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Energy Neutral Districts in 2050 – the Dutch Approach

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Summary

According to the EPBD, from the end of 2020 on all new buildings should be built as nearly zero energy buildings.
Instead of focusing on buildings only, a district approach to energy supply and consumption can be advantageous as regards the energy performance and economics. The potential of renewable energy technologies can be utilized to a larger extent while fewer energy generators are needed. An example is a so called energy-hub, in which exchange, conversion and seasonal storage of energy can lead to energy neutral districts before 2050. The Dutch study Transition in Energy and Process for a Sustainable District Development (Transep-DGO), financed largely by the AgentschapNL, has shown that this is possible.
For energy neutral district development in 2050, six innovative energy concepts have been elaborated and the extent of energy neutrality in 2020, 2035 and 2050 calculated.
Three concepts are based on an idea of an energy hub - bio hub, geo hub and a solar hub. Other concepts are all-electric, conventional and hydrogen concepts. Calculations show that implementation of each of the concepts can lead to energy neutral districts in 2050 or even earlier. When personal transport is included, energy neutrality in 2050 is not feasible.
Based on the six general concepts, the most optimal energy concepts tailored for four Dutch cities have been elaborated as pilots, in close cooperation with municipality representatives.
Solar hub has been dynamically simulated in order to show the added value of the exchange, conversion and storage of energy flows on a district scale. Energy Pattern Generator (EPG) has been applied for simulation of a virtual district with 1,000 dwellings of various categories.
A solar hub with collective heat storage can reduce the demanded storage capacity by 26%, and the total required solar collector surface by 30% at maximum compared to individual seasonal heat storage capacity in dwellings that are not connected in an energy hub. Energy hub concepts can contribute considerable to energy neutral built environment in 2050. The effect can be intensified by an exchange of surplus sustainable energy with neighbouring districts and import of energy in case of a shortage.

Keywords: energy neutrality, district, energy concept, energy hub, all-electric, district modelling

1. Introduction

The Netherlands is one of the countries exploring possibilities of energy neutral built environment within several decades. In order to reach this future vision, we need to take certain steps today, develop innovative and integral energy concepts for renovation and new housing and apply them to entire districts.
The Dutch study Transition in Energy and Process for a Sustainable District Development (Transep-DGO), financed largely by the AgentschapNL, has shown that energy neutral districts are possible.

2. Energy Concepts for 2050

Six general energy concepts for 2050 have been elaborated (Table 1). Three concepts are based on the idea of an energy hub. Energy hub is a central point in a district where all energy distribution systems including smart district heating, cooling and electricity networks meet each other. In an energy hub, generation, storage, conversion and exchange of energy are taking place. The three concepts are: a geo hub (using waste heat and/or geothermal energy), a bio hub (waste heat and/or biomass) and a solar hub (only solar energy). The fourth concept is an all-electric concept, based predominantly on heat pumps, solar modules (PV) and conversion of high temperature heat from vacuum collectors to electricity. The fifth concept uses conventional technologies (like (bio)gas boilers, solar collectors and PV) that have been applied since the second half of the previous century, and the sixth one is based on hydrogen.
The energy performance, which is expressed as the extent of energy neutrality, has been calculated for each concept variation for 2020, 2035 and 2050.
The first step in all energy concepts is a radical reduction of energy demand. This can be reached by building and renovating according to the passive house standard or other concepts that go even further and by use of high-performance heat recovery from all household waste water.

Table 1: Energy concepts for 2050 and degree of neutrality in 2020, 2035 and 2050 [ECN]

				Degree of energy neutrality [%]					
				2020		2035		2050	
	ENERGY CONCEPTS	Individual / collective	Cooling	Transport					
				excl	incl	excl	incl	excl	incl
1	**Waste Heat and/or Geothermy (Geo-Hubs)**								
	High temperature waste heat utilization or geothermy	District heating	Compression cooling by PV or sorption cooling by solar	96	61	120	73	**164**	**96**
2	**Waste Heat and/or Biomass (Bio-Hubs)**								
	Moderate temperature waste heat utilization	District heating	Compression cooling by PV or sorption cooling by solar	93	60	119	72	**163**	**95**
3	**All-Solar concepts (Solar-Hubs)**								
	High temperature storage of solar heat	District heating	Compression cooling by PV or sorption cooling by solar	53	34	73	45	**130**	**76**
	Low temperature storage with ORC or heat pumps			47	30	72	43	**131**	**76**
4	**All-Electric concepts**								
	Individual electric heat pumps, PV and solar collectors	Individual	Free cooling by ground heat exchanger	71	45	102	61	**150**	**87**
	Individual electric heat pumps and PV			73	47	106	64	**157**	**92**
5	**Conventional concepts with PV**								
	Individual gas boilers with PV	Individual	Compression cooling by PV	36	23	64	38	**112**	**65**
	Individual gas boilers, solar collectors and PV		Compr. or sorpt. cooling by solar	38	24	65	40	**114**	**67**
6	**Hydrogen concepts**	Individual	Free cooling by ground heat	15	7	57	30	**115**	**54**

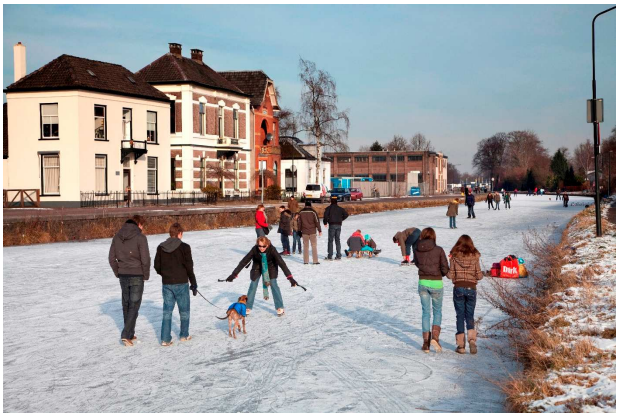
3. Energy Concepts for Dutch Cities

The above mentioned general energy concepts serve as blueprints for the selection of specific energy concepts for the cities of Almere, Apeldoorn, Nijmegen and Tilburg. The selection depends on several aspects such as district features, availability and type of energy sources, characteristics of existing

buildings, available infrastructure and energy visions of the municipalities. Mostly, the tailored energy concepts for cities are a mix of two or more concepts in order to utilize the given district features optimally.
For residential areas in Almere, Nijmegen and Tilburg, concepts based on an energy-hub idea have been selected. For Apeldoorn, an all-electric concept with low-scale district heating has been selected. As an example, this concept is briefly highlighted below.

4. Energy Concept for the City of Apeldoorn

The Roadmap 2020 (Apeldoorn is bursting with energy; 2010), shows the aspiration of Apeldoorn to become energy neutral in 2035. For the Kanaalzone area in Apeldoorn, the all-electric concept combined, possibly with a small-scale solar hub has been selected.
The Kanaalzone will be restructured until 2025 (Masterplan Kanaalzone Noordoost, 2010). The district is characterized by a mix of existing buildings, small-scale industry and by plans for a new housing development and recreation (Figures 1 and 2). The industrial buildings will be gradually replaced by offices and dwellings. The Apeldoorn municipality strives for a combination of living, working and recreation while the small-scale character and cultural, historical and natural values will be preserved.



Figures 1 and 2: Mix of residential buildings, small-scale industry and recreation in the Channel Zone of Apeldoorn [Source: municipality of Apeldoorn]

As in all concepts, buildings (offices included), will have to be built and renovated according to the passive house standard. Electricity will be generated by solar modules (PV) installed on the roofs and possibly by small-scale wind turbines in the industrial part of the area.
A part of the heat needed for space heating and especially domestic hot water can be generated by solar collectors on roofs. Heat and cold can be further generated by ground-based heat pumps and heat and cold storage installations. In addition, the Apeldoorn channel can be used for generation of heat by heat pumps and as a cold source. For this, it is necessary that the water flows sufficiently. At present, the channel water is nearly stagnant but it can be put into flow while creating surplus of

energy. This will be achieved by pumping water up and letting it flow back into the channel at certain locations outside the district that have the required level differences.
Biomass and domestic refuge will be upgraded to natural gas quality outside the city and transported back to the city where the biogas will be converted into heat and electricity in combined heat and power installations on biogas.

5. Modelling Solar Hub

One of the concepts, a solar hub supplying a residential area of 1,000 households, has been simulated using the Energy Pattern Generator. Household appliances as predicted in 2050, household profiles (users' behaviour), energy use, types of houses that represent a typical Dutch mix in a residential area have been the input for the modeling.
Each household is connected to a bi-directional heating network, which can be used for hot water and space heating, as well as day heat storage. The heating network is connected to a seasonal storage for which an exhausted geothermal doublet is used. If the heat generation is higher than the total heat demand, the excessive heat is fed back into the heating network and exhausted geothermal doublet.

6. Conclusions

The study has shown that a district approach including nearly zero energy buildings can have certain advantages. Buildings on at least passive house level are a prerequisite for energy neutral districts.
Calculations show (Table 1) that in 2050, all concepts can lead to energy neutrality in the built environment. The energy neutrality ranges from 114% (conventional concepts), 131 % (solar hubs), and 157% (all-electric) to 164% (geo hubs). If personal transport is included, energy neutrality in 2050 cannot be reached.
The modelling of a solar hub shows that under the assumption of equal heat losses of the individual storages and the collective storage, an energy hub with collective heat storage can reduce the demanded storage capacity with 26%, and the total required solar collector surface with 30% at maximum.
This shows the added value of energy hubs with exchange, central storage and conversion of energy on a district level and suggests that costs of an energy hub can be optimised, becoming financially more attractive than houses with individual seasonal heat storage. However, research on financial aspects of energy hubs has still to be carried out.

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