International Gas Research Conference 2014

International Gas Union Research Conference

IGRC COPENHAGEN 2014

September 17-19

ALL GAS DISTRICT

DEMONSTRATION OF THE ADDED VALUE IN USING HYBRID GAS AND ELECTRICITY INFRASTRUCTURES TO POWER A SUSTAINABLE NEIGHBORHOOD

M.J.T. Geurds MSc (Alliander), M.A.W. Vermue MSc (Alliander), I.M. Bouwman MSc (DNV GL),
E.E. Hardi MSc (Alliander), Ir. M. Bongaerts MBE (Liander), Ing. J.J. Overdiep (GasTerra),
Dr. Ir. W.J.T. van Gemert (Hanze University of Applied Sciences Groningen),
Ir. J. van den Berg (EnTranCe)
The Netherlands

Subject: **Optimizing the energy performance of residential areas using hybrid gas and electricity energy infrastructures.**

Keywords: **Price - performance optimization for investments in an energy supply system, micro-CHP, Power-to-Gas, energy storage, all-gas, end-users, environment, appliances.**

ABSTRACT
THE ALL-GAS DISTRICT

The All Gas District (AGD) concept will demonstrate the added value of a gas grid in a neighbourhood with large amounts of decentralized electricity generation. The concept is shown in figure 1. Components within the AGD will regulate the balance between energy demand and intermittent renewable energy production, while connected households can keep using their existing appliances. Hence there is no need for smart appliances within houses and comfort levels remain untouched.

Figure 1 Representation of the All Gas District

The AGD will maximize the use of renewable energy to fulfil electricity and heat demand. In case of local renewable electricity production, first the direct demand for electricity will be satisfied. When there is a surplus of renewable electricity, it is stored in batteries or converted to (synthetic) natural gas by Power-to-Gas technology. When there is a deficit of electricity (i.e. renewable electricity production is lower than electricity demand) first the batteries are discharged. Any remaining deficit is satisfied using Gas-to-Power technology.

The heat demand in the AGD will be satisfied by using local produced heat coming from Gas-to-Power and Power-to-Gas technology and individual gas fired boilers.

Currently the project is in a proof-of-concept (PoC) phase. This PoC will be done at the EnTranCe research facility in Groningen, the Netherlands, in collaboration with project partners Alliander, GasTerra , Gasunie, Hanze University of Applied Sciences Groningen and EnTranCe. For the real life implementation of the AGD in an existing neighbourhood, additional partners and a location still need to be selected. Multiple aspects are being investigated, i.e. the technical, economical, institutional and societal aspects (Figure 2).

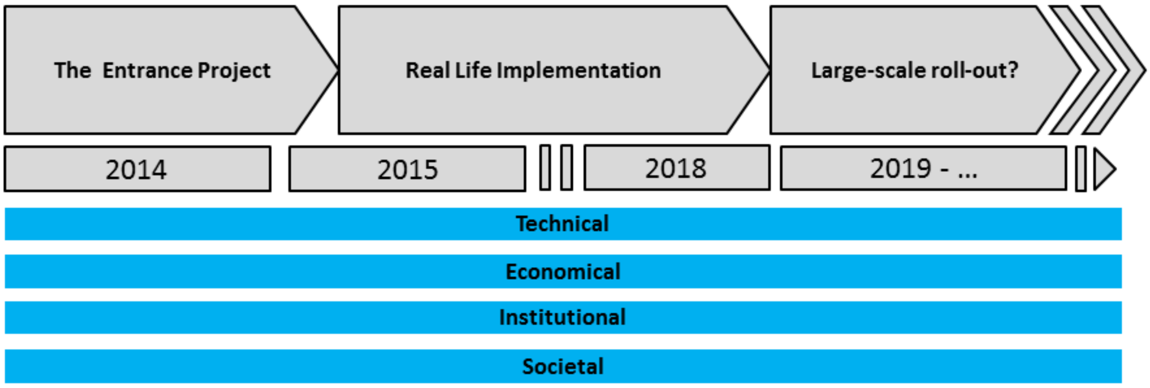

Figure 2 Project timeline

CONTENTS

CURRENT SITUATION

The EU has set energy efficiency and climate change mitigation targets for its member states in its roadmap 2050. The intermediate targets for 2020, the so-called “20-20-20 targets”[i], have been translated into national targets for each member state[1]. For the Netherlands, this comprises a 20 % greenhouse gas (GHG) emission reduction (compared to 1990 levels) and 14 % of all energy consumption coming from renewables in 2020. From 2020 on new and retrofitted buildings are required to be energy neutral, meaning that net consumed energy on a yearly basis is less than or equal to zero.

To meet energy and climate targets, the Dutch government plans to increase installed wind power capacity to 6000 MW onshore in 2020 and 4450 MW offshore in 2023. In 2014 installed and approved wind capacity is around 2000 MW onshore and 1000 MW offshore[2]. For decentralised solar power production by individual households and housing corporations no specific target is set by the Dutch government. However by means of incorporating tax advantages, decentralized solar photovoltaic power production is stimulated.[3] By the end of 2013 installed solar photovoltaic power was 722 MW[4], a doubling of the installed capacity of the previous year. Lower costs for solar photovoltaic power installations are expected to lead to a further increase of installed solar photovoltaic power in the coming years.

There are around 7.3 million houses in The Netherlands, most of which are not well-insulated. Around 46 % were built before 1971[5]. More than half of the domestic energy consumption is used for space heating (Figure 3). With a household gas connectivity of approximately 95 % most space heating is gas-based. The Dutch gas grid has a high reliability - on average only 56 seconds of interrupted supply in 2012[6], compared to 24.9 minutes for the Dutch electricity grid. The energy required for space heating should decrease in the coming years due to increased energy performance of new-built and renovated houses. However the number of new-built houses over the last fifteen years is below 100,000 per year and also the number of renovated houses per year is still low[7]. This means especially that the third EU 20-20-20 target – achieving a 20 % improvement in energy efficiency – will require some significant effort to achieve in the coming years.

Current knowledge on social acceptance of energy technologies is still limited. Innovators in most cases naively assume that society welcomes all changes that results from introduction of new energy technologies. In reality, however, stakeholders such as end-users, (local) governments and NGO’s often have different and conflicting visions on technology and the way it should be implemented. When these differences are neglected this can lead to resistance against implementation. Therefore a solid understanding of factors affecting social acceptance is needed with every innovation.

---

[i] 20% reduction in EU greenhouse emissions from 1990 levels, raising the share of EU energy consumption produced from renewable resources to 20% and a 20% improvement in the EU’s energy efficiency. The targets were set by EU leaders in March 2007 and were enacted through the climate and energy package in 2009.

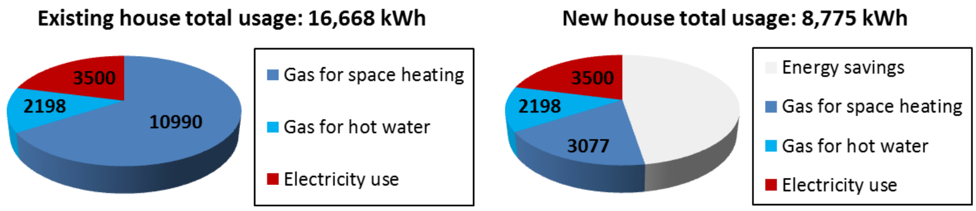

Figure 3 Domestic energy usage for existing (left) and new-build houses (right) in The Netherlands

CHALLENGES

With the introduction of large scale renewable electricity production (solar photovoltaic and wind power) the energy system is facing several challenges. Solar photovoltaic power and wind power are intermittent energy sources. The first challenge for the energy system is to account for the imbalance between power production by such intermittent renewable sources and the instantaneous power demand for electricity.

The second challenge is related to the production side. The electricity grid must be able to cope with peak electricity production loads that stem from wind and photovoltaic electricity generation. Large scale sustainable energy production facilities such as wind and solar photovoltaic farms are often located far from main load centres, requiring additional electrical transport capacity to transport the power to where it’s needed. At a decentralized level, a large scale implementation of photovoltaic panels can lead to peak loads in the distribution grid. This may require expensive electricity grid reinforcements. For the integration of (mainly) solar photovoltaic power and wind into the energy system, a cumulative investment between 20 and 71 billion euros is estimated until 2050.[8]

The third challenge for the electricity grid is the increase of concurrent electricity use by certain high power electric appliances. This holds for appliances that are used simultaneously in the grid, such as electric heat pumps and electric vehicles. Replacing gas with electricity can only be done to a limited extent. Most electricity distribution stations are designed to cope with an average electric load of 1.2 kW per household, while for gas distribution an average of 1.5 Nm^3/hr natural gas per household is used. The latter corresponds to around 15 kW of heat. In figure 4 a yearly energy consumption profile for a typical household is shown. It can be seen that the gas usage far exceeds the electricity usage. Even when differences in efficiencies of gas and electric appliances are taken into account, it can be seen that replacing gas with electricity will exceed the assumed electric load per household. Based on that, electricity grid reinforcements will be needed, while the gas grid will be largely unused. This provides opportunities for the gas grid to provide additional power when needed, which will be discussed next.

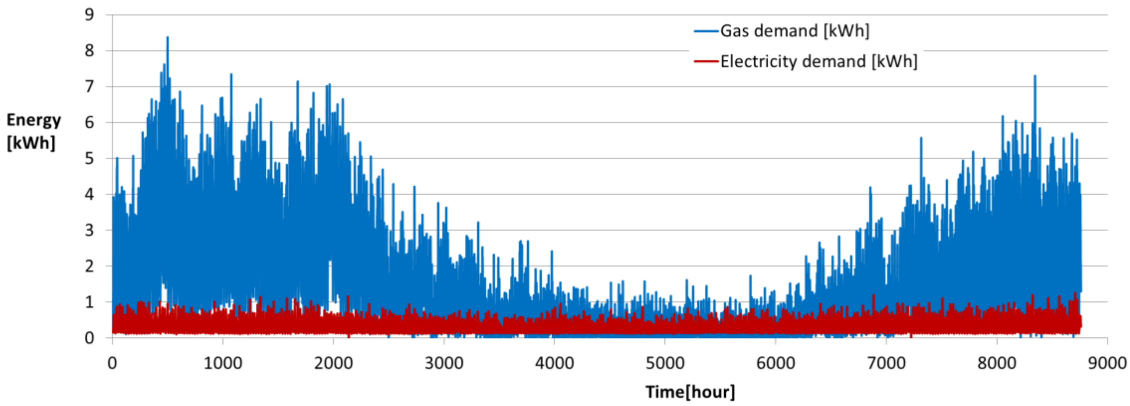

Figure 4 Yearly energy demand profile of a typical Dutch household (3005 kWh electricity and 1523 Nm^3 natural gas)

OPPORTUNITIES

In this section it will be discussed how the gas infrastructure in the Netherlands can help the energy system to become more sustainable.

The main challenges that the electricity grid is facing are the need to balance intermittent sustainable power production with a fluctuating demand and the need to cope with peak loads on the electricity grid. This requires large capacity investments in the electricity grid. There are several ways to cope with these challenges, for example by incorporating energy storage in the system, by demand side management or by using an alternative energy source. A logical choice for a complementary energy source that can help to balance the Dutch energy system is gas. Below, the opportunities that gas can provide to make the energy system more sustainable, reliable and at the same time more affordable are discussed.

Lower CO_2 emissions for balancing power compared to central electricity supply

At times of low sustainable energy production, gas can be converted locally into power and heat using (micro) combined cycle plants based on combustion or fuel cell technology. The efficiency of this combined process is higher than the efficiency of central electricity supply, resulting in a significant reduction of CO_2 emissions compared to electricity supply by the national grid.

The Dutch government set the ambition to replace 50 % of the Dutch natural gas supply by biomethane by 2050. Using green gas for local combined heat and power production to balance the electricity grid will further reduce CO_2 emissions.

The gas grid has a large overcapacity that can be used to reduce peak electricity grid loads

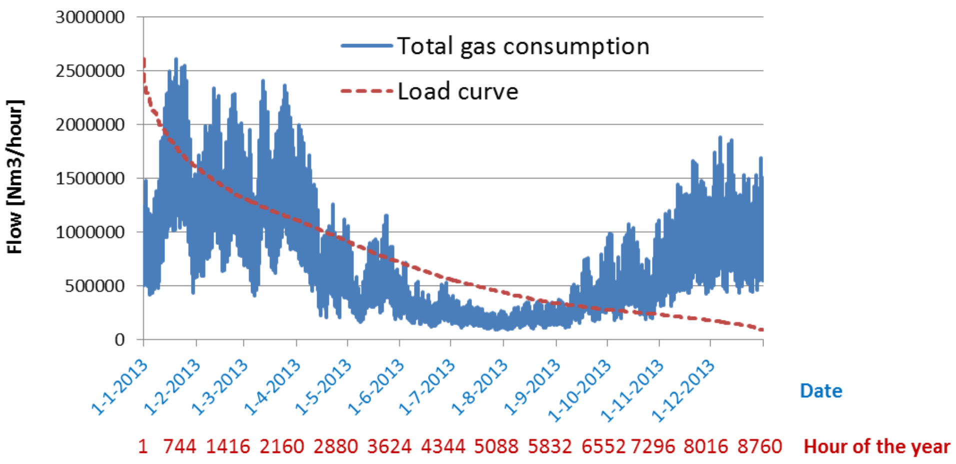

Figure 5 Total gas consumption in the Alliander grid in 2013

The gas grid in the Netherlands is widespread, with around 11,600 kilometres of high-pressure transportation grid operated by Gasunie and another 115,000 kilometres of distribution grid operated by regional grid operators such as Alliander, Delta, Enexis and Stedin. The design lifetime of the gas grid is 50 years. In figure 5 the total gas consumption via the Alliander distribution grid is shown, corresponding to some 2.3 million end-users. The gas consumption shows a strong seasonal pattern. The calculated peak capacity is around 4 million Nm^3/hr, hence the figure shows actual flows are always well below this limit.[9] This clearly shows that the gas distribution grid has a large overcapacity which will only increase when buildings become more energy efficient. This overcapacity can be applied to reduce the load on the electricity grid, by converting gas into power when the demand in the electricity grid is high. Vice versa, when there is a large surplus of sustainable electricity production, this surplus of electricity can be converted into gas, either to hydrogen or to synthetic methane. The gas infrastructure can then be used to store and transport this green gas.

Using the gas grid to reduce peak electrical loads minimizes the need for additional investments in the electricity grid. This can result in societal cost savings compared to an all-electric solution. These savings can then be applied to invest in further sustainable energy production capacity.

The thesis of this research is that combining renewable electricity sources with a gas grid enables a sustainable energy system, an All Gas District (AGD), at lower costs than an all-electric solution - with equal sustainability - can provide.

THE ENTRANCE PROJECT

The technical proof of concept is currently being investigated at the EnTranCe research facility of the Energy Academy Europe in Groningen. Components have been sized in order to operate the AGD with several households (figure 6). At EnTranCe the components will be installed in a porta cabin for operational and research purposes. The educational value of the project is important and will be established in two ways. First, among the people working on the project there are several teachers, researchers and students from Hanze University of Applied Sciences Groningen contributing to the simulation models and hardware testing. There are also researchers from Hanze University of Applied Sciences involved in the investigation of economical, institutional and societal aspects. Second, the EnTranCe project will be used as a showcase which can be visited by a broader public to gain understanding of the AGD. Furthermore the EnTranCe facility will be used for testing the hardware to gain knowledge and experience for real life implementation.

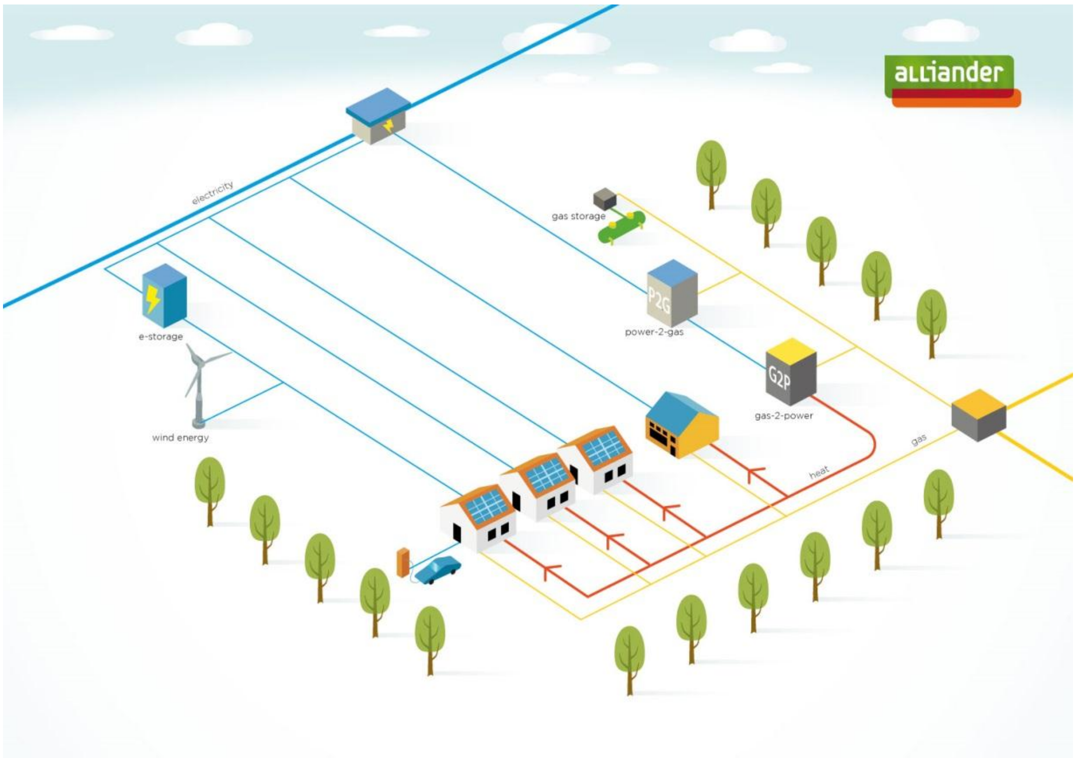

Figure 6 Representation of the All Gas District

In the EnTranCe project the following technical subsystems are used:

- Renewable energy (solar photovoltaic or wind energy, 5 kWe)
- Gas-to-Power technology (natural gas fired fuel cell, 2 kWe and 0.4 kWth)
- Power-to-Gas technology (electrolyser)
- Electricity storage (10 kWh Li-ion battery pack)
- Hydrogen storage
- Electricity consumption module (using predefined profiles or connected electrical appliances)
- Heat storage (heat vessel)
- Heat consumption module

Technical aspects to consider are the interaction between the different subsystems in the AGD. A control strategy will be developed which maximizes the use of local renewable energy using the different subsystems in an optimal manner.

Economic aspects to consider are the market model and the business case. A market model will be developed. This will be used to determine the business case for each stakeholder, taking the required investments, operational expenditures and revenue streams into account.

The institutional aspects that will be investigated are divided into two parts, i.e. the position of end-users on one side and the production, transport, storage and distribution of energy on the other side. For the first part the rights and duties of end-users (i.e. households) are investigated, both in the current energy system and in the AGD. For the second part the rights and duties of several stakeholders in the AGD are investigated, i.e. the owner and the operator of the energy storage, the energy supplier, the grid operator and programme responsible parties.

The societal aspects will be investigated by extending the business case with effects of the AGD on labour and public space usage. It will also include the contribution the AGD can make to enable local energy communities. Currently there are around 110 energy communities in The Netherlands, most of which strive for energy saving, local energy production and strengthening local economies.[10] The Dutch government is making an effort to stimulate this trend by using tax advantages and making it easier for energy communities to apply for specific subsidies.

REAL LIFE IMPLEMENTATION

The project goal is to successfully implement the AGD in an existing neighbourhood between 2015 and 2018. A location still needs to be selected and there are openings for additional project partners. A number of households (in the order of 150 to 500) will be facilitated using the AGD concept. The number of households and the capacities of used subsystems will be based around a commercially available electrolyser and methanation system. The public acceptance and the willingness of households and local governments to participate in implementing the AGD concept is of crucial importance. Typically the AGD will be implemented in a neighbourhood with an active energy community that can benefit from the All Gas District.

REFERENCES

[1] Renewables Directive, EU (2009) [link]
[2] RVO (2014)
[3] Rapport Energieakkoord, SER (2013) [link]
[4] Rapportage Hernieuwbare Energie, RVO (2014) [link]
[5] Rijksoverheid (2012) [link]
[6] Kwaliteits- en Capaciteitsdocument Gas en Elektriciteit, Liander (2013) [link]
[7] Planbureau voor de Leefomgeving (2014) [link]
[8] Net voor de Toekomst, CE Delft (2011) [link]
[9] Belastingprognose Gas, Liander (2013)
[10] Planbureau voor de Leefomgeving (2014) [link]