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Review

Financing the future infrastructure of sustainable energy systems

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Abstract: The development of suitable financing models plays an important role for long-term investments in green energy infrastructures necessary to achieve energy and climate targets. In this context, it is important to state that people do not demand energy per se, but energy services such as mobility, heating, cooking and lighting. These services are provided by a combination of different energy carriers and technologies. In this paper, the focus lies on the optimal financing of innovative technologies from the society's point-of-view. Therefore, long-term financing models of new energy solutions play a key role in three core areas: (i) investments in renewable energy technologies, e.g., large solar thermal, PV, wind power systems, (ii) investments in new network infrastructure for electricity, district heating, hydrogen, charging stations for battery electric vehicles, etc.; (iii) investments in energy efficiency. In this paper we observe that there is practically no degree of freedom in the market regarding choice of financing parameters such as interest rate and depreciation time. In real life, all long-term investments, e.g., in the area of electricity or district heating networks, are located in a strictly regulated environment.

Keywords: energy service; infrastructure; energy efficiency; green bonds; renewable energy; risk

JEL Codes: G15, C40

1. Introduction

1.1. Motivation

The major motivation of this paper is that the transition towards a sustainable economy is currently one of our society's core goals. Heading towards sustainable economies means heading towards a sustainable energy system, hence providing energy services in an optimal way from society's point-of-view.

However, people do not demand energy carriers—oil, gas, pellets—per se, but energy services such as mobility, heating, cooking, and lighting. These services are in general provided by a combination of different energy carriers and technologies, see (Haas et al., 2008) and (Walker & Wirl, 1993). The three major inputs are: flow energy, energy conversion technology, and energy infrastructure technology. In general, more environmentally benign energy services require higher inputs of capital to finance technologies and lower expenses for the commodity energy. In addition, energy services provided by non-commodity energy carriers, such as wind or solar require less (almost zero) flow energy inputs.

An over-all goal of this paper is to identify ways for heading towards sustainable provision of energy services and how to finance these technologies in an optimal way for society. The development of suitable financing models plays an important role in the implementation of long-term investments green energy infrastructures necessary to achieve climate goals through greenhouse gas (GHG) emission reduction.

As this transformation of the energy system progresses, the dependence on fuel-based technologies is decreasing, turning towards mainly long-term infrastructure technologies such as grids, thermal and electrical storage, heat exchangers and heat recovery units.

Within the energy system there are three major areas in which long-term financing models play an important role: (i) Investments in renewable energy (RE) technologies, e.g. large solar thermal, photovoltaic and wind power systems, (ii) Investments in network infrastructure for electricity, district heating, charging stations for electric vehicles (EVs) and hydrogen refuelling stations for fuel cell vehicles (FCVs), storage, etc. (see e.g. (Ajanovic et al., 2020; Ajanovic & Haas, 2018; Ajanovic, 2015)); (iii) Investments in reducing energy demand and energy efficiency, e.g. by applying "Energy Performance Contracting", such as thermal insulation of buildings. This means:

a) There are segments that pay off in the short term, in which market incentives are of central importance and in which, for example, start-ups can play an important role, such as in the marketing of temporary surplus electricity from wind or photovoltaic systems, in load management or in decentralized battery storage;

b) However, there also are long-term market segments of a much larger financial scale, since investment is intensive and requires appropriate financing strategies.

These two views emphasize the contrast between public service thinking and individual profit thinking. Furthermore, short-term markets, e.g., for electricity and heat, do not provide long-term investment incentives. These would have to be secured by appropriate financing mechanisms and framework conditions, which is an important task for policy-makers and can be achieved by supporting certain financing models or by hedging risks.

As described above, there is clearly a need for a systematic analysis of different financing models depending on the investment source and different characteristics (i.e., private, public or private-public partnership) and other significant parameters such as yield, taxes, etc. In addition, there is a requirement for policy-makers to reformulate and implement new boundary conditions, for example, in private-public partnership (PPP) models, and to introduce views of public-sector financing.

1.2. Core objective

The core objective of this paper is to document and to identify approaches that allow to obtain the economically optimal solution for the provision of services and for the optimal choice of technology in practice. The conditions for optimal long-term financing technologies from society's point-of-view are to be identified. This paper aims at answering the following research questions:

- What are the basic financing models for investments in technologies with a long life and/or depreciation period?
- Which main factors influence long-term investments?
- Which of these factors can be influenced by politics and how should this be achieved?

At least two major issues play a specific and crucial role in this context: (i) What are justified costs of capital (interest rate or weighted average cost of capital—WACC)? Costs of capital are characterized by the magnitude of the interest rates (on debt capital) and expected rate of return (on equity capital). A low interest rate/rate of return is more beneficial for the user, while high rates are more beneficial for the investor/provider of money. (ii) What is the corresponding risk for an investor? In finance, risk is the likelihood "that actual results will differ from expected results" (Corporate Finance Institute, 2021), i.e. that actual rate of return from the investment will differ, from the investor's point-of-view, from the expected/required values. Installation of energy efficient lighting in public buildings or thermal retrofit of a multi-apartment dwelling are examples of low-risk investments, because these technologies are well established (once installed there are no competing technologies) and they have a secure technical life time. Expansion or installation of charging and refuelling infrastructure (e.g., for hydrogen fuel cell or battery electric vehicles) are examples of high-risk investments because of insecurities in some of the key parameters of the system: life time, size of the technology design, service demand, market prices or the existence of a compensation system. Hence, regarding risk it is likely that a higher return-on-investments (ROI) is expected when the risk is high and vice versa.

1.3. Contribution

The major new contribution of this paper is a systematic overview of the problems and the possible solutions for long-term Green Financing. In addition, it builds on a sound and comprehensive formal framework, where all models discussed fit into.

1.4. Major references

The major contributions from peer-reviewed literature to this topic are briefly described here. Note, that these are fundamental papers. Works focusing on specific issues such as energy efficiency measures, renewable energy technologies, financing infrastructure, green bonds, and risk are presented in Chapter 2.

Haas et al. (2008) explain the concept of providing energy services comprehensively. Based on this work, (Ajanovic & Haas, 2012) show the problems arising with improving the efficiency of a technology, e.g. of a car, mainly associated to the rebound effect.

Sachs et al. (2019) present a fundamental discussion of the importance of green finance for achieving sustainable development goals and energy security. They argue that investments through new financing instruments and new policies are the major cornerstone for heading towards sustainability. Without investments, no energy transition will take place.

Wagner & Wagner (2020) provide a comprehensive and detailed overview on investment assessments. An important reference on public investment in the energy sector is the book "Public investments in Energy Technology", published in 2012 (Gallaher et al., 2012). This book addresses the social importance of new energy technologies and deals with public investments in the energy sector from the US perspective. This book also provides a comprehensive overview on the basics of Green Financing. The starting point is the consideration that increasing energy consumption and the associated CO_2 emissions are a very important social problem for the USA as well as the whole world. The authors state that there is no doubt about the need for new technologies, but that there is no international consensus on how to develop them. (Becker, 2020) states that steering the global economy away from coal and oil towards renewable energy sources will involve spending a great deal of money.

The main methodological approaches and theories, on which the following analyses are based, are:

- The energy service approach (see e.g. (Haas et al., 2008)).
- Dynamic investment assessment and cash flow analysis (see (Plenty et al., 1999) and (Wagner & Wagner, 2020)).
- Business management approach (investment calculation, annuity and present value method, risk assessment, etc.).
- Microeconomic approach (e.g. influence of state intervention (Hall & Rosenberg, 2010), energy policy, Averch-Johnson effect) and
- Welfare economic approach (e.g. maximising social welfare) (Arrow et al., 2010).

1.5. Structure of this paper

The paper is structured as follows: In Chapter 2 the state-of-the-art related to financing the infrastructure of sustainable energy systems is provided. Chapter 3 documents the basic concept of providing energy services. Chapter 4 describes the basics of the investment and profitability analysis. The approaches of the annuity and net present value methods are presented. Also, the significance of the WACC approach for the various forms of financing is documented. Chapter 5 describes the concept of financing energy services. The dependence of the capital stock on permitted profit is analysed in Chapter 6. Aspects of long-term financing models and different forms of financing are documented in Chapter 7. Chapter 8 deals with Green Bonds. Different approaches of contracting are described in Chapter 9. Private-public-partnership models are investigated in Chapter 10. Conclusions and an outlook on future research complete this paper.

2. State-of-the-art

In this chapter, a survey on the state-of-the-art related to this paper is provided. The main references with the most important contributions from peer-reviewed literature are described below. Fundamental papers were presented and already discussed in Chapter 1. Next, papers focusing on specific issues e.g., technologies, energy efficiency, infrastructure, green bounds, and risk are discussed.

Brown et al. (2019) provide an evaluation of alternative finance mechanisms for residential retrofit. The central aim of (Gouldson et al., 2015) is to analyse the suitability of so-called “revolving funds” for financing energy efficiency measures in households with a focus on the UK. They show the potential of revolving funds as an innovative financing mechanism that could reduce the need for financial sources and increase the impact on investment by recouping and reinvesting some of the savings generated by early investment.

With respect to financing of renewables (Salm et al., 2016) reports on a large-scale survey among 1990 German private investors. Using a sample of 1041 respondents who expressed an interest in investing in municipal renewable energy projects, this study provides a unique dataset that provides new insights into private investors’ risk-return expectations. The study showed that, apart from return on investment, respondents were particularly sensitive to minimum holding periods and community renewable energy offerings.

The financing of renewable energy infrastructures via financial citizen participation for the case of Germany is discussed by (Yildiz, 2014). He states that the financing of decentralised renewable energy infrastructures in Germany is a complex issue, as the authorities lack the necessary capital and institutional private investors generally face constraints such as high transaction costs and risk-return concerns. Therefore, alternative financing concepts must be developed to keep the energy system transformation in motion. Said article illustrates empirical results on the relevance of financial participation of citizens in the German renewable energy sector.

Angelopoulos et al. (2017) deal with financing approaches for RES in Greece with special focus on risk and the Weighted Average Cost of Capital (WACC). The motivation of the paper is that significant investments in RE are necessary to achieve the EU’s RE targets for 2020 and beyond. The most interesting result is that the risk element in the design of support policies, e.g., feed-in tariffs, tradable certificates or tenders, is the one that has the greatest impact on the cost of capital and thus on investment in RES.

With the support of national policies, China’s renewable energy industry has experienced a period of rapid development and has become a world leader, particularly in terms of installed capacity and the speed of newly installed capacity. Ming et al. (2014) provide a review of renewable energy investment and financing in China. However, with the rapid development of renewable energy, the power generation industry is facing increasing challenges, especially in terms of investment and financing.

Broughel & Hampl (2018) state that small investors are increasingly recognised as a valuable source of private finance necessary for successful energy change. This study examines the effects of socio-demographic and socio-psychological characteristics on the willingness of individuals to invest in renewable energy projects in Austria and Switzerland.

Community-private sector partnerships in renewable energy are analysed by (Eitan et al., 2019). This study focuses on the rapidly growing and significant phenomenon of partnerships with the community and the private sector in the field of renewable energies, which are a fundamental building block of the global transformation of renewable energies.

Inderst (2017) deals with the need for investment in the UK in the country's infrastructure in general. It provides an overview of UK infrastructure investment and financing in an international context and provides interesting facts and findings for investors and policy makers worldwide. The UK is one of the leading countries when it comes to private sector involvement in infrastructure, with decades of experience in regulating privatised utilities and developing public-private partnerships (PPP).

In recent years, especially "Green Bonds" have gained attention. (IRENA, 2020) claims that "reallocating global capital into sustainable solutions requires a greater supply of effective and desirable capital market instruments".

With respect to risk in (Gatzert & Vogl, 2016) a model is presented that allows the quantification of policy measures taking into account risks related to energy prices, resources and inflation, and analyses their impact on investments in renewable energy. This paper, focusing on onshore wind farms in Germany and France, shows that political risk has a strong influence on investments. A major finding is that the potential risk for investors in renewable energy could be reduced by diversification through investments in different countries.

Mazzucato & Semieniuk (2018) investigate the "direction" of innovation that financial actors create. They use entropy-based indices to measure skewness and create a heuristic risk index that varies by technology, time and country of investment to measure risk. The financial actors differ considerably in the composition of their investment portfolios, thus creating an orientation towards specific technologies.

Polzin et al. (2019) analyse how policies mobilize private finance for renewable energy in principle. They review 96 empirical studies on the impact of policy on two key decision-making indicators for investors: investment risk and investment return. Investors are only willing to participate in RE projects if both indicators meet their expectations.

3. The basic concept of providing energy services

The basic premise of this analysis is that people do not demand energy per se but energy services such as mobility, washing, heating, cooking, cooling, and lighting. These services are in general provided by combining different inputs of energy, technology, human and physical capital, and environment (including natural resources). Given the fact that human and physical capital is largely accumulated in the technical efficiency of the (conversion and infrastructure) technologies used, a general equation for the production of a specific energy service (S) is (see Haas et al. (2009)):

$$S = f\big(E, \eta(T)\big) \tag{1}$$

with:

E … Energy input

$\eta(T)$ … Technical efficiency of the technologies; the term "technology" encompasses conversion technologies $\eta(T_{CON})$, but also aspects such as infrastructure and system efficiency $\eta(T_{IS})$;

However, $\eta(T)$ is not a free lunch; higher efficiencies are associated with higher investment costs:

$$IC(\eta_{high}(T)) > IC\big(\eta_{Low}(T)\big) \tag{2}$$

If in the short-term sufficient infrastructure is available, Equation (1) can be re-written in a simpler way (see (Walker & Wirl, 1993)):

$$S = E\eta(T) \tag{3}$$

The major point of this relationship is of course that the better the efficiency, the lower is the required input of energy.

4. Basics of investment assessment

Hence, a major question is to provide the optimal solution for η(T) in Equations (1) and (2) from society point-of-view. This is done by identifying the investment costs $IC_0(\eta(T))$. The starting point for all methods of investment calculation is that interest is incurred in a dynamic view.

The most important approaches here are the annuity method and the net present value method. With the annuity method, the average annual costs are determined, which are calculated for the depreciation period of the investment, considering the interest rate for calculation and the respective changes in operational cost. Under the net present value method, an investment is assessed according to the total expenditure it generates within a given period.

4.1. Annuity method

The conversion of an investment IC_0 (or the present value determined by discounting the individual investment expenditures during project lifetime) into equal annual amounts (annuities) is done by multiplying the investment (or the present value) with the capital interest- or capital recovery factor. The annual charges from these total investments include:

- Depreciation time
- Interest rate
- Taxes
- Property and liability insurance (at nominal value)

The capital recovery factor records depreciation and interest as a percentage of the investment costs. The annuity describes the investment as an even annual payment depending on interest, depreciation and initial investment costs. Depreciation and interest are thus called annuity and are considered as constant payments A (see (Zweifel et al., 2017)):

$$A = CRF \cdot IC_0 \tag{4}$$

with:
CRF … Capital recovery factor
A … Annuity of the investment IC_0 (EUR/year)
and

$$CRF = \frac{r \cdot (1+r)^n}{(1+r)^n - 1} \tag{5}$$

with:
r … Expected rate of return (annuity interest rate or WACC) (%)
n … Depreciation period (lifetime of the investment) (years)

It should be mentioned that in the case of more complex forms of financing the so-called WACC is used instead of the interest rate; for details see Chapter 4.4. Figure 1 shows the basic principle of allocating investments to annuities. The extended capital recovery factor also takes insurance and capital-dependent taxes into account as annual expenses.

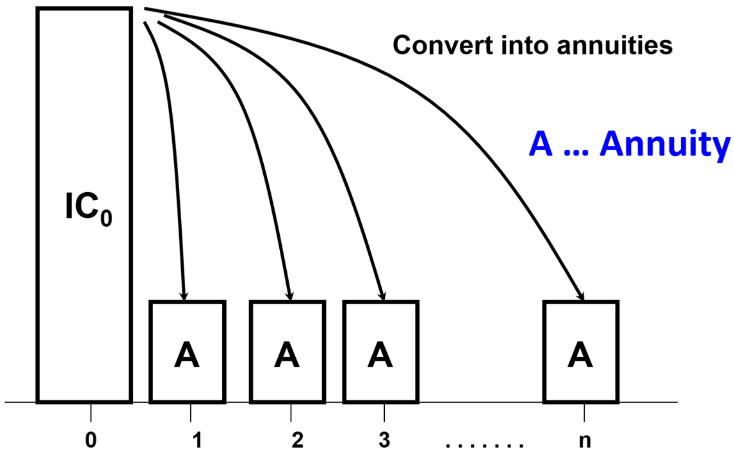

Figure 1. Allocating/converting investments into annuities.

In addition, there are yearly expenses that are not dependent on capital. The annual costs C are then added for a system for energy use, see e.g. (Ajanovic & Haas, 2019; Ajanovic & Haas, 2018):

$$C = A + C_E + C_{O\&M} \quad (6)$$

C_E … Energy costs (EUR/year)
$C_{O\&M}$ … Operation & maintenance costs (EUR/year)
Note that A is also noted as CAPEX (capital expenditures) sometimes and O&M as OPEX (operation expenditures).

In principle, it should be noted here that the annuity method is particularly well suited to problems that arise in the energy industry and has clearly established itself, especially where major investment decisions have to be made, mainly due to its intuitive unit EUR/year.

4.1.1. Sensitivity of the capital recovery factor

The capital recovery factor can practically have a considerable bandwidth. According to Figure 2, for interest rates from 0% to 10%, the capital recovery factor varies between 0.13 and 0.07 for a depreciation period of 15 years (range of factor 2), and between 0.02 and 0.10 for a depreciation period of 50 years (range increases to factor 5).

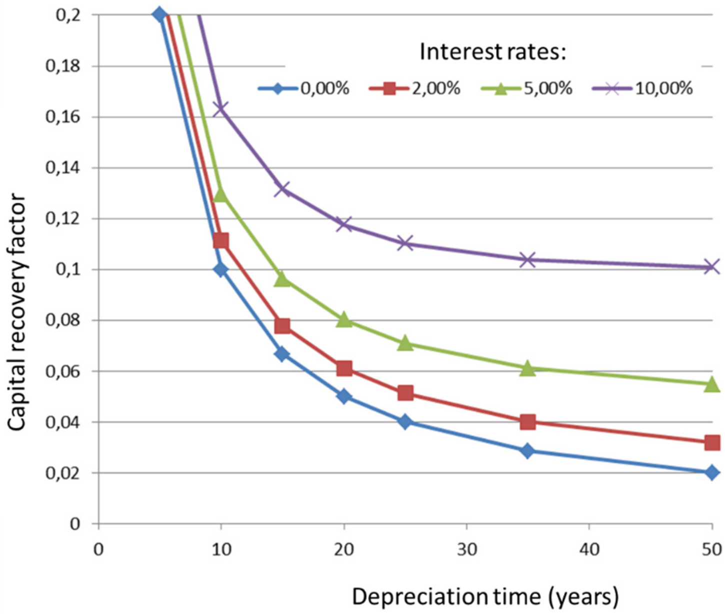

Figure 2. Sensitivity of the capital recovery factor depending on interest rate and depreciation period.

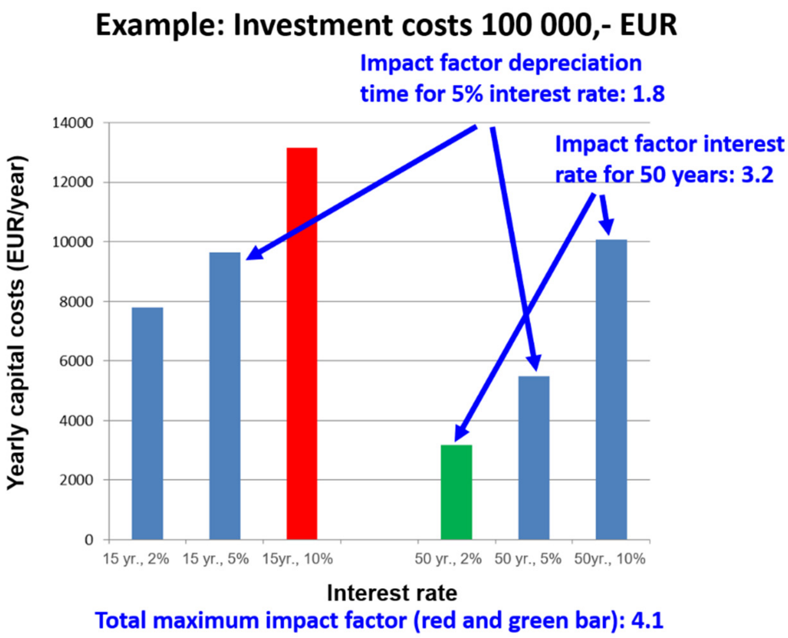

Figure 3. Example of the sensitivity of the repayment of an investment of EUR 100,000.

Figure 3 shows how the sensitivity of an investment can be estimated as a function of interest rate (or WACC) and depreciation period using the example of an investment of EUR 100,000. The influence of the time factor at an interest rate of 5% is 1.8 comparing 15 years and 50 years depreciation periods, and the influence of the interest factor (WACC) at 50 years depreciation period is 3.2 (between 10% and 2% interest).

4.1.2. Net present value method

We now assume that income or expenditure will occur once only at different points in time. In the energy industry, one possible case is that a one-off investment is offset by income and expenditure in the following years.

The annual expenses K consist of the work-related, operating costs and the expenses for insurance and capital-related taxes. The latter depend on the fixed capital and are therefore included in the capital recovery factor CRF. Comparing several project variants, the most favourable project from an economic point of view has the lowest total expenditure at the time of analysis. This comparative amount is called the cash value of the investment and the corresponding calculation method is known as the net present value method.

Monetary values that arise before the reference date are compounded, while those after the reference date are discounted. A special case—the net present value at the start date—is explained in more detail below.

Assuming that the annual costs K remain unchanged during the useful life, an assumption that is usually made for economic efficiency calculations, the present value of constant expenditures at the start date can be obtained by discounting (see (Zweifel et al., 2017)):

$$PVF = \frac{(1+r)^n - 1}{r(1+r)^n} \tag{7}$$

This results in the present value of all expenditures:

$$NPV = IC_0 + PVF \cdot K \tag{8}$$

with:
PVF … Present value factor
K … Yearly expenditure (EUR/year)
IC_0 … Investment costs (EUR)
NPV … Net present value of all expenditures related to the start time (EUR)

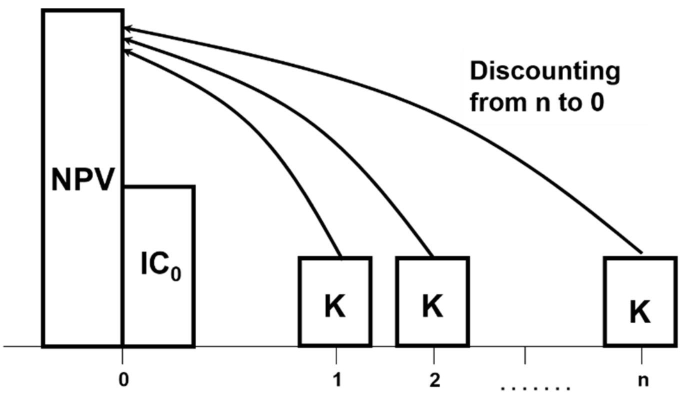

Figure 4. Discounting of annually incurred expenses to the initial net present value (NPV).

4.2. Cashflow analysis—the dynamics of investment

An important approach for analysing the monetary balance over the lifetime of an investment is the cashflow analysis. It depicts the aggregated annual expenses and revenues for every year over the life-time. Figure 5 depicts the expected cashflow of an investment. The red area shows the deficit in the first years until the break-even point. Afterwards, the green area illustrates the expected profit.

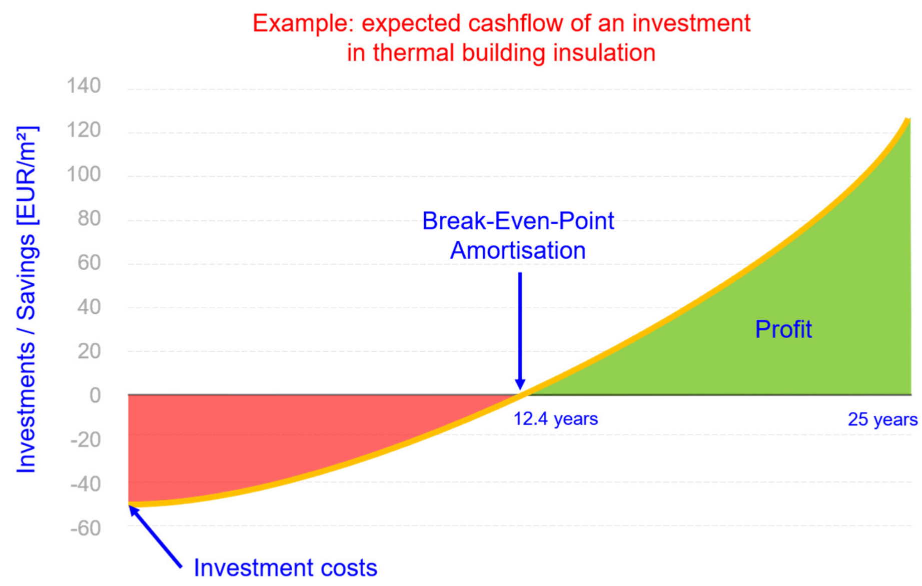

Figure 5. Cashflow analysis of an investment in thermal building retrofit.

4.3. The importance of the WACC approach to long-term financing

As mentioned, the WACC approach plays an important role in long-term investment decisions. The starting point is that companies have several options to cover their long-term capital requirements and close short-term financial gaps. In the mainstream business management literature, the so-called WACC procedure is considered a suitable model for determining the financing costs. This procedure has also been used in recent regulations in Austria and by the majority of regulatory authorities in Europe (e.g., for setting prices for electricity transmission and distribution). An exception is, for example, the German regulatory practice, where a separate determination of return on equity and return on debt is carried out.

The WACC interest rate is a weighted average of the costs of equity and debt capital. It is possible to determine the WACC value both after and before taxes. The WACC rate after taxes is calculated as follows (see (Farber et al., 2006)):

$$WACC_{after\ taxes} = r_E \frac{E}{E+D} + r_D (1-T) \frac{D}{E+D} \tag{9}$$

r_E … Cost of equity
r_D … Cost of debt
E … Equity capital (at market value)

T … Tax rate
D … Debt (at market value)
E+D … Total capital (at market value)

This WACC definition considers the tax advantage from external financing (tax shield). Since interest before tax must be calculated to determine the financing costs in regulation, the calculation must be modified accordingly for regulation purposes. Taxes are usually corporate taxes and not personal income taxes. Corporate income taxes vary between countries, e.g., 25% in Austria and 19% in the Czech Republic, so the price of debt capital varies under otherwise identical conditions.

The modification to a WACC before tax is made by dividing the WACC after tax by (1-T)—assuming for simplification that the tax credit is received when the interest payment is made. As a result, the formula for calculating the WACC before tax is as follows:

$$WACC_{before\ taxes} = \frac{r_E}{(1-T)}\frac{E}{E+D} + r_D\frac{D}{E+D} \quad (10)$$

Pre-tax WACC is widely used by regulatory authorities, e.g., for tariff regulation (because the revenues generated need to be sufficient to pay any tax liabilities).

The cost of equity is usually determined using the Capital Asset Pricing Model (CAMP) (see (Brealey et al., 2019)).

Example on WACC from the Czech reality

An example of using WACC as a measure of the permitted rate of return is the system of setting guaranteed purchase prices of electricity from RE applied in the Czech Republic between 2006 and 2012. Guaranteed purchase prices of electricity (Feed-in-Tariffs-FITs) were calculated using reference models for individual types of RE technologies. The basic idea of the system was enough to motivate investors to invest so that the Czech Republic meets the indicative target of 8% share of electricity from RE by 2010. The implementation of each project is unique due to the possibility of financing by the investors and also due to their expectations on rate of return on equity capital. The condition that the discounted sum of all project cash flows, including the investment, would be zero was used to calculate the FITs. The investor then realizes the return on invested capital in the amount of the discount used to calculate the NPV. The discount then has the meaning of WACC after taxes in this case. The WACC = 7% was chosen in the Czech Republic to set purchase prices, and 6.3% since 2010. The amount of return on equity then depends on the tax rate, the share of foreign capital and its price. Thanks to the leverage effect, the return on equity reaches higher values than the price of debt capital.

5. The concept of financing energy services—solving the problem of the "payback gap"

An important issue in this context is the so-called payback gap. The payback gap refers to diverging depreciation times and returns-on-investment (ROI), as well as different risk for demand and supply with respect to different parties. For example, a private industrial company expects a depreciation time of about three years, a ROI of more than 10% and is not ready to accept any risk with respect to an investment in energy efficiency measures. On the contrary, a public energy utility reckons with 20 years depreciation times, 3% (or below) ROI, and is exposed to some (limited) risk when constructing a power plant.

The optimization approach of the implementer of a technology is:

$$\text{Max } R(S)S - C_E - CRF \cdot IC(\eta(T)) \quad (11)$$

with:
R(S) … Revenues from selling service, e.g. EUR/m²/year heated
S … Service demand, e.g. area heated per year
C_E … Energy costs per year
CRF … Capital recovery factor
IC(η(T)) … Investment costs of technology T

Revenues include all revenues from the technology's own operation and all possible direct financial subsidies (e.g. green bonus). Similarly, energy costs include costs associated with carbon charges (taxation, emission allowances). The basic problem of the "payback gap" is the difference between the expected return-on-investment of society and of individual investors.

The difference in the interest rate or WACC applied is shown in Figure 6 where π refers to the interest rate applied by society and r is the interest rate of an individual household or a firm as investor. $\Delta E_{society}$ depicts the difference between the current situation (Index 0) and the optimal solution from society's point-of-view, e^c.

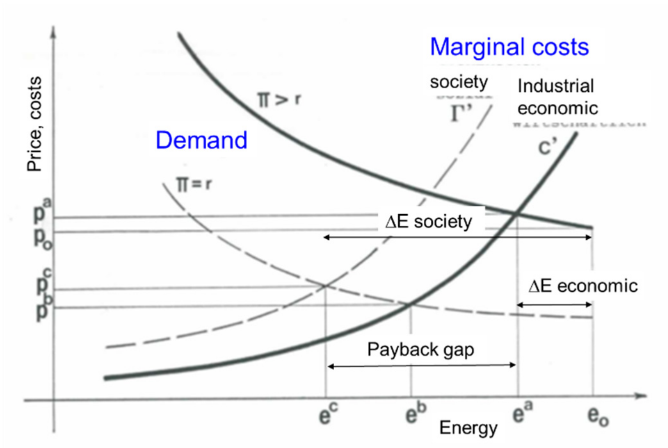

Figure 6. Equilibrium between supply and demand depending on the interest rate applied. (Haas, 1992).

6. Dependence of the capital stock on permitted profit

This chapter analyses the impact of private and public financing models on the level of financing—the capacity or capital stock (CS) provided—under the constraint of a maximum allowed rate of return. For a description of the principal difference between private and public financing models, and a discussion of the differences with and without government intervention, see Figure 7. This figure shows that the private optimum with maximum profit $CS_{private} = CS(Profit_{max\_IE})$ can be far from the optimum of a public company CS_{public} = CS (Profit = 0). It can also be seen that the business maximum CS_{Privat} does not necessarily correspond to the economic maximum. Ultimately, the question arises as to whether and how (for example, through subsidies, taxes, and legislative regulations) an improvement can be achieved from a societies' point of view, see $CS_{Society}$ at the economic maximum in Figure 7.

This effect is also called Averch-Johnson effect (see (Boyes, 1976)).

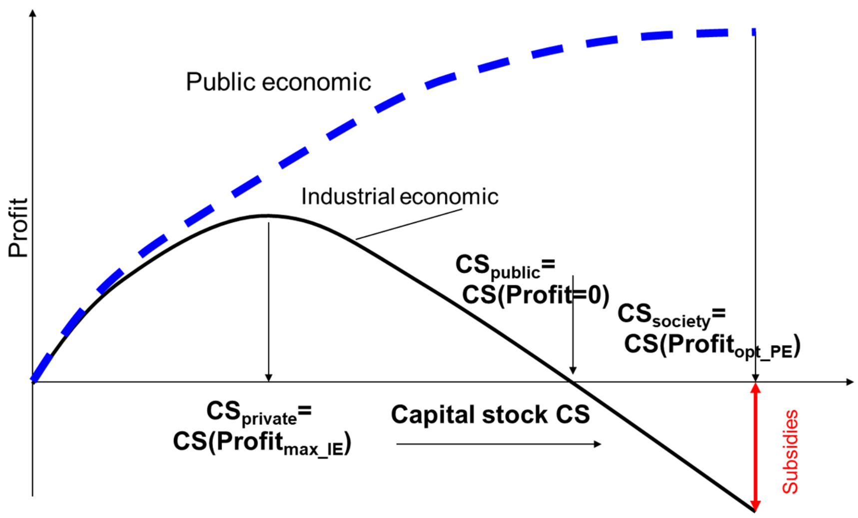

Figure 7. Profit function of companies depending on the allowed profit and possible subsidies

7. A survey on long-term financing models

Based on the described basics of investment and profitability calculations, the central aspects of financing, especially long-term financing models for durable technologies, are now explained.

Traditional credit financing by banks for municipalities and public enterprises is becoming increasingly difficult. On the one hand, in the course of the global financial crisis, some credit institutions withdrew from the municipal finance business to a large extent. On the other hand, Basel III is making lending conditions more stringent. Therefore, it is becoming increasingly interesting to involve citizens in the financing of projects, and thus also to increase the acceptance of energy (infrastructure) projects.

In order to implement projects for which own funds or direct subsidies are not available in sufficient quantities, it is necessary to borrow from outside funds, e.g., from Green Bonds (see next chapter). The procurement of capital to cover the financial requirements for the realisation of investment projects is referred to as financing. The choice of the right form of financing depends on the object of financing. Tax motives or products linked to services (e.g., leasing) can also be decisive. In principle, the forms of financing can be divided into classic and special forms of financing.

7.1. Bottom-up vs. top-down approaches in financing

First, a distinction must be made between bottom-up and top-down approaches to financing. Figure 8 shows the fundamental differences between bottom-up vs. top-down approaches. While bottom-up financing is tailored to the individual project, top-down financing models such as “green bonds” are offered on the market and are characterised by predefined preconditions/targets that a project must meet in order to obtain financing.

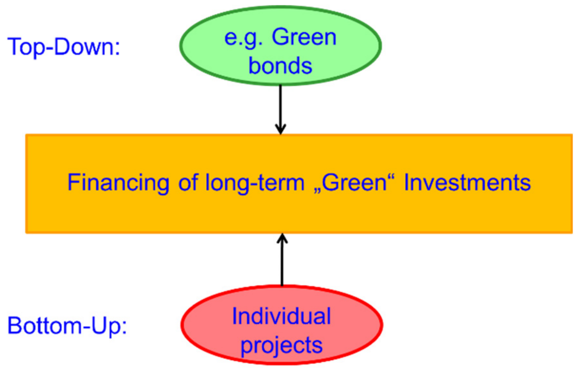

Figure 8. Bottom-Up vs Top-Down financing approaches**.**

The classic financing triangle is shown in Figure 9. The subject of desire is only realized if a suitable mix of investor and liability is achieved. This means that the realization of a certain project depends on whether there is a sufficient incentive for an investor and, in parallel, an institution or a public body is willing to assume liability.

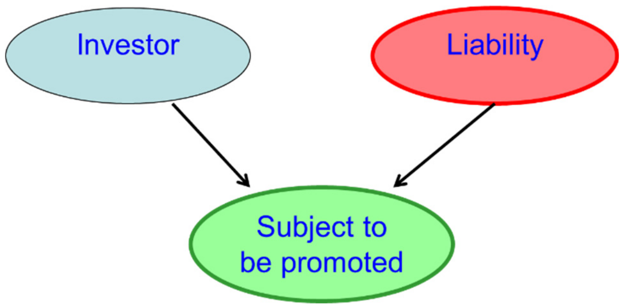

Figure 9. The classic financing triangle.

7.2. Financing models

7.2.1. Traditional financing (loans)

Credit financing is based exclusively on a written contractual agreement and normally runs over a longer period of time. The loan amount is made available for a one-off utilisation and is subsequently repaid in periodic instalments. The instalments include both the repayment and the interest charged on the loan amount.

7.2.2. Leasing

"Leasing is a legal transaction of its own kind concerning the transfer of use of assets against payment, whereby their selection and specification is usually carried out by the user. However, in contrast to a lease or inventory agreement, the investment risk (economic risks and opportunities) as well as the material and price risk are predominantly transferred to the user (lessee). At best, the lessor also provides economically related services that go beyond the mere transfer of use". (VÖL, 2017).

a) Finance leases

A typical form of leasing is the finance lease. Here, the lessor transfers the investment risk to the lessee. The lessor therefore only bears the credit risk. During the term of the contract, the lessor is the economic owner of the leased object.

In the case of finance leasing, a fixed basic leasing period is agreed, during which termination by the lessee is excluded. The term of the contract is based on either the economic life or the service life.

Key features of finance leases:

- Fixed lease term without right of termination over a large part of the useful life.
- Credit risk borne by the lessor.
- Investment risk is borne by the lessee.
- Various options after the basic leasing period (purchase, return, etc.).
- Measures to maintain the value are borne by the lessee (in particular maintenance, insurance).
- In principle applicable to all goods; leasing object can also be a custom-made product for the lessee, which cannot be used by third parties (in this case, full amortisation agreements are usually concluded or the lessor has a right of tender vis-à-vis the lessee, whom he can thereby oblige to purchase the leasing object at the calculated residual value after expiry of the contractual term).

b) Operating Leasing

Operating leasing is largely similar to rental, but in many cases includes other services not typical of rental.

Key features are:

- No fixed leasing period and therefore the right to terminate the lease at any time within the periods of notice or
- Very short leasing period, within which, however, it is not possible to terminate the contract
- Lessor bears the full investment risk and capitalizes the leased asset in his balance sheet (depreciation over useful life)
- Lessee recognizes the lease payments as expenses
- Additional services such as maintenance and repair are borne by the lessor

c) Bonding model

The bail bond model is often used in the public sector. Here, the residual value is saved by means of (VAT-exempt) deposits within the scope of tax options. The aim is to keep the rent low and the deposit high by designing the modalities accordingly. At the end of the lease term, the deposit payments made are offset against the purchase price.

Key features are:

- Optimisation of the value added tax: initially there is the option of standard taxation (if possible), after the end of the correction period there is the option of a change to non-genuine exemption (e.g. in accordance with § 12(10-12) UStG -German Value Added Tax Act).
- This results in a minor assumption of influence and risk by the lessor. The lessee is responsible for drawing up the construction contract. As a rule, this includes the planning and the selection of the construction planners.
- In the deposit model, the contracts usually provide for a right of tender.
- In this model, the focus is on financing.

- The deposit model means that the economic result of the contract is more likely to be a loan than a rent.

For example, in the case of a property, a leasing and deposit rate is paid. The deposit is saved until the end of the term in the amount of the residual book value of the property, so that the deposit usually corresponds to the purchase price at that time.

7.2.3. Contracting

The most important types of contracting are described below.

a) Energy-(service) contracting

Energy contracting is the name given to a contractually agreed model for third-party financing of energy services. In this model, an external specialist (contractor) undertakes services for the realisation of investments with the aim of saving ongoing energy consumption. Under a contract for a specific period of time, the contractor thus bears the investment risk and receives a performance-related fee in consideration of the agreed performance guarantee.

b) Plant-contracting

Plant contracting or energy supply contracting is a form of energy contracting and refers to the operation of an energy generation plant (newly built or existing) for the purpose of supplying energy on the basis of long-term contracts. The contractor is responsible for the necessary investments and operational management or provides the useful energy. In this way, the technical and economic risk is transferred to the contractor and energy-efficient plants can be used by e.g. a municipality.

c) Savings-contracting

Savings contracting (performance contracting) is a contractually agreed model in which energy-saving measures or energy management are pre-financed by the contractor and paid for from the energy cost savings achieved.

7.2.4. Public-private-Partnership

Public Private Partnerships (PPP) are forms of cooperation between units of public corporations, private companies and/or non-profit organizations that are designed to be process-oriented over a longer period of time and due to an incomplete service specification. This approach is described in more detail in Chapter 9.

8. Green bonds

What is a bond? A bond is a type of loan or IOU (document acknowledging a debt) which companies, governments, and banks use to finance projects. The issuer of the bond (the borrower) owes the holder (the creditor) a debt and, depending to the terms they agree on, is obliged to pay back the amount lent within a certain amount of time and with a certain interest.

What is a Green Bond? A Green Bond is financial instrument designed specifically to support specific climate-related or environmental projects. The majority of the green bonds issued are green "use of proceeds" or asset-linked bonds. Proceeds from these bonds are earmarked for green projects but are backed by the issuer's entire balance sheet.

Green bonds are typically asset-linked and backed by the issuing entity's balance sheet, so they usually carry the same credit rating as their issuers' other debt obligations. Green bonds finance projects aimed at energy efficiency, pollution prevention, sustainable agriculture, fishery and forestry, the protection of aquatic and terrestrial ecosystems, clean transportation, clean water, and sustainable water management. They also finance the cultivation of environmentally friendly technologies and the mitigation of climate change.

In theory, Green Bonds proceeds could be used for a wide variety of environmental projects, or even parks development; but in practice they have mostly been the same as Climate Bonds, with proceeds going to climate change projects. The key takeaways on Green Bonds are:

- A green bond is a fixed-income instrument designed specifically to support specific climate-related or environmental projects.
- Green bonds typically come with tax incentives to enhance their attractiveness to investors.
- The World Bank issued the first official green bond in 2008 (see (World Bank, 2018)).
- Around $157 billion worth of green bonds were issued in 2019.

What do green bonds finance?

Green bond proceeds can go toward new or existing projects that are meant to have positive environmental or climate effects. Inside that, the range is vast. It covers energy, transport, waste management, building construction, water and land use. Some definitions also include communications and information technology.

Green bonds come with tax incentives such as tax exemption and tax credits, making them a more attractive investment compared to a comparable taxable bond. These tax advantages provide a monetary incentive to tackle prominent social issues such as climate change and a movement to renewable sources of energy. To qualify for green bond status, they are often verified by a third party such as the Climate Bond Standard Board, which certifies that the bond will fund projects that include benefits to the environment.

8.1. History of green bonds

As recently as 2012, green bond issuance amounted only to $2.6 billion. But in 2016, green bonds began to sprout. Much of the action was attributable to Chinese borrowers, who accounted for $32.9 billion of the total, or more than a third of all issuances. But the interest is global, with the European Union and the United States among the leaders too.

In 2017, green bond issuance soared to a record high, accounting for $161 billion worth of investment worldwide, according to the latest report from the rating agency Moody's. Growth slowed a bit in 2018, hitting only $167 billion, but rebounded the following year. Moody's estimates that global issuances in 2019, when finally tabulated, could top $250 billion. The Climate Bonds Initiative, an international, investor-focused not-for-profit organization, puts the figure at $257.5 billion (see (World Bank, 2018)).

In 2008, the World Bank issued the first so-labelled green bond for institutional investors. The 2010s saw the development of green bond funds, broadening the ability of retail investors to participate in these initiatives. Allianz SE, Axa SA, State Street Corporation, TIAA-CREF, Blackrock, ax World Funds, and HSBC are among the investment companies and asset management firms that have sponsored green bond mutual funds or ETFs.

Dating back to the first decade of the 21st century, green bonds are also referred to as climate bonds. Climate bonds are used to finance—or re-finance—projects needed to address climate. They range from wind farms and solar and hydropower plants, to rail transport and building sea walls in cities threatened by rising sea levels. Only a small portion of these bonds have actually been labelled as green or climate bonds by their issuers.

In some cases, a portion of proceeds have gone to areas seen as environmental but not necessarily related to climate change. For example, proceeds from RaboBank's green retail bonds in the Netherlands may go to organic farm loans as well as to climate change related areas like sustainable buildings.

Table 1. Types of green bonds (Bloomberg, 2019[1]; Climate Bonds Initiative, 2013).

Type	Proceeds raised by bond sale are	Debt recourse	Example
"Use of Proceeds" Bond	Earmarked for green projects	Recourse to the issuer: same credit rating applies as issuer's other bonds	EIB "Climate Awareness Bond" (backed by EIB); Barclays Green Bond
"Use of Proceeds" Revenue Bond or ABS	Earmarked for or refinances green projects	Revenue streams from the issuers though fees, taxes etc are collateral for the debt	Hawaii State (backed by fee on electricity bills of the state utilities)
Project Bond	Ring-fenced for the specific underlying green project(s)	Recourse is only to the project's assets and balance sheet	Invenergy Wind Farm (backed by Invenergy Campo Palomas wind farm)
Securitisation (ABS) Bond	Refinance portfolios of green projects or proceeds are earmarked for green projects	Recourse is to a group of projects that have been grouped together (e.g. solar leases or green mortgages)	Tesla Energy (backed by residential solar leases); Obvion (backed by green mortgages)
Covered Bond	Earmarked for eligible projects included in the covered pool	Recourse to the issuer and, if the issuer is unable to repay the bond, to the covered pool	Berlin Hyp's green Pfandbriefe; Sparebank 1 Boligkreditt green covered bond
Loan	Earmarked for eligible projects or secured on eligible assets	Full recourse to the borrower(s) in the case of unsecured loans. Recourse to the collateral in the case of secured loans, but may also feature limited recourse to the borrower(s).	MEP Werke, Ivanhoe Cambridge and Natixis Assurances (DUO), OVG
Other debt instruments	Earmarked for eligible projects		Convertible Bonds or notes, Schuld-schein, Commercial Paper, Sukuk, Debentures

[1] Bloomberg (2019) What Are Green Bonds and How 'Green' Is Green? Bloomberg.Com. Available from: https://www.bloomberg.com/news/articles/2019-03-24/what-are-green-bonds-and-how-green-is-green-quicktake.

The green "use of proceeds" bond market has developed around the idea of flat pricing—where the bond price is the same as ordinary bonds. Prices are flat because the credit profile of green bonds is the same as other vanilla bonds from the same issuer. Therefore, green bonds are pari pasu to vanilla issuance.

9. Contracting

Energy contracting is a financing and operating model for energy efficiency and renewable energy and is known as a smart, multi-purpose-instrument, which may help to overcome market barriers for energy efficiency and closing the payback gap. Main references for contracting are (Sorrell, 2007), (Bleyl, 2009) and (Bleyl et al., 2019).

Most energy contracting definitions fall short with regard to important properties of performance-based contracting services such as outsourcing of risks to the energy service provider, guarantees for outcomes and "all-inclusive" cost of the measures implemented, modularity of the service package or optimization according to project life cycle cost. These features constitute important quality attributes of energy contracting value propositions in comparison to simpler, input driven energy services. And they often constitute an added value compared to standard in-house implementation models. These features may constitute an added value in comparison to standard in-house implementation.

Therefore, in a narrow sense we define performance-based energy contracting as a comprehensive energy service concept for executing energy efficiency and renewable projects in buildings or production facilities according to minimized project cycle cost. Energy contracting is particularly interesting for larger energy plants or extensive renovation measures. An Energy Service Company (ESCo) typically acts as a general contractor and implements a customized energy service package (consisting of e.g. design, building, (co-)financing, operation & maintenance, optimization, fuel purchase, user motivation). As key features, the ESCo's remuneration is performance based, it bears commercial as well as technical implementation and operation risks and guarantees outcomes and all-inclusive cost of the services package for the duration of the project (see (Bleyl & Schinnerl, 2008)).

The energy contracting service concept shifts the focus away from selling units of final energy (like fuel oil, gas or electricity) towards the desired benefits and services derived from the use of the energy carrier. The ESCo's remuneration depends on the output of the services provided and not the inputs consumed (investments are refinanced by the energy savings achieved or from energy sales), thus inducing an intrinsic interest for the service provider to increase efficiency and to reduce final energy demand. Also, contracting services are not about any particular technology or energy carrier. Instead, they are flexible and modular delivery mechanisms to execute energy efficiency and (renewable) supply projects, according to the goals of the facility owner, e.g. to minimize life or project cycle cost, including the operation phase of the building.

9.1. Financing of contracting

The contracting party pays only for the demonstrably achieved energy cost savings (energy service performance contracting) or the actual amount of heat or electricity consumed (plant contracting) and the contractor overtakes all technical and economic risks.

In standard energy savings contracting, the contractor carries out energy saving measures, which leads to lower energy costs and guarantees a certain saving. These savings are used to finance the contractor's investment costs. All costs incurred by the contractor (planning, investment, financing, possibly also service and operation) are covered by the savings.

As investments need to be financed from savings only, the following condition applies to determine profitability for a contractor:

$$R > C \tag{12}$$

R … Project cycle revenues from savings per year
C … Project cycle costs per year

$$R = p_E E_0 + C_{O\&M,0} \tag{13}$$

$$C = A_{Saving} + p_E(E_0 - \Delta E_{saved}) + C_{O\&M,1} \tag{14}$$

E_0 … Total initial energy consumption
p_E … Energy price
ΔE_{saved} … Amount of energy saved
$C_{O\&M,0}$ … Initial operation & maintenance costs
$C_{O\&M,1}$ … Operation & maintenance costs after measures
A_{Saving} … Annuity (capital cost) of investment in saving measure

In plant contracting, the contractor constructs a renewable energy plant, e.g., a biomass or solar heating plant directly at the contracting company. The contractor takes care of planning, investment, financing, but also service and operation of the plant and assumes the functional and performance risk. The (useful) energy supply can include, for example, heat, cold, steam, electricity or compressed air.

The energy price, e.g. the heat price, the annual heat price adjustments are specified in the contract. The heat price is made up of the basic price, labor price and metering price. In this case of contracting, a comparison to baseline costs is possible, however no criterion of profitability is applied. The illustration of the effect of contracting is demonstrated in Figure 10.

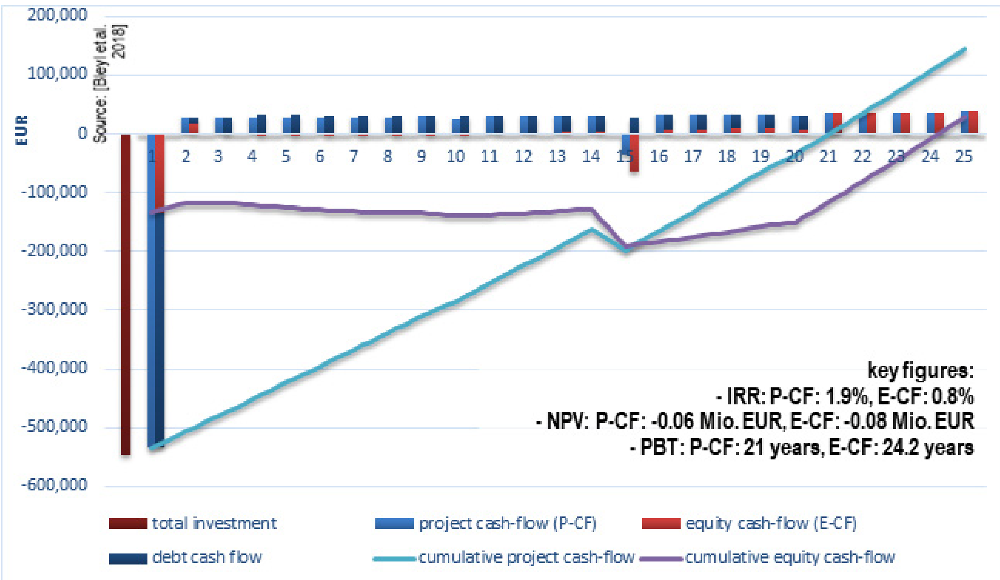

Figure 10. Illustration of the effect of contracting on the project cash flow (case study of DER, from (Bleyl et al., 2019)).

9.2. Lessons learned

Energy contracting models offer integrated solutions for an entire project life cycle (planning, construction, and operation and maintenance) and an interdisciplinary approach (technical, economic, financial, organizational, and legal aspects) to achieve guaranteed performance and results of the efficiency technology deployed. Contracting models offer output and performance guarantees over the entire project cycle (not just the warranty period).

As an integrated and multidimensional approach, energy contracting can overcome barriers and opens up solutions, which are not achievable through a standard, disintegrated implementation process. contracting projects can overcome obstacles such as financing bottlenecks or lack of know-how, but they cannot substitute the client's decision to engage in energy efficiency and in a general contractor model. Successful market development—in particular for energy contracting—is often demand side/buyer driven. Potential energy contracting customers defined their needs and goals for energy service packages with the support of independent facilitators. To foster market development, the role of independent market and project facilitators as mediators between energy contractors and their (potential) clients has proven to be of great value.

10. Private-Public-Partnership—Financing models

This chapter analyses the relevance of so-called Private-Public-Partnership (PPP) financing models. PPP models are forms of cooperation between units of public corporations, private companies and/or non-profit organisations that are designed to be process-oriented over a longer period of time and due to an incomplete service specification. With regard to the concrete design of PPPs, there are numerous variants that can be differentiated in terms of the scope of services, structure, financing and the object of the service. PPPs are considered as organisational alternatives in almost all areas of public task fulfilment.

A PPP is a contractually regulated cooperation between public authorities and private sector companies in a special purpose entity. The aim of a PPP is the division of labour, whereby the private partner assumes the responsibility for the efficient provision of the service, while the public sector ensures that public interest objectives are observed. The public sector expects the partnership with the private sector to relieve the strained public budgets, as the private entrepreneur provides all or part of the financing himself and must therefore ensure that the project is economically viable.

A PPP is usually similar to a lease or rental agreement. A PPP involves opportunities and risks for both the public sector and the private partner.

10.1. Definition and history

There is not yet a generally accepted definition of PPP due to the diversity of its fields of application. Business parlance has now adopted the fact that PPP is only present in terms of both meaning and terminology when the partners combine their different strengths. Pure financing transactions, including sale and lease back, are therefore not part of the term. According to today's functional understanding of the term, PPP is thus the contractual cooperation between the public sector and the private sector, usually on a long-term basis, in which the necessary resources (e.g. know-how, operating resources, capital, personnel, etc.) are contributed by the partners for mutual benefit in a common organisational context and existing project risks are distributed according to the risk management competence of the project partners.

The historical increase in public debt resulting in scarce financial resources and simultaneously upcoming public investments prompted the public sector to look for new financing possibilities. With the exception of concessions for the development of water, gas and electricity infrastructure projects (which already existed in the 19th century), it was not until 1987 that public authorities were no longer strictly opposed to private capital as the basis for financing public projects. An early example is the Neues Frankfurt project between 1925 and 1930, where the city and private investors each contributed half of the costs.

10.2. International significance of PPP as financing models

The European Investment Bank's involvement in PPP projects dates back to the loans granted in the UK, the country of origin, after the Eurotunnel project (France/UK) was established in July 1987 (EIB, 2005). The UK Private Finance Initiative (PFI) of December 2001 is considered to be the first systematic government-designed project by a government to harness private capital for public projects (House of Commons—Treasury Committee, 2001, 2011). Most PPP projects have been implemented in the UK.

The largest PPP market is Great Britain with a share of EUR 42.2 billion (57%), followed by Italy (EUR 29.8 billion; 40%), Germany (EUR 9.5 billion; 13%) or Greece with a share of EUR 6.3 billion. In England 2002 saw the launch of the prestige project for the refurbishment and operation of the London Underground. London was to pay a total of EUR 45 billion in rents to investors over 30 years. But the investors went bankrupt in 2007. London had to take over the investors' obligations and start from scratch under its own management (Rügemer, 2014). Structural deficiencies were found in school projects, while hospitals and prisons are being cut back on staff to such an extent that the quality of care and security is often jeopardized. Often the initial investors sell the contracts on to other investors who are looking for higher returns. In 2011, a committee of the British parliament concluded that no evidence of the advantages of the PPP procedure could be found. The long duration makes the contracts inflexible, the awarding of contracts is expensive. The long-term rents agreed are in fact a disguised form of borrowing, but are not shown in the public budget (House of Commons—Treasury Committee, 2011).

The granting of a loan to a project company is a constitutive element of a PPP structure. The project companies, which are mostly organised under private law, act as borrowers. They sell or assign their claims against the municipality to a bank; at the same time, the municipality waives all its objections to the bank.

In the meantime, in most countries the legal prerequisites have also been created or contractual arrangements developed by the PPP partners to enable the private sector to borrow within PPP projects at better municipal loan conditions. In general, this is permissible if the claims of a project company organised under private law against the public sector are sale/assigned to banks within the scope of a genuine forfaiting and at the same time the public debtor waives all defences at least in the amount of the loan service. Due to the waiver of defences, the public sector still has to meet the claim even if the project company fails to perform, so that credit institutions are thus placed in the same position as if they had concluded a loan agreement directly with the public debtor (BAFin (former BAKred), 1997), since the servicing of the loan is not impaired by any defaults within the contractual relationship between the municipality and the project company.

10.3. Criticism of PPP

Public authorities are not fully convinced of the usefulness of PPP as an alternative procurement method. Nor are all concepts fully developed at present. As a result, many decision-makers, bodies and civil servants are more inclined to carry out planning and procurement on their own, as before, in the face of untried administrative procedures with PPP. In many areas in Germany, there is also still a considerable amount of legal and administrative uncertainty. In general, there is also a risk that PPP projects will become more expensive than their possible purely public alternatives. The idea of a win-win situation and its extension to the area of services of general interest is criticised. There is a conflict of objectives. Politics is oriented towards the common good and therefore, when allocating resources, has to take into account the interests of those people who are unable to meet their needs, or who can only do so inadequately through their purchasing power. The main goal of a company, on the other hand, is to maximize profits for its owners. As a result, there is a risk that the range of services offered will deteriorate due to the exclusive contracts, which are usually monopoly-like.

Especially in Germany, the term PPP has been used in an undifferentiated manner since its inception and has been perceived in a fuzzy manner. It has been used to describe a wide range of activities and ideas that are only very remotely related to the original idea of PPP:

- PPP is a form of functional privatisation.
- The private financing of public construction services is sometimes referred to as PPP. PPPs are not financing models but organizational models. A financing service can very well be understood as a task.
- The term PPP is often associated in local authorities with the hope of being able to implement projects that could not previously be financed. It is true that a project cannot be implemented as a PPP without appropriate financial resources.

For the Attac organisation, the often practiced practice of keeping privatisation contracts secret is the biggest criticism of PPPs (Attac, 2011). It is therefore often not possible to make statements about the profitability of PPP projects. According to the principal-agent problem, the problem of asymmetrical distribution of information exists.

11. Discussion

In recent years there has been remarkably growing sensitivity to the issue of financing energy technologies with a long life-time. In addition, the number and variety of possible financing models has increased significantly. This gives hope for an optimistic dissemination of efficient and sustainable financing solutions for the provision of energy services in the next years.

Long-term financing models play an important role for the optimal implementation of long-life technologies in future green energy infrastructures from society's point-of-view, especially, with respect to three core areas: (i) investments in renewable energy technologies e.g. large solar thermal, PV, wind power systems, (ii) investments in new network infrastructure for electricity, district heating, hydrogen, charging stations for EVs and fuel cell vehicles, storage etc.; (iii) investments in energy efficiency for providing energy services more efficient, e.g. thermal insulation of residential or office buildings, more efficient lighting in schools, high-efficient motors e.g. in industry.

In any financing case, the decision ultimately boils down to whether there is an appropriate balance between risk and return-on-investment. The risk can be reduced by an appropriate regulatory body. The lower the risk is estimated, the lower is the expected return. In the end the state or public authorities will always have to bear the risk. Hence, the central question is: What amount of risk remains to be carried by the state? Of course, the risk should be as low as possible.

Hence, at least three major issues play a crucial role in assessing the performance of financing a specific project:

- Are the costs of capital (interest rate or WACC) justified (from societies' point-of-view)?
- What is the depreciation time accepted by the provider(s) of capital?
- What is the corresponding risk to get the money invested back?

Regarding these three issues, two examples with completely different, even opposite performance are described in the following.

First example: The risk is rather low for the investment in a public electricity grid, or an installation of efficient lighting in a school, or thermal retrofit of a multi-family dwelling, because these technologies are well established (once installed there are no competing technologies) and they have a secure technical life time.

Second example: The installation of a district heating system based on biomass comes with the following uncertainties: life time, size of the technology design, service demand, market price of biomass or the existence of a compensation system (e.g. if buildings are better insulated, oversized demand could decline, etc.).

Another specific category of problems is how in (social) housing investments in energy efficiency and/or renewable energy can be allocated to the rental costs in an acceptable way, i.e. how a "warm rent" can be financed. In this context, the question of acceptable depreciation periods is also important.

The approach of the North German city of Bottrop is interesting in this respect (Berger, 2018). Here, it was recognised that the greatest savings in energy consumption can be achieved by refurbishing apartments. Bottrop relies on feasible, low-cost methods: "If you insulate the upper floor ceiling, you have an effect that can be classified as between 90 and 95 percent compared to a completely new roofing, but it does not cost €30,000, only €3,000." As far as the distribution of costs for the refurbishment is concerned, the principle applies that the cold rents may increase, but the warm rent must remain the same. This concept is now being applied throughout the Ruhr area in Germany.

It is important to have a clear structure of the relevant dimensions regarding the environment and the boundary conditions the project is embedded in. Overall, we find that there are three key dimensions for financing durable technologies:

1. Is the environment of the investment regulated or non-regulated?
2. Is the investor a public or a private enterprise or a PPP?
3. Are the investments built solely on equity of the company or also on debts?

Regulation plays an important role in two aspects: Price regulation and assumption of risk. A very important finding is that practically all long-term investments, e.g. in the area of electricity or district heating networks, but also in office and apartment buildings are located in a strictly regulated environment. Price regulation is important in two dimensions:

- Allowance for apportionment to the rental costs.
- Approval of recovery of money by regulated tariffs, e.g. for electricity or district heating networks.

Regarding the nature of ownership—private, public or PPP—in general, there is no preference for one of these forms for long-term investments. While public companies are generally satisfied with lower returns, private ones are considered to be more efficient. However, this is also not a generally applicable and valid statement.

12. Conclusions

Our work proves that the room for manoeuvre in the "free" markets—in the economic system—is very small. In this private market, the limitation is given by the corresponding expected returns on investments. Furthermore, in the free capital markets, the periods for the repayment of loans are very limited and can only be realized under the marginal conditions of risk assumption by a third party—typically a government agency.

The most important conclusion of this work is that there is practically no degree of freedom in the market regarding choice of financing parameters as interest rate and depreciation time.

Another important conclusion is that the lower the investment risk the lower the expected returns-on-investment by the investors. Hence, practically all long-term investments, e.g. in the area of electricity or district heating networks, are located in a largely strictly regulated environment. The positive aspect is that this allows to apply lower interest rates, because it reduces risk for the investors.

In the end, the two most important characteristics are: (1) the more durable the technology, the more important the influence of public regulation; (2) private initiatives can practically only play a relevant role in niches, (3) foundations are the only realistic private opportunity for funding.

The three most interesting issues for the future are:

- Who will cover the risk?

It is very likely that also in future only public bodies will be available here.

- How will green bonds develop and how will these stimulate the investments?

The great expectation on green bond is that cheaper, easier access to larger quantities of capital for green investments will be available. And finally:

- Which new model approaches will be provided by the "free" competitive capital market?

With respect to this issue currently no reliable forecasts are possible.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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