Energy Services in the Dutch social housing sector.

A benchmarking study on housing corporations' in practice performance.

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Preface

This report is the result of a research about the performance of housing corporations in energy efficiency projects in the Dutch social housing sector. With this report I finalize my study Construction Management & Engineering at Eindhoven University of Technology. The research was performed under the KENWIB foundation, a cooperative knowledge cluster of the municipality of Eindhoven, the Eindhoven University of Technology and the Province of Noord-Brabant, aimed at an energy-neutral living.

Early on in the graduation process, my attention was drawn to the challenges of the Dutch social housing sector. The topic finds a perfect balance in my interest in decision making processes in (semi-)governmental institutions, the build environment and the overall wealth and equal chances for all people. With the background of KENWIB and the opportunity to perform this research at PVM and Innovation in Building & Maintenance, I think I have been able to carry out both an interesting and certainly relevant research topic.

This report would not have been possible without the support of and cooperation of my family and friends, which provided the needed distraction during the creation of this thesis. Of course, I would like to thank my supervisors from the TU/e and Innovation in Building & Maintenance. Thank you Paul for your inspirational enthusiasm and practical knowledge, thank you Brano for keeping the focus on the academic level of the thesis and thank you Roy for enabling me to see things in perspective. Moreover, I would like to thank all the interviewees for their time and effort and for providing the project data, without which this research couldn't be possible.

A very special thank you is for my girlfriend. Thank you for your understanding and patience and keeping me on track during the times when I needed it the most.

Barry Kroon
March 6, 2013

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Management summary

With over one third of the Dutch total housing stock under their exploitation, housing corporations are an important factor to take into account by the government when implementing national legislation, regulations and norms for on the housing market. The main task of these housing corporations is to provide affordable and qualitative housing for people that are not able to do so themselves. The increasingly older social housing stock, of which most was built post WWII op to the seventies, faces a deteriorating quality in relation to current norms and newly build dwellings.

Moreover, the affordability of these dwellings is increasingly becoming an issue, since at the time of their construction, little to no emphasize was placed on their energy efficiency. Currently, this lack of emphasize causes expensive energy to leak out of the dwellings and tenants especially are faced with increasingly higher total housing costs. To keep the dwellings affordable and improve their overall quality, the Dutch housing corporations stand for the enormous task to renovate 2 million Dutch social houses up to current standards.

However, the speed and extent to which energy efficiency measures are implemented is hindered by the sector's inherent 's*plit-incentive'*, the phenomenon that tenant and letter have different interest and make different considerations regarding investments in energy efficiency measures. An increasingly heard solution to overcome the split incentive and widen the positive cash flows of housing corporations, is for them to become active in the Energy Services, aimed at lowering energy demand and supplying sustainable energy for the remaining demand.

This research applies Data Envelopment Analysis (DEA) to benchmark the performance of several, high-end, energy efficiency projects of housing corporations. These project will be benchmarked on their ability to convert the capital investment per dwelling in added quality and financial benefit for both the tenant as the corporation. By doing so, the suggested benefit of energy delivery for housing corporations as a means to lower the split incentive is assessed and any new insight can be used as input in the discussion about the role of housing corporations in controlling the total housing costs.

The DEA results indicate that projects that implement energy supply measures are relatively more efficient in converting their investment into financial benefit for the corporation than projects that only implement energy demand decreasing measures. At the same time, these projects are able to reach a better absolute energy efficiency level. Taking on the role of energy supplier can thus be of substantial additional value for a housing corporation.

However, Dutch legislation and regulations prohibit housing corporations from fully utilizing the potential of energy delivery. Here lies an important role for the government: in order to conduct feasible energy efficiency projects and comply with increasing energy efficiency standards, housing corporations should be stimulated to do so by ambitious goals and, more importantly, broader legal conditions.

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1. Introduction

1.1. Context

An increasing energy demand and decreasing availability on fossil fuels has continuously driven up fuel prices over the last few years (SenterNovem, 2005). Dutch energy consumption has grown to 3258 PJ in 2011 (CBS, 2012a), of which an estimated 478.8 PJ by Dutch households alone (CBS, 2012b).

Since the increase in energy costs for Dutch households (SenterNovem, 2005) has increased at a faster rate than the income (SenterNovem, 2007), the share of household-income that is spent on energy-related expenses is rising. Research shows that some groups are especially vulnerable for this development (Nibud, 2009): The lower incomes; the lower educated; and tenants, see figure 1 & 2.

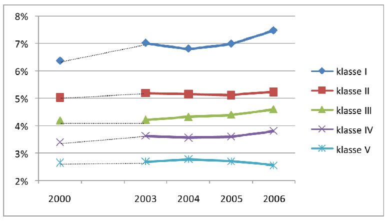


Figure 1: Average energy budget-share for 5 evenly distributed income classes in the Netherlands. Source: Nibud, (2009)

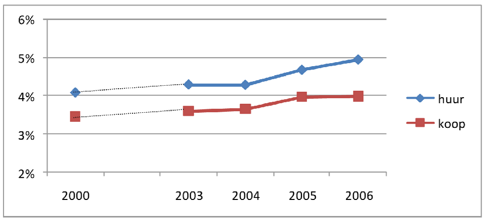


Figure 2: Average energy budget-share for rental and house-owning households. Source: Nibud, (2009)

The European commission conducted an EU-wide research on the relative housing costs of its households (European Commission, 2009). Relative housing costs in this research was defined as the housing costs – rent and utilities as water, gas and electricity – relative to the disposable income. The Netherlands has the highest relative housing costs with a percentage of 30.9%, where the EU-average is only 22.2%. More so, the lowest incomes' relative housing costs is 47.4%, including 61.2% of all the Dutch households around the poverty threshold (European Commission, 2009).

Most of the lower income households in the Netherlands are not able to buy or rent a home on the private market and are reliant on the social housing sector, which in the Netherlands exploits 34% (Ministry of Infrastructure of the Italian Republic, 2006) of all the 7.2 million Dutch homes (CBS, 2011). Given its size and the financial vulnerability of its tenants, the sector plays an important role in reducing the energy-related expenses by improving the (energetic) quality of their housing stock. The sector has made agreements on improving this energy efficiency with the national government (BZK, 2012), but despite of their ambitious goals the investments of the sector in the existing housing stock is decreasing (CFV, 2012)

Due to several developments and new regulations, the financial possibilities of the average housing corporation have tightened and the prognosis on new construction projects shows a decreasing trend (CFV, 2012). This puts more emphasize on the energetic renovation and improvements of the existing housing stock, but the renovation rate, also, is lower than needed (CFV, 2012).

An explanation on why these developments are taking so long is the fact that the (financial) benefits of an energetic renovation of the existing housing stock are all for part of the tenants, whereas the corporations primarily bear the costs of the renovation. This split incentive makes it unattractive for corporations to heavily invest in further energy measures (Quirijns, 2011), let alone install expensive durable energy generating solutions.

This is a concerning development, since several experts point out the necessity of investing in the energy efficiency of the existing social housing stock. They argue that without these investments the vast majority of the social houses will no longer be within financial reach for the target group of the corporations by the year of 2030, due to the increased total housing costs, see figure 3. This makes it absolutely necessary for housing corporations to expand their focus and offer social housing with an affordable long-term housing costs prospect (Renda, 2012).

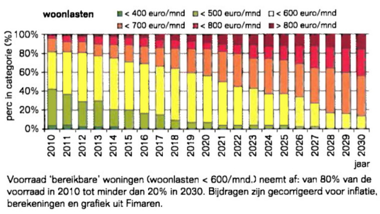


Figure 3: Percentage of rental dwelling within reach of target group. Source: Renda (2012).

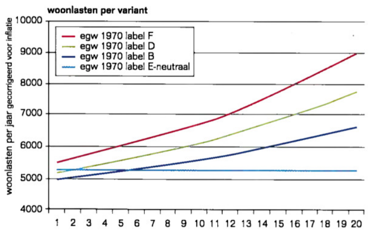


Figure 4: Development of housing costs for different energy labels. Source: Renda, (2012).

As seen in figure 4, only neutral houses show steady housing costs over time. Since bringing the real estate up to energy neutral housing standards asks for additional investments in a time where housing corporations are struggling, some suggest that housing corporations should focus on bringing Energy Services, or ESCO's: A service concerned with maximizing efficient and cost-effective supply and end-use of energy for their customers (GEA &EESI, 2009).

A business model like this has several opportunities for housing corporations: it could reduce the housing costs for their tenants; provide additional income for the corporations; serve as an incentive to invest in energetic renovations by reducing the split incentive; and it could provide the financial boost to upgrade the existing housing stock to energy neutral standards by implementing durable sustainable energy solutions.

Aware of the possibilities, Aedes – the association of Dutch social housing corporations – has set up several pilot projects and research groups on how to implement Energy Services in the social housing sector. These projects show promising results and opportunities, however, the best implementation of Energy Services in the field is not mentioned, nor is it clear on which aspects the performance of these projects should be judged. Moreover, corporation involved in such projects could be considered pioneers in this field, since most corporations are not yet convinced or aware of the full potential of Energy Services.

1.2. Problem statement & Research objective

Following section 1.1, the upcoming challenges for the Dutch social housing sector and the presumed benefits of the Energy Services sector in relation to these challenges, the following preposition is stated:

> ***Preposition:***
> *Given their societal goal of guaranteeing affordable housing for those that are not able to do so themselves, housing corporations should play an active role in controlling and minimizing the growing housing costs of their existing housing stock by becoming an active player in the Energy Services field.*

The problem statement, derived from the introduction and based on the preposition, is as following:

> ***Problem statement:***
> *Most housing corporations are hesitant to become fully active in the Energy Services sector, despite positive results and experience of their colleague corporations. The decision-motives underling these hesitations and their interrelationship are not known. Also, a clear view on the effects of Energy Services on important aspects are not known.*

The research objective therefore is:

> ***Research objective:***
> *To gain insight in the effects of Energy Services on energy efficiency targets, and use these as discussion input for policy makers.*

Clear understanding of the effects of Energy Services on energy efficiency targets makes it easier for policy makers in the sector and the Dutch government to come to a sector-wide view on the role of Energy Services. Also, legislation and policies can be adjusted in such a manner, that barriers and drawbacks are minimized.

1.3. Research question

To find a possible solution to the problem, the research question is formulated as:

> ***Research question:***
> *What are the effects of Energy Services on energy efficiency targets of energy efficiency projects in the Dutch social housing sector?*

The sub-questions, supporting the main research question, are stated as:

1. What are Energy Services and how do they contribute to improving energy efficiency of the built environment?

2. To what extent do different energy services affect the energy efficiency targets of housing corporations?
   2.1. What are the most important energy efficiency targets in the Dutch social housing sector?
   2.2. Which organisational differences and differences in the perception of barriers could explain the differences in accomplishment on energy efficiency targets between individual housing corporations?

3. What opportunities in the energy services are of interest for the Dutch social housing sector, and what measures, policies and legislation affect the position of housing corporations in the energy services sector?

1.4. Research boundaries

The research's main boundary is the focus on the energetic renovation of the existing social housing stock and the role that energy services play on the energetic performance of a housing complex after such a renovation. The energetic performance will be measured on energy efficiency targets, which will be derived from the literature research.

Second, only Energy Services conducted through an active role of the housing corporations will be incorporated. This will enable seeing the effects of Energy services on the side of the tenants as well as on the side of the housing corporation. Energy Services conducted by third parties are therefore not taken into account.

1.5. Research relevance

Increasing energy efficiency has the increasing attention of the Dutch social housing sector. It is not clear however, what the most effective way towards increasing energy efficiency is. Energy Services are mentioned many times as an important element in this process and has already been implemented in several (pilot-) projects. A quantitative exploration or benchmarking of such projects to measure their efficiency is missing, however. Also, qualitative comparison between the corporations, which perform these projects, has not yet been conducted. Corporations could still learn a lot by relating themselves to best-practice corporations and taking over their way of approach.

1.6. Research design

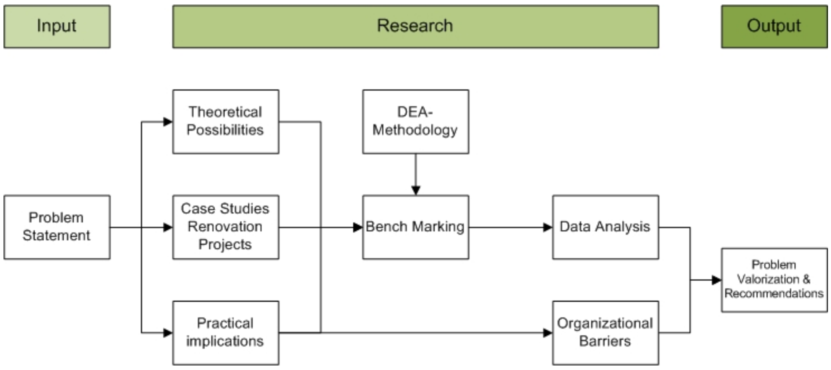


Figure 5: Research design.

The problem statement will serve as input for the actual research. The first part will consists of an extensive literature research on the Dutch social housing sector and the opportunities for Energy Services within this sector. Next to these opportunities and possibilities, the practical implications will also be investigated. These can consist of legal, financial or organizational boundaries which could affect the perceived attractiveness of the Energy Services sector for the housing corporations and their willingness to enter this market.

Case studies of renovation projects that will be investigated must have incorporated a form of energy services and will be used to assess the performance on energy efficiency targets, derived from the theoretical background. The research methodology that will be used is Data Envelopment Analysis: a benchmarking technique which will express the relative performance of the case studies on the investigated energy efficiency targets. The implications, experienced by the housing corporation during the renovation projects and the use of energy services, will be used to form an overview of experienced organizational barriers.

The analyzed quantitative data will be assessed and differences will be tried to be made clear using the qualitative, organisational barriers, perceived by the housing corporations. The valorisation will provide recommendations on how the organization of a housing corporation should treat the organizational barriers to use energy services in such a way that the best energy efficiency targets can be achieved.

1.7. Reading guide

This report consists of three main parts. The first part is the contextual orientation, in which the theoretical background on the research topic is elaborated upon. The first chapter describes the Dutch social housing sector. It briefly addresses its history, before the legal framework in which corporations operate is described. The financial position and continuity of the sector is described next, after which the current state and issues of the sector are explained. The second chapter of the first part addresses the Energy Services sector. The main elements that define Energy Services are defined, as well as its main contracting models. Next, Energy Services within the social housing sector are examined: To what extent can they be called pure Energy Services and how are they positioned in the conventional legal, financial and organizational framework of the corporation?

The second part of the report is the research application. In the first chapter, the used methodology and its main principles are explained. The second chapter combines the first part 'contextual orientation' with the research methodology. The chosen research model is argued and the research variables are described, before the data collection is elaborated and the data preparation steps are stated.

The last part of the report is the validation and recommendation. First, the results of two DEA-analyses will be elaborated. The first will analyze the actual performance of several projects in the Dutch social housing sector. The second analyzes the same projects on their potential performance. The conclusions and answers on the research questions will be given in the next chapter. The last chapters holds the recommendations on the possible future of the social housing sector regarding energy services.

2. Dutch social housing system

In this chapter, the playing field of the Dutch social housing is assessed. Section 2.1 adopts a historical perspective on the sector, using Snuverink (2006). The legal framework in which the corporations operate will be explained in section 2.2. The financial position and continuity of the social housing sector, both internally and externally, is described in section 2.3. Section 2.4, assessed the current challenges of the sector, combining the knowledge of the previous sections. Section 2.5 states the conclusion.

2.1. History

Although the first organisation active in the public housing sector originates from 1852, the first national legislation the '*Woningwet*', marking the active involvement of the Dutch government in the sector dates back to 1901. Since then, housing corporations received state-aid, to be used '*in het belang van verbeteringen van de volkshuisvesting'*. Any excesses had to be returned to the government.

Between 1900 and 1940, about 1 million Woningwet-houses were built with state-aid. After WWII, the corporations played a large role in rebuilding the Dutch cities: between 1947 and 1985, the public housing stock grew to 1.6 million houses. The active involvement of the government however led to large financial risks and the first steps were taken towards a more independently functioning public housing sector.

Housing corporations were given opportunities to build up financial reserves, initiate building projects and were expected to bear their own risks. Since 1988, active financial support from the government stopped.

To still be able to receive loans under attractive conditions, needed for the investments of the social housing sector, the '*Waarborgfonds Sociale Woningbouw'*, WSW, was established. This private fund, solely focused on providing guarantees on loans of individual corporations on the capital markets under strict conditions, still is the main source of capital for corporations. More information about the WSW can be found in section 2.3

Moreover, corporations collectively had to come up with the means necessary to be able to reorganize financially weak corporations. This led to the establishment of the '*Centraal Fonds Volkshuisvesting'*, CFV, in 1990. More information about the CFV can be found in section 2.3.

The new approach of the government followed a path of less interference; a discharge of redundant rules and a decentralization of tasks and authorization towards municipalities and independency of corporations. This new approach called for a revised view on the tasks of corporations. This led to the introduction of the first '*Besluit Beheer Sociale Huursector'*, BBSH, or Decree Management Social Housing sector in 1993. Apart from their primary task of building, exploiting and allocation of social housing, corporations were now able to perform other task, as long as they could prove that they were beneficial for their primary goal of providing public housing. The first BBSH comprised four performance fields, whereas the newest BBSH holds six performance fields. More information about the newest BBSH can be found in section 2.2.

The last direct strings between the government and the corporations were cut in 1995, with the '*Wet Balansverkorting'*. This formed the last step of the financial independence of the sector after the establishment of the WSW and the CFV.

The ambiguous role of corporations – a private organization with a public goal and orientation -, still raises questions: How should it be organized and to what extent should it be controlled? Several reports (Min. EZ, 2004; WRR, 2004; SER, 2005) informed the government on this topic in the beginning of the 2000's, with the advice:

- A societal organization holds a position between the government and the free market. A connection with the government will always exist.
- Societal legitimacy is not a given, but should always be earned by the organization.
- Housing is in the beginning a local and regional matter. This means that housing corporations should structurally involve local governments and local stakeholders on setting policy priorities.
- If internal supervision fails, the government should be able to intervene.

These remarks have played a leading role in the formulation of the newest BBSH and other governmental documents regarding the position of the social housing sector. These will be explained in the following section.

2.2. Legal framework

The legal framework that determines the legal, financial and organizational position of the sector has been mostly formed by the Dutch national government. In the last years, however, the position of the sector has also been formed by the means of higher European law. European law has the character of providing directives, or guidelines, to which national governments should adjust their national legislation. Directives leave room for interpretation so that they are more easily implemented in existing national laws. First, the European directives and regulations that influence the Dutch social housing sector will be described, because they are of a higher legal authority. Next, Dutch legislation will be described. Dutch national implementation of European directives will also be pointed out here.

2.2.1. European legal framework

The European Union finds its origin in economic cooperation between member-states. One of its main focus-points is providing an internal market, free for traffic of goods, services, persons and capital (EU, 2012). A free internal market means equal chances for organizations in any sector, without favourable conditions for an organization over another. State-aid can be seen as giving an organization a more favourable position over another organization and is therefore illegal. However, the European Commission leaves some room for state-aid which is necessary to conduct services which are considered Services of General Interest (Dutch: '*Dienst Algemeen Economisch Belang'*, *DAEB*), from now on called DAEB-activities.

DAEB-activities comprise all market services which are deemed of special interest by a governmental body and for which it has special public services obligations. A public service obligation is the obligation of an organization, which it would not, or in lesser extent, have taken on, if it would have taken into account its own commercial interest (BZK, 2008). Most of these activities comprise economic services with a social goal, of which the exploitation is not profitable.

Whether or not a DAEB-activity legally receives state-aid and if these are to be reported to the European Commission, is assessed on four cumulative criteria, known as 'Altmark-criteria' (BZK, 2008). A DAEB-activity must satisfy all four criteria to acquire compensation, unless the activity is configured to fit the conditions of the exemption clauses. Under these clauses, the primary goals of the Dutch social housing sector have been labelled DAEB-activities that legally receive financial compensation or support (EU, 2009).

Apart from the DAEB-guideline and the Altmark-criteria, the European Commission has put further restrictions on what type of activities of housing corporations can claim state-aid and which activities are labelled as state-aid (EC, 2009). State-aid by the Dutch government is considered to be:

- The reorganisation and project support of the CFV;
- The financial backing of the government with the guarantee on loans for corporations by the WSW;
- Possible lower ground prices when buying ground from a municipality.

Under the conditions of the European Commission, these types of state-aid are only legitimate for the construction and letting of dwellings with a maximum rent of € 664,66 (price level 2012). Also, 90% of the dwellings of a housing corporations should be allocated to households with an income under € 34.085 (price level 2012), with the exception for people in need of special care. Both numbers are adjusted for inflation annually.

State-aid is also possible for the construction and hire of certain societal real estate (community centres, space for societal aid and healthcare). Societal real estate may only use state-aid if it will be rented by organizations with a societal goal or governmental bodies.

2.2.2. National legal framework

The main national legal document for the social housing sector is the '*Besluit Beheer Sociale Huursector'*, BBSH, of 2005 (VROM, 2005) which has been updated regularly since then. The BBSH states that the tasks of housing corporations lies within the field of social housing and determines the responsibility-fields of the social housing sector:

- To accommodate the target group;
- To ensure quality of housing;
- To involve tenants in policy-making and exploitation;
- To provide financial continuity of housing;
- To provide quality of live;
- Housing & Care;

Furthermore, the BBSH mentions the relationship between the corporation and the municipality; encompasses regulations on reporting; and arranges the external supervision on housing corporations.

The domain of the social housing sector is thus determined under EU-legislation (EC, 2009) and comprises all housing with a maximum rent of € 664,66 per month, called the liberalization boundary. Housing with a higher rental price is no longer considered 'social' housing and falls under the private sector, a sector with less protecting measures for the tenants and more room for housing corporations to ask higher rental prices. Given their societal goal, housing corporations deliberately keep most of their rent under this boundary. The average rental price lies at 72% of the maximum rental price (Aedes, 2011), which is determined using a point-based system (Dutch: *WoningWaarderingStelsel, WWS*) that expresses the quality of a dwelling.

The target group of a housing corporation is determined by the income of the household that wishes to find accommodation via the corporation. Under EU-law, the maximum income that should find housing in the social housing sector is set at € 34.085,- per year. However, since the Dutch housing market has a deficiency of available housing for incomes just above this threshold, the 90%-mark has been set as the minimum amount of housing that should be rented by the lower-income (under € 34.805,-). The other 10% is still available for the higher incomes.

2.3. Financial position & continuity

In general, housing corporations have to be self-sustainable in conducting a financially sound business management, but because of their societal goal and of the interest of their tenants, their financial position is guarded and secured by organisations as the WSW and the CFV. In this paragraph, the main internal cash flows of housing corporations are addressed, after which the external financial liability towards the WSW and the CFV is described.

2.3.1. Internal finances

The main source of income for the housing corporations has traditionally been the rental income, related to the exploitation of their social houses. In the monthly rental sum, only dwellings specific non-movable goods can be taken into account (BZK, 2012). Movable goods and related services are invoiced by the service costs, covering activities as the delivery of energy and water, administrative costs, furniture and possibly a caretaker (I&M, 2012).

An important source of income is to lend capital on the international markets as a way of financing their investments. To be able to access these markets under the most beneficial conditions, a financial backing system for the entire sector has been applied, which will be explained in section 2.3.2.

When the government stopped providing active financial support to the sector in 1988, the business model of the corporation was based on value (-development) of its real estate. In the first decade, the value of the properties rose significantly to cover the losses of the exploitation of the social dwellings. This loss is called the *'onrendabele top'* or unprofitable loss: the percentage of the establishment costs that cannot be retained by the rent. The rent of such dwellings is intentionally held low to remain affordable for the target group. The value development of the real estate was used as liquidity for new investments in housing, care or other strategic development projects. As can be seen in figure 6, the property value of dwellings in the Netherlands has been increasing substantially over time. The value development is a determinant of the investment possibilities of the corporations. The continuous increase in the value of real estate made it possible for housing corporations to invest billions, partly unprofitable, in the liveability of districts and neighbourhoods, as well as the construction of new houses.

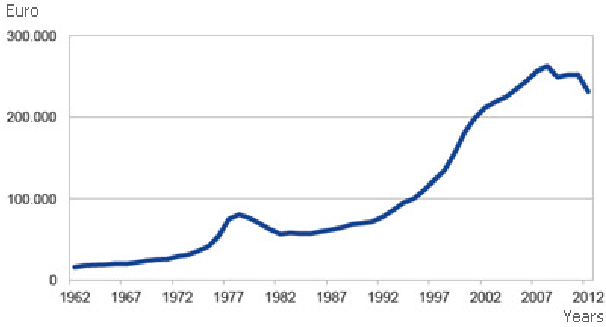


Figure 6: Value increase of dwellings in the Netherlands over time. Source: Calcasa WOX (2012)

In the last five years, value development of the existing housing stock has stalled and decreased, see figure 6. This has put serious constraints on the investment possibilities of housing corporations. Figure 7, depicts these developments and shows that the difference between company value and long-term debt per dwelling is decreasing. The increase in net operating expenses per dwelling is one explanation for this development. These costs rise at a higher rate than the maximum increase in rent, which is regulated at the rate of inflation. The amount of long term debt per dwelling keeps increasing sector-wide, while the company value per dwelling is declining, due to higher exploitation and personnel costs. It is expected that in the future, the long term debt will overshoot the company value (WSW, 2011)

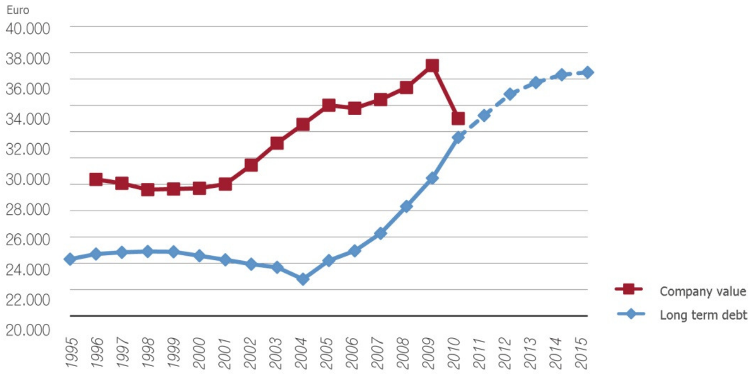


Figure 7: Company value and long term debt per dwelling. Source: WSW, (2011)

Since the positive difference between these two lines is a determinant for the investment possibilities of housing corporations, it is clear that these are becoming slim. More regulations of the EU (EC, 2009) and expected additional national taxes reduce the financial possibilities of the corporation sector. Higher construction costs and limited income possibilities also led to an expected unprofitable loss of 37% in 2016 (CFV, 2012), which results in a guaranteed loss of € 70.000 euro per dwelling.

Other formerly profitable activities, such as the selling of newly build houses also stalled, and profit has reduced to only € 1.100 Euro's per dwelling, or 0.6% profit margin (CFV, 2012).

It is therefore not surprising, that the overall trend on expected construction projects and expensive demolition projects are both decreasing (CFV, 2012). This puts more emphasize on renovation and improvements of the existing housing stock.

2.3.2. External finances

As explained in section 2.1., the Waarborgfonds Sociale Woningbouw and the Centraal Fonds Volkshuisvesting play an important role in providing and securing the financial continuity of the social housing sector. Together with the municipalities, the WSW and the CFV form the backings system of the corporations providing financial security for the DAEB-activities of the corporations.

The backing system enables housing corporations to lend capital for beneficial tariffs and under favorable conditions. The structure gives the financers 100% security that they will get a positive return on their investments. The structure consists of three backing levels (WSW, 2012).

The primary level is the financial position of the housing corporation themselves, mainly its liquidity and equity. National thresholds for several economic ratios exist for housing corporations, which should provide a financial healthy position for the corporation and enable them to settle their own obligations. The financial position of each individual corporation is supervised by the CFV, the independent external financial supervisor of the Dutch social housing sector. It assesses the financial position and the financial prospects of a corporation and the sector as a whole.

The second backing level is the bail-reserve of the WSW. If a housing corporation is not able to pay their debt and other financial obligations, the financer has the possibility to attend the WSW for repayment. The WSW has an immediately available equity of 3.7 billion Euros (WSW, 2012). In 2011, the WSW provided guarantee for a total sum of 86.3 billion Euros, which has never been opted by the corporations. The guarantee fund of the WSW has been given the highest rating, Triple-A and Aaa by the credit agencies Standard & Poor's and Moody's.

The third level is the backing position of the national government and the municipalities. Only if the WSW is not possible to settle the financial obligations, it can turn to the government and the municipalities which have to provide the WSW an interest-free loan. This option, however, has never been used.

The financial backing of the WSW is only possible for credit-worthy housing corporations. Therefore, the credit-worthiness of each housing corporations is assessed annually and placed in different monitoring profiles, according to its credit-worthiness. If assessed as non credit-worthy, the housing corporations looses the possibility of applying for new loans of the WSW and existing loans will have to be refinanced. The refinancing of the housing corporations is performed by the CFV, which offers restructuring and reorganizational aid for housing corporations which have been assessed as being in a negative financial position. In order to receive this aid, the housing corporation has to hand over multiple legal and financial documents and a restructuring plan. Only if the CFV has labeled the corporations as credit worthy it will be able to receive loans from the WSW.

The difference between the WSW and the CFV is that the WSW provides the corporations with funds to continue their operations. The CFV assesses the financial position and financial prospects, given the current operations of the housing corporation. With these two independently operating financial supervisors, the main activities of housing corporations, providing affordable housing for the lower incomes, is secured.

2.4. Current affairs

In recent years, some housing corporations made the news, because of speculative derivatives investments. During positive financial times the risks involved with such investments where limited, however when prospects changed it became such a financial burden that the corporations had to apply for aid of the WSW and the CFV for financial restructuring (CFV, 2012). Since housing corporations are each other financial back up, see section 2.3.2, other corporations are obliged to provide financial aid as well, with an estimated total amount of at least € 700 million. All corporations are therefore affected by this incident, resulting in restrictions on intended building and renovation plans.

Governmental plans regarding the social housing sector also limits the future plans of the sector. One of the governmental plans is the implementation of a letter-fee 'Verhuurderheffing', to stimulate the Dutch housing market. It obliges housing corporations to annually pay a fee, based on a percentage of the value of their total housing stock. In 2013, this percentage is 0,0014% of the value, which will increase to 0.231% in 2014. (Min. Financiën, 2012) This would cost the sector 485 million in 2014, increasing to 1.2 billion in 2017.

The effects of the governmental plans and policies on the finances and investment possibilities of housing corporations have been investigated by the Dutch Economic Institute of Construction (EIB, 2012). The report concludes that by 2017 housing corporations have lost € 1 billion in cash flows.

Although these plans are widely debated and have not yet been applied, the mere intentions of the government has put the sector in uncertainty. Because of this uncertainty and the negative financial consequences for housing corporations, the WSW has stated to no longer guarantee new loans for housing corporations, since under these new conditions, 47 % of the corporation would no longer comply with the criteria of the WSW (WSW, 2012).

2.5. Summary

The Dutch social housing sector has been very successful in providing enough affordable housing for the lower incomes. With 1/3 of the market under their exploitation, the Dutch social housing corporations are an important element of the total Dutch housing market.

However, the sector is struggling to maintain this position in the future. Due to several developments, the financial position of corporations is decreasing, meaning lower investment possibilities. In the past, losses in the sector could be covered up with the increased value of the real estate itself. Now that this is minimized, the unprofitable losses are putting more and more stress on the position of the housing corporations. Long-term debt is increasing, while the company value, the expected positive income during the exploitation period, is decreasing.

3. Energy efficiency in the Dutch social housing sector

This chapter elaborates on the role of energy efficiency in the Dutch social housing sector. Section 3.1 describes how energy efficiency is determined. Section 3.2 elaborates on the current state of the social housing stock regarding their energy efficiency and how this relates to the housing costs of these dwellings. Described in section 3.3 is the '*convenant energiebesparing huursector*', the latest national document stating the ambitions and agreements of the sector and the national government to improve the energy efficiency of social housing. Section 3.4 elaborates on Energy Services. The implementation of Energy Services in the Dutch social housing sector is mentioned in section 3.5 and its implications in section 3.6. The chapter's conclusions are stated in section 3.7.

3.1. Assessing energy efficiency

In accordance with the European Energy Performance of Buildings Directive, EPBD (EP, 2003), the Dutch government implemented national legislation, guidelines and documentation regarding measuring the energy performance of buildings. The national legal frame is documented in the '*Besluit Energieprestatie Gebouwen'*, (BZK, 2006a), and the '*Regeling Energieprestatie Gebouwen'*, (BZK, 2006b).

The energy efficiency of a dwelling is expressed using the '*Energie Prestatie Coefficient'*, EPC, for new dwellings, and using the '*Energie Index'*, EI, for existing dwellings. These numerical values are used to determine the energy label of a dwelling. The relation between the Energy Index and the energy label can be seen in figure 8.

Energy Label	G	F	E	D	C	B	A	A+	A++
EI-scale	≥ 2,91	2,41 - 2-90	2,40 - 2,01	1,61 - 2,00	1,31 - 1,60	1,06 - 1,30	0,71- 1,05	0,51 - 0,70	< 0,50

Figure 8: Energy labels and underlying Energy Index scale.

3.2. Existing social housing stock

A large part of the 2.4 million existing social houses in the Netherlands has been built before 1980. During that time, attention for the energy efficiency of houses was minimal, which can be seen in *Appendix A*, showing a table representing 1.8 million social houses which have been awarded an energy label and their construction year (Statline, 2012). The largest part, 86.5%, of the labeled houses are labeled energy label C, D, E, F or G. Extrapolated to the total amount of social houses in the Netherlands, this means that around 2.1 million houses lack a green label (A or B).

The low energy labels of a large part of the social houses means that these are not energy efficient, and increasingly more expensive energy (SenterNovem, 2005) is unnecessarily leaking out of these houses. Research showed that during the period 2000 – 2005, the average increase of energy costs for Dutch households was 42%, while in the same period their income has increased at a lower rate (SenterNovem, 2007). The share of household income spent on energy related expenses is therefore increasing (NiBud, 2009), a development that has more impact on tenants than on home-owners. EU-wide research on the relative housing costs of its households showed that the Netherlands has the highest relative housing costs, with a percentage of 30.9%, where the EU average is 22.2%. For the Dutch' lowest incomes, this percentage is even higher with 47.4% (Ministry of Infrastructure of the Italian Republic, 2006). This development has led to 'energy poverty': households which are not able to pay their monthly energy bills (RIGO, 2009)

3.3. Energy saving agreement in the rental sector

Acknowledging these developments, and the importance of the Dutch social housing sector, the Dutch ministry of Internal Affairs and Aedes, the association of Dutch social housing corporations, signed a new agreement concerning the energy performance of dwellings in the sector, the agreement Energy saving Rental sector or 'Convenant Energiebesparing Huursector', (BZK, 2012).

The agreement states important points and considerations regarding energy savings in the social housing sector for the period up to 2020. Amongst others, important starting points of the agreement are:

1. Energy savings is an adequate measure to stabilize the total housing costs of households.
2. Housing corporations have the ambition to save 20% of the total gas-use of the existing housing stock in the period 2008-2018.
4. The energy label, which has been introduced in the Netherlands since January 2008, is an important stimulus to improve the energy efficiency of buildings.
5. It is to be expected that the European targets regarding energy savings and renewable energy will be increased in the future.
6. All parties see the importance of energy savings in relation to the total housing costs.
8. Successful energy savings demand a set of coherent activities and measures.
16. To control the housing costs in the long run, energy savings does not suffice and the introduction of durable, renewable energy sources is necessary.

The agreement states that corporations intend to reach an average Energy Index of 1.25, (Energy label B) for the total housing stock in 2020. This ambition concerns the building and installation related energy use, in particular heating, warm water and ventilation.

Furthermore corporations will assess the possibilities for the large scale implementation of durable energy in the housing stock, i.e. Solar panels (PV and sun-boilers), wind energy and thermal storage. Also, they assess if a business cases with lower housing costs for the tenants is feasible and what barriers should be overcome to reach be able to do so.

3.3.1. Implications.

The agreement states positive developments regarding energy efficiency in the social housing sector. At the same time, the ambition–level of the agreement has been questioned by several experts (Renda, 2012). They argue that it is not ambitious enough and more investments are needed, since under current policies about 80% of the current social housing stock will no longer be within financial reach of the target group as mentioned in the BBSH by the year 2030, see figure 9.

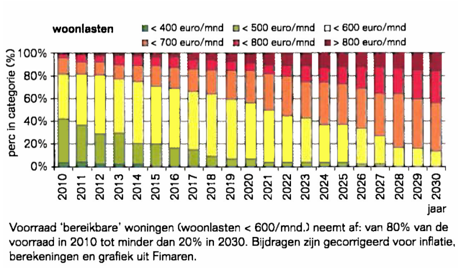


Figure 9: Percentage or rental dwellings within reach of the target group. Source: Renda, (2012).

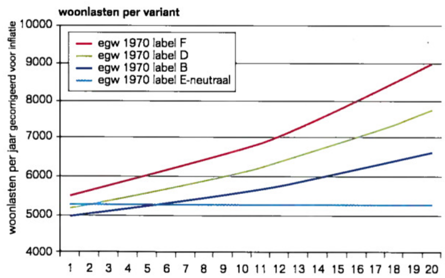


Figure 10: Total housing costs prospects per label. Source: Renda, (2012).

It is necessary for housing corporations to expand their focus and offer social housing with an affordable, long-term housing costs prospect. The better the energy label, the longer these prospects are assured, see figure 10, but only energy-neutral standards, energy label A++++, ensures the inhabitants with steady housing costs over a longer period of time (Renda, 2012).

Although the agreement states that housing costs should be stabilized, the ambition level regarding energy efficiency is not enough to comply with these goals. When comparing the mentioned *average* Energy Index of 1.25 for existing buildings with the *minimal* requirements for newly build houses, the difference is very clear, see table 1. The energy label is mentioned as an important stimulus for housing corporations to improve the energy efficiency and although 1.25 is an improvement on the average energy label, see *appendix A*, it is definitely not enough to stabilize the total housing costs.

Table 1: Difference in energy efficiency requirement level between new and existing dwellings.

Commencing date	Energy Performance Coefficient (EPC)	Energy Index (EI)
1-1-1996	1.4 (C Label)	
1-1-1998	1.2 (B Label)	
1-1-2000	1.0 (A Label)	
1-1-2006	0.8 (A label)	
1-1-2011	0.6 (A+ Label)	
1-1-2015	0.4 (A++ Label)	
1-1-2020	0.0 (A++ Label), (Min. EZ, L & I, 2011)	1.25 (B-label)

The agreement also states that it is to be expected that the European targets regarding energy savings and renewable energy will be increased in the future. As seen in table 1, the prospects for new dwellings is expected to be at an EPC-level of 0.0 (A++++ Label) in 2020 (Min. EZ, L & I, 2011), which equals energy-neutrality. The ambition to reach *an average* energy label B for existing dwellings by 2020 stands in sharp contrast with the outspoken ambition to stabilize the housing costs.

3.3.1.1. Energy delivery

The agreement mentions that housing corporations should examine the possibilities of implementing sustainable energy solutions in the housing stock to control the housing costs in the long run and that a coherent set of activities and measures are needed to do so, (BZK, 2012). The last starting point of the agreement states that, to control housing costs in the long run, energy savings alone is not enough and energy delivery by renewable energy is necessary. Applying renewable energy sources in dwellings is new for corporations, but opens up opportunities to further improve energy efficiency.

The mentioning of a coherent set of activities and measures to control the housing stock and the addition that, in the long run, this can only be achieved with the combination of energy savings and energy delivery, shows comparison with the Trias Energetica. The Trias Energetica is a commonly used strategy when implementing energy efficient measures. First mentioned in 1996 by Novem (E. Lysen, 1996), it was later worked out as an energy efficiency strategy at the TU Delft in the Netherlands focusing on three consecutive steps towards efficiency energy savings. These are stated below, and can be seen in figure 13:

1. Minimize the demand for energy;
2. Use energy from renewable sources for the remaining energy demand;
3. Use energy from fossil fuels as efficient as possible.

The Trias Energetica has overtime become a useful strategy towards efficient energy savings. The use of renewable energy to further increase the energy efficiency of buildings is mentioned as the logical next step towards efficient energy use.

3.3.2. Split incentive

However, the implementation of renewable energy sources by housing corporations requires heavy investments and a whole new business approach to cover these investments.

An often mentioned barrier for corporations to invest in energy saving measures is the so-called 'split incentive': housing corporations hesitate to invest in these measures because the financial gains of that investment – savings in energy – are all for the part of the tenants.

Private home owners that make large capital expenses to improve the energy efficiency of their dwelling cover this investment by the reduction in operating expenses. Over time, the added savings on operating expenses cover the initial capital expenses and the private home owner has made a lucrative investment. In the social housing sector, the building owner has to make the large capital expenses to improve the energy efficiency of their dwellings, but the reduction in operating expenses are for the building user, the tenant. In addition, the earnings capacity by increasing the rental sum to cover the capital expenses is limited by the liberalization boundary of € 664,66. Therefore, building owners in the rental sector therefore have little incentive to undertake expensive energy retrofits.

The split incentive makes it unattractive for corporations to heavily invest in further energy measures (Quirijns, 2011), let alone install expensive renewable energy generating installations as proposed in the agreement of BZK (BZK, 2012).

3.3.2.1. Total housing costs

A solution for this split incentive problem might be found in the focus on housing costs itself. If corporations could use both the rent and the energy costs as a means of income, i.e. become responsible for some of the operating expenses of their property, the possibilities of covering the capital expenses increases and the split incentive can be overcome.

However, focusing on total housing costs deviates from the main performance fields of housing corporations as mentioned in the BBSH (VROM, 2005). This brings a discussion to what extent corporations should operate in such non-DAEB-activities, given that their mandate mainly covers DAEB-activities.

Nonetheless, housing corporations are slowly but steadily investing in renewable energy solutions and assessing their possibilities of covering the investments. By doing so, they enter the market of energy services or energy contracting. Energy services use the expected savings on operating expenses to cover the investment in the energy saving measures that creates these savings. Apart from energy savings, energy services also focus on efficiently delivering and exploiting renewable energy sources to improve energy efficiency.

The analogy with the main points of the '*convenant energiebesparing huursector*', (BZK, 2012) in relation with finding a more feasible business model is evident. Energy contracting is therefore mentioned as a possible solution for the problems of the social housing sector (Compact, 2010), that can help to overcome market barriers for energy efficiency (Bleyl-Androschin, 2009a).

3.4. Energy Services

Energy Services, also called Energy Contracting (or ESCo), is a comprehensive energy service product to sustainably improve energy efficiency and cost efficiency of buildings or production facilities. The entity performing energy services implements a customized efficiency package, consisting of (Bleyl, 2008):

- Planning
- Building
- Operation & Maintenance
- Optimizations
- Fuel purchase
- (Re)Financing
- Technical and commercial implementation
- Bearing operational risks
- Providing energy savings guarantee
- Influencing user behavior

Energy Services originates from the U.S., where the sector has experienced a rapid growth of about 22% annually (ICF, 2007), mainly in the MUSH-market (Municipals, Universities, Schools and Hospitals) and federal market, because of the large energy savings potential. One of the main elements of Energy Services is that it used the realized savings on operating expenses to cover the initial capital expenses. This construction stimulates the ESCo to perform well; more savings means more income. Furthermore, the ESCo guarantees a certain amount of energy savings, with which the performance risk is transferred from the building owner to the ESCo.

Energy Services has been stated as a multi-purpose instrument, which will help to overcome market barriers for energy efficiency (Bleyl-Androschin, 2009a). Two distinct main contracting types emerged within the Energy Services sector (Bleyl-Androschin, 2009b):

Energy Performance Contracting, EPC, which is aimed at reducing the energy demand of a building and thus on energy savings, and Energy Supply Contracting, ESC, which is aimed at efficiently fulfilling remaining energy demand and thus on energy supply.

These contracting types are not about any particular technology or energy carrier, but rather must be seen as a modular 'efficiency tool' useful for energy efficiency projects, focusing on lowering energy demand and fulfilling energy supply in a more efficient, reliable manner. Although they both strive for efficient energy use and are part of energy contracting, their business model and implemented measures differ. In the next paragraphs, these two contracting types are elaborated, before their implementation in the social housing sector is investigated.

3.4.1. Energy Performance Contracting

Energy Performance Contracting's main goal is to reduce energy consumption by implementing demand side efficiency measures. This includes high insulation values for facades and windows, technical installations and influencing user behavior. The business model is based on delivering savings, compared to a predefined energy-use baseline before implementing the energy efficiency measures. The business model is best explained by figure 11:

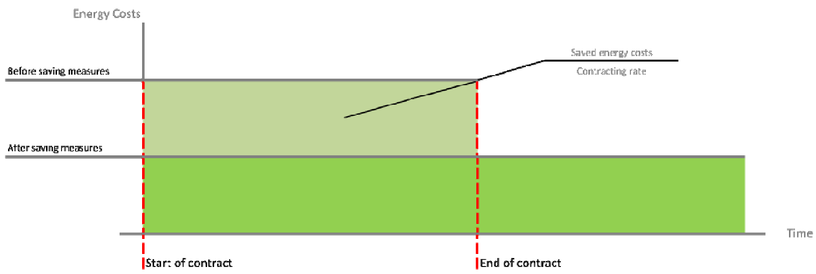


Figure 11: Energy Performance Contracting, graphic representation of the duration business model.

The previous energy costs of the client serves as the baseline: the energy costs that will be used to express the measured savings of the energy efficiency measures. The ESCo implementing the measures, assesses the property and composes a package of efficiency measures. When these measures are implemented, the energy demand of the building decreases, resulting in lower energy costs. The generated savings, avoided costs for the client, will then be used by the client to repay the initial investment during the confirmed contract period. During this period all savings on energy costs will be transferred to the ESCo. Once the contracting period is over, the client can enjoy the financial benefits of the efficiency gain as well.

A variant of this model can be seen in figure 12. The difference with the previous model is the division in the share of savings that the client receives from the beginning of the contracting period. When a client receives some of the savings early on, he might be more willing to implement the EPC-savings. The percentage of savings flowing back to the client is negotiable, but will result in an elongated contracting period. However, the model is a good instrument for an ESCo to convince the client to agree with the project.

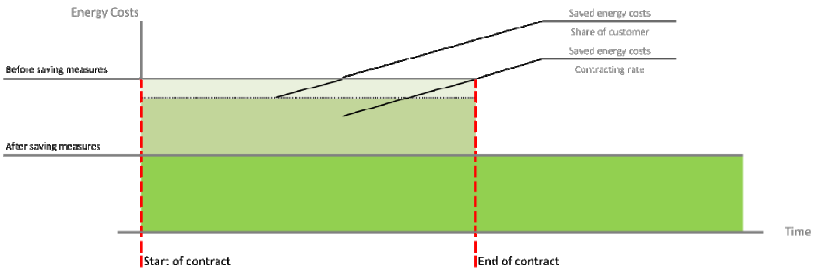


Figure 12: Energy Performance Contracting, graphic representation of the participation business model.

The advantage for the client in both EPC-models is that he does not need to invest large sums of capital, but can repay the investments with costs he normally would have made anyway. Also, since only the energy savings will be used to repay the ESCo, there is an incentive for the ESCo to perform well and realise the maximum amount of energy savings for a higher profit. To assess the actual savings on energy, there is an internationally used verification protocol, IPMVP, the International Performance Measure and Verification Protocol (ICF, 2007).

3.4.2. Energy Supply Contracting

Energy Supply contracting differs from EPC in the sense that it is not used for the realization of energy savings, but to provide maximum efficiency of the energy supply and providing the security of supply. The subject of the contract therefore is not the energy value as in EPC, but the utility value per volume items of energy. The ESC business model can be seen in figure 13. The efficiency gain results in lower costs for the client, while the ESCo acts as an energy provider.

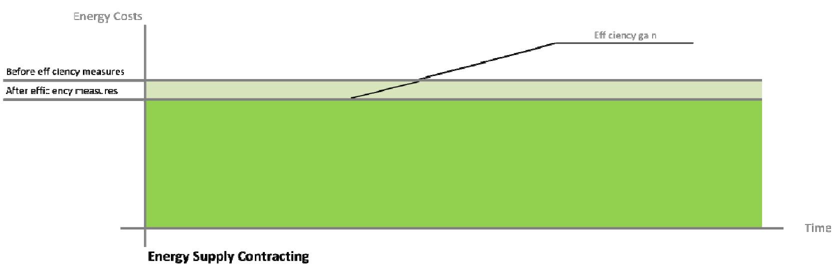


Figure 13: Energy Supply Contracting, graphic representation of the business model.

Within this contract, CHP-plants, combined heat and power plants and renewable energy solutions are frequently included (EU.BAC, 2010). Competent ESCo's have already installed innovative, high efficient and renewable technologies, such as bio-mass plants, solar energy, thermal energy systems, local heating networks or renewable fuels (Bleyl-Androschin, 2009a).

3.5. Energy Services in the Dutch social housing sector

To what extent are energy efficiency projects in the Dutch social housing sector similar to Energy Services? Bourgois (Bourgois, 2011) stated six elements that comprise the main characteristics of EPC and ESC projects. These characteristics serve as an analogy for assessing the business model's possibilities of energy efficiency projects in the social housing sector. Any sector specific implications and deviations due to legislation and regulations for housing corporations will be briefly stated. For a more elaborate comparison, see *Appendix B*.

3.5.1. Energy performance contracting, EPC

The EPC characteristics of Bourgois are stated and described in table 2.

Table 2: EPC characteristics, similarities and differences for the Dutch social housing sector.

Characteristics	Energy Performance Contracting (EPC), (Bourgois, 2011)	Projects in Dutch social housing sector
Client	User of existing units	Tenants
Target	Realization of energy savings potential	Realization of energy savings potential
Services by contractor	Partly renewal (financing incl.), operations & maintenance	Renewal, financing, planning, operation & maintenance
Re-financing	Energy savings	Housing costs savings
Risks borne by contractor	Risks of actual energy savings, operation & maintenance	Risk of actual energy savings, if guarantee is given
Economic advantages for client	Energy savings, guaranteed by contract.	Housing costs saving, possibly guaranteed

The distinction between dwelling owner and dwellings user, characterizing the social housing sector, affects the initiation phase of a project. Although the housing corporation owns the property, the position of the tenant is well protected under Dutch law, and the permission of at least 70% of a complex' occupants is needed before a rent-increasing renovation project can commence (Rijksoverheid, 2012). Since EPC- or demand reducing measures become part of the real estate, their investments can only be reclaimed by an increase in rent, stated by Dutch law (BZK, 2012).

To persuade their tenants to agree with the intended measures, housing corporations use the savings on total housing costs as a persuasive argument: although the rent will increase, the energy costs will decrease even more, meaning a net saving for the tenant.

Typically for EPC-projects is the risk allocation to the contractor, guaranteeing that a certain level of savings will be obtained. In the social housing sector, a corporation is free to provide such guarantee, but not obliged to do so. However, to convince tenants and reach the 70%-norm, a '*Woonlastenwaarborgfonds*' – housing costs guarantee fund – has been developed by Aedes (Aedes, 2009), which corporations can use to guarantee their tenants that the project will results in net savings on total housing costs. Corporations applying this fund have been awarded more appraisal and trust of their tenants and their project led to higher efficiency targets (Aedes, 2011).

Apart from the voluntary woonlastenwaarborgfonds, a second boundary restricts housing corporations in reclaiming their investment with rent increases. The liberalization boundary of € 664,66 poses a maximum level, which the corporations generally do not want to cross, since this would affect the position of the tenant and thus the ability to reach the 70%-norm.

The additional services of providing EPC-measures aren't different to the conventional services of a housing corporation, stated in the BBSH (VROM, 2005). The period in which the measures will be reclaimed is not a predefined contract period, but the elongated exploitation period of the real estate. This results in a lower, yet permanent rent increase.

3.5.2. Energy supply contracting, ESC

The EPC characteristics of Bourgois are stated and described in table 3.

Table 3: ESC characteristics, similarities and differences for the Dutch social housing sector.

Characteristics	Energy Supply Contracting (ESC), (Bourgois, 2011)	Projects in Dutch social housing sector
Client	Energy consumer	Energy consumer (tenant)
Target	Energy supply	Energy supply
Services by contractor	Planning, construction, operation & maintenance, financing	Planning, operation & maintenance, financing
Re-financing	Energy sales	Energy sales
Risks borne by contractor	Risks of construction, operations, maintenance, finance and purchase	Operation & maintenance, finance and purchase
Economic advantages for client	Avoided investments, purchase/ bulk buying advantages, reallocation of risk	Avoided investment, purchase, bulk buying advantages, reallocation of risks

Where an ESC is characteristically performed by an ESCo, in the social housing sector this is performed by a housing corporation or a possible subsidiary company. This does not affect most of the characteristics, but does imply some restraints on the full implementation of ESC-features. The most important restraints are related to the financial aspects of the ESC-business model.

Housing corporations conventionally have two tenant-related cash flows. The most important is the rent, which can only be used to cover the costs of dwellings-specific non-movable goods (BZK, 2012b). Since energy is a movable good, it may not be included in the rent. It could be invoiced trough the service costs, covering additional services of housing corporations and some administrative costs, however, these may only cover the costs of the service without room for profit (I&M, 2012). It thus depends on the cost-covering or market-driven attitude of the housing corporations if the service costs may be used.

If housing corporations intend to use energy delivery as a profitable undertaking, it can be invoiced separately by the corporation or a subsidiary company, '*Energy B.V'*. Because energy delivery is generally not a DAEB but an open market activity, a housing corporation cannot apply for the financial backing of the WSW, and it takes on more financial risks when doing so. Since the financial risks involved with non-DAEB activities could affect the financial position of the housing corporation and its main DAEB-activities, the Dutch government wants to implement an administrative separation between the DAEB and non-DAEB activities of corporations. Risky non-DAEB activities can no longer affect DAEB activities and state-aid cannot be used to perform market activities.

3.6. Market barriers

Energy Supply Contracting has the potential to become of importance for housing corporations, given their current financial position and the agreements in the covenant 'Energie Besparing Huursector' (BZK, 2012). For example, ESC seems to have more and wider possibilities for corporations to finance their projects. Also, the implementation of renewable energy sources, as stated in the covenant, is particularly suitable for Energy Supply Contracting. Moreover, with the help of ESC, dwellings can become energy neutral and inhabitants are no longer dependant on fossil fuels and increasing fuel prices.

However, housing corporations mainly perform energy efficiency projects with the characteristics of an EPC whereas ESC-type projects are only performed by a handful pioneering corporations. The regulations concerning non-DAEB activities and the high capital expenses of ESC-measures lower the attractiveness and feasibility of such projects. However, the combination of EPC with ESC could substantially improve the energy efficiency potential for the residential sector (Bleyl-Androschin, 2009a).

Legal and financial drawbacks have become market barriers for housing corporations to become active in the Energy Service sector. Many corporations mention that it is difficult for a corporations to delivery energy or implement energy delivering measures and that this is a reason for them not to become active.

Three main aspects hinder the large-scale implementation of Energy Services in the Dutch social housing sector: The attitude of the sector towards energy services and total housing costs; Utilization of ESC's earnings potential; and the Energy Index assessment.

3.6.1. Sector's position in energy services and total housing costs

Managing total housing costs by bringing energy services is mentioned in the covenant (BZK, 2012) as an important element for corporations to maintain affordable housing. However, in the BBSH (VROM, 2005), total housing costs are not mentioned. This causes divergence between performance goals and performance possibilities.

The interpretation of the main legislative document of the sector, the BBSH (VROM, 2005), is subject to discussion when it comes to the role of the housing corporation and energy services. This could explain the lack of a sector-wide acknowledged view on this matter.

Opponents of energy services point to the fact that, since these services are not mentioned in the BBSH, they are not part of the activities of a housing corporation and should be left to the private market. Proponents, however, state that although energy services are not mentioned explicitly, they are in line with, or are an extension of the activity fields, especially:

- To ensure quality of housing;
- To provide financial continuity of housing;
- To provide quality of life;

Since without energy services the quality of housing will worsen and the quality of life would depreciate. Also, when energy becomes more expensive, the low and energy inefficient, quality of social rental dwellings would lead to disproportionate expenses on energy and social rental dwelling could fall out of financial reach for its target group, see figure10.

A complicating factor is the role of the DAEB-regulations (EC, 2009), in relation to the BBSH. The overlapping domains of these two legislative documents cause vague areas and interpretation errors to occur. The intersecting domains of the BBSH and the DAEB-regulations are depicted in figure 14.

The domain of the BBSH is not restricted by the DAEB, but divided in three categories:

I	; Activities with state-aid,	(BBSH/DAEB)
II	; Activities without state-aid,	(BBSH/non-DAEB)
III	; Commercial projects without state-aid,	(non-BBSH/non-DAEB)

The discussion remains in what category Energy Services belong, and thus how they can be financed.

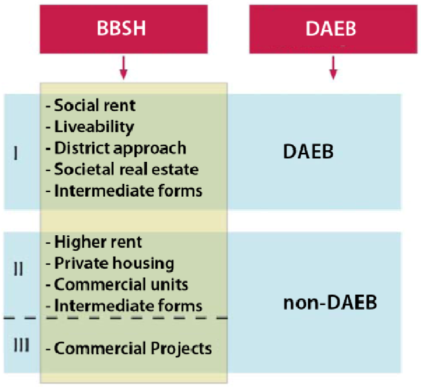


Figure 14: Domain restrictions and differences between BBSH and DAEB. Source: Aedes, (2011)

3.6.2. Earnings potential

Housing corporations encounter difficulties in utilizing the full earnings potential of ESC-measures and often adopt a more conventional EPC-like approach by increasing rent or by a user fee, instead of accounting for the actual energy use in kWh or MJ. Several regulations and legislative agreements hinder the corporations in covering the investments in EPC and ESC measures.

3.6.2.1. Liberalization Boundary

For EPC-like constructions in the higher segment of the social housing sector, the liberalization boundary is a big barrier to perform energy efficiency project. Since the higher segment lies just under this boundary, any rent increases due to EPC-measures could overshoot the boundary. In effect, the boundary can prohibit corporations to fully cover their investments in energy efficiency measures. This could translate into a lower financial return for the corporation or a lower project ambition level.

3.6.2.2. 70% approval rate

Moreover, the 70% approval rate of tenants lowers the negotiation position of housing corporations in determining the rent increase due to energy efficiency measures. To persuade the tenants to approve the planned measures, the rent increase is often sacrificed to a lesser amount as desirable. This issue is directly related to the split incentive that is inherent to the sector: since building owner and building user are two separate entities, the financial construction, together with the national legislation, is not optimal.

Especially when the costs of improving the energy efficiency becomes higher when aiming at higher energy labels, this problem could hinder the implementation of such measures.

3.6.2.3. Net-metering

Net metering, or 'virtueel salderen' in Dutch, means the recalculation of produced and used electricity. This is particularly important for the deployment of energy delivery installations with varying yield, such as PV-panels and windmill parks. Most of such installations generate electricity during the day, when most households aren't home. Since energy cannot be feasibly stored yet in large amounts, the produced electricity is delivered to the national grid for a low tariff. Once the households' demand for electricity rises again at night, it uses the same national grid for electricity supply, but with higher costs. The advantage of net-metering is that the tax and VAT on this electricity does not have to be paid, saving € 0,15 per kWh, which has an enormous influence on the feasibility of such projects..

However, the rules concerning net-metering leave room for interpretation and is particularly difficult for complexes with multiple households sharing one roof, as is the case with large apartment complexes of housing corporations. A research performed by Atrivé, (Atrivé, 2012) about a feasible business case for PV-panels in the social housing sector concluded positively regarding environmental and financial aspects, but advises corporations to wait until the juridical boundaries and political developments regarding the subject changes to more preferable conditions.

3.6.2.4. Warmtewet

The Dutch 'warmtewet', protects the vulnerable clients of closed heating systems from high costs, see *Appendix B*. This included 7.000 closed heating networks such as city heating projects, city block heating networks and thermal heating networks and affects 250.000 households in the Netherlands. The intended heating law will mean large administrative costs for the exploiting entity, which will be treated the same as nationally operation energy corporations. These additional costs will negatively affect the feasibility of newly intended networks. The law is yet to be officially installed, but has already been announced, placing another uncertainty over the sector.

3.6.3. EI determination process.

A more urgent barrier for the deployment of heating networks and other district measures is that they are not taken into account in determining the Energy Index of existing dwellings connected to the particular network. In newly build dwellings, this problem is accounted for with the implementation of a new methodology to determine the energy efficiency of these dwellings.

This new methodology consists of two new norms, the EPG and the EMG. The EPG, formalized by NEN 7120 is called '*EnergiePrestatienorm van Gebouwen'*, which focuses on building-related energy use. The EMG, formalized by NVN 7125, is called '*Energieprestatie voor Maatregelen op Gebiedsniveau'*, focusing on measures on complex or district scale.

For existing dwellings however, the EPG and EMG do not apply, which is a significant barrier for the implementation of larger-scale energy delivery networks in ESC-construction. The domain difference of the EPG and the EMG can be seen in figure 15.

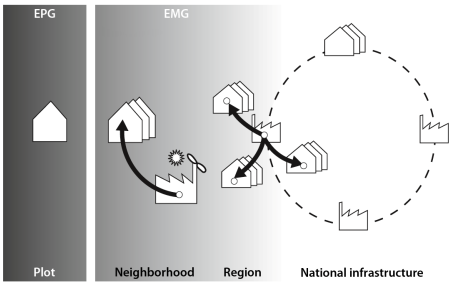


Figure 15: Difference in domain of the EPG(NEN (7120) and the EMG (NVN 7125).

Although the new methodology opens up opportunities for new dwellings, the lack of appreciation of district-scale measures in the energy efficiency assessment of existing dwellings, forms a barrier for energy supply contracting especially. Although a housing corporations is free to implement such measures, they do not contribute to the Energy Index of the involved dwellings, which makes it unattractive for corporations.

3.7. Conclusion

It is evident that the energy efficiency of most of the Dutch social dwellings needs to be improved to remain within financial reach of the lower incomes. The stated ambition of the sector, however, is not ambitious enough to ensure its affordability in the long run.

A complicating factor for the implementation of energy efficiency measures in the social housing sector is the split incentive: The lack of (financial) benefit for a housing corporation investing in energy efficiency measures. Together with the current precarious financial situation of the sector, this affects the willingness of housing corporations to invest in such measures.

A suggested solution to overcome these barriers is for housing corporations to become active in the Energy Services and use its inherent earnings potential to cover the investments (Renda, 2012; Atrivé, 2012). Also, by implementing durable energy solutions, the affordability of the dwellings in the long run would be more stable.

However, no research has been performed yet that assesses these theoretical assumptions. This restricts the discussion about a possible future of housing corporations in the energy services sector. Also, the influence of regulatory or legislative barriers on the performance of energy efficiency projects remains in the theoretical framework.

This research adopts a practical standpoint in this discussion by using a benchmarking methodology to assess the performance of energy efficiency projects and interviewing the responsible project leaders. This allows assessing the performance differences between EPC- and ESC-like projects in the Dutch social rental sector and the influence of market barriers on their performance. The research should provide new useful input and recommendations in the discussion about a possible future of housing corporations in the energy services sector.

4. Methodology

In this chapter, the methodology used to assess the characteristics and efficiency of different Energy Services in the social housing sector is explained. First, the use of benchmarking techniques is described in section 4.1, before the Data Envelopment Analysis method is described in section 4.2. The basic principles of DEA are explained in more detail in the following section. Section 4.4 briefly addresses the different DEA-models and orientation. The book of Cooper et al. (2000) is used as a basis for these explanatory paragraphs. Section 4.5 states the conclusions of this chapter.

4.1. Benchmarking techniques

Benchmarking can be described in multiple manners, but most definitions cover the following:

Benchmarking is a measurement of the quality of an organization's policies, products, programs, strategies etc. and their comparison with standard measures or similar measures of its peers. The objectives of benchmarking are:

- To determine what and where improvements are called for;
- To analyze how other organizations achieve their high performance levels;
- To use this to improve performance.

A typical benchmarking study process is depicted in figure 16 based on Compact, (2008).

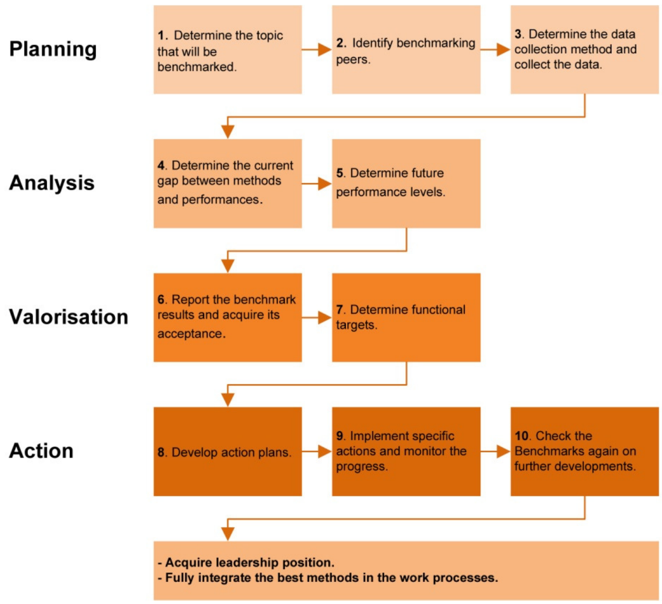


Figure 16: Benchmarking steps to increase performance. Source: Compact, (2008).

Benchmarking studies can be divided into two main categories: informal and formal benchmarking. As the name suggests, formal benchmarking is conducted consciously and more systematically then informal benchmarking. Within the formal benchmarking techniques, Performance Benchmarking and Best Practice Benchmarking are conducted.

Both approaches where mentioned in a study (Mann, 2010) as some of the benchmarking techniques that are likely to increase in the near future. Performance Benchmarking compares processes to identify opportunities for improvement and to set performance targets. Best Practice Benchmarking searches for the most optimal process by studying multiple organizations that are high performers within a specific field. In this graduation thesis, the formal benchmarking technique Data Envelopment Analysis, DEA, is adopted to perform both a best practice and a performance benchmarking study of energetic renovation project in the Dutch social housing sector. DEA provides with enough quantitative analysis tools to conduct both analyses simultaneously.

4.1.1. Benchmarking in the social housing sector

Because of its ability to help organizations perform better, based on the performance of best practices of similar organizations, benchmarking studies are often used to develop insight in the efficiency of Dutch housing corporations. Different benchmarking products have been developed specifically for this sector (Compact, 2008):

- *aeDex/IPD corporatie vastgoedindex*; Measures the yield on the real estate, used to visualize the financial-economic performance as well as societal performance of corporations.
- *KWH-Prestatie-Index;* Aims at ordering the societal performance of corporations which are part of the 'Kwaliteitscentrum Woningcorporaties Huursector', KWH. Assessed aspects are provision of service, occupant participation, social entrepreneurship and employership.
- *Woonbench;* Focuses on multiple elements and their interrelationship. Elements taken into account are costumer judgment, employee judgment, judgment of social partners and financial and operational performance.
- *Benchmark Onderhoudslasten;* Benchmarks the maintenance costs of corporations.
- *Benchmark Personeelslasten;* Benchmarks the corporation's employee costs and its effect on performance.

Aedes, together with KWH, Woonbench and CFV, is working on establishing the '*Corporatie Benchmark Centrum'*, CBC, a basis-benchmark with the possibility to benchmark key figures of corporations (Aedes, 2012a). The CBC is said to become a learning environment in which corporations can compare their performance with those of relevant colleague corporations. With these results, they acquire insight in their strengths and weaknesses, as well as opportunities to increase their performance. With the CBC, the sector is aiming at a quality increase of the entire corporation sector.

4.2. Data Envelopment Analysis, DEA

Data envelopment analysis was first introduced by Charnes, Cooper and Rhodes in 1978 (Charnes et al. 1978). It is a data oriented approach for evaluating the performance of a set of a relatively homogenous set of peer entities called Decision Making Units, DMUs. The methodology has grown into a powerful quantitative analytical tool for evaluating performance efficiency (Cooper et al, 2004). DEA is a relatively easy mathematical programming method, which identifies efficiency frontiers for a peer group of entities and has been proven to be particularly useful for estimating multiple input and multiple output production correspondences. In the past it has been used to assess the relative efficiency of schools, (branches of) banks and other business units and has intensified in recent years in management sciences for assessing efficiency. Zhou et al (2008) conducted a survey of the application of DEA in Energy and Environmental studies.

DEA opens up possibilities for use in cases which have been resistant to other approaches because of the complex and often unknown nature of the relations between the multiple inputs and outputs involved in many of these activities (Cooper et al., 2004). DEA has also been used to supply new insights into activities and entities that have previously been evaluated by other methods. DEA gives the researcher two important insights: it identifies the sources and amounts of inefficiencies in each input and output for every assessed entity, while also providing an overall measure of efficiency of each entity or activity that may be of interest. For an extended description of Data Envelopment Analysis and the underlying mathematical formulas and conditions, see *appendix C*.

4.3. Basic principles of DEA

As mentioned, DEA assesses the relative efficiency of a peer group of entities, called Decision Making Units, DMUs. A commonly used measure of efficiency is the following:

$$\frac{Output}{Input} \tag{4.1}$$

The biggest input to output ratio results into absolute or optimum efficiency and any improvements can only be achieved with new technologies or changes in the production process. When graphically represented, multiple ratios of different DMUs can clearly be overviewed. A simplified example can be seen in figure 17, showing a comparison between different branch stores and their sales/employee ratio.

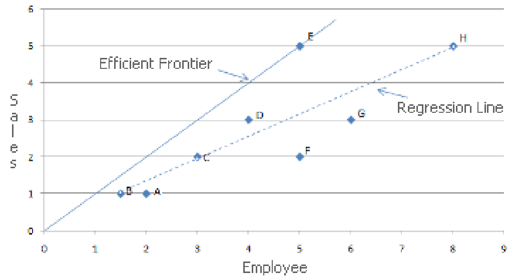


Figure 17: Sales/Employee ratios of different branch stores.

In figure 17, two lines can be seen. The dotted line is the regression line, the average sales/employee ratio based on the data of all branch stores combined. The second line is the Efficient Frontier: the line through the origin with the highest slope that touches at least one of the points. When using regression analysis, one could state the points lying above the regression line as excellent, and the points below the line as inferior, compared to the average performance. The Efficient Frontier, used in DEA, designated the performance of the best practice and measures the performance of the other points by deviations from this best practice. This difference between the methods could also affect the suggested improvement for inefficiency points. In regression analysis, characteristics of the most inefficient store (F) will also affect the improvement suggestions. In DEA only the best entities are used as a benchmark and to suggest improvements.

The efficiency of the DMUs is expressed with reference to the efficiency of the best practice DMU:

$$0 \leq \frac{Sales\ per\ employee\ of\ other\ DMUs}{Sale\ per\ employee\ of\ best\ practice\ DMU} \leq 1 \tag{4.2}$$

The best practice will therefore always receive the score of 1. All others are expressed as a percentage of the performance of this best practice. Improvements for the inefficient DMUs are given using their position relative to the Efficient Frontier. Improvements can be obtained by decreasing the input or by increasing the output. Decreasing the input translates into a movement on the input-axis towards the Efficient Frontier until the DMU reaches the line. It than also receives the score 1 and is labelled efficient. Similarly, increasing the output translates into a movement on the output axis towards the Efficient Frontier.

Exact relations between the inputs and outputs aren't always clear and differ per DMU. DEA uses an approach to overcome these difficulties by applying variable weights to the different inputs and outputs. Often, pre-selected fixed weights would by applied, but in DEA variable weights are used which are derived directly from the data. This means that a priori assumptions regarding relations between the variables are avoided (Sale, undated). The variable weights of DEA are assigned in such a way that they are optimal for every individual DMU. This means that the resulting input/output ratio for every DMU is maximized relative to the other DMUs and a discussion about arbitrarily chosen weights is avoided. The mathematics of the variable weighting scheme is explained in *appendix C*.

4.3.1. DMU's

The definition of a DMU is very broad and flexible. They can be any decision making entity such as individuals, company departments, governmental bodies or other entire organizations. The only requirement for a group of DMUs is that they exist in the same basic environment or work field and convert the same set of inputs into the same set of outputs. The processes and consideration which the DMUs employ for this conversion of input into output can therefore differ from one another. With similar quantitative goals the DMU's can still be benchmarked and a best process can be determined based on the analysis.

4.3.2. Input & output

The inputs and outputs used to conduct the benchmarking of the DMUs are selected by the researcher, based on available literature and expert's opinion. Whether or not a variable is considered input or output can generally be determined by assessing its desirability. Variables considered as desirable are outputs, undesirable variables mostly are inputs.

The number of inputs and outputs varies per benchmarking study, as long as they capture the performance of a DMU's key activities. It is customary that the number of inputs and outputs is kept at the minimum amount that still measures the full performance of a DMU. The reason for this it that with more of inputs and outputs, there are more variables on which a DMU can be labeled 'efficient' and nothing much is gained with the benchmarking study. Similarly too few inputs and outputs relative to the number of DMU's cannot show the truly efficient DMUs.

It is therefore necessary to have some mathematical approach to come to the necessary number of DMUs (*n*) based on the number of inputs (*m*) and outputs (*s*). Generally speaking, if the number of DMUs (*n*) is less than the number of inputs and outputs (*m + s*), a large proportion of DMUs will be identified as being efficient and the efficiency discrimination among the DMUs is questionable due to low discriminative power. A precise relationship between the DMUs and inputs and outputs is not provided, however there are some rules of thumb available, see table 4. There is no consensus on the exact amount, but they do provide a useful starting point.

Table 4: Relationship between number of DMUs and input and output variables.

Author	Rule of thumb
Boussofiane et al. (1991)	$n_{min} = m * s$
Golany and Roll (1989)	$n \geq 2 * (m + s)$
Bowlin (1998)	$n > 3 * (m + s)$
Dyson et al. (2001)	$n = 2 * (m * s)$

4.3.3. Sensitivity

Since the DMUs as well as the inputs and outputs on which they are assessed, are determined by the researcher, DEA results are particularly sensitive for measurement errors. It is important that the chosen inputs and outputs cover the performance of the DMUs and that the chosen DMUs represent their colleague entities which are not all taken into account in the benchmarking study.

Furthermore, if one DMU's inputs are understated and/or its outputs are overstated, this DMU could become a significant outlier that affects the position of the Efficient Frontier and reduces the efficiency scores of the other DMUs. In a regression study this problem is accounted for and does not have a large effect on the results. In DEA however, this effect could greatly influence the results. It is therefore important that the researcher critically assesses not only the qualitative, but also the quantitative aspects of the inputs and outputs.

4.4. DEA-models

Over the years different DEA-models have been developed with their own purpose. However, two basic DEA-models exist together with two main approaches towards process improvement.

4.4.1. CRS and VRC model

In figure 17 the Efficient Frontier is a straight line through the origin, which seems to suggest that there is a constant relationship between the input and the output of a DMU on the

Efficient Frontier. In DEA-terms, it is based on the assumption of Constant Return to Scale, CRS: if an activity (*x, y*) is feasible, than any other scalar form (*tx, ty*) is also feasible. A DEA-model built on this assumption is called a CRS-model, or CCR-model named after its introducers Charnes, Cooper and Rhodes.

However, it is not always reasonable to believe that the Efficient Frontier stretches out to infinity with the same slope. Non-linear scalar effects of production functions of DMUs are assessed using a different DEA-model, based on the original CCR-model. This model allows the researcher to take into account a Variable Return to Scale of a production function. The model is called a VRS-model or BCC-model after the introducers Banker, Charnes and Cooper. The difference in Efficient Frontiers of both models can be seen in figure 18.

The difference between the two frontiers makes it important for a researcher to choose the correct model. As the Efficient Frontier influences the efficiency score of a DMU, a wrongfully chosen model affects the results of the research and any conclusions that will be taken from it. E.g. the efficiency of DMU 'B' in figure 18 will be greater when using a VRS-model than when using a CRS-model, because its position is closer to the VRS-Frontier. If the CRS or the BRS model should be applied, depends on the scale of the chosen input and output variables.

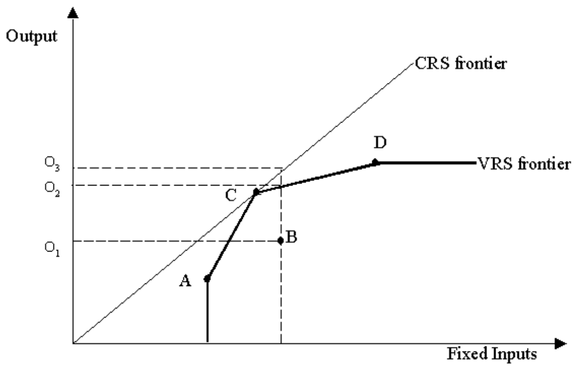


Figure 18: CRS and VRS Efficient Frontiers.

Extended information about the CRS and VRS model and the mathematics behind the models can be found in *Appendix C*.

4.4.2. Output-oriented and input-oriented

The improvement suggestions for inefficient DMUs can be determined using two approaches:

Input-oriented:
This models objective is to minimize inputs, while producing at least the given output levels.

Output-oriented:
This models objective is to maximize outputs, while using no more than the observed amount of any input.

4.5. Conclusion

Data Envelopment Analysis has proven to be a useful benchmarking tool for efficiency assessments in performance fields where a vast amount of data is not yet available. Also, it is able to perform a quantitative benchmarking study in performance fields where the actual transformation processes are complex and unknown and differences exists between DMU's processes, but where the actual goals of these different processes are alike.

This makes the methodology applicable for assessing the performance of energy efficiency projects in the Dutch social housing sector. The approach of such projects and the deliberations of individual housing corporations are largely unknown and can differ from one another, although they share common goals. In DEA, this does not influence the analysis and the projects can still be compared.

Furthermore, the variable weights of DEA, which are specifically applied to each DMU's individual situation, give the opportunity to assess difference between DMUs with EPC or ESC measures. The assumed advantages of the ESC-construction, mentioned in chapter 3, can thus be assessed in comparison with the EPC-construction.

5. Research Application

This chapter outlines the use of Data Envelopment Analysis as the method to assess the performance of energy efficiency projects of housing corporations. Section 5.1 addresses the research variables. The assessed projects, the DMUs, are briefly described in section 5.2 after which the conclusions are given in section 5.3.

The results of the Data Envelopment Analysis show how the selected energy efficiency projects perform on the chosen variables and which are labeled efficient or inefficient. From these results a possible verdict can be given on which Energy Service, EPC or the combination of EPC and ESC, performs best on which variables. With this insight an advice can be given for the sector to what extent they should embrace Energy Services.

5.1. Research variables

As described in chapter 4, the selection of both input and output variables and the DMUs must be performed with the greatest care to minimize measurement and sensitivity errors. Also, the selected variables must cover the actual performance of the DMUs without any external interference that could influence the results.

The input and output variables of a DEA must capture the full performance of the DMU's process, whilst keeping the total number of variables to a minimum. The input and output variables have been selected, using literature of (inter)national reports as well as published articles and interviews with individual housing corporations. They can be seen in table 5.

Table 5: Input and output variables.

Input (*m*)	Output (*s*)
Costs per dwelling	Savings on total housing costs
	Energy Index
	Present value of additional income

The input and output variables have been mentioned in several reports and articles as important parameters for projects aimed at increasing energy efficiency and in applying energy services, as seen in table 6.

Table 6: Input and output references.

Variable	References
Costs per dwelling	Renda, (2012); Compact, (2010); Aedes, (2012).
Savings on total housing costs	Renda, (2012); Compact, (2010); Aedes, (2012); BZK, (2011); AgentschapNL, (2011); BZK, (2012).
Energy Index	Renda, (2012); Compact, (2010); Aedes, (2012); BZK, (2011); BZK, (2012).
Present value of additional income	Renda, (2012); Compact, (2010), Aedes, (2012); Energiesprong, (2011); AgentschapNL, (2011).

These variables comprise the elements that have to be taken into consideration by every corporation performing an energy efficiency project; cover the characteristics of energy services; and incorporate the split incentive.

The increased energy performance, the main goal of any energy efficiency project, is expressed using the *Energy Index*. The *Costs per dwelling*, associated with improving energy efficiency, is used as sole input variable. The extent to which these costs are re-earned by the corporations is captured by the *Present Value* variable and the financial benefit for the tenant is captured with the *Savings on total housing costs.*

5.1.1. Costs, (X_1)

The input of any DEA must generally hold those variables that the DMUs will try to minimize. The number one element that all housing corporations will try to minimize when performing a renovation is the capital expenses needed to perform the renovation. Since the financial position of housing corporations is not very positive, any savings on the investments of renovation projects is desirable.

$$C_{ep;dwelling} = \frac{TC_{ep}}{n} \tag{5.1}$$

$C_{ep;dwelling}$	Costs of energy efficiency increasing measures per dwelling.	[€]
TC_{ep}	Total project costs of energy increasing measures.	[€]
n	Number of dwellings	[-]

Since energy-performance renovation projects are often performed in combination with other dwelling-related maintenance operations, such as the installation of a new kitchen or a bathroom, special attention should be given to the specification of the capital expenses. For this research, only the costs related to energy efficiency increasing measures are of importance, since only improvements may result in an increase in rent (BZK, 2012b). Maintenance costs fall under the normal costs of a corporation and are therefore not included in this variable.

5.1.2. Savings on Total Housing Costs, (Y_1)

The savings on total housing costs will measure the financial benefit for the tenants after the energy performance of their dwelling has been improved. In the agreement ‘Convenant Energiebesparing Huursector’ (BZK, 2012), it is stated that energy efficiency measures must lead to lower housing costs for the tenants. By assessing total housing costs the net value of all the earnings and costs for tenants is taken into account. In formula:

$$THC_{savings} = R_{increase} - E_{decrease} \tag{5.2}$$

$THC_{savings}$	Savings on monthly total housing costs	[€]
$R_{increase}$	Increase in monthly rental costs	[€]
$E_{decrease}$	Decrease in monthly energy costs	[€]

Housing corporations often use the savings on total housing costs as a measure to convince their tenants to agree with the suggested renovation plans. The expected savings are determined using the tenants' energy usage of previous years and the theoretically determined energy usage after the implementation of the energy efficiency measures. However, the actual energy use patterns of the individual tenants could deviate from this theoretical pattern, resulting into lower or higher savings.

5.1.3. Energy Index, (Y_2)

As explained in section 3.1, the Energy Index is used to express the energy efficiency of existing buildings. The score on the Energy Index determines which energy label the particular building will receive. By assessing the Energy Index of a building after an energy efficiency project, the quality of the energy efficiency measures of ESC or EPC are determined on an already existing scale.

The Energy Index of an existing dwelling is calculated by taking into account the building's engineering details, such as the Rc-values and U-values of the façades, roof and windows, as well as the building's installations for heating, energy supply, water, ventilation and lighting. The energy index is determined using standard weather conditions and standard user behavior, so that dwellings can easily be compared on their individual performances. Using these data, the following formula from ISSO 82.1 gives the building's Energy Index:

$$EI = \frac{Q_{total}}{(155 * A_g + 106 * A_{loss} + 9560)} \tag{5.3}$$

EI	Energy Index	[-]
Q_{total}	Total energy use of the dwelling under standard conditions, as stated in ISSO 82.3.	[MJ]
A_g	User surface	[m^2]
A_{loss}	The sum of all surfaces of the outer facades, weighted in accordance to the expected heat loss due to transmission losses.	[m^2]

Two values regarding the Energy Index are obtained per DMU. To capture the improved energy performance of the dwelling, the Energy Index after renovation is used, EI_{after}. The Energy Index of the same dwellings before the renovation enables to express the added quality of the measures on the EI-scale. This variable will be called ΔEI.

The lower the score on the Energy Index, the better the energy efficiency of a dwelling. Since an output variable in DEA should be expressed on an increasing scale of desirability, the data of the Energy Index needs to be adjusted to fit this rule.

5.1.4. Present Value, (Y_3)

The additional income per rental dwelling is taken into account to express the financial benefits of the energy efficiency project for the housing corporation. This is measured using the Present Value, PV, of the expected additional cash flows related to the renovated dwelling, during its extended exploitation period. In formula, this is:

$$PV = \sum_{t=1}^{n} \frac{(R_t + E_t)}{(1+r)^t} \quad (5.4)$$

PV	Present value	[€]
R_t	Additional income on rent per term	[€]
E_t	Energy-related income per term	[€]
r	Discount rate	[-]
t	1, … , n	[-]
n	Number of terms (years) in the extended exploitation period	[-]

The PV is a common accounting method with which corporations express the value of their property. To incorporate the full advantage of ESC, the energy income per term is added into the conventional PV calculation in the sector. The applied discount rate differs per individual housing corporation. In this research the discount rate is fixed at a rate of 5.25%, which is the same discount rate applied by the external financial supervisor CFV in their assessment on the financial positions of housing corporations.

In their annual reports for the CFV and the WSW, housing corporations apply the Net Present Value to state the value of their housing stock. In this NPV, the expected end value of the dwelling after the exploitation period is also added. This addition can substantially influence the property value and lead to a better result. However, the value of the property after the exploitation period is somewhat subjectively determined by the housing corporations to achieve more positive project results.

As the applied discount rate differs per housing corporation and the method of taking into account the property value after exploitation is done subjectively to influence the financial performance of the projects, these are not taken into account in this research. Since DEA determines a DMU's performance relative to the other DMUs and outliers, due to subjectively acquired data, could substantially influence the analysis, it is important to use similarly calculated, objective data.

5.2. DMUs

As stated in table 4 in section 4.3.2 the number of DMUs needed to conduct a DEA is related to the number of input and output variables. Since a total of four input and output variables are assessed, the number of suggested DMUs can be seen in table 7. The number of DMUs assessed in this research will be twelve, satisfying the highest rule of thumb.

Table 7: Number of DMUs needed.

Author	Rule of thumb	DMUs
Boussofiane et al. (1991)	$n_{min} = m * s$	4
Golany and Roll (1989)	$n \geq 2 * (m + s)$	8
Bowlin (1998)	$n > 3 * (m + s)$	12
Dyson et al. (2001)	$n = 2 * (m * s)$	8
DMUs in research		*12*

Furthermore, the group of DMUs must entail a good representation of the sector. Especially when performing a best practice benchmark, it is important to incorporate DMUs that are said to be the best in the field. Any awards or special credit for a particular DMU or the corporations performing the DMU regarding energy efficiency related performances is therefore stated.

Of the twenty-two initially contacted housing corporations, thirteen responded positively and were interviewed. Twelve of them handed over useful data. These DMUs can be found in *Appendix D,* stating the basic info of the DMUs.

5.3. Summary

The research goal is to gain insight in the effects of different energy services on energy efficiency targets and to use the results as input for the discussion on the role of housing corporation in the energy services sector.

The chosen input and output variables cover the main elements attributed to energy efficiency projects, namely the quality increase of the renovated dwellings, the financial benefits for the tenants and additionally acquired income for the corporations.

To be able to assess the influence of the two energy contracting types, EPC and ESC, DMUs were chosen which incorporate either an EPC or the combination of EPC and ESC. The number of DMUs enables the DEA analysis to determine truly efficient DMUs, without being so high that many 'efficient' DMUs will emerge.

6. Data

This chapter holds the obtained performance data from the DMUs in section 6.1.. The data preparation steps are described in section 6.2..

6.1. Data collection

All DMUs were visited and assessed on the research variables. Responsible project managers were interviewed to be able to understand the project details. The interviewees per DMU can be found in table 8. The interview question list can be seen in *Appendix E*.

Table 8: Interviewees per DMU.

DMUs	Contact	Function
DMU1	Jasper Bitterling	Projectsupervisor
DMU2	Joop ten Brink	Project leader
DMU3	Jo Bijsmans	Manager real estate
DMU4	Maurice Vinken	Project leader
DMU5	Eugène Korff	Senior real estate advisor
	Gert van Otterloo	Project leader
DMU6	Ronald Jonker	Project leader
DMU7	Sander Hooglugt	Project leader
DMU8	Bernard van Dam	Project leader
DMU9	Bernard van Dam	Project leader
DMU10	Dick Verburg	Project leader
DMU11	Ditmer Salverda	Project leader
DMU12	Jan Jaap Westhof	Project leader

The DMUs performance on the DEA input and outputs was determined with the information of the project managers. The collected input and output data per DMU are stated in table 9, below. An example of a DMU's information and calculations can be found in *Appendix F*.

Table 9: Data collection.

DMUs	**Input**	**Output**			
	Costs	Savings on Housing costs	Energy Index Before	Energy Index after	Present Value
1	€ 3.800,00	€ 7,00	2.38	1.20	€ 2.745,70
2	€ 60.000,00	€ 16,50	1.99	1.09	€ 6.666,94
3	€ 50.000,00	€ 28,00	2.32	0.88	€ 7.778,10
4	€ 77.000,00	€ 28,02	1.91	0.38	€ 15.802,79
5	€ 14.320,75	€ 8,00	2.31	1.49	€ 9.736,95
6	€ 20.881,60	€ 60,00	2.13	0.96	€ 0,00
7	€ 5.592,00	€ 30.58	1.87	1.25	€ 1.020,93
8	€ 45.000,00	€ 9,00	2.21	0.85	€ 9.228,81
9	€ 130.000,00	€ – 40,00	2.21	0.15	€ 45.553,39
10	€ 14.416,67	€ 63,00	2.38	1.16	€ 3.073,35
11	€ 40.000,00	€ 30,00	2.01	0.95	€ 0,00
12	€ 27.437,50	€ 7,00	2.31	1.02	€ 5.000,20

As explained in chapter 5, the input variable 'Costs' only covers the costs of the measures that improve the energy efficiency of the specific dwelling. The output variable 'Savings on total housing costs', depicts the monthly savings for tenants in relation to their previous housing costs. The variable 'Present Value' only takes into account the additional rent and/or other costs increases related to the energy efficiency measures. The 'Energy Index' variables indicate the dwelling's performance on energy efficiency as describe in ISSO 82.1.

6.2. Data preparation

Before the raw data can be used to perform a Data Envelopment Analysis, it must be prepared to fit favorable conditions. The steps taken to prepare the data of table 9 for analysis are described in this section.

6.2.1. ΔEI and EI_{After}.

As explained in section 5.2.2., the variable expressing the energy efficiency of the dwellings, the Energy Index, is split into two separate variables, and is then analyzed in two separate datasets.

ΔEI

The difference between the two obtained EI-values of the DMUs expresses the added energy efficiency quality and is found using equation 6.1.

$$\Delta EI = EI_{before} - EI_{after} \quad (6.1)$$

EI_{after}

The Energy Index after renovation depicts the end-value of the dwelling after renovation.

6.2.2. Increasing scale of desirability

Output variables undergoing DEA must have an increasing scale of desirability, i.e. the higher the output value the better the performance. If an output has a decreasing scale of desirability, i.e. the lower the output the better the performance, it is termed an 'undesirable output'. Since the energy index has a decreasing scale of desirability, the EI_{after} value has to be adjusted to a scale of increasing desirability. However, this must be done without adjusting the relative scale differences between the DMUs. Otherwise the DEA-results will be affected.

To overcome this problem, taking the inverse of the output variable is recommended (Sarkis, 2002), which maintains the integrity of the relationships of the data. This does not affect the efficient frontier for output-oriented BCC-models (Pastor, 1996). See equation 6.2.

$$EI_{after;new} = \frac{1}{EI_{after}} \quad (6.2)$$

6.2.3. Negative and zero values.

The dataset shows a negative number as well as some zero values. However, the 'positivity'-requirement of DEA (Sarkis, 2002), implies that all values must be non-negative and preferably strictly positive.

Following Bowlin (Bowlin, 1998), the negative value can be substituted with a very small positive value, if the variable is an output. Since DEA-models characteristically put each DMU in the best light possible and emphasize those outputs on which the DMU performs best (by means of the variable weights), Bowlin argues that an output with a very small positive value would not be expected to contribute to a high efficiency score, which would also be true for a negative value. Thus, the substitution of the negative value with a very small positive value would generally not inappropriately affect the efficiency score.

Of course, the substituted small positive value must not be larger than any other output value in the dataset. In the case of this research, the efficiency score is not affected, since the applied DEA-model, the output-oriented BCC-model, is translation invariant (Ali and Seiford, 1990) and therefore not affected by adjusting scales and unfavorable variables.

All negative and zero values in the dataset are therefore replaced with the value 0,0001.

$$Y_n = 0{,}0001 \tag{6.3}$$

Subject to $Y_n \leq 0$

6.2.4. Mean normalization.

Most DEA-analysis software can experience difficulties regarding scale difficulties between the variables under analysis. The imbalance between variable magnitudes causes problems in the execution of the software and round-off errors may occur. To overcome this problem and express the output-variables in more similar magnitudes, mean normalization is applied. The process of mean normalization is taken in two simple steps. The first step is to find the mean of the data set for each input and output, see equation 6.4.

$$\overline{V_i} = \frac{\sum_{n=1}^{N} V_{ni}}{N} \tag{6.4}$$

Where $\overline{V_i}$ is the mean value for column i, which can be input or output, N is the number of DMUs under assessment and V_{ni} is the value of DMUn for the input or output i.

The second step is to divide each DMU's individual input or output by its mean value, see equation 6.5.

$$VNorm_{ni} = \frac{V_{ni}}{\overline{V_i}} \tag{6.5}$$

Where $VNorm_{ni}$ is the normalized value for the associated DMUn and input or output in column$i$. The fully prepared and normalized datasets, for ΔEI and EI_{after}, can be seen in table 10 and 11.

Table 10: Prepared dataset 1, (EI_{after}).

DMUs	Input	Output		
	Costs (X_1)	Saving on Housing costs (Y_1)	EI_{After} (Y_2)	Present value (Y_3)
1	0,093368034	0,29258088	0,532772298	0,309063668
2	1,474232112	0,689654932	0,58653831	0,750449406
3	1,22852676	1,170323521	0,726507679	0,875524682
4	1,89193121	1,171159467	1,682438835	1,778806223
5	0,351868492	0,334378149	0,429078361	1,096018314
6	0,51135215	2,507836117	0,665965372	1,12563E-08
7	0,137398433	1,278160474	0,511461406	0,114918735
8	1,105674084	0,376175418	0,752149126	1,038820655
9	3,194169576	4,17973E-06	4,262178383	5,127616935
10	0,354503682	2,633227923	0,551143756	0,345944868
11	0,982821408	1,253918059	0,672975534	1,12563E-08
12	0,67415406	0,29258088	0,626790939	0,562836491

Table 11: Prepared dataset 2, (ΔEI).

DMUs	Input	Output		
	Costs (X_1)	Saving on Housing costs (Y_1)	ΔEI (Y_2)	Present value (Y_3)
1	0,093368034	0,29258088	0,966552901	0,309063668
2	1,474232112	0,689654932	0,737201365	0,750449406
3	1,22852676	1,170323521	1,179522184	0,875524682
4	1,89193121	1,171159467	1,253242321	1,778806223
5	0,351868492	0,334378149	0,671672355	1,096018314
6	0,51135215	2,507836117	0,958361775	1,12563E-08
7	0,137398433	1,278160474	0,507849829	0,114918735
8	1,105674084	0,376175418	1,113993174	1,038820655
9	3,194169576	4,17973E-06	1,687372014	5,127616935
10	0,354503682	2,633227923	0,999317406	0,345944868
11	0,982821408	1,253918059	0,868259386	1,12563E-08
12	0,67415406	0,29258088	1,05665529	0,562836491

7. Analysis

This chapter analyzes the results of the Data Envelopment Analysis. The results of the DEA of are shown in section 7.1, after which the different elements of DEA are also assessed. Section 7.2 states the preliminary conclusions on these first DEA results. Section 7.3 holds a second DEA analysis, on the potential performance of the same DMUs. The findings on this second analysis are stated in section 7.4. Section 7.5 summarizes the chapter.

7.1. DEA of actual performance

The applied DEA-model is the output-oriented BCC-model or Variable Return to Scale-model. Since the variables 'ΔEI', 'EI_{after}' and 'Savings on housing costs' are bounded by scale and are not indefinite, the CCR-model would not have been applied appropriately. The BCC-model is oriented towards achieving maximum output, as the goal of Energy Services is to achieve the biggest improvement on the energy efficiency of dwellings. Corporations strive to achieve a maximum benefit for their tenants on the housing costs as well as covering their own investment costs.

The datasets are analysed using the DEA-program 'PIM DEASoft-V3' (PIM Limited, 2011), of which the results can be seen in table 12 and 13.

The 12 DMUs under assessment are numbered following the sequence of *Appendix D.* The DMU number is shown in the second column of table 12 and 13. The first column shows the specific energy service that has been applied by the specific DMU. Their θ-score, or relative efficiency score, is shown in the third column. The formula to find θ is stated in *Appendix B.* The θ-score can be compared between DMUs. The fourth column states the reference set of peer-DMUs for the inefficient DMUs.

The last four columns represent the variable weights that have been individually determined for each DMU. The higher the variable weight, the more the corresponding variable contributes to the relative efficiency score of the specific DMU. Since the variables weights are DMU-specific, they cannot be directly compared between DMUs.

Table 12: DEA results for dataset 1, (EI_{After}).

ES	DMU	θ	Reference set	v_1	v_2	v_3	u_1
ESC	2	0.39	DMU_9 (0.33); DMU_{10} (0.67)	0.91		0.50	
	4	0.78	DMU_9 (0.43); DMU_{10} (0.57)	0.42	0.30		
	5	1	-			0.91	1.29
	9	1	-		0.23		0.28
EPC	1	1	-		1.88		2.26
	3	0.59	DMU_9 (0.24); DMU_{10} (0.76)	0.61		0.33	
	6	0.99	DMU_9 (0.03); DMU_{10} (0.97)	0.34	0.24		
	7	1	-	0.78	1.20		4.88
	8	0.52	DMU_5 (0.53); DMU_9 (0.27); DMU_{10} (0.21)	0.28		0.86	1.19
	10	1	-	0.38			
	11	0.57	DMU_9 (0.17); DMU_{10} (0.83)	0.58	0.41		
	12	0.52	DMU_1 (0.49); DMU_7 (0.33); DMU_9 (0.18)	0.12	1.54		1.84

The θ-value shows the relative efficiency of a DMU on a scale from 0 to 1. The reference set is determined for the non-efficiency DMUs as an indication of improvement possibilities. v_1, v_2, v_3 and u_1 represent the individually determined weights per DMU, corresponding with Y_1, Y_2, Y_3 and X_1, respectively.

Table 13: DEA-results for dataset 2, (ΔEI).

ES	DMU	θ	Reference set	v_1	v_2	v_3	u_1
ESC	2	0.58	DMU_1 (0.16); DMU_9 (0.41); DMU_{10} (0.44)	0.02	1.34		0.31
	4	0.92	DMU_9 (0.52); DMU_{10} (0.48)	0.17	0.64		
	5	1	-			0.91	1.29
	9	1	-			0.20	0.28
EPC	1	1	-		1.03		0.24
	3	0.97	DMU_1 (0.24); DMU_9 (0.33); DMU_{10} (0.43)	0.01	0.84		0.19
	6	0.96	DMU_9 (0.00); DMU_{10} (1.00)	0.16	0.62		
	7	1	-	0.52	0.66		4.74
	8	0.93	DMU_1 (0.59); DMU_9 (0.32); DMU_{10} (0.09)	0.01	0.89		0.21
	10	1	-	0.35		0.20	
	11	0.75	DMU_1 (0.15); DMU_9 (0.23); DMU_{10} (0.62)	0.01	1.13		0.26
	12	0.96	DMU_1 (0.79); DMU_9 (0.18); DMU_{10} (0.03)	0.01	0.94		0.22

The θ-value shows the relative efficiency of a DMU on a scale from 0 to 1. The reference set is determined for the non-efficiency DMUs as an indication of improvement possibilities. v_1, v_2, v_3 and u_1 represent the individually determined weights per DMU, corresponding with Y_1, Y_2, Y_3 and X_1, respectively.

7.1.1. Relative efficiency

Θ-values of 1 represent full BCC-efficiency for the respective individual DMU. It is important to note again that being labeled efficient in Data Envelopment Analysis means that a DMU converts its input into a combination of outputs in such a way that it lies on the efficient frontier. The Production Possibility Sets, or PPS-charts, showing the DMUs and their position in relation to the Efficient Frontier, are found in figure 19,

7.1.1.1. Efficient DMUs.

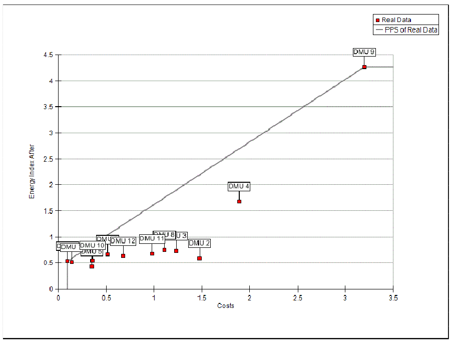
Full BCC-efficient DMUs are DMU_1, DMU_5, DMU_7, DMU_9 and DMU_{10}. These efficient DMUs are the same for both datasets. The other BCC-inefficient DMUs generate different θ-values for the two datasets.

The efficient frontiers, on which the efficient DMUs are placed, are a first indication of their relative strong points. DMU_1 is placed on all frontiers, shown in figure 19; DMU_5 is only placed on the frontier of figure 19.4 'Present value'; DMU_9 is placed on the frontier of figures 19.1, 'EI_{after}', 19.2, 'ΔEI' and 19.4,; finally, DMU_{10} and DMU_7 are placed on the frontier of figure 19.3 'savings on total housing costs'.

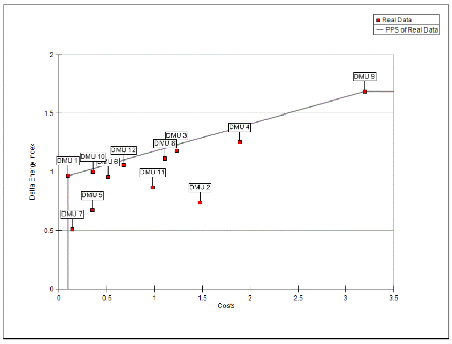
To evaluate the combination of variables of the efficient DMUs that are placed on multiple frontiers, the individual weights will have to be assessed. This is performed in section 7.3.

7.1.1.2. Inefficient DMUs.

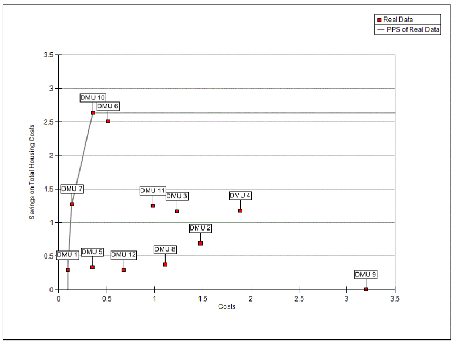
Almost all inefficient DMUs have higher θ-values for dataset 2, meaning that they are relatively more efficient in converting their input into the outputs of dataset 2.. Since the total performance of the DMUs is assessed, a change in the combination of all output variables is responsible for the difference in θ-value. However, since only the EI-variable changes for dataset 1 and 2 it can be concluded that in general the DMUs are more effective in making large steps on the Energy Index, than they are in achieving a very high Energy Index end-value.



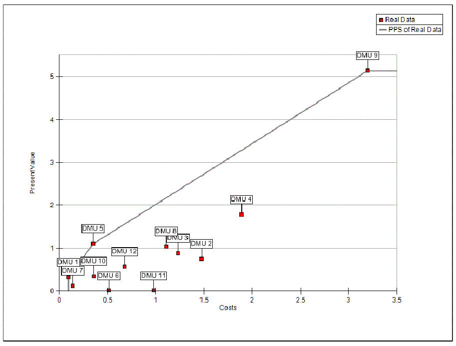
19.1: PPS chart. Costs vs. EI_{After}, dataset 1.



19.2: PPS-chart. Costs vs. Δ-EI, dataset 2.



19.3: PPS-chart. Costs vs. savings on total housing costs, dataset 1 & 2.



19.4: PPS-chart. Costs vs. Present Value, dataset 1 & 2.

Figure 19: Production Possibility Sets, PPS-charts, of the DMUs' performance.

The inefficient DMUs show some remarkable efficiency score differences between the two datasets. Most of the ESC-DMUs score well: DMU_5 and DMU_9 are efficient and DMU_4 scores reasonably well. DMU_2 however scores lowest on both sets, with θ-values of 0.39 and 0.58 resp.

The EPC-DMUs particularly are more relative efficient on dataset 2 'Δ EI', than they are on dataset 1 'EI_{after}'. The θ-values of DMU_3, DMU_6 and DMU_{12} increase dramatically from 0.52 – 0.59 to 0.96 – 0.97, almost being full efficient.

The variable weighting scheme of DEA can provide further insights into the combination of variables that attributed to each DMU's efficiency score.

7.1.2. Variable weights

In DEA the attributed weights for the selected output-variables are determined using a variable weighting scheme. The assigned weights, specified for each individual DMUs, results in the highest input-to-output ratio for that DMU, relative to all other DMUs if these weights were given to all DMUs.

The benefit of these variable weights, therefore, is that it emphasizes the strong aspects of an individual DMU, without generalizing for all DMUs combined. Also, other than the θ-values, which can be compared between DMUs, the weights cannot be directly compared with the weights of other DMUs, since they are DMU-specific. Their indication of strong points however, can be compared.

The variable weights for the two datasets can be seen in table 14 and 15.

Table 14: Variable weights for dataset 1, (EI_{after}).

	DMU	v_1	v_2	v_3	u_1
ESC	2	0.91		0.50	
	4	0.42	0.30		
	5			0.91	1.29
	9		0.23		0.28
EPC	1		1.88		2.26
	3	0.61		0.33	
	6	0.34	0.24		
	7	0.78			4.88
	8	0.28		0.86	1.19
	10	0.38			
	11	0.54	0.41		
	12	0.12	1.54		1.84

The weights correspond with the following variables: v_1 with savings on housing costs; v_2 with EI_{after}; v_3 with the present value; and u_1 for costs.

Table 15: Variable weights for dataset 2, (ΔEI).

	DMU	v_1	v_2	v_3	u_1
ESC	2	0.02	1.34		0.31
	4	0.17	0.64		
	5			0.91	1.29
	9			0.20	0.28
EPC	1		1.03		0.24
	3	0.01	0.84		0.19
	6	0.16	0.62		
	7	0.52	0.66		4.74
	8	0.01	0.89		0.21
	10	0.35		0.20	
	11	0.01	1.13		0.26
	12	0.01	0.94		0.22

The weights correspond with the following variables: v_1 with savings on housing costs; v_2 with ΔEI; v_3 with the present value; and u_1 for costs.

7.1.2.1. *Efficient DMUs*

Solely looking at the efficient DMUs, each DMU has found a combination of variables that made them efficient in relation to the other DMUs. For each efficient DMU the following can be said:

DMU_1

In dataset 1, the variable that has been attributed the highest weights is 'Costs', (u_1= 2.26). The output variables of DMU_1 might not be high in absolute terms, but given its low costs input, its input to output ratio is high, placing it on every Efficient Frontier. However, only 'EI_{after}' is attributed with weight (v_2 = 1.88), indicating that only variable is a distinctive aspect. For dataset 2, the main contributor to its efficiency score is ΔEI (v_2 = 1.03). In figure 19.2, it can be seen that, although its cost are low, the added Energy Index score is higher than other DMUs with higher costs.

DMU_7

For dataset 1, following similar reasoning as DMU_1, the highest weight for DMU_7 is attributed to 'Costs', (u_1= 4.88). The Efficient Frontier it is placed on is related to the Savings on total housing costs variable (v_1= 1.20), seen in figure 19.3. In dataset 2, the costs of DMU_7 is again the most influential u_1 = 4.74. Also, its savings on total housing costs and ΔEI are awarded weight of v_1 = 0.52 and v_2 = 0.66 respectively.

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DMU_1 and DMU_7 are both EPC-DMUs and the two DMUs with the lowest absolute costs. These low costs positively influence their input-to-output ratio and which has made them efficient. Therefore their 'Costs' variable is attributed with high weights.

DMU_{10}

DMU_{10} in particular is labeled efficient because of its high savings on housing costs (v_1 = 0.38), where it is placed on the Efficient Frontier, see figure 19.3. For dataset 2, the 'Present Value' variable is also attributed some weight.

DMU_5

DMU_5 is the first ESC-DMU that is labeled efficient. Its variable weights are the same for both datasets. The financial variables of 'Present value' (v_3= 0.91) and 'Costs' (u_1= 1.29) are its clear strong points.

DMU_9

DMU_9 is the second efficient ESC-DMU. In dataset 1 it received its highest score for the variable 'Costs", (u_1= 0.28), closely followed by 'EI_{after}' (v_2= 0.23). Remarkably, its high absolute score on present value is not rewarded with any weight in dataset 1, indicating that EI_{after} is of more discriminative power for this DMU. For dataset 2, the present value is given weight (v_3= 0.20), while costs remains the strongest variable (u_1= 0.28). Although it is placed on the efficient frontier in figure 19.2, it is not rewarded any weight for its ΔEI-score.

From this can be obtained that the most BCC-efficient DMUs receive their efficiency score because of the financial variables. Either the DMUs have kept their relative costs low (DMU_1, DMU_7) or kept their income relatively high (DMU_5, DMU_9). DMU_{10} is the only DMU that is solely labeled efficient because of one contributor, namely the savings on housing costs. From the Energy Index variables, only ΔEI is distinguishable enough for a DMU to be the main contributor to an efficient θ-value score.

7.1.2.2. EPC- and ESC-DMUs

Comparing the efficiency performance of the EPC- and ESC-DMUs, important differences, both in relative as in absolute values can be seen.

For the input variable 'Costs', the most expensive projects are all ESC-DMUs and the EPC-DMUs are much cheaper. However, these higher costs do translate into some better absolute values on the output variables.

Regarding EI_{after}, all EPC-DMUs score below average in absolute terms, and two of the ESC-DMUs score significantly higher on this variable. This does not, however, translate into significant difference in the attribution of the variable weights. Even with lower costs, an EI-score relatively close to the Efficient frontier can be achieved. All DMUs, apart from ESC-DMU_5, score at least a B-label.

For ΔEI, no significant differences arise between the two different energy services types. The overall performance of the DMUs tends to be better on this variable as the costs of the project rises. Many DMUs find themselves close to the Efficient Frontier, an explanation for the higher θ-values and higher weights for v_2 in dataset 2.

EPC-DMUs score much better on the savings on total housing costs than ESC-DMUs. This is also depicted by the weights for v_1. That these weights are higher for dataset 1 than dataset 2 depends on the relative better performance of the EPC-DMUs in dataset 2 and ΔEI specifically, which lowers the discriminative power of the savings on total housing costs, and thus its weight.

ESC-DMUs score much better on the present value of the projects, with three of the highest absolute values. Relatively also, the ESC-DMUs are more efficient in transforming their costs into present value, especially in dataset 2 where the EPC-DMUs receive almost no weight for v_3. However, this does go at the expensive of their savings on total housing cost, where ESC-DMUs score low to mediocre.

Although ESC-DMUs show better absolute scores on most of the variables then EPC-DMUs, their sometimes lower input-to-output ratio due to higher costs, are an important consideration for housing corporations when choosing between ESC or EPC projects. Especially since almost all DMUs are able to meet the B-label norms, ESC must have a distinct advantage over EPC before it will be widely implemented.

7.1.3. Reference sets

As indication to become more efficient, inefficient DMUs are given reference DMUs: DMUs with which they can compare their performance in order to become more efficient. The reference DMUs are always efficient, since there are located on the efficient frontier.

For all non-efficient DMUs, DMU_9 is mentioned as a reference DMU in both datasets. Recalling that DMU_9's strong point are its financial variables, as its high present value and its high absolute EI_{after} score, this indicates that inefficient (EPC-)DMUs should move towards the input-to-output ratio of DMU_9. As DMU_9 used the earnings potential of the implemented energy delivery measures, inefficient DMUs should adopt this method to improve performance . As an additional advantage, the implementation of such measures would also improve the Energy Index of the dwellings.

The other efficient DMUs that often serves times as reference DMU is DMU_{10}. Its high savings on total housing costs serves as an improvement point for almost all DMUs. It must be said however, that DMU_{10} has no present value, since it charged no rent increase. Although this does translate into high savings for the tenant, it puts stress on the financial feasibility of such projects for the corporation itself.

DMU_1 is mostly mentioned as a reference DMU in dataset 2. Since it is placed on the Efficient Frontier in figure 19.2 (Δ-EI) and other DMUs are relatively close to this frontier and have high θ-scores, any large absolute improvement by adopting DMU_1's approach is not expected.

7.2. Preliminary conclusions on actual performance

The fact that most of the efficient DMUs obtained their efficiency because of low cost and not necessarily because of higher EI scores is a good representation of reality and characterizes the discussions and deliberations of housing corporations: If small yet norm-sufficient improvements can be made with a minimum amount of investments, is it worth the effort to strive for further improvements if the related costs raise disproportionately?

The fact that all DMUs have a higher θ-value for dataset 2 indicates that it is not very attractive to strive for high EI_{after} values because of the higher costs that these measures entail. DMU_5 and DMU_9 prove that it is possible to be efficient as an ESC-DMU, not on a high EI_{after} score, but mostly because of the high present value achieved by utilizing the earnings potential of the ESC measures. Even though the costs of DMU_9 are by far the highest of all DMUs, its ability to re-earn a relatively large part of their investment by bringing Energy Services has led to its relative efficiency.

Although it was expected that ESC-DMUs would score much better on their Energy Index variables, this is not the case. Therefore, in communicating the advantages of Energy Supply Contracts, more emphasize should be placed on its ability to cover the large investments. Given the current financial position of some corporations this argument could even have more impact. The higher absolute Energy Index that will be achieved when implementing ESC is less influential regarding their efficiency score, but is a second advantage of ESC regarding the absolute energy efficiency score.

The other ESC-DMUs, DMU_2 especially, scores the lowest θ-value on both datasets. An explanation could be that their earnings potential of the ESC-measures was not fully utilized. The earnings potential of ESC-measures cannot always be utilized due to national legislation and other perceived barriers, lowering the relative efficiency of ESC constructions.

7.3. DEA of potential performance

The previous section concluded that ESC-DMUs perform not as efficient as potentially possible. The reason for this is that Energy Supply Contracting's income structure is not always possible because of outdated national legislation and decrees as well as lagging revisions of norms in the social housing sector, which have been described in section 3.6.

These barriers and difficulties affect the performance of the ESC-DMUs. To find the full potential of the assessed ESC-DMUs, their initial data is corrected to values as if these barriers were not in place. To do so, the following steps are taken:

1. The Energy Index of DMU_5 is recalculated to the Energy Index that it would have had is the heating network was taken into account. This is determined using the EMG or NVN 7125 '*Energiemaatregelen op gebouwniveau*' and the accompanied calculation-tool of the NEN, (AgentschapNL, 2011).

2. The full earnings potential of the ESC-measures of DMU_2, DMU_4 and DMU_9 is determined using NEN 7120.20 '*Gebouwgebonden productie van elektriciteit op het eigen perceel'* and NEN 7120.21 '*Klimaatgegevens*'.

The recalculations can be found in *Appendix I.* The results of the recalculations can be seen in table 16, in which the altered values are highlighted. This data will be used as input for a new Data Envelopment Analysis based on the potential performance.

Table 16: DMUs' variables, improved for ESC-measures.

DMUs	Input	Output			
	Costs	Savings on Housing costs	Energy Index Before	Energy Index after	Present Value
1	€ 3.800,00	€ 7,00	2.38	1.20	€ 2.745,70
2	€ 60.000,00	€ 13,74	1.99	1.09	€ 6.983,55
3	€ 50.000,00	€ 28,00	2.32	0.88	€ 7.778,10
4	€ 77.000,00	€ 14,39	1.81	0.38	€ 16.596,76
5	€ 14.320,75	€ 8,00	2.31	1.12	€ 9.736,95
6	€ 20.881,60	€ 60.00	2.13	0.96	€ 0,00
7	€ 5.592,00	€ 30.58	1.87	1.25	€ 1.020,93
8	€ 45.000,00	€ 9,00	2.21	0.85	€ 9.228,81
9	€ 130.000,00	€ - 32,09	2.21	0.15	€ 43.120,06
10	€ 14.416,67	€ 63,00	2.38	1.16	€ 3.073,35
11	€ 40.000,00	€ 30,00	2.11	0.95	€ 0,00
12	€ 27.437,50	€ 7,00	2.31	1.02	€ 5.000,20

7.4. Findings

Following the same data preparation steps as in section 6.2, a second Data Envelopment Analysis is performed of which the results are shown in table 17 and 18.

Table 17: DEA-results for potential dataset 1, EI_{after}.

ES	DMU	θ	Reference set	v_1	v_2	v_3	u_1
ESC	2	0.37	DMU_5 (0.02); DMU_9 (0.39); DMU_{10} (0.59)	0.32		1.01	1.32
	4	0.65	DMU_1 (0.04); DMU_5 (0.08); DMU_9 (0.55); DMU_{10} (0.34)	0.07	0.34	0.21	0.70
	5	1	-			0.90	1.21
	9	1	-		0.24		0.28
EPC	1	1	-		1.90	1.07	2.26
	3	0.59	DMU_9 (0.25); DMU_{10} (0.75)	0.56		0.34	
	6	0.99	DMU_9 (0.03); DMU_{10} (0.97)	0.32	0.24		
	7	1	-	0.74			4.88
	8	0.53	DMU_5 (0.54); DMU_9 (0.27); DMU_{10} (0.20)	0.27		0.85	1.10
	10	1	-	0.30			
	11	0.57	DMU_9 (0.17); DMU_{10} (0.83)	0.54	0.41		
	12	0.52	DMU_5 (0.20); DMU_7 (0.57); DMU_9 (0.16); DMU_{10} (0.08)	0.19	1.09	0.46	1.97

The θ-value shows the relative efficiency of a DMU on a scale from 0 to 1. The reference set is determined for the non-efficiency DMUs as an indication of improvement possibilities. v_1, v_2, v_3 and u_1 represent the individually determined weights per DMU, corresponding with Y_1, Y_2, Y_3 and X_1, respectively.

Table 18: DEA-results for potential dataset 2, Δ-EI.

ES	DMU	θ	Reference set	v_1	v_2	v_3	u_1
ESC	2	0.58	DMU_1 (0.23); DMU_9 (0,42); DMU_{10} (0.35)	0.01	1.38		0.31
	4	0.91	DMU_1 (0.21); DMU_9 (0.56); DMU_{10} (0.23)	0.01	0.81		0.18
	5	1	-			0.90	1.21
	9	1	-			0.20	0.27
EPC	1	1	-		1.06		0.24
	3	0.96	DMU_1 (0.24); DMU_9 (0.33); DMU_{10} (0.43)	0.01	0.86		0.19
	6	0.96	DMU_9 (0.00); DMU_{10} (1.00)	0.15	0.64		
	7	1	-	0.49	0.68		4.74
	8	0.91	DMU_1 (0.59); DMU_9 (0.32); DMU_{10} (0.09)	0.01	0.92		0.21
	10	1	-	0.33		0.20	
	11	0.75	DMU_1 (0.15); DMU_9 (0.23); DMU_{10} (0.62)	0.01	1.16		0.26
	12	0.96	DMU_1 (0.79); DMU_9 (0.18); DMU_{10} (0.03)	0.01	0.97		0.22

The θ-value shows the relative efficiency of a DMU on a scale from 0 to 1. The reference set is determined for the non-efficiency DMUs as an indication of improvement possibilities. $\boldsymbol{v_1}$, $\boldsymbol{v_2}$, $\boldsymbol{v_3}$ and $\boldsymbol{u_1}$ represent the individually determined weights per DMU, corresponding with $\boldsymbol{Y_1}$, $\boldsymbol{Y_2}$, $\boldsymbol{Y_3}$ and $\boldsymbol{X_1}$, respectively.

In comparison with the DEA-results obtained from the real dataset, the θ-values changed minimally. It is remarkably however that DMU_2 and DMU_4 received lower θ-values in dataset 1 especially. The relative position changes of the DMUs can be seen in figure 20 depicting the new PPS-charts.

7.4.1. EI_{after} of DMU5

Figure 20.1 and 20.2 visualize the changes in the Energy Index variables. Since the EI_{after} of DMU_5 increased significantly, the mean of the EI-variables increased as well and the relative position of the other DMUs therefore decreases. DMU_5's position increases on both variables, of which the increase in Δ-EI is the most noticeable, see figure 20.2. That this is not depicted by the weights of DMU_5,($v_2 = 0$) for both datasets, is due to the position of DMU_5 on the efficient frontier of figure 20.4.

Nonetheless, it means that when collective ESC-measures on district scale would be taken into account in determining the Energy Index of existing dwellings, the energy efficiency and thus the attractiveness of such projects for housing corporations would increase.

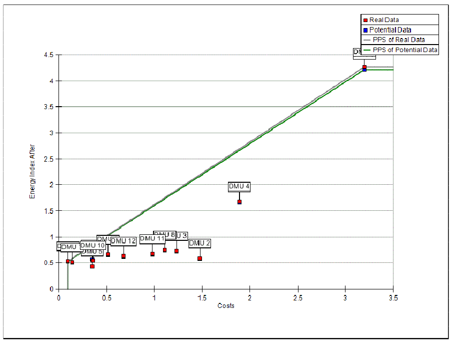
7.4.2. Earnings potential of DMU_2, DMU_4 and DMU_9

The earnings potential of the remaining ESC-DMUs, which increased for DMU_2 and DMU_4 but decreased for DMU_9 is depicted in figure 20.4. The higher Present Value of DMU_2 and DMU_4 goes at the expense of the savings on total housing costs, see figure 20.3

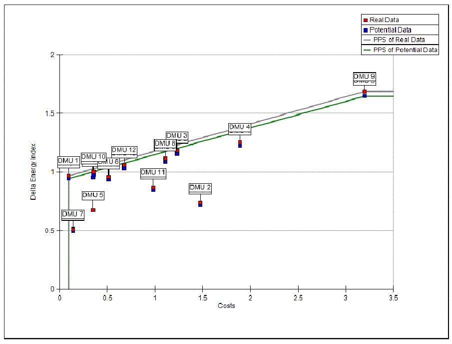
Since the savings on total housing costs was the most influential variable of these DMUs in the real dataset, their θ-value decreases. However, with the use of the potential dataset, the real strong points of EPC and ESC projects are found.

The variable weight $\boldsymbol{v_1}$ of the ESC-DMUs decreases in both datasets. This exemplifies that generating savings for the tenant is not a strong point of Energy Supply Contracting in comparison with Energy Performance Contracting.

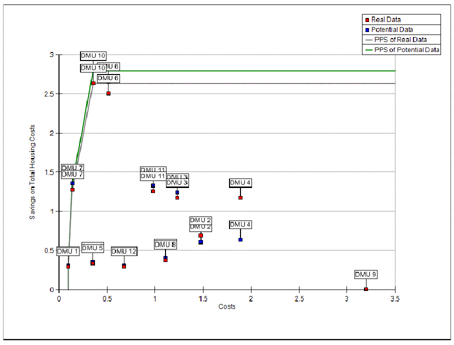
The findings and conclusions on the assessed input and output variable per Energy Contracting type can be found in *Appendix J*.



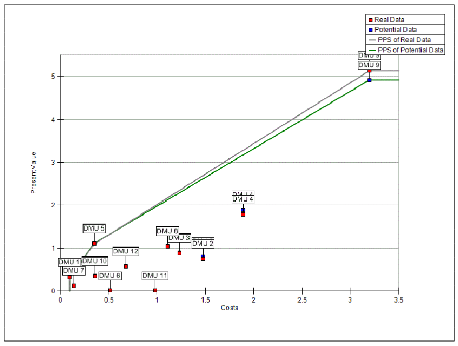
20.1: PPS chart. Costs vs. EI_{After}, dataset 1.



20.2: PPS-chart. Costs vs. Δ-EI, dataset 2.



20.3: PPS-chart. Costs vs. savings on total housing costs, dataset 1 & 2.



20.4: PPS-chart. Costs vs. Present Value, dataset 1 & 2.

Figure 20: Production Possibility Set, PPS-chart, of the DMUs' potential performance. The new efficient frontiers are colored green.

7.5. Summary

The two energy services types, Energy Performance Contracting and Energy Supply Contracting, and their characteristics provide for an useful framework to capture the performance of energy efficiency projects in the Dutch social housing sector. Moreover, the two income structures provide the opportunity to evaluate the performance of the conventional approach of the sector (EPC) with the approach that is proclaimed to be the future of the sector (ESC & EPC).

The assessed energy efficiency targets in this research are chosen to represent both the main targets of an energy efficiency project as performed by housing corporations and to cover the main characteristics of the two energy service types. Simultaneously, they fit the requirements of Data Envelopment Analysis.

The variables therefore cover the quality of the projects in the two Energy Index variables, whereas the other variables are based on the financial aspects of the project. The financial variables exemplify the differences in cost and income structure of the two Energy Services and the balance between financial benefit for corporations and tenants.

8. Conclusions

This chapter states the overall conclusions and answers on the research question in section 8.1, based on the assessed literature, the interviews with DMUs' project leaders and the DEA results. The results of the research will be reviewed for its ability to comply with the research objective and to answer the main research question and sub questions. These were stated as:

> ***Research question:***
> *What are the effects of energy services on energy efficiency targets of energy efficiency projects in the Dutch social housing sector?*

1. *What are energy services and how do they contribute to improving energy efficiency of the built environment?*

2. *To what extent do different energy services affect the energy efficiency targets of housing corporations?*
   2.1. *What are the most important energy efficiency targets in the Dutch social housing sector?*
   2.2. *Which organisational differences and differences in the perception of barriers could explain the differences in accomplishment on energy efficiency targets between individual housing corporations?*

3. *What opportunities in the energy services are of interest for the Dutch social housing sector, and what measures, policies and legislation affect the position of housing corporations in the energy services sector?*

8.1. Effects of energy services on energy efficiency targets.

To answer the main research question, this research has used the business-approaches of energy services as a framework to assess the quality and financial performance of energy efficiency projects, as performed by housing corporations. The sub-questions are briefly assessed before the final conclusion is stated.

8.1.1. Contribution of energy services

Energy Services can be divided into two distinct business models that apply different approaches to improve energy efficiency. These are Energy Performance Contracting, EPC, and Energy Supply Contracting, ESC.

Energy performance contracting improves energy efficiency by reducing energy demand. The implementation of demand-side measures such as insulating facades, roofs, floors and windows improves the energy performance of a dwelling. The capital expenses on the investment are covered by lower operating expenses on energy costs due to the achieved energy savings. A similar approach is widely applied in the Dutch social housing sector

Energy supply contracting approaches energy efficiency by fulfilling the remaining energy demand and is applied in combination with EPC. The implementation of supply-side measures such as CHP-plants and renewable energy sources as wind, water and solar energy improves the efficiency of energy supply by lower energy costs and less vulnerability for energy prices fluctuations. The larger capital expenses are covered by selling the units of energy. This approach has only been applied on a handful of projects in the Dutch social housing sector, even though the combination of these two energy services is said to *'help to overcome market barriers for energy efficiency'* (Bleyl-Androschin, 2009).

8.1.2. Energy efficiency targets

The assessed variables were chosen to represent the energy efficiency targets and ability to cover the business approaches of the two energy services. The energy efficiency targets on which these approaches are assessed are two energy index variables: EI_{after} to express the energy performance after renovation; and ΔEI to express the added improvement of the renovation on the energy performance. The other variables cover the financial aspects of the projects and the energy services approaches: The costs of the energy efficiency measures; the financial benefit for the tenants; and the financial benefit for the corporation. With these variables, the effect of the two energy services on the split-incentive of the sector regarding energy efficiency projects can be evaluated

8.1.3. Conclusion

Important performance differences have been found between the two energy services on these variables.

Energy Performance Contracting projects are able to achieve a reasonable Energy Index after renovation. This Energy Index meets current the norms, but will not surpass an average A-label. The affiliated costs of the projects are lower than those of Energy Supply Contracting. However, the ability of EPC to cover these costs are lower than those of ESC and a split incentive remains. The savings on total housing costs are directly related to the present value of the projects. The more savings on total housing costs for the tenants, the lower the potential present value of the project and vice versa.

Energy Supply Contracting has the ability to achieve a much higher Energy Index, up to almost energy neutral standards. The costs of these projects are often higher than EPC-projects, but by utilizing the earnings potential of the energy supply measures, they are able to achieve a relatively high present value and cover a relatively larger part of their costs. This lowers, but doesn't entirely remove, the split incentive for housing corporations. The higher present value means that the savings on total housing cost for ESC-projects isn't a strong aspects.

Overall, projects with ESC's characteristics will perform better on energy efficiency, indicated by a lower energy index, while the earnings potential of the energy supplying measures improves their present value. They are still able to generate savings for the tenants, albeit a small advantage. EPC projects performs lower on energy efficient, but still meets the energy efficiency norms with lower costs and with the ability of high savings for the tenants, but with lower added income for the corporation.

9. Recommendations

This last chapter states the recommendations that can be extracted from the conclusions and the literature research for both housing corporations and the Dutch government in section 9.1 and section 9.2 resp. Section 9.3 states the recommendations for future research on this topic.

9.1. Housing corporations

The performance of the assessed DMUs, EPC and ESC, all comply with the current energy efficiency norms. The ability of combining Energy Supply Contracting with the conventionally adopted approach of Energy Performance Contracting to achieve a lower -thus better - Energy Index, while utilizing the earnings potential of its energy supply installations, is therefore not perceived as an immediate necessity by most housing corporations. Corporations seek a balance between their societal objective and their financial arguments regarding their investment behavior. The practical implementation of the sector's societal goal is thus dependant on the financial possibilities. This explains why the cheaper energy performance contracting is still the conventional approach of the sector.

These quick and short-term energy efficiency improvements minimize the long-term state and affordability of the social housing stock in the long run. Where instead, the exploitation of social housing should require housing corporations to adopt a long-term view on the current state ánd future of their housing stock.

Housing corporations exist under the societal condition to provide high quality, affordable housing. Although many of them see the possibilities of energy delivery regarding this condition, most of them choose not to take the step. By doing so, the possible quality of the dwellings is compromised: by only doing what is minimally necessary, a permanent solution is denied and problems are postponed instead of solved.

To guarantee affordability and quality of housing in the long run, and to avoid a second costly renovation to meet future norms, housing corporations should live up to their intrinsic obligation to provide affordable, quality housing. If only minimal improvements are applied, tenants will remain vulnerable for energy price fluctuations and consequently keep having higher relative housing costs then private house owners. Energy supply contracting has been shown to be the instrument that reaches higher norms and thus lowers the vulnerability of tenants. Housing corporations have to be more pro-active and ambitious regarding ESC.

Apart from the intrinsic motivation of housing corporations to strive for the highest energy efficiency norms, rules and regulations should facilitate innovative energy efficiency initiatives. Here lies an important role for the Dutch national government.

9.2. National government

Short-term market barriers must not become long-term business obstacles that prevent housing corporations from fulfilling their main goal of providing high quality, yet affordable housing for the lower incomes. To prevent this, the current legislative framework and energy efficiency norms need revision and take in a more facilitating character, instead of the barrier they are perceived as today.

First, the current ambition of the sector (BZK, 2012) to reach an average energy index of 1.25 is not set at such a level that long-term affordability is provided for. Renda (2012) showed that the stated ambition will not stabilize the total housing costs of households, which are already excessively high in the Netherlands in comparison with the rest of Europe and only energy neutrality – energy Index of 0.00 - will.

Under more ambitious norms, energy supply contracting will have to be adopted by the sector in some way, given the ability of ESC to reach higher EI-norms as shown by this research. This is even stated in the 'Convenant Energiebesparing Huursector' (BZK, 2012), although only mentioned in the very last consideration: *'To control the housing costs in the long run, energy savings does not suffice and the introduction of durable, renewable energy sources is necessary'*. The fact that these contradictory aspects are stated in the same document maintains the standstill and the ambivalent stance of the sector towards energy services.

Explicitly mentioning energy services or managing total housing costs in the BBSH (VROM, 2005) in one of the performance fields could provide the security and policy space for housing corporations regarding the implementation of ESC-measures especially. Simultaneously it should be considered as a DEAB-activity by the EU as well, which will opening up opportunities for WSW-backing for the more expensive ESC-measures. This would be a logical step, following the reasoning that long-term affordability of the social housing sector is only assured by taking into account the total housing costs and thus the implementation of ESC-measures.

This could also lower the current boundary of energy efficiency measures in the higher social renting class up to the liberalization boundary of € 664,66 per month. Consequently, small scale decentralized energy generation and delivery must be encouraged with facilitating legislation. Net metering must be enforced onto the national energy giants to make solar panels on apartment complexes financially feasible. Finally, district-scale measures must become part of the energy performance assessment for existing dwellings on a similar manner as new dwellings.

The active involvement and large savings potential of the (semi-)public sector in the US made energy services successful: a billion dollar industry with a 22% annual growth rate (ICF, 2007). Pro-active legislation in the Netherlands could similarly trigger such developments, that not only improves the housing and financial position of tenants, but also help to reach Dutch national environmental goals.

For example, energy services in the Dutch social housing sector could play an important role in meeting national targets on CO_2-reduction, energy reduction and share of renewable energy sources, in which the Netherlands performs low, even though the ambitions are high. Although the current Dutch government aims at a 16% share of renewable energy in 2020, the actual figures show that the Netherlands saw their share decrease from 4.1% in 2009 to 3.8% in 2010, where the EU-average is 12.4% (Eurostat, 2012). This placed the Netherlands in the lowest four of twenty-seven EU-countries.

9.2.1. Woonakkoord

The last agreement on the Dutch housing market the is called the 'Woonakkoord', (BZK, 2013). The first of four mentioned 'pillars' of the agreement is *'encouraging (durable) investments'*, which is elaborated with a revolving fund of € 150 million and a VAT-decrease from 21% to 6% for renovation projects for the period of one year. Although this seems impressive, it is relative to the GDP, again, one of the lowest of the EU (Kennislink, 2013). Moreover, it obligates all housing corporations to fulfill a 'verhuurdersheffing' or letter-fee of € 1.7 billion sector wide, which lowers the investment possibilities. To come up with these costs, housing corporations have the ability to raise the monthly rent for those households outside the target group. This raises the already high total housing costs, without any decrease on energy expenses.

This again points out that the Dutch government has yet to apply structural adjustments of legislation concerning energy efficiency and investments in energy efficiency. Merely implementing a temporary fund and VAT-reduction will not provide the structural changes that are needed.

9.3. Review and future research

This final section gives a review and recommendations on the research process and the research method DEA. Next, follow-up considerations for further research are given.

Process

The last couple of years, I have become increasingly more interested in the workings of (semi-)governmental organizations and their long-term stance and attitude on societal problems. From the last master project, I got interested in Energy Services and its capabilities. Early on in the graduation process I wanted to assess these capabilities as a possibility for housing corporations to overcome some of their sector's issues.

The research used Data Envelopment Analysis to assess these possibilities. DEA has some useful characteristics that make it applicable for this kind of performance benchmarking research, such as the variable weighting scheme and the ability to perform the analysis without a priori knowledge about the complex and often unknown transformation process.

DEA, however, also has some drawbacks. First, the choice for input and output variables influences the results and could leave other important variables out of the analysis. This could also influence the efficiency score of the individual DMUs. Second, DEA is inherently a very sensitive methodology, since one positive outlier greatly affects the outcomes of all individual efficiency scores.

Nonetheless, its ability to capture the complex processes of energy efficiency projects in just a few main variables make it an understandable methodology that can provide useful insight in an otherwise vague area. This simplification also helped the interviewees to understand the research process and to distinguish between energy efficiency increase and financial benefit for tenants and corporation.

Considerations

This research has tried to provide insight in the performance difference of EPC- and ESC-like projects by assessing these projects on fundamental variables. Since this research focuses on the Energy Index increase and three financial variables, other elements that influence the decision motives of housing corporations regarding such projects are not taken into account.

For possible further studies, the following recommendations or additions are given:

- The best balance between the financial benefit for the tenant and the financial return for the corporations;
- Possible cooperation between housing corporations and external ESCo's, and how this affects the performance level and financial balance of energy efficiency projects.
- The financial consequences, opportunities and possibilities for housing corporations of invoicing a full total housings costs sum instead of only the rental sum.
- The exact financial differences of an ESC-project under DAEB and non-DAEB regulations.
- The relation between the number of dwellings of a housing corporation and its energy efficiency performance;
- The relation between the geographical position of a housing corporation and its energy efficiency performance;

List of abbreviations

Dutch abbreviations are stated as following '…'

BBSH, 'Besluit Beheer Sociale Huursector'
BCC, Banker, Charnes & Cooper
CBC, 'Corporatie Benchmark Centrum'
CBS, 'Centraal Bureau voor de Statistiek'
CCR, Charnes, Cooper & Rhodes
CFV, 'Centraal Fonds Volkshuisvesting'
CHP, Combined Heat and Power
CRS, Constant Return to Scale
CME, Construction Management & Engineering
DAEB, 'Dienst Algemeen Economisch Belang'
DEA, Data Envelopment Analysis
DMU, Decision Making Unit
EC, European Commission
EC, Energy Contracting
EI, Energy Index
EMG, 'Energieprestatienorm Maatregelen op Gebiedsniveau'
EPC, 'Energie Prestatie Coëfficiënt'
EPC, Energy Performance Contracting
EPG, 'Energieprestatienorm Gebouwen'
ES, Energy Services
ESC, Energy Supply Contracting
ESCo, Energy Service Company
EU, European Union
IinBM, Innovation in Building & Maintenance
MJ, Megajoule
NEN, 'Nederlandse Norm'
NiBud, 'Nationaal instituut voor Budgetvoorlichting'
NMDA, 'Niet Meer Dan Anders'
NVN 'Nederlandse voornorm'
PBL, 'Planbureau voor de Leefomgeving'
PV, Present Value
PV, Photovoltaic
TU/e, 'Technische Universiteit Eindhoven'
VRS, Variable Return of Scale
WSW, 'Waarborgfonds Sociale Woningbouw'

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Energy Services in the Dutch social housing sector.

A benchmarking study on housing corporations' in practice performance.

Appendices

Appendix A, Energy labels of rental dwellings in the Netherlands

	Onderwerpen	Totaal woningen met energielabel	Woningen met energielabel A en B	Woningen met energielabel C en D	Woningen met energielabel E, F, G
Bouwjaar	Perioden	*aantal*			
Totaal	2011	1 839 719	247 477	1 062 165	530 077
< 1906	2011	12 213	1 450	6 024	4 739
1906-1930	2011	77 323	4 758	31 790	40 775
1931-1944	2011	26 417	860	10 477	15 080
1945-1959	2011	268 283	7 700	106 445	154 138
1960-1970	2011	399 010	16 904	199 885	182 221
1971-1980	2011	361 364	15 031	235 265	111 068
1981-1990	2011	405 610	47 100	338 803	19 707
1991-2000	2011	193 612	70 076	121 402	2 134
2001-2010	2011	95 713	83 426	12 072	215
>2010	2011	174	172	2	-

Appendix B, Energy Services characteristics in the social housing sector

Energy performance contracting

Characteristics	Energy Performance Contracting (EPC), (Bourgois, 2011)	Projects in Dutch social housing sector
Client	User of existing units	Tenants
Target	Realization of energy savings potential	Realization of energy savings potential
Services by contractor	Partly renewal (financing incl.), operations & maintenance	Renewal, financing, planning, operation & maintenance
Re-financing	Energy savings	Housing costs savings
Risks borne by contractor	Risks of actual energy savings, operation & maintenance	Risk of actual energy savings, if guarantee is given
Economic advantages for client	Energy savings, guaranteed by contract.	Housing costs saving, possibly guaranteed

Client.

One important difference with conventional EPC-projects and renovation projects in the social housing sector, is the difference between building owner and building user. In EPC-projects, these are mostly the same, whereas they are always separate in the social housing sector. Under normal conditions the client initiates an EPC-project, the housing corporation as building owner decides on the renovation of a complex. However, the rights for tenants are well preserved, and the permission of at least 70% of a complex' occupants is needed before the actual renovation process can start (Rijksoverheid, 2012). The corporation is obliged to inform the total renovation plan. For most tenants, a financial gain could be a reason to approve the renovation.

Target

The realization of energy savings potential is in both cases the target. In EPC-contracts there is a direct relationship between the amount of savings and the potential profit for the contractor. This is one of the most important elements, since the performance risks of the project is transferred towards the contractor, see *Risk borne by contractor*

In renovation projects, this relationship is not necessarily present, but can occur using additional agreements, see *Risk borne by contractor.*

Services by contractor

The services related with EPC-projects are performing the renewal activities, providing the financing and performing operations and maintenance tasks. These activities are also described as being the main performance fields of corporations, described in the BBSH, see section 2.2.2., One difference which could occur, is the efficiency verification of the project. Whether or not this is done, depends on whether or not a savings guarantee was provided for by the corporation.

Re-financing

Financing of EPC-projects is based on the expected energy savings. Money that is saved on the energy bill now gets transferred to the ESCo, until the project costs and the profit margin are repaid. In the social housing sector, the possibilities of a corporation to finance a renovation project are limited, and based on savings on total housing costs, rather than energy costs. When a renovation project is performed, tenants will benefit by lower monthly costs of their energy bill. Part of these savings is then used to repay the corporations through an increase in the rental costs. In total, however, the tenant will still have a financial benefit.

The amount of additional monthly rental costs for the tenants is determined by the housing corporations. Since EPC-measures become part of the real estate, any improvement on the real estate can only be reclaimed by corporations in the rental costs, as stated in the Dutch law (BZK, 2012). This can be determined in two ways:

- Based on existing rent
  Most, if not all, corporations do not charge their tenants with the maximum reasonable rental price, as determined by the WWS. The average rental price lies at 72% of this maximum (Aedes, 2012b). A margin is thus still available to retrieve the made investments.
- Based on the raise on energy label.
  The quality increase due to the renovation project is taken into account in the energy label. The energy label is awarded points, which are taken into account in the WWS. The relation of the energy label and the appreciated points can be seen in table 3.

Table 19: Appreciated WWS-points, based on the acquired energy label. Source: BZK, (2011)

Energy Label	Points one-family dwellings	Points multiple family-dwellings
A++	44	40
A+	40	36
A	36	32
B	32	28
C	22	15
D	14	11
E	8	5
F	4	1
G	0	0

As can be seen, appreciated points per rise in energy label differ, as well as the appreciation between dwelling-types. If a renovation project was to be repaid based on the increase in energy label, and the additionally awarded points in the WWS, the rent increase for families in the same complex would be disproportionally divided (Atrivé, 2012).

More importantly, a boundary exists in the rental price of a dwelling, which could substantially influence the decisions and possibilities of a corporation, regarding the questions whether or not to renovate, and the targets of such projects. When the rental price of a dwelling falls above the liberalization threshold of € 664,66 (price level 2012), the specific dwelling is no longer labeled a 'social housing dwelling'. The tenant will no longer have the same protection by law and is no longer viable to receive the rent-incentive 'Huurtoeslag' from the government. This could be an important reason for a tenant to decline the renovation project. A corporation, on the other hand, could choose not to perform a renovation project; to set lower standards; or to implement a minimal raise in rent to keep the rental costs below the liberalization threshold.

In most cases, investments done by housing corporations can never be fully re-earned by the sole increase in rent. The WSW can then be used to provide additional investments, provided that the investments are DAEB-activities.

Risks born by contractor
The performance risk of EPC-projects lies with the contractor, providing an incentive for an ESCo to perform well and improve energy efficiency as much as possible. For the client, this guarantee helps in the decision to start the energy efficiency project.

In renovation projects in the social housing sector, there is not always a guarantee that certain targets will be achieved and that (financial) compensation will be given when they are missed. Housing corporations have been renovating their real estate for a long time, but until recently, did not set environmental targets or energy efficiency targets, and did not make agreements with tenants on the performance. Since such guarantees could be an important tool to reach the 70% approval norm, Aedes therefore came with the 'Wooninglastenwaarborgfonds', or Housing costs guarantee fund (Aedes, 2009). The fund can be used by corporations towards their tenants and guarantees a predefined amount of savings on housing costs. Research after two years showed that when housing corporations use the fund, they receive more approval and trust of their tenants and has led to higher efficiency targets (Aedes, 2011).

Economic advantages for client.
Apart from the advantages in comfort level, safety and general quality of the dwelling, an EPC-project must always lead to economic advantages of the building's user. Where in an EPC-project these economic advantages are the guaranteed, lower energy bill, for a renovation project in the social housing sector the economic advantages are lower housing costs.

Contract period
In EPC-projects, the contract period is the predefined period in which all, or a large part of, the energy savings are transferred to the ESCo. During this period, the initial investments and profit margin must be earned. In the social housing sector, however, there is no predefined contract period, but an exploitation period in which the investments must be returned. Since the sector has a mutation ratio of about 8 % (CFV, 2011), and building occupants change often, a predefined period with temporary higher costs would not be fair. Also, housing corporations do not strive for profit, and therefore the investments are spread out over the expected exploitation period, resulting in a lower, yet constant rental price increase.

Energy Supply Contracting

Characteristics	Energy Supply Contracting (ESC), (Bourgois, 2011)	Projects in Dutch social housing sector
Client	Energy consumer	Energy consumer (tenant)
Target	Energy supply	Energy supply
Services by contractor	Planning, construction, operation & maintenance, financing	Planning, operation & maintenance, financing
Re-financing	Energy sales	Energy sales
Risks borne by contractor	Risks of construction, operations, maintenance, finance and purchase	Operation & maintenance, finance and purchase
Economic advantages for client	Avoided investments, purchase/ bulk buying advantages, reallocation of risk	Avoided investment, purchase, bulk buying advantages, reallocation of risks

Client

The client of an ESC always is an energy consumer, which in the case of the social housing corporation as the energy supplier, will be the tenants of a complex or individual tenants.

Target

The target of an ESC always is the efficient supply of units of energy and the security of its supply. In ESC the units of energy are delivered by the ESCo, in the social housing sector, this will be done by the corporation or an external third party. However, in this research only the delivery by a corporation or a subsidiary company will be assessed.

Services by Contractor

Services regarding an ESC contain the planning, construction, operation and maintenance and financing of the installations. In the social housing sector, these services can be performed by the corporations, or outsourced to an external company.

Re-financing

Return on investments of the ESCo and the housing corporation in an ESC will always be obtained by the sales of the supplied units of energy. Where an ESCo will simply send their client an energy bill, this is somewhat more complex for housing corporations.

The supply and billing of energy may not be settled within the monthly rent due to Dutch law (Rijksoverheid 2012), stating that only dwelling-specific, unmovable additions to a property may be taken into account in the height of the rental price. This is an important difference with EPC, which is settled in the rental price. Since the delivery of units of energy, ESC, is a movable good, it may not be included in the rent.

The remaining options for corporations to settle the costs of the ESC are:

- The service of supplying energy units must be settled with the tenant through the service costs, which, among other services of the housing corporations, should contain energy delivery (I&M, 2012).
- For the sake of distinction, the housing corporations can also choose to settle their energy delivery bills through a separate invoice.
-

In practice, this means that a corporation has two options to reclaim their investments when PV-panels or solar panels have been placed on the roof of an individual dwelling. If the rent is increased with a certain additional amount, this means that they are an EPC and the solar panels are seen as a dwelling specific addition or an unmovable good. If the units of energy, generated by the solar panels, are settled in the service costs, they are an ESC and seen as a movable good.

This difference exists because the current regulations are based on older technologies and renewables and their implications for these regulations are not yet taken into account. This does, however, brings uncertainty in the social housing sector about the deployment of such panels and chances are missed. Atrivé has pointed this out and the Dutch department of BZK and the 'Huurcommissie' are reassessing legislation (Atrivé, 2012).

The tariff for the delivery of units through smaller energy networks is regulated by the Dutch Warmtewet, or Heatinglaw. Inhabitants of a dwelling, connected to such a network, e.g. district heating, must be protected from unfair competition. Since the network is not accessible for every supplier, the supplier that exploits it must commit itself to have tariffs which are not more expensive as would have been when connected to the normal energy network. In Dutch, this is called the NMDA-principle, 'Niet Meer Dan Anders', or not more than else. The heatinglaw has changed overtime and been made applicable to all closed energy networks of any size, and therefore is of importance for housing corporations in the ESC-sector.

Risks borne by contractor
When an ESC-project is performed b a housing corporation, the activities, concerned with the ESC and the financial risks attached to it, could affect the financial position of the housing corporation and its main activities of the BBSH. The financial risks concerned with ESC are bigger than the risks of EPC, since ESC is in general not a DAEB-activity and thus do not apply for WSW-funding.

Housing corporations performing an ESC has made the calculated decision to bear the financial risks of the project. However, if the project goes wrong, these additional financial risks could seriously affect the financial position of the corporation to such an extent that it can no longer perform its main DAEB-activities. The Dutch government is currently in the process of renewing its 'Woningwet', or Dwellinglaw, in which is stated that a housing corporation must apply an administrative separation between its DAEB-activities and non-DAEB activities. The risk that DAEB-activities are (financially) affected by unprofitable non-DAEB activities is avoided under these new regulations. Also, it meets EU-policies on free trade and competition: Corporations cannot use state-aid to perform non-DAEB activities and therefore do not have a competitive advantage over commercial players.

Financial risks concerned with ESC therefore must be taken on by the housing corporation and must be financially sufficient on itself.

Economic advantages for client

The client benefits because of the efficiency supply of sustainable energy. Energy tariffs must, at least, be the same as normal tariffs, but in the case of a housing corporations performing the ESC, the societal goals of the corporation could translate into significantly lower tariffs. The depends on the focus of the contractor: Cost-covering or Market-driven.

The above mentioned points and the differences between a conventional ESC-project and an energy efficiency renovation project in the social housing sector are clarified in *Appendix B*

Appendix C, DEA mathematics

This appendix is a summary based on the first four chapters of the book 'Introduction to data envelopment analysis and its uses with DEA-solver software and reference', by William W. Cooper, Lawrence M. Seiford and Kaoru Tone. (Cooper, W.W., Seiford, L.M., Tone, K. 2006)

As explained in the main report, Data Envelopment Analysis measures the efficiency of a Decision Making Unit. The common ratio used to express efficiency is the following,

$$\frac{Output}{Input} \qquad (1.1)$$

Often, the measure of productivity or efficiency is 'Output per worker', or 'Output per worker employed'. These are referred to as 'partial productivity measures', to distinguish them from 'total factor productivity measures' which take into account all outputs and all inputs. Moving from partial to total factor productivity by combining all inputs and all outputs into one ratio helps to avoid imputing gains to one factor (input or output) that are really attributable to a different factor. However, total factor productivity measures encounter difficulties with choosing the inputs and outputs and the weights to be attributed to these factors. DEA utilizes techniques such as mathematical programming which can handle large number of variables and relations and this relaxes the requirements that are often encountered when one is limited to choosing only a few inputs and outputs because the employed technique will otherwise encounter difficulties.

To explain the basic DEA-models and the mathematics behind the models, simple examples are used together with exemplifying graphical representation of the data. When working on models with multiple inputs and outputs, the used mathematics stay the same, but the graphic representation becomes difficult.

DEA basics, efficiencies and weights.

The most simple example of DEA assesses one input and one output. Table 23 states the input (Employees) and output (Sales) for 8 different branch stores.

Table 20: Single input and single output case

Store	A	B	C	D	E	F	G	H
Employee	2	3	3	4	5	5	6	8
Sale	1	3	2	3	4	2	3	5
Sale/Employee	*0.5*	*1*	*0.667*	*0.75*	*0.8*	*0.4*	*0.5*	*0.625*

The efficiency ratio, dividing output by input is shown in the last row of table 1. The highest ratio represents the highest efficiency and vice versa. Then store B can be identified as the most efficient and store F as the least efficient. The input and output variables can also be represented in a graphic expression, seen in figure 21. The slope of the line through the origin and the different points representing the stores, represents the sales per employee. The line with the highest slope, through store B, represents the Efficient Frontier. All other points are on or below this line. The name Data Envelopment Analysis, as used in DEA, comes from this property, because in mathematical parlance, such a frontier is said to envelop these points.

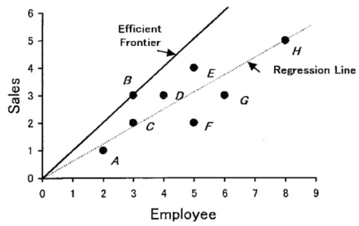

Figure 21: Single input and single output case, graphic representation.

The second line in figure 21 is the regression line, which is typically used in statistics to determine the middle of the available data. All points above the regression line are excellent, and the ones below are unsatisfactory. The efficient frontier line designates the performance of the best store, in this case B. This is the fundamental difference between statistical approaches via regression and DEA. Regression analysis reflects to the average performance, whereas DEA reflects to the best performing entity and deviations from the frontier line. This difference can also translate into different improvements possibilities.

In the example the Efficient Frontier stretches to infinity with the same slope, which is not always reasonable to believe. However, in some cases it is effective in the range of interest and is called the constant return to scale assumption, or the CCR model. The variable return to scale model, or BCC-model, will be explained later on.

Compared with store B and the efficient frontier, all other stores are inefficient. The relative efficiency of the stores in comparison with store B is measures as:

$$0 \leq \frac{\text{Sales per empoyee of others}}{\text{Sales per employee of B}} \leq 1 \qquad (1.2)$$

Resulting in the following relative efficiency scores:

Table 21: Relative efficiency scores.

Store	A	B	C	D	E	F	G	H
Relative Efficiency	*0.5*	*1*	*0.667*	*0.75*	*0.8*	*0.4*	*0.5*	*0.625*

Now that the efficiency scores are known, performance improvements can be assessed and inefficient stores can be made more efficient by moving them towards the efficient frontier. This can be achieved by reducing input or by increasing output, see figure 22.

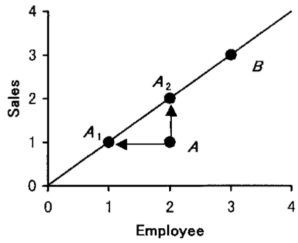

Figure 22: Improvement possibilities of store A.

Using this example, the efficiency ratio of sales per employee is used. However, for DEA assessment, a unit of measure is not needed as the mathematics are not affected. This is very useful when using multiple inputs and outputs, as in the case of a single input and two output. the method remains the same, yet the graphic representation is slightly altered.

Table 22: Single input and two outputs.

Store		A	B	C	D	E	F	G
Employees	x	1	1	1	1	1	1	1
Customers	y^1	1	2	3	4	4	5	6
Sales	y^2	5	7	4	3	6	5	2

The data of table 25 is graphically displayed in figure 23, together with the efficient frontier. The radial lines through the origin to the efficient frontier and the points A and D are used to calculate their respective efficiency. For point D, this would be:

$$\frac{d(O,D)}{d(O,P)} \tag{1.3}$$

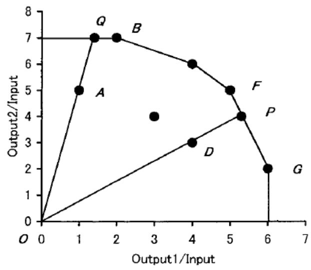

Figure 23: Single input and two outputs.

The ratio of (1.4) is called the radial measure and can be interpreted as the ratio of two distance measures, which can be calculated using Euclidean measures and is 0.75. Meaning that point D performance only at a level of 75% efficiency. By calculating the reciprocal of this value, 1.33, it can be said that D has to increase both its outputs by 4/3 to become efficient. Hence, the coordinates of D, multiplied with 1.33 will translated into point P. The inefficiency which can be eliminated without changing the proportions of input or output is called technical inefficiency. Another type of inefficiency, which can be eliminated only by changing the proportions of input or output is called mix inefficiency, which can be explained by the inefficiency of store A in figure 5. Similarly as before, the inefficiency of A is obtained with the radial measure:

$$\frac{d(O,A)}{d(O,Q)} = 0.714 \tag{1.4}$$

By multiplying the coordinates of A with the reciprocal of its radial measure, the coordinates of Q are obtained as (1.4; 7).

This is the improvement in technical efficiency , however this movement to Q does not remove all the inefficiencies of A. Even though Q lies on the efficient frontier, it is not an efficient part of the frontier. If Q is compared to B, it is clear that Q falls short in output 1. Further improvement of can thus be achieved by a lateral movement of Q towards B. Since correcting output 1 without correcting output 2 will change their proportions, this is no longer a technical efficiency measure. When the proportion of output or input are altered, the efficiency measure is referred to as mix efficiency measure. Point A, therefore, has two inefficiencies: First, the technical inefficiency via the radial measure, second, the mix inefficiency of the shortfall in output 1 after the technical inefficiency has been removed. The amount of excessive of shortage of an output or input in a mix inefficiency is referred to as the slack.

When working with multiple inputs and outputs, the graphic representation of the data becomes impossible and analysis could become very burdening. DEA uses an approach that does not require large numbers or arbitrary assumptions. This is done by using varying weights, explained using table 23 and 24.

Table 23: Two inputs, two outputs.

Hospital	A	B	C	D	E	F	G	H	I	J	K	L
Doctors	20	19	25	27	22	55	33	31	30	50	53	38
Nurses	151	131	160	168	158	255	235	206	244	268	306	284
Outpatients	100	150	160	180	94	230	220	152	190	250	260	250
Inpatients	90	50	55	72	66	90	88	80	100	100	147	120

In table 23, two inputs (Doctors, Nurses) and two outputs (Outpatients, Inpatients) are given. The relationship between the inputs and outputs are not known but this could be simplified by using a fixed weighting scheme, and the resulting yield is then used to assess efficiency:

$$v_1(Weight\ for\ Doctors): v_2(\ Weight\ for\ Nurses) = 5:1$$

$$u_1(Weight\ for\ Outpatients): u_2(Weight\ for\ Inpatients) = 1:3$$

Resulting in the efficiency yields of the row “Fixed” in table 26. Although this has simplified efficiency calculations, the fixed weighting scheme is arbitrary. DEA uses variable weights, which are chosen in a way that assigns the best set of weights to each hospital. Which means that the assigned weights results in the highest input-to-output ratio for each hospital relative to all other hospitals when these weights where to be assigned to every hospital. The results of this efficiency calculation can be seen in table 6 in the "CCR"-row.

Table 24: Difference between arbitrary fixed weights and the variable optimal weights of DEA.

Hospital	A	B	C	D	E	F	G	H	I	J	K	L
Fixed	1	.90	.77	.89	.74	.64	.82	.74	.84	.72	.83	.87
CCR	1	1	.88	1	.76	.84	.90	.80	.96	.87	.96	.96

Since the weighting scheme is optimal for all individual hospitals, there is no debate about whether of not an individual's performance could have been better using a different fixed weighting scheme.

DEA software automatically identifies the technical and mix inefficiencies of each entity and their amounts are given. Furthermore, the reference set of the inefficient entities are also stated. One of the biggest advantages of DEA is that it requires no a priori, arbitrary, assumptions on a weighting scheme and it does not require the relations between the variables to be the same for all entities.

In the next section, the mathematics that is applied in the software is explained, with references to the mentioned examples in the first part of this appendix.

DEA-mathematics

To explain the mathematical rules behind DEA, the CCR-model is used. The CCR-model is the oldest and most commonly used DEA-model and is also referred to as the CRS-model, or Constant Return to Scale. After this model has been introduced, the BCC-model, or VRS-model, Variable Return to Scale model, is given.

CCR-model

The efficiency of a DMU (o) is measured by the ratio of its virtual input and output and their corresponding weights (v_i) and (u_r):

$$\text{Virtual input} = v_1 x_{1o} + \dots + v_m x_{mo}$$

$$\text{Virtual output} = u_1 y_{1o} + \dots + u_s y_{so}$$

The efficiency θ is obtained by maximizing the ratio:

$$\frac{Virtual\ output}{Virtual\ input}$$

The values for the input and output weights are obtained by the following fractional programming problem:

$$(\text{FP}_0) \quad \max_{v,u} \theta = \frac{u_1 y_{1o} + u_2 y_{2o} + \cdots + u_s y_{so}}{v_1 x_{1o} + v_2 x_{2o} + \cdots + v_m x_{mo}} \tag{2.1}$$

$$\text{Subject to} \quad \frac{u_1 y_{1o} + \cdots + u_s u_{sj}}{v_1 x_{1o} + \cdots + v_m x_{mj}} \leq 1 \; (j = 1, \dots, n) \tag{2.2}$$

$$v_1, v_2, \dots, v_m \geq 0 \tag{2.3}$$

$$u_1, u_2, \dots, u_m \geq 0 \tag{2.4}$$

The constraints prohibit the ration of virtual output and virtual input of exceeding 1. The objective is to obtain weights v_i and u_r to maximize the ratio of DMU_o, being the DMU under evaluation. Because of the constraints, the value θ is at most 1.

Now, the precise definition of efficiency in the CCR-model can be stated:

1. DMU_o is CCR-efficient if θ=1 and there is exists at least one optimal (v , u), with v > 0 and u > 0.
2. Otherwise, DMU_o is CCR-inefficient.

If θ < 1, in the case of an inefficient DMU, the reference set of a DMU is obtained with:

$$E_o' = \left\{ j : \sum_{r=1}^{s} u_r y_{rj} = \sum_{i=1}^{m} v_1 x_{ij} \right\} \tag{2.5}$$

The subset E_o of E_o', composed of CCR-efficient DMUs is the acquired reference set of DMU_o. The set E_o is called the efficient frontier of DMU_o.

BCC-model

The previous models were built on the assumption of constant return to scale. In other words, if (X , Y) is a possible point, then (tX , tY) also is feasible. The BCC-model, however, is based on a variable return to scale assumption and its efficient frontier spans the convex hull of the DMUs. This difference is clearly visible in figure 24.

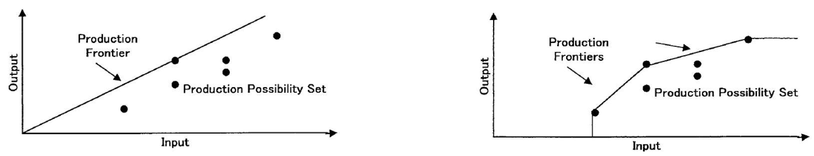

Figure 24: Difference in Efficient Frontier of the CCR-model (left) and the BCC-model (right).

The efficiency calculation is therefore also performed slightly different, as seen in figure 25.

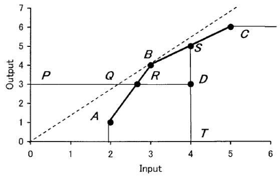

Figure 25:Difference in efficiency calculation in the CCR and BCC model.

The input-oriented BCC-efficiency of D is evaluated by $\frac{PR}{PD}$,whereas the CCR-efficiency is calculated as $\frac{PQ}{PD}$.

The output-oriented BCC-efficiency is calculated with $\frac{ST}{DT}$, whereas the CCR-efficiency is obtained by the reciprocal of its input inefficiency.

The Production Possibility set of an BCC-model is defined by:

$$P_b = \{(x, y) | x \geq X\lambda, y \leq Y\lambda, e\lambda \geq 0\} \tag{3.1}$$

Where $X = (x_j) \in R^{m*n}$ and $Y = (y_j) \in R^{s*n}$ are the data set, $\lambda \in R^n$ and e is a row vector with all elements equal to 1. The BCC model differs with the CCR-model in the addition of the condition:

$$\sum_{j=1}^{n} \lambda_j = 1, \lambda_j \geq 0, \forall j \tag{3.2}$$

Which is also written as $e\lambda = 1$, where e is a row vector with all elements unity and λ is a column vector with all elements non-negative. Combined with the condition $\lambda_j \geq 0$, for all *j*, this imposes a convexity condition in which the *n* DMUs may be combined.

The input-oriented BCC-model evaluates the efficiency of DMU_o (o = 1, … , *n*) with:

$$(BCC_o) \quad \min_{\theta_b, \lambda} \theta_b \tag{3.3}$$

$$\text{Subject to} \quad \theta_B x_o - X\lambda \geq 0 \tag{3.4}$$

$$Y\lambda \geq Y_0 \tag{3.5}$$

$$e\lambda = 1 \tag{3.6}$$

$$\lambda \geq 0, \tag{3.7}$$

In which θ_B is scalar.

The dual multiplier form of this linear program (BCC_o) is expressed as:

$$\max_{v,u,u_o} z = uy_o - u_o \quad (3.8)$$

Subject to $vx_0 = 1$ (3.9)

$$-vX + uY - u_o e \leq 0 \quad (3.10)$$

$$v \geq 0, u \geq 0, u_o \, free \quad (3.11)$$

In which v and u are vectors and z and u_o are scalars and the latter may be positive, negative or zero. The BCC fractional program is obtained from this as:

$$\max \frac{uy_o - u_o}{vx_o} \quad (3.12)$$

Subject to $\frac{uy_j - u_o}{vx_j} \leq 1 \; (j = 1, \dots, n)$ (3.13)

$$v \geq 0, u \geq 0, u_o \, free \quad (3.14)$$

The difference between the BCC-model and the CCR-model is the free variable u_o, which is associated with the constraint $e\lambda = 1$, which also doesn't appear in the CCR-model.
The solution for BCC_0 is represented by ($\theta_B^*, \lambda^*, s^{-*}, s^{+*}$), where s^{-*} and s^{+*} represent the maximum input excesses of output shortfalls, or slacks, respectively.

The definition of BCC-efficiency therefore is:

1. If an optimal solution ($\theta_B^*, \lambda^*, s^{-*}, s^{+*}$) obtained for ($BCC_o$) satisfies $\theta_B^* = 1$ and has no slacks (s^{-*} and s^{+*} = 0), then, the DMU_o is called BCC-efficient.
2. Otherwise, DMU_o is called BCC-inefficient.

The reference set of an inefficient DMU is based on an optimal solution λ^* by:

$$E_o = \{j | \lambda_j^* > 0\} (j \in \{j, \dots, n\}) \quad (3.15)$$

If there are multiple optimal solution, one must be chosen to find that:

$$\theta_B^* x_o = \sum_{j \epsilon E_o} \lambda_j^* x_j + s^{-*} \quad (3.16)$$

$$y_o = \sum_{j \epsilon E_o} \lambda_j^* y_j + s^{+*} \quad (3.17)$$

With this, a formula for improvement via the BCC-projection is obtained:

$$\widehat{x_o} \Leftarrow \theta_B^* x_o - s^{-*} \quad (3.18)$$

$$\widehat{y_o} \Leftarrow y_o + s^{+*} \quad (3.19)$$

The output-oriented BCC-model is conducted in a similar manner:

(BCC-O_o) $$\max_{\eta\theta_B,\lambda} \eta_B \quad (3.20)$$

Subject to $$X\lambda \leq x_o \quad (3.21)$$

$$\eta_B y_o - Y\lambda \leq 0 \quad (3.22)$$

$$e\lambda = 1 \quad (3.23)$$

$$\lambda \geq 0, \quad (3.24)$$

The dual multiplier form of this linear program (BCC-O_o) is expressed as:

$$\min_{v,u,u_o} z = vx_o - v_0 \quad (3.25)$$

Subject to $$uy_0 = 1 \quad (3.26)$$

$$vX - uY - vu_o e \geq 0 \quad (3.27)$$

$$v \geq 0, u \geq 0, uv_o\, free \quad (3.28)$$

Where v_o is the scalar associated with the $e\lambda = 1$in the envelopment model. Finally, the fractional programming formulation for the multiplier model is:

$$\min \frac{vx_o - v_o}{vy_o} \quad (3.29)$$

Subject to $$\frac{vx_j - uv_o}{uy_j} \leq 1\, (j, 1, \ldots, n) \quad (3.30)$$

$$v \geq 0, u \geq 0, v_o\, free \quad (3.31)$$

Appendix D, DMUs description

The DMUs mentioned in this appendix are all renovation projects which have been performed to improve the energy efficiency of social housing (complexes). The performed energy services, ESC or EPC, are stated to be able to compare them later on. If a DMU has applied energy delivery installations, the DMU is regarded as an ESC-DMU. Only noteworthy project features or corporation characteristic regarding energy efficiency are mentioned

DMU1			
Project:	*Minervalaan*	Type:	*EPC*
Corporation:	*SWZ*	City:	*Zwolle*

DMU2			
Project:	*Vechtzoom*	Type:	*EPC, ESC*
Corporation:	*Mitros*	City:	*Utrecht*
Project features:	- *Total surface of solar panels of 8300 m^2, one of the largest surfaces of the Netherlands.*		

DMU3			
Project:	*Nulland*	Type:	*EPC*
Corporation:	*Land van Rode*	City:	*Kerkrade*

DMU4			
Project:	*Bestaande wijk van morgen*	Type:	*EPC, ESC*
Corporation:	*Hestia*	City:	*Landgraaf*
Project features:	- *Part of the national pilot-project 'De wijk van morgen', a collaboration of government, educational institutions, research institutions and entrepreneurs. http://www.dewijkvanmorgen.nl/* - *Renovation using passive house concept.*		

DMU5			
Project:	*Ibisplein*	Type:	*EPC, ESC*
Corporation:	*De goede woning*	City:	*Apeldoorn*
Project features:	- *First implementation of a durable district heating system in existing housing based on a wood pellet installation. No connection to the national gas grid network.* - *Possible monumental status.*		
Corporation characteristics	- *Business plan for energy bv in development. Postponed until legislation and regulations are more clear.* - *Involved in GEN, Gebieden Energie Neturaal, a knowledgecluster to develop energy neutral areas.*		

DMU6			
Project:	*FloraDomijn*	Type:	*EPC*

Corporation:	*Domijn*	City:	*Enschede*

DMU7			
Project:	*Savornin Lohmanstraat*	Type:	*EPC*
Corporation:	*Groenwest*	City:	*Woerden*

DMU8			
Project:	*De Poorterstraat*	Type:	*EPC*
Corporation:	*Groenwest*	City:	*Montfoort*
Project features:	- *Housing type the same as DMU9, but less ambitious.*		

DMU9			
Project:	*De Poorterstraat, Active House*	Type:	*EPC, ESC*
Corporation:	*Groenwest*	City:	*Montfoort*
Project features:	- *First 'Active House'- concept renovation in the Netherlands. Part of pilot-project. Has been widely renowned for its high energy and climate ambitions by experts and in multiple magazines. http://www.activehouse.info/cases/de-poorters-van-montfoort*		

DMU10			
Project:	*Thorbeckstraat*	Type:	*EPC*
Corporation:	*Quawonen*	City:	*Bergambacht*

DMU11			
Project:	*Modernisering Dronten Centrum*	Type:	*EPC*
Corporation:	*Oost-Flevoland Woondiensten*	City:	*Dronten*
Corporation characteristics:	- *Acknowledged as a leading corporation in energy efficiency. Has achieved 30% savings on energy use in relation to 2000.* - *Exploits own energy bv for new housing* - *First corporations to achieve 25% savings in energy savings.* - *Winner NET-trophy, 'Nationaal Energy Toekomst trofee.* - *Winner themeprice glass house 2009 and 2010, 'verantwoorden over duurzaamheid.* - *Fierce proponent of delivering durable energy by housing corporations.*		

DMU12			
Project:	*De grote Pekken*	Type:	*EPC, ESC*
Corporation:	*Patrimonium Veenendaal*	City:	*Veenendaal*
Corporation characteristics:	- *Exploits own energy bv for new housing 'Patrimonium Energie B.V.', which exploits a wood pellet installation and a PV-system.*		

Appendix E, Interview questions

1. General	
Name:	Function:
Corporation:	Municipality:
# of rental dwelling:	

2. Corporation
2.1. Policy
1. To what extent is improving energy performance of existing dwelling and a decrease of total housing costs for the tenants interwoven with the everyday policy of the corporation?
2. Are there certain sustainability-norms for the existing housing stock to meet?
2.1. What are these norms, and in what year should these be obtained?
3. What has been the most important reason and goal to perform the maintenance and renovation project? □ *Improving the quality of the dwellings.* □ *Lowering the housing costs* □ *Meet the norms of the corporations* □ *Comply to the covenant of BZK (2012)* □ *Participation in a pilot-project*
4. To what extent have there been made agreements on the project performance, regarding the energy efficiency of the dwellings?
4.1. What are the restricting factors regarding such an agreement?
4.2. Are there consequences when the agreements or norms are not being met?
5. Do tenants have the possibility to influence the measures that will be implemented?
6. Has the corporation made adjustments or concessions on the project to meet the 70% approval rate of the tenants?

3. Project
3.1. Energy saving measures
1. What energy savings measures have been applied in the project?
3.2. Energy Delivery measures

1. Have energy delivery measures been implemented in the project? If so, which ones?
1.1. Yes. What was the reason the apply these measures?
1.2. No. Has this been considered?
1.2.1. Yes. What was the reason not to install these measures?
1.2.2. No. Why not?
2. Is the exploitation of the energy delivery measures performed by the corporation, or a subsidiary company?
2.1. Corporation. Via rent, service costs or separate invoice?
2.2. Subsidiary. In the form of an Energy B.V.?
2.3. No. Is it exploited by an external company?
3. Does the corporation see any future in delivering energy to its tenants?
3.1. Would the reason be to increase energy performance of to increase the corporation's earnings potential?

4. Project finances
1. Which financing tools have been used for the project?
2. Where there any originally planned measures that have not been applied, because or lower financial possibilities?
3. Does the WSW provide financial backing for the project?
4. Is the intended rent increase constrained by the liberalization boundary?
5. Did the European DAEB-regulations restrict the project in any way?

5. Project performance
5.1. Investments
1. What is the investment per dwelling, when only taking into account the energy efficiency measures?
1.1. What is the investment for all energy savings measures?
1.2. What is the investment for all energy delivery measures?

5.2. Energy Index
1. What was the energy index before the energy efficiency measures where applied?
2. What is the energy index after the energy efficiency measures have been applied?
5.3. Present Value
1. What is the new exploitation period of the dwellings after the energy efficiency project?
2. What was the rent increase after the energy efficiency project?
2.1. How has this increase been determined?
3. Have part of the measures been settled by an increase in service costs or a separate invoice?
3.1. Was energy delivery one of them?
5.4. Housing costs
1. Does the renovation lead to a decrease in total housing costs for the tenants?
1.1. If so, with what monthly amount?
2. How has this decrease been determined?
3. Have the tenants been given the guarantee that the applied measures would result in a certain amount of savings?

6. Review
1. What barriers did the corporations encounter during the project that influenced the project's organization, finances or energy performance?

Appendix F, DMU information and calculation example

1. General			
Name:	*Eugène Korff, Gert van Otterloo*	Function:	*Senior real-estate advisor, Project leader*
Corporation:	*De Goede Woning*	Municipality:	*Apeldoorn*
# of rental dwelling:	*Approx. 8200*		

2. Corporation
2.1. Policy
1. To what extent is improving energy performance of existing dwelling and a decrease of total housing costs for the tenants interwoven with the everyday policy of the corporation?
The housing corporation is focused on reducing the total housing costs when performing a renovation project. All new construction projects have been stalled for the next two years and we are only focusing on renovation of the existing housing stock.
2. Are there certain sustainability-norms for the existing housing stock to meet?
2.1. What are these norms, and in what year should these be obtained?
The corporation current policy is to have an average C-label in 2015, which is currently almost obtained.
3. What has been the most important reason and goal to perform the maintenance and renovation project? ■ *Improving the quality of the dwellings.* □ *Lowering the housing costs* □ *Meet the norms of the corporations* □ *Comply to the covenant of BZK (2012)* □ *Participation in a pilot-project* *The main reason to perform the maintenance and renovation project is to improve the quality of the dwelling. Housing costs will automatically improve when the quality is improved. Because of the special status of the property (it is about te become a monument) and the existing collective heating system, we also saw it a sort of pilot to see what kind of measures were possible to implement.*
4. To what extent have there been made agreements on the project performance, regarding the energy efficiency of the dwellings?
There has been made agreements with the tenants, stating that they will not pay more than previously. This is being monitored on a 2 to 3 year average, to adjust for cold winters. Also, in the renovation contract they agreed with an individual monitoring of energy use.
4.1. What are the restricting factors regarding such an agreement?
-
4.2. Are there consequences when the agreements or norms are not being met?
No.
5. Do tenants have the possibility to influence the measures that will be implemented?
Tenants did not have influence on the energy savings and delivery measures.
6. Has the corporation made adjustments or concessions on the project to meet the

70% approval rate of the tenants?
No, we received about 85% permission, the remainders were then compelled to join. This did take house-to-house visitations to persuade tenants to agree.

3. Project
3.1. Energy saving measures
1. What energy savings measures have been applied in the project?
Floorinsulation, cleftinsulation, roofinsulation, HR++ glazing and CO2-controlled ventilation.
3.2. Energy Delivery measures
1. Have energy delivery measures been implemented in the project? If so, which ones?
Heating network for hot water and heating facilities, including a wood pellet installation, of which the individual use per dwelling is monitored.
1.1. Yes. What was the reason the apply these measures?
Mostly because the existing network was old and we wanted to see what we could do to improve the installation in the most durable way that was feasible.
1.2. No. Has this been considered?
-
1.2.1. Yes. What was the reason not to install these measures?
1.2.2. No. Why not?
2. Is the exploitation of the energy delivery measures performed by the corporation, or a subsidiary company?
The exploitation of the energy delivery is performed by the corporation itself. That means that the tenants pay the corporation for both the rent as the energy use. This is done by a standing charge in the servicecosts and a market-oriented price per GJ. We are not currently active within an energy BV, although I'm personally an big supporter of this. The reason is that the board did not see any advantage in putting these activities in a separate entity.
2.1. Corporation. Via rent, service costs or separate invoice?
2.2. Subsidiary. In the form of an Energy B.V.?
2.3. No. Is it exploited by an external company?
3. Does the corporation see any future in delivering energy to its tenants?
Yes, living has both a rent component and an energy component. At the moment and under the current policies and legislation these are separated. The housing corporation handles the rent component and an energy supplier handles the energy component. Since these components influence each other, it is only logical for corporations to focus on the combination of these components. However, under the current legislation, this has not been made easy. *In our case, the measures are not taken into account in the energy label, as this only focuses on measure on the plot itself. It does influence performance, but is not taken into account. Also, for corporations to see energy delivery as a means to increase earnings, we have to become active as an energy BV.* *Personally I think this is the future and given the positive end results of this project I definitely see a future.*

3.1. Would the reason be to increase energy performance of to increase the corporation's earnings potential?
Both

4. Project finances
1. Which financing tools have been used for the project?
For this project we have mostly used our own liquidity, but also a loan with WSW-guaranteed backing.
2. Where there any originally planned measures that have not been applied, because or lower financial possibilities?
No.
3. Does the WSW provide financial backing for the project?
Yes, for all measures, including the wood pellet installation.
4. Is the intended rent increase constrained by the liberalization boundary?
No, the rent was still relatively low and the boundary was not at all in sight. This could be a problem with other projects though.
5. Did the European DAEB-regulations restrict the project in any way?
Not yet, although in the future this kind of project could become more difficult, since we have to apply a differentiation between DAEB and non-DAEB dwellings. This is a costly administrative task. Also, regarding finances, we were lucky to achieve a WSW backing for the wood pellet installation. In the future this will not be possible anymore and the extra capital will have to be paid for by the corporation itself. With such high initial costs this could become a problem.

5. Project performance
5.1. Investments
1. What is the investment per dwelling, when only taking into account the energy efficiency measures?
1.1. What is the investment for all energy savings measures?
€3000 average per dwelling for the energy saving measures, which included: *- floor insulation for ground located dwellings* *- additional cavity wall insulation* *- Roof insulation for upper dwellings* *- HR++ glazing for all dwellings*
1.2. What is the investment for all energy delivery measures?
1.2 million for 68 + 38 dwellings, including: *- Central heating with radiators* *- Wood pellet installation including infrastructure.*
5.2. Energy Index
1. What was the energy index before the energy efficiency measures where applied?
An average of 2.31 (energy label E), obtained from (INNAX bouwkundig adviseurs, 2010)
2. What is the energy index after the energy efficiency measures have been applied?
An average of 1.49 (energy label C), obtained from (INNAX bouwkundig adviseurs, 2010)
5.3. Present Value

1. What is the new exploitation period of the dwellings after the energy efficiency project?
The exploitation period is an additional 40 years.
2. What was the rent increase after the energy efficiency project?
The rent increase is € 8,- or the energy savings measures. Which has been determined using the EPA-program package VABI. This rent increase in 50% of the predicted theoretically savings, which is a very modest prediction. I believe it could also have been €15,- but, we went for the most modest prediction.
2.1. How has this increase been determined?
3. Have part of the measures been settled by an increase in service costs or a separate invoice?
Yes, the energy delivery measures are charged with a standing charge of € 350,- annually and we apply a NMDA-based price per GJ of €21,-.
3.1. Was energy delivery one of them?
5.4. Housing costs
1. Does the renovation lead to a decrease in total housing costs for the tenants?
Yes, the renovation should save €16,- in energy costs. Together with the €8,- rent increase this adds up to €8,- decrease in total housing costs per month.
1.1. If so, with what monthly amount?
2. How has this decrease been determined?
This has been determined based on a very modest theoretical prediction using VABI.
3. Have the tenants been given the guarantee that the applied measures would result in a certain amount of savings?
No.

6. Review
1. What barriers did the corporations encounter during the project that influenced the project's organization, finances or energy performance?
Mostly, the legislation, norms and policies on a national scale are not in line with current development on the energy field. The norms are running behind and this provides no stimulus for corporations to invest in these kinds of technologies. Even then, legislation is largely based on large-scale delivery of energy. For example, if we wanted to add solar panels on the roofs of an apartment complex, we may not charge the tenants on their individual use. Without this, a proper way of determining what each individual households should pay for the used energy does not exist. Therefore, a large potential for renewable energy is already made obsolete. *The monitoring of the CFV and the WSW has also become more strict, which influences the feasibility of the projects.*

7. Data
1. Investment per dwelling
E*nergy savings measures* *€3000,-* *Energy delivery measures*

€1.200.000,- /(68+38) = € 11.320,75
Total
€14.320,75

2. Savings on total housing costs

50% of estimated minimal energy savings of €16,- ,determined with BRL 9501 approved method VABI-W(KOMO, 2011), equals a decrease of €8,-.

3. Energy Index before renovation

2.31 (INNAX, 2010)

4. Energy Index after renovation

1.49 (INNAX, 2010)

5. Present Value

Attributed to rent:
€ 8,- rent increase over 40 years.
Annually corrected with an inflation of 2%, which is the 20-years average for the Netherlands, corrected to full percentages.(Inflation.eu, 2012)

Attributed to energy services:
Income per dwelling
annual fixed amount of € 350,- over 25 years
Average monthly energy bill € 40,-

Operating costs per dwelling:
Annual estimated maintenance costs of pellet installation: € 12.000,- / (68+38) = € 113,20
Pellet use per year 210.000 kg (for two 300 kW installations), pellet price of € 0.15 = € 31.500 /(68+38) = € 297, 17. (increase in pellet price of 5% annually)

Total:
Rent: € 2.222,31 (over 40 years)

$$\boldsymbol{PV_{rent}} = \sum_{t=1}^{40} \frac{\left((\mathbf{8} * \mathbf{12}) * \mathbf{1.02}^{t}\right)}{(\mathbf{1} + \mathbf{0.0525})^{t}}$$

Services (€ 16.728,33 - € 9.213,69 =) € 7.514,64 (over 25 years)

$$\boldsymbol{PV_{services}} = \sum_{t=1}^{25} \frac{\left((\mathbf{40} * \mathbf{12}) * \mathbf{1.05}^{t} + \mathbf{350}\right)}{(\mathbf{1} + \mathbf{0.0525})^{t}} - \sum_{t=1}^{25} \frac{\left((\mathbf{113,20} * \mathbf{1.02}^{t}) * (\mathbf{297.17} * \mathbf{1.05}^{t})\right)}{(\mathbf{1} + \mathbf{0.0525})^{t}}$$

Total
€ 9.736,95

References:

- INNAX, 2010. De goede woning, maatwerkadviesrapport EIA, complexrapportage complex 33. INNAX bouwkundig adviseurs. Rapportagenummer 7980.103.01, 21 oktober 2010.

- KOMO, 2011. KOMO attest nummer K44532/06

- Inflation.eu, 2012. http://nl.inflation.eu/inflatiecijfers/nederland/historische-inflatie/cpi-inflatie-nederland.aspx

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Appendix G, Data recalculations

EI of DMU_5

To take the collective heating network of DMU5 into account in the Energy Index assessment, its equivalent generation-yield has to be determined using the methodology of NVN 7125.

The NVN 7125, or EMG is used to calculate the influence of the following area-wide energy systems on the energy performance of the dwellings, connected on the particular system (NEN, 2011):

- Collective heat systems for heating and hot water supply installations.
- Collective circulation systems for hot water supply installations.
- Collective cold systems.
- Collective electricity generation in the area, e.g. windmills or collective PV-panels.

The acquired equivalent generation yield entails all energy use and loss for the heat and cold energy systems. It is then used to acquire the new EPC of the dwelling, with the collective heating system taken into account. In the case of this research, the EI is used instead of the EPC, as it addresses an existing dwelling.

Using basic characteristics of the dwelling-type of DMU_5, its known Energy Index and the technical characteristics of the wood-pellet heating system obtained from the distributor and standard values for unknown data, the Equivalent Generation Yield of the areal heating system was determined at 1.52, or 152%. See figure 26 for a print out of the calculation tool.

Following the Dutch innovation institute TNO (TNO, 2012), stating that a collective heat system with an equivalent generation yield of 150% will translate in to a 25% lower EPC, the Energy Index of the dwellings of DMU5 is determined by (3.1).

$$EPC_{EMG} = 0.75 * EPC_{EPC} \quad (7.1)$$

If $R_{equivalent} \geq 1.5$

Given that the original EI_{after} of DMU_5 was 1.49, see section 6.1, the new EI_{after} will be 1.12. The mere addition of taking into account all of the installed measures, instead of solely taking into account the measures on the plot itself, meant a decrease of the EI of 0.37. The addition would mean an energy label step increase from C to B.

Verklaring conform norm NVN 7125

Opgesteld met: EMG rekentool v1.0
Datum 3 januari 2013

Projectgegevens

Aanvrager
Naam: Barry Kroon
Adres: Echternachlaan 26
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Woonplaats: Eindhoven

Project
Omschrijving: Hercalculatie Energie Index Ibisplein

Plaatsnaam: Apeldoorn
Exploitant: De Goede Woning

Betrokken partijen
Partij 1: De Goede Woning
Partij 2: BAM Woningbouw
Partij 3:

Resultaten

	Equivalent opwekkingsrendement [-] Aansluiting op:	
Collectieve warmte en/of koudevoorziening	**Primair net**	**Secundair net**
- Verwarming	n.v.t.	1,52
- Warmtapwater	n.v.t.	n.v.t.
- Koeling	n.v.t.	n.v.t.

	Elektriciteitslevering per m2 gebruiksoppervlakte [MJe/m2]
Collectieve elektriciteitsvoorziening	n.v.t.

Disclaimer: Hoewel bij deze uitgave de uiterste zorg is nagestreefd, kunnen fouten en onvolledigheden niet geheel worden uitgesloten. Agentschap NL en/of degene die aan deze uitgave hebben medegewerkt aanvaarden derhalve geen enkele aansprakelijkheid, ook niet voor directe of indirecte schade, ontstaan door of verband houdend met toepassing van deze rekentool.

Figure 26: Declaration of the equivalent generation yield of DMU_5's heating network.

Earnings potential of DMU_2, DMU_4 and DMU_9

The earnings potential of DMU_2, DMU_4 and DMU_9 is determined by assessing the technical characteristics of the installed PV-panels and the average annual yield. This is then added to the Present Value variable of the respective DMU, applying a fixed exploitation period of 25 years. To obtain the electricity contribution of the PV-panels to the dwellings and apartments, the calculation method of NEN 7120.20 '*Gebouwgebonden productie van elektriciteit op het eigen perceel'* is used, based on the European norm for solar power NEN-EN 15316-4-6.

The annual contribution of the PV-system is determined using (7.2).

$$E_{pr;el;PV} = \sum_i E_{pr;el;PV;i} \qquad (7.2)$$

Of which $$E_{pr;el;PV:i} = \frac{RF_{PV;i} * S_{PV;i} * c_{s;PV;i} * Q_{PV;i;opv}}{1000} \qquad (7.3)$$

where $$S_{pv;i} = \frac{P_{PV;i}}{A_{PV;i}} \qquad (7.4)$$

In which $$Q_{PV;i;opv} = F_{sh;ob;an} * A_{PV;i} * \sum_{mi} (I_{sol;mi} * t_{mi}) \qquad (7.5)$$

Where:

$E_{pr;el;PV;i}$	Yearly contribution of the PV-system *i* in MJ.
$RF_{PV;i}$	Dimensionless contribution factor of the PV-system.
$S_{PV;i}$	Peak power of the PV-system per m^2 in W/m^2.
$c_{s;PV;i}$	Dimensionless correction factor for the influence of shade.
$Q_{PV;i;opv}$	Yearly amount radiation on the PV-system *i* in MJ.
$P_{PV;i}$	Sum of the watt-peak powers of the PV-panels of the PV-system *i.*
1000	Numeric value of the reference power in W/m^2.
$A_{PV;i}$	Surface of the PV-panels in m^2.
$F_{sh;ob;an}$	Dimensionless shading factor of the PV-system.
$I_{sol;mi}$	The amount of sun radiation falling on the panels in month *mi*.
i	Dimensionless rank number of the PV-system.
t_{mi}	Calculation value of the length of the month *mi* in Ms.

The value for $S_{PV;i}$ in (7.4) must be rounded off on multiplications of 5 W_p/m^2. Most variables can be determined using provided tables in NEN 7120.20. The last four variables, concerning climate data, are determined by tables in NEN 7120.21 '*Klimaatgegevens*'. Remaining variables are PV-system-specific data.

Table 25: Data of PV-systems per DMU.

	DMU2	DMU4	DMU9
$A_{PV;i}$	8	13.3	18.6
$\sum_{mi}(I_{sol;mi} * t_{mi})$	624.49	4012.79	3280.62
$F_{sh;ob;an}$	1.0	1.0	1.0
$Q_{PV;i;opv}$	4995.92	53384,04	61019.47
$S_{PV;i}$	155.0	175.0	185.0
$c_{s;PV;i}$	1.0	1.0	1.0
$RF_{PV;i}$	0.7	0.7	0.7
$E_{pr;el;PV;i}$	542	6539,5	7902

For DMU4, which has multiple dwelling-types with different orientations, a weighted average is taken for $A_{PV;i}$, $\sum_{mi}(I_{sol;mi} * t_{mi})$ and $Q_{PV;i;opv}$.

The obtained value of the three PV-panel installations is their energy contribution in Mega Joules. Expressed in kWh, these are 150.56, 1920.28 and 2195 kWh for DMU_2, DMU_4 and DMU_9 respectively. Applying the normal kWh-tariff of the Dutch energy-market of € 0,22 per kWh, price level 2012/2013 (MilieuCentraal 2012), the annual earnings potential of the PV-panels is obtained, which are stated in table 26.

Table 26: Monetary values of PV-systems annual energy contribution.

	DMU2	DMU4	DMU9
kWh	150.56	1816.54	2195.0
Monetary value	€ 33.08	€ 399,64	€ 482.09

Since DMU_2 had not incorporated the energy earnings of the PV-system in their increased rental sum, the € 33.08 can be added to the additional annual income of the corporation. The increase in costs for the tenant would mean a slight decrease in savings on monthly total housing costs.

For DMU_4 the situation is different. The respective corporation asked a rent increase of 75% of the savings that could be contributed to the PV-system. When the full potential of the PV-system is recharged to the tenant, the present value is only slightly increased, whereas the savings on housing costs for the tenant decreases with more than 50%.

DMU_9 charges a monthly contribution fee of € 48.08 of the tenants to cover the total costs of the PV-system. The monthly contribution of the system is less then this contribution fee, resulting in a lower present value, but a higher value for the savings on housing costs.

Table 27 shows the new variables of the DMUs, in the situation where the earnings potential of the ESC-measures are fully utilized. Changes are highlighted in yellow.

Table 27: DMUs variables, improved for ESC-measures.

DMUs	Input	Output			
	Costs	Savings on Housing costs	Energy Index Before	Energy Index after	Present Value
1	€ 3.800,00	€ 7,00	2.38	1.20	€ 2.745,70
2	€ 60.000,00	€ 13,74	2.01	0.99	€ 6.983,55
3	€ 50.000,00	€ 28,00	2.32	0.88	€ 7.778,10
4	€ 77.000,00	€ 14,39	1.81	0.38	€ 16.596,76
5	€ 14.320,75	€ 8,00	2.31	1.12	€ 3.914,14
6	€ 20.881,60	€ 60,00	2.13	0.96	€ 0,00
7	€ 5.592,00	€ 12,50	2.09	0.86	€ 2.640,10
8	€ 45.000,00	€ 9,00	2.21	0.85	€ 9.228,81
9	€ 130.000,00	€ -32,09	2.21	0.15	€ 43.120,06
10	€ 14.416,67	€ 63,00	2.38	1.16	€ 3.073,35
11	€ 40.000,00	€ 30,00	2.11	0.95	€ 0.00
12	€ 27.437,50	€ 7,00	2.31	1.02	€ 5.000,20

Appendix H, Differences between EPC and ESC

	Energy Performance Contracting	Energy Supply Contracting
Θ-value: 'Relative Efficiency'	Four EPC-DMUs were found to be BCC-efficient: DMU_1, DMU_7 and DMU_{10}. All other EPC-DMUs got mediocre Θ-values for dataset 1, but scored significantly better ($\theta > 0.75$) on dataset 2.	Two ESC-DMUs were found to be BCC-efficient. The lowest Θ-value in both datasets, DMU_2 is also an ESC-DMU. All other ESC DMUs score better on dataset 2 than on dataset 1, but with varying efficiency ($0.58 > \theta < 0.91$)
Input X_1: ***'Costs'***	The DMUs performing EPC have made the lowest absolute costs. With these low costs, they were able to generate a considerable level of output. The BCC-efficient EPC-DMUs received high variable weights for u_1. This indicates that keeping costs low is definitely a strong aspect of EPC-measures.	Three of four ESC-DMUs have the highest absolute costs of the entire set of DMUs. Of these, two DMU are efficient, with high weights attributed to the costs variable. The other inefficient ESC-DMUs are also attributed high weights for u_1. This indicates that ESC projects' input is processes well into the several outputs.
Output Y_1: ***'Savings on Total Housing Costs'.***	In absolute terms, the EPC-DMUs are able to generate very high savings for the tenants. For DMU_{10} this contributed to its BCC-efficiency. The most EPC-DMUs are given weights for v_1, showing its efficiency on this aspect.	The absolute savings on total housing costs for EPC-DMUs are all below average, with DMU_9 even being negative. The v_1 values for the inefficient ESC-DMUs are low. Clearly, generating total housing costs savings is not an efficient point of ESC-DMUs.
Output $Y_{2.1}$: ***'Energy Index After'.***	The lowest absolute Energy Index for an EPC-DMU is 0.85, equivalent to energy label A, the highest is 1.25, a label B. Whether or not v_2 influences the Θ-value of a DMU depends on the ratio $cost/EI_{after}$. A high Energy Index can be achieved with EPC, but none of the EPC-DMU achieve an energy label higher than A.	The two best scoring DMUs regarding the Energy Index, DMU_4 and DMU_9, are ESC-DMUs. However, only DMU_9 is placed on the Efficient Frontier and has a v_2-value of 0.24. For DMU_4, its high Energy Index is not influential for its Θ-value. Even so, EPC-DMUs can achieve a very high Energy Index, making this a strong aspect.
Output $Y_{2.2}$: ***'Delta Energy Index'.***	One EPC-DMU is placed on the Efficient Frontier regarding the increase in Energy Index. The other EPC-DMUs receive high v_2-values for this variable, explaining the difference in Θ-value between dataset 1 and 2. The Δ-EI variable is clearly a strong point of EPC, especially since this can be achieved with relative low costs.	Only DMU_9 is placed on the Efficient Frontier, although its v_2 is zero. Apparently the other variables are more distinguishable for this DMU. Other ESC-DMUs score well on their v_2-value. The ratio Costs/ Δ-EI for ESC-DMUs is good, but not distinctive from EPC-DMUs'.
Output Y_3: ***'Present Value'.***	DMU_1 is the only EPC-DMU located on the Efficient Frontier. Of the EPC-DMU that have been attributed weight, the v_3-values differ a lot but only for dataset 1. The Θ-value of these DMUs in dataset 1 is lower than in dataset 2, suggesting that the Present Value is not a strong point of EPC. In absolute terms and in the ratio Costs/Present Value, the EPC-DMUs score relatively low, apart from the low-cost DMU_1.	DMU_5 and DMU_9 are located on the Efficient Frontier. For DMU_5 this is its main contributor for BCC-efficiency. For dataset 1 EI_{after} is more distinguishable for DMU_9, but the other ESC-DMUs receive reasonably well v_3-values. In dataset 2, DMU_9 scores well on v_3. In absolute terms DMU_4 and DMU_9 were able to achieve the highest Present Value, depicting the ability of ESC to utilize more revenue possibilities.

Energy Services in the Dutch social housing sector.

A benchmarking study on housing corporations' in practice performance.

Extended summary ENG & Summary NL

ENERGY SERVICES IN THE DUTCH SOCIAL HOUSING SECTOR
A benchmarking study on housing corporations' in practice performance

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ABSTRACT
The energy efficiency of most social housing dwellings does not meet current norms, which unnecessarily increases the total housing costs of the tenants. Housing corporations must invest in improving energy efficiency to improve performance, but come across several barriers that prevent them from covering their costs. An often mentioned solution is bringing energy services, which has to distinct approaches and business models, aimed at lowering energy demand and fulfilling the remaining energy demand. This research assesses twelve projects in the Dutch social housing sector, in which these energy services have been applied, on energy performance and project finances. Especially small-scale, decentralized energy delivery by housing corporations has the ability to improve energy performance, while using the earnings potential of energy delivery. Given these advantages, outdated rules and legislation should be changed to facilitate this development.

Keywords: Energy services; Housing corporations; Energy efficiency; Energy Performance Contracting; Energy Supply Contracting.

INTRODUCTION
An increasing energy demand and decreasing availability on fossil fuels has driven up prices of the last few years. Since the increase in energy costs for Dutch households has increased at a faster rate than the income, the share of household-income that is spent on energy-related expenses is rising. Research shows that three groups are especially vulnerable for this development (Nibud, 2009): The lower incomes; the lower educated; and tenants.

Most of the lower income households in the Netherlands are not able to buy or rent a home on the private market and are reliant on the social housing sector, which in the Netherlands exploits 34% of all the 7.2 million Dutch homes. These dwelling are exploited and maintained by housing corporations: a private organization with the public goal of providing qualitative and affordable housing to those that cannot themselves. The target group for social housing has been determined by European law to be households with an annual income up to € 34.085 (price level 2012). Housing is considered to be social housing when the monthly rent is lower than € 664,66.

The main task of housing corporations is stated in the main national legal document for the social housing sector 'Besluit Beheer Sociale Huursector', or BBSH (VROM, 2005), in six main performance fields:

- To accommodate the target group;
- To ensure quality of living;
- To involve tenants in policy-making and exploitation;
- To provide financial continuity;
- To provide quality of life;
- To provide housing and care.

Given its size and the financial vulnerability of its tenants, the sector plays an important role in reducing the energy-related expenses by improving the (energetic) quality of their housing stock. The sector has made agreements on improving this energy efficiency with the national government (BZK, 2012). Most of the social housing was built in a period in which few to none attention was given to energy efficiency. The room for improvement is therefore large. Despite of the goals, the investments of the sector in the existing housing stock is decreasing (CFV, 2012).

Due to several developments en new political decisions, the financial position and investment possibilities of housing corporations have decreased. The prognosis on new building projects therefore shows a decreasing trend and many projects have been postponed. This makes investments in the existing housing stock and in improving energy efficiency even more important. However, the speed and number of such projects is falling behind.

This is a concerning development, since several experts point out the necessity of investing in the energy efficiency of the existing social housing stock (Renda, 2012). They argue that without these investments, the vast majority of the social houses, 80%, will no longer be within financial reach for the target group of the corporations by the year 2030, due to the increased total housing costs, see figure 1. This makes it necessary for housing corporations to expand their focus and offer social housing with an affordable, long-term housing costs prospect.

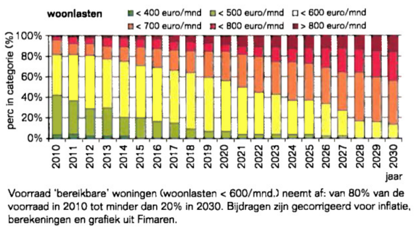

Figure 1: Percentage of rental dwellings within Financial reach of the target Group. Source: Renda (2012).

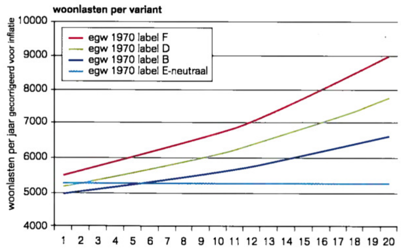

Figure 2: Development of housing costs for different energy labels. Source: Renda, (2012).

Figure 2 shows that steady housing costs on the long term are only reached by energy-neutral houses. Energy neutral dwelling are dwellings that use as much energy as they generate over the net period of one year. Since bringing real estate up to energy neutral standards means additional investments in energy generating installations and measures in a time where housing corporations are already struggling financially, the implementation of such measures is minimal.

SPLIT INCENTIVE

An explanation for the low investments in energy efficiency and the slow implementation of such measure is the split incentive. The capital investments for improving the energy performance of the dwellings are done by the housing corporations, but the (financial) benefit of these improvements are experienced by the tenants in the form of lower energy costs. This imbalance in costs/benefits makes it unattractive for housing corporations to invest in improving energy performance and thus forms an important obstacle for the sector.

A possible solution for this problem of housing corporations could be found in bringing energy services: A package of energy efficiency improving measures, concerned with maximizing efficiency and cost effective supply and end-use of energy for their customers (GEA & EESI, 2009).

Several opportunities are addressed to such energy services: It lowers the housing costs for the tenants; generates additional income for housing corporations and thus lower the split incentive; and it could provide for the financial boost to bring dwellings up to energy neutral standards by implementing durable energy generating solutions.

ENERGY SERVICES

Energy services have been stated as a multi-purpose instrument, which will help to overcome market-barriers for energy efficiency (Bleyl-Androschin, 2009) Two distinct approaches to energy efficiency exist in the energy services: energy performance contracting, EPC, and energy supply contracting, ESC. EPC is aimed at reducing the energy demand of a dwelling and thus on establishing energy savings, whereas ESC is

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aimed at efficiently fulfilling the remaining energy demand, and thus on energy supply.

These contracting types are not about any particular technology or energy carrier, but rather must be seen as a modular efficiency tool. Although they both strive for efficient energy use, their business model and type of implemented measures differ.

Energy performance contracting

Energy performance contracting's main goal is to reduce energy consumption by implementing demand side efficiency measures. This includes high insulation values for facades, floors roofs and windows. The business model is based on delivering savings compared to a predefined baseline. The investment, or capital expenses, of the EPC-measures, is covered by the avoided energy costs, or a decrease in the operating expenses. In the Dutch social housing sector, a similar approach is used. The implemented EPC-measures lower the energy costs of the tenant and the housing corporation increases the rent. As long as the rent increase is lower than the savings on energy costs, this results into lower housing costs for the tenant.

Energy supply contracting

Energy supply contracting's main goal is to provide maximum efficiency of the energy supply and to provide the security of supply. The subject of the contract therefore is not the avoided energy costs, but the delivered units of energy. Within this contract innovative, high-efficient and renewable technologies such as bio-mass plants, solar, wind and water energy, thermal systems and local heating networks have been implemented. In the Dutch social housing sector however, the implementation of ESC-measures is minimal and only performed by a handful pioneering housing corporations, which show promising results.

RESEARCH STATEMENT AND RESEARCH QUESTIONS

The research statement is as following: 'Most housing corporations are hesitant to become fully active in the energy services, despite positive results and experience of their colleague corporations. The decision-motives underlying these hesitations and their interrelationship are not known. Also, a clear view on the effects of energy services on important energy efficiency targets is not known.'

The main research question is formulated as:
'What are the effects of energy services on energy efficiency targets of energy efficiency projects in the Dutch social housing sector? '

METHOD

The effect of energy services on energy efficiency targets is assessed by benchmarking projects that have been performed by housing corporations with the intention to improve the energy efficiency of the dwellings.

This research uses the formal benchmarking technique Data Envelopment Analysis, which is applied to perform both a best practice and a performance benchmark of these energy efficiency projects in the Dutch social housing sector.

Data envelopment analysis

Data envelopment analysis is a data-oriented approach for evaluating the performance of a set of a relatively homogenous set of peer entities, called Decision Making Units or DMUs. It is a relatively easy mathematical programming method, which identifies efficiency frontiers for a peer group of entities and has been proven particularly useful for estimating multiple input and multiple output production correspondences.

DEA opens up possibilities for use in cases which have been resistant to other approaches because for the complex and often unknown nature of the relations between the multiple inputs and outputs involved with many of these activities. (Cooper et al., 2004). DEA has also been used to supply new insights into activities and entities that have previously been evaluated by other methods.

DEA assesses the relative efficiency of a peer group of entities by using the efficiency ratio, output divided by input, of each individual DMU. The DMU with the highest efficiency ratio is thus the most efficient and serves as an example for the other DMUs. However, the exact combination of inputs and outputs can differ between DMUs due to different approaches and decisions. The aspects on which a DMU can be called efficient can thus also differ. DEA enables the researcher to assess these DMU-specific combinations by implementing a variable weighting scheme.

DEA assigns weight to each input and output variable for each DMU's transformation process. It determines which weighted combination of input and output results into the highest input-to-output ratio for a DMU, when the same weight-combination would have been applied to all DMUs. By doing so, the relative strong points of a DMUs transformation process become clear

Variables

The input and output variables on which the DMUs are assessed have been determined by literature study, experts' opinion, national agreements and ability to assess the two energy service approaches. The input and output variables of this research can be seen in table 1.

Table 1: Input and output variables.

Input	Output
Costs per dwelling	Savings on total housing costs
	Energy Index
	Present value of additional income

Costs per dwelling (X_1)

The costs per dwelling only cover the costs of the energy efficiency measures. Often, such measures are applied during a renovation, in which sanitation and kitchen appliances are replaced. These costs however are not taken into account as only dwelling improving measures may legally results into a rent increase. (BZK, 2012)

Savings on total housing costs (Y_1)

The savings on total housing costs measures the monthly financial benefit for the tenant, after the measures have been applied. In the agreement 'Convenant Energiebesparing Huursector' (BZK, 2012) it is stated that energy efficiency measures must lead to lower housing costs for the tenant.

Energy Index, EI (Y_2)

The Energy Index, EI, is the obligated index that measures the energy efficiency of existing dwellings. Two values of the EI are obtained per DMU: EI_{after} to capture the EI-score after renovation, and ΔEI to capture the added quality of the improvements.

Present value of additional income (Y_3)

The present value of the additional income is taken into account to express the financial benefit of the energy efficiency project for the housing corporation. It holds all the expected additional positive cash flows related to the renovated dwelling during its extended exploitation period.

FINDINGS

Data Collection

Twelve DMUs have been assessed in this research. Eight of these implemented EPC-measures, the other four implemented both EPC- and ESC-measures. The DMUs were visited and the responsible project leaders were interviewed. The obtained data collection can be seen in table 2.

Table 2: Data collection.

DMUs	Input	Output			
	Costs	Savings on Housing costs	Energy Index Before	Energy Index after	Present Value
1	€ 3.800,00	€ 7,00	2.38	1.20	€ 2.745,70
2	€ 60.000,00	€ 16,50	1.99	1.09	€ 6.666,94
3	€ 50.000,00	€ 28,00	2.32	0.88	€ 7.778,10
4	€ 77.000,00	€ 28,02	1.91	0.38	€ 15.802,79
5	€ 14.320,75	€ 8,00	2.31	1.49	€ 9.736,95
6	€ 20.881,60	€ 60,00	2.13	0.96	€ 0,00
7	€ 5.592,00	€ 30.58	1.87	1.25	€ 1.020,93
8	€ 45.000,00	€ 9,00	2.21	0.85	€ 9.228,81
9	€ 130.000,00	€ – 40,00	2.21	0.15	€ 45.553,39
10	€ 14.416,67	€ 63,00	2.38	1.16	€ 3.073,35
11	€ 40.000,00	€ 30,00	2.01	0.95	€ 0,00
12	€ 27.437,50	€ 7,00	2.31	1.02	€ 5.000,20

Analysis

Two DEA analyses have been performed. One on the actual performance, using the data of table 2, and one on the potential performance, using recalculated data to represent the DMUs' performance unhindered by rules and legislation. This second analysis more accurately represents the true strong points of EPC- and ESC-projects and shows the influence of rules and legislation on the direct performance of these projects. The results of this second analysis can be seen in table 3 and 4.

Table 3: DEA results for the potential performance on dataset 1 (EI_{after})

ES	DMU	θ	Reference set	v_1	v_2	v_3	u_1
ESC	2	0.37	DMU_5 (0.02); DMU_9 (0.39); DMU_{10} (0.59)	0.32		1.01	1.32
	4	0.65	DMU_1 (0.04); DMU_5 (0.08); DMU_9 (0.55); DMU_{10} (0.34)	0.07	0.34	0.21	0.70
	5	1	-			0.90	1.21
	9	1	-		0.24		0.28
EPC	1	1	-		1.90	1.07	2.26
	3	0.59	DMU_9 (0.25); DMU_{10} (0.75)	0.56		0.34	
	6	0.99	DMU_9 (0.03); DMU_{10} (0.97)	0.32	0.24		
	7	1	-	0.74			4.88
	8	0.53	DMU_5 (0.54); DMU_9 (0.27); DMU_{10} (0.20)	0.27		0.85	1.10
	10	1	-	0.30			
	11	0.57	DMU_9 (0.17); DMU_{10} (0.83)	0.54	0.41		
	12	0.52	DMU_5 (0.20); DMU_7 (0.57); DMU_9 (0.16); DMU_{10} (0.08)	0.19	1.09	0.46	1.97

The θ-value shows the relative efficiency of a DMU on a scale from 0 to 1. The reference set is determined for the non-efficiency DMUs as an indication of improvement possibilities. v_1, v_2, v_3 and u_1 represent the individually determined weights per DMU, corresponding with Y_1, Y_2, Y_3 and X_1, respectively.

Table 4: DEA results for the potential performance on dataset 2 (ΔEI)

ES	DMU	θ	Reference set	v_1	v_2	v_3	u_1
ESC	2	0.58	DMU_1 (0.23); DMU_9 (0,42); DMU_{10} (0.35)	0.01	1.38		0.31
	4	0.91	DMU_1 (0.21); DMU_9 (0.56); DMU_{10} (0.23)	0.01	0.81		0.18
	5	1	-			0.90	1.21
	9	1	-			0.20	0.27
EPC	1	1	-		1.06		0.24
	3	0.96	DMU_1 (0.24); DMU_9 (0.33); DMU_{10} (0.43)	0.01	0.86		0.19
	6	0.96	DMU_9 (0.00); DMU_{10} (1.00)	0.15	0.64		
	7	1	-	0.49	0.68		4.74
	8	0.91	DMU_1 (0.59); DMU_9 (0.32); DMU_{10} (0.09)	0.01	0.92		0.21
	10	1	-	0.33		0.20	
	11	0.75	DMU_1 (0.15); DMU_9 (0.23); DMU_{10} (0.62)	0.01	1.16		0.26
	12	0.96	DMU_1 (0.79); DMU_9 (0.18); DMU_{10} (0.03)	0.01	0.97		0.22

The θ-value shows the relative efficiency of a DMU on a scale from 0 to 1. The reference set is determined for the non-efficiency DMUs as an indication of improvement possibilities. v_1, v_2, v_3 and u_1 represent the individually determined weights per DMU, corresponding with Y_1, Y_2, Y_3 and X_1, respectively.

Results

The efficient DMUs are the DMUs that have scored a θ-value of 1. The DMUs that have received lower θ-values are thus inefficient. For the efficient DMUs, it can be

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said that they receive their full efficiency score mostly because of their financial variables, which have been awarded the highest variable weights. Either the DMUs kept their costs relatively low (DMU1, DMU7), or kept their income relatively high (DMU5, DMU9). DMU10 was able to achieve very high savings on total housing costs.

Also, most inefficient DMU's receive a far higher θ-score for dataset 2 than for dataset 1. This indicates that they are more successful in achieving big improvement on the Energy Index (ΔEI), than they are in reaching high end-value (EI_{after}).

Regarding the differences in type of applied energy service, important differences can also be found.

Energy Performance Contracting projects are able to achieve a reasonable Energy Index after renovation. This Energy Index meets current the norms, but will not surpass an average A-label. The affiliated costs of the projects are lower than those of Energy Supply Contracting. However, the ability of EPC to cover these costs is lower than those of ESC and a split incentive remains. The savings on total housing costs are directly related to the present value. The more savings on total housing costs for the tenants, the lower the potential present value of the project and vice versa.

Energy Supply Contracting has the ability to achieve a much higher Energy Index, up to almost energy neutral standards. The costs of these projects are often higher than EPC-projects, but by utilizing the earnings potential of the energy supply measures, they are able to achieve a relatively high present value and cover a relatively larger part of their costs. This lowers, but doesn't entirely removes, the split incentive for housing corporations. However, the higher present value means that the savings on total housing cost for ESC-projects isn't a strong aspect.

Overall, projects with ESC's characteristics will perform better on energy efficiency, indicated by a lower energy index, while the earnings potential of the energy supplying measures improves their present value. They are still able to generate savings for the tenants, albeit a small benefit. EPC projects perform lower on energy efficiency, but meet the energy efficiency norms with lower costs and with the ability of high savings for the tenants, yet lower added income for the corporation.

DISCUSSION & RECOMMENDATIONS

Housing corporations

The performance of the assessed DMUs, EPC and ESC, all comply with the current energy efficiency norms. The ability of combining Energy Supply Contracting with the conventionally adopted approach of Energy Performance Contracting to achieve a lower – thus better – energy index, while utilizing the earnings potential of its energy supply installations, is therefore not perceived as an immediate necessity by most housing corporations. Corporations seek a balance between their societal objective and their financial arguments regarding their investments behavior. The practical implementation of the sector's societal goal is thus dependant on the financial possibilities. This explains why the cheaper energy performance contracting is still the conventional approach of the sector.

Housing corporations exist under the societal condition to provide high quality, affordable housing. Although many of them see the possibilities of energy delivery regarding this condition, most of them choose not the take the step. By doing so, the possible quality of the dwellings is compromised: by only doing what is necessary, a permanent solution is denied and problems are postponed instead of solved.

Apart from the intrinsic motivation of housing corporations to strive for the highest energy efficiency norms, rules and regulations should facilitate innovative energy efficiency initiatives. Here lies an important role for the Dutch national government.

National government

Short-term market barriers must not become long-term business obstacles that prevent housing corporations from fulfilling their main goal of providing high quality, yet affordable housing for the lower incomes. To prevent this, the current legislative framework and energy efficiency norms need revision and take in a more facilitating character, instead of the barrier that it is perceived as today.

First, the current ambition of the sector to reach an average B-label or EI of 1.25 in 2020 (BZK, 2012) will not guarantee long-term affordability. Renda (Renda, 2012) shows that this ambition will not stabilize the total housing costs of households and only energy neutral houses will. Under more ambitious norms, ESC will have to be applied given its ability to reach higher EI-norms, as shown by this research. This is even stated in the same agreement (BZK, 2012), maintaining the ambivalent stance of the sector towards energy services and managing total housings costs.

Explicitly mentioning energy services or managing total housing costs in the BBSH as one of the performance fields of housing corporations could provide them the security and policy space regarding the implementation of ESC-measures especially. Simultaneously, such activities should fall under the activities of housing corporations eligible for state-aid, opening up opportunities for more beneficial financial funding for the high capital expenses on ESC-measures.

This would be a logical step, following the reasoning that long-term affordability of the social housing sector is only assured by taking into account the total housing costs, and thus the implementation of ESC-measures.

Structural solutions are called for by the Dutch government, creating opportunities for housing corporations in laws and legislation, by facilitating small-scale decentralized energy generating solutions.

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This summary is the result of my graduation thesis on the performance of Dutch housing corporations on the implementation of energy services to improve the energy efficiency of their housing stock. The research was performed in collaboration with Innovation in Building & Maintenance in Eindhoven. With this report, I end my Masters education Construction Management & Engineering at Eindhoven University of Technology.

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ENERGY SERVICES IN THE DUTCH SOCIAL HOUSING SECTOR

A benchmarking study on housing corporations' in practice performance

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SAMENVATTING

De energetische kwaliteit van de meeste sociale huurwoningen voldoet niet aan de huidige eisen, waardoor de woonlasten van veel huurders onnodig hoog zijn. Woningcorporaties moeten investeren om de kwaliteit van hun vastgoedportefeuille te verbeteren, maar kunnen door verscheidene redenen deze kosten moeilijk dekken. Een veelvuldig genoemde oplossing voor woningcorporaties is het brengen van energie services. Energie services kent twee verdienmodellen, gericht op het verlagen van de energie vraag en energie levering. Dit onderzoek beoordeeld een twaalftal projecten in de sociale woningsector, waarbij een of beide energie services zijn toegepast, op energetische kwaliteit en financiën. Vooral decentrale, kleinschalige energie levering door corporaties verbetert de energetische kwaliteit van de woning in hogere mate, waarbij de verdiencapaciteit van energielevering zorgt de financiën van projecten sterk verbeterd. Gezien de voordelen van energielevering door corporaties is het noodzakelijk dat wet- en regelgeving wordt aangepast om dit te faciliteren.

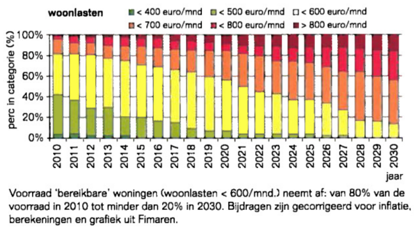
Kernwoorden: Energie services, Woningcorporaties, Energie efficiëntie, Energy Performance Contracting, Energy Supply Contracting.

INTRODUCTIE

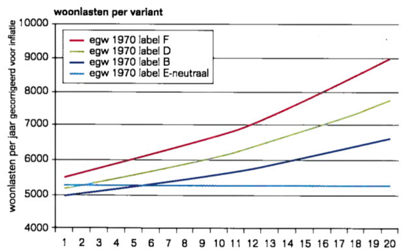
Door toenemende vraag en verminderde beschikbaarheid van fossiele brandstoffen is de energieprijs de afgelopen jaren continu gestegen. Het inkomen van Nederlandse huishoudens stijgt in mindere mate, waardoor de totale woonlasten stijgen. Onderzoek toont aan dat drie groepen bijzonder kwetsbaar zijn voor deze ontwikkeling (NiBud, 2009): Lagere inkomens, lager opgeleiden, en huurders. Verreweg de meeste lage inkomens in Nederland zijn niet in de positie om een eigen woning te kopen en zijn daarom afhankelijk van de sociale huursector. De sociale huursector in Nederland is groot en betrekt 34% van alle woningen. Deze woningen worden geëxploiteerd en onderhouden door woningbouwcorporaties, private instellingen met de publieke taak om kwalitatieve en financieel bereikbare woningen aan te bieden aan hen die dit niet zelf kunnen.

Door de grootte van de sector en de financiële kwetsbaarheid van de huurders, spelen de woningbouwcorporaties een belangrijke rol in het verlagen van de totale woonlasten van hun huurders. De sector en de overheid hebben daarom afspraken gemaakt om de energetische kwaliteit van de sociale huurwoningen te verbeteren (BZK, 2012). Ondanks de afspraken nemen de investeringen van de sector in de bestaande woningen echter af (CFV, 2012).

Dit is een zorgwekkende ontwikkeling gezien de financiële bereikbaarheid van de sociale huurwoningen. Zonder ingrijpen zullen deze woningen op termijn niet meer te betalen zijn voor haar doelgroep, zie figuur 1 en 2.



Figuur 1: Percentage sociale huurwoningen binnen financieel bereik van de doelgroep. Bron: Renda (2012).



Figuur 2: Ontwikkeling van de totale woonlasten per energielabel. Source: Renda, (2012).

SPLIT INCENTIVE

Een verklaring voor het uitblijven van grootschalige investeringen van corporaties is de zogenaamde ‘split incentive’. Investeringen in het verbeteren van de energie prestatie van woningen worden gedaan door de woningcorporatie, terwijl de (financiële) voordelen van deze verbetering voor de huurder zijn. Deze scheve kosten/baten verhouding maakt het onaantrekkelijk voor woningcorporaties om te investeren in het verbeteren van de energie prestatie en vormt een obstakel.

Een genoemde oplossing voor dit probleem is een actieve rol van woningcorporaties binnen energie services: een dienst gericht op het maximaliseren van energie efficiëntie en kosteneffectieve levering van energie aan hun klanten. Er worden een aantal kansen toegedicht aan energie services door woningcorporaties: Het verlaagt de woonlasten van huurders; Het genereert extra inkomsten voor corporaties en verlaagt hiermee de split incentive; En het kan de financiële boost zijn om woningen tot energieneutraal niveau te renoveren door de implementatie van duurzame energie oplossingen.

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ENERGIE SERVICES

Er bestaan twee bedrijfsmodellen binnen energie services: Energy Performance Contracting, EPC, gericht op het verlagen van de energie vraag en Energy Supply Contracting, ESC, gericht op het efficiënt leveren van de resterende energie vraag. Beide modellen zijn al toegepast in verschillende projecten in de sociale huursector. Door deze projecten met elkaar te vergelijken en hun prestatie te beoordelen op relevante criteria, doet dit rapport een uitspraak over de kansen van energie services voor woningcorporaties, een eventuele toekomst van de sector in de energie services en wat er gedaan moet worden om dit te stimuleren.

METHODE

Twaalf projecten waarbij de energie efficiëntie van de woningen is verbeterd, zijn meegenomen in de analyse, waarvan 8 EPC- en 4 ESC-projecten. De projecten zijn geanalyseerd met de methode 'Data Envelopment Analysis', DEA, een benchmark-methodiek die de relatieve efficiëntie van de projecten bepaald. Een voordeel van deze techniek is dat er geen voorkennis nodig is van de projecten of de manier van aanpak gedurende het project. Enige voorwaarde is dat de projecten hetzelfde doel beogen te bereiken.

Variabelen waarop de projecten worden geanalyseerd zijn: Kosten van de ingrepen per woning; Gerealiseerde besparing in maandelijkse woonlasten voor de huurder; Bereikt niveau in energie prestatie, uitgedrukt in Energie Index; Contante waarde van de extra inkomsten voor de corporatie, voortvloeiend uit een huurverhoging dan wel energielevering.

Twee DEA analyses zijn uitgevoerd. De eerste analyse beoordeelt de prestatie van de projecten in de conditie zoals ze daadwerkelijk zijn uitgevoerd. De tweede analyse beoordeelt de projecten op basis van hun potentie, wanneer zij niet gehinderd zouden zijn door wet- en regelgeving. Deze tweede analyse is een betere afspiegeling van de daadwerkelijke sterke kanten van EPC en ESC en toont de invloed aan van de wet- en regelgeving op de directe prestatie van de projecten.

RESULTATEN

Er bestaan belangrijke prestatieverschillen tussen EPC- en ESC-projecten. ESC-projecten presteren beter op energie efficiëntie, terwijl het verdien potentieel van de maatregelen zorgt voor hogere inkomsten en relatief meer kostendekking. Hoewel de besparing voor de huurder kleiner zijn dan bij EPC-projecten, gaan zij er ook op vooruit. EPC-projecten scoren lager op energie efficiëntie, maar voldoen aan de norm, tegen lagere kosten dan ESC-projecten en met de mogelijkheid om grote besparingen te realiseren voor de huurder. Inkomsten en kostendekking voor de corporaties is echter minimaal.

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CONCLUSIE EN DISCUSSIE

Onder de huidige marktomstandigheden en de onzekere financiële toekomst van woningcorporaties neigt de ambigue rol van woningcorporaties – een private partij met een publieke taak en doel – meer naar de private kant. Het publieke doel blijft een belangrijke motivator, maar financiële argumenten spelen de boventoon. In de praktijk betekent dit dat de realisatie van het publieke doel afhankelijk is van de financiële speelruimte, wat een verklaring kan zijn waarom EPC-projecten de conventionele aanpak blijft, ondanks de voordelen van een ESC constructie.

Een ander gehoord argument van woningcorporaties is dat de focus op het beheersen van de totale woonlasten geen kerntaak is van de sociale huursector, zoals beschreven in het Besluit Beheer Sociale Huursector, BBSH (VROM, 2005). Hetzelfde BBSH wordt echter door voorstanders gebruikt in hun argument dat, om te kunnen voldoen aan het aanbieden van kwalitatieve en financieel bereikbare woningen, de focus op totale woonlasten een vereiste is. Een sectorbrede overeenstemming ten opzicht van totale woonlasten mist. Pas wanneer dit vermeld wordt, zullen meer corporaties gaan overwegen om ESC-projecten uit te voeren.

Tegelijkertijd is het ambitieniveau van de huidige energie prestatie normen te laag om op de lange termijn de betaalbaarheid van de sociale huur te kunnen garanderen. De norm ligt op een gemiddeld B label in 2020, terwijl dit voor nieuwbouwwoningen energieneutraal zal zijn. De achtergestelde positie van huurders ten opzichte van kopers hierdoor dan ook niet verbeteren.

Voordat de voordelen van een breder mandaat en striktere normen kunnen worden benut, is het van belang dat woningcorporaties de (juridische) mogelijkheden krijgen om hieraan te voldoen zodat de korte termijn barrières geen lange termijn obstakels worden. Belangrijke barrières die geslecht moeten worden is de financiering van de duurdere ESC-maatregelen. Een rol voor het Waarborgfonds Sociale Woningbouw zou de druk van de hoge kosten kunnen verminderen. Over het algemeen is het van belang dat decentrale, kleinschalige energie opwekking wordt gestimuleerd door faciliterende regelgeving. Hier is een rol weggelegd voor de nationale overheid.

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