Building Deep Energy Retrofit: Using Dynamic Cash Flow Analysis and Multiple Benefits to Convince Investors

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Abstract

Deep energy retrofit (DER) of the existing building stock is a meaningful strategy to reduce fossil fuel consumption and CO_2 emissions. However, the investment volumes required to undertake DER are enormous. In Europe, cumulative demand for DER is estimated at close to 1,000 billion EUR until 2050. Public expenditures and political measures can help to stimulate DER, but substantial private investments are required to achieve significant results.

In this paper, we analyze the economic and financial implications for investors renovating an office building to the 'Passive House' standard. This is achieved by applying a dynamic Life Cycle Cost & Benefit Analysis (LCCBA) to model the cash flows (CF). The model also includes an appraisal of debt and equity-financing implications, and a multi-parameter sensitivity analysis to analyze impacts of input parameter deviations. In the second part of the paper, we use the 'Multiple Benefits' (MB) concept to identify project-based co-benefits of DER, to make the business case more attractive. We categorize the identified MBs in: 1) monetary, 2) unquantified project, and 3) societal benefits.

Results show that the DER project cash flow over a 25-year period achieves a 21-year dynamic payback with an IRR of below 2%. Levelized Cost of Heat Savings is 100 EUR/MWh with a 70% capital expenditure and 15% interest cost share. The Loan Life Cover Ratio comes out to 1,2. To make the business case more attractive, pecuniary MBs identified are increased rents, real estate values, (employee) productivity, and maintenance costs and CO_2 savings, in addition to societal benefits.

Compared to simpler economic modeling, the dynamic LCCBA cash flow model provides solid grounds for DER business case analysis, project structuring and financial engineering, but also for policy design. CFs from future energy cost savings alone are often insufficient in convincing investors. However, they can co-finance DER investments substantially. Consideration of MBs can offer meaningful monetary contributions, and also help to identify strategic allies for project implementation; however, the 'split incentive' dilemma is still present. Furthermore, the approach supports policy makers to develop policy measures needed to achieve 2050 goals.

1. Introduction

The energy saving potential in the building sector is enormous. Deep energy retrofit (DER)[1] of the existing building stock would be a meaningful strategy to reduce fossil fuel consumption and transition towards a decarbonized energy system. However, at current building renovation rates of below 1%/a, it appears to be largely under-developed. To pursue this strategy on a level capable of achieving climate protection goals, enormous

[1] As defined by IEA Annex 61, a Deep Energy Retrofit is a major building renovation project in which site energy use intensity, including plug loads, has been reduced by at least 50% from the pre-renovation baseline.

investment volumes would be needed. For example, in Europe, cumulative investment demand for DER until 2050 is estimated at 937 billion EUR (present value) in the Buildings Performance Institute Europe's "Deep" scenario (BPIE 2011). This amount cannot be financed from public sectors alone, and will require substantial private sector engagement. A similar situation can be assumed for many other parts of the 'developed' world.

If the assumption for the necessity of more private sector involvement is true, a thorough understanding of the economic and financial implications of DER project cash flows (CF) are needed as a basis for further discussion and strategy development with relevant stakeholders. Likewise, it is important to communicate and present investment opportunities in a business language that potential investors are familiar with. Technical performance parameters of energy efficiency (EE) measures, or static economic analysis, are less meaningful and unlikely to attract interest from financial decision makers. Therefore, this requires a dynamic CF modeling, and economic and financial key performance indicators (KPI) including sensitivity and risk analysis, of DER. The goal of the first part of the paper is to shed light on these questions.

Given the long payback time of more than 20 years for most DER cases, the economic rationale cannot be justified by CF from future energy cost savings alone, nor could these CFs convince potential investors. By applying the concept of the 'Multiple Benefits of Energy Efficiency' (IEA 2014) to the context of DER, we are attempting to capture additional benefits, revenues, and drivers on the microeconomic level. The purpose of this application is to find approaches on how to make the business case more attractive to investors, which is the focus of the second part of the paper.

The application of MBs for building DER is supported by other authors as well. Among others, the BPIE states that "limiting the discussion about energy efficient buildings only to climate change considerations would ignore the many additional benefits which are created through the retrofitting of the European building stock. The revitalization of urban quarters, improved comfort levels and quality of living and working spaces, helping people out of fuel poverty and creating long term employment are just some of the many positive effects." (BPIE 2011) However, there is no discussion on providing quantifications for the MBs of DER. The Rocky Mountain Institute provides guidelines on "How to calculate and present deep retrofit value." These guidelines state "These types of retrofits reduce operating costs and are able to improve the satisfaction and health of occupants", highlighting multiple stakeholders and beneficiaries of DER, and its benefits beyond just energy cost savings (RMI 2015). Other authors focus more on technical implications of DER and the need for an integrated design approach during building design phase in order to achieve nearly zero energy buildings (nZEB), mainly for new buildings (Integrated Design 2017). As a common theme, all authors highlight the actuality of MBs of EE measures and their multiple beneficiaries on individual, institutional and societal levels. At the same time, approaches for quantification and integration, particularly on the project level, are still rare.

This paper presents work that is original content and has not been published before. After the methodology section, we present a DER office building case study. This is followed by an analysis of relevant MBs in the context of DER, focusing on quantification approaches on the project level to allow integration into the business case. The modeling does not focus on topics such as tax, public debt or policy implications - the latter are addressed in the conclusion section only. In addition to approaches to MB quantification, results are discussed from the perspectives of potential investors, building users and financiers.

2. Methods

2.1 DER case study and dynamic Life Cycle Cost Benefit Analysis

For the first part of the paper we use a case study (Yin 2014) to assess economic and financial implications of a DER project (including building envelope insulation to the 'Passive House' standard). This bottom-up approach is based on a real life DER project (Passive House Institute 2015). The capital expenditures (CAPEX) of the DER are based on actual construction costs, excluding the general, non-energy related costs of the building renovation ("Differential Cost" approach, also referred to as "Anyway cost"). A cost reduction results from the application of so-called "cost-efficient passive house components" for windows and doors.

The economic and financial Life Cycle Cost Benefit Analysis (LCCBA) is built on a dynamic cash flow model of the DER case study, with a focus on the perspectives of potential investors and financing institutions. For this purpose, the projected income and expense CFs are modeled[2] over an entire project cycle of 25 years. Economic KPIs are the internal rate of return (IRR), the net present value (NPV) and a dynamic amortization period, sepa-

[2] with the degree of detail of a pre-feasibility study

rately for the project (P-CF) and the equity cash flow (E-CF). Furthermore, the 'Levelized Cost of Energy' (LCoE) (IEA, NEA 2015) concept is applied to calculate levelized cost of energy savings as a simple comparison variable to different energy supply and savings variants. On the financing side, the influence of typical debt ratios of 70% on the remaining equity CF, as well as liquidity, is examined using the financial KPIs 'Cash Flow Available for Debt Service' (CFADS) and the 'Loan Life Coverage Ratio' (LLCR).

The analysis also includes a multi-parameter sensitivity analysis of the IRR and NPV with respect to deviations of relevant input parameters, e.g. investment costs (CAPEX), operating costs (OPEX), price development of the energy cost baseline or project duration, and to determine threshold values for MB contributions. Throughout the paper, all monetary figures are excluding VAT, and tax effects are not considered.

2.2 Inclusion of Multiple Benefits

Investments in energy-saving projects often produce benefits beyond reduced energy consumption and peak demand. Many of these benefits contribute to the objectives of organizations implementing the projects and can have significant added value for those making investment decisions (SEEAction, 2012). These benefits are not always understood or quantified. However, when energy-saving projects are only marginally attractive to investors or lack support from other stakeholders, a thorough understanding of the benefits and internalization of key benefits in economic analysis can make the difference between projects moving ahead or not. Since these impacts are usually beneficial to investors, other stakeholders, and society, we use the term Multiple Benefits (MBs) to describe them, as used by the International Energy Agency in their 2014 paper "Capturing the Multiple Benefits of Energy Efficiency" (IEA, 2014). The terms Non-Energy Benefits (NEBs) and Non-Energy Impacts (NEIs) are also common.

A growing body of research recommends the systematic assessment of MBs for both individual energy efficiency projects and for analysis of policies or programs encouraging EE. When evaluating EE programs, the Regulatory Assistance Project (RAP) recommends classifying benefits according to their primary beneficiary: Participant (individual or business implementing the project), Utility (electric utility or fuel delivery companies that deliver energy to the Participant), or Society in general (Lazar and Colburn, 2013). For analysis of project-specific benefits of the case study described in this paper, the differentiation between Utility and Society benefits was not deemed to be important, nor was in-depth investigation of MBs in either of those categories. A more important distinction was between MBs that apply to different stakeholders within the Participant category. Figure 1 presents an adapted MB classification scheme for individual projects that includes common scenarios of Participant facility ownership: "Occupant/Owner" (one who owns and occupies the property), "Lessor/Owner" (one who owns and leases the property), and "Property Developer" (one who owns the property but intends to sell after upgrades are completed). These labels represent possible stakeholder scenarios and each one would not necessarily exist for every project.

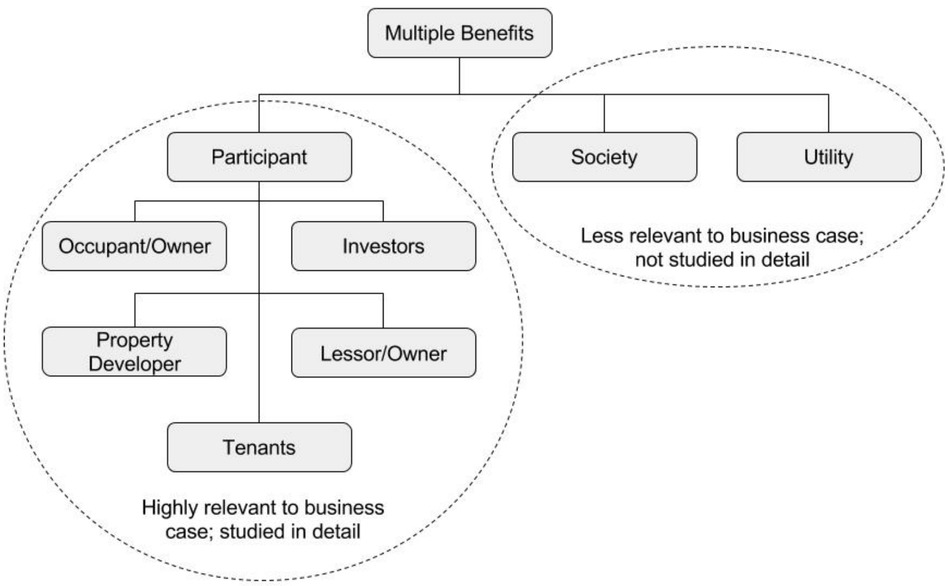

Figure 1: Classifications of multiple benefits according to primary beneficiary

Regardless of the classification scheme used, any individual MBs may be relatively easy or difficult to quantify. Methods of quantification vary widely between benefits, and depend on the desired accuracy of financial estimates. Decisions regarding policy or public investment in energy efficiency programs often estimate MBs as a numerical multiplier applied to estimated energy savings; a higher degree of accuracy is typically sought when evaluating MBs at the project level. Those MBs that cannot be quantified should still be discussed with stakeholders as they often have some bearing on investment decisions, and can help identify new potential investors. For the case study project introduced in Section 3, a five-step methodology was followed to include MBs:

1. List all potentially significant MBs for the project;
2. Classify each MB according to the primary beneficiary: Participant, Utility or Society, as well as any important sub-classifications;
3. Decide which benefits can be quantified, select quantification methods, and quantify in either financial or non-financial terms;
4. Incorporate significant financial results into economic analysis; and
5. List un-quantified and quantified non-financial MBs as additional arguments to support the project.

For the case study described in this paper, individual Participant benefits are investigated in sections 4.1 through 4.5, and benefits for Utility and Society are identified in section 4.6. Several benefits were quantified according to various methods that are currently available, and are described in the respective subsections, with those that could be readily expressed in financial terms then included in project economic analysis.

3. Deep energy retrofit (DER) case study and LCCBA model

In this section a DER office building case study is analyzed with a dynamic Life Cycle Cost & Benefit Analysis (LCCBA) to model project and equity cash flows. The goal is to better understand economic and financial implications of DER projects, and to appraise debt and equity financing implications. This model shall serve as a basis for business case analysis, MB evaluation and discussion of results for different stakeholders.

The case study concerns a 1960´s era office building, with 1,680 m^2 of heated area, situated in southern Germany. The building was renovated to the 'Passive House' (PH) standard in the years 2010/11. The EE renovation included ceiling, wall, and basement insulation, windows and doors (with cost-efficient PH components), airtightness, ventilation, heating, and lighting retrofit. The investment costs of the DER amounted to 0.56 million EUR or 330 EUR/m^2.[3]

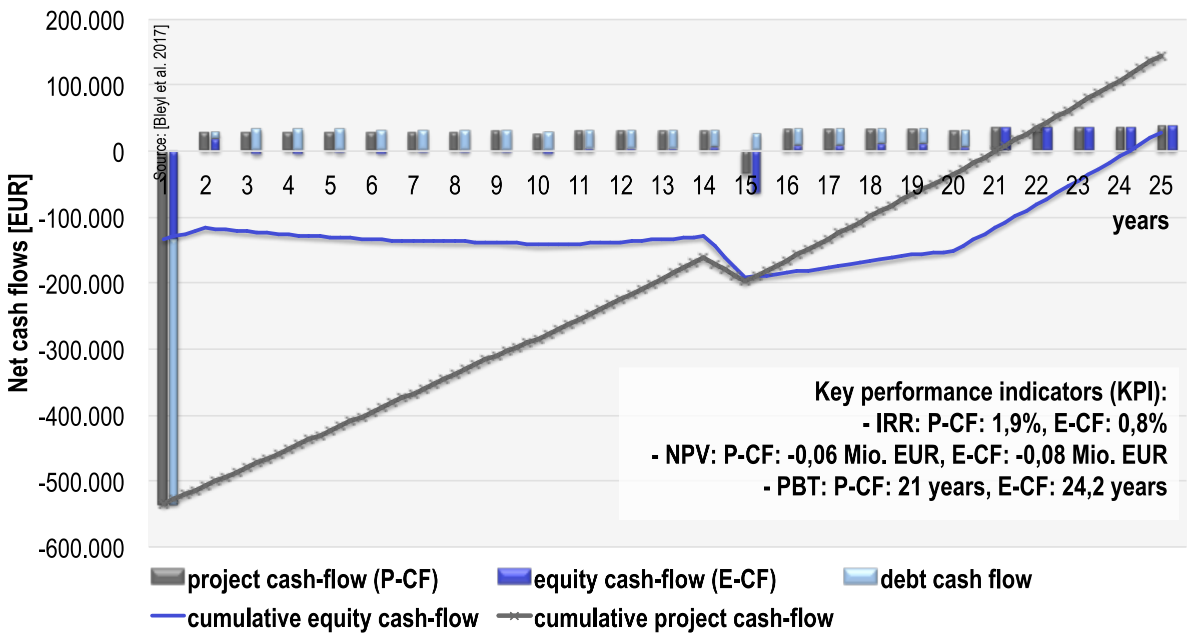

Figure 2: Net project, equity and debt cash flows (annual and cumulative)

The energy costs before the renovation (baseline) were 45,000 EUR/year (36,500 EUR/year for gas and 8,500 EUR for electricity). After DER, Gas costs are reduced by 88% after the renovation; electricity cost savings are limited to 17% due to the additional ventilation systems. The energy and all other price increases are assumed to

[3] According to the differential cost approach, this figure excludes general, non-energetically relevant costs of the building renovation of 167 EUR/m^2 for building site equipment, scaffolding, plastering, facade, fire and noise protection ...

be on average 1.5% per annum. From the 6th year onwards, building users participate in the savings with 3% as a small incentive. Maintenance cost savings are not factored into the business case, however, additional maintenance cost for ventilation systems are accounted for. The cost for a general overhaul of the heating system in year 15, as well as regular lamp replacements, is also included.

Financing of the investment is modeled with a mix of 75% debt capital (20 years term with an effective interest rate of 2.52%) and 25% equity with a yield expectation of 4.5% for the Weighted Average Cost of Capital "WACC" calculation. No subsidies were accounted for to avoid distorting the results. CAPEX is refinanced from the future savings cash flow over a 25-year project term.

Results of the LCCBA CF analysis are displayed in Figure 2. The analysis of the project CF over 25 years results in accumulated energy cost savings of EUR 810,000 resulting from an investment of EUR 550,000, and maintenance costs of EUR 120,000. The result is a positive P-CF of EUR 145,000, with an internal rate of return of just 1.9%, a negative NPV of EUR -62,000, and a dynamic payback period of 21 years. For the equity-CF an IRR of 0.8% results with a payback period of 24 years; discounted at 4.5%, the NPV of the E-CF is -77,000 EUR (Figure 2). The sensitivity analysis in Figure 3 shows the influence of a percentage change of selected input parameters on the project IRR[4].

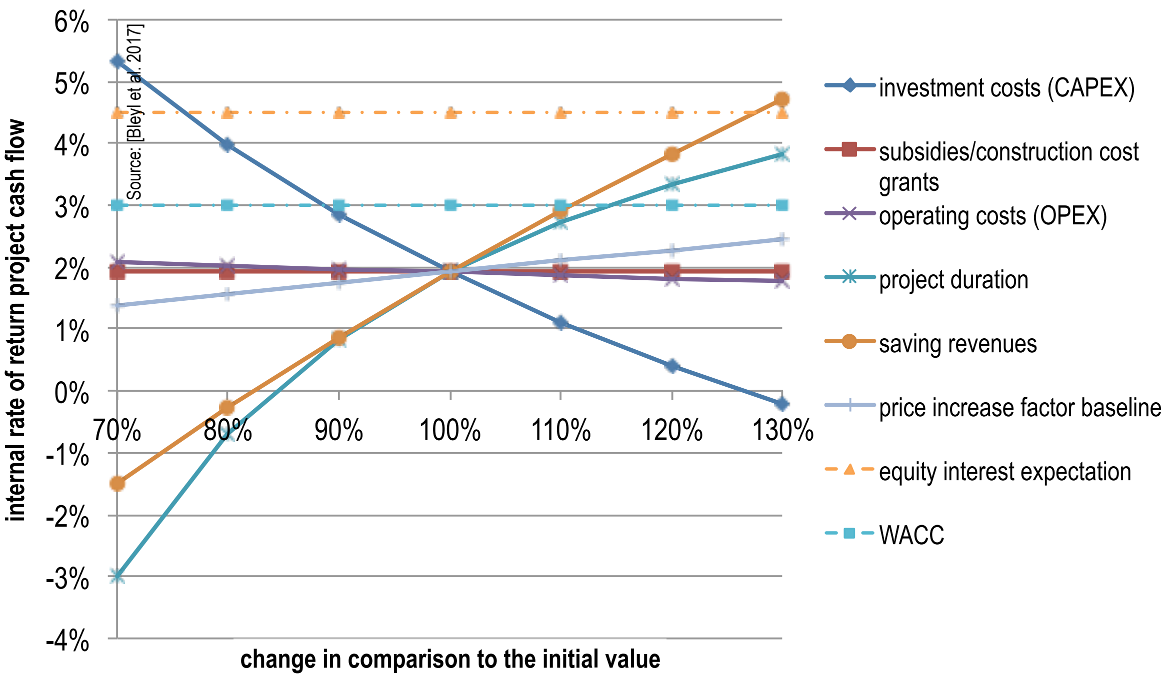

Figure 3: Sensitivity of project IRR to relative change of input parameters

Investment costs, followed by saving revenues, project duration, and baseline price development, are the most sensitive to relative changes of input parameters. For a break-even with the WACC (NPV = 0), the CAPEX would need to be decreased by 11% or the savings increased by 10%, respectively a 13% longer project duration.

The DER business case results will be discussed after the next section on MBs in building DER.

4. Multiple Benefits in Building DER

Energy efficiency measures such as the above example of a DER business case induce 'Multiple Benefits' beyond energy cost savings. In this section, we identify, structure, and - where possible - monetize relevant MBs for different stakeholder groups. The primary goal is to identify sources of additional revenues for DER business cases. In a broader picture, co-beneficiaries, who might have a vested interest to become strategic allies for DER programs, shall be identified. MBs are grouped in 1. Financially quantified (sections 4.1 – 4.4) and 2. Unquantified project Participant benefits (section 4.5). Beyond the project level, 3. Benefits to society and utilities are shown in section 4.6.

[4] The model provides a similar analysis for the equity IRR and NPV

4.1 Higher work productivity

An office building DER leads to an improvement in comfort for the building occupants through enhanced indoor climate and air quality. Wall insulation, and triple glazing of windows, also lowers noise and smog infiltration. Switching to LED lighting allows for greater adjustable illumination. Increased comfort will also reduce the incidence of sick leave of employees, which, using the Netherlands as an example, can account for 4% of salary costs[5]. Improvement in work productivity of office building workers has been linked to direct impacts such as lowered risk of illness, and to indirect physical and mental health benefits (Thomson et al., 2013).

The satisfaction scores of employees can be measured by performing a web-based comfort survey tool[6] with the building occupants, to assess the impact of the working environment (thermal environment, etc.) on work productivity. In a performance-based contract, the Comfort score can be used as an additional performance target in addition to the usual energy-saving target. Therefore, the energy service provider will become financially motivated to optimize the comfort satisfaction and thus productivity of the building occupants. Results show an increase in productivity of about 0,3% is possible, equating to 80.000€ per year in an office of 10.000m², or 8€/m^2 per year[7]. This is approximately 50% of the value of energy cost savings of a DER, and is significant as the productivity of the staff can be greater than 100 times higher than the energy cost. On top of this productivity advantage, the expected saved costs due to reduced sick leaves - which is presently not yet quantified - should be added.

The above observation may provide one reason why successful companies invest in high quality office space for their employees. The same logic can apply to higher productivity in industrial production processes, where the value may be much higher than energy cost savings.

4.2 Higher revenues from rent or sales

There is growing evidence from studies such as Eichholtz, Kok & Quigley (2010), Kok & Jennen (2011), Chegut et al. (2011), Fuerst & McAllister (2011), Reichardt et al. (2012) and Laurenceau (2013) indicating that sustainable building features like energy efficiency, and its MBs, have a positive impact on building values. The studies compare certified green buildings with non-certified buildings, and find a positive correlation with rental rates and the transaction prices of commercial property (corrected for non-energy efficiency related characteristics such as location, age and size).

According to these sources, investing in energy efficiency, and thus obtaining green or sustainable building certification, translates to higher rent ranging from below 4% up to 21%. Numbers for higher market valuations (transaction or sales prices) range from below 10% to up to 30% (US) or 26% (Europe)[8]. In other words, businesses and individuals are willing to pay a rental or sales premium for "green" property.

However, energy efficiency is just one of several "green" building features. For the purpose of this research we propose to conservatively allocate 25% of the premiums to EE. For the rental premium this results in a range of 1 - 5,3% of an assumed monthly net office rent of 10 EUR/m^2. For the sales premium, a range of 2,5 – 6,5% of a sales price of 4,000 EUR/m^2 is assumed, which gives us a sales premium range of 100€/m² to 260€/m². Furthermore, it is important to consider that benefits are capitalized by different stakeholders in the commercial property market such as tenants and buyers.

The ongoing and future mandatory adoption of energy performance certifications or energy labels by the market will increase the availability and transparency of energy consumption data in buildings, and thus improve the effectiveness of the certifications and labels. For tenants and buyers, it will then be much easier to take energy efficiency into their financial models when making commercial property decisions.

4.3 Valuing avoided CO2eq emissions

Higher energy productivity leads to a reduction in final fuel and electricity demand, and respective CO_2 emissions. These reductions can contribute to climate change mitigation. Besides its social benefits, reducing CO_2

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[5] Dutch Green Building Council (2015), Gezondheid, Welzijn & Productiviteit in Kantoren, page 4 .

[6] The survey tool polls the comfort experience of building occupants through more than 50 questions related to different comfort aspects, such as temperature, sound and air quality, which was developed in collaboration with several European universities in the frame of amongst other the R&D-project GeoTabs. For more information about Comfortmeter: www.comfortmeter.eu/en.

[7] Especially if the DER is contracted via a performance based contract. More information: GuarantEE project (www.guarantee-project.eu/be) and Coolen, J., Wuyts, S. 2012

[8] These price premiums are for "sustainable buildings" whereby the "energy efficient" component is one aspect of the sustainability besides accessibility, water and waste management, indoor quality and building management. Other intangibles such as market conditions, market size, increase of global quality of buildings, the mentioned employee productivity increase and green image also play a role price premiums.

emissions could lead to additional financial advantages for project proponents, depending on the country's climate cost internalization policies. This is the case if building owners can generate certificates out of the CO_2 reductions that can be traded in an emission-trading scheme, or by saving CO_2 levies on fossil fuels.

The European Union (EU) has established the world's largest Emissions Trading System (EU ETS). 11.000 European businesses and aircraft operators (with flights within Europe) participate in the EU ETS. It is a market-based instrument that internalizes the external cost of CO_2 emissions with the goal of reducing greenhouse gas emissions cost-effectively while achieving its climate objectives.[9] An emission allowance offers the right to emit 1 ton of CO_2. Currently, there is a surplus of emission allowances leading to low costs. In the period January-March 2017, price for one emission allowance was around EUR 5.[10] It remains to be seen whether new EU climate goals, based on the Paris agreement, can lead to stronger policy measures and a substantial increase of emission allowance prices in the near future.

Besides an emission trading system, some countries impose a CO_2 levy on heating fuels. For example, Switzerland introduced such a levy and currently charges 84 Swiss Francs (approx. EUR 79) per ton of CO_2.[11] This is a significantly higher value than the current EU ETS prices.

Applied to the DER case study, 318 MWh of natural gas and 6 MWh of electricity are saved, which results in CO_{2eq} savings of about 80 t/year[12]. Valued at current EU ETS prices results in savings of about 400 EUR/year. Valued with the Swiss CO_2 levy on heating fuels, savings of about 6,300 EUR/year result. In both cases transaction costs to realize CO_2 revenues are not accounted for.[13]

4.4 Maintenance cost savings

Building DER also encompasses retrofit of existing, and often aged, building technologies. Besides energy cost savings, this leads to a net reduction of maintenance cost and/or replacement investment for the building owner, which can be factored into the business case. This approach is applied in energy savings contracts with ESCos.

DER will typically decrease maintenance costs due to the fact that a newer installation typically requires less maintenance. In the case of performance based outsourcing of maintenance in the DER project (using the NEN 2767, see below), the contractor will choose installations with lower maintenance costs, and optimize the maintenance process. However, this positive cost-saving effect could be partially offset due to increased maintenance costs that result from a more complex and maintenance-intensive building, generated by the DER.

In our DER case study, two effects on maintenance cost were observed: 1. A cost reduction of 2,1 EUR/m^2 for the existing systems, and 2. Additional maintenance cost of 0,9 EUR/m^2 due to the added ventilation systems (which have already been accounted for in the case study calculation in section 3). In the Belgian office building case study[14], maintenance cost savings were found to be 3 EUR/m^2 .

These numbers are based on the assumption that in the reference scenario, the maintenance in the building is conducted in a standard approach, and that the corresponding maintenance costs are made.

An interesting metric to measure maintenance levels of technical systems was identified in the Netherlands. The Dutch maintenance standard NEN 2767 advises on a uniform way to inspect and assess the construction and installation of technical infrastructures, and to assess their technical condition by assigning so-called "condition scores". This allows quantification of maintenance levels in an objective way, and can be applied as a metric.

4.5 Un-quantified Participant Benefits

In addition to the aforementioned benefits, there are several other benefits that are challenging to quantify, but still enhance the value of the project. The following benefits were identified as primarily benefiting the Participant, but were not quantified or included in the economic analysis. They were, however, discussed and considered by project stakeholders prior to making investment decisions.

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9 http://ec.europa.eu/clima/policies/ets_en (visited at 26.01.2017)

10 https://www.eex.com/en/market-data/.../european-emission-allowances-auction#!/ (visited 13.03.2017)

11 https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/climate-policy/co2-levy.html (visited 26.01.2017)

12 CO_{2eq} emission factors: Natural gas: 250 kg/MWh, electricity: 700 kg/MWh (Source: GEMIS http://iinas.org/gemis-de.html, visited 13.03.2017)

13 The resulting revenue of a reduced CO_2 levy for an investor or landlord also depends on the cost sharing between landlord and tenant. Often the fuel costs are paid by the tenant who would profit from the investments of the landlord, which leads to the well-known landlord-tenant dilemma or principal-agent problem.

14 Coolen, J., Wuyts, S. 2012

Sustainable Image and Environmental Designations

A DER can allow a building to achieve certain globally-recognized, environmentally-conscious designations, such as Passivhaus in the case study. These designations have benefits to the building owner in the form of enhanced public image, and gaining reputation as a leader in social/environmental entrepreneurship. This directly increases building value, but is difficult to quantify, as the range of values can be large (Woodroof et al, 2012).

Asbestos Removal

Environmental health improvements often accompany efficiency measures, such as improving attic ventilation while insulation is installed (RAP, 2013). A concern in many older buildings is the presence of asbestos, which can become a major health and environmental issue if not dealt with appropriately. Energy efficiency retrofits that include building envelope upgrades may by necessity include additional costs for safe removal and disposal of the material. Once asbestos is removed, the overall building safety has been increased, and there is a greater ease of selling or leasing the building to prospective tenants (DNV GL, 2015).

Building Aesthetics

By retrofitting a building, the interior and exterior appearance of the building are enhanced. This can heighten tenant satisfaction, and improve the overall aesthetics of the surrounding neighborhood.

4.6 Utility and Society Benefits

Benefits to Utility and Society were not deemed to have significant influence on the business case for this project, and were not investigated in detail. Their identification is still an important exercise, as these benefits may have the potential to engage additional funding partners with niche interests (e.g. the prospect of job creation could potentially be used to obtain funding from local development authorities). If this were the case, it would make sense for that benefit to be classified as a Participant benefit.

The Utility and Society MBs identified for the case study were as follows:

- Boost of local economy and job creation
- Reduced greenhouse gas emissions
- Improved local air quality resulting from reduced fossil fuel combustion and associated reduced health system costs
- Reduced fossil fuel import and improved national energy security
- Avoided electric and natural gas utility system infrastructure costs

Because of the project approach, these benefits to utilities and society were not pursued further in this paper.

5. Discussion

5.1 LCCBA model and DER business case study based on energy cost savings

For the first part of the discussion, results of the dynamic LCCBA DER model based on energy cost saving CF only are discussed.

Despite positive cumulated CFs of the case study, the business case appears not to be attractive to investors. Appraised solely by the economic and financial KPIs based on DER energy cost savings CF, it will be difficult to attract private sector investments. This is due to negative NPVs, long payback periods, low IRRs of P-CF and E-CF, project risks, and liquidity shortfalls in early project years.

Also the Levelized Cost of Heat Savings of 100 EUR/MWh, which can be used as a comparison with alternative heat generation costs, does not indicate an economic saving potential when compared to typical average[15] cost of heat supply. In conclusion, building DER is typically not a stand-alone business case if based on future energy cost savings alone, even with a long-term investment horizon of 25 years.

The above KPIs are not sufficiently reflected in standard, economic appraisals like simple payback or annuity calculations (often with residual book values for individual assets, which typically consider averaged values instead of CFs and do not reflect 'time value of money'). The differences in approach explain why assessment of economic viability of DER with different economic models may come to dissenting results. For long-term DER investment and financing decisions, as well as enabling policy design, a dynamic life-cycle cost and benefits appraisal is needed, as proposed with the LCCBA model. Dynamic modeling is also required, because of the

[15] It is even less attractive, when compared to the marginal cost of heat supply, which is the more appropriate comparison.

high sensitivity[16] of price and cost development scenarios, which underlines the risks of compound interest effects due to long project durations.

From a different angle, future energy cost saving CF may be viewed as a highly potent source for co-financing DER investments. As can be seen from the sensitivity analysis of the case study, 88% of CAPEX could be refinanced if an NPV of 0 is chosen as a goal of the P-CF. The opportunity to substantially co-finance DER investments with future savings CFs deserves much more attention. This would require a multi-year project cycle perspective across CAPEX and OPEX budgets, and adjustment of respective accounting guidelines and procedures, which in return would require enabling policy guidelines and their implementation. To reduce CAPEX, imputable investment cost for DER can be deducted by so called “anyway” cost of building maintenance (or other cost items) through a ‘differential cost approach’.

Opportunity cost of delaying investments in saving opportunities is substantial (28,000 EUR/year for the case study), which is often not discussed nor factored into the timing of EE investment decisions. Instead of waiting for CAPEX budgets to be available, it would often be cheaper to pay for debt capital or other third party financiers like ESCos, and be able to invest and profit from savings sooner. Unfortunately, this way of thinking is not common practice for public or private sector building owners.

The DER life cycle cost structure is characterized by high capital and low operating cost portions: The share of CAPEX is 70% of total project cost, with interest accounting for another 15%, and just 15% for OPEX. This cost structure is an indicator of societal benefits of DER, as there is a substitution of OPEX on (imported) fossil fuels, with CAPEX on (local) construction companies and labor (c.f. IEA 2014). Furthermore, the low interest rate favors comprehensive energy efficiency investments in buildings.

5.2 MB Classification, Quantification, and Relevance to Different Stakeholders

Before discussing integration of MBs into the DER business case, a few considerations on classification and relevance of MBs to different stakeholders are presented.

The three-part classification scheme of MBs into Participant, Utility and Society benefits is typically applied to MB analysis for government policies or utility programs, but can also be useful at the project level, provided that Participant sub-classifications are used. As described in Section 4.6, even those societal MBs that initially seem to have little relevance to the project could potentially be investigated for outside funding opportunities or other types of strategic support. Therefore, the authors encourage tabulation and classification of all potential MBs as a first step to their meaningful inclusion in project development.

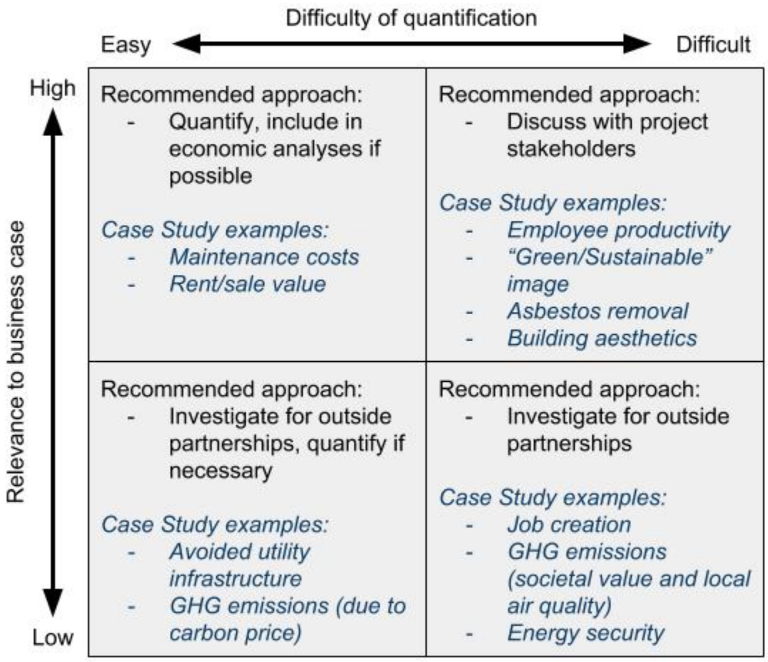

Figure 4: Multiple Benefits classification grid

[16] Impact of absolute changes of energy price development is even more sensitive, e.g. ±1% result in an NPV of +3.000 EUR, or -120,000 EUR respectively

The relative difficulty in quantifying an individual MB adds another dimension to the classification. Project proponents may find the use of a grid to be helpful in early project development, as shown in Figure 4. The two dimensions of the grid are ‘relevance to the business case’ and ‘difficulty of quantification’; the result being four quadrants for MB placements. The recommended treatment of each MB is then determined based on its respective quadrant. In our case study, the top half of the grid (MBs that are ‘highly relevant to the business case’) mainly include MBs that benefit the Participant. When evaluating ‘relevance to the business case’ for a particular MB, it may be helpful to develop an order-of-magnitude estimate of its impact relative to project costs and other benefits before investing time on more formal quantification.

While this method helps determine which MBs should be quantified, it does not prescribe methods of quantification. As the industry shifts to a greater focus on the inclusion of MBs in project economics, it is expected that new tools will be developed to aid in quantification of benefits in different applications. Industry experts should stay aware of these developments, and actively seek new and better methods of quantification.

In terms of laying the procedural groundwork for attainment of future savings, engineers should work to move MBs from right to left on the grid (i.e. develop new methods of quantification) while policy-makers should work to move MBs from bottom to top on the grid (i.e. create financial conditions that value a wider range of impacts). As a policy example, raising the price on carbon emissions would gradually move “GHG emissions” from the bottom-left to the top-left quadrant by “internalizing” these social costs into the business case. In our case study, the financial value of avoided emissions was easily quantified and directly benefits the Participant, but was relatively insignificant in the context of total project costs and savings, so it was placed in the bottom-left quadrant.

Another benefit that may result from pursuing MBs is a potential to engage with strategic partners or other funding sources that may be concerned with these benefits (or risks). Important drivers for the building refurbishment of the case study from section 3 were: Noise protection from a busy street, ventilation, and fire protection due to changes in use and structure of the building. In the case of asbestos removal, the local health department would have a vested interest in providing support to the building owner to ensure effective and safe removal of the asbestos, and could offer both financial and labor contributions to the project. Similarly, strategic allies may be identified for MBs benefitting Utility or Society. For example, elimination of a large peak electricity load may help the distribution utility defer costly growth-related upgrades to local distribution infrastructure. This cooperation perspective acknowledges the fact that energy cost savings from DER are often not high enough to build a stand-alone business case, which is proposed by other authors as well (e.g. BPIE 2011; RMI 2015). In many cases DER will need strategic partners, with a vested interest in its MBs, in order to move forward.

5.3 Integration of monetized MBs into the DER business case

The goal of this subsection is to discuss potential values of different multiple benefits identified in section 4 to the deep energy retrofit business case and their accountability to different participating stakeholders.

To recap, financially quantified MBs identified in the context of building DER are: 1. Work productivity increase; 2a. Rental income increase; 2b. Building sales price increase; 3. CO_2 emission reduction; 4. Maintenance cost savings and 5a. Energy cost savings during project term (already considered in base case scenario in section 3); 5b. Additional energy cost savings technical lifetime (beyond project term).

A positive correlation of these MBs to stakeholder benefits can be assumed to be consensus, however, quantification methods are certainly subject to further discussion. The ranges of monetary values of the MBs presented are a first attempt, to the best of our knowledge, based on case studies and literature (not on any broader empirical bases). In order to find a comparable metric to which readers can relate to more easily, quantified MB value ranges are presented in EUR/m^2/y and respective NPVs in EUR/m^2[17] in table 1[18].

The comparison on the left side of table 1 reveals relevant orders of magnitude of potential MB values compared to energy cost savings, with the exception of CO_2 savings valued at current ETS prices. The MBs value contribution, needed to reach a minimum economic threshold level (P-CF = 0), is at least 12% of the CAPEX (as can also be seen from the sensitivity analysis in figure 3), which translates to 1.8 EUR/m^2/y, or an NPV of about 65,000 EUR. Compared to a plausible range of MBs contributions as outlined in table 1, this appears to be in a reasonable, and even surpassable, range. These results generally support the approach to factor MB values into

[17] For the NPV calculation, a 25-year project term with a WACC of 3% as discount rate and 1,5%/year price increase was applied (equal to the case study analysis in section 3).

[18] Except for the “property developer”, the values in 2b. for the building sales price are in parentheses and not considered in the totals, because they depend on the time of sale; similar logic for 5b “tenant” values.

DER business cases, and should make DER more attractive to investors.

The right side of table 1 reveals substantially different benefit values for different beneficiaries. This underlines the necessity to differentiate between stakeholders for MB analysis (c.f. section 5.2). Occupant-owners have the highest benefit values of the different types of building owners, but tenants also have substantial net benefits.

Table 1. Pecuniary values of Multiple Benefits of DER (in EUR/m2) and their accountability to different stakeholders

		Valuation		Beneficiaries			
				Different owner perspectives			
Multiple Benefits of DER	Range	EUR/ (m^2 * y)	NPV: EUR/m^2	Property develop.	Occupant -owner	Lessor -owner	Tenant
1. Work productivity increase (0.3%)	Lower	8.0	169	-	169	-	169
	Upper	8.0	169		169		169
2a. Rental income increase (1 - 5.3%)	Lower	1.2	25	-	-	25	-25
	Upper	6.4	134			134	-134
2b. Building sales price increase (2.5 - 6.5%)	Lower	100		100	[100]	[100]	-
	Upper	260		260	[260]	[260]	
3. CO_2 savings (5 - 79 EUR/t)	Lower	0.2	5	-	5	-	5
	Upper	3.8	79		79		79
4. Maintenance cost savings (2.1-3 EUR/m2/y)	Lower	2.1	44	-	44	44	-
	Upper	3.0	63		63	63	
5a. Energy cost savings project term (25 years)	Lower	16.8	354	-	354	-	354
	Upper	16.8	354		354		354
5b. Add. energy cost savings over techn. lifetime (40 y)	Lower	16.8	157	-	157	-	[157]
	Upper	16.8	157		157		[157]
Totals			Lower NPV:	100	729	69	503
			Upper NPV:	260	822	197	468

Source: [Bleyl et al. 2017]

When comparing differential DER investments of 330 EUR/m^2 to the MB values, the occupant-owner's benefits are greater than the cost by a factor of up to 2.5. This is a clear indication for a potentially interesting business case. By example of the occupant-owner case, the project-IRR would go up to 7.6% and equity-IRR to 16.8%, if the total of the lower MB values in figure 3 could be realized over the 25 year project period (excluding 5b.).

On the other hand, the lessor-owners appear to have very small benefits, because of low rental premiums (even smaller than sales premiums). The same applies to property developers, where price premiums for DER buildings are not sufficiently reflected in market prices, probably due to a lack of LCCBA assessments on the buyer side of the market. In both cases, the 'split incentive'[19] dilemma is apparent, because investors do not capitalize from OPEX reductions of building occupants. From this perspective, it would be justified to allow building owners in regulated markets to charge higher rents in return for investments in tenant's savings. In this context, guaranteed OPEX reductions, as applied in performance-based energy services, would be helpful. Based on the MBs values, tenants should also have a vested interest to rent DER renovated "green" buildings. Alternatively, long-term tenants have grounds to invest their own money, provided they are aware of the benefits.

In any case, investors' appetite for DER will still require low debt capital interest rates (as is currently the case), a very long-term perspective of 20+ years investment horizon, and rather low expectations on equity return. In return, investments must be structured with a very low risk profile (because of low returns). For the business model, this will require a stable savings-CF scenario with low technical risks and simplified M&V (c.f Bleyl et al. 2013) for the verification of the savings CF, which is generally compatible with DER cases. Furthermore, business cases must be structured, guaranteed (e.g. through performance-based energy services) and reported in a standardized format, and aggregated in larger volumes to reduce transaction costs[20].

[19] For a further discussion of the split incentive problem, and the development of possible solutions, we refer to the H2020-project GuaranteE (http://guarantee-project.eu/be/)

[20] For approaches to standardization, certification of bankable energy efficiency projects you may refer to the Investor Confidence Project (ICP) (http://www.eeperformance.org/)

6. Conclusions

In summary, the following conclusions can be drawn with regard to our research questions:

1. Results of the dynamic LCCBA cash flow model provide solid grounds for DER business case analysis, project structuring, and financial engineering, but also for policy design (as compared to static payback analysis or other types simpler economic modeling). Equally important, it can bridge the language and communication gap between decision makers and other stakeholders, particularly with economic and financial backgrounds, such as potential DER investors.
2. For DER projects, CF from future energy cost savings alone is typically not enough to convince (private sector) investors. Even with a long-term investment horizon of more than 20 years, DER is not a stand-alone business case. However, savings CF can be structured to co-finance DER investments substantially by up to 85%. This approach may open up new perspectives for project implementation with rather small co-financing needed.
3. In addition, DERs can generate tangible and quantifiable benefits beyond energy cost savings, such as higher rents and real estate values, maintenance cost and CO_2 savings, and higher work productivity, in addition to other societal benefits. These MBs can offer meaningful contributions to make a business case more attractive, even if they are difficult to quantify in some cases. And they can help to identify strategic allies for DER programs and project development. However the well-known 'split incentive' dilemma requires differentiation between tenants and different types of investors.
4. Currently, low interest rates provide a huge opportunity for capital-intensive programs. However, for a meaningful DER implementation strategy including private sector financial engagement, policy makers would need to define clear and mandatory goals (e.g. minimum renovation rates), remove barriers to private sector involvement (e.g. revise EUROSTAT accounting rules for public debt, increase investment security) and structure policy frameworks that allow 'internalization' of MB values into the business case (e.g. creating economic incentives for a wider range of impacts, taking measures to raise EU ETS prices, allowing investors to capitalize from OPEX reductions, e.g. through higher rents) in order to achieve 2050 climate goals. Another important issue to foster investors' appetite is the streamlining of due diligence processes as requested by EEFIG and implemented by the Investor Confidence Project or the SEAF. Also, reducing CF risks by agreeing on simplified M&V procedures would decrease investors risk perspectives.

The approach to combining energy cost savings with the added values of MBs to enhance DER business cases appears to be promising. Nevertheless work remains to be done: 1. An encouraging and stable DER policy framework is needed; 2. Consolidation with potential long-term and "green" investors (e.g. institutional investors like pension funds or the like) and project developers and 3. Increase and enhancement of the MB quantification approaches also through performance-based services. The proposed classification approach for MBs may be helpful to structure and analyze future MBs research and project implementation.

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