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System integration: what gas infrastructure has to offer to a sustainable energy supply

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Abstract

- **“System integration: what gas infrastructure has to offer to a renewable energy supply”**
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- Topic: CONVERGENCE OF GAS APPLIANCES AND INFRASTRUCTURE WITH ELECTRIC SYSTEMS AND RENEWABLE ENERGY
- Abstract text [as submitted by Janneke Hermes]:

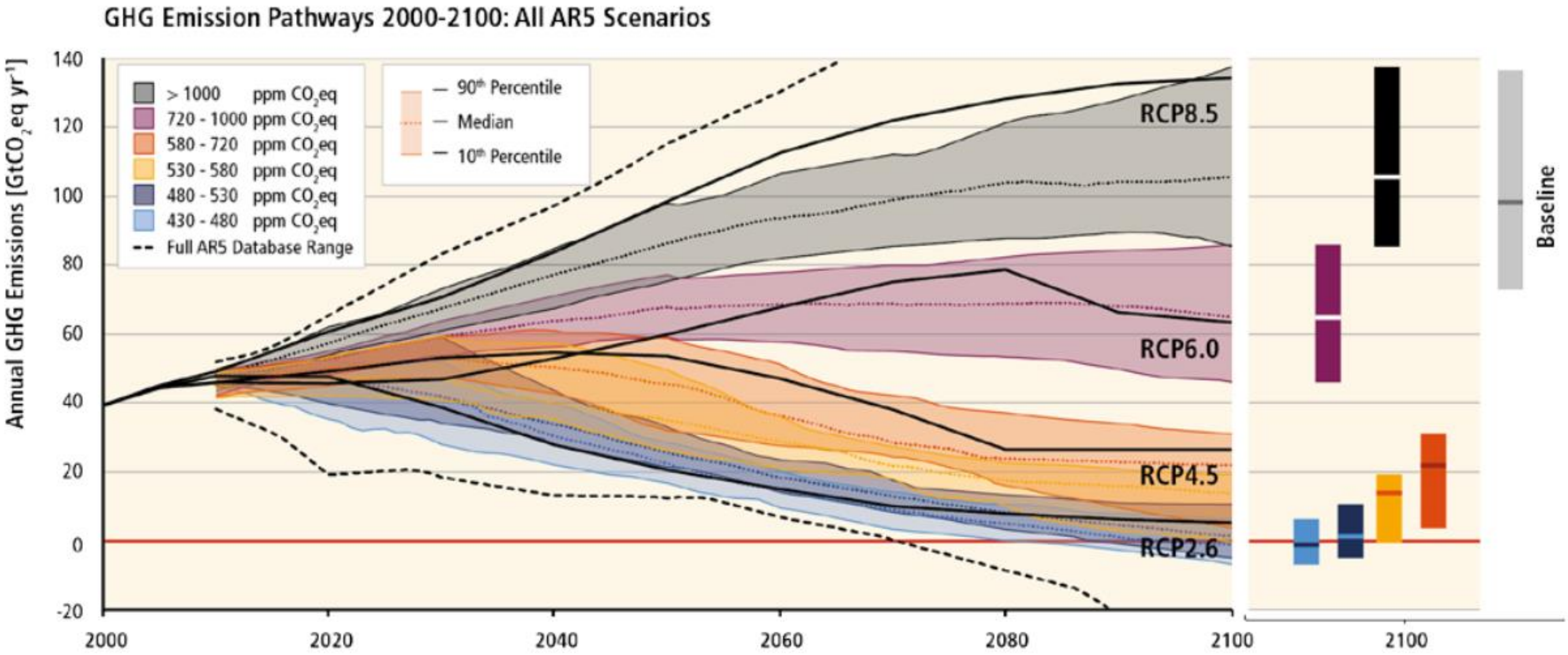
- The energy supply and use of feedstock in Europe will gradually become more sustainable and in the end all-renewable. This transition is undoubtedly the greatest challenge the energy sector will face the coming decades: Enhancing sustainability for sectors like feed stock-industry, built-up environment and long distance transport is daring, intermittent renewables need back up and system flexibility, the number of energy production points is increasing, we want to make the best use of our existing infrastructure all whilst retaining public acceptance and keeping the affordability and reliability of our energy system at an acceptable level.
- This means that our image of the old energy system, where we were used to a clear distinction between upstream and downstream, producers and consumers, separated electricity, heat and gas systems and one-direction energy transport, will fade. The new energy system will be bi-directional and integrated between electricity, heat and gas and it will be able to store energy over short and long periods of time. It will ensure that an energy need can be served when and where the user wants, independently of how, where and when the energy is produced.
- We will show that there is no *one* solution to this challenge, but that a sustainable energy supply demands combinations of technologies, partnerships between different sectors and understanding of the peoples’ needs and whishes (i.e. NIMBY).
- This paper discusses why gas infrastructure deserves an important role in the future energy system. We will argue that the strengths of gas infrastructure will be able to make the transition to a renewable future affordable and reliable and in addition that gas infrastructure will have a sustainable role in an all-renewable energy supply.
- Previous and ongoing studies will be combined to show that taking into account the whole energy system (both central and decentral,(renewable) gas, heat and electricity, storage options) in stead of looking at isolated parts of the system will lead to optimal solutions for society.

Background and aim

- Background
  - Society asks for a sustainable energy mix and a significant CO_2 reduction (EU 80-95% in 2050). In Europe, the role of gas in this future sustainable energy mix is not undisputed: While some advocate an all electric, fossil free energy mix, others see a limited role for gas due to competition from cheap coal and renewables (with low operational costs, subsidies and preferential feed-in)
- Aims
  - This presentation aims to show that gas and gas infrastructure should play a role in the future energy mix to make it not only sustainable, but also reliable and affordable
- Methods
  - Summary and synthesis of various studies, which have been undertaken by Gasunie, often together with partners, and public sources

Greenhouse gas emission should be reduced

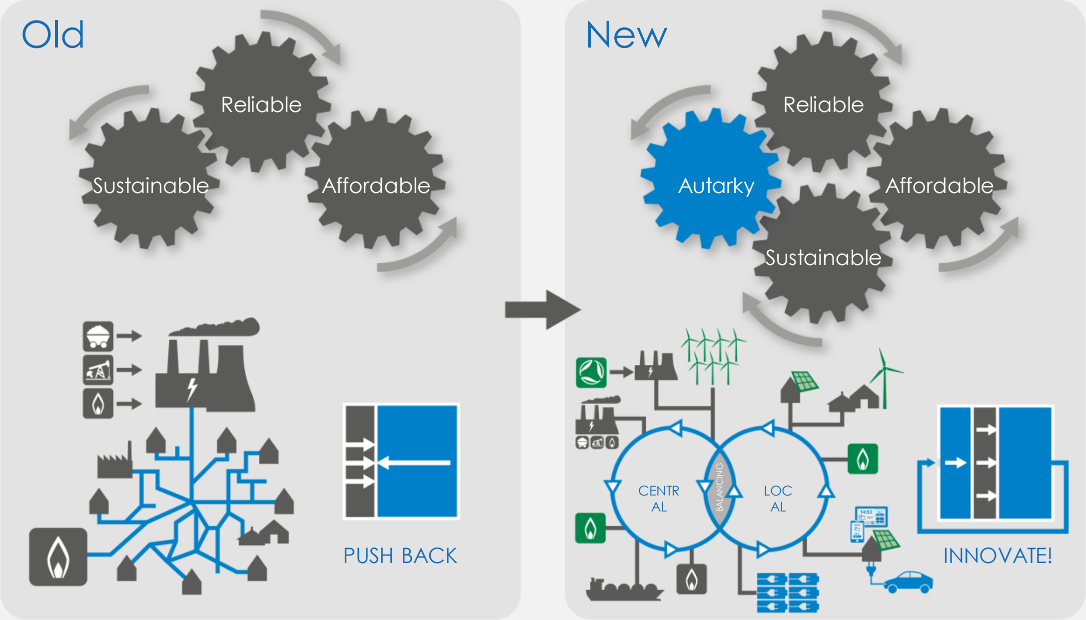
Global warming of more than two degrees comes at great societal and economic costs; greenhouse gas emissions should be reduced drastically to limit global warming



Source: IPCC 2014

Society asks for a sustainable energy mix

The role of gas in the sustainable energy mix is not undisputed

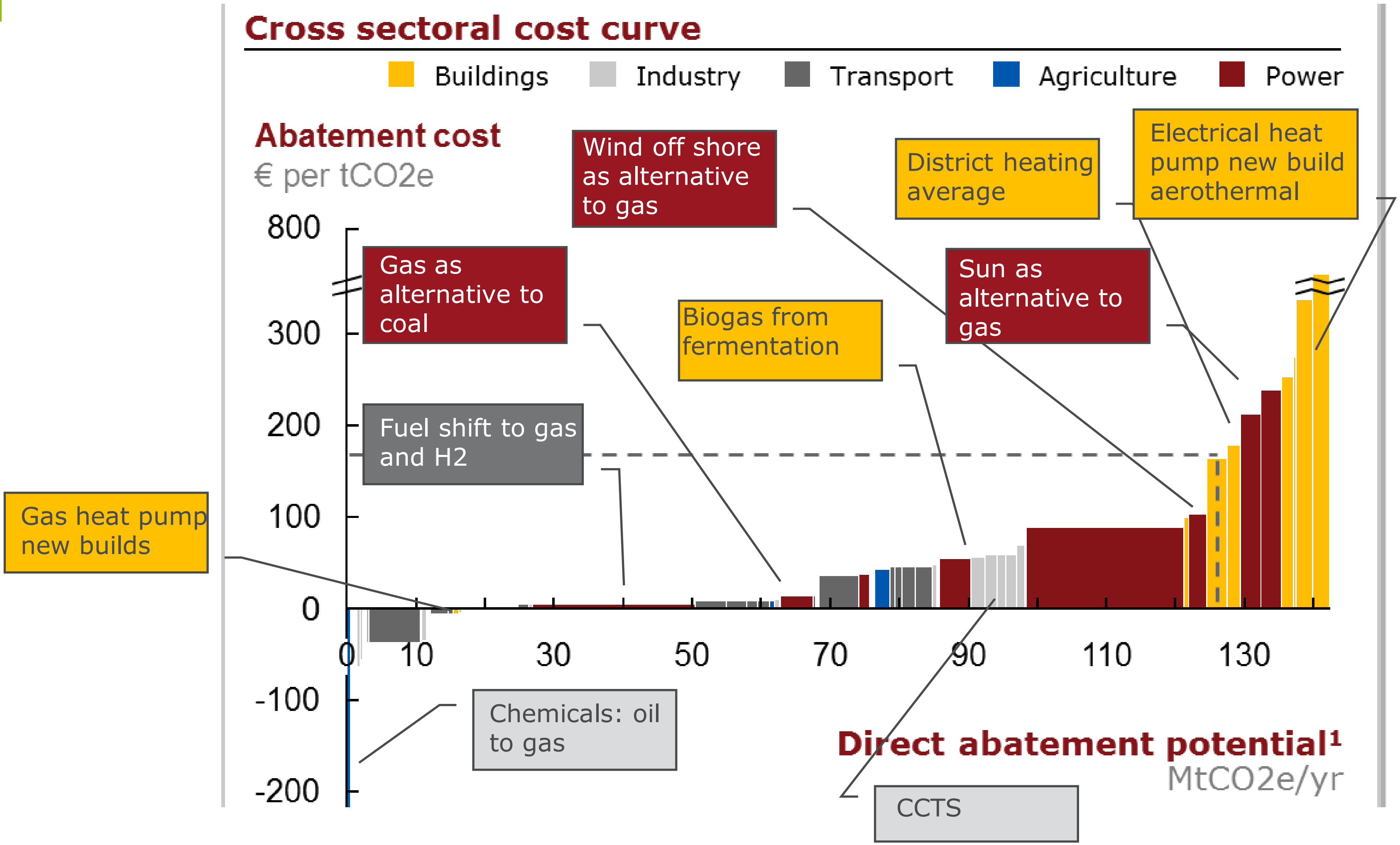


- Focus on electricity in government policy and public debate; "electricity is easy to green"
- Increasing costs for RES are becoming an issue (mainly in Germany)
- Consumers are becoming prosumers, energy production taking place downstream in the value chain
- Business models for conventional energy producers are under distress; gas experiences competition from cheap coal and renewables that have very low operational costs
- Renewable electricity requires back-up
- System integration: future gas, electricity and heat systems interconnected through
  - Central gas-to-power
  - Power-to-gas production
  - De-central gas-to-power

Gas and gas infrastructure have a lot to offer in a sustainable energy mix. Gas is the energy carrier that can make a sustainable future reliable and affordable

RES: Renewable energy system

The transition to the sustainable energy mix does not follow the economic logic of the abatement cost curve



The role of gas and gas infrastructure in a sustainable energy mix

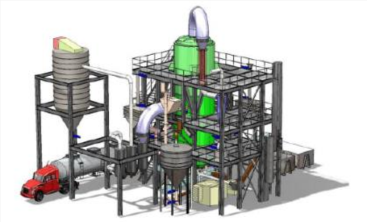
- Biomethane as a direct contribution to a sustainable energy mix
    - Anaerobic digestion
    - Gasification
- Flexibility and back-up for the sustainable energy mix: Power to gas and gas to power
    - Central
    - Decentral
- Emission reduction by gas in transport
    - LNG and LBG for shipping and heavy transport
- Conclusion

Biomethane from anaerobic digestion and gasification as a direct contribution to a sustainable energy supply

Anaerobic digestion (fermentation)

- Biological process
- Input: Wet biomass from
  - Agriculture (manure, residues, energy crops)
  - Households (organic fraction of household waste, waste water)
  - Food industry waste
- Local production; relatively small scale, limited by availability of biomass
- Technology is readily available with opportunities for improvement (combination with P2G)
- Biomethane production is generally more energy efficient than using biogas to produce electricity, as residual heat typically cannot be used
- Production costs, including injection in gas grid, depend on feedstock and scale, starting at 0.0436 EUR/kWh (NL), CAPEX: 2400-5500 € m^3/hr. Fixed OPEX: 200-350 € m^3/hr
- Positive side effects
  - Nutrients can be recovered from waste streams
  - Prevention of methane emissions to the air from manure

Gasification



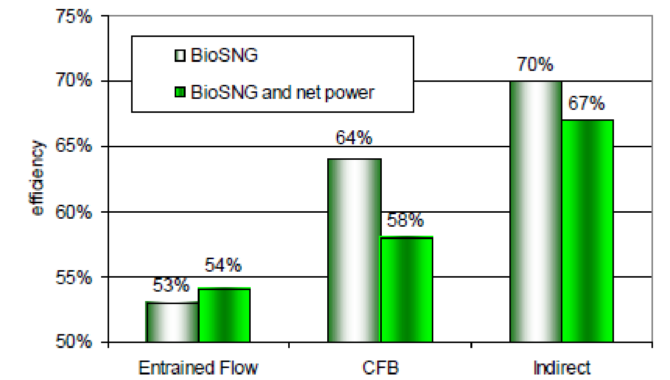
- Chemical process
- Input: Dry biomass
  - Wood (chips, pallets, torrefied)
  - RDF/Waste (refuse derived fuel RDF)
- Industrial production (10 MW up to potentially 400+ MW)
- Technology is still in development
- Gasification of biomass is more efficient (up to 70% efficiency) than co-fireing of biomass
- Central gasification allows for CO_2 sequestration, which is typically not possible when using biomass locally for electricity or heat production

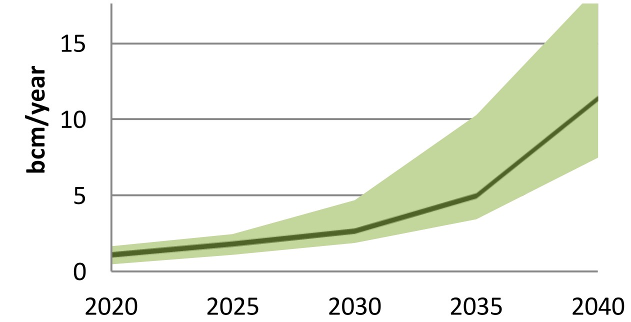
P2G = power to gas

Source: RVO 2014, ECN 2014, Gasunie 2014

Gasification for large scale biomethane production

Gasification of sustainable biomass offers a highly efficient and competitive contribution to a sustainable energy mix



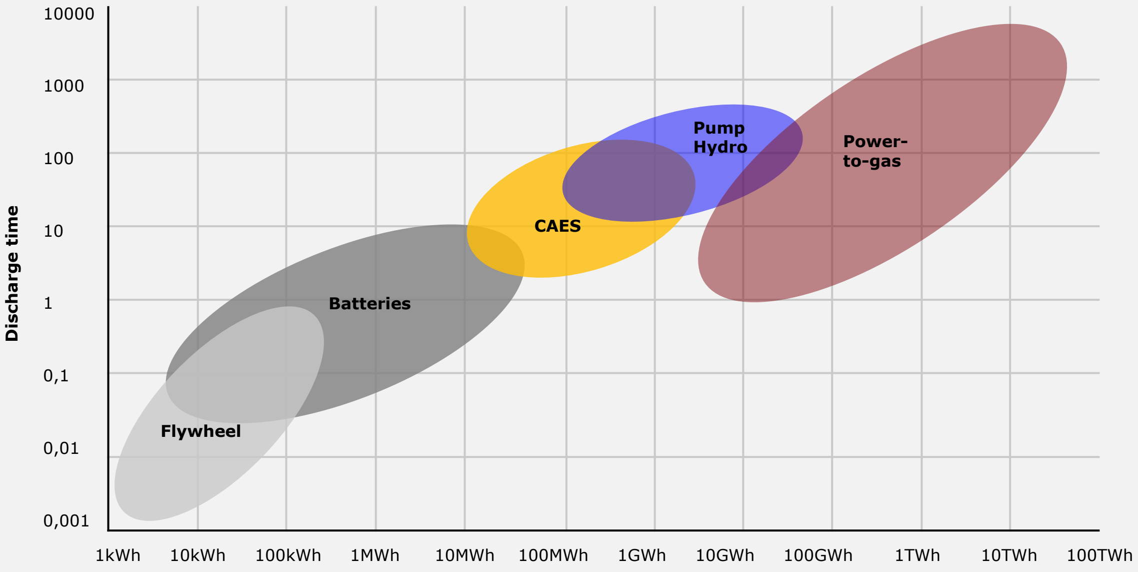


- Gasification converts biomass to bioSNG with an efficiency of up to 70%
- Competitive costs between 14 US$/GJ (low cost biomass, 2 US$/GJ) to 24 US$/GJ (high cost biomass, 9 US$/GJ) (ECN 2014)
- Estimates for sustainable biomass available for energy production vary widely, but the potential is substantial (200-400 EJ/year)
- Additional potential considering gasification of waste (5 – 8 bcm gas, EU 28)
- CO_2 emissions of burning bio-methane produced by gasification of residual wood are 70% lower than for natural gas and 83% lower than for coal
- CO_2 emissions are negative if the CO_2 that is removed from the raw product gas is sequestrated

Source: ECN 2014, Gasunie 2015

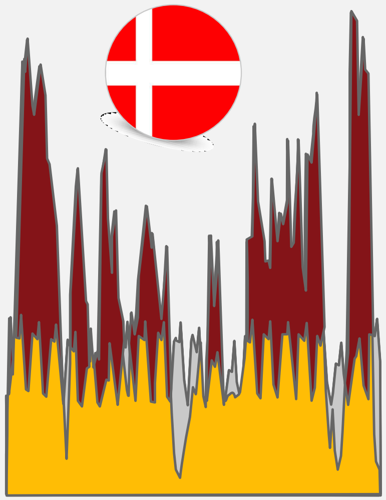
Production profile of electricity will change and requires system flexibility

Power-to-gas offers the possibility for seasonal storage



Production profiles will change

3 week prognosis for wind in Denmark:

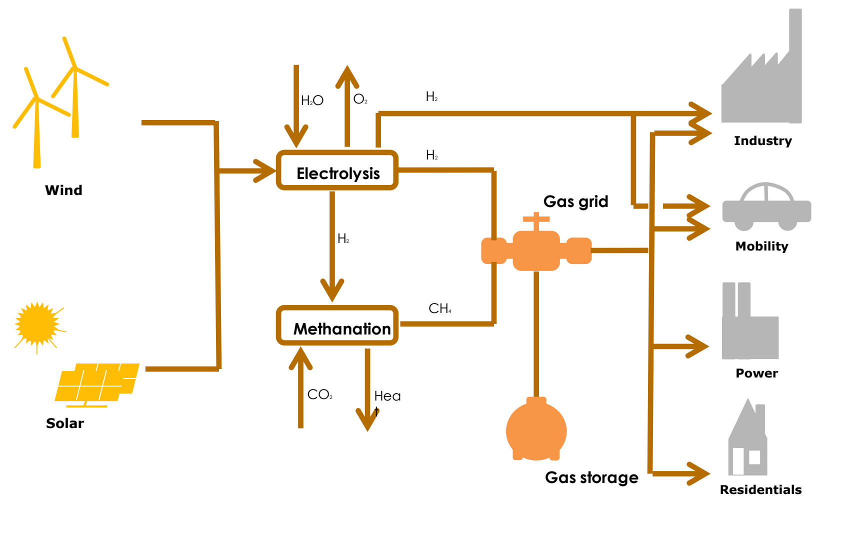


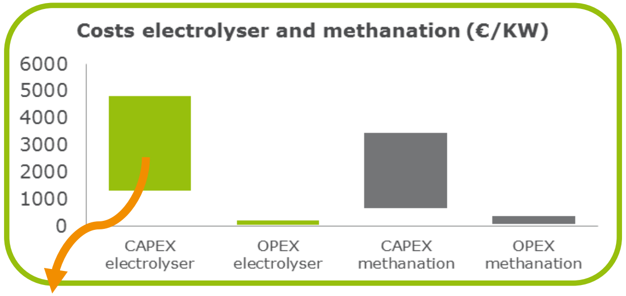
- 2012 ~30% of consumption
- 2035 ~75% of consumption
- 2050 ~140% of consumption

Sources: Fraunhofer, Gasunie

Power-to-gas: the gas network as enabler of sustainable energy growth

Power-to-gas brings flexibility to a sustainable energy system





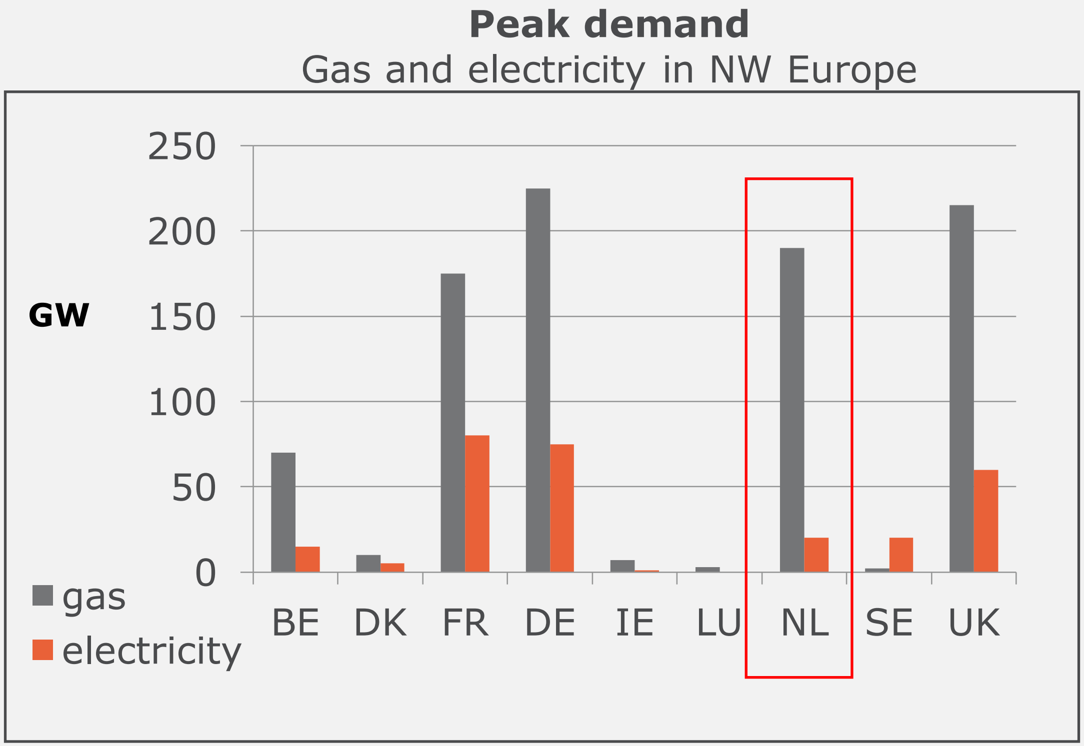
rapidly declining

- Power to gas (methane and hydrogen) brings flexibility to a sustainable energy system; several routes are possible
- Power to gas
  - For abatement in difficult markets (high heat requirements, feedstock)
  - Storage of energy
  - Long distance transport of energy
- Efficiency power to hydrogen 65-75%
- Efficiency power to methane 50-60%
- CAPEX: 1300-4500 €/KW (rapidly declining). OPEX: 4% of CAPEX, mainly electricity costs
- (Potential) issues
  - Challenging economics due to low energy and storage prices
  - Feed in restriction of H_2
- Opportunity: connection with fermentation, using the released CO_2 to produce methane

*Source: Gasunie 2014; Fact sheets DNV GL. Load factor; 3000 hours assumed.

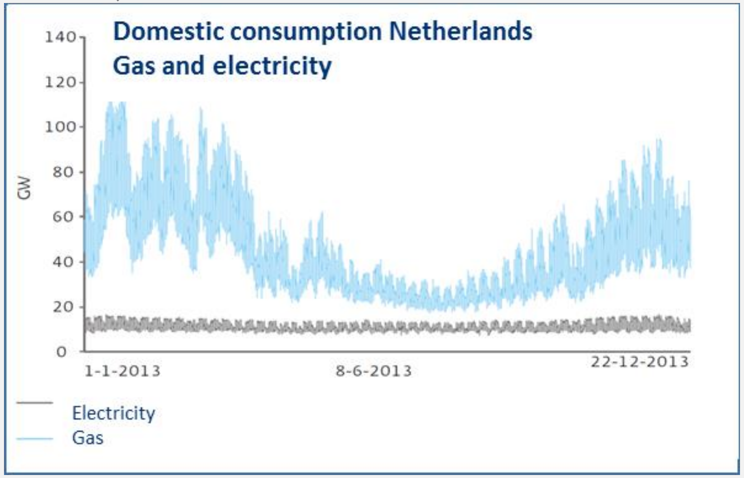
Gas peak demand is a multiple of electricity peak demand; gas cannot easily be replaced

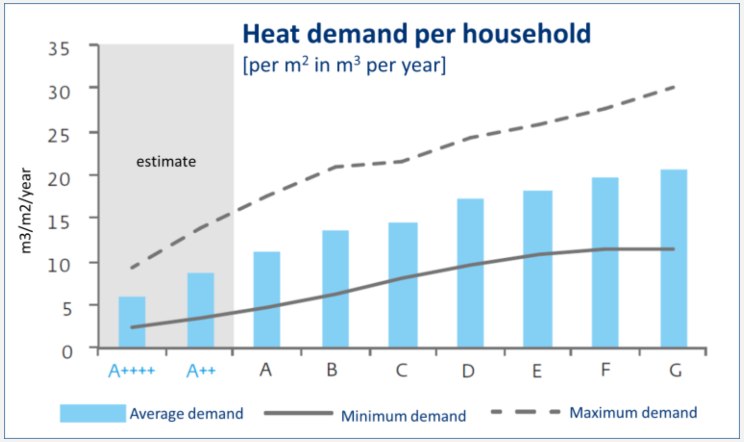
Dutch peak gas demand is 10x higher than peak electricity demand



High peak demand due to domestic heating

Domestic heat demand causes high peak demand; different technologies need to be used to reduce heat demand and CO_2 emissions

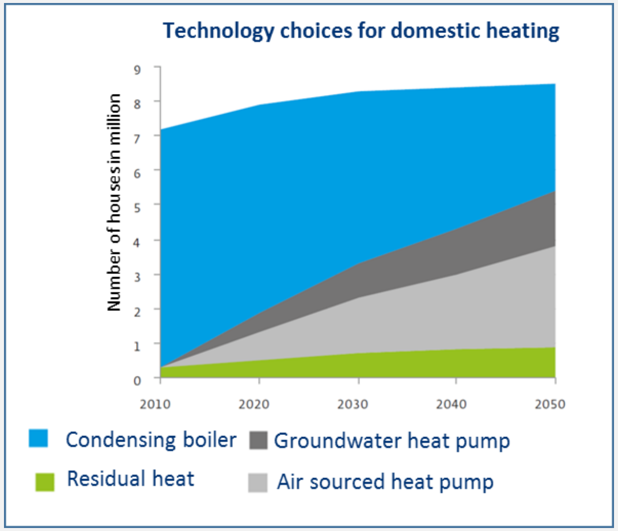




To reach sustainability targets, sustainable heating is necessary, which has a large impact on peak demand – also after far-reaching **insolation** measures.

Main technology options are

- District heating (geothermal or residual industry heat); cannot be developed in all cases
- Heat pumps (ground water heat pump, air sourced heat pump)
- Solar thermal (limited applicability in Northern Europe)
- Biomass (wood chips and pallets)

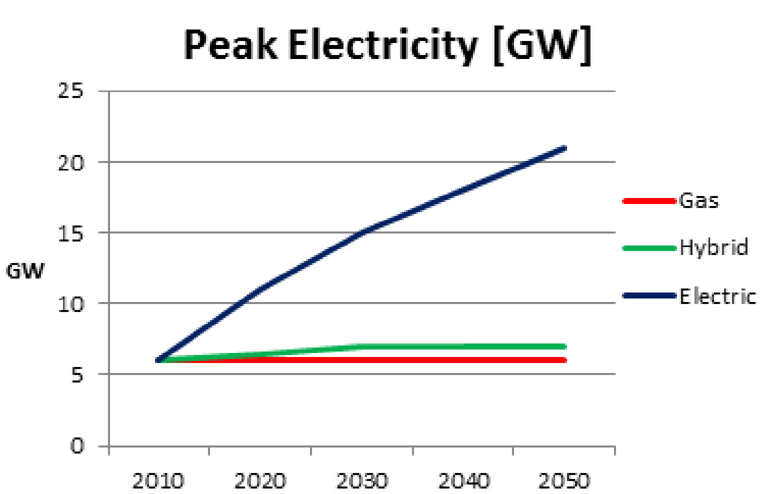


All data for NL

Source: DNVGL2014, Gasunie 2015

Hybrid heat pumps avoid network investments

Hybrid heat pumps offer nearly the same CO_2 reduction potential as all-electric heat pumps but avoid significant investment in electricity infrastructure



There are two types of heat pumps: **air sourced (AHP**) and **groundwater sourced (GHP**). Both existing techniques are used to provide space heating, hot water and cooling in buildings. **Highly efficient (400%)**, but this **efficiency strongly decreases with lowering temperatures** (especially AHP). The negative correlation between performance and weather conditions of heat pumps results in high peak demand (capacity) and could **require a near doubling of the electricity grid** in case of electricity back up, or be **overcome by using hybrid (gas for peak) technologies**. A combination of heat pumps and condensing boilers results in high efficiency and low investments in energy infrastructure and under the currently foreseeable power generation mix in the least CO_2 emission, compared to an all-electric.

Hurdles and roadblocks

- Costs: Capex of condensing boiler: €1.800. Capex of heat pumps: €6.000 (AHP) to €15.000 (GHP)
- Costs for renovation existing houses: €19.000 to install floor heating and remove radiators
- GHP have a much higher efficiency than AHP, but can often not be built in existing houses
- Wrt Hybrid systems (heat pump and condensing boiler for peak): Popular support for all-electric based on assessment of local implications instead of network wide implications.

System integration

- Hybrid heat pumps integrate and optimise the use of electricity and gas
- Gas as backup for electricity; gas network as energy stroage storage
- No energy efficiency losses due to conversion

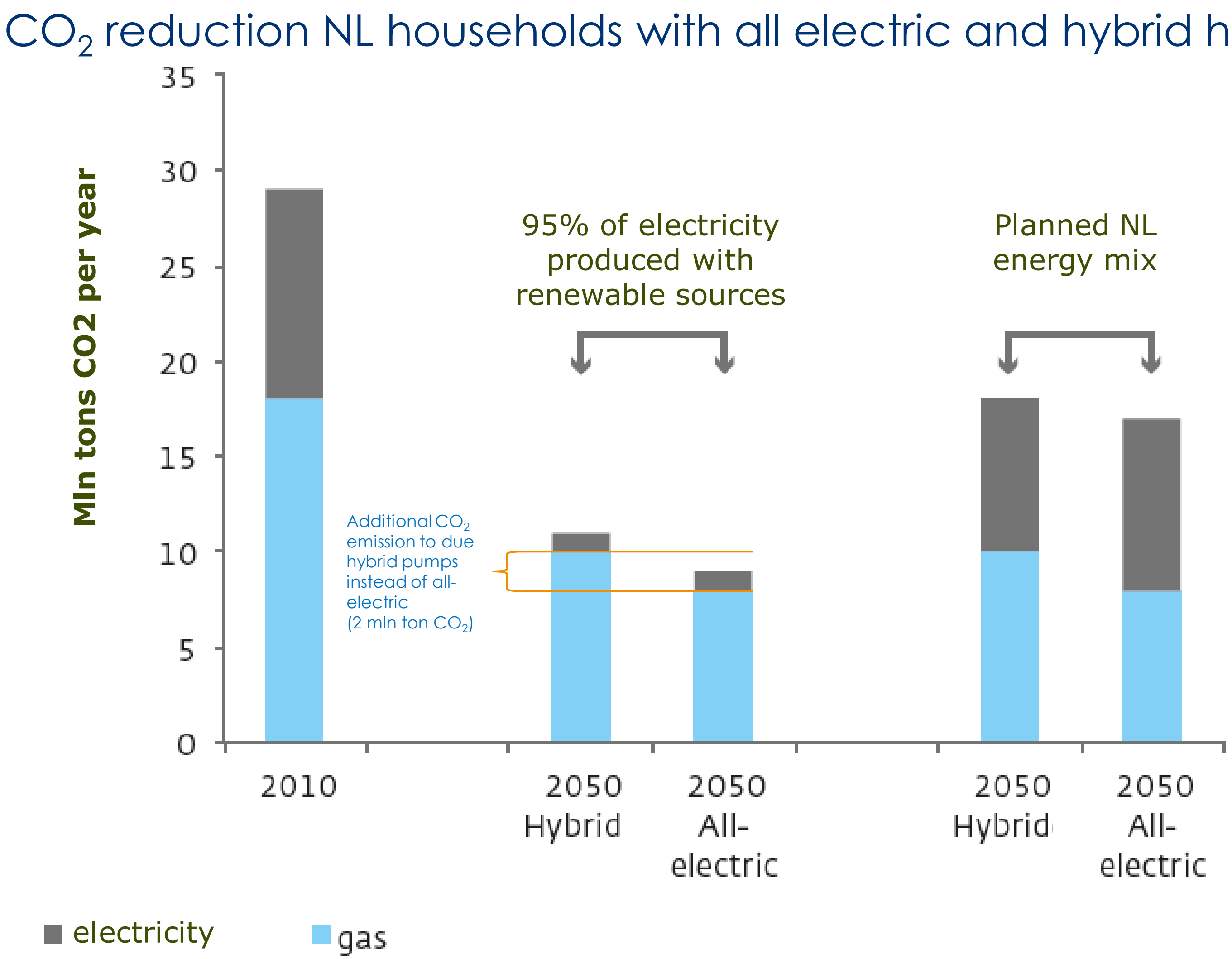
Further development

- Fuel cell/micro-CHP can be seen as a next-step in the hybrid system approach

All data for NL; peak = -17 ° C average effective daily temperature

Source; DNVGL2014, Gasunie

Hybrid heat pumps have only marginally higher CO_2 emissions than all-electric heat pumps

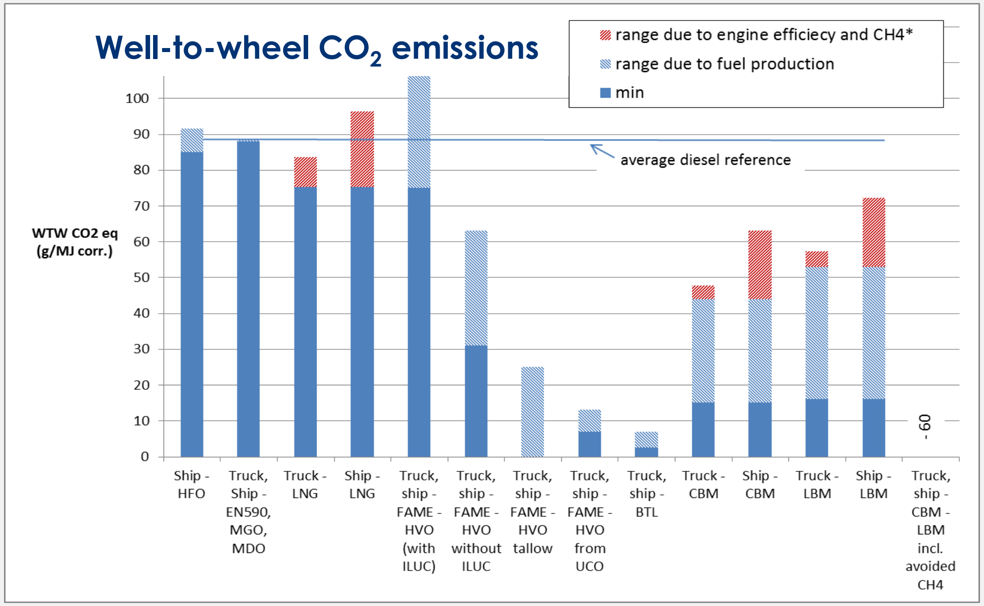


All data for NL; in a scenario with a fully renewable heat supply, additional CO_2 emission/year is 4 mln ton from 2 bcm of natural gas, which could also be supplied from biomethane to reduce the CO_2 emissions to zero

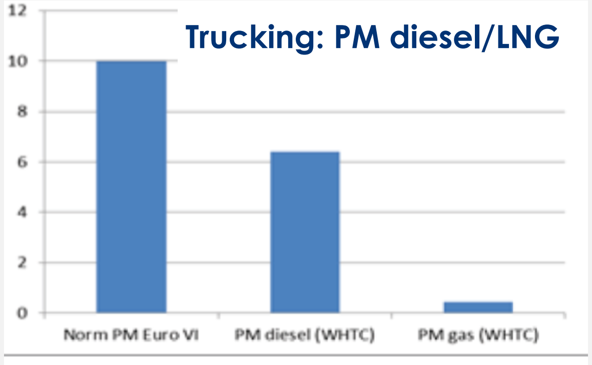
Source: DNVGL2014, Gasunie

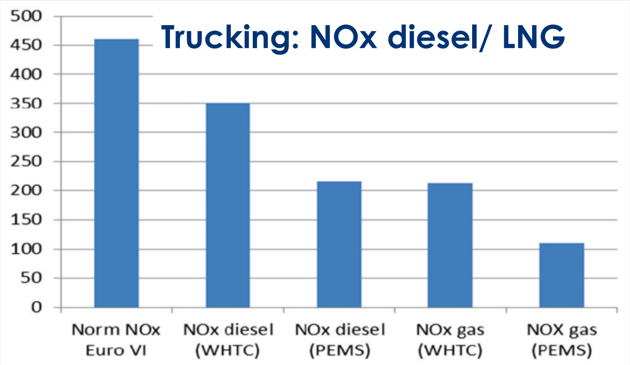
LNG and LBG in shipping and heavy road transport bring significant sustainability advantages

LNG brings great NO_x and PM reduction; LBG also great CO_2 emission reduction in the transport sector



- Limited CO_2 emission reduction of LNG compared to diesel in shipping; by reducing methane slip however, a reduction of 15-20% is technically feasible
- CO_2 emissions can be reduced by 80% using LBG if derived from manure and waste
- LNG infrastructure is in development, supported by EU emission and infrastructure development targets
- Current LNG prices are an economic incentive for fuel switching





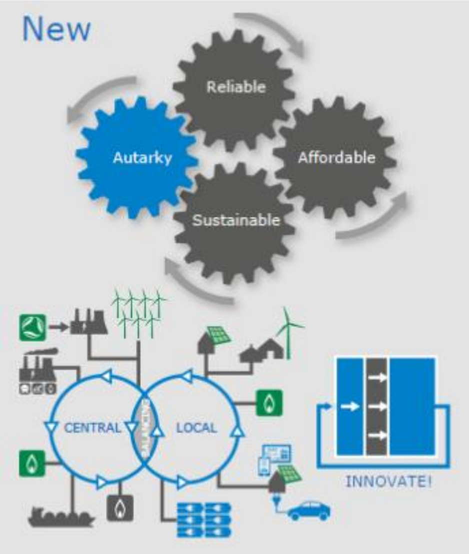
Diesel emissions of particulate matter (PM) and NO_x are within the Euro VI norm, but LNG offers significant improvement in lab tests (WHTC) as well as in practical tests (PEMS)

PM = Particulate matter

Sources: National LNG Platform; TNO

Society asks for a clean energy mix. This requires a new way of thinking

Building blocks for a sustainable future



- Enhance the sustainability of the current energy supply and increase energy efficiency
- Intelligent physical connections between electricity, gas and heat/cold networks, on a central and decentral level
- Energy storage facilities both on central and decentral level that provide open access to all energy users
- Central back-up generation capacity
- An integral (electricity/cold/heat/gas) system to ensure optimal use of the (existing) energy systems
- Support by society
- Laws and regulations that stimulate and facilitate the energy transition

Embrace a new way of thinking, accept that gas demand and in time capacity will decrease.
Seek the best solution for society, even if it is not gas.
This will ensure the ticket to ride for gas and gas infrastructure.

Our added value to society and sustainability goals

Technology	Added value to society and sustainability goals	Customer needs
Households – heating / hot water	▪ Hybrid systems can contribute to the reduction of the final energy consumption. For the Netherland, by an average of 1,5% per year and 100 petajoule of energy reduction in the final energy consumption by 2020	**Clean**
Carbon Capture Transport and Storage	▪ CCTS – for gas fired power plants and gasification – can have a substantial contribution to the EU CO_2 reduction targets	
Green gas (fermentation and gasification)	▪ Green gas will contribute to renewable energy production ▪ The target of the Dutch government to produce green gas is 1.5 bcm in 2020 and 3 bcm in 2030	**Available**
(Bio) LNG for transport	▪ (Bio)LNG can contribute to the target of reducing CO_2 emissions and LNG brings significant NO_x and PM reduction compared to diesel	
Power to gas (P2H, P2M and hydrogen storage)	▪ P2G facilitates the use of renewable electricity through a different energy carrier (hydrogen, synthetic methane) in other parts of the energy system that are difficult to electrify directly ▪ P2G can contribute in the facilitation of the wind and solar targets	**Affordable**

Vision of a sustainable energy system and the role of gas infrastructure