WP2 TASK 1

Energy resources and their efficiencies

ABSTRACT

The activities of task 2.1 involved the detailed analysis of Finland's renewable electricity and CO_2 sources in the strategic context of energy infrastructure planning. The task identified PtX-related regional opportunities and challenges by comparing and evaluating location-specific metrics like electricity usage, district heat demand, industrial CO_2 emissions, and available land space. Geographic information system (GIS) tools were used to identify the exact location and the production potential of renewable electricity. Furthermore, the identified wind and solar potentials were compared against current and expected future electricity demand and compared with the location of large-scale CO_2 point sources, and district heat demand. The analysis suggests that Finland has the potential to produce even above 10% of EU's renewable electricity due to significant wind and solar potential. Our land-use based estimate for theoretical maximum wind power potential reached 1600 TWh (sensitivity analysis ranged between 700 – 2500 TWh), of which around 70% was clustered in North Ostrobothnia and Lapland. Theoretical maximum solar PV potential was evaluated to be 186 TWh for all rooftops, peat areas and meadows, increasing to about 1300 TWh when all agricultural fields are included. Although the solar PV sites are scattered into small segments, a significant portion of the potential is located along the coastal area in Southern and South-Western Finland. These estimates provide a basic understanding about energy transport needs between the areas of Finland, providing a solid foundation for Finland's further energy infrastructure planning.

MOTIVATION

A renewable electricity-based energy system will require diverse infrastructural elements, and the renewable power production and power grids will be the key enables of that. The new electricity infrastructure will need to be capable of connecting renewable power resources, alleviating the national bottlenecks, and ensuring transmission to neighboring countries. Molecule-based energy transmission will be necessary to deliver fuel and feedstock in hard-to-abate sectors such as steel manufacturing and heavy-duty transportations. Achieving carbon-neutrality objectives on time requires foresight in investment timing and efficient allocation of funds to the areas where the transmission needs are the greatest. Just and rational decision-making depends on an accurate understanding of resource locations, technical realities, and the socio-economic impacts of various energy solution pathways. This work enables data-driven strategic energy system planning in Finland.

RESULTS

Regional renewable power production potentials were evaluated on the basis of land availability. The land availability in turn, is highly dependent on the underlying assumptions regarding setback distances and various types of limiting criteria. This type of bottom-up approach allows a detailed analysis of the placement of individual wind turbines, providing baseline information for energy system studies, and for the power grid development, in particular. The detailed study that was made resulted a total production potential for wind power from around 700 TWh to an impressive 2500 TWh of annual production. Solar PV production potential could similarly reach 1300 TWh, although the majority of this potential lies on agricultural land which is currently in active use. Therefore, these figures represent the highest theoretical potential from a land-use perspective, and it can be assumed that the realistic production capability will be less than that. Combined production potentials for solar and PV are illustrated in **Figure 1**.

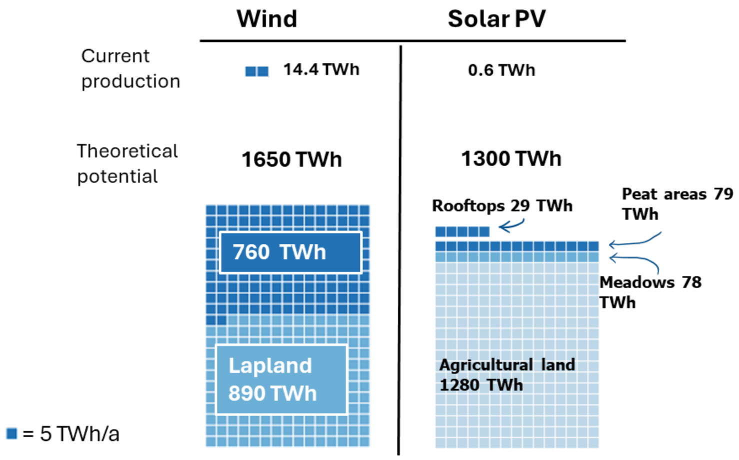

Figure 1. Finland's annual wind and solar PV production potential as obtained from the land-availability analysis.

In a future energy system, electricity will serve as a primary and flexible feedstock that can be converted into other energy carriers and products. The future energy system will be sector coupled and significant development steps have already been in that. In the future, production of hydrogen will couple electricity and heat sectors, and hydrogen production and use will further extend these coupling opportunities to other industrial sectors. One practical example of this extension is methanol, a versatile industrial feedstock and fuel that may be synthetized from H2 and CO2.

Figure 2 presents a regional overview of these opportunities. The figure points out renewable wind potential alongside current electricity demand in the area. Additionally, it shows the amount of electricity that is required to convert the available CO2 from large industrial point sources into methanol. In addition, the amount of heat produced in electrolyses and in syntheses is approximated. Full utilization of bio-based CO2 sources (into methanol) would require twice the amount of electricity currently used in Finland. Coupling the electrolyser waste heat to district heat network might be a challenge, as the availability of renewable power generation sites and hydrogen production will not take place in the regions having the largest district heat demand.

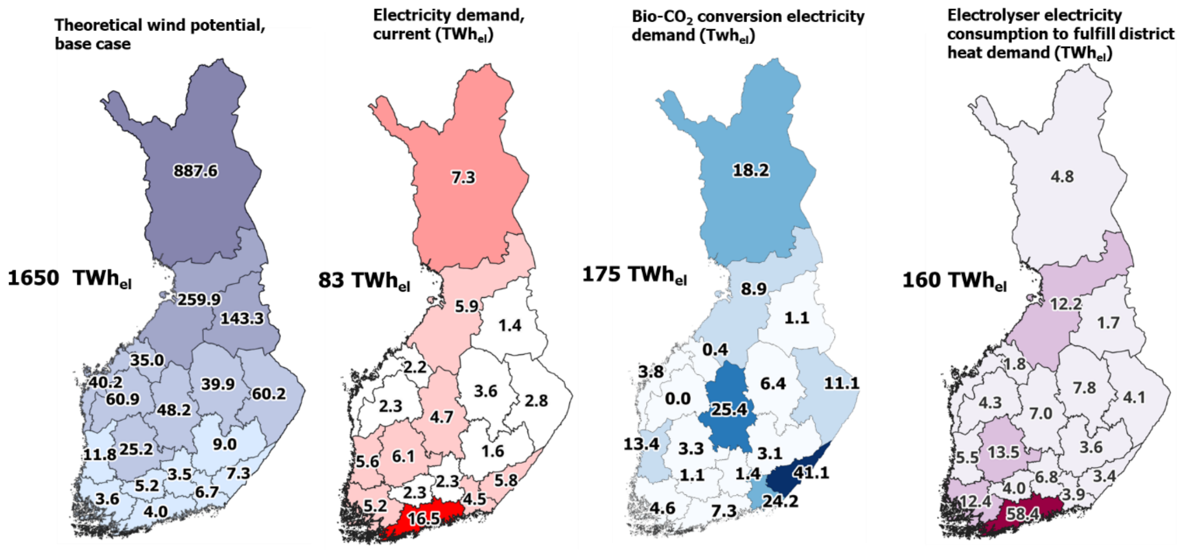

Figure 2. Regional overview of renewable wind production potential, current electricity demand, methanol, and heat potentials.

Hydrogen and CO_2 capture activities are likely to locate in special industrial sites, similar to the Porthos CCUS hub in Rotterdam. Implementing the first electrolyser plants alongside suitable CO_2 sources is relatively straightforward due to small volumes involved. However, as production volumes increase and the most accessible sources have been utilized, transport distances will increase as resources will need to be gathered from a larger area.

Figure 3 illustrates the situation where each wind site is integrated to the closest point source of CO_2. The figure shows that, some regions have a significant renewable wind generation potential but no CO_2 source, and vice versa. Transportation of CO_2 has been implemented on an industrial scale for decades. The study highlights the fact that CO2 will be a potential raw material to get transported alongside electricity and hydrogen pipeline transmission. Each of the stream will have their own characteristic transportation challenges and costs. So far it seems that no single transport solution can be said to be better the other.

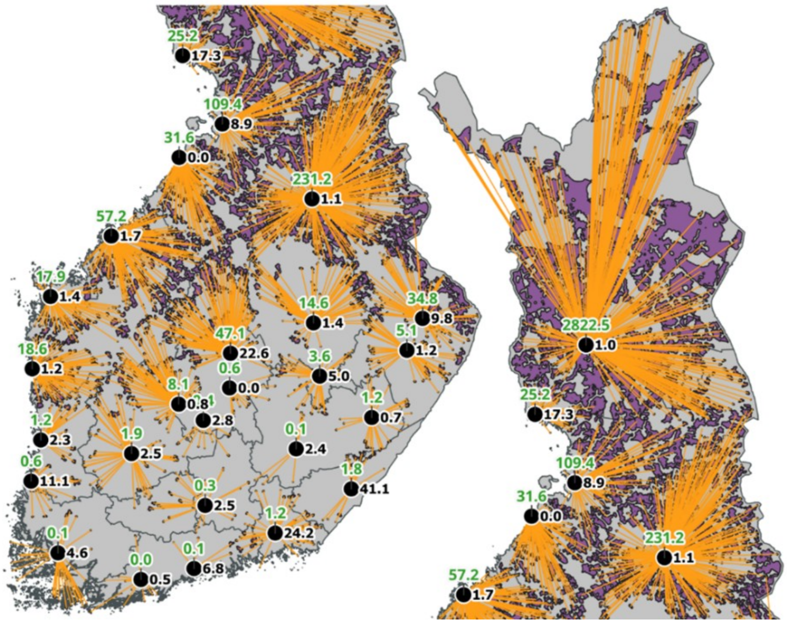

Figure 3. Demonstration of integration of wind sites with nearest CO2 sources.

APPLICATIONS/IMPACT

The land-use analysis indicates that Finland has the potential to generate more energy than it currently utilizes, providing a huge potential to convert and export the surplus electricity and PtX products. Renewable hydrogen (H_2) and bio-CO_2 hubs can be established into several locations, but effective transport solutions will be needed to fully utilize these resources. If implemented, Finland would have a significantly larger role as part of European economy. Some of Finland's renewable electricity potential locates in sensitive nature areas, meaning that deliberate actions are necessary to balance the economic interests with considerations of biodiversity, landscape, and social equity. Additionally, it can be noted that a major part of the bio-CO_2 resources locates in areas that are facing risks of lagging behind the development and these resources provide unique opportunities for them.

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