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A full supply with 100% renewable energies including storage is already competitive today and would reduce energy costs

The German example

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Short Study
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Executive Summary:

For about a decade, scientific studies have been showing that the costs of conventional energies (oil, natural gas, coal & nuclear power) significantly surmount those of renewable energies, if the immense damage costs are included (Fraunhofer Institut ISE, 2021; Reuster & Küchler, 2013). However, this realization has not yet resulted in a change of political direction that would bring about a full supply of 100% renewables by 2030. The main counterargument is that electricity generation costs from conventional energies are lower than those from renewable energies. The external damage costs are often ignored, although they could be largely avoided by employing renewable energies.

Since around 2017, however, the electricity generation costs of solar and wind power have fallen far below the electricity generation costs of conventional power plants such as natural gas, coal or nuclear (Fraunhofer Institut ISE, 2021). Yet, this new development is likewise largely rejected based on the argument that the total system costs, including for instance, the storage costs necessary for complete security of supply, are far above those of conventional power generation.

According to this short study, however, the latest developments in the price decline of renewables and storage technologies in conjunction with the price increases of conventional power generation paint a different picture: Since 2021, reliable power supply from 100% renewables is cheaper than power from newly built conventional power plants, also when storage costs are included. From 2025 onwards, conventional power plants that are already in service will no longer be economically competitive with newly built full-supply systems with 100% renewable energy. This study shows that even without considering the damage costs, a full supply with renewable energies would allow cheaper electricity costs in the near future.

Especially now, in the energy price crisis triggered by fossil and nuclear power generation, switching to renewable energies can be demonstrated to offer a path to socially acceptable energy costs that relieve the burden on the economy. Numerous studies indicate that electromobility already has cost advantages over gasoline- and diesel-powered private transport (ADAC, 2021; BMU, 2021) and heating with green electricity is also significantly cheaper than with petroleum or natural gas (BDEW, 2021). Since green electricity costs will continue to fall in the coming years according to this EWG short study, the conversion of all energy sectors to 100% renewable energy is the all-important way out of the current and coming energy cost surges. Consumers as well as production companies can reduce their energy costs by a complete conversion to renewable energies. Depending on the object, the necessary investments should pay off within a few years against the costs of purchasing increasingly expensive energy from oil, natural gas, coal or nuclear power.

This study shows that there are no more excuses: Climate protection with 100% renewables pays off compared to climate-destroying conventional energies even if the external damage costs are disregarded and a year-round security of supply is aimed for.

The results in detail:

The cost of a full system transformation has fallen sharply by 2020 - and will continue to fall. This is according to calculations using the Energy Watch Group's Energy System Model, which show how the costs of a new, 100% renewable and reliable energy system to supply all sectors have evolved over the last decade and are on track for the coming years with rapid expansion of renewables and storage.

In contrast, the costs of conventional power generation have continued to rise. Cost drivers are rising natural gas and coal prices as well as carbon prices (Federal Reserve Bank of St Louis, 2021; index mundi, 2021; icap carbon action, 2021). This is also visible on the power market, where price quotations are mainly determined by the cost of conventional power generation. In September 2021, these rose to the highest level since the European liberalization of energy markets in the late 1990s (Statista, 2021). At the same time, the urgency of transforming the energy system to be climate-compatible is constantly increasing, while reducing emissions with renewables such as wind and solar is steadily becoming cheaper.

Most importantly, even the cost of year-round reliable energy systems based on renewables has fallen sharply over the past decade. These systems, integrated by sector coupling with full renewable supply, deliver energy from renewables for all energy sectors - heat and electricity for industry, households, commerce and mobility - even in weeks of *Dunkelflaute*- at every hour of the year. As a result, the system costs of full renewable energy supply will be below the total costs of coal and nuclear power plants at current input costs as early as 2025. Since 2010, when renewable energy was still non-competitively high, the costs have steadily fallen until today, even below those of non-sustainable energy options. This is valid even if the environment is only partially taken into account in the cost calculation.

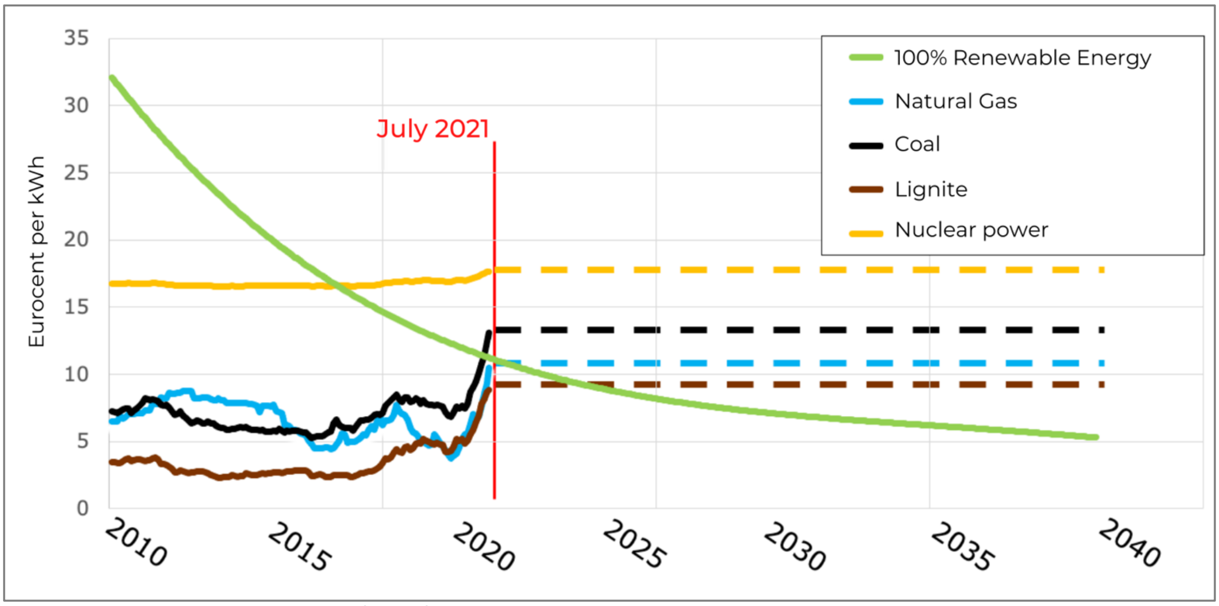

Figure 1: Average energy costs for a fully renewable energy-based system in Germany and current electricity production costs of conventional power generation technologies. Optimization of the renewable energy system based on data from EWG Scenario 2 presented in the Germany study (Traber, Hegner & Fell, 2021) and learning curves based on Ram, et al. (2019). The data for the development of natural gas and coal prices are based on data from the Federal Reserve Bank of St Louis (2021) and index mundi (2021) and were adjusted to continental Europe. Prices for emission rights in European emissions trading can be found at icap carbon action (2021). Here, nuclear energy is set at a premium of 3.5 euro cents per kWh to hedge nuclear risks (Günther, Karau, Kastner, & Warmuth, 2011). The presented constant costs for conventional energy supply after 2021 do not represent an energy forecast, but are only intended to visualize its foreseeable inefficiency.

Figure 1 shows that the costs of an optimal full-supply mix of 18 generation and conversion technologies and storage [1] for given costs and potentials, will fall significantly, soon rendering conventional energy sources entirely uncompetitive.

In 2010, an average zero-emission investment project for full supply (24x7 hours a week & 52 weeks a year) for electricity, heat and transport had costs of 32 euro cents per kWh, while in 2020 it was only 12 euro cents. Costs will average 9 euro cents in 2025. In contrast, the private electricity generation costs with fossil fuels like natural gas, hard coal and lignite coal, which are also shown, have risen sharply in the last decade, while nuclear power has been uncompetitive for several years, even though the unresolved costs of final storage of radioactive waste continue to be passed on to the community.

Another result of the calculations shows that even depreciated conventional plants will soon make annual losses from their day-to-day operation (Fig. 2). By 2028 at the latest, conventional energies will no longer be able to cover their costs in a competitive environment, even after the investments have been written off. And only the coverage of nuclear energy risks by the society, with billions of euros burdening the state budgets, can postpone the situation for this technology until around 2040. This means that by 2028 at the latest, not only all conventional new plants but also conventional existing plants will be economically obsolete due to the low costs of renewable full supply. Since prices cannot exceed the costs of the cheapest - i.e. renewable - energy sources in the medium and long term given functioning competition, it is already foreseeable that the

[1] Rooftop and ground-mounted photovoltaics, onshore and offshore wind, small and large bioenergy power plants, battery storage and battery storage interfaces, heat pumps, heat storage, hydrogen storage, hydrogen electrolysers, fuel cells and thermal hydrogen power generation (CCGT), geothermal and heating rods are considered. In addition, there are run-of-river and pumped storage power plants, which are assumed here to be non-expandable.

operation of conventional plants is no longer worthwhile on the market. The subsidies for conventional plants and the regulatory obstacles for renewables can therefore only postpone the transformation, but not permanently prevent it.

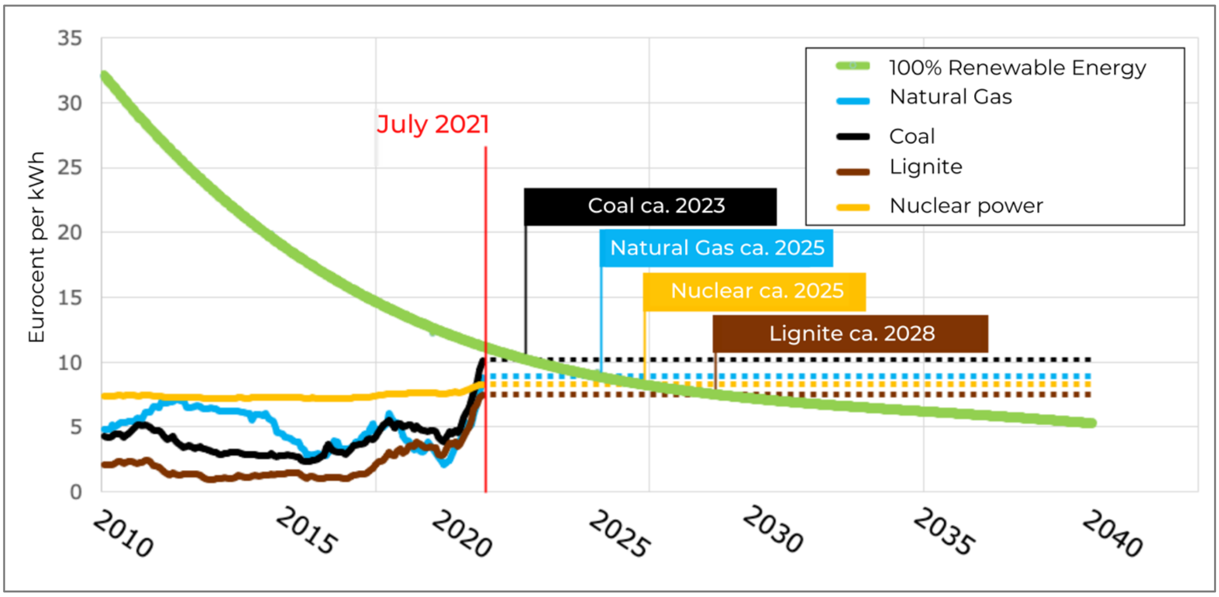

Figure 2: Operational costs of conventional plants versus full costs of renewable energy systems. These costs have fallen below the costs of unsustainable energy options from an uncompetitively high level in 2010, and that holds true even when the environment is not fully accounted for in the cost calculation.

This revolution in the fundamentals of energy economics is only being perceived very slowly in society. Mostly, it is just referred to the dramatic cost reduction of wind and solar power generation. However, this finding is then frequently invalidated in the public discussion by the question of winter supply at night and during periods of no wind. Thus, by clarifying low full-supply costs for 100% RE systems with their now comparably low system costs for storage, which hardly account for more than 20% of full-supply costs, it becomes apparent that the *Dunkelflaute* argument is nowadays only of secondary importance, at least from a technical-economic point of view.

As a basis for climate protection, the scale of the transformation to renewables must match the pace of past technological revolutions and cannot be held up by a protracted discussion of targets (e.g., climate neutrality by 2045). Crucial to the dynamics in such a transformation is the point at which the utilization of the old capital stock declines ever more rapidly. The old infrastructure then is hit by fixed cost progression: the lower the demand for these infrastructures, the higher become their unit costs and thus the cost-covering prices. This in turn leads to an accelerated decline in demand, and so on. If one wants for instance to keep the German lignite industry in operation because of the jobs in structurally weak areas, growing additional subsidies would have to be paid. This applies similarly to the use of natural gas, which has long since triggered a permanent and growing need for state subsidies due to state-subsidized infrastructures.

If, in contrast, the tipping point in economic viability caused by declining infrastructure use and presented in this study is facilitated by very ambitious and clear expansion scenarios, especially at the regional level, the path is paved for an emission-free, cost-effective, and climate-protecting energy supply with 100% renewables by 2030. This can also be expected to result in an increase in employment.

Literaturverzeichnis

ADAC. (2021). *Kostenvergleich e-Fahrzeuge + Plug-in Hybride gegen Benziner und Diesel.* Von https://assets.adac.de/image/upload/v1617875633/ADAC-eV/KOR/Text/PDF/E-AutosVergleich_zh4t1e.pdf abgerufen

BDEW. (2021). *Heizkostenvergleich Alt- und Neubau 2021.* Von https://www.bdew.de/presse/presseinformationen/bdew-veroeffentlicht-heizkostenvergleich-alt-und-neubau-2021/ abgerufen

BMU. (2021). *Effizienz und Kosten: Lohnt sich der Betrieb eines Elektroautos?* Abgerufen am 10 2021 von https://www.bmu.de/themen/luft-laerm-mobilitaet/verkehr/elektromobilitaet/effizienz-und-kosten

Federal Reserve Bank of St Louis. (20. 10 2021). *Global Price of Natural Gas, EU*. Von https://fred.stlouisfed.org/series/PNGASEUUSDM abgerufen

Fraunhofer Institut ISE. (2021). *Stromgestehungskosten Erneuerbare Energien.* Von https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/DE2021_ISE_Studie_Stromgestehungskosten_Erneuerbare_Energien.pdf abgerufen

Günther, B., Karau, T., Kastner, E.-M., & Warmuth, W. (2011). *Berechnung einer risikoadäquaten Versicherungsprämie zur Deckung der Haftpflichtrisiken, die aus dem Betrieb von Kernkraftwerken resultieren.* Von https://www.bee-ev.de/fileadmin/Publikationen/Studien/110511_BEE-Studie_Versicherungsforen_KKW.pdf abgerufen

icap carbon action. (2021). *Allowance Price Explorer*. Von https://icapcarbonaction.com/en/ets-prices abgerufen

index mundi. (2021). *Coal, Australian thermal coal Monthly Price - US Dollars per Metric Ton*. Von https://www.indexmundi.com/commodities/?commodity=coal-australian&months=120 abgerufen

Ram, M., Bogdanov, D., Aghahosseini, A., Gulagi, A., Oyewo, S. A., Child, M., & Caldera, U. (2019). *Global Energy System Based on 100% Renewable Energy*. Von http://energywatchgroup.org/new-study-global-energy-system- based-100-renewable-energy abgerufen

Reuster, L., & Küchler, S. (2013). *Was die Energiewende wirklich kostet.* Forum Ökologisch-Soziale Marktwirtschaft e.V. (FÖS). Abgerufen am 2021 von https://foes.de/publikationen/2013/2013-09-FOES-Studie-Was-die-Energiewende-wirklich-kostet.pdf

Statista. (2021). *Börsenstrompreis am EPEX-Spotmarkt für Deutschland/Luxemburg von August 2020 bis August 2021*. Von https://de.statista.com/statistik/daten/studie/289437/umfrage/strompreis-am-epex-spotmarkt/ abgerufen

Traber, T., Hegner, F., & Fell, H.-J. (2021). *An Economically Viable 100% Renewable Energy System for All Energy Sectors of Germany in 2030*. Von https://doi.org/10.3390/en14175230 abgerufen

Appendix

€-cent per kWh	100% renewable energies
2010	32,0
2015	19,9
2020	12,2
2025	9,1
2030	7,2
2035	6,1
2040	5,3

Table 1: Electricity production costs of full supply of all energy sectors with renewable energies, source: own calculations with the linear energy system model of the Energy Watch Group.

Capex		2010	2015	2020	2025	2030	2035	2040
PV open space plants	€/kW	2100	950	431	333	275	235	204
PV roof systems	€/kW	2700	1360	907	737	623	542	484
Wind onshore	€/kW	1400	1250	1150	1060	1000	965	940
Wind offshore	€/kW	3700	3220	2880	2700	2580	2460	2380
Cogeneration plant	€/kW	799	725	651	577	503	429	355
CHP Biogas	€/kW	3750	3500	3250	3000	2750	2500	2500
Battery	€/kWh	700	400	251	163	117	94	80
Battery interface	€/kW	300	200	135	91	67	54	46
Heat pump	€/kW	868	850	810	768	740	718	704
Heat storage	€/kWh	60	50	40	30	30	25	20
H2-Electrolyzer	€/kW	915	800	685	500	363	325	296
H2-CCGT	€/kW	5000	3000	2000	975	950	925	900
Geothermal	€/kW	6228	5637	5045	4470	3850	3244	2700
Fuel cell	€/kW	7754	6500	5280	4060	2806	2200	1835

Table 2: Cost development of investments in crucial plants for full supply with renewable energies in accordance with (Ram, et al., 2019). Unmentioned technologies as in (Traber, Hegner, & Fell, 2021).

Opex yearly fixed		2010	2015	2020	2025	2030	2035	2040
PV open space plants	€/(kWel*a)	9	8	8	7	6	5	4
PV roof systems	€/(kWel*a)	9	8	8	7	6	5	4
Wind onshore	€/(kWel*a)	24	23	23	21	20	19	19
Wind offshore	€/(kWel*a)	135	113	92	84	77	71	67
Cogeneration plant	€/(kWel*a)	19	18	17	16	15	14	13
CHP Biogas	€/(kWel*a)	19	18	17	16	15	14	13
Battery	€/(kWel*a)	3	3	3	3	2	2	2
Battery interface	€/(kWel*a)	2	2	2	1	1	1	1
Heat pump	€/(kWel*a)	17	16	16	15	7	7	7
Heat storage	€/(kWel*a)	1	1	1	0	0	0	0
H2-Electrolyzer	€/(kWel*a)	30	27	24	18	13	11	10
H2-CCGT	€/(kWel*a)	19	19	19	19	19	19	19
Geothermal	€/(kWel*a)	0	0	0	0	0	0	0
Fuel cell	€/(kWel*a)	3	3	3	3	2	2	2

Table 3: Development of the annual fixed operating costs of essential plants for the full supply of renewable energies. Variable Opex as in (Traber, Hegner, & Fell, 2021).

		Natural gas	Coal	Lignite	Nuclear power
Capital expenditures	€ per kW	775	1500	1500	8000
Efficiency	-	60%	41%	40%	30%
Full-load hours 2018	h	2837	3081	6725	6570
Life span	a	35	35	35	35
Interest rate	real yearly	5%	5%	5%	7%
Fuel prices	€-cent per kWh_therm	3,7	1,5	0,1	1,0
Emissions costs *	€-cent per kWh	2,0	5,8	6,9	1,2
Fuel costs		6,2	3,7	0,3	3,3
Fixed operating costs		0,7	0,6	0,3	0,3
Fix costs	€-cent per kWh	1,7	3,0	1,4	9,3
Liability premium					3,5
Operative Kosten gesamt	€-cent per kWh	8,8	10,1	7,5	4,8
Total power generation costs	€-cent per kWh	10,5	13,1	8,9	17,6

Table 4: Cost calculation fossil and nuclear power generation July 2021. *Based on prices for emission rights of 58 euros per ton of CO2.