Infographic for EU-Scores publication
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Multi-source offshore energy parks can play an important role in our future renewable electricity system

The countries around the North Sea are building out a renewable energy system at a remarkable speed. Especially wind and solar capacity is added fast. In the Ostend Declaration of energy ministers, the energy ministers of Belgium, Denmark, Germany, France, Ireland, Luxembourg, the Netherlands, Norway and the UK have set targets to install 120 GW of offshore wind in 2030 and 300 GW in 2050 [1]. The Netherlands have set offshore wind targets of 21 GW in 2030 [2] and 70 GW in 2050 [3]. Recently the government also set a target of 3 GW offshore floating solar in 2030 [4].

Several countries, like Belgium, Germany, Denmark and the Netherlands, are also developing Energy Islands. These artificial islands will serve as hubs to which several multi-source offshore energy parks can be connected and on which multiple auxiliary systems can be installed like battery storage, power-to-X converters, data centers, HVDC equipment and interconnection with other countries. Also, maintenance services and accommodation for personnel can be installed on the islands (see figure 1).

Figure 1: Artist impression of the Danish energy island VindØ (image source: VindØ consortium)

Multi-source offshore renewable energy parks can play an important role in this emerging renewable energy system. By combining wind, solar and/or wave energy in one park, more efficient use can be made from the available space (see figure 2). The capacity factor of the whole park can be raised by combining different sources of renewable energy. In this way more efficient use of the electrical infrastructure can be made and the overall system costs are reduced.

Figure 2: Artist impression of a multi-source offshore energy park consisting of wind and solar installations (source: EU-Scores)

In the DMEC led EU-SCORES project the first multi-source offshore energy parks will be demonstrated. The company Oceans of Energy will demonstrate a 3 MW offshore floating solar PV plant off the coast of Belgium and the company CorPower will demonstrate an array of four wave energy devices off the coast of Portugal with a total installed capacity of 1.2 MW [5]. These two companies will be supported by 15 partner companies and institutions from nine European countries.

All these developments are part of the complete overhaul of the energy system, from a fossil fuels-based system to a renewables-based system. The big difference between these two systems is that fossil fuels deliver dispatchable power. This is power that can be delivered on demand. While the main renewables (solar and wind) are non-dispatchable, or only dispatchable in the sense that they can be switched off (curtailment). A system with a base load of solar and wind needs a method to balance supply and demand on an hourly basis, and the day-ahead electricity market price will serve as this intermediate to balance supply and demand.

Since the installed capacity of solar and wind will be much higher than the peak electricity demand, there will also be an important role to play for flexible loads. These are processes that only switch on when the electricity price is below a certain level. For example, the Netherlands is planning to install 70 GW of offshore wind power in 2050, while the average electricity demand will be around 25 GW at that time [6]. The surpluses will be consumed by these flexible loads.

Since solar and wind production will form the basis of the whole energy system, the average price of electricity (per MWh) will be lower than the average price of fuels (per MWh) that are derived from this electricity. In a fossil fuel-based system this is the other way round and thus there is a preference to apply fuel, while there will be a preference to use electricity in a solar and wind-based system. This is called electrification and will affect all sectors of the energy system and especially transportation, space heating and industry. An important aspect is that by using electricity, much higher process efficiencies can be reached than by using fossil fuel. Electric cars are around three times more efficient than fuel-based cars and electric heat pumps are three to five times more efficient than fuel-based heaters. This also means that the primary energy production can be reduced considerably. When there is a very high production of renewable power, the electricity can also be used directly for heating (power to heat).

There are also other options than solar, wave and wind for a future Dutch zero CO_2 electricity system like for example biomass and nuclear power. The installed capacity of biomass electricity production is now around 1.5 GW. About half of this is biogas and the other half is mostly wood pellets that are co-fired in coal plants. The government wants to stop this co-firing in 2025 since the coal plants are phased out. The Dutch government is planning to build two new nuclear power stations with a total installed capacity of 3 GW. Since nuclear power is baseload power, the average kWh price over a year will be rather low. Nuclear power can only compete if very strong cost reductions are assumed for future nuclear plants and if the Dutch government guarantees the financing during development as well as the future electricity price [7].

DMEC created an infographic for the Dutch situation for a renewable electricity system with the technologies under development and their role in the system (see figure 3). Companies have performed simulations for the electricity system for The Netherlands around 2050 [6,7]. Within the EU-Scores consortium LUT university of Finland is specialized in this work. These simulations generally show that a fully renewables-based system is not only possible but also cost effective in a zero CO_2 emission energy system.

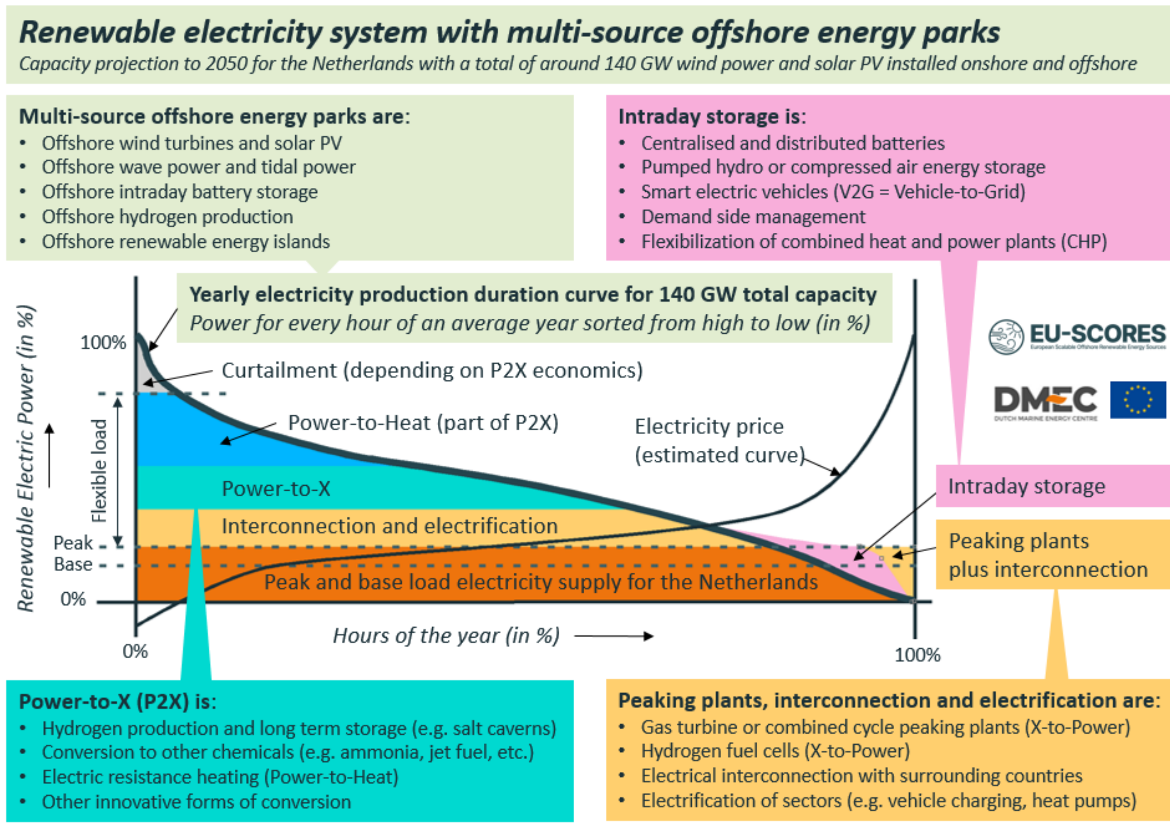

Figure 3: Infographic for the future renewable electricity system with multi-source offshore energy parks. Capacity projection for the Netherlands with a total (onshore and offshore) installed capacity of around 140 GW wind and solar.

In the projection for the year 2050, we assume around 140 GW installed solar and wind capacity in 2050 [6], of which around 70 GW wind and 70 GW solar. The thick black line in the graph shows the hourly power production of these plants sorted from the highest (left side) to the lowest (right side) and expressed as a percentage of the maximum power. This is called a duration curve. Almost the whole year round the solar and wind production is sufficient to fulfil the peak and base load electricity of the Netherlands (dashed horizontal lines for peak and base load). If the solar and wind parks produce around 20% of their maximum capacity, they already reach this production level. So, we could call this the baseload production level. At the right side of the graph, we see that there are some periods where the baseload production is not reached. In that case the electricity price goes up (thin black line) and other, more expensive, technologies step in to cover the demand. Because of the big differences in electricity price that will occur within a single day (think of night and day on a clear summer day), there will be a good business case for intraday electricity storage, like battery storage. Only if these intraday storages are not able to supply sufficient demand, the peaking plants will be switched on to deliver the remaining power. These are the most expensive producers in the system (in euro per MWh) and they will use green hydrogen or biogas to deliver power. These plants will also guarantee that there is always sufficient dispatchable power available to fulfil the demand. According to a recent simulation study [8], these will be open cycle gas turbines. Combined cycle plants (gas turbines with an extra steam cycle) will be too expensive (in euro/MWh), because of the rather low full load hours of the peaking plants (in the order of magnitude of 500 hours per year).

On the left side of the graph, we see that there will be large surpluses, which will be used to supply electricity to surrounding countries (interconnection) or to deliver electricity to sectors that nowadays still mostly run on fossil fuel (electrification). Remaining surpluses will be converted to hydrogen, to other chemicals or directly to heat (together called Power-to-X; where X can be anything). There might still be a small surplus for which there is no application (grey top left part), because it only occurs very occasionally with strong winds and clear skies across the country. During these hours, solar and wind plants might have to reduce their production (curtailment), which is financially not a burden but a benefit as the electricity price will be negative during these hours (thin black line).

Wave and tidal energy will have their role in this emerging renewable power system. Electricity prices will be high when there is not much production of wind and solar. Tidal power has the advantage that it is not related to wind and solar power, and it is fully predicable. Wave power is produced by wind power; however, waves can roll on for thousands of kilometres. The waves that batter the Portuguese coast are also generated in the more northerly Atlantic Ocean and thus far less related to local winds than the waves in the Dutch North Sea, which are mostly generated by more local winds. The great wave potential along the European Atlantic coasts can deliver supplementary production to solar and wind production [9]. Wave energy potentials like these can be found all around the world's oceans and will be further assessed in subsequent publications by DMEC.

DMEC has developed a simulation tool with which the hourly production of offshore multi-source parks can be calculated as well as the day-ahead electricity price in the Dutch electricity market. With this tool, multi-source offshore renewable energy parks can be optimised, and the business case of intraday electricity storage and power-to-x investments can be calculated. The results of the simulations will be presented at the upcoming European Wave and Tidal Energy Conference: EWTEC-2023 in Bilbao in September.

References:

1. Ostend declaration on the North Seas as Europe's green power plant, April 2023
2. Offshore wind 2030 The Netherlands: https://www.rijksoverheid.nl/actueel/nieuws/2022/06/10/planning-windenergie-op-zee-2030-gereed
3. Offshore wind 2050 The Netherlands: https://www.rijksoverheid.nl/actueel/nieuws/2022/09/16/nederland-maakt-ambitie-wind-op-zee-bekend-70-gigawatt-in-2050
4. Offshore solar 2030 The Netherlands: https://www.rijksoverheid.nl/actueel/nieuws/2023/04/26/extra-pakket-maatregelen-dicht-gat-tot-klimaatdoel-2030
5. EU-Scores website: https://euscores.eu/
6. B. den Ouden c.s. Klimaatneutrale Energiescenario's 2050 (scenario: nationale sturing), Berenschot, March 2020
7. E.J. van Druten c.s. Scenariostudie kernenergie, Witteveen en Bos, eRisk Group, September 2022
8. ETN global, Hydrogen Deployment in Centralized Power Generation, April 2022
9. Kássio Silva c.s., Inter- and intra-annual variability of wave energy in Northern mainland Portugal: Application to the HiWave-5 project, Energy Reports, Elsevier, 2022