Innovations for a carbon free Dutch housing stock in 2050

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Abstract. In 2019 the Dutch government agreed together with all relevant stakeholder organisations on a new Climate Agreement. This agreement combines high ambitions for the reduction of CO2 emissions with policies and measures to achieve these goals. In 2030 CO2 emissions have to be reduced to 49% compared to 1990. In 2050 we should have an 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 to be renovated to a nearly zero energy performance. In a few years’ time we will have to speed up the renovation rate to 200,000 carbon free renovations per year, a pace that is needed to make the entire stock of 6 million homes carbon free in the 30 years up to 2050. To support these goals a large innovation program is needed.

Method: This paper will elaborate on the analyses of the current state and the needed innovations, hereby also referring to results of evaluation research of the progress in energy renovation in the recent years.

Results: The required innovations will be presented in a systemic way. Furthermore, a model is presented of how to organize the innovation (research, applications in practices, pilots etc) in a long running, broad organization incorporating many stakeholders. For this purpose, a new platform, the BTIC (Building and Technology Innovation Center) has been developed. In BTIC all relevant research and innovation parties collaborate closely, like the Technical Universities and the national applied research institute TNO. The author is the scientific director of BTIC.

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 1.5 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 in the Netherlands. Ever since then, most Dutch houses and other buildings were heated by this cheap 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. Then the government decided to completely stop the gas extraction in 2030 and a few years later this was set on 2023. 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 foreseeable solutions are either connecting the houses to new to be developed district heating networks, with heat from e.g. a power plant or industry park (or biofuels), or heat from geothermal source, find alternative gas solutions (bio gas, hydrogen), or go to all-electric solutions with heat pumps. The all-electric solution is only useful if the house is very well insulated. Renovation solutions for such concepts are available, but so far too expensive to be cost effective.

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. By 2021 yearly more than 50,000 new to build homes per year will have to be delivered nZEB without 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 to be reached in a few years from now, a pace that is needed to make the entire stock carbon free in the 30 years up to 2050.

This paper will elaborate on the analyses of the current state and the needed innovations, hereby also referring to results of evaluation research of the progress in energy renovation in the recent years. The required innovations will be presented in a systemic way. Furthermore, a model is presented of how to organize the innovation (research, applications in practices, pilots etc) in a long running, broad organization incorporating many stakeholders. For this purpose, a new platform, the BTIC (Building and Technology Innovation Center) has been developed. In BTIC all relevant research and innovation parties collaborate closely, like the Technical Universities and the national applied research institute TNO.

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 for the built environment 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 proposed a phased and programmatic approach, on the one hand working on an intensive start and on the other hand on the conditions for innovations and later up-scaling and rollout. It is important that supply parties quickly learn, through, among other things, the so called ‘Starter motor’ projects (projects of housing associations with subsidies to make the investments budget neutral), how to efficiently (more) make large numbers of homes more sustainable. In this phase it will mainly be done by connecting houses to district heating networks. Another initiative is called the ‘Renovation Speed-Up’ programme. This is a subsidy programme to stimulate larger projects (streams) of home renovations. Several housing associations combine houses with similar typology in large tenders. 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 renovate. 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 where announced to be set no later than 1 July 2019, but are currently still being developed. 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 buildings will not be mandatory for owner-occupiers in the first years, 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 for 2010-2014][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 reliable label. Every year AEDES, collects the energy label data of all housing associations. In 2018 the data of more than 80% of the whole social housing stock was collected in this way. This database is called SHAERE. Research with the SHAERE 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. Therefore 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.

Besides the physical characteristics of a dwelling that determine energy labels, the actual domestic energy use is largely influenced by the use and behaviour of the tenants. 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 practise 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).
This research was first 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. Later the research was expanded with the data of SHAERE of about 2 million dwellings of the housing associations. Also for these houses the labels were related to real energy use and the same findings came out.

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. Stimulation of innovations
The Climate Agreement sets very challenging targets: in a few years from now 200,000 dwellings and other buildings will have to be renovated on a high level. This is about 1000 per day, where currently we don’t see more than 10 per day. Many questions have to be answered and technical and social innovations will be needed to overcome this.

**Energiesprong**

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-off, of the programme several projects have started and some monitoring results are available [4]. Energiesprong is also working also in the UK and France. The programme is running now for several years and we can see that the planned number of projects and dwellings stayed far behind. The investment costs are still too high: ranging from about €70,000 to more than €100,000 per dwelling. Most of the projects only delivered small numbers of dwellings, because of the high investments by the housing associations. It will only become a feasible business case if the cost could be reduced to about €40,000. The progress of the initiative slowed down.

**Innovation issues for the next years**

The Dutch Government acknowledged that millions will be needed to stimulate innovations on many levels to realise the targets. The existing technologies are too expensive, not performing accurate, require too much capacity of the construction sector and are not fully accepted by all building owners and users. The Building and Technology Innovation Centre (BTIC) was established in 2019 as a sector broad collaboration of Government, construction sector and knowledge institutes to define and organise the required innovation. The BTIC develops the knowledge and innovation agendas for various challenges of the construction sector, like Circular building economy, Digitisation, Climate change and Energy transition in buildings. In 2019 a programme was formulated and is now running covering a broad spectrum of topics like: new renovation concepts, data driven performance optimisation, industrialisation of the production, digitisation, increasing the demand, a decision-making framework, construction chain optimisation, new (hybrid) heat pumps and compact heat storage. It is a programme with 125 partner organisations and a total budget of €23 milj. In 2020 the programme will be expanded with more emphasis on office buildings and smart building concepts.

**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 the real reduction of CO2 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. Large scale technical and social innovations
will be needed to make the goals of a renovations pace of 200,000 dwellings and other buildings per day feasible.

7. References

[1] Rijksoverheid, 2019, Klimaatakkoord. https://www.klimaatakkoord.nl/
[2] Filippidou, F, Nieboer, N, Visscher, H, 2017, Are we moving fast enough? The energy renovation rate of the Dutch non-profit housing stock using the national energy labelling database, Energy Policy 109, 488-498.
[3] Rovers, R., (2014), New energy retrofit concept: ‘renovation trains’ for mass housing, Building Research and Information, 42 (6) 757-767.
[4] Energiesprong, 2016, Eerste ervaringen met prestatiegarantie voor nul op de meter woningen (First experiences with performance guarantees for zero on the meter dwellings). http://energielinq.nl/resources/monitoringprestatiegarantie
[5] Filippidou, F., Nieboer, N. & Visscher, H. 2019, Effectiveness of energy renovations: a reassessment based on actual consumption savings, Energy Efficiency. 12, 1, p. 19-35.
[6] Majcen, D., Itard, L. and Visscher, H.J. 2013a, Theoretical vs. actual energy consumption of labelled dwellings in the Netherlands: Discrepancies and policy implications, Energy Policy 54, 125 – 136.
[7] Majcen, D., Itard, L., Visscher, H.J. 2013b, Actual and theoretical gas consumption in Dutch dwellings: What causes the differences? Energy Policy, 61, 460-471.
[8] Majcen, D., Itard, L., Visscher, H.J. 2015, Statistical model of the heating prediction gap in Dutch dwellings: Relative importance of building, household and behavioural characteristics, Energy and Buildings, 105, 43-59.
[9] Brom, P van den, Meijer, A. and Visscher, H., 2018, Performance gaps in energy consumption: household groups and building characteristics, Building Research and Information, 46-1, 54-70
[10] Brom, P van den., Meijer, A. and Visscher, H. (2019), Actual energy saving effects of thermal renovations in dwellings—longitudinal data analysis including building and occupant characteristics, Energy and Buildings, 182, p. 251-263
[11] Brom, P. van den, Hansen, A. R., Gram-Hansen, K., Meijer, A. & Visscher, H. (2019), Variances in residential heating consumption – Importance of building characteristics and occupants analysed by movers and stayers, Applied Energy. 250, p. 713-728
[12] Visscher H., Meijer F., Majcen D., Itard L., 2016, Improved governance for energy efficiency in housing, Building Research & Information, 44:5-6, 552-561, DOI: 10.1080/09613218.2016.1180808