutional set-up and internal procedures that enable sustainable energy investments.
- An assessment of SIP objectives and impacts show that the results are highly context and country specific. Several criteria such as distributional impacts, risks, acceptance or democratization of energy infrastructure assets strongly benefit from a broad population coverage.
- An assessment of the key elements required for successful operation of a SIP scheme suggests listed, direct project finance debt as most suitable financing instrument for SIP investments from a risk-revenue perspective. An independent, sovereign institutional set-up with a transparent disclosure and investment policy including appropriate investment criteria and democratic stakeholder involvement are required for creating sufficient public legitimacy of SIP reforms.
- The discussion of the SIP concept shows that some common characteristics exist nonetheless most elements require the choice between different options. The theoretical analysis suggests that a "blueprint SIP" would be based on a DB funded, mandatory, public, centralized institution with strong internal capacities. However again, country and context-specific factors might lead to different results. This characteristic is further discussed in the context of the two case studies.
- Without appropriate framework conditions in the pension and energy supply sector, a SIP scheme will not be able to successfully operate. Particularly stable, transparent and predictable market conditions based on an appropriate regulation and economic incentive mechanisms are important. Also, a pipeline consisting of mature, bankable sustainable energy projects is a prerequisite for identifying sufficient SIP investment opportunities.

5. Case Study Germany

This case study follows the hypotheses and methodological steps as defined in section 2.1. Thus, the key objectives are to explore

- *whether the existing institutions managing private pension capital are already investing in energy transition assets and whether they are eligible and suitable for such investments,*
- *what reforms, alternative options or innovative institutions could unlock additional volumes for energy transition investments,*
- *what volume of energy transition investment needs could be matched by private pension capital resources over the energy transition implementation period under the discussed options, and*
- *what benefits and drawbacks can be expected by increased investments of private pension capital in energy transition assets.*

For achieving these objectives, the following sections analyse firstly the status-quo of the German energy transition and related barriers, the pension provider landscape as well as the regulatory framework and the capabilities of these institutions to engage in infrastructure financing. Secondly, four different options for mobilizing private pension capital are outlined. A spread-sheet model simulates quantitatively the long-term potential for energy transition investments under these options until 2050. Thirdly, country-specific advantages and disadvantages of private pension capital investments in financing energy transition elements are discussed qualitatively. This assessment builds on the theoretical discussion in chapter 4.3. Finally, recommendations are given how to unlock private capital, what limitations are given and what conditions would be required to realize an implementation of the four options.

5.1. Introduction and status quo of the energy transition

Germany is in the process of substantially restructuring its energy supply system. The Government committed to phase-out nuclear power by 2022 and pledged to achieve carbon neutrality by 2045. This can still include carbon sinks or emissions trading, full decarbonisation with negative emission are targeted from 2050 onwards (BMU, 2021, p. 5ff; see BMWi, 2018, p. 9). Core element to achieve these objectives is the German energy transition with the aim of decarbonizing the economy, promote energy efficiency and increase the share of renewable energies in the energy supply sector while guaranteeing affordability and security of supply. In this context, the German Government formulated several quantitative targets related to the energy transition (compare Figure 18).

Figure 18: Quantitative targets of the German energy transition

		2016	2020	2030	2040	2045
GHG emissions	GHG emissions (*base year 1990*)	-27.3%	-40%	-65%	-88%	Carbon neutrality
Renewable energies	Share of gross final energy consumption	14.8%	18%	30%		
	Share of gross final electricity consumption	31.6%	35%	80%		up to 100%
	Share of heat consumption	13.2%	14%			
Energy efficiency	Primary energy consumption (*2008*)	-6.5%	-20%			-50%
	Gross electricity consumption *(2008)*	-3.6%	-10%			-25%
	Heat consumption buildings (*2008*)	-6.3%	-20%			
	Final energy consumption transport (*2005*)	+4.2%	-10%			-40%

Source: Table based on BMWi (2018, p. 8), BMU (2021, p. 5ff), BMJ (2022, p. 1247)

An achievement of the targets is broadly on track for the renewables but faces challenges for the other objectives. Particularly energy efficiency in the transport and building sector is lacking behind the formulated targets. According to BMWi (2018, p. 46), the strong economic development, an increase of population and per-capita room space as well as weather impacts diminished energy efficiency gains in the building sector. The Government reacted with several policies and incentive schemes.

The transport sector is responsible for almost one third of Germanys final energy consumption. An achievement of the overarching energy transition goals will not be possible without significant energy consumption reductions. Compared to the base year 2005, the energy consumption has been increased by 4.2% in 2016 instead of decreasing towards the target of -10% by 2020. Thus, the target for 2020 will likely not be reached before 2030. While railway bound traffic and shipping reduced their energy consumption since 2005, air and road traffic diminished this effect by significant consumption increases.

Besides achieving quantified targets towards decarbonization of the economy, the Government highlighted additional qualitative targets that shall be fulfilled through the energy transition. Among these are security of supply, affordability, competitiveness, environmental integrity, grid extension, sector linkage, digitalization, research and innovation as well as investments, economic growth and employment (see BMWi, 2018, p. 9).

Other stakeholders supplement the target formulation by the Government with further objectives and analysis. For instance Agora Energiewende (2018, p. 13) identified two additional "megatrends" for the energy transition, including a "dominance of fixed costs" and "democratization of the energy system" that have not been explicitly reflected by the Government yet and should to be taken into account. As high fixed costs are directly affected by the costs of capital that is mobilized for energy transition investments and the democratization of energy assets is linked to the investor's structure, both elements are of importance in the context of the SIP-Fund discussion. Democratisation of assets is also stressed as a decisive success factor by Bertram et al. (2018, p. 13), postulating that a decrease of dependence on business and geopolitical interests supports the acceptance. A study by BCG and Prognos for the German Industry Association (BDI) highlights that the distribution of efforts should be balanced adequately across the societal actors. They argue that climate policy therefore needs a linkage with socio-economic and industry policy (compare Gerbert et al., 2018, p. 128).

5.1.1. Planned measures for continuing the energy transition

Despite the challenges to achieve the GHG reduction targets in some sectors such as transportation, Germany continues the energy transition pathway. In this context, the Government and its institutions have implemented new laws and regulations to address shortcomings. The responsible ministries for environment as well as economic affairs and energy have published several strategies and plans containing hundreds of measures and steps since 2014. Most important are the "Action Program for Climate Protection 2020" from the year 2014 and the "Climate Protection Plan 2050" from the year 2016. While the first program defines a broad range of activities to achieve the GHG reduction target for 2020, the latter is the most recent strategy document defining milestones for 2030 and strategic measures for all relevant sectors that lead largely to carbon neutrality by 2045 (see BMUB, 2016, p. 6). One important step in this context is the phase-out of lignite and hard-coal power generation by the year 2038 latest, a respective law has been approved in 2020 (compare BMJ, 2020, p. 1819).

Both the Government (see BMUB, 2016, p. 33, 2014, p. 26) and the research community (see for instance Agora Energiewende, 2018, p. 27; or Gerbert et al., 2018, p. 46ff) highlight the need for a rapid extension of renewable energies, the implementation of energy efficiency measures and a successful transformation of the transport sector as key measures to progress the energy transition.

5.1.2. Estimating the energy transition investment needs

Since the initial formulation of the energy transition long-term targets in 2010, various studies attempted to estimate the investment needs and costs for the energy transition. Also, an expert commission appointed by the Ministry of Economic Affairs and Energy derived an estimation of infrastructure funding gaps, including the energy supply (compare Fratzscher, 2015a, p. 70ff). Most of the scientific studies estimate costs for the German economy and society, including various assumptions such as the fuel costs, O&M costs, financing costs, CO_2 allowances, feedback effects on economy or the internalization of external costs. A common challenge for the estimation of investment needs in the cost debate is a differentiation between a reference and a more ambitious "energy transition" scenario. Also, the projection of technology prices in the future has been identified as difficult aspect by most authors. During the recent decade, investment costs for renewables but also storage or energy efficiency equipment have decreased tremendously (compare for instance Agora Energiewende, 2018, p. 39f). A higher decrease would slightly reduce the overall investment needs, while lower regression rates would slightly increase the overall expenditures.

Overall, the studies come to similar conclusions regarding the total investment needs of the energy transition. Including grid extension, renewable capacity for power and heat supply and their system integration, power storage and energy efficient building refurbishment and a transformation of the transport sector lead to additional expenditures that are estimated to sum up to more than EUR 1 trillion until 2050. According to Fraunhofer ISE, total cumulated investments for the energy transition by 2050 range from EUR 1,415 billion to EUR 1,885 billion while financing costs range from

EUR 1,174 billion to EUR 1,659 billion, depending on the ambition level (compare Henning and Palzer, 2015, p. 40). This highlights the influence of capital costs and the rate of return on investments. Also, Fraunhofer IWES distinguishes between investment needs and capital costs. The total investment requirement from 2011 to 2050 is estimated to about EUR 1,500 billion for technologies only, wind onshore representing the highest investment volume with almost EUR 400 million, followed by building refurbishments with about EUR 250 billion (compare Gerhardt et al., 2014, p. 20ff). The study also assessed the maximum inflation adjusted rate of return to compete with a reference scenario without additional CO_2 allowance prices and with stable fossil fuel costs until 2050, resulting in 2.3% per anno. Higher capital costs disadvantage the renewable energy full supply scenario compared to the reference scenario. A Boston Consulting Group study confirms the Fraunhofer results by estimating investment needs of ~EUR 1,500 billion for the 80% GHG reduction scenario and ~EUR 2,300 billion for the 95% GHG reduction scenario between 2015 and 2050. The compared reference scenario requires investments of ~EUR 530 billion over the same time period (Gerbert et al., 2018, p. 87).

In the context of this thesis, it is important to distinguish between the various energy transition assets as they inherit different investment characteristics. Thus, the attractiveness of investments for the SIP-systems consequently differs. Therefore, a broad range of data sources including the above-mentioned studies has been evaluated to identify investment need ranges for specific energy transition elements. In the following, each identified element in the energy transition context is briefly outlined and data sources are listed.

Renewable power capacity extension

In 2021, the renewable share of total consumed electricity in Germany has been 41%, generated by a total installed renewable capacity of 139 GW (compare BMWK, 2022a, pp. 15–18). The defined targets aim to increase this share to a minimum of 80% by 2030 and up to 100% by 2045 (compare chapter 5.1.1). According to the German Government, about 10 billion EUR have been invested in 7.5 GW of renewable capacity in 2021. The average investment between 2011 and 2021 has been ~14.5 billion EUR annually (compare BMWK, 2022a, p. 18 and p.43). Nitsch et al. (2012, p. 207) estimate a slightly increased annual investment need of about 18 billion EUR for the upcoming decades. According to the Allianz climate monitor, absolute investment needs for power infrastructure in Germany cumulate to USD 23 billion per anno until 2035 (Liesch et al., 2017, p. 38). This volume is supported by Fraunhofer IWES, estimating about EUR 20 billion per anno until 2050 (Gerhardt et al., 2014, p. 16) while BCG and Prognos derive lower values of only EUR ~7.2 billion in average per anno until 2050 (compare Gerbert et al., 2018, p. 87). Summing up, an average value of EUR 17 billion annually is assumed.

Renewable heat supply

As the consumption of fossil fuel for heating and cooling has to be reduced to almost zero by 2050, alternative technologies are required. According BMWK (2022a, p. 43), about EUR 3 billion have been invested into renewable heat capacity between 2011 and 2021. Gerbert et al (2018, p. 84) stress that particularly heat pumps and district heating systems are suitable solutions for the future. Additional investments in biomass and solar thermal heating cumulate to EUR 190 billion until 2050. Gerhardt et al. (2014, p. 15f) estimate the costs for heat pumps to EUR 100 billion. Summing up, an average value of EUR 4 billion annually is assumed.

Power transmission and distribution grids

With an increased share of fluctuating renewable energy sources in the grid, the German grid regulator has identified the need for 1,800 km of high voltage transmission lines back in the year 2009. Finalization of these projects was planned for 2015. However, according to the fifth energy transition monitoring report, only 35% have been realized by the end of 2016. In 2015, the German Government defined a further need of 3,050 km of additional transmission grid lines and 3,050 km of improved grid lines by 2024 (see BMWi, 2017, p. 41). Within the last years, transmission grid operators invested between one to two billion EUR annually in new grid lines (see Bundesnetzagentur, 2016).

To avoid resistance among local affected population and to increase the speed of implementation, the Government decided to prioritize cables below earth since January 2016. As earth cabling incurs significantly increased costs compared to landlines, additional cumulative investment costs of 3 to 8 billion EUR can be expected in the upcoming years (see Löschel et al. 2016, p.93). BCG and Prognos (2018, p. 87) support this value with expected investment needs due to offshore connections of about EUR 5 billion per year until 2050. Agricola et al. see additional investment needs of 2 billion EUR annually (compare Agricola et al. 2012, p. 9). For refurbishment of the existing distribution system, Blazejzak et al (2013, p. 21) estimate 1.5 billion EUR per year. Gerhardt et al. (2014, p. 16) calculate with about EUR 1.5 billion per anno until 2050. Finally, Graichen and Kleiner (2017, p. 22ff) estimate annual needs of about EUR 1.1 billion for the extension of distribution grids, EUR 0.85 billion for offshore grids and EUR 1.7 billion for transmission grids until 2050. Summing up, an average value of EUR 4.3 billion annually by 2020 which is decreasing to EUR 3.5 billion annually by 2030 is assumed.

Electricity storage

Fluctuating generation and demand will still require a substantial amount of electricity storage devices (compare BMWi, 2015, p. 81). Currently hydro pump storage plants with investments of about 5.5 billion EUR are planned. Blazejak et al. (2013, p. 13) estimate a constant requirement of 1 billion EUR for storage technology in the next decades. Both Fraunhofer IWES and Agora Energiewende expect investment needs for storage facilities of about EUR 2 billion per anno until 2050 (Gerhardt et al., 2014, p. 16; Graichen and Kleiner, 2017, p. 22ff). Summing up, an average value of EUR 1.7 billion annually is assumed.

Energy efficiency measures in buildings

Energy savings are considered as the "sleeping giant" of the energy transition. Particularly energy efficiency measures in the building sector can contribute significantly to Germany's ambitious GHG reduction target. The share of buildings' energy consumption from total final energy consumption was 35.3% in 2015 (BMWi, 2018, p. 37). Hereby heating was responsible for 27.5% of total energy consumption. Since 2008, heating consumption has decreased by more than 10% however large investment volumes in energy efficiency measures will be required to continue this trend (see BMWi 2018, p.40-42). Blazejak et al. estimate a continued requirement of 9 billion EUR annually, the Government further identified needs of additional 13 billion EUR per year in order to achieve the efficiency targets (compare e.g. Blazejczak et al., 2013, p. 21). BCG and Prognos derive lower values for building refurbishment of only EUR ~6 billion per anno until 2050 but also provide estimations for the more ambitious 95% GHG reduction pathway of additional EUR 80 billion per year (compare Gerbert et al., 2018, p. 87). Fraunhofer IWES estimates about EUR 6.1 billion per anno until 2050 (Gerhardt et al., 2014, p. 16). Summing up, an average value of EUR 9 billion annually is assumed.

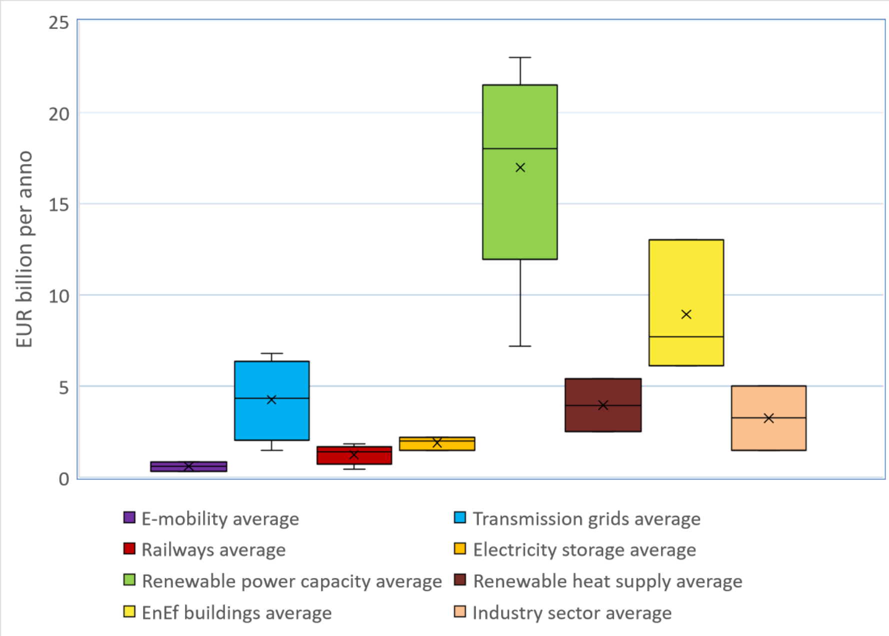
Industry sector

According to Gerbert et al. (2018, p. 88f), the industry sector has accumulated investment needs of EUR 120 billion from 2015 to 2050 and requires additional EUR 110 billion for implementing Carbon Capture and Storage infrastructure under a 95% GHG reduction pathway. Also, an increased application of Power-to-X to substitute fossil fuel derivates with synthetic fuels is considered in these estimations, translating to average annual investment needs of about EUR 5 billion. Fraunhofer IWES also considers investments in synthetic fuels and estimates about EUR 1.3 billion per year. Summing up, an average value of EUR 3.3 billion annually is assumed.

Transport sector

Since the year 2000, several Governmental Expert Commissions have intensively worked out investment gaps for the transport sector. Roads and highways, railways as well as waterways' funding requirements have been explored and the aggregated investment gap has been estimated by 6.5 to 7.5 billion EUR (Bodewig, 2013, p. 39ff; Fratzscher, 2015b; Kunert and Link, 2013, p. 36). For railways, that represent a sector with high relevance for GHG mitigation, investment needs until 2030 range between 0.5 and 1.8 billion EUR annually (Bodewig, 2013, p. 39ff; Daehre, 2012, p. 37; Kunert and Link, 2013, p. 36). BCG and Prognos (2018, p. 87) focus on railway and waterway improvements with about EUR 1 billion per anno and e-mobility extension where infrastructure measures alone are estimated to EUR 850 million per year until 2050. This also includes the implementation of power lines for highway freight traffic. Fraunhofer IWES estimates e-mobility infrastructure requirements of about EUR 0.5 billion per anno until 2050 (Gerhardt et al., 2014, p. 16). Summing up, an average value of EUR 1.3 billion annually for railways and EUR 0.6 billion for E-mobility road transport is assumed. Based on the analysis of investment volume needs derived by the sources discussed above, the potential range of the different energy transition assets is illustrated in Figure 19).

Figure 19: Data comparison of annual investment needs of energy transition elements until 2050; illustrated by a box-and-whisker diagram



Source: Based on references listed in chapter 5.1.2; Explanation: The x in the box represents the mean value. The middle line of the box represents the median dividing the data set into a bottom half and a top half. The bottom line of the box represents 1st quartile, the top line the 3rd quartile. The whiskers (vertical lines) extend from the ends of the box to the minimum maximum value of the dataset.

With a mean volume of about EUR 17 billion annually, renewable power capacity investments require most funds followed by energy efficiency refurbishment of buildings with an average volume of about EUR 9 billion annually. Power grids are estimated to require an average volume of about EUR 3.5 to 4.5 billion annually, renewable heat supply about EUR 4 billion annually and industrial processes about EUR 3.3 billion per year. Railways, e-mobility infrastructure and electricity storage will require less investments of about EUR 1 to EUR 2.5 billion annually. These average volumes aggregate to about EUR 42 billion by 2020, slowly declining over time to about EUR 37 billion by 2050. The resulting cumulated volume required for German energy transition investments from 2020 to 2050 aggregates to EUR 1,150 billion. Chapter 5.4.5 assesses how these investment opportunities match the requirements and characteristics of the SIP-system.

5.1.3. Investors structure for energy transition investments

So far, investments into energy infrastructure have been undertaken by many different actors. There is no transparent overview of the detailed investor's structure for energy transition assets, but some research contributions estimate the distribution among shareholders. For instance, Kemfert and Schäfer (2012, p. 8) illustrate that private shareholders with small scale investments are responsible for about 40% of the renewable power capacity funding. Project developers and utilities follow with 14% and farmers with 11% respectively while funds and banks are on the fifth place only. This allocation of renewable capacity assets is broadly confirmed by Agora Energiewende (2018, p. 65) listing private and citizen shares with almost 50% of the portfolio, followed by project developers, institutional and strategic investors with about 40% and energy providers with about 10% only. A study by trend:research provides an even more detailed split, highlighting that private persons with about one third, project developers with almost 15%, banks and commercial actors with both about 13.5% hold the majority of assets (compare trend:research, 2018, pp. 1–2). With a stronger development of large-scale offshore wind parks and tendering of onshore capacity, the share of private, citizen and farmer will decrease in future, while traditional utilities as well as institutional investors and banks shares' are going to grow (compare also Dichtl, 2018, p. 244f). For energy efficiency refurbishment of buildings, the private households or landlords are mainly responsible for the investments. With regards to distribution and transmission grids, it is private equity from the operators, combined with leveraged debt financing that realizes the investments (compare e.g. Fratzscher, 2015b, pp. 71–75; Kemfert and Schäfer, 2012, p. 8).

5.1.4. Challenges for the energy transition

Mobilizing sufficient finance

The subprime crisis in the United States in 2008 led to a collapse of large banks and investors resulting in decreased trust of financial institutions in each other's and lenders capabilities with the final consequence of significant drawbacks in investments, production and trade globally. This crisis affected particularly the Euro Zone intensively. Many states including Germany introduced emergency programmes to stabilize financial institutions and encourage domestic consumption. As the programmes were mainly financed on public debt, deficits of Euro Member States increased significantly between 2009 and 2012. Due to the leading economic philosophy of austerity in Europe, this phase of spending was followed by harsh fiscal consolidation programmes leading to high restrictions for public spending (compare Fratzscher, 2015b, pp. 12–30).

Germany also suffered a rapid increase of indebtness as a result of the financial crisis. This in turn created a political majority to implement "debt brakes" for German state institutions on the national, regional and municipal level. The national debt brake limits the annual debt deficit to 0.35% of the GDP, regional states have individual debt brakes. An additional "fiscal pact" on the EU level requires Member States to keep their annual debt deficit below 0.5% of GDP. These instruments reduce the financial flexibility of the state significantly, affecting all areas of public spending. At the same time expenditures for social services significantly increased in Germany during the recent decades due to demographic development as well as a reorganization of responsibilities among different state levels (compare also chapter 5.2.1). These restrictions lead to a significant public finance gap for infrastructure investments in Germany, including energy transition elements.

Thus, many private associations and research institutions such as the DIW or the German Advisory Board on Global Change (WBGU) specifically highlight the need of private capital for a successful implementation of the energy transition (see Kemfert and Schäfer, 2012, p. 10ff; WBGU, 2012, p. 9ff). The WBGU concludes that "contrary to many heavily indebted states, private entities and households are holding significant financial property that is principally available for investments in the transition of energy systems" (WBGU, 2012, pp. 9–10). As discussed in chapter 3.2.1, most of private capital-based investments would not be possible without the mobilization of debt capital from private and public institutions such as institutional investors, commercial banks or public institutions like the Kreditanstalt für Wiederaufbau (KfW). However, commercial investors face increasing regulation due to Solvency II for insurers or Basel III for banks, decreasing their appetite for long-term investments due to high equity back-up requirements.

Hereby, one cannot generalize that a funding gap for the German energy transition exist. For instance, some renewable energy capacity seems to be sufficiently financed, others lacks sufficient support. While for large-scale solar PV tendering, proposals have strongly exaggerated the available volumes since 2015 (Bundesnetzagentur, 2022a), biomass and on-shore wind power tenders constantly perceived a shortfall of sufficient bids (Bundesnetzagentur, 2022b). Reasons are mainly unmet profitability objectives of the tender participants, among some shortcomings with the legal and regulatory framework (compare Technischer Fachverlag, 2022). With regards to financing instruments, Dichtl (2018, pp. 160–163) revealed in an empirical assessment that particularly the supply of sufficient debt capital is given for renewable capacity activities while attracting equity capital is slightly more challenging. The transmission grid operators seem to be sufficiently equipped with funding, the related shortcomings of grid extension are rather depending on acceptance problems (compare next section).

However, due to existing barriers (compare chapter 3.3), private capital is not always used efficiently for the construction of long-term infrastructure in the context of the German energy transition. Rather mature assets such as renewable capacity expansion or energy efficiency measures are partly characterized by inefficient financing conditions as capital costs are structured according to perceived unattractive and risky conditions leading to higher interest rates for capital (compare also barriers for institutional investors in chapter 3.3). As incremental investment costs represent the main expense of renewable energy and energy efficiency assets, this characteristic has considerable influence on the overall costs of the transition (compare Agora Energiewende, 2018, p. 44; Gerhardt et al., 2014, p. 22ff; Henning and Palzer, 2015, p. 39ff).

Some less mature, innovative sectors of the energy transition such as smart grids, new energy efficiency solutions or power storage infrastructure are partly underfinanced. Research and development investments, non-mature technologies as well as regulatory barriers are partly unattractive and associated with high risk compared to other funding opportunities. This leads to financial gaps for some required innovations as „barriers for external funding are particularly high if project types are perceived as new and therefore risky" (see Kemfert and Schäfer 2012). Both commercial and public sponsors provide not sufficient financial volumes for promoting required innovation in energy transition elements (compare Dichtl, 2018, p. 198f). However, some rather innovative energy transition elements have received significant amounts of public assistance. For instance, "green hydrogen" research and initial implementation can expect large-scale financing support until the end of the decade (compare BMWK, 2022b). Concluding, the energy transition faces two financial challenges:

- First, a funding gap for specific elements inheriting innovation such as electricity storage facilities or a scattered landscape of contractors such as building isolation making private investments unattractive while the public sector is limited due to fiscal debt restrictions. Also, some renewable capacities such as onshore wind experience shortfalls in sufficient investments.
- Second, unfavourable investment environments for mature energy transition assets likely lead to higher revenue requirements of private investors that increase the overall costs of the transition as well as consumer levies at the end of the day.

Implementation challenges of the energy transition

Besides investment barriers, the energy transition in Germany also faces significant barriers that are universally discussed in the context of transformations (compare discussion in chapter 4.3). There are shortcomings in terms of ownership, participation and communication of costs and benefits leading to acceptance problems. Such insufficiently addressed issues impede effective implementation.

For instance, despite massive financial and regulatory support through the government, only 40% of the rapid expansion plan for the German high voltage transmission grid has been finalized by 2018. Initially the plan envisaged a completion by 2015. For the follow-up phase, the national grid regulator formulated required expansions of about 6,000 km by 2024 but only 150 km have been realized by 2018 (see BMWi, 2018, p. 133; dena, 2012). Hereby, lack of acceptance among the impacted population represents a crucial barrier, various claims have been brought to the courts. Schnelle and Voigt (2012) evaluated that "current experience of transmission grid operators show that public acceptance for grid-extensions is a relevant criterion in affected regions, having significant influence on effort, planning and investment security and pace of progress". Several surveys tried to quantify the acceptance of large infrastructure implementations among the impacted population. Albrecht et al. (2013, p. 35 and 91f) identified that about two thirds of the questioned citizens perceive available participation mechanisms as insufficient or do not have sufficient information about them, 71% even generally favour protests against infrastructure projects.

These results are supported by sociological assessments. Renn et al. (2015, p. 78ff) reveal that a successful transformation of the German energy system can only be achieved if it is understood as a societal project that includes technical innovation, organizational change, effective governance and steering processes of markets, state and civil society.

According to the authors the three "golden objectives" of the energy supply, namely security of supply, environmental integrity and economic efficiency need to be flanked with social integrity across all objectives in order to achieve acceptance. They see the need to create a common identification of the society with this generational mission. All stakeholders emphasize the importance of transparent communication and involvement of affected citizens. This in turn can however create conflicts of interest. The divergency of "hard" top-down steering mechanisms and ambitious timelines meeting with "soft" discursive processes for local population that leave highly limited room for adjustment can lead to a "bundling trap", hindering progress in implementation (compare definition of bundling trap by Radtke, 2016, p. 82).

To address these barriers, the Government and the transmission operators have increased their communication capacities and introduced new regulations. In the case of transmission grid expansion the new law for instance prefers underground cabling to overhead transmission lines, leading to significantly increased investment needs (compare BMWi, 2018, pp. 134–136). Whether these measures are sufficient to speed-up the transformational process remains to be seen.

The assessment shows the potential for an economically sound option that resolves the financing gap, reduces the overall costs of the energy transition and is beneficial for a majority of the German population as well as in line with the Governments debt reduction strategy. Therefore, this case study explores the potential of leveraging domestic private pension capital to finance elements of the energy transformation. Hereby the funds from state subsidized pension schemes are considered as available resources that can be invested domestically in sustainable energy infrastructure. As discussed generally in chapter 4.5, the pension system "investments must meet certain sustainability criteria to balance investment risks for the contributors while guaranteeing environmental sustainability and a an adequate profit level" (Röben and Köhler, 2016, p. 5). A long investment horizon with stable cash-flows for the SIP scheme can be a suitable match to the requirements of energy transition infrastructure with long amortization periods and lifetimes such as renewable capacity, power grids or storage facilities. The following chapters describe the background of the German retirement system with focus on the subsidized private capital schemes, their governance structure, eligibility criteria for investments and their current investment portfolio. Further it discusses its potential role in the energy transition. As different approaches are possible, the thesis discusses four examples that include more or less severe interventions in the existing private pension systems. Hereby the respective benefits but also barriers that are associated with the options are discussed. Finally, the thesis explores what volume of private pension capital could realistically be mobilized for the energy transformation until 2050 under the four options. Hereby the specific energy transition investment needs on the one hand and the mobilized private capital under the different options on the other hand are analysed quantitatively and qualitatively.

5.2. Assessment of Germany's pension system

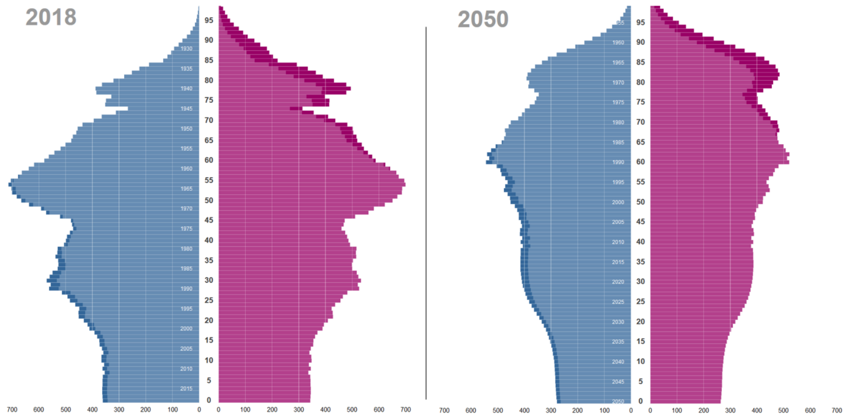
Germany has introduced publicly subsidized occupational, private capital-based retirement schemes already since the 1970s. Due to demographic pressure, benefits from the public redistributive pension scheme have been reduced since the beginning of the 2000s while private capital-based pension schemes have been extended and strengthened. The following chapter analyses the characteristics and financial volumes of these capital-based retirement schemes and estimates the mobilization potential for energy transition investments.

5.2.1. Overview of the German pension system

The German redistributive, second pillar PAYG defined benefit pension system was successful for decades. This intergenerational contract was based on payments of many employed people supporting a minor share of pensioners. Hereby a share of the gross salary, predefined by the legislative, is collected through the pension operator. This share is fixed at 18.9% since the year 2018 and split equally between the respective employer and the employee. In 2016, about 80% of the population is covered actively or passively by the public redistribution system (see BMAS, 2016, p. 8 and 28f).

Due to the demographic development leading to a reduced share of employees and a significantly increased number of pensioners in the future, the public redistribution system will face challenges in the next decades. Figure 20 illustrates that about 60 employees have to finance 40 seniors and adolescents in 2018. For the year 2060 the statistical agency expects a ratio of 50 to 50. This means, one employee would have to finance one pensioner/minor. As policy makers oppose to constantly increase pension payments of employees and employers, Germany started to subsidize pensions from the federal budget. About 85 billion Euro have been transferred in 2021, a volume that significantly reduces the scope of Governmental expenses in other areas (compare Deutsche Rentenversicherung, 2022, p. 4). Hereby, recently approved legal reforms such as a pension subsidy for mothers or early pensions after 45 years of contribution payments lead to further state budget expenses.

Figure 20: The development of the population age ratio in Germany (blue: male population per age in 1,000; pink: female population per age in 1,000)



Source: Federal Statistical Office 2015

Despite these subsidies, the level of pension payments for new pensioners has been constantly decreased due to an automatized “pension adjustment formula”, constituting an average gross DB pension of 48% of the average gross salary in 2018 while the statutory pension age increases to 67 by 2029 (Deutsche Rentenversicherung, 2018). The Government plans to stabilize this level until 2025 while capping contributions by a maximum of 20% of gross salaries (see CDU-CSU-SPD, 2018, p. 91). Post 2025, the Government envisages to adjust the system according to recommendations of an expert commission that elaborates scenarios for the mid-term. It is likely that either a further decreased pension level below 48% or an increased pension age beyond 67 is among the suggestions. Projections demonstrate that already the 48% level jeopardizes sufficient pensions for some future retirees. Börsch-Supan et al. (2016, p. 24f) demonstrate that future pensioners will receive about 12% less benefit payments by 2030 and about 20% less by 2060 compared to the pre-reform situation. This trend will likely inflate with additional decreasing pension levels. Even though Government and experts project it as unlikely development, a decreased pension level in combination with high inflation rates could create additional poverty among future elderly (compare BMAS, 2016, p. 171f; Börsch-Supan et al., 2016, p. 31).

To address an increasing pension gap and avoid potentially increased poverty rates, the government introduced incentives to promote private insurance, third pillar direct contribution schemes. These private capital-based schemes include the occupational pension scheme for employees, the Riester-pension scheme for employees and civil servants and the Rürup-pension scheme for self-employed. These three systems are mainly successful due to subsidization and regulation from the state. Therefore, state interference can directly affect their investment behaviour and motivation of members to contribute financial resources. Beyond these regulated systems exists a rather unregulated and non-subsidized market of private capital investments that is also used for retirement protection which is ignored in the scope of this thesis as is not directly depending on state intervention.

Occupational pension schemes

Occupational pension plans exist in Germany since the 1970s. They have been mainly introduced by large corporations in order to strengthen the connection and identification of their employees as well as to allow economic participation. Since the private pension scheme reforms in 2001, employees have the right to demand occupational pension plans from their employer. Hereby five different options are available, among these are book reserves often combined with support funds, direct insurances, pension providers, pension funds and public suppliers. The main difference among these options is the relevant institution that manages the funds and assets, being it the employer itself, public entities or private actors. Further, the contractual arrangements between employer and retirement provider or employee and insurer differ. All options represent defined benefit schemes, meaning that contributions may fluctuate over time while the benefits are linked through a formula to certain parameters such as the length of contributions or the average member salary. Up to 4% of the maximum social insurance contribution ceiling can be transferred to the occupational pension plan with tax benefits, deductible from the employee’s taxable income. Investment returns are tax free and only benefit payments during the pension period are taxed (compare OECD, 2008, p. 196f). According to the Government, the active occupational pension plans have been increased from 14.6 million in the reform year 2001 to more than 20 million in 2015. Thus about 57% of the regular employees in 2015 are occupational pension scheme members. Main plans are book reserves including support funds with 4.7 million, direct insurances with 5.1 million, pension providers with 4.8 million, public suppliers with 5.4 million and pension funds with 0.4 million contracts (see BMAS, 2016, p. 132f).

There is no transparent and consistent overview of the assets and investments of occupational pension schemes. According to the private insurer association, managing about three quarter of all contracts, the aggregated contributions to support funds, direct insurances, pension providers and pension funds sums up to more than EUR 415 billion in 2017 (compare GDV, 2018b, p. 35).

Riester-pension

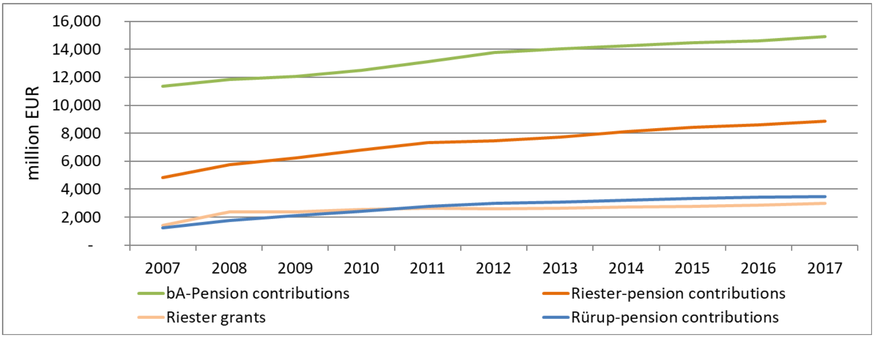
For the capital-based Riester-pension system, named after the former Minister of Labour Walter Riester, many insurance companies offer insurance models with slightly different frameworks. The common element is developing a personal capital stock based on individual contributions. The respective insurance company invests these funds, tries to maximize returns while guaranteeing a minimum interest rate on the capital and charges fees of 10-15% of the total invested capital (see Börsch-Supan et al., 2016, p. 54). Tax reliefs and public grants incentivize this private insurance system. End of 2016, about 16.5 million people representing more than one third of the total German workforce obtained such a Riester insurance (see BMAS 2017). It is based on two incentive mechanisms, direct annual supplements and tax deductions (see BMF, 2018a). In order to receive the full supplements, contractors have to contribute at least 4% of their annual gross income. The German government provides information about annual contributions and subsidies (compare BMF, 2018b, Table 1). According to this information, about 30% of the contractors do currently not contribute to their Riester accounts, the rest of the Riester-pensions is operational, the average annual contribution is about 940 EUR per contract (compare aba, 2015). The number of Riester-contracts and individual volume of contributions have grown strongly in the last decade but the increase slowed down significantly since the financial crisis. They reached slightly more than EUR 8.6 billion in the year 2016, the additional state subsidies sum up to about EUR 3.9 billion of which supplementary grants represent about EUR 2.9 billion and tax deductions about EUR 1 billion annually. Due to the decreasing growth of both new contracts and individual contributions one can expect a continuous adhesion at constant level. The aggregated development of the estimated contributions and supplementary grants reached a combined capital value of about EUR 120 billion in 2017.

Rürup-pension

With the introduction of the Riester-pension scheme and the strengthening of the occupational pension scheme in 2001, employees and civil servants had two state subsidized products as option for private old-age provision. Contrary, self-employed had no incentivized option besides voluntary contributions to the redistributive system. To address this imbalance, the legislative created the "Rürup-pension", named after the former chairman of a commission suggesting the introduction of such pension scheme in the year 2005. Rürup-pensions benefit from the same tax exemptions as contributions to the public redistributive system. The system relies on individual capital-stocks, managed by private entities, mainly insurances. According to the Government, the number of operational contracts are about 2.1 million and the aggregated, contributed capital is estimated at about EUR 31 billion in 2017 (compare BMAS, 2016, p. 148f; GDV, 2018b, p. 15ff). Compared to the Riester-pension the number of contributors is significantly lower but the individual contributions from members are substantially higher.

An aggregated view on all three capital-based, private pension systems shows that there exists a constant increase of contributions and supplementary grants for the Riester option (compare orange line in Figure 21). Even though the total number of members developed very slowly for Rürup and occupational systems and even stagnates for the Riester system since 2014, an annual increase of salaries still leads to increased contribution volumes.

Figure 21: Annual contributions to Riester-, Rürup- and occupational pensions (bA) from 2007 to 2017



Source: (own calculation based on BMF, 2018a, 2018b; GDV, 2018b)

5.2.2. Benefits and shortcomings of the privatized pension schemes

Börsch-Supan et al. (2016, pp. 1–7) recognize the achieved aims of shifting the labor-focused redistributive pension system towards capital-based systems. They posit that an over-proportional burden of the younger generations' labor income can be avoided through stabilization of social security contributions. This additionally strengthens the competitiveness of the German economy, a declared aim of e.g. the Riester reforms. Supplementary grants of the Riester system benefits particularly individuals with low income and families with several children while the tax benefits successfully support mid- to high income households. Furthermore, the broad demand for Riester-, Rürup- and occupational pension-products is currently sufficient to close the pension gap created by the decreased pension level of the regular public system.

Despite this successful development of contracts and contributions for the outlined state subsidized private pension schemes, experts from consumer agencies, research institutions and social associations argue that the partial privatization of the German pension system in the realized way implies significant shortcomings.

First, the coverage of capital-based pension schemes among low-income population has not been successful. Regardless of minor success with Riester contracts among the low salary owners due to high supplementary grants, the risk of requesting basic welfare during pension age and thus losing the private pension savings discouraged these population parts to participate in Riester or occupational pension schemes (compare Bonin, 2009, p. 19f). Further, the Riester scheme mainly subsidizes the top income households. According to Corneo et al. (2015, p. 20), only about 7.3% of the subsidies accrues to the bottom quintile of the income distribution while about 38% are flowing to the top quintile. Hereby higher income correlates with both a progressive amount of subsidies and the participation rate. Additionally the authors revealed that the scheme does hardly generate any additional savings of population but rather displaces unsubsidized savings with subsidized savings, creating tax financed windfall gains for the beneficiaries (compare Corneo et al., 2015, p. 3).

Second, Hagen et al. (2011, p. 10ff) have identified key drivers for the stagnation of Riester contracts. Amongst these are an insufficient certification, an unrealistic mortality table determining future life expectancy and significantly reduced, guaranteed interest rates as a result of the financial crisis. For an average Riester contract signed in 2011, the authors have calculated that, depending on the product, the pensioner would have to reach 77 to 88 years of age in order to achieve an interest rate of 0% on the invested capital. If contributors look for a rate of return of 2.5%, for example to compensate the inflation rate, they would have to reach already an age of 87 to 124 years. A rate of return of 5% is usually not achievable for average Riester products. Also, the conditions for distributing surplus capital stemming from higher revenues, lower costs or particularly the discussed pre-statistical death profits have been adjusted. While in 2001 a share of 90% of all surpluses had to be shared among the members and 10% flew to the managing institution as profits, member benefits have been decreased to 75% for pre-statistical death profits and 50% of the cost savings after the reforms in 2005 (see Kleinlein, 2011, p. 24). Thus, the authors suspect that the design of the Riester system mainly redistributes wealth from private and public contributors to insurers. "Based on these findings, a fundamental change of Riester products is appropriate" (Hagen et al., 2011, p. 14). Börsch-Supan et al. (2016, p. 6) support the criticism of partly extraordinary high signature, administration and management fees combined with the unrealistic mortality tables leading to an adverse selection of potential customers. All experts claim significant shortcomings regarding the transparency and complexity of the contracts. Due to the complicated structure of many products, it is highly difficult to compare those and particularly estimate the total costs over the lifetime of the contract. Assessments came to the conclusion that cost quotas between 2.5% and 20% for similar products are possible (see Börsch-Supan et al., 2016, p. 7). Further it is claimed that the certification of products is insufficient, it should entail standardized elements and request clear cost-transparency to facilitate a comparison between different contracts (compare Fischer et al., 2013, p. 65).

Besides this partly unfavourable framework of the Riester scheme design, there might be also systemic shortcomings regarding permitted investments foreseen for pension payments. For many cases the capital is invested internationally in stocks and government bonds and does not remain in the respective economy. This lowers domestic investments on the one hand, on the other hand international investments might be associated with higher risks. This was evident during the international financial crisis since 2007, leading to a decreased guaranteed rate of return from 3.25% in the year 2002 to 0.9 % only for new Riester contracts from 2017 onwards (compare Statista, 2018a). Börsch-Supan et al. (2016, p. 6) emphasize the high costs to guarantee the availability of contributions and supplementary grants at the beginning of the pension age in this low-interest context. This can only be achieved with a high share of government bonds in the portfolio which is, due to the low-interest rate environment, significantly less profitable than e.g. stocks. They conclude that even with a default likelihood of less than 1% the implicit costs of the guarantee can aggregate to up to five times the achievable revenues.

Regarding occupational pension schemes that do not explicitly include a guarantee for contributions, Fischer et al. (2013, p. 51ff) state that about 80% of the contractual arrangements do not have sufficient guarantees for the employer that is finally liable for providing at least the contributions to his employees. They posit that OECD countries have already and will increasingly open up investment opportunities for pension schemes in order to enable the pension providers yielding the contractually defined revenues. This however comes along with additional risks that have to be covered in case of default. Whether this is the state as during the financial crisis, employers that are liable for providing occupational payments, the shareholders of the financial intermediaries or the end-user that might be confronted with losses cannot be answered consistently.

5.2.3. German investment guidelines and portfolio of the insurers

Private capital managed by insurers, pension funds, pension mutual funds and certified Riester and Rürup providers cannot be allocated without limitation. Contrary, most options are strongly regulated to preserve the contributed capital until retirement and partly guarantee a rate of return. Hereby mainly four regulations are of importance:

- According to the insurance regulation (Versicherungsaufsichtsgesetz [VAG]), up to 30% of the investment portfolio can be allocated to volatile assets such as stocks. The remaining capital has to be invested conservatively and with high securities. This characteristic limits the portfolio allocation for Riester providers (compare Kleinlein, 2011, p. 33).
- The investment regulation (Anlageverordnung [AnlV]) is responsible for mutual pension funds and small insurers with maximum contributions of EUR 5 million per anno. It defines eligible asset classes with maximum investment limits and prescribes diversification ranges for debtors and single investments (compare BMJV, 2016a, §1-4).
- Pension funds, eligible for managing occupational pensions since 2001, are less regulated through the pension fund supervision regulation (Pensionsfonds-Aufsichtsverordnung [PFAV]). It regulates eligible asset classes with maximum investment limits and diversification ranges for debtors and single investments less stringent the regular investment regulation (compare BMJV, 2016b, §1-4).
- Based on the experience from the financial crisis 2008 and 2009, the EU Commission started a process to increase protection of insurance funds. This process resulted in the Solvency II regulation for insurance companies. It includes qualitative regulation for management and due diligence, transparency and reporting requirements and most relevant in the context of this thesis quantitative regulations for risk-based, solvency capital that has to be refrained for each investment. If an insurer wants to invest in e.g. infrastructure through a specific financial instrument, it has to withhold a percentage of equity on its balance sheet in order to balance default risks.

Table 9 summarizes the investment limitations for different asset classes under the regulations discussed above. It is indicated under which asset classes energy transition investments are eligible or likely eligible. Diversification ranges for debtors and single investments will not be considered in this context as the precise investment portfolio of the capital managing institutions are not publicly available and a future investment allocation cannot be predicted precisely.

Table 9: Definition of SIP asset class allowable ranges based on portfolio value

Asset Class	AnlV	PFAV	Solvency II	VAG
Bonds, debt with government securities	10-35 %	Flexible, appropriate according to individual pension plan	No quantified targets for asset classes. Regulation is risk focused, solvency capital has to be withheld on balance sheet. Equity requirement infrastructure: 30% solvency capital Debt requirement infrastructure: 20% solvency capital	Conservative investment with high securities
Debt to enterprises with high rating	Max. 5%			
Pivate equity	Max. 35%			Max. 30%
Real estate	Max. 25 %			
Asset-backed securities	Max. 7.5 %			
Others	Max. 7.5 %	Max. 10%		

Source: Own table based on analysis in chapter 5.2.3

In an empirical study based on interviews with institutional investors in Germany, Dichtl (2018, p. 121ff) points out that lobbyism among policy makers was successful to improve the infrastructure investment conditions for institutional investors. For instance, the German Bank Association was arguing to facilitate equity demands for infrastructure investments and create infrastructure as an won asset class within the Solvency regime (see VOEB, 2016, p. 10). Both the Sovency II regulation as well as the German AnlV and PFAV have been reformed in 2016 and further interpreted through the regulator in 2018 (compare BaFin, 2018). This leads to facilitated investment requirements for infrastructure and company debt products. Particularly reduced equity requirements on the balance sheet of the investor enable more external debt provision and increase the attractiveness of infrastructure investments (compare Dichtl, 2018, p. 122). Separated per pension scheme, the following limitations are given:

- With regards to occupational pension plans, the eligible investments are subject to the respective option. While direct insurances and public suppliers fall under Solvency II regulation for insurances, pension providers and pension funds fall under the pension fund supervision regulation. Both theoretically allow direct equity or debt engagement in infrastructure up to certain limitations.

- For Riester pensions, eligible investments comprise of equity in stocks and debt in government or corporate bonds. Thus, only indirect investment in stocks or bonds of companies active in the field of the energy transition could be acquired under the current regulation.
- Rürup pensions fall under the classification of life insurances, thus Solvency II regulation applies. Thus, direct equity or debt engagement in infrastructure up to certain limitations is eligible.

5.2.4. Existing investments of pension capital in energy transition assets

In order to address one key hypothesis of this thesis it is required to analyse whether the existing investments of the German private pension system already cover energy transition assets. As a central data source for such investments does not exist, it is a challenging exercise to identify information. For the most prominent elements of the energy transition publicly available studies exist:

Concerning renewable energy development, institutional investors slowly grow their shares, in the most recent assessment about 13.4% of the capacity was owned by banks and funds. The renewable lobby association highlights that "this development shows the growing attractiveness for institutional investors" (Agentur für Erneuerbare Energien, 2018). Dichtl (2018, p. 117ff) analysed publicly available sources from large institutional investors in Germany, such as the Allianz Group, Munich Re, Axa Group, Generali Group, BVV Pensionfonds and the Swisslife Group. She revealed through desk reviews and empirical interviews that they allocate less than 1% of their total portfolio to infrastructure activities with energy transition context which is in line with the international experience as discussed in chapter 3.2. Besides direct project investments, indirect ownership of renewables is given through stocks of utilities. Institutional investors including pension funds and insurers held the majority of E.ON and RWE, two of the four largest German utilities that also include some renewables in their portfolio (compare E.ON SE, 2018; RWE AG, 2018). According to the association of German insurers, the cumulated investments in renewable energies by insurers has been about EUR 4.5 billion in 2015, slowly increasing to about EUR 5 billion in 2017 (compare GDV, 2018a, p. 5). As about half of the insurers total managed funds are stemming from pension schemes, one can consequently consider that this equals about EUR 2.5 billion of energy transition assets.

Regarding transmission grids, institutional investors are holding significant shares of two out of the four big operators. A consortium consisting of large insurers and pension funds led by Commerz Real AG purchased 74.9% of Amprion's shares in 2011 and the Australian Industry Fund Management held 40% of 50Hertz' shares until mid of 2018. Since then, 50Hertz' shares are split among the German KfW with 20% and the Belgian grid operator Elia which is owned by multiple shareholders including public and private actors (compare 50Hertz GmbH, 2018; Amprion GmbH, 2018). The transmission grid operator TenneT Holding B.V. is exclusively owned by the Dutch Ministry of Finance, and Netze BW GmbH is predominantly owned by the state of Baden Württemberg and related municipalities.

5.2.5. Barriers for investments in energy transition assets

Besides the regulatory limitations for infrastructure investments described in chapter 5.2.3, institutional investors face additional barriers for energy transition investments. They are broadly consistent with the barriers that have been identified on the global level. As described in chapter 3.3, institutional investors in Germany are particularly confronted with the following challenges:

- **Structural barriers:** Generally, institutional investors act according to typical characteristics including investment targets, investment vehicles, liquidity, capital allocation and requirements on specific investment options, particularly the risk-revenue ratio (compare also general discussion in chapter 4.5.1). These structural barriers can also be identified for German pension managers. Dichtl (2018, p. 126ff) describes that they focus on common and mature asset classes, prefer standardized project pipelines, rely on internal experience, compare a new asset class with existing options and emphasise illiquidity that is particularly linked to investments with high incremental costs and a non-existent or non-mature unlisted market as many energy transition assets inherit. The criterion of sustainability, neither economically nor socio-ecologically, does usually not exist or plays an underrepresented role. The internal processes that lead to investment decisions are complex and dominated by conservative decision making, avoiding innovation and unfamiliar asset classes.

- **Revenue attractiveness:** While the German feed-in tariff was successful for almost two decades, the recent developments decreased the attractiveness for investments. Since 2017, large-scale renewable power projects face limitations and are realized through tenders. This might limit the attractiveness for institutional investors in future.
- **Capacity challenges:** According to Dichtl (2018, p. 137f), most of the German institutional investors do not have sufficient experience with energy transition assets. Additionally, smaller institutions do also not have sufficient capacity to build up internal teams that can operate in this relatively new field. They have to rely on external service providers or funds, operated by external asset managers. This creates additional transaction costs reducing the rate of return for shareholders and financial institutions thus decreasing the attractiveness of investments in energy transition elements.

5.2.6. Required framework conditions for energy transition investments

The framework conditions defined in chapter 4.6 are assessed in the context of the German energy transition and the German private pension capital management landscape to present a qualitative evaluation result, based on the analysis in the previous chapters.

Political and legal framework

The World Bank's "Ease of Doing Business Index" places Germany on rank 24 of 190. Germany scores comparably high on the underlying indicators of "dealing with construction permits", "getting electricity", "getting credit", "enforcing contracts" and "resolving insolvency" (compare World Bank, 2019a, p. 173). This shows that Germany has a stable political and legal system with a high degree of legal security. This is also backed by Transparency International's "Corruption Perception Index" which ranks Germany 11th of 180 (see Transparency International, 2019). Government holdup is hardly not evident as the analysis of the investor's structure in chapter 5.1.3 shows. However, Germany faces severe acceptance problems within civil society, particularly with regards to the large-scale implementation of new energy infrastructure such as transmission lines or wind parks (compare chapter 5.2.5). Despite those acceptance barriers, the political and legal framework conditions are sufficient for SIP activities.

Regulatory framework for investors

Institutional investors can rely on a comprehensive and operational regulatory framework. As discussed in chapter 5.2.3, limitations for the allocation of SIP related asset classes are imposed for different investors. Since the regulatory reforms in 2016, investments in infrastructure are facilitated, reduced equity requirements enable more external debt uptake. However, strong limitations prevail for some key investor groups, e.g. Riester funds can only allocate resources to indirect assets. Thus, the regulatory framework for SIP investors is not evaluated as entirely sufficient and would require further flexibility.

Regulatory framework and incentive framework / financial mechanism for energy transition

Germany was ranked as country with the highest RISE score globally by ESMAP in the year 2017 (ESMAP, 2018, p. 74). On all relevant aspects such as the "legal framework for renewable energy", the "incentives and regulatory support", the "attributes of financial and regulatory incentives" or "counterparty risk", Germany received excellent evaluation scores. This is particularly due for mature elements of the energy transition such as RE capacity, grid extension or energy efficiency measures. However, innovative elements such as storage or sustainable transport are not sufficiently regulated yet (compare analysis in chapter 5.1). Finally, the EU energy market legislation could limit engagement by potential SIP actors since it requires vertical unbundling of power transmission and generation thus prohibiting control of such assets by the same investor (compare EC, 2013). Despite those potential challenges for some investors, the overall regulatory and incentive framework for the energy transition is evaluated as sufficient for a SIP engagement.

Priorities of investors

Chapter 5.2.5 discusses that German insurances and pension funds share the typical institutional investor priorities. They prefer stable cash-flows and attractive risk-revenue ratios of mature asset classes. Those characteristics are met by renewable capacity or electricity transmission infrastructure. However due to their focus on bonds, indirect investments, liquid assets due to mark-to-market accounting (see also chapter 3.3.1) and a strong preference of broadly diversified portfolios, German institutions also inherit unfavorable priorities for SIP investments. Thus, a broad engagement of the existing institutional investors would require an adoption of adjusted investment targets and priorities.

Experience and capacity of investors

Since German institutional investors are rarely engaged in energy infrastructure, their internal experience is limited (compare chapters 5.2.4 and 5.2.5). Mature market support from external service providers through e.g. standardized financial products or ratings has not yet been sufficiently established. Investments in assets the investors are not familiar with would come with an increased need for due diligence. Thus, high transaction costs occur. Moreover, smaller institutions do not have sufficient resources to build up internal expertise, further limiting the range of potential SIP investors. This concludes in an insuffient evaluation result regarding SIP related experience and capacity of existing institutional investors that need enhancement before large-scale SIP investments can take place.

Project pipeline

Various project developers prepare and elaborate energy transition project options. For smaller project tranches, specialized providers offer an aggregation of assets to increase attractiveness for institutions that look for larger-scale investments. Also, the reformed auctioning mechanism for renewable capacity tends to favour institutional investors that intend to invest larger volumes (compare analysis in chapter 5.1).

However, only scarce pooled investment opportunities of smaller assets are on the market so far, limiting direct engagement of interested investors. This is particularly due for energy efficiency measures that can be highly scattered and complicated to aggregate. Thus, the structuring of an attractive project pipeline across all energy transition elements would need further enhancements, either directly from the project developers side or through external financial market service providers.

Potential to leverage debt

As outlined in World Bank's Ease of Doing Business Index, Germany provides an "in-depth credit information index" and shows a "broad coverage of credit providers". The banking landscape is manifold and has gathered already partial experience in energy infrastructure financing (compare the shareholder and investor structure presented in chapter 5.1.3). Finally, also public banks such as the KfW are available to support large-scale debt provision in the context of the energy transition. A KfW evaluation finds that KfW provided about 25% of the total debt financing for renewable energy in the power and heat sector in 2019 and 2020 (see Bickel and Kelm, 2021, p. 3). However, the Basel III regulation decreases attractiveness of long-term bank credits and limit the length of credit lines, imposing potential barriers for SIP investors to rely on the banking sector as typical provider of debt (compare chapter 3.3.2). Those regulations might have to be adapted to form a sufficient debt market to leverage SIP equity investments.

Table 10 summarizes the evaluation results of the discussed framework conditions in the German context.

Table 10: Assessment of framework conditions to unlock pension capital for energy transition assets

Framework condition	Indicator results, references	Interpretation in the German context	Evaluation result
Political and legal framework	Ease of doing business index: 78.9 of 100 (Rank 24 of 190) Corruption Perception Index TI: 80 of 100 (Rank 11 of 180) (see Transparency International, 2019; World Bank, 2019b)	Germany has a stable political and legal system with a high degree of legal security; Government holdup hardly not evident; acceptance problems within civil society	✔ ✔
Regulatory framework for investors	Compare analysis in chapter 5.2.3	Since the 2016 regulatory reforms, investments in infrastructure are feasible, but posits limitations e.g. indirect investments for Riester only. Institutional investors' lobby demands further deregulation.	✔
Regulatory framework for energy transition	RISE score 97 (rank 1) (see ESMAP, 2018) Compare analysis in chapter 5.1	Mature elements of the energy transition (RE capacity, grid extension, energy efficiency) are well regulated and provide a secure environment; innovative elements (storage, transport) are not sufficiently regulated yet; the EU energy market legislation requires vertical unbundling of power transmission and generation thus prohibiting control of such	✔ ✔

		assets by the same investor (compare EC, 2013)	
Incentive framework / financial mechanism for energy transition	RISE score 97 (rank 1) (see ESMAP, 2018) Compare analysis in chapter 5.1	For mature elements such as renewable capacity or transmission grid expansion, powerful financial mechanisms are in place. For more innovative elements such mechanisms are not yet implemented	✔ ✔
Priorities of investors	Compare analysis in chapter 5.2.4 and 5.2.5	Positive: Stable cash-flows, attractive risk-revenue ratios Negative: Focus on bonds and indirect investments; preference of liquid assets due to mark-to-market accounting, diversification focus	✔
Experience and capacity of investors	Compare analysis in chapter 5.2.4 and 5.2.5	Hardly no experience; no standardized ratings; increased need for due diligence; high transaction costs; reliance on external service providers	⃠
Project pipeline	Compare analysis in chapter 5.1	Positive: Many RE project options; specialized providers for aggregation of assets Negative: Limited pooled investment opportunities; disadvantage for smaller investors with tendering; energy efficiency assets highly scattered	✔
Potential to leverage debt	Compare analysis in chapter 5.1.3	Positive: Broad banking landscape with partial experience in ET financing; public banks available Negative: Due to Basel III, long-term bank credits unattractive; limited length of credit lines	✔

Source: Own table based on analysis in chapter 5.2; ✔ ✔ indicates sufficient conditions, ✔ medium conditions and ⃠ not sufficent conditions

While some of the framework conditions such as stable and favourable investment conditions for energy transitional assets or the regulation of the financial sector can be directly addressed or improved through the regulator and legislative, other limitations are due to internal characteristics of the institutional investors. These internal constraints hinder a broad engagement of institutional investors in the energy transition so far. Nevertheless, some dynamic increase of activities can be observed reflecting that the political and regulatory framework seem to provide sufficient attractiveness. The low-interest environment pushes institutional investors towards new asset classes that are associated with higher rate of returns and infrastructure is one option. Also, the changing environment with climate change impacts and regulation in the context of the Paris Agreement goals (compare UN, 2015, para 2) demands increasing resilience against accumulation of carbon-intensive assets and the avoidance of stranded assets in carbon-intensive sectors through fossil-fuel divestment. Thus, energy transition assets have attractive characteristics for institutional investors however they need to resolve internal challenges for successfully ramping up investments.

5.2.7. Assessment results

Despite a successful development of renewable energy capacity during the recent two decades, the German energy transition has not achieved all of its 2020 goals. While renewable power and heating capacity is on track, the expansion of grids, energy efficiency improvements and the transportation sector failed the defined targets. Besides regulatory shortcomings, particularly acceptance problems among impacted population and partial funding gaps hinder a progressive development. The latter will likely not be addressed by the currently existing investor structure as public funding potentials are limited through austerity instruments while commercial investors are not capable or interested to fill the gap.

The German redistributive pension system provides its members declining pension payment levels in the future, representing insufficient resources to allow pensioners holding their living standard. Established capital-based alternatives, mainly the Riester scheme, seem not be sufficiently reliable to cover the gap. Contentious design parameters disadvantage contributors and strengthen the private managers of individualized, capital-based pensions. Low revenues on capital contributions due to the decrease of interest rates through the European Central Bank as a reaction to the financial crisis jeopardize profitability and put pressure on expanding investment opportunities with increased risk. Adjusted regulation generally allows insurers and pension funds to invest in infrastructure including energy transition assets up to certain limits, but they rarely do. Hereby rather internal structural deficits and barriers are responsible for the cautious behaviour than the regulatory and financial environment.

5.3. Long-term potential of private pension contributions for energy transition investments

So far, the volume of pension capital that could be mobilized for energy transition investments in Germany has not been scientifically explored. This part of the case study assesses the quantitative SIP scheme potential. Hereby the three-step methodology as defined in the methodology section (chapter 2.1) is applied to derive the maximum available capital provisions until 2050 under four different scenarios, reflecting increasing levels of policy reform stringency.

5.3.1. Step 1: Estimation of private pension capital mobilization potential

The estimation of the SIP system's potential to leverage private capital from its members is based on the cash-flow methodology and depends on several parameters. As defined in the methodology chapter 2.1, "most important elements are the demographic development of the population as well as cash inflows and outflows of the system". The following section summarizes the key parameters, lists the relevant references and explains the assumptions that have been used for the simulation (see also Table 11 for a comprehensive overview of applied references as well as Table 12 for the SIP mobilization potential, Table 13 for cash-inflows and Table 14 for cash-outflows).

Table 11: Overview of data sources

Parameter	Applied data	Data source
Demographic development of population	Number of work force, unemployed and pension age; average gross salary (annually)	(DESTATIS, 2018; Pötzsch and Rößger, 2015; Statista, 2018b)
Riester pension information	Number of Riester contracts, contributions, subsidies, aggregated capital, benefit payments (annually)	(BMAS, 2016; BMF, 2018a, 2018b; GDV, 2018b)
Rürup pension information	Number of Rürup contracts, contributions, subsidies, aggregated capital, benefit payments (annually)	(BMAS, 2016; BMF, 2018a; GDV, 2018b)
Occupational pension information	Number of occupational pension contracts, contributions, aggregated capital, benefit payments, administration costs (annually)	(BMAS, 2017a, 2017b, 2016; Fischer and Siepe, 2016, 2015; GDV, 2018b; Heien and Heckmann, 2016)

Asset allocation of private pension systems; average rate of return	Asset classes and shares of private and public institutions managing Riester, Rürup and occupational pensions, average rate of return	(GDV, 2018b; Kleine and Krautbauer, 2012; Mönch, 2015; OECD, 2017b, 2017c, 2008)
Energy transition characteristics	Asset classes, investment lifetimes, rate of return, administrative costs	Results from chapter 4.4, (Dichtl, 2018)

Source: Compilation of research results

Table 12: Applied data for simulation of SIP mobilization potential, according to equations and parameters as defined in case study methodology in chapter 2.1

Parameter	Explanation and unit	BAU Scenario	Regulatory Scenario	SIP-Fund Scenario	Mandatory Scenario
i	Start year of modelling	2020	2020	2020	2020
n	Final year of modelling	2050	2050	2050	2050
INV_{TOT}	Total available investment capital, in billion EUR_{2018}	117 (2020) decreasing to 116 (2050)	116 (2020) decreasing to 113 (2050)	26 (2020) increasing to 167 (2050)	31 (2020) increasing to 136 (2050)
INV_{TRA}	Traditional investment allocation, in billion EUR_{2018}	738 (2020) increasing to 1,281 (2050)	735 (2020) increasing to 1,088 (2050)	Not applicable	Not applicable
SIP_{IN}	Cash-inflows to the SIP scheme, in billion EUR_{2018}	155 (2020) increasing to 282 (2050)	155 (2020) increasing to 279 (2050)	27 (2020) increasing to 244 (2050)	32 (2020) increasing to 181 (2050)
SIP_{OUT}	Cash-outflows from the SIP scheme, in EUR_{2018}	39 (2020) increasing to 166 (2050)	39 (2020) increasing to 167 (2050)	1 (2020) increasing to 77 (2050)	1 (2020) increasing to 44 (2050)

Own table based on parameters defined in Chapter 2.1 and "SIP simulation_Germany" model results

Demographic development:

Since demographic development influences both cash-inflows and outflows of the pension systems, it is of an overarching importance. As outlined in chapter 5.2.1, the number of pensioners will significantly increase compared to the population in working age. The Federal Statistical Office published forecasts for the composition of the German society until 2060 that can be used for the simulations (see Pötzsch and Rößger, 2015). Hereby the basic scenario, that is applied in the context of this thesis, assumes a fertility rate of 1.4 children per woman. The strong immigration in the years 2015 and 2016 due to the Syrian refugee crisis is reflected with net immigrants decreasing from 500,000 in 2015 to 100,000 per year from 2021 onwards. The model allows to compare annual cohorts of the work force from an age of 20 up to the increasing statutory pension ages of 66 in 2021 and 67 by 2029 to the cohorts of population in pension age. The highest number of potential pensioners in this scenario is reached with 22.3 million in the year 2037 afterwards declining to 21.6 million by 2050. The maximum work force has been almost 52 million at the beginning of the 2000s, steadily declining to about 46 million in 2020 and 37 million by 2050.

Simulation of cash-inflows from members:

Contributions by pension scheme members are the main source of cash-inflows in 2017. In the German context, the contributions are differently structured according to the three private pension systems: Occupational scheme members provided more than EUR 30 billion in 2017, stemming mainly from employed personnel but also from employers. Contributions to the Riester system amounted to EUR 8.9 billion and almost EUR 3 billion of supplementary grants from the state budget. The Rürup system contributions have been almost EUR 3.5 billion. Thus, the total, nominal contribution to subsidized, private pension schemes has been more than EUR 46 billion in 2017. To project cash-inflows until 2050, the model assumes a decreasing total number of members of the work force while considering a slight increase of contributing member shares and salaries based on the development within the years 2012 to 2017.

Table 13: Applied data for simulation of cash-inflows, according to equations and parameters as defined in case study methodology in chapter 2.1

Parameter	Explanation and unit	BAU Scenario	Regulatory Scenario	SIP-Fund Scenario	Mandatory Scenario
PEN_C	Pension contributions, in billion EUR_{2018}	46 (2020) increasing to 61 (2050)	46 (2020) increasing to 61 (2050)	25 (2020) increasing to 68 (2050)	32 (2020) increasing to 38 (2050)
SG	Supplementary grants by the state (if applicable), in EUR_{2018}	3 (2020) increasing to 4 (2050)	3 (2020) increasing to 4 (2050)	2 (2020) increasing to 5 (2050)	Not applicable
INV_{REF}	Reflows from relieved investments, in billion EUR_{2018}	75 (2020) increasing to 154 (2050)	74 (2020) increasing to 138 (2050)	0 (2020) increasing to 39 (2050)	0 (2020) increasing to 34 (2050)
INV_{REV}	Revenues from investments, in billion EUR_{2018}	31 (2020) increasing to 64 (2050)	31 (2020) increasing to 77 (2050)	0 (2020) increasing to 132 (2050)	0 (2020) increasing to 108 (2050)
POP_E	Total employed population	44 (2020) decreasing to 36 (2050)	44 (2020) decreasing to 36 (2050)	44 (2020) decreasing to 36 (2050)	44 (2020) decreasing to 36 (2050)
SIP_{MC}	Share of employed population with SIP-membership, in %	80% (2020) increasing to 90% (2050)	80% (2020) increasing to 90% (2050)	40% (2020) increasing to 90% (2050)	100%
INC_{POP}	Average employment income of population, in EUR_{2018}	37,000 (2020) increasing to 54,000 (2050)	37,000 (2020) increasing to 54,000 (2050)	37,000 (2020) increasing to 54,000 (2050)	37,000 (2020) increasing to 54,000 (2050)
CON	Average SIP contribution share of total employment income, in %	Average of all capital pension forms 3.9% decreasing to 3.6%	Average of all capital pension forms 3.9% decreasing to 3.6%	3.9%	2%

Own table based on parameters defined in chapter 2.1 and "SIP simulation_Germany" model results

Simulation of cash-inflows from traditional investment assets:

Traditional investments are the second main source of cash-inflows. Hereby relieved capital from investments coming to the end of its financial lifetime and investment returns provide the inflows. According to GDV (2018b, pp. 30–31), OECD (2017c, p. 17) and Mönch (2015, p. 38), pension managers allocate the resources mainly to government and corporate bills and bonds that represent about half of the portfolio. Stock shares represent about 35%. The remaining assets are distributed among cash and deposits, loans, real estate and land as well as a minor element of "others" that can include infrastructure investments. The average rate of return is explored by different institutions, the model applies an average value between 4.1% of effective revenue rate (compare Fischer and Siepe, 2015, p. 3ff; GDV, 2018b, p. 30; Mönch, 2015, p. 37; OECD, 2017c, p. 12). It has to be taken into account that maintaining such a high rate after the financial crisis was only possible due to realization of hidden assets stemming likely from overestimation of provisions or underestimation of asset values (compare calculation parameters in GDV, 2018, p. 30). To allow for a conservative comparison to the infrastructure investments in the SIP scenarios, this higher average rate of return is maintained over the assessment period.

Relieved capital is calculated as reflows from debt activities. For short-term assets the average investment lifetime is assumed with two years, for medium-term assets ten years and for long-term assets 30 years. Thus, each year half of the short-term and one tenth of the medium-term asset value is flowing back to the Fund. Real estate equity investments are expected to have a lifetime of up to 100 years. Thus, it is assumed in the context of this assessment that such assets are not traded out of the portfolio thus no relieved capital is generated from real estate.

Simulation of cash-outflows to members:

Cash-outflows to members consist of pension and other benefit payments. They amounted to about EUR 30 billion for occupational pensions, EUR 150 million for Rürup and about EUR 800 million for Riester payments in 2017. Thus, the aggregated outflow of the schemes has been about EUR 31 billion in 2017, dominated by the mature occupational schemes, while the rather young Riester and Rürup schemes have no larger outflows yet. This however will change significantly in future as soon as the majority of current Riester and Rürup contributors reach pension age which will likely happen by 2028 (compare BMAS, 2016, p. 143). According to the BAU simulation, from the end of the 2020s outflows from Riester schemes will be higher than inflows, for Rürup schemes this situation is going to occur mid of the 2030s. Existing and future occupational pensions as well as Riester and Rürup pensions will be considered with the average 4.14% return rate discussed above. Further management fees and transaction costs are not deducted.

Simulation of cash-outflows for traditional investments:

Besides benefit payments, new investments are the second main cash-outflow. The model allocates investments according to the selected option. For the options that maintain the existing private system, the existing legal limitations presented in chapter 5.2.3 are respected. Predefined asset class ranges, based on the value of the portfolio, determine possible investment decisions. For the other options, reforms of these ranges are considered and explained. Further information on the selected investments is provided in chapter 5.3.2 and the description of the four scenarios below.

Simulation of cash-outflows for administrative and transaction costs:

The operation of the three explored pension schemes are subject to administrative and transaction costs that are reflected as annual cash-outflows. As described in chapter 5.2.2, the administrative costs particularly for the Riester schemes can be substantial. There exists no comprehensive overview of the detailed cost split however BMAS (2017b, p. 283) presents aggregated numbers for the private and public occupational schemes of EUR 715 million and EUR 1.060 million respectively. For Riester and Rürup the estimations from GDV (2018b, p. 31) are applied, suggesting an average value of ~0.5% annually for the aggregated volume of existing capital and 4.7% annually for new contracts.

Table 14: Applied data for simulation of cash-outflows, according to equations and parameters as defined in case study methodology in chapter 2.1

Parameter	Explanation and unit	BAU Scenario	Regulatory Scenario	SIP-Fund Scenario	Mandatory Scenario
PEN_P	Pension and other benefit payments, in billion EUR_{2018}	35 (2020) increasing to 160 (2050)	35 (2020) increasing to 160 (2050)	0 (2020) increasing to 73 (2050)	0 (2020) increasing to 41 (2050)
AC	Administrative costs, in billion EUR_{2018}	4 (2020) increasing to 6 (2050)	4 (2020) increasing to 7 (2050)	1 (2020) increasing to 4 (2050)	1 (2020) increasing to 3 (2050)

POP_R	Total retired population, in million	19 (2020) increasing to 22 (2050)	19 (2020) increasing to 22 (2050)	19 (2020) increasing to 22 (2050)	19 (2020) increasing to 22 (2050)
SIP_{MR}	Share of retired population with SIP-membership, in %	39% (2020) increasing to 88% (2050)	39% (2020) increasing to 88% (2050)	0% (2020) increasing to 88% (2050)	0% (2020) increasing to 98% (2050)
CON_{RC}	Historic pension contribution of the respective cohort in year i till y, in billion EUR_{2018}	10 (2020) increasing to 248 (2050) for Riester/Rürup, unclear for bA[6]	10 (2020) increasing to 248 (2050) for Riester/Rürup, unclear for bA	0 (2020) increasing to 570 (2050)	1 (2020) increasing to 420 (2050)
PEN_T	Average pension payment duration, in years	20	20	20	20
RR	Effective rate of return on individual capital stock, in %	4.14%	4.14%	4.14%	4.14%
y	Number of years of contribution	Average of 15-18 (2020) increasing to 35 (2050)	Average of 15-18 (2020) increasing to 35 (2050)	0 (2020) increasing to 30 (2050)	0 (2020) increasing to 30 (2050)
AC_M	Administrative costs for member account mgmt, in billion EUR_{2018}	4 (2020) increasing to 6 (2050)	4 (2020) increasing to 6 (2050)	0.6 (2020) increasing to 1.5 (2050)	0.7 (2020) increasing to 0.9 (2050)
AC_{EM}	Administrative costs for SIP equity asset mgmt, in million EUR_{2018}	5 (2020) increasing to 100 (2050)	5 (2020) increasing to 540 (2050)	0 (2020) increasing to 2,650 (2050)	0 (2020) increasing to 2,170 (2050)

Own table based on parameters defined in chapter 2.1 and "SIP simulation_Germany" model results

5.3.2. Step 2: Simulation of investment cash-flows

As described in the section on traditional investments above, all available capital resources stemming either from relieved capital or from a surplus of member contributions and investment revenues beyond outflows are allocated according to the eligible asset portfolio ranges of the SIP system. These ranges differ according to the scenario. With regards to energy transition assets, the model applies a prioritization of

[6] Since there exists no transparency on capital contributions of different demographic bA pension member cohorts, future bA pension payments are extrapolated based on historic payments in relation to active pensioners.

different asset classes according to the specific attractiveness that is explained in the following section.

Attractiveness of different energy transition investment options

As discussed in chapter 4.4, various parameters influence investment decisions of institutional investors. Decisive factors are for instance the political framework, maturity of technology, evaluated risks, revenue expectations, liquidity needs and the investment horizon. In the following, the SIP investment options are briefly discussed according to their likelihood for prioritization. Hereby the assumptions depend on the current regulatory and economic incentive framework in Germany in 2018, taking into account potential reforms over the upcoming years.

- Renewable power capacity for electricity supply: The development of renewable capacity has been very successful over almost two decades. The technologies are mature and proofed increasing reliability. The expected revenues are depending on the tenders that are conducted by the German regulative supervisor. Dichtl (2018, p. 145) expects for the German context 9% rate of revenue for wind onshore and PV while investors demand 15% rate of return for offshore wind, averaging at 11% in the simulation. For debt financing, the model considers a lower interest rate of 8%. This reflects the lower risk and the advantage of predictable cash-flows leading to lower rates of return (compare also chapter 4.3.1) The assumed investment period is 20 years and the potential to liquify the assets is considered as medium. Overall, investments in renewable capacity seem to be particularly attractive during the upcoming years when large-scale tenders are still in place and offshore wind is strongly developed.

- Extension of the power grid: The regulative authority in Germany defines the eligible return on equity for the investor. From 2019 onwards, this rate is fixed at 6.91% and will be adjusted frequently all five years for new investments (Bundesnetzagentur, 2016). The simulation considers a lower interest rate on debt of 5%. Associated risks of realized activities are considered being low as grid extension is a mature procedure and the grid operators are familiar with the business. "While the investment horizon is very long, lifetimes of more than 50 years are usual for electricity grids and assumed in the model, the potential for liquifying the assets is considered rather low" (Köhler, 2020, p. 10). For new activities, the risk of hold-up through civil society engagement is high as the experience of recent developments show (compare implementation challenge of the energy transition in chapter 5.2.5). "Thus, investments in the power grid can be seen as a long-term option with very low operation risk and stable cashflows" (Köhler, 2020, p. 10). However, liquifying assets seems to be associated with high transaction costs and the realization of new investments faces significant acceptance problems by local population. The latter can theoretically be addressed through the SIP, subject to the precise design option.

- Electricity storage: As described in chapter 5.1.2, the potential for traditional, large-scale electricity storage such as pump storage facilities in Germany is limited. Innovative approaches aim for renewables-based hydrogen production and the storage in the existing natural gas grid, power to fuel synthesis or districtheating applications. As this involves innovative technologies and higher default risks, the model assumes a return on equity of 15% and interest rates on debt of 10%. While the investment horizon is considered as long, liquidity potential is comparably low as no market for unlisted storage facilities exist. The assumed investment period is 50 years.

- E-mobility: Later stages of the energy transition aim to transform the transport sector through the roll-out of e-mobility, development of public transport and strengthening of rail-bound traffic. To enable energy supply for those expanded transportation means, additional renewable capacity and flanking infrastructure investments are required. As several innovative technologies are involved, an average rate of return on equity of 13% is assumed. 10% interest rates on debt are simulated with an investment period of 20 years. The liquidity of assets in the e-mobility sector is assumed to be comparably low.

- Energy efficiency and renewable heating: Energy efficiency investments for the household and industry sector are an important element of the energy transition. Small-scale loans with low interest rates between 1% and 2% for energy efficiency refurbishment and renewable heating in residential buildings are provided by the KfW. These loans are subsidized with about EUR 2.5 billion annually by the government (see Bundeskabinett, 2018, p. 6f). The related interest rates are expected to increase as soon as the low-interest environment changes. For unsubsidized loans the model assumes 5%. Equity investments are rather relevant for industry related, larger-scale energy efficiency investments. In this context also equity might play a minor role, the related rate of return is simulated with 7%. Energy investments in the industry sector are expected to have shorter lifetimes while KfW building refurbishment loans are granted for 30 years. Thus, an average lifetime for energy efficiency and renewable heating investments of 15 years is assumed.

Table 15: Evaluation of energy transition investment opportunity attractiveness

	Revenue expectation	Associated risks	Investment horizon	Liquidity realization
Renewable capacity	Medium (in initial phase) to low	Low to medium	Medium	Medium to high
Grid extension	Low	Low	Long	Medium to high
Electricity storage	High	Rather high	Long	Low
E-mobility	High	Rather high	Medium	Low
Energy efficiency (only considered for option 3 & 4)	Medium	Medium	Short to medium	Low

Source: Compilation of research results

Summing up, the attractiveness of the different energy transition opportunities can be anticipated based on general characteristics (see Table 15). This translates into the following investment priority scenario for the energy transition until 2050:

- Capacity implementation phase (year 2020 to 2030): Due to the attractive risk-revenue ratio of renewable capacities, the SIP prioritizes investments in offshore wind, followed by onshore wind power and solar PV capacity. In parallel, investments in an extension of the power grid play a key role as the main share of the grid expansion shall be realized during the next decade. Energy efficiency investments also play a key role for achieving the governmental and EU targets.
- Sector-linkage phase (2030 to 2035): During this period, renewable investments decrease in their attractiveness due to sinking economic incentives and higher

competitiveness. Sector-linkage, particularly the transformation of the transport and heating sector will increase in importance. Renewable heating and e-mobility infrastructure might be interesting for SIP investments.

- Consolidation phase (2035 to 2050): During this stage, the storage question will have to be answered and realized, requiring substantial investments. This might also include synthetic fuel innovations such as power-to-X technologies. Assuming a favourable regulatory framework, SIP actors have an attractive option for a long-term investment with stable cash-flows and attractive revenues.

Taking into account these considerations, it is assumed that the SIP system will focus its investments on renewable capacity and grid expansion during the initial ten years, flanked by energy efficiency and followed by substantial investment volumes for e-mobility and renewable heating. Power storage facilities and renewable fuel production complement the investment portfolio from 2035 onwards, subject to the economic framework and associated investment risks.

Implications and related additional leverage potential of debt and equity

As broadly discussed in chapter 4.5.1, the selection of the financial instrument for infrastructure investments includes significant differences regarding revenues, stability of cash-flows, risks, responsibilities, transaction costs, taxes and leveraging co-finance. Due to the German and European regulatory framework compelling a strong application of debt as well as the inherent characteristics of debt products, it is assumed that the existing investors' landscape as well as a new SIP-Fund would mainly apply bonds and loans as investment vehicles (compare also the discussion in chapter 4.5.1). Furthermore, it is likely that mature markets for trading energy transition asset products will emerge in Germany over time, allowing to better standardize, compare, rate and exchange related debt products thus enabling increased liquidity. The option of equity investments through stock purchase or direct project financing is expected to be applied less frequently. Depending on the institutional structure of the SIP scheme, equity based direct project financing might be an attractive alternative in mature energy transition activities as it allows higher revenues. Based on the results from chapter 4.5.1, the following paragraph discusses the implications and the co-financing potential for both instrument classes from the SIP scheme perspective.

"As discussed by Sawant (2010), Underhill (2010), Dichtl (2018) or Nelson and Pierpont (2013), the rate of return on equity is likely higher than on debt. But equity comes also with higher risks, higher fluctuation of cash-flows and higher transaction costs. Depending on the legal and institutional structure of the investments, also supervision rights and management responsibilities might be included, requiring additional effort from the SIP institutions" (Köhler, 2020, p. 14).

With regards to debt, "either bonds issued by the project investment vehicle or loans could be applied for direct project financing. Main advantage for the SIP scheme would be low transaction costs, low responsibility and management requirements and a high stability of pre-defined cash-flows. Also, risks are lower than with equity investments, [as debt has a priority over stockholders in case of default]. The drawbacks are a slightly lower revenue expectation compared to equity and a lack of control and oversight rights" (Köhler, 2020, p. 15).

For the simulation, the investment strategy for energy transition assets is broadly consistent with the current insurers and pension fund split between equity and debt investments. According to GDV (2018a, p. 8, 2018b, p. 24), about 80% of the existing assets are debt. Due to a stronger focus on equity in the existing energy transition investments, the model assumes that about 70% of the overall investments by the SIP scheme will be realized as debt.

5.4. SIP scheme simulation results

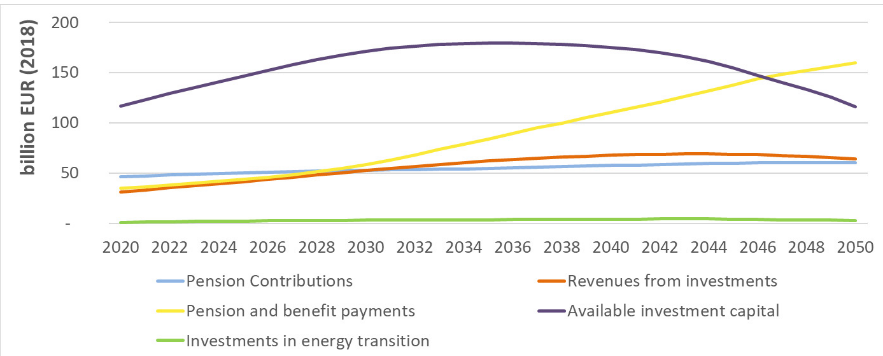
In the following, four different SIP scenarios are presented with their specific assumptions, parameters and quantitative modelling results. The first scenario simulates the Business as Usual (BAU) development based on the existing pension investors. The second scenario models a stronger regulation of pension resource allocation towards energy transition assets. Scenarios 3 and 4 project a replacement of the currently existing private pension landscape with either a voluntary or a mandatory SIP scheme. A qualitative discussion of the different results follows after the quantitative scenarios in chapter 5.5.

5.4.1. Option 1: Business as Usual scenario

Kleine and Krautbauer (2012, p. 20) estimate that institutional investors allocated about 0.5% to infrastructure in 2012. They further expect that institutional investors in Germany will increase this volume to about 1% in future. Based on the recent dynamic envisaged in the energy sector (compare chapter 5.2.4), it is assumed in the BAU scenario that the full volume is allocated to energy transition infrastructure, notably renewable power capacity and transmission grids as rather mature investment opportunities. Due to the adoption of the Paris Agreement as well as regulatory changes facilitating investments into infrastructure assets, it is assumed in BAU simulation that institutional investors managing pension capital will voluntarily ramp up their allocation ratio for energy transition assets to 5% in 2050. This is interpreted as a conservative development.

As the main objective of the simulation is to reveal the maximum capital available for energy transition investments, all three publicly supported pension systems are presented jointly as one SIP system. The result shows a steady development of pension and benefit payments (yellow line) starting at about EUR 35 billion in 2020, steadily rising to about EUR 45 billion in 2025 (see Figure 22). Afterwards, the first cohorts of population that substantially invested in Riester and Rürup schemes arrive at pension age and receive benefit payments. This leads to an increased cash-outflow, reaching about EUR 160 billion per year by 2050.

Figure 22: Development of annual in- and outflows of key SIP parameters until 2050, BAU scenario; in billion EUR_{2018}

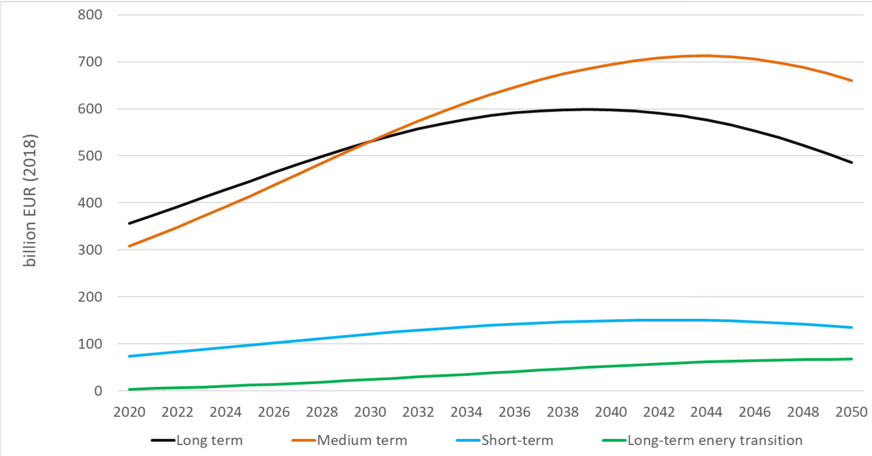


Source: Own illustration based on BAU scenario in “SIP simulation_Germany”

While pension contributions (blue line) and investment revenues (orange line) also increase over time, a spread to the outflows reduces the annually available investment capital (purple line) from 2035 onwards. The annual cash-flows allocated to energy transition assets (green line) steadily increase from about EUR 600 million to a maximum of about EUR 4.5 billion around 2042.

This characteristic is in line with the development of the total cumulated asset portfolio. As demonstrated in Figure 23, mid-term assets (orange line) and long-term assets (black line) excluding energy transition investments reach their highest level by 2044 and 2039 with EUR ~715 billion and EUR ~599 billion respectively. Short-term investments (blue line) represent constantly 10% of the asset portfolio reaching the maximum cumulated value of about EUR 151 billion by 2042. Afterwards these assets have to be liquified to guarantee further outflows for pension and other benefit payments. In this scenario, the cumulated energy transition investments (green line) will reach more than EUR 66 billion by 2050, translating into average financial flows of about EUR 2.2 billion annually over the 30-year period. This volume is not neglectable but represents a limited contribution of about ~6% to the total investment needs of the energy transition of about EUR 37 to EUR 40 billion annually. Furthermore, the main share of the investments will be enabled in the second half of the energy transition pathway diminishing some of the potential benefits associated with an enhanced involvement of private capital (see chapter 5.4.5 for further information).

Figure 23: Development of cumulated asset portfolio until 2050, BAU scenario; in billion EUR2018



Source: Own illustration based on BAU scenario in "SIP simulation_Germany"

5.4.2. Option 2: Regulatory scenario

The second scenario emphasizes the public need for sustainable investments from institutional investors. Insurance or banking associations such as VOEB (2016, p. 4ff) or GDV (2018a, p. 3ff) recurrently emphasize the intention of their sector to contribute to the implementation of sustainable infrastructure as an argument for policy reforms and deregulation of investment conditions. Though this purpose has hardly been realized, as demonstrated in chapter 3.2 and 5.2.4. Also, the quantified results of the BAU scenario simulate very limited contributions from pension investors.

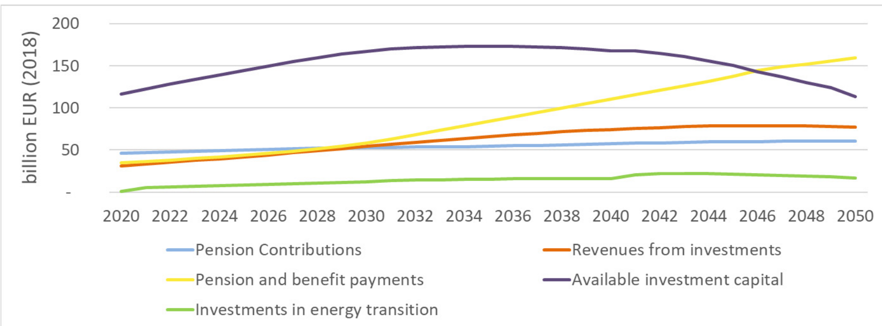
To address this shortcoming, the second scenario simulates strong regulatory governance regarding capital allocation. It is assumed that the legislative requests minimum allocation targets to energy transition infrastructure in the long-run, if the respective capital managers intend to maintain public incentives in form of supplementary grants and/or tax benefits. As minimum portfolio allocation to energy transition assets the following requirements are defined for the simulation:

- 7.5% by 2030,
- 15% by 2040, and
- 25% by 2050.

These targets are broadly in line with the eligible thresholds currently defined for the most important legal structures (compare chapter 5.2.3). Potentially, the regulatory bodies have to adjust the investment regulation for some institutional investors to enable all affected institutions to fulfil the sustainable investment targets. Further, the low minimum target in 2030 allows the institutional investors to build up sufficient capacity or external structures to fulfil the requirements. It also gives sufficient time for project developers to elaborate suitable project pipelines that allow an absorption of the estimated capital flows. All other parameters such as the annual interest rate on contributions or the assumptions for pension and benefit payments are kept identical to the BAU scenario.

The simulation result shows a slightly lower volume of available investment capital until mid of the 2040s compared to the BAU scenario (see Figure 24). This effect is due to lower reflows from relieved capital allocated to traditional investment opportunities with shorter maturity. As the assumed equity and debt returns from energy transition (ET) investments outperform the average returns from traditional investments, the overall revenues are higher. By 2050, the annual returns in the regulatory scenario are simulated at EUR 77 billion compared to EUR 65 billion in the BAU scenario. Pension contributions and pension as well as benefit payments are identical to the BAU scenario.

Figure 24: Development of annual in- and outflows of key SIP parameters until 2050, regulatory scenario; in billion EUR_{2018}

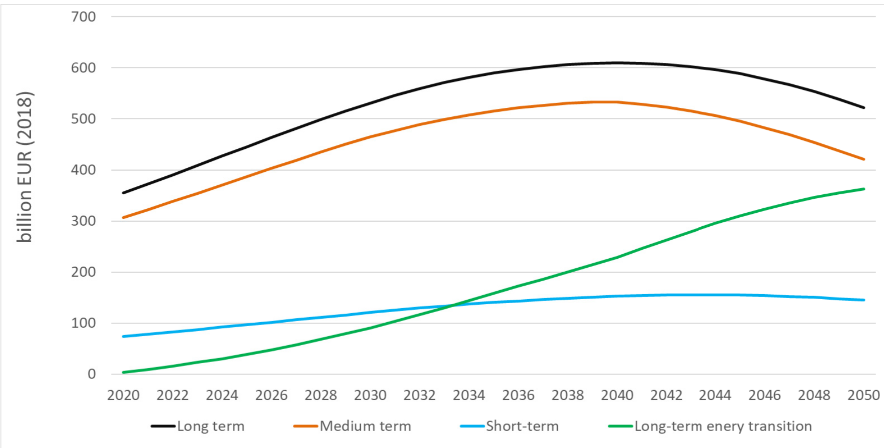


Source: Own illustration based on regulatory scenario in "SIP simulation_Germany"

Main difference in the regulatory scenario is the allocation of capital to energy transition assets. In 2050, more than EUR 18 billion are invested in energy transition assets, the cumulated volume stands at about EUR 360 billion over the 30 years period, translating into EUR ~12 billion in annual average (see Figure 25). This represents a significant increase compared to the EUR 2.2 billion in the BAU scenario and theoretically covers almost one third of the energy transition investment needs. However comparable to the BAU scenario, the main share of capital for energy transition assets will be allocated in the second half of the transformation only.

As demonstrated in Figure 25, the asset portfolio by 2050 comprises mainly of long-term and medium-term as well as energy transition assets. Its aggregated volume stands at EUR 1.45 trillion which is about EUR 100 billion higher than in the BAU scenario. This is mainly due to the higher revenues from energy transition investments that are reinvested over time.

Figure 25: Development of cumulated asset portfolio until 2050, regulatory scenario; in billion EUR_{2018}



Source: Own illustration based on regulatory scenario in "SIP simulation_Germany"

While the availability of large volumes of private pension capital within the existing system is doubtless, it is unclear what allocation targets would be required to cover all average investment needs of the energy transition. Thus, a sensitivity analysis complements the assessment of how the existing private pension manager landscape can finance the energy transition. Hereby the objective is to achieve an aggregated investment volume for energy transition assets of EUR ~1,150 billion by 2050, translating into an average of EUR 37.5 billion annually. To achieve this objective the allocation targets for energy transition assets would have to be increased ambitiously by about 160%. Consequently, the sensitivity analysis provides the following allocation targets:

- 20% by 2030,
- 39% by 2040, and
- 65% by 2050.

This approach is not possible within the current regulatory framework. Existing allocation targets in the German regulation would need revisions and potentially the Solvency II regime would not allow such focused allocation for insurers.

5.4.3. Option 3: Public SIP-Fund scenario

The third simulate option represents a fundamental change, that would largely replace the existing private pension provider landscape. As proposed by the expert commission for enhancing infrastructure investments, the establishment of a centralized fund responsible for sustainable infrastructure investments would be a feasible solution to address the German investment gap. Private actors can be included through the emission of long-term bonds. Potentially a state guarantee, comparable to the "Hermes-guarantee", could lower revenue expectations, realize projects with lower risk-revenue ratio and address risks of scattered contracting such as small-scale loans for building refurbishment (compare Fratzscher, 2015b, p. 74). Bönke and Harnack (2017, p. 9ff) discuss options for SWFs in Germany from the perspective of improved pension provisions, intergenerational redistribution, inclusive growth and development of infrastructure. While the authors distinguish between these four options, a SIP-Fund would incorporate the characteristics of pension provisions, intergenerational redistribution and infrastructure development. Inclusive growth, meaning direct capital transfers to the whole population as a form of basic annual income is not coherent with the SIP approach.

The authors suggest two institutional options for such a fund that are based on international experience (compare also chapter 4.2). As first option, the responsible institution, usually the Ministry of Finance, provides an operational mandate to the

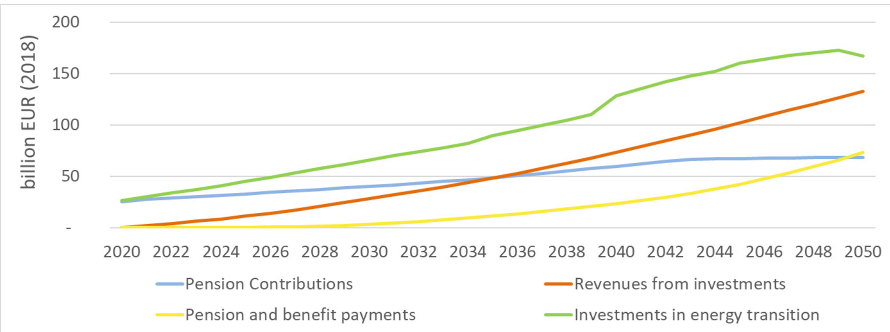
National Bank. In Germany this is the Deutsche Bundesbank which has already experience with managing fund resources. For instance, it is responsible for several pension funds. A supervision Board or Commission could steer the investment decisions according to the agreed investment criteria (see also chapter 4.5.2 for the discussion of investment criteria). The second option would be the establishment of an independent, public management institution that is exclusively responsible for the SIP system. An outsourcing of the activities and responsibilities to an external, private fund manager is not recommended except for developing countries with very low institutional and human capacity (compare Bönke and Harnack, 2017, p. 20ff).

Transformative SWFs are also suggested by the WBGU (2016, pp. 24–25) as key solution to achieve the SDGs and the objectives of the Paris Agreement. Financed through CO_2 taxes, revenues from emission trading and a progressive inheritance tax, the funds shall invest in transformative sectors to accelerate the transition towards carbon neutrality. Long-term investments and sectors with financing gaps from the private sector are main investment targets. According to the authors, the dividend of these "future funds" can be used to flank social and structural changes of the transformation. With regards to the fund's governance, the authors suggest considering principles that guarantee for instance economic efficiency, participation through discussion of investment strategies in the Parliament, transparency and the request to contribute to the societal wellbeing. Further, an increased democratization of financial and economic power can be achieved through such SWFs. Explicitly mentioned by the WBGU is also the need to achieve intergenerational fairness. While the financing mechanism of the SIP system discussed in this thesis differs from the WBGU concept, key elements and objectives of the "future funds" would be realized in the establishment of a SIP-Fund.

For the SIP-Fund scenario, the simulation applies identical demographic and macroeconomic parameters as for the BAU and regulatory scenario. It is assumed that the SIP-Fund is operational from 2020 onwards and provides the identical supplementary grants and tax benefits as for the currently existing system. To further incentivize the transition of clients to the new institution, all grants and tax benefits for the existing options could be removed. However, such intervention would have negative implications on the objective of democratization (see chapter 4.3.4) and is therefore further discussed in the context of SIP impacts (see chapter 5.5.4). Alternatively, a higher rate of return compared to the existing schemes might be offered to increase membership. As the contribution system is based on voluntary participation, not all clients will immediately transfer their contracts. Thus, it is assumed that the SIP-Fund starts with 50% of the clients and contributions from the existing system and increases its share by 3% annually. This means that by the beginning of the 2040s, all remaining Riester, Rürup and Occupational Pension contracts are absorbed and between 80% and 90% of the labour force has one voluntary contract with the SIP-Fund. The contribution rate of 3.9% is identical to the average of the current system. Regarding investments, the SIP-Fund only invests in energy transition assets, thus the average rate of return is higher than with the BAU and regulatory scenario. However also the maturity of investments is significantly higher due to the long lifetime of e.g. grid and storage investments leading to less debt assets reaching maturity and flowing back to the Fund's balance sheet over the analysed time period.

As a new capital stock has to be developed over time, the simulation result shows a significantly lower volume of available investment capital until the end of the 2040s compared to the other scenarios (see Figure 26). As the assumed equity and debt returns from ET investments outperform the average returns from traditional investments and the outflows for pension payments is growing slower, the overall revenues are significantly higher. By 2050, the annual returns in the SIP-Fund scenario are about 180%-200% the volume as in the other scenarios. Pension contributions are lower until all remaining contracts from the existing system are absorbed by the beginning of the 2040s. Pension payments ramp up later as clients need to build up pension demands over time. By 2050, the annual payments are about half the value as in the other scenarios.

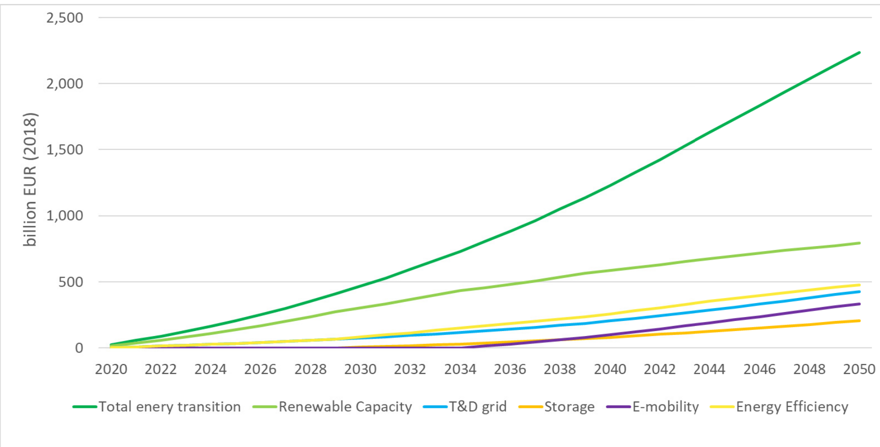
Figure 26: Development of annual in- and outflows of key SIP parameters until 2050, SIP-Fund Scenario; in billion EUR2018



Source: Own illustration based on regulatory scenario in "SIP simulation_Germany"

As the SIP-Fund allocates capital exclusively to energy transition assets, about EUR 175 billion are theoretically invested in energy transition assets in 2050. The cumulated volume stands at about EUR 2.3 trillion over the 30 years period which is higher than in all the other scenarios (see Figure 27). This characteristic is due to the compound interest stemming from higher revenues that are constantly invested in assets that again generate higher revenues. The cumulated energy transition volume translates into EUR ~77 billion in annual average. This volume represents two times the average investment needs for the energy transition, theoretically enabling additional investments beyond the German energy transition elements as defined in literature and the scope of this thesis (compare chapter 5.1). Thus, it might be discussed whether the Fund could engage in additional, sustainable investments or expand the geographical focus beyond Germany. Alternatively, the contribution rate could be decreased or the interest rate on capital for pensioners increased. The latter might allow to circumvent the removal of subsidies for the existing schemes and therefore avoid negative impacts on the democratization aspect.

Figure 27: Development of cumulated asset portfolio until 2050, SIP-Fund Scenario; in million EUR_{2018}



Source: Own illustration based on regulatory scenario in "SIP simulation_Germany"

A sensitivity analysis reveals what contribution rate would lead to an average investment of EUR 38 billion over the 30 years' timeframe, as required by the energy transition. With a share of 1.8% of the contributor's gross salaries or an interest rate on contributions and supplementary grants of about 9.2% massively benefitting future pensioners, the aggregated investment by 2050 would reach EUR 1,150 billion, covering the expected total investment needs of the German energy transition. These options however would either diminish the intended mitigation of the pension level gap or jeopardize the long-term sustainability of the Fund.

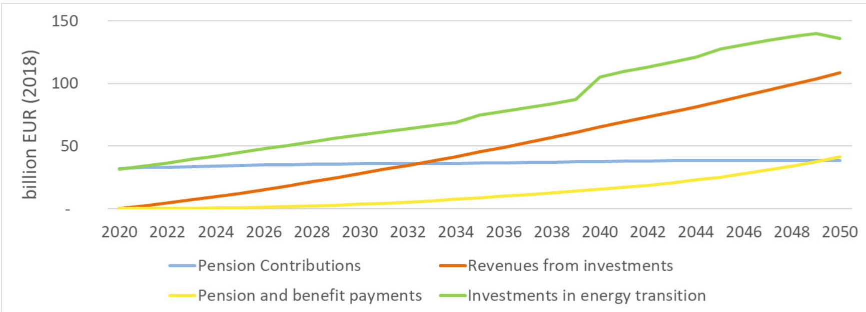
5.4.4. Option 4: Mandatory SIP system

While the three scenarios presented above are based on the existing approach of voluntary contribution schemes, the fourth option explores a mandatory approach for financing the SIP-Fund. This concept builds on the idea of Flämig (2016, p. 117ff), who discussed a German "climate protection pension". As outlined in chapter 4.1, the related pension levy shall be mandatory for the total labour force, including employees, employers, self-employed, civil servants and apprentices and be fixed at 2% contribution rate. Such mandatory system might have negative implications on the SIP objective of democratization, to be further discussed in chapter 5.5.4. While some aspects of the climate protection pension are presented in detail, for instance the envisaged contributors, the level of the pension levy, the administrative and disbursement framework or the mezzanine instrument, other key elements remain undescribed and vague. For instance, an assessment of the required legal framework, a solid quantitative projection of the mobilized funds or a matching with quantified investment needs is not conducted (compare Flämig, 2016, chap. 9 and 10). This thesis attempts to provide such quantitative exploration.

For the mandatory SIP-Fund scenario, the simulation applies identical demographic and macroeconomic parameters as for the other scenarios. It is assumed that the SIP-Fund is operational from 2020 onwards and provides the identical tax benefits as for the current PAYG system, supplementary grants are not provided. As the contribution system is mandatory and includes the total labour force, additional incentives to attract clients are not required. The assumed contribution rate of 2% is consistent with Flämig's approach. Contrary to the climate protection pension, the simulated SIP-Fund only invests in energy transition assets.

As a new capital stock has to be developed over time and the contribution rate of 2% is lower than in the other scenarios, the simulation result shows a significantly lower volume of available investment capital until end of the 2040s compared to the other scenarios (see Figure 28). However, as the whole labour force is mandatorily included, the SIP-Fund has substantial inflows from the beginning. Over time, the pension contributions are almost continuous, slowly increasing from about EUR 32 billion in 2020 to about EUR 38 billion by 2050. Regarding pension payments, cash-outflows already exist in 2021 as the system covers the whole labour force. As clients need to build up pension demands over time, the level of pension payments constantly increases. The annual returns surplus pension contributions in the year 2032 and by 2050 they are significantly higher than in scenario 1 and 2 but less the volume of scenario 3.

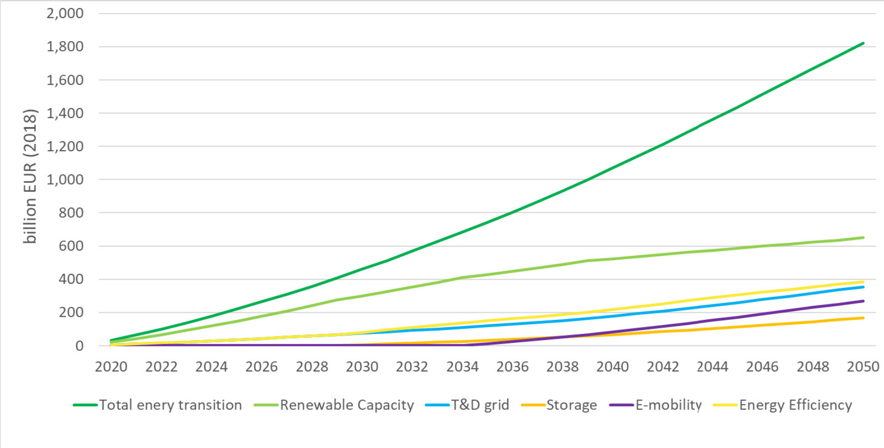
Figure 28: Development of annual in- and outflows of key SIP parameters until 2050, mandatory SIP-Fund Scenario; in billion EUR_{2018}



Source: Own illustration based on regulatory scenario in "SIP simulation_Germany"

As the SIP-Fund allocates capital exclusively to energy transition assets, almost EUR 140 billion are invested in ET assets in the year 2050. The sharp increase in the year 2040 can be explained with the reflow of debt investments undertaken in the year 2020 that has reached maturity. The cumulated volume stands at about EUR 1.8 trillion over the 30 years period which is about 500 billion lower than in scenario 3 but significantly higher than the two initial scenarios (see Figure 29). This cumulated volume translates into EUR ~60 billion in annual average allocations. This volume represents more than 1.5 times the average investment needs for the energy transition, demonstrating the potential to either decrease the contribution rate over time or look for investment opportunities beyond the defined German energy transition elements.

Figure 29: Development of cumulated asset portfolio until 2050, SIP-Fund Scenario; in billion EUR2018



Source: Own illustration based on regulatory scenario "SIP simulation_Germany"

Summing up, the simulation confirms that the idea of a mandatory SIP scheme would provide sufficient resources to finance the estimated energy transition needs with the potential to expand the investment scope or reduce contributions. Whether the generated capital also matches the energy transition needs over time, demonstrates the following chapter 5.4.5.

5.4.5. Matching available SIP resources with GER ET investment needs

While the total estimated energy transition investment needs cumulate to ~ EUR 1.150 billion until 2050 (compare chapter 5.1.2), the four assessed SIP implementation options can mobilize own resources of ~ EUR 66 billion in the BAU scenario to up to EUR 2.3 trillion in the voluntary SIP-Fund scenario (see Table 16).

Table 16: Comparison of key scenario results, all in USD billion (2018)

	BAU scenario	Regulatory scenario	Voluntary SIP-Fund	Mandatory SIP-Fund
Total asset volume 2050	1.4	1.5	2.3	1.8
Energy transition asset volume	0.07	0.36	2.3	1.8

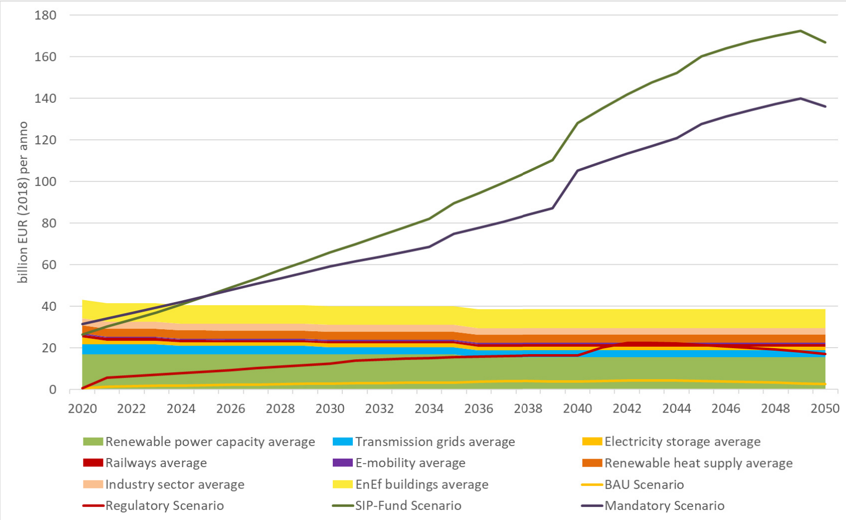
Share of energy transition investment needs	6%	31%	200%	156%

Source: Rounded results of model "SIP simulation_Germany

A full coverage of the cumulative investment needs would be possible under the voluntary and mandatory SIP-Fund scenarios. However, a proper matching needs to compare available capital and investment needs over time. Further, the applied funding instrument, equity or debt, has significant impact on both the risk and revenue expectation as well as the potential to leverage co-funding for larger investment coverage. All assessed studies that estimate the investment needs for the German energy transition do not separately express these requirements over time (compare Agora Energiewende, 2018; compare Blazejczak et al., 2013; Bodewig, 2013; Daehre, 2012; Fratzscher, 2015b; Gerbert et al., 2018; Gerhardt et al., 2014; Henning and Palzer, 2013; Liesch et al., 2017; Ziesing et al., 2015). Only a few limited investments, for instance for enhanced transmission grid extension, are considered within certain timeframes (compare e.g. Blazejczak et al., 2013). Therefore, the cumulated investment needs are translated into a mainly averaged and linear investment forecast. As demonstrated in Figure 30, the total investment needs range between EUR_{2018} 37 billion and EUR_{2018} 42 billion per anno.

In a second step, the estimated results of the four scenarios are combined with the investment needs. SIP capital mobilized in the BAU scenario could provide up to 2.5% of the investment needs in the beginning, increasing to about 10% from the mid-2030s onwards (compare yellow line in Figure 30). The regulatory scenario with higher compulsory shares for energy transition asset allocation provides about 15% of investment needs in the beginning, rising rapidly to almost 50% by mid of the 2030s and even more than 60% by the beginning of the 2040s (compare red line). Both the voluntary and mandatory SIP-Fund scenarios provide about ¾ of the required resources from the beginning, covering 100% of the investment needs already by 2024 (compare green line for the voluntary and purple line for the mandatory scenario). Afterwards the mobilized resources significantly exceed the estimated energy transition investment needs. By mid of the 2030s both scenarios lead to about the double amount of required funds, increasing to about almost 4 times the needs by 2050 in the mandatory and 4.5 times the needs in the voluntary SIP-Fund scenario.

Figure 30: Estimation of annual energy transition investments and mobilized capital under the four SIP scenarios until 2050



Source: Own illustration based on "SIP simulation_Germany"

From a comprehensive macro-perspective of the German government, the potential to leverage co-financing from domestic or international banks is also a relevant element. As equity typically accounts for 20% of infrastructure investments (compare chapter 4.5.1), the SIP capital could theoretically mobilize additional 80% of debt from other sources. Thus, even the SIP BAU scenario capital of about EUR 66 billion could leverage additional ~EUR 260 billion if suitable investment structures are applied. Under the regulatory scenario, theoretically the entire investment needs of the energy transition could be covered by SIP equity combined with high shares of leveraged co-finance debt. Though, the existing German institutional investor landscape favour debt investments to direct equity therefore this scenario is rather unlikely (compare discussion in chapter 5.3.2).

5.5. Impact of SIP energy investments

As discussed in chapter 4.3, a SIP engagement is likely to "have additional impact on society, the sustainability of private pension schemes and the energy transition beyond mobilization of private capital at scale" (Köhler, 2020, p. 15). In coordination with the findings of chapter 4.3, the expected positive and negative impacts in the German context are analysed in the following. Hereby some of the scenarios have different implications due to their design characteristics and the range of covered population. In these cases, the impact is separately outlined, highlighting main differences of the four proposed options. A compiled overview of the expected impacts can be found in Table 17 below.

5.5.1. Investment revenues and distributional impacts

The argumentation that an increased SIP engagement in energy transition infrastructure generates higher rates of return than traditional investment alternatives in the current low interest-rate environment (compare also chapter 5.2.2 and chapter 5.3.1) is confirmed by the scenario results. As insurers and other pension providers have already mobilized hidden assets to continue average interest rates of 4-5% on member contributions, it is likely that this spread will further increase as long as the European Central Bank keeps interest rates close to 0%. Also, the outlined distributional challenge of balancing efficiency gains between electricity users and SIP members is likely a serious task in Germany. The political discussions about the balance of feed-in tariff exposure on industry and consumers have shown that policy makers and society are sensitized about energy-economic effects. Regarding distinct impacts of the scenario settings, the distributional challenges will be of higher relevance, as lower the coverage rate of the SIP scheme across the population is. Particularly scenario one and two might create conflict of interests among politicians and effected population groups in the future. According to the current portfolios of German pension managers, a potential crowding-out of resources is limited to price level fluctuations of government bonds, corporate bonds and stocks in scenario 1 and 2. As scenario 3 and 4 represent a substantial shift of the existing insurers resources towards a new SIP institution, decreasing demand for government and corporate bonds might lead to stronger state budget or corporate financing implications. Finally, direct SIP investments in mature and well financed energy transition elements such as solar PV capacity might crowd-out existing funding. This could decrease the assets' cost of capital and consequently reduce power tariffs since the SIP system potentially comes with lower revenue expectations and/or higher efficiency gains. Further distributional impacts depend on the applied instrument (see also chapter 4.5.1). Crowding out debt finance from e.g. banks would channel existing funds in either alternative energy transition elements or other sectors. Substituting equity finance from project developers or utilities can shift those funds in either other energy transition elements or force those investments out of the German market. In a promising case, those equity volumes finance energy infrastructure in other countries, in a negative case the respective entities do not find alternative investment opportunities and face existential risks for their business model.

5.5.2. Investment risks

Energy infrastructure investments face a set of typical risks (compare chapter 3.3.1). In the German context with solid regulatory frameworks for many energy transition fields, the risk associated with successful energy transition investments is likely lower than with other financial market products. An additional advantage is that the assets exist physically in the fourth largest economy worldwide. Being broadly independent from micro-economic developments and structural changes, energy infrastructure will be able to generate revenues as long as demand exists. With regards to the protection of critical infrastructure, the German Government actively hindered a Chinese corporation to purchase a 20% share of the transmission grid operator 50Hertz (Zeit Online, 2018a). Further the responsible Minister Altmaier announced that the Government will improve protection measures for critical infrastructure such as transmission grids. In cases where a purchase cannot be avoided through the application of law, he would personally seek for investors (Zeit Online, 2018b). This reflects the political desire to actively engage in protection measures, a SIP scheme could serve as suitable instrument.

With regards to systemic risks of large-scale SIP engagement in the energy sector, corruption and embezzlement are rather not a likely challenge (compare the low corruption index of Germany presented in chapter 5.2.6). However, the monopolistic character of a SIP fund as simulated in scenario 3 and 4 might lead to strongly decreased competition and therefore price increases. Particularly tendering renewable power capacity with reduced numbers of bidders due to strong SIP engagement could counter the potential distributional efficiency gains.

As discussed in chapter 4.3, "the existing risks associated with infrastructure implementation can only be adequately addressed if the relevant institutions inherit sufficient experience, know-how and capacity" (Köhler, 2020, p. 15). This requires either large institutions that are able to build up such capacity internally (scenario 3 and 4, potentially also possible for some institutions in scenario 2) or specialized experts providing support to smaller institutions.

5.5.3. Acceptance

While opinion polls indicate that generally an extremely high share of more than 90% of the German population supports the energy transition (compare e.g. Berlin Energy Transition Dialogue, 2016, p. 14), affected people created significant political and social resistance against the implementation of renewable capacity and flanking activities such as grid extension. Overcoming this hurdle is a task for policy makers, society and economy. Approaches in economic participation and decision-making processes as well as compensation models that offset negative implications from e.g. transmission grid extensions or power facility constructions can have beneficial impacts (see e.g. Becker and Naumann, 2016, p. 26ff; Schnelle and Voigt, 2012, p. 4). The SIP schemes have the potential to positively incentivize broader acceptance of covered parts of the population as they directly profit from the implementation through enhanced pension payments.

According to an empirical, interview and survey-based analysis by Albrecht et al. (2013, p. 89f), about half of 1,500 surveyed German citizens consider financial participation as very helpful or helpful solution to increase acceptance for energy transition projects. When asked for specific assets, more than 50% were interested in financial participation for grid extension, PV and wind power capacity. Among the surveyed assets, only biomass investments received less than 50% interest. One of the critical issues that has to be considered in this context is the required minimum capital for participation. In many cases this volume is around EUR 5,000 which seems too high for large parts of the population. A prominent example is the "Citizen Bond Westküste" that has been issued by the Northern Germany grid operator with the aim to increase acceptance of a EUR 200 million transmission grid expansion. However of the envisaged EUR 6 million equity from impacted citizen, only about EUR 830k have been realized due to exclusionary high minimum volumes, a perceived high risk and complexity as well as unattractive risk-revenue ratios (compare Lenk, Thomas; Rottmann et al., 2014, p. 33f). This problem has also be assessed by Radtke (2016, p. 80), concluding that "citizen energy investments" can increase acceptance but only profits the ones that have sufficient equity capital. According to a survey with 2.800 participants, this minimum capital barrier can even decrease general acceptance or create massive tensions in a specific region, if broad parts of the population are excluded. According to Messinger-Zimmer and Zilles (2016, pp. 47–50), regional conflicts on distribution of profits and burdens from wind power projects have been successfully addressed through more equitable spreading of returns and broader economic participation. These examples demonstrate that a broad coverage of population through a SIP scheme would also allow broad participation thus likely increase acceptance and help to address existing implementation barriers among impacted citizens in Germany.

5.5.4. Democratization

Democratized energy transition assets, particularly renewable power capacity, has been one decisive success factor of the German energy transition so far. According to Agora (2018, p. 18), the upgrade of consumers to prosumers (producers and consumers) has been essential for the strong growth of renewables. As shown in chapter 5.1.3 about half of all German renewable power capacity assets are owned by private or community corporations. A SIP scheme “could further increase ownership and motivation for energy transition infrastructure deployment among the population” (Köhler, 2020, p. 17).

Contrary, the two centralized SIP schemes discussed in scenarios 3 and 4 might come with negative implications on democratization. Since members of existing capital-based pension schemes would use their tax and grant benefits under a strict implementation of scenario 3, a democratic perception of the new SIP system might be jeopardized. The mandatory option discussed under scenario 4 might be perceived as an amplified violation of democratic principles. Implementing a non-voluntary increase of pension contributions without choice to drop out could lead to a general rejection. For instance, Evensen et al (2018, p. 1) find in a UK based survey on the relationship between justice and acceptance of energy transition costs that “public support, even for laudable programmes, is not certain if they must pay”.

5.5.5. Energy justice and energy finance

Following the reflection of energy transition justice principles as suggested by Hall et al. (2018, p. 773ff) lead to diverse outcomes for the four scenarios. With regards to governance, the German institutions and frameworks provide a solid framework (compare also analysis in chapter 5.2.6) while the investors’ institutional set up is based on the current landscape of actors in scenario 1 and 2. For scenario 3 and 4 a new institution adapting requirements defined in chapter 4.5 would have to be established. The choice of the institution responsible for the SIP investments also determines related processes and transparency standards. As analysed by Hall et al., the intergenerational conflict, that the energy transition poses upon the population can be resolved by economic participation. A SIP schemes "would offer broad economic participation of the working generation through enhanced pension payments, the benefits of the transformation would be shared more equally" (Köhler, 2020, p. 17).

5.5.6. Political feasibility

As the four assessed approaches are characterized by different levels of state interference into the existing market and framework, one can expect varying levels of political feasibility. While the BAU scenario, if at all, requires minor adjustments of the legal framework only, the regulatory scenario implies substantial adjustments of the underlying eligibility regulation for subsidies. Several federal laws would need reforms in order to define minimum investment shares for energy transition assets within the overall portfolio. In this context, the German association of insurers and pension funds GDV (2018a, p. 11) highlights that the freedom of individual allocation and investment decision has also to be guaranteed for sustainable investments, otherwise lower revenues and a reduced diversification will occur in the portfolios (compare also GDV, 2018a, p. 17). At the same time the authors acknowledge a focus of existing studies on equity investments that are underrepresented in institutional investor portfolios as well as a general lack of sufficient assessment results. Nevertheless, strong state interference with regulated allocation targets for certain asset categories would likely create resistance among affected institutions.

The voluntary SIP-Fund would likely create an even higher confrontation between the state and the private pension providers. As state subsidies for the existing private pension schemes are stopped in the assessed scenario, the profitable ground of these investors would disappear. The strong growth of managed capital, profits and clients they have succeeded since the Riester, Rürup and occupational reforms at the beginning of the 2000s as well as the increase of attractiveness for insurers due to the reforms in 2010 would be largely lost. It can be expected that the affected institutions would intensively fight for their business grounds trying to impede the establishment of such SIP-Fund.

Finally, the mandatory SIP-Fund would be complementary to the existing pension schemes thus likely receive less resistance from the institutional investors. As it would however increase the labour costs for employers and employees, strong confrontation from potentially labour unions and particular business lobbies can be expected. Consequently, also Flämig states that the political feasibility to implement the climate protection pension in the near future is unlikely due to the current situation in German politics, that is "characterized by lobbyism and distributional disputes" (Dähn, 2018, p. 43).

Table 17: Comparison of expected benefits and shortcoming results for the four simulated SIP scenarios

	BAU Scenario	Regulatory Scenario	Voluntary SIP-Fund	Mandatory SIP-Fund
Distributional benefits	Low	Medium	High	High
Distributional conflicts of interest	Medium	Medium - High	Low - Medium	Low
Associated risks	Low	Medium - High	Low - Medium	Low - Medium
ET acceptance benefits	Low	Medium	High	High
Democratization benefits	Low	Low	Medium - High	Medium - High
Energy justice improvements	Low	Low	High	High
Political feasibility	High	Medium	Low - Medium	Low

Source: Compilation of research results

5.6. Conclusion and recommendations

Germany's energy transition is in the middle of implementation. While some interim targets have been achieved, others failed. Despite being able to mobilize sufficient finance for the core elements, there are partial funding gaps. Additionally, the energy transition faces acceptance problems and resistance in several dimensions. At the same time the German pension system is facing demographic challenges that led to strengthened private, capital-based schemes that do not fulfil sufficiently their objectives. Whether a SIP scheme can address both the energy transition and pension system challenges in different facets, has been analysed quantitatively and qualitatively. The initially defined hypotheses have been partially confirmed and partially disapproved.

First, the existing landscape of institutional pension investors does already invest in energy transition assets, however on a low level. On the one hand, there is interest and financial pressure to expand the engagement. On the other hand, there are significant barriers that have rather internal institutional characteristics than regulatory ones.

Without any further regulatory or governmental interference, only a very moderate engagement in the energy transition can be expected. The discussed alternatives comprise of mandatory allocation targets for the existing private pension management institutions, a centralized, publicly managed but voluntary SIP-Fund and a mandatory SIP scheme covering the whole labour force.

Second, a quantitative assessment demonstrates the capital mobilization potential of these four options. While the BAU scenario would cover up to 6% of the energy transition investment needs, the scenario with mandatory allocation targets for pension providers increases this share up to one third. Both centralized SIP-Fund scenarios, the voluntary and the mandatory one, exceed the total expected energy transition needs by two to three times.

Third, the associated qualitative benefits and shortcomings are highly dependent on the selected option. The privately managed scenarios incur on the one hand higher risks and less impact on acceptance, democratization and inter-societal conflicts. On the other hand, the large amount of bound capital can be used from the start and the political feasibility is comparably high. For the publicly managed SIP-Funds the result is the opposite. They are expected to significantly increase acceptance while having lower risks due to high number of covered population that acts as voters the same time. Further they are likely not as exposed to potential conflicts of interest as they include more members. Impacts on democratization and identification with the energy transition could be twofold. On the one hand, they might face negative implications due to the mandatory characteristics of the centralized SIP-Funds. On the other hand, they lead to an increased ownership of energy transition assets among the population, strengthening the objective of democratization. Thus, among all assessed options the centralized SIP-Funds represent the most beneficial combination of capital mobilization potential on the on hand and improvements regarding pension system and energy transition on the other hand. However, these schemes face low political feasibility as they represent substantial reforms on the cost of either the private pension management sector or business in general. A general issue across all scenarios that requires careful consideration is the distribution of additional monetary benefits that would likely be associated with a stronger engagement of pension providers. These wins must be distributed between energy consumers and SIP scheme members, a dispute between the different affected groups can be expected.

Moreover, a potential crowding-out of existing investments could lead to negative impacts for affected entities.

With regards to the process of setting up a centralized SIP-Fund as sketched in scenario 3 and 4, elements discussed in chapter 4.4 would need to be reflected in detail. Among these are broad stakeholder participation that is needed on the country level to clarify society's preferences in terms of infrastructure development and sufficient consideration of co-benefits and negative impacts. High fiduciary standards have to be guaranteed and legal requirements have to be analysed and reflected appropriately to avoid embezzlement. The outcome of such stakeholder process has to be reflected in the institutional design of the fund. In all cases, strong safeguards for sufficient transparency, monitoring and evaluation schemes as well as communication will be essential to achieve long-lasting backing by the respective population.

6. Case Study Seychelles

This case study was published in the Seychelles Research Journal in the year 2020 (see Annex I). It provides a quantitative simulation that reveals the potential of the Seychelles Pension Fund (SPF) for financing the Seychelles 100% Renewable Energies Strategy (SeyRES 100). It further assesses the constraints and barriers that might hinder the SPF to mobilize its members' private capital for SeyRES 100 investments, following the hypotheses and methodological steps as defined in section 2.1. Thus, "the key objectives are to explore:

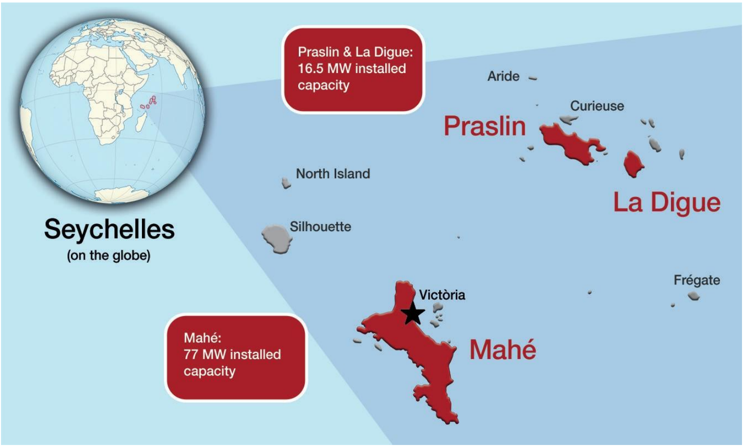
- *whether the SPF is eligible and suitable for investments in SeyRES 100 assets;*
- *what volume of SeyRES 100 investment needs could be matched by SPF resources over the energy transition implementation period; and*
- *what benefits and drawbacks can be expected by increased investments of private pension capital in sustainable energy assets"* (Köhler, 2020, p. 63).

Key elements of the case study including an assessment of SPF's structure and operation, the quantitate simulation of SPF's long-term potential for SeyRES 100 investments and the qualitative discussion of socio-economic impacts can be found in Annex I. To complement the assessment, the following sections provide additional information on the background of the envisaged energy transition on the Seychelles, list the applied data per parameter as defined in the methodology in chapter 2.1 and summarize the case studies' key results including an extended comparison of SPF mobilization potential and investment needs.

6.1. Introduction and context of the energy transition

The Seychelles are a Small Island Developing State (SIDS) consisting of 115 islands, the majority being unpopulated (compare Seychelles Energy Commission, 2016, p. 9ff). Figure 31 shows the three main granite islands Mahé, Praslin, and La Digue with a population of approx. 96,000 inhabitants (see National Bureau of Statistics Seychelles, 2018). Whereas in the past the economy was heavily based on agriculture and fishing, today the Seychelles mainly rely on tourism and finance services as well as exporting processed goods such as coconuts, vanilla and seafood (see Wehner et al., 2017, p. 11). Regarding energy supply, the Seychelles' economy is dependent on the import of fossil fuel for power generation and transport. The fuel costs constitute 90% of the power costs. Price fluctuations of crude oil affect both the overall economy and the end-consumers (see Seychelles Energy Commission, 2017, p. 23). In response to this significant drain of hard currency, the Seychelles are currently developing a comprehensive energy strategy named "Seychelles 100% Renewable Energies Strategy" to shift towards 100% renewable energy supply by 2035 (see Wehner et al., 2018, p. 3f).

Figure 31: Geographic location of Seychelles' main islands



Source: Wehner et al. (2017); Adopted from Wikipedia

6.1.1. Electricity supply and related CO2 emissions

In 2017, the electricity supply in the Seychelles "consists of two separated systems of 77 MW in Mahé and of 16 MW in Praslin and La Digue, respectively" (compare Wehner et al., 2018, p. 3). The dominant power source are diesel generators fueled with light and heavy fuel oil, whereas the share of solar and wind power in the electricity mix is about 2.5% only. Mahé as the main island is characterized by a reliable power supply system, which services practically every citizen and has very few downtimes.

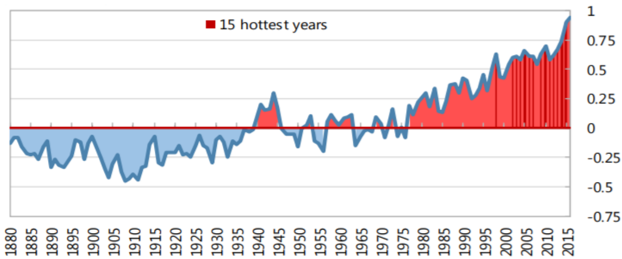
About 90% of the domestic CO_2 emissions are due to power generation and road transportation. The Public Utilities Corporation (PUC) and auto-producers in the Seychelles emitted 0.28 $MtCO_2$/a in the context of electricity generation in 2015. Baseline emissions are assumed to increase to 0.44 $MtCO_2$/a by 2030, a rise of almost 60%. Road transportation was responsible for emissions of 0.09 $MtCO_2$/a in 2015, this value is assumed to increase to 0.15 $MtCO_2$/a in 2030” (compare Wehner et al., 2018, p. 3).

6.1.2. Vulnerability of the Seychelles economy

The Seychelles face extremely high and fluctuating power costs resulting from almost 100% dependency on mineral oil imports for power generation and fuel for transportation. Although crude oil prices have declined since 2015, Seychelles’ power generation remains expensive and extremely vulnerable to price changes. In case of significant changes of import prices due to crude oil price increases or currency exchange fluctuations, GDP outflows can create significant challenges for the Seychellois economy. For instance during the years 2011 to 2013, with average oil prices above USD 100/barrel (Statista, 2019) more than 10% of the Seychelles’ annual GDP was used for fuel imports (see Seychelles Energy Commission, 2017, p. 23). Since power generation costs are heavily subsidized by the state, increased transfers to PUC for oil imports can also create significant gaps in the public budget that faces already a perilous debt stress situation (compare 6.1.5). Thus, an expansion of the fossil-fuel based energy supply system poses high threats to the energy security of the country.

Besides these economic and public budget challenges, the International Monetary Fund (IMF) undertook an analysis of the island state’s vulnerability to climate change and suggested necessary investments for adaptation and mitigation measures. “Climate change, compounded by the recent El Niño, has put Seychelles’ archipelago and biodiversity systems at higher risk. 14 of the 15 warmest years on record have occurred since year 2000, resulting in a drastic change of Seychellois weather patterns” (Abdychev et al. (2017, p. 1), compare alsoFigure 32). Global warming has also contributed to rising sea levels and massive damage of corals, which are of significant importance to islands. For the Seychelles, which relies heavily on fishing and tourism, the potential damage could be significant, both economically and socially. Thus, even being located outside the cyclone belt, the average economic cost of natural disasters in Seychelles is roughly 1 % of GDP and almost twice as much the average damage cost of sub-Saharan Africa peers. Highest economic impact in the recent decades was due to a tsunami in 2004 and a tropical cyclone in 2013, leading to GDP damages of 3.5% and 0.7% respectively (see Abdychev et al., 2017, p. 4ff).

Figure 32: Seychelles surface temperature, deviation from 20th – century average temperature



Source: (Abdychev et al., 2017, p. 4)

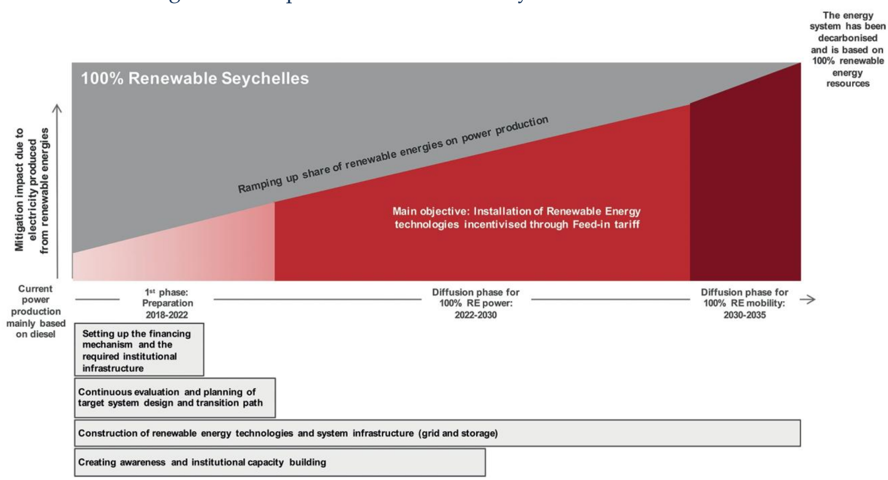
To address the challenges imposed by climate change, the IMF recommends reinforcing ex-ante resilience policies. This includes the energy sector where "Seychelles could benefit from a more resilient energy base with greater emphasis on renewable energy where possible. In addition, efficient fuel-based land transport and more use of electric vehicles charged with renewable energy technology is recommended" (Abdychev et al., 2017, p. 9).

6.1.3. Political support for a 100% renewable energy supply

Already before the recommendations by the IMF, the Seychelles intended to reduce its GHG emissions and diversify its energy supply system. In its National Climate Change Strategy and Intended Nationally Determined Contribution (INDC) the Government commits to reduce its GHG emissions by 21.4% in 2025 and 29.0% in 2030 relative to baseline emissions subject to international support (Republic of Seychelles, 2015, p. 1). Furthermore, the country defined targets for renewable energy consumption at 5% by 2020 and 15% by 2030 (compare Seychelles Energy Commission, 2016, p. 3). According to the countries' Sustainable Development Strategy 2012-2020 the "reliance on fossil fuels should be gradually reduced as they are not sustainable sources" and the "energy independence should be increased to reduce economic vulnerability through use of local sources of energy" (see Wehner et al., 2018, p. 4).

In 2016, a proposal to develop a 100% Renewable Energy Roadmap for Seychelles was adopted and approved by the Cabinet of Ministers in April 2016.[7] Since then, the Ministry of Environment, Energy and Climate Change (MEECC) is working on SeyRES 100, which foresees a "major transformational change for the energy system by aiming at full decarbonisation through a supply of 100% renewable energy sources by 2030, and through inclusion of e-mobility by 2035" (Hohmeyer, 2017, p. 2f; Wehner et al., 2020). The envisaged implementation pathway to increase the share of renewable energy until 2035 is illustrated in Figure 33. This objective has been reiterated several times, most recently by the Minister of Finance at the 2018 public budget discussion in parliament, highlighting that "renewable energy is an unstoppable revolution. The Seychelles must make sure as a nation that we profit from the technological advances being made. And to achieve energy security we clearly need to shift away from fossil fuel and embrace energy efficiency and renewable energy on a large scale as this will enable us to meet the energy needs, lower carbon emissions and mitigate the adverse effects of climate change, provide energy to our population at affordable prices and achieve UN SDG 7 on access to affordable, reliable, sustainable and modern energy for all" (quote based on IMF, 2017, p. 54).

Figure 33: Implementation of the SeyRES 100 until 2035



Source: Wehner et al. (2017, p. 5)

[7] Cabinet Memorandum on "A proposal to develop a 100% renewable energy roadmap for Seychelles", 20th April 2016. In May 2016, the Cabinet and President approved the recommendation to reach 100% renewable electricity as soon as possible, informed by scoping work carried out by Europa-Universität Flensburg Center for Sustainable Energy Systems (CSES).

6.1.4. Estimating the SeyRES 100 investment needs

In the context of the Cabinet Decision from April 2016, a pathway towards 100% renewable energy supply by 2030, including e-mobility by 2035, has been explored by Hohmeyer (2016) and the Center for Sustainable Energy Systems (CSES) Flensburg. An initial electricity supply model demonstrates the technical feasibility. About 56 MW of installed wind power capacity, 140 MW of installed solar PV capacity and an assumed volume of 6,000 t biodiesel combined with an electricity storage plant with 1.25 GWh storage capacity would be sufficient to cover the expected annual power demand of the three main islands. Storage will be required as a high share of solar and wind energy leads to a fluctuating electricity production. According to Hohmeyer (2016, p. 15ff), "the storage power generation has to be available within a few minutes due to the fast changes in the residual load" and the capacity of the power production from the storage needs to be "equivalent to the maximum load of the electricity system and the storage volume should be in the order of at least twelve hours of demand". Thus, the simulation estimates for the power supply of Mahé and the islands of Praslin and La Digue, a storage volume of about 1.25 GWh, a storage generation capacity of about 72 MW and a pump capacity of about 144 MW to make the best use of the available, renewable overproduction. With regards to the most effective and efficient storage technology, the report suggests a hydro pump storage plant with about 600 meters of altitude difference as most suitable application.

The simulation by CSES also suggests a transformation of the transport sector as an additional step towards energy independence. As large distance travelling is not usual on small islands like Mahé, Praslin or La Digue, efficient electric vehicles can be an attractive alternative to cars with combustion engines. Their ability to also act as temporary battery storage as long as they are grid-connected increases their favourable characteristics to stabilize the grid in the SeyRES 100 context. The simulation of transitioning the transport sector towards e-mobility demonstrates a need for increasing the solar PV capacity by 44 MW to 184 MW in total, while wind, biomass imports and the storage facility remain as required for power supply only. What has not been considered in the initial simulations yet is a strengthening and expansion of the existing power grid. Particularly if large volumes of decentralized solar PV will flow into the distribution grid and the central storage shall serve all three island, a significant strengthening of the distribution and extension of the transmission grid will be required (compare Wehner et al., 2018, p. 24f).

The CSES analysis also estimates the required investment needs for implementing the simulated renewable capacity and construct the storage facility. With specific investment costs of USD 1,725 per kW of solar PV capacity and USD 1,200 per kW of wind capacity the total investment volume including e-mobility sums up to USD 390 million. The pump storage facility approximately requires about USD 180 million of investment capital for construction including the turbines. PUC estimates USD 10 million of investments for an additional upgrade of the distribution grid (compare Wehner et al., 2018, p. 24f). Thus, the overall investment needs for the implementation of all SeyRES100 elements sum up to about USD 580 million, based on equipment prices and exchange rates in 2018 (see Table 18). Since the global average of specific solar PV investment costs per kW has decreased by about 80% between 2010 and 2021 and tend to further decline (compare IRENA, 2022, p. 79), it can be expected that the value of USD 1,725 per kW is not representative for the whole energy transition period. Thus, total investment needs will likely be lower than estimated by Hohmeyer (2016) and Wehner et al. (2018). A sensitivity analysis shows that applying a value of USD 1,000 per kW solar PV would decrease the overall SeyRES 100 investment needs by about 25% to USD 445 million.

Table 18: Estimated investment needs for SeyRES 100 elements (all USD_{2018})

Energy system component	Unit	Total	Specific investment cost (USD/kW)	Total investment required (million USD)
Solar PV - electricity grid only - with e-mobility	 MW MW	 140 188	 USD 1,725 USD 1,725	 USD 241 USD 324
Wind	MW	56	USD 1,200	USD 67
Total (solar and wind) - electricity grid only	 MW	 196		 USD 308
- with e-mobility	MW	244		USD 391
Pump storage				USD 180
Upgrade of low-voltage distribution grid				USD 10
Total investment needs with e-mobility				**~USD 580**

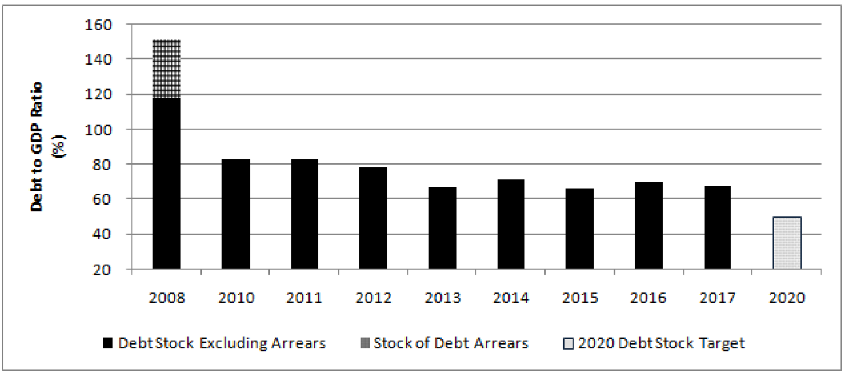
Source: Adapted from (Wehner et al., 2018, p. 7)

So far, investments into energy infrastructure have almost exclusively been undertaken by public institutions. Mainly the parastatal utility PUC invested in power generation capacity as well as the transmission and distribution grid. Required financial resources have been provided by the state budget.

6.1.5. Challenges for financing the energy transition on the Seychelles

"An approach of shifting the full responsibility for SeyRES 100 investments to PUC and the public budget will not be feasible as the Seychelles are recovering from a severe balance of payments and debt crisis that hit the country in 2008" (Köhler, 2020, p. 62). The public debt level inflated 150% of the country's GDP at that time (see Figure 34). Based on an initial debt restructuring program that forced creditors to write off about 45% of debts, three consecutive IMF programs required the country to conduct macroeconomic policies and implement structural reforms, leading to substantial primary fiscal surpluses and strong economic growth since 2009. Due to the successful implementation of the reform programs, paired with strong economic growth driven by the tourism sector, the public-debt-to-GDP ratio has been reduced by almost two thirds since end-2008, reaching 67% by the end of 2017 (see Figure 34).

Figure 34: Seychelles public debt to GDP ratio since 2008



Source: (Government of the Seychelles, 2017, p. 6)

Based on a debt sustainability analysis undertaken by the IMF (2017), Seychelles' public debt is still considered as high-risk but further destresses provided that the authorities continue to implement fiscal consolidation measures. Risks are mainly mitigated by the composition of external debt and the maturity profiles of domestic debt. However, there are still some uncertainties whether the Seychelles can meet the reduction target for public debt. First, the Seychelles remain vulnerable to exogenous shocks such as real exchange rate shocks or macro-fiscal shocks. Second, economic growth, which is centred on fisheries and tourism, may also be impacted by external factors such as extreme weather events. Third, substantial volumes of external debt provided to state-owned enterprises might inherit operational risks. Preliminary analysis suggests additional debt liabilities of the state-owned entities to total around 13 percent of GDP. While most of the state-owned enterprises are profitable, their non-guaranteed debt implies sizable contingent liabilities and could potentially pose significant fiscal risks (compare IMF, 2017, p. 11).

Under the obligations of the Public Debt Management Act of 2008 and guided by the updated "Debt Management Strategy 2018-2020" (Government of the Seychelles, 2017), the country wants to keep its debt on a sustainable path and to pursue sound debt management practices. The government's fiscal target is to achieve a debt to GDP ratio of 50% by the end of 2020. An IMF policy coordination instrument outlined several policy options to achieve this aim, including the strengthening of medium-term fiscal sustainability, locking in price and external stability, buttressing financial stability, reducing fiscal risks and enhancing inclusive growth (compare IMF, 2017, pp. 6–15). The last option includes public investment projects planned for the upcoming years. Among the envisaged public investments specifically electricity grids in Southern Mahé, water distribution networks as well as marine resource management and fishery upscaling are prioritized (IMF, 2017, p. 14). Despite considering that economic growth continues and that the country will not be adversely affected by any exogenous shock, the scenario by the IMF shows that ambitious funding of additional climate change adaptation and mitigation measures would slow down the public debt reduction pathway by several years. Thus, significant investments beyond the pre-defined activities will not be possible at least until the year 2021, strongly limiting the state budgets' capabilities to finance elements of SeyRES 100.

Since the Seychelles only have limited public resources to finance climate mitigation activities, other adequate financing sources have to be mobilized. Solutions suggested by the IMF include an increase of the efficiency of public investment, an effective use of Public Private Partnerships, finding concessional external sources and creating further fiscal space over the medium-term through e.g. better targeting social welfare by raising the retirement age, tax reforms or streamlining public agencies (compare IMF, 2017, pp. 52–56). To mobilize international funds, engaging in innovative financing solutions like a Blue Bond for sustainable marine and fishery projects in cooperation with World Bank have been initiated (World Bank, 2018c). Concluding, the required investment volume for SeyRES 100 infrastructure cannot be provided by Seychellois public sources or the parastatal PUC only. Therefore, the energy transition will have to include significant amounts of international or domestic private capital.

"In order to reflect an economically sound option that is beneficial for a majority of the Seychelles population and in line with the Governments debt reduction strategy" (Köhler, 2020, p. 62), the case study in Annex I explores the potential of leveraging domestic pension capital to finance elements of the energy transformation. Hereby it is analysed whether and how the public SPF can invest domestically in sustainable energy infrastructure. A long investment horizon with stable cash-flows for SPF can be a suitable match to the requirements of SeyRES 100 infrastructure with long amortization periods and lifetimes such as renewable capacity, power grids or storage facilities. As discussed generally in chapter 4.5, SIP pension system investments would have to "meet certain sustainability criteria to balance investment risks for the contributors while guaranteeing environmental sustainability and an adequate profit level" (Röben and Köhler, 2016, p. 5). The case study describes the background of the SPF, its governance structure, eligibility criteria for investments and its current investment portfolio. Hereby, SPF's potential role in the context of SeyRES 100 as well as positive and negative implications for the Seychellois population associated with such an innovative financing approach are discussed. Moreover, the case study describes the barriers that will have to be addressed if SPF shall successfully participate in the energy transformation. Finally, the case study explores the important question what volume of SPF capital could realistically be mobilized for the energy transformation until 2035. Hereby the specific SeyRES 100 investment needs on the one hand and SPF's potential to mobilize private capital to match these requirements on the other hand are analysed quantitatively and qualitatively.

6.2.Required framework conditions for energy transition investments

Supplementary to the analysis in Annex I (section 3.1.5), the framework conditions generally defined in chapter 4.6 are assessed against the Seychellois energy transition context and SPF's investment framework.

Political and legal framework

The World Bank's "Ease of Doing Business Index" places the Seychelles on rank 96 of 190. The country scores comparably high on the underlying indicators of "registering property", "paying taxes" and "resolving insolvency" (see World Bank, 2019a, p. 201). This shows that the Seychelles have a comparably stable political and legal system for a SIDS. This is also backed by Transparency International's "Corruption Perception Index" which ranks the Seychelles 28th of 180, an excellent score for a developing country. That the SPF can operate in the general investment environment is also proofed through the various real estate engagements in the past (compare Annex I, section 3.1.4). However, the political stability is prone to external impacts. As discussed in chapter 6.1.2, the Seychelles' economy is extremely vulnerable to climate change impacts, fluctuating oil prices and currency exchange rates as well as dependent on foreign currency generated in only a few economic sectors such as tourism. Despite those external dependencies, the general political and legal framework conditions are evaluated as appropriate for SIP activities.

Regulatory framework for investors

The SPF can rely on a well-elaborated, comprehensive and operational regulatory framework. As discussed in Annex I, section 3.1.3 portfolio targets for different asset classes guide the allocation of SIP resources, an internal limitation for SeyRES 100 investments does not exist. Both equity and debt financing is theoretically eligible, for the latter guarantees from e.g. the Government of the Seychelles would be required under the current conditions of the investment policy (compare SPF, 2017, p. 4). Overall, SPF's regulatory framework is well prepared for SIP investments.

Regulatory framework and incentive framework / financial mechanism for energy transition

The Seychelles are not covered by the ESMAP's RISE scoring. As discussed in the barrier analysis of Annex I (section 3.1.5), a comprehensive energy regulation and sufficient economic incentives to unlock private capital investments in sustainable energy are still lacking on the Seychelles, making an autonomous engagement of SPF in the SeyRES 100 context nearly impossible. The implementation of a suitable framework for the generation, transmission and sale of renewable energy has to be addressed by the Seychelles Government, before any larger SPF investments can take place.

Priorities of investors

Generally, the SPF shares the common investment characteristics of institutional investors discussed in chapter 4.5.1. Also, the internal guidance aims for "capital preservation, earn highest yields with minimal risks, diversify its portfolio, consider sufficient liquidity and guarantee cautious and prudent fund management" (Köhler 2020, p.66). Hereby, impact investments with social and environmental co-benefits, as it can be expected in the SeyRES 100 context, are a preferred focus for the upcoming years. Renewable energies are specifically highlighted (see SPF, 2018, p. 84). This indicates willingness and interest of both the operational management and the Board consisting of, inter alia, Government members. However, no investments in the field of energy infrastructure have been taken yet and the absence of markets to trade energy assets limit liquidity.

Experience and capacity of investors

The current operational management staff of the SPF has not sufficient expertise to adequately take direct project financing decisions in the SeyRES 100 sectors. External support, new hired staff, capacity building and knowledge transfer are required to overcome this barrier. First activities from SPF side will require substantial due diligence and highly favourable conditions to overcome the barrier of investing in non-mature and non-familiar contexts. Also, experienced consortium partners will be required to allow SPF to take positive investment decisions on SeyRES 100 activities (compare exchange with SPF staff, 2018).

Project pipeline

Since PUC controls most of the energy generation capacity and the power grid on the Seychelles, there exists no adequate project pipeline yet. Thus, currently only a direct cooperation between SPF and PUC would allow for a SIP engagement. With the set-up of a functional regulatory and incentive framework for SeyRES 100, additional investment opportunities driven by the private sector might emerge in future.

Potential to leverage debt

According to World Bank's "Ease of Doing Business Index", the Seychelles rank very low in the category "getting credit" (see World Bank, 2019a, p. 201). Also, in terms of available volume, there exists only a small banking and investors sector on the Seychelles (SPF Staff, 2018). However, the Seychelles actively try to mobilize international debt from e.g. Multilateral Development Banks or the GCF (compare chapter 6.1.5). As an advantage, this debt might come with a higher level of concessionality such as low interest rates. Since international mobilization of capital would likely require active governmental support, the potential to leverage debt is evaluated as medium.

Table 19 summarizes the evaluation results of the discussed framework conditions in the Seychellois context.

Table 19: Assessment of framework conditions to unlock SPF capital for SeyRES 100 assets

Framework condition	Indicator results, references	Interpretation in the Seychellois context	Evaluation result
Political and legal framework	Ease of doing business index: 62.4 of 100 (Rank 95 of 190) Corruption Perception Index TI: 66 of 100 (Rank 28 of 180) (see Transparency International, 2019; World Bank, 2019b)	The Seychelles have a comparably stable political and legal system with sufficient legal security for business activities; public debt and high exposure to exogenous impacts might jeopardize investments.	✔ ✔
Legal and regulatory framework for institutional investors	Compare analysis in Annex I, section 3.1.3	There is a clear investment framework for SPF, investments in infrastructure are theoretically feasible, facing some limitations.	✔ ✔
Legal and regulatory framework for energy transition	Compare analysis in Annex I, section 3.1.3	There exists currently no regulatory framework for the generation, transmission and sale of renewable energy	⦸
Priorities of investors	Compare analysis in Annex I, section 3.1.3	SPF and the supervising Board show interest in renewable energy investments	✔ ✔

Experience and capacity of investors	Compare analysis in Annex I, section 3.1.3	Hardly no SPF experience with renewable energy infrastructure	⃠
Project pipeline	Compare analysis in Annex I, section 3.1.3 and chapter 6.1	Apart from some minor activities by PUC, there exists no project pipeline for renewable energy infrastructure	⃠
Potential to leverage debt	Compare analysis in chapter 6.1.5	Due to the high level of public debt, state budget finance is highly limited; there exists only a small banking and investors sector on the Seychelles. International, concessional funding might be a promising option for the future	✔

Source: Own table based on analysis in chapter 6.1 and Annex I, section 3.1.5; ✔ ✔ indicates sufficient conditions, ✔ medium conditions and ⃠ not sufficient conditions

While some of the insufficient framework conditions such as the lack of incentives for renewable capacity implementation or a favourable regulatory framework for sustainable energy assets can be directly addressed or improved through the government and legislative, others are subject to external actors. The general structure and policy of SPF allows SeyRES 100 investments and there is willingness and interest among the top management and the Board. However, the operational staff needs capacity development and the Seychelles Government has to provide a suitable enabling framework as well as favourable conditions for the initial investments to unlock the private capital managed by SPF.

6.3. Overview of applied data and parameters

The model follows the equations of the cash-flow methodology defined in chapter 2.1. Table 1 in section 3.2.1 of Annex I by Köhler (2020, p. 68f) shows the key data and assumptions including the respective sources applied in the model. To provide full transparency on the applied data and the detailed simulation results, the following tables show additional parameter and their input values or calculated values for the two SeyRES 100 scenarios analysed in the case study of Annex I.

Table 20: Applied parameter values for simulation of SPF mobilization potential, according to equations as defined in case study methodology in chapter 2.1

Parameter	Explanation and unit	SeyRES 100 scenario (unadjusted)	SeyRES 100 scenario (adjusted*)
i	Start year of modelling	2020	2020
n	Final year of modelling	2035	2035
INV_{TOT}	Total available investment capital, in million USD_{2018}	32 (2020) decreasing to 0 (2035)	37 (2020) to 37 (2035)
INV_{TRA}	Traditional investment allocation, in million USD_{2018}	15 (2020) decreasing to 0 (2035)	17 (2020) increasing to 30 (2035)
SIP_{IN}	Cash-inflows to the SIP scheme, in million USD_{2018}	65 (2020) increasing to 82 (2035)	71 (2020) increasing to 133 (2035)
SIP_{OUT}	Cash-outflows from the SIP scheme, in USD_{2018}	33 (2020) increasing to 94 (2035)	33 (2020) increasing to 96 (2035)

Source: Own table based on parameters defined in chapter 2.1 and "SIP simulation_Seychelles" model results; *contribution rate adjusted by +20%

Table 21: Applied parameter values for simulation of cash-inflows, according to equations as defined in case study methodology in chapter 2.1

Parameter	Explanation and unit	SeyRES 100 scenario (unadjusted)	SeyRES 100 scenario (adjusted*)
PEN_C	Pension contributions, in million USD_{2018}	28 (2020) increasing to 57 (2035)	34 (2020) increasing to 69 (2035)
SG	Supplementary grants by the state (if applicable), in USD_{2018}	Not applicable	Not applicable

INV_{REF}	Reflows from relieved investments, in million USD_{2018}	22 (2020) decreasing to 13 (2035)	22 (2020) increasing to 28 (2035)
INV_{REV}	Revenues from investments, in million USD_{2018}	14 (2020) decreasing to 12 (2035)	14 (2020) increasing to 36 (2035)
POP_{E}	Total employed population, in thousands	62 (2020) increasing to 66 (2035)	62 (2020) increasing to 66 (2035)
SIP_{MC}	Share of employed population with SIP-membership, in %	70% (stays constant over time)	70% (stays constant over time)
INC_{POP}	Average employment income of population, in USD_{2018}	10,800 (2020) increasing to 12,500 (2035)	10,800 (2020) increasing to 12,500 (2035)
CON	Average SIP contribution share of total employment income, in %	6%(2020) increasing to 10% (2035)	7%(2020) increasing to 12% (2035)

Source: Own table based on parameters defined in chapter 2.1 and "SIP simulation_Seychelles" model results; *contribution rate adjusted by +20%

Table 22: Applied parameter values for simulation of cash-outflows, according to equations as defined in case study methodology in chapter 2.1

Parameter	Explanation and unit	SeyRES 100 scenario (unadjusted)	SeyRES 100 scenario (adjusted*)
PEN_{P}	Pension and other benefit payments, in million USD_{2018}	27 (2020) increasing to 83 (2035)	27 (2020) increasing to 83 (2035)
AC	Administrative costs, in million USD_{2018}	7 (2020) increasing to 11 (2035)	7 (2020) increasing to 13 (2035)
POP_{R}	Total retired population, in thousand	10 (2020) increasing to 17 (2035)	10 (2020) increasing to 17 (2035)
SIP_{MR}	Share of retired population with SIP-membership, in %	55% (2020) increasing to 70% (2035)	55% (2020) increasing to 70% (2035)

CON_{RC}	Historic pension contribution of the respective cohort in year i till y, in million USD_{2018}	Not applicable, DB system with regulated pension and other benefits payments	Not applicable, DB system with regulated pension and other benefits payments
PEN_T	Average pension payment duration, in years	Not applicable, DB system with regulated pension and other benefits payments	Not applicable, DB system with regulated pension and other benefits payments
RR	Effective rate of return on individual capital stock, in %	3%	3%
y	Number of years of contribution	Not applicable, DB system with regulated pension and other benefits payments	Not applicable, DB system with regulated pension and other benefits payments
AC_M	Administrative costs for member account mgmt, in million USD_{2018}	4.1 (2020) increasing to 8.5 (2035)	4.1 (2020) increasing to 8.5 (2035)
AC_{EM}	Administrative costs for equity asset mgmt, in million USD_{2018}	2.5 (2020) increasing to 2.6 (2035)	2.5 (2020) increasing to 4.2 (2035)

Source: Own table based on parameters defined in chapter 2.1 and "SIP simulation_Seychelles" model results; *contribution rate adjusted by +20%

6.4. Results of the case study simulation: Matching available SPF resources with SeyRES 100 investment needs

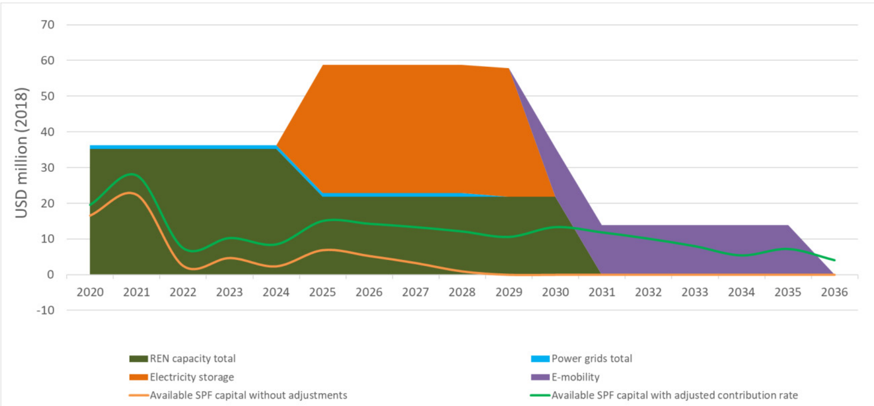
As discussed in chapter 6.1.4, the total estimated SeyRES 100 investment needs including a transformed transport sector and a pump storage facility cumulate to ~ USD 580 million until 2035. According to the case studies' results in Annex I (Köhler 2020, p.70f), the SPF can mobilize own resources of a maximum of ~USD 60 million for SeyRES 100 investments over this time period, reflecting existing conditions and eligibility ranges. Thus, a full match of all SeyRES 100 investment needs is not possible. Nevertheless, there are open research questions that can significantly influence SPF's impact on the overall financing picture of the energy transformation. For instance, it is worth to explore the available capital volume over time, as SeyRES 100 needs different volumes of capital during specific periods of the transformation. This also relates to the implemented hardware, the future degression of installation costs (compare discussion of solar PV degression rate in chapter 6.1.4) and its' characteristic and attractiveness for the SPF. Thus, a prioritization of investment options according to the institutional investor's appetite discussed in chapter 4.5 is a helpful step for understanding priorities from SPF perspective. Finally, the applied funding instrument by SPF, equity or debt, has significant impact on both the Fund's risk and revenue expectation as well as the potential to leverage co-finance for larger SeyRES 100 investment coverage. Those aspects are analysed in the case study (Annex I, section 3.2.3 and 3.2.4) and summarized in the following section.

According to Hohmeyer (2016), all investments would be required prior to 2035 for the rapid transformation option. An averaged and linear investment forecast assumes renewable energy capacity investments for power production until 2030, hereby reflecting wind power implementation between 2020 and 2025. Afterwards the storage facility investments could take place until 2030 in parallel to additional PV implementation. Grid strengthening can be estimated as a parallel process to increased shares of grid-connected renewable capacity. Finally, the e-mobility infrastructure is implemented between 2030 and 2035. As demonstrated in Figure 35, the total investment needs range between USD_{2018} 15 million and USD_{2018} 55 million per anno.

When combined with the availability of SPF capital in the scenario that does not consider any adjustment of the contribution rates, there is an indication that the Fund could provide capital for SeyRES 100 infrastructure in the initial years of implementation (see Annex I, Figure 2, p.72 and compare orange line in Figure 35). From such a SPF coverage of more than 50% of the total SeyRES investment volume in 2020, this share decreases to zero by 2028. Afterwards its assets have to be liquified due to the unsustainable outlook of the SPF with the current parameters. This means that the Fund can contribute to the investment of renewable capacity, grid extension and the storage facility while e-mobility investments are out of the possible investment range under the standard scenario.

Since the simulated cash-flow predicts an insolvency of the SPF by the year 2040, it is recommended to actively address the unsustainable outlook of the Fund beyond 2030. Hereby an adjustment of pension benefits or the contribution rate or a mixture of both are suitable solutions according to the model results. The simulation described in Annex I assumes an increase of the contribution rate by 20%, translating into an average increase of the annual contribution of about USD 250 per member by 2035. Thereby, a sustainable outlook of the SPF beyond 2030 can be achieved and the potential coverage of SPF investments increases significantly. Under such a scenario with adjusted contribution rates, the Fund is able to mobilize up to USD 170 million during the timeframe 2020 to 2035. This volume could cover about 30% of the required SeyRES 100 investments including pump storage (see green line in Figure 35). Particularly during the initial and the last 5 years of envisaged implementation it can cover more than half of the total investment needs.

Figure 35: Estimation of SeyRES 100 investments and SPF coverage until 2035; contribution scenario



Source: Own illustration from model "SIP Simulation_Seychelles"

To cover the full SeyRES 100 investment needs including storage of USD 580 million, SPF would theoretically require an increase of the contribution rates by about 60% until 2035, translating into contribution shares of the gross salary of about 16%, instead of the currently envisaged 10%. Alternatively, as discussed in section 3.2.4 in Annex I, applying the SPF capital as direct equity investment could theoretically mobilize up to additional 80% of debt from other sources. Thus, even in the SPF scenario without adjustments, the mobilized ~USD 60 million could leverage up to ~USD 240 million of co-finance. The combined volume could cover more than half of the estimated SeyRES 100 investment needs. Under the contribution rate scenario, theoretically up to USD 680 million of co-finance debt could be leveraged, representing more than the entire SeyRES 100 investment needs. This option might allow to allocate equity to real estate and energy infrastructure investments, resolving partly the potential distributional and societal conflicts of interest (compare discussion in section 3.3.1 of Annex I).

7. Comparison of Literature and Case Study Findings

This chapter compares the key findings from the literature assessment and the two case studies with the aim to identify elements that are concurrent or diverse under the disparate characteristics of theory and the two countries. Furthermore, the analysis attempts to derive generalizations that can be transferred to other contexts and countries. Hereby the analysis distinguishes between the findings on status quo conditions, quantitative results of the cash-flow assessments until 2050 and the qualitative findings of SIP impacts on energy transition, retirement schemes and society.

7.1. Findings on the status quo conditions

As described in chapter 2.1, the two case study countries are characterized by highly diverse conditions. This includes the level of development, economy, GDP per capita income, size, geographical location but particularly the status of the energy transition and its enabling framework. Both countries have in common, that the public debt to GDP ratio increased significantly since the start of the financial crisis in 2007. High debt rates limit the state's possibilities to invest in infrastructure as it prevents the uptake of additional debt. Thus, Germany and the Seychelles are not able to mobilize more public capital raised on capital markets for energy transition investments beyond the current levels (compare findings from chapter 5.1.4 and chapter 6.1.5) This phenomena can be observed globally, according to the IMF (2018), industrialized countries increased their debt to GDP ratio from 71% in 2007 to 103% in 2018. Emerging economies and developing countries experienced a ratio growth from 36% to 50%. Therefore, it can be expected that many countries worldwide face similar limitations of mobilizing state funding for sustainable infrastructure. This highlights the need for mobilization of private capital. Hereby, investors require appropriate enabling environments that incentivize investments.

While Germany has already progressed along an energy transition pathway and adopted various laws, regulations and economic mechanisms over the last 20 years, the Seychelles are at the beginning of such a development. This discourages an engagement of the SPF, hampering reliable investments in energy transition assets as due diligence under the current conditions leads to negative investment decisions. In contrast, German pension investors show already limited activity in the field of direct and indirect energy asset investments and gather first experience. This indicates that appropriate framework conditions as discussed in chapter 4.6 can unlock pension institutions investments without any further state interference. However, it seems that such voluntary and unregulated engagement proceeds slowly. Thus, appropriate enabling environment conditions are rather an ample condition for transformation than a sufficient solution for ambitious energy transition investments. Moreover, internal capacity constraints limit SIP activities significantly. This is demonstrated by literature findings (compare chapter 3.3.3), analysis of the German institutional investors (compare chapter 5.2.5) and the Seychellois SPF (see chapter 6.2).

With regards to the pension system, the situation in both case studies is again very different. While Germany has a functional three pillar scheme with various public and private direct benefit (DB) and direct contribution (DC) institutions covering the whole population, the Seychelles rely on two pension schemes with a minimal state-funded pension for everyone and one contribution-based DB institution (the SPF) that covers about 70% of the workforce and 50% of the pensioners by 2018. While the German capital-based pension managers predominately invest in internationally listed bonds and equity stakes, SPF focuses on unlisted domestic real estate, combining development objectives and reliable investments in the Seychelles.

7.2. Quantitative results

The quantitative analysis of the future development of the capital-covered retirement schemes reveals significant differences between the German and the Seychellois system. As the German capital-based institutions are predominantly organized as DC schemes, the economic risk of performance bear mainly the insured members. On the one hand this approach stabilizes the system, it is expected to be operational and solvent in the long-term. On the other hand, it will likely not provide the benefits future retirees and politicians expect. As discussed in chapter 5.2.2, revenues are highly limited in the current low-interest environment and hardly compensate the transaction costs and high life expectancies of the private insurers.

In contrast, the SPF is organized as a direct benefit scheme with the pension institution bearing the risks of performance. Low contribution rates during the system's initial phase lead to an unsustainable long-term future. The simulations show that the intended contribution share increases will not suffice to stabilize the scheme. High numbers of pensioners with defined benefit payments surplus the contributions while asset aggregation is too small and does not provide sufficient revenues, leading to a default of the system around the year 2040. As identified by Andrews (2006, p. 23f) and the literature analysis in chapter 3.4.1 including the Australian examples, this characteristic is typical for many DB systems, particularly in developing countries. In capital-based retirement schemes, this problem can be addressed through higher contribution rates from the beginning that allow the aggregation of larger asset portfolios providing more revenue inflows to the system. Contribution rates can also be adjusted at later points of time but need higher increases in these cases. Alternatively, the defined benefit payment level can be decreased to reduce outflows. The latter options seem to be politically unattractive as they are likely opposed by many pension scheme members.

An attempt to generalize a sustainable contribution rate can be based on the average levels in different world regions. According to Pallares-Miralles et al. (2012, p. 44), the rates for public DB schemes in high income OECD countries as well as Europe and central Asia are fixed between 15% and 25%. In these countries the marjority of systems is DB based, the average gross income replacement rate lies between 35% and 80%. For instance, the German public DB system requires 18.6% of gross salaries for a stable operation, providing a gross replacement rate of about 48% in 2018. Until 2025, the government announced to keep this replacement rate stable while the contribution rate will stay below 20% (compare also chapter 5.2.1) . This shows that the Seychelles with their current contribution rate of 6% and an intended increase to 10% on the one hand and a provision of a gross replacement of ~50% by 2035 on the other hand combine an unrealistic mix compared to the international experience.

With regards to revenue performance, the low rates of return in Germany are partly due to limited investment opportunities subject to the existing regulation. On the Seychelles, direct investments in unlisted domestic real estate seem to harness significantly higher revenues. Whether such approaches are bearing higher risks, is determined by various factors (compare chapter 3.3.1). As analysed in chapter 4.4, the major risk of government holdup declines with increased coverage of population under the respective SIP scheme. The encompassing options in the German context, the voluntary and mandatory SIP-Fund, as well as the SPF on the Seychelles fulfil this criterion.

Regarding the quantitative potential for covering energy transition investment needs, the case studies provide the following insights (compare Table 23 for summarized scenario results):

- A regulated, centralized and specialized institution leads to significantly higher allocation of resources to energy transition assets. Despite low pension scheme contribution rates of only 2% - 3.5%, it can mobilize sufficient resources for covering the whole energy transition capital needs until 2050 in an industrialized country context with high salaries, as Germany represents it. Hereby no additional debt from the financial sector would be required. For a developing country like the Seychelles with significantly lower salary levels, it is hardly possible to cover the full investment needs of sustainable energy investments. Due to a preference of equity investments, there is the theoretical option of leveraging additional external debt that covers the remaining share of capital needs. For both cases, a voluntary and unregulated process driven by existing pension institutions is comparably slow and unambitious, allocating significantly less resources to sustainable energy assets.

- Due to the expected higher revenues from direct, unlisted, equity-based energy transition investments compared to traditional investments, the cumulated total asset value of the scheme rises proportionally to the share of energy transition assets in the portfolio.

- Without significant adjustments of key parameters, the Seychelles pension scheme is insolvent by the year 2040. Assuming a contribution rate increase of ~20% leads to a stable system beyond 2050 and theoretically provides sufficient resources to cover about 30% of the energy transition investment needs. Focusing on equity investments could leverage additional co-finance debt, sufficient to theoretically cover the entire SeyRES 100 investment needs until 2035.

Table 23: Comparison of scenario results across case studies, all in billion USD(2018)

	Germany				Seychelles	
	BAU scenario	Regulatory scenario	Voluntary SIP-Fund	Mandatory SIP-Fund	SeyRES 100 scenario (unadjusted)	SeyRES 100 scenario (adjusted*)
Target year	2050				2035	
Cumulated energy trans. investment needs until target year	1,360[8]				0.58	
Total pension scheme asset volume in target year	1,650	1,800	2,700	2,125	0.16	0.4
Total pension scheme energy asset volume in target year	80	425	2,700	2,125	0.06	0.17
Coverage of energy transition investment needs in target year	6%	31%	200%	156%	0%	30%

Source: Rounded results of models "SIP simulation_Germany" and "SIP simulation_Seychelles"; *contribution rate adjusted by +20%

The quantitative simulation results also show that the countries' average salary level and the economy size significantly influence the required contribution share level. While for the German case a share of less than 2% theoretically suffices to cover the estimated energy transition investment needs (see chapter 5.4.5), the Seychelles would theoretically need a significantly higher share of about 16% of gross wages by 2035 (compare chapter 6.4). Such share would be comparable to other OECD countries (see discussion above) but likely face significant resistance from contributors that expect contribution rates of about 10% in future.

[8] All EUR values are translated to USD based on the average 2018 currency exchange rate by OECD (2019)

7.3. Findings on impacts of SIP energy investments

The assessment of expected impacts from an enhanced engagement of pension schemes in energy transition investments reveals some consistent and several diverse results between the two cases but also between different implementation options within Germany. The main differences between the two cases are identified with regards to distributional implications, investment risk, acceptance, governance and political feasibility.

Concerning distributional impacts, the positive or negative influence of a SIP scheme in Germany mainly focuses on the coverage of population. The more people are members of the scheme, the higher is the likelihood for positive inter- and intra-generational outcomes while potential distributional conflicts between energy users and future retirees are declining. As the SPF scheme covers the majority of the population mandatorily, the Seychelles do not face such challenges and diverse outcomes. In their case, one key advantage and one major disadvantage has been revealed. A negative, serious distributional impact is the divestment from real estate assets. In case a strong SPF engagement in SeyRES 100 assets leads to significant divestments in housing and commercial space, the population might perceive a deterioration of real estate development thus potentially opposing SPF's energy transition investments. This conflict of interest could be mitigated by enabling investments in both sectors through the combination of SPF equity and leveraged co-finance debt. The positive influence of a stronger energy transition engagement is the accelerated independence of the state and economy from the cost-intensive fuel imports. Every year of earlier energy self-supply will relief the state budget and lead to more fiscal space in a debt-stressed situation.

With regards to investment risks, benefits are expected for retirement systems and economies in both cases. Besides a likely more profitable risk-revenue ratio compared to alternative assets, particularly enhanced protection of critical infrastructure is identified as additional advantage in the German context. In two scenarios, the SIP shows monopolistic characteristics that might counter potential efficiency gains that theoretically decrease energy transition costs. The Seychelles profit from increased energy security and potentially less default risk of SPF investments due to stronger independency from international markets and currency fluctuations.

Democratization of energy assets is in the interest of both case studies' population. The SIP approach supports strong ownership and identification with the energy transition. Acceptance problems represent a significant barrier for the energy transition in Germany and it is expected that broad SIP coverage and engagement can successfully address this challenge. On the Seychelles, public resistance against energy transition activities does not occur yet. Potentially the phenomenon will increase with a higher share of renewable energy supply and related large-scale interventions such as a pump storage facility or offshore-wind.

Regarding institutional capacity development, the situation on the Seychelles is more streamlined than in Germany. With the SPF exists one key institution that could be upgraded with the required capacity and knowledge for successful engagement in SeyRES 100. Contrary, the German context would either require the constitution and implementation of a new, large-scale and highly specialized institution or solutions for a fragmented insurer and pension fund landscape with various actors. However, with regards to governance, investments in the German energy transition can be realized on the basis of a functional and robust enabling environment.

Finally, political feasibility is a key precondition for a successful realization of SIP schemes. While political feasibility regarding SPF regulation does not constitute a major issue on the Seychelles, the German context is prone to resistance from powerful interest groups. With raising ambition of the different assessed SIP options, decreased political feasibility is expected. The strong financial sector with insurers and pension fund managers is not expected to accept a deconstruction of its lucrative business field of private pension management. Alternatively, business and work force likely oppose increased pension levies in the context of an additional, mandatory SIP scheme.

Summing up, the outcome of the comparison of findings on the status quo of existing conditions, the quantitative results of the cash-flow assessments until 2050 and the qualitative findings of SIP impacts on energy transition, retirement scheme and society are partly consistent for both case studies and partly highly diverse. Generally, one can derive the conclusion that industrialized and developing countries and economies share similar benefits and challenges about SIP implications:

One key finding demonstrates that a broad coverage of population increases distributional benefits and reduces conflicts of interests.

Moreover, ambitious SIP investments accelerate the achievement of energy security objectives and support the protection of critical infrastructure.

Regarding investment opportunities, energy transition assets provide higher revenues with a more advantageous risk-revenue ratio than most other options.

Furthermore, a robust legal, regulatory framework with an operational economic incentive mechanism is a precondition for investments.

On the subject of political feasibility, the Seychelles case has shown that systems with less pension pillars and involved institutions facilitate the implementation.

Finally, existing institutions are not ready for large-scale SIP engagement. They lack experience, knowledge and internal capacity. Alternatively, an appropriate external support structure is also not available yet.

Some identified elements are particularly relevant for developing countries. For instance, they might more often apply capital-covered pension schemes for development purposes. The impact of resource divestment towards SIP assets might jeopardize sufficient funding of other development objectives. As a positive economic impact, SIP engagement can accelerate and enable independence from fossil fuel imports and international capital dependencies. Regarding asset trading, listed markets for energy assets are non-existing or highly limited. Thus, the liquidity of the SIP portfolio is low and requires careful consideration. With regards to the comparably low salary levels in developing countries, high contribution rates are required for covering large-scale energy infrastructure capital needs. Apart from possible resistance against such reforms, higher contribution rates stabilize potentially unsustainable DB schemes.

Finally, some identified elements concern particularly industrialized countries. Due to high salary levels, already smaller contribution levels lead to volumes of capital sufficient for ambitious energy transition investments. Moreover, the emergence of a monopolistic actor with large volumes of capital might disturb a functional energy asset market leading to exceeded purchase price levels of assets. This can diminish efficiency gains in energy transition financing.

7.4. Preferable design features for SIP systems

Despite the need to consider design features and implications in a specific country context, there are strong indications what generally constitutes a preferable SIP scheme. Hereby the findings from the background analysis and the two case studies suggest that the following two characteristics lead to maximized positive results with regards to quantitative and qualitative impacts:

First, a broad coverage of population is preferable in different ways. Quantitatively, it increases the capital mobilization potential of the respective scheme thus facilitating large-scale coverage of energy transition investment needs. Qualitatively a broad coverage of population maximizes positive distributional impacts and minimizes potential conflicts of interest between different parts of the society and economy. This allows to enable the outlined acceptance, democratization and identification benefits among the majority of the population.

Second, a centralized SIP institution, or a set of a few large SIP institutions address the challenge of internal capacity constraints in the most streamlined manner. It allows the development of skilled staff and appropriate operational procedures to undertake direct and indirect allocation of resources while limiting risks and transaction costs. This has been demonstrated with e.g. the SPF for real estate investments or Australian, Canadian or Dutch pension funds as well as the UK EIB for infrastructure investments (compare chapter 4.2). Hereby, concentration of market power and financial resources requires effective oversight structures, a high level of transparency and stakeholder involvement as well as strong safeguards against corruption and embezzlement.

Thus, following the discussion of different scheme design options in chapter 4.4, the findings suggest centralized and specialized institutions with broad coverage of population as generally most appropriate structure for SIP schemes. For other design elements and characteristics, the findings do not allow generalizations but rather highlight the need for country-specific assessments.

8. Synthesis of results

This chapter summarizes the main results and evaluates the plausibility of the initially formulated hypotheses:

- *Energy transitions face funding challenges.*
- *Pension systems do not considerably invest in energy transition elements.*
- *Under appropriate conditions, capital-based pension systems can cover the investment needs of energy transitions in developed and developing countries.*
- *Large-scale pension investments for transformative infrastructure benefit both the sustainability of pension systems as well as the transition of the energy sector.*

The four hypotheses were analysed qualitatively and quantitatively by means of different scientific methods, including literature reviews and cash-flow simulations in the context of a theoretical assessment and two case studies. Based on the main findings from chapters 3 to 7, the following section synthesizes the key results to confirm or disapprove the respective hypotheses.

8.1. Energy transitions face funding challenges

Currently, worldwide investments in fossil-fuel and renewable energy supply assets aggregate to about USD 1.8 trillion per year (see chapter 3.1). This volume enables the provision of mainly fossil-fuel based energy to most people globally. Nevertheless, more than 1 billion people still lack electricity access. To achieve the climate change and universal energy access targets adopted in the Paris Agreement and the Sustainable Development Goals, the literature assessment in chapter 3.1 reveals additional annual sustainable energy investment needs between USD 1 to 2.6 trillion on the global level. There is no clear answer what share of this volume can be covered with the existing public and private financing structure and what remains as funding gap. Chapter 3.2 and 3.3 indicate that the magnitude of such global sustainable energy financing gap differs significantly between countries. In this context, the case studies (chapter 5.1.4 and 6.1.5) show that industrialized, economically powerful countries face overall less financing constraints than developing countries even though they share similar public funding limitations. Literature analyzed in chapter 3.3.4 emphasizes that wide-spread public debt limitations and reforms of the private financial market regulation in the aftermath of the financial crisis require the development of innovative capital sources. In this context, the large-scale mobilization of private capital will play a pivotal role. Summing up, the findings do not support a generalization of the hypothesis on a global level to date. Though, the analysis shows that the current funding landscape will not be sufficient for providing the required resources in many countries in future, emphasizing the need for implementing approaches beyond the existing investors structure.

8.2. Pension systems do not considerably invest in energy transition elements

Pension insurers and funds manage vast amounts of private capital and the ongoing retirement scheme reforms in many countries will further increase these volumes (see chapter 3.4). As assessed in chapter 3.2.4, retirement schemes' direct investments in infrastructure are very low. Less than 1% of sustainable energy assets globally have been financed by pension funds or insurers. The few available scientific assessments of the future financing potential find strong limitations and constraints. However, the literature analysis in chapter 4.2 and the German case study in chapter 5.1.3 also show that there are growing activities in markets with rather mature legal and regulatory frameworks. This is also a response to the low-interest rate environment in which pension managers currently operate. As long as interest rates stay low, it can be expected that pension capital will increasingly flow into energy transition assets in the future, partly disproving this hypothesis for the moment.

8.3. Capital-based pension systems can cover the investment needs of energy transitions in developed and developing countries

Chapter 3.3 describes challenges of pension investors to engage in sustainable energy infrastructure and chapter 4.6 sketches appropriate framework conditions to address some of these barriers. Assuming an appropriate enabling environment for large-scale, long-term direct energy transition investments, potential pathways for maximized allocation of pension capital towards sustainable energy assets have been simulated through cash-flow quantifications in the two case studies. Both cases find that energy transition investments until the year 2050 remain very limited without any further governmental intervention. Though with additional regulation and support, the investment volume could be significantly scaled up, being able to cover more than the expected investment needs in Germany and about half of the requirements on the Seychelles through direct debt and equity allocations. As analyzed in chapter 7, mainly the level of salaries and contribution rates as well as the share of covered work-force determine the mobilization potential. Favorable investment framework conditions and a capital-based pension scheme are necessary preconditions for SIP investments. If adequate regulation and support in different policy fields such as energy, social systems and financial markets are successfully synchronized, they can theoretically lead to the provision of the total required energy transition investments. These findings serve as a generalized indication for countries with comparable characteristics. Thus, the case study results confirm the general validity of this hypothesis but also emphasize country-specificity and the role of policy interventions to achieve full coverage of investment needs.

8.4. Benefits of large-scale pension investments

In chapter 4.3, this thesis explores qualitatively SIP scheme impacts on investment, distribution, risk, acceptance of energy transition, democratization of assets, energy justice and political feasibility. Such implications are considered from the perspective of retirement schemes as well as for the implementation of energy transitions.

For the stability and sustainability of the pension system, particularly an attractive risk-revenue ratio is of importance. The aspect of domestic SIP investments embedded in an enabling environment that provides appropriate economic returns allows to fulfil this criterion. Further, the legal and institutional set-up of the SIP scheme is decisive to guarantee robust investment decisions. In case inefficient investment decisions are taken, the reputation and stability of the scheme is jeopardized. This in turn can lead to the termination of memberships in a voluntary system or opposition and political pressure against the SIP in a mandatory system. With regards to institutional capability, most existing institutions are not ready for large-scale SIP engagement. They lack experience, knowledge and internal capacity.

From the perspective of energy transition implementation, this thesis finds several benefits SIP schemes can provide. They can reduce energy costs, increase energy security, reduce resistance against energy infrastructure implementation, democratize the asset ownership structure, enhance environmental benefits through contributing to core objectives of the Paris Agreement or the SDGs and lead to inter- and intra-generational energy justice and energy finance. Since literally the majority of the population owns their energy infrastructure under a SIP scheme, long-term identification with the energy transition could be sustained and associated short-term burdens would rather become acceptable.

However, the analysis also reveals potential negative implications of a SIP scheme. Among these are distributional conflicts between reduced energy costs and pension payments, energy market dominance or crowding out of finance in other important sectors leading to higher costs of corporate or state financing and potentially competing development objectives, as identified for the Seychelles case in Annex I, section 3.3.1. In this context, positive or negative implications often depend on the specific SIP design features. A broad coverage of workforce and future pensioners is the key element to maximize distributional, acceptance, democratization and energy justice benefits while minimizing risks. However, large SIP schemes with broad coverage also likely to experience reduced political feasibility. Resistance against SIP reforms can be particularly expected in countries with several existing pension providers operating in multi-pillar pension schemes that would face market share losses. Moreover, a broad coverage might come with elements diminishing democratization. Eliminating incentives for existing schemes or a compulsory participation as discussed for the German scenarios 3 and 4 can jeopardize identification with the SIP system. Thus, the thesis' results cannot entirely confirm the hypothesis. It finds significant positive implications generated by SIP schemes but also identifies negative impacts that can be partly addressed by consideration of an appropriate country- and context-specific SIP design.

9. Conclusion

The final chapter of this thesis summarizes and interprets the findings. It describes the contribution to existing literature, assesses the applicability and limitations of the applied methodology and gives recommendations for further research. To reflect the practical dimension of the findings, the thesis also provides conclusions for shaping of policies in countries that intend to implement SIP scheme elements.

9.1. Conclusions for shaping of policies

So far, a linkage of pension capital and sustainable energy infrastructure development has not been prominently featured through policy interventions. Besides regulatory adjustments to facilitate the direct allocation of resources managed by institutional investors towards infrastructure, policies have not been framed to specifically support SIP approaches yet. Since the results of this thesis demonstrate SIP scheme opportunities on a theoretical level and for two diverse case studies, it can be expected that positive implications also prevail in other contexts. Therefore, the findings are likely not only of specific interest to policy makers in Germany and the Seychelles but also to other countries that face challenges with pension system reforms and energy transitions. The highest potential can be expected in developing countries that still lack pension schemes for the majority of their population (compare chapter 3.4) and that face significant energy infrastructure investment needs at the same time. The SIP approach would help to achieve these two development objectives domestically without having to rely on large-scale international finance flows from abroad.

This study elaborates a methodology for case study assessments relying on four main assessment objectives and four related research steps (compare chapter 2.1). Countries that intend to implement SIP scheme elements are recommended to apply a similar approach. Country-specific evaluations of SIP schemes are suggested to reflect the following elements:

First, an assessment of the status quo includes an analysis of existing pension systems' current investment portfolios as well as its legal and operational suitability to allocate resources directly and indirectly towards sustainable energy assets. Interested countries are recommended to conduct such an assessment as initial step. Depending on the existing retirement scheme structure, also different options might be sketched as it was conducted for the German case study. In order to forecast SIP relevant investment options, the status of the energy transition and its future development should be evaluated in accordance with the countries energy roadmaps, strategies or national policies.

Second, a quantitative evaluation of the capital mobilization potential reveals the retirement schemes opportunity for coverage of sustainable energy investment needs. This step requires demographic, macroeconomic and pension scheme specific data that are projected over the duration of the energy transition period. As described in chapter 2.1, the cash-flow approach is deemed suitable for macroeconomic analysis focusing on the stability and mobilization potential. For simulations focusing on the profitability of particular pension funds or schemes, also levelized models could be applied.

Third, positive and negative implications of a SIP engagement should be identified and discussed qualitatively. This assessment can serve as the basis for a societal debate about the concrete design features of the pension scheme. Chapter 4.4 provides the theoretical background and gives general indications about typical impacts. Partly diverse outcomes of the two compared case studies emphasize the need to strongly consider country-specific characteristics.

Finally, a concrete set of policy adjustments required for establishing the preferred SIP option has to be elaborated. This can include regulatory and legal reforms of both the pension scheme and the energy sector or modifications of related incentive mechanisms. During this process, different governmental institutions or ministries responsible for e.g. energy policy, social security or the financial sector are required to coordinate efforts. Potentially also the implementation of a new private or public SIP institution is required to operationalize a country-tailored approach. Regardless of SIP activities, appropriate enabling environments typically constitute a precondition for any sustainable energy investments. Chapter 4.6 outlines typical conditions that need to be fulfilled before allocation of pension resources towards energy investments can take place, among these are appropriate legal and regulatory frameworks, capacity of the SIP investors or a sufficient project pipeline.

9.2. Critical discussion of the methodology and results

This section critically reflects the findings and results generated by this thesis. It discusses the contribution to the existing research and available literature and evaluates the appropriateness and limitations of the applied methodology.

9.2.1. Contribution to scientific understanding

There exist only few references that specifically analyse the potential and implications of combining retirement systems and sustainable energy supply. Moreover, there exists no detailed quantification of a countries' pension capital mobilization potential for energy investments in current literature. To address these existing scientific gaps, this thesis expands the scientific understanding of pension investments for infrastructure development as well as the literature on sustainable energy infrastructure financing. It provides an evaluation of required features and options for the design of potential SIP schemes and discusses positive and negative implications. These findings bear the potential to address typical risks and barriers of infrastructure investments described in the literature. Assuming fulfilled preconditions such as an appropriate investment environment and internal capability of the SIP institutions, the approach provides strong arguments for successfully resolving major investment risks such as portfolio concentration or government holdup. Concerning the barriers for ambitious and accelerated energy transitions, the thesis results' combine several literature findings on how to address distributional, financial, acceptance or justice challenges in a coherent and comprehensive manner.

Apart from the background analysis, qualitative and quantitative case study assessments deliver country-specific results and show the funding potential of SIP schemes in different contexts for the first time in literature. A comparative analysis finds that several of these case study results are applicable in similar countries. In combination with the theoretical assessment, the case study findings lead to general arguments about the effectiveness of the SIP scheme approach to address energy transition and pension reform challenges. Thus, with the scientific exploration of the SIP approach, this thesis formulates an innovative and alternative option for addressing the upcoming energy transition investment gap while sustaining capital-based pension schemes.

9.2.2. Applicability and limitations of methodology

Considering the adequacy of assessing the postulated hypotheses, the applied methodology as described in chapter 2.1 provides an appropriate framework to generate robust results. Conducting the background analysis through a detailed literature review produces a comprehensive overview of relevant barriers for infrastructure investments from pension schemes. It also provides a solid summary of applicable solutions for coping with the identified challenges and barriers. The analysis of best practice examples in chapter 4.2 creates the background for deriving required design features and optional choices for potential SIP approaches in chapter 4.4. A comprehensive analysis of SIP implications from both the perspective of the retirement system and the energy transition reveals a broad range of benefits but also negative impacts and challenges.

These theoretical results are successfully verified in the two case studies. The assessment of the status-quo and future needs and constraints of both the energy transition and the retirement scheme mainly confirms the theoretical findings but also adds some important elements such as the debt limitations for public energy investments or inadequacies of pension schemes in place. The simulated application of the SIP concept in concrete, country-specific environments allows to discuss different potential institutional set-ups and their implications in a more detailed manner. Most important, the simulation of mobilized pension saving capital until 2050 and its matching with the respective sustainable energy investment needs demonstrates the quantitative potential of the SIP approach. It emphasizes that the selected cash-flow simulation approach is useful for providing macroeconomic findings on the sustainability of pension schemes and total mobilization volume.

However, the methodology also shows some limitations. Regarding the scope of the cash-flow simulation, the spreadsheet model reflects a simplification of macro-economic developments. Consequently, economy-wide implications due to an implementation of the SIP scheme as well as feedback effects on the SIP scheme are not reflected in the model.

A simulation of different energy transition development pathways is outside the scope of the thesis. Therefore, only existing studies and assessments are considered to analyze the matching potential between mobilized SIP capital and energy transition investment needs.

Pension capital data availability in the German case is limited as the private operators do not disclose information transparently and the government reports only aggregated sub-information in different administrations without coherent consolidation. This poses some uncertainties on the quantitative results.

Institutions have internal procedures and policies that are often not published. More direct interaction with relevant stakeholders involved in existing best practice institutions could further improve the section on SIP design features.

Finally, the case studies show that only some elements of the SIP concept can be generalized while a comprehensive assessment of mobilization potential and positive as well as negative implications is only possible in the specific country-context. An application in further countries would likely also focus on additional impacts and strengthen the base for further generalization.

9.3. Further research recommendations

This thesis expands literature on the interrelations and beneficial correlation of capital-based pension schemes and energy transition investments, and it provides solid findings on SIP impacts. Future work should extend the scope of assessed and evaluated details. This section suggests further research activities that can help to increase the approaches' scientific understanding, practical likelihood of application, scope and that might maximize its positive results.

As described in chapter 1, the thesis reflects the situation prior to the COVID-19 pandemic, the cutoff date for data applied in the case studies was May 2019. The pandemics' influence on global fiscal and economic developments was tremendous. "Mobility restrictions, lockdowns, and other public health measures necessary to address the pandemic rapidly produced the largest global economic crisis in more than a century" (World Bank, 2022, p. 1). Countries reacted with emergency and recovery programmes leading to fiscal deficits and significant increases of public debt. This likely exacerbates the limitations of public budgets to finance energy infrastructure. Moreover, interrupted supply chains hindered economic production (see for instance World Bank, 2022, p. 35ff). Russia's invasion of Ukraine further disrupted economic activities and international trade, as a consequence "inflation has soared to multidecade highs" (IMF, 2022, p. 1). Those macro-economic effects have a direct impact on some of the assessed characteristics of a SIP scheme. For instance, high inflation rates on the one hand increase revenues from existing capital-pension systems, on the other hand customers might require higher rates of return. For the solid understanding of such a changed environment impacting the existing pension scheme landscape and a potential SIP approach, additional research is recommended. Hereby some of the thesis' findings on appropriate SIP design elements and required framework conditions might have to be adjusted. Finally, the impacts on energy security, supply, demand and related infrastructure resulting from the sanctions against Russia constitute a field of further required research. Particularly the energy transition development pathways, related investment needs and SIP impacts in the German case study context should be updated (compare IEA, 2022, p. 83ff).

Although Germany and the Seychelles cover two diverse geographical, socio-economic and cultural contexts, there are other country groups with deviating characteristics such as LDCs or emerging economies that can serve as interesting cases for further applications and assessments. There are some initial explorations of SIP potentials in India (compare Röben and Köhler, 2016), further research activities might cover additional countries.

As analysed in the chapters 3.2.4 and 4.4, energy transition assets inherit attractive investment conditions for institutional investors, but direct financing activities are rare. Reasons for this cautious behaviour are on the one hand the discussed requirement for economic incentives and an appropriate legal and regulatory framework. On the other hand, the pension management institutions need to resolve internal challenges for successfully ramping up investments. Besides the discussion of the processes of existing institutions in chapter 4.2 and general options for establishing suitable internal capabilities in chapter 4.5.2, additional research on options for such institutions to build sufficient expertise and robust procedures for successfully engaging in sustainable energy financing is recommended. An in-depth assessment of operational, legal and regulatory SIP design features with their high dependency on country specific laws and legal frameworks would further enhance the understanding of a precise SIP set-up. Research on the development of SIP-appropriate investment option pipelines through e.g. aggregation of assets could facilitate the operation of potential SIP schemes. Furthermore, the state's possible role in successfully supporting a reform of these internal procedures to unlock additional investments should be investigated in detail. These elements constitute interesting fields for further research.

Since two potential SIP options in the German context would provide more resources for direct energy transition investments than required according to the scenarios, a possible research question deals with additional elements that could be financed in a SIP context. This can for instance consider an expansion of the geographical and the technical scope. With regards to the first aspect, this research limited the scope to domestic investments only. This characteristic also led to several positive implications as described in chapter 4.3. However also investments outside the contributor's country are possible. In some contexts, activities in neighbor countries might bring additional benefits of cross-border engagement. Examples are for instance pan-European transmission systems connecting renewable power supply, storage and consumption (see e.g. Bökenkamp, 2014, p. 5ff). A SIP scheme from a developed country could also engage in sustainable energy infrastructure of developing countries. While the risks, particularly the one of government hold-up are expected to increase, co-benefits in a developing country such as improved electricity access or health benefits could be significantly higher as in the developed country thus potentially justifying an investment.

With regards to the SIP's technical scope, the term sustainable infrastructure in the context of this thesis is limited to activities of energy supply and consumption. But "sustainable infrastructure" can also include elements and sectors beyond energy. For instance, UK's Green Investment Bank interprets the term as applicable if the infrastructure contributes to the reduction of GHG emissions, an advancement of efficiency in the use of natural resources or the protection of natural environment or biodiversity (UK GIB, 2013, p. 2). Some institutions give also technology specific definitions such as renewable power generation, carbon capture and sequestration and energy smart technologies such as smart grids, inter-connectors, energy efficiency, storage and vehicles (OECD, 2015, p. 20) and go beyond mitigation technologies by including sustainable agriculture, floodplain levees or coastal protection (compare OECD, 2016c, p. 18). As different geographical and technological scopes inherit individual positive and negative implications, thorough research and further case studies are recommended to expand the SIP approach.

10. Bibliography

50Hertz GmbH, 2018. Finanzen und Investoren [WWW Document]. URL https://www.50hertz.com/de/50Hertz/Ueber-uns/Finanzen/Investoren (accessed 9.8.18).

aba, 2015. aba-Statistikreihe 2015. Arbeitsgemeinschaft betriebliche Altersvorsorge (aba).

Abdychev, A., Bari, M., Garnaud, B., Konuki, T., Samuel, W., Sanchez, L.A., Sienaert, A., Viseth, A., 2017. Enhancing Resilience to Climate and Natural Disasters in Seychelles. International Monetary Fund.

Action, D.I., 2017. CDP Climate Change Report 2017. CDP Worldwide gGmbH.

Agentur für Erneuerbare Energien, 2018. Bürgerenergie bleibt Schlüssel für erfolgreiche Energiewende - Agentur für Erneuerbare Energien [WWW Document]. URL https://www.unendlich-viel-energie.de/buergerenergie-bleibt-schluessel-fuer-erfolgreiche-energiewende (accessed 9.6.18).

Agora Energiewende, 2018. Energiewende 2030: The Big Picture.

Al-hassan, A., Papaioannou, M., Skancke, M., Sung, C.C., 2013. Sovereign Wealth Funds : Aspects of Governance Structures and Investment Management.

Albrecht, R., Grüttner, A., Lenk, T., Lück, O., Rottmann, O., 2013. Optionen moderner Bürgerbeteiligung bei Infrastrukturprojekten Ableitungen für eine verbesserte Beteiligung auf Basis von Erfahrungen und Einstellungen von Bürgern, Kommunen und Unternehmen 100.

Allianz, 2015. The illiquidity advantage of Infrastructure Debt. Allianz Global Investors GmbH, UK Branch.

Allianz Capital Partners, 2019. Investing in Renewables [WWW Document]. URL http://www.allianzcapitalpartners.com/our-business/renewables/

Amprion GmbH, 2018. Shareholders [WWW Document]. URL https://www.amprion.net/Amprion/Finance/Shareholders/ (accessed 9.8.18).

Andreas, E., Kabisch, S., Oppermann, B., Schetula, V., Carrera, D.G., Leggewie, C., Reisch, L., Schreurs, M., Großmann, K., Ohlhorst, D., Steuwer, S., 2015. Aspekte der Energiewende aus sozialwissenschaftlicher Perspektive, Schriftenreihe Energiesysteme der Zukunft. Deutsche Akademie der Technikwissenschaften e. V.

Andrews, E.S., 2006. Pension Reform and the Development of Pension Systems: An Evaluation of World Bank Assistance. World Bank, Washington, DC.

BaFin, 2018. Auslegungsentscheidungen - Infrastrukturinvestitionen – Behandlung von

Risiken im Rahmen des Grundsatzes der unternehmerischen Vorsicht [WWW Document]. Bundesanstalt für Finanzdienstleistungsaufsicht. URL https://www.bafin.de/SharedDocs/Veroeffentlichungen/DE/Auslegungsentscheidung/VA/ae_180328_ppp_infrastrukturinvestitionen_va.html;jsessionid=586C154745ED7A340FA787FDCC190A84.1_cid298 (accessed 9.6.18).

Becker, S., Naumann, M., 2016. Energiekonflikte nutzen. Wie die Energiewende vor Ort gelingen kann. Leibniz-Institut für Raumbezogene Sozialforschung, ZukunftsAgentur Brandenburg, Europasekretariat Local Governments for Sustainability.

Beltran, M., Wilkins, M., Fudji, T., 2017. New Capital Rules For EU Infrastructure Investments Mask Pipeline Deficiency. S&P Global.

Berlin Energy Transition Dialogue, 2016. Press Fact Sheet: The German Energy Transition. pp. 1–16.

Bertram, R., Primova, R., 2018. Energieatlas 2018 - Daten und Fakten über die Erneuerbaren in Europa. Heinrich-Böll-Stiftung.

Bickel, P., Kelm, T., 2021. Assessment of environmental and social impacts of the KfW loan programme " Renewable Energies – Standard " for the years 2019 and 2020 (Summary Results). Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg.

Birdsall, N., Nellis, J., 2003. Winners and losers: Assessing the distributional impact of privatization. World Development 31, 1617–1633. doi:10.1016/S0305-750X(03)00141-4

BIS, 2017. Basle Committee on Banking Supervision Basel III: Finalising post-crisis reforms. Bank for International Settlements. doi:10.1159/000365926

Bitsch, F., 2012. Infrastructure Funds - Their Role in Financing Infrastructure Investments. Technischen Universität München.

Blazejczak, V.J., Diekmann, J., Edler, D., Kemfert, C., Neuhoff, K., Schill, W., 2013. Energiewende erfordert hohe Investitionen. DIW Wochenbericht, No. 26 784–792.

Bloom, D.E., McKinnon, R., 2013. The Design and Implementation of Public Pension Systems in Developing Countries : Issues and Options. Institute for the Study of Labor.

BMAS, 2017a. Sozialbudget 2017. Bundesministerium für Arbeit und Soziales.

BMAS, 2017b. Sozialbericht 2017. Bundesministerium für Arbeit und Soziales.

BMAS, 2016. Ergänzender Bericht der Bundesregierung zum Rentenversicherungsbericht 2016. Bundesministerium für Arbeit uns Soziales.

BMF, 2018a. Entwicklung der Riester-Verträge. Bundesministerium der Finanzen.

BMF, 2018b. Statistik zur Riesterförderung. Bundesministerium der Finanzen.

BMJ, 2022. Gesetz zu Sofortmaßnahmen für einen beschleunigten Ausbau der erneuerbaren Energien und weiteren Maßnahmen im Stromsektor. Bundesministerium der Justiz.

BMJ, 2020. Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung und zur Änderung weiterer Gesetze (Kohleausstiegsgesetz). Bundesministerium der Justiz.

BMU, 2021. Bundes-Klimaschutzgesetz 2021. Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit.

BMUB, 2016. Klimaschutzplan 2050 – Klimaschutzpolitische Grundsätze und Ziele der Bundesregierung. Bundesministerium für Umwelt, Bau und Reaktorsicherheit.

BMUB, 2014. Aktionsprogramm Klimaschutz 2020 | Kabinettsbeschluss vom 3. Dezember 2014. Bundesministerium für Umwelt, Bau und Reaktorsicherheit.

BMWi, 2018. Die Energie der Zukunft: Sechster Monitoring-Bericht zur Energiewende. Bundesministerium für Wirtschaft und Energie.

BMWi, 2017. Ergebnispapier Strom 2030. Bundesministerium für Wirtschaft und Energie.

BMWi, 2015. Vierter Monitoring-Bericht zur Energiewende. Bundesministerium für Wirtschaft und Energie.

BMWK, 2022a. Erneuerbare Energien in Zahlen. Bundesministerium für Wirtschaft und Klimaschutz. doi:10.5771/9783845237343-121

BMWK, 2022b. IPCEI Wasserstoff: Gemeinsam einen Europäischen Wasserstoffmarkt schaffen [WWW Document]. Bundesministerium für Wirtschaft und Klimaschutz. URL https://www.bmwk.de/Redaktion/DE/Artikel/Energie/ipcei-wasserstoff.html (accessed 7.12.22).

Bodewig, K., 2013. Konzeptdokument Kommission "Nachhaltige Verkehrsinfrastrukturfinanzierung."

Bökenkamp, G., 2014. The Role of Nowergian Hydro Storage in Future Renewable Electricity Supply Systems in Germany: Analysis with a Simulation Model. Europa Universität Flensburg.

Bonin, H., 2009. 15 Years of Pension Reform in Germany: Old Successes and New Threats. The Geneva Papers 34, 548–560. doi:10.1057/gpp.2009.20

Bönke, T., Harnack, A., 2017. Ein Staatsfonds für Deutschland ? Grundüberlegungen und internationale Vorbilder. Bertelsmann Stiftung.

Börsch-Supan, A., Bucher-Koenen, T., Goll, N., Maier, C., 2016. 15 Jahre Riester – eine Bilanz, Munich Center for the Economics of Aging (MEA), Max-Planck-Institut für Sozialrecht und Sozialpoitik. Munich Center for the Economics of Aging, Max-Planck-Institut für Sozialrecht und Sozialpoitik.

Bowman, A., 2015. An illusion of success : The consequences of British rail privatisation. Accounting Forum 39, 51–63. doi:10.1016/j.accfor.2014.10.001

Bridge, G., Özkaynak, B., Turhan, E., 2018. Energy infrastructure and the fate of the nation: Introduction to special issue. Energy Research and Social Science 41, 1–11. doi:10.1016/j.erss.2018.04.029

Brycz, B., Pauka, M., 2012. Analysis of Cash Flow Statement. Financial Sciences - Wrocław University of Economics.

Buchner, B., Carswell, C., Meattle, C., Padraig, O., Wang, X., Wuester, H., Strinati, C., 2018. Global Landscape Of Renewable Energy Finance. International Renewable Energy Agency, Abu Dhabi.

Buchner, B., Falconer, A., Hervé-Mignucci, M., Trabacchi, C., 2013. The Global Landscape of Climate Finance 2013. Climate Policy Initiative.

Buchner, B.K., Oliver, P., Wang, X., Carswell, C., Meattle, C., Mazza, F., Bird, N., Bonnel, A., Cronenberg, C., Elizondo, U., Ellis, J., Gjonaj, M., Haider, J., Javier, E.P., Jung, M., Kleiterp, N., Sedemund, J., Thwaites, J., Wabbels, S., 2017. Global Landscape of Climate Finance 2017. Climate Policy Initiative.

Bundeskabinett, 2018. Regierungsentwurf des Bundeshaushalts 2019.

Bundesnetzagentur, 2022a. Beendete Ausschreibungen für Solaranlagen Freifläche [WWW Document]. URL https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/Ausschreibungen/Solaranlagen1/BeendeteAusschreibungen/start.html (accessed 12.12.22).

Bundesnetzagentur, 2022b. Beendete Ausschreibungen Windenergieanlagen an Land [WWW Document]. URL https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/Ausschreibungen/Wind_Onshore/BeendeteAusschreibungen/start.html (accessed 12.12.22).

Bundesnetzagentur, 2016. Bundesnetzagentur legt Eigenkapitalrenditen für Strom- und Gasnetze fest [WWW Document]. URL https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2016/161012_EKZ.html (accessed 11.7.18).

Bundock, B., Holyoake, D., Hill, K., 2011. Towards the Green Investment Bank Act.

ClientEarth.

Carrington, D., 2012. How a green investment bank really works [WWW Document]. The Guardian. URL https://www.theguardian.com/environment/damian-carrington-blog/2012/may/24/green-investment-bank-energy-efficiency

CDU-CSU-SPD, 2018. Ein neuer Aufbruch für Europa - Eine neue Dynamik für Deutschland - Ein neuer Zusammenhalt für unser Land: Koalitionsvertrag zwischen CDU, CSU und SPD. Deutscher Bundestag.

Chand, S.K., Jaeger, A., 1996. Aging populations and public pension schemes, IMF Occasional Papers. International Monetary Fund.

Cichon, M., Latulippe, D., 1998. Maintaining Prosperity In An Ageing Society: the OECD study on the policy implications of ageing. Ageing Working Papers 34.

Climate Bonds Initiative, 2019. About us | Climate Bonds Initiative [WWW Document]. URL https://www.climatebonds.net/about

Corbell, S., Kim, Y., Dwyer, S., Teske, S., Kelly, S., 2018. Supercharging Australia's Clean Energy Transition. Insitute for Sustainable Futures, 350.org.

Corfee-Morlot, J., Kennedy, C., 2012. Mobilising Private Investment in Low Carbon , Resilient Infrastructure. Organisation for Economic Cooperation and Development.

Corneo, G., Schröder, C., König, J., 2015. Distributional Effects of Subsidizing Retirement Savings Accounts : Evidence from Germany. School of Business & Economics: Discussion Paper.

Cummine, A., 2014. How Temasek has driven Singapore's development. East Asia Forum Quarterly 6, 44. doi:10.1080/02692179700000032

Daehre, K.-H., 2012. Zukunft der Verkehrsinfrastrukturfinanzierung. Kommission „Zukunft der Verkehrsinfrastrukturfinanzierung".

Dähn, A., 2018. Dreifachvorsorge. neue energie 02/2018, 38–42.

Della Croce, R., Kaminker, C., Stewart, F., 2011. The Role of Pension Funds in Financing Green Growth Initiatives, OECD Working Paper on Insurance and Private Pensions. Organisation for Economic Cooperation and Development, Paris.

Della Croce, R., Paula, J., Laboul, A., 2015. Infrastructure Financing Instruments and Incentives. Organisation for Economic Cooperation and Development, Paris.

Della Croce, R., Yermo, J., 2013. Institutional investors and infrastructure financing. OECD Working Papers on Finance, Insurance and private pensions 1–35. doi:10.1787/5k3wh99xgc33-en dena, 2012. Ausbau- und Innovationsbedarf der Stromverteilnetze in Deutschland bis 2030. Deutsche Energie-Agentur.

DESTATIS, 2018. Erwerbstätigkeit - Arbeitsmarkt - Statistisches Bundesamt (Destatis) [WWW Document]. URL https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/Arbeitsmarkt/Erwerbstaetigkeit/TabellenErwerbstaetigenrechnung/BevoelkerungErwerbstaetigkeit.html

Deutsche Rentenversicherung, 2022. Rentenatlas 2022.

Deutsche Rentenversicherung, 2018. Wann Sie in die Rente gehen können [WWW Document]. URL https://www.deutsche-rentenversicherung.de/Allgemein/de/Inhalt/1_Lebenslagen/05_Kurz_vor_und_in_der_Rente/01_Kurz_vor_der_Rente/03_wann_sie_in_rente_gehen_koennen.html (accessed 11.7.18).

Di Nucci, M.R., Brunnengraber, A., 2017. In Whose Backyard ? The Wicked Problem of Siting Nuclear Waste Repositories. European Policy Analysis 3, 295–323. doi:10.1002/epa2.1028

Dichtl, J., 2018. Finanzwirtschaft, nachhaltige Entwicklung und die Energiewende. Springer Gabler.

E.ON SE, 2018. Shareholder structure - E.ON SE [WWW Document]. URL https://www.eon.com/en/investor-relations/stock/shareholders-structure.html (accessed 9.8.18).

EC, 2018. Commission legislative proposals on sustainable finance | European Commission [WWW Document]. European Commission. URL https://ec.europa.eu/info/publications/180524-proposal-sustainable-finance_en

EC, 2013. Ownerhip Unbundling - The Commission's practice in assessing the presence of a conflict of interest including in case of financial investors. EU Commission.

EC, 2009. Pension Schemes and Pensions Projections un the EU-27 Member States 2008-2060, European Economy Occasional Paper. European Commission. doi:10.2765/54270

EIOPA, 2018. Solvency II [WWW Document]. European Insurance and Occupational Pensions Authority. URL https://eiopa.europa.eu/regulation-supervision/insurance/solvency-ii

ESMAP, 2018. Regulatory Indicators for Sustainable Energy. International Bank for Reconstruction and Development / The World Bank, Washington, DC.

Etikkradet, 2018. Council on Ethics - Annual Report 2017. Council on Ethics for the Norwegian Government Pension Fund Global.

European Parliament, 2018. Foreign investment to be screened to protect EU countries' strategic interests [WWW Document]. URL http://www.europarl.europa.eu/news/sv/press-room/20180528IPR04446/foreign-investment-to-be-screened-to-protect-eu-countries-strategic-interests (accessed 11.5.18).

Evensen, D., Demski, C., Becker, S., Pidgeon, N., 2018. The relationship between justice and acceptance of energy transition costs in the UK. Applied Energy Volume 222, 451–459.

EY, 2014. Renewable energy assets. Ernst & Young Global Limited.

Fischer, A., Nullmeier, F., Rulff, D., Schroeder, W., Sellin, P., Wiesenthal, H., 2013. Sicherheit und Fairness in der alternden Gesellschaft. Heinrich-Böll-Stiftung.

Fischer, F., Siepe, W., 2016. Zusatzversorgungskassen unter Handlungsdruck.

Fischer, F., Siepe, W., 2015. Zahlen , Daten und Fakten zur Zusatzversorgung.

Fixsen, R., 2018. Norway's SWF: no to private equity, yes to green infrastructure [WWW Document]. International Publishers Limited. URL https://www.ipe.com/countries/norway/norways-swf-no-to-private-equity-yes-to-green-infrastructure/www.ipe.com/countries/norway/norways-swf-no-to-private-equity-yes-to-green-infrastructure/10024092.fullarticle (accessed 11.2.18).

Flämig, D., 2016. Weiter Denken: von der Energiewende zur Nachhaltigkeitsgesellschaft. Springer AG. doi:10.1007/978-3-662-49939-9

Fratzscher, M., 2015a. Bericht der Expertenkommission "Stärkung von Investitionen in Deutschland."

Fratzscher, M., 2015b. Increasing Investment in Germany. Expert Commission's Report on Increasing Investment in Germany.

Fulton, M., Capalino, R., 2014. Investing in the Clean Trillion: Closing the Clean Energy Investment Gap. Ceres / Energy Transition Advisors.

GCF, 2014. Investment Framework GCF/B.07/06. Green Climate Fund.

GDV, 2018a. Berücksichtigung von Nachhaltigkeit in der Kapitalanlage. Gesamtverband der Deutschen Versicherungswirtschaft e.V.

GDV, 2018b. Die deutsche Lebensversicherung in Zahlen. Gesamtverband der Deutschen Versicherungswirtschaft.

Gennaioli, C., Tavoni, M., 2016. Clean or dirty energy: evidence of corruption in the renewable energy sector. Public Choice 166, 261–290. doi:10.1007/s11127-016-0322-y

Gerbert, P., Herhold, P., Burchardt, J., Schönberger, S., Rechenmacher, F., Kirchner, A., Kemmler, A., Wünsch, M., 2018. Klimapfade für Deutschland. The Boston Consulting Group, Prognos AG.

Gerhardt, N., Sandau, F., Zimmermann, B., Pape, C., Bofinger, S., Hoffmann, C., 2014. Geschäftsmodell Energiewende. Fraunhofer IWES, Bremerhaven.

Government of the Seychelles, 2017. Debt Management Strategy for the years 2018 - 2020.

Graichen, P., Kleiner, M.M., 2017. Erneuerbare vs. fossile Stromsysteme : ein - Kostenvergleich. Agora Energiewende.

Grasso, C., 2017. The Dark Side of Power : Corruption and Bribery within the Energy Sector, in: Research Handbook on EU Energy Law and Policy. Edward Elgar, pp. 237–256.

Hagen, K., Kleinlein, A., Geyer, J., Wagner, G.G., 2011. Riester-Rente: Grundlegende Reform dringend geboten. DIW Wochenbericht 47.

Hall, S., Roelich, K.E., Davis, M.E., Holstenkamp, L., 2018. Finance and justice in low-carbon energy transitions. Applied Energy 222, 772–780. doi:10.1016/j.apenergy.2018.04.007

Harrabin, R., 2011. PM's pledge of greenest government "vanishingly remote" [WWW Document]. BBC News. URL https://www.bbc.com/news/science-environment-13312901

Heien, T., Heckmann, J., 2016. Alterssicherung in Deutschland 2015. TNS Infratest Soziaforschung, München.

Henning, H.-M., Palzer, A., 2015. Was kostet die Energiewende? Fraunhofer ISE, Freiburg.

Henning, H.-M., Palzer, A., 2013. Energiesystem Deutschland 2050. Fraunhofer ISE, Freiburg.

Hirschhausen, Christian von; Beckers, Thorsten; Mitusch, K., 2004. Trends in infrastructure regulation and financing: international experience and case studies from Germany. Edwar Elgar Publishing Limited.

Hirth, L., Steckel, J.C., 2016. The role of capital costs in decarbonizing the electricity sector Balancing Green Power. Environmental Research Letters.

Hohmeyer, O., 2017. Economic Analysis to Facilitate the Establishment of a Stable Price for Electricity from Renewable Sources. Global Sustainable Energy Consultants Ltd. (GSEC) Barbados.

Hohmeyer, O., 2016. A 100 % renewable Seychelles - Report 1: Mahé, ZNES Discussion Papers. Center for Sustainable Energy Systems (CSES).

Holmes, I., 2013. Green Investment Bank: The History [WWW Document]. E3G. URL https://www.e3g.org/library/green-investment-bank-the-history

Holzmann, R., 2012. Global Pension Systems and Their Reform: Worldwide Drivers, Trends, and Challenges. Institute for the Study of Labor.

IEA/IRENA, 2017. Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System. International Energy Agency, International Renewable Energy Agency.

IEA, 2022. World Energy Outlook 2022. International Energy Agency.

IEA, 2017a. Energy Access Outlook 2017. International Energy Agency.

IEA, 2017b. World Energy Investment 2017. International Energy Agency, Paris. doi:10.1787/9789264277854-en

IEA, 2012. Energy Technology Perspectives 2012 Pathways to a Clean Energy System. International Energy Agency, Paris. doi:10.1787/energy_tech-2012-en

ILO, 2017. World Social Protection Report 2017-19. International Labour Organization.

ILO, 2014. Social protection for older persons : Key policy trends and statistics. International Labour Organization.

IMF, 2022. World Economic Outlook: Countering the Cost-of-Living Crisis. International Monetary Fund, Washington, DC.

IMF, 2018. World Economic Outlook - General government gross debt [WWW Document]. International Monetary Fund. URL https://www.imf.org/external/datamapper/GGXWDG_NGDP@WEO/OEMDC/ADVEC/WEOWORLD

IMF, 2017. IMF Country Report Seychelles. International Monetary Fund, Washington, DC.

Inderst, G., 2010. Infrastructure as an asset class. EIB Papers 15, 70–105. doi:10.1002/9781119205852

Inderst, G., Della Croce, R., 2013. Pension Fund Investment in Infrastructure. A Comparison Between Australia and Canada. OECD Working Papers on Finance, Insurance and private pensions.

IPCC, 2014. Climate Change 2014: Mitigation of Climate Change, Working Group III

Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change. doi:10.1017/CBO9781107415416

IPE Research, 2018. Top 100 Infrastructure Investors [WWW Document]. International Publishers Limited. URL https://realassets.ipe.com/top-100-and-surveys/top-100-infrastructure-investors/realassets.ipe.com/top-100-and-surveys/top-100-infrastructure-investors/10026765.fullarticle

IRENA, 2022. Renewable Power Generation Costs in 2021. International Renewable Energy Agency, Abu Dhabi.

IRENA, 2018. Global Energy Transformation: A roadmap to 2050. International Renewable Energy Agency, Abu Dhabi.

IRENA, 2016. Unlocking Renewable Energy Investment: The Role of Risk Mitigation and Structured Finance. International Renewable Energy Agency, Abu Dhabi.

ISIF, 2019. History of the Ireland Strategic Investment Fund [WWW Document]. Ireland Strategic Investment Fund. URL https://isif.ie/about-us/history (accessed 1.8.19).

Joachim Nitsch, Thomas Pregger, Scholz, Y., Naegler, T., Sterner, M., Gerhardt, N., Oehsen, A. Von, Pape, C., Saint-Drenan, Y.-M., Wenzel, B., 2012. Langfristszenarien und Strategien für den Ausbau der Erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. Schlussbericht BMU - FKZ 03MAP146, Bmu - Fkz 03Map146. Bundesministerium für Umwelt, Bau und Reaktorsicherheit.

Juretzek, D.S., 2018. Allianz Group Sustainability Report 2017. Allianz SE.

Kemfert, C., Schäfer, D., 2012. Energiewende braucht private Investoren. Deutsches Institut für Wirtschaftsforschung, Berlin.

Kessides, I.N., 2005. Infrastructure privatization and regulation: Promises and perils. World Bank Research Observer 20, 81–108. doi:10.1093/wbro/lki003

Kleine, P.D.J., Krautbauer, M., 2012. Infrastrukturinvestments in Europa. Steinbeis Research Center for Financial Services.

Kleinlein, A., 2011. Zehn Jahre "Riester-Rente" - Bestandsaufnahme und Effizienzanalyse. Friedrich Ebert Stiftung.

Köhler, M., 2020. Exploring the Potential of the Seychelles Pension Fund to Finance the Renewable Energy Transition. Seychelles Research Journal 2, 62–82.

Kollewe, J., 2018. Green Investment Bank sell-off described as a disaster by critics [WWW Document]. The Guardain. URL https://www.theguardian.com/environment/2017/apr/20/green-investment-bank-sell-off-dubbed-a-disaster-by-critics

Kunert, U., Link, H., 2013. Verkehrsinfrastruktur: Substanzerhaltung erfordert deutlich höhere Investitionen. DIW Wochenbericht 26, 32–39.

Laboul, A., Dell Croce, R., 2014. Private Financing and Government Support To Promote LTI in Infrastructure. Organisation for Economic Cooperation and Development, Paris.

Laes, E., Gorissen, L., Nevens, F., 2014. A comparison of energy transition governance in Germany, The Netherlands and the United Kingdom. Sustainability (Switzerland) 6, 1129–1152. doi:10.3390/su6031129

Lenk, Thomas; Rottmann, O., Grüttner, A., Albrecht, R., 2014. Finanzielle Bürgerbeteiligung. Bertelsmann Stiftung.

Liesch, T., Lütkehermöller, K., Tewari, R., Höhne, N., Haase, I., Nascimento, L., Burck, J., Marten, F., Grasi, C., 2018. Allianz Climate and Energy Monitor 2018. Allianz SE.

Liesch, T., Ruiz-Vergote, S., Tewari, R., Höhne, N., Moisio, M., Burck, J., Uhlich, T., Freundt, M., Riechers, K., 2017. Allianz Climate and Energy Monitor 2017: Assessing the needs and attractiveness of low-carbon investments in G20 countries. Allianz SE.

Ma, T., 2016. Basel III and the Future of Project Finance Funding. Michigan Business & Entrepreneurial Law Review 6.

Martimort, D., Straub, S., 2007. Infrastructure privatization and changes in corruption patterns: The roots of public discontent. Journal of Development Economics 90, 69–84. doi:10.1016/j.jdeveco.2008.08.002

Max Neef, M.A., 1992. Human Scale Development. Conception, application and further reflections. Zed Books Ltd.

Mazzucato, M., Semieniuk, G., 2018. Financing renewable energy: Who is financing what and why it matters. Technological Forecasting and Social Change 127, 8–22. doi:10.1016/j.techfore.2017.05.021

Messinger-Zimmer, S., Zilles, J., 2016. (De-)zentrale Energiewende und soziale Konflikte : Regionale Konflikte um die Vertretung des Gemeinwohls. Deutsches Institut für Wirtschaftsforschung, Berlin.

Mönch, M., 2015. Performance und Asset Allocation von Pensionskassen in Deutschland. Absolut Research GmbH.

Mooren, R., Hardy, D., Cutts, M., Learmouth, B., 2017. Third Global Infrastructure Investment Index 2016 - Bridging the investment gap. Arcadis.

Nahem, J., Lindvag, D., 2018. Executive summary - Risks and Responsibility in Unlisted Infrastructure Investments. Government Pension Fund Global.

National Bureau of Statistics Seychelles, 2018. Statistical Bulletin - Population and Vital Statistics 2017.

Nelson, D., Pierpont, B., 2013. The Challenge of Institutional Investment in Renewable Energy. Climate Policy Initiative.

Norges Bank, 2018. Government Pension Fund Global [WWW Document]. URL https://www.nbim.no/en/the-fund/

Norwegian Ministry of Finance, 2017. The Management of the Government Pension Fund in 2016.

OECD, 2019. Exchange rates [WWW Document]. Organisation for Economic Cooperation and Development. URL https://data.oecd.org/conversion/exchange-rates.htm

OECD, 2018. Survey of Large Pension Funds and Public Pension Reserve Funds. Organisation for Economic Cooperation and Development, Paris.

OECD, 2017a. Investing in Climate, Investing in Growth. Organisation for Economic Cooperation and Development, Paris.

OECD, 2017b. Pensions at a Glance 2017: OECD and G20 Indicators. Organisation for Economic Cooperation and Development, Paris.

OECD, 2017c. Pension Markets in Focus. Organisation for Economic Cooperation and Development, Paris.

OECD, 2016a. Business and Finance Outlook 2016. Organisation for Economic Cooperation and Development, Paris.

OECD, 2016b. OECD Pensions Outlook 2016. Organisation for Economic Cooperation and Development, Paris.

OECD, 2016c. Green Investment Banks: Scaling up Private Investment in Low-carbon, Climate-resilient Infrastructure, Green Finance and Investment. Organisation for Economic Cooperation and Development, Paris. doi:10.1787/9789264245129-en

OECD, 2015. Mapping Channels to Mobilise Institutional Investment in Sustainable Energy. OECD report to G20 finance ministers and central bank governors. Green Finance and Investment series 1–142. doi:10.1787/9789264224582-en

OECD, 2013a. Annual Survey of Large Pension Funds and Public Pension Reserve Funds: Report on pension funds' long-term investments. Organisation for Economic Cooperation and Development, Paris.

OECD, 2013b. Recent pension reforms and their distributional impact. Organisation for Economic Cooperation and Development, Paris.

OECD, 2008. Pension Country Profile : Germany. Organisation for Economic Cooperation and Development, Paris.

Ohri, O., Horster, M., Dreher, C., Jochum, C., Lutz, V., Jorisch, D., Stadelmann, M., 2016. Klimafreundliche Investitionsstrategien und Performance. Center for Social and Sustainable Products AG, South Pole Carbon Asset Management Ltd.

Pallares-Miralles, M., Romero, C., Whitehouse, E., 2012. International Patterns of Pension Provision II: A Worldwide Overview of Facts and Figures, Social Protection & Labor Discussion Paper. World Bank.

Park, D., Estrada, G., 2013. Emerging Asia's public pension systems: Challenges and reform efforts. International Monetary Fund.

Parkes, M., Chavers, K., Synnott, A., Pilibossian, A., 2015. Infrastructure investment: Bridging the gap between public and investor needs. BlackRock Inc.

Pötzsch, O., Rößger, F., 2015. Bevölkerung Deutschlands bis 2060. Statistisches Bundesamt, Wiesbaden.

Pratley, N., 2018. Green Investment Bank: why did ministers dodge the real problem? [WWW Document]. The Guardian. URL https://www.theguardian.com/environment/nils-pratley-on-finance/2018/mar/14/green-investment-bank-why-did-ministers-dodge-the-real-problem

PwC, 2017. Global infrastructure investment. PricewaterhouseCoopers LLP.

Radtke, J., 2016. Energiewende in der Verflechtungsfalle : Chancen und Grenzen von Partizipation und bürgerschaftlichem Engagement in der Energiewende. Deutsches Institut für Wirtschaftsforschung, Berlin.

Ram, M., Bogdanov, D., Aghahosseini, A., Oyewo, S., Gulagi, A., Child, M., Fell, H.-J., Breyer, C., 2017. Global Energy System based on 100% Renewable Energy. Lappeenranta University of Technology and Energy Watch Group.

REN21, 2014. Renewables 2014 Global Status Report. REN21 Secretariat, Paris.

Republic of Seychelles, 2015. Intended National Determined Contribution (INDC).

Reuters, 2017. One Planet summit turns to private sector for climate action [WWW Document]. URL https://www.reuters.com/article/us-climatechange-summit-pledges-factbox/factbox-one-planet-summit-turns-to-private-sector-for-climate-action-idUSKBN1E61VB (accessed 1.12.19).

Röben, F., Köhler, M., 2016. India´s pathway to 100 % renewable power generation - Exploring capacity mix, costs and innovative financing tools. the greenwerk. GbR.

Ruthner, L., Johnson, M., Chatterjee, B., Lazarus, M., Fujiwara, N., Egenhofer, C., du Monceau, T., Brohe, A., 2011. Study on the Integrity of the Clean Development Mechanism. Carbon Market Watch.

RWE AG, 2018. Shareholder structure RWE AG [WWW Document]. URL https://www.group.rwe/en/investor-relations/the-rwe-share/shareholder-structure (accessed 9.8.18).

Saha, D., Nair, T., Ho Hong, S., 2018. Private Participation in Infrastructure. World Bank.

Sanzillo, T., Chung, Y., Buckley, T., 2017. Making the Case for Norwegian Sovereign Wealth Fund Investment in Renewable Energy Infrastructure. Institute for Energy Economics and Financial Analysis.

Sawant, R.J., 2010. Infrastructure Investing: managing risks & rewards for pensions, insurance companies & endowmendts. John Wiley & Sons, Inc.

SCF, 2016. UNFCCC Standing Committee on Finance. UNFCCC Secretariat.

Schnelle, K., Voigt, M., 2012. Energiewende und Bürgerbeteiligung: Öffentliche Akzeptanz von Infrastrukturprojekten am Beispiel der, Thüringer Strombrücke. Germanwatch e.V., DAKT, Heinrich-Böll-Stiftung Thüringen e.V.

Schreiner, P., 2018. Von der Teilprivatisierung der Rente zu Öffentlich-Privaten Partnerschaften [WWW Document]. Lunapark 21. URL https://www.lunapark21.net/von-der-teilprivatisierung-der-rente-zu-oeffentlich-privaten-partnerschaften/ (accessed 9.6.18).

Schwarz, A.M., 2006. Pension System Reforms, Social Protection Discussion Papers and Notes. World Bank.

Seychelles Energy Commission, 2017. Seychelles energy report 2015.

Seychelles Energy Commission, 2016. Integrated Energy Study for the Seychelles 2015-2035 - Volume 2.

Sharma, R., 2015. Sovereign Wealth Funds Investments in Sustainable Development Sectors.

Singer, S., Denruyter, J.-P., Jeffries, B., Deng, Y., Cornelissen, S., Klaus, S., 2011. The Energy Report - 100% Renewable Energy by 2050. World Wide Fund for Nature.

SPF, 2018. SPF Annual Report 2017. Seychelles Pension Fund.

SPF, 2017. SPF Investment Policy. Seychelles Pension Fund.

Statista, 2019. OPEC oil prices 1960-2018 [WWW Document]. Statista GmbH. URL https://www.statista.com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/

Statista, 2018a. Garantiezins: Entwicklung bei Lebensversicherungen bis 2017 | Statista [WWW Document]. Statista GmbH. URL https://de.statista.com/statistik/daten/studie/167936/umfrage/garantiezins-der-lebensversicherer-fuer-neuvertraege/ (accessed 9.6.18).

Statista, 2018b. Bruttolohn/ Bruttogehalt im Monat je Arbeitnehmer in Deutschland [WWW Document]. Statista GmbH. URL https://de.statista.com/statistik/daten/studie/161355/umfrage/monatliche-bruttoloehne-und-bruttogehaelter-pro-kopf-in-deutschland/

SWFI, 2018. Sovereign Wealth Fund Rankings [WWW Document]. Sovereign Wealth Fund Institute. URL https://www.swfinstitute.org/sovereign-wealth-fund-rankings/

Szado, E., 2014. Investing in Infrastructure. University of Massachusetts, Amherst.

Tapia, W., 2008. Description of Private Pension Systems, OECD Working Paper on Insurance and Private Pensions. Organisation for Economic Cooperation and Development, Paris. doi:10.1787/237831300433

Technischer Fachverlag, 2022. Wind- und Bioausschreibungen grandios unterzeichnet [WWW Document]. URL https://www.erneuerbareenergien.de/technologie/onshore-wind/wind-und-bioausschreibungen-grandios-unterzeichnet (accessed 5.12.22).

Temasek Holding, 2018. Temasek overview 2018.

Teske, S., Giurco, D., Morris, T., Nagrath, K., Mey, F., Briggs, C., Dominisch, E., Florin, N., Watari, T., Mclellan, B., Pregger, T., Naegler, T., Simon, S., Pagenkopf, J., van den Adel, B., Deniz, Ö., Schmid, S., Meinshausen, M., Dooley, K., 2019. Achieving the Paris Climate Agreement Goals - Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG. Springer AG.

The Climate Bonds Initiative, 2015. Climate Bond Standard. doi:10.1038/nature08017.

The White House, 2018. Order Signed by the President regarding the Acquisition of Four U.S. Wind Farm Project Companies by Ralls Corporation [WWW Document]. URL https://obamawhitehouse.archives.gov/the-press-office/2012/09/28/order-signed-president-regarding-acquisition-four-us-wind-farm-project-c (accessed 11.5.18).

Transparency International, 2019. Corruption Perceptions Index 2018 [WWW Document]. URL https://www.transparency.org/cpi2018 trend:research, 2018. Eigentümerstruktur: Erneuerbare Energien. trend:research GmbH.

Ueli, M., 2004. Projecting pension fund cash flows. Zuercher Kantonalbank, Zürich.

UK GIB, 2017. Annual Report and Financial Statements 2016-2017. UK Green Investment Bank.

UK GIB, 2016. Green Investment Policy. UK Green Investment Bank.

UK GIB, 2013. Our Green Investment Principles. UK Green Investment Bank.

UK NAO, 2017. The Green Investment Bank. UK National Audit Office.

UN, 2019. List of SIDS - Sustainable Development Knowledge Platform [WWW Document]. United Nations. URL https://sustainabledevelopment.un.org/topics/sids/list

UN, 2018. The Sustainable Development Goals Report 2018. United Nations.

UN, 2015. Paris Agreement. United Nations.

UN, 2010. Report of the Secretary-General's High-level Advisory Group on Climate Change Financing. United Nations.

UN, 1992. United Nations Framework Convention on Climate Change. United Nations.

Underhill, M.D., 2010. The Handbook of Infrastructure Investing. John Wiley & Sons, Inc.

Varadarajan, U., Huxham, M., O 'connell, B., Nelson, D., Posner, D., Pierpont, B., 2017. Mobilising low-cost institutional investment in renewable energy. Climate Policy Initiative.

VOEB, 2016. Infrastrukturoffensive für Deutschland – jetzt! Bundesverband Öffentlicher Banken Deutschlands.

Wagstaff, C., Farrand, L., 2016. Intelligent Thinking: What constitutes a First Class Pension System? Threadneedle Investments, Columbia.

WBGU, 2016. Entwicklung und Gerechtigkeit durch Transformation. Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen.

WBGU, 2012. Finanzierung der globalen Energiewende. Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen.

Wehner, S., Dransfeld, B., Köhler, M., 2020. A Strategic Approach towards 100% Renewable Energy in the Seychelles. Seychelles Research Journal 2.

Wehner, S., Hohmeyer, O., Dransfeld, B., Köhler, M., Callsen, S., Nettersheim, C., 2017.

Achieving 100 % Renewable Energies for Small Island Developing States. the greenwerk. GbR.

Wehner, S., Köhler, M., Dransfeld, B., Nettersheim, C., 2018. Pre-Feasibility Study SeyRES100. the greenwerk. GbR.

Woetzel, J., Garemo, N., Mischke, J., Hjerpe, M., Palter, R., 2016. Bridging global infrastructure gaps. McKinsey Global Institute.

World Bank, 2022. World Development Report 2022: Finance for an equitable recovery. The World Bank Group, Washington, DC. doi:10.1596/978-1-4648-1730-4.

World Bank, 2019a. Doing Business 2019 - Training for Reform, World Bank. International Bank for Reconstruction and Development / The World Bank, Washington, DC.

World Bank, 2019b. Ease of Doing Business Score 2018 [WWW Document]. URL http://www.doingbusiness.org/en/rankings (accessed 5.3.19).

World Bank, 2018a. GDP (current US$) 2017 [WWW Document]. URL https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?year_high_desc=false (accessed 10.23.18).

World Bank, 2018b. Ease of Doing Business Score and Ease of Doing Business Ranking. Washington, DC.

World Bank, 2018c. Seychelles launches World's First Sovereign Blue Bond [WWW Document]. URL https://www.worldbank.org/en/news/press-release/2018/10/29/seychelles-launches-worlds-first-sovereign-blue-bond (accessed 4.2.19).

World Bank, 2017. World Bank Group Announcements at One Planet Summit [WWW Document]. URL https://www.worldbank.org/en/news/press-release/2017/12/12/world-bank-group-announcements-at-one-planet-summit (accessed 12.1.19).

Wyman, O., 2014. Direct Investing by Institutional Investors : Implications for Investors and Policy-Makers. World Economic Forum.

Zeit Online, 2018a. Bundesregierung verhindert Einstieg eines chinesischen Konzerns [WWW Document]. URL https://www.zeit.de/wirtschaft/unternehmen/2018-07/stromnetz-50hertz-kfw-20-prozent-anteil (accessed 5.12.18).

Zeit Online, 2018b. Wirtschaftsministerium: Peter Altmaier kündigt neue Industriepolitik an [WWW Document]. URL https://www.zeit.de/wirtschaft/2018-10/wirtschaftsministerium-peter-altmaier-industriepolitik-anschubfinanzierung-hilfeleistung-unternehmen (accessed 5.12.18).

Ziesing, H.-J., Repenning, J., Emele, L., Blanck, R., Böttcher, H., Dehoust, G., Braungardt, S., Eichhamer, W., Elsland, R., 2015. Klimaschutzszenario 2050. Öko Institut, Berlin; Fraunhofer ISI, Karsruhe.

Annex I: Seychelles Research Journal, Volume 2, Number 1, February 2020