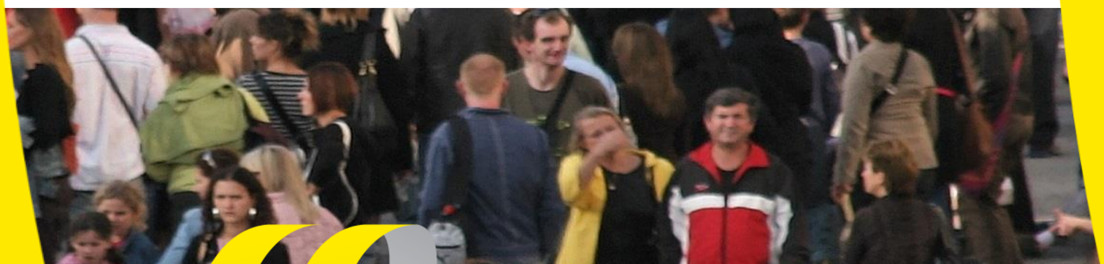
Gas as a solar fuel

An exploration of the role of gas as an energy carrier for renewable energy post-2030



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1 Introduction

Investing in renewable energy

If you have € 5,000 to invest in renewable energy, where should you put your money? At present you might buy some solar panels and put them on your roof. Payback: around 7 years. Each kWh you generate is worth 21 €ct and if you've paid a good price for your panels this will mean you've paid around 20 €ct per kWh. But if you want to invest another € 5,000, where do you put your money then? Not on your own roof again, as that will probably now be full. Then you'll invest in a wind turbine, one of those now on offer from a project developer, with a pretty solid payback.

But let's extrapolate to 2023. The SER Agreement on Energy for Sustainable Growth has then been fully rolled out, there's 6 GW onshore and 5 GW offshore wind and another 4 GW solar PV. Then it's no longer as easy to invest € 5.000 profitably. Your roof's still full, as the panels have a long life. And projects for more wind and 'solar fields' aren't really appealing.

The price of solar panels may then well be a quarter of what it is today, let's say, and wind has also become a lot cheaper, but subsidies for wind and solar are probably a thing of the past. There's enough solar and wind in the energy system and half the time each additional MW of capacity needs to be shifted to times when the sun's not shining or the wind's not blowing. This means expensive storage or selling on the cheap to industries that convert the power to heat. If you're lucky enough to have a robust enough power grid in your neck of the woods, that is – because in some places you'll have to pay a considerably higher connection tariff, or switch off your systems when there's a surplus. If I were you, I'd invest in a solar project in Spain...

Returns per kW are twice as high as they are here, so if a kWh here costs 5 €ct, it'll cost 2.5 €ct there. But of course that won't mean much, as the Spanish grid will then also be saturated.

2 More renewable energy

But that Spanish solar power provides a good way of producing a ‘solar fuel’ – hydrogen or syngas, say - which we then transport to the Netherlands and market here at a good price for times when the sun isn’t shining or there’s only a feeble wind (around 1,500 to 2,000 hours a year), or for powering our cars, or for heating our low-energy homes in the mid-winter. Converting a kWh of solar power to solar fuel involves losses, of course, but that also applies if it’s produced here. We’ll have to get used to the fact that around half the energy will be lost.

But as long as the power comes from the sun, that’s not really a problem; the energy we do ultimately use is no more expensive. A kWh that can be switched on any time you want (i.e. produced when you need it) will cost around 10 €ct per kWh (before any taxes on it). That may be from solar cells combined with a battery, or from solar-generated hydrogen combined with a fuel cell.

An additional advantage of solar fuel is that it can limit the role of biomass, which will always be problematical as well as highly uncertain in terms of sustainability and pricing. Solar fuel can be produced in areas that aren’t as suitable for food production and in sparsely populated regions. For countries like Spain, Portugal, Italy and the North African nations it would mean a great opportunity for new industrial activity as well as trade. For Dutch companies it would mean an opportunity to establish trade with Spanish regions, for investments and for converting the gas grid from natural gas to solar fuel, for example.

For Gasunie we have explored the role that can be played by gas in the energy systems of the future.
The conclusion: once renewable capacity in the Netherlands exceeds around 20 GW solar and wind, it becomes cheaper to use solar from Spain or biomass from Scandinavia than to generate additional power from Dutch solar or wind. What’s more, solar-generated gas and biomass can help meet energy demand for heat and transport.

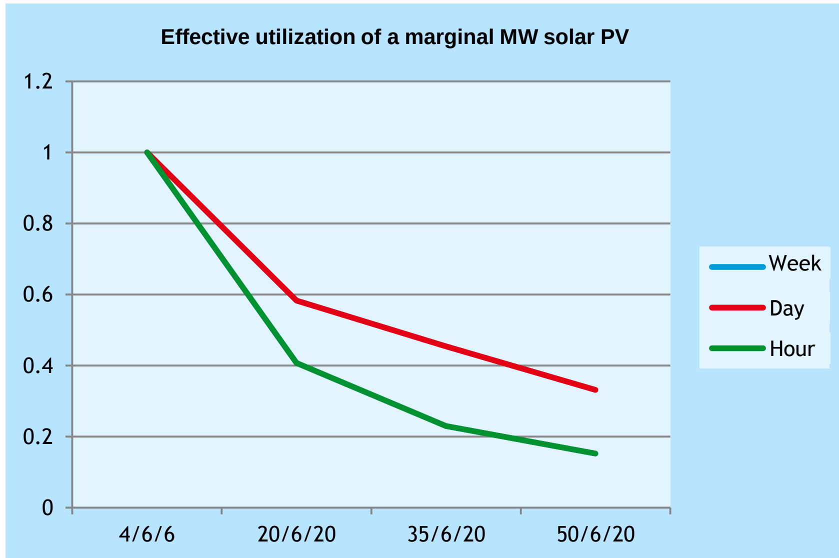
3 Additional renewables in the Netherlands?

Demand for electricity will rise in the future because demand for heat will be supplied partly by electrical heat pumps and heat/cold storage, while transport will be partly electrically powered.

A large portion of this increased demand for electricity can be met using domestic Dutch solar and wind, but there'll come a time when an increasing fraction of the additional power from solar and wind can no longer be directly used, but will have to be stored or 'time-shifted' using some form of flex solutions. We're talking about the period 2023-2030.

Each additional MW of solar or wind will to some extent have to be stored in order to match demand. Figure 1 shows, for four different configurations of solar and wind, the fraction of a marginal MW that can be effectively utilized. The green line indicates how much is utilized if the MW output needs to be used within an hour (possibly with short-term battery storage). The red line indicates how much is used if the output can be switched on day-to-day basis (using battery-stored solar PV for evening lighting, for example). This means slightly more effective utilization. But what's clear is that with 20 GW solar and 26 GW wind half the electricity produced will have to be stored in one way or another for more than a day.

Figure 1 Effective utilization of a marginal MW solar PV



4/6/6 means: 4 GW solar, 6 GW onshore wind & 6 GW offshore wind.

4 First-pass chain analysis

Figure 1 shows that once hourly production exceeds 20 GW solar + 26 GW wind, only half of any additional wind or solar can be directly utilized. This is equivalent to the energy lost during conversion and distribution, plus reconversion if the solar or wind power is stored. Above this 46 GW solar PV + wind the question arises whether it makes sense to:

1. Install additional solar PV and/or offshore wind plus cables and power lines in the Netherlands. Or
2. Produce a 'wind fuel' (hydrogen or SNG) using offshore wind. Or
3. Import a 'solar fuel' from Spain or Scandinavia.

The wind or solar fuel can then be converted to electricity at the desired location (with no congestion) and at the desired time (most expensive hours) using a fuel cell or CCTG. Because both time of utilization and location vary substantially, a storage and a transport medium are required, for which a number of options have been studied, viz. hydrogen, ammonia, iron oxide and SNG.

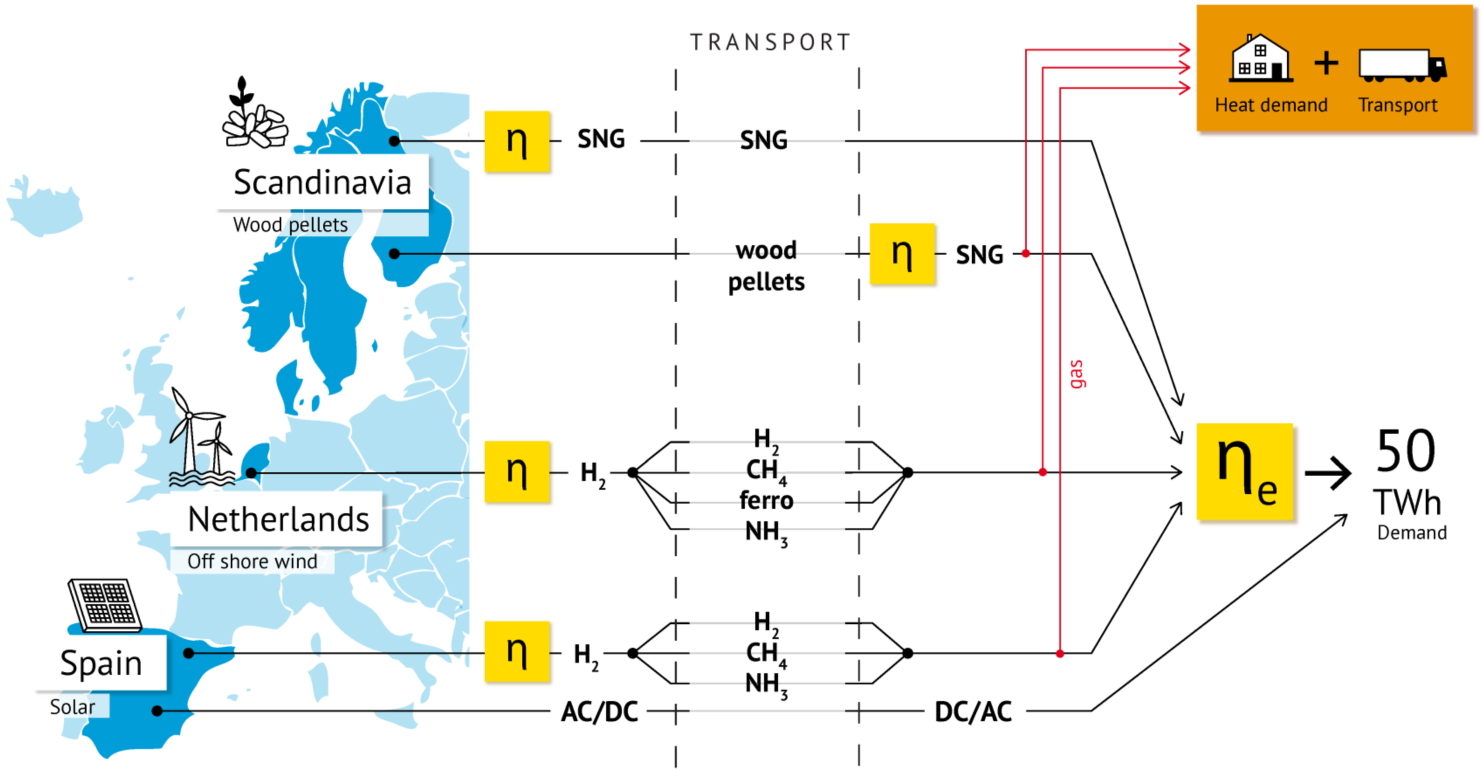
For the conversion plant and transport mediums to provide sufficient on-line availability, a storage reservoir is required. Calculations have also been made for a reservoir designed to match production with demand (Spanish solar PV with a HVDC connection). Here, we have assumed the cable is used only for limited periods: during the hours of shortfall of solar and wind generated locally in the Netherlands.

Figure 2 shows the chains investigated.

Figure 3 shows the costs, with a breakdown for the various distribution and conversion steps.

4 First-pass chain analysis

Figure 2 Renewable energy production, distribution and storage chains



5 Conclusions

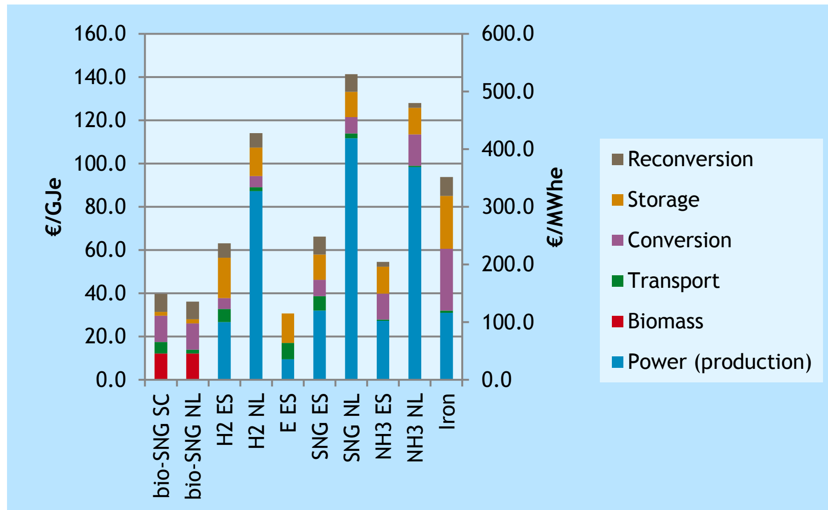
Based on the exploratory analysis, the following conclusions can be drawn if the Netherlands installs 50 TWh new renewable energy on top of the baseline figure of 46 GW solar PV/wind:

- the cheapest ways of topping up electricity output when there's a shortfall of solar/wind in the Netherlands are:
  - electricity from Spain via a HVDC connection;
  - biomass plus SNG production in Scandinavia;
- slightly more expensive options are:
  - Spanish electricity converted to hydrogen;
  - Spanish electricity converted to SNG;
  - Spanish electricity converted to ammonia;
- options involving production of over 46 GW renewable electricity in the Netherlands with some form of storage are substantially more expensive.

Many of these routes will have serious social impacts. HVDC connections will mean planning issues and NIMBY objections. With biomass there'll be problems of limited supply of certified sustainably produced materials.

Besides the financial consequences, due consideration will therefore also have to be given to scalability and scope for practical implementation. If these issues are properly handled, the options involving conversion of Spanish solar PV to various gaseous fuels and storage and distribution to the Netherlands would appear to be the most attractive.

Figure 3 Overall production costs of renewably sourced electricity



SC = Scandinavia; ES = Spain; SNG = Synthetic Natural Gas.

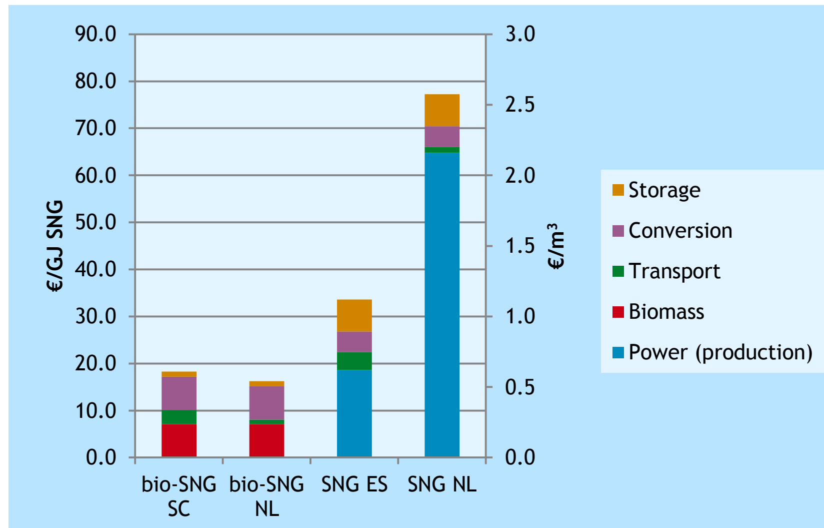
5 Conclusions

The above analysis is based on power output exceeding 50 TWhe. For the other energy functions (heat, transport) a great deal of renewable energy (RE) is also required to replace fossil fuels.

In the scenario with 100% RE this already amounts to 700 PJ per annum. In the other scenarios (with less efficiency improvements) the figure rises to even more than 700 PJ per annum. If that amount must likewise be renewably sourced, this could be provided by gas from biomass pellets or by gas from solar/wind power.

Producing gas from offshore wind in the North Sea is not competitive with production of gas from Spanish solar PV via the various chains (hydrogen, ammonia, SNG). Prices for the latter are similar: € 20 per GJ (around €ct 60 per m^3), cheaper than production of green gas from Dutch biomass.

Figure 4 Overall production costs of gas from renewable sources



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This is a summary of the study '*Gas als zonnebrandstof, verkenning*' (Gas as a solar fuel: An exploratory study)

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