100% Renewable Electricity System in a 100% Renewable Energy System

Tomas Kåberger*, **

1. Introduction

During the 21st century electricity production from renewable energy has grown at accelerating speed as accumulating industrial experience has decreased costs. This process was predicted in a book, "Experience Curves for Energy Technology Policy" by Clas-Otto Wene, published by the OECD in the year 2000[1]. Wene described how solar and wind utilizing technologies had the potential to produce cheap electricity and suggested that if countries subsidize the industries while they were still expensive, the costs will fall to the level where the further growth would be driven by simple market competitiveness.

Some countries did so. Especially in Europe, and most remarkably substantial support to solar and wind development was provided in Germany where the successful ambition has been to grow the electricity production of electricity from renewable energy fast enough to be able to simultaneously decrease the use of fossil fuels and completely end the operation of nuclear power plants[2].

All over Europe renewable energy use has increased, and targets are not only set at national level but also by the European Union. For the European Union the ambitions are increasingly important. The European Union is, like Japan, dependent on importing fossil fuels and uranium. The most important supplier has been Russia, and this dependence has been particularly frustrating since Russia started to invade Ukraine[3].

2. Some factors behind the European success

The European Union is based on cooperation between European countries based on transparent fair competition between all companies in the region disregarding national borders. This requires regulation that must be respected by all member states[4]. In the electricity markets this has been a challenging reform, as electricity was traditionally considered to be of national importance and the idea of allowing power plants in other countries to compete was not easily accepted by all.

But more important was that rules prescribing open, fair competition provided for new decentralized electricity production outcompete the large-scale centralized generations controlled by the traditional electricity companies.

One of the principles of the electricity market is separation of the control of the electricity transmission system and the operation of electricity production. Electricity generators who want to connect to and use the electricity grid must fulfill some technical criteria regardless of what energy sources or technologies they use.

Trading electricity between producers and customers require a party to be balance responsible and economically responsible for the customers using the same amount of electric power as the producer provide at the same time. The transmission system operator is relying on a transparent short term balancing market to ensure balance, while the costs for these short-term balancing is passed on to the balance responsible actors who have failed to meet, they balance responsibility.

Unlike what some expected, the predictable variation of solar and wind power has proven easier to manage at low cost while the large and unpredicted failure of large nuclear and coal fired generators result in large costs for balancing large imbalance situation bring at short notice.

The stabilization of frequency and voltage in the very short fraction of a second to minute timescale is also technically important to manage. Traditionally this has been managed partly by the kinetic energy directly connected to the electricity grid via synchronous generators.

But with the development of battery technologies and power electronics, when this is no longer an

*Chair of Executive Board, Renewable Energy Institute
**Professor, Chalmers University of Technology

internal matter for power companies by dealt with by transmission system operators using an open transparent market the stabilizing services are increasingly provided by batteries and power electronics in connection with solar or wind installations. This is not only a European development, but also well known in the US [5], and in Australia [6]. Further it is not only in theory, but also in practice [7].

It has become obvious that the stabilizing energy provided by "rotating mass", or "inertia"of the old generators is small compared to what can be provided by batteries. In the ongoing auction for fast frequency response held by the Swedish transmission system operator, one integrator is offering half the purchased stability based on coordinated, privately owned, batteries [8].

The total cost of wind power in northern Europa has now fallen to a level that is lower the world market price of oil, often lower than the price of fossil gas and sometimes even lower that coal. If the European cost of CO_2-emissions is included it is generally true, that wind electricity is cheaper per unit energy than the fossil fuels [9].

As a result, several projects are in operation or under construction where fossil free electricity is used to produce fuels replacing fossil fuels. This happens in the steel industry with HYBRIT® and H2 Green Steel, but also for production of shipping fuels [10], and as feed stock for the traditionally fossil supplied chemical industry [11].

The operation of such plants, producing fuels from electricity, is price sensitive：When electricity cost more than fuels they will not operate. As a result, they will contribute to the balancing of the electricity system. In the longer term the replacement of fossil fuels outside the electricity system will make the balancing of the electricity system itself easier [12]. The understanding of this potential transition of the entire energy system has motivated the EU to develop a strategy for hydrogen development [13].

3. Conclusion

The success in making the predicted cost reduction into reality has not only made the replacement of fossil fuels in electricity generation economically beneficial but also opened for the replacement of fossil fuels in the whole energy system.

References

1) IEA, "Experience Curves for Energy Technology Policy", https://www.iea.org/reports/experience-curves-for-energy-technology-policy (July, 2000) (Accessed on December 25, 2023)
2) Wikipedia, "German Renewable Energy Sources Act", https://en.wikipedia.org/wiki/German_Renewable_Energy_Sources_Act (Accessed on December 25, 2023)
3) European Commission, "REPowerEU", https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en (Accessed on December 25, 2023)
4) European Commission, "Electricity market design", https://energy.ec.europa.eu/topics/markets-and-consumers/market-legislation/electricity-market-design_en (Accessed on December 25, 2023)
5) National Renewable Energy Laboratory (NREL), "Understanding Inertia Without the Spin" https://www.youtube.com/watch?v=b9JN7kj1tso (Accessed on December 25, 2023)
6) Mountain, B.R and Percy, S., 2021. "Inertia and System Strength in the National Energy Market：A report prepared for the Australia Institute". VEPC, Melbourne. https://australiainstitute.org.au/wp-content/uploads/2021/03/VEPC-system-security-report-FINAL.pdf (Accessed on December 25, 2023)
7) Andy Colthorpe, 2022. "Upgrade at Tesla battery project demonstrates feasibility of 'once-in-a-century energy transformation' for Australia". https://www.energy-storage.news/upgrade-at-tesla-battery-project-demonstrates-feasibility-of-once-in-a-century-energy-transformation-for-australia/ (Accessed on December 25, 2023)
8) Check Watt, "CheckWatt lämnar anbud på hälften av kapaciteten för snabb frekvensreglering", https://www.mynewsdesk.com/se/checkwatt/pressreleases/checkwatt-laemnar-anbud-paa-haelften-av-kapaciteten-foer-snabb-frekvensreglering-3293175 (Accessed on December 25, 2023)
9) Tomas Kåberger, 2018. "Progress of renewable electricity replacing fossil fuels" Global Energy Interconnection, Volume 1, Issue 1, January 2018, Pages 48-52, https://www.sciencedirect.com/science/article/pii/S2096511718300069 (Accessed on December 25, 2023)
10) Ørsted, 2022. "Ørsted assumes full ownership and takes final investment decision on FlagshipONE, the largest green e-methanol project in Europe". https://orsted.com/en/media/news/2022/12/20221220609311 (Accessed on December 25, 2023)
11) Louise Rasmussen, 2023. "LEGO, Novo Nordisk agree to buy green methanol for plastic production". https://www.reuters.com/business/sustainable-business/lego-novo-nordisk-agree-buy-green-methanol-plastic-production-2023-04-20/ (Accessed on December 25, 2023)
12) Kåberger, T. (2022). Turning around the direction of the fuel-electricity system. Academia Letters, Article 5578. https://doi.org/10.20935/AL5578 (Accessed on December 25, 2023)
13) European Commission, "Key actions of the EU Hydrogen Strategy". https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/key-actions-eu-hydrogen-strategy_en (Accessed on December 25, 2023)

＜About the Author＞

Tomas Kåberger

Tomas Kåberger has been the Chair of Executive Board of Renewable Energy Institute since its foundation in 2011. Academically, he got an MSc in Engineering Physics, a PhD in Physical Resource Theory, and Docent in Environmental Science at Chalmers. He has been professor in International Sustainable Energy Systems at the International Institute for Industrial Environmental Economics at Lund University, and he is currently affiliate Professor of Industrial Energy Policy at Chalmers University of Technology.

Industrially, he has had leading roles in companies providing fuels and technology in the bio-energy industry, another company developing sustainable energy solutions for the automotive industry, and a company operating wind power plants. Currently he serves on the board of Persson Invest, a company building wind and solar plants and a retailer of cars, trucks and busses; increasingly electric. He is also the Chairman of the Swedish Delegation for a Circular Economy.

He has served as Director General of the National Swedish Energy Agency, Board of Director of the power company Vattenfall, and as member of the Swedish Climate Policy Council.

Other key positions he has held include board of the Swedish and European environmental citizens organizations, government committees and commissions on energy and environmental policy in Sweden, as well as member task forces under China International Council for Cooperation on Environment and Development.

He is a member of the Royal Swedish Academy of Engineering Sciences and the Swedish Society of Energy Economists.