EIRES-KIVI Webinar "Design of a Dutch carbon-free energy system"

16 April 2021

Answers to questions asked in the chat

[10:18 AM]

Solar on roof(Variations) why not facades!?

Reply: We do not exclude the option to use facades. It is generally a good idea to diversify the orientation of PV-panels, to reduce the peak energy generation somewhat. Our study assumes that half of the panels are oriented slightly east, and the other part slightly west.

[10:20 AM]

Current primary energy demand is based on loss of thermal at generations. future primary demand is corrected for this efficiency improvement with electrification?

Reply: The study is based on the energy demand at the consumer side (homes, industry, ...), not on the primary energy currently needed to supply this demand. The reduction of thermal losses is the consequence of the main use of wind turbines and PV panels what produce very little thermal losses. The only thermal losses come from the production of hydrogen and the use of fuel cells but then again the thermal losses of the production of hydrogen will be used for district heating.

[10:21 AM]

I see CO2 in the system. No carbon-free system apparently. So, the correct term would be "a climate-neutral energy system".

Reply: You are right: the system still includes the use of synthetic fuels, which is CO2-neutral but not CO2-free. In the transition towards this system, CO2 will also still be produced of course.

[10:22 AM]

Wat staat er op de horizontale as in slide 5, bottom panels.

Reply: it is the day of the month.

[10:26 AM]

Did I miss, did the last model also account for stress conditions for summer heat?

Reply: (this answer was also given in webinar) Stress conditions for the summer heat have a lower priority we think. A modest use of cooling has been taken into account. We mainly focused on stress conditions for cold winter weeks.

[10:29 AM]

You only considered batteries and hydrogen as storage options? No hydro, compressed air, metal powders and other options? (1 liked)

Reply: Indeed the main storage options we use are batteries and hydrogen. Heat storage can also play a role for example in district heating. The options you mention are either not very useful for the Netherlands or need further development. They have been considered, and may also become part of the storage diversity. Since technically and economically viable storage solutions are still developing, we limited the options to batteries, hydrogen and heat largely for simplicity's sake.

[10:30 AM]

Did you take into account that battery capacity is lower at lower temperatures?

Reply: The same issue occurs with batteries in electric vehicles during very cold weather. Several methods are being developed for this application that can be used for batteries in the energy system. It is also expected that home batteries will be used to a large extent, that don't have this problem.

[10:32 AM]

It feels like there should be a 4th option: Hydrogen for direct consumption by industry (e.g. for ammonia production) (1 liked)

Reply: Hydrogen for direct consumption by industry is part of the concept. See slide 4: the High Temperature heat demand is largely industrial and supplied by hydrogen and also the use of hydrogen form ammonia production has been included in the plan

See EnergyNL2050 report, Appendix B page 27:

"**High temperature heat demand: 76 TWh. Electricity is 26 TWh and hydrogen is 60 TWh.**
High Temperature demand from the in industrial sector shall also be fully based on electricity and hydrogen as energy carriers, resulting in significant energy savings.
. No refinery energy will be required, as transport is based on electrification.
. The basic steel production will use hydrogen as the deoxidizing medium, resulting in CO2 free steel making and also some energy saving.
. HT Heat energy demand with temperatures between 100-250 degrees Celsius will be produced with industrial heat pumps with a coefficient of performance (COP) of 2 or higher.
. Ammonia and the associated fertilizer industry will be based on green hydrogen.
Together with some smaller energy savings the HT Heat demand will be 76 TWh**.**
Remark: The plastics industry output will have an energy value of 160 TWh. In 2050 we expect that 50% will be produced from recycled plastic material and for the other new plastics biomass will be the basic input material."

[10:33 AM]

And did you consider heat storage?

Reply: Although it is not visible in the system diagram (slide 4), heat storage is part of the concept.

[10:33 AM]

37% roundtrip efficiency for the electricity hydrogen storage -> electricity path is higher than i heard so far.

Reply: This figure is calculated from our ref. Hers et al., 2018 77% for electrolyzer efficiency and from our ref. James et al., 2017 for fuel Cell efficiency 55% and taken into account 8% loss in the H2 storage as well as 5% overall additional loss. It should be taken into account that the efficiency of electrolyzers and fuel cells will still show improvement in the future. This can be found in recent literature.

[10:33 AM]

From the topic I thought this talk was about overall energy in the Netherlands (including transport, agriculture, industry) but now I am guessing it is only about electricity?

Reply: The system includes all Dutch energy demands referenced in the 'Klimaatakkoord'. The aggregation level may hide that somewhat, but the energy plan only excludes the energy needs of international transport (mainly via air and water). These are substantial, but will have to be solved in a European or global context.

[10:34 AM]

Supposing batteries as a storage medium seems unrealistic; Batteries only to be used for grid stability. Refer to South Australia. (1 liked)

Reply: Our calculations show that batteries are very helpful in reducing the consequences of peak supply and demand and are primarily used to shift the contributions of PV and wind electricity with respect to each other over a short period of time. That limits the amount of curtailment significantly. Of course there is a grid stability issue, but it also reduces the need for enlarging grid capacity.

[10:34 AM]

Does the model take into account the relatively high annual degradation of storage capacity of lithium based battery storage system? - and does the model take into account a degrading round trip efficiency of a BESS?

Reply: Yes, see Appendix E. Based on our ref. Fraunhofer, 2018 there is one replacement of the batterries taken into account during the 25 year lifetime of the battery storage system. Unfortunately the full reference has been left out in our report, it should be

Kost et al, 2018, LEVELIZED COST OF ELECTRICITY RENEWABLE ENERGY TECHNOLOGIES , Freiburg, Fraunhofer Fraunhofer Institutefor Solar Energy Systems ISE

[10:34 AM]

How much residue can be avoided by users scaling down their consumption when less power is available?

Reply: Probably substantial, but we do not know. Our target was to study the possibilities of a carbon-free energy system given current energy demand patterns and associated behavior. The only aspect that touches on consumption change is the flexibility we assume in the moment of charging BEVs. But also the use of home batteries may help to reduce the peak demands in the home.

[10:37 AM]

Is there a scientific reference for the prize of 2.25 euro for H2

Reply: Yes. Our reference Hers et al. 2018, section 3.2, page 31.]. This is the price that would be comparable to the price of hydrogen obtained from natural gas, also taking into account the CO2 emission that is avoided.

[10:39 AM]

I have a question about the space required for the offshore wind and the PV

Reply: The space required for offshore wind can be easily computed. The desired density of wind turbines at sea is about 7 MWatt per km2. This density figure is independent of the power rating of the wind turbines. For PV, we estimate we need about 60% of the current roof surface in the Netherlands.

[10:41 AM]

We are working on the development of an >85% instead of 37% eff for e to storage and back to e again (high energy density, long term and easy to transport and store) . Believe it or not. The principals are proven. (2 liked)

(see answer below, 10:47)

[10:41 AM]

I have put your electricity mix and flex options in the Energy Transiton Model. Seems to match well with your graphs: https://pro.energytransitionmodel.com/saved_scenarios/10642 (2 liked)

[10:42 AM]

Why isn't nuclear energy included in the analysis? (3 liked)

Reply: The target of the study was to answer the question if it could be done with only sun and wind.

In addition, we can say the following. Technically, there is room to include some 9 GW nuclear capacity into the mix. We have done an initial analysis of the dynamic behavior of a system optimized for this set-up and the resulting cost. This system has significantly less back-up electrolyser, fuel cell and hydrogen storage capacity and correspondingly less system cost. However, this cost saving is not enough to compensate for the expected higher LCoE of current and fourth generation nuclear systems. This in addition to existing concerns with respect to nuclear power especially long-term storage of nuclear waste. A second disadvantage of nuclear energy is that it not expected to be introduced at sufficient capacity before mid-2030s, which is quite late regarding the required pace of the energy transition.

[10:42 AM]

We have power connections with Norway and Scotland for hydro-storage of energy. Can that be a significant part of the solution? (1 liked)

Reply: Surely energy import and export are a significant part of the solution. Our concept includes 10% of net import, which can either be hydrogen or electricity. There is a plan to have an electricity network between all North Sea countries, mainly to connect the wind parks from the North Sea. This network can also be used for the exchange of electricity between the North Sea countries.

For more on this: https://northseawindpowerhub.eu/

[10:43 AM]

40GW electolysis, 80GWh in batteries, 33GW in fuel cells. it sounds completely detached from reality. And at the end of the day all the energy is coming from wind and solar in this scenario. Is this really realistic? I don't believe that. Why is nuclear not part of the solution? It is an obvious way to generate very large amounts of power with a small land area. (2 liked)

Reply: (see also response to question [10:42 AM]) The starting point of the study was to show the feasibility of a system based on sun and wind. The study shows that such a system is able to provide the energy demanded, and with acceptable costs (slide 10). A similar exercise for nuclear energy show that costs are higher.. The use of land (and sea) area is underpinned by several detailed studies and regarded acceptable by many people.

For more info consult the analysis by the Klimaatakkoord on the space requirements from 2018: https://www.klimaatakkoord.nl/documenten/publicaties/2018/02/21/ruimtelijke-verkenning-energie-en-klimaat.

[10:44 AM]

Do you consider a constant annual energy consumption or can there be savings due to the higher efficiency of electric cars or high effectivity of heat pumps?

Reply:. The primary energy demand will be much reduced compared to today’s demand due to avoided energy conversion losses indeed very significantly visible in electric cars and in the use of ambient heat in heat pumps.

[10:44 AM]

Wikipedia lists the maximum efficiency of a fuel cell as 83%, and the maximum theorectical efficiency of an electrolyzer as 94.5%. How can this lead to a round-trip efficiency >85%?

Reply: The roundtrip efficiency we use is 35%. The 85% percent is the assumed efficiency of an electrolyzer plant.

[10:44 AM]

Great analysis. Focus like McKinsey seems to be on lowest cost, however I think we must now look at decarbonisation strategy with lowest CO2 emissions. Investing in e.g., solar means large CO2 emissions now.

[10:45 AM]

or net zero?

Reply: This study targets a final situation which is CO2-neutral. But it will of course be desirable to try and compensate for those CO2-emissions which result from getting there. Very little attention is given to this issue. It is needed to extract CO2 from the air or from sea water to compensate for the current CO2 emissions. There are some interesting recent proposals how this might be done.

[10:45 AM]

Investment is 1,5 € billion per year until 2050 ? That is not so much! (1 liked)

Reply: We also conclude that the necessary investments are affordable. The figure we mentioned is the annual cost of the system , it should not be divided by 30 (from 2020 till 2050).

[10:45 AM]

In the report, it's mentioned that there is a 5% "future" renewable energy source that has 8000 full load hours per year. Which energy source would this be?

Reply: There is currently no single source which is sufficiently promising to name here..)Sources that may be used in the Netherlands are blue energy , tidal energy and wave energy.

[10:46 AM]

Grand, Yonis le (Guest) Fusion hopefully?

Reply: (See previous question) Yes, but it will come too late.

[10:48 AM]

80 GW in batteries is how much in installed GWh? (1 liked)

Reply: The Installed power is 80 GWh. Simulations show actual energy stored is 18 TWh per year.

[10:48 AM]

Did you look at the timeline, how much time is likely needed to realize this plan?

Reply: See our 4th presentation at the KIVI annual congress, slides 4 and 5. We have based our cost calculation on a linear increase of the installed components. On-shore wind power already has reached its target today. Off-shore wind power is developing at a too slow pace at the moment. . Solar power is more or less on track. Storage facilities are not keeping up to the pace, nor are the changes needed to use hydrogen. This is not a real problem today, as can be seen in slide 4 and 5 mentioned above. In some areas increase of the energy grid capacity is already needed now but will certainly become urgent after 2030, especially if no distributed fuel cell backup capacity is deployed

[10:49 AM]

Who is going to carry out this plan? what is needed to get this started?

Reply: The answer to this question must come from our government, by setting clear targets and by providing laws, rules and regulations which support changes towards this target.

[10:49 AM]

I don't see how this picture covers things like agriculture, cement, steel, etc. What about carbon capture and storage?

Reply: In general, the system takes the scope of the Paris treaty, so all direct emissions generated in the Netherlands, including steel and fertilizer but not cement and plastics (end-of-life emission). Also this implies that international bunker fuels are not included. The aggregation level of this presentation is high, so they were not mentioned here explicitly. They can be found in the report, however. Carbon capture and storage can be used for only a limited period of time until the storage capacity in the North Sea has been used.

You will find some info in the North Sea Energy Outlook study (NEO, dec 2020) by DNV-GL https://www.rijksoverheid.nl/documenten/kamerstukken/2020/09/01/rapport-noordzee-energie-outlook .

In the NEO report the limited capacity forCO2 storage will last till roughly 2100.

[10:49 AM]

40 GW in electrolysers is not totally crazy. Two of the Climate Neutral Energy Scenario's 2050 have more than 40 GW
https://www.rijksoverheid.nl/documenten/rapporten/2020/03/31/klimaatneutrale-energiescenarios-2050 (1 liked)

Reply: You are right, many current other scenarios have similar quantities.

[10:50 AM]

Are there similar studies done for NL, and if so, what are the key new messages from the current study?

Reply: See slide 3 of the presentation that mentions Similarities and Variations. There are several similar studies, with conclusions which largely align with ours. Our concept's essential difference is that it includes local load control, especially smart charging of BEVs, fuel cells for back-up, integral use of a "one-day" battery storage and use curtailment as a design tool.

[10:50 AM]

Let me share this here: Molten salt reactor - Wikipedia (2 liked)

[10:52 AM]

You have 2,5 GW of Other renewables in the mix with 8000 full load hours. What are these other renewables? I assumed that was nuclear, or is it maybe geothermal?

Reply: We do not know yet. See more detailed answer above, at 10:45. Geothermal energy is one of the ideas, but also one of the many which still needs to mature.

[10:54 AM]

But there might be attractive nuclear options in the pipeline that hopefully will be available after 2030 (I do not mean fusion). (3 liked)

Reply: See the other answers to nuclear-power-related questions. It was our goal to study how far we could get with a system based on sun and wind. The resulting concept appears to be feasible and economically competitive. As of now, nuclear power technology, like many other options for generating energy, is at a development stage which will not allow us to complete the energy transition before 2050.

[10:57 AM]

The potential of blue energy is max 6 TWh based on low river discharge of our main rivers, so not enough fully to fill the 20 TWh of other renewables https://www.stowa.nl/publicaties/perspectieven-elektriciteit-uit-water-nationaal-potentieel-voor-2030-en-2050 (1 liked)

[10:59 AM]

I would encourage you to put your assumptions in an Energy Transition Model scenario, so also others can play with the assumptions.

Reply: That is a suggestion we will follow up on.

[11:01 AM]

If you think electrical you find electrical storage solutions, but i would consider a link with thermal solutionsefor storage!

Reply: Heat storage is a relevant part of the concept. It is not mentioned in the presentation, but needed to match heat production to (mainly low-temperature) heat demand. It is assumed that it will be used extensively in district heating systems in the future.

[11:01 AM]

Good suggestion to put assumptions in an scenario and evaluate the assumptions on regular basis. (1 liked)

Reply: See above, this is a welcome suggestion.

[11:02 AM]

This is my attempt a the KIVI scenario
https://pro.energytransitionmodel.com/saved_scenarios/10642 (1 liked)

[email]

Land area required. “The Dutch landscape is preserved as much as possible by proposing only a very limited amount of wind power on land, and only a very small amount of solar parks”. Is this correct?

Reply: You are correct.

[email]

On page 2, table 2.1 you mention: “The functional energy demand 2050 is about half the energy demand nowadays”. According to the CBS the present (2019) primary energy consumption is about 680 TWh/year. You calculated a primary energy consumption of 434 TWh/year for 2050. This is 64% of the present consumption, and not 50%.

Reply: The primary energy consumption will probably decrease from now on every year. The CBS figures we used are from 2015. We actually mention a reduction in functional energy, not primary energy. See Table 2.1. 2015 had 640 TWh functional energy and in 2050 this will be 211 TWh electric and 107 TWh hydrogen _and 20 TWh heat for heat nets. This is 53% of 2015.

[email]

For this consumption you require installed generating capacity of 77 GW In PV, and 60 GW in offshore wind. When I calculate the land area required for this I arrive at a total surface several times larger than you calculated.

1. PV: 77 GW.

According to ACRESS (Application Centre for Renewable Resources), an institute associated with the University of Wageningen polycristaline solar panels in an optimal setup have a power density of 0,5 MW/ha. This means that 154.000 ha. or 1.540 km2 is needed for the 77 GW. With 400 km2 on roofs of residential and commercial buildings 1.140 km2 must be found on land. This means all of our dry non-cultivated land (840 km2) plus 10% of our forests or 5% of all agricultural land.

2. Offshore wind: 60 GW

You assume that 16% of the Dutch Exclusive Economic Zone (EEZ) is available for all the wind turbines: this is 8.800 km2. The cabinet published a North Sea Policy Note in which 2.900 km2 is reserved for wind parks. The rest of the EEZ is assigned to Natura- 2000 areas, a large military area, international shipping lanes and anchoring areas, areas for gas and oil exploitation, cables and pipelines, and areas for miscellaneous activities. 2.900 km2 with a power density of 7 MW/km2 provides for 20.300 MW or about 20 GW. Additional space must be found on land for 40 GW.

With a power density of 4 MW/km2 this means that 10.000 km2 is required, if the wind turbines on land would have the same full load hours as the off-shore turbines, 4.500 hours/year. However their full load hours are 2.500 hours/year, or 56%. This means that for the same electricity production 10.000/.56 = 17.857 km2 is needed. If you add to this the 1.140 km2 needed for the solar parks a total land surface of 18.997 km2 or 81% of the total agricultural land is needed.

Reply 1: We do not recognize these figures. Moreover we assume that majority of PV will be in the built environment on roofs. TKI has published a scenario referred to in the first session at the KIVI congress at position 52:08.

Dakoppervlak voor 71 TWh

		Ambitie 70 TWh/jr	
		Variant 'focus op daken'	
Landgebruik type	totaal oppervlak [km2]	Deel van potentieel benut	Opwek (TWh/jr)
Daken (en gevels) woningen	544	35%	25
Daken (en gevels) overige gebouwen	607	35%	29
Infra+erven stedelijk	4.190	1,6%	10
Landschap	26.880	0,1%	4
Binnenwater	5.146	0,5%	2
Buitenwater	61.801	0%	0
Totaal NL			**70**

Bron : recente presentatie van **Robin Quax TKI**

This show how 70TWh (same as our PV assumption) can be generated by using 35% of the available roofs and 1.6% of the infrastructure and just 1.6% of the landscape.

Recently the study was published at:
https://www.topsectorenergie.nl/sites/default/files/uploads/Urban%20energy/publicaties/Ruimtelijk%20potentieel%20van%20zonnestroom%20in%20Nederland.pdf

Reply 2: The policy note you refer to is a document from 2015 and describes the status at the time of the energy agreement (Energie Akkoord). In the meantime, new developments have happened. Now the goal is "Het Klimaat Akkoord" with extended goals for CO2 reduction.

In September 2020 is de Noorzee Energie Outlook aangeboden door minister Wiebes aan de Tweede Kamer. https://www.rijksoverheid.nl/actueel/nieuws/2020/12/04/noordzee-energie-outlook-brengt-randvoorwaarden-voor-toekomstige-groei-windenergie-op-zee-in-kaart

Op pagina 6 van dit rapport is te lezen:

> **Wind op zee**
> De elektriciteitsproductie in Nederland kan in de periode 2030 tot 2050 voor het grootste deel afkomstig zijn van wind op zee. In de scenario's wordt rekening gehouden met een verwachte groei tot respectievelijk 38 GW (Importafhankelijk) en 72 GW (Zelfvoorzienend). Om dit in 2050 te bereiken is een hoger groeitempo nodig dan de huidig geplande groei in de periode 2020-2030. De industrie is bij voldoende toekomstperspectief naar verwachting in staat om voldoende op te schalen.

In het zelfvoorzienende scenario is dit is dus nog 12 GW meer dan voorzien in NL2050.

Dit rapport bouwt op een analyse van het Klimaatakkoord over de ruimtelijke mogelijkheden van de Noordzee uit 2018 (388 pagina's) waarin ook de opties voor veel meer wind op zee worden geanalyseerd. https://www.klimaatakkoord.nl/documenten/publicaties/2018/02/21/ruimtelijke-verkenning-energie-en-klimaat

Ook het PBL heeft een advies geformuleerd in 2018 over de future of the north sea waarin ook de grotere hoeveelheden windenergie in de beschouwing worden meegenomen en als realistisch worden gezien. https://www.pbl.nl/en/publications/the-future-of-the-north-sea

Natuurlijk moet er een grondige discussie plaatvinden over de belangen van de verschillende functies van de Noordzee. Daarvoor is recent (2020) een Akkoord voor de Noordzee gesloten met de meeste belanghebbenden. Ook daarin komen de mogelijke grotere behoefte aan windenergie aan de orde. https://www.rijksoverheid.nl/documenten/rapporten/2020/06/19/bijlage-ofl-rapport-het-akkoord-voor-de-noordzee

[email]

Pricing and privacy: On page 21: "A financial viable system is possible when the average price one gets for delivering electricity to the net is around € 7 per kWh or more. I presume that this must be 7 cts per kWh."One can assume that in the future the network manager can access the electrical power that is consumed and also delivered by each home on a continuous basis".

Don't you expect problems with the privacy watchdog because this is a violation of the AVG?

Reply: The usual warrants apply, as they are currently in place for the "slimme meter", see:

https://autoriteitpersoonsgegevens.nl/nl/onderwerpen/financiën/slimme-energiemeter