CE Delft

Committed to the Environment

Towards a climate-neutral built environment in 2050

The built environment in the Netherlands consists of approximately eight million buildings, over seven million of which are houses. Most of these buildings will still be in use by 2050. Most of these, some 95%, are heated by a system using natural gas, be it a gas-condensing boiler, gas stove, or Combined Heat and Power (CHP) for district heating, the latter ones possibly in combination with a geyser/heater.

If the built environment were to be climate neutral, this would have a tremendous impact on the way in which our homes and offices, schools and hospitals would be heated. And even though 2050 seems far away in the future, decisions taken now will have implications as to what options are open to us, even after 2050: energy infrastructure is constructed for forty years or more, renovation projects for rental housing complexes are developed for the next few decades. In short, one should start to think now to prevent possible negative lock-in effects.

Residential areas differ from each other, and consequently there is a large diversity in ways in which we can get to a climate-neutral future. What is or is not possible in a specific area depends on factors such as year of construction and building density. What might be the ideal solution for the city centre could be a very expensive option in the countryside or a suburban area. For each area type tailor-made solutions are required.

Step by step from natural gas to renewable sources

- In the built environment that is climate neutral (in 2050), there is no place for natural gas.
- In the intervening years, natural gas consumption will decrease because of energy savings and more efficient gas technologies, but also because areas will switch to alternative heat sources (Aquifer Thermal Energy Storage (ATES), heat pumps, geothermal energy, residual heat, biomass CHP), where often there remains a role for natural gas as provider of peak capacity in cold periods (backup boilers).
- Energy savings are always the first step, but some demand for heating will remain in most buildings.
- The use of green gas is limited by a restricted availability of this renewable fuel.
- Green gas will replace natural gas in many areas where there are no heat sources and a district heat infrastructure is too expensive.
- The adjustments towards a climate-neutral energy supply will be locally dictated by the necessary replacement of gas infrastructure, renovation of buildings, and municipal policies aimed at climate neutrality.
- In 2050, many energy resources will be used (geothermal heat, solar radiation, ground heat, green gas) and many infrastructures (gas, electricity, district heat). Local availability of heat sources and building density will dictate what is used.

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The research by CE Delft

The CE Delft research was carried out in three steps:

1. **Fifteen residential area types**. Each of the 12,000 neighborhoods in the Netherlands were categorized according to year of construction, degree of urbanization and function, resulting in fifteen distinct residential area types. For these types, a number of relevant characteristics of the buildings are determined, such as energy demand, average degree of isolation, stacked or ground-based buildings, ownership or floor area.
2. **Energy saving**. For each area type, based on key figures for that type, the costs and effects of three energy savings packages (limited, extensive and maximal) are determined. This results in three sets of energy-demand patterns for space heating, tap water and electricity for each area type.
3. **Climate-neutral heat**. Finally, ten technologies were considered that can be used to satisfy the energy demand. These groups can be further characterized as green gas, all-electric, heat supply and biomass. For these groups, the costs of energy distribution, heat production and installation are determined. Together with the costs of the energy savings packages from the previous step, these provide an overall image of the costs in the total supply chain.

Vision for 2050

For each residential area type, thirty demand-technology combinations were assessed according to total costs in the chain, both for residential as well as for commercial buildings. The combinations were ranked according to these total costs in the chain (network, savings, installation and consumption) from low to high.

Changing the existing infrastructure for heating demand takes time, money and effort. How much depends strongly on energy costs: a major uncertainty here is the future costs of green gas. Therefore three scenarios were considered: where the cost of green gas costs per m^3 are € 0.75 in scenario A, € 1.10 in scenario B, and € 0.85 in scenario C, respectively. In all scenarios the end user price for electricity is assumed to be € 0.07 per kWh and for natural gas is assumed to be € 0.34 per m^3, both excluding taxes.

The easiest and, given the above assumptions, also financially most attractive option is the replacement of natural gas by green gas. Even though the costs of green gas are higher, the total costs over the whole chain are lower (up to a price of € 1.10 per m^3 of gas). Only for areas where district heating or geothermal heat is already available is this the most attractive option. For commercial buildings ATES is generally cheaper. The use of green gas in the built environment is restricted by the limited potential for the production of green gas from indigenous sources, which is insufficient to satisfy the overall heating demand. Thus other options will have to be deployed, in particular additional savings as well as substitution by all-electric, district heating (from various sources from ATES to residual heat) and solid biomass. In the end, gas remains the cheapest option for the old city centers in the Netherlands, all-electric is the dominant technology in the rural areas, while for the highly urbanized areas district heating is the cheapest option.

Table 1 Resulting energy demand for heating and tap water

Energy source	Demand
Green gas	0.9 bcm
Electricity	2.4 bcm_{eq} (for heating and tap water)
District heating	4.0 bcm_{eq} + 0.4 bcm green gas for peak
Biomass	0.0 bcm_{eq}
Total	**7.7 bcm_{eq}**

Table 1 illustrates the final results for the energy demand where the green gas price is € 0.85 per m^3, and there are affordable sources for district heating. The total demand for heating is expressed in terms of bcm (billion m^3) or the energy equivalence (bcm_{eq}) and decreased on average by 1% per annum until 2050. This is a relatively modest decrease, mainly because the more extensive savings measures in that case do not pay off. This is to some extent due to the fact that taxes are not included in the calculations.

Transition in heating demand

The replacement of natural gas in the built environment will be a gradual process. In some neighborhoods, zero-energy buildings will be built that are not connected to the gas grid. But not all existing houses can be refurbished into zero-energy houses in a cost-effective manner. In many cases, houses will be insulated considerably to reduce the energy demand and sometimes this will be combined with the installation of a district heat grid, possibly in combination with ATES and with gas as a fuel to provide peak demand. When renovating building complexes, the connection to the natural gas grid is no longer automatically maintained. In areas with district heat the adjacent areas will be connected to this grid.
The speed of these changes depends on the political decisions concerning the speeds of CO_2 reduction, including the way in which such policies are translated into regulation and price incentives (CO_2-based taxes, for example).
In the transition period from the current system to one which is completely climate neutral, natural gas will retain an important role as fuel for the colder periods, as supply for peak demand. This may however shift from the individual building level to the area level. Where gas is replaced by (all-electric) heat pumps, the additional costs of the electricity infrastructure expansions needed to cover the colder periods should be taken into account.
The analysis of the outcomes shows that it is possible to shift to a completely climate-neutral built environment by 2050, and it illustrates the role that gaseous energy carriers can take in this shift. Based on the study, policymakers for municipalities, local grid operators, energy companies and building corporations can estimate the consequences of a climate-neutral built environment for the Netherlands. Here costs play an important role, but other elements such as timing of replacement investment, maintenance plans, investment requirements and the local situation (e.g. availability of ground heat, residual heat or degree of urbanization) have to be taken into account.

Route to climate neutrality

Finally, as an afterthought to the Dutch summary, the route to climate neutrality is explicitly drafted for three specific types of area. This serves as an illustration that what may work for one location may not work for the others. The examples given are an old city center (built before 1900), a recently built area of moderate to high degree of urbanization (built after 1990) and a rural area. For each of these, a concrete step-by-step plan to the final situation is drafted.