RAULI PARTANEN

WRITING ABOUT ENERGY

A COMPANION FOR JOURNALISTS AND READERS INTERESTED IN ENERGY ISSUES

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Contents

Introduction

Accuracy, fairness, and disclosure of all essential facts. The most important goal for our publication is the trust of our readers.

Expressions like the above sentiment regularly appear in the stated principles of mainstream publications. These methods guide journalists in writing and reporting. And since we now live in the age of internet, when anyone can become a "publisher" and disseminate misinformation or outright disinformation without consequences, such principles prove more valuable than ever—for writers to get the facts right, readers to stay informed, and society to adopt evidence-based policies.

As a result of this expanded information "market," many publications feel pressure to generate ever-growing number of clicks and views, not in the least because these interactions produce revenue. And psychologically speaking, the easiest and fastest way to draw in views, likes, and shares is an appeal to emotion—the stronger the better. Of course, this approach does not typically equate to good journalism, as the latter displays its value over time and at a deeper level.

Unfortunately, news and misinformation cycles of recent years offer a clear warning of the dark places lack of trust, fairness, accuracy, and disclosure of essential facts can lead societies around the world. Likewise, opinions and ideology have come to dominate while respect for science and evidence continues to recede. Each day, public figures say increasingly outrageous things without repercussions, and social media platforms intensify polarization and division rather than encouraging discussion or learning.

Combine this situation with our need to mitigate climate change rapidly, and disaster obviously looms. The reality is any effective climate solution needs virtually all humanity behind it. Indeed, not just Greens, not just Democrats or Republicans, not just left or right, and not just Christians or Muslims or those of any other belief system—the planet simply needs *everyone*. And Earth not only needs them, but needs them to agree. As such, this represents one of the biggest challenges facing our species—not a technological challenge, or perhaps even an economic one, but just the sheer difficulty of getting large numbers of people to agree, work together, and accomplish significant changes at scale.

At bare minimum, that scenario requires the dissemination and accessibility of high-quality, unbiased information. And to that end, this handbook aims to provide a rubric for evaluating information. The text can help aspiring or veteran journalists write more informative pieces on energy and climate issues. It can also aid policymakers and climate activists read such journalism with a more critical eye. Some of the key topics include the following:

Basic concepts and units. If we discuss quantities with wrong or unclear units, we risk adding to confusion rather than dispelling it, and the same goes for concepts and technical terms. For example, the distinction might sound insignificant to a layman, but “power” and “energy” refer to different concepts, just like “energy” and “electricity.” Similarly, “renewable energy”, a very broad and somewhat ill-defined term, is often used when “wind and solar” would fit more accurately. And since human actions and success depend considerably on the language used to describe problems and solutions, it should remain as accurate and informative as possible.

Understanding the scale of the required energy transition is paramount, so as to dispel any notion the problem is already solved or that we can accomplish the overall goal with small individual contributions. Indeed, size matters, and scale needs context. With blinders on and no wider context, fairly meaningless energy innovations can appear as legitimate breakthroughs. Without an understanding of the true scale, news stories can give the false impression big problems can be solved with only small actions, in turn leading to a lack of urgency in deploying large-scale solutions.

Understanding the essential role energy plays in our complex society also proves essential if one aims to write informative articles. Admittedly, this topic covers a large range of issues, which is why the second part of this handbook explores some of the most important. Indeed, in the Advanced Concepts section of this handbook, you can find more about various energy concepts, markets, and systems, such as the differences between price, value, and cost of energy.

The final section focuses on understanding science, balancing different viewpoints, and the crucial importance of proper context. It features arguments and articles related to nuclear power as case studies, given the authors’ experience in the field, writing several books and dozens of articles on related topics, and abundance of examples in the media and academia.

Energy and climate are tightly linked, which increases the urgency to "get it right" with energy issues. It is true sectors like agriculture, land management, and forestry contribute significantly to rising CO_2 levels and environmental degradation, as well as suffer from many of the same journalism-related issues as energy. But energy use accounts for roughly two thirds of manmade greenhouse gas emissions. So if we aim to slow climate change, net greenhouse-gas emissions from the energy sector must drop close to zero, and fast.

Further, energy is also a deeply geopolitical issue. A too high dependence on some other country to provide us energy at all times, without strings attached, is linked firmly to our ability to function and choose our own destiny and values to pursue. Day-to-day energy access and geopolitics operate on a different, shorter time scale than climate mitigation, but the importance of communicating the facts and issues clearly and correctly is critical for both. Hence, this handbook concentrates on energy.

Part One – Basic Concepts and Units

Power and Energy

Power and energy represent some of the most basic concepts, and unfortunately, people misunderstand them far too often. Watts (W)—often complimented with kilo (k), mega (M), giga (G), or tera (T)—is a unit of **power**. A watt hour (Wh) is a unit of **energy**. Our energy systems need both, and both are important. To simplify the comparison, "energy" refers to the phenomenon producing emissions and appearing in annual statistics, while "power" is what keeps society running from one second to the next. As a simple expression, energy equals power use over time. So if we use one kilowatt (kW) of power for an hour, that corresponds to one kilowatt hour (kWh). With this in mind, the following thought experiment can help explain the importance of both energy and power, as well as their differences.

First, imagine you received a full year's worth of food directly on your doorstep one afternoon. Then imagine an alternative scenario where it arrives every few days, specifically as you need it and according to your actual storage capacity.

Both examples deliver the same amount of food per year, but in the first example, you receive everything in a single day, so the "power" at which these calories arrive is enormous, likely overwhelming your capability to receive and store the vast majority of the food. All your fridges, freezers, tabletops, and closets will fill quickly, leaving most of the food to spoil before you can use or preserve it. Indeed, only a small fraction of the goods delivered will be used, while the nutrients, calories, and flavours of all the rest get wasted. By contrast, the second scenario would provide the same amount of food at a lower rate (i.e., lower power), one you can accommodate and manage.

One can easily see the first example makes no sense and would prove highly impractical at large scale. Yet public conversations largely focus on energy delivered over a period of time. Meanwhile, they ignore power and its relation to demand even though these topics are vitally important. For example, say a certain energy project can deliver 100 GWh of electricity over a year. As that story makes the news, much often remains unclear. Indeed, authors and commentators need to discuss the nature of delivery for that energy, not just the amount of energy: will it be delivered evenly across the year, according to demand, or unevenly and perhaps at impractical times?

This distinction is especially important when talking about energy sources like wind and solar—I.e., those that depend on the weather, a variable and unreliable phenomenon to say the least. People buy “wind power” from their utility, but in reality, they receive normal electricity from the grid (where all sources merge before distribution) as they need it, no matter the weather, yet subsequently provided with certificates indicating a certain amount of wind energy was produced over a certain period. During hours when wind cannot provide sufficiently to meet demand, other energy sources like natural gas or hydro cover the difference. And when wind is powerful and abundant, the extra production counts toward annual quotas, in turn earning certificates for sale.

Mixing energy and power can happen easily enough, and even more so for forgetting to add “hours” after megawatts (MW) when talking energy. Most informed readers can recognize these types of mistakes, but most casual readers will find the distinction far less obvious, potentially leading to big misunderstandings. For example, the “difference” between MW and MWh is often a thousand-fold! Further scenarios will accentuate this point.

For instance, imagine a power plant constantly running at one gigawatt for a full year, 24/7. It produces 1 GW of power at any given moment, but over the calendar year, it yields 8760 gigawatt hours of electricity, since a normal year consists of 8760 hours. But if an author confuses these two quantities, readers can be led far astray. Indeed, imagine an article saying either “A new power plant produces electricity at 8760 gigawatts,” or “A new power plant produces electricity at one gigawatt hours.” In fact, both are horribly wrong.

The latter one is much rarer, perhaps because forgetting to add “hours” in the end seems a more likely blunder than adding it mistakenly. In terms of content, the latter inaccuracy appears somewhat underwhelming as news, as a power-plant producing one GWh per year would be quite a small one. The former example, on the other hand, would mean the powerplant in question would have to be roughly 1,000 times larger than the biggest current power plants!

There are three basic types of power production. First is baseload power production, or power that is almost always on. This variety only changes production levels over longer time periods such as hours, days, or weeks. Baseload power sources include most coal, some natural gas, some biomass, some hydro, and most nuclear.[1] Next is variable power production, which produces energy depending on weather and time of year/day, and includes wind and solar power. And then there is flexible (or dispatchable) production, which can ramp production up or down rapidly when needed. Flexible production sources include most hydro, natural gas, some nuclear, and certain coal plants.

GIGA	MEGA	KILO	WATTS	
22	500	000	000	W Total generating capacity of the Three Gorges Dam
1	650	000	000	W The net power output of a European Pressurized Reactor (EPR), the most powerful nuclear power reactor available
	14	000	000	W Max power output of Haliade-X, world's largest commercial wind turbine by GE, with a 107-meter blade and a height of 260-meters
		10	000	W Maximum output of a working horse
		2	000	W A short burst of max power from an athlete. A hairdryer running at max power. An average heating element of a cooking stove
			700	W Average microwave oven. The level a horse can sustain for extended periods of time (i.e., one horsepower)
			400	W Peak human power sustainable for a couple minutes
			250	W Average maximum output capacity of a single solar panel
			75	W A sustainable average output of a healthy labourer for an 8-hour workday

Powerlevels of different things (approximate)

From an individual household to a nation of millions, developed societies feature a constant baseload demand for energy, and not just electricity, but also heating, cooling, transportation fuels, and industrial process steam. Indeed, even if electricity only accounts for a fifth of final energy use (we will come back to this point later), it remains the most familiar for many people, so using it as an example will prove instructive.

"Baseload demand" represents the minimum rate of electricity always in use "around the clock" for the entire year. The degree to which it varies from peak

1 All these have exceptions. Some countries such as France and Germany use nuclear to ramp up and down, for example.

PETA	TERA	GIGA	MEGA	KILO	WATTHOURS		
27	000	000	000	000	000	Wh	World total electricity generation in 2019
3	900	000	000	000	000	Wh	The electricity use of the United States
	13	000	000	000	000	Wh	The annual output of an EPR reactor, the output of the Danish wind sector in 2016. Annual electricity consump tion of a medium-sized city
		8	000	000	000	Wh	The annual output of a medium-sized wind turbine
			20	000	000	Wh	Electricity usage of a single home house with electric heating in north Europe (this varies a lot)
			2	000	000	Wh	Annual output of a small, 2-kilowatt solar PV panel installation
				1	000	Wh	The amount of physical work a person can put out in a day
					25	Wh	Heating a meal in the microwave oven (~2 mins), an hour of work on a laptop

Graph: Energy usage levels of different activities

demand depends on many factors, including climate, average house insulation, and heating/cooking methods (e.g., gas, electric, or oil). Locations in Scandinavia usually show peak demand in winter, because heating and illuminating residences becomes a priority, and many citizens use electric heating or heat pumps. On the opposite end of the spectrum, tropical regions and warmer climates typically see peak demand during summer months, when air conditioning and cooling needs spike. As an example, Finland's base level of demand is roughly 6 GW and represents 63% of annual electricity use. Seasonally, winter demand roughly doubles that of summer, with peaks reaching as high as 14 GW during especially cold periods. For comparison, Germany's base level is ~35 GW and represents roughly 60% of total annual electricity demand, while in the Netherlands, this share is roughly 68%.

Below we have a graph of the Nordpool power market including Norway, Sweden, Finland, Denmark, Estonia, Latvia, and Lithuania. The figure shows hourly consumption for 13 October 2020. The baseload demand sits around 40 gigawatts and appears between midnight and around 5 a.m.. Peak demand occurs from 8 a.m. to noon and then again between 6:00 and 8:00 p.m. at around 52 gigawatts. Some countries are on different time zone (1 hour difference) than others, which evens out the highs and lows somewhat. Most of this daily variation is covered with hydro power, as three of the countries in this market (Norway, Sweden, and to a lesser extent Finland) possess significant hydro resources.

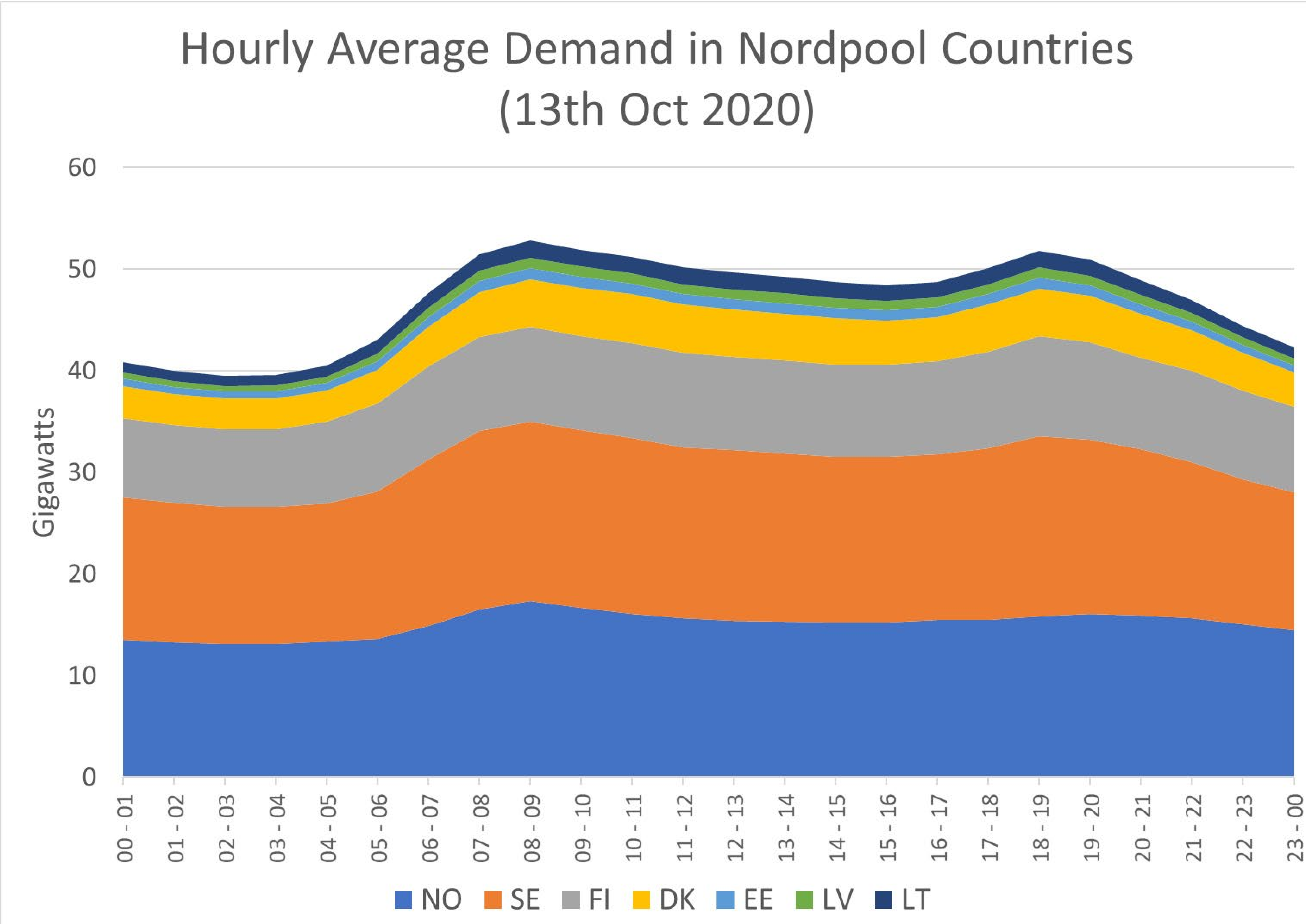


Figure 1: Hourly average demand in Nordpool countries for 13 October 2020. Data: Nordpool.

If one looks at daily demand (average for the 24 hours) for the same area over a period of one month (13 Sep to 13 Oct), weekdays clearly feature higher demand than weekends, when many factories and various other businesses are closed, meaning most employees are not at work. The minimum baseload sits around 39 GW and peak demand reaches about 45 GW. One might also notice the base and peak both increase gradually toward the end of the period, implying the weather is getting colder and heating season has begun. The average demand for the 13th Oct in the first graph is around 47 GW.

This variation in average daily demand over the course of a week appears globally, as most countries function such that workdays see higher demand than weekends.

Seasonal variation in average demand appears in Figure 3, showing average monthly demand over a two-year period from September 2018 to August 2020. Baseload level for summer months reaches around 38 GW, while the winter peak hovers around 55 GW and even exceeds 60 GW during one month (January 2019).

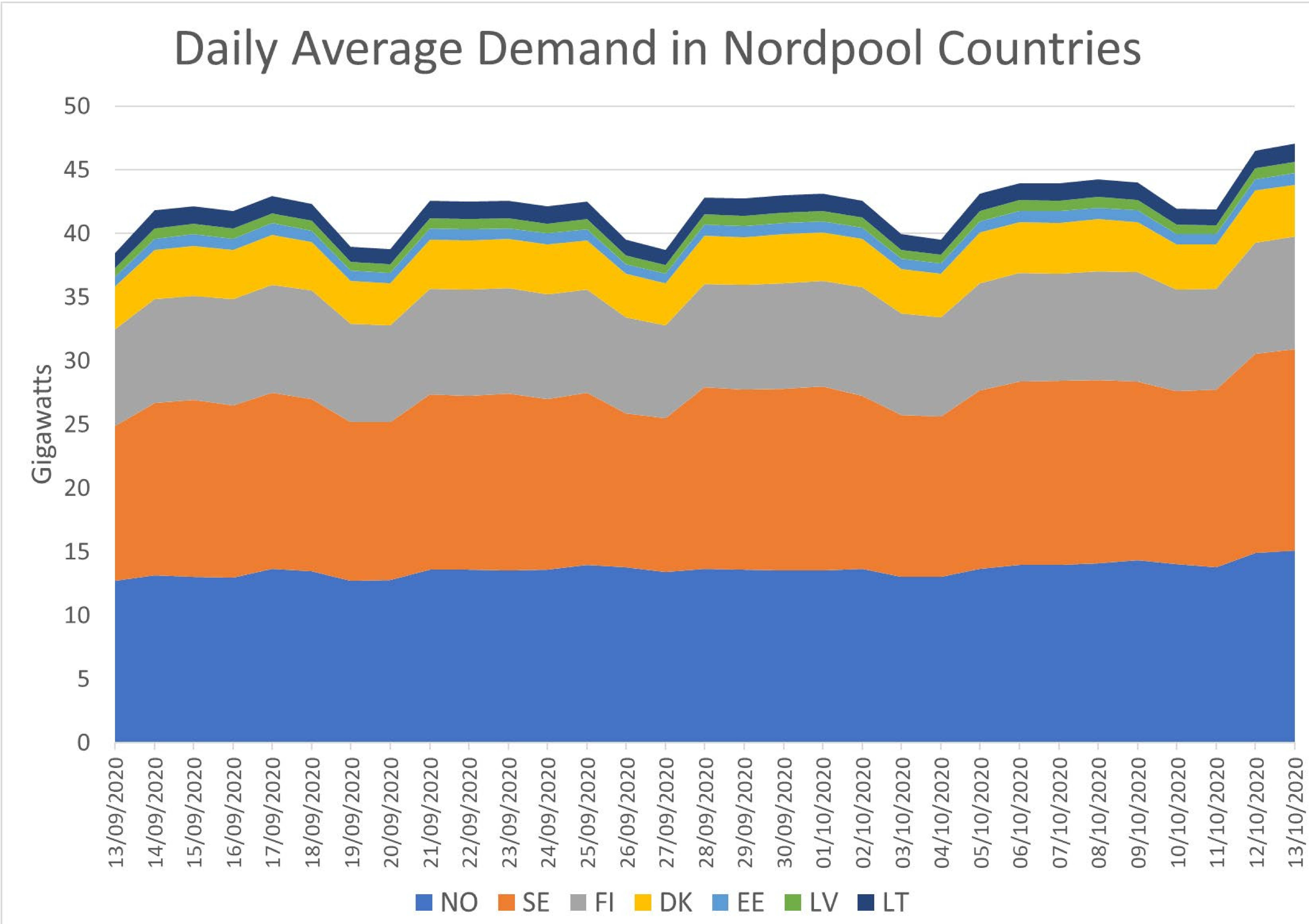


Figure 2: Daily average demand in Nordpool countries from mid-September to mid-October 2020. Data: Nordpool

As shown, multiple temporal levels of baseload demand exist, including short term (seconds to minutes), hourly, daily, weekly, and seasonal variations, and all can be partly mitigated with various technologies and activities. For example, grid-connected batteries work well for fast response (from seconds to hours) but not that well as weekly or seasonal energy storage. Two distinct approaches exist to overcome this, though they are used simultaneously and connect with each other: demand-side flexibility and supply-side flexibility. A couple simple examples will illustrate their important characteristics.

Demand flexibility happens when energy demand shifts in time (or space), usually from the optimal to a slightly lesser state. For example, instead of washing my clothes at 6 PM, when electricity demand is highest, I wash them at noon, or perhaps midnight. If my actual preference is to do laundry when I return from work in the evening, these other options—perhaps interrupting my normal sleep schedule, or requiring an extra trip home—will seem notably less convenient for me. However, I can mitigate that inconvenience with a timer-based wash-

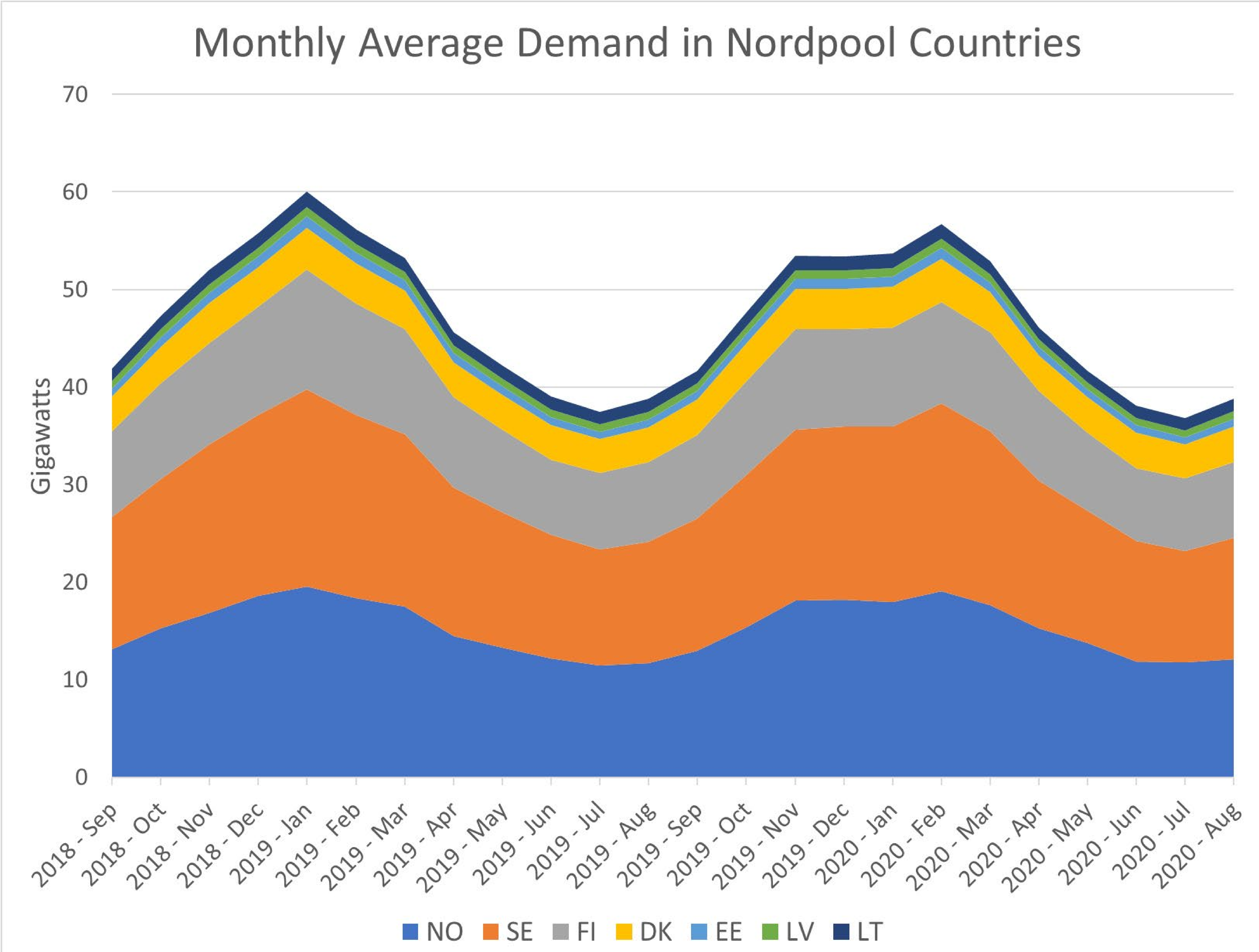


Figure 3: Monthly average demand in Nordpool countries from September 2018 to August 2020. Data: Nordpool.

ing machine, allowing it to operate automatically at the desired time. Indeed, automatically timed solutions often represent the least inconvenient option in this context. Even so, demand flexibility usually causes some degree of inconvenience, with demand and inconvenience levels typically rising in lockstep.

Another, all-too-real form of demand flexibility in Europe during the 2021 energy crisis relates to people who cannot afford energy even if demand clearly exists. An example of this type of "flexibility" would be a family not heating their house to a comfortable level because fuel is too expensive. In fact, this quasi-"demand flexibility" does not really represent flexibility (a desirable status) per se, but rather, a form of energy poverty (an undesirable condition).

ROLLING BLACKOUTS AND BROWNOUTS

When supply cannot meet demand, the quality of grid electricity begins to degrade, which can damage equipment or cause other serious consequences. Equipment damage can be mitigated by limiting some areas' access to the grid, and then shifting that limitation across different sectors. This is called a rolling blackout. Alternatively, operators could enact a "brownout," meaning they cap electrical availability in a given area rather than cutting it altogether. Even so, both options severely impact people and businesses in the locations involved.

At the other end of the demand-management spectrum, a lack of sufficient electricity can halt expensive industrial processes mid-project or lead to rolling blackouts or brownouts, all of which can push costs much higher. In addition, too much demand flexibility risks elevating energy poverty, as poorer citizens often face enforced changes to their behaviour causing notable inconvenience (and, ironically, less productivity) before wealthier people, especially when energy prices rise extremely high. One common means for enticing demand flexibility is achieved by creating different "day" and "night" tariffs for power, thus encouraging households to use cheaper night-time electricity when, say, heating their hot-water boilers, as they can use the resulting hot water throughout the next day.

Supply flexibility simply means the ability of production to ramp up and/or down at different speeds and scales. Some solutions like energy storage with pumped hydro or batteries can achieve both, since they can increase demand by storing energy, or increase supply by releasing it.

IS BASELOAD DEAD?

Various commentators have proclaimed the "death of baseload" for years.[2] *As seen above, the demand side of baseload still exists, at least for now. That status could obviously change, but such a departure would depend on several factors. On average, societies (i.e., people and businesses) prefer to use energy mostly when they need it (on demand), and on average, that results in a predictably fluctuating curve following the intra-day/night, week/weekend, and seasonal weather cycles observed earlier. Indeed, the modern concept of society inevitably rests on reliable availability of relatively cheap energy, as well as the increase in productivity it provides.*

But how energy systems and utilities meet baseload demand is another matter. Historically, countries have maintained this threshold largely through baseload power generation (nuclear, coal), supplemented by more flexible capacity like hydro or gas turbines. If we can find inexpensive methods to increase demand flexibility and if we also have a system with considerable baseload energy production, the demand curve will tend to flatten as demand is moved from high-demand periods to cheaper low-demand times.

Capacity and Capacity Factor

Different energy production technologies can display quite different capacity factors, so comparing them along capacity alone leaves out a great deal of information and can cause misunderstanding. Indeed, it is borderline meaningless, a bit like discussing cars and concentrating just on theoretical maximum speed instead of also talking about their reliability, boot space, or fuel economy—or, in the case of EVs, range on a full charge and charging speed. A simple example from Reuters illustrates this reporting misstep clearly.[3]

While the story mainly repeats what the Swedish wind lobby says, a diligent journalist would also mention the amount of energy produced by these sources. A 10 second Google search found a Statista page showing that in 2019, nuclear produced 39% of Sweden's electricity, while wind power produced 12%. Emissions diminish only through clean energy production, not capacity addition.[4]

2 https://www.zdnet.com/article/why-baseload-power-is-doomed/ from 2012 is one example.

3 https://www.reuters.com/article/us-sweden-wind-idUSKBN1X3145

4 https://www.statista.com/statistics/1013726/share-of-electricity-production-in-sweden-by-source/

COMMODITIES NEWS OCTOBER 24, 2019 / 12:52 PM / UPDATED 2 YEARS AGO

Sweden's wind power to surpass nuclear this year: lobby

By Lefteris Karagiannopoulos 2 MIN READ

STOCKHOLM (Reuters) - Sweden is set to have more wind power capacity than nuclear this year, Swedish wind energy association Svensk Vindenergi estimated on Thursday.

Installed wind turbine capacity should reach 9.4 gigawatts (GW), topping nuclear capacity of about 8.4 GW, it said.

Figure 4: A headline and story from Reuters referring to capacity additions but omitting the important part: energy production.

As can be seen in Fig. 5, 100 megawatts of solar PV or onshore wind remains quite different from 100 MW of geothermal or nuclear.

Earlier we discussed the difference between power and energy. Capacity means the maximum power that an energy source can produce. To calculate how much energy a given capacity of energy production yields over a given time—typically a year in practice—we need an average capacity factor (CF).[5] Capacity factor is a number between 0 and 1, or a percentage between 0 and 100. To calculate how much a 100 MW solar farm operating at 20% average capacity factor produces over a year we do the following calculation:

Capacity (100 MW) * hours in a year (8760 h) * CF (0.2) = 175,200 MWh

One should note that capacity factor represents an annual average. Indeed, wind turbines do not generate power at full capacity for 4000 hours straight and then suddenly stop and remain motionless for the rest of the year, nor does it function at 45% capacity constantly. Rather, it mostly fluctuates between about 5% and 95% of its full capacity. By contrast, solar PV alternates between “on” and “off” status more regularly, as it understandably stops producing at night, though even daytime production fluctuates in relation to cloud cover and the

5 This concept is also referred to as “load factor.”

sun's orientation.

Figure 5 shows a table with capacity factors seen in the US and the amount of energy a 100-MW facility produces in a year at average capacity factor.

Generation Type	Example Project Size (MW)	Capacity Factor Range (US Avg.)	Energy Production based on U.S. Avg. Capacity Factory (MWh)
Solar PV	100	15–27% (20%)	175,200
Onshore Wind	100	20–45% (35%)	306,600
Hydro	100	35–60% (42%)	367,920
Offshore Wind	100	28–55% (43%)	376,680
Biomass	100	59–65% (62%)	543,120
Geothermal	100	80–90% (85%)	744,600
Nuclear	100	87–93% (90%)	788,400

Sources:

The National Renewable Energy Laboratory, NREL Annual Technology Baseline (2019).

U.S. Energy Information Administration, U.S. EIA (2020). Table 6.07.B. Capacity Factors for Utility Scale Generators Primarily Using Non-Fossil Fuels.

Figure 5: Different low carbon or renewable energy sources and their capacity factors, and how that affects their annual energy production. Image credit: LucidCatalyst.

MWH OR HOUSEHOLDS? WHAT UNITS TO USE TO COMMUNICATE ENERGY USE UNDERSTANDABLY?

A "megawatt hour" often means nothing to a layman. The term offers no context, no real-world example to indicate whether it refers to a lot or a little. So if the concept is too arcane or remote from everyday life, should commentators and journalists describe energy use and production with familiar, everyday examples like "households"? This approach would likely precipitate headlines like, "The new wind farm produces electricity to power 100,000 households."

The problem with this standard is "household" can translate to a wide range of energy use. Is it a modest single-family home, a sprawling, multi-story mansion, or a tiny studio apartment? Does the occupant heat with electricity, gas, or district heating? When was the residence built, and does it have quality insulation? One can imagine any number of permutations to answer these questions depending on the "household" in question, and these differences could easily mean twenty-fold variations in electricity consumption, all *the way from 2 MWh per year to 40 MWh per year![6] So while only a handful of people understand the nuances of the term "megawatt hour," even fewer will know how to define "household" in a broadly applicable manner. Moreover, this approach to expressing the data leaves the "power vs. energy" topic unclear, potentially creating further misunderstanding for readers.*

As such, I recommend using both standards while also providing appropriate context. In practice, this could still mean invoking the term "household," but also making sure to define it precisely and indicate the annual consumption figures. For example, a responsible journalist utilizing this approach might write something like, "The new wind farm produces 250,000 megawatt hours per year, enough to power 100,000 apartments."

Energy vs Electricity: What's the Difference?

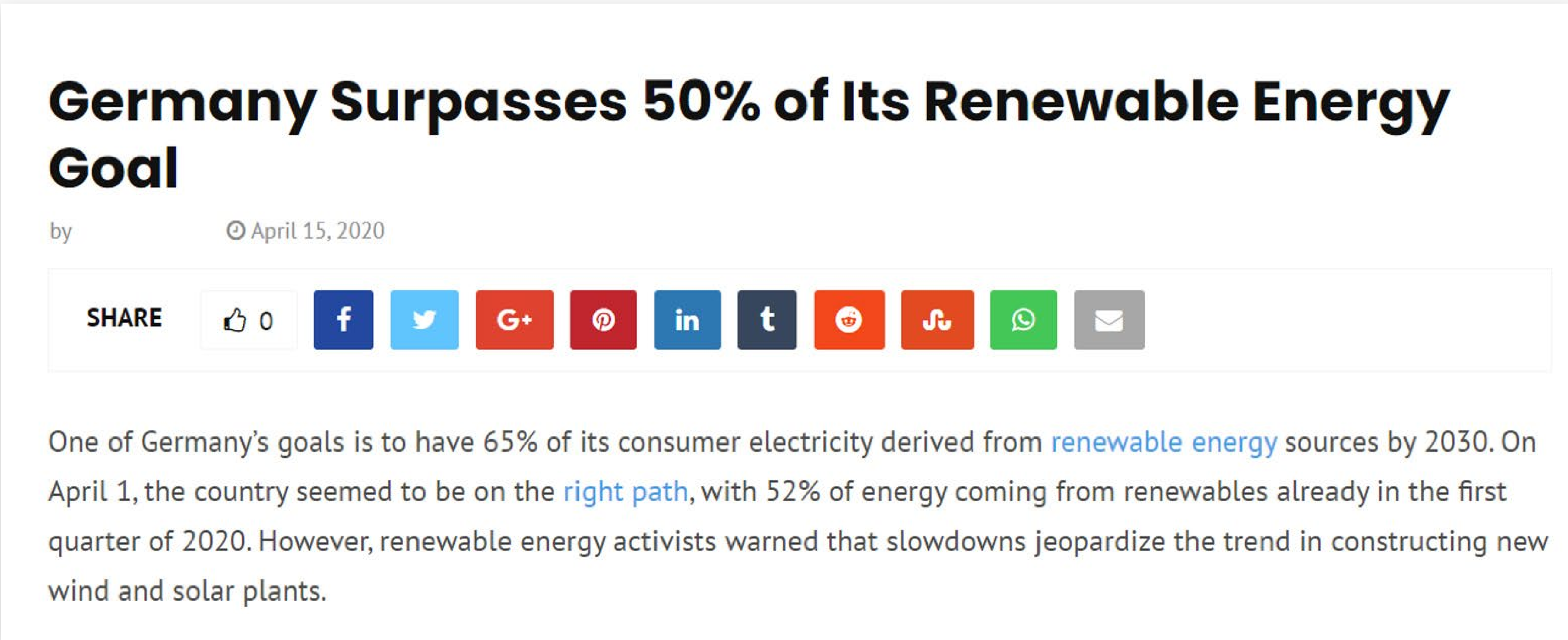
Electricity is an energy carrier, and one of the many forms in which we use energy. We also use natural gas and oil for heating and gasoline for driving. Along these lines, one of the most common mistakes in energy reporting relates to the usage of the terms energy and electricity interchangeably. Furthermore, many people see electricity as the main factor impacting climate change. But both of these convictions can lead to severe misunderstandings concerning the sheer scale of the challenge of decarbonizing global energy systems. And if both types of mistakes are combined in a single report, informational chaos can result.

To begin with, electricity only represents about 1/5 of global final energy use (slightly more in developed nations and less in developing ones). The share has continued to grow at a rate of roughly 2% per decade, even as total energy consumption has grown at a similar rate. This means electricity use has increased its relative share of the expanding total consumption, thus growing faster than other types of energy consumption.

With all this in mind, confusing electricity and energy clearly represents a major problem. And indeed, Fig. 6 provides a tangible example of this phenomenon, showing an article from April 2020 in which the author confuses energy

6 For example, a small apartment with district heating or natural gas boiler to a large single house with electric heating.

and electricity quite egregiously.[7]



Germany Surpasses 50% of Its Renewable Energy Goal

by April 15, 2020

SHARE 0

One of Germany's goals is to have 65% of its consumer electricity derived from renewable energy sources by 2030. On April 1, the country seemed to be on the right path, with 52% of energy coming from renewables already in the first quarter of 2020. However, renewable energy activists warned that slowdowns jeopardize the trend in constructing new wind and solar plants.

Figure 6: An example of a news article where energy and electricity gets mixed, causing confusion.

There are multiple problems in this writing. First, the headline claims Germany surpassed 50% of its renewable **energy** goal. In the actual text of the article, it corrects this error by indicating Germany's goal is to generate 65% of consumer **electricity** through renewable sources—which, incidentally, they surpassed by 80%, not 50% (as 52% / 65% = 0.8). Yet right after this, the text again incorrectly suggests 52% of **energy** came from renewables in the first quarter, when that statistic actually refers to **electricity**.

When one says "energy" but actually means "electricity," they unwittingly cause a significant difference in scale, as electricity production leads to slightly more than a third of total energy-related emissions (36% in 2019), and about a quarter of our total emissions (which also includes land use, agriculture and a few other sectors).[8] As such, solving electricity emissions only fixes part of the problem. Indeed, it merely resolves a third of all emissions-based problems and quarter of the total emissions problem. And unfortunately, this crucial message often fails to appear in reporting, especially when journalists use "energy" and "electricity" interchangeably. Moreover, these articles omit the sobering reality that electricity actually represents the easiest sector to transform. By contrast, decarbonizing industrial processes, chemical-industry feedstocks, transportation fuels, and agricultural production will likely prove much harder.

7 https://www.intelligentliving.co/germany-50-renewable-energy-goal/

8 https://www.iea.org/articles/global-co2-emissions-in-2019

ELECTRIFICATION

The simple answer to decarbonizing the energy sector amounts to (1) decarbonizing electricity production first, then (2) electrify everything. Of course, like most simplifications, this approach leads to multiple problems. First, this "electrification" of energy use has already progressed at a steady rate of roughly 2 percentage points per decade. Engineers and operators could possibly accelerate this through policy changes and intensified innovation, but only up to a point. For example, road transport (passenger and freight) only accounts for about 12% of global emissions (excluding land use and forestry).[9] So electrifying most road transportation will only increase the overall share of electricity by perhaps 10 percentage points. Second, many energy uses might prove extremely difficult and expensive to electrify directly, including long-haul trucking, marine transportation, aviation, and industrial processes using high-temperature heat. With all this in mind, the share of total energy use global society can reasonably expect to electrify reaches maybe 60%, give or take 10%.

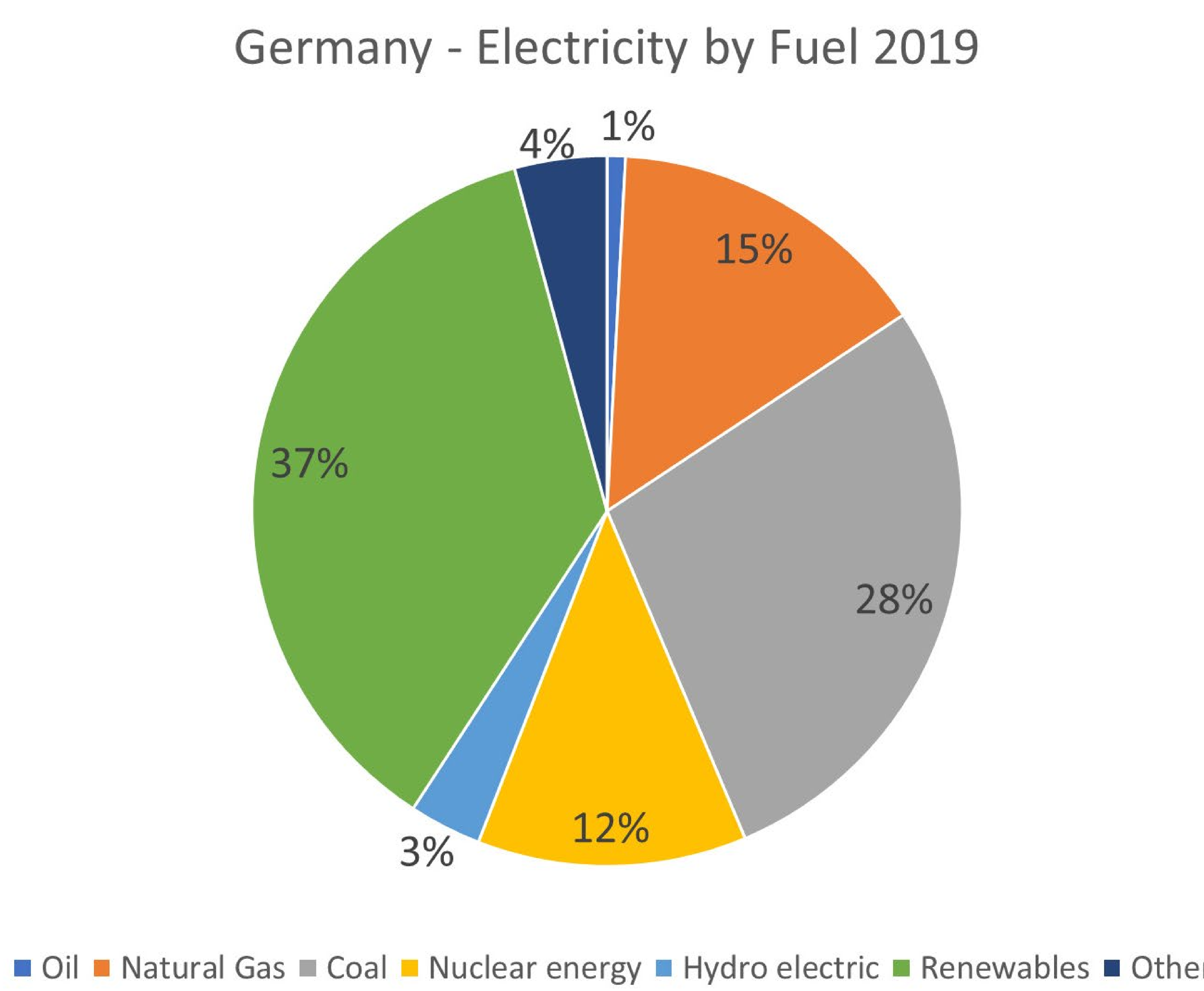


Figure 7: Germany's electricity production by fuel. Source: BP2020

Consider another example of the difference between electricity and energy. Figure 7 depicts Germany's *electricity* production by fuel as a pie chart.[10] It indicates renewables and nuclear combined produce over half of Germany's electricity. To clarify, "renewables" include wind, solar, and biomass, as well as a few other minor sources, while hydro remains separate. All count as low carbon, though bioenergy's designation in that regard seems debatable (see below). Thus, more than half of

9 For more information on emissions from different sectors, see https://ourworldindata.org/emissions-by-sector.

10 This data comes from the 2020 BP Statistical Review of World Energy dataset.

Germany's electricity comes from low-carbon sources.

But if one looks at Germany's *energy* sources by fuel in Figure 8, the situation changes drastically. Oil—used mainly in transportation and chemical feedstock—becomes the major energy source, while natural gas—employed mostly for heating and cooking, electricity production and industrial uses—grows significantly, as well. In this context, the share of clean, low-carbon energy shrinks to just 22%.

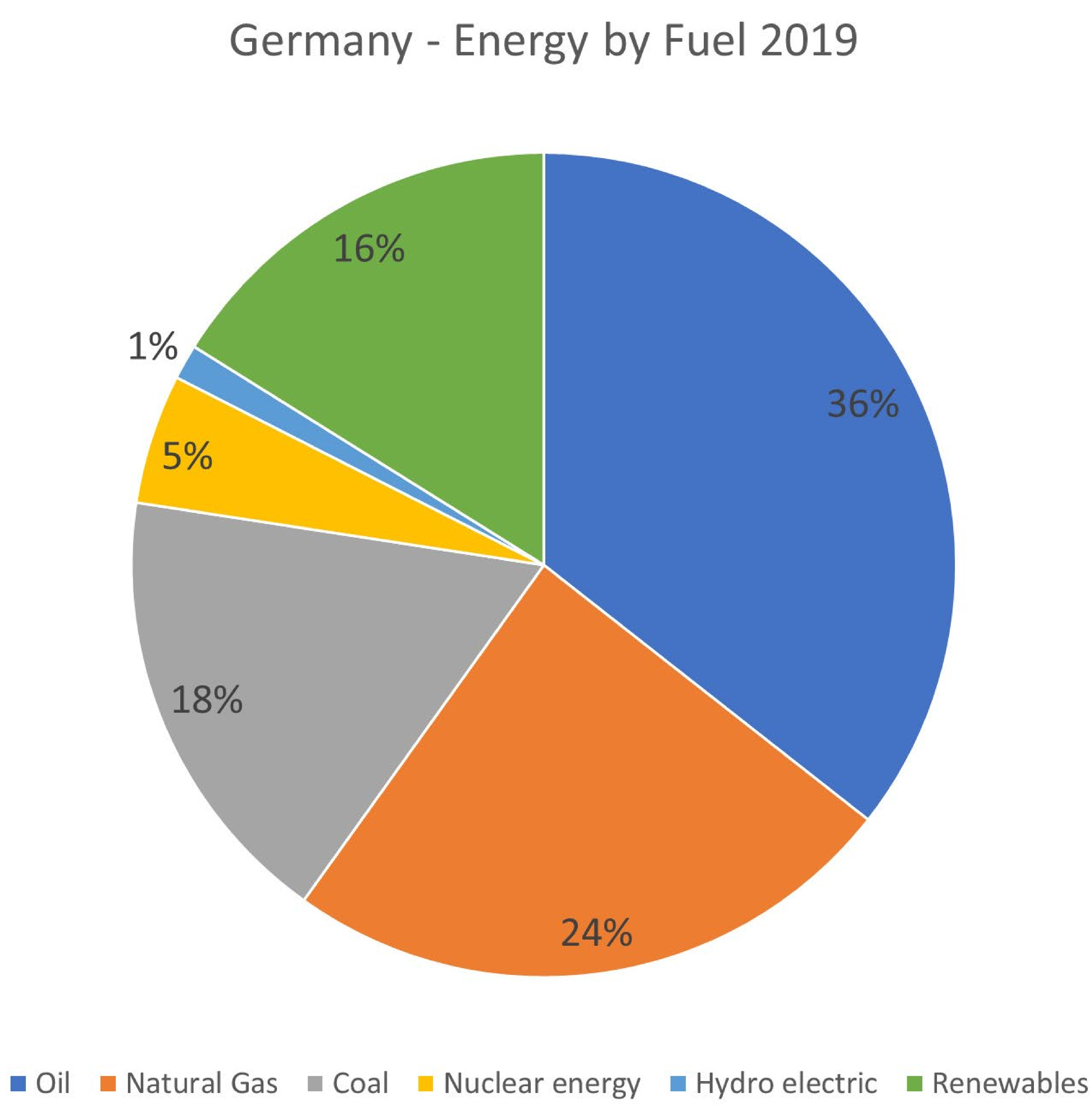


Figure 8: Germany energy production by fuel. Source: BP2020.

Further, adding up "renewables" in a single quantity is problematic and obscures important information. For example, few readers will know biomass actually represents the majority of "renewables." In fact, biomass represented 59% of all renewable energy use throughout Europe in 2017.[11] This results from biomass being the only renewable capable of serving as a reliable fuel for heat and steam, both of which remain critical to global energy needs.

Next, we need to explore how various terms related to energy sources are defined and employed in public media, as well as how those tendencies mislead and confuse rather than inform and educate.

11 Bioenergy Landscape Statistical Report 2019, https://bioenergyeurope.org/

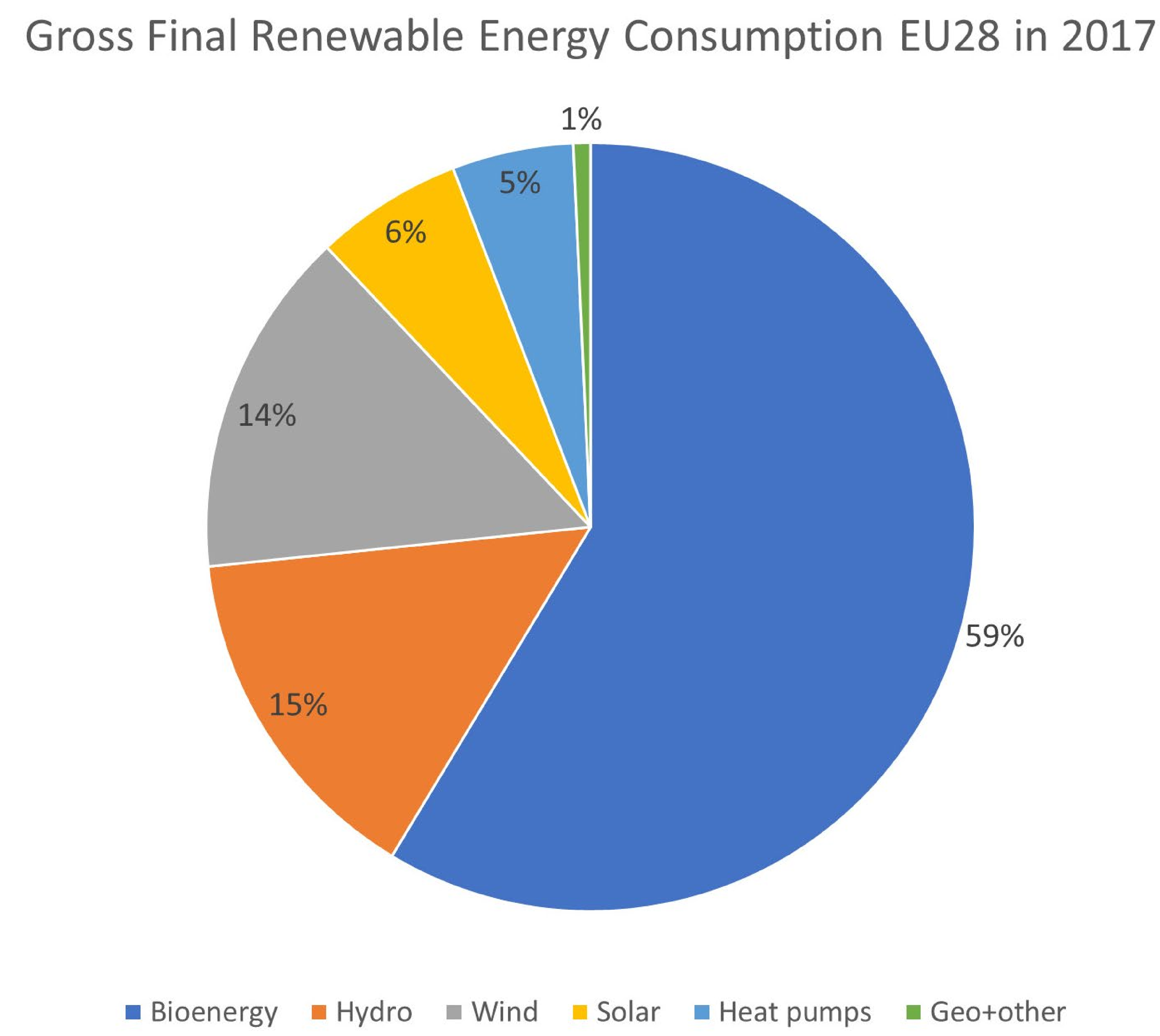


Figure 9: Gross final renewable energy use in EU28 in 2017.

ELECTRICITY

Analysts often consider electricity more valuable than the majority of other energy carriers since it proves so flexible and versatile. For example, a microwatt hour of electricity could perform a task in a microprocessor while that electricity is produced far away in a gigawatt-scale powerplant. That said, the value remains situational, so combining different energy carriers essentially amounts to comparing "apples and oranges" to some degree. In truth, we need multiple energy carriers in our society, selected case-by-case and based on type of use and available infrastructure.

What is Renewable Energy?

The term "renewable energy" appears ubiquitously and has comfortably entered both popular and technical media. In discussions, policies, and scientific articles, *renewable* often appears synonymously with words like "clean," "low (or zero) carbon," "sustainable," and "green." But all these terms bear notably different meanings, so using them interchangeably is sloppy and can cause misunderstanding. As such, let's examine these other terms before attempting to define "renewable energy."

"**Clean**" mainly refers to an entity or process that does not release (much) pollution into the environment. In this context, "pollution" can include both excessive CO_2 and particulate matter, as well as various toxins.[12] It serves as a useful, if also somewhat vague term. After all, every form of energy production will result in some kind of pollution. "Clean" is therefore a term in need of comparison—"clean" compared to what? Indeed, a new coal plant is often cleaner than older ones because scrubbing technology and overall efficiency has improved over the years, so "clean coal" has now become a common catchphrase. But on a wider view, the label "clean" seems suspect at best, at least compared to non-combustion technologies or even other fossil-fuel plants (such as those employing natural gas).

"**Green**" is a colour. Describing energy sources or policies with colours is very subjective, ambiguous, and misleading. It gives the recipient a certain feeling or image without imparting any coherent information. Indeed, people often use colours to ascribe values or qualities (both positive and negative) to a wide variety of phenomena. This causes confusion for numerous reasons, including personal and cultural differences toward various colours and their supposed meanings, as well as the absence of information on the environmental impact of a colour category. In this vein, multiple societies and cultures use green as a positive adjective, essentially meaning a stamp of approval or confirmation.

ALL THE COLOURS OF THE RAINBOW

Recent discourse concerning European hydrogen has ascribed colours to different sources in an attempt to order them by preference. In these classifications, hydrogen made with renewable energy (meeting some further conditions) has been designated green, whereas hydrogen made from fossil fuels is depicted as grey, while hydrogen made from fossil fuels using carbon capture and storage to decrease emissions is labelled blue, and low-carbon hydrogen made with nuclear energy is often described as pink or purple. These colours tell us little of the actual environmental impact of each.

"**Low or zero carbon**" represents one of the more precise and useful terms in climate-change discussions. It is preferable to use "low carbon," because "zero carbon" is semantically narrow and absolute. Even if an energy source does not require combustion, and therefore produces no direct emissions, lifecycle

12 While some say CO_2 is not pollution and is essential for life, excessive atmospheric CO_2 concentration will undeniably cause harmful effects by warming global climate, with the impact becoming more acute when environmental changes occur rapidly—a reality now seen in multiple regions of the planet.

emissions will still exist, as with transportation, mining, steel, concrete, glass manufacturing, and the refining of raw materials. Figure 10 offers a graph from a recent lifecycle analysis published by the United Nations Economic Commission for Europe, in which different energy sources are compared.[13]

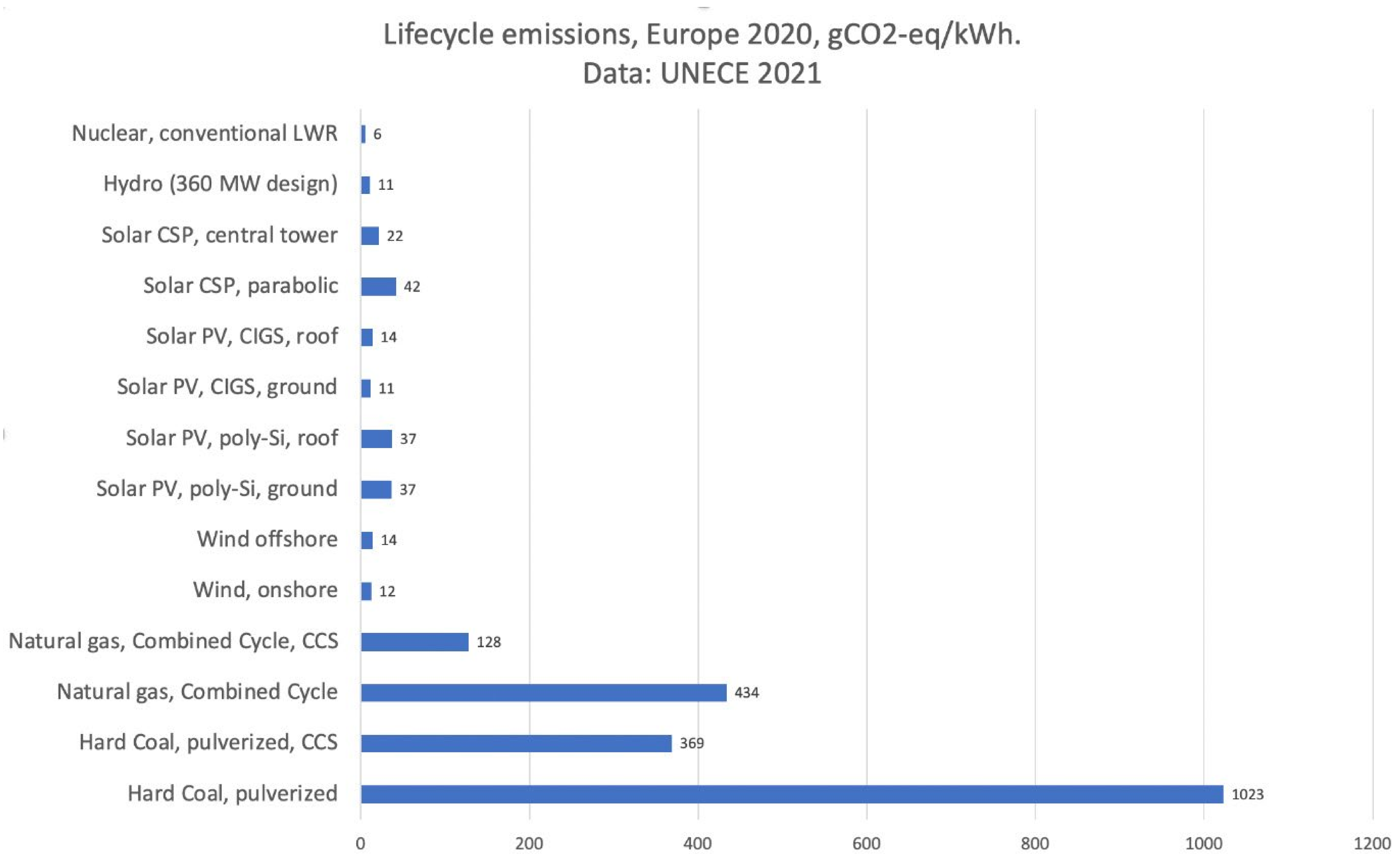


Figure 10: Full lifecycle emissions of different electricity sources in Europe. UNECE 2021.

The definition of "low carbon" differs slightly depending on context, but the phrase typically refers to (1) less than 50 grams of CO_2/kWh of electricity produced and (2) around a third of that quantity per kWh of heat or steam produced, all based on a full lifecycle assessment. Natural gas is also labelled "low-carbon" in certain situations, especially in conjunction with carbon-capture and storage (CCS). Granted, according to the UNECE 2021 report, this actually proves incorrect, though even so, natural gas with CCS gives off significantly lower carbon than coal power. Of course, a modern, more efficient coal plant is also "lower carbon" than an older, inefficient one, so a reasonable start to clarifying these discussions would be to distinguish between comparative and individual assessments.

"**Sustainable**" is a potentially useful term that unfortunately suffers from var-

13 https://unece.org/sed/documents/2021/10/reports/life-cycle-assessment-electricity-generation-options

ious misunderstandings in public discourse. Intuitively, most people can comprehend what "sustainable" means, but rarely does that comprehension involve deeper and more precise knowledge of the concept in real-world contexts. In a broader sense, the famous 1987 Brundtland Commission report articulated the most pervasive definition of "sustainable development" as "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs." (WCED, 1987)

A "sustainable" energy source would therefore be capable of meeting the needs of current generations without compromising the ability of future generations to satisfy *their* needs. Of course, a crucial and often forgotten part of this understanding amounts to the opposite—ensuring future generations can accommodate their needs while still allowing current, living humans to achieve a respectable quality of life and economic status. For example, if families and individuals today need to use a certain amount of fossil fuels in their everyday lives, a sudden and complete ban will prove harmful and unsustainable.

Even so, the continued use of such fuels depletes limited global reserves and weakens the atmosphere's ability to handle waste products like CO_2, not to mention the ability of various ecosystems to adapt to contaminants like microplastics and other chemicals derived from oil. So a reasonable path forward will always represent a compromise between consumption and pollution today (on the one hand) and allowing future generations to consume and pollute in proportion with their needs (on the other). As such, nothing is inherently "sustainable" or "unsustainable" without further context, as everything depends on local circumstances, scale, and a large number of assumptions about the present and future. Thus, using "(un)sustainable" as a blanket label for a broad category of activities might prove highly misleading in certain cases.

(UN)SUSTAINABILITY THROUGH POLITICAL DECISION?

When science and evidence disagree with people's preferred way of seeing a certain situation, they tend to ignore or reject them. One of the most prominent cases appears in the European Taxonomy and the 2022 Complementary Delegated Act (CDA) for the sustainable investment Taxonomy.[14] *The CDA, which got accepted into the Taxonomy in summer of 2022, frames natural gas as a potentially "sustainable" activity. But if regula-*

14 https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2

tors deem the extraction and large-scale use of gas a "sustainable activity" despite considerable evidence, will people just take that designation as justification for continued dependence on gas? A similar yet inverse situation exists with nuclear energy, which the CDA also addresses. In fact, even though the report commissioned from the European Joint Research Centre identified nuclear as clearly sustainable (at least as much as other energy sources in the taxonomy),[15] German negotiators want it left out entirely.[16] Austria is even threatening to take the whole CDA into court over this.[17] This complete ignorance of science over personal ideology is a scary trend.

As a provocative example, building and operating a coal plant in a developing country lacking electricity infrastructure can still prove sustainable, since it brings enormous benefits to current generations, not to mention aiding with further construction, technology, and institutions—thus benefitting future generations, as well. Of course, it might be even more sustainable if they received reliable electricity from a source other than coal, but that option might prove difficult, impractical, and/or prohibitively expensive at that moment.

Defining Renewable Energy

The catch-all, umbrella term "renewable energy" refers to numerous energy sources with divergent properties. The following primer lists several of them, along with key features.

Hydropower. In hydropower, the potential energy stored in the upstream water of a river spins turbines as it flows downstream. Several sub-types of hydropower exist, but the most relevant is large-scale reservoir hydro. Hydropower is the largest source of clean, low-carbon electricity available, representing roughly 15.6% of global electricity (6.4% of energy) in 2019. But hydro can also cause environmental problems, such as when reservoirs (i.e., artificial lakes) end up submerging large areas—as well as the ecosystems they support. This proves especially true in tropical regions, as biomass submerged in reservoirs can produce methane emissions, increasing hydro power's lifecycle emissions.

15 https://publications.jrc.ec.europa.eu/repository/handle/JRC125953

16 https://www.cleanenergywire.org/news/environment-minister-says-germany-prepares-clear-no-nuclear-eu-taxonomy

17 https://www.euractiv.com/section/energy-environment/news/austria-to-challenge-taxonomy-in-eu-court/

Operationally, hydro can power both baseload production and short-term, day/night, and intra-week load following, as seen in Figure 12 below.

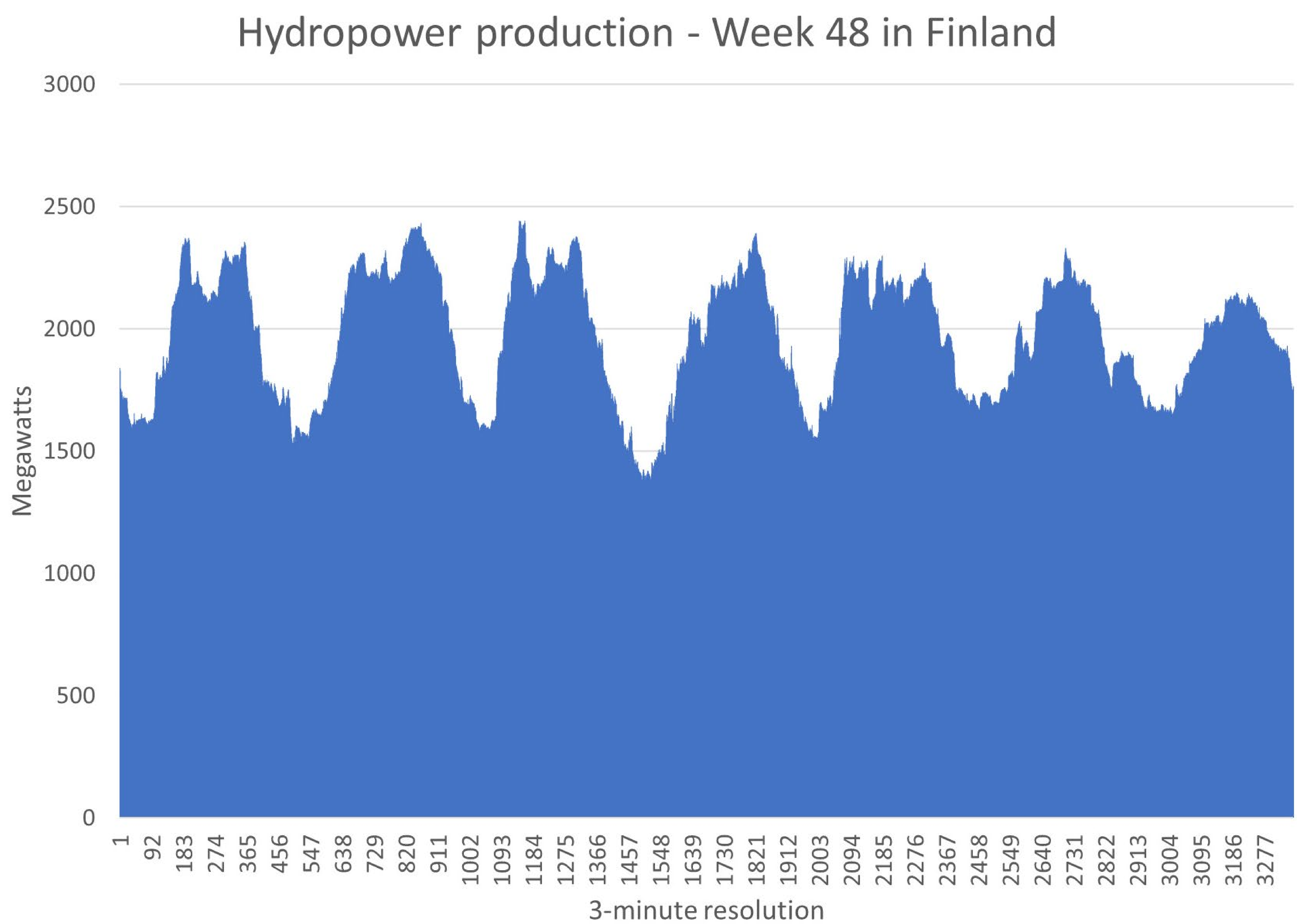


Figure 11: Hydropower production in Finland follows day/night demand fluctuation. Data: Fingrid.

Bioenergy. "Bioenergy" refers to a broad category of different fuels. This grouping includes crop residues (e.g., straw), energy crops (like corn for corn ethanol, or various oil plants for biodiesel), forest-based bioenergy (such as wood chips made from various feedstocks like branches or defective round-wood), pulp-industry byproducts like black liquor and bark, and perennial grasses such as Switchgrass. Its lifecycle emissions can vary from negative to worse than coal depending on the type of biomass and timeframe.[18] If the latter is lengthy—say, a century or more—most of the biomass will have time to grow back. But in the case of short timespans like a single decade, additional bio-based carbon dioxide can cause a significant climate-forcing effect in the atmosphere.

Writing about bioenergy features two levels of controversy. First, it appears un-

18 Sometimes it is better to burn some waste/side product rather than leave it to rot, which releases methane!

der the umbrella label “renewable energy,” which tends to greenwash all bioenergy as good and sustainable—a demonstrably inaccurate suggestion. Second, journalists and authors frequently use the term “bioenergy” as one large homogenous category, when it actually refers to a range of drastically different materials with widely varying environmental impacts and degrees of sustainability. As such, an important first step for journalists writing about bioenergy would be to specify clearly what type they are writing about.

Waste incineration. Burning waste for energy can be classified as “renewable” or “bioenergy,” which seems understandable on the one hand (since we produce a constant stream of waste and burning it for energy represents a reasonably good management strategy) yet confusing on the other (since waste is often made of or with fossil fuels, even though policymakers should be incentivising the reduction of waste streams). Moreover, burning waste definitely releases CO_2 into the atmosphere, whereas storing it in a landfill might not (since many plastics do not decompose at relevant timescales, meaning their carbon would remain locked away for centuries). Still, ever-growing piles of waste present other problems, meaning the burning of waste for energy will remain a preferable option.

Wind power. Wind power is an example of Variable Renewable Energy, or VRE. This means its production correlates with weather, not demand. As such, wind is perhaps the most common source people consider when they hear or read “renewable energy,” as well as solar PV panels. Of course, the materials used to make wind turbines and other related infrastructure are not renewable (though some can be recycled) even though the winds they harness are. Regardless, life-cycle emissions of wind are among the lowest.

Solar PV. Solar PV represents another variable renewable energy source, but with a different profile of variability than wind power. Indeed, solar production drops to zero every night and can also vary significantly throughout the seasons, especially at more extreme latitudes. Along these lines, solar resources in northern Europe in the winter remain extremely poor—precisely at the time of year when energy consumption hits peak levels due to heightened demand for heating and lighting.

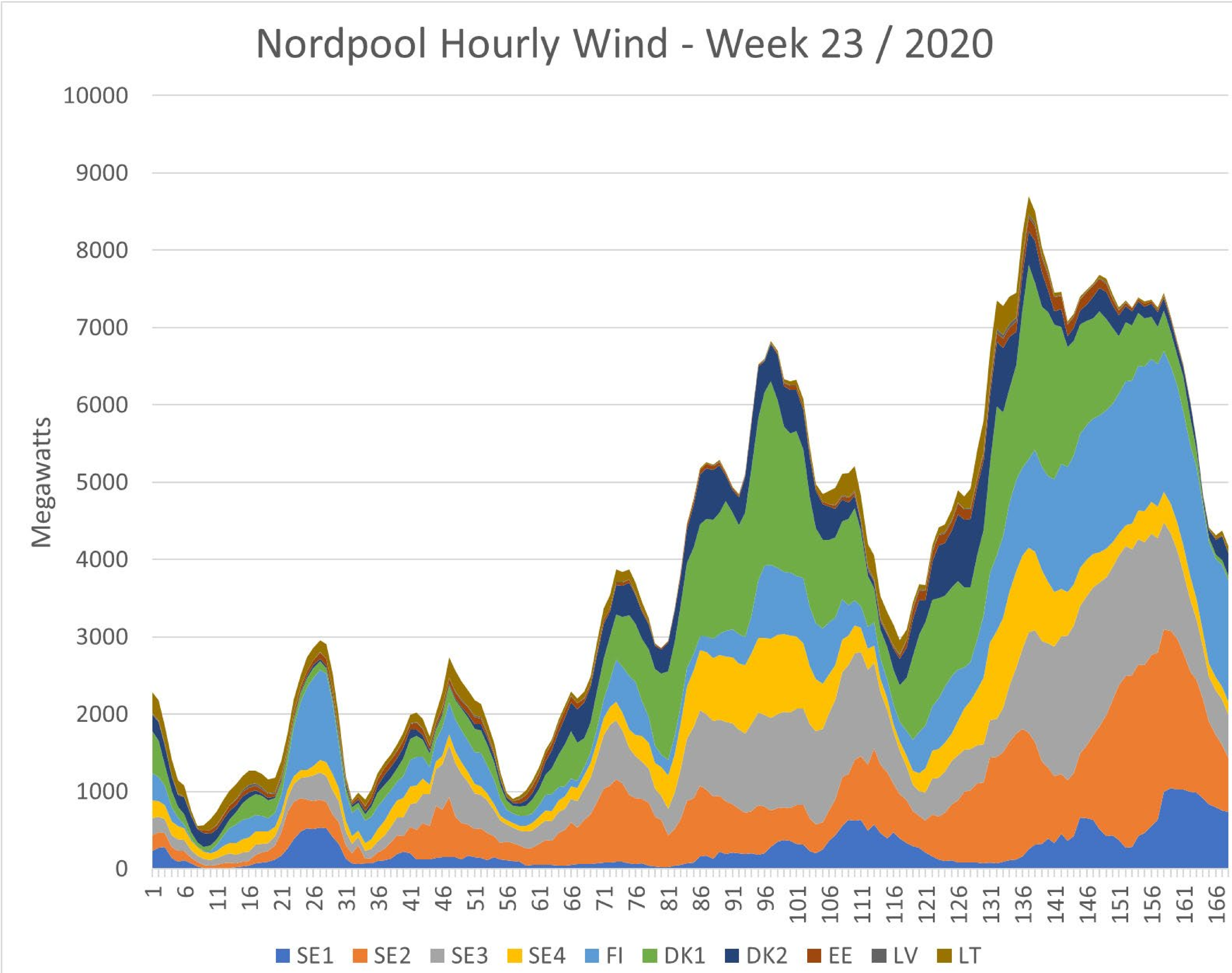


Figure 12: Hourly wind-power production from the Nordpool power market in different market areas. Data: Nordpool.

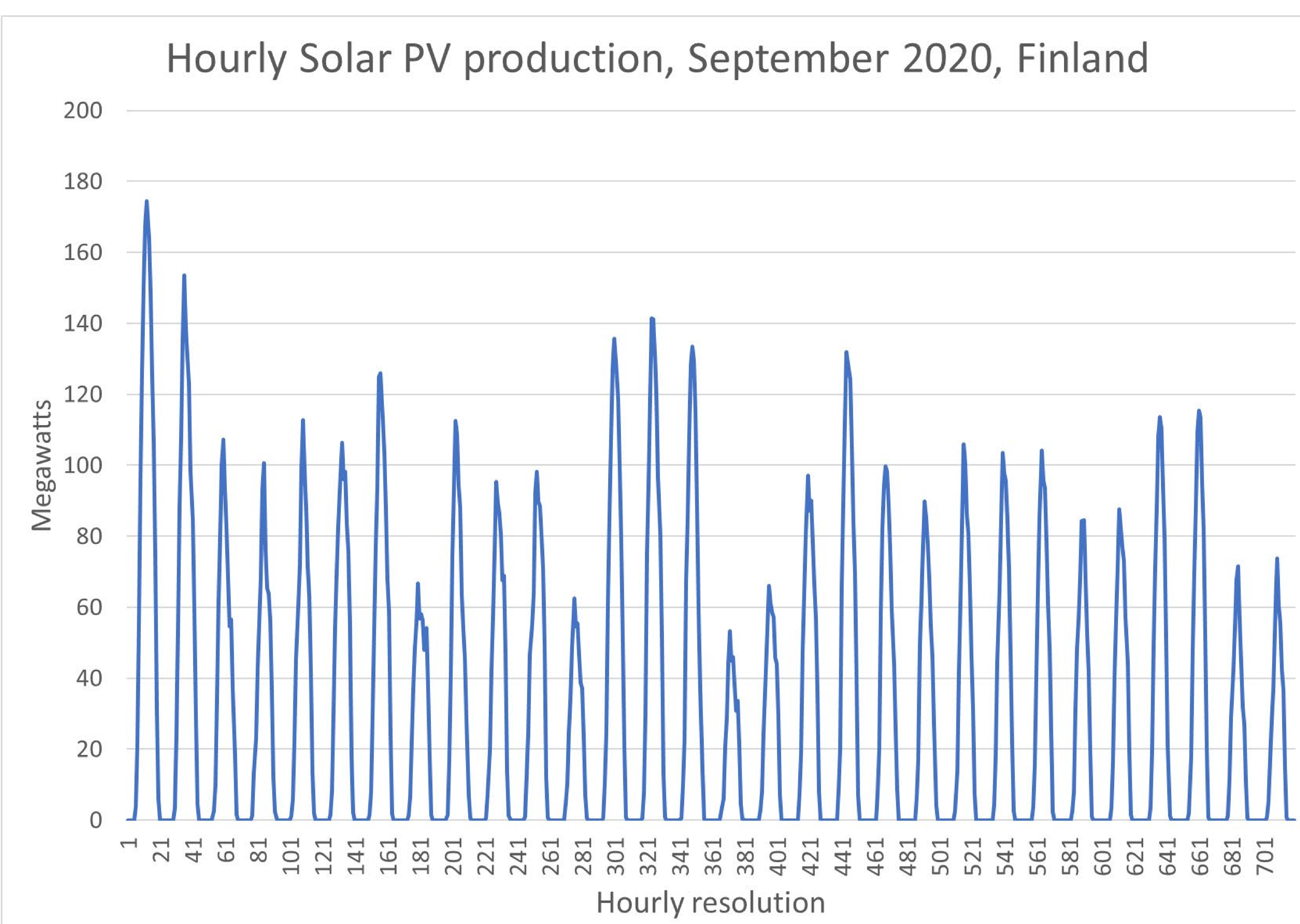


Figure 13: Hourly solar PV production in Finland, September 2020. Data: Fingrid.

Solar collectors. Solar collectors amass solar energy as heat, which can then be stored in a local water boiler. These devices can collect much more solar radiation than photovoltaic panels, and the corresponding water boilers prove relatively cheap. However, hot water remains much less valuable as energy than electricity, and most production comes during parts of the year with the lowest demand for heating (though obviously many citizens need hot water throughout the year).

Concentrating solar power (CSP). CSP uses mirrors to heat a central tower which has a high-temperature heat storage in it, for example some molten salt. This heat then boils water and drives a turbine. The benefits of this system compared to solar PV relate to its ability to store energy in molten salt, thus enabling more constant production. On the other hand, downside does exist: the high costs of building and running these facilities, a prohibitive factor that has led to only a few such facilities being constructed globally.

As we can see from the list above, "renewable energy" might well be among the most used but least scientifically/semantically precise concepts in energy-related literature and public discourse. It is used throughout in scientific materials, institutional reports, scholarly articles, mainstream news, and—deriving from these various appearances—public policy.

Yet not everything renewable is clean and sustainable. Imagine chopping down an old forest for woodchips for burning, with all the carbon dioxide and particulate pollution released and biodiversity and ecosystems destroyed. Similarly, not everything clean, low-carbon, and sustainable proves renewable. But scientific data shows nuclear energy is exceptionally clean, safe, and low-carbon.[19]

COMM'S TIP

In light of these vague and misleading understandings of "renewable energy", authors and public figures should simply refer to clean energy or low-carbon energy, or even better, specify the particular energy sources in question. For example, the following sentence presents the relevant terminology clearly and accurately: "To decarbonize our energy system by mid-century, we need to expand low-carbon energy sources like wind, solar, and nuclear tenfold compared to today's levels—within 30 years."

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19 For example, see https://ourworldindata.org/safest-sources-of-energy.

Characteristics of Renewable Energy

In addition to these considerations, one should learn various characteristics of other renewable energy sources. By definition, renewable energy is constantly "renewed," mostly through light from the Sun. The energy received through sunlight drives photosynthesis, which increases biomass, enhances wind patterns, and facilitates evaporation of water (thus enabling hydro power). To harvest these energy flows, engineers must design devices from non-renewable materials and minerals. Moreover, such flows often prove dilute and inconsistent—ultimately a good thing, as otherwise human settlements and infrastructure would be ravaged by constant hurricane-level winds and/or scorched by relentless solar radiation)—so wind turbines, solar PV panels, and agricultural crops require considerable space to collect significant amounts of energy. And by extension, those spaces will no longer be available (or become less practical) for other uses, whether by humans or other animals, though one notable exception exists: rooftop solar and other types of collectors built or woven into various structures, thereby allowing that space to serve multiple functions.

Harvesting biomass for daily or professional uses can cause a number of environmental impacts no matter how renewable the source. Biomass results from nature's primary production, growing out of solar radiation and photosynthesis. Indeed, life on earth depends on this primary production, and the more humans harvest it for food and other uses, the less that remains for maintaining complex and essential ecosystems, to say nothing of the multitude of species inhabiting them.

Biomass has received considerable policy support through inclusion as renewable energy. For example, it counts as zero carbon in the energy sector in the European Emissions Trading system, despite releasing significant emissions when burned. In fact, biomass emissions register in the land-use sector instead. This has led to a situation in which the energy sector can "decarbonize" simply by moving to bioenergy, thereby transferring the emissions from their own books to another sector. Figure 15 offers a revealing graph from the European Environment Agency, indicating that between 1990 and 2017, biomass emissions have increased 182%, almost mirroring the decrease of emissions in energy supply. And in the 2000s, the decrease of emissions from the energy sector appears nearly identical to a concurrent increase in CO_2 from biomass.

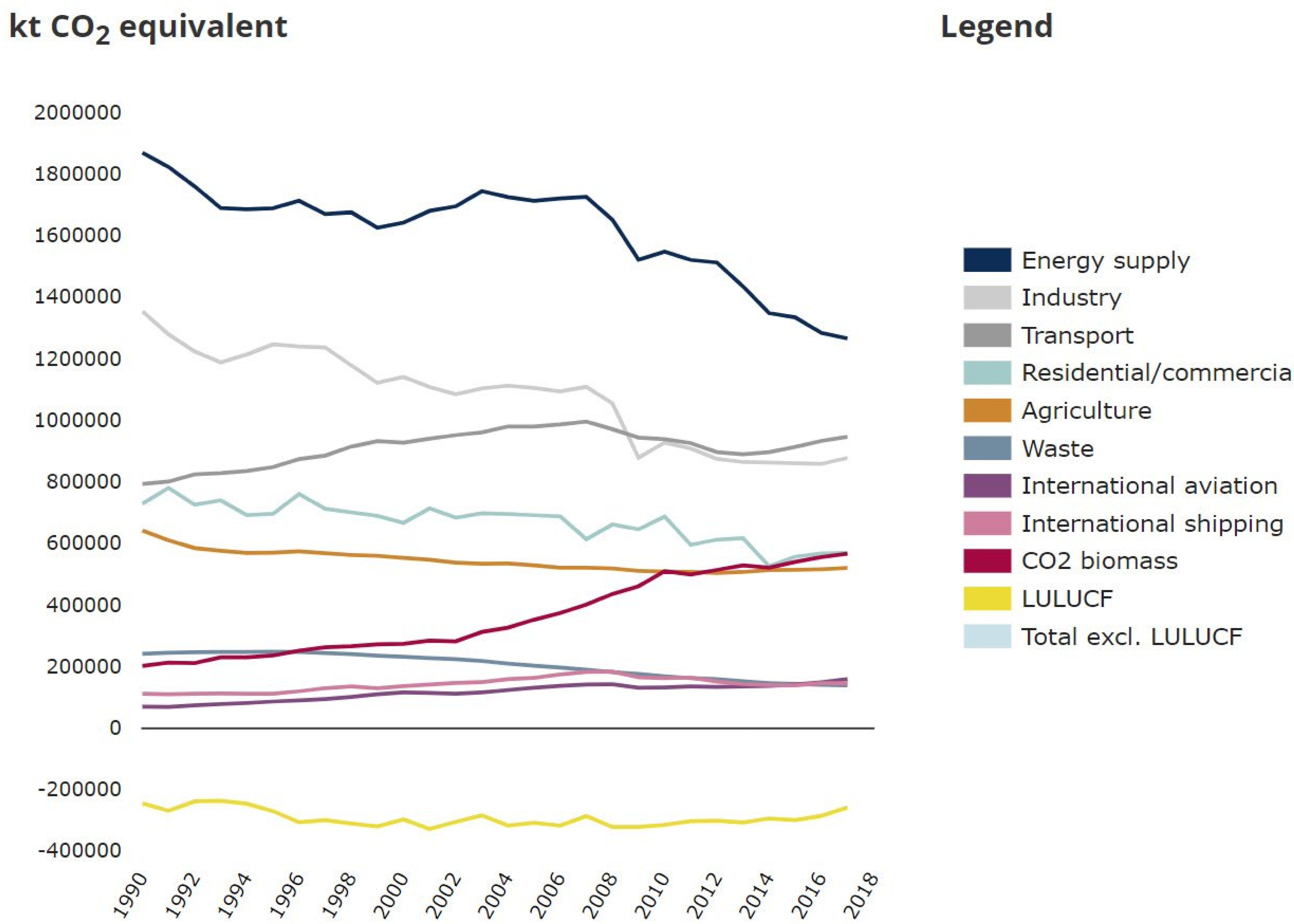

Figure 14: Emissions by sector, 1990-2017. Source: European Environment Agency.[20]

Energy systems with a significant share of variable wind and solar energy require a growing amount of support mechanisms—e.g., demand flexibility, energy storage, backup generation—to facilitate reliable service. And such support mechanisms incur additional costs and deplete resources, and produce waste. Demand flexibility can also cause energy poverty, as poorer citizens will face the most pressure to reduce energy use when prices increase.

So while certain renewables may prove effective and sustainable in particular contexts, none of them are uniformly viable or sustainable in all times and places. For this reason, including various renewable energy sources under one umbrella term is problematic and can lead climate and environmental conservation efforts astray. For example, European leaders have declared three targets for energy and climate policy: increase the amount and share of renewable energy, improve efficiency of energy use, and reduce emissions. But only the

20 https://www.eea.europa.eu/data-and-maps/daviz/ghg-emissions-by-aggregated-sector-5#tab-dashboard-02

last of these policies directly lowers emissions. And yet in various public and policy discussions, “emissions reductions” has become virtually synonymous with increasing renewables or efficiency.

But simply adding renewable energy might not be the most effective means of decreasing emissions, nor is improving energy efficiency alone. Commentators and analysts need to see these tools as effective in practice but not by definition. For example, the French government forcing additional renewables into a grid already very low-carbon due to the sizeable French nuclear fleet will likely increase emissions and lead to additional costs.

Part 2 – Advanced Concepts

This section delves deeper into energy sources, systems, and markets. It aims to impart a more comprehensive understanding of energy and the pivotal role it plays in enabling our modern societies. This understanding and insights can aid both those writing and reading about energy and climate issues. As such, this section includes more analysis, opinion, and subjective perspective than the foregoing material.

Energy in Society – What Does It Do, and Why It Is Important?

In all its various forms, energy keeps modern society humming. By definition, "energy" is the ability to do work—and that it does. Indeed, it heats and cools homes and offices, transports people near and far, keeps food fresh or frozen, allows chefs to cook and drivers to deliver, powers our computers, phones, and information networks, and quite literally brings light to darkness. It melts steel, makes aluminium, digs for raw materials, distributes fertilizers and pesticides, builds factories, and runs machinery to manufacture goods and appliances. Without energy, life simply cannot exist. And without modern energy services, neither can modern life.

Our society is dependent on many forms and flows of energy delivered just on time. The most visible of these is electricity, accounting for a fifth of global energy use. Heat in various forms represents around half of all energy end-use, roughly one half of which heats buildings, while another third is dedicated to industrial processes (often as steam) and daily needs like hot water. Most of the rest is deployed as liquid fuels for transportation and machinery.

This on-demand delivery of energy ensures high productivity, and through it, high material living standards compared to nearly all global citizens only a century ago. Indeed, many humans can now do what they need, when we need, and with great efficiency. A number of machines make previously tedious manual tasks much easier and faster, while other enable activities otherwise impossible. And all those machines run on external energy. But just what do people mean when they speak of "energy?" Perhaps unsurprisingly, this can vary a great deal.

Primary Energy and Secondary Energy

What is the difference between "primary" energy use and "final" energy use? The answer is surprisingly big. Secondary energy, or the "final energy we use," derives from primary energy. Traditionally, this means either combustion, refining, or fission.

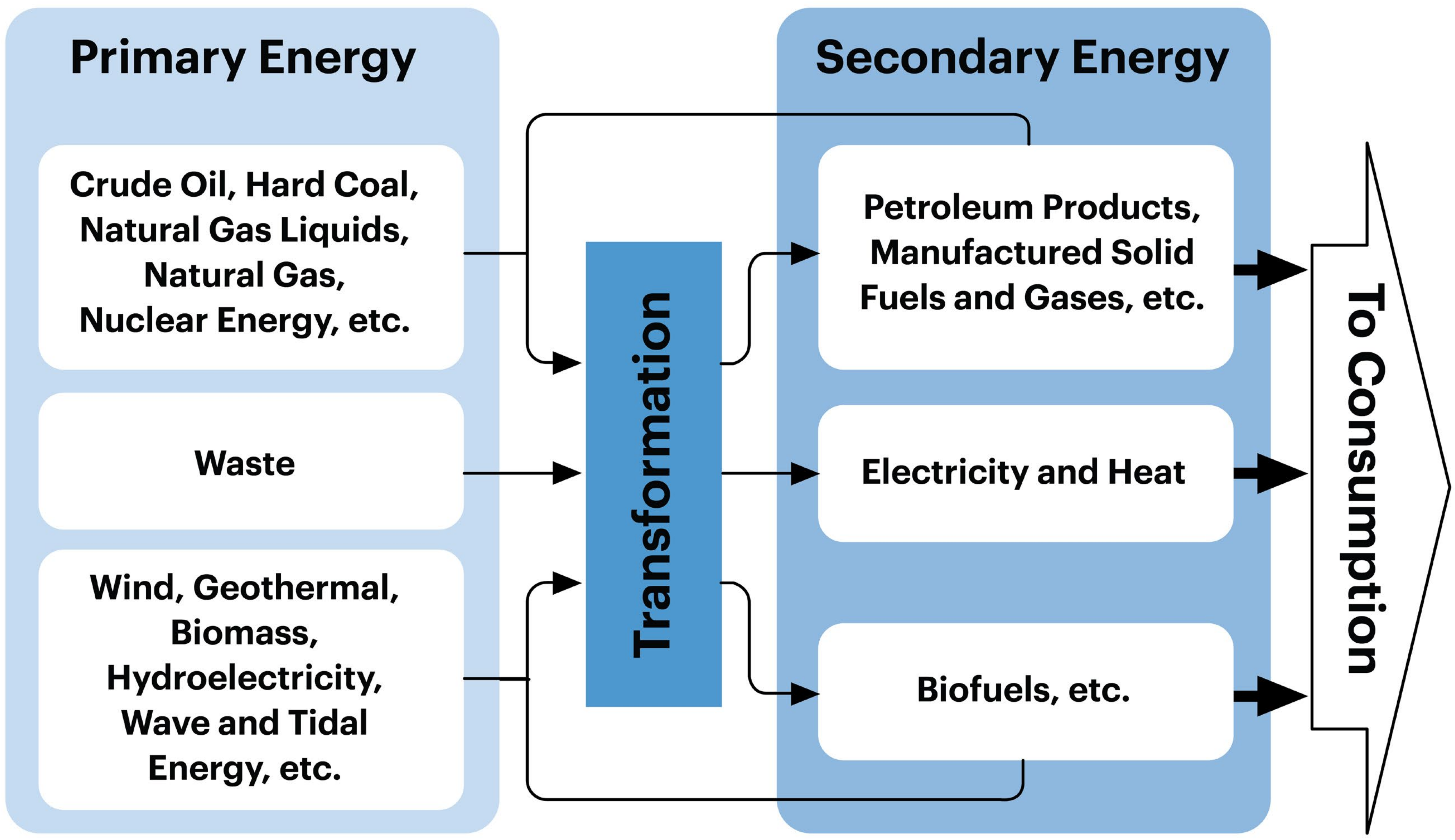

Figure 15: Primary energy is used to generate secondary energy, which people then use for work. Source: https://www.watt-watchers.com/activity/energy-resources-primary-vs-secondary/

The definitions seem a bit fluid, but a series of examples will help illustrate. Coal (primary energy) can burn to make steam (secondary energy), which can then help produce electricity (also secondary energy). Crude oil (primary energy) can be refined into gasoline, diesel, Jet A, and other fuels (secondary energy), which can then be combusted to generate heat (secondary energy) and ultimately motion. Wood (primary energy) can be turned into wood chips, pellets, or firewood (secondary energy), which can then burn to make heat and steam, either for direct consumption or conversion into electricity (all secondary energy). Crucially, though, every one of these transitions from one energy carrier to another yields a degree of loss due to the laws of thermodynamics.

PERPETUAL MOTION MACHINE IS NOT

One could design a machine that uses fuels like methane (natural gas) to make electricity, then use that electricity to make hydrogen with electrolysis, and ultimately employ the hydrogen as feedstock to make synthetic methane, which can then be burned in the machine to make further electricity. But at every step of the way, losses will occur, so the amount of synthetic methane feeding back into the machine after the first "round" proves much lower than the original quantity of fossil-based methane. In the above case, and depending on specific efficiencies and processes, it might register at roughly half the energy content.

Secondary energy is utilized for useful work, such as lighting a room, moving a car, or removing heat from a fridge. But how efficient are such functions? For example, how much of the energy content in gasoline can engines turn into useful motion? How much electricity received by a light bulb turns into light? And what portion of the electricity used by a fridge actually keeps the contents cool? In all these cases, wasted energy releases into the environment, often as low-quality heat.

To add further complexity, some energy sources can be called "primary electricity" because they produce electricity directly, without boiling water or making steam first. Such sources include solar photovoltaics, hydro power plants, and wind turbines. The important factor to remember here is producing one megawatt-hour of wind energy to replace one megawatt-hour of coal electricity actually substitutes about 3 megawatt-hours' worth of coal in primary energy content. This is because a large part of the energy content in fuels is wasted when they convert to electricity through a steam or gas turbine. In the context of global climate, nuclear reactors also produce a kind of "primary electricity," even if part of that energy releases as waste heat (i.e., nuclear reactors release nuclear energy as heat, which boils water into steam that then powers a turbine, with an overall efficiency of around 35%). As this waste heat produces no CO_2 emissions, the fact that much of the original energy content is wasted proves unimportant.[21]

21 1:3 ratio is arbitrary and used here for simplicity's sake. It implies a coal plant having 33% efficiency in electricity production. BP energy statistics use 1:2.78 as the ratio, as coal plants are normally a bit more efficient in electricity production than 33%.

EROEI

Humans need to use energy to produce energy. And in modern societies, the net energy received from that process can be employed to keep those communities running. The amount of net energy we get from an investment is called EROEI, or Energy Returned on Energy Invested. Of all the concepts in the field of energy, it remains one of the most important, but also one of the most ignored.

Historically, most global investments in wind and solar have gone to subsidized markets, meaning they flow to projects not necessarily inherently profitable, but which someone—a politician, lobby group, or local government—is willing to make profitable. This hides the true competitiveness of such energy sources, which would prove immensely valuable for analysts and policymakers regarding wider decarbonization efforts. So far, the main lesson has been a moderate to high political willingness to use tax/rate-payer money to support these investments. But a more comprehensive and accurate study would need information on the possibility and size of these investments without subsidies, on a level playing field, because only there can an energy source prove itself capable of growing into significant shares. Indeed, societies cannot use subsidised energy to provide the surplus needed to pay for those subsidies. Or, slightly more provocatively, the "energy revolution" has actually been mostly an "energy policy revolution", at least so far.

Jobs

Many political speeches, headlines, and articles regularly tout the number of jobs a certain energy project or entire energy sector might create. This seems like good news for the local economy, but on a wider view, fewer jobs in "primary sectors" like energy production, mining, and agriculture is desirable. This remains true because people are expensive, so the more people working in primary production, the more expensive those sectors will become, ultimately further depleting resources and disposable income, thus taking them away from other needs like services and savings. As with investments, the particular amount is not especially important—only the payoff.

Generally, the more productive a job, the higher the wage. And the more employees to pay, the lower the bottom line. Thus, a coal power-plant with a staff of 100 will produce much cheaper electricity for the surrounding society than the same plant with a staff of 1,000. Cheaper energy leads to higher productivity in society, which generates economic growth and raises the potential for higher wages, thereby creating more disposable income. In recent decades, automation and robotics have shown they can replace many jobs, and modify others for much higher productivity per worker hour. The potential impact for society if such jobs are not replaced with others will have to remain a topic for another book (and hopefully, serious political discussions).

EVERYBODY WORKING!

To understand why jobs in energy production actually prove far less desirable than media commentators suggest, imagine a politician pushing for policies to ban all tractors and combine harvesters by arguing this would create a lot of jobs. Ridiculous, right? Before the Industrial Revolution, nearly everyone worked jobs in primary production, but living standards remained quite low precisely for that reason. Why do so many people seem eager to accept similar arguments in energy production, where jobs are often one of the main arguments for a certain policy? In this vein, if local jobs increase through exporting energy or related technology, then greater exports are, ipso facto, good for the local economy.

Price, Cost and Value of Energy

What is the difference between the cost, price, and value of energy, and why do these distinctions matter? Producing energy always incurs a **cost**. But energy is only **valuable** if delivered to the user at the right time and in the right form. Analysts often use markets to define the **price** at which demand for and supply of a given energy service can meet. If one assumes a freely operating open market where external costs are fully included in prices on a level playing field, these three would follow each other quite rigorously. Producers would generate energy with the lowest costs possible and sell it to consumers at the highest price they could get consumers to pay (beyond a certain threshold, consumers would buy from another provider or go without). And if demand existed for more energy even at higher prices, the producers would undoubtedly invest in additional production. But with lower demand, prices would drop, and more expensive/older facilities would halt operations or perhaps decommission permanently.

REGULATED AND DEREGULATED MARKETS

Today, energy is sold in both regulated and deregulated markets, though historically it was typically regulated. But how do these market-types differ in practice? For starters, regulated markets normally feature a single utility-company selling energy in a given area, and this company handles all production, transmission, and other related services. As such, no competition exists in these local service-area bubbles, though corporations' profits and activities remain tightly regulated. By contrast, deregulated markets display much less vertical integration and far more competition as a result of multiple producers competing for customers, with energy producers often selling their product to a common market, from which retail-sellers and/or customers then buy. In some cases, buyers can achieve considerable flexibility in terms of how and from whom they purchase energy, thereby intensifying competition between producers and often reducing prices. One of the rising issues of deregulated markets has been the unwillingness (due to lack of incentives) of any of the players to ensure long-term security of supply also in exceptional times.[22]

But the actual market is not free or open, nor are external costs included, even in "deregulated markets." So while cost, price, and value are related, they often refer to notably different data. And more problematically, mistaking one for the other can cause serious misunderstandings. The following discussion focuses on the electricity market, but the principles hold in relation to other energy products as well.

Price

One might think price a simple concept, but in energy markets, this assumption often proves mistaken. Indeed, enormous differences can exist between the market price of electricity (whether short-term spot-price or long-term contract) and the electrical bills customers in that area pay (whether residential or business). To that point, electricity price usually constitutes only part of the actual amount charged for electricity service. Moreover, a household typically pays a variety of fees, surcharges, and taxes. For example, a random electrical bill might include a fixed-grid cost per month, a per-kWh transmission cost,

22 An excellent introduction to the North American situation is Meredith Angwin's 2020 book "Shorting the Grid: The Hidden Fragility of Out Electric Grid."

taxes for electricity and transmission, a value-added tax , a payment for security of supply, and/or a fee for renewable-energy subsidies—all of which will affect customers' bottom line independent of the specific market price.

So, basically a market might include both "free" (at times) and expensive electricity at the same time. This is true in Germany, where high penetration of variable wind and solar may occasionally push electricity prices negative, but where customer costs remain quite high because of all the added surcharges, fees, and taxes, some of which go to the producers of renewable electricity as feed-in-tariffs.

Generally speaking, governments would be wise to concentrate on incentivizing demand flexibility and energy storage rather than investing further in wind and solar, at least until the number of negatively priced hours stops growing and perhaps begins decreasing. It makes little sense to support additional forms of power generation if much of that addition ends up produced for a market with no demand for it.

CASE GERMANY

The energy market in Germany continues getting more and more confusing. The cost of maintaining a secure electricity supply in Germany has been growing. In the 1st quarter of 2019, this cost grew by a third compared to the 1st quarter a year earlier, from 355 to 473 million euros. Additionally, wind producers failed to transfer all their production into the grid due to insufficient grid connections. Despite this lack of efficiency, they were compensated to the tune of 364 million euros. During the three months in question, 3.2 million megawatt hours (3.2 terawatt hours) of wind electricity needed to be wasted to prevent the grid from overloading.[23] That electricity could have powered over 5 million apartments (at 2.5 MWh per year or 0.63 MWh/quarter) during those months. This odd dynamic produces strange situations. For example, **German households have been able to heat their homes with natural gas at lower costs compared to installing an electric heater or heat pump—even if the price of electricity hit zero.**[24]

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23 See this well-reported story used here as a source for data: https://www.cleanenergywire.org/news/germanys-grid-management-costs-soar-high-winds-overstrain-capacity.

24 See https://kaikenhuippu.com/2020/02/18/why-germans-wont-heat-their-homes-even-with-free-electricity/. Further, since late 2021, the situation has been changing as the prices of natural gas have skyrocketed even faster than those of electricity.

In some countries, certain costs do not appear in energy or electricity bills but are ultimately collected in general taxes. For example, in Finland, the guaranteed price for wind and various other renewable electricity production is paid to producers directly from a government budget, which is then collected as taxes or taken as debt. This hides their cost more efficiently than the German method, in which specific costs appear in consumer bills, though their government now seems to be moving toward funding renewable subsidies directly from budget too. Paying them from the budget does alleviate energy poverty, but the state will then have less money for other priorities—including social security and other services aimed at helping lower-income citizens. See Figure 16 for a visual depiction of the process by which market prices can reach negative value while subsidized energy sources still get paid.

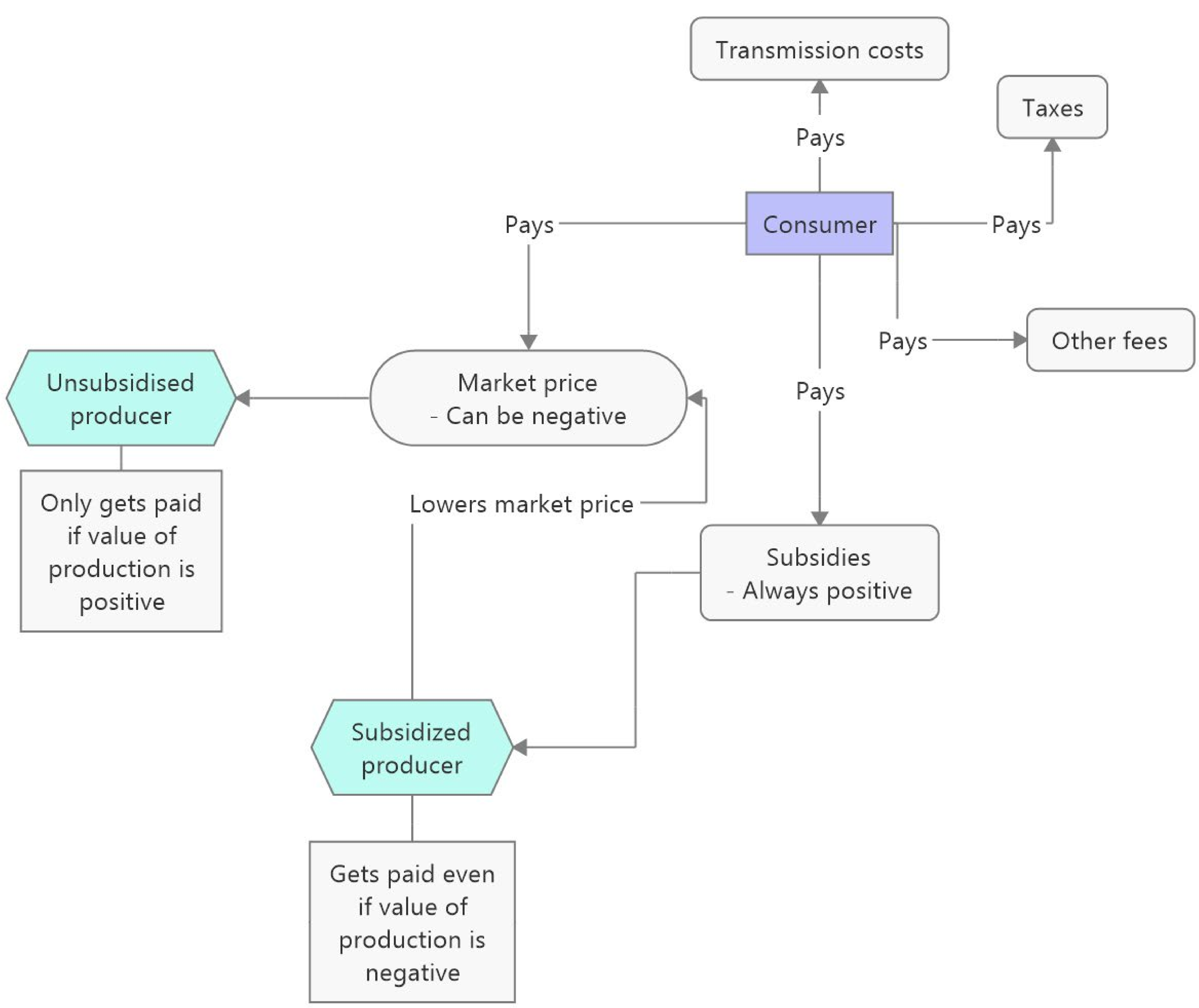

Figure 16: One possible "high level" description of money flows in a mix of subsidized and market-based approach.

To summarize, the selling price usually remains quite different from the price consumers pay for electricity, and such differences also vary across countries. Many articles highlight the *price* of electricity as zero or negative on the spot-market; but the *price* a German consumer pays in her electricity bill remains about 30 cents per kWh due to the extra fees, surcharges, and taxes. Moreover, the price a German producer receives for their product at a given moment might be negative, zero, or perhaps 10 cents per kWh depending on the way that electricity was produced and whether the production was subsidized.[25]

Cost

While "price" refers to the market price or total price consumers pay for energy, "cost" relates to the expenses of producing and delivering energy service. In principle, the situation should express quite simply: total average cost of energy production must remain lower than the average selling price. But as with prices, real-world situations for cost prove more complex. For example, a producer of a certain type of energy might pay a different level of taxes than others, or they may receive subsidies and grants while competitors receive none. And such taxes or subsidies do not necessarily reflect the existence of external costs (see box), as specifics will vary heavily depending on the situation. Indeed, some countries and states maintain portfolio standards, meaning a certain share of energy must come from a particular origin—no matter the cost. Any such cost, of course, is subsequently passed onto consumers.

EXTERNALITIES

Externality is a well-known concept in economics. It refers to a cost producers of a given product or service do not pay but externalize into the environment or society. This enables said producer to sell their product for lower cost at the market, thereby gaining competitive advantage over producers not externalizing their costs to same degree, a dynamic that can ultimately push the latter companies out of business, all while the environment suffers and public health worsens. In free markets, external costs are internalized into products as fully and reasonably as possible. In practical terms, this might take the form of taxes or cap-and-trade systems, tighter regulation on pollution and environmental impacts, or prohibitions/restrictions on certain activities altogether.

25 For more on the German subsidy-system and tariffs for renewable energy, see https://tinyurl.com/y4noo2nl

An energy producer might also externalize some costs to society and the environment, while others need to include theirs more fully. For example, coal combustion releases harmful particulate pollution, and often remains free to do so (if within local regulations). Depending on how societies value a statistical "human life"—and by extension, public health more broadly—the cost of this could register at, say, 5 cents per kilowatt-hour, a figure much higher than the historical fuel cost of producing electricity at most coal plants. And though only an example, that figure sits within the valid range suggested by reports. Indeed, **according to Europe's Dark Cloud, health costs of coal plants in Europe alone measure between 32 and 62 billion euros per year, depending on the statistical value used for loss of life.**[26] **If these costs were internalized in coal combustion at the plants, the average cost of coal-powered electricity would increase by roughly 3-6 cents per kilowatt hour (30-60 €/MWh)**.

Analysts often compare costs through Levelized Cost of Electricity (LCOE), a metric that aims to include at least some expenses of energy production in a uniform way. Unfortunately, energy sources prove so fundamentally different that any "uniform way" actually depends on numerous assumptions either favouring or disfavouring certain types of production. Generally speaking, only projects based on similar technologies should be compared, like comparing solar installations with panel technology A or B, or contrasting the efficiency of installations at locations A and B. Otherwise, **this desire to apply a uniform rubric could become something akin to comparing the cost of a tent to that of a house**. Indeed, levelized electricity costs are only "levelized" after the application of several assumptions, knowingly or otherwise, including interest rate and assumed operational lifetime. This means the LCOE of an energy source might fluctuate wildly depending on the specific set of assumptions used by a given analyst.

LCOE does not include delivery costs for reliable energy service, only that of producing a kWh of energy. One can see this when solar electricity from PV panels shows a low LCOE, as that low price only applies when the sun shines brightly, which may or may not correspond to society's energy needs. Independently, local solar electricity reaches a cost approaching infinity at night; no

26 https://wwf.panda.org/?272916/Europes-dark-cloud-How-coal-burning-countries-make-their-neighbours-sick

matter how many panels a person installs on their roof, they produce nothing when the sky is dark. Still, this cost can be mitigated with storage or long-distance, high-voltage power transmission lines connecting different regions. Of course, when storage and intercontinental power lines enter the equation, the discussion has undeniably moved beyond mere low-solar LCOE. Ultimately, this means comparing variable energy sources like wind and solar with sources producing energy “on demand” using LCOE alone is problematic, as their value to society varies too significantly.

Value

Finally, we have the “value” of energy. From the three, this term and concept is the most important, least used, and hardest to understand. Generally speaking, “value” can relate to an individual consumer or society as a whole. For energy specifically, value depends greatly on demand for it at any given moment and place, as well as available infrastructure.

An extreme example will help illustrate. If a house is fully lit and comfortably warm, with the fridge, freezer, and other appliances running normally, any extra electricity or fuel will be of little value to the homeowner at that moment, even if they received it for free. Its marginal utility would remain low for the family in question, as their demand would already be satisfied. But if the family was stuck and freezing in the dead of winter due to lack of fuel and a prolonged blackout, they would likely pay a considerable sum for any firewood, gasoline (if they have a car or generator), electricity, or other suitable energy source. Indeed, if it prevented their premature deaths, the family would likely pay everything they had (plus an arm or leg, as required) just to prolong their lives even a couple more hours and thereby survive the ordeal. As such, the marginal utility—and more importantly, the *value*—for energy at that precise moment would approach infinity for a family in those dire straits.

Of course, even in this extreme situation, conditions would exist. For instance, electricity would prove useless if the family possessed no appliances. Likewise, firewood and other fuels would remain relatively useless if the family had no place or means to burn them. And sunshine in some other place or time would offer exactly zero help to the family in their particular situation, unless they had means of transferring it through space (transmission cables) or time (batteries or other suitable storage mechanism). Moreover, electricity and even diesel oil would prove worthless for transportation if the family's car used gasoline. Similarly, if nearby gas stations do not have electric charging ports for an EV, even a gigantic amount of gasoline would possess little value.

These examples explain the fundamental reasons humans originally started using fuels and other dispatchable energy sources: to provide energy when and where it is needed. They display high marginal utility and greatly increase productivity by enabling activities requiring energy when most convenient and prudent, such as washing clothes or dishes with a suitable appliance. Societally, examples include a manufacturing plant, grocery store, and hospital. Such venues offer services in predetermined hours, sometimes all day and seven days a week, as with emergency hospitals. A service and facility like that can only exist with a constant supply of high-quality energy.

Let's now compare these fundamentals of value with cost of production and the price in a given marketplace. The value of an energy service may or may not appear in the short-term market price. For example, if a region has enough solar panels to produce more than it can reasonably use on a sunny day, the following outcomes might occur:

- The **cost** of solar energy remains the same, mainly reflecting capital investment, interest payments, profit margin, and other potential costs like land-rents and maintenance. (LCOE)
- The market **price** of electricity in the grid can drop to zero, resulting in zero profits for anyone selling electricity to the grid at that moment and allowing consumers to buy it at rather low cost (depending on other fees or surcharges).
- The market **price** of electricity might even go negative, making electricity a waste and forcing producers to pay someone to use it, such as running an industrial appliance (say, a large pump) unnecessarily, or a utility to curtail their production. This applies for all electricity sold in the short-term spot market, though not the portion sold at long-term fixed prices.
- Solar producers might still get a substantial **price** for each megawatt hour produced if a subsidy or feed-in-tariff is enacted. This subsidy hides negative prices and other externalities for solar producers. Indeed, as long a subsidy for new solar installations is in place, an incentive to install more solar will exist, exacerbating the situation for all producers.

- The **value** of electricity produced for society remains high as long as people have use for it. But the marginal value of overproduction is negative, as society simply does not require extra energy and will therefore need to find ways to get rid of it, incurring further costs.

So while variable solar PV or wind might have the lowest LCOE in a given scenario, the conclusion the market will fill with solar PV appears highly dubious, even if a low LCOE might, independent of other considerations, logically suggest that. Indeed, the value of these energy sources to society (followed by spot prices on the market) drops drastically after a certain threshold is breached. This process is called “cannibalization.”

CANNIBALIZATION OF VALUE

Why does variable energy production’s value drop faster than average prices as their share increases? In any given region, sun shines mostly at the same time everywhere, so most solar PV panels produce at the same time. Wind also blows mostly at the same time even in larger regions. This means whenever sun shines and/or wind blows, any region with a sizeable share of these resources will see market prices for electricity fall toward zero, or even dip below. This outcome affects all other production as well, though only when wind and sun prove abundant. With high volumes of wind, turbines rotate to produce electricity, eventually bringing the value of wind energy down as it expands its share of total production during such times.

What is the share or threshold after which the value of solar or wind begins decreasing more rapidly? The answer depends on numerous factors, including the current energy mix, availability of low-cost flexible supply, flexibility of demand, and interconnections to neighbouring markets, as well as *their* flexibility and energy mix. **With current technology, the share different markets can adopt of variable production without experiencing too much cannibalization usually sits between 20 to 40% of annual electricity demand (not total energy demand).** Some exceptions exist, such as Norway with its highly flexible hydro capacity, but such local exceptions do not exist in most situations, and the principles therefore cannot be generalized.

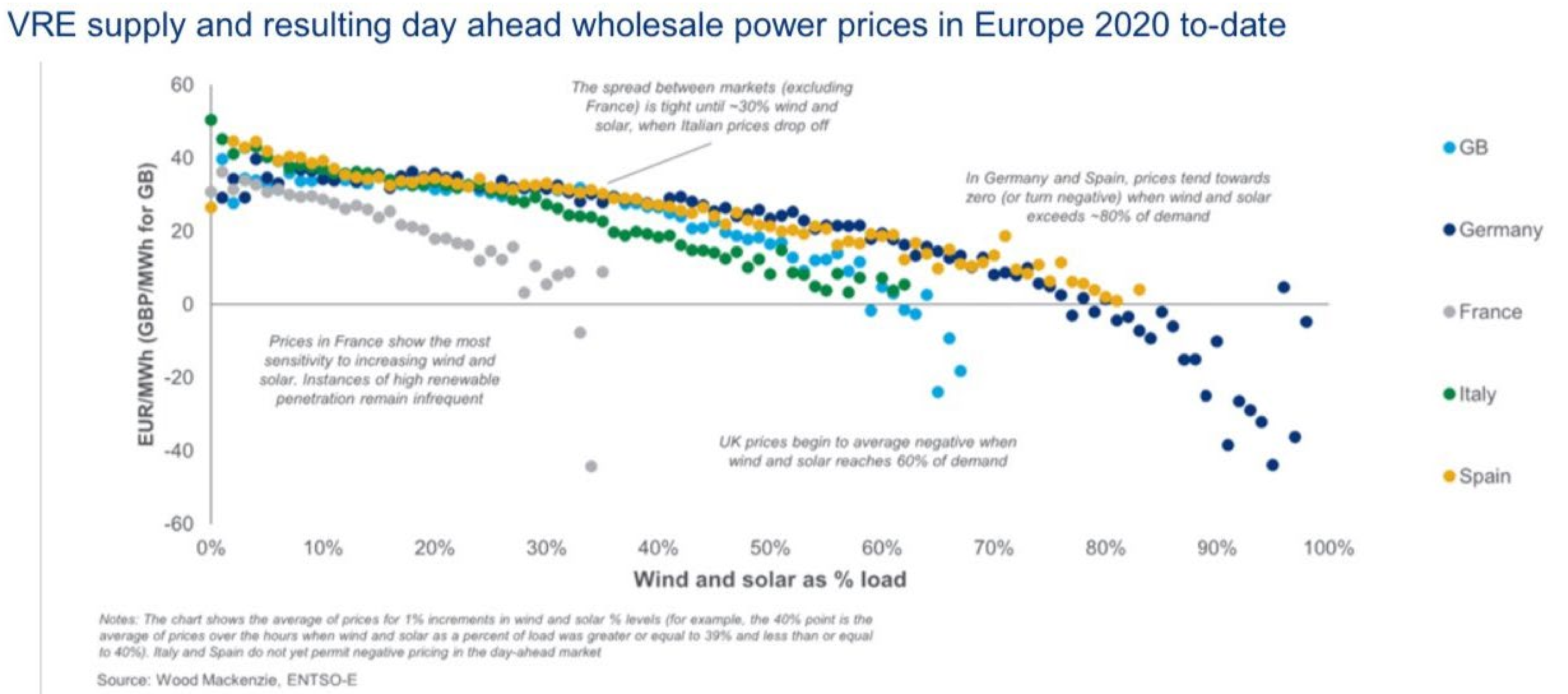

Figure 17: VRE supply and resulting day ahead wholesale power prices in Europe

In Figure 17, the share of VRE (wind and solar) supply appears plotted with day-ahead wholesale electricity prices in Europe. The larger the share, the faster the drop in wholesale prices. In fact, the figure shows the effects on prices for all types of production, not just wind and solar, so it actually underestimates cannibalization for wind and solar while overestimating it for other production (which can produce also during higher prices when wind and sunshine prove less abundant).

THE GRID

The modern electricity grid represents a modern technological marvel. Through its structure, numerous producers of electricity provide almost the exact amount millions of consumers use every second. Indeed, if production deviates from consumption too much, quality of electricity drops. Moreover, the voltage changes and can damage appliances, though grid operators use a range of automated mechanisms to prevent such surges. This constant and necessary balance between supply and demand poses one of the prime obstacles for the prospects of wind and solar increasing their share—they do not produce power when demand actually exists, but only when weather is optimal. And storing the resultant electricity in sufficient quantities for suitable timespans remains prohibitively expensive for now.

Energy and Power Density

Our energy sources exhibit different energy and power densities. These qualities are important in many ways, though their significance remains underappreciated. A low energy-density for a fuel means more disruptive mining, pumping, extracting, harvesting, transportation, and storage are needed to produce and use a given amount of energy. When it comes to fuels, two major types exist: chemical and nuclear. And the popular online-comic XKCD illustrates the difference in energy density between these two types quite beautifully.[27]

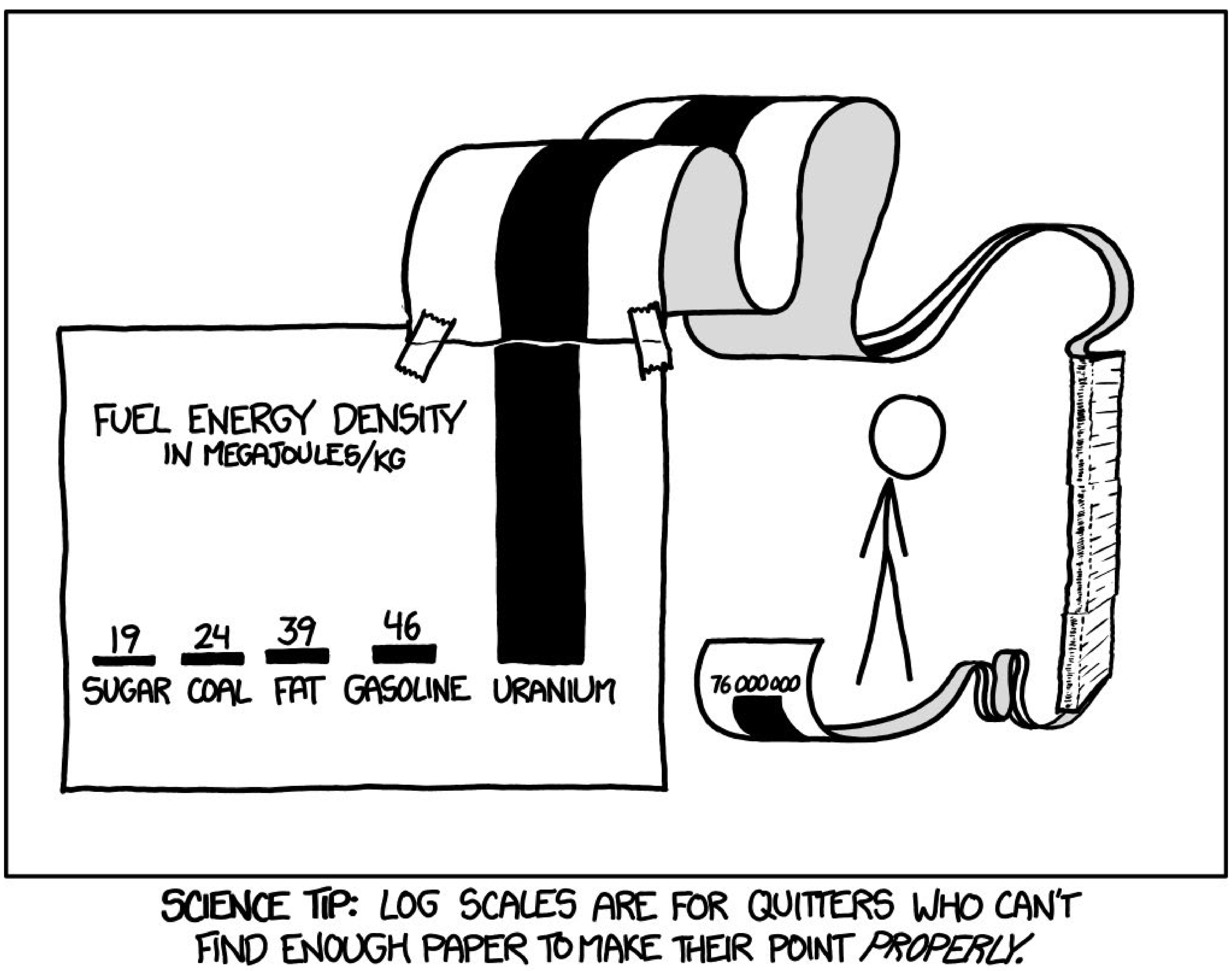

Figure 18: Energy density. Source: XKCD-comic.

Power density also serves as an important metric.[28] It describes the average amount of power produced per square meter of area in watts per m². With power plants using fossil fuels or uranium, the power density is normally in the range of hundreds to thousands of watts per square meter (including mining for fuel). With wind, solar and hydro, the range remains in single digit watts/m², and the figure actually drops below 1 watt/m² with biomass and biofuels.

27 The comic presents gravimetric energy density, MJ/kg. One could also use volumetric energy density, MJ/litre, though these two approaches have slightly different applications.

28 See Vaclav Smil, *Power Density: A Key to Understanding Energy Sources and Uses* (Cambridge, MA: MIT Press, 2015).

Power densities, W/m^2		
	Lower limit	Upper limit
Biomass	0,1	0,5
Biofuels	0,01	0,1
Hydropower	0,5	3,0
Wind (wind park)	0,5	1,5
PV and CSP	4,0	10
Coal	100	1000
Natural gas	200	2000
Oil	100	20000
Nuclear power	200	1000

Table 1: Examples of power densities between energy sources. Data is from Vaclav Smil 2015.

The low-power density of renewable energy sources stems from the dilute energy-flows they harvest from. Environmentally, power density matters, as lower numbers translate to larger areas needed for—and therefore impacted by—energy production. The particular type and force of environmental impact also proves vitally important. For example, with wind farms, limited agricultural and forestry-related activities remain possible in the area because turbines need considerable space in between to avoid disrupting each other. Similarly, nuclear plants typically feature exclusion zones surrounding the area with limited activities as well, often designated as nature conservation areas. Rooftop solar does not replace any ecosystems, but on-land panels require vast space and use it intensively, leaving little space or resources for nature. By contrast, biofuels can replace an entire ecosystem with a monoculture harvested annually or every few decades (as with forestry).

Sustainability from Different Perspectives

“Sustainability” represents a very complex and context-dependent concept. This chapter includes subjective, interpretive thoughts on the subject, which will hopefully enable readers to approach it from new angles. Still, these ideas are not presented definitively or dogmatically, so feel free to disagree. That established, most people consider the idea of sustainable development—allowing current generations to meet their needs without compromising the ability of future generations to meet their needs—reasonable and desirable. But what that phrase means tangibly and practically in a given situation varies greatly depending on numerous factors and happenstantial circumstances in a certain time and place. And the concept has precipitated conflict between different generations, as seen in relation to various demands from younger climate activists in recent years.

For example, demanding people stop driving vehicles powered by fossil-fuels seems a simple and straightforward goal to reduce pollution and greenhouse-gas emissions, thus allowing future generations to meet their needs while avoiding or at least mitigating the worst effects of climate change. But we humans of the 21st century live in societies built upon great personal mobility, specifically with cars, so demanding people stop driving them suddenly and entirely will compromise many people's ability to meet their needs today.[29] After all, most citizens around the world could not realistically switch to a bicycle or EV immediately without causing major or even prohibitive problems in their lives, and those who could afford the change (financially the physically) may not want to cycle to work or social commitments. As such, a more realistic and reasonable timeline for changing the fundamental infrastructure and dominant transportation models in cities and towns around the world runs into several decades or even centuries.

Yes, the "adults" should be ashamed for stealing the future from coming generations, but most people around the world simply try to provide for their families in various circumstances, without which no future generations can exist in the first place. This conundrum poses a great difficulty for decision-making in the present, and many valid viewpoints and nuances exist on the matter, so simplified "solutions" rarely prove helpful. Indeed, far from a black-and-white scenario with clear, distinct choices, an ever-shifting and conceptually grey landscape awaits all who try to solve this paradox. Indeed, another prominent factor in this complexity is the growing conflict between wealthy nations demanding less consumption—often for everyone—and developing societies (which represent the majority of earth's population), where most people strive to consume *more* rather than less, and quite understandably so, given their poverty and entirely reasonable desire for a higher quality of life.

One admittedly unpopular way to analyse this situation emerges when one combines two facts: (1) poor citizens around the world face the most severe impact of climate change, as their poverty prevents them from easily or quickly adapt-

29 This seems regrettable from the point of view of sustainability, yet it stands as something all humans must live with and base future actions upon all the same.

ing to the effects, and (2) reducing poverty means increasing energy use in households, businesses, and entire industries—and historically, doing so has involved fossil fuels. Obviously, if such citizens can adopt low-carbon energy sources as much as possible, this will benefit the Earth overall, but such choices are rarely simple or feasible. Indeed, climate change is already happening and will continue for decades if not centuries no matter how much societies reduce emissions today. If policymakers and voters in more affluent countries want to minimize the harm climate change does to poor people, helping them increase their wealth and enabling them to better respond to the growing impacts seems like a reasonable aim, but does that hold true even if it means more cumulative emissions? This type of question remains difficult for both practical and moral reasons.

Measuring Success

Climate change, ocean acidification, shrinking biodiversity and habitat loss pose the most pressing environmental issues in the context of energy currently. But conceptually, how do we know if our actions are successfully mitigating the dangers? Because certain solutions might seem to improve one obstacle, only to lead to regression in other important areas.

The growing use of bioenergy offers an enlightening example in this regard. To begin with, one should ask whether societies can use significantly more of this renewable energy source in a way that will prove sustainable. In practice, bioenergy has been included in most renewable energy policies and subsidy-schemes of recent years, but expanding use of biomass for energy and raw material can threaten biodiversity and local ecosystems. Further, its ability to slow climate change remains debatable and appears mostly based on political agreements instead of actual science and evidence. As such, one can reasonably question whether measuring success in mitigating climate change in terms of the share of renewable energy represents a good idea or not. Indeed, any careful and honest assessment would have to say no (or at least, "not really"). Despite this, many policies now aim for precisely that target, with media outlets then entrenching that perspective further through uncritical coverage.

The most important figure for Earth's climate is the absolute amount of greenhouse gases in the atmosphere, including CO_2, methane, nitrous oxides, and a mixture of other minor gases.[30] And in this context, CO_2-eqv concentration is the crucial factor. Indeed, global society must stop increasing this metric, and ideally bring it well below current levels in future decades and centuries.

For us humans specifically, however, the important metric proves more complex. On a daily level, the trend of the gases in question and their concentrations matter. For example, we need to know how much the concentration of GHGs in the atmosphere has changed compared to earlier years, and decide what levels will still be relatively "safe" long-term. In this situation, "safe" means the costs of climate change remain relatively low, and the risk of large positive feedback-loops and runaway climate change stays small. Fortunately for us here on Earth, atmospheric emissions and GHG levels prove relatively straightforward to measure.

But climate is not the only consideration, and emission reductions should not be our only focus. After all, for what purpose are we trying to mitigate climate change if not to protect human wellbeing, as well as that of the other species here on Earth? Would it even make sense to propose policies or actions decreasing human wellbeing significantly if they only reduced emissions a small fraction? Obviously, this represents an opportunity cost, and policymakers need to think carefully about where the cost/benefit ratio turns optimal. Making matters more difficult, that optimal ratio varies according to time, space, local conditions, available technology, and even personal preference. To cast the situation somewhat provocatively, sacrificing human wellbeing to protect human wellbeing seems bizarrely counterintuitive, especially if the sacrifices are greater than the gains.

Another important question concerns the measurement of human wellbeing. Several options exist, each with its own pros and cons. Overall living standards and happiness for most of the population seems a strong contender, though such qualities and quantities will prove difficult to measure empirically. On the other hand, Gross Domestic Product (GDP) per capita is certainly easier to measure, but has its limits analytically, as GDP can divide unevenly or be created by activities that do not increase current or long-term wellbeing. Ultimately, all metrics like GDP, GPI (Genuine Progress Indicator or Global Peace Index), and ISEW (Index of Sustainable Economic Welfare) remain subjective, but that fact

30 These factors also affect the amount of water vapour, another important greenhouse gas, as does the temperature of the planet.

alone should not preclude their use. Perhaps the wisest choice would be using a couple metrics in tandem to generate a broader view. Indeed, any analysis with a singular measurement will necessarily offer a narrow perspective on a wide and deeply complex topic.

Combining emissions with wellbeing—however one measures it and to whatever degree one considers other living creatures on Earth—results in ratios like emissions per dollar of GDP/capita created, or an emissions trend compared to a GPI trend. Ultimately, the most important considerations relate to the level of wellbeing humans have and how much that causes emissions and other environmental harm, as well as the corresponding trends—not the amount of nuclear or renewable energy in the grid, not the amount of energy consumed per person, not the efficiency of the economy (dollars of GDP per energy consumed for example) nor the amount of dollars invested, and not the number of jobs created. Indeed, the truly important intergenerational aspect comes from how we discount the wellbeing of future generations compared to today. Discounting as an aspect of societal discussion (rather than investor analysis, where the term is more common) is the final advanced topic to address.

Discounting

The basic idea of discounting is based on humanity's preference for the immediate rather than the distant. That is to say, many people would prefer 1 million in cash now rather than 2 million ten years in the future. After all, a lot could happen in ten years—most notably, one could die—and if invested wisely, the 1 million might double or increase even more over that same period, while also offering the opportunity to spend some of it as needed. As such, this preference for the immediate is measured through a discount rate, an annual percentage akin to interest. The greater the discount rate, the more the present is prioritized over the future. Put in the context of intergenerational sustainability, a low discount gives more voice to future generations in the discussions and decisions of today, whereas a high discount rate means higher preference for consumption now. Moreover, in the context of technological development, faster rates of development call for higher discount rates: why build a house that lasts a century if one can build a better house much cheaper in 30 years due to development in materials and methods? Assumptions about price trends function similarly: if the price of solar panels is falling rapidly, one might decide to wait another year or two and hope for a cheaper installation. But as long as development continues at a rapid pace, the situation will remain the same two years from now.

In intergenerational discussions, recognizing our assumptions will prove vital. Indeed, how do we think humanity and its wealth will develop, and what assumptions are those predictions based on? Historically, the economy has grown steadily, so an expectation it will continue to do so seems reasonable on the surface. But before the use of fossil fuels and the Industrial Revolution and the higher productivity they enabled, the economy actually did not grow much even across millennia. So what, then, is normal, and how do we know? How will runaway climate change affect economic growth and human wellbeing? What is the cost of lost ecosystems, and how do we quantify them in the first place? These questions all need to feature prominently in public discounting-discussions among policymakers, media, and citizens. Indeed, virtually no public discourse about discounting exists currently. But if societies are to make informed policy decisions amid all the challenges and dangers the Earth now faces, we simply need to discover its nuances, as well as the assumptions, reasons, and decisions behind a given rate.

In the final part, we examine the importance of understanding science, balancing views, and giving proper context, all through a case study in one extremely special energy source: nuclear.

Part 3 – Case Study on Common Pitfalls

Most people tend to get things wrong when it comes to writing about nuclear. While the reasons for this are numerous and historical, the discussion here will remain more focused.[31] In fact, perhaps a short example is in order. Specifically, some studies suggest the majority of citizens in modern, highly educated western countries do not know nuclear energy is low carbon—even though that should be obvious since nuclear energy is produced without combustion of fuels.

But it is clearly not obvious to people in these countries. Far from it, in fact. Indeed, as seen in Fig. 19 below, almost half the respondents think nuclear contributes to unhealthy air pollution and climate change.[32] Meanwhile, just over half the respondents think natural gas adds to pollution or climate change. In France, where electricity is among the cleanest in all industrialized nations (thanks to nearly three-quarters of it coming from nuclear), 69% of the population thinks nuclear energy contributes to climate change.[33]

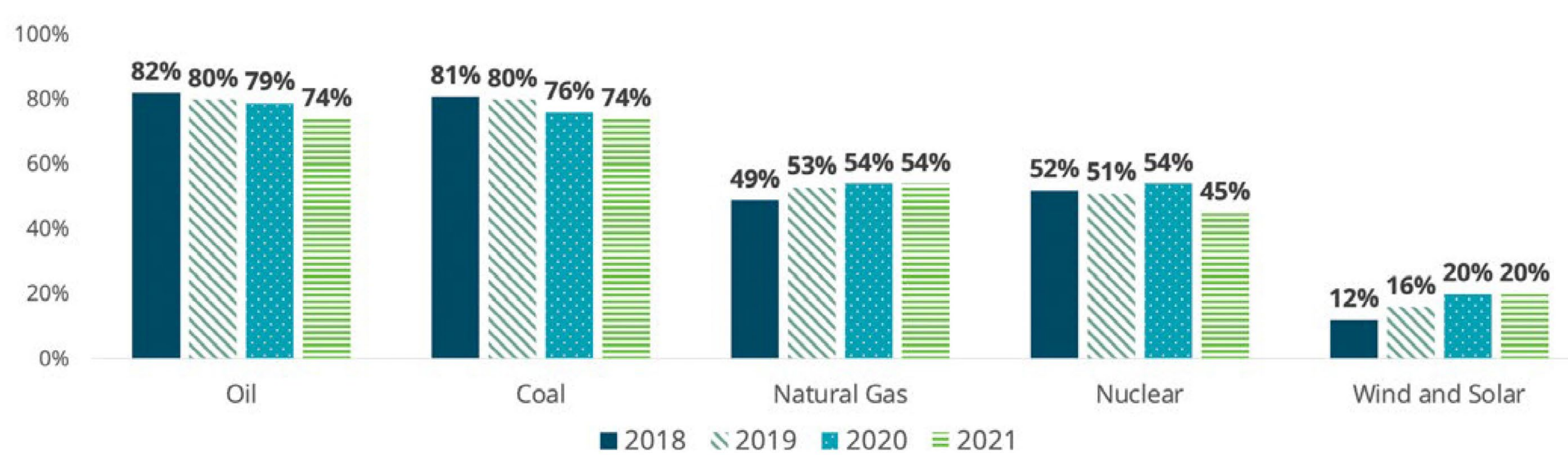

Figure 19: How much does each of these energy sources contribute to unhealthy air pollution and climate change? 1,097 national respondents, % “A lot, Some” and “A Lot More, More”. Source: ecoAmerica 2021.

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31 See Spencer R. Weart’s excellent treatise on the topic of why people fear nuclear, The Rise of Nuclear Fear (Cambridge, MA: Harvard University Press, 2012).

32 Speiser, M., Hill, A. N. (November 2021). American Climate Perspectives Survey 2021. Energy Attitudes: Americans Support Clean Energy. ecoAmerica. Washington, DC. https://ecoamerica.org/american-climate-perspectives-survey-2021-vol-v/

33 See this poll from 2019: https://www.bva-group.com/sondages/francais-nucleaire-sondage-bva-orano/

Clearly, much work remains in improving science literacy and educating the public about energy, not in the least because numerous biases—and maybe even willful misinformation in some cases—complicate the issue. While the previous sections of this book explored basic and advanced concepts related to energy, this portion uses case-studies and examples to push understanding farther and deeper.

Journalists tend to make a handful of common mistakes when writing about energy, and these result in the vast majority of errors and misrepresentations in print media. And unfortunately, such mistakes are by no means exclusive to nuclear. Indeed, as wind and solar have grown from small, quaint projects to enormous industries with colossal impact, they have both lost some of the "benefit of doubt" credit they enjoyed in earlier years, and have recently drawn increasing opposition as they disrupt people's lives and businesses. Many of these misunderstandings and misrepresentations trace back to intuition or cultural understandings and local context. Expressions of this type often start with phrases like "Well, everybody knows that..." But the function of science is to examine every claim and hypothesis without preconceptions, even if that means rejecting the validity of "common sense" ideas, personal intuition, or cultural beliefs. Only through such impartial and independent evaluation can human knowledge advance. And in turn, journalists concerned with professionalism and credibility must write about globally important topics like energy and climate change accurately, as their publications strongly influence the ways in which voters and policymakers see the past, present, and future of our planet.

This chapter delves into three types of common mistakes. First, understanding the practice of science without being a scientist is vital if one writes about the details and results of studies. Of course, scientists are people and hold biases too, but often the most important aspect of a new study concerns the assumptions used to produce the result, not the result itself.

Second, even inside scientific research, disagreements and divergent schools of thought exist within any given field; indeed, those disagreements and debates remain crucial to the practice of science and advancement of its various fields. But one must understand why particular disagreements exist, what (if any consensus) has emerged, and which perspectives they promote in their writings. People who have no strongly held opinion on a matter tend to believe "the truth is in the middle" when confronted with two differing opinions. So offering them a mainstream consensus along with an extremely fringe set of scientific claims can skew opinions far afield of the consensus, despite it likely being closer to the truth than any fringe studies. Also, many people enter a debate with a pre-established opinion already engrained, leading them to search for any confirmation of their own opinion rather than addressing the data as objectively as possible (i.e., confirmation bias). Scientists train themselves to better fight this tendency, but journalists would do well to heed the lessons at hand too.

Finally, emphasizing context and broader perspectives remains critically important to writing about energy and the Earth's climate. Indeed, we otherwise risk imparting only a single datapoint to the reader, a fragment of the larger story that could prove useless or even net-harmful, as that lack of context may lead to false comparisons or further misunderstandings. To once again illuminate with an extreme example, the sentence "eating is dangerous, because one can choke on the food" represents a true statement, as this can indeed happen; but anyone thinking of the larger context will surely recognize eating remains crucial to avoid starving, even if it does carry a tiny risk of choking on food.

Understanding the Science

To achieve genuine understanding, do not simply believe headlines, but search beyond press releases and read more than just abstracts. Again, the most enlightening lessons in science often come from the methods, data, and assumptions used, not merely the results. Indeed, scientists are human beings like the rest of us, and they can bring agendas and ulterior motives to their work despite the principles of science. And unfortunately, for those who have determined their conclusion in advance, complex regression models allow for the manipulation of data to produce a desired result irrespective of accuracy in a wider context.

Let's take a paper by Benjamin Sovacool et al. from 2020 as an example.[34] This paper claims deployment of nuclear energy around the world has not reduced carbon emissions, while the deployment of renewable energy has. To start, one can reasonably ask the purpose of such a study, given that such data already exists in reputable sources. For example, one could research the impact on emissions in France and Sweden during their deployment of nuclear power from the 1970s to the 1990s—namely, they fell rapidly and significantly. In fact, Sovacool

34 https://www.nature.com/articles/s41560-020-00696-3

wrote a highly similar paper a few years earlier, but that got retracted.[35] At this point, a cynical person might even conclude he deliberately wants to write a paper showing nuclear energy is bad for climate mitigation, a dubious claim that authors and journalists can then (and have) cited in other papers making similar arguments.

Next, one can fairly ask how the authors managed to arrive at such an unusual result. Indeed, Fell et al. posed that very question in their reply to Sovacool and his coauthors in 2021.[36] The latter team's result—using the same dataset as Sovacool and his colleagues—proved notably different: both nuclear and renewable energy deployment have helped decrease emissions.

Another issue related to this is the tendency to cherry-pick studies in a way that fits existing narrative or position. If someone doesn't know much about energy in general or nuclear in particular, but have had the "nuclear must be bad" attitude imprinted in their mind already, they will be more inclined to believe nuclear must be harmful for climate as well. Again, studies like those from Benjamin Sovacool are time and again put forward as "evidence" of nuclear energy's supposedly high lifecycle emissions, even though this is contradicted by the relevant evidence.

The meta-study, titled "Valuing the Greenhouse Gas Emissions from Nuclear Power: a Critical Survey" is featured at Sovacool's Rational Wiki page, along with many more of his studies deserving a critical eye.[37] It lists many problems with the selection process for studies (e.g., multiple entries of virtually identical studies, some not even peer-reviewed, and many fictional/widely debunked) and highlights other questionable practices.[38] Still, Sovacool's paper continues to be cited as evidence in place of much more careful and thorough analyses,

35 This paper was a similar attempt to suggest nuclear deployment would not lead to emissions reductions: https://retractionwatch.com/2016/11/28/authors-retract-paper-linking-nuclear-power-slow-action-climate-change/

36 https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3762762 and https://www.nature.com/articles/s41560-021-00964-w

37 For example, see https://www.sciencedirect.com/science/article/abs/pii/S0301421508001997?via%3Dihub

38 The publication by Jan Wollem Storm van Leeuwen, discussed here: https://rationalwiki.org/wiki/Jan_Willem_Storm_van_Leeuwen

such as those by UNECE, IPCC, and NREL.[39] Indeed, a recent Deutche Welle article cites the conclusion from Sovacool's paper, a mean of 66 gCO2/kWh, as pretty much the scientific consensus on the matter:

> *"It's long been assumed that nuclear plants generate an average of 66 grams of CO2/kWh"* [40]

Right before that statement, the article refers to the IPCC estimates as well, giving them a range of 3.7 to 110 gCO2/kWh. This makes Sovacool's 66gCO_2/kWh seem downright spot on. But is it? Not really, and the reason is instructive. Sovacool's study was a *meta-study*, i.e., a literature overview looking into other studies done in the field and seeing what the "consensus" of those studies are; the IPCC report is also in this style. But the devil is in the details, as the expression goes. That is to say, Sovacool uses *mean* to get his number—not standard practice for these analyses—since using mean gives more weight to outlier results. And as seen above, Sovacool included multiple references to the same group of dubious studies with outlier results in his calculation.

So how did Sovacool pull off this bit of academic chicanery? IPCC's median result, which Sovacool chooses not to mention, is 11 gCO_2/kWh, as low-carbon as pretty much anything else. Yet the author of the DW article regurgitates Sovacool's higher number as if it was the accepted scientific consensus, which it definitely is not. Indeed, as discussed earlier, the most recent broad study by UNECE found nuclear to display the lowest full lifecycle emissions of any energy source, with an average of 5.6 gCO_2/kWh.[41]

The article then refers to studies quoting even higher numbers, many of them built on highly questionable assumptions. For example, a study by M. Z. Jacobson—a quite famous researcher promoting a global energy system 100% powered by wind, water, and solar energy—assumed a small-scale nuclear war happening every now and then and counted burning cities as emissions caused

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39 UNECE 2021, https://unece.org/sed/documents/2021/10/reports/life-cycle-assessment-electricity-generation-options; IPCC 2014, https://www.ipcc.ch/report/ar5/wg3/; National Renewable Energy Laboratory, https://www.nrel.gov/analysis/life-cycle-assessment.html.

40 https://www.dw.com/en/fact-check-is-nuclear-energy-good-for-the-climate/a-59853315

41 https://unece.org/sed/documents/2021/10/reports/life-cycle-assessment-electricity-generation-options

by civilian nuclear energy.[42]

Jacobson also counted nuclear power-plant planning and construction times and assumed electricity during those periods will come from coal, so he then tallied those emissions for nuclear as their "opportunity cost." Even if one justifies this analysis as an opportunity to investigate opportunity-cost emissions, a more reasonable and comprehensive approach would include a similar exercise for coal emissions caused by any solar panel or wind turbine not producing at full capacity.

This is just scratching the surface, but should suffice in giving pause to any journalist relying solely on press-releases and abstracts of newly published studies when writing about these vitally important subjects. Still, do we expect too much of columnists and op-ed writers in wanting them to develop a deep understandings of these issues, to the point of challenging peer-reviewed papers and the assumptions behind them? Should all journalists be expected to see through misuse of complex regression models and dubious appeals to opportunity-costs? Indeed, these matters might very well take deep subject matter expertise and a lot of time and work to master.

Even so, plentiful reasons exist exercise caution and avoid drawing hasty, ill-considered conclusions just for the sake of a catchy headline. Readers should likewise keep these concerns in mind when engaging with headlines and press-releases, because they rarely explain the most important detail—*how* a study came to a conclusion.

False Balance and Getting It Right

People have a strong tendency when faced with conflicting views to conclude the truth must be somewhere in the middle. This is illogical, as the truth simply is what it is, and does not depend on the "location" of various fringes and outlier results. Yet many in the media make a point to offer "balance" in their stories, and fair to say, presenting more than a single side of any story is admirable. But journalists and pundits must be careful in this respectable impulse to avoid *false balance*. For example, a panel of experts debating the efficacy of different vaccination programs can bring balance; but including a fringe an-

42 https://www.theguardian.com/environment/blog/2009/jan/02/nuclear-war-emissions, the study can be found at: https://pubs.rsc.org/en/content/articlelanding/2009/ee/b809990c

ti-vaccination YouTuber with no actual background in the subject matter creates false balance.

This false balance muddles many important topics and causes pundits and media outlets to present them in confused and misleading ways. If a "climate debate" includes an experienced and reputable climate scientist who only states claims from peer-reviewed, mainstream studies and, beside her, a non-expert with made-up but convincing-sounding jargon and unsupported theories arguing the opposite, many people will inevitably give equal weight to these viewpoints, ultimately concluding "both must be wrong" and thinking the actual truth is likely somewhere in between—or maybe just believing whoever proves more charismatic or skilled in debate, or perhaps just based on the celebrity status of one participant. The more outrageous the non-scientific claims and the wider the differences in perspective, the more viewers will perceive uncertainty and seek out a false "middle road."

A particularly nasty example of this is the Deutsche Welle article discussed above, where the author first sets the "lower bound" of nuclear lifecycle emissions at a level a full order of magnitude higher than the actual consensus figures, and then proceeded to present even higher numbers from debunked studies built on highly questionable assumptions. Indeed, from the reader's point of view, the "balance" of this article lies somewhere between "way too high result achieved with questionable assumptions and methods" and "absurdly high numbers from studies with extremely questionable assumptions." With this wider context, the goal of the article seems quite clear: to make a highly inflated number somehow seem like the conservative estimate.

Perhaps the most salient example of this false balance is nuclear safety and what happened after the Chernobyl nuclear accident. The most credible and scientifically sound information regarding the Chernobyl accident and the health impact of radiation released comes from the Chernobyl Forum, which included the following organizations:

- the IAEA (International Atomic Energy Agency)
- the FAO (Food and Agriculture Organization)
- the OCHA (United Nations Office for the Coordination of Humanitarian Affairs)
- the UNDP (United Nations Development Programme)

- the UNEP (United Nations Environment Programme)
- the UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation)
- the WHO (World Health Organization)
- the World Bank
- the governments of Belarus, Russia and Ukraine.[43]

Regarding Chernobyl, its impact, and the way in which reporters have covered the story, a perfect example comes from a 2018 article in Time magazine.[44] The piece begins by telling the reader Chernobyl has caused around 50 fatalities so far, which is close to the number in the latest, most comprehensive report from United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).[45] Statistically, some 4,000 further fatalities may exist due to the radiation, at least according to some models. However, these models use what the UNSCEAR calls "unacceptable uncertainties at these low doses," and it has recommended they not be used for epidemiological purposes.[46]

After stating this number, Time then decides to include "other experts" on the matter, saying:

> *"Current estimates place it between the 4,000 deaths estimated by United Nations agencies in 2005 and the 90,000 suggested by Greenpeace International."*

Suddenly, the 50 or so confirmed victims gets compared to a Greenpeace International's number of 90,000, with the author failing to mention Greenpeace's study was not peer-reviewed, nor does it explain any of the underlying methodologies. As it turns out, the method in Greenpeace's study was rather curi-

43 https://en.wikipedia.org/wiki/Chernobyl_Forum

44 https://time.com/5255663/chernobyl-disaster-book-anniversary/

45 New Report on Health Effects due to Radiation from the Chernobyl Accident, United Nations Information Service, 2011. See press release: https://unis.unvienna.org/unis/en/pressrels/2011/unisinf398.html and the report summary: https://www.unscear.org/unscear/en/areas-of-work/chernobyl.html

46 'ICRP Publication 103: the 2007 recommendations of the International Commission on Radiological Protection', Ann ICRP. 2007;37(2-4):1–332; and 'Report of the United Nations Scientific Committee on the Effects of Atomic Radiation Fifty-ninth Session (21-25 May 2012)', New York, NY: UNSCEAR; 2012: Report No. A/67/46.

ous: any area with any amount of fallout was included. If there were any increased fatalities in a given area after 1986, these were attributed to Chernobyl. This dubious method meant increased fatalities due to, say, liver cirrhosis were promptly attributed to the effects of Chernobyl. Yet no credible studies suggest radiation causes liver cirrhosis (whereas alcoholism, on the other hand, is a well-known cause, and was widespread in the area, especially during the years of the Soviet Union's dissolution).

This leaves the reader with a false "balance" between 50 and 90,000 fatalities, and makes the scientifically credible number of 50 somehow look like the naïve outlier.

The Bigger Picture – Context is King

The last type of bad journalism relates to lack of context and wider perspectives. One can easily say, "nuclear radiation is dangerous." But this leaves out the more important question: "How dangerous is it? And 'dangerous' compared to what?"

Ionizing radiation—the type that can disrupt cells and harm humans—is a complex matter few laypeople understand. In part due to this complexity and opacity, many people find it quite scary. And in the world of journalism, anything scary, unknown, and seemingly dangerous is perfect for generating headlines, selling copies, and gaining subscribers.

One example of forgetting the bigger picture and failing to provide context appear in headlines and articles from over 10 years ago, with radioactive water leaking from Fukushima into the sea. Tens of trillions of becquerels worth of radioactive material leaked into the Pacific Ocean, according to headlines and stories at the time.[47] And fundamentally, this figure was accurate, so the anti-nuclear NGOs and activists proceeded to paint a highly worrying picture in light of this obviously massive number.

Not many publications provided the crucial context for the large number, however. But an article in Forbes did, leading with the headline, "The Fukushima

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47 One of the calmer stories came from Reuters: https://www.reuters.com/article/us-japan-tepco/sea-radiation-from-fukushima-seen-triple-tepco-estimate-idUSTRE7882E720110909

Radiation Leak Is Equal To 76 million Bananas."[48] Put another way, a leak of 20 to 40 trillion becquerels of radioactive material (mostly tritium) was comparable to 20-40 smoke alarms (some of which use tritium, in fact) drifting in the Pacific Ocean, eventually dissolving and diluting into it. Lacking this context, however, other articles about this story sounded far more scandalous and terrifying than the situation actually was. Such is the result of bad journalism.

Another example of not contextualizing it is the very common claim that *nuclear waste is deadly or dangerously radioactive for hundreds of thousands of years*. This sentence, or a variation of it, can be read in hundreds of articles, yet almost none of them offer any context on the actual danger or harm. Yet we know that after several centuries, most of the dangerously radioactive isotopes (mostly gamma-radiation sources) have disappeared from the spent fuel (in a process called gamma-decay or γ-decay), and only the least dangerous ones remain (mostly alpha-emitters like uranium). Moreover, alpha-radiation is stopped by a sheet of paper, skin and such so it is mainly harmful only when inside the human body for extended periods. The claimed harmfulness of spent fuel, usually a solid, non-soluble substance, begs us to ask one question that is almost never asked, even by nuclear professionals: What would be the delivery method for getting that radioactive material to a place where it could cause serious harm (inside a human body, stuck there permanently) for large amounts of people? How would that work, from a logistical perspective?[49]

As it turns out, one needs to employ a series of questionable assumptions in order to arrive at the conclusion cited above in the first place, including:

- Assuming any amount of radioactivity is dangerous (there is no conclusive evidence of this)
- Assuming we cannot and will not do anything to protect ourselves from spent fuel (which is technically rather easy to do)
- Assuming future generations thousands of years from now will go in hordes to eat the spent fuel, right after grinding it to powder to maximise exposure (they won't)

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48 https://www.forbes.com/sites/timworstall/2013/08/10/the-fukushima-radiation-leak-is-equal-to-76-million-bananas/?sh=3cdbb29677d7

49 See a more thorough article on this topic: https://www.blog.geoffrussell.com.au/post/there-is-a-nuclear-waste-problem-but-it-s-not-what-you-think

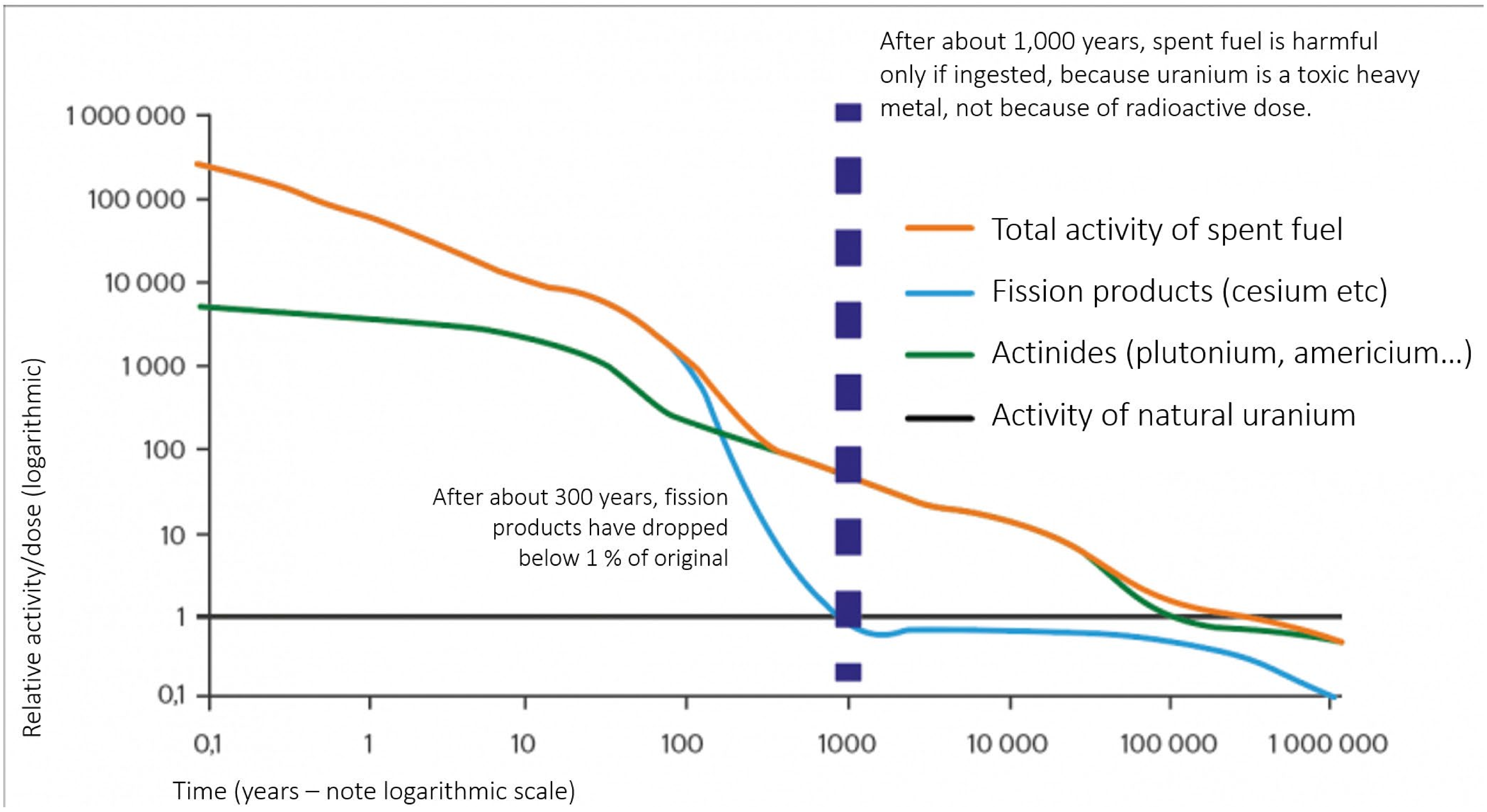

Figure 20: Spent nuclear-fuel radioactivity dosage over time. Note the logarithmic scales.

- Forgetting said fuel would mainly be harmful due to the toxic properties of heavy metals present, not its radioactivity (a scientific fact)

So, is spent nuclear fuel genuinely deadly and dangerous for millennia to come? Is this a prominent risk we should be worried about today, compared to particulate pollution, or accelerating climate change? To date, no evidence exists to indicate spent fuel from civilian reactors has ever harmed a single person. This information should appear in publications discussing these issues, thereby providing crucial context. Indeed, a truly thorough article would compare nuclear to other ways of producing energy, or even other human activities more broadly. Figure 21 shows the share of total dosage of ionizing radiation from the nuclear fuel cycle, including waste disposal.

Particulate pollution, released by combustion of chemical fuels, causes millions to fall sick and die prematurely each year. Greenhouse gases released into the atmosphere during the production and combustion of chemical fuels cause Earth's climate system to change in harmful ways for generations to come. The processing and refining of rare-earth elements—used in the wind, solar, and battery industries—too often occurs without serious regulation or oversight, resulting in considerable local and regional pollution. For example, the global production of NdPr oxide (neodymium + praseodymium, mostly used in permanent

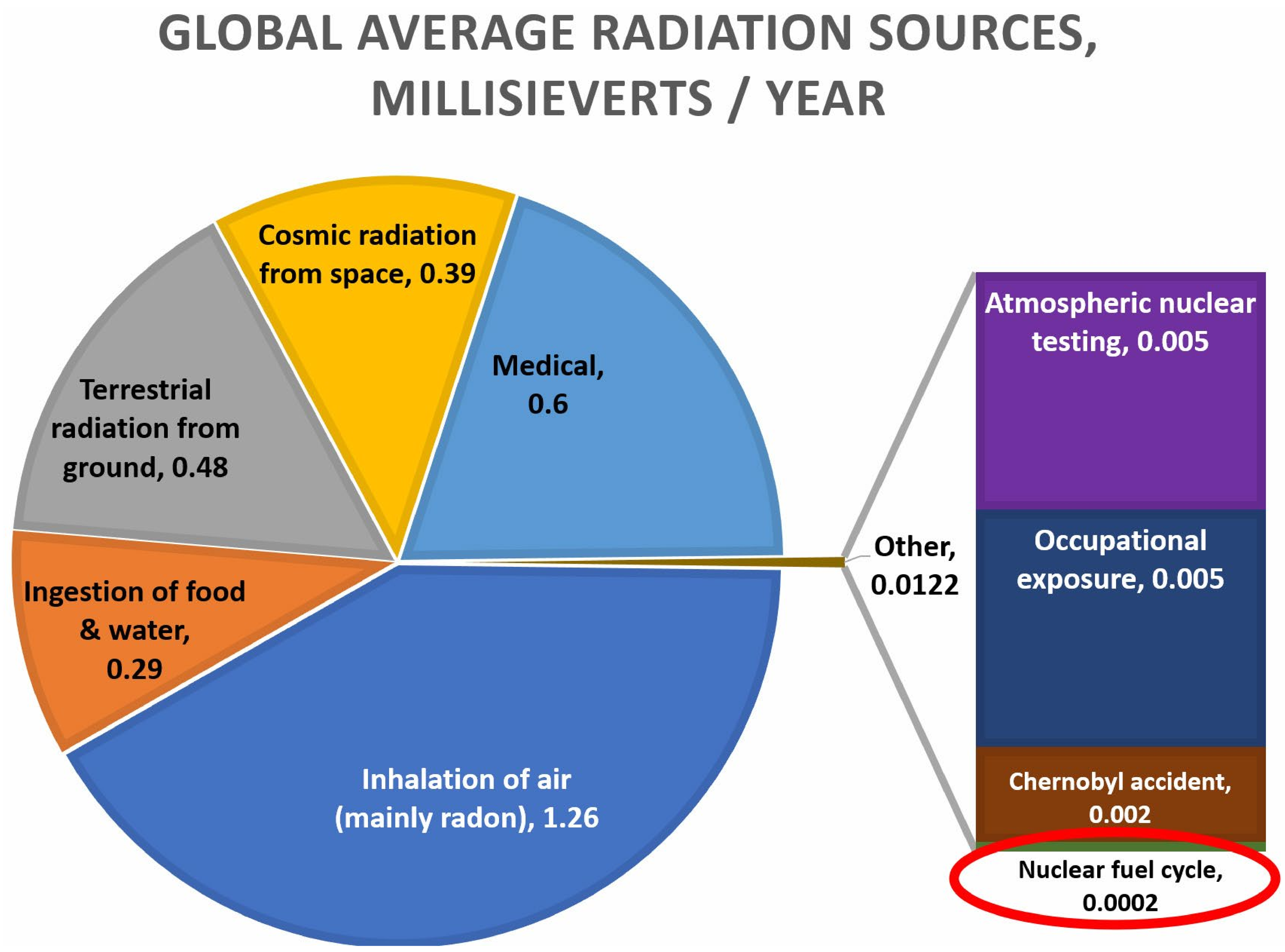

Figure 21: Global average radiation by dose, data source: UNSCEAR 2008.

magnets for wind turbines and EV motors) reached about 37,000 tonnes in 2018, of which around 15% came from undocumented and illegal Chinese sources.[50]

To be clear, this is not an argument that such materials cannot or should not be managed better in the future. But in many countries, regulation and enforcement for the extraction and processing of rare-earths is nowhere near the level of oversight in place for nuclear waste, even though extremely toxic and hazardous materials are involved. As such, governments and regulators should use similar standards when comparing the positives and negatives of different energy sources.

As seen above and elsewhere in life, things are not always what they seem. Chances are that you, dear reader, may already feel skeptical about some of the above claims and graphs, no matter how credible the sources seem. Fair to say, even the author here had to doublecheck them many times over the years, often because they appeared so different from the headlines and abstracts in the media.

This leads to a final interesting situation: a conceptually neutral article on nuclear is often called “biased in favor of nuclear” simply because it refuses to repeat common misconceptions (or discusses them within a wider context with comparisons to other energy sources). And if someone dares to write a positive article about nuclear—something regularly seen with other clean-energy sources—they will surely face accusations of being “a shill” in the pocket of the big, bad industry, and will have labels like “incompetent,” “naïve,” and/or “short-sighted” levied against them. Indeed, the author has faced and witnessed all of these

50 According to https://www.arultd.com/products/supply-and-demand.html

personally on multiple occasions, even from academics who really should know better given the focus in academia on avoiding bias. But the reality is, even in the Ivory Tower, people will go to disturbing lengths to protect their beliefs and preconceptions.

Even so, nuclear proves much more popular than many think, and support has been rising rapidly as climate awareness has become more mainstream. In Finland where the author lives, 74% of the population thinks nuclear should play a role in the energy mix at current (24%) or even higher (~50%) levels.[51] Sweden displays an even larger support with total of 84% accepting nuclear, with 56% willing to build more nuclear if it is needed and 28% content on the current level.[52] similar 70%+ share of current and/or new nuclear supporters. In the ecoAmerica study mentioned earlier, 59% of US respondents support existing nuclear power and 57% support R&D into next-generation reactors. Support has been growing especially among Democrats.

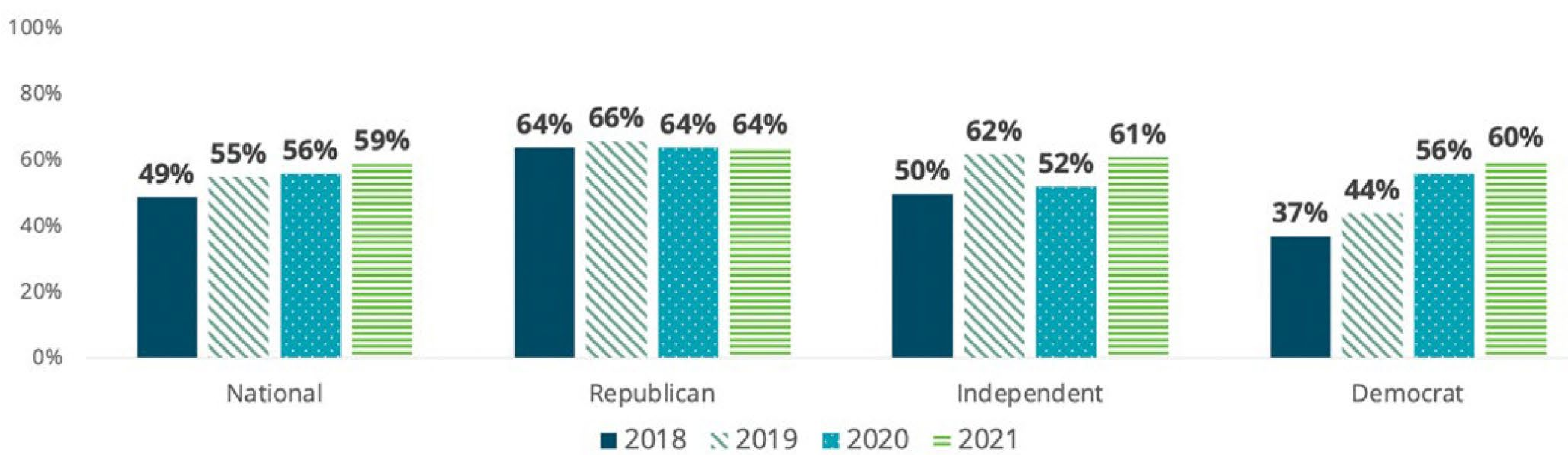

Figure 22: Survey question: "America's traditional nuclear power plants produce around 20% of our electricity. Which is closest to your opinion? "Strongly support nuclear power" and "Somewhat support nuclear power" 1,110 national respondents. +/- 3% margin of error". Source: https://ecoamerica.org/american-climate-perspectives-survey-2021-vol-v/

Even in Germany, long a bastion of anti-nuclear sentiment and policies, the public attitude towards using nuclear as a way to combat climate has been rapidly shifting. Recent (spring 2022) polls show some 65% of people support nuclear as a climate tool for Europe, while only 28% oppose it. Only the Greens still show more opposition than support for nuclear.

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51 https://energia.fi/files/6606/Energia-asenteet_2021.pdf

52 https://www.analys.se/opinion/. Results cited are according to March 2022 polling.

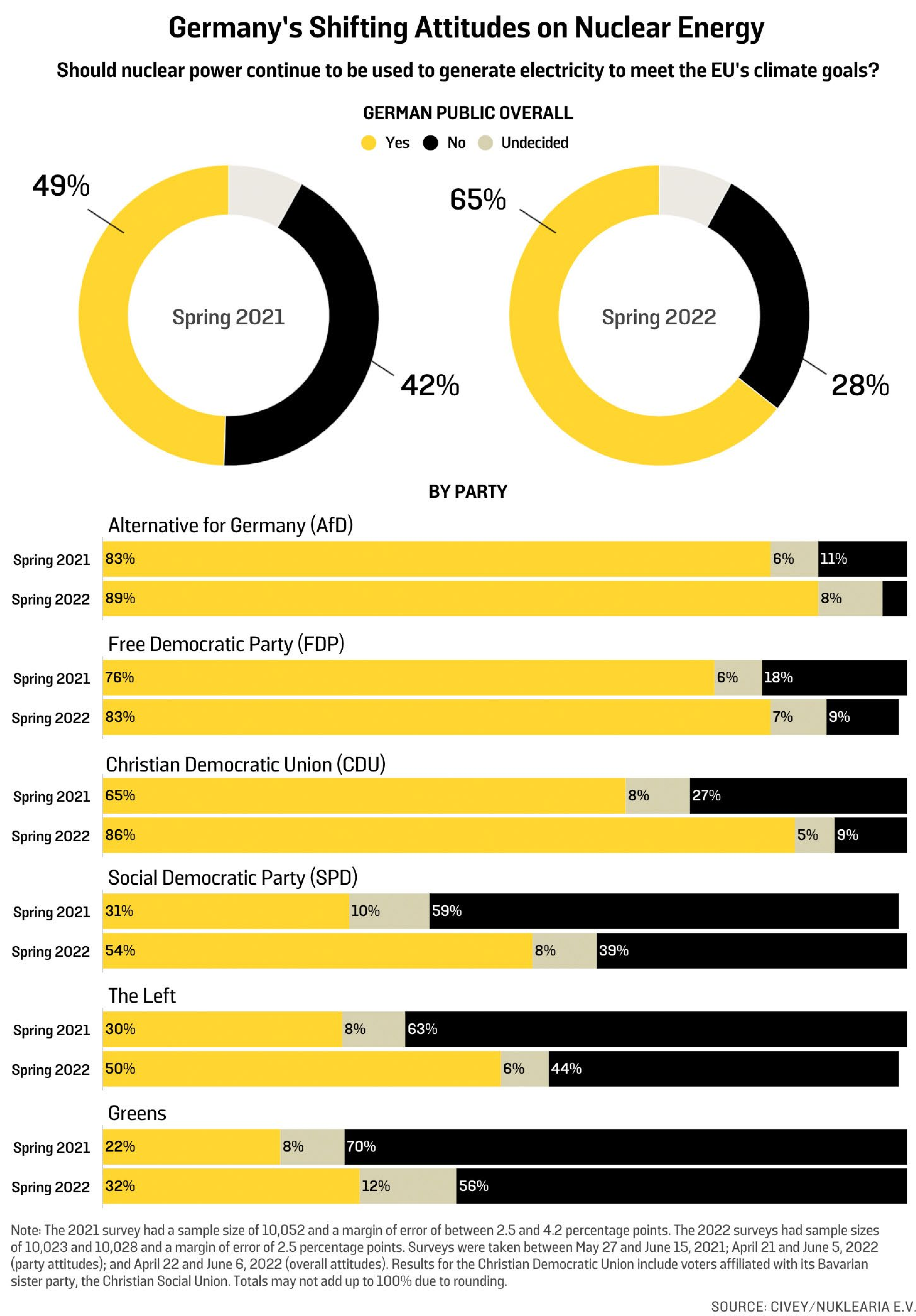

Figure 23: Support for nuclear as a climate tool has been rapidly increasing in Germany.[53]

Alas, this change in public opinion has not yet manifested itself in the actions of political leaders in Germany.[54] While they are stubbornly refusing to continue operating their last three nuclear power plants beyond 2022 (not to mention restarting the other three Germany closed at the end of 2021), German leadership is now planning to restart some 10 gigawatts of mothballed coal plants to help reduce reliance on gas. This might be necessary to keep the lights on and homes warm in Germany come next winter, but only because German leaders refuse to seriously consider the option of keeping their nuclear plants open.

The road to more effective and less risky climate mitigation starts with better and more honest public discussion, and these are typically framed by us writers and journalists. We should, and we can, do better.

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53 Graph source: https://foreignpolicy.com/2022/06/20/germany-nuclear-power-energy-weapons-nato-russia-ukraine-war-energy-crisis-greens/

54 As of June 2022.

Final Thoughts and Full Disclaimer

I hope you enjoyed this short handbook for energy and climate journalism. And even more than that, I hope you learned something and found it useful. I tried to distil much of my personal experience and professional observations into it, though inevitably some details will be left out, badly explained, or muddled by verbose passages. Such shortcomings are expected in any finite project, but please do send me feedback at raulipartanen@gmail.com. If any errors prove significant, I will strive to correct them and update the text at the earliest opportunity.

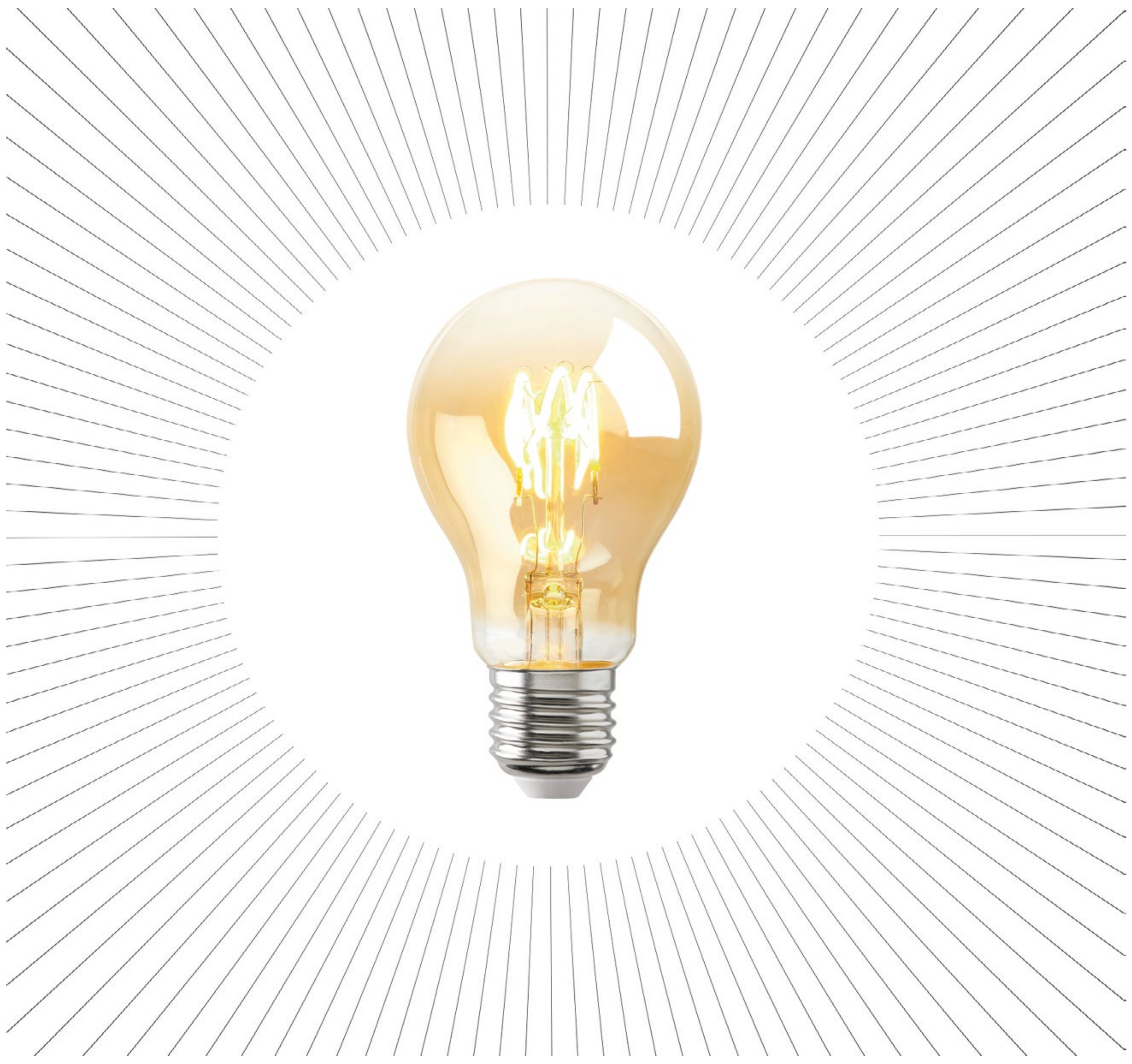
This handbook is distributed free of charge in electronic format, and I happily make no profit from it. But how do I feed my family, then? I am glad you asked. Briefly explained, this is how I ended up doing what I do, and who pays for it:

I started blogging (in Finnish) about energy, the environment, and resource scarcity—as well as the impacts those issues might have on global society—in 2010. This represented a hobby initially, a way for me to think these things through and receive feedback, but eventually turned into a more serious pursuit with the publication of my first book in 2013 (translated into English in 2014), followed by a second book in Finnish and English in 2015, a third in 2016 (printed in English in 2020), and a fourth in 2017 (in English in 2022). I wrote these books either on my own time or with help from writing grants from non-industry related funds and foundations in Finland. Towards the end of the decade, I was able to make a living from writing articles, publishing studies, and giving presentations.

I have since continued to write, publishing multiple studies and reports on energy, and have more recently focused on nuclear energy, as I co-founded a non-profit think tank called Think Atom in 2018. Some of my writing and analysis is for the energy and nuclear industries, and I also consult with them, especially on topics like communicating about nuclear energy. For this work, I get paid. Depending on the year, the share of my income from work done for the energy industry falls between 30-50 %. The rest comes from non-industry funds and foundations, or from work done for other think tanks and environmental NGOs.

More narrowly, the work underlying this book was funded by the Anthropocene Institute and Quadrature Climate Fund. For this, I give them my heartfelt thanks. RePlanet, the new European science and evidence based environmental NGO was of great help with the publication and dissemination of this book.

I would also like to extend a warm thank-you to the people involved in reviewing the drafts along the way. Special thanks go to Marco Visscher for his excellent feedback on messaging and Matt Snider for his thorough copy editing. I alone am responsible for any errors that remain.



WRITING ABOUT ENERGY

A Companion for Journalists and Readers Interested in Energy Issues

RAULI PARTANEN

Rauli is an award-winning science writer, energy communicator and environmental activist. He has written independently about energy for more than a decade, and has been co-founding two pro-science environmental organizations, The Ecomodernist Society of Finland and the publisher of this book, RePlanet Europe. His most recent book is the English version of the award-winning "The Age of Energy - Understanding Growth, Prosperity, and Environmental Destruction" with Aki Suokko. Currently Rauli leads a non-profit think tank Think Atom, which he also co-founded.

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