Discount rates in energy system analysis

Discussion Paper

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Commissioned by the
Buildings Performance Institute Europe (BPIE)

May 2015

Content

Summary

The Buildings Performance Institute Europe commissioned Fraunhofer ISI to investigate the current status of existing options and use of discount rates in energy efficiency policy modelling, with a specific focus put on the building sector and taking studies from different countries into account.

Why are discount rates so important and high in the current climate and energy debates? What are they?

Discount rates reflect the capital cost and expected rate of return of investments, and are thus paramount to assess the costs and long-term benefits of different policy scenarios.

The harmonisation of present and future values within an economic assessment of investment opportunities or within economic systems requires discounting of payment and income streams. This allows a conversion of future outcomes into annualised costs at present value. Thus, outcomes such as overall (social) costs of different policy options or the economic assessment of energy efficiency potentials are highly influenced by the choice of discount rate.

This paper summarises the role of discount rates in energy system analysis with two perspectives:

- Social discount rates are applied for evaluating total costs and benefits of energy systems from a societal perspective;
- Individual discount rates are applied to model investment decision making reflecting the expected return of an investor.

The risks to consider as well as the different approaches taken in energy system analysis and policy evaluation are described. Based on the examined case studies the following conclusions can be drawn for future definition of discount rates:

For the use of social discount rates in energy system analysis:

- Considering the methodology to derive social discount rates, the applied discount rates by government agencies as well as discount rates used in the analysed energy scenarios, social discount rates for EU Member States can be assumed to be in a range between 1 % - 7 %.
- The social perspective should be reflected by risk-free discount rate declining over long time horizons. Interest rates of government bonds with long-term maturity can serve as a good proxy which is easily observable.

For the use of individual discount rates of investors in energy system analysis:

- Discount rates should be differentiated according to different investors.
- For households, discount rates should reflect the market price of capital. Considering that the market price rather depends on the individual economic situation of the household than on the applied technology, a differentiation of discount rates by socio-economic parameters of individual investors is recommended.
- Following the concept of expected rate of return, higher discount rates should be assumed for commercial and industrial investors, than for private investors in the household sector. The level of discount rates for commercial and industrial investors applied in the analysed studies range from 6 % to 15 %. For households, the range is between 3 % and 6 %, except in the PRIMES model.
- The use of high discount rates to map non-economic barriers and bounded rationality is not suitable. In order to simulate real-world investment decisions, it is rather recommended to apply behavioural models which consider individual decision criteria as well as barriers to energy efficiency explicitly.

1 The role of discount rates in energy system analysis

The harmonisation of present and future values within an economic assessment of investment opportunities or economic systems requires discounting of payment and income streams. This allows a conversion of future outcomes into annualised costs at present value. Thus, outcomes such as overall (social) costs of different policy options or the assessment of energy efficiency potentials are highly influenced by the choice of discount rate. With regard to energy system analysis, two types of discount rate need to be distinguished [1]. The first one reflects the perspective of an individual investor (descriptive approach), whereas the second one reflects a social perspective (prescriptive approach).

1.1 Individual investor perspective

From an individual investor perspective, discount rates are applied as a behavioural parameter to model economic investment decision making. Therefore, this type of discount rate is also described as a “behavioural discount rate” [2]. The fourth assessment report of the IPCC denotes it as a descriptive approach of discounting “*based on what rates of discount people (savers as well as investors) actually apply in their day-to-day decisions.”* [3, p. 136]. In economic theory, it reflects the cost of capital being the “*expected rate of return demanded by investors in common stocks or other securities subject to the same risk as the project*” [4, p.18].

Accordingly, the discount rate determines different dimensions within economic evaluation of investment opportunities, as follows:

- <u>Forward-looking</u>: It defines how an investor weighs present expenditures or revenues towards future ones expressing individual time preferences
- <u>Opportunity costs</u>: It is a measure of alternative investment opportunities that an investor could follow instead, revealing the individual investor’s expected return.
- <u>Market price of capital</u>: Following the previous point, discount rates are directly linked to the interest rate on the capital market: on one hand, as a measure of alternative investment opportunities, on the other hand, to express the cost of capital to finance an investment opportunity.
- <u>Risk</u>: It evaluates the risk of an investment opportunity.

1.1.1 Risk considerations

With regard to energy system related investments, a risk evaluation might include policy-induced risks, country-specific risks, as well as technology-related risks [5].

Policy-related risks refer to the respective support framework, in case income streams are uncertain over the lifetime – e.g. retroactive adjustment of feed-in tariffs or quota systems – whereas country-specific risks are associated with the specific economic situation. Technology-related risks are especially relevant for technologies at an early stage of market maturity considering higher failure rates due to less experience. Nevertheless, these risk components might already be included in the market price for capital, especially if standardised financial products are available for energy efficiency investments. Policies such as low-interest loans address potential risk surcharges by lowering financing costs for investors and thus, their individual discount rates. Regarding energy efficiency investments in the building sector, the majority of investors are private households who are more likely to face risk surcharges linked to their individual socio-economic situation. Therefore, distinguishing discount rates with respect to age and income is reasonable in an energy system analysis (see 2.2.)

1.1.2 Modelling technology diffusion

Following the presented concept of expected rate of return, discount rates of private investors (households) should generally be below the discount rates of commercial or industrial investors. Some energy system models consider discount rates as a parameter in model technology diffusion. Thereby, high discount rates are justified by an implicit representation of financial constraints, information gaps or bounded rationality (other decision criteria) in the behavioural model of an investor.

However, discount rates are only relevant if an investor performs a dynamic evaluation of economic efficiency (e.g. net present value). If the existence of non-economic barriers and other decision criteria is considered to be relevant, an application of purely economic optimisation is obviously not the correct measurement to simulate investor decision making and thus, discount rates are not appropriate as a parameter for capturing barriers and other decision criteria. Therefore, models which aim to simulate real world behaviour instead of optimisation of energy systems use other methods (e.g. logit approach[1]) to consider market failures in modelling technology diffusion. For an overview of simulation models for the building sector and methods to incorporate individual decision making, refer to [6].

[1] see Train (2002). *Discrete Choice Methods with Simulation. http://eml.berkeley.edu/books/choice2.html*

1.2 Social or macro-economic perspective

The social perspective follows a prescriptive approach and is also denoted as “evaluative discount rate” [2]. For instance, it is applied for a comparison of total costs and benefits induced by different policy instruments. Contrary to the individual investor perspective, market failures as well as individual risk should not be included in a social discount rate. According to Kolstad et al., there is a consensus favouring “*declining risk-free discount rates over a long time horizon*” to describe the social perspective [7, p. 6]. Thus, the social discount rate is determined by the social rate of time preference weighting intergenerational welfare. There remains the question of the level of this time preference compared to the individual or observed discount rate on capital markets. The following reasons argue that the social time preference rate is lower (higher weight on future benefits) than the individual time preference [4,cited in 5]:

- Free-rider issue: Individuals save and invest less than is optimal for society
- Individuals as part of society: Individuals have different inter-temporal preferences depending on whether they act as a citizen of society or as a consumer. In the citizen role, lower discount rates are applied than in the consumer role, which is especially evident in an assessment of environmental resources.
- Market interest rates missing intergenerational preference: Market interest rates are based on the time preference of the current generation. Since the life time of individuals is limited, the individual time preference rate is higher than the one considering preferences of future generations. An application of market interest rates to evaluate policy outcomes bears the risk that favourable framework conditions for investments, important for future generations, are not developed. This is particularly relevant for a transformation of the energy system and climate mitigation measures which exhibit long time horizons.

1.2.1 Deriving social discount rates

In order to derive the level of the social rate of time preference, two methods have been suggested in literature [10]. One method uses the after tax rate of government bonds or other low-risk marketable securities as a proxy. The advantage of this approach is that these values are easily observable on the capital markets. However, as described above, market interest rates reflect individual rather than societal time preferences. The other method calculates the social rate of time preference based on the so-called *Ramsey* formula which is composed of the following three parameters [10,11]:

$$SRTP = \rho + \theta \cdot g$$

$SRTP$	*Social Rate of Time Preference (social discount rate)*	
ρ	*Utility discount rate reflecting pure time preference*	*~0.1 % – 3 %*[2]
θ	*Elasticity of the marginal utility of consumption*	*~1 % – 2 %*[2]
g	*Long-term average of real GDP growth per capita*	

A determination of the average GDP growth rate is straightforward, whereas an estimation of the other two parameters is more complicated. However, they have been analysed empirically in various studies [10]. One of these studies is the well known Stern Review [12] which calculates a social discount rate of 1.4 % based on the Ramsey formula. **Figure 1** shows the range of social discount rates resulting from the combination of different estimates of these parameters. The social discount rate is calculated for four different levels of long-term average GDP growth rates per capita. With regard to the economic development in Europe with an average growth rate between 1 and 2 % in the last ten years, a range of social discount rates between 0.5 % and 6.9 % can be justified based on this method using the estimators derived in empirical studies. On average, a discount rate of 2.6 % results for a per capita GDP growth of 1 % per year. For a GDP growth of 2 % per year, the discount rate would be 3.9 %.

2 Range of *utility discount rate* and *elasticity of the marginal utility of consumption* determined in empirical studies surveyed by Zhuang et al. [10]

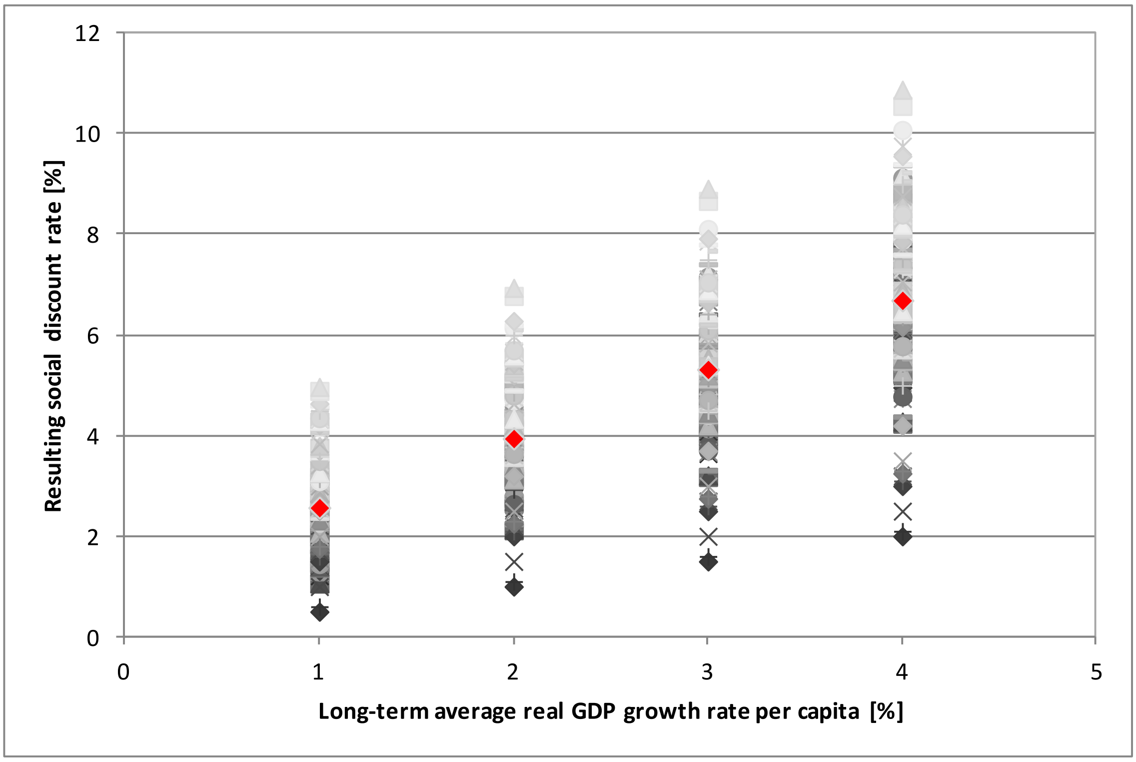

Figure 1: Calculated social discount rate for different GDP growth rates (Source: Own calculation based on meta-analysis by [10])

Another approach suggests the social discount rate to be approximated by the marginal pre-tax rate of riskless private investments based on the concept of social opportunity costs [10]. Applying this approach for the United States based on annual yields of long-term corporate bonds with AAA rating in the period from 1947 until 2005, Boardman et al. [13] calculated a social opportunity cost rate of 7.3%. Other approaches attempt to reconcile both methods in order to calculate the social discount rate[3].

[3] “Weighted average approach” and “shadow price of capital approach”. For a detailed discussion of the different approaches refer to [10]

2 Applied discount rates in energy system analysis and policy evaluation

2.1 Discount rates applied by public agencies

Since there is a wide range in the level of social discount rates depending on the methods and estimators, discount rates of countries and individual public agencies used for an assessment of public investments vary. **Table 1** compares the current discount rates of Germany, United Kingdom and the United States specified by the respective agencies for economic efficiency evaluations of long-term investment projects[4]. Both Germany and the United States derive discount rates based on observed market values of long-term government bonds, whereas the UK applies a calculation of social time preference based on the Ramsey formula.

Table 1: Comparison of discount rates applied by different countries (Sources: [14–17])

Country	Agency	Discount rate
Germany	Federal Finance Ministry	1.7 % nominal (base 2013) Based on government bonds with same period for long-term investments: 2.54 % average 2013 for 30 years
United Kingdom	HM Treasury	Based on calculation of social rate of time preference 3.5 % for 0 – 30 years 3.0 % for 31 – 75 years declining to... 1.0 % for 301+ years
United States	Department of Energy (DOE)	Based on long-term treasury bonds averaged over a 12-years period. Discount rates related to energy conservation and RES: 2.5 % nominal /3.0 % real (2013)

[4] For an overview of discount rates applied by public agencies in different countries (database before 2008) see also [33]

2.2 European energy scenarios

In this section, the discounting approach of the PRIMES model used in the impact assessment of the 2030 targets [18], as well as in reference projections of the European Commission, is compared to the approach applied in the evaluation study of the current energy efficiency policy framework in the EU [19] which was also commissioned by the European Commission (DG-ENER).

Table 2 shows the discount rates of the PRIMES model which are differentiated by sectors. Non-economic barriers are represented in the discount rates, leading to relatively high values for the household sector. No differentiation is made between the individual investor and the social perspective. Thus, the same discount rates are applied to model technology diffusion and to evaluate total system costs on a macro-economic level.

Table 2: Discount rates applied in the PRIMES model (Source: [18])

Discount rates	Standard PRIMES	Modified due to EED	
		2015	2020 - 2050
Power generation	9 %	9 %	9 %
Industry Sector	12 %	12 %	12 %
Tertiary Sector	12 %	11 %	10 %
Public Transport	8 %	8 %	8 %
Trucks/ Inland navigation	12 %	12 %	12 %
Private cars	17.5 %	17.5 %	17.5 %
Households	17.5 %	14.75 %	12 %

The study evaluating the energy efficiency policy framework applies sector-specific bottom-up models (FORECAST, INVERT/ EE-Lab, ASTRA) to calculate scenarios until 2030. Discount rates are not only differentiated by sector but also by end-uses and countries. In addition, the building sector model differentiates investors by socio-economic properties (income, age) (Table 3). The study assumes different levels of discount rate in the different scenarios reflecting policy assumptions and impacts. Furthermore, discount rates are not as important to technology diffusion as in the PRIMES model since barriers are also taken into account by other factors such as low amortization times or explicit modelling of preferences, risk aversion and information gaps.

Table 3: Discount rates applied in the evaluation of the energy efficiency policy framework in the EU (Source: [19])

Sector	Scenario	Model	Discount rate
Household – Space heating and hot water	All	Invert/ EE-Lab	3.1% to 3.7%
Tertiary – Space heating and hot water	All	Invert/ EE-Lab	4.7% to 5.4%
Household - Appliances	AM Potential_2030_LPI	Forecast	Typically 6% (discount rates vary between different countries, appliances)
	Potential_2030_HPI Potential_2030_NE	Forecast	2% (assuming removal of barriers from 2020)
Tertiary - Appliances	Base_NoEA	Forecast	40%
	Base_inclEA / Base_WM	Forecast	30%
	AM	Forecast	20%
	Potential_2030_LPI	Forecast	15%
	Potential_2030_HPI	Forecast	5%
	Potential_2030_NE	Forecast	5%
Industry	Potential_2030_LPI	Forecast	Paypack time ≤ 2 a accepted by 50% of companies heating systems: 15%
	Potential_2030_HPI	Forecast	Paypack time ≤ 5 years accepted by 60% of companies heating systems 15%
	Potential_2030_NE	Forecast	Companies accept longer payback periods heating systems 3%

2.3 Discount rates applied in energy system analysis for Germany

The following overview summarizes the role of discounting and the justification for the different levels of discount rates in recent energy scenarios for Germany.

"Lead Study" –Long term scenarios for the development of RES in Germany (2004, 2007, 2008, 2010, 2012) [20–24]	
Commissioned by	Federal Ministry of Environment, Nature Conservation and Nuclear (BMU)
Compiled by	DLR Institute of Technical Thermodynamics, IfnE, Fraunhofer IWES (only 2012)
Scope	The "Lead study" has been commissioned by the BMU regularly since the year 2004. It analyses long-term scenarios for the future development of renewable energy sources in Germany until 2050. The analysis focuses on the supply side evaluating costs of electricity and heat generation technologies. Energy efficiency measures (e.g. retrofitting of buildings) are not considered in the system cost analysis.
Discounting	All studies assume a discount rate of 6 % to reflect financing costs. The approach of the study is normative, that is the discount rate is mostly relevant for the assessment of overall costs (social perspective), not for the results in terms of technology diffusion.

Energy scenarios for an Energy Concept of the Federal Government (2010) [25] **and Energy reference projection (2014)** [26]	
Commissioned by	Federal Ministry of Economics and Energy
Compiled by	Prognos, EWI, GWS
Scope	The study is the scientific basis for the targets defined in the "Energy Concept" and the "Energiewende" by the German government in 2010. The same model framework has been applied in the follow-up study which was published in 2014. The study models normative scenarios for the whole energy system in Germany until 2050 including an economic impact analysis with a macro-economic model.

Discounting	Discount rates are not applied to evaluate the overall results of the study. Instead costs and benefits of each scenario are evaluated towards a reference development by comparing economic indicators such as GDP or employment. On an individual perspective, market interest rates are assumed as discount rates. The interest rate to finance RES-E is assumed to be 7%[5]. However, investments which are not economically feasible under market conditions are still considered, depending on the policy assumptions in the scenarios. Thus, discount rates do not play a significant role in the overall results in terms of technology diffusion as well as in terms of assessment of economic impacts.

Policy Scenarios for climate protection VI (2013) [27]	
Commissioned by	UBA Umweltbundesamt
Compiled by	Oeko-Institute, Fraunhofer ISI, IEK-STE, DIW
Scope	The study analyses the impact of different policy instruments on the energy demand and supply as well as total greenhouse gas emissions. It follows an explorative approach to model the energy system in Germany until 2030.
Discounting	The study differentiates between social discount rates to evaluate the overall results of the scenarios and individual investor specific discount rates. With regard to the social perspective, a discount rate of 3.5 % is assumed. This is based on the interest rate of government bonds with 10 years maturity. On the individual investor perspective, discount rates are differentiated between private households and commercial/industrial investors. A discount rate of 4 % is assumed for private investors in the household sector which is reasoned by the average long-term capital market interest rates. For all other sectors, a discount rate of 8 % is assumed. It is justified by higher profit expectations of commercial and industrial investors.

5 If the same discount rate is assumed for investments in energy efficiency measures and heating systems is not explicitly stated.

Development of an integrated heating and cooling strategy for Germany (2012, 2013) [28–31]	
Commissioned by	Federal Ministry of Environment, Nature Conservation and Nuclear (BMU)
Compiled by	Fraunhofer ISE, Fraunhofer ISI, Oeko-Institute, BEI, IREES
Scope	The first part of the study calculates explorative policy scenarios to evaluate the impact of policy instruments for the heating and cooling sector. The second part analyses long-term developments of the building sector by modelling normative scenarios until 2050. The study uses the model Invert/EE-Lab including its agent-specific decision module which considers the individual decision making behaviour of different investor agents.
Discounting	Discount rates as a parameter for technology diffusion are less important within this study since it aims at an explicit consideration of individual decision criteria and barriers such as risk aversion or information gaps. Thus, discount rates on an individual investor perspective are only relevant for investors which are assumed to assess investment opportunities based on a net present value calculation. Results of the normative scenarios until 2050 are assessed from a macro-economic perspective as well as from the individual investor perspective. The latter applies a discount rate of 4% for private investors and 7.6% for commercial investors. For the macro-economic evaluation, different sensitivities are calculated ranging from discount rates of 0 % to 7.5%.

Costs and potentials of greenhouse gas abatement in Germany (2007) [32]	
Commissioned by	BDI –Federation of German Industries
Compiled by	McKinsey & Company
Scope	The study analyses costs and potentials of greenhouse gas abatement measures in Germany until 2030.
Discounting	The study differentiates the social/macro-economic and the individual investor perspective. For the macro-economic evaluation a discount rate of 7 % is assumed. For the analysis of the potentials from the individual investor perspective, discount rates of 4 % for private households and 9.5 % for industry are assumed. Furthermore, different amortization periods are assumed in the individual investor and in the macro-economic evaluation.

3 Conclusions

Discount rates are a crucial parameter in energy system analysis whereby two types need to be differentiated:

- Social discount rates are applied for evaluating total costs and benefits of energy systems
- Individual discount rates are applied to model investment decision-making based on leverage costs of energy (NPV) calculation reflecting the expected return of an investor

Recommendations for the use of social discount rates in energy system analysis:

- Considering the methodology to derive social discount rates, the applied discount rates by government agencies as well as discount rates used in the analysed energy scenarios, social discount rates for EU Member States can be assumed to be in a range between 1 % - 7 %.
- Thereby, the social perspective should be reflected by risk-free discount rate declining over long time horizons. Interest rates of government bonds with long-term maturity can serve as a good proxy which is easily observable.

Recommendations for the use of individual discount rates of investors in energy system analysis:

- Discount rates should be differentiated according to different investors.
- For households, discount rates should reflect the market price of capital. Considering that the market price rather depends on the individual economic situation of the household than on the applied technology, a differentiation of discount rates by socio-economic parameters of individual investors is recommended.
- Following the concept of expected rate of return, higher discount rates should be assumed for commercial and industrial investors, than for private investors in the household sector. The level of discount rates for commercial and industrial investors applied in the analysed studies range from 6 % to 15 %. For households, the range is between 3 % and 6 %, except in the PRIMES model.
- The use of high discount rates to map non-economic barriers and bounded rationality is not suitable. In order to simulate real-world investment decisions, it is rather recommended to apply behavioural models which consider individual decision criteria as well as barriers to energy efficiency explicitly.

Generally, it is recommended to calculate sensitivities on the range of discount rates to capture the influence of this parameter on the overall results.

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