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Innovations for a carbon free Dutch housing stock in 2050

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Abstract. In 2017 the new Dutch coalition government agreed on high ambitions for the reduction of CO2 emissions to meet the Paris agreement and policies to achieve this were detailed in a Climate Agreement between the government and many stakeholder organisation in June 2019. In 2030 CO2 emissions have to be reduced to 49% compared to 1990. In 2050 we should have a CO2 emission free and energy neutral built environment. The existing housing stock plays a major role in the realisation of these goals. The Dutch housing stock comprises of 7.5 million dwellings. The majority of which has a rather bad thermal energy condition and are mainly heated by natural gas. All these houses have to be renovated to a nearly zero carbon performance. By 2021 yearly more than 50,000 new homes per year will have to be delivered on nZEB level without a natural gas connection and at least 50,000 existing dwellings will have to be made gas-free per year. These are steps towards 200,000 zero carbon renovations per year, a pace that is needed to make the entire stock carbon free in the 30 years up to 2050. To support these goals a large innovation programme is currently being developed. This paper presents the required innovations. Research on the impact of the policies and measures applied in the recent years point to the challenges that have to be overcome. A particular challenge is to realize the intended performance and really save energy and reduce CO2 emissions on a large scale.

Keywords: Nearly zero energy housing renovation; CO2 free built environment, Guaranteeing high performance houses

1. Introduction

In 2017 the new Dutch government set some severe goals to meet with the Paris agreement of limiting the global heating to a maximum of 2 degrees Celsius. To operationalise the goals the government installed some 'round tables' with many stakeholder groups to negotiate a new national Climate Agreement. In June 2019 the Agreement was a fact and it contains many detailed goals, policies and regulations to achieve the goals [1].

In the 1960's natural gas was discovered in the northern province Groningen and was heavily exploited. Ever since then most Dutch houses were heated by this gas. From 2010 however, earthquakes started to happen in Groningen and geological investigations proved a direct causal relation to the extraction of gas form the earth. Since then the earthquakes appeared more and more often and became heavier, causing cracks in the houses and creating unsafe situations. The pressure on the government to reduce the extraction of the gas, increased. The production is already largely reduced. Finally, recently the government decided to completely stop the gas extraction in 2030. The gas from Groningen has another caloric composition than e.g. Norwegian or Russian gas and the existing heaters in Dutch homes cannot use the other gas. So, besides the climate argument, also the simple fact that Dutch houses have to find another energy source is a very strong argument for the energy transition in the Dutch housing stock. The currently available solutions are either connecting the houses to a district heating network,

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with heat from e.g. a power plant, or heat from geothermal source, find alternative gas solutions (bio gas, hydrogen), or go to all electrical solutions with a heat pump. At the moment such a solution is only sensible if the house is very well insulated.

According to the Climate Agreement CO2 emissions have to be reduced to 49% in 2030 compared to 1990. In 2050 we should have a CO2 emission free and energy neutral built environment. The existing housing stock plays a major role in the realisation of these goals. The Dutch housing stock comprises of 7.5 million dwellings. The majority of which has a rather bad thermal energy condition and are mainly heated by natural gas. All houses have to be renovated to a zero-carbon performance. By 2021 yearly more than 50,000 new homes per year will have to be delivered nZEB without natural gas connection and heating and at least 50,000 existing dwellings will have to be made gas-free per year. These are steps towards 200,000 zero carbon renovations per year, a pace that is needed to make the entire stock carbon free in the 30 years up to 2050.

2. Climate agreement

The goals have been worked out into detailed proposals for policies and measures laid down in the Climate Agreement [1]. This is the result of months of negotiations by the so called 'sector round tables' with representatives of all relevant stakeholder groups like home owners, construction companies, building service companies, other relevant industries, energy companies, the financial sector and many more. In order to achieve the target of 3.4 Mton CO2 reduction in the built environment in 2030, approximately 1.5 million existing homes have to be made sustainable and the CO2 emissions in existing utility buildings must be reduced by 1 Mton extra in 2030.

In order to make the challenge manageable, the sector table proposes a phased and programmatic approach, on the one hand working on an energetic start and on the other hand on the conditions for innovations and later up-scaling and rollout. It is important that offering parties quickly learn, through, among other things, the so called 'Starter motor' projects (projects of housing associations with large subsidies to make the investments budget neutral), how to efficiently (more) make large numbers of homes more sustainable. The lessons from this first larger bundled demand offers opportunities for technical and organizational innovations. This allows providers to develop a more efficient and cheaper offer. Clients gain experience with tending larger numbers of renovations. These are necessary conditions for actual up-scaling. There will have to be broad experience with what is cost-effective and practically feasible in different situations, before tackling scaling up and being able to roll out on a large scale. That also gives time to work out the conditions for later scaling up and deployment carefully.

For homes, the approach is a combination of seduction and direction through the 'Neighbourhood-oriented approach'. Building owners can also be tempted at an individual level to become more sustainable. This approach succeeds if sustainability can be recouped through the (decreased) energy bill. In order to finance these investments through energy saving and lower energy costs and make them affordable, much innovation and cost reduction is still required. That is why will be started with experiments and with an innovation program to systematically learn and experiment, so that after some years a cost-effective up-scaling and roll out can take place. The conditions for up-scaling, innovation, greater efficiency and cost reduction will be realized by, making funding available and making proposals to take away the remaining unprofitable summit of building-related measures, infrastructure and sustainable sources through pricing and subsidizing. This involves a slider in the energy tax, which stimulates investments in sustainability and attractive financing methods, which means that investments can also be paid. Further incentives and action perspectives are offered by making known through standardization which (final) situation buildings have to be brought in order to be able to be heated without natural gas in the future.

To summarize: A broad spectrum of policies, measures and financial support will be applied to boost the renovations of homes. In the first years his won't be cost effective, but because of innovations and up-scaling the cost should be reduced to a cost-effective level. By then regulations and financial arrangements will more or less force all home owners to take part in the renovation programme.

This paper will focus on new and improved regulations for the energy transition in houses. Research on the impact of the policies and measures applied in the recent years point to the challenges that have to be overcome. A particular challenge is to realize the intended performance and really save energy and reduce CO2 emissions on a large scale.

3. Goals and policy measures

According to the European Energy Performance of Buildings Directive (EPBD) all new buildings will have to meet an Energy performance standard. By 2021 the standard will be on the level of nearly zero energy (nZEB – nearly Zero Energy Building). Currently member states still have their own calculation tool and performance level for the interpretation of 'nearly zero'. In the Netherlands this will be: total energy demand 25 kWh/m2.yr; primary fossil energy use 25 kWh/m2.yr and share renewable energy 50%. For existing buildings an Energy Performance Certificate is required at the moment of selling or renting out. The EPC, or energy label, is a presentation of the theoretical energy performance of the building. Only for large renovations the standard for newly built buildings is required. For existing buildings there is currently no tool to force improvement.

The new Climate Agreement [1] proposes the development of a new Standard to better facilitate and to force the renovation to fossil free houses. The ideas for this new standard are proposed as follows: It is possible to determine 'sensible' sustainability renovation option for dominant or characteristic types of housing in the Netherlands, based on cost benefits and desired reduction of heat demand. A so-called 'regret-free' refurbishment with which the building owner is assured that several times within the technical lifespan a radical adaptation to the same building parts is not necessary, in anticipation of the alternative to natural gas that is chosen in the neighbourhood-oriented approach. This standard is formulated at the level of the entire house (net heat demand in kWh / m2 / year, following the NTA8800 determination method). By determining the standard, the sensitivity of the standard for the (later) definitive choice of the heat alternative is explored. Not everyone will be able to renovate the whole house. For renovations, where only one or a few building parts are being tackled (such as roof, façade, floor), target values are given for insulation (in Rc, or U values) and required ventilation. The standard for the entire house is leading, the target values for building parts contribute to this. The standard and the target values will be set no later than 1 July 2019. The standard can be considered as one of the inputs for the guideline and therefore for choosing the most suitable heat source for a district. The 'regret-free' standard is a means to achieve the intended purpose of a low-carbon built environment. The intended standard for the existing building is not mandatory for owner-occupiers yet, but gives interpretation about the desired energy performance of existing homes in advance of the neighbourhood-oriented approach. In 2025, the standard will be evaluated on the basis of criteria to be determined, in conjunction with other instruments and the neighbourhood-oriented approach. After that, the standard can be tightened up if necessary, better supported or it can get a more binding character.

Unlike owner-occupiers, tenants do not have the freedom to decide for themselves how the houses will be adapted to meet the minimum requirements imposed on the dwelling from the alternative heat source. In order to give landlords an action perspective and to protect tenants against high energy costs, the standard in 2050 is therefore mandatory for homes intended for letting. The obligation for landlords does not mean that they disproportionately share in collective costs (volatility risk). Landlords are responsible for adapting a home, so that it meets the standard at the time that the housing is connected to the new infrastructure via the neighbourhood-oriented approach. Tenants will lend their cooperation to the necessary adjustments to prevent them or subsequent tenants from being left out in the cold or receiving very high energy costs. In order to optimally inform homeowners of all options to renovate their homes, validated information on sustainability measures and the accompanying indicative energy savings and investment profiles will be provided on a website as of 1 January 2020. This is linked to financing and subsidy opportunities.

4. Research findings: impact of policies in recent years

While developing new policy tools for the up-scaling or renovations and energy saving measures we should take in to account some lessons we learned from the applied regulations and measures in the recent years.

One of the most important policy tools required by the EPBD in the European Member States is the issuing of Energy Performance Certificates (or EPCs). These EPCs give an indication of the required energy to provide a certain average temperature in the building and depend on physical characteristics of the building. The certificate has no mandatory implications in the sense that owners could be forced to improve their buildings to certain levels. Nonetheless it is a crucial instrument for benchmarking and formulating policy goals. Building owners in all EU Member States have to obtain an EPC for a building at the moment it is sold or rented out. This is not yet current practice everywhere, mostly due to lack of enforcement. This especially applies to the private housing stock.

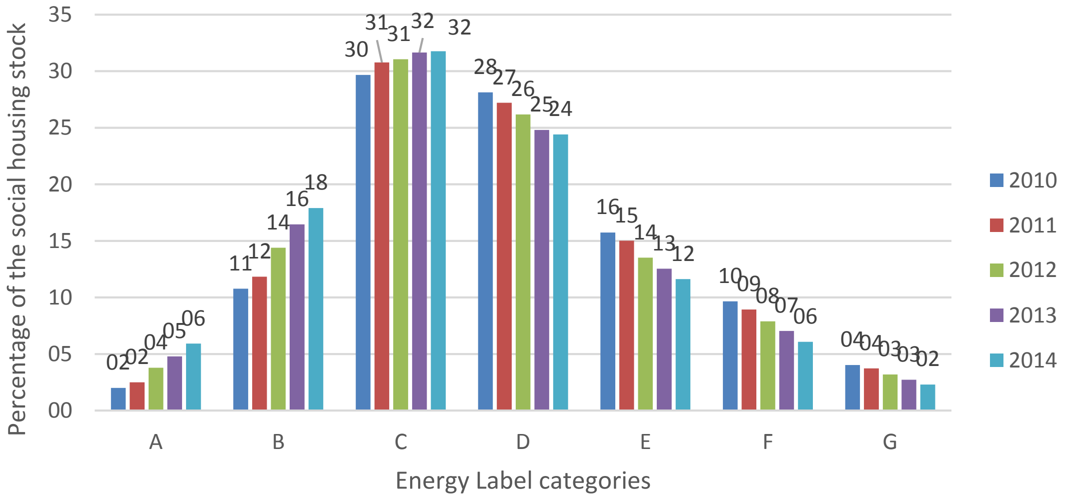

Figure 1: Distribution of the energy labels of the non-profit rented housing sector in SHAERE database [2]

The social housing sector in the Netherlands agreed with the government and the national tenants' union to a covenant about energy renovation goals. This was initiated in 2008 and updated in 2012. Most important goal is to initiate renovations that lead to an average energy label B in the beginning of 2021 for the whole sector, which comprises 2.3 million dwellings (35% of the total housing stock in the Netherlands). All social housing is already labelled for many years. Since 2010 nearly all dwellings have a fairly reliable label. Every year AEDES, the national umbrella organisation of the housing associations, collects the energy label data of all housing associations. Every year more associates really do so. In 2015 the data of more than 60 % of the whole social housing stock was collected in this way. This database is called SHAERE. Research with the SHAERE data base enables showing the progress in renovation. Figure 1 demonstrates the label steps over the years 2010 to 2014. It can be noted that most of the renovations lead to small improvements. If the current figures are extrapolated to 2021, we can see that the goals of an average label B will not be reached (Figure 2). The label indexes relate the calculation of the Energy Index, which is for label B 1,25. In 2015, the calculation method for the EI changed with the purpose to simplify it. Due to the changes the labels form before and after the change are difficult to compare. Therefor also the continuation of the improvement line can't be drawn and it is also hard to conclude about whether or not the targets of the covenant will be met in 2021. On the other hand, the progress between 2010 and 2015 shows clearly that the formulated goal won't be reached. At this moment the actual goals for the built environment are reconsidered. Also, the housing association are debating about the goals for 2050 and the scenarios for reaching these.

Stimulated by government policies in 2013 an agreement was made by a group of 27 housing associations and buildings and the Dutch government to work on a programme for 111,000 houses to Net Zero Energy (E=0) levels. This was called Energiesprong (Energy leap) [3]. E=0 means, annually a house does not consume more energy for heating, hot water, lights and appliances than it produces. The concept is based on refurbishments financed by the energy cost savings; a refurbishment executed within 10 days and a 40-year energy performance warranty from the builder. The approach is further based on organizing a massive demand for a Net Zero Energy (E=0) refurbishments, making financers and governments tune their financing offerings and regulations towards this product and challenging the construction sector to start an ambitious innovation process. Since the take of of the programme several projects have started and some houses are yet already taken into use and even some monitoring results are yet available [4]. Recently Energiesprong is working also in the UK and France to get an independent market development team set up to drive a similar approach as in the Netherlands.

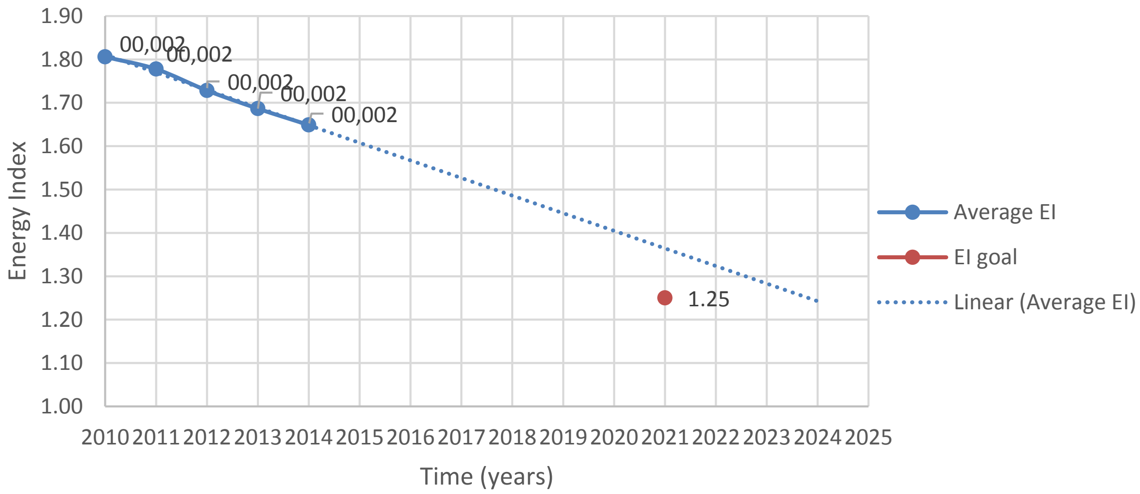

Figure 2: Development of the EI in the Dutch non-profit housing sector since 2010. [5]

The costs for Net Zero Energy refurbishment are substantially more than the net present value of today’s energy bill. Therefore, an intensive innovation process in the construction sector is needed focused on reduction of costs and process time and energy performance guarantees. This will require moving from doing one-off projects towards developing mass-produced refurbishment packages with a performance standard. And then the idea is that these packages will be sold in shops, which are cosy and have helpful staff. To catalyse that innovation process, a large demand volume this new product is needed.

The financing of the refurbishment is done by giving the tenants an “energy plan” including a guarantee for a hot house (22o), warm water (certain amount of shower time per day) and an electricity bundle for electric appliances for which they together pay a fixed monthly fee. If they exceed that agreed amount of energy performance, they pay the additional electricity consumption to the utility. The bundle fee is paid to the housing association (HLM). This pays of the investment. In the private sector it works similarly, with an increase in mortgage instalments to finance the investment covered by the reduction in energy costs. In the Dutch case, the cost of living stays therefore the same for tenants or private homeowners. Investing in factories are required to pre-fabricate these refurbishment solutions with a view to scale. It helped the government to change regulation (i.e. ability for associations to collect the energy plan money) and it made the financier revalue the properties that would be refurbished in order to free extra room to borrow money. The first 200 prototypes and test houses have been built. By the end of 2016, there should have been 10000 Net Zero Energy refurbishments completed. Following that deal, Energiesprong is now working to bring these refurbishment packages to the private homeowner sector.

A common question is whether this only works for certain houses that all look the same. In fact, it is mass customization. Houses are all 3D scanned and refurbishment packages are individually produced because even a set of row houses are not all exactly the same, even if it looks like they are. The focus until now has been on the most prevalent typologies of houses in the Dutch market of which 2.3 million houses in the Netherlands exist, but flexibility will increase over time with the number of possible solutions. The first designs will establish whole new supply chains based on prefabricated industrially production methods providing new platforms for further, interactive innovation process (very much like the car industry).

The programme is running now for a few years and we can see that the planned number of projects and dwellings are not yet renovated and / or in development. The investment costs are still too high: about €70.000. It will only become a feasible business case if the cost could be reduced to about €40.000. The housing associations that invested in the start-up of the programme with the expectation that the cost would drop if the numbers would increase. Currently the progress seems to slow down.

The actual domestic energy use is besides the physical characteristics of a dwelling, largely influenced by the use and behaviour of the tenants. Some preliminary figures demonstrate the difficulty in 'forcing' reduced energy use by improvements of dwellings. The dwellings with the worst EPC (G) in practise use far less energy as expected, while the most advanced dwellings (A) use much more. This is probably due to a combination of the rebound effect and an increase in comfort level of the dwellings [6,7,8] and underperformance of the buildings and installations. The large difference between theory and practice is called the performance gap and is recognised in more and more international studies. In a research project by [6,7] the actual energy consumption was compared with the theoretical use according to the EPC's (Figure 3).

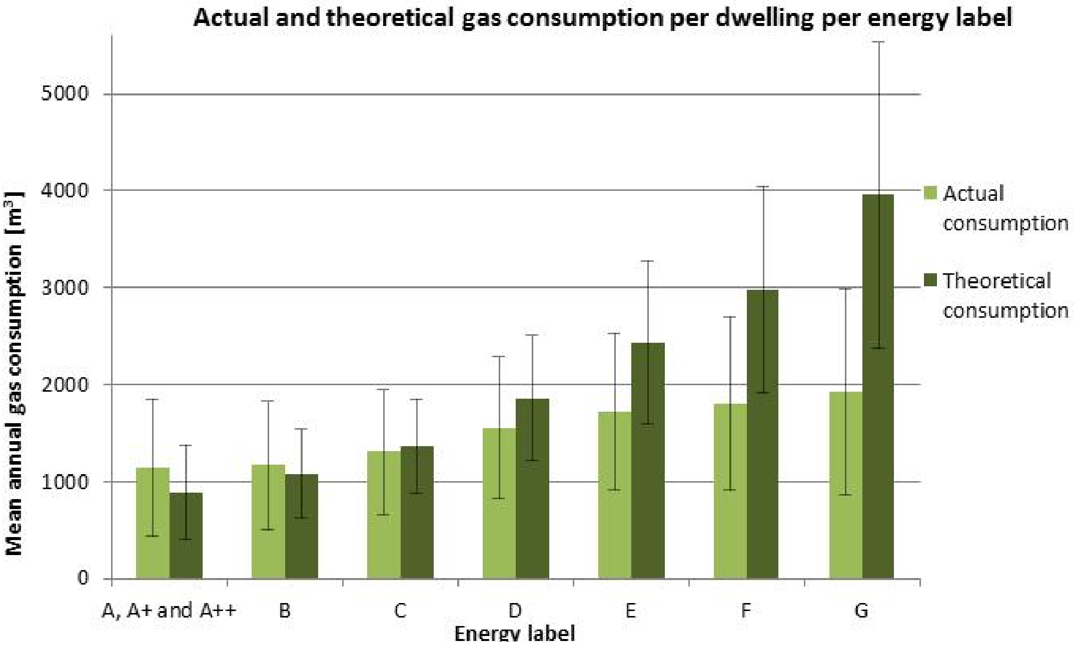

Figure 3 Actual and theoretical gas consumption in Dutch dwellings - per m2 dwelling area. [6]

This research was based on the Dutch energy labels issued in 2010 - a total of over 340,000 cases with 43 variables (regarding building location and technical characteristics, the properties of the label itself etc.). This data set was derived from the publicly available database of the EPCs. This data was, on the basis of the addresses of the households, linked to actual energy use data. The energy data was provided by the CBS (Statistics Netherlands), which collected this data from the energy companies. The combined data file was then cleaned by deleting incomplete or obvious incorrect EPCs. This resulted in

193,856 usable cases. This still large sample proved to be representative for all housing types and energy label classes.

To understand how the energy label relates to the discrepancies, the gas and electricity consumption in various label categories were examined and analysed. The actual and theoretical gas use per dwelling was compared and then analysed per m2 of dwelling (Figure 5). Little difference exists between the actual and theoretical energy use calculated per dwellings and per m2 , except the difference in actual gas use between label A and label B. At the level of individual dwellings, the actual consumption was identical, but at the level of m2 the dwellings in category A use less gas than dwellings in category B. This may relate directly to the fact that dwellings in label category A were found to be considerably larger than all other dwellings. From these figures it is clear that although better labels lead to higher actual gas consumption, there is a clear difference between the mean theoretical and mean actual gas consumption for each label. For the most energy-efficient categories (A, A+ and A++) and for category B, Figure 5 shows that the theoretical calculation underestimated the actual annual gas consumption. This is in contrast to the rest of the categories for which the theoretical calculation largely overestimated the actual annual gas consumption. This research indicates that the energy label has some predictive power for the actual gas consumption. However, according to the labels, dwellings in a better label category should use on average significantly less gas than dwellings with poorer labels, which is not the case [9, 10, 11]. This finding also has a major impact on the way the improvement policies for the energy use in the housing stock are formulated [12] and what can be expected from the renovations.

5. Discussion

Without any doubt there is a necessity to drastically reduce the use of fossil-fuel energy sources by reducing the demand for energy and switching from fossil to renewable sources. Buildings account for 40% of Europe’s energy consumption and three-quarters of the floor area of the building stock is residential. The targets are clear and the technical solutions are available. Good insulation and product innovations can reduce the energy demand for heating and cooling for a large part. The remaining energy demand can be delivered by renewables like sunlight and heat, district heating, heat pumps, etc. The remaining electricity demand for appliances can in the first place be reduced by further product innovation and then be provided by photovoltaic panels. There are no reasons not to apply these solutions in new buildings at a large scale on the short term. Evaluations of the current practice show however that there is a lot to be gained here. To improve this situation, it has to be assured that constructions and installations are installed properly and in such way that they are not vulnerable for unpredictable or misuse by the occupants. This will set demands on both the construction industry as on the control and enforcement process (and the parties responsible). The improvement of the existing building stock is a huge challenge. The potential energy savings are large, but the barriers to overcome are also high. As stated before, almost three quarters of the future housing stock (2050) has already been built. Studies show however that it is hard to increase the rate and depth of energy renovations of the existing stock. Actual energy (and financial) savings in renovated dwellings stay behind expectations because of rebound effects. There are important barriers. Many owners believe that the benefits of the measures do not outweigh the costs. Besides that, the cost of improving the energy performance of a dwelling does not (proportionally) increase the value of the dwelling. The new Dutch Climate Agreement should deal with these challenges.

6. Conclusion

The Paris agreement in combination with the fact that the availability of own natural gas in the Netherlands will stop in 2030 urges for a policy and innovation plans with very high ambitions. The government will apply a large arrange of policies, measures and financial support. The standards to calculate the energy demand of buildings will be renewed to better facilitate a step wise, no-regret improvement to gas free solutions. Technical and process innovations and up-scaling should make renovations cheaper. In the next years many new approaches have to be developed and implemented. By all of this we should keep monitoring the real impact of the policies and regulations and also measure

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the real reduction of CO_2 emissions. Previous research has shown the failure of calculation tools and renovation agreements. Furthermore, the plans and renovation standards might have to be adapted to external developments like price developments and developments of the availability of renewable energy and the possibility of storage of renewable energy.

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