Appendix
Best Practice DER Business Models

A.1 DER Business Models in the U.S. Federal Sector [1]

Two different models have emerged for implementing DER projects in the U.S. federal sector: (1) through conventional EPC project, and (2) through EPC projects that are combined with comprehensive building renovations.

The U.S. Army is experimenting with the combined approach (2). The model would use two different contractors: a renovation contractor funded by appropriated funds to accomplish non-energy-related upgrades, and an ESCo, which obtains private financing to implement energy upgrades. The advantage is that the cost of envelope-related conservation measures, which are not often included in EPC projects, can be reduced by coordinating them with the activities of the renovation contractor.

For example, the ESCo's cost to replace wall cavity insulation will be lower if the renovation contract includes replacement of wallboard. However, several challenges exist: coordination of project design and construction, management of the overall project, and dispute resolution between the two contractors. While a procurement strategy exists on paper, the Army is still considering pilot sites at which to implement this approach.

The GSA has had success in reducing the energy use of its buildings (Fig. A.1) by 2012 progress had begun to stall. For this reason, GSA began a program focused on achieving deeper energy savings using the conventional ESPC process. To this end, in March 2012, GSA issued a Notice of Opportunity (NOO) for a nationwide deep energy retrofit (NDER). The NOO included a list of 30 GSA-owned buildings covering a total occupied area of 16.9 million square feet in 29 states and the U.S. Virgin Islands. Among the objectives for the project were:

- Retrofit plans that move a building toward net zero energy consumption
- Use of innovative technologies
- Use of renewable energy technologies.

R. Lohse and A. Zhivov, *Deep Energy Retrofit Guide for Public Buildings*,
SpringerBriefs in Applied Sciences and Technology,
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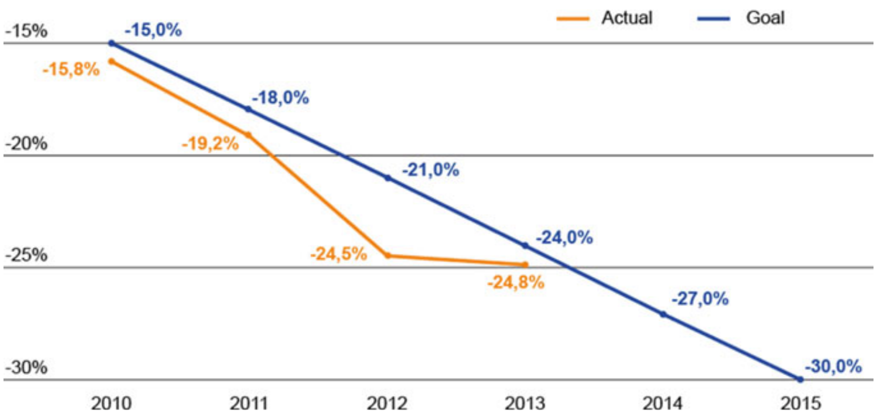
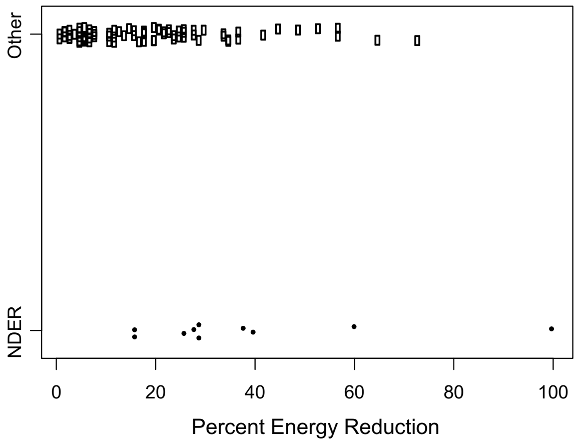


Fig. A.1 Energy intensity reduction in GSA buildings since 2010 (*Source* Oak Ridge National Laboratory [ORNL])

Evaluation of GSA's NDER Projects

GSA ultimately awarded 10 EPC Task orders with a total value of $172 million distributed among seven ESCOs. The projects covered a total of 1,365 million square meters of space in 23 buildings. It will reduce GSA's energy consumption by 108 GWh per year, resulting in a first-year guaranteed cost savings of $10.8 million, which will be used to pay pack the investment over time. A key result from the project was the average 38.2% proposed energy savings over the baselines, which is more than double the average proposed energy savings in a sample of 80 other recent federal EPC awards. Figure A.2 compares the percent of energy reduction of the GSA projects (filled circles) with the percent energy reduction of the other federal projects (open circles).

Fig. A.2 Percent energy reduction of NDER projects compared with other U.S. federal ESPC projects. *Source* ORNL



While GSA's NOO expressed a preference for innovative technologies and renewables, it is noteworthy that the majority of savings in the NDER projects were achieved using conservation measures similar to those encountered in other projects: lighting upgrades, controls retrofits, chiller and boiler replacements, etc. The assessment of the GSA NDER projects showed a couple of KPI that second the implementation of DER EPCs:

- The majority of the selected buildings should have not undergone recent energy retrofit projects and still provide the combination of "low hanging fruit" and ambitious energy and infrastructure measures.
- Framework settings for the public procurement process: So far, EPC was considered to provide energy savings between 20 and 30%. The emphasis from GSA to target DER encouraged ESCOs to propose longer-payback ECMs, and regional facility managers to accept these suggestions even when the cost effectiveness is lower than in the "business as usual" approach.
- To identify DER ECMs, the ESCOs have been requested to participate in a thorough energy audit process steered by the regional facility managers. This approach targeted an integrated design approach that considers the building, its occupants, and energy consuming equipment as a holistic system. In these concepts, the refurbishment of the building envelope was not a major factor in achieving deeper savings.
- What is not (necessarily) required to achieve deeper energy savings in EPC: The assessment of the DER projects steered by GSA led to a couple of interesting insights:
  - The level of energy savings obtained in the projects was unrelated to site energy prices.
  - The level of savings in the projects was unrelated to baseline energy intensity.
  - Large "buy downs" of appropriated funds in the form of initial payments from savings were not needed: The level of savings was unrelated to the size of the upfront payment.

A.2 DER in Belgium´s Public Buildings via Advanced EPC [2]

The Belgian facilitator "Factor4" has been involved in a number of EU projects such as Transparense [3], the "European Energy Service Imitative 2020 (EESI 2020)" [4] and in IEA DSM Task 16 research work [5]. To enhance the implementation of DER in the Belgium Factor 4 developed an advanced "SmartEPC" business model. The model was implemented in 2015. The first contract period will end in autumn 2016.

Integrating Non-energetic Measures and Benefits in EPC

Investment decisions for a general refurbishment of a building are often driven by the aspiration to increase the building´s functionality. Energy efficiency is merely a positive "side-effect" of a building refurbishment. However, "business as usual" EPC structures are related only to the energy savings. The integration of non-energetic measures and benefits into the scope of EPC projects intends to increase investment costs dramatically by a factor of 2 or 3. To keep the balance between investment costs and savings, "SmartEPC" inherits non-energy-related savings into the cost balance:

1. increased value of the building,
2. a higher level of indoor climate and user comfort.

"SmartEPC" provides calculation methods to make the non-energy-related savings accountable and, with regard to their bankability, gives guidance on how to assess and to verify their performance. The business model requires the fulfillment of basic project requirements (functionality of the refurbished building, safety, legal standards, etc.), but offers large decision autonomy for the ESCO in choosing the strategy to achieve these energy and non-energy-related benefits.

Concept

The decision-making criteria are like the criteria used in most of the EESI 2020 driven EPC procurements, i.e., they select the ESCO with the maximum net-cost saving. The net-cost saving is the annual guaranteed energy cost savings added to the increased value at the end of the project minus the annual remuneration of the ESCO (Fig. A.3).

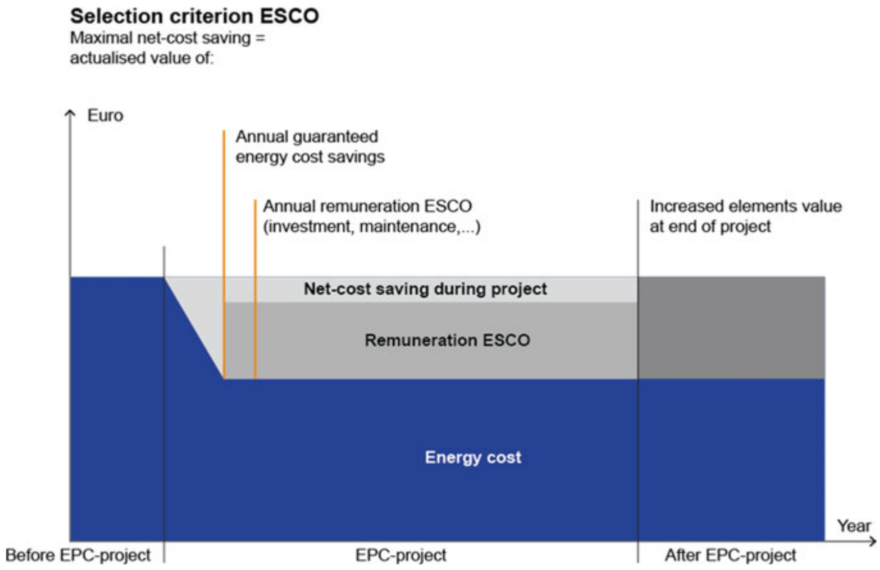


Fig. A.3 Awarding criteria in the procurement process. (*Source* Factor4)

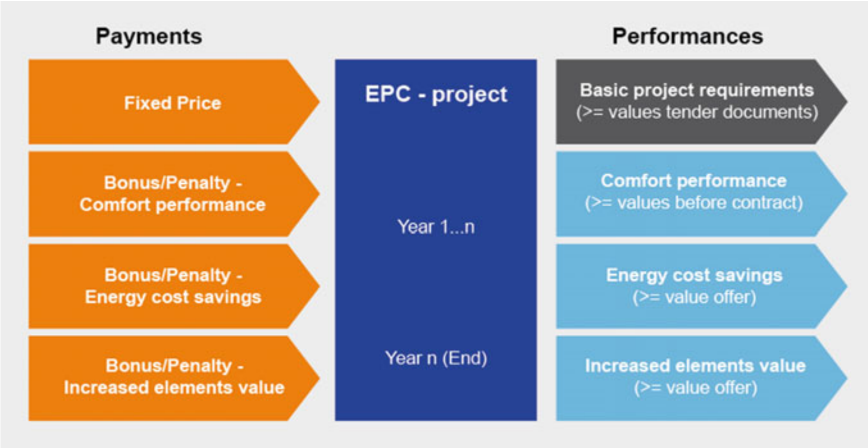


Fig. A.4 Revenues within the EPC project. (*Source* Factor4)

The "SmartEPC" accounts for the following performance criteria to determine the revenue streams and services between building owner and ESCo:

- Fixed price (payment) during the contract period related to the fulfillment of basic project requirements (maintenance of new and existing HVAC equipment, building automation) defined in procurement requirements
- Bonus-malus payments if defined comfort parameters are under- or over-performed
- Energy savings validated with fixed energy prices during the contract period related to the measured and verified energy savings during the contract period
- At the end of the contract period, a bonus-malus payment according to the increased or declined elements and building value is settled if an additional value is achieved, e.g., by appropriate maintenance, the ESCO is awarded a down payment at the end of the contract period (Fig. A.4).

Energy Performance

In the "Smart EPC" concept, ESCOs take over the energy-saving performance risk and are paid according to the measured and verified energy-saving performance—similar to "the business as usual" EPC. The money that the customer saves on energy costs (or part of them) is forwarded to the ESCo during the contract period.

Maintenance Performance

In "SmartEPC," the ESCo is technically and financially responsible for operation, maintenance, and replacement costs for the whole building including installations in and at the building such as the thermal envelope, windows, roof, HVAC, lighting, elevators, distribution grids and ducts. In exchange for taking over the risks for existing and replaced equipment, the ESCo receives a fixed price as an extended maintenance fee. "SmartEPC" provides an additional incentive for the ESCo for high level maintenance by evaluating the condition and value of the whole building [6] at the end of each year and at the end of the EPC contract period. The ESCo participates in increased values and is penalized if the condition is not appropriate. This approach provides strong incentives to conduct a sustainable maintenance program by putting in place measures with long technical lifetime.

Comfort Performance

In business as usual (BAU) EPC contracts, the indoor climate and the indoor quality is only a qualitative factor in the sense of a basic requirement that should be met by the ESCo after the refurbishment. The money value of comfort performance is not taken into account in a BAU-EPC contract, which also has an optimization potential regarding specific regulations related to high-level building comfort performance because:

- The definition of the indoor climate quality is inflexible and bears questionable parameters that may not fit to different levels of usages.
- The value of comfort aspects e.g., customer-friendliness of ESCo, is not a performance criterion.
- In the BAU-EPC approach, the building owners are mostly not involved in the design of measures that may affect the indoor comfort level. To involve the users may help to distinguish non-critical and critical comfort aspects from the buildings users' perspective.
- The M&V of the comfort performance level is expensive due to the needed metering and reporting efforts.

"Smart EPC" Allows for Accounting Comfort Performance

A DER offers the opportunity to increase the comfort performance and to create additional value for the building users and owners. For example, wall insulation and high-efficiency windows will reduce cold or hot indoor surfaces, which as a result, will allow good quality working places to be located much closer to external walls.

"Smart EPC" introduces mechanisms to increase the remuneration streams by transparently validating and monetarily quantifying the comfort performance. Comfort parameters are metered using a "Comfort meter" (www.comfortmeter.eu), which is an online questionnaire for the building users to qualify the indoor comfort conditions and to set up a **comfort score**.

The "Comfortmeter," which was developed by Factor 4 in close cooperation with two universities, reduces the investment costs compared to a large M&V program.

The ESCo guarantees a minimum comfort score; each score beyond that minimum level may increase the remuneration of the ESCo. The scale of the remuneration is calculated assuming, for instance, that an increased comfort score of +1% generates 0.2% productivity increase. This relation between comfort score and (self) reported productivity was proven via a Comfortmeter survey of 1500 employees working in 35 buildings. The Comfortmeter questionnaire polls the comfort experience of the employees via 35 comfort questions related to different comfort aspects, such as temperature, sound, and air, but also the expected effect of the comfort on their productivity. Through a statistical analysis of the 1500 survey results, the mentioned relation between comfort score and productivity could be estimated. In total, the additional remuneration from the comfort score can be up to 9 €/m^{2}year or more.

Conclusions: Within “SmartEPC,” ESCOs are more focused on higher comfort and employee satisfaction. “SmartEPC” is thus able to create additional value to contribute to the financing of cost intensive DER by: (1) monetarily quantifying comfort performance, and (2) providing a business model in which incentives for a high level maintenance program are given based on the ESCO’s participation in the increased building´s component value at the end of the EPC contract. Both financing contributions extend the financing scope of BAU-EPC business models significantly.

A.3 EPC Business Models in Latvia´s Residential Building Sector [7]

The Housing Market in Latvia

Latvia and other east European countries from the former Soviet Union are facing serious challenges in their existing building stock. The severe housing deprivation [8] rate is more than three times higher than the EU-27 average [9]. The overcrowding rate [10] of almost 60% is the highest among the EU-27, more than three times the EU-27 average. About 60% of the Latvian people are at risk of poverty, twice as high as the EU-27 average. On the national level, Latvia´s floor area per person is very limited. A further degradation would lead to a severe housing crisis. Currently, two major challenges have arisen:

- The buildings were designed in the 1960/70s to be built “cheap and fast” with an expected lifetime of ±30 years. They were not properly designed to withstand harsh weather conditions. Consequently, external parts are now corroding due to the effects of weather; panel joints are becoming crushed; balconies are crumbling; and roofs are leaking. Internal parts such as water, sewage, and ventilation networks, which were poorly designed, have become heavily corroded.
- Ninety-seven percent of Latvia’s building stock is owner occupied. After the breakdown of the Soviet Union, tenants became owners of their flats. However, many people cannot afford to undertake the necessary conservation measures. Most importantly, they lack the organizational capacity to live up to their responsibilities.

RenESCo’s EPC Business Model for the Housing Sector

RenESCo is a residential private ESCo and a social enterprise that finances housing modernization through energy conservation. The ESCo is driven by the challenges of the deprived and overcrowded building stock. RenESCo won the European

Energy Service Award 2011 in the category "Best Provider" for its commitment and its innovative approach.

RenESCo´s business model is based on an EPC contract, in which RenESCo takes over the whole conservation and modernization process of the apartment buildings, and also assumes responsibility for operation and maintenance for 20 years. The flat owners are obliged to pay the energy cost savings to RenESCo during the EPC period (20 years). RenESCo has the responsibility for the planning, implementation, funding, operation, maintenance, and M&V.

Roughly 60% of the funding of the projects comes from the energy cost savings financed by RenESCo, and 40% comes from the ERDF-funded national renovation program.

Sixty percent of RenESCo's share of the investment currently consists of debt-financing from a Latvian bank. The bank financing is based solely on the EPC contract. No other collateral is used. RenESCo must bring in the remaining 40% of the funding as its own equity capital.

Benefits for Residents

For the apartment owners, the momentum to engage in the RenESCo business model is only indirectly related to energy performance. Other concerns are:

- Increased indoor comfort, health, and reliability of the building, which are all part of the services provided by RenESCo.
- Conservation and modernization of apartments, which results in a 20-40% increase of the market value and directly benefits the residents.
- The refurbishment creates more comfortable and acceptable looking houses to live in. RenESCo guarantees a temperature level of 21.5 °C. (Currently, many apartments are severely under-heated).
- The flat owners incur no additional refurbishment costs.
- There is a 20-year guarantee on all construction and therefore no additional cost for maintenance during the contract period.
- After 20 years, apartment owners will have recuperated their costs from energy savings. The savings are estimated to be in a range from 50-80%.
- RenESCo offers an additional value preposition and an incentive for the apartment owners to contribute to keep the energy consumption as low as possible by offering a 25% profit share of RenESCo's net result.

Achievements

RenESCo provides a DER for the buildings:

- Within 5 years, RenESCo financed 100% of the cost and performed deep renovations of 15 typical Soviet-era apartment buildings using an EPC business model.
- The DER measures for this specific building type include the refurbishment of the complete building envelope in a thermal insulation composite system (TICS) with an average thickness of 10cm, installation of new domestic hot water and

networks, new heating network, new ventilation with heat recovery systems, and cosmetic repairs.

- The existing “natural ventilation” system creates airflow from the leaking building envelope and windows to the indoor floor area and an uncontrolled exhaust air network in the bathrooms. The new ventilation system is a mechanized ventilation system with (90%) heat recovery and a control system. In the summer, free cooling is provided. The DER reduces the building´s leakage rate to 10% of the value before the refurbishment.
- Improvements are made to the heat supply, which is typically city heating. Where possible, geothermal heat pump systems with vertical probes have been installed.

An evaluation by Ekodoma and the Riga Technical University has shown that the RenESCo business model provides a high level DER. The energy-saving guarantees and the EPC contracts have proven themselves to be bankable by a local financier. RenESCo’s projects clearly illustrate a successful DER that includes a wide scope of non-energy-related measures at the same or lower costs and that results in better quality than other municipal and private sector projects in Latvia.

Credit Rating of Housing Owners

A perceived barrier that must be overcome is that from financing institutions assume that low- and medium-income people will not be able to pay the bills. RenESCo’s experience shows a different picture. Even during a time of economic crisis with high unemployment rates, RenESCo received 97% of payments on time, and 0% non-payment during its 6 years of operation. This can be explained by the explicit connection between apartment ownership and the heating and maintenance bills. Poor owners have a strong incentive to pay their utility bills because they will otherwise be forced to sell their renovated flats and move to flats with has similar utility costs, but less comfort.

RenESCo’s Credit Rating

Apart from the doubted creditworthiness of its customers, financiers fear that the expected energy savings will not be achieved, or that they will fall after some years of performance. RenESCo’s experience shows that expected and performed savings are usually within a 2–5% range of error and that they remain constant over time. Since the building stock in RenESCo’s projects is more or less of the same age, energy consumption per m^2, and scope of measures, there was already a record of experience that helped mitigate performance risks (Table A.1).

Nevertheless, there is no suitable financing available. Many approved projects had to be cancelled due to lack of finance. Despite the recorded experience of reliable payments by the apartment owners and reliable predictions on the energy-saving performance, RenESCo´s cost of capital is still much too high ($\sim$7%). Creating a forfeiting fund to buy up the RenESCo’s future cash flows is considered a viable option to lower RenESCo’s financing costs and to enable a quicker recapitalization, but this has not yet been put in place.

Table A.1 Real and perceived risks in Latvian housing sector (*Source* RenESCo)

Barrier/Risk type	Perceived barrier	Real or Red Herring?
Performance	Low and medium income people have to pay the bills. Many will not be able to	Proven Red Herring. Banks love to talk this up in order to increase the interest rates they can charge, or collect extra guarantees from governments. Track record of renovation finance is excellent in Eastern Europe
	Expected energy savings will not be achieved, or will drop after some years of performance	Proven Red Herring. Thousands of similar buildings Expected savings usually within 2–5% margin n of error. Savings do not decrease over time
Policy	Lack of consistent policy. Start/Stopping of programs	Major problem. It takes 1–2 years to develop projects years to develop capable organizations Stopping programs destroys projects and renovation companies
	Transection costs. Complexity of support programs. Procurement rules	Real Consumes at least 70% of RenEsco staff time, Adds 10–15% to the total project costs. Creates many unnecessary risks ait pro.eet failures Leads to silly and poor decisions.
	No financing variable. Subsidy yes, finance no. Especially problem for small private sector companies	Real Many approved projects cancelled because lack of finance 1% lower interest over 20 years = 9% investment subsidy. ESCO cost of capital is much to high (7–10%)

RENESCO's Experience in Finding Workable Programs and Finance

In the last period (2007–2013), many countries offered loan and subsidy programs that excluded third parties such as ESCo as borrower or grant receiver. The European Commission and International financial institutions went along with this, preventing ESCOs or other third parties to develop. One major challenge in the support of third private parties with public seed money or subsidies involves tight market regulations ("de-minimis") that target a market situation of "equal opportunities for all," which may not derailed by public grants. To bridge that issue, building owners should have access to public grants under the obligation that they engage an ESCo to implement the project.

The greatest barrier to implementing DER in residential buildings in most eastern European countries does not originate from the realization of energy savings. Instead it originates mainly from the lack of consistent policies from governments and financial institutions to realistically deal with the post-Soviet housing legacy. Local and international financial institutions still hesitate to give proper consideration to the example of successful projects like RenESCo's to allow, for example, EPC contracts to serve as collateral to secure financing streams. An evaluation of the practice and the development of PF structures could contribute to overcome this barrier.

A.4 Implementation of Advanced DER EPC Business Models in Dormitories in Mannheim/Germany [11]

A.4.1 Initial Situation

The building owner, the student´s union (Studierendenwerk Mannheim) is a public institution. The main aspects of the work of Studierendenwerk Mannheim are concentrated in: (1) student housing (19 apartment buildings with some 3,150 apartments), (2) catering and dining (13 canteens and cafeterias), and (3) tuition fee funding and loans—BAföG (approx. 10 million Euro in funding per year). In 2008, SW Mannheim installed an energy management structure that commissions the energy consumption of all buildings. Also a master planning process includes a 10-year refurbishment roadmap for all apartment buildings was crafted in 2008. After some experience with low performing DER projects, the building owner decided to continue the refurbishment process only if the responsibility of the energy performance were provided by the contractor. In 2015, it was agreed to set up the first German DER EPC project in the Ludwig Frank quartier.

Prepare the minimum requirements and the energy baseline in a building energy audit: The building energy audit is carried out in a staged process and prepares all data required for the EPC measure list, and for the energy and water/sewage and cost baseline. The global cost baseline is 446k€/yr, which is relatively small for a typical EPC project (Fig. A.5, Tables A.2 and A.3).

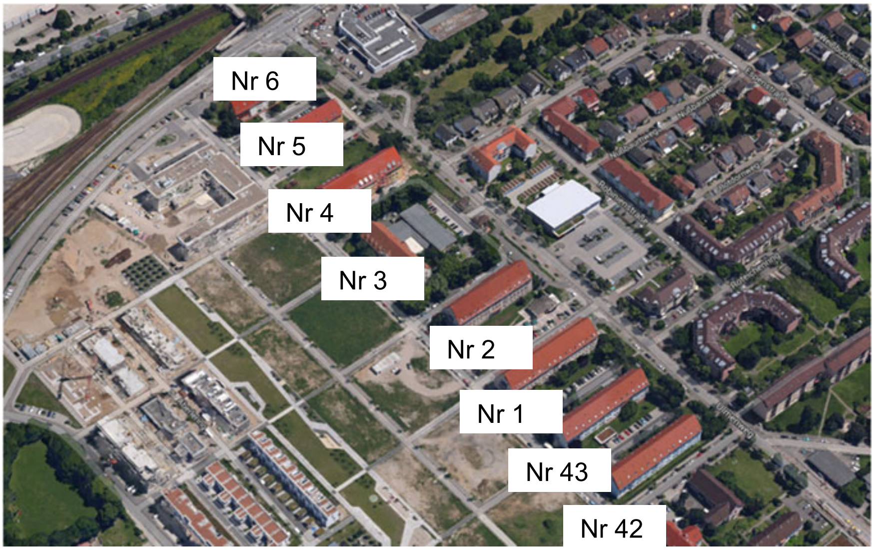


Fig. A.5 Top view on Ludwig Frank quartier

Table A.2 Ludwig Frank quartier heating baseline and benchmarks

Heating (district heating)								
Building	Baseline climate adj. (kWh/a)	Baseline price (€/kWh)	Load (kW/a)	Load (€/kW)	Fixed price (€/a)	Cost baseline (€/a)	EUI_{Heat} (kWh/m^{2}year)/ kBtu/ft^2	CUI_{Heat} (€/m^{2}year) (€/ft^{2}year)
42	328,293	0.0459	42	106.21	206,83	19,736.30	95 (30)	5.7 (0.52)
43	347,907	0.0459	43	106.21	155,13	20,691.09	101 (32)	5.8 (0.52)
1	384,342	0.0459	65	106.21	155,13	24,700.08	90 (28.6)	5.6 (0.52)
2	417,097	0.0459	49	106.21	86,18	24,435.22	108 (34.2)	6.35 (0.57)
3	303,087	0.0459	144	106.21	155,13	29,361.06	131 (41.5)	12.6 (1.14)
4	308,633	0.0459	50	106.21	86,18	19,562.93	78 (24.7)	4.97 (0.45)
5	237,184	0.0459	38	106.21	88,16	15,010.89	81 (25.6)	5.1 (0.46)
6	236,777	0.0459	38	106.21	88,13	14,992.17	88 (27.9)	5.8 (0.52)

Table A.3 Ludwig Frank Quartier buildings

No.		Year of construction, inhabitants	Floor space	Recent refurbishment
42, 43		1960 97 in.	2.666 m^2 (28.697 ft^2)	1994 Windows partly refurbished, attic floor insulated, new roof tiles
1, 2		1933 139 inhabitants	3.691 m^2 (39.730 ft^2)	1998 Windows partially refurbished, 5 cm mineral wool on attic floor
3		1933 44 inhabitants, Restaurant in ground floor	2.790 m^2 (30.032 ft^2)	1998 Windows partially refurbished, 5 cm mineral wool on attic floor
4		1933 110 inhabitants	3.200 m^2 (34.444 ft^2)	1998 Windows partially refurbished, 10 cm mineral wool on attic floor, basement ceiling 5 cm, roof tiles, entrance doors
5, 6		1960 88 inhabitants	2.257 m^2 (24.294 ft^2)	1998 Windows partially refurbished, 10 cm mineral wool on attic floor, basement ceiling 5 cm, roof tiles, entrance doors

A.4.2 De-Risking Approaches

A DER EPC in which an ESCo takes responsibility for the energy performance of a thermal retrofit has not been carried out before. The goal of the project is to carry out the DER concept in combination with a performance guarantee in which the remuneration system is related to the verified performance of the implemented project measures. A DER EPC that includes the holistic refurbishment of a building envelope has not yet been carried out in Germany. During its working phase, the German IEA Annex 61 ST B working group organized three workshops with the ESCO association VfW (German Association of Heating Suppliers, Chapter EPC; www.vfw.de) and four interested ESCOs that identified a number of DRMs:

- **QA of the modeling process (DRM1)**: The evaluation of 12 German and Austrian DER projects [12] indicated that one major reason for the failure of modeling results was that they lacked back-calibration. It was agreed that KEA is providing a PHPP role model in the software PHPP, which depicts the pre-refurbishment status of the building, and which also provided one potential technical modeling solution to achieve −55% of energy savings. This database was provided for the ESCOs in the tendering and procurement data basis.
- **De-Risking of the DER project by pool building (DRM2)**: With regard to the performance-related remuneration, the major concern of the ESCOs was the risks coming from a significant failure of the calculated savings combined with high investments. If the DER building does not perform appropriately, the risks can be mitigated by the results of seven other buildings with only standard ECMs put in place. Still under discussion is an idea in which major parts of the savings are fixed after their success has been proven for 3–5 years.
- **Monitoring and Verification process-tolerance (DRM3)**: In early projects, some ESCOs received contract awards by promising high savings without actually ever intending to achieve these performance values. Many standard European EPC contracts now penalize unfulfilled performance guarantees. These penalties have been excluded from the DER EPC contract for the first 3 years of the contract period to allow the project a "learning curve" for the ESCOs. The remaining risk of receiving only the verified energy savings is not touched by DRM3.
- **Bidding cost reduction (DRM4)**: One part of the risks involves the expenditures of the ESCOs during the bidding process. These costs have been minimized by providing a "basic solution" with a functional description of all necessary details of the design of the external walls, the windows (size, format and position in the wall). Also, one cost-optimized technical specification was provided that fulfilled the minimum requirements. This approach avoids the cost created when ESCOs spend engineering costs to design minimum requirements.
- **Investment cost and QA of planning (DRM5)**: In an EPC, the ESCOs are also responsible for the total investment costs of the measures. The tendering of materials provides a functional description of the insulation measures. To reduce the risks for the DER measures, the ESCOs are required to transfer the

functional description of the thermal envelope into a more detailed specification, to collect bids from subcontractors, and to refer to this in the tendering process. The reliability of the specification and the subcontractor prices are reviewed by a small team of experts (building owner, three experienced architects). In the first DER EPCs, this mandatory quality check helped to improve the reliability of the planning and investment calculation of the DER and to avoid cost increases.

- **Collect "avoided maintenance costs" from refurbishment measure plan (RMP)**: The RMP considered the technical condition and obvious need for action of the walls, roofs, windows, HVAC installations with regard to their technical lifetime. From national reference figures [13], the refurbishment and maintenance costs were calculated over a time line of 5 years. For each building, these investment costs were cumulated and, with an interest rate of 4% over time period of 20 years (equivalent to their average expected technical lifetime), transferred into annuities of total 44 k€/year. These annuities, which reflect the need for action to keep the buildings functional, are considered as avoided building maintenance costs; ESCOs can take this quantity into account for ECMs that replace or refurbish these components (see DRM6).
- **Limitation of maintenance and replacement cost risks (DRM7)**: In most standard EPC contracts, the ESCo takes the responsibility for the availability, functionality, and energy efficiency of the measures the ESCo has implemented. In many cases, the ESCo services also include a troubleshooting service. All these responsibilities exceed the "normal" guarantee provided by manufacturers. The incorporated risks are well known and available as empirical data that reflects each ESCo's practical knowledge of HVAC measures. This project will implement a combination of HVAC and DER measures. The individual measures have a technical life time expectation of 8 years (for a building automation device, speed controlled hot water pumps) and 30 years (for windows) if German standards [14] are considered. DER EPC will have extended contract periods (in comparison with HVAC EPCs) that will automatically lead to increased and unforeseeable risks. In the first DER EPC, these risks are limited to one life cycle for larger HVAC parts, two life cycles for smaller HVAC devices, and to certain responsibilities in the DER investment parts. (For the maintenance of the windows and the thermal envelope only a limited cost capacity of 0.3 €/m^{2}year must be provided.) In case this is not sufficient, the building owner will pay the difference needed to maintain the functionality.
- **Decision-making criteria for the tendering process (DRM8)**: this approach refers to the integration of non-energy-related criteria [15] into the decision-making process (Table A.4).
- **Technical specification**: The technical specification should provide all necessary information that helps to limit the effort for the ESCOs to calculate. However, the specification should invite the ESCo to provide their own ideas in the bidding process. Hence a functional specification is provided with a description of the boundaries and interfaces, and technical functionality. The design, color, and shape of the external walls; the window partition; color and measures of the frame are all described in all details to avoid any

Table A.4 Award Criteria of business as usual EPC and DER EPC Mannheim

	German EPC (business as usual)	DER EPC
Award criteria for EPC tendering	**(1) N**et **P**resent **V**alue of savings in total and remaining with administration 70–80%	(1) Net present value of savings in total and NPV of the partition of the savings remaining with building owner 50%
	(2) Contract period 10–20%	(2) Sustainable measures and Concept 40%
	(3) Carbon Footprint 10–20%	(3) Carbon Footprint 10%
Additional terms	–	Avoided maintenance costs for the replacement of existing installations are part of the saving

misinterpretation. In addition, the functional specification also provides the minimum requirements for the building U-values with reference to the KfW standards KfW 100 (which equates to the energetic quality of a new building) [16] and the definition of minimum HVAC measures.

- **Transparent tendering process**: To accommodate highly complex EPC projects (e.g., integration of biomass and infrastructure measures), this DER EPC tendering process is to be conducted in three stages:
  - Selection of three ESCOs with primary experience in ECMs at the thermal building envelope and with experience in the use of modeling tools at least on a monthly basis.
  - Tendering, negotiation, and EPC contract award: the selected ESCOs receive the contract and process documents including the baseline and the functional specification, and create their technical concept and commercial bid. Both will be presented in two negotiations, decision-making will then be prepared and one ESCo will be awarded. This is happening at this point of time (June 1, 2016).
  - Detailed planning phase: the awarded ESCo together with SW Mannheim will prepare a detailed technical plan. External experts with expertise in DER and building physics will provide the QA of the technical plan. After agreeing on the detailed planning, the second implementation phase will begin in September 2016.
- **Least-cost planning—Overview of results**: The bundling of ECMs and energy supply measures (ESMs) can increase the cost-effectiveness of a DER EPC significantly. That cost-effectiveness will consequently reduce the investment and performance risks for the ESCOs. In the Ludwig Frank quartier, the combination of HVAC measures and PV in seven buildings, along with the CHP and a DER in one building can provide a dynamic payback period of global investment costs in 17.4 years without any seed money. Table A.5 lists the cumulated impacts of these measures on the payback (Fig. A.6).

Table A.5 Cost optimization of the DER EPC project at Ludwig Frank quartier

	Investment	Energy savings	E-cost savings K€/Yr (€/m^{2}year)	Cumulated static payback (years)
B 42 DER envelope, ventilation, HVAC, lighting	982 T€ (263 €/m^2)	57% (54% heating, 3% power)	11.5 k€ (3 €/m^{2}year)	91
B2 HVAC, lighting, PV	118 T€ (36 €/m^2)	43% (10% heating, 33% power)	4.5 k€ (1.5 €/m^{2}year)	75
B3 HVAC, lighting, PV	118 T€ (35 €/m^2)	26% (10% heating, 16% power)	6.1 k€ (2.1 €/m^{2}year)	61
B4 HVAC, lighting, PV	115 T€ (35 €/m^2)	31% (10% heating, 21% power)	5.1 k€ (1.8 €/m^{2}year)	55
B5 HVAC, lighting, PV	105 T€ (33 €/m^2)	46% (10% heating, 36% power)	15.1 k€ (5.2 €/m^{2}year)	40
B6 HVAC, lighting, PV	119 T€ (38 €/m^2)	41% (15% heating, 26% power)	11.2 k€ (3.8 €/m^{2}year)	35
B7 HVAC, lighting, PV	120 T€ (38 €/m^2)	53% (15% heating, 38% power)	12.7 k€ (4.0 €/m^{2}year)	31
B8 HVAC, lighting, PV	115 T€ (35 €/m^2)	56% (15% heating, 41% power)	6.6 k€ (2.2 €/m^{2}year)	31
Buildings 1-8 supply solution CHP, Gas peak boiler,	+749k€ (overall 28 €/m^2)		113 k€/year (overall: 4.2 €/m^2)	20
Total	2.541 k€ (93.1 €/m^2)		185.8 k€ (7.2 €/m^{2}year)	
Partition of avoided M&R to achieve 17 years			44 T€/year (1.6 €/m^2)	13.8 years (static payback)

A.4.3 Conclusion of the Advanced EPC Case Study Mannheim

The facilitation of the first German DER EPC has provided significant progress in terms of the development of EPC as an instrument dedicated to take advantage of “low hanging fruits” using a sustainable vehicle that can help implement European legislation (EBPD) and national implementation strategies. The following conclusions may be drawn from this DER EPC case study:

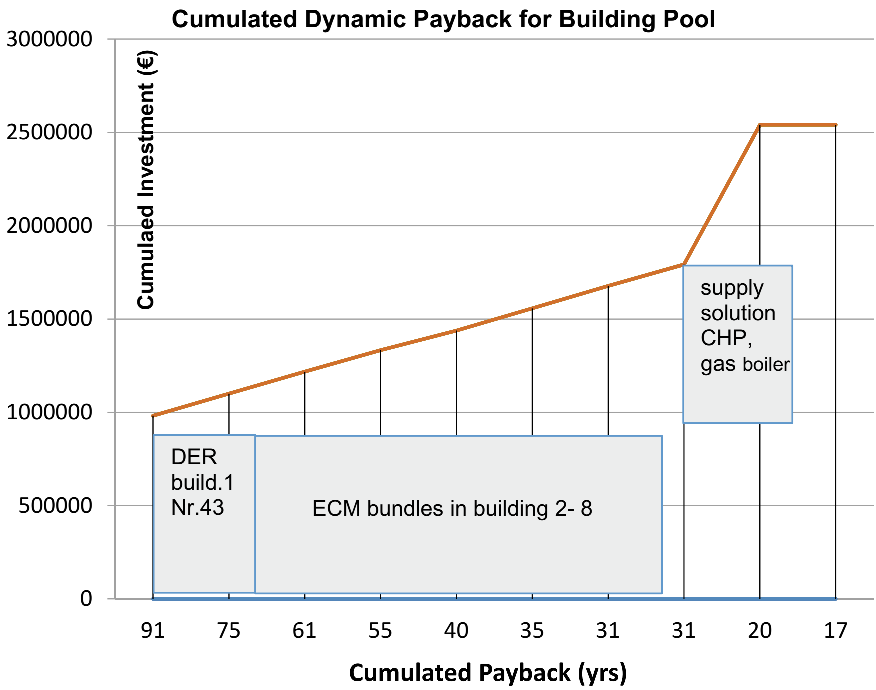


Fig. A.6 Cumulated investment over cumulated payback period for the DER EPC project in Ludwig Frank quartier

1. A DER EPC can be feasible and can attract ESCOs if certain risks are made transparent and are distributed between the building owner and the ESCOs. In this case study, the major de-risking steps were:
   a. maintenance costs for equipment with a technical life time < than the contract period
   b. simplification of M&V process
   c. the planning and design of minimum and architectural details in the preparation of the tendering
   d. transparent tendering and decision-making process
   e. the setup of a building pool with combined DER and HVAC measures.
2. Cost effectiveness can be achieved by integrating non-energetic life-cycle costs into the performance scheme and by combining DER with renewable energy sources for self-sustainable use in the buildings.

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10. Lohse et al. Investing in Energy Efficiency in Buildings, Brussels, 2015 based on RenEsco calculations based on EU-SILC 2009 – revision 1 of August 2011, A person is considered as living in an overcrowded dwelling if the household does not have a minimum number of rooms per person
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