

We are *not on track* to meet the Paris Agreement's objectives. What should we do?

World Energy Markets
Observatory 2024 | 26th Edition



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Global Outlook

Contents

5

Primary energy demand is an outdated concept

10

Electricity Consumption is not rising as predicted in Europe

1

How to make money from renewables?

2

The Realistic case for Gen AI

3

The Business Case for Batteries needs to be clearer

4

Which net zero Pathway are we on?

6

The need for a Demand Side Energy Transition

7

Focus Hydrogen on hard to abate industries

8

How to meet Data center AI/Gen AI consumption increase?

9

SMRs are part of the answer

11

Geopolitical impacts will maintain uncertainty in energy markets

12

Industrial Heat is in the blind spot of energy transition

13

Permitting is still not fast enough and is slowing down the energy transition

14

IRA impact and progress





Global Outlook





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This 2024 World Energy Markets Observatory outlook will be structured in three main paragraphs:

In the first paragraph, we will look at *the energy markets developments in the last 12 months* in the present very tense geopolitical situation: the energy prices “normalisation”, the progresses in carbon free technologies implementation (nuclear electricity, intermittent renewables and their negative impact on grid balancing, storable renewables), the status of electricity consumption management, the storage solutions deployment and the green hydrogen reality.

In the second paragraph, we will ask ourselves *what should be done to limit the rise in global temperatures*: including technology deployment at scale, well fitted regulations adoption, company and citizens contributions, financing schemes improvements and disruptive technologies (including Generative Artificial Intelligence) impacts.

The last paragraph will be devoted to *the energy sovereignty concerns* in the current context including relationship between Western economies and countries like China and Russia and the Western policies to produce domestically critical equipment.

We will end with a general conclusion.

I wish you a good reading.



Energy markets developments in the last 12 months

The year 2023 as well as the first half of 2024 were characterized by strong **geopolitical tensions**:

The continuation of the war in Ukraine, after Russia's unjustified invasion, combined with Russia's threat to use "special weapons" and the existence of nuclear reactors in combat zones is a matter of great concern.

An additional concern is linked to Israel's war against Hamas after the October 7, 2023 massacre perpetrated by Hamas against the civilian Israeli population. There is a serious risk that it spreads beyond Israel, with Iran entering in the war. This could inflame the entire region that is rich in oil and gas. In addition, Houthi missiles against cargos in the Red Sea make this area unstable and forces tankers to go through the Cape of Good Hope, increasing logistics costs (as the tankers' journey is around 30 days compared to 22 days via the Suez Canal).

In Asia, tensions around Taiwan (which is home to around 70% of the world's foundries for electronic chip manufacturing¹), with Chinese threats of taking over this territory by force are also a matter of concern.

In 2024, the result of the American election could have a significant geopolitical impact and slow down American policy in the fight against climate change.

European election results on June 9, 2024, showed centrist parties keeping their majority, but right-wing and far-right parties sceptical of the EU's "Green Deal" package gained seats and green parties experienced heavy losses.

The EU packages aimed at developing clean energy and cutting GHG² emissions should be hard to undo. But a more climate-sceptical EU Parliament could attempt to weaken those laws, since many are due to be reviewed in the next few years – including the EU 2035 phase-out of the sale of new combustion engine cars, which faces criticism.

The European Parliament will also have to negotiate a new, legally binding target to cut emissions by 2040 with EU countries. The Labour Party, which came to power in the UK after the July 2024 elections, is committed to double onshore wind, triple solar power, and quadruple offshore wind by 2030. They pledge to invest in carbon capture and storage, hydrogen and marine energy. They aim at extending the lifetime of existing nuclear plants and completing Hinkley Point C. They recognize that new nuclear power will play an important role in helping the UK achieve energy security and clean power.

On the fossil fuels side, the freshly elected government ordered the immediate ban on new North Sea oil and gas licenses.

After the French elections in July 2024, there will be no majority in parliament and there is a risk of a standstill on legislation concerning France's energy transformation.

Despite these tensions, **energy prices** have remained moderate. Between August 2023 and August 2024, Brent oil has traded between \$74/bl and \$93/bl, below what many OPEC+ members need to balance their budgets. This is reflecting the increase in USA shale **oil production** in a gloomy economic context and high interest rates. In June 2024, OPEC+^{3 4} decided to extend most of its oil output cuts well into 2025 (cuts of 5.86 million barrels per day, or about 5.7% of global demand) without impact on oil price.

¹ <https://www.statista.com/statistics/867223/worldwide-semiconductor-foundries-by-market-share/>

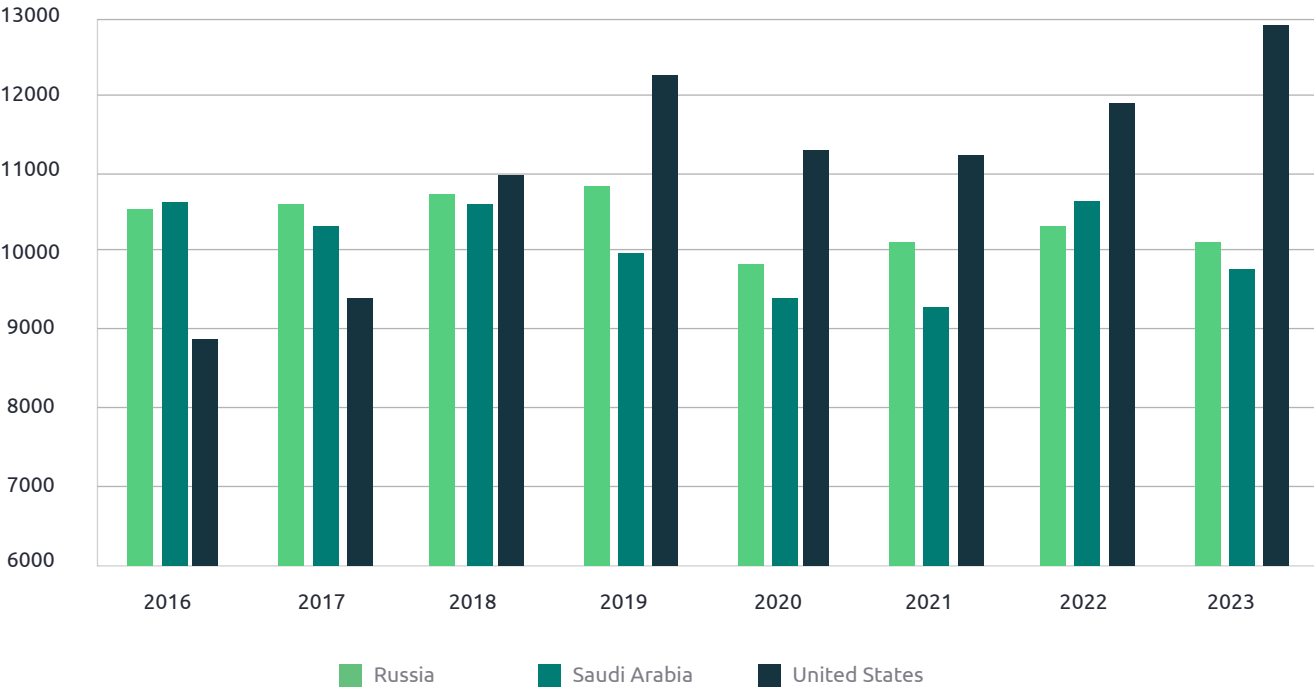
² GHG: Green House Gases

³ OPEC+ includes the members of OPEC (Organization of the Petroleum Exporting Countries) and allies led by Russia

⁴ <https://www.reuters.com/business/energy/opec-seen-prolonging-cuts-2024-into-2025-two-sources-say-2024-06-02/#:~:text=OPEC%2B%20members%20are%20currently%20cutting,the%20end%20of%20June%202024.>



FIGURE 1
The United States produced more Crude in 2023 than any country, ever



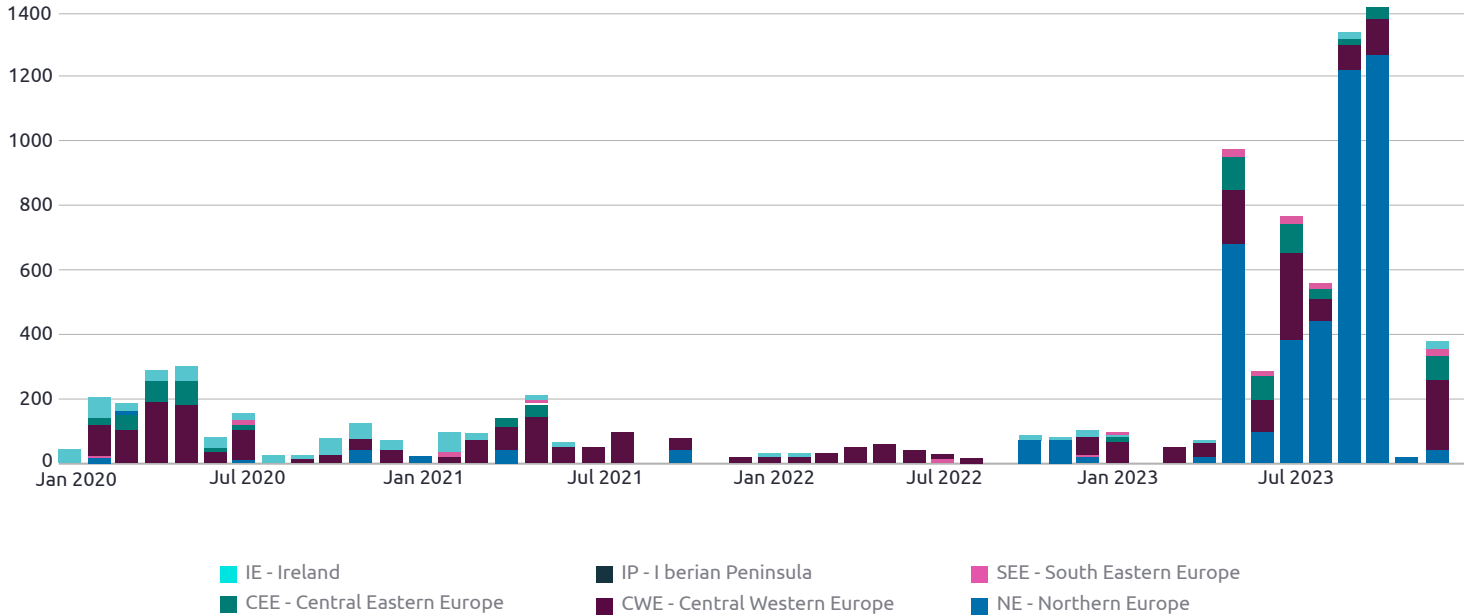
Source: U.S. Energy Information Administration, International Energy Statistics, Data as of Decemeber 31, 2023

The *electricity* market in Europe has turned upside down once again. In 2023, EU electricity spot prices returned to pre-crisis levels and the number of negative hours reached a record of 6870 in European markets, compared to 569 in 2022⁵. (see figure).

⁵ https://energy.ec.europa.eu/document/download/d48ec6b0-987f-4702-af0a-76bfb4fbce0c_en?filename=New%20Quarterly%20Report%20on%20European%20Electricity%20markets%20Q4%202023.pdf



FIGURE 2
Number of negative hourly wholesale prices in Europe



Source: ENTSO-E

6 Energy Intensive Industries are: food, pulp and paper, basic chemicals, refining, iron and steel, nonferrous metals (primarily aluminium), and non-metallic minerals (primarily cement).

7 For example energy costs account between 20% and 40% of the total cost of steel production.

8 World Energy Market Observatory 2023 edition <https://www.capgemini.com/insights/research-library/world-energy-markets-observatory/>
9 <https://www.atlanticcouncil.org/content-series/russia-tomorrow/oil-gas-and-war/>
10 <https://energyandcleanair.org/russia-sanction-tracker/>

This contrasts sharply with the energy crisis at the end of 2021 and 2022 when prices reached historic highs. Electricity prices for energy-intensive industries in the European Union in 2023 were almost double those in the USA and China. Despite an estimated 50% price decline in the European Union in 2023 versus 2022, Energy Intensive Industries⁶ in Europe continued to face far higher electricity costs compared with their American competitors. The price gap between energy-intensive industries in the European Union and those in the USA and China, which already existed before the 2021-2022 energy crisis, has widened. As a result, the competitiveness of EU Energy Intensive Industries is expected to remain under pressure.⁷

After a huge increase in 2021-2022, European *gas* prices returned to their pre-crisis level in 2023. Thanks to the USA shale gas production, gas in this country is around five times cheaper than in Europe giving (as for electricity usage) a strong competitive advantage to USA firms.

After the unjustified invasion of Ukraine by Russia, the EU and other G7 countries-imposed sanctions on Russian oil and coal. Meanwhile Russia cut nearly all the piped gas that it exported to the EU.⁸ It seems that EU and G7 sanctions including embargo on Russian coal, oil and oil products have had a significant impact on the Russian oil and gas industries and on the related budgetary revenues that come from them.^{9 10}



In December 2022, the Price Cap Coalition countries¹¹ established an oil price cap mechanism on Russian seaborne crude oil and petroleum products. These countries operators are only allowed to provide maritime transport for Russian crude oil and petroleum products if these are sold at or below the relevant price caps.

The sanctions initially forced Russia to increase the discount on the price of its oil sold to attract new buyers and replace sales that previously went to Price Cap Coalition countries. The resultant losses were significant, with Russian oil export revenues falling by 14% (€ 34 bn) in the 12 months after the sanctions were implemented. The losses peaked at €180 million/ day in the first quarter of 2023, before shrinking to € 50-90 million/ day in the second and third quarters of the year.

On the gas side, the share of Russian pipeline gas member states imported fell from 40% of the total in 2021 to about 8% in 2023. In contrast, EU's LNG¹² imports from Russia have increased, by 37.7% between 2021 and 2023.¹³ So when LNG is included the total share of Russian gas in the EU's total was 15% in 2023.

In June 2024, the Council adopted a 14th package of economic and individual restrictive measures against Putin's regime This package includes Russian LNG imports.¹⁴

Another way to cut Russia's export revenues further will be to drive down the oil price cap that is presently at \$60/bl. Also, the G7 countries should conduct a comprehensive critical oil-and-gas technology review. and impose embargos on them.

2023 energy landscape at a glance

Global energy related GHG¹⁵ emissions hit record high in 2023, despite rapid deployment of renewable energy.¹⁶

Primary energy consumption reached a record level of 620 exajoules (EJ) in 2023, compared to 537 EJ ten years earlier (a 15% increase). It grew by roughly 2% between 2023 and 2022.¹⁷ The world's demand for electricity grew by 2.2% between 2023 and 2022, roughly at the same pace as the global primary energy consumption while according to forecasts it should grow much quicker. While China, India and numerous countries in Southeast Asia experienced robust growth in electricity demand,

Western economies posted substantial declines due to a weak macroeconomic environment which reduced industrial output. More than half of the electricity demand rise in 2023 was from five technologies: electric vehicles (EVs), heat pumps, electrolyzers, air conditioning and data centres. The development of these technologies should fuel the future growth in electricity consumption.

In Europe: electricity demand in 2023 was lower than in 2005 as it reached its lowest level in 20 years!

This drop in consumption is linked, on the one hand, to the ongoing individual behaviours to control electricity consumption that began in 2022 under the pressure of very high prices and fears about the security of electricity supply (see WEMO edition 2023¹⁸). On the other hand, the European economy in general has been stagnant and the activity of the industrial sector, which accounts for 35% of the total electricity consumption,¹⁹ has decreased.

The stagnation in electricity consumption and the non-increasing penetration rate of electricity consumption within the total energy mix in Western Countries **reflect a significant delay in achieving the energy transition objectives** as electricity is the privileged vector for decarbonized energies sources (wind, solar, hydro and nuclear)

11 Members of the Price Cap Coalition: Australia, Canada, the European Union, France, Germany, Italy, Japan, New Zealand, the United Kingdom, and the United States <https://home.treasury.gov/news/press-releases/jy1796>

12 Liquefied Natural Gas

13 https://www.google.com/search?q=russian+LNG+importation+in+EU&rlz=1C1ONGR_frFR1088FR1088&eq=russian+LNG+importation+in+EU&qslcrp=EgZjaHJvbWUyBggAEEUYOTIICAQABqWGB4yCggCEAAyqAQYogQyCggDEAAyqAQYogTSAQoxNzUxNmowajE1qAllsAIB&sourceid=chrome&ie=UTF-8

14 <https://www.consilium.europa.eu/en/press/press-releases/2024/06/24/russia-s-war-of-aggression-against-ukraine-comprehensive-eu-s-14th-package-of-sanctions-cracks-down-on-circumvention-and-adopts-energy-measures/>

15 GHG: Green House Gases

16 <https://www.energyinst.org/statistical-review>

17 <https://www.statista.com/statistics/265598/consumption-of-primary-energy-worldwide/#:~:text=Global%20primary%20energy%20consumption%20reached,percent%20in%20comparison%20to%202022.>

18 <https://www.capgemini.com/insights/research-library/world-energy-markets-observatory/>
19 In 2022, the EU Industrial electricity consumption accounted for 35% of the total electricity consumption. <https://www.statista.com/statistics/265598/consumption-of-primary-energy->



In 2023, growth in solar and wind electricity resulted in 30% renewables share in global electricity generation for the first time²⁰ despite drought conditions that resulted in a fall in hydropower (that remains the main source of renewables).²¹

Combined with nuclear, the world generated almost 40% of its electricity from low-carbon sources in 2023. As a result, the CO₂ intensity of global power generation reached a new record low, 12% lower than its peak in 2007.

Despite these achievements and because of the fossil fuels consumption growth (1.5%), global **energy-related CO₂ emissions²² reached 37.4 bn tonnes - a 1% increase compared to 2022.**²³

The year 2023 was the warmest year since global records began in 1850 at 1.18°C above the 20th-century average of 13.9°C. Regarding GHG emissions, the situation is contrasted between Western economies, where these emissions are decreasing and emerging economies where they are still increasing due to their economic development and fossil fuels usages (notably in China and India)

Advanced economy GDP²⁴ grew by 1.7% but emissions fell by 4.5%, a record decline outside of a recessionary period. This 2023 decline was caused by a combination of structural and cyclical factors, including strong renewables deployment, coal-to-gas switching in the USA, but also weaker industrial production in some countries, and milder weather.

Even though China is the solar and wind generation leader, its emissions grew around 565 Mt in 2023, by far the largest increase globally. Per capita emissions in China (8tCO₂eq/capita) are now higher than the global average (6,76tCO₂eq/capita). In India, strong GDP growth drove up emissions by around 190 Mt however, per capita emissions remain far below the world average (2tCO₂eq/capita).

It is legitimate for developing countries to aim at increasing the standard of living of their growing population and hence an increase in energy usages. However, it is to be hoped that given the drop in the decentralized electricity production costs, local solutions will be implemented to allow a more sustainable development and global improvement of life conditions. We must hope, but this is not the current trend, that these countries can conceive a way of life less energy-intensive than the Western model, while aiming to an equivalent quality of life.

²⁰ <https://ember-climate.org/insights/research/global-electricity-review-2024/#executive-summary>

²¹ This shortfall in hydropower was met by an increase in coal generation.

²² Energy-related greenhouse gas emissions account for the majority of all anthropogenic emissions – about 80% in the USA and the European Union

²³ <https://www.iea.org/reports/CO2-emissions-in-2023/executive-summary>

²⁴ GDP: Gross Domestic Product





2023 was marked by a renewed interest in **nuclear electricity** that provided about 10% of the world's electricity (about one-quarter of the world's low-carbon electricity).

Asia and notably China remained the main driver for nuclear power growth.²⁵

Moreover, in August 2024, China has authorised 11 new nuclear reactors in \$31bn worth of investment.

However, in 2023 the startup/closure balance was negative by 1 GW as reactors totalling 5 GW (gigawatt) of new nuclear capacity became operational while 6 GW were closed.

Thirteen years after the Fukushima accident, *Japan is returning its nuclear reactors to operation*. As of year-end 2023, 12 reactors have returned to commercial operation, with 8 reactors were planning for a restart. Another 5, have passed a government safety review, among them, the world's biggest nuclear plant Kashiwazaki-Kariwa²⁶ could restart in October 2024. However, in many locations, a nuclear plants restart is confronted to local opposition.

This nuclear revival helps Japan to decrease its LNG imports, meet its environment targets and decrease electricity prices.

The EU Nuclear Alliance launched early 2023 includes 12 countries²⁷ that intend to build new nuclear plants. In addition, other countries such as South Africa and Saudi, are launching tenders for new reactors.

French government has announced a program to build 6 EPRs in a first step and then 8 more in a second step.

After more than 12 years of delay and an estimated cost of € 19 billion (compared to the initial budget of €3.3 bn), the French Flamanville 3 reactor should be connected to the grid in H2 2024. This would be the 4th EPR to enter in commercial service. The others, Taishan 1 and 2 in China and Olkiluoto in Finland, are operating at full power.

There is a lot of hope on SMRs (Small Modular Reactors) development. SMRs are smaller size reactors using the same processes and design as large reactors. They are usually light water-cooled reactors of 60MW capacity They are assembled by modules to reach on average a 600MW size (the average size of a coal plant).

Many projects are developed worldwide. Globally, there are more than 80 SMR designs at different stages of development across 18 countries. While countries such as the USA, UK, Canada, Japan, and the South Korea are actively developing their own designs, Russia and China connected their first SMRs to the grid in 2019 and 2021, respectively.²⁸

²⁸ https://energy.ec.europa.eu/topics/nuclear-energy/small-modular-reactors/small-modular-reactors-explained_en#:~:text=Globally%2C%20there%20are%20more%20than,in%202019%20and%202021%2C%20respectively.

²⁹ <https://www.eenews.net/articles/nuscale-cancels-first-of-a-kind-nuclear-project-as-costs-surge/>

³⁰ <https://ieefa.org/resources/eye-popping-new-cost-estimates-released-nuscale-small-modular-reactor>

We can acknowledge these benefits:

- ✓ Their smaller individual size will allow to manufacture in factories many components that would be assembled on site. Factory environment is far better to ensure a good quality of the equipment and thus of the plant.
- ✓ Thus, they should be quicker to build.
- ✓ Their smaller size allows to connect them to less robust grids.
- ✓ SMR heat transfer reactors which also provide district heating solutions represent an interesting solution because they have a better energy yield and relief the grids.

However, prerequisites for their massive deployment are:

- ✓ Cost competitiveness

End 2023, the USA first expected commercial SMR developed by Nuscale was stopped.²⁹ The project consisted of six 77MW SMRs, with a total capacity of 462 MW. It was supposed to come online in 2029. But the project experienced substantial cost overruns and delays. Initially, it had a target of delivering 40 years of electricity at \$55 per megawatt-hour. However, the target price soared to \$89/MWh due to a 75% increase in the estimated construction cost for the project, from \$5.3 to \$9.3 billion dollars.³⁰ Remarkably, the new \$89/MWh price of power would have been around \$120/MWh without IRA and DOE³¹ \$30/MWh subsidies.

²⁵ In 2023, out of 59 reactors under construction worldwide, 22 are being built in China

²⁶ With a capacity of 8000MW

²⁷ Bulgaria, Croatia, Czech Republic, Finland, France, Hungary, the Netherlands, Poland, Romania, Slovakia, Slovenia and Sweden.

³¹ DOE: Department of Energy



- ✓ To benefit from components industrialization, the same type of SMR design must be deployed at industrial scale in several different countries, hence, the needed cooperation between different National Safety Authorities.
 - ✓ Miniaturization is not so easy. For example, in July 2024 the French Nuward governance body has decided to completely overhaul the design of its SMR. Specifically, the innovative idea of an integrated boiler (combining the reactor vessel and steam generators) used in submarine small reactors has been discarded in favour of a more traditional design.
 - ✓ Acceptance procedures and local acceptance in many sites could be challenging (while in developed countries new large reactor are built on existing sites where grid connection exists, and local population welcomes nuclear facilities).
 - ✓ Non-proliferation control of scattered nuclear material
- Hopefully, these challenges will be overcome and SMRs will be deployed alongside with large size reactors.

Uranium resources are better distributed around the world than those of oil or gas and nuclear electricity producers have large strategic stocks.

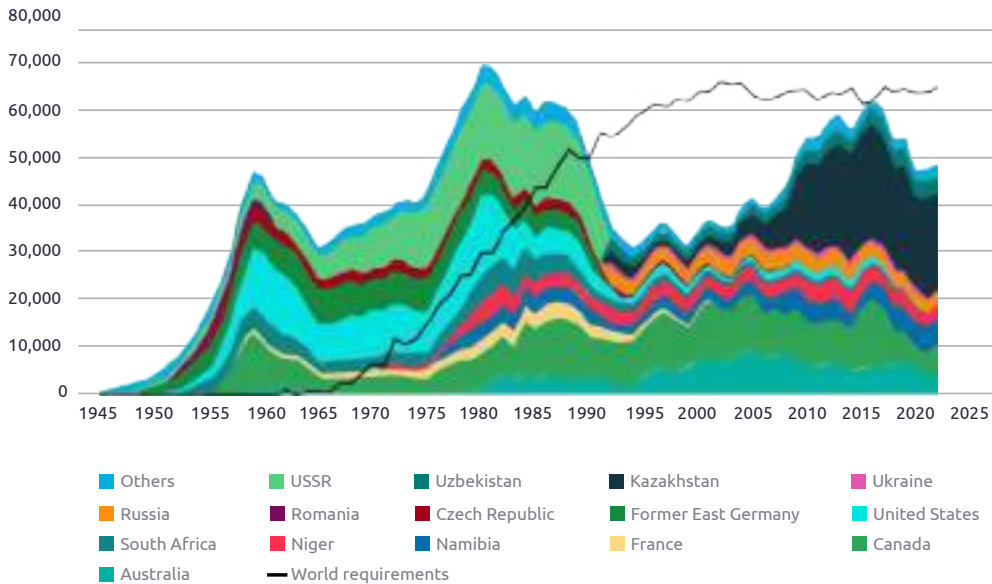
However, the price of uranium increased significantly during the last three years³² from 30\$/lb³³ in June 2021 to 86\$/lb in June 2024 with a peak of 106\$/lb in January 2024

This price increase is linked to new nuclear reactor construction programs announcements, and to the unstable situation in certain producing countries such as Niger. This country, where the former government was overthrown in July 2023,

announced in June 2024, that it had withdrawn from the French nuclear group Orano its operating permit for the Imouraren deposit, one of the largest in the world.³⁴

FIGURE 3

World uranium production and reactor requirements, 1945-2022, tU



As will be detailed below, the Advanced Modular Reactors projects based on breeder generation, will make it possible to produce around 100 more electricity with the same quantity of uranium than the reactors currently in service.

In addition, China is developing projects using thorium instead of uranium as the fissile element. Thorium is even more abundant than uranium in nature.

The availability of uranium resources is therefore not a concern in the medium term. In the short term, tensions could exist, particularly linked to the time needed to open new mines.³⁵

³² <https://tradingeconomics.com/commodity/uranium>

³³ Uranium price is expressed in \$/U3O8 pound https://www.uranium.info/unit_conversion_table.php

³⁴ Niger produces 5% of world uranium supplies but 15% of French supplies

³⁵ <https://www.scmp.com/news/china/science/article/3224183/china-gives-green-light-nuclear-reactor-burns-thorium-fuel-could-power-country-20000-years>



Renewables

Intermittent renewables growth:

2023 was the 22nd year in a row that renewable capacity additions set a record.

Year on year, total renewable energy capacity increased by 14% with a larger capacity expansion of solar (32%) than wind (13%). Solar PV alone accounted for three-quarters of renewable capacity additions worldwide.

China commissioned as much solar PV as the entire world did in 2022, while its wind additions also grew by 66% year-on-year.

The wind offshore sector has encountered difficulties:³⁶ In 2023 global wind offshore installed capacity amounted to 73 GW³⁷ out of which 34 GW are in Europe (which was the first region to instal offshore wind turbines) 31 GW in China³⁸ and 3 GW in the USA (which is catching up).

In 2023 large offshore wind turbine manufacturers were confronted with operational and financial difficulties. While this crisis impacted European players as Vestas, Siemens Energy or Vattenfall, it had large consequences in the USA.

Big companies such as Ørsted, Equinor, BP and Avangrid, cancelled contracts or sought to renegotiate. Pulling out meant

the companies faced cancellation penalties ranging from \$16 million to several hundred million dollars per project.

It also resulted in Siemens Energy, the world's largest maker of offshore wind turbines, anticipating financial losses in 2024 of around \$2.2 billion.

These cancelled projects capacity amounted to more than 12 GW in the USA, around half of the capacity in the pipeline.

There are a few reasons for these difficulties:

- To win large wind offshore farms projects, offshore wind operators (Utilities, Oil companies, Investment funds) have put price pressures on their suppliers. To sell their equipment, these suppliers have lowered their prices, and they were thus unable to amortize their R&D costs.
- Added to this, there were difficulties linked to regulations and the post-Covid crisis. In the USA and in Europe, the process to obtain all the permits and approvals for a wind offshore project, takes years. The post-COVID crisis and the war in Ukraine resulted in high inflation, high interest rates, logistics issues that increased costs of commodities (like steel or copper) as well as construction and capital costs. However, there were no price renegotiation clauses in the contracts agreed by the operators before the Covid crisis, hence, the choice of turbine suppliers or future operators to renounce these contracts and pay penalties rather than incur even more important losses.

³⁶ <https://www.npr.org/2023/12/27/1221639019/offshore-wind-in-the-u-s-hit-headwinds-in-2023-heres-what-you-need-to-know>

³⁷ <https://www.statista.com/statistics/>

³⁸ <https://www.offshorewind.biz/2023/06/30/china-now-has-31-gw-of-offshore-wind-installed-country-on-track-to-hit-wind-and-solar-targets-five-years-early-report-says/#:~:text=China%20Leads%20in%20New%20Offshore%20Wind%20Capacity%20Second%20Year%20in%20Row&text=The%20total%20capacity%20of>



- In addition, an old American legislation from 1920 “the Jones Act” prevents ships to operate in USA waters unless they are built, operated, and staffed by American companies. In the USA, there are presently no Wind Turbine Installation Vessel able to ship turbines of around 250m length. Hence, wind turbine manufacturers, had to use barges which are expensive.

Remediation measures are underway in the USA, which should make the projects more attractive. Thus, the new contracts will allow price renegotiations, the regulatory process should be streamlined, and the IRA provides for federal incentives in the form of tax credits. In addition, companies, as Dominion Energy of Virginia, are constructing their own American ship.³⁹

President Biden's objective is to have 30 GW of offshore wind power in 2030 (It compares to a 60 GW target in the EU). However, because of the above-mentioned issues, the present forecast is only at 15GW.

Intermittent renewables impact on the grid:

The power grid plays a fundamental role to a successful energy transition.

As recently pointed out by Tatsuya Terazawa, Chairman and CEO of the Institute of Energy Economics of Japan “Without transmission, No transition”

Intermittent renewable costs are increasing with their penetration rate

Additional costs linked to grid balancing issues must be added to the LCOE⁴¹ to make a fair comparison between intermittent renewable generation costs and dispatchable generation costs. According to Lazard 2024 report⁴² after an increase between 2021 and 2023, wind and solar LCOE⁴³ averages in the USA remained stable in 2024.

However, with higher penetration rates in the electricity mix the timing imbalance between customer demand and renewable electricity production is increased. As such, the optimal grid balancing solution is to complement new renewable energy technologies with a “firming” resource such as energy storage or dispatchable generation technologies. The renewable costs must include this externality, more precisely the “firming” resource generation cost.

While in Europe, the nuclear generation (which is dispatchable technology with no GHG emissions) helps to balance the missing renewable generation, in the USA Combined Cycle Gas Turbine is the most used firming generation source despite its GHG emissions.

The incremental cost of firming intermittent electricity varies regionally depending on the rate of renewable source penetration and the grid operating rules. According to Lazard report, this additional cost varies in the USA from 56% of the LCOE (PJM TSO⁴⁴) where renewable penetration is 7% to 200% of the LCOE (CAISO⁴⁵) where renewable penetration is 52%

⁴⁰ https://eneken.ieej.or.jp/en/chairmans-message/chairmans-message_202401.html

⁴¹ LCOE: Levelized Cost of Electricity. See definition: <https://corporatefinanceinstitute.com/resources/valuation/levelized-cost-of-energy-lcoe/>

⁴² <https://www.lazard.com/research-insights/levelized-cost-of-energy-plus/>

⁴³ LCOE: Levelized Cost Of Electricity

⁴⁴ PJM Interconnection coordinates the movement of electricity through all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia.

⁴⁵ CAISO: California ISO

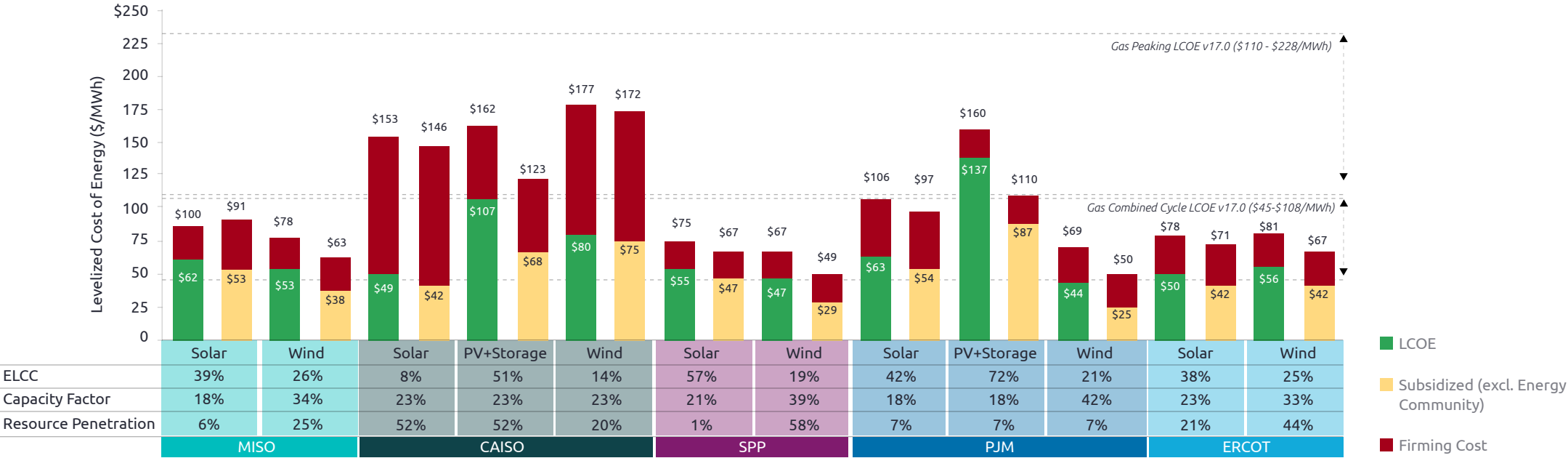
³⁹ This 472-foot vessel will be able to transport wind turbine components domestically and avoid unnecessary costs and delays



FIGURE 4
LCOE including levelized firming cost (\$/MWh)

Growth of intermittent renewables (solar and wind) penetration rate in electricity generation is also increasing grid stability problems that translate into **difficulties to stabilize the power system frequency**. Some Countries or Regions with high shares of variable renewable generation are establishing minimum requirements for system inertia that helps enhance the power system’s resilience during disturbances.⁴⁶

Additionally, various countries including the United Kingdom, Ireland and Australia have been introducing measures such as fast frequency response and similar services that stabilise the power system rapidly after disruptions. Battery storage systems can provide such services for grid stability while enhancing system flexibility (see below).



46 A property typically provided by conventional generators with spinning rotors that helps enhance the power system’s resilience during disturbances. Wind and PV solar that don’t need turbines cannot provide this stabilizing feature



The duck curve⁴⁷: As more solar capacity comes online, grid operators in sunny regions as California have observed a drop in power load in the middle of the day when solar generation tends to be highest. This dip is followed by a steep rise in the evenings when solar generation drops off. This load pattern is called the “duck curve”. As solar capacity continues to grow, the midday dip in load is getting lower and the following rise is getting stiffer, presenting challenges for grid operators. This situation has created a large blackout in California during the 2020 summer. Since then, the State has adopted a plan to build dispatchable generation plants (i.e CCGTs⁴⁸)

Curtailment: When those services don't exist or are insufficient, grid operators have curtailed renewables and sometimes nuclear generation.

In 2023, PV and wind generation curtailment has increased in many European countries, notably in Germany where it reached 8%. The main reason is that grid expansion did not keep pace with offshore wind growth (located in the North of Germany) and geographical consumption location (in the South of Germany).⁴⁹

In the EU, variable renewables penetration is expected to reach in 2028, more than 50% in seven countries, (90% in Denmark). Although EU interconnections help integrate solar PV and wind generation, grid bottlenecks will pose significant challenges and lead to increased curtailment in many countries.

⁴⁷ <https://www.eia.gov/todayinenergy/detail.php?id=56880>

⁴⁸ CCGT: Combined Cycle Gas Turbine

⁴⁹ In Germany wind offshore generation is located in North sea while electricity demand is mainly in the South of the country

In the USA, wind electricity curtailment was in 2022 at an average of 5.3%(increasing over the last years).

China has tried to limit curtailment of renewable energy to 5%.⁵⁰ However, it can be larger: for example, curtailment for Huaneng Power International, a major state-owned generator, rose to 7.7% in Q1 2024 from 3.1% in 2023.

Moreover, in a survey of six provinces' ability to absorb distributed solar ⁵¹, China's energy regulator found five provinces expected to have to impose restrictions on new renewable projects in 2024.

Consequences on new projects profitability: Renewables and nuclear being energy generation with a very high capex proportion in the kWh final cost, frequent episodes of curtailment (meaning hours with no revenue while cost have already occurred) negatively impacts their profitability. This lowered Return on Investment questions the attractiveness of new constructions.

For renewables, the question arises less because they benefit from subsidies of various kinds (“Contract for Difference”, tax exemption, subsidies, etc.)⁵² while it arises in Europe for new nuclear plants constructions.

Given the grid balancing problems related to intermittent renewable energies such as solar and wind, nuclear dispatchable

⁵⁰ <https://www.reuters.com/business/energy/chinas-blistering-solar-power-growth-runs-into-grid-blocks-2024-05-22/>

⁵¹ <https://www.reuters.com/business/energy/chinas-blistering-solar-power-growth-runs-into-grid-blocks-2024-05-22/>

⁵² These subsidies, paid by the end customer or the taxpayer, have enabled the development of wind and solar electricity generation, they should now be removed as they distort the electricity markets functioning.

electricity (see above) and *storable renewable energies development* should be accelerated.

First **hydropower**:⁵³ It remains the largest renewable source of electricity, generating more than all other renewable technologies combined. It provides a range of electricity grids services, such as storage and flexibility to balance solar and wind intermittency.

Pumped Storage Hydropower (PSH) provides more than 90% of all stored energy in the world. It can store months of electricity consumption, while batteries allow only a few hours.

The more variable renewable electricity (solar and wind) is developed the more pumped hydropower will be required to provide grid balance.

In 2023, global hydropower fleet grew to 1,416GW. Conventional hydropower capacity grew less than previous years by 7.2GW to 1,237GW, while pumped storage hydropower grew by 6.5GW to 179GW.

Capacity increases are going on an average at about half the rate they need to be on the pathway to net zero.

⁵³ Hydropower <https://www.hydropower.org/publications/2024-world-hydropower-outlook>



Historically, hydropower has been funded by state or intergovernmental actors, but their ability to put more resources into the sector is limited. If the build rate of hydropower is to double, then private investment is needed so that annual capital flows can also double, from \$65 billion to \$130 billion. Beyond technical and financing challenges, policies and market mechanisms must ensure that investment in sustainable hydropower is attractive.

“Green heat”

Heating and cooling for residential and commercial buildings and for the industry accounts for about half of the global final energy consumption. It is the largest source of energy end use, ahead of transportation (30%), and is responsible for more than 40% of global energy-related CO₂ emission. In 2021, fossil fuels' share in heat generation was around 75%.⁵⁴

Despite remote-controlled heating and cooling systems that enable savings, the global energy demand for cooling is expected to increase by 45% by 2050, compared with 2016 levels.⁵⁵ One reason for this is rising standards of living in developing countries; another is that global temperatures will probably rise. Cooling solutions are predominantly powered by electricity.

⁵⁴ <https://www.irena.org/Innovation-landscape-for-smart-electrification/Power-to-heat-and-cooling/Status#:~:text=The%20share%20of%20fossil%20fuels,95%25%20of%20global%20heating%20demand.>

⁵⁵ <https://www.irena.org/Innovation-landscape-for-smart-electrification/Power-to-heat-and-cooling/Status>

To decarbonize heating a mix of sustained solutions should be implemented: electricity, solar hot water, biomass, geothermal resources.

- Electrification of heating by using heat pumps, is strategic for decarbonising heating and cooling. However, it will not suffice. For example, in Irena pathway to achieve the 1.5°C target by 2050, heat pumps installations are forecasted to increase by 14-fold from 2023 to 2050 which is not realistic. This scenario bets also on large wind and solar developments which is also questionable notably because of grid balancing issues (as described above).

- Solar domestic hot water constitutes an interesting source of decarbonization on one side and energy storage on the other side. France was a pioneer by offering, for more than 30 years, to residential customers, night-day rates which favour the heating of water during off-peak hours for its use during peak hours.
- Use of “green heat” coming from biomass, used notably in district heating systems (burning urban waste) and geothermal energy.





*Geothermal is a sustainable and reliable energy resource*⁵⁶ that is widespread over the globe.

This underground heat resource has a wide range of temperatures depending on the reservoir's depth and the locations.

For low temperature subsurface resources (wells up to 500m depth), a geothermal heat pump can be used to increase heating and cooling system's efficiency.

Medium temperature geothermal resources are used for industrial processes and in district heating distribution systems. The deep and high temperature resources (wells up to 5000m depth) can be used for both heat and electricity dispatchable generation.

Geothermal power plants can provide both energies with a capacity factor of more than 80%.

Moreover, the hot salty water, or geothermal brine, which is pumped to the surface, can also yield lithium

Between 2021 and 2022, the global weighted average LCOE of ten newly commissioned geothermal projects fell by 22% to \$56/MWh which is comparable to wind or solar farms LCOEs.

However, the initial cost capital cost is high with an installed cost of \$3478/kW.⁵⁷ Also, operation and maintenance are considerably more complex compared to solar or wind and require a high level of experience.⁵⁸

⁵⁶ <https://www.irena.org/Publications/2023/Feb/Global-geothermal-market-and-technology-assessment>

⁵⁷ In 2023 the capital cost for U.S. nuclear power ranged between \$13952/kW and \$8475/kW <https://www.statista.com/statistics/654401/estimated-capital-cost-of-energy-generation-in-the-us-by-technology/>

⁵⁸ Between 2021 and 2022, the global weighted average levelized cost of electricity (LCOE) of ten newly commissioned geothermal projects fell by 22% to \$0.056 kWh.

Electricity generation from geothermal energy has grown at around 3.5% annually, reaching a total installed capacity of approximately 16 GWe⁵⁹ in 2021. On the other hand, geothermal deployment for heating and cooling grew at an average rate of around 9% annually between 2015 and 2020 to reach 107 GWth⁶⁰ in 2020. The relatively low growth could be attributed to factors such resource's location, drilling equipment availability, permitting delays and high upfront capital.

In the USA, in 2023 geothermal provided 3.7 gigawatts (GWe) (1%) of electricity in the USA, mostly from hydrothermal resources in California, Nevada, and Utah. Assessments⁶¹ indicate that with present technologies a potential of 18 GWe could be deployed in 2050.

In the EU, low temperature geothermal energy is currently used in just 2 million of the 100 million home heating systems, and it generates only 0.2 % of the total electricity consumed.

According to the Implementation Working Group for geothermal⁶² with today's technology, 25 % of the European population could cost-effectively deploy geothermal heating. Geothermal power plants could provide up to 10 % of Europe's power demand. Furthermore, the geothermal industry could become a key player in the production of sustainable lithium made in Europe.

⁵⁹ GWe: GW of electricity generation

⁶⁰ GWth: GW of thermal generation. One needs roughly 3 GWth to generate one GWe

⁶¹ <https://iopscience.iop.org/article/10.1088/2753-3751/ad3fbb>

⁶² https://setis.ec.europa.eu/implementing-actions/geothermal_en

As a conclusion, geothermal resource can provide sustained heat and dispatchable sustained electricity. This resource needs to be better exploited. This is why, in January 2023, the European Parliament adopted a resolution calling for a European strategy on geothermal energy. It calls for mapping geothermal assets, launching an industrial alliance on geothermal energy, and the introducing a harmonised insurance scheme to mitigate financial risk.





Demand side management

Demand-Side Management (DSM) such as direct load control, demand response, and energy efficiency has been used for decades to lower costs, increase usages efficiency, improve the grid balancing and increase security of electricity supplies.

- **DSM** has become more complex because of decentralized electricity production growth, leading to increased bidirectional flows and greater network balancing needs. Contrary to California in 2020(see above) it is thanks to its demand response and energy flexibility programs that ERCOT⁶³ the Texas grid operator avoided blackouts in June 2023. These programs provide financial incentives to energy consumers to reduce demand during times of electricity grid stress or shift consumption to times of day when grid pressures and power prices are lower. Demand response payments were 20 times higher that year, rewarding those who participate in the programme.⁶⁴ However, these spendings are negligible compared to what a blackout would have cost.
- **Technical devices** as smart meters, increased sensors on networks and at customers' premises and more sophisticated management algorithms improve the demand management situation.

- **Sharing consumption data**, within the limits authorized by law, should make it possible to develop services allowing better electricity grid management and significant savings for the community. For example, better management of congestion on the network could help avoid the construction of new lines.
- On the economic side, **time of use tariffs** if well explained and well understood and adopted by customers⁶⁵ help manage the demand and reduce customer bills.
- Customer demand is influenced by economic aspects such as price increases or **psychological biases**, such as a perception of shortage risk. These factors were important in explaining the drop in electricity consumption in Europe over the winter of 2022-2023. This economic sobriety was maintained the following winter. Also, all economic conservation campaigns launched by utilities or public authorities must consider human aspects at the risk of unpleasant surprises (rebound effect⁶⁶).

⁶⁵ It is the fear that customers would not understand these variable tariffs that prevented the EU to make them mandatory

⁶⁶ <https://blog.rexel.com/en/a-world-of-energy/the-rebound-effect-the-hidden-face-of-energy-efficiency/>

Electricity storage

Different electricity storage technologies are available. Their performance and cost depend on the storage scale and duration. For large storage capacity and long durations Pumped Hydro Storage (if geography allows) and Diabatic Compressed-air energy storage (CAES) are the best options.⁶⁷ However, diabatic CAES is not a zero-emission technology, since it uses fuel such as natural gas in the discharge cycles.



⁶³ ERCOT: Electric Reliability Council of Texas

⁶⁴ <https://www.enelnorthamerica.com/insights/blogs/demand-response-2023-texas-heatwaves>

⁶⁷ <https://www.pnnl.gov/sites/default/files/media/file/ESGC%20Cost%20Performance%20Report%202022%20PNNL-33283.pdf>



FIGURE 5
Total installed storage cost comparisons



Batteries Energy Storage Systems (BESS) have their value mostly in short-term balancing of the grid (1 to 4 h time scales). Thanks to electrical cars development, stationary battery performances and costs are improving quickly.

Stationary batteries demand is set to grow in line with the increasing percentage of intermittent renewables connected to the electricity grids. For example, in the EU roadmap they would reach more than 65% share in the electricity mix by 2030 as the need for flexibility in the electricity system will increase significantly in all EU countries, reaching 24% of total EU electricity demand in 2030.⁶⁸

Some Institutes⁶⁹ predict that annual stationary storage deployments will grow at a CAGR⁷⁰ of 30% from 2023-2033 to reach a capacity exceeding 2 TWh. To reach these optimistic predictions, big improvements are needed in policy frameworks, technology and profitability.

68 https://energy.ec.europa.eu/topics/research-and-technology/energy-storage/recommendations-energy-storage_en

69 <https://www.idtechex.com/en/research-report/batteries-for-stationary-energy-storage-2023-2033/905>

70 CAGR: Compound Annual Growth Rate



Clear policy frameworks are starting to be implemented in some countries as China, Australia where state-level storage incentives are key drivers for their high historical and forecasted BESS⁷¹ installation growth.

In certain Chinese regions, association of PV and batteries is compulsory to connect new solar farm to the grid. Several USA States have energy storage and renewables mandates. With more states announcing new battery storage targets, and expanding older targets (such as New York), this trend is expected to continue and will be a key driver for USA BESS growth. Let's note that the cost of PV farms with BESS are significantly higher than without batteries⁷² but better services is provided.

Batteries technical improvements: stationary battery storage improvements include the extension of their life cycle; their size and physical footprint reduction, cost decrease, limited use of critical metals and easy recycling.

Over the past decade, Li-ion batteries have become an increasingly important stationary energy storage technology. LFP and NMC⁷³ chemistries are the most popular in storage application. A shift towards LFP for grid-scale batteries is

witnessed because of lower costs, better safety properties, and longer life cycles.⁷⁴

The grid-scale market is leaning towards longer duration of battery storage to accommodate growing volumes of renewable energy capacity on electricity grids.

Li-ion may not be well suited to long-duration storage in future, whereas Redox Flow Batteries(RFB)⁷⁵ can store more than 10 hours of energy. However, this technology is still in its early stages, with grid-scale proof-of-concept projects starting to emerge. For instance, in 2022, Sumitomo Electric brought one of the world's largest vanadium RFBs online in Japan.

Batteries manufacturing: Worldwide battery mega factories are mainly installed in Asia, with a dominant position for China where over 80% of global lithium-ion battery production takes place. Europe has succeeded in attracting battery factories built by European or Chinese or other Asiatic firms. However, some European battery manufacturers are encountering technical problems notably linked to the anode⁷⁶ graphite⁷⁷ quality and the factory yield.

Batteries profitability increase: it will of course benefit from battery costs decrease⁷⁸ and if it is the case of electricity prices

increase that allow quicker amortisation of the “renewable plus batteries” systems.

Similarly to renewable costs, Li-ion battery costs have decreased in a spectacular way in the ten last years. In 2021 and 2022, very high prices for critical materials (Lithium and Graphite) have resulted in cost growth. In 2023 and H12024, the decrease in these critical metals price notably Lithium (that decreases by 80% in H1 2024 from its 2022 peak.), have resulted in significant costs decrease.⁷⁹

However, at the same time electricity prices have significantly fallen, erasing part of the cost decrease benefits.

Presently BESS are considered unprofitable in spot market trading cases, especially in the day-ahead market. According to AEPIBAL,⁸⁰ in the current markets first BESS entrants have between 6 to 8% project IRR.⁸¹ These values are low for this type of business model (high merchant risk and new technology) so additional revenue streams such as peak shaving and other ancillary services are needed to reach an acceptable profitability level. In regions where there are capacity markets⁸² and/or subsidies, the BESS projects IRR will be improved.

71 A Battery Energy Storage System (BESS) is a system that uses batteries to store electrical energy. They can fulfil a whole range of functions in the electricity grid or the integration of renewable energies <https://flex-power.energy/school-of-flex/battery-energy-storage-system-bess/>

72 For example, in California the LCOE cost of PV farm is more than doubled: from \$49/MWh without BESS to \$107/MWh with BESS

73 LFP: Lithium-Fer-Phosphate, NMC: Nickel Manganese Cobalt

74 The same shift is happening for EV batteries

75 See WEMO 2023

76 Anodes are made in graphite that is imported at 100% from China

77 Graphite is imported from China(see below)

78 Grid-scale battery costs can be measured in \$/kW or \$/kWh terms. Thinking in kW terms is more helpful for modelling grid resiliency. A good rule of thumb is that grid-scale lithium-ion batteries

will have 4-hours of storage duration

79 The average 2024 price of a BESS 20-foot DC container in the U.S. is expected to come down to US\$148/kWh, down from US\$180/kWh in 2023 and \$270/kWh in 2022 according to Clean Energy Associates <https://www.cea3.com/cea-blog/bess-prices-in-us-market-to-fall-a-further-18-in-2024>

80 <https://aleasoft.com/revenue-stacking-the-solution-for-battery-viability/>

81 IRR: Internal Rate of Return

82 <https://www.nrg.com/insights/energy-education/electricity-markets-what-s-the-difference-between-a-wholesale-en.html>



Hydrogen

Green hydrogen allows long term electricity storage in fuel cells, but its usage is focused at achieving industrial and transportation sectors decarbonization.

Global hydrogen use reached 95 Mt in 2022, a nearly 3% increase year-on-year, low-emission hydrogen⁸³ accounting for just 0.7% of total hydrogen demand

By the end of 2023, China's installed electrolyser capacity reached 1.2 GW – 50% of global capacity⁸⁴ – with another new world record-size electrolysis project (Kuqa plant, 260 MW), which started operation. This Kuqa plant operated by Sinopec is expected to produce 20,000 tonnes of low-carbon hydrogen per year.

The conditions for the green hydrogen development are:

- **Technology improvement:** in 2023 and early 2024 low emission hydrogen production in Europe and China encountered difficulties linked to malfunctioning electrolyzers. Even alkaline, the most advanced technology (50% of current production), had unexpected failures when the electrical load rate was in below 40%. Unfortunately, this means that today electrolyzers cannot use directly over abundant green electricity as the latter is available intermittently.

It is because of the poor function of the John Cockerill electrolyzers, that the French, Masshyla green hydrogen megaproject, from TotalEnergies and Engie has been revised downwards.⁸⁵

At this stage, most manufacturers encounter similar difficulties. Other problems are linked to increase of the size of the electrolyzers, which is evocative of the problems encountered by other young industries.

- **Lowering low emissions hydrogen costs** is essential for its development.

In 2023, grey hydrogen⁸⁶ LCOE varied between \$0.98-\$2.93/kg; for green hydrogen it was between \$4.5-\$12/kg.⁸⁷

In Europe, TotalEnergies has launched a call for tenders for 500,000 tonnes of renewable hydrogen for use in its refineries. The price obtained was €8/kg.⁸⁸ However, thanks to subsidies this was an acceptable price.⁸⁹

Cost reduction should come from the drop in the price of low-carbon electricity and the reduction in the capital and operational cost of electrolyzers.

- ✓ **The cost of electricity used:** After the huge drop of renewable costs these last ten years, wind and solar electricity generation costs decrease will be limited, and

costs from new nuclear plants are higher than that of existing ones.

However, with the increase of the intermittent renewable rate in the electricity mix, the number of hours when this electricity is curtailed will increase. If electrolyzers plants are collocated with renewable plants, they could use this free electricity and green hydrogen cost would decrease significantly. Unfortunately, today electrolyzers have difficulties to operate with a variable electricity load⁹⁰ that also reduces their lifetime.

- ✓ **The cost of electrolyzers drop** could come, as for renewables and batteries, from mass production but presently the large electrolyzers plants have difficulties, and the market is not yet there (see below).

The difficulties of green hydrogen cost decrease are confirmed by "Futurible" study mid-March, 2024⁹¹ that concludes that cost reductions are insufficient to significantly narrow the competitiveness gap with grey hydrogen.

⁸³ Low emission hydrogen is produced by water electrolysis using either electricity produced by renewables (green hydrogen) or nuclear electricity.

⁸⁴ In 2023, 50% of world's hydrogen installed capacity was in China, 25% in Europe and 10.5% in the U.S.

⁸⁵ The plant should now not exceed 40MW of capacity instead of the planned 120MW.

⁸⁶ Grey hydrogen is produced by gas -methane- reforming

⁸⁷ <https://about.bnef.com/blog/green-hydrogen-to-undercut-gray-sibling-by-end-of-decade/>

⁸⁸ According to Patrick Pouyanné April 2024 Ryad economic forum

⁸⁹ If a refinery uses green hydrogen and replaces its grey hydrogen not only will it avoid paying emission rights but it will get EU CO₂ emissions free allowances that it can trade.

⁹⁰ It seems that they cannot function if the electricity input is below 40% of the nominal input.

⁹¹ <https://www.futuribles.com/hydrogene-bas-carbone-perspectives-de-deploiement-a-lhorizon-2050/>

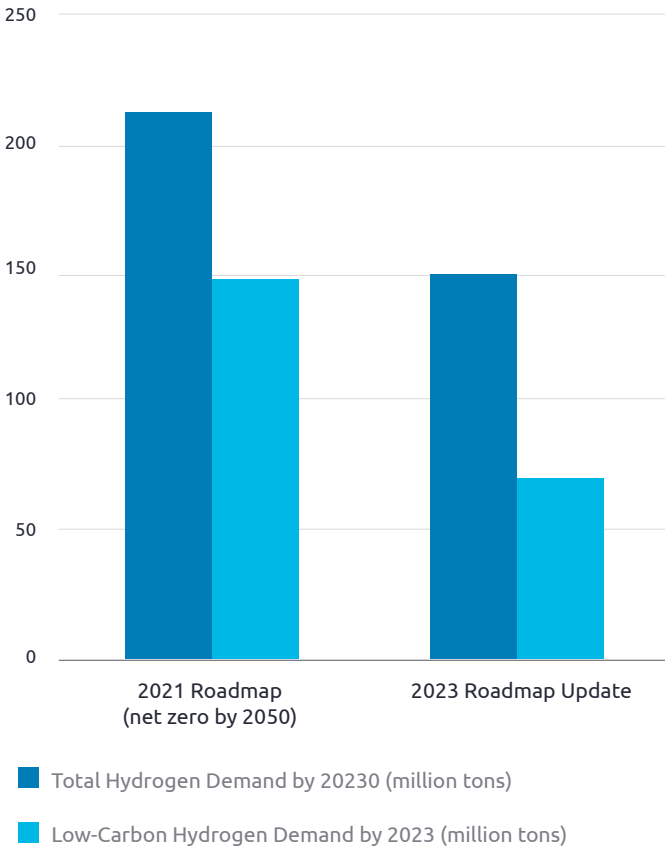


To narrow the cost difference between low emission hydrogen and grey hydrogen, authorities in the USA and EU are implementing various subsidies plans. In the USA, under the IRA (Inflation Reduction Act) legislation, renewable hydrogen producers can receive up to \$3/kg of low emission H2 produced during 10 years after production start. The European Commission should offer subsidies to renewable hydrogen producers in the form of a fixed premium (between €1.7 and € 2.5/per kg of hydrogen produced) for 10 years after production start. In addition, producers of green hydrogen will receive free CO₂ emission allowances that they can trade. Contrarily to EU the subsidies structure under the IRA, does not involve lengthy, burdensome, and uncertain application processes.

✓ The availability of low-carbon electricity is an important condition for low-carbon hydrogen development . The last IEA study published early 2024,⁹² forecasts a 35% lower global renewable electricity capacity⁹³ dedicated to hydrogen production, than a year ago. As mentioned in the previous WEMO⁹⁴, renewables electricity development in Europe is behind objectives and moreover, more renewable electricity is needed to replace Russian gas.

Green hydrogen manufacturing outside Europe, for example in countries like Morocco that are very sunny, and its shipping to Europe is seriously considered to fill the renewable electricity availability gap. However, countries like Morocco need green electricity for their growing domestic energy and freshwater demand. Moreover, hydrogen long distance transportation to Europe is complex (see below). Nuclear electricity could also power electrolyzers. In this case, new reactors construction program should be accelerated or the existing reactors lifetime of should be extended to 80 years (see above). With the present nuclear industry dynamics in Western countries, it will be a slow decision process.

FIGURE 6
Total hydrogen demand by 2030, comparing 2021 and 2023 forecasts



Source: IEA Hydrogen review 2021, and 2023

⁹² <https://www.reuters.com/business/energy/iea-lowers-renewables-forecast-clean-hydrogen-2024-02-01/>
⁹³ By 2028
⁹⁴ <https://www.capgemini.com/insights/research-library/world-energy-markets-observatory/>



- **Solving transportation issues:** Hydrogen is the smallest molecule and very inflammable in contact with air. Hydrogen transportation security has to be carefully assessed.

✓ Long distances hydrogen transportation as liquid at very low temperature (-273.15°C) has a very poor energy efficiency.⁹⁵ It is possible to transform green hydrogen in green ammonia and transport it. At destination, ammonia would be reconverted into hydrogen. However, ammonia is a corrosive molecule, and two conversions processes are inefficient.

Research on hydrogen transportation in Zeolite has been pursued for years.⁹⁶ Also, new technologies are emerging as the one developed by Hydrogen Storage Research Group in Australia to transport this very small molecule as a powder, which is safer and cheaper than other methods.⁹⁷ This is not yet available at an industrial scale.

- ✓ Mid distances hydrogen transportation by pipeline is possible. Gas network operators that are aware that natural gas consumption is falling, are getting ready to transport hydrogen in their existing pipes. We can cite the Hydrogen European Backbone initiative, a network of 5 corridors for the import of hydrogen into Europe and its transport within Europe.



Using gas pipelines dedicated to natural gas to transport hydrogen, requires adaptations because hydrogen is a smaller molecule than methane with different physical and chemical properties. The concerns are related to the weakening of the tubes by hydrogen if the operating conditions lead to a large amplitude of pressure. It is also necessary to ensure the tightness of the infrastructures. Ultimately the objective is to circulate in the pipes 10% of the consumption planned for 2030, or 10 million tonnes.

- **Creating a large enough market demand:** Increasing hydrogen production only makes sense if there is sufficient demand. Thus, there is a need to develop hydrogen usages. For example, the replacement natural gas by green hydrogen allows to decarbonize industries that are otherwise difficult to decarbonize, such as chemistry, steel and fertilizers.

Let's cite the two European projects initiated by InnoEnergy:

On one hand, GravitHy dedicated to speeding up the decarbonization of the steel industry (responsible for approximately 8% of the global CO₂ emissions),⁹⁸ and on the other hand FertigHy⁹⁹ that aims to produce, low-carbon fertilisers for European farmers.¹⁰⁰

However, these usages are probably not sufficient for green hydrogen production mass development. The transportation market (car, lorries or ships) conversion to hydrogen would significantly increase the demand. However, green hydrogen fuelled vehicles must be competitive compared to electrical vehicles whose costs are decreasing thanks to batteries improvements.

⁹⁵ To obtain 1l of liquid hydrogen containing 2,4 kWh, it is necessary to spend 4.8 kWh <https://www.h2-mobile.fr/dossiers/lh2-hydrogene-liquide-definition/#:-:text=Un%20litre%20d'hydrog%C3%A8ne%20liquide,au%20total%204%2C8%20kWh.>

⁹⁶ https://www.researchgate.net/publication/269478417_Zeolite_as_material_for_hydrogen_storage_in_transport_applications

⁹⁷ <https://www.mining.com/project-to-turn-hydrogen-into-a-powder-for-easy-export-gets-a5-million-in-funding/#:-:text=The%20HSRG%20research%20team%20is,be%20reused%20to%20transport%20hydrogen.>

⁹⁸ <https://gravithy.eu/>

⁹⁹ <https://fertighy.com/>

¹⁰⁰ The agriculture sector alone is responsible for 10% of the EU's total greenhouse gas emissions



Projections

The previous analysis shows that *low emissions hydrogen development should be much slower than previously expected* for cost reasons, technical problems, difficulties in long distance transportation and lack of demand.

Manufacturers have announced plans for further expansion, aiming to reach 155 GW/year of manufacturing capacity by 2030, but only 8% of this capacity has at least reached FID.¹⁰¹

The SISYPHE study¹⁰² shows a huge gap between the EU objectives and the low-carbon hydrogen demand projection in Europe by 2040. The low emission hydrogen demand projected by the study is thus 2.5 million tonnes in 2030 and 9 million tonnes in 2040, a huge gap with the objectives set by the European Commission of 20 million tonnes per year by 2030!!

Moreover, in its July 17, 2024 report the European Court of Auditors has stated that “2030 EU goals for renewable hydrogen production and demand were overly ambitious”¹⁰³

As a *conclusion, the growth in low-carbon hydrogen production has been “oversold” in Europe* both by politicians and by the industrial companies involved. Governments should review their unrealistic objectives at the risk of spending precious subsidies not for the right technology and creating stranded assets.

As the above analysis shows, **the energy transformation is falling behind schedule**

We can give a few more examples:

- ✓ *The penetration of electric cars has slowed*, and some countries such as the UK have pushed back the date of banning the sale of internal combustion cars from 2030 to 2035.
- ✓ *Big oil companies, we are returning to more realistic and less proactive positions* concerning Oil and Gas exploration. They now acknowledge the need to continue to develop new fields to cope with the existing fields depletion (even with unchanged or decreasing oil consumption).

This means that the objectives of the energy transformation, as announced by many countries, are too optimistic and too close in time.

Indeed, this transformation impacts not only the production and use of energy but also the way of living of our fellow citizens. It also reduces their purchasing power, which is a key area of concern that emerges in all opinion polls.

The objectives of the Paris Agreement will very likely not be met (barring a major crisis as the Covid pandemics or as a global war) by 2030.

Today the forecast is for an increase of 3°, even 3.5° by 2050 in global temperature with the disastrous consequences that we know about.

The question that must be asked is:

What should be done to limit the rise in global temperature?

101 FID: Final Investment Decision

102 <https://www.cea.fr/presse/Documents/CEA-etude-hydrogene-sisyphe.pdf> This projection is based on the reality of projects committed and on the vision of some 70 European manufacturers questioned about their potential needs into hydrogen

103 <https://www.eca.europa.eu/en/news/NEWS-SR-2024-11>



What should be done to limit the rise in global temperature?

Current technologies would make it possible to get closer to the objectives of the Paris agreement *if they were deployed at scale*. Of course, *research must continue in disruptive technologies* even if it is for a horizon further than 2030.

Let's first analyse the conditions of deploying at scale present technologies before analysing some disruptive energy related technologies and generative AI impact on the sector.

Scaling up existing technologies requires industrialization efforts, sound regulations (including simplified and accelerated procedures) faster and greater funding and stronger public acceptance.

Existing technologies deployment acceleration:

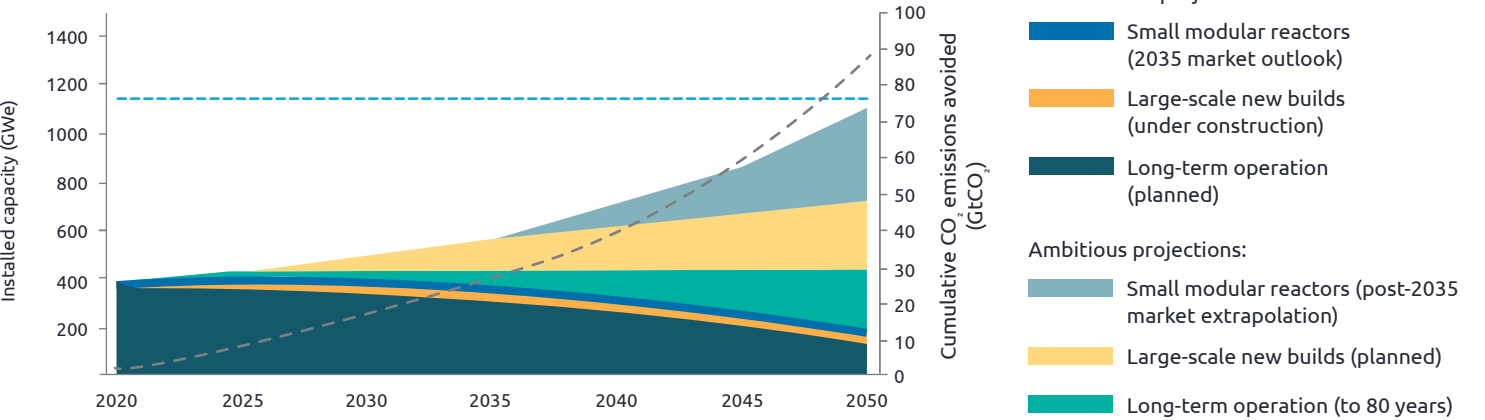
Wind and solar power are developing rapidly with photovoltaic solar production dominating. However, this development is not fast enough compared to the COP 28 objectives as confirmed by the June 2024 IEA report.¹⁰⁴ Analysed policies, plans, and estimates of almost 150 countries reveal an intention to install nearly 8,000 GW of renewables worldwide by 2030, representing 70% of the required (11000GW) amount to achieve the tripling goal by 2030 agreed at the COP 28. Moreover, governmental targets that are usually too optimistic are rarely met.

¹⁰⁴ <https://www.pv-magazine.com/2024/06/06/iea-urges-countries-to-accelerate-renewables-deployment/#:~:text=A%20new%20report%20from%20the,decade%2C%20as%20agreed%20at%20COP28.>

In addition to the acceleration conditions set out above, there is a need to solve offshore wind turbines technical problems, resolve the grid balancing problems that arise when the penetration rate of intermittent renewables is high and ensure that sovereignty issues will not disrupt these technologies deployments (see below).

Nuclear electricity: The 90 pathways for the 1.5°C scenario considered by the IPCC require on average *nuclear energy capacity to triple* and to reach 1 160 gigawatts of electricity by 2050.¹⁰⁵

FIGURE 7
Full potential of nuclear contributions to net zero



¹⁰⁵ https://www.oecd-neo.org/icms/pl_90816/the-neo-small-modular-reactor-dashboard-second-edition

To meet this ambitious target a few things must happen:

- ✓ lifetime extension (up to 80 years) of existing nuclear power plants,
- ✓ large-scale plants new builds acceleration
- ✓ SMRs deployment at scale

Source: https://www.oecd-neo.org/icms/pl_90816/the-neo-small-modular-reactor-dashboard-second-edition



The main prerequisites for this successful development are:

- **Delivering nuclear projects on time and on budget.** Simplify design and do not start the construction phase before the detailed design is approved.

As mentioned above, this has been a challenge in Europe and in the USA, less so in China, UAEs and probably Russia.

- **Demonstrate the SMR economic competitiveness**¹⁰⁶ their local acceptance and the strict control of the nuclear materials scattered on multiple sites.

- **Unlocking access to significant amounts of capital** at competitive rates.

Governments that support nuclear expansion should provide access to financing. It is not always the case, for example, in France, the financing of the first 6 EPR construction, forecasted at €6.4 bn, is not yet assured.

However, the European Investment Bank has included nuclear power financing in its June 21, 2024, document that outlines its investment strategy for the period 2024-2027.¹⁰⁷

- **Ensuring a healthy and resilient supply chain.** While the nuclear industry benefits from an international nuclear supply chains built up over 70 years, new nuclear technologies such as SMRs

will require changes to use factory production instead of on-site construction.

- Building and maintaining public confidence.
- Ensuring a skilled white collars and blue collars workforce.

Carbon Capture and Storage (CCS)¹⁰⁸ is considered as one of the solutions to decarbonize hard to abate industries (mainly gas and coal fired plants, cement and steel industries). Deploying massively CCS is also key for countries as China that accounted in 2023 for 95% of the world's new coal power construction. It is part of the country critical technologies¹⁰⁹ to reach their objective of peak carbon emissions by 2030.

The USA has been the first region to push CCS development supported by Oil and Gas majors. The federal government has provided financial support for those projects and more recently IRA has significantly boosted annual funding.¹¹⁰

- **Full scale CCS clusters are actively developing.**

In the USA, 15 CCS facilities are currently operating. Together, they have the capacity to capture about 22 million tons of CO₂ per year, or 0.4 percent of the USA's total annual emissions. An additional 121 CCS facilities are under construction or in development.

China has nearly 100 CCS projects in operation or under construction, with over half already operational, according to incomplete statistics. These projects have a combined CO₂ capture capacity of 4 million tonnes and an injection capacity of 2 million tonnes per year.

EU commission is pushing to expand CCS capacity from current projects totalling 4 million tonnes per year¹¹¹ to 100 million tonnes per year by 2030. Consistently, European governments are actively introducing regulations to grow the CO₂ storage capacity by a factor of 100 by 2030.

The Northern Lights project in Norway is building the world's first opensource CO₂, transport and storage infrastructure. Once the CO₂ is captured from its source, it will be liquefied and transported by custom designed ships, injected, and permanently stored 2,600 metres below the seabed of the North Sea.

- **Financing:** CCS projects are a multibillion capital projects, which under present conditions, have a IRR in a range of a medium to high single digit. In the USA, DOE funding and

¹⁰⁶ It is the cost overruns and delays of Nuscale, SMR (the first in Western) world that led to its construction cancellation <https://www.eenews.net/articles/nuscale-cancels-first-of-a-kind-nuclear-project-as-costs-surge/>

¹⁰⁷ <https://www.sfen.org/rqn/bientot-de-largent-public-europeen-pour-financer-le-grand-carenage/>

¹⁰⁸ <https://www2.deloitte.com/fr/fr/pages/explore/climat-developpement-durable/carbon-capture-and-storage.html>

¹⁰⁹ <https://www.carbonbrief.org/china-responsible-for-95-of-new-coal-power-construction-in-2023-report-says/>

¹¹⁰ <https://www.cbo.gov/publication/59832#:~:text=Status%20of%20Carbon%20Capture%20and,under%20construction%20or%20in%20development>

¹¹¹ Which has taken Final Investment Decisions)



subsidies under the IRA 2 and IJJA 3 (Infrastructure Investment and Jobs Act) are aimed at meeting the potential demand. While the first CCS projects are receiving significant government subsidies, scaling up the next wave will require private investments.

The UK has designed an investable CCS business model by implementing the Regulated Asset Base (RAB) approach on the whole infrastructure. Emitters in the UK, Netherlands and Denmark receive local subsidies to cover the gap between CO₂ capture costs and the EU ETS price.

To enable CCS development, more Contracts for Difference or subsidies should be introduced across Europe to support the emitter business cases.

- **Cross border CO₂ transport and storage** (i.e., London Protocol) should be enabled to allow emitters to access ideal storage locations, as well as to promote competition among developers and mitigate storage underutilisation risks through access to a wider pool of emitters.

Sound and predictable regulations:

They are important levers to implement energy transition policies. Stable and predictable regulations are key for investors in sustained energy installations to decrease their risks and increase their return on investments.

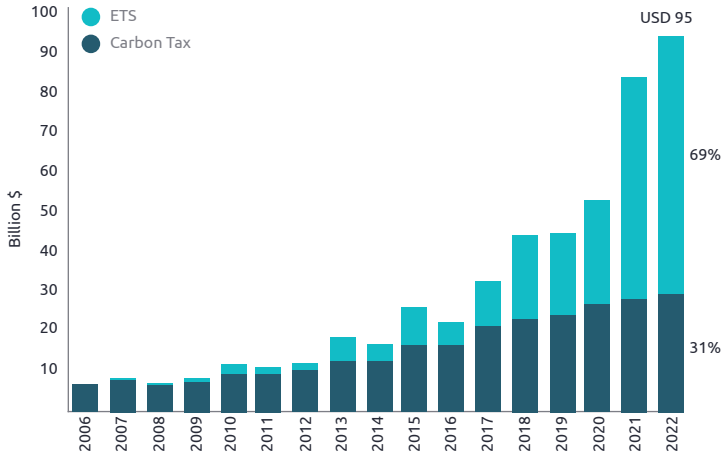
Before looking into details into some legislations, let’s note that too many regulations are slowing down the energy transition. For example, many Western countries have passed laws to remove their numerous regulatory obstacles to the installation of wind farms. The objective is to decrease the permitting duration, by lowering the number of local consultations and their duration while preserving a democratic process.

Also, some regulations have negative secondary effects. For example, in France there are costly regulations on refurbishing flats to increase isolation and decrease their energy consumption. This seems good, however, some flat owners, that cannot afford these refurbishing costs, prefer not to rent their flats thus reducing the offerings for rent in a market that is already tense.

Carbon pricing coverage should be extended, and prices increased:

As stated by IPCC¹¹² researchers, our planet temperature increase is directly linked to anthropogenic GHG emissions. Carbon taxes aimed at GHG emitters is a virtuous measure. However the range of sector covered needs to be large enough, the prices high enough and the revenues generate need to be invested only in climate transition projects.

FIGURE 8
Evolution of global revenues by type of carbon price: ETS and Carbon tax". Graphs source: World Bank



Source: <https://www.ciat.org/wp-content/uploads/2023/08/Grp03.png>

In 2024 there were worldwide 75 carbon pricing instruments (Emission Trading Systems-ETs- or carbon taxes) in operation in 89 jurisdictions covering around 24% of global greenhouse gas emissions.¹¹³ The prices ranged between 0.46 to 167\$/tCO₂e. These taxes generated \$104 billion in government’s revenues. However, only 1% of global GHG emissions were covered by a direct carbon price.¹¹⁴

112 IPCC: Intergovernmental Panel on Climate Change

113 <https://www.homaio.com/post/eu-ets-revenues-what-do-the-member-states-use-the-proceeds-for#:~:text=The%20rules%20on%20EU%20ETS%20revenues%20use,-The%20European%20Law&text=Yet%2C%20most%20countries%20are%20using,for%20climate%20and%20energy%20purposes.>

114 In 2017, a report by the High-Level Commission indicated carbon prices need to be in the \$50-100 per ton range by 2030 to keep a rise in global temperatures below 2C. Adjusted for inflation those prices would now need to be in a \$63-127 per ton , the World Bank report said.



In addition, in some large emitting countries, such as India (the third largest emitter), there is no system in place, and in China (the largest emitting country), the present system is on a voluntary basis.

Set up in 2005, the EU ETS is the world's first international emissions trading system. It covers greenhouse gas emissions from around 10,000 installations in the energy sector and manufacturing industry as well as aircraft operators.

From 2024, it also covers emissions from maritime transport and incineration of municipal waste

In 2022 in Europe, 90% of the auctioning revenues (€30bn) were redistributed to member states. The remaining 10% of the proceeds go to the innovation fund and the modernisation fund. Member state spent only an average of 76% of these revenues for climate and energy purposes in a vast range of programs.¹¹⁵

As part of the 2023 revisions of the ETS Directive, a new emissions trading system named ETS2 was created.¹¹⁶ It will cover new sectors mainly from fuel combustion in buildings, road transport and additional sectors and become fully operational in 2027. Although it will be a 'cap and trade' system like the existing EU ETS, it will cover upstream emissions. The ETS2 cap will be set to bring emissions down by 42% by 2030 compared to 2005 levels.

EU ETS prices have been decreasing from a maximum of €100/t to €70/t (in August 2024).

On October 1st, 2023, the Carbon Border Adjustment Mechanism (CBAM) a tool to fight carbon leakage¹¹⁷ entered into application in the EU for a transitional phase until 2026. In this phase, CBAM will only apply to a limited number of goods imports: cement, iron and steel, aluminium, fertilisers, electricity and hydrogen. EU importers of those goods will have to report on the volume of their imports and the greenhouse gas (GHG) emissions embedded during their production, but without paying any financial adjustment. As of 2026, importers will need to buy and surrender the number of "CBAM certificates" corresponding to the GHGs embedded in imported CBAM goods.

It is much too early to assess the effectiveness of this very complex innovative tool.

As a conclusion, carbon emissions rights allocations systems associated with emissions trading systems are a good way to incentivize Companies to invest in decarbonization projects. However, they should have a much larger coverage both on sectors and geographies and the emission prices should be higher.

A limitation on these high prices is that, at the end of the day, industrial companies will pass their extra costs to their end customer by increasing the price of their goods endangering customers and citizens acceptance of the energy transition.



¹¹⁵ <https://www.homaio.com/post/eu-ets-revenues-what-do-the-member-states-use-the-proceeds-for#:~:text=The%20rules%20on%20EU%20ETS%20revenues%20use,-The%20European%20Law&text=Yet%2C%20most%20countries%20are%20using,for%20climate%20and%20energy%20purposes.>

¹¹⁶ https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/scope-eu-emissions-trading-system_en

¹¹⁷ The phenomenon where industries relocate their operations to regions with less stringent emissions regulations, potentially increasing global emissions.



Circular economy is essential:

Currently, only 7.2% of used materials are cycled back into the economies after use. This has a significant burden on the environment. If current trends were to continue, we would need three planets by 2050!

A circular economy is essential for fighting climate change.¹¹⁸ Countries and regions (USA, EU, Australia...) have or are adopting laws to implement such a circular economy.

Circular economy allows to reduce material use, redesign materials and products to be less resource intensive, and recapture “waste” as a resource to manufacture new materials or equipment’s. Moreover, by extracting critical metals (from used products) and reusing them, countries increase their sovereignty.

Examples can be given for the energy sector:

- The EU Digital Product Passport (DPP) is designed to provide a digital record of products throughout their lifecycle. In 2026, batteries, that use a lot of critical metals, will be the first product category to be legally required to comply with DPP.
- By reusing metals from recycled batteries, security of supply is enhanced as dependence on mining countries and other suppliers is decreased. It’s why Europe will require new batteries to contain at least 6% recycled lithium and nickel

by 2031, and the state of New Jersey made it illegal to discard EV batteries in landfills.

- Battery recycling plants are being built near batteries Gigafactories in China but also in Europe, for example in Dunkirk in France.
- Extending solar panels lifetime beyond 20-30 years by appropriate maintenance or selling used solar panels on secondary markets.
- If safety allows, extending nuclear plants lifetime to 80 years or beyond.
- PV solar panels recycling to recover raw materials. According to the International Energy Agency, 70% of the photovoltaic sector's silver needs could be covered by recycling, the coverage rate being 20% for silicon and copper.
- Recycling the carbon fibre contained in windmill blades and reusing it in other equipment’s.

There are many challenges in implementing a circular economy, among them: the redesign of products and processes, the availability of recycling and repairing infrastructures and the consumer behaviours. This in-depth transformation of our economies will take a long time, but it has started.



More public and private financing

Global investment in the energy transition hit a new record of \$1.8 trillion in 2023, up 17% on the previous year.¹¹⁹ These clean energy investments come in addition to \$1.05 trillion investments in fossil fuel¹²⁰ as a dual economy (renewables and fossil fuels generation) will remain for at least a decade. This creates a financial burden on citizens.

According to different institutions (World Bank, IEA) around \$3.5 trillion a year of capital investment will be needed on average between now and 2050 to build a net-zero global economy.¹²¹ This is equivalent to around 1.3% of the average annual global GDP over the next 30 years.

¹¹⁸ <https://climatepromise.undp.org/news-and-stories/what-is-circular-economy-and-how-it-helps-fight-climate-change>

¹¹⁹ <https://about.bnef.com/blog/global-clean-energy-investment-jumps-17-hits-1-8-trillion-in-2023-according-to-bloombergnef-report/>

¹²⁰ <https://www.iea.org/reports/world-energy-investment-2023/overview-and-key-findings>

¹²¹ <https://www.energy-transitions.org/keeping-1-5c-alive/financing-the-transition/>



In developed economies there is still a gap in financing the energy transition.

In the USA and EU new laws have been passed to reduce this gap.

- In the USA, the Inflation Reduction Act (IRA) aiming at combatting climate change through a series of tax incentives, grants, and loans for clean energy was passed in August 2022, channelling nearly \$400 billion in federal funding into clean energy. Since then, around 300 major clean energy projects have been announced creating around 103,900 new jobs. They amount to nearly \$121 billion in capital investment. However, according to an August 2024 report,¹²² nearly 40% of major manufacturing projects are delayed. The uncertainty of policies during the election year coupled with deteriorating market conditions and slowing demand have led the manufacturing companies to alter their plans.
- In 2023, the EU climate investments grew by 9% in 2022, reaching €407 billion.¹²³ However, to meet the Green Deal objectives, the Region faces an additional €620 billion clean investment gap each year until 2030.¹²⁴ It is to be seen if the net zero Industrial Act adopted early 2024, will be as effective as IRA to attract private financing.

However, the present tense geopolitical situation has pushed many Western countries to increase their military budgets. There are fears that these increases will come at the expense of budgets dedicated to the fight against climate change.

- Two forms of financial flow are required for the energy transition: capital investment, and subsidies. These flows will come from public (20 to 40%) and private (60 to 80%) funds. Public financing comes mainly from taxes or from obligations as emission certificates (providing \$104bn in 2023). Whatever tax types (directly to citizens or consumers or to companies that pass them to their own customers), it is the citizen/customer who will pay. This burden added to often tight personal income is negatively impacting citizen energy transition acceptance (see below). Hence, most financing will have to come from private financial institution or companies.

Public subsidies enhance the energy transition projects Return on Investments as has been seen for at least a decade, on solar and wind generation projects.

Also, firm date bans, for example on the sales of internal combustion engines (e.g., by 2035 in Europe), create a demand and attracts investments.

In contrast, very volatile electricity (and gas in a lesser way) spot markets don't give a clear signal for investments. In early 2024 the combination of low electricity prices in Europe with a decrease of the emission certificates prices has lowered the appetite for energy and carbon savings projects.

The 2023 EU electricity market reform has finally recognized the need for long term investments in the electricity sector. It aims at giving long term electricity prices signals by encouraging PPAs and accepting "guaranteed sale prices" with systems as CfD or RAB.¹²⁵ Even so, it is extremely difficult to attract private funds to finance large projects as nuclear plants.

¹²² <https://www.ft.com/content/afb729b9-9641-42b2-97ca-93974c461c4c>

¹²³ <https://www.unpri.org/policy/implementing-a-2040-climate-target-for-a-competitive-and-just-european-greendeal/12242.article#:~:text=The%20EU%20faces%20an%20investment,for%20the%20net%20zero%20transition.>

¹²⁴ https://www.i4ce.org/wp-content/uploads/2024/02/European-Climate-Investment-Deficit-report-An-investment-pathway-for-Europe-future_V1.pdf

¹²⁵ PPA: Power Purchase agreement, CfD: contract for Difference, RAB:



Developing economies: At the COP 28, the growing gap between the needs of developing countries for adaptation efforts and action to mobilize and provide support to protect people from climate extreme has been pointed out. To be specific, that growing gap to fund the climate transition equates to the difference between the \$100 billion annually committed by donor countries¹²⁶ and the more than \$2.4 trillion needed per year.¹²⁷

In addition, some analysts pointed out that rich countries are overstating their contributions to the \$100 billion pledge, because a portion of their climate finance flows back home through loan repayments, interest, and work contracts. In addition, around 20% of the loans are at market-rate interest which is not the norm for climate-related and other aid projects, which usually carry low or no interest.¹²⁸

It has also to be verified that receiving countries are using these funds for energy transition projects.

Also, closing coal mines, polluting plants (as coal fired plants) or small coal fuel furnaces will generate an economic cost and job losses.

Subsidies to offset these costs in middle- and low-income countries (excluding China) may therefore be essential and could amount to around \$0.3 trillion a year by 2030.

¹²⁶ In 2022 developed countries provided and mobilised a total of \$115.9 billion in climate finance for developing countries, exceeding the annual \$100 billion goal for the first time

¹²⁷ <https://blogs.worldbank.org/en/ppps/laser-focused-bridging-climate-finance-gap-cop28#:~:text=To%20be%20specific%2C%20that%20growing,COP28%20President%20Dr.>

¹²⁸ Reuters report May 23, 2024

In conclusion, during the last years, in developed countries, there was noteworthy progress in financing energy transition. However, the needs of developing countries (that will become the larger GHG emitters) are not well addressed and despite donor countries efforts, there is a huge gap between the needs and the financing commitments. Fixing these financial issues is a key success factor for achieving Paris accord climate objectives.

Enhanced companies and citizen's contributions:

Companies: One must salute the efforts of many companies that are committing on a trajectory to reduce carbon emissions by 2030 as it is an important operational step on the 2050 net-zero

trajectory. Beyond the personal convictions of their leaders, these commitments are taken by companies under pressure from the rating agencies and proxies and from their employees that want to work for environmental conscious Companies.

Scopes 1,2, 3 are measuring GHG¹²⁹ emissions over different perimeters.¹³⁰ Most companies are mastering scopes 1 and 2 emissions. It is less the case for scope 3 emissions that are all emissions a firm is responsible for, but which happen outside of its walls. Scope 3 emissions calculation requires wide-scale collaboration along the value chain raising concerns around lack of information, data quality and confidentiality, Generative AI could provide help in those calculations.



¹²⁹ The GHGs included in the framework are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF₆), and nitrogen trifluoride (NF₃) They are measured in CO₂ equivalent

¹³⁰ Scope 1, Scope 2, and Scope 3 is a classification system for greenhouse gas (GHG) emissions a firm is creating through its operations, energy usage, and the wider value chain.



Achieving these GHG emissions reduction targets are more and more often part of the short- and long-term compensation incentives for employees, which increases the probability that they will be met.

There remain two important points of vigilance: the quality and taxonomy of emissions data which are generally not measured but established from public data and the methodology for measuring the reduction achievements where there are too many tools and indexes (e.g. SBTi, Carbon Trust.. start-ups). Agreeing on one common tool would allow comparability between companies from a same sector and between sectors.

Citizen's attitudes: In Western countries, citizens are conscious about the damage that climate change could cause and the need to fight against this change. However, their attitude can change when energy transition measures result in extra spending (for example to buy an electric car instead of the existing internal combustion car) or if they hinder their activity. This was evident in France at the beginning of 2024 when the farmers' demonstrated against Brussels' measures concerning agriculture, particularly the ban on certain pesticides.

In response, the French government has undertaken to plead in Brussels for the modification or removal of these regulations. Another example concerns the ban on the sale of internal combustion vehicles from 2035. Several political parties are committed to pushing back this date.

Understanding global climate phenomena and their issues is complex and there is great confusion. Indeed, the scientific and financial knowledge of our fellow citizens is not sufficient to allow them to form their own opinion and very often scientists are not listened to. Explanations are given by certain institutions or companies, but this is insufficient, and often political statements add to the confusion.

Many product sellers claim that their products are environmentally friendly, which is not verified. On this side we must salute the recent European Commission's proposal for a Directive on Green Claims that aims to prevent companies from misleading consumers with false environmental claims. The proposed directive sets minimum requirements for the substantiation, communication, and verification of explicit environmental claim.

*To conclude this paragraph, let's quote the French author Albert Camus
« **Mal nommer les choses c'est ajouter au malheur du monde** » which means
"Naming things wrongly is adding to the world's misfortune"!*



Albert Camus
French philosopher and author

• • •



Be prepared for disruptive technologies deployment after 2040

Nuclear advanced technologies

Fusion is often considered as the energy source of the future because its fuel can be extracted from seawater. It would produce no carbon emissions and only relatively short-lived radioactive waste.

Most government-funded efforts have focused on magnetic confinement machine called tokamaks, such as the international €20bn cost ITER project under construction in France. However, this huge project is undergoing a major setback: in June 2024 it has announced an €5billion extra cost and a 10 year delay.¹³¹ The first plasma is now planned for 2035 and the start of deuterium-tritium operation in 2045!

A more promising technology is based on laser confinement. In December 2022, researchers at Lawrence Livermore Laboratories in the USA have ignited an inertial confinement nuclear fusion reaction that produced a net return on energy.¹³²

Many national programs have been announced by governments to catalyse the establishment of this new industry.¹³³ There has also been an exponential increase in the establishment of private laser fusion companies.

The Chinese government's current five-year plan makes research facilities for fusion projects a priority for the country's science and technology. China could be spending \$1.5bn each year on fusion, almost double what the USA government allocate in 2024 for this research.

A lot of developments on laser and photonics technology, deuterium-tritium targets manufacturing, large supply chain for lasers and photonics construction needs to occur before commercial deployment can take place. Nuclear fusion will also require appropriate and comprehensive monitoring by safety authorities.¹³⁴ Finally funding is crucial as for example building an ignition-scale machine for a credible ignition experiment by the 2030s will cost around \$2.5billion.

It is doubtful that all these challenges will be overcome on a short enough timescale to support the fight against climate change by 2030.

In the meantime, promising **Generation IV nuclear reactors** could be built by 2030-2040.

Let's recall that during World War II, to propel submarines, the American company, Westinghouse developed light water nuclear reactors LWR.¹³⁵ This technology was then scaled up and adopted by many European (including Russia) and Asia countries

that built PWRs¹³⁶ or BWRs¹³⁷. This technology represents most of the Generation II reactors that are operating presently. Following nuclear incidents and a few accidents, increased safety features were included in Generation III reactors as the EPR(Europe), AP1000(USA), VVER 1200(Russia) or Hualong One(China).

Other technologies that were developed in the U.S. DOE, the French CEA National laboratories and the Russian Kurchatov Institute were not (for various reason) deployed at large commercial scale. Presently, these technologies are considered again to build reactors, but unlike previously, the industrial deployment is focused on small modular reactors called AMRs (Advanced Modular Reactors)

It is to prepare for these Generation IV reactors deployment that thirteen countries¹³⁸ created in 2001, the Generation IV International Forum (GIF) seeking to develop the research necessary to test the feasibility and performance of fourth generation nuclear reactors. The GIF has selected six reactor technologies¹³⁹ for further research and development. These technologies are often those developed since the 80's and 90's in the National Laboratories mentioned above. Their designs include thermal and fast neutrons, closed and open fuel cycles. The reactors range in size from very small to very large.

131 <https://www.newscientist.com/article/2437314-is-the-worlds-biggest-fusion-experiment-dead-after-new-delay-to-2035/>
132 https://www.photonics.com/Articles/Nuclear_Fusion_Drives_Laser_Development/a68807
133 These include the U.S. IFE S&T Hubs (IFE STAR) and the UK's fusion energy roadmap, and Germany has published its Memorandum on Inertial Fusion Energy.

134 <https://www.polytechnique-insights.com/en/columns/energy/nuclear-fusion-the-true-the-false-and-the-uncertain/>
135 Using French research done by Frédéric Joliot Curie
136 PWR: Pressurized Water Reactors

138 Argentina, Australia, Brazil, Canada, China, France, Japan, Korea, Russia, South Africa, Switzerland, the United Kingdom and the United States), as well as Euratom.
139 These 6 technologies are: the gas-cooled fast reactor (GFR), the lead-cooled fast reactor (LFR), the molten salt reactor (MSR), the sodium-cooled fast reactor (SFR), the supercritical-water-cooled reactor (SCWR) and the very high-temperature reactor (VHTR).



Depending on their respective degree of technical maturity, the first-Generation IV systems are expected to be deployed commercially around 2030-2040. They have advantages compared to the present LWR. For example, fast neutron and breeder technologies allow in principle, to extract almost all the energy contained in uranium, decreasing fuel requirements by a factor of 100 compared to today. Molten salt reactors don't need water cooling that create rivers heating (especially with potential increasing temperatures) and hence limit the nuclear plants electricity output.

Combined with start-up innovative spirit and new private and public funding these AMRs could fuel a real nuclear renaissance.

In the USA, the ADVANCE¹⁴⁰ Act that passed Senate agreement in June 2024 and that should go shortly to President Joe Biden for signature, is notably aimed at accelerating the licensing and creating new incentives for AMRs.

TerraPower (sponsored by Bill Gates) has developed a 345 MWe sodium-cooled fast reactor with a molten salt-based energy storage system. The construction of the first plant (Natrium) has started in June 2024 in the USA.

Space-Based Solar Power (SBSP)¹⁴¹

Sunlight is, on average, more than ten times as intense at the top of the atmosphere as it is at the surface of the Earth. Moreover, at a sufficiently high orbit sunlight would be available on a continuous basis. This would lift fundamental limitations that solar panels have on Earth as they can only generate power during the daytime and much of the sunlight is absorbed by the atmosphere during its journey to the ground.

Space-based solar power would be transformed into electricity via photovoltaic cells in geostationary orbit around Earth. The power would then be transmitted wirelessly in the form of microwaves to dedicated receiver stations on Earth, which convert the energy back into electricity and feed it into the local grid.

Technological advancements have made the concept of SBSP more feasible as the space launches cost has decreased, and the photovoltaics cells performance has improved.

However, there are challenges. A big one is the efficiency of the microwave beam. It spreads out when the wave progresses so that the receiving antenna on the surface must be huge (many square kilometres), which limits where to build them.

Another important challenge is the high initial costs of launching solar panels and other necessary materials into space. Also, building large structures in orbit and maintaining them is complex and expensive.

In early 2023, the European Space Agency launched the SOLARIS program, starting with a technology development and feasibility analysis that aims to enable the Agency to decide, by 2025, whether to continue with a program of large-scale development and use of space-based solar power.

On the opposite, in January 2024, NASA¹⁴² released a report that concluded that generating power from orbit was too expensive, especially compared with solar power made on Earth.¹⁴³

*White hydrogen*¹⁴⁴, also known as natural hydrogen, is found in the earth's subsurface along tectonic plates, both underwater and on the surface. Deposits have been discovered on every continent and in many countries around the world, but scientists are reluctant to estimate the quantities of natural hydrogen available. It is therefore impossible to say what share white hydrogen could supply in a few years' time.

¹⁴¹ https://www.esa.int/Enabling_Support/Space_Engineering_Technology/SOLARIS/Space-Based_Solar_Power_overview

¹⁴² National Aeronautics and Space Administration

¹⁴³ <https://www.scientificamerican.com/article/nasas-hopes-for-space-solar-power-are-looking-dim/>

¹⁴⁴ <https://www.alcimed.com/en/insights/white-hydrogen/>



As opposed to oil or natural gas production, continuous production would be possible for white hydrogen thanks to a rapid regeneration time of 10 years. Its production emits very little CO₂ compared with grey hydrogen that is extracted from natural gas.



The projected cost of extracting white hydrogen, €0.5/kg to €1/kg, would be competitive with grey hydrogen cost. In addition, helium is often a co-product of natural hydrogen, and its market price ranges from €30 to €70/kg. This co-product should make natural hydrogen deposits even more profitable.

Only one company is currently exploiting a white hydrogen deposit in Mali.

Industrial groups in the energy sector as well as players in the Oil & Gas industry and numerous start-ups, are present at the early stages of development, mostly by obtaining exploration permits. Australia is very active in this field, with over 35 permits already completed.

If presently, the industrial exploitation of natural hydrogen is not a reality, it could become one around 2030.¹⁴⁵

Generative AI: Since 2022, generative Artificial Intelligence (ChatGPT, Gemini, Perplexity, Mistral..) has become available to a large public and is raising both hopes and concerns. While the generative AI technology applies to a much broader scope than the only energy sector, it will have a major impact on it.

This impact has two facets: it helps optimize energy resources and combat climate change, but the current algorithmic choices require computation and data centres consuming a huge amount of energy and water.

• **On the positive side** let's note:

✓ **Complex modelling ability:** As AI makes it possible to analyse, correlate, and generate a lot of data, it can improve complex situations modelling.

Electricity consumption modelling is indeed complex. Consumption depends on temperature, season of the year, activity, prices, self-consumption and customer's behaviours that are influenced by economic situations, fears on prices increase or risks on security of supply, among others.

Better forecasting electricity consumption and finer optimization scenarios will help to improve grid balancing.

Another example is processes modelling for example, for electrolyser plants to improve hydrogen production.

¹⁴⁵ <https://www.rystadenergy.com/news/white-gold-rush-pursuit-natural-hydrogen>



✓ **Strong forecasting ability:** For example, weather forecasting: Google DeepMind Graph Cast model delivers 10-day weather predictions at unprecedented accuracy in under one minute. This helps to better forecast sun and wind power generation and thus to better balance the grid, with much lower processing power than currently used by weather super calculators.

A second example is provided by the city of Zurich. By integrating AI into the management of its public lighting and thanks to traffic forecasts, it managed to reduce its energy consumption by 70%, by switching lightening on only when it was needed.

✓ **Energy consumption reduction:** At Google, reducing energy usage has been a major focus over the past 10 years. It has built its own superefficient servers, invented more efficient ways to cool its data centres and invested heavily in green energy sources.

In five years, it improved by 3.5 times the computing power out of the same amount of energy.

A breakthrough was achieved by applying DeepMind's machine learning to Google data centre. It resulted in lowering the amount of energy used for cooling by up to 40%.¹⁴⁶

On the negative side:

✓ **Huge consumptions:** As AI makes it possible to analyse, correlate, and generate a lot of data, it can improve complex situations modelling.

Chat GPT 3 training would have emitted around 502 tonnes of CO₂, which is the equivalent of what 56 French people emit for a year. Each single query generates, only for computation, around 5g of CO₂.

More generally, Microsoft increased its greenhouse gas emissions by 30% between 2020 and 2023 due to 16 infrastructures for artificial intelligence (which were not always installed near decarbonized electricity sources).

Today data centres consume around 1% of global electricity, or 194 TWh. So far, the increase in the number of calculations has been nearly offset by gains in energy efficiency. As a result, data centre's consumption increased by only 6% between 2010 and 2020.

If AI keeps its current trend, this consumption should grow significantly.

The energy required to run AI tasks is already accelerating with an annual growth rate between 26% and 36%. This means that by 2028, AI could be using more power than the entire country of Iceland used in 2021!

The AI lifecycle impacts the environment in two key stages: the training phase and the inference phase. In the training phase, models learn and develop by digesting vast amounts of data. This training phase is very intensive, and usually performed several times to adjust the meta-parameters of the algorithms. Once trained, they step into the inference phase, where those models are applied to solve real-world problems. The consumption of each request is much smaller (equivalent to a few grams of CO₂), but the number of requests can be massive.

At present, the environmental footprint is split, with training responsible for about 20% and inference taking up the lion's share at 80% for large public systems. As generic AI models gain traction across diverse sectors, the need for inference and its environmental footprint will escalate.

¹⁴⁶ <https://deepmind.google/discover/blog/deepmind-ai-reduces-google-data-centre-cooling-bill-by-40/>



✓ ***How to master this consumption evolution?***

- » More parsimonious, eventually targeted use of generative AI is needed as well as the optimization of the type of model used.
- » It is already possible to optimize some core elements in the models. With the re-usability of neural network infrastructure choice, and the data centre location (where the energy mix is less carbon-intensive), GHG emissions can be divided between 100 and 1,000 times.
- » Improvements can also be made to microprocessors and cooling so that they consume less energy and to algorithms so that they become more efficient and require less data and computing power for training.
- » Research is emerging about other actionable steps that can be taken today to align AI progress with sustainability. For example, capping power usage during the training and inference phases of AI models presents a promising avenue for reducing AI energy consumption by 12% to 15%, with a small trade-off on time to finish tasks with GPUs expected to take around 3% longer.

In data centres, the objective is to reduce the PUE (Power Usage Effectiveness) through various technologies (see WEMO 2023¹⁴⁷) through the development at scale of innovative cooling methods such as immersing servers in an oil bath or direct cooling of the chips themselves. Microsoft Azure and Google Cloud aim to achieve a PUE below 1.125 or 1.120, which means that their energy efficiency will be greater than 89%.

Conclusion: Adaptation measures

From the previous analysis one can conclude that the world is not on the right trajectory to meet the Paris agreement objectives. Besides mitigation measures that were outlined above, politicians, public services and Companies must also demonstrate realism by launching adaptation measures to combat the negative effects of climate change which will be inevitable (see WEMO 2023¹⁴⁸).

¹⁴⁷ <https://www.capgemini.com/insights/research-library/world-energy-markets-observatory/>

¹⁴⁸ <https://www.capgemini.com/insights/research-library/world-energy-markets-observatory/>



In the current geopolitical context, energy sovereignty is a major concern

In recent years, various events have changed the Western countries energy doctrine and led them to strengthen their energy sovereignty.

In 2020-2021, the health crisis linked to Covid 19, and the resulting lockdowns, slowed down global trade. This has led to a desire to develop national production to shorten supply chains.

In 2022, **Russia's** unjustified invasion of Ukraine, highlighted Europe's dependence to Russian gas (especially certain countries like Germany). Russia has gradually reduced and almost stopped its gas supplies via pipelines to Europe.

To deal with this crisis, European countries have encouraged their citizens to reduce their energy consumption¹⁴⁹; they have diversified the origin of their gas supplies and accentuated the transition to renewable energies.¹⁵⁰

As a measure of retaliation, the Europeans and Americans have launched embargoes against Russia, particularly on coal, oil (see above) and more recently the American embargo on Russian enriched uranium.

In May 2024, the USA President Joe Biden signed a ban on Russian enriched uranium even though the country imports around 20% of its needs from Russia. The law unlocks about \$2.7 billion in funding to build out the USA uranium fuel industry. The European Company, Urenco has already decided to increase its New Mexico plant capacity by 15% from 2025 and the French Orano is looking at building an enrichment plant in the USA. In Europe, missing Russian supplies will be met thanks to the extensions of Urenco enrichment plant in the Netherlands (by 15% from 2027) and Orano plant in France¹⁵¹ (by 30 % from 2028).

Natural uranium and SWU^{152,153}, prices have increased.¹⁵⁴ However, this price increase has little impact on the final cost of nuclear electricity because the enriched uranium cost represents only 5 %¹⁵⁵ of the total nuclear electricity generation cost.

China: during his term, President Trump launched an economic war against China to try to curb its economic dominance notably in the clean technologies.

Indeed, China has become by far the world's largest producer of hydroelectric, wind and solar power thanks to its massive deployment of renewable capacities (see above).



- ✓ China accounted for more than half of all new renewable capacity installed last year.
- ✓ It is building the biggest number of large nuclear reactors¹⁵⁶, it has already one SMR in operation and is building both SMRs and AMRs,^{157,158}
- ✓ in 2023, it has installed half of the world's electrolyzers to produce hydrogen,
- ✓ It is for a few years already the largest batteries and EV manufacturer.
- ✓ More recently it has launched plans to install CCS facilities which are badly needed as the country is burning increasing volumes of coal and gas.

152 Separative Work Unit (SWU) is a unit that defines the effort required in the uranium enrichment process

153 In 2023, the average price paid by the Civilian Owners/Operators was \$106.97 per SWU up 6% from 2022. <https://www.eia.gov/uranium/marketing>

154 <https://www.eia.gov/uranium/marketing/>

155 https://www.iaea.org/sites/default/files/publications/maazines/bulletin/bull59-2/5920405_corr.pdf

156 China is on pace to add as many as 10 reactors a year and may surpass the United States' total nuclear capacity by 2030.

157 <https://www.ans.org/news/article-5861/>

[chinas-new-linglong-one-reactor-just-one-piece-of-nuclear-expansion/](https://www.ans.org/news/article-5861/chinas-new-linglong-one-reactor-just-one-piece-of-nuclear-expansion/)

158 <https://www.reuters.com/world/china/china-starts-up-worlds-first-fourth-generation-nuclear-reactor-2023-12-06/>

149 Fear of electricity or gas cuts and high prices have led to drops in consumption of around 10%

150 WEMO 2023 <https://www.capgemini.com/insights/research-library/world-energy-markets-observatory/>

151 <https://www.sfen.org/rqn/uranium-enrichi-orano-valide-le-projet-dextension-de-georges-besse-2/>



By mid-2024, China's energy administration has declared that it will meet its 2030 renewable energy targets by the end of 2024.¹⁵⁹

With such industrial development and exportation capacities, China is increasing year after year its dominance on the energy sector. Let's analyse this in more detail.

On the equipment side, for example, China has a PV Solar panels production capacity much larger than its own needs. It produces around 80 to 90% of key elements of the PV solar global chain as wafers and cells. For 2024 analysts expect China to add 500-600 GW of PV module production capacity, while it should install around 260 GW of new capacity.¹⁶⁰ This will result in a significant overcapacity that will be sold notably in Europe (as the USA supply only 1% of their imports directly from China¹⁶¹)¹⁶² threatening the existing domestic manufacturers.¹⁶³

159 China On Track To Meet 2030 Renewable Energy Targets By The End Of 2024

A new report from the China Renewable Energy Engineering Institute (CREEI) research body has stated that the country is likely to meet its 2030 renewable energy targets, an impressive 6 years ahead of target. This is for the most part due to incredibly quick growth in the solar and wind sectors which was apparent in 2023 and continues throughout 2024.

By the end of 2024, China is expected to add 260GW of renewable energy capacity, after previously adding just over 300GW in 2023. This meant that last year, China provided 60% of all global renewable energy

160 It installed 300GW in 2023

161 <https://www.japantimes.co.jp/business/2024/02/06/companies/us-solar-indian-china/>

162 [https://ember-climate.org/insights/research/](https://ember-climate.org/insights/research/china-spare-solar-climate-energy-opportunity/#supporting-material)

[china-spare-solar-climate-energy-opportunity/#supporting-material](https://climateinsider.com/2024/03/15/unpacking-chinas-solar-panel-overproduction-a-global-perspective/)

163 [https://climateinsider.com/2024/03/15/](https://climateinsider.com/2024/03/15/unpacking-chinas-solar-panel-overproduction-a-global-perspective/)

[unpacking-chinas-solar-panel-overproduction-a-global-perspective/](https://climateinsider.com/2024/03/15/unpacking-chinas-solar-panel-overproduction-a-global-perspective/)

Tariffs and embargos: since a few years, to protect their domestic industry, Western countries (especially the USA) have voted tariffs on Chinese equipment.

In 2024, the USA tariff rate on solar cells increased from 25% to 50%. This tariff increase aims to counter China manufacturers to sell in the USA solar cells at discounted prices inhibiting the development of domestic solar cell capacity.

A recent illustration of USA manufacturers difficulties is SunPower, that in August 2024 filed for chapter 11 bankruptcy and is winding down its operations¹⁶⁴

Moreover, the USA administration has raised import tariffs on battery cells from China used in electric vehicles and energy storage systems. In 2024, tariffs for electric vehicle battery cells will increase to 25%, with energy storage tariffs increases following in 2026.

On June 12, 2024, following an anti-subsidy investigation, the European Commission disclosed that it would provisionally impose import tariffs ranging from 27.4% to 48.1% on electric vehicles (EVs) from China. This comes a month after the USA

164 [https://www.reuters.com/legal/](https://www.reuters.com/legal/us-bankruptcy-court-approves-stalking-horse-bid-sunpower-assets-2024-08-29/)

[us-bankruptcy-court-approves-stalking-horse-bid-sunpower-assets-2024-08-29/](https://www.reuters.com/legal/us-bankruptcy-court-approves-stalking-horse-bid-sunpower-assets-2024-08-29/)

announced that their own tariffs on Chinese EVs would rise to an unprecedented 102.5 %. In August 2024 Canada followed by imposing 100% tariffs on China-made electric cars.¹⁶⁵

However, these measures will have a limited effect:

- ✓ Solar cells: the direct USA import of solar cells from China is less than 1% and Chinese solar panel enter the USA market though other countries supplies (notably through India).
- ✓ For energy storage, while a tariff increases to 25% for cells is notable, it may have its impact softened by expected price reductions. In the 2023 summer, battery cell prices in China ranged from \$120/kWh to \$130/kWh but were expected to drop to \$40/kWh or less in 2024 summer. A 25% tariff on a battery price around \$40/kWh, results in an increase of just \$10/kWh. This increase remains modest compared to the overall price reduction of around \$80/kWh.

The question is whether to fight against the massive arrival of Chinese clean equipment's (which contributes to the energy transition cost decrease) or try to find alliances.

165 [https://www.reuters.com/business/autos-transportation/](https://www.reuters.com/business/autos-transportation/trudeau-says-canada-impose-100-tariff-chinese-evs-2024-08-26/)
[trudeau-says-canada-impose-100-tariff-chinese-evs-2024-08-26/](https://www.reuters.com/business/autos-transportation/trudeau-says-canada-impose-100-tariff-chinese-evs-2024-08-26/)



Regulations to promote domestic production

The USA¹⁶⁶, Canada¹⁶⁷, Japan¹⁶⁸ and Europe¹⁶⁹ have passed laws to encourage domestic critical equipment production. This is very positive for the region's industrial development as these laws create a large market for investors (domestic or non-domestic). One drawback is that the higher labour costs and more stringent regulations than in China, lead to higher prices. To combat this, it is urgent that Western regions boost their R&D and innovation incentives to create new and cheaper solutions and processes. We have analysed above the benefits of the IRA.

The EU Net Zero Industrial Act (NZIA) stipulates that by 2030, 40% of clean tech products must be supplied in Europe. In this framework the European Commission has launched the Holosolis project. The factory located in Sarreguemines in France, is expected to produce 10 million solar panels annually—enough for around one million households—and generate over 2000 jobs by 2028 with an investment of €850 million. However, at least at the beginning, the silicon ingots will be imported from China.

Unlike in the USA, where the IRA offers generous subsidies, the EU's Green Deal Industrial Plan provides little new finance, and its implementation is much slower than IRA's. For example, the European Green Deal was launched in 2020, and in 2024, 60% of the money has still not been spent while the IRA planned spending envelope has been totally paid out two years after it was voted.

Rare earths, graphite and rare metals:

Western countries realized that to implement their energy transition they were not only dependent on Chinese clean tech equipment but also on certain raw materials: (as rare metals and rare earths) and graphite (for battery anodes)¹⁷⁰.

Driven by a desire for independence (or at least less dependence) on these strategic materials, manufacturers have evolved their technologies to use less of them. For example, by developing battery cells without cobalt and with less manganese and nickel.

Also, the regulations that have been adopted on the circular economy will oblige battery manufacturers to use recycled metals, thereby reducing the need to extract these metals (see chapter on the circular economy).



166 IRA: Inflation Reduction Act passed in 2022

167 <https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/clean-electricity-regulation.html>

168 https://www.enecho.meti.go.jp/en/category/special/article/detail_178.html

169 NZIA: Net Zero Industry Act voted in 2024

170 <https://chinaobservers.eu/de-risking-rare-earths-the-greenland-stalemate-and-the-critical-raw-materials-act/>



As for clean tech equipment, Western countries have adopted **specific legislations** on these raw materials:

- ✓ In 2021, the USA American Critical Mineral Independence Act¹⁷¹ was adopted to provide support for a domestic supply of critical minerals.
- ✓ The EU has adopted in Q1 2024 its new Critical Raw Materials Act (CRMA)¹⁷², and has been seeking to develop mining projects within EU borders. Various economically exploitable deposits have been found. For example, the mining company LKAB announced that it found a deposit of over 1 million tons of rare earths in Northern Sweden¹⁷³. At the beginning of June 2024, Rare Earths Norway Group announced that their Fensfelter¹⁷⁴ deposit in south-east Norway should contain 8.8 million tonnes of rare earths¹⁷⁵ and that mining could begin in 2030. Investment in the project is estimated at €900 million. Other areas in Southern Europe, such as the Balkans, may also contain considerable resources, but remain largely underexplored at present.

Rare Earths Elements (REE¹⁷⁶): Contrary to what their name suggests, they are abundant in the earth's crust, but they are found in low concentrations and are hard to separate from other elements, which is what makes them "rare."

They are used in various high-tech applications including, smartphones, wind turbines, electrical motors, hard disk drives, LEDs, and more. They are key for the energy transition as an electric car requires six times the mineral inputs of a conventional car, and a wind plant requires nine times more minerals than a gas-fired plant. REEs market is forecasted to grow from 2024 to 2031, with a projected CAGR between 10% and 13% and could increase six-fold by 2040.

China entered the (REE) market in the 1980s and the Western countries were initially happy to let it takeover these material extraction and refining activities as they release toxic chemicals and radioactive wastes.

They paid little attention to China's increasingly significant lead. Yet, China's dominance over the sector gave it a significant political leverage. In September 2010, after a spike in tensions between China and Japan related to a territorial dispute, China appeared to place an unofficial embargo on rare earth exports to Japan.

In 2024, China's accounts for one-third of known worldwide rare earth reserves, 60% percent of mined production and 85% percent of processing capacity.

Graphite is used for batterie's anodes. The need for graphite will increase by 25 times due to electric vehicle (EV) manufacturing growth alone.

In 2023, the USA imported 100% of its natural graphite of which 42% from China. The EU has a similar dependence. Western dependency was exploited in 2023 when China imposed graphite export restrictions in retaliation for USA limits on semiconductors sales.

171 <https://www.congress.gov/bills/117/congress/house-bill/2637>

172 https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials/critical-raw-materials-act_en

173 <https://lkab.com/en/press-eu23/#:~:text=LKAB%20has%20identified%20significant%20deposits,electric%20vehicles%20and%20wind%20turbines.>

174 <https://www.ngu.no/nyheter/fensfeltet-satt-pa-europa-kartet-storste-forekomst-av-sjeldne-jordarter>

175 Rare Earths are a family of 17 metals with special electromagnetic properties that make them indispensable to the energy transition).

176 REE describe the 15 lanthanides on the periodic table (La-Lu), plus Scandium (Sc) and Yttrium (Y).



IRA law prohibits manufacturers from sourcing battery components and critical minerals from Foreign Entities of Concern (FEOC) starting in 2024 and 2025, respectively. FEOCs include China, Russia, Iran and North Korea. However, the final rules, released May 2024, would delay the restrictions on graphite and some critical minerals until 2027.

In this context, China, Europe and USA companies are eying [Greenland](#) which is thought to have the second-largest reserves of REE, surpassing Vietnam, Brazil, and Russia.¹⁷⁷ Greenland has also large graphite deposits: it's 6 Mt of known graphite resources could exceed the projected EV graphite demand for 2040 (3.5 Mt) and counter Chinese mineral supremacy. Greenland has also large Oil and Gas reserves. This is probably why, in 2019, USA President Donald Trump discussed the idea of purchasing Greenland!

However, mining Greenland resources would be complex for various reasons such as remoteness, harsh climate, lack of infrastructure and limited workforce but also for political reasons. Indeed, in 2021, a ban on Uranium extraction¹⁷⁸ was decided which also challenges REE extraction, as uranium is commonly combined with REE in deposits.

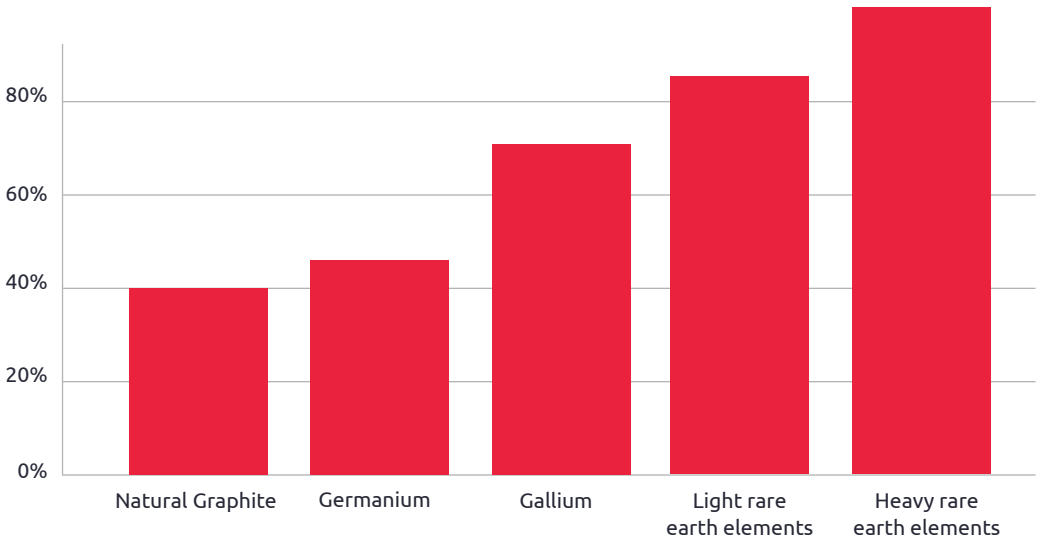
¹⁷⁷ <https://ip-quarterly.com/en/dont-buy-greenland-buy-its-minerals#:~:text=Mining%20Politics%20in%20Greenland&text=The%20ban%20was%20instated%20following,is%20commonly%20found%20alongside%20deposits.>

¹⁷⁸ <https://ip-quarterly.com/en/dont-buy-greenland-buy-its-minerals#:~:text=Mining%20Politics%20in%20Greenland&text=The%20ban%20was%20instated%20following,is%20commonly%20found%20alongside%20deposits.>

Reducing the significant dependency on rare earths for Western countries would still require partnerships with third countries. Additionally, the USA and the EU are substantial importers of

key components and finished products that use rare earths, especially green technologies that China dominates (see above).

FIGURE 9
EU reliance on select Chinese material imports



Source: European Council, May 2024



Lithium and critical metals:

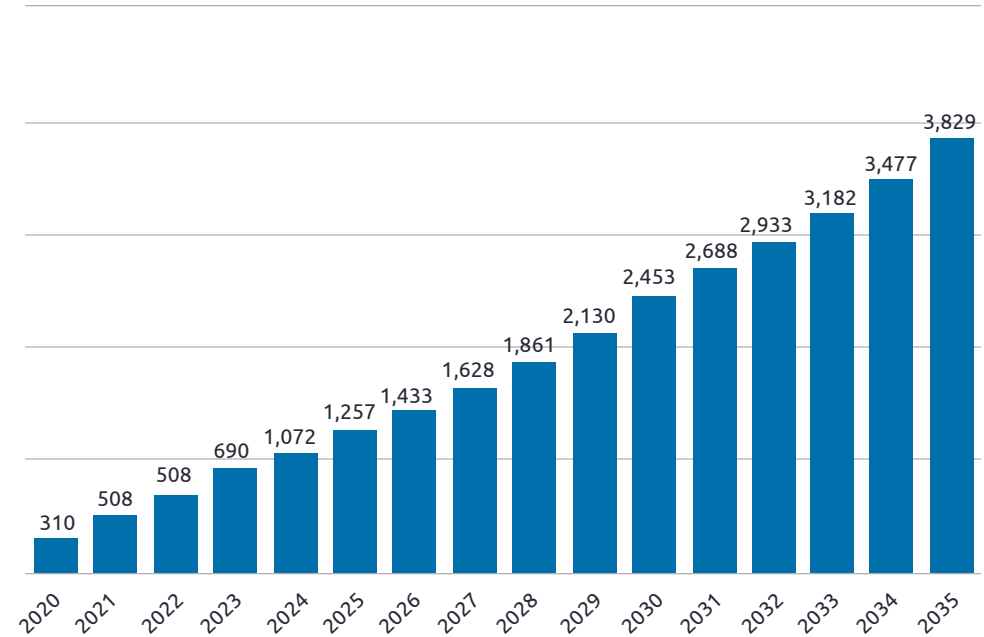
Critical metals notably, nickel, cobalt, lithium and copper are central to the production of EVs, batteries, wind turbines, photovoltaic panels and electrical grids.

Increasing their control on these metals production is part of the USA and EU legislations analyzed above. In addition to legislation and public funding, private financing is mobilised. For example, in 2023, the French government launched the first European Union's private critical metals fund. InfraVia was selected to manage this €2 billion fund, which will be supported by French government and European manufacturers in the automobile, renewable energy and aeronautics sectors, as well as by financial investor.¹⁷⁹

Lithium is used for batteries (see above). Its demand growth is forecasted to follow EVs growth, from around 1 070 million tons of lithium carbonate equivalent in 2024 to 3 800 million tons in 2035.

Despite holding less than 7% of the world's lithium reserves, China has managed to secure an 80% share of global refined lithium production.

FIGURE 10
Lithium worldwide demand



Source: Statista 2024

¹⁷⁹ <https://home.cib.natixis.com/articles/securing-critical-metal-supplies#:~:text=The%20critical%20metals%20fund%20%E2%80%93%20a%20metal%20than%20we%20do%20currently>



Western companies are reacting on this dominance

- Mid-2024, the French Company, Eramet inaugurated its plant in Argentina where it invested \$870 million¹⁸⁰. The objective is to produce 24 000 tons of Lithium Carbonate Equivalent (LCE) in 2025 (around 2% of 2024 demand) increasing to 80 000 tons in the future.
- Chile has the world's largest lithium reserves and is the second largest producer after Australia. The Chilean government's plan, adopted in 2024, should increase lithium production by 70% by 2030. At the beginning of June 2024, Chile's Codelco and SQM¹⁸¹ signed an agreement to join forces to exploit the lithium in the Atacama Desert in the North of the country. The aim is to achieve a total additional production of 300 000 tons of LCE in 2025-2030. This increase in lithium production will be achieved through improvements in process efficiency, the adoption of new technologies and the optimization of operations.
- Despite falling lithium prices¹⁸² new players are entering this market: geothermal companies as Arvern Group¹⁸³ and large Companies as Exxon-Mobil. In 2023, the latter announced that it aims at becoming a leading producer

of lithium, and work has begun for lithium production in southwest Arkansas. It should start producing lithium in 2027, and by 2030 it would be able to supply batteries for 1 million EVs per year.¹⁸⁴ The off taker would be “SK on” the South Korean battery manufacturer.

Conclusion

While increasing sovereignty on critical equipment and raw materials is important for the energy transition success, the interconnections between countries are strong and complex. It will thus be difficult to cut links with countries such as China.

Also, embargos are very often circumvented. For example, the “energy hub in Turkey” project is nothing more than an attempt to launder Russian gas supplies by mixing them with gas from other producers like Azerbaijan and Iran.

Moreover, these sovereignty policies will lead to cost and prices increases that must be accepted by taxpayers and citizens.

Finally let's not forget the saying “a bad agreement is better than a good economic war”.

Given the current geopolitical tensions, it is probably not the right time to implement these cooperative solutions. Let's hope that cooperation will be possible in a more peaceful future world.

¹⁸⁰ <https://www.aramet.com/en/news/2024/07/aramet-inaugurates-its-direct-lithium-extraction-plant-in-argentina-becoming-the-first-european-company-to-produce-battery-grade-lithium-carbonate-at-industrial-scale/>

¹⁸¹ https://www.codelco.com/prontus_codelco/site/docs/20160401/20160401130745/310531_comunicado_acuerdo_codelco_sqm_en.pdf

¹⁸² From a peak of \$81000/ton in November 2022 to \$14000/ton in June 2024

¹⁸³ Lithium is found in deep geothermal brines.

¹⁸⁴ <https://www.reuters.com/markets/commodities/exxon-aims-make-key-lithium-technology-decision-by-year-end-2024-02-15/>



General conclusion

In 2023 and 2024, geopolitical tensions increased with the continuation of the war between Russia and Ukraine following the unjustified invasion of Ukraine and tensions in the Middle East following the Hamas massacre of Israeli civilians on October 7, 2023. These tensions have led many countries to increase their military budgets. They have also resulted in a global economic slowdown.

Despite these tensions, commodity and **energy prices have not generally risen**. On the contrary, spot electricity and gas prices fell significantly in early 2024 in Europe, while demand remained stagnant. The price of certain strategic metals such as lithium has dropped by a factor of 2.5.

2023 was a record year for the installation of new renewable production capacity.

Year on year, these new capacities increased by 14% with a larger capacity expansion of solar (32%) than wind (13%). Solar PV alone accounted for three-quarters of renewable capacity additions worldwide. China commissioned as much solar PV as the entire world did in 2022, while its wind additions also grew by 66% year-on-year.

There has been a revival in nuclear power, with a burgeoning number of large and small reactors potential projects, finally recognising the fact that nuclear power does not emit greenhouse gases.

However, at the same time, fossil fuels consumption rose by 1.5% in 2023, driven by growth in developing countries and China.

Consequently, when compared with the previous year, energy-related **greenhouse gas emissions rose by 1% in 2023**.

Renewables intermittent sources of energy increase poses a problem on grid balancing. Thus, there is a need to increase sensors deployment on the grid and in customer premises, storage capacity, low emission dispatchable generation as nuclear or pumped Hydro Storage, and cover heating demands with more storable green heat produced with biomass or geothermal energy.

Intermittent renewables penetration rate in electricity generation lead to more frequent episodes of negative prices, which in turn is hampering the future profitability of new renewable or nuclear power generation capacity, which have a high CAPEX component.

If there is too much renewables generation, grid operators curtail the surplus. Using this free electricity to produce green hydrogen (by water electrolysis) would help to bring down its cost. However, these electricity input variations are causing problems to electrolyzers functioning and are accelerating their ageing.



The massive production of green hydrogen is encountering problems as its cost is much higher than grey hydrogen's, the availability of additional quantities of renewable energy and nuclear power is limited, and the long-distance transport of hydrogen remains complex. In this situation a large enough green hydrogen market is not foreseen. One can therefore assume that the **European political promises of a very rapid increase in volumes of green hydrogen will not materialise within the timeframes announced.**

The world is not on track to meet the Paris Agreement's target of a 1.5% increase in global temperature by the end of the century, with the current trajectories leading to an increase of more than 3°C.

To get closer to these targets, **existing technologies** (intermittent renewables, hydroelectricity, green heat, nuclear including SMRs.) **would have to be deployed at scale by 2030.** This deployment requires favourable legislation, public and private funding, which is currently lacking (especially in developing countries).

Public acceptance is increasingly difficult to get because of the energy transition related price rises caused by the cohabitation of two subsidized energy systems: fossil fuels and renewables. By 2040, some technologies may be promising, such as Advanced Modular Reactors, White Hydrogen or Space-Based Solar Power, but they have yet to prove their industrial and economic viability. Despite progress in laser fusion, it is very likely that nuclear fusion will not produce significant amounts of electricity before 2050.

While **Generative Artificial Intelligence** is not specific to the energy sector, it will have a major impact on it: it helps to combat climate change, but the associated data centres will consume a huge amount of energy and water. Besides construction of massive renewable or nuclear production plants, measures should be taken to limit this consumption increase.

In conclusion, **in addition to mitigation measures to limit GHG emissions, adaptation measures fast implementation is needed** to increase energy infrastructures (and other





infrastructures) robustness to exceptional events and rethink their operating conditions.

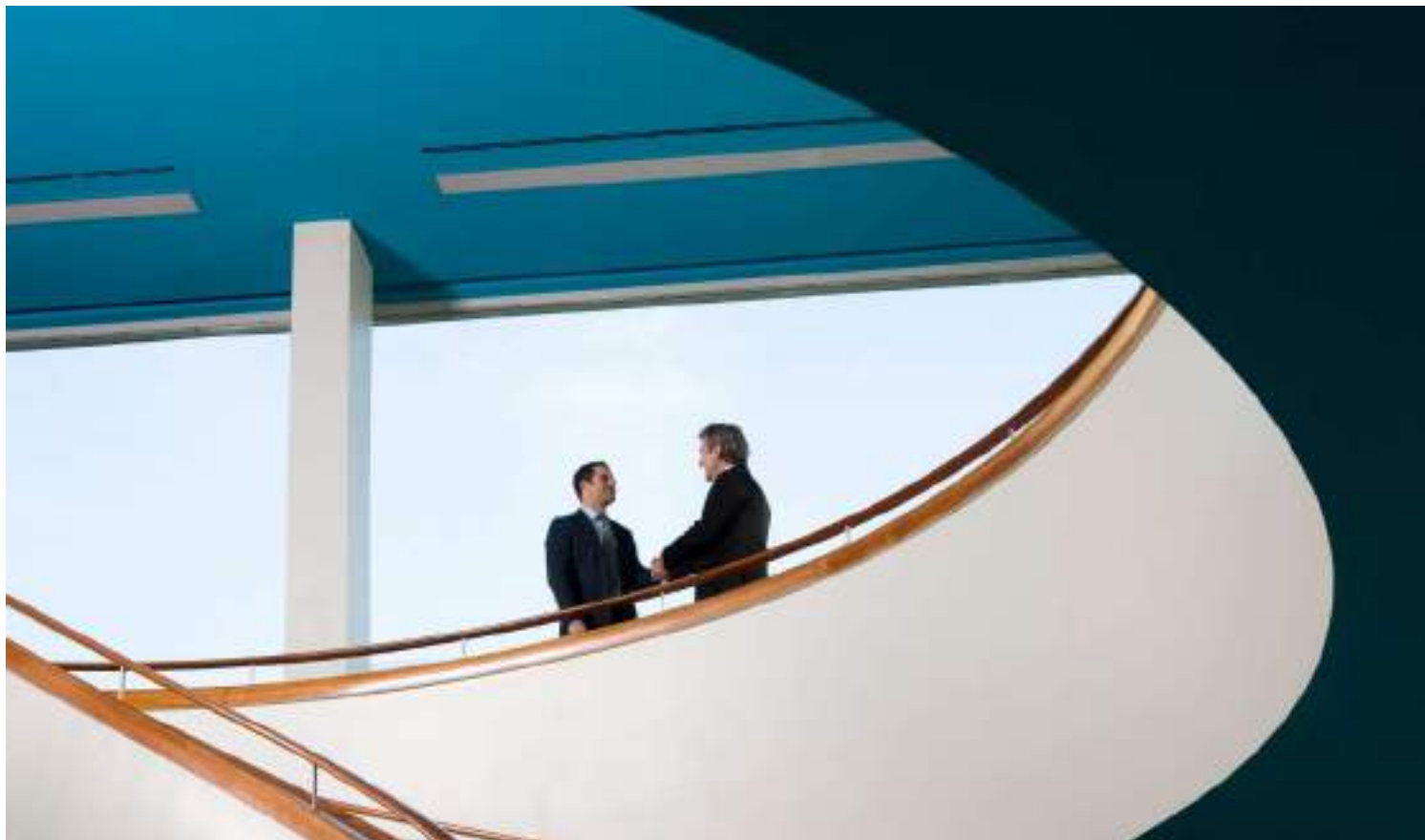
China has continued to increase its dominance in clean technologies and strategic raw materials. Western countries have responded by imposing **sovereignty measures** and passing laws to create domestic markets for local production of the needed equipments and favourable conditions for local extraction of strategic minerals.

It is good that sovereignty is finally being considered in public policy. But let's not have illusions about the effectiveness of customs barriers and embargoes.

Peaceful agreements between countries are the best way of achieving the objectives of the energy transition, especially as pollution is global. However, the present geopolitical tensions should ease to make this possible.

Colette Lewiner

Paris, September 16th, 2024



01

How to make
money from
renewables?





**Florent
Andrillon**
Global Climate Tech
Leader, Vice President
Capgemini



Florent leads the strategy and development of climate technologies services globally for Capgemini group. He focuses on innovation, partnerships and helping climate tech players scale their solutions, reduce time to market, and optimize profitability.



Rémi Dachicourt
Renewables &
Decarbonized Power
Generation Leader
Director - Capgemini
Engineering



Rémi leads renewable energy services for Capgemini Engineering. His past experience includes both technical and consulting projects, supporting his customers transitioning away from fossil fuels by achieving a profitable growth of the renewable power generation.

1. Wind, solar, and nuclear energy are all struggling to attract investment. Because of this, government intervention is often necessary. For example, the UK's RAB model for nuclear and CfD for offshore wind are examples of such interventions. Major oil and gas companies see renewables as costs rather than value-generating assets.
2. Renewable energy is less profitable than oil and gas. However, fossil fuels are still subsidized in many parts of the world.
3. Companies need to change how this business is viewed, managing it as an asset.
4. Diversification of client base – need a risk portfolio, some assets traded on market, some in PPAs, some for storage

Introduction

The last decade has seen a surge of renewable capacity as the industry has experienced remarkable growth spurred by increasing environmental concerns and technological advancements. Global renewable capacity increased 12% in 2023, driven by solar PV and wind.

A recent International Renewable Energy Agency (IRENA) report showed that almost two-thirds of renewable power added in 2022 had lower costs than the cheapest coal-fired options in G20 countries, despite cost inflation.

However, despite the growth in capacity and generation, the sector continues to suffer from relatively low profits compared to traditional power generation, like coal or gas-fired plants.

Cost reductions, particularly in solar PV, and efficient engineering and supply chains are crucial for improving margins. Government policies, such as the U.S. Inflation Reduction Act, provide vital support, but regulatory challenges persist, especially in Europe.

Diversification, including renewable hydrogen and energy storage, offers new revenue streams. Additionally, addressing challenges like negative power prices through energy storage and grid modernization is essential.

Ultimately, most successful renewables players activate various strategies to enhance profitability, emphasizing the importance of operational excellence, policy support, well-executed financial discipline and innovation, particularly in the context of increasing negative power price periods due to over capacity.



Renewable energy: Growth and profitability trends

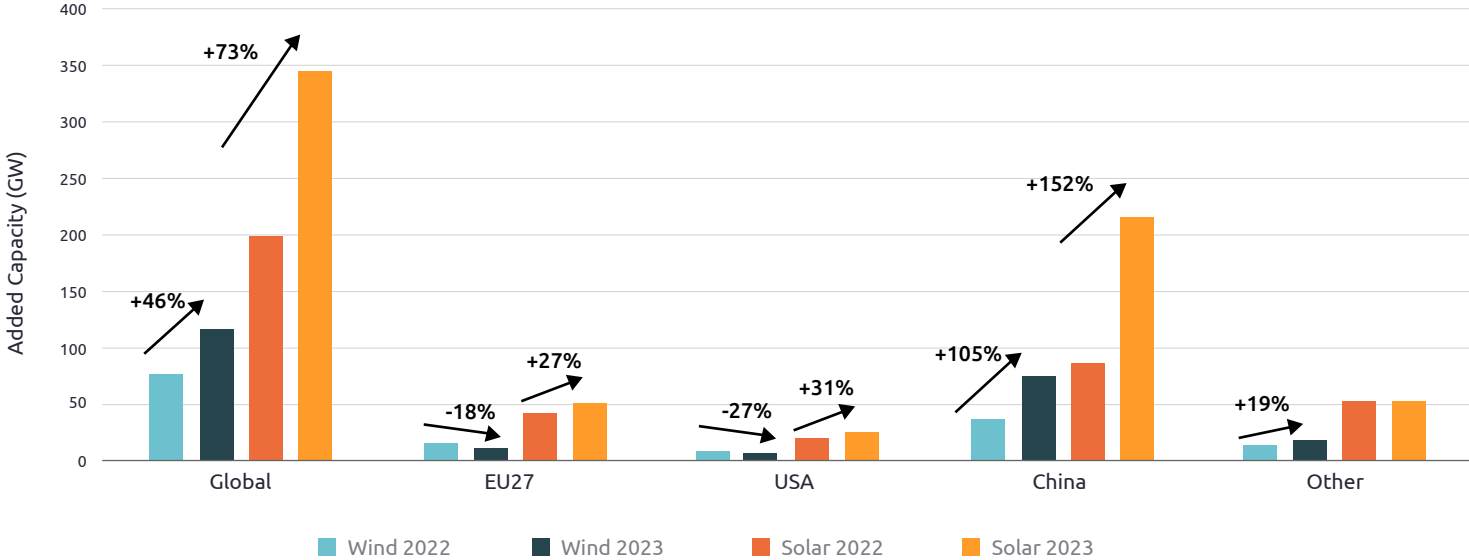
The renewables industry has seen remarkable growth in recent years. According to IRENA, in 2023, global renewable energy capacity increased by as much as 12%, hitting 3,372 gigawatts (GW). Solar PV and wind power were the two leading sources of growth, with 20% and 10% growth rates, respectively. In the first half of 2024, EU's wind and solar power even surpassed fossil fuels, reaching a share of 30% of electricity generation.

Global spending on renewables also hit a new record of \$735 billion in 2023, driven by solar PV and wind.

- North America: The USA saw a significant increase in utility-scale solar capacity, adding nearly 24 GW in 2023, driven by federal incentives and state-level mandates. However, wind capacity additions lagged, with only 8 GW added due to permitting delays and supply chain issues.
- Europe: The EU's REPowerEU plan aims to reduce dependence on Russian fossil fuels and accelerate the green transition. In 2023, Europe added 40 GW of renewable capacity, with a strong focus on offshore wind and solar PV. However, profitability remains a challenge due to high land and labor costs.
- Asia: As show in figure 1. China continues to lead in renewable energy capacity additions, with close to 300 GW added in 2023. The country benefits from lower production costs and economies of scale but faces challenges in grid integration and curtailment.

Despite this growth, renewables still have the lowest profit margins compared to other energy sector capacities. Coal, or oil and gas are more established industries than renewables and possess a level of profitability that renewables struggle to achieve.

FIGURE 1
Global added wind and solar capacity in 2022 and 2023



Source: Renewable Energy Capacity Statistics 2024 (IRENA)



However, while renewable companies in advanced economies saw improved profitability in 2023, lower prices for natural gas and deeper market penetration by low-cost renewables are starting to put pressure on wholesale electricity prices, creating uncertainties for their revenue streams.

In 2023, the weighted average net margins of renewable energy companies were significantly lower compared to large utilities and oil majors. For instance, according to the International Energy Agency (IEA), while oil majors reported net margins of around 10-15%, renewable energy companies averaged around 5-10%, as show on figure 2. This is why strategic steps must be taken to ensure the profitability of renewables.

Considering this gap between the internal rate of return (IRR) on oil and gas and on wind and solar, it's unsurprising that most of the oil & gas companies stick to their core business. While it's easier to invest in wind and solar, these companies have less of a competitive advantage in electricity markets, which are more volatile than oil markets.

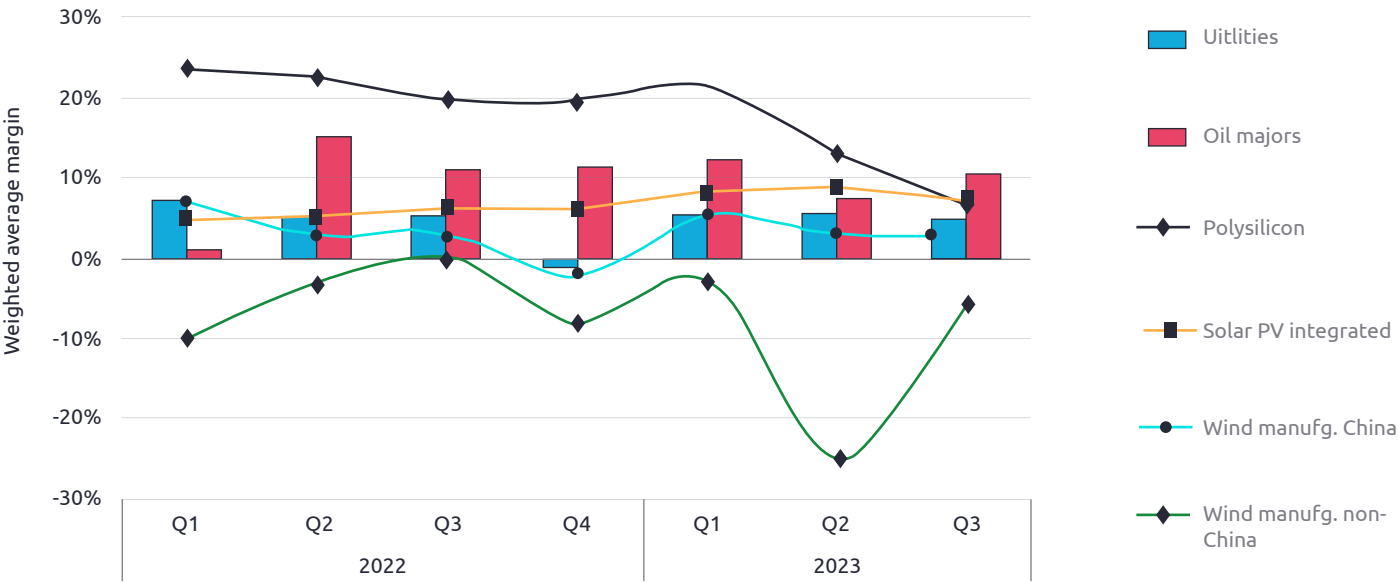
Renewables also rely on subsidies and tax credits. Even if these incentives are quickly decreasing in many parts of the world, they can make renewables look more attractive in the near term without creating a more volatile spot market for electricity. Corporate power-purchase agreements can offer more reliable revenue streams. But often very large-scale renewables projects will need to compete in more volatile power markets.

Support mechanisms is not a new phenomenon in energy systems: Fossil-fuel subsidies surged to a record \$7 trillion in 2022 according to the International Monetary Fund (IMF), the equivalent of 7.1% of the global gross domestic product.

Expecting renewables to achieve self-sufficiency without significant reforms in electricity markets is unrealistic. It's time to acknowledge that renewables won't reach a level of self-sufficiency that has never been demanded of coal, oil, and gas.

Nevertheless, the more mature renewable energy players are now looking to optimize their capital and operational expenditures and differentiate themselves through innovation, their goal being to increase profitability and reach levels of IRR way above 10%. They intend to do this while quickly growing their assets base.

FIGURE 2
Weighted average net margins of renewable energy companies, large utilities and oil & gas majors



Source: IEA, Renewables 2023



Boosting profitability across the renewable value chain

Increased market competition, coupled with reduced government support, rising capital costs, and inflation, is putting pressure on renewable returns. The days of 'invest and forget' in the renewable energy industry are over. Renewable executives are now looking for ways to operate more efficiently and find new revenue sources.

Historically, industry management has focused primarily on growth and investment, often overlooking cost control. The Levelized Cost of Energy (LCOE) has declined significantly in the last decade. Utility-scale solar fell from \$79 to as low as \$29 per MWh by June 2024, and onshore wind from \$74 to \$50 per MWh on average, according to Lazard's latest report. The main factors behind this decline are cheaper solar modules and wind turbines, larger turbine blades capturing more power, and improved operational practices (e.g., better planning and execution of maintenance).

In parallel, as renewable companies have expanded, their level of corporate complexity has grown exponentially. The increased number of assets, geographic spread, and diverse technology partnerships has made it more difficult to manage and track asset performance, as well as to make informed decisions and operate efficiently.

Additionally, companies are more exposed to merchant risk as the share of feed-in tariffs declines, and as cost pressures increase from reverse auctions.

Cost reduction strategies

To cope with the challenges of the new environment and drive their profitability, companies will need to focus on optimizing their activities to reduce costs at each phase of a renewable asset lifetime. This is especially true in early phases of a project, which represent 80-90% of the CAPEX and OPEX.

Improving efficiency during the origination and development phase

Project origination and development typically accounts for 40-45% of the total financial value creation, including costs for site selection, permitting, interconnection and securing financing. Developers constantly scramble to identify new sites with increasing speed. Standardizing their approach with the right toolbox for the team in charge of origination, improving the monitoring of their pipeline through commercial excellence programs, and increasing the efficiency of the development processes are some of the levers that can be activated.

Industrializing engineering and leveraging technology and digitization in renewable energy system design

Engineering and construction (E&C) represents about 40-45% of the value creation. It involves the design of the renewable energy system and its actual building and installation.

In engineering, for instance, operators will need to optimize plant design to maximize wind yield and minimize costs. Advanced analytics solutions can, for instance, help them optimize wind farm design to increase the energy yield.

Optimizing equipment choices is also important, as equipment typically accounts for over half of the CAPEX in new renewable projects, with costs rising as projects scale. Technological advancements, especially in major machinery like larger turbines, cheaper solar modules, and better software, have contributed to lowering LCOE. Taking advantage of the most advanced technology with optimized set up can also be a source of improved CAPEX efficiency.

More experienced companies are leveraging industrialized engineering to expand and standardize their wind and solar engineering capabilities globally. By establishing their own engineering centers, or outsourcing to engineering partners in low-cost regions, they can benefit from cost optimization, predictability, and access to a specialized pool of engineers who can work according to their standards and processes.

Efficient management of construction costs and timelines

Construction delays and cost overruns can negatively impact returns, with a negative cost deviation of 5-10%, potentially erasing a developer fee. Efficiency during the execution phase is, therefore, critical. Better contracting strategies (e.g., massifying procurement, optimizing EPC prices), combined with improved work planning and construction readiness (e.g., harmonizing KPIs for EPC performance, standardizing construction organization, enforcing use of standard project control tools, improving claims management) can reduce cost uncertainty.



Excellence in industrialization, operations and digitalization

The Operation & Maintenance (O&M) stage typically accounts for 15-20% of the value creation. This includes maintenance and operational management. Effective O&M practices can reduce downtime and maintenance costs, thereby improving IRR. Predictive maintenance and advanced monitoring systems can also enhance operational efficiency.

Ramping up from several to hundreds of GW portfolios requires both intense M&A and integration activities, and fast-paced operation scaling. Consequently, renewable players generally end up with unoptimized organizations and colorful landscapes of business processes and IT/OT urbanizations. To restore profitability and operational cost-efficiency, the renewable industry must undergo a deep transformation. This includes adopting industrialization strategies, excelling in operations, rationalizing the IT portfolio, and implementing data-driven architecture and business processes.

Unlocking operational agility and scalability

Determining the most scalable target operating model begins with a thorough core/context analysis, pinpointing key differentiating activities and margin generators, along with the best candidates for outsourcing. Effective industrialization relies on a clear strategic intent, trust in the partner ecosystem handling outsourced tasks and the seamless efficiency of continuous processes, ultimately creating an extended enterprise.

Achieving operational excellence

Developing a best-in-class and granular asset operations program and ensuring the deployment of the improvement levers at scale supports profitability. Clear and standardized business processes reduce operational hurdles, improve collaboration and reduce contingency costs in execution, and increase asset profitability in operation. This will also enable a focus on assets that generate the most value and/or have the greatest potential for improvement.

Additionally, building an asset performance monitoring solution can facilitate continuous improvement by sharing common tools and key performance indicators. This can help set target operating expenses for different types of plants.

Optimizing O&M contracts

Establishing appropriate KPIs and optimal service-level agreements (SLAs), benchmarked against similar sites and leading O&M providers, is essential to ensure performance and asset availability. Asset availability KPIs are considered more accurate than production level KPIs to evaluate O&M services.

Implementing a bonus/penalty mechanism in contracts incentivizes partners to meet or exceed performance goals, particularly in downtime avoidance. Penalties are typically capped at the contract's annual value, while bonuses can reach up to 50% of the contract value for surpassing SLA targets.

Performing regular audits and benchmarks of assets and O&M providers are crucial. This includes evaluations of service catalogs, SLAs, innovation, technology and competencies. Extending these audits to equipment and spare parts providers is essential due to the impact of their quality on operations.

Securing long-term maintenance contracts could lead to cost savings through economies of scale and by maintaining high-quality standards. This is because service providers typically offer discounted rates for guaranteed long-term commitments.

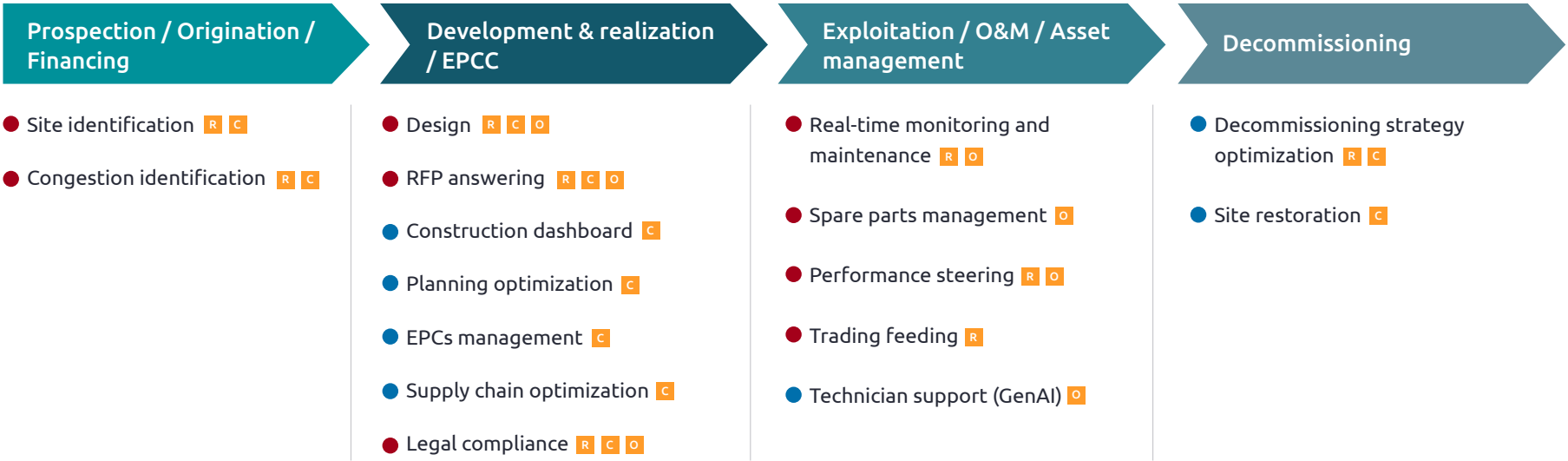
Innovation & digitization

Streamlining IT/OT landscape via post-merger integration and strict tooling guidelines while expanding portfolios, is key to enhancing and sustaining profitability. Adopting new technologies and data-driven asset management processes (e.g. performance forecasting, maintenance optimization and weather management) boost performance and reduces asset TCO. These advancements ensure business processes evolve, maximizing the value of technology integration.

Figure 3 illustrates how the widespread availability of internal and external data and use friendliness, drive innovation across the renewable energy value chain. Organizations now focus on unified architecture, database and advanced analytics to enhance asset intelligence. Top asset managers use comprehensive datasets to create smart dashboards for CxOs, utilizing GenAI for real-time resource and investments decisions.



FIGURE 3
List of data-driven Use-cases along the renewable value chain



- Transversal
- Portfolio vision R C O
 - Financial vision R C O
 - Digital twin R C O
 - Stakeholders mgt L
 - Sustainability L B
 - Workforce safety L B

Legend

Priority P1 P2

Impact

- R Revenue
- C CAPEX
- O OPEX
- B Brand image
- L License to operate



Better financing

Since renewable projects are capital-intensive, access to low-cost financing and favorable terms can enhance IRR.

To improve financing renewable power assets, it's essential to define a financing strategy tailored to the project's context – location, technology, regulatory environment, and risk profile. Early access to non-recourse financing, which relies on project assets rather than the developer's balance sheet, can significantly enhance financial stability and attract investors without over-leveraging the company.

Exploring new financing schemes, such as green bonds, public-private partnerships, or crowdfunding, can create innovative funding opportunities. Diversifying funding sources reduces reliance on traditional lenders and boosts financial flexibility.

Additionally, industrializing the financing process and optimizing modeling streamlines operations and can improve accuracy. Developing robust templates, checklists, and replicable procedures, can significantly reduce time, costs, and complexity from project conception to financial close, which is particularly beneficial when scaling portfolios of projects.

A best-in-class organization is required to support the financing process effectively. Invest in top-tier tools and skilled personnel to ensure models are robust, transparent, and adaptable.

Adjusted ownership strategies

Using farm-down as sources of funding

In the dynamic renewable energy sector, companies must adopt adjusted ownership strategies to remain competitive and maximize long-term portfolio value. This involves capital recycling, structured products, and active asset management throughout their lifecycles.

Using non-conventional funding sources, such as farm-downs, divestment of non-core assets, and hybrid capital, can provide additional financial flexibility. The farm-down or "Build-Sell-Operate" (BSO) model allows developers to sell stakes in their renewable assets at various development stages to institutional investors seeking long-term, stable yields.

By selling a portion of their mature assets, companies can de-risk their investments, secure immediate capital, and still benefit from future returns. BSO is less capital intensive due to debt deconsolidation, sell-down margin, and limited equity injection. An example is TotalEnergies Renewables' \$689 million deal in 2023 for a 25.5% equity stake in the Seagreen offshore wind farm. Several players like Orsted, Engie, EDPR or Nextera also have implemented farm-down strategies.

Regularly evaluating the portfolio to identify assets suitable for divestment helps optimize the asset mix and maintain a high-performing portfolio.

This approach can be industrialized by implementing standardized procedures for executing farm-down deals, including thorough due diligence, accurate asset valuation, and strategic partner selection to ensure favorable terms and successful transactions.

Diversification and innovation

Two key ways to boost profitability are diversifying revenue streams and innovating to maximize the value of renewable electrons

Renewable hydrogen, biofuels, and energy storage are providing new markets and revenue streams. For example, as demand for clean hydrogen increases, this could become a significant source of revenue.

Renewable energy can be made more profitable by combining its output with other sectors, using synergies to stimulate growth and create partnerships with other industries. For example, partnerships with electric vehicle charging operators can lead to increased demand for renewable energy, boosting revenues for renewable players.

Diversification and new revenue stacking will mainly be enabled by the accelerated deployment of large-scale battery energy storage systems (BESS), as battery prices reduce. BESS will play a crucial role in building a new paradigm: while current electricity markets assume electricity cannot be stored, the introduction of a flexible generation asset will offer developers opportunities to generate new revenue from renewable generation, such as arbitrage trading on the wholesale market, capacity payments, and monetized ancillary services.

Therefore, the development and integration of BESS is crucial for diversifying renewable revenue streams. Rapid advancements in battery management technology are essential to ensuring the long-term reliability of storage assets and their seamless integration into grid infrastructure and trading ecosystem.



Leveraging government policies and regulatory support

Renewable players can leverage government support and regulatory frameworks to enhance their financial performance

In the USA, the Inflation Reduction Act has been instrumental in supporting renewable energy projects through substantial subsidies, tax credits, and grants. For instance, the act provides a 30% tax credit for solar and wind projects, significantly improving their economics. Streamlining permitting processes can also cut project timelines up to 50%, enabling quicker deployment and faster returns on investment.

In Europe, the European Union's Green Deal and REPowerEU plan offer robust policy support for renewable energy. However, regulatory complexity and permitting delays remain significant challenges that can hinder project timelines and profitability.

In the UK, recent energy policies have introduced new incentives and support mechanisms to boost renewable energy investments, although specific details are pending.

In Asia, China has implemented aggressive policies to support renewable energy, including subsidies and favorable tariffs. Despite these efforts, regulatory uncertainty and grid integration issues continue to pose challenges.

These geographical contrasts highlight the varying levels of policy support and regulatory environments that impact the profitability and development of renewable energy projects worldwide.

Addressing negative power prices

The growing phenomenon of negative power prices from renewable energy overproduction poses a serious profitability challenge. In regions like southern Australia and southern California, wholesale electricity prices have been negative for about 20% of the time since last year. Similarly, Europe's key economies saw record hours of zero or negative prices in early 2024 at times of low demand.

Producers must more frequently pay to offload power or stop their plants when supply of electricity exceeds demand, leading to price drops. Prolonged negative prices could threaten new and existing renewable energy projects due to curtailment risks.

To address this issue, several strategies can be implemented:

1. **Curtailment:** Intentional reduction of generation when prices are too low or negative can safeguard profitability. In 2023, Britain's wind farms curtailed 5% of output, losing 4.3 TWh, costing £300 million in constraint payments.
2. **Energy storage solutions:** Investing in batteries to store excess energy stabilizes prices and improves profitability. According to the IEA, without storage or other flexibility sources, developers "may see a drop in potential revenues during peak generation – hampering profits and discouraging investment."
3. **Demand response programs:** Incentivizing consumers to shift energy usage to off-peak times balances supply and demand, reducing negative prices. European countries are particularly focused on these programs.

4. **Grid modernization:** Upgrading grid infrastructure to better integrate renewable energy sources and manage fluctuations enhances grid stability and reduces negative pricing events. The USA and European countries are investing heavily in grid modernization efforts.





Our Convictions

- Get granular by drilling down in the OPEX and CAPEX structure to identify optimization levers. A detailed analysis in origination and development activities, engineering and construction costs and asset operations can reveal cost and efficiency opportunities.
- Standardize business processes and deploy top-tier asset management practices to streamline onboarding of new team members and partners, while also enabling continuous benchmarking of assets, especially as it relates to those generating the most value.
- Adopt scalable and flexible operating models to excel across the value chain, whether in-house or outsourced. Companies need clear make-or-buy decisions, a defined role for OEMs (especially for O&M activities) and lean site operations.
- Embrace digital solutions to boost efficiency and enable data-driven decisions. These tools are crucial for staying competitive throughout the asset life cycle—from site identification to project execution, predictive maintenance, and revenue analysis.
- Improve project financing by streamlining the process with skilled personnel and tools; adjust ownership strategies to generate additional revenues and maximize the asset portfolio value.
- Continuously innovate and diversify. This will be essential to optimizing profitability.



02

The *Realistic* case for Gen AI





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Philippe leads the AI and Data Engineering practice as well the Capgemini Invent Research and Innovation Lab. Before joining Capgemini, he has worked for major multi-energies companies for more than 15 years.

The Realistic Case for Generative AI

- 1. Generative AI technology is mind blowing but not limitless, despite its rapid progress.
- 2. Even though building demonstrators is easy, scaling is hard. It requires quality data, integration with core IT, high levels of performance and change management.
- 3. High-value use cases are relatively few in number and require more than just a multi-agent based, multimodal large language model (LLM) to unlock value.
- 4. Gen AI can create tremendous value in the energy field, especially as it relates to energy transition.

Introduction

Even though Gen AI gained widespread public attention with the release of ChatGPT in 2022, its origins date back to the 1950s and extend far beyond language models in all their variations. It truly began to take off in the mid-2010s with the development of GANs, the first technology used to create deepfakes.

In 2023, there has been a bit of science fiction around the potential of the technology, be it in terms of impact on the global economy or the job market. After a year of frantic exploration, companies realized that scaling Gen AI is hard. It's time for for them to reset their approach with respect to Gen AI and remember the hard lessons learned from digital and AI transformation: steer by value; upskill people; set up the technology architecture; ensure data quality; and commit to the ethical and responsible development and use of Gen AI.

Moreover, the transformation brought by Gen AI should not be considered in isolation but alongside broader AI transformation efforts, with a strong emphasis on change management. Only by integrating these elements can the full value potential be realized, enabling deep process re-engineering and enhancing organizational efficiency.

In the energy industry, particularly in the context of the energy transition, Gen AI has a crucial role to play. It can act as a catalyst for discovery of e-fuels, contribute to the design of new batteries or wind turbines, advance synthetic biology, and provide augmented insights from multiple data sources to support better-informed decision-making.



What we are seeing

After a year of Gen AI potential exploration, most companies are taking a step back to take stock and determine which direction to move forward.

Companies are starting to realize that there may have been over-promises on the value creation potential of this technology and that scaling is much harder than planned. Scaling requires deep integration with core IT and existing tools, access to large knowledge and data corpuses of high quality (which quality is generally not high), numerous iterations to optimize the system prompt to minimize wrong or not relevant answers.

High-value uses cases need complex process re-engineering, coupling AI and Gen AI in agentic LLM workflows.





New catalysts discovery for e-fuel

About e-fuels

E-fuels are synthetic fuels made of carbon dioxide (or monoxide) and hydrogen, produced with decarbonized energy. They are alternative solutions, fungible in the energy system, to decarbonize sectors without alternatives, like long-range aviation. They are part of the toolbox to achieve short-, medium-, and long-term climate objectives.

As new electrical energy vectors, e-fuels enable indirect electrification, particularly as it relates to the hardest-to-decarbonize sectors, such as heavy mobility (aviation and maritime fuels) and the chemical industry (transformation reagents). Additionally, they facilitate the recycling of unavoidable CO₂ emissions, like those from the cement industry.

However, those fuels are very expensive to produce, costing up to 100 times more than conventional petroleum¹. To decrease those costs, a number of levers can be activated, especially:

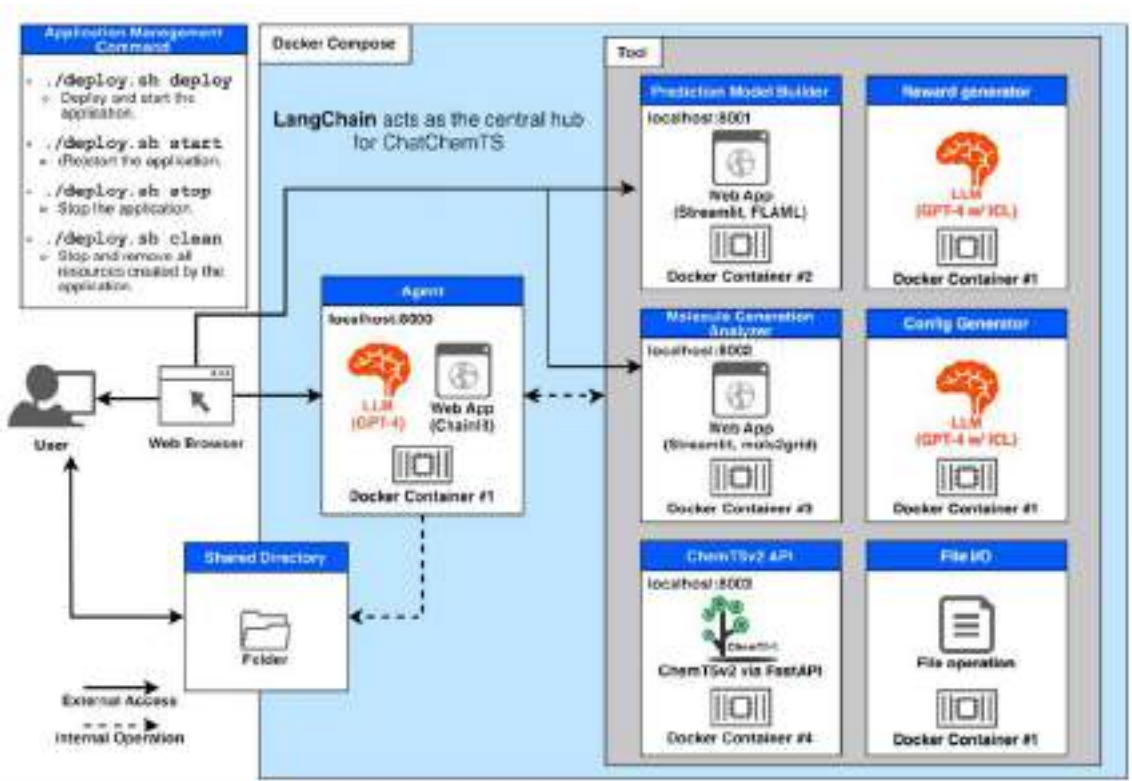
- the decarbonized electricity cost used to capture CO₂ and produce hydrogen
- the catalyst efficiency for the CO₂ to syngas reaction or for the Fischer-Tropsch reaction

One can leverage multi-agent LLM to orchestrate several highly specialized agents. one generates new formula, a second one predicts the desired properties for the application, in the case of catalysts, stability and activation energy) of the generated molecule. Finally, one can leverage the planning and reasoning ability of the Large Language Model to analyze the results and propose a new molecule.

Each reasoning step is performed until the LLM reaches an optimal point. It must be noted that experiments will still be required from time to time to constrain the prediction model and ground the LLM with real-world data. With such an approach, new catalysts may be suggested to the chemists in a few minutes, a limiting step in real-world experiments.

How Gen AI can be leveraged to accelerate e-fuels development?

Designing better catalysts is critical to lowering the global energy bill required to produce e-fuel and thus its production costs.



¹ https://www.pik-potsdam.de/members/Ueckerdt/E-Fuels_Stand-und-Projektionen_PIK-Potsdam.pdf

Source: <https://chemrxiv.org/engage/api-gateway/chemrxiv/assets/orp/resource/item/66220456418a5379b0297f8d/original/large-language-models-open-new-way-of-ai-assisted-molecule-design-for-chemists.pdf>



New batteries

About batteries

Batteries are an essential part of our energy transition journey. Obviously in EVs, they play a key role of decarbonizing lightweight vehicles. Moreover, battery energy storage systems (BESS) and large gigabatteries play a crucial role in ensuring electric grid stability as renewable energy sources and electric vehicle adoption rates increase. Indeed, due to the inherent intermittency of renewable electricity production and the growing use of charging stations, there may be significant stress on the electric grid. In such cases, large gigabatteries play a crucial role as buffers, stabilizing the grid until other measures can be activated to meet the demand.

For those batteries to be as efficient as possible, one must increase their energy density as well their power density. The first one is to increase the quantity of energy in the battery, while the second one is to increase the speed of charge/discharge.

How can Gen AI help in designing better batteries?²

As for e-fuels, Gen AI can be used to discover electrolytes with better properties to increase energy density. It can also be used to discover new binders that play a key role in dispersing the active material in the slurry and its adhesion to the current collectors to improve ionic and electrical conductivity.

To improve power density, one should play on the 3D porous network design optimization of the battery. In this step, we will rely on generative design approaches, where the engineers will specify the objectives and requirements of the final products, including manufacturing constraints.

² <https://interestingengineering.com/energy/lq-energy-solution-ai-battery-designing>

Bio-engineered fuels through synthetic biology

About synthetic biology

Synthetic biology is an interdisciplinary field between biology, engineering, and computer science to design and build new biological systems or to re-design existing ones for new purposes. It involves the modification of organisms' genetic material to create novel functions that do not exist in nature. By applying engineering principles to biology, synthetic biology aims to make biological processes more predictable, scalable, and efficient. The field holds potential for innovations in healthcare, agriculture, environmental sustainability, and industrial manufacturing. It also raises ethical and safety considerations due to the power of reprogramming living organisms.

How Gen AI can be leveraged to accelerate new bio-engineered fuels ?

Traditional biofuels, such as ethanol from corn or biodiesel from vegetable oils, have limitations in efficiency, scalability, and environmental impact. Synthetic biology addresses these challenges by designing organisms that can convert a wider range of feedstocks, including non-food biomass, waste materials, and even carbon dioxide, into fuels.

One of the key advancements is the engineering of microbes to produce advanced biofuels like butanol, isobutanol, and fatty acid-derived fuels, which are more energy-dense and compatible with existing fuel infrastructures.

Synthetic biology enables precise control over metabolic pathways within these organisms, optimizing the conversion of sugars, cellulose, or other feedstocks into desired fuel molecules.

For example, engineered strains of E. coli or yeast can be designed to break down lignocellulosic biomass (plant material) into simpler sugars and then convert these sugars into biofuels. Additionally, synthetic biology can be used to create organisms that fix carbon dioxide and convert it directly into fuels or even convert directly feedstocks into hydrogen, offering lower carbon footprint alternatives.

Moreover, synthetic biology facilitates the rapid development and testing of new fuel-producing pathways through techniques like DNA synthesis, CRISPR-based genome editing, and metabolic modeling. This accelerates the discovery of efficient fuel production methods, reducing costs and increasing scalability.

Overall, synthetic biology's ability to engineer organisms for specific biofuel production processes holds the potential to revolutionize the energy industry by providing sustainable, renewable, and environmentally friendly alternatives to fossil fuels, contributing to energy security and the reduction of greenhouse gas emissions.



Our Convictions

- Generative AI technology, when coupled with AI, has the power to accelerate technology discovery for energy transition.
- As examples, those technologies can be used to
 - Discover new catalysts to convert CO₂ into fuels
 - Accelerate battery design to the 1-day scale
 - Design new living organisms that generate biofuels or biohydrogen with lower carbon footprints and much more robust processes
- However, one should not forget that those technologies are still generating substantial amount of wrong or irrelevant answers.
- Humans must verify through real world experiments that the designed molecules or systems do have the properties predicted by the agentic LLM workflow. If not, additional training phases, with reinforcement learning by example, will be required to improve the performance of the system.



03

The Business Case
for *batteries* needs
to be clearer





Pete King

Global Energy and
Utilities Leader
Vice President
Capgemini Invent



Pete King leads the Global Energy and Utilities sector for Capgemini Invent. He focuses on new business models, transformational programs and developing digital platforms for clients across Europe, APAC and North America.



**Isobel Sheldon
Obe**

Founder and Principal
Consultant
Oakpolytech



Isobel Sheldon OBE has been a leading figure in advancing battery technology to support the decarbonization of energy and transportation for over 22 years. She offers industry insights and consultancy services to companies aiming to leverage opportunities in the global energy transition.

**How to make money from
a battery**

- 1. There is money to be made in batteries, but market conditions need to be right for this to happen.
- 2. In the regions such as North America, Europe and Australia, making money in EV batteries will depend on the extent to which governments consider this a strategic industry and protect companies from fierce Chinese competition.
- 3. Making money by attaching batteries to the electricity grid is also possible but relies on regulators establishing the right market conditions and taking a long-term commitment to maintaining them. Stationary grid battery technology will follow where automotive manufacturers lead.
- 4. It's clear that we can't hit net zero without batteries, so work is needed to make them an attractive investment.

Introduction

There should be many ways to make money from a battery: sell it to a motor manufacturer; attach it to the grid and export electricity for more than it costs; sell it to homeowners to go with their solar panels; put it next to a windfarm to avoid curtailment issues when the network cannot cope.

Yet, around the world, many are struggling to make money, and plans are being re-evaluated. Having batteries in the energy system helps us to decarbonize carbon-intensive use cases, like transport and home heating. They also make renewable energy more predictable and usable.

Despite a brief increase in 2022, battery costs have been falling consistently for a decade and are now at 20% of their cost from a decade ago. The business case should be accelerating. There are cases of money being made from batteries which provide clues of how good returns can be made. Tesla has six gigafactories and its automotive business is making money. Texas is planning to install over 6 GW of capacity this year and the Hornsdale 100 MW Big Battery in South Australia has been operating at good margins.

The role of China cannot be ignored as, China currently accounts for about half of global production, with plans to increase this share to three-quarters by 2030. With one player so dominant, questions need to be asked about what other countries and businesses should do to respond.

However, governments and regulators are not uniformly creating the environments required for batteries to thrive.



The vertically-integrated EV battery manufacturer

The battery value chain encompasses a wide range of roles, from design and manufacturing to ownership, operation, and end-of-life management.

The model of the vertically-integrated automotive manufacturer, where the same company produces both the car and owns the manufacturing part of the value chain for the battery, is beginning to dominate.

Key reasons include the critical nature of battery manufacturing to the future of automotive players. They cannot rely on global supply chains for such a critical component and need to develop battery technologies that match the brand promise and expectations of buyers. Porsche buyers have different expectations than Toyota buyers, after all.

This results in limited standardization in batteries. Operating characteristics and form factors will also be manufacturer specific.

FIGURE 1
Share of battery capacity of electric vehicle sales by Chemistry and Region, 2021-2023





Building a better battery

Huge resources are currently devoted to designing better batteries. The rewards for finding batteries with longer lives, greater energy density, and cheaper production costs are huge.

LFP is the technology currently used by Tesla and BYD accounting for over 30% of EV usage. The LMFP battery seeks to improve LFP energy density and usable cycle performance by introducing manganese. Both LFP and LMFP rely on a liquid electrolyte between the cathode and diode, replacing this with a solid electrolyte promised further increases in performance and reductions in cost.

Proving new battery developments will take time and battery adoption is likely to rely on existing technologies for many years.

Battery development and industrialization programs have primarily focused on the next big leap in energy density and chemistry or solid-state technology. However, they have also overlooked the need to achieve better price points for existing materials and techniques.

Limited development capital has been deployed in achieving improved processes and pricing for finished active materials. This has led to a slowdown in European and American efforts to enhance process efficiency and supply chain development for existing proven materials, which are often sufficient for most applications, such as low-cost LFP in affordable EVs and stationary energy storage.

There has been hope that a re-established technology lead will counter China’s dominance of the battery industry. However, new battery developments historically take near-decade timescales to reach volume industrialization. Many of the newer technologies may not deliver the cost benefits hoped for in the next decade. In the meantime, Chinese dominance continues unbridled.





Stationary grid scale batteries

Buy low, sell high is normally a certain way to make money—especially in an electricity system with very predictable price swings across a day. This looks very low risk, so why aren't battery owners printing money?

The battery is a very expensive asset and, by comparison, the electricity it stores is very cheap. A 1 kWh battery might cost \$200, but the electricity that it stores could be worth as little as \$.30.

The spread of cost between cheap and expensive electricity might be \$.25, meaning that the battery needs to cycle 800 times before it breaks even. The price of electricity typically cycles across the day, so it would take 800 days to break even.

800 cycles is close to the design life of some forms of batteries, which means no returns. A battery that can handle 3,000 cycles is possible, resulting in positive returns after its eight-year life. If the life can be extended for a further four years, the last years are very profitable. But this is a long time to wait for returns.

An alternative model for grid operators is to build a big cheap battery and only discharge it when the conditions are right and prices very high. These batteries may only cycle a few times, but when they do, they earn large sums. Relying on automotive manufacturers for battery supply creates issues for stationary grid batteries. A lack of standardization means grid operators cannot assume that all installations will behave the same. A previous assumption that end-of-life batteries from the automotive industry could be used for grids and homes is also looking unsafe, as the calendar life of batteries is an increasing concern. A potential outcome is that stationary grid batteries will be built on production lines that are obsolete for automotive manufacturers. The higher volumes required by the automotive industry drive faster development of production assets

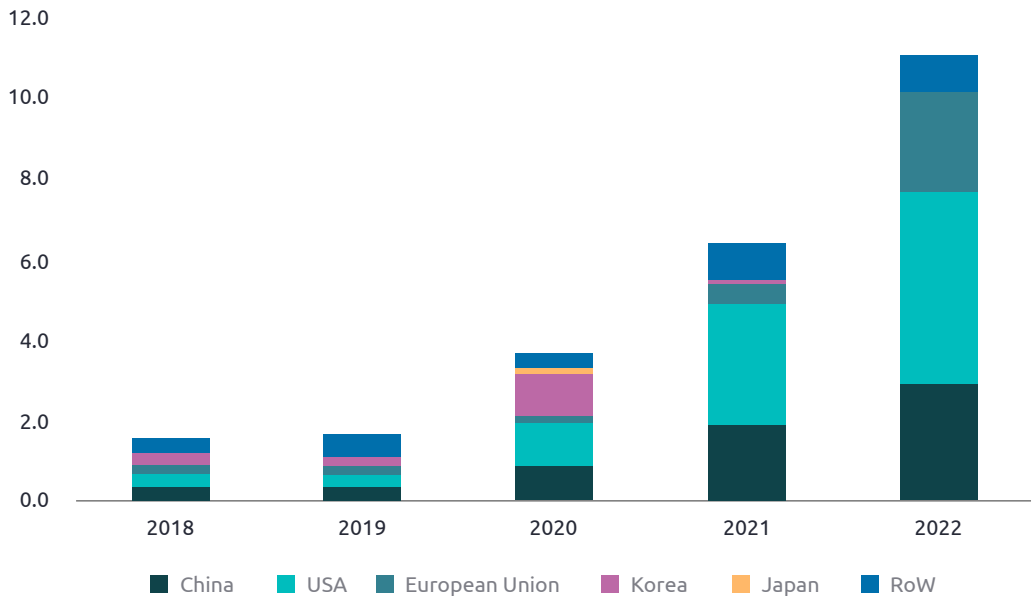
and reduce price points quickly, so adjacent industries can capitalize on the benefits of an automotive-first approach. This is also been seen as cost efficient for both R&D and equipment CAPEX.

Oil & Gas companies are seasoned investors in long-term assets, but they are used to faster and greater returns than grid scale batteries can offer.

Utility companies view assets in the long term and may have investors willing to wait longer if the risk is also low. A condition is that they must trust governments and regulators to provide stable market conditions over this longer term. This will depend on consistent and clear long-term government policy driven from well researched governmental initiatives.

FIGURE 2
Annual grid-scale battery storage additions, 2019-2022

All Figures in GW



Source: IEA

Box – economics of grid batteries

Cost = \$200 per kWh, elect in = \$0.05, elec out = \$0.30, spread = \$0.25. 200 / 0.25 = 800 cycles to break even.

365 days per year = 2 ¼ years to break even.

If life of battery is 3,000 cycles then life is 8 ¼ years. 3,000 cycles x \$0.25 = \$750 returns, = \$550 profit over 8 years.

If life extended to 12 years then returns = \$1,095.



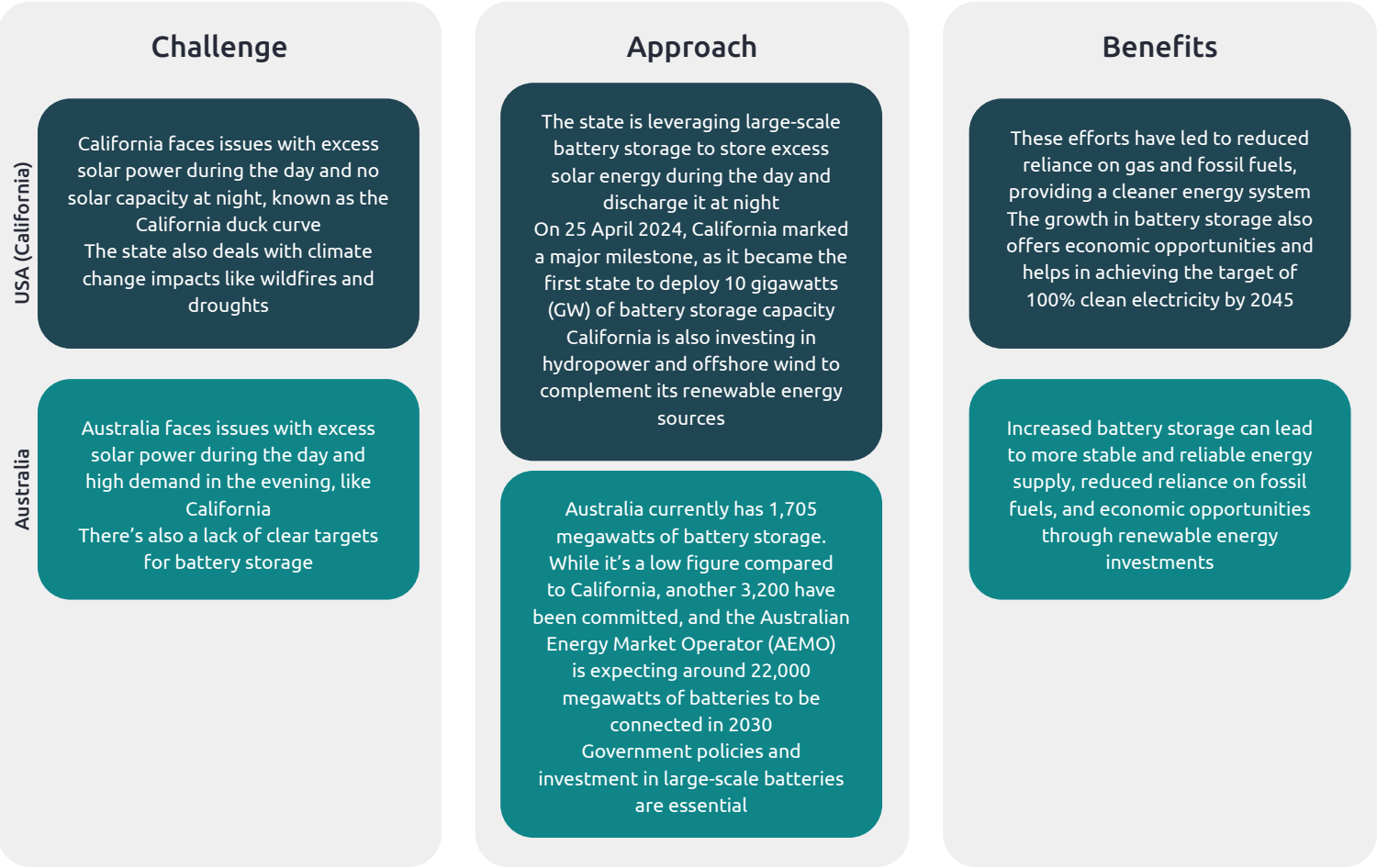
Renewables need batteries

Experience in California and Australia is highlighting the need to couple renewables with batteries to create an effective energy system. Many existing electricity systems fill the gaps between total demand and renewable production with dispatchable fossil fuels generation (often Combined Cycle Gas Turbine CCGT). Capturing the carbon from this generation is a possible way to run a renewables-dominated system, although this has not been proven at any scale. Batteries are good candidates to fill this gap.

Regulators have not made great progress in linking the roll out of renewables with batteries. Many schemes, such as the UK's CfD auctions, have encouraged renewable deployment, but they have not been matched with similar schemes for batteries.

There are further issues with the way metering works, with the UK serving as a clear example. The point that is metered is very important to the interaction between renewables and batteries. If they are separately metered, then some of the opportunity to collocate and increase returns is lost as it relies on both network capacity and interoperability of market schemes for renewables and batteries.

FIGURE 3
USA (California) and Australia Case Studies





Market regulation for batteries

Many opportunities exist to make markets more battery friendly.

Capacity markets exist to support security of supply through payments for having capacity connected to the grid that can be called upon when needed.

In the UK’s most recent capacity market auction, 67% of the contracts by capacity were awarded to gas producers. The 112 successful battery sites accounted for just over 2% of capacity, though many of these sites have not yet been built.

Various forms of locational pricing have been adopted in some networks. This gives different prices for electricity at different points on the network, rather than a uniform whole network price. In Texas, which has prices at each network node, revenues to battery owners have roughly doubled in the past two years. These revenues are now twice those expected from batteries in other states.

Further opportunities exist for batteries to provide services to support the operations of the grid. Imagine what happens if a major generator like a nuclear power station suddenly goes offline. Batteries can respond in less than a second, whereas spinning up a gas-fired station might take minutes. Grid operators are increasingly willing to pay for these services.

Steps towards market reform are needed in all countries to accelerate the pace of battery deployment. To enable this, a commitment to providing regulatory stability is required to ensure that investments are unlocked.

Money can be made, but it depends on market structures

Regulatory and market conditions need to be optimised for money to be made in batteries.

Grid connected batteries can make money, but in many markets limited locational price signals, immature ancillary services markets, and structural metering issues are hindering this. A long-term stability of market structures is required to attract investment, which seeks certainty of returns over many years. .

Governments need to consider batteries as a strategic industry and take steps to protect companies from fierce Chinese competition,

Stationary grid battery technology will take the price advantage of following where automotive manufacturers have led and already invested.

It’s clear that we can’t hit net zero without batteries, so work is needed to make them an attractive investment.

The turnaround time for changes in regulation are far slower than the ability to create and adopt newer technologies.

The UK exemplifies a situation where battery energy storage technology has been available for some time, but deployment has been significantly delayed due to challenges in adapting market structures to make the installation and operation of stationary storage systems financially viable.

Grid connections are facing years-long approval delays, with massive backlogs of projects and limited prospects for improved business model economics. This situation hampers the ability to deliver the grid stability needed during the transition to intermittent renewables as part of decarbonization efforts, as well as the connection of infrastructure like public charging facilities to support electric vehicle adoption.

The 8-hour battery

This is simply a battery that can supply its location for eight hours. Today most batteries have durations up to four hours. Extending this to 8 hours brings significant advantages in grid stability and compensates for the peaks and troughs of renewables production.

Key operating characteristics of batteries are its total storage capacity in MWh and its peak power production in MW. The duration of the battery is the capacity divided by the production.

$$\frac{3,000 \text{ MWh Capacity}}{750 \text{ MW Production}} = 4 \text{ hour duration}$$

$$\frac{6,000 \text{ MWh Capacity}}{750 \text{ MW Production}} = 8 \text{ hour duration}$$

04

Which *net zero*
Pathway are we
on?





Elfije Lemaitre
Head of Resources & Energy Transition,
Capgemini Americas



Elfije leads our Americas business for Resources & Energy Transition. Her career has been focused in the energy and utilities space, with a specialization in helping companies create and execute transformation strategies.

Are we on the right pathway to net zero emissions by 2050?

- 1. No matter which scenario you look at, achieving 0% fossil fuels usage by 2050 is unachievable.
- 2. We’re not just addressing the energy demands of today, but the increase in demand associated with the growing global population and improving prosperity of developing nations.
- 3. We are making progress with the energy transition, but are not on track with the growth of green energy sources and need to look at additional mitigation and adaptation options.

Introduction

By now, we all know the crucial importance of achieving net zero emissions globally. Our carbon budget is running out rapidly, with 2050 commonly referred to as a “due date”. Agencies around the world are scrambling to generate scenarios of how we will get there. The reality is that the challenge is far greater than most people realize.

The global population will keep growing and nations will continue to move up the prosperity line – both of which will generate increases in energy demand. A path to net zero requires accommodating demand growth while constantly finding new and better ways to decarbonize our economy.

While we made strong progress over the past decade, the reality is that we are far from being on track for the 2050 net zero goal. We must dramatically increase the rate and pace of growth for carbon-free energy sources, but that alone will remain only part of the equation. In every realistic scenario, fossil fuels, such as oil and natural gas, will also continue to play an essential role in our global energy ecosystem. We need to increase our focus on how to mitigate their impacts, not just with scalable carbon reduction technologies, but with policy and behavior changes as well.



What we are seeing

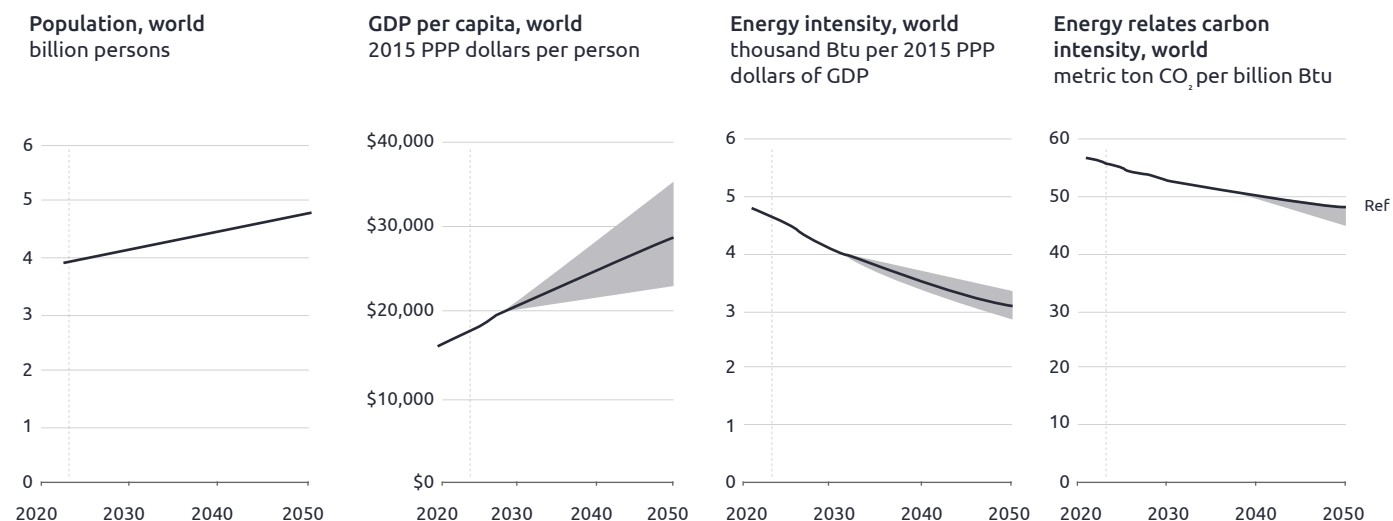
By 2050, the world's population will grow to nearly 10 billion and the average GDP per capita will increase nearly 150%.

The result will be a net increase in energy demand, even with partial efficiency offsets. This compounds the challenges we face with reducing global emissions.

Key data

FIGURE 1

The upward pressures of population and GDP growth outweigh the downward pressures of energy and carbon intensity on emissions



Data Source: U.S. energy information administration, international energy outlook 2023 (IEO2023)

Note: Shaded regions represent maximum and minimum values for each projection year across the IEO2023 reference case and side cases.

Our global population assumptions do not vary across side cases. GDP=gross domestic product; PPP=purchasing power parity; Btu=British thermal units; Ref=Reference case.

Source: <https://www.eia.gov/outlooks/ieo/>



There are no realistic scenarios for achieving 100% carbon-free energy by 2050

Scenarios for minimizing climate impacts

You've heard about 1.5- and 2-degree scenarios, which provide targets to achieve by 2050 to prevent (or delay) some of the more catastrophic consequences of climate change. You may have even heard about the IEA's NZE (net zero emissions) scenario, which lays out one example of what the energy mix would need to transition to in the next 26 years.

Each scenario is comprised of thousands of assumptions, from advances in technology to changes in regulation.

The IEA NZE scenario is viewed as a goal post, but scientists and economists around the world comment that it is highly unrealistic, as demonstrated in the following two pages.

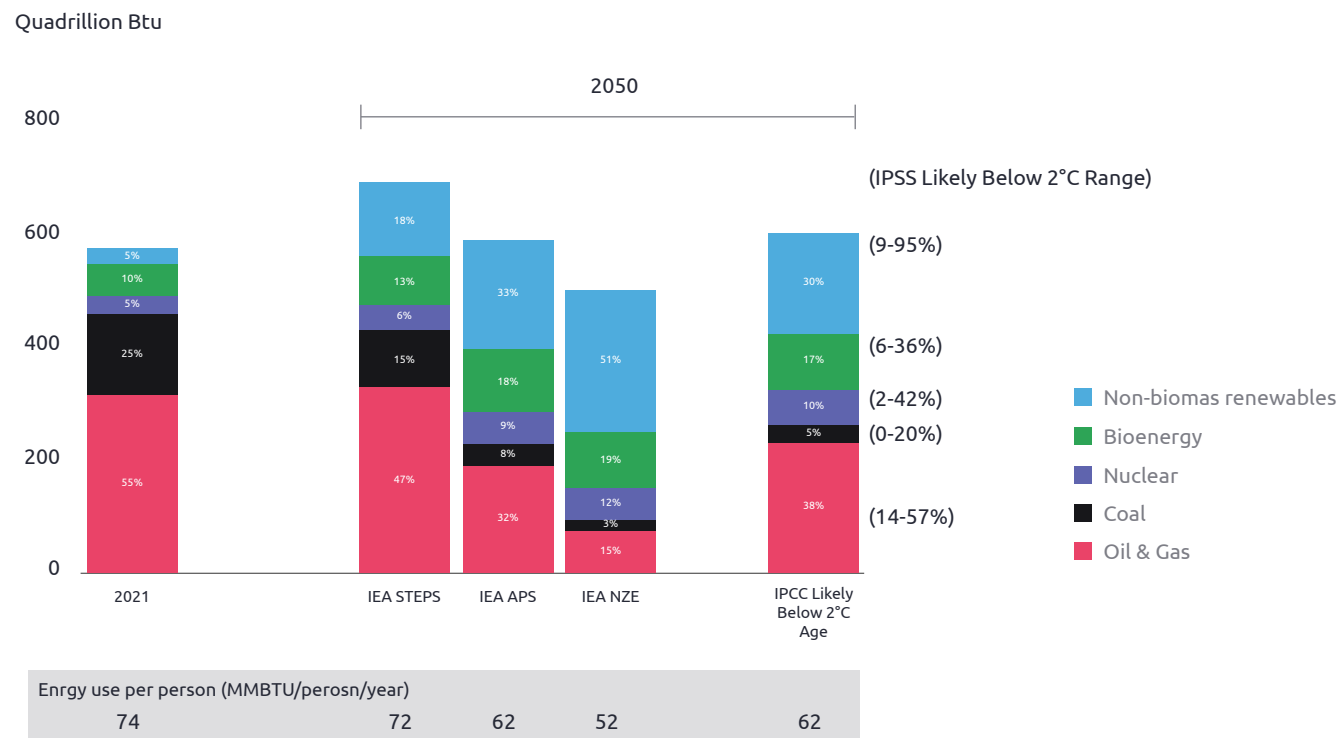
It is impossible to know which model or scenario will be closest to reality, but a pattern is noticeable in each.

Fossil fuels remain a key part of the energy mix

To accommodate the projected growth in energy demand, all sources of energy will still be required, including fossil fuels. In fact, the Intergovernmental Panel on Climate Change's (IPCC) mostly likely scenario for 2050 indicates that fossil fuels will still need to make up as much as 43% of the energy mix. Low-carbon energy sources simply cannot grow at a fast enough pace to fill this gap. Since oil and gas production is naturally depletive, continued investment must be made to accommodate an additional 55 million equivalent barrels per day needed by 2050.

FIGURE 2

2050 Energy mix



Source: ExxonMobil 2023 global outlook, IEA world energy outlook 2023, IPCC sixth assessment report
<https://spotlight.bloomberg.com/story/global-oil-outlook-to-2050/page/4/2>



Client Story



Wade Maxwell

Vice President, Engineering

In a keynote address at the 2024 ARC Forum, Wade spoke about ExxonMobil's efforts towards energy transition. He introduced "the AND equation".

ExxonMobil

What we are seeing

"Alternate sources of energy like solar and wind are playing an increasing role in the global energy mix. However, under most credible scenarios, including the net zero pathways, oil and gas will continue to play a significant role for decades to come. With that in mind, we are continuing to work in multiple areas to meet the needs of society today for reliable and affordable energy products while working to reduce our own greenhouse gas emissions as well as helping others do the same. That's the 'AND' equation."

What we are doing

ExxonMobil is innovating new technology across multiple disciplines, including carbon capture, direct air capture (DAC), Hydrogen, and Lithium. "We plan to invest more than 20 billion dollars in lowering emissions between 2022 and 2027," Maxwell said. "About half of that investment is intended to reduce emissions from our own operated assets. The balance is reducing emissions from other companies. We are delivering on both sides of the 'AND' equation."



Pathway to net zero is insufficient across almost all dimensions

Deployment progress to be made by technology – main levers (1/2)

Regions	Today (Parc / Production2023 YE)	2030 pace / objective	2050 pace / objective	Are we on track?
Wind 	2023 total capacity: 1,021 GW (Fleet) 2023 added: 115.0 GW	150 GW / y	500 GW / y	
Solar PV 	2023 total capacity: 1,418 GW (Fleet) 2023 added capacity: 345 GW	550 GW / y	615 GW / y	
Nuclear 	2023 total capacity: 396 GW (440 units) (Fleet) 2023 added capacity: 33.0 GW	541 GW (Fleet)	1,160 GW (Fleet)	
Low-carbon Hydrogen 	2023 total capacity: 1 Mt / y 2023 added capacity: 0.3 Mt / y	125 Mt / y	523 Mt / y	
Storage 	96 GWh stationary 8,500 GWh pumped	600 GWh	6,000 GWh 10,000 GWh	

Wind:
<https://www.statista.com/statistics/268363/installed-wind-power-capacity-worldwide/>
<https://www.irena.org/Energy-Transition/Technology/Wind-energy>
https://gwec.net/wp-content/uploads/2023/04/GWEC-2023_interactive.pdf
Solar:
[IRENA Renewable Capacity statistics 2024](#)
Nuclear:
<https://www.iea.org/data-and-statistics/charts/global-nuclear-power-capacity-and-cop28-pathway-2030>
<https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today>
<https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions/executive-summary>
<https://world-nuclear.org/our-association/publications/world-nuclear-performance-report/global-nuclear-industry-performance#:~:text=In%202022%20the%20end%20of,down%207%20GWe%20from%202021.>
Low-carbon Hydrogen:
<https://www.woodmac.com/press-releases/oil-gas-majors-share-just-8-of-global-low-carbon-hydrogen-capacity/>



Pathway to net zero is insufficient across almost all dimensions

Deployment progress to be made by technology – main levers (2/2)

Regions	Today (Parc / Production2023 YE)	2030 pace / objective	2050 pace / objective	Are we on track?
Electric transportation 	40 M (Fleet) 14 M (2023 sales +35% YoY)	360 M (Fleet)	2180 M ((Fleet)	
Heat pumps 	200 M units (Fleet) + 18 M pa / +11% YoY (Growth)	450 M (Fleet)	800 M (Fleet)	
Carbon Capture and Storage 	0,4 GT capture / y (production)	1.7 GT / y	3.3 GT / y	
Energy Intensity improvement 	1.3% / y (growth)	3.3% / y	2.8% / y	

Energy Intensity Improvement:
https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2023/Jun/IRENA_World_energy_transitions_outlook_2023.pdf?rev=db3ca01ecb4a4ef8accb31d017934e97
<https://www.iea.org/energy-system/energy-efficiency-and-demand/energy-efficiency>



Climate change is inevitable – how do we prepare?

Mitigation must accelerate

We are already seeing the impacts of climate change around the world. It seems that each year continues to claim “the hottest year on record” and the impacts of wide-spread droughts, large-scale floods, and increasing weather extremes are more noticeable than ever.

We must start thinking of the “AND” scenario – utilizing fossil fuels where absolutely necessary AND improving energy efficiency AND rapidly developing negative carbon tech. All levers must be pulled.

Governments can’t do it alone. Market-based solutions must accelerate to drive the right behaviors. Examples include a carbon tax on businesses and incorporating the cost of climate impacts in the price of goods and services that emit greenhouse gases.

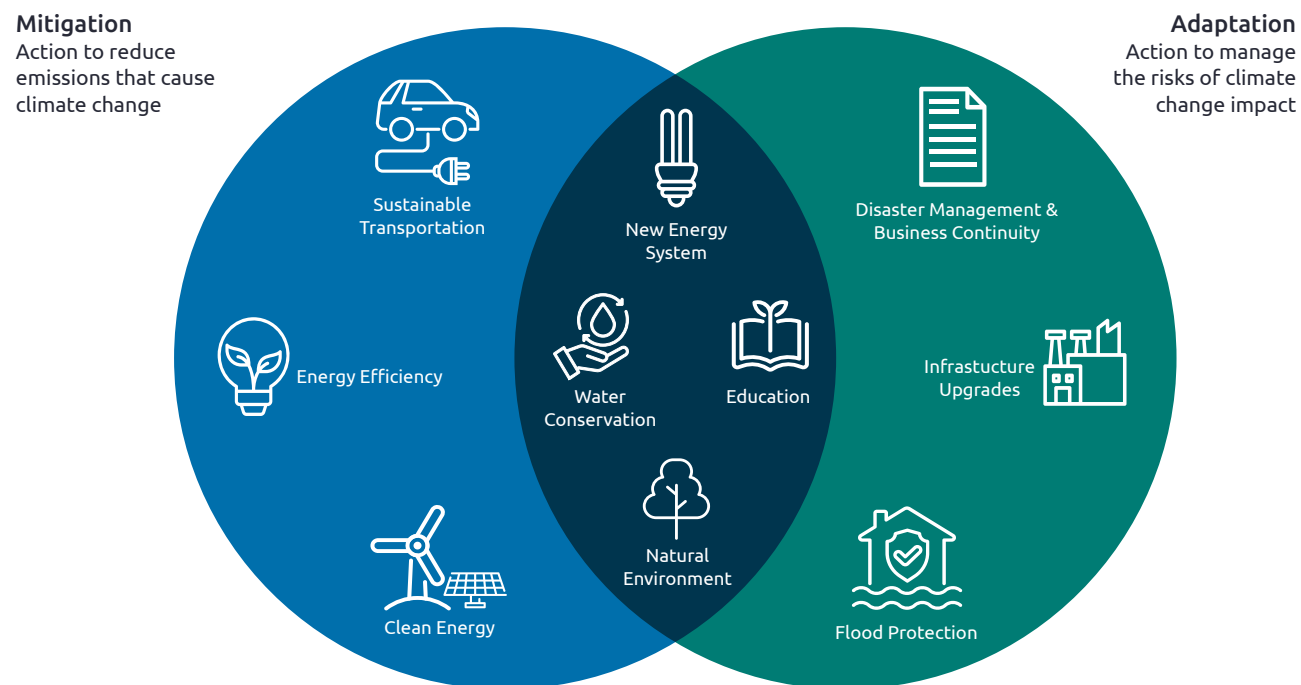
Adapting our lives will be essential

While focusing on solving the root cause of climate change is a natural priority, we must not forget the importance of preparing for what’s inevitable.

Engineers will need to build roads and bridges that withstand higher temperatures and storms. Cities will need to improve drainage for flood prevention. Farmers will need to plant and diversify drought-resistant crops and find ways make irrigation more efficient. Buildings will need better insulations, improved cooling technologies and more shade trees. Water conservation will have to become an everyday standard, enforced through restrictions and incentives. Families will need to consider relocating from at-risk coastlines and prepare for longer weather events that impact electricity, water and food supplies. Governments will need to prepare for a wider-range of disaster scenarios and need to fund mitigation efforts.

FIGURE 3

Mitigation & Adaptation



Source: <https://connectedcountyofhuron.ca/corporate-climate-change-adaptation-plan>



Our Convictions

- The rate and pace of our current low-carbon energy efforts has improved but is not nearly enough to meet targets. Future growth must be on an exponential scale.
- While it's clear that oil and gas will continue to play an essential role in our global energy ecosystem for many decades to come, we must accelerate the ways in which we offset its impact.
- Negative carbon technologies must be a substantial part of the equation. Carbon capture, utilization and storage (CCUS) is one example where technology advances are needed to modularize, improve affordability, and ultimately scale globally. We must move from capturing 0.4 GT/yr today to over 3.3 GT/yr by 2050 and will need to develop additional technologies to achieve this.
- Changing consumer behavior on a global scale is imperative and will only happen with market-based solutions.
- We must focus both on mitigation actions and how we adapt to the inevitable.



05

Primary energy demand is an *outdated* concept





James Forrest
EVP: Global Industry Leader for Energy
Transition & Utilities



James leads Capgemini’s global business for energy and utilities. He has three decades of experience in energy across retail, generation, operations, and the energy transition. He has lived and worked in Europe, Asia Pacific and North America.

Key points

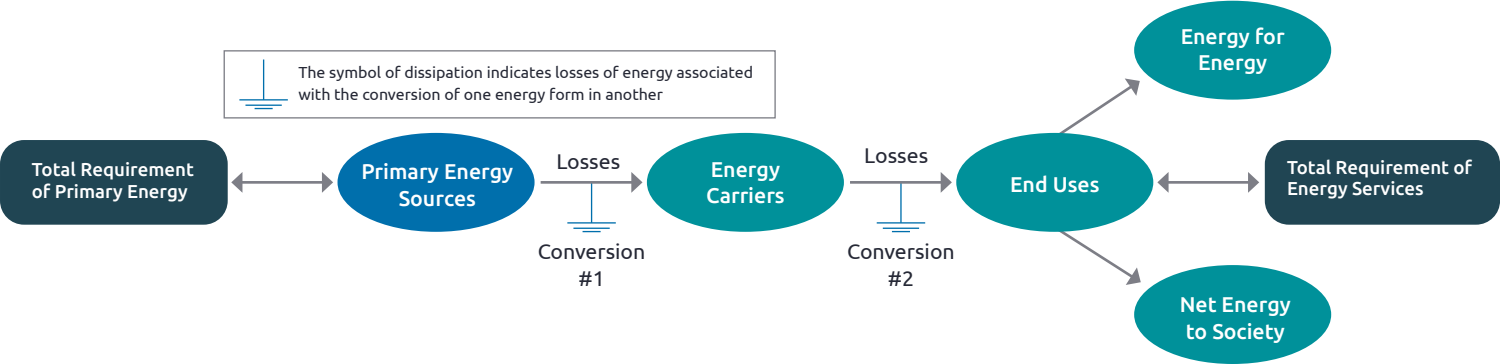
- 1. There is too much focus on the present analysis of replacing all current energy usage with clean energy.
- 2. This ignores several facts: that new electric services are generally more efficient; that a lot of fossil fuels are wasted in the generation of energy; and that a lot of energy is wasted on finding and processing fossil fuels.
- 3. The world will need a lot less clean electricity than fossil fuels for the same end-energy services.

Introduction

For years, the U.S. Energy Information Agency (EIA) and International Energy Agency (IEA) have measured primary energy demand. Governments have used this measure extensively and it has proven very useful in previous energy crises. It is defined as follows: Primary energy consumption refers to the direct use at the source, or supply to users without transformation, of crude energy, that is, energy that has not been subjected to any conversion or transformation process.



FIGURE 1
Primary Energy Demand definition



Source: IEA, EIA

Reducing CO₂ in the energy transition requires widespread electrification of energy uses (e.g., electric vehicles (EVs), domestic heat, and industrial heat). All climate change scenarios have electrification moving from 20% today to dominating the energy systems in the future. Electricity energy demand to perform these tasks is significantly lower than primary energy as measured for fossil fuels. If we replaced all the fossil ‘primary energy’ today in the new electric world, we would need a lot less energy.

As economies grow, switching focus to energy services work done and not primary energy as the input will help us make better decisions. As result, we believe the concept of primary energy demand is flawed and not a relevant concept for energy transitions, since it reinforces the old world.

The new electric energy services

Electrification will dominate the new energy system

Energy is required for many purposes around the world: mobility, heating, lighting, industrial processes, and agricultural processes. Most of the net zero scenarios published by the IEA envisage new electricity services to reduce the CO₂ footprint.

For transport, the world is well on the way to electrification. Globally 18% of cars sold were electric last year, albeit there are concerns on the deployment of charging networks.

Heat pumps are revolutionizing domestic heating and will become universal once the costs of gas are equalized. Electrification of building heat is progressing well.

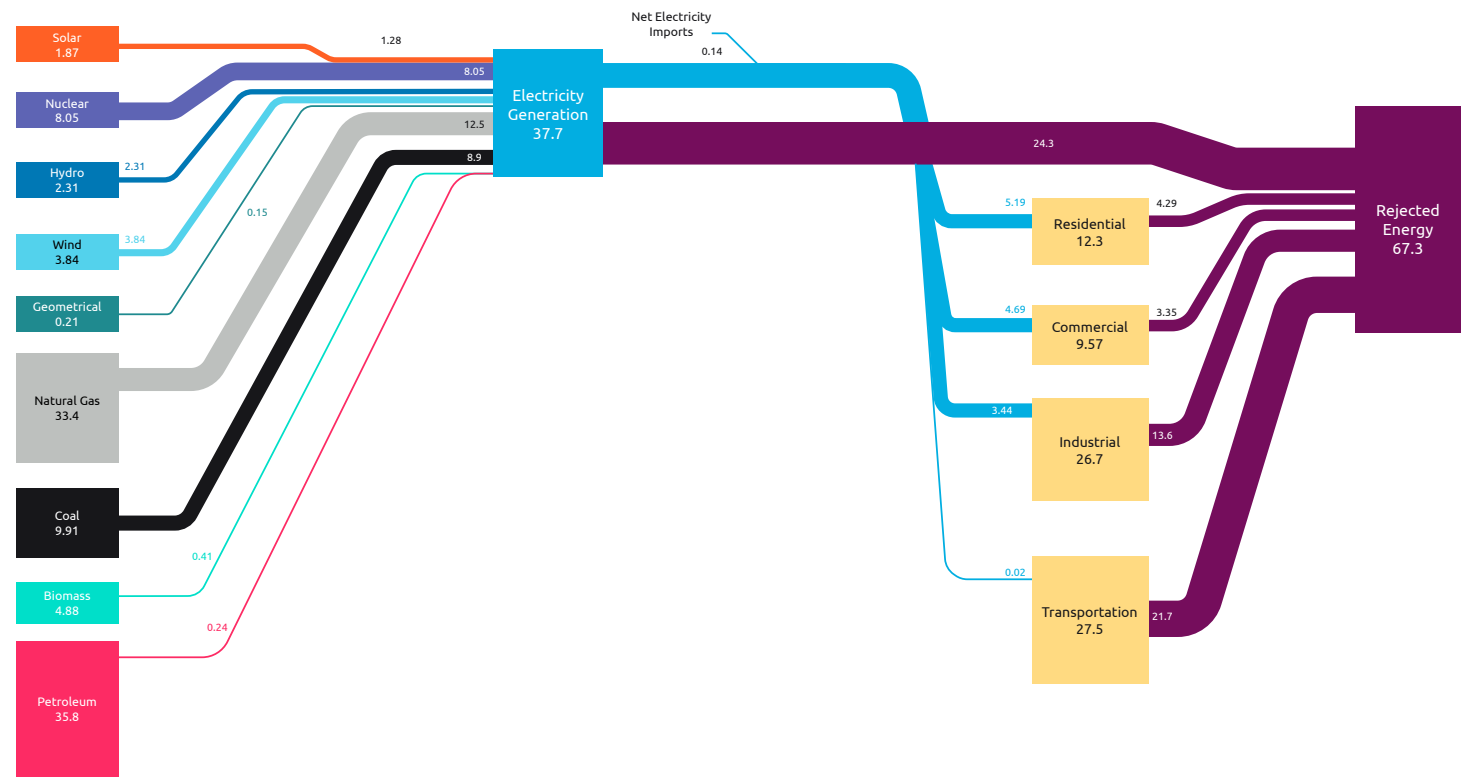
Industry is electrifying (e.g., aluminium and steel), though there is still work to be done.

‘Hot rocks’ are moving fast for industry process below 1200 degrees. Commercial solutions are becoming available and there is more activity required.



Energy lost burning fossil fuels to generate electricity

FIGURE 2
USA energy lost to generation



Source: Lawrence Livermore National Laboratory

Energy lost in generation

The average efficiencies of power generation are 35% for coal, 45% for natural gas, and 38% for oil-fired power generation. What this means is that 35% of the energy in coal results in electric power, while the 55-65% that is wasted goes "up the stack" as heat. The latest analysis from Lawrence Livermore (see Figure 2) shows that for the USA in 2022, 64% of energy wasted was on burning coal and gas.

Energy lost in low-carbon generation

Of course, wind, solar and nuclear also have inefficiencies that are being improved upon. However, unlike fossil fuels the energy is not wasted, it is just an opportunity to harvest more energy from the sources. All electricity generation suffers loss in transmission and distribution of approximately 10%. High voltage direct current (HVDC) lines are being introduced to reduce these losses over longer distances.



EVs/LEDs and heat pumps are more efficient

Most people around the world are moving towards LED light for homes and offices. Figure 3 shows that LEDs are more efficient and use 13% of the energy of a normal bulb. It also shows that primary energy demand is the wrong way to look at the low-carbon generation available to support the new, more efficient lighting service.

Electric vehicles are also more efficient. For every dollar you put in your diesel or petrol car, only 30 cents is used for moving you forward—the rest is wasted heat. EVs provide the same transportation service, but for every dollar you put in, 90 cents is used for moving you forward.

Finally, gas boilers have become much more efficient. For every kilowatt hour (kWh) of energy you put in, 10% is waste heat. However, with air source heat pumps, the latent energy in air is used. So for every kWh of energy you put in, you get between 2 and 4 kWh of energy back. This is transformational compared to gas boilers.

Example

FIGURE 3

Why Primary Demand creates the wrong measure of progress



Let's say you light your living room in rural India with a 75-watt normal lightbulb for five hours every night and consume 135 kWh per year. If you power the bulb with electricity from a coal plant with 35% efficiency and add 10% grid loss, then you create a primary energy demand of 435 kWh.

The same amount of light can be delivered by a 10-watt LED bulb. India is moving rapidly to solar, so if you run the LED on local panels, you will consume 18 kWh per year and you will have reduced your primary energy demand by 96% and eliminated its CO₂ emissions. However, you have still delivered the same energy service.

Source: The Better India News



Energy lost to find, mine, refine and transport fossil fuels

Bloomberg New Energy Finance estimates that 15% of global energy is used to find, extract, and transport fossil fuels.

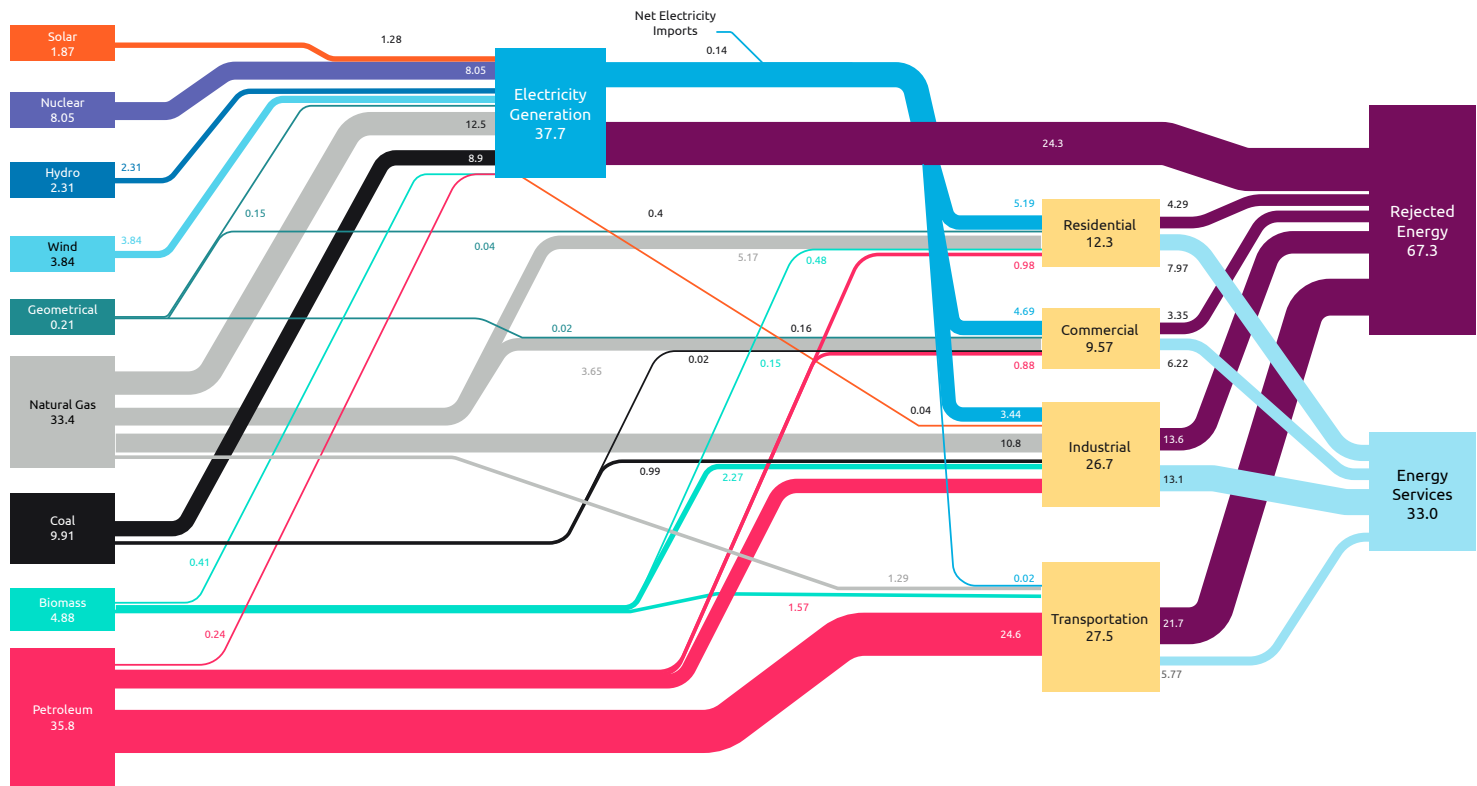
In the USA, oil and gas extraction consumes nearly 2% of energy; refining crude oil consumes nearly 8%, while transportation consumes approximately 3%.

Of course, we need to offset the savings here with the energy used to build new sources of generation, such as wind turbines, solar panels and expanding the use of batteries. In general, these costs are one-off and have a lot less energy consumption when compared to the yearly energy usage outlined above.

Putting it all together: The final numbers

FIGURE 4

Estimated USA Energy Consumption in 2022: 100.3 Quads



Source: Lawrence Livermore National Laboratory



Putting it all together: The final numbers

A good estimation of the how much energy we would use if everything was electricity is the Lawrence Livermore work in the USA. If we take the USA as a proxy for advanced economies, this analysis shows 67% rejected or wasted energy (see Figure 4 – this is shown in the Sankey diagram). This analysis also shows that if most services were electric and more efficient, then the USA would only need 33% of the energy it currently uses to satisfy the the existing energy services demand. However, we need to add back in the losses in the electric world, such as transmission and distribution losses.

Saul Griffiths has done some detailed work on all the energy services in the USA and estimates that if services were significantly electrified, the USA would need 42% of the primary energy demand today. Capgemini estimates that the

range is 40-50%, depending on the take up of the new electrified energy services (e.g. the adoption of heat pumps and the electrification of industrial heat).

If we continue to use primary energy demand, we will over inflate the energy that the world requires, as we electrify our energy services and confuse government policy.

Therefore, the decarbonization challenge is a lot smaller than primary energy demand would suggest. The concept of primary energy demand is outdated and should shift towards a focus on energy services, emphasizing the amount of clean energy required to fulfill future needs.

Our Convictions

- Primary energy demand was a useful concept in previous energy crises.
- Today, with the energy transition well underway, it is an outdated concept.
- Retaining it confuses the progress that is being made to a low-carbon future and the electrification of energy services.
- It would be much better to to talk about the kWh required to deliver the energy services that the world demands.

06

The *need* for a demand side Energy Transition





Hariharan Krishnamurthy

Global Head of ET&U,
Capgemini Engineering



Dr. Andrea Nuesser

Grid Modernisation Leader



Carl Haigney

Segment Head, Energy Retail and Central
Markets UK



Bragadesh Damodaran

ET&U Industry Platform Leader



Missing piece in the energy transition puzzle: how the demand side will reshape the energy landscape

- 1. Debates around the energy transition focus too much on the supply side and the amount of investment needed to meet future electricity needs
- 2. In the pursuit of a sustainable energy future, the demand-side transition, encompassing energy efficiency, demand-side management, and demand response, remains a pivotal yet often underappreciated component
- 3. We need to refocus the conversation and put consumers back at the center

Introduction

The International Energy Agency (IEA) identifies energy efficiency as crucial for maintaining the 1.5 °C climate target, yet global investment falls short. The current 2% annual improvement rate needs to double by 2030, requiring a tripling of investment within five years. Despite challenges in the building and industry sectors, 2023 saw resilient global energy efficiency and electrification investments, boosted by strong EV sales.

The U.S. Energy Information Administration (EIA) shows that energy efficiency has kept USA energy consumption stable since 2000, even with economic growth. The recent rise in electricity demand for AI data centers highlights the ongoing need for demand-side focus.

The Australian Energy Market Operator (AEMO) projects that enhanced demand-side management could cut peak demand by 10% by 2030, reducing the need for new infrastructure.

Engaging consumers and leveraging technology is essential for an effective and fair energy transition.

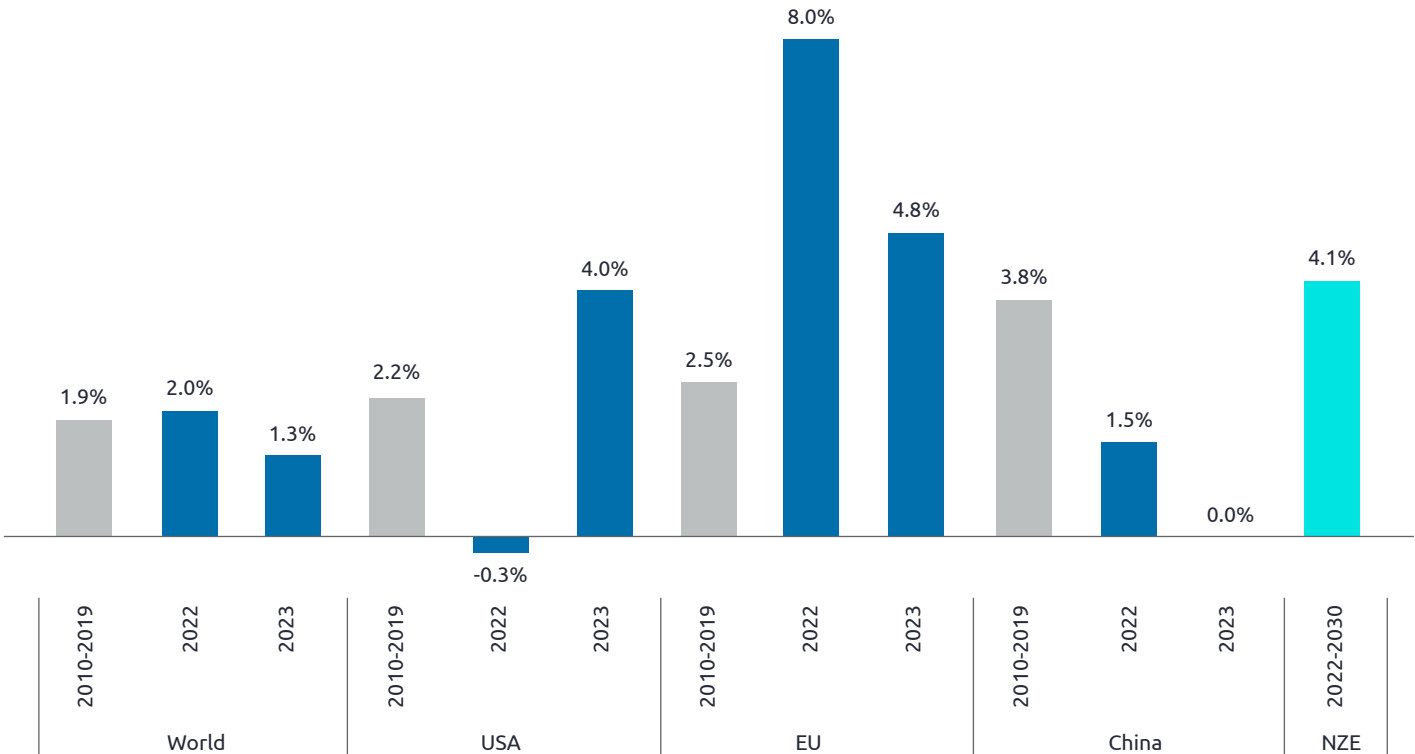


What we are seeing

- Customers becoming from prosumers to omnisumers, individually or collectively (energy communities)
- Technology Advancements that empowers customers
- Interesting Cross Industry Collaborations
- New Markets, New Opportunities, and New Entrants

FIGURE 1

Slower global intensity improvement in 2023 masks significant progress at the country and regional levels (USA – 4%, European Union – 4.8%)





Customer engagement matters

Customer Choices Add Complexity

The energy transition is transforming traditional power systems. Electricity demand is rising as customers adopt electric vehicles (EVs), electric heating, and other electric devices. Data center consumption further contributes to a significant increase in electricity demand. Simultaneously, customers are enhancing energy efficiency in their homes and businesses and investing in distributed energy resources (DERs) like rooftop solar and battery storage to reduce bills and improve resilience. This shift creates a more intricate system with greater load flexibility and more pronounced peaks. To manage this increasingly complex system, electricity providers must rethink their planning and operations. New tools are required to balance supply and demand in real-time, with flexible resources and non-wires alternatives (NWA) complementing traditional infrastructure solutions.

Consumers Hold the Key to Unlocking Grid Value

Customers across all segments are increasingly investing in smart devices that monitor and control energy usage, such as smart thermostats, battery storage systems, and programmable EV chargers. These devices offer significant grid benefits when energy providers actively engage customers and incentivize participation in demand response programs. By leveraging customer-owned controllable devices, utilities can reduce peak demand and build flexible resources, like virtual power plants (VPPs), which help defer or avoid capital investments.

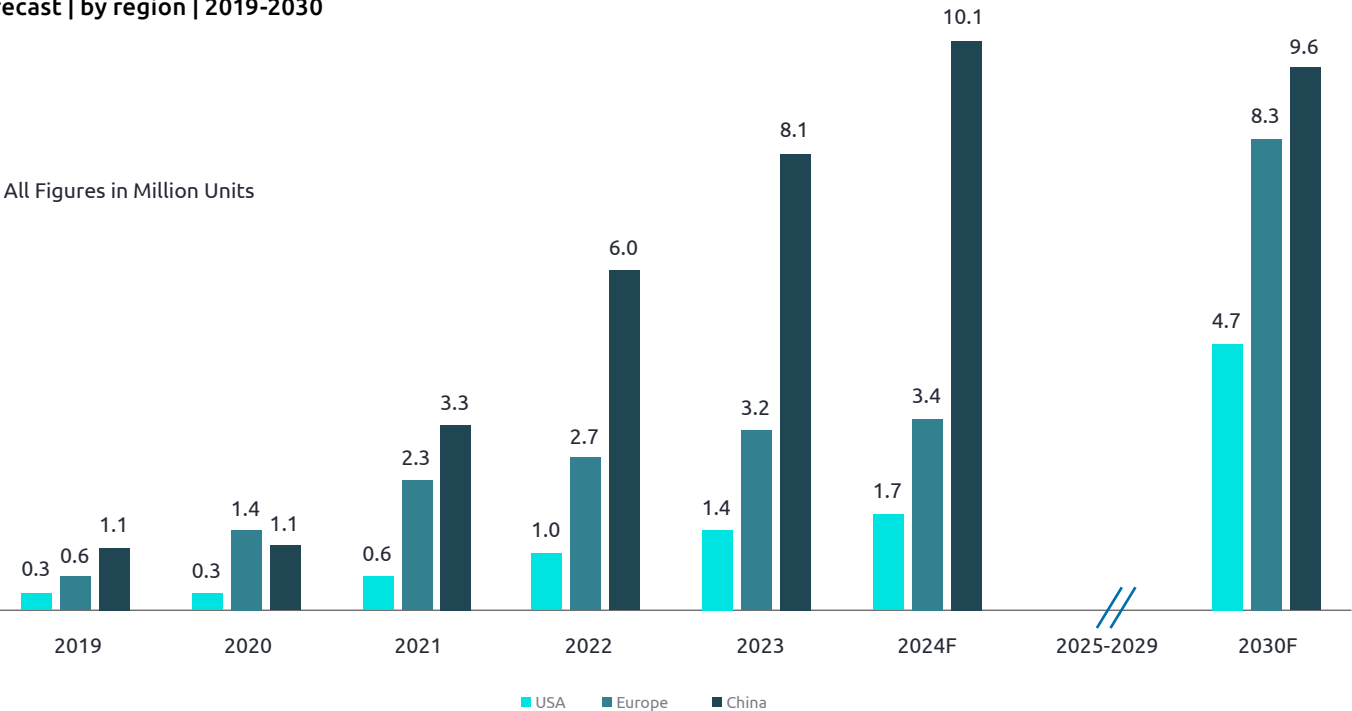
However, customers commonly invest in smart energy devices or energy efficiency for their own benefits—to lower their energy bills, increase the comfort of their homes, or reduce their carbon footprint—rather than benefits for the grid.

To unlock the grid value of these customer investments, electricity providers need to find new ways of engaging

customers that make it easy and attractive for them to participate. At the same time, utilities must trust customers as active participants or “prosumers” for these benefits to materialize and to keep customer costs low. It’s essential to empower everyone, regardless of economic means, to participate in a fair and just energy transition.

FIGURE 2

EV Sales Forecast | by region | 2019-2030



Source: IEA, EVAAdoption, USB



Client Story



Giselle DeGrandis

Manager, Business Development, Hydro One

Giselle is part of the Customer Strategy & Energy Transition team and leads Hydro One's residential demand response (DR) program, called myEnergy Rewards.



How we see this market / issue

- Tapping into customer demand flexibility offers Hydro One a new and cost-effective way (a non-wires alternative) to meet emerging system needs and help alleviate some upward pressure on rates.
- Hydro One is ideally positioned to engage DER-owning customers, reward them for their investments, and aggregate the value of their participation in the operation of a clean and reliable grid by creating a Virtual Power Plant (VPP).

What we are doing

- Hydro One is collaborating with the IEA in a study to test and evaluate customer engagement methods that result in desired energy behavior change.
- Hydro One is aggregating customer smart devices into a geographically segmented, all-season, multi-DER VPP by incentivizing customer participation.
- The OEB provides funding to income qualifying customers for base-board smart thermostats.
- Planning and Operations teams are assessing how this helps them meet local distribution needs and quantify the deferral value of planned system investments.

Demand Response and Time-Variable Pricing in USA Utilities

Most USA utilities offer DR options to their commercial and industrial customers. Additionally, the country's seven independent system operators/regional transmission organizations (ISO/RTOs) sponsor DR programs, allowing demand response capabilities to bid into markets for energy, capacity, or other grid-support services. These capabilities often include reducing consumption or using behind-the-meter generators.

Time-variable pricing (TVP), where electricity prices vary by time of day and season, is widespread. Common TVP options include time-of-use (TOU) rates, real-time pricing (RTP), day-ahead hourly pricing, and block-and-index pricing. TOU rates typically feature higher prices during afternoon peaks, lower overnight rates, and intermediate "shoulder" periods.

DR programs and TVP arrangements reflect the dynamic nature of electricity production costs, which can vary significantly. These programs incentivize consumers to manage their loads, providing substantial benefits for those who can adjust their usage in response to market signals, thereby helping to stabilize the grid and reduce costs.

The more these flexibility are automated, the more efficient DR programs and price signals are.



Energy Command center (ECC)



Schneider Electric's leading connected products, edge control, and advisory applications help organizations efficiently manage their energy supply across multiple assets, such as factories, offices or other infrastructure, while also reducing energy consumption across their operations in one integrated platform.

How we see this market / issue

- Designed to help organizations accelerate their journey towards smarter and greener facility management, energy efficiency and demand side transition, the Energy Command Center leverages a unique end-to-end combination of digital solutions and cutting-edge technologies, to both simplify energy management and optimize its consumption.

What we are doing

- An innovative energy management platform that will enable organizations to monitor and manage the performance of energy assets across their operations
- Capgemini brings its expertise in data integration and processing, AI and machine learning, and the integration of all products and software in a central decision-making platform.
- Leveraging next-generation technology to significantly increase energy efficiency and improve asset utilization.

Technology advancements empowering customers

Introduction

Tackling the energy and climate crises is paramount, and energy efficiency and demand side transition plays a key role in mitigating these challenges. Decarbonization through electrification and digitization is a necessity for a sustainable future.

Technological advancements are fundamentally transforming the demand side of the energy equation, empowering consumers to play an active role in the energy transition. Through smart grids, Headend Management systems, DERs, demand response programs, EVs, blockchain, AI, and IoT, consumers can optimize their energy usage, reduce costs, and contribute to a more sustainable and resilient energy future.

Key data



>25%

Energy efficiency
increase / saved cost



>20%

Reduction in
maintenance costs



>30%

Asset utilization
improvement



ECC – An integrated and Centralised Platform

The Energy Command Center solution, developed by Capgemini and powered by Schneider Electric, is an integrated and centralized platform to monitor, control and optimize all building assets consuming energy including data centres or critical environment rooms. Using real-time energy consumption and carbon emission data combined with modular and interoperable building management software and systems, the Energy Command Center helps to lower energy consumption and spend to help achieve organizational goals while accelerating towards a net-zero future. The platform combines advanced artificial intelligence (AI), machine learning logics and algorithms, and the Internet of Things (IoT) technologies to measure and predict various metrics like energy intensity, health of critical assets, critical operations, renewable energy generation, and the overall performance across all energy assets





Cross industry collaborations

Energy reduction has been an increasing part of our domestic and industrial mindset for some time – the clearest manifestation of this arguably being the 2021 forced rescale of the European energy labels because of the rapid evolution of more energy efficient products. The efficiency classes above A (A+, A++ etc.) were saturated with, for example, over 90% of refrigerators sold being class A or above.

Whilst clearer labelling and better understanding helps reduce usage, reductions have been partly countered with an increase in the number of devices – from home technology to EVs. This ‘stagnation’ is driving an increasing interest and demand in cross-industry collaboration, not only to reduce consumption at source, but also to reduce demand through the energy networks and generators.

As an example, the UK has successfully trialed demand-reduction techniques, using retailer incentives (loyalty points) to drive down consumption when supply is constrained. This brings together the Electricity System Operator (ESO) with the retailer(s) and consumers, but the key players are all in the energy industry. The more interesting area, though, is the growing recognition that demand can be managed more effectively locally to reduce overall draw through substations. Being beyond-the-substation, this is, by definition, local and what we are seeing is that the time of the intelligent self-balancing energy communities is here

Energy Sharing Communities Europe

The European Commission first set up the rules for energy sharing communities in 2019. Initial progress was disappointingly slow, but there is now a building momentum in these groups which bring together DSO, house builders, storage companies (including mobility) and technology companies. We are approaching a tipping point driven by constrained capital investment budgets, demand increase through house building and public pressure for secure supply.

These are more than peer-to-peer energy saving arrangements. These are evolving to be intelligent networks, optimising local production and consumption, import and export, based on predictive analytics in the home, neighborhood, district, environment and on the networks. The home builders are incentivised to invest in the opportunity of being part of the long-term energy community operating company, as well as gaining extra revenues from building houses with storage and generation capacity. There is a further benefit for the builder and the DNO in that the substation demand is lower – shortening supply cycles and lowering the capital costs.

Portugal seems to be leading the way, already having rolled out enabling legislation, but other nations are rapidly gaining momentum. As an example, The Cleanwatts Living Lab aims to bring together capabilities including peer-to-peer energy trading, using EVs and battery storage to help balance local and national grids, thus driving grid flexibility. The Cleanwatts approach has, importantly, engaged the consumer (with an

app) and brought together technology providers, the grid operator, regulator and the retailers. All this is bundled into a replicable solution.

Many other examples exist – for example, in the Netherlands, 110,000 properties are part of local energy communities – nearly 1.5% of the entire residential estate. In the UK, the new government has announced plans to drive thousands of local energy projects through its Great British Energy corporate vehicle.

Energy communities also encompass the rapidly-evolving heat networks programmes where lower-temperature systems are driving greater efficiencies.

In all these cases, momentum is being driven by accessibility of the technologies to the consumers, enabled normally by smart metering and the digitisation of the grid. Volatile energy prices, low cost solar and the growth in EVs in particular is providing an impetus for consumers to engage and invest, whilst looking for realising the benefits of having generation and storage assets in the home or community. Large energy and mobility enterprises are on the cusp of working out how to make money from community schemes and this will further spur on the market.



EV-Grid-Integration Group in the USA

The formation of the EV-Grid-Integration Group in the USA marks a significant milestone in the collaborative efforts between the automotive and utility industries. This group, which includes major auto players such as GM, Ford, and Utilities such as PG&E, and Consolidated Edison, exemplifies how industries can come together to address the challenges and opportunities presented by the rapid growth of electric vehicles (EVs).

Given the surge in EV adoption, as highlighted by recent data showing a substantial increase in USA electricity demand due to EVs, this collaboration is timely and essential. By working together, these industries can pave the way for a more integrated and efficient energy ecosystem. The formation of this group is not just a response to current demands but a proactive step towards a sustainable future, where the synergy between automotive and utility sectors can drive innovation and progress in the energy transition.

If successful then the outcomes will be seen in exploiting the storage assets that are EVs whilst allowing optimisation of capital spend on networks.

New markets, new opportunities, and new entrants

This is only the start of the transformation, though, and the rapidly-evolving smart energy world is delivering data opportunities which are attracting new approaches and hence new entrants. Most importantly, enabling the energy transition will require a new energy ecosystem, where new players, such as aggregators and market operators, play critical roles in leveraging all available energy resources.

As reported in prior editions of WEMO, the legacy world of energy retail is starting to be disrupted by new entrants from other sectors. This threat to the revenue and profit streams has been seen before in the finance and telco worlds.

The signs are clear – customers are taking control, buying energy assets to reduce demand and become prosumers. They are also, perhaps unwittingly, buying huge storage devices in the form of EVs and largely (currently) failing to exploit the full value of all the assets they own.

Held back by slow processes, a lack of expertise in the asset domain and brand/investment issues, the market is open for new entrants to thrive....but which ones are coming into the market?

A few examples of market disruptors

Coming in from a mobility and storage angle we have the headline-grabbers such as Tesla (with its VPP offerings in UK, Spain, USA) and the potential expansion into a broad energy services company which includes the transactional energy retail elements.

From home services we have Ikea and its recently-launched Energy Insights feature enabling consumers to monitor their energy consumption. How long before AI is applied to automatically optimize your home energy use, production and export?

Be it a mobility/storage entrant, a home services entrant, or another (telco examples exist, spilling over to energy based on brand/customer experience), the disintermediation of the traditional retailer from its customer is starting to happen.

This is the start, though. Once the full suite of smart solutions are implemented, the power of the data can be fully leveraged – offering new opportunities to optimize home energy services at a household, community or national level. The winners in the future will be the firms that can capitalize on this data in near-real time – blending an individual's predicted demand (home and car) with the market pricing and storage options every 30 minutes of every day.



Our Convictions

- **Consumers are the New Power Brokers:** The future of energy is decentralized and consumer-driven. Consumers must be empowered with the tools and information to make informed energy choices.
- **Cross-Industry Collaboration is Non-Negotiable:** The convergence of the automotive, utility, and technology sectors is essential.
- **Data is the New Currency:** Data from smart meters, connected devices, and energy management systems is invaluable. AI and machine learning will play a pivotal role in optimizing energy use, predicting demand patterns, and integrating renewable energy.
- **Equity and Inclusion in Energy Transition:** The benefits of the energy transition must be accessible to all, regardless of income or location. Policies should ensure that low-income households have access to energy efficiency programs and renewable energy solutions.
- **Regulation Must Evolve:** Regulators need to create frameworks that encourage innovation, support new business models, and ensure that utilities can recover the costs of investments in smart grid technologies and energy efficiency programs.
- **Behavior Change is Critical:** Technological solutions alone are not enough. Behavioral science must be leveraged to encourage energy-saving behaviors among consumers. Programs that provide feedback, set goals, and use social norms to promote energy conservation can be highly effective



07

Focus *hydrogen*
on hard to abate
industries





Benoît Calatayud

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Head of Strategy, H2V



Florent Andrillon

Sustainability Services and Group Head of
Climate Tech



Key Points

- 1. The Hydrogen Recalibration: A strategic shift from a universal decarbonization tool to a niche player, primarily focusing on sectors like heavy industry (representing 42% of the targeted low-carbon hydrogen use by 2030 under the EU's RED III) and heavy-duty transportation (5.5% of fuels used in transport shall be biofuels or RFNBO by 2030, with a minimum 1% RFNBO), where electrification faces significant challenges.
- 2. Deployment Challenges and Varying Willingness to Pay: An in-depth look at the obstacles hindering hydrogen deployment, including securing cost-competitive low-carbon electricity and addressing infrastructure limitations. We also examine the disparity in willingness to pay across sectors, with aviation and shipping potentially leading due to limited alternatives and rising carbon costs.
- 3. The Role of Regulation: An analysis of how regulatory schemes, particularly in the EU, are shaping the hydrogen market through incorporation targets and incentives like the French TIRUERT, driving the adoption of greener solutions

Introduction

The hydrogen landscape is undergoing a profound transformation, marked by a significant recalibration of expectations. Once envisioned as a panacea for decarbonization across all sectors, hydrogen is now finding its strategic niche in hard-to-abate industries. It's a « realistic » moment for the Hydrogen sector.

In this note, we delve into the complexities of the hydrogen market, examining the factors that have led to a 50% reduction in the International Energy Agency's (IEA) projected low-carbon hydrogen demand for 2030. From escalating production costs and competition with electrification to regulatory frameworks and the varying willingness to pay across sectors, we provide a comprehensive overview of the hydrogen landscape.



Hard-to-abate sectors: Betting on hydrogen's unproven promises

1. The great hydrogen recalibration: From a universal decarbonizer vector to strategic niche player

A. This situation is explained by the increasing costs of low-carbon hydrogen production, competition

- **Hydrogen produced by electrolysis will not decarbonize all uses**

When hydrogen strategies emerged across developed countries about four years ago (the French hydrogen strategy was launched in September 2020 and now more than 50 national strategies are deployed worldwide), low-carbon hydrogen was seen as a vector for decarbonizing numerous sectors. Indeed, the role of hydrogen as a means of decarbonization was very broad, including mobility, industry, stationary storage, heating, etc., with very ambitious goals.

- **To meet these decarbonization needs, the goals are far too ambitious. Only certain uses have strong potential: heavy industry and air/maritime mobility.**

Whatever the source, 90 million tons of low-carbon hydrogen by 2030 would be enough to sustain claims that the world is on track to limit warming to 1.5°C above pre-industrial levels.

But is this realistic? After all, 150 million tons in 2030 would be a 50% increase over the current 95 million tons of annual demand in seven years. This would only require a 6% compound annual growth rate. The International Energy Agency's (IEA) October 2021 net zero by 2050 roadmap showed a figure of 212 million tons of hydrogen by 2030 (150 million must be low-carbon).

The 2023 update of this roadmap saw the IEA reduce the total figure to 150 million tons in 2030 and drop the low-carbon figure to 70 million.

Projection	2021 Roadmap net zero by 2050	2023 Roadmap Update
Total hydrogen demand by 2030 (million tons)	212	150
Low-carbon hydrogen demand by 2030 (million tons)	150	70

The evolving landscape has led to a strategic refocusing of hydrogen's role. It's no longer about replacing every fossil fuels molecule but about identifying sectors where its unique properties align with decarbonization challenges. This includes sectors with high-temperature processes that are difficult to electrify directly (e.g., steelmaking, chemical

industry) and sectors that rely on liquid fuels for long-distance transportation (e.g., aviation, shipping).

In Europe, the steel and refinery sectors are leading the way, with first projects under construction. In France, the 200 MW Normand'HY project, initiated by H2V and acquired by Air Liquide, has entered the construction phase. It will supply 15 kta to TotalEnergies' oil complex in Normandy. In Portugal, Galp invested in a 100 MW production capacity for its Sines refinery; and in Rotterdam, Shell's Hydrogen Holland project is also under construction to supply 25 kta to the Shell Energy and Chemicals Park. In Germany, RWE plans to commission 300 MW of electrolysis capacity in three stages by 2027. The aim of the project, GET H2 Nukleus, is to initiate the development of a regional hydrogen infrastructure together with partners.

"After a period of adjustment to the reality of green hydrogen prices, industrial offtakers are now ready to enter into long-term agreements with producers. The example is the massive tenders launched by German steelmakers (SHS, Thyssenkrupp and Salzgitter AG) or by TotalEnergies to supply six of its European refineries. This means almost one million tons a year of low-carbon or renewable hydrogen by 2030."

**B. This situation is explained by the increasing costs of low-carbon hydrogen production, competition between uses, and regulations, particularly in the European Union.**

- **Production cost**

According to a recent Capgemini study¹, Hydrogen market players generally agree today that the price for low-carbon hydrogen production will decrease below €7/kg by 2030. However, there is no real consensus here, which is leading to a lot of uncertainty overall. (As of today, the actual price range of carbon hydrogen production is estimated to be between €1-3 per kilogram).

This figure is far from the previous prediction, with production prices expected below €2-3/kg by 2030. In its 2023 Global Hydrogen Review, the IEA maintains that low-carbon hydrogen could be produced in Europe for €1.60/kg by 2030. Meanwhile the market has seen hydrogen production costs increase by 30-65% between 2021 and 2023, according to the World Hydrogen Council.

Currently, there is no common vision and a lot of real uncertainty, with estimates far away from previous predictions made just a few years ago—a time when the consensus was that renewable hydrogen production costs would dip below €3/kg.

- **Competition of hydrogen with other decarbonization technologies, especially for electrification**

In some cases, hydrogen as an energy vector is in competition with other decarbonization technologies, particularly when it comes to electrification. This is especially the case for road mobility. The electrification of land transport, such as heavy goods vehicles or buses, is carried out via batteries or via a fuel cell powered by hydrogen.

Given technological advances, electric batteries are becoming more efficient. Therefore, in increasingly frequent cases, hydrogen is not competitive compared to batteries for electrifying uses, particularly in heavy mobility.

“Public authorities have stopped investing in hydrogen-powered buses, which are too expensive and complicated to operate. Truck manufacturers are focusing their efforts on battery-powered vehicles. The hydrogen-powered engine could still restore H₂ to its rightful place and put European OEMs back in the international game thanks to their expertise in internal combustion engines.”

Similarly, the use of hydrogen as a means of storage does not appear competitive compared to other means of flexibility (notably batteries), except in rare cases in island areas not connected to the grid.

- **Regulation, particularly in the European Union, encourages the use of hydrogen in heavy industry and air/aviation mobility sectors**

EU regulation schemes have the merit of being exhaustive and serve as a model for the rest of the world, particularly regarding the definition of renewable hydrogen.

Indeed, the revised Renewable Energy Directive (RED III) introduces renewable fuels of non-biological origin (RFNBO) into targets for developing the use of low-carbon hydrogen in the sectors most difficult to decarbonize.

The objectives vary significantly according to sector. RED III targets 42% low-carbon hydrogen in the industrial sector by 2030 and 60% by 2035.

“Current consumers of grey hydrogen, including ammonia producers, are concerned that overly restrictive regulatory targets for the incorporation of green hydrogen into their processes would undermine their competitiveness in a global market. That's why a recital has been added to the European RED III regulation, aimed at excluding some usages from the hydrogen greening objectives.”

https://www.capgemini.com/wp-content/uploads/2024/02/Capgemini-PoV_Hydrogen-Position.pdf

For the transport sector, 5.5% of fuels used in transport shall be biofuels or RFNBO by 2030, with a minimum 1% RFNBO.

Member states with ports should also aim to ensure that RFNBO occupies 1.2% of the total amount of energy supplied to the maritime transport sector by 2030.

“Ultimately, the transport sector is most regulated by Europe. The Refuel EU Aviation and Fuel EU Maritime regulations provide for dissuasive penalty mechanisms for the maritime and aviation sectors, which have no choice but to move rapidly towards hydrogen-based fuels (methanol for maritime and eSAF for aviation).”

2. While deployment challenges remain numerous, the level of penetration of low-carbon hydrogen will not be the same across sectors, and the willingness to pay among industrialists and consumers will vary

A. Deployment challenges remain numerous, differing between sectors

Deploying low-carbon hydrogen faces several challenges, including securing competitively priced low-carbon electricity, rising interest rates, finding suitable partners—especially EPC partners—and addressing transportation issues such as costs and insufficient infrastructure.

This situation differs between sectors. It is indeed easier to obtain low-carbon hydrogen in a gaseous state, particularly in industry, compared to the mobility sector. In the maritime and aviation sectors, it is necessary to convert the hydrogen molecule into e-fuel (e-methanol/ammonia) to be used as fuel.

B. The willingness to pay is not the same across sectors

The economic viability of hydrogen projects depends heavily on the willingness of industries and consumers to pay a premium for low-carbon solutions (see table below). Sectors like aviation and shipping, where alternatives are limited and the cost of carbon emissions is increasingly factored in, may be more willing to adopt hydrogen-based fuels despite their higher price. Conversely, sectors with readily available and cheaper alternatives may be less inclined to switch to hydrogen.

Low-carbon hydrogen is not sufficiently competitive with fossil fuels or fossil-based hydrogen, particularly for industrial uses or road transportation.

Competitiveness is achieved when the price of low-carbon hydrogen reaches the opportunity cost (i.e., the price of fossil-based hydrogen or equivalent energy, including carbon taxes and the TIRUERT² within road transportation.)

² TIRUERT stands for Taxe Incitative Relative à l'Utilisation d'Energie Renouvelable dans les Transports, which translates to Incentive Tax Relating to the Use of Renewable Energy in Transport. It's a French mechanism introduced by the 2022 Finance Law to promote the use of renewable energy in the transportation sector. How it works:

- **Certificate Generation:** Operators of electric vehicle charging stations can generate and sell certificates of renewable electricity (called "certificats TIRUERT").
- **Certificate Purchase:** Fuel distributors are obligated to incorporate a certain percentage of renewable energy into their fuel mix. They can meet this obligation by either:
 - Blending biofuels into their products
 - Purchasing TIRUERT certificates
- **Incentive:** If fuel distributors don't meet their renewable energy obligations, they have to pay a tax. By purchasing TIRUERT certificates, they avoid this tax, hence the "incentive" aspect.



Final use of hydrogen	Market price (willingness to pay)(2024 conditions)	Regulatory /market deadline to switch to green H ₂	Typical gap between market price and production cost	Analysis of underlying drivers
Refineries	€7-8/kg H ₂ (RFNBO)	Immediately	<€0.50/kg H ₂	The national transposition of the RED directive imposes a share of renewables in fuels, on penalty of a tax (in France, the TIRUERT). The renewable hydrogen used in refineries meets this obligation. The market price is therefore calculated based on the price of grey hydrogen, CO ₂ quotas and the tax avoided thanks to the renewable hydrogen.
Aviation fuel (e-SAF)	[€5.2-6.6] k/t _{eSAF}	Starting in 2030 Turning point in 2035	<€0.50/kg H ₂	The Refuel EU Aviation regulation requires the use of an increasing proportion of e-SAF from 2030, under penalty of heavy fines. This extra-budgetary mechanism limits the need for public support, despite fuel costs being five times higher than kerosene.
Maritime fuel (e-Methanol)	[€1200-1600]/t _{MeOH}	Starting in 2030 Turning point in 2035	<€1/kg H ₂	The FuelEU Maritime regulation requires shipping companies to progressively reduce CO ₂ emissions, which will involve a change of fuel. Methanol offers an effective alternative for achieving these objectives, with a global market price determined by the competitiveness of different solutions (bioLNG, biofuel, e-Methanol).
Steel production (DRI)	[€2-3]/kg H ₂	Immediately	~€4/kg H ₂	The use of hydrogen in steelmaking through the direct reduction process reduces the sector's CO ₂ emissions by over 90%. As a result, subsidies allocated to offset the price differential with natural gas offer unrivalled efficiency (€subsidy/tCO ₂ avoided).
Road transportation (fuel cell vehicle)	[€4-5]/kg H ₂ (RFNBO)	Between 2035 and 2040	~€5/kg H ₂	In the short term, the total cost of ownership (TCO) of a hydrogen truck should be balanced with that of a diesel, i.e. €4-5/kg H ₂ at fuel station. After 2040, the end of fossil fuels engines will naturally increase the size of the market, making hydrogen indispensable as a complement to electric power.
Ammonia production	[€2-3]/kg H ₂	2030 to 2035, according to RED III national transposition	~€4/kg H ₂	In the short term, existing ammonia plants cannot accept more than 15% green hydrogen, limiting the size of the market. A major process change will be required for full decarbonization. Without specific penalty from RED III transposition, market price is based only on grey hydrogen, adjusted for the price of CO ₂ quotas.
Chemical industry	[€2-3]/kg H ₂	2030 to 2035, according to RED III national transposition	~€4/kg H ₂	Without specific penalty from RED III transposition, market price is based only on grey hydrogen, adjusted for the price of CO ₂ quotas.
Industrial heating	[€2-2.5]/kg H ₂	No dedicated regulatory framework	NC	Green hydrogen could eventually replace natural gas. In the short term, the market is limited by the compatibility of existing installations, and by the absence of eligible subsidies for this segment.



A subsidy of €4.58/kg H₂ would be necessary to make low-carbon hydrogen competitive for industrial use in France; and a subsidy of up to €5.53/kg H₂ for road transportation would be required to offset the opportunity cost.

In comparison, low-carbon hydrogen is more competitive with the production of e-methanol and e-ammonia. Its production cost is 37% lower and it therefore requires a much lower subsidy of €1.34/kg H₂.

The “hydrogen recalibration” is underway, shifting hydrogen’s role from a universal decarbonization tool to a strategic niche player. While initial ambitions were high, the reality of production costs, competition with other decarbonization/electrification technologies, transportation challenges and regulatory frameworks has led to a more focused approach.

Hydrogen’s potential now lies primarily in hard-to-abate sectors like heavy industry and heavy transportation sectors (maritime and aviation), where electrification faces challenges. This strategic refocusing is prompting organizations to:

- Mobilize the necessary investments to create new low-carbon hydrogen assets
- Finance the gap between prices and production costs of low-carbon hydrogen

Regulatory schemes, particularly in the EU, play a crucial role in driving this transition. By setting incorporation targets and requirements for low-carbon hydrogen adoption and providing incentives like TIRUERT in France, they create market pull for greener solutions.

However, deployment challenges remain. The availability of competitive low-carbon electricity, rising interest rates, and infrastructure limitations pose significant hurdles. Moreover, the willingness to pay for low-carbon hydrogen varies across sectors, influencing adoption rates.

Ultimately, the successful integration of low-carbon hydrogen hinges on striking a balance between technological advancements, cost reductions, supportive policies, market demand and the willingness of consumers to pay. As we navigate this complex landscape, it is crucial to focus on sectors where hydrogen’s unique technical, economic, and environmental properties can make a tangible difference in the fight against climate change.

The road to a hydrogen-powered future might be longer and more nuanced than initially envisioned, but with strategic planning and collaborative effort, it remains a vital pathway towards a decarbonized economy.



08

How to meet Data center AI/Gen AI consumption increase?





Caroline Vateau
Sustainable IT Director
Capgemini Invent



Caroline Vateau is one of the French national experts on sustainable IT, she has been working for more fifteen years to measure and reduce the environmental impacts of digital technology from semi-conductors, to datacenters, cloud, applications and information systems. She also manage the Digital Tech for Green Program aiming to identify and assess the digital technologies that could be leverage to accelerate the path to ecological transition.

IT needs to accelerate data center decarbonisation

1. Global IT energy use is already larger than that of many countries, yet its flexible nature makes it a strong candidate for rapid decarbonisation.
2. The levers available include shifting compute power around the world, improving optimisation of the use of data centers, improved design, and use of waste heat in heat networks.
3. Recent alliances between technology companies and power companies are evidence of the strategic nature of power to IT.

Introduction

IT is already a major energy user, and with accelerating energy demand due to advances such as AI, 5G and IOT, IT must be a major contributor to decarbonisation. This will be achieved through continuing the efficiency push, increased compute flexibility, careful locating of data centers, and reuse of waste heat. There is a risk that data centers could destabilise grids by rapidly increasing or decreasing demands, so greater collaboration at the data center to grid interface is needed.

Technology advances are also an important enabler to the Energy Transition, and we will need sophisticated energy management systems, advanced designs for turbines, and better predictive models, all of which will be underpinned by AI and generative AI.



The digital economy accounts for approximately 6-12% of global electricity consumption, translating to 1-2% of global energy use.¹ This results in an estimated 0.69-1.6 gigatons of CO₂ emissions, or about 1.5-3.2% of global greenhouse gas emissions in 2020.²

While data centers represent just one aspect of the IT sector, they are the most concentrated in terms of energy consumption, accounting for 460 TWh, approximately 2% of global electricity demand in 2022, according to the International Energy Agency (IEA).³ The electricity consumption magnitude of a country like France!

This figure is expected to increase significantly given the rising demand for new and advancing technologies, like AI and generative AI, as well as blockchain and cryptocurrency operations. By 2025, global data volume is expected to reach 175 zettabytes (ZB), a marked increase from the 2018 level of 33 ZB.⁴

While data center operators have been actively working on energy efficiency improvements for decades and achieved notable results, the rapid and substantial growth in data and compute power requirements from intelligent technologies, AI, IOT-enabled devices, and 5G, is outpacing these efficiency gains. This growth is, in turn, putting immense pressure on some local power systems and grids, which are struggling to provide the necessary electricity at the required speed, especially during peak periods.

To meet the growing demand for compute power while striving to reduce their environmental impact, data centers need to innovate and integrate more sustainable energy production methods into their operations and even become energy producers themselves. In this article, we explore how the dual challenge of increasing energy efficiency and managing escalating demand underscores the critical role of strategic planning and technological advancements in the future of the digital sector.

The impact of data centers on the grid

The energy profile of data centers has a unique impact on the electric systems due to its relatively flat and stable electricity consumption. Unlike other forms of energy usage that experience significant variations throughout the day or year, data centers maintain a consistent level of demand. This, predictability, is advantageous for systems and grid operators, as it allows for more accurate forecasting and planning.

In one way, this makes data centers a prime opportunity to be served through decarbonized energy sources. However, to enable this shift, organizations must address the challenges of:

- Energy storage since renewable energy sources are intermittent while data center needs are constant.
- Local production to avoid grid developments.

At the same time, there are potential drawbacks: If data centers switch from the grid to backup generators, it often means that they will shift from clean energy to fossil fuels. This can negate or undermine the environmental benefits of using green energy sources.

This issue highlights the need for sustainable backup and storage solutions, as well as local green electricity production to ensure that the environmental impact of data centers is optimized even during power disruptions.

1 UN Trade & Development: Digital Economy Report 2024. <https://unctad.org/publication/digital-economy-report-2024>

2 UN Trade & Development: Digital Economy Report 2024. <https://unctad.org/publication/digital-economy-report-2024>

3 IEA: Electricity 2024. <https://iea.blob.core.windows.net/assets/18f3ed24-4b26-4c83-a3d2-8a1be51c8cc8/Electricity2024-Analysisandforecastto2026.pdf>

4 IDC: Data Age 2025. <https://www.seagate.com/files/www-content/our-story/trends/files/Seagate-WP-DataAge2025-March-2017.pdf>



Decentralizing compute power

The decentralization of compute power is poised to significantly transform the data center model and its associated energy dynamics.

One of the most prominent forms of decentralization is the development of edge data centers. These smaller facilities, located close to the network edge and, by extension, end-users offers several important advantages, including the ability to be powered by local renewable energy sources. This makes them ideal for supporting advanced digital use cases, such as 5G communications, which require high compute and low latency.

In addition, smaller, edge-based data sites can be more easily integrated into local energy management schemes, allowing for the reuse of waste heat, as well as better alignment with renewable energy source availability and avoid grid developments. This localized approach not only enhances energy efficiency but also contributes to a more sustainable and resilient energy ecosystem.

Data centers as an energy producer

The decentralization of compute power could lead to a parallel decentralization of energy production. With respect to data centers, this means developing their own electrical production and/or storage capabilities.

With the potential to establish micro-electric power sites or connect directly to renewable energy sources, data centers could become more self-sufficient and reduce their reliance on traditional power grids.

For example, in Ireland, new policies are being introduced that would allow private companies, most notably, data center operators, to build their own energy infrastructure. This could provide a workaround for a de facto moratorium on data center developments in the greater Dublin area that is in effect through 2028.

Taking a holistic approach to energy management

While the growing use of advanced digital technologies are increasing energy consumption, these very same applications can also have the potential to significantly enhance sustainability efforts for energy companies.

For example, AI and generative AI can support the reduction of electricity consumption through optimized energy management and predictive maintenance. AI can also be used to analyze vast amounts of data to identify patterns and inefficiencies within energy grids, buildings, factories, and transportation systems. This analysis can lead to smarter energy distribution and consumption strategies, minimizing waste and lowering overall electricity usage.

The “push and pull” nature of these technologies highlight the need for organizations to take a holistic approach to sustainability measurement, assessing both the direct and indirect impacts of AI implementation. It also requires companies to have a more complete understanding of the total impact of new technologies.

For example, optimizing the efficiency of EVs through AI could lead to more extensive use of these vehicles, potentially offsetting some of the initial gains in efficiency—a phenomenon known as the rebound effect.

To truly enhance sustainability, energy companies must consider the broader implications of AI and generative AI applications, ensuring that the overall environmental impact remains positive. Integrating AI thoughtfully into operations can help energy companies achieve a more sustainable future while navigating the complexities of energy consumption and ecological impact.



Actions: Making IT more sustainable

IT functions are increasingly challenged to make better and more sustainable decisions to reduce their environmental impact. Here we explore several key actions to effect change:

1. Optimize existing resources. Within IT departments there is a notable potential for optimizing existing resource utilization. For example, analysis conducted by the Capgemini Research Institute revealed that 30% of cloud resources were either unused or misused. By addressing such inefficiencies, IT departments can reduce energy consumption and minimize the environmental footprint of their digital operations. This optimization extends beyond mere energy savings, encompassing the broader potential of digital tools to accelerate the ecological transition.
2. Integrate eco-design into project management and digital service conception. Eco-design is a global approach that allows environmental issues to be integrated at the earliest stages of the project lifecycle. This is crucial because an estimated 80% of emission
3. Repurpose waste heat and embrace direct liquid cooling (DLC) to improve data center operations. Data center operators have an opportunity to repurpose waste heat generated in data centers. While the waste heat from data centers typically has a lower temperature than what is required for district heating systems, the use of heat pumps or similar converters can be used to increase the temperature and make it suitable for various applications, such as heating swimming pools, supporting agricultural activities in greenhouses, or warming nearby neighborhoods. Integration of these solutions into the broader energy management schemes of new industrial zones can enhance their overall efficiency and sustainability.

Further, data center operators can also implement innovative cooling technologies to further reduce the environmental impact of data centers. DLC, which uses a refrigerant or water directly at the processor and server levels to optimize cooling efficiency, offers a more effective cooling system than traditional air-based systems. As this technique gains traction among data center operators, IT functions have the possibility to substantially lower their energy consumption, contributing to a more sustainable digital infrastructure.

5 Capgemini Research Institute: World Cloud Report. <https://www.capgemini.com/insights/research-library/world-cloud-report/>

6 ScienceDirect: Sustainable Production and Consumption <https://www.sciencedirect.com/science/article/pii/S2352550920314433#bib0040>

09

SMRs are *part*
of the answer





Paul Shoemaker
North American Nuclear Transformation
Director



Paul leads our North American Nuclear business, based on decades of experience in nuclear energy, to include operations, engineering, nuclear services, nuclear fuel, and IT systems to support fleet operations.

SMRs are the key to net zero

1. Two fundamental shifts have established nuclear as the key to reaching net zero
 - COP 28 has committed to tripling nuclear energy
 - Nuclear energy is now widely considered clean and enjoys significant public support
2. Massive electricity demand to achieve net zero and rapidly emerging demand from data centers for AI, has tipped the scales towards nuclear.
3. SMRs (AR's) can rapidly be industrialized via proven and defined roadmaps.

Introduction

Nuclear power enjoys strong public support globally as concerns about climate change mount. However, in a watershed moment at COP 28, there was a commitment by 22 members to triple nuclear generation and, most importantly, the formal acceptance for nuclear as a low-zero emissions technology to fight climate change.

The scale for decarbonization of all industries is massive along with the emerging demand for data centers to power AI is driving an unprecedented interest in clean energy. Nuclear with it's dense and firm power is recognized as the key technology to meet this demand.

SMRs, to include Advanced Reactors, broaden the use cases for nuclear as compared to traditional reactors, to address the diverse energy demands for net zero. As result, SMRs have gone from a potential solution to achieve net zero to a critical asset to achieve net zero by 2050.

While nuclear has had it's challenges in the past, the path forward of other renewable technology also has challenges. The difference for nuclear is that the roadmap to success is well understood and proven and all it takes commitment to overcome these obstacles.



Significant Global Support for Nuclear

COP 28

The 28th United Nations Climate Change Conference (COP 28) specifically acknowledged nuclear energy as zero or low emission technology for fighting climate change. Additionally, 22 of the COP member states signed a declaration to triple nuclear generation capacity by 2050 in a clear endorsement of nuclear as a key technology in reaching net zero.

“The OECD Nuclear Energy Agency welcomes the outcome of the COP 28 global stocktake, which for the first time acknowledges the crucial role that nuclear energy could play in helping countries to lower their carbon emissions. Global emissions must reach net zero by 2050.”

General Magwood

NEA Director

• • •

COP 28 was a fundamental turning point in the acceptance of Nuclear power as a key technology in fighting climate change and sent a strong signal to developers and the finance market, that nuclear enjoys considerable government support – thereby de-risking the development of nuclear power.





Public Acceptance

The Public Attitudes towards Clean Energy index shows strong support for nuclear across 20 countries to include

- 1.5x more people support nuclear than opposing nuclear
- Nuclear is preferred over onshore wind, biomass, or carbon capture and storage

Support for Nuclear

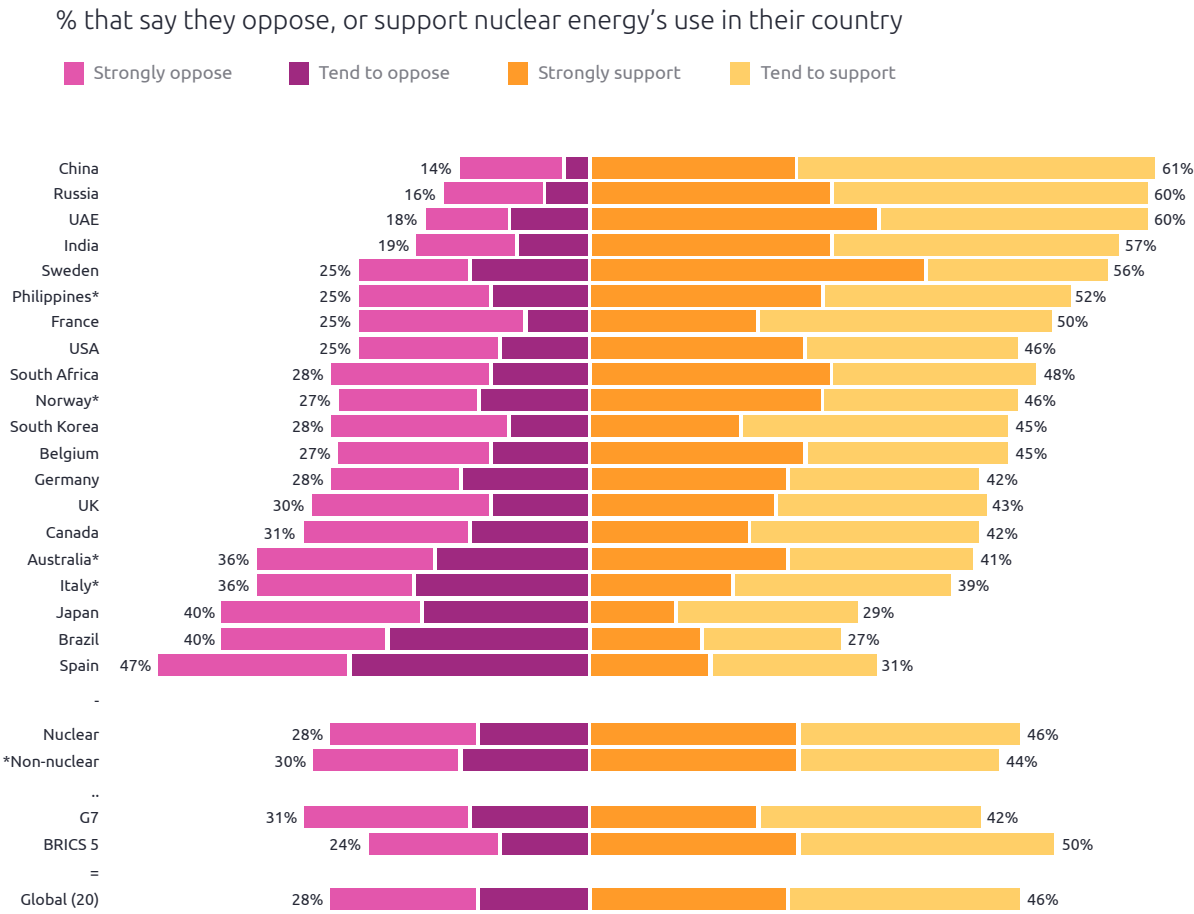
Government and public acceptance of nuclear is a “must have” for the successful development of nuclear, from both a regulatory and a financing perspective. With the spectra of climate change on the horizon and rising energy demands, nuclear is emerging as a clear winner in the path to net zero.

Canada is leading the West

Canada with it’s commitment to net zero by 2050, strong government support and incentives, a close cooperation with the government and the crown corporations that generate electricity, and an aggressive carbon tax policy is leading the way for new nuclear.

OPG has placed orders for 4 SMRs, Bruce Power is reviewing RFI’s for upwards of 4.8 GW of nuclear power, NB Power as launched two projects; one for advance reactors, and one for SMRs for up to 750W of power, and Sask Power is embarking on a project to become a nuclear utility and bring SMRs to Saskatchewan.

FIGURE 1
More people support using nuclear energy than oppose it



Source: <https://www.radiantenergygroup.com/reports/public-attitudes-toward-clean-energy-2023-nuclear>



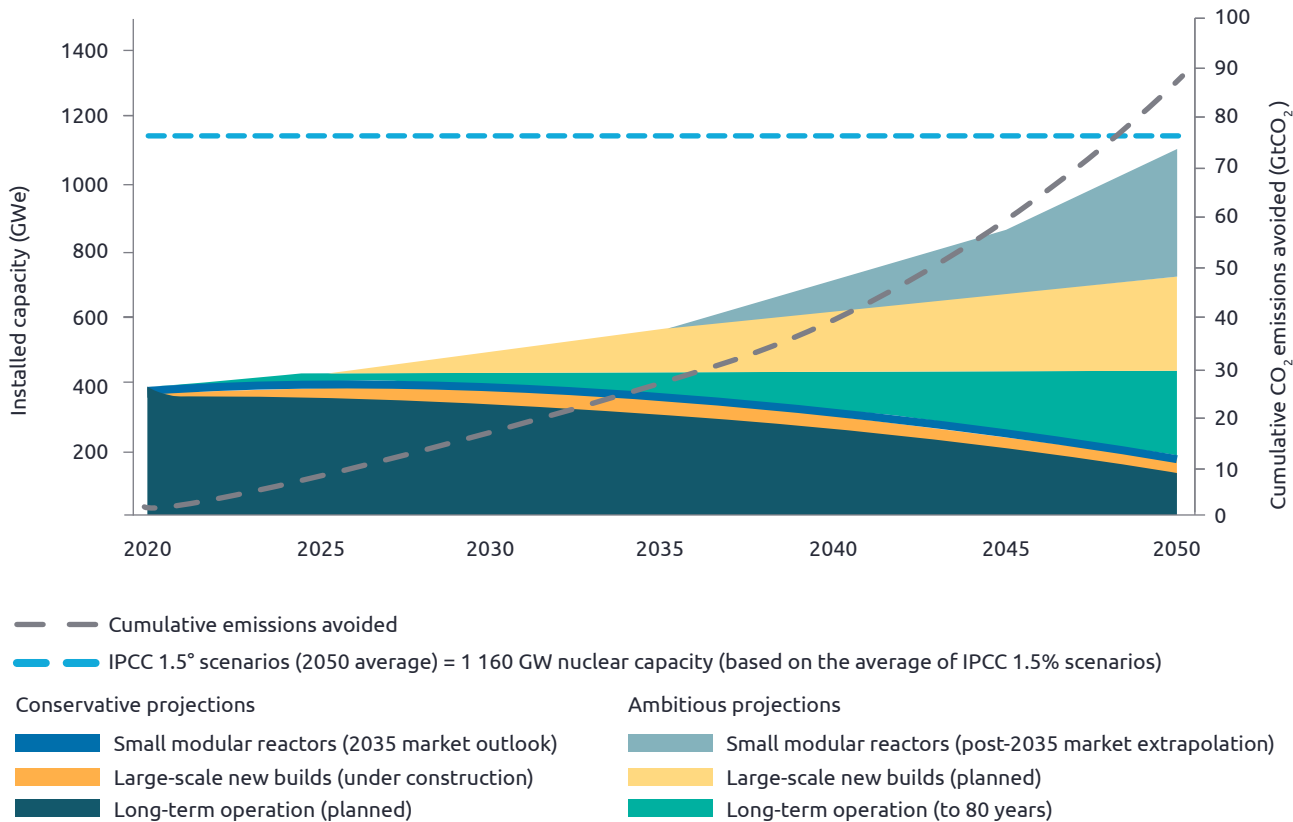
Demand

Global Demand

The [U.S. Energy Information Administration’s 2023 International Energy Outlook](#) predicts global energy demand will increase by 30% - 76% by 2050, with most of that demand met with zero-carbon technologies, like nuclear. To meet that demand the OECD-NEA projects up to 1160 MW of nuclear capacity by 2050, with SMRs contributing >50% of new nuclear as shown:

To meet net zero industrial users will need convert energy usage for electricity and process steam to clean energy. While electricity can be provided by renewables and nuclear, high-temperature process steam will require nuclear to meet this demand at scale. For example, at the SMR Conference 2024 Dow Chemical spoke of an annual all-in energy demand of 7GW at their facilities – this represents about 7 large nuclear plants, or 21 utility -scale SMRs, or 70 advanced reactors. That is just one industrial client, which helps put in perspective the enormity of decarbonization.

FIGURE 2
Full potential of nuclear contributions to net zero



Source: https://www.oecd-nea.org/icms/pl_90816/the-nea-small-modular-reactor-dashboard-second-edition



Rapidly Evolving Demand

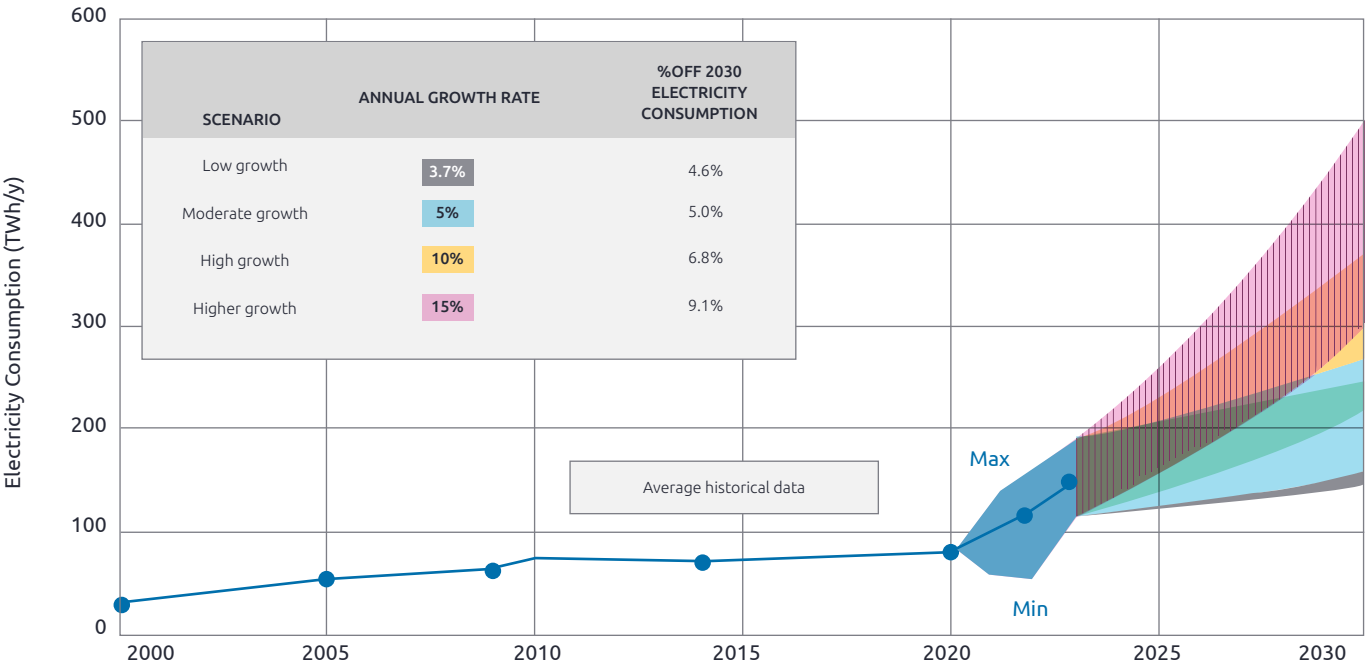
The above reference report was released in October, 2023 and well before the exponential growth of AI that was observed in 2023 after the late 2022 release of ChatGPT. AI is a wild-card in the already rapidly evolving demand forecasting to support net zero targets.

As a result, there are several interesting development by the hyperscalers to secure clean energy. In March of 2024, AWS acquired a 960MW nuclear powered data center from Talen at their Susquehanna Nuclear Station. Microsoft, Google, and Nucor joined forces to aggregate their energy demands to promote and secure clean energy, to include nuclear power.

[Electric Power Research Institute’s Powering Intelligence 2024 White Paper](#) projects data center demand will double by 2026 and represent 9% of the total USA demand by 2030.

FIGURE 3

Projections of potential electricity consumptions by USA data centers: 2023-2030. % of 2030 electricity consumption projections assume that all other (non-data center load increases at 1% annually.



Source: <https://www.epri.com/research/products/3002028905>



Why are SMRs the Key to net Zero

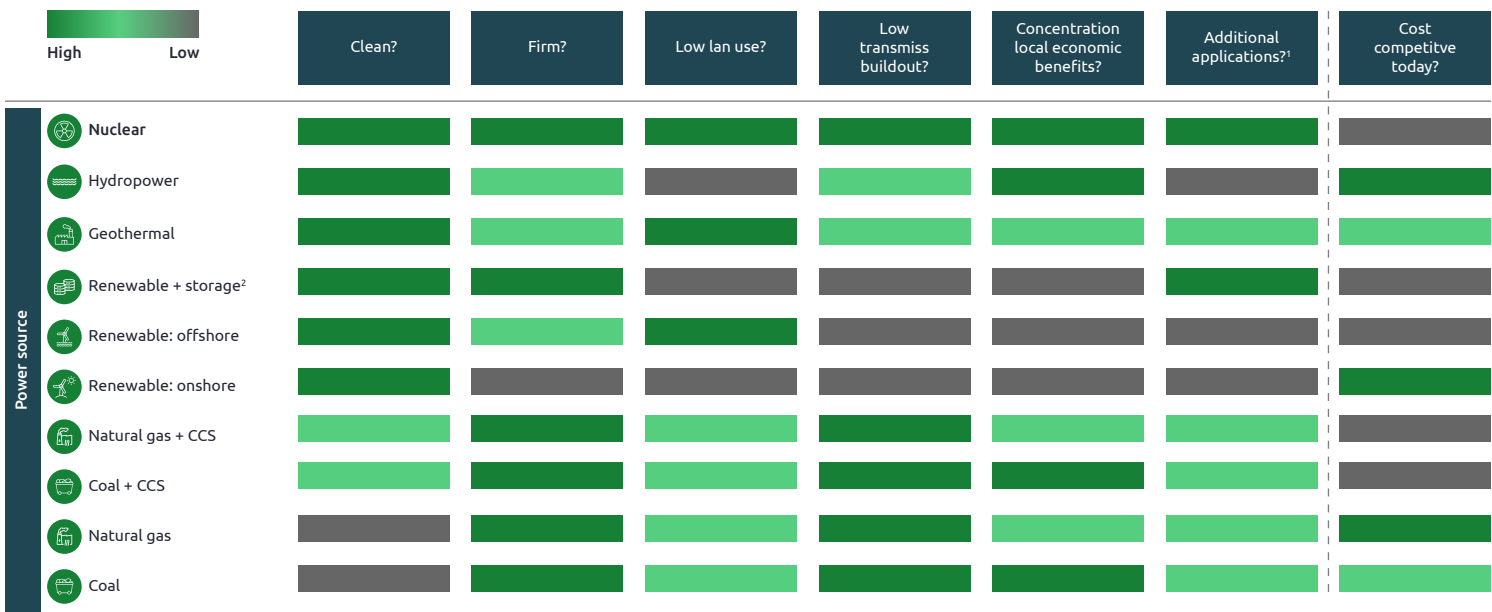
Nuclear the Clear Choice

With strong government and public support for nuclear coupled with a strong growth forecast along with converting the existing demand to clean energy, the market requires large scale expansion of clean energy. The [U.S. DOE Liftoff Report](#) provides a telling comparison of technologies showing a clear advantage for nuclear as the obvious choice for clean energy.

Traditional Large Nuclear

Large, light water reactors, like those that are in service today are sized over 1GW can and will bring significant clean energy capacity to the grid. However, the primary use case for large nuclear is to power the established grid, which does not address the many use cases required for decarbonization.

FIGURE 4
Nuclear the clear choice



1. Additional applications include clean hydrogen generation, industrial process heat, desalination of water, district heating, off-grid power, and craft propulsion and power
2. Renewables + storage includes renewables coupled with long duration energy storage or renewables coupled with hydrogen storage

Source: <https://liftoff.energy.gov/advanced-nuclear/>



SMR Use Cases

SMRs are sized from 10-300 MW using either existing light-water reactor technology. AMRs (Advanced Modular Reactors) use processes developed in large USA federal laboratories or in institutes as the French CEA. There were not built at a large scale, thus the industrialization will be more complex. However, they can offer advantages as simultaneous heat and power production, no need for cooling water, burning nuclear waste.. As a result, SMRs have a variety of use cases that make them the Key to achieving net zero targets:

- On-Grid - to serve more rural areas, repower existing fossil plants, new utility entrants to nuclear, site closer to demand
- Off-Grid – micro-grids, behind the meter supply, Cogeneration, powering industrial and or data center facilities, remote communities, mining, oil/gas extraction
- District Heating – sited close to the demand and replace fossil, biomass, or trash to energy facilities
- Process Heat – as well as electricity for industrial applications
- Shipping
- Desalination
- Hydrogen and SynFuel production

Real World Examples

- Dow Chemical: 4 advance reactors to provide process heat and steam to its Seadrift facility
- Diamondback Energy: Nuclear for drilling operations in the Permian Basin
- Synthos Green Energy: Planning to repower its industrial base in Poland
- Ontario Power Generation: Building 4 SMRs for on-grid application
- Green Energy Partners: A nuclear-powered data center next to Surry Nuclear Station
- Norway: SMRs to power data centers and as well as powering an isolated community

Challenges ahead

Not First of a Kind

SMRs aren't really new, and that fact is often lost in the discussions re the viability of SMRs. Hundreds of small light water reactors have been built and in service today for naval reactors in several nations. Whereas advanced reactors have been proven in national labs with decades of experience. So, the challenge is not technology, but industrialization of the technology. For example, the industrialization of the French SMR Nuward has proven complex and has led to a delay in the design of this platform.

Industrialization

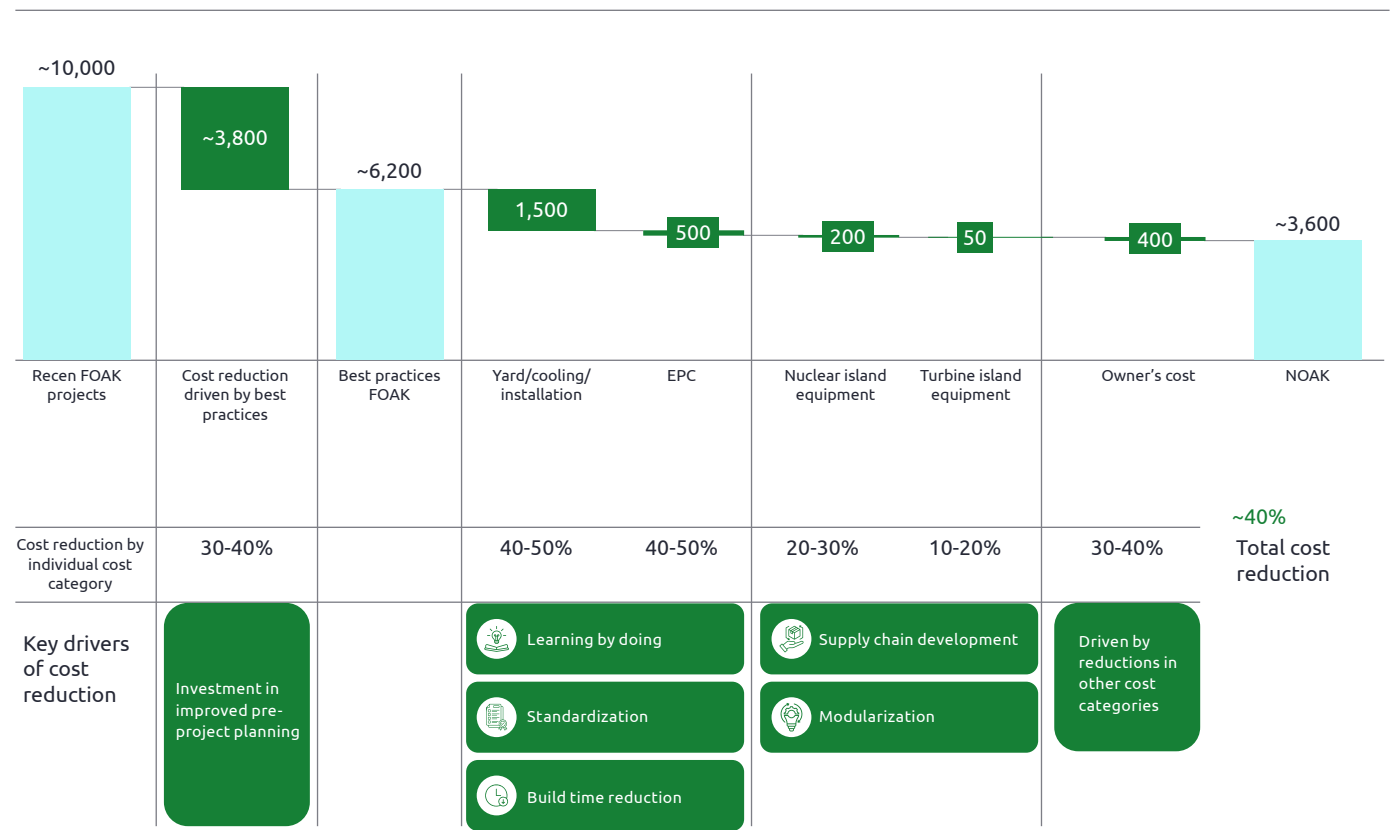
As shown in the U.S. DOE Liftoff report all of the many competing clean technology, necessary to reach net zero, haven't been industrialized to the point of cost competitiveness. However, in nuclear there is a lot of operation experience, and lessons learned, so the roadmap to cost competitiveness is well defined. The DOE anticipates that a minimum order of 10 units will be necessary for the industrialization of a particular platform.

The issue is not competency - it is simply a critical mass of back orders to facilitate investment to industrialize and drive down costs. Much like the model for new airliners – the OEM's design a platform, but don't build until they have a confirmed order book. GE Hitachi, with it's 4 confirmed OPG orders, and significant potential backlog will likely lead this new market. With GE's success the challenge will not be how to get the industry off the ground, but how to meet the demand.



The U.S. DOE’s Lift Off report shows a path to drive NOAK costs to a competitive \$3,600/KW, yet still above Korea’s \$2,300/KW over 7 reactors.

FIGURE 5
Potential advanced nuclear FOAK to NOAK overnight capital costs \$/kW



Source: <https://liftoff.energy.gov/wp-content/uploads/2023/05/20230320-Liftoff-Advanced-Nuclear-vPUB-0329-Update.pdf>

Our Convictions

- The support, both from governments and the public, is at an all-time high and increasing. This support is paramount for the industry to succeed.
- Energy demand, primarily for electricity and process heat, is significant, requiring an enormous expansion of current capacity.
- Rapidly growing data center demand is disrupting the current demand landscape and which will necessitate reliable and firm clean energy
- Nuclear is a clear and overwhelming winner for firm, reliable, and dense power that will be required for the massive energy demand to support net zero
- SMRs and AMRs with their multiple technologies and uses cases will support wide-scale adoption for a multitude of clients, breaking free from the utility monopoly and becoming the Key to achieving net zero

10

Electricity
Consumption
is not *rising* as
predicted in
Europe





COLETTE LEWINER
Energy & Utilities Expert



Colette Lewiner is a worldwide Energy expert with more than 40 years of experience, and deep knowledge from industrial operations, IT consulting and Companies management and governance. She is also an Independent Director on boards of public or private Companies.

Key Points

- 1. Net zero Carbon scenarios forecast a very significant increase in electricity consumption
- 2. This will result in an increased electricity percentage in the energy mix.
- 3. In addition, new large electricity needs will arise from the Artificial Intelligence development
- 4. In contradiction with above, electricity consumption in Europe in 2023 was lower than in previous years.
- 5. The article below analyses this phenomenon and concludes that the energy transition is lagging

Introduction

All the net-zero-carbon scenarios for 2050 forecast a very significant increase in electricity consumption, which is set to quadruple in 30 years.

To combat the growth in greenhouse gas emissions linked to energy consumption, the growth in energy demand has to be limited and fossil fuels must be replaced by renewable electricity (hydro, solar and wind) and low-carbon nuclear electricity. The overall result is an increased electricity percentage in the energy mix.

In addition, the technological transition will involve massive use of data needed to develop artificial intelligence, and in particular generative artificial intelligence. The increase in the number of data centres needed to process this data will result in a sharp rise in electricity consumption.

However, electricity consumption in Europe in 2023 was lower than in previous years!

This is in contradiction with the forecasts described above.

The article below analyses this phenomenon and concludes that the energy transition is lagging.

This is confirmed by the low growth, over the last twenty years, of the electricity penetration rate in total energy consumption in Europe and North America.



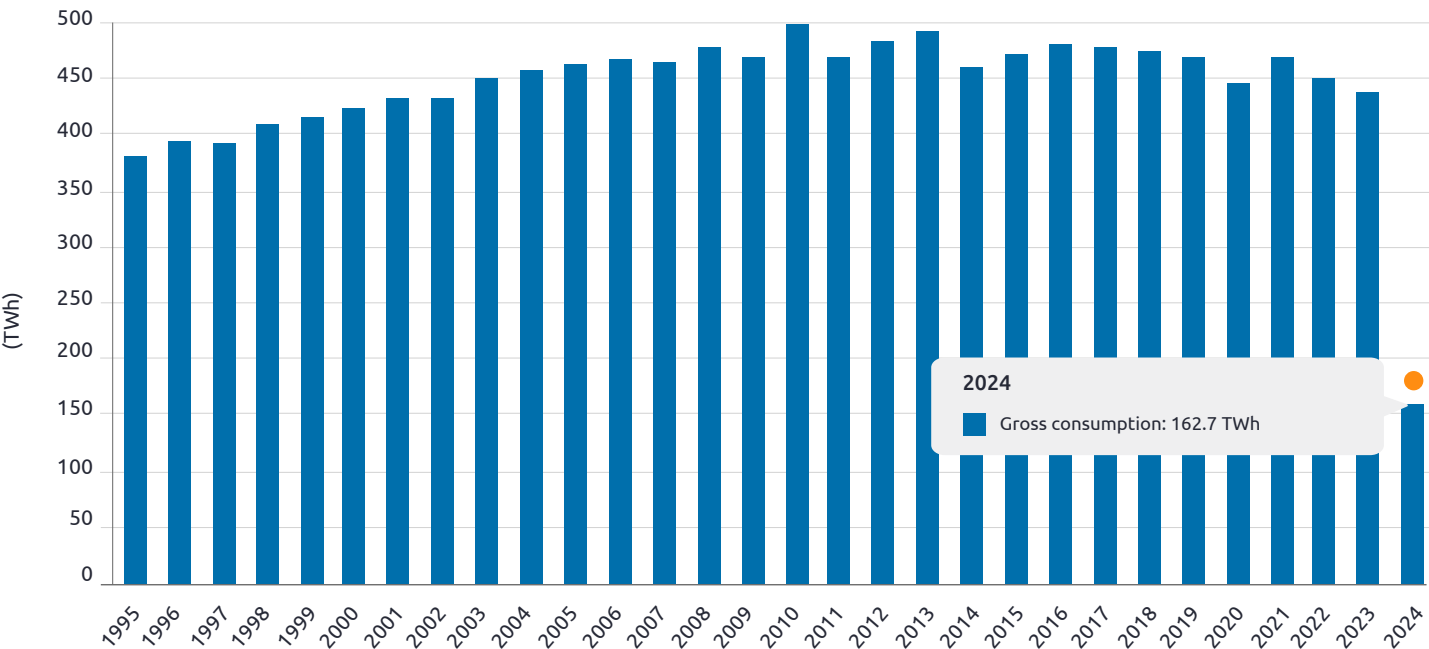
France: Electricity consumption

In 2023, electricity consumption in France, corrected for temperature effects, was equal to that of 2007.

This is contrary to forecasts which estimate that global electricity consumption would increase by a factor of four by 2050.

This drop in consumption is linked, on the one hand, to the persistence of individual behaviors to control electricity consumption initiated in 2022 under the pressure of very high prices and fears about the security of electricity supply (see WEMO 2023). On the other hand, the French economy, in general, has been stagnant (growth of 0.9%) and the activity of the industrial sector, which consumes electricity, has decreased slightly.

FIGURE 1
French electricity consumption corrected from temperature effects





As a result, spot electricity prices were negative on certain days and a few nuclear power plants were shut down (for nuclear fuel savings) because they were not needed on the grid.

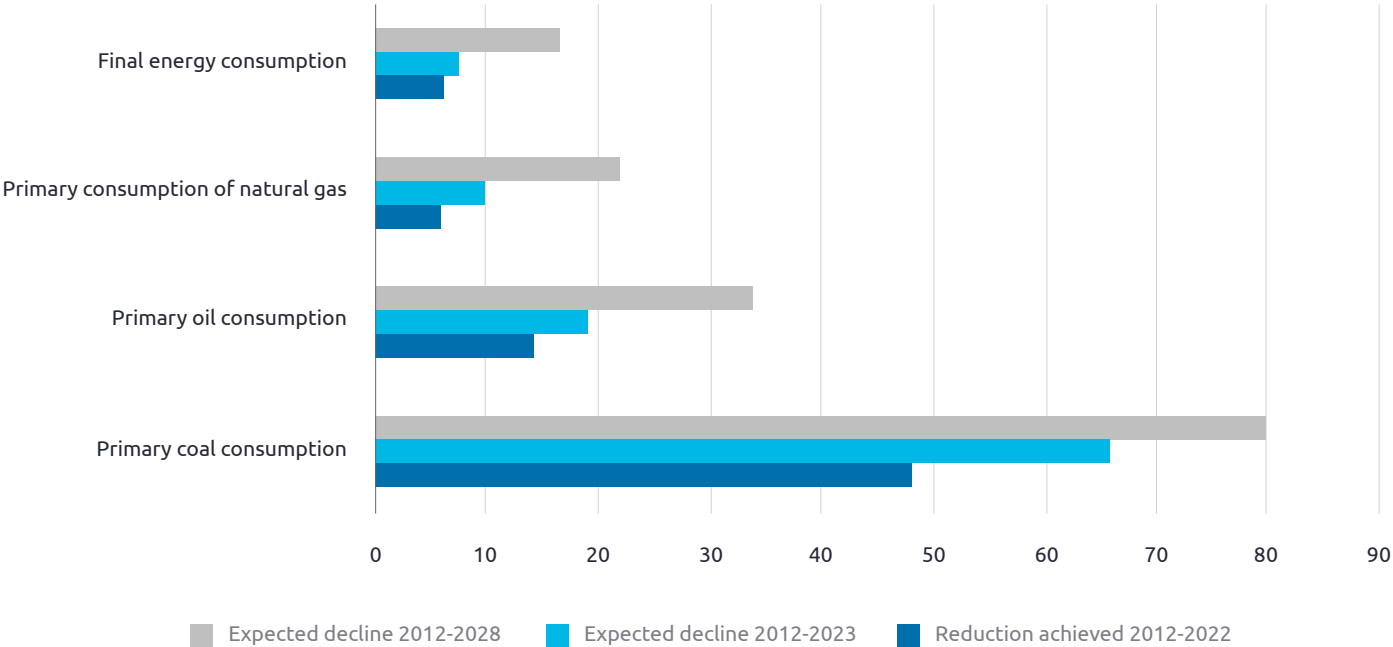
If this situation persists, the return on investment for the construction of new nuclear power plants will deteriorate.

This is, theoretically, also true for wind and solar farms which are, like nuclear electricity, very capital-intensive electricity generation technologies. However, these renewable energies often benefit from subsidies or guaranteed sales prices.

The non-growth in electricity consumption and the stability of the penetration rate of electricity consumption in total energy consumption (see figure 3) reflect a significant delay in achieving the objectives of the energy transition (see figure 2).

For example, certain industrial sectors could be decarbonized by using electricity instead of gas or coal (in ovens, for example). However, this requires heavy investments that manufacturers are hesitant to decide on in periods of low growth and low energy prices.

FIGURE 2
Energy transition perspective





EU electricity consumption

EU electricity demand fell by 3.4% (-94 TWh) in 2023 compared to 2022 and was 6.4% (-186 TWh) lower than 2021 levels (when the energy crisis began). It reached its lowest level in 20 years!

As for France, slowdowns in European economies are mainly accountable for the decrease in demand. The industrial slowdown was responsible for two-thirds of the net reduction in EU electricity demand in 2022.

According to the IEA report¹, overseas subsidies such as those included the U.S. Inflation Reduction Act of 2022 (IRA) and Japan's Green Transformation Policy "are influencing production curtailment, plant closures, and the pausing and diverting of investment."

Rate of electricity in the total energy consumption

The share of electricity consumption in total energy consumption differs between developed and developing countries.

Since electricity production and distribution require significant and capital-intensive infrastructures, the electricity penetration rate is higher in developed countries than in developing countries (see figure 3).

The evolution over the last 20 years shows a very small increase in the share of electricity consumption in total energy consumption in developed countries, such as those in Europe and the United States, and a much stronger increase in developing countries. For example, from 2000 to 2022 this rate increased modestly in Europe from 18.6% to 21.5% and from 19.8% to 22.3% in North America. Meanwhile, in Asia, it increased from 13.6% to 24.2% and from 12.5% to 16.6% in the Middle East. However, during these years this share remained low (around 10%) in Africa.

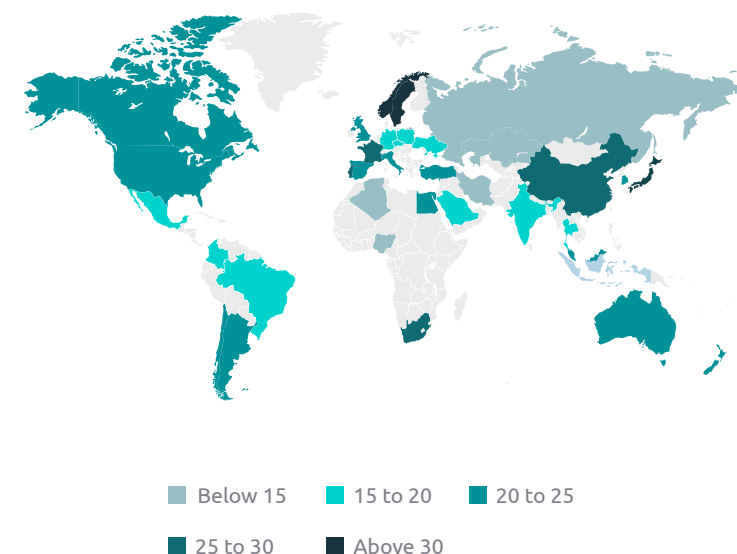
This shows that economic development goes hand in hand with an increase in the electricity penetration rate. Therefore, we can predict that the global increase in electricity consumption will mainly come from developing countries.

Let's hope that this electricity will be produced from clean energy sources. If that is the case, it would be an important decarbonization factor. If not, it would have a very negative impact in the fight against climate change.

FIGURE 3

Share of electricity consumption in total energy consumption by region

Share of electricity in total final energy consumption - 2022



Source: www.enerdata.net

¹ IEA...

11

*Geopolitical
impacts*
will maintain
uncertainty in
energy markets





Philippe Vié
Senior Advisor
Energy Transition and Utilities



Philippe has led the Capgemini Energy sector and now serves as an advisor for Capgemini, as well as large utilities or equipment suppliers. Philippe has been observing the market for many years and has sponsored the WEMO survey for more than a decade.

1. Not a day passes without news about physical or cyber energy infrastructure attacks.
2. In response, sovereignty measures are being taken daily by regions and countries to protect against geopolitical tensions or market uncertainties.
3. In 2024, there are many national elections, the results of which can impact the country’s energy transition strategies.
4. Key questions include:
 - What are the actual situations and threats on the energy systems?
 - How are states and players managing these risks?
 - What are the consequences, notably on supply chain, continuity of energy supply and energy prices?
 - How should we move forward fast enough to decarbonate the planet with such uncertainties?
 - How do we achieve a fair and balanced path to decarbonization while also achieving both sovereignty and affordable energy prices?

Geopolitical events and uncertainties will impact the pace at which we can decarbonize the energy system, as more money is diverted to ensuring sovereignty and security of supply.

Introduction

The world needs certainty to build large energy assets. Growing and decarbonizing energy systems to meet demand means building large electricity assets, such as power plants, energy storage systems, and energy infrastructures. Large asset construction requires policies and regulation stability, supply chain continuity, and the ability to secure private and public funding, which annually requires trillions of dollars in investments. Demand-side flexibility is also becoming critical as use of intermittent renewable generation grows, which needs positive consumer engagement enabled by governments.

However, the world is currently facing conflicts, such as Russia’s invasion of Ukraine and the Israel-Hamas conflict, where energy assets are frequently targeted. Additionally, tensions between China and the USA are leading developed countries to implement energy sovereignty measures, often using the U.S.’s Inflation Reduction Act as a model.

Finally, elections taking place this year in many countries highlight different black and green energy visions from the candidates, which also leads to uncertainty.



Wars are impacting energy systems

- Physical and cyberattacks on vital energy systems are becoming more and more frequent.
- Energy and utilities players are reinforcing physical and cyber protections.
- Governments and regulators are acting to put requirements for protections in place. For example, the European Union Network and Information Security 2 (NIS2) policy requires increased levels of cybersecurity across sectors.

The economics of energy are becoming more volatile

- Costs of borrowing are increasing for energy players, where costs for large clean tech assets (renewables, nuclear, hydrogen, grids, batteries) represent about 80%+ CAPEX, 20%- OPEX.
- Commodities and equipment prices are becoming more volatile and are generally increasing.
- Investment payback uncertainties are slowing down investment decisions (FIDs) and project development, leading to slightly higher energy costs to consumers and a slower path to decarbonization.

Sovereignty is becoming a priority

- Concentration of energy technologies and resources in China: China now leads all low-carbon technologies markets, thanks to a very large domestic market combined with low labor costs and protectionist policies.
- Energy markets principles to encourage inward investment must be reinvented; they must also encourage flexibility to balance renewables.
- Protectionist measures are being developed in the USA and Europe.





Tensions, threats and uncertainties

Attack multiplication, physical and cyber

Physical attacks



Kakhovka Dam (2023/06)



Nord-stream II (2022/09)

Cyberattacks (extract)

- 2015/12: Ukrainian electric network hacked by Russia.
- 2018/03: The U.S. Department of Homeland Security revealed that Russia was regularly penetrating its energy network since 2017.
- 2024/01: Schneider Electric's sustainability business division experienced a ransomware attack and data breach.
- 2023: Iranian gas stations network hacking.
- 2023/08: The monespaceprime.engie.fr website, managed by an Engie subcontractor, experienced a data breach. The personal data of 110,000 clients was stolen.
- 2022/03: In Germany, remote maintenance of wind turbines was compromised after the KA-SAT network, operated by the American company Viasat, was attacked by Russia.
- 2021/07: Hackers infiltrated the IT systems of the U.S. Colonial Pipeline, a network spanning 8,850 kilometers that transports 2.5 million barrels per day. As a precaution, Colonial shut down the pipeline following the ransomware attack, which was launched by the DarkSide gang.
- 2017: Hackers used the Triton virus to remotely take control of the security systems of a Saudi Petrochemicals plant and shut it down.
- 2022: A large-scale cyber-espionage campaign targeting Chinese gas fields and offshore parks has been carried out by the cybercriminal group TA423.
- 2024/02: The hacktivist group LulzSec has claimed responsibility for stealing data from EDF's retail branch, affecting 500,000 B2B and B2G client accounts. EDF has confirmed about 20 unauthorized client access incidents and has advised these clients to change their account access details.

Energy & Utilities sector reports that hacktivists (69%) and state-sponsored actors from foreign powers (62%) pose a greater cyber threat than criminals, terrorists, or vandals.



EDF European net zero scenario: a pivotal step towards energy sovereignty and net zero Emissions in Europe (1/2)



Catherine Bauby
EDF Group Strategy Director

Since more than 20 years, Catherine has held many management positions in the EDF Group, including transformation director for the finance direction. Catherine is also board member of Enedis and UFE.



EDF European net zero scenario for 2050. Balancing decarbonization, sovereignty and competitiveness

Being net zero by 2050 in Europe is a given for EDF, which has published this spring 2024, its recommended technico-economically optimized energy transition scenario. Europe is starting from a final energy consumption of ~60% fossil fuels, mostly imported, and 20%+ electricity, with a still carbonized electricity mix (coal and gas power plants). The EDF scenario relies on two main pillars:

“Consume less, consume better ” by: • changing behaviors (10%) • electrifying energy uses (60%) • being energy efficient (30%)	Central role of electricity • 60% final energy demand coverage (from 20%+ today) • a fully decarbonized electricity mix made of renewables (77%), nuclear (16%), and decarbonized thermal
-40% final energy demand vs 2021	100% decarbonized electricity to cover 60% of the energy demand

With this share of intermittent and distributed electricity generation, developing grids and enabling enough flexibility at various time scales (from intraday to seasonal) are critical.

Governments have a key role to enable any optimized net zero scenario. It includes :

- Aligning policies on what is required : heat pump and EV fast development for instance.
- Also supporting large assets investments in renewables, nuclear, grids and storage notably.
- Setting CO₂ meaningful price signals, and reinvesting collected climate taxes to support vulnerable consumers and industries competitiveness.



[To discover more about EDF net zero scenario](#)



EDF European net zero scenario: a pivotal step towards energy sovereignty and net zero Emissions in Europe (2/2)



What should Europe do to increase its energy sovereignty?

The EDF net zero scenario brings sovereignty:

- **Fossil fuels**, mostly imported, are declining in the energy mix from 63% today to about 4% gas CCS-equipped.
- **Electricity** produced locally in the 2050 mix, covering 60% of energy demand.
- Europe has the potential to maintain or strengthen its industrial leadership in several key technologies: nuclear energy, wind turbines, heat pumps, and electrolyzer factories now, and battery gigafactories in the near future.

Industrial issues:

Europe depends on imports, particularly from China, for certain technologies and resources like solar panels and critical raw materials. However, it has the potential to boost its resilience in the future, for example, through recycling initiatives as proposed by the European Critical Raw Materials Act.

The Energy Transition presents a significant development opportunity for European industry, provided it is supported by proactive industrial policies at the European level. This includes the effective implementation of the NZIA package and strong support for European champions in the energy sector—companies need to be large enough to compete internationally. This approach requires an evolution of current European competition policies.

Finally, **the energy technologies industries are creating jobs between now and 2050, including:** 530K total FTEs for nuclear; 320K for offshore wind; 650K for solar; 160K for heat pumps; 150K for batteries in the 2030s, and many more for electrolyzers, gigafactories, and electric grids.

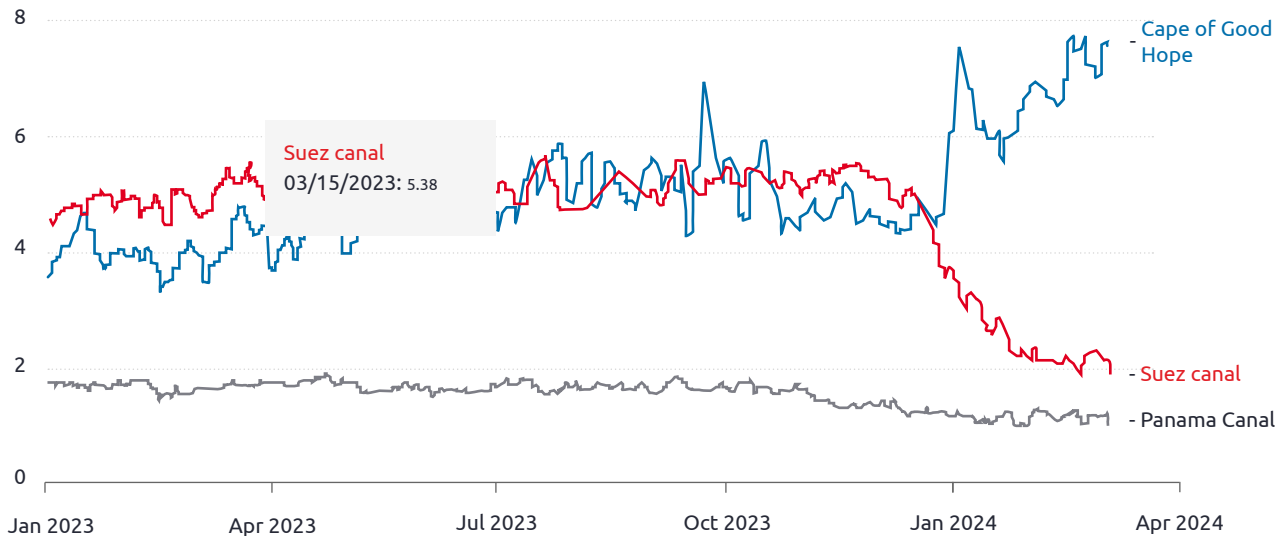


Tensions, threats and uncertainties

Supply chain disruptions

Attacks in the Red Sea are disrupting the LNG supply chain and increasing slightly the gas transportation price.

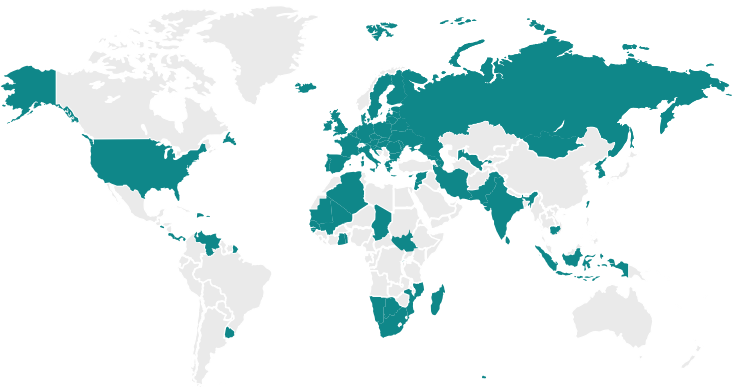
FIGURE 1
Daily transit trade volume
(million metric tons, 7-days moving average)



Source: UN Global Platform, IMF PortWatch

Elections could influence the energy policies

National elections are scheduled or expected in at least 64 countries in 2024, as well as the European Union, which together represent almost half of the global population.



Source: <https://time.com/6550920/world-elections-2024/>

Politicians are generally elected for 4 to 5 years and have the power to completely shift energy policies, when an energy asset lifetime is counted in multiple decades. And their planning and construction may take 10 to 20 years.



Sovereignty initiatives and impact on final prices

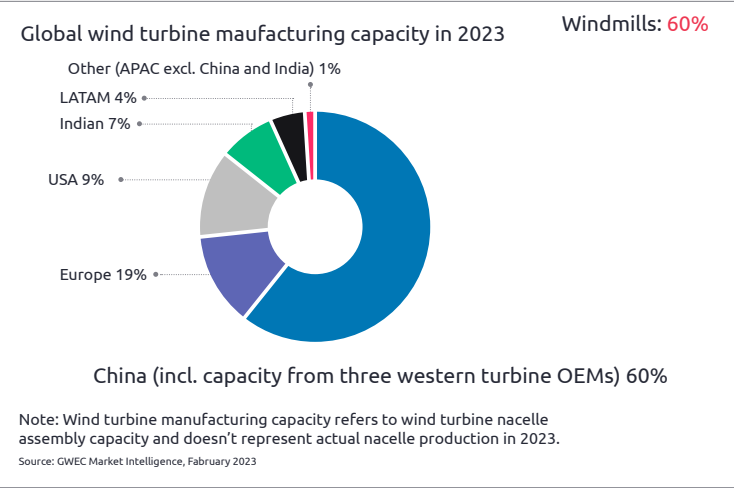
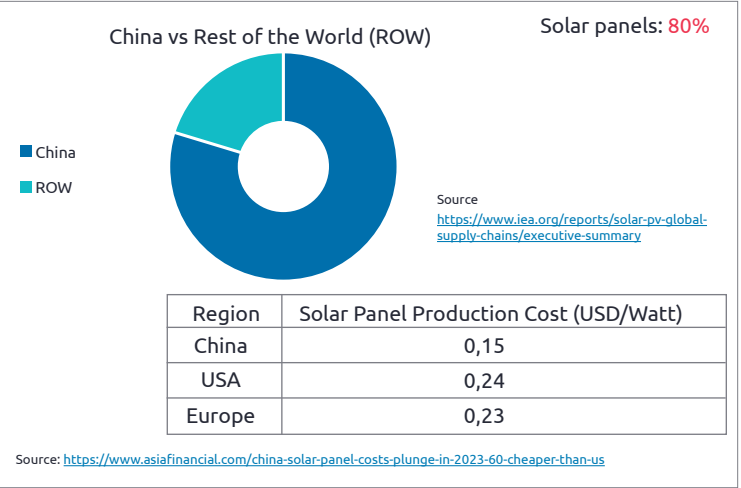
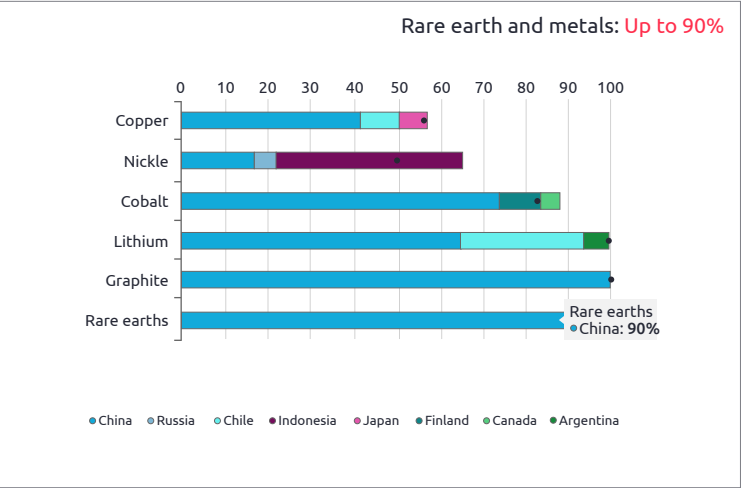
The 2022 **Inflation Reduction Act** in the USA aims to boost low-carbon energy and the American economy, with support exclusively for USA-based companies. The goal is also to lower local energy prices, though there are ongoing debates about the actual impact of this regulation on electricity price reductions. Additionally, the USA has implemented taxes to curb the influx of Chinese electric cars and diminish the competitiveness of Chinese solar panels.

- Europe has voted on many regulation packages devoted to climate change, energy and industry, notably:
- **Fit for 55** (decarbonation)
- **Net zero Industry Act** (revitalizing European industry from a climate change perspective)
- **REPowerEU** (managing the Ukraine/Russia war consequences and securing European energy supply)
- **Energy Market Reform**

Europe is more advanced than the USA in terms of energy transition. However, the USA is showing the way forward as it relates to **sovereignty**. The USA, which is largely self-sufficient and even an exporter of fossil fuels, is successfully attracting low-carbon projects such as gigafactories. In contrast, European sovereignty measures, which are significantly less robust than those in the USA, are likely to result in higher energy prices for consumers.



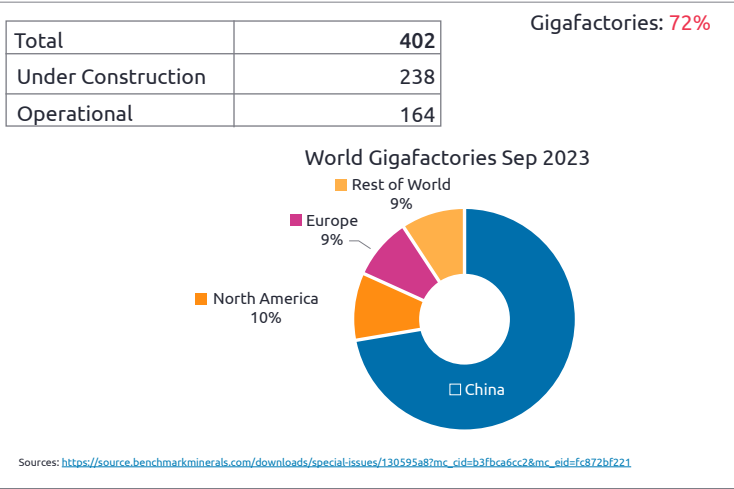
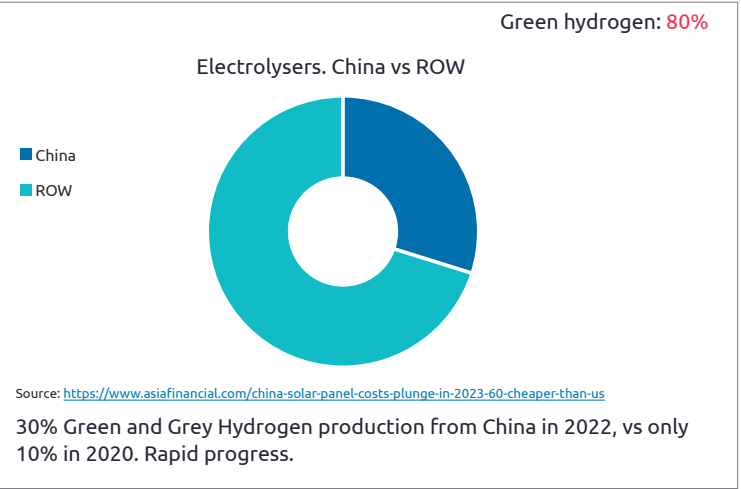
China's dominance in low-carbon technology is so significant that the world relies on China for the energy transition.



Nuclear 3rd generation reactors

Country	Units	Status	Chinese tech?
China	2 (Taishan 1 and 2)	Operational	Yes
France	1 (Flamanville 3)	Under construction	No
Finland	1 (Olkiluoto 3)	Operational	No
UK	1 (Sizewell C)	Planned	No
UK	1 (Hinkley Point C)	Under construction	No

3rd generation technology (EPR) dominating up to now is coming from French EDF and AREVA. China currently has the second-largest nuclear fleet across all generations (after the USA and ahead of France) and is on track to become the largest in the near future.





Energy conservation and flexibility have been forgotten

Expanding large assets to ensure sovereignty is only one side of the coin. Building new assets comes with costs, which ultimately affect the customer's bill. Reducing energy consumption through extensive conservation programs and efficiency measures is a clear strategy to limit demand and the need for capital expenditures. Recent experiences, particularly with price increases due to the Russia-Ukraine conflict, have demonstrated conservation results ranging from **10% up to 30%** in optimal conditions.

Flexibility is another issue that can limit assets development. Flexibility varies from one location to another, depending on the demand (on public grids), the generation potential reserves (gas plants, hydro dams, etc.), the processes interruption or shifting reserves, as well as the storage capacities. Here also, a peak shaving potential can go up to 15%, combining the three major levers of customer participation, tariff signals and automation, in an aggregated perspective. This enables use of distributed and small resources.

Enough compensated capacity markets are to be organized.

Flexibility means new services enabled by system operators and regulation rules and tools, such as capacity markets. These services must be integrated for capacity reserve mechanisms, procurement, use and remuneration of capacity. There are no silver bullets here—only the willingness of authorities to get and set appropriate remuneration. Each market will have its own customized solutions.

Our Convictions

- Geopolitical tensions will continue, resulting in uncertainty remaining in energy systems and markets.
- A tough balance needs to be found between energy sovereignty (independence) and affordable energy for customers in an accelerated net zero pathway.
- All levers are necessary to fight against climate change:
 - Clear and stable policies are critical for new energy asset development, at least at the regional level, and must be rock solid;
 - Energy system long-term planning is highly recommended, with government support;
 - Energy conservation and flexibility are becoming crucial.
- It's important to put in place mechanisms and tools to:
 - Stimulate investments in the chosen dimensions (long-term contracting mechanisms, CfD for instance, public support);
 - Enable energy conservation and flexibility;
 - Support market relevant principles (wholesale, flexibility, carbon markets) preventing price volatility and a significant shift from local reality to prices formation
- Acceleration innovation in energy technologies is essential – wind, solar, smart grids, and batteries.

12

Industrial Heat is
in the *blind spot* of
energy transition





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Key points

1. Decarbonization of Heat is Crucial: Heating accounts for 50% of global energy demand, with over 70% generated from fossil fuels. This highlights the urgent need to decarbonize heating and cooling, which collectively contribute to 39% of global CO₂ emissions, particularly in the industrial sector, where industrial heat alone accounts for 22% of global emissions.
2. Technological Solutions Exist: Proven low-carbon technologies, such as heat pumps and electric boilers, are already delivering results for medium and low-temperature industrial processes, which represent 60% of heat consumption. For energy-hungry industries that require extremely high temperatures—such as steel, chemicals, and cement—shifting to alternatives like hydrogen, green ammonia, and biofuels is essential, as these solutions hold significant potential for reducing emissions.
3. Collaboration and Innovation are Key: Successfully addressing the complexities of decarbonization demands partnerships across diverse sectors, including industry, academia, and regulatory bodies. By creating a collaborative ecosystem that supports new business models; by minimizing investment risks and leveraging digital technologies, organizations can accelerate the adoption of climate solutions and effectively tackle the challenges of decarbonizing heating and cooling systems.

Introduction

Heating accounts for half of the world's energy demand, yet the efforts to decarbonize heating and cooling—responsible for a staggering 39% of global CO₂ emissions—have not kept pace with the urgency required to combat climate change. The challenges associated with transforming how we generate and use heating and cooling are multifaceted, varying primarily by sector, industry, process type, and temperature level. In this article, we will delve into the current status of decarbonization efforts within the buildings and industrial sectors, highlighting the specific challenges they face in transitioning to sustainable heating and cooling solutions.

Additionally, we will provide a comprehensive list of actionable steps and enabling factors that can help overcome these complexities and accelerate the path toward a more sustainable energy future.



The decarbonization of heat is a key challenge

50%¹ of the demand for energy is for heat. Over 70%² of that heat is generated directly from fossil fuels. This stark fact emphasizes that the decarbonization of heat – and cooling – is critical to the future of our planet. The shift from generating heat from fossil fuels, to generating heat from zero emissions, is essential to mitigating the impacts of climate change.

Shift the spotlight to heat

As we focus on energy transition and the journey towards net zero, the decarbonization of heat has not yet been a sufficient priority. Yet the rewards are significant and not all opportunities are in hard-to-abate sectors.

Efforts to decarbonize heating and cooling, which is responsible for 39%¹ of global CO₂ emission, have been lagging. Now is the time to shift the spotlight to decarbonization.

¹ International Energy Agency, Renewables 2022 <https://www.iea.org/reports/renewables-2022/renewable-heat>

² IRENA: Power to heat and cooling: Status

Industrial heat in focus

Industrial heat is a significant part of these emissions, with 20%³ of global emissions being currently produced by industrial heat. Decarbonizing energy-hungry industries that require extremely high temperatures, like steel, chemicals and cement, is challenging. But the potential positive impact of shifting to solutions like hydrogen, green ammonia, and other biofuels or, where possible, electrification sources, is huge.

Medium and low temperature industrial processes, which include pulp and paper, food and beverages, plastics, and some chemicals, make up 60%⁴ of heat consumption. Here, proven low-carbon energy alternatives, such as heat pumps and electric boilers, are already established and delivering impressive results.

Time to get moving

Established methods are available to directly reuse or upgrade waste heat from industrial processes. The applications can include low temperature processes, space and water heating, as well as cooling provided via heat pumps.

³ McKinsey & Company: Industrial heat pumps: Five considerations for future growth

⁴ IEA: Industrial heat demand by temperature rang

Newer technologies also allow for the storage and transfer of heat energy for onward use. They are already replacing heat generation from fossil fuels at the higher end of the temperature scale.

Thermal batteries store heat using a variety of technologies and can be used in a wide range of industrial use cases. They contribute to improved sustainability and lower cost of heat via two routes. The first is by decoupling timing of energy consumption and heat consumption. For example, by charging when electricity is cheap and then using heat when it's needed. And the second is by providing flexibility in the grid, enabling asset owners to be paid to use electricity when there is overcapacity / supply surplus in the grid.



Don't underestimate residential and civic demand

Demand for the heating of residential and civic buildings is almost the same as industrial demand for heat. This observation is less surprising when you realize that district heating is mainly used by buildings and not industry. In fact, according to the International Energy Agency⁵, industrial processes account for 53% of demand, buildings account for 44%, and agriculture the remaining 3%.

However, the shift away from gas to green technologies, such as heat pumps, is accelerating in civic and residential buildings. Likewise, district heating and cooling systems are increasingly viable and attractive. Especially in urban, multiple occupation locations providing shared access to low-cost, low-carbon heat and cooling.

District heating, also known as a heat network, is a system for distributing heat generated in a centralized location through a system of insulated pipes. It satisfies residential and commercial heating requirements, such as space heating and water heating as well as low temperature industrial process heating.

Overcoming complexity

Various challenges need to be overcome to accelerate the scale and speed of the decarbonization of industrial, civic, and residential heating and cooling.

We must consider variations in technological and supply chain maturity. The establishment of appropriate financial, investment, incentive, subsidy and regulatory models. The role of partnerships and collaborative innovation in overcoming technical hurdles. The identification of new and cost-effective ways of replacing key components within traditional industrial processes. And, of course, the huge role of digital and AI.

⁵ International Energy Agency, Renewables 2022 <https://www.iea.org/reports/renewables-2022/renewable-heat>



To enable decarbonization at speed, we've identified several actions and enablers:

Actions:

Support for new business models. Governments can reduce the risk of embracing new technologies by lowering the barriers for industry players to test and adopt. For example, by providing funding for trial schemes where a third party owns and operates the asset and sells back heat-as-a-service, less risk is carried by the plant where the asset is installed.

Research into proving technology to system integration is needed. Assess the impact of decarbonization on existing systems, including impact on overall costs, product performance, reliability, sustainability, and compliance. This means modelling scenarios and running simulations that assess these impacts and feed into the organization's climate tech adoption strategy, de-risking investments.

Explore ecosystem integration. Work as part of an ecosystem of organizations across the value chain and wider industry to address the complexities of decarbonization. All ecosystem members will need to work closely with a broad group of stakeholders including industry peers, academics, startups, regulators, and non-governmental organizations (NGOs).

Move from analog to digital. Develop digitally enabled industrial systems, such as power plants, energy infrastructure, and steel plants, which can be optimized and modernized as climate tech evolves. For instance, in transitioning steel plants to green steel production using low-carbon hydrogen, digital enablement becomes crucial, given the long operational lifespan of a steel plant.

Enablers:

Securing access to finance. Organizations should tap into increasing public and private funding, including government grants, subsidies and tax credits, VC funding, and debt financing, to fast track the development and deployment of decarbonization solutions. Designing and scoping projects for eligibility for funding is key.

Developing new skills. They should also partner with startups and academics to access new skillsets and invest in employee reskilling and upskilling programs. For example, Enel has set a target of upskilling and reskilling 70% of its employees before redeployment from coal plants between 2023 and 2025.⁶



⁶ Enel, "Zero Emissions Ambition," retrieved from <https://www.enel.com/content/dam/enel-com/documenti/investitori/sostenibilita/zero-emissions-ambition-report.pdf>.



Decarbonization innovation in action

Innovation is already having a significant impact on initiatives to decarbonize heat. For example, the seenergies.eu project provides open-source heat demand data as well as industrial waste heat potential and a planning toolbox. Allowing public authorities to identify, analyze, model demand and map resources and solutions to supply energy needs within their territories.

Positive outcomes may include development of industrial hubs in which organizations share low-carbon heat not only with their business neighbors, but with nearby residential and public buildings too. And potentially provide grid balancing services, easing supply and demand pressures.

Another example is the innovative Kyoto Group in Norway, which acts as a flexible asset on the grid, providing services for industry and transmission system operators (TSOs). Kyoto enables charging a thermal battery during off peak hours and retrieving thermal energy when needed. It shields businesses from price volatility, CO₂ taxes, and grid tariffs. This helps to prevent global warming and contributes to a new license to operate when policy makers want CO₂ emission to end. And it provides a secure option for energy delivery.

No time to spare

The time to act is now. Accelerating decarbonization of heat is critical to mitigating the impact of climate change, as well as other environmental challenges. A variety of challenges need to be overcome to accelerate the scale and speed of the decarbonization of industrial, civic, and residential heating and cooling, but these are not insurmountable.

Viable solutions exist and help is at hand to address the complexities of decarbonization. Adopting new climate technologies, as well as embracing the key actions and enablers that we have identified, accelerates decarbonization. Collaborating with the partners, as part of an ecosystem of organizations across the value chain and wider industry is critical.

Without doubt, rapidly addressing the decarbonization of industrial heat is a key part of our fight against climate change and our journey towards net zero.



13

Permitting is still not fast enough and is slowing down the energy transition





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Length of permitting for clean power and clean mobility

- 1. Government efforts focused on reducing the time required for procedures and appeals in many countries, particularly in the member states of European Union, have been introduced.
- 2. Therefore, administrative approval procedures lag technological advances in renewable energy projects.
- 3. The technological resources evolution could be used in procedures to compensate for administrative slowness.
- 4. Geopolitical events and uncertainties will impact the pace at which we can decarbonize the energy system, as more money is diverted to ensuring sovereignty and security of supply.

Introduction

We are at a time when the global energy transition is in full swing. With the climate crisis becoming a matter of urgency, countries must now rise to the challenge of achieving carbon neutrality by 2050. Carbon neutrality is a global balance between greenhouse gas emissions and their removal from the atmosphere. This objective was set by the 2015 Paris Agreements, to which the countries with the highest greenhouse gas emissions, such as the EU, the United States and Brazil, are the main parties.

For countries, reducing gas emissions means gradually replacing their consumption of fossil fuels (gas, coal, oil) with low-carbon energies (nuclear), before making a complete transition to renewable energies (wind, solar). These countries are therefore facing major challenges to overhaul their production systems and switch to renewable energy, which requires speeding up the development of renewable energy projects.

The European Union and Australia have shown themselves to be innovative by introducing tools to simplify and accelerate their project authorization procedures. However, with 2030 fast approaching, it is becoming necessary for governments to turn to means other than administrative reform. Increased investment in networks and the use of fast-growing technologies such as AI would appear to be necessary to achieve the targets set for 2030.



What we are seeing

Some countries are therefore leaders in speeding up permit procedures. This is thanks to innovative solutions that call on a variety of resources, whether financial, technological or human. However, in some countries, consuming renewable energy is not (yet) an attractive option. This is the case in the United States, for example, where consumption patterns remain mainly dependent on fossil fuels. This can be explained by the fact that most of those countries are fossil fuels producers, as well as a great deal of competition on the fossil fuels market, particularly from shale gas. For the USA, shale gas consumption increased by 71% since 2009 to counter Canada's energy dependence. For countries in which shale gas consumption is important, such as the USA, the shift from fossil sources to low-carbon is not the most economical option because the investment cost of changing consumption patterns of shale gas would be difficult to recoup.

Government efforts focused on reducing the duration of permitting and legal proceedings, particularly in the EU

Shorter administrative procedures within the EU

The European Union's objective was to rapidly reduce its dependence on natural gas as a result of the war in Ukraine, and to achieve the targets set for 2030 by the Paris Agreements and the Green Deal.

Following the revision of the RED II Directive in 2023, which required member states to shorten administrative authorization procedures, the European Commission published a report on progress in 2024. The report shows that Sweden had shortened the time taken to develop the networks by ensuring that the works were carried out in parallel. It had also tightened up

the provisions of RED II, which set the time limit for granting permits at one year, by deciding that extensions to this time limit would be subject to force majeure. These development policies have made Sweden one of Europe's leading green electricity producers (60.1%) along with Germany, Spain and Portugal.

Some projects are being slowed down because they are being challenged in the courts. For example, France has reduced the number of possible appeals against environmental authorizations for onshore wind projects to two years since 2018. Some projects, such as cross-border grid developments, are considered to be of national importance. For example, in Latvia, these projects are given priority, and their assessment is accelerated.

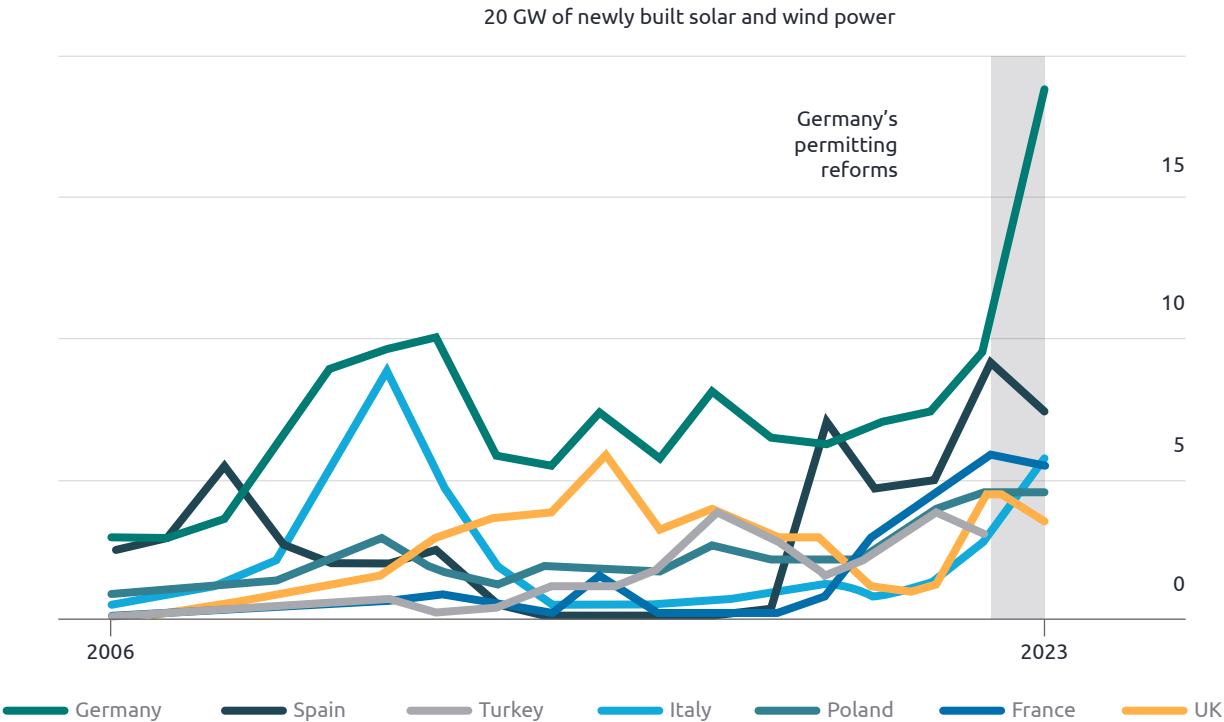


Permitting reforms in Europe

The Figure 1 shows how Germany since 2022, has been leading the way in reforming the procedures for granting renewable energy permits in Europe (according to Bloomberg). It is interesting to note that Germany by reducing the environmental requirements (EIA) and the possibility of legal challenges, is in line with the ambitious objective set out in Article 16 of the EU Renewable Energy Directive (no more than one year in obtaining the permits).

FIGURE 1
Germany leads the way in permitting reforms

Germany has pursued the most aggressive permitting reforms across Europe since 2022, which shows in its renewables buildout



Source: BloombergNEF



Client Story



French-owned state railway operator, SNCF, has recently created a new subsidiary called SNCF Renouvelables with the aim of launching photovoltaic projects on all its land in France (Voltaferro Project).

How we see this market / issue

SNCF Renouvelables aims to cover 15-20% of the Group's current electricity needs and deliver a first tranche of photovoltaic plants covering 1,000 acres by 2030, providing a capacity of 1,000 MWh of electricity (Voltaferro Project).

What we are doing

We advised SNCF on the structuring and the design of the project. Our task was to identify the legal procedures that would speed up the harmonized implementation of the projects by using the exemption from public procurement rules and by centralizing the implementation of the projects in the dedicated subsidiary.

Today, 94 sites spread over 633 hectares have already been studied. The first operations, including environmental impact studies, are due to take place in autumn 2024.

Partner Story



Enedis is the main French distribution system operator, managing 95% of the electricity distribution grid in France.

How we see this market / issue

In order to improve the connection of renewable energy producers to the distribution grid, Enedis is trying to simplify the technical rules for grid connection by proposing new measures in French law.

What we are doing

We advised Enedis to find the best way to integrate its proposals into the government's legislative project and to propose that these rules be adopted by ordinance in order to speed up the process of implementing the measures. These measures included, for example, simplifying the amendment process for the regional connection schemes for renewable energy sources, establishing new rules for the sharing of connection costs, and simplifying the public consultation procedures for works on the public electricity distribution grid.



The need to adapt technological specifications in the time between permit application and project construction

The problems of technological advances in the face of slow administrative procedures

Although the procedures for granting permits have been simplified, and appeals reduced, it regularly happens that certain network projects that have been approved are no longer up to standard. In fact, the granting of a permit can sometimes take so long that the approval relating to the specific technological features of the project has become obsolete. To compensate for this, some states have adopted models that allow developers to define a series of technological parameters in their permit applications, enabling them to maximize energy production if they were to modernize their projects. This mainly concerns wind farm projects, which are increasingly in demand in Europe. As a result, their energy production capacity is doubling between the final investment decision and the granting of permits.

This is the case in Sweden, where wind farm project approvals include the option of modifying the technical specifications of the turbines themselves. The revision of the RED II directive in 2023 has also made it possible for constant updates to be made

to the permit, depending on the length of the procedure and, if justified by the importance of the project, to compensate for the slowness of the administrative procedures in the face of technological advances.

The Public policy on specific energy projects

Adaptation needed at local level

For renewable energies produced on a small scale by households or energy communities, regulatory barriers to the market aggravate their production. For example, countries such as Portugal and Ireland have introduced exemptions for renewable energy communities from due diligence depending on their use of the local public grid. Projects are generally subject to environmental impact assessments measured within the local perimeter. However, the environmental impact assessment deadlines are sometimes extended, thereby delaying the launch of the project. To avoid such delays, member states such as France and Italy have shortened these environmental impact assessment periods to one to two months.



The Administrative procedure simplification

The widespread use of one-stop shop

To speed up the energy transition within the European Union, the RED II directive allows the use of the "one-stop shop" concept. This involves the designation by a member state of an entity as the reference person for the authorization procedures of renewable energy infrastructure projects.

This concept enables developers to facilitate the administrative procedures for granting permits, as everything is centralized. As a result, processing times are reduced, and developers can more easily monitor the progress of their applications via a dashboard. The member countries have set up several types of one-stop shop, depending on the project. In particular, there is the one-stop shop for projects of common interest (infrastructure) used by Denmark and Sweden, which brings together all the information needed to build renewable energy installations. There is also the digital one-stop shop, where the procedure is carried out online, as is the case in the Netherlands.

Some countries have noticed the benefits of this concept and have adopted it, notably the United States. Indeed, the Biden administration has developed an automated authorization tool for rooftop solar facilities, which automates certain approvals, making processing more efficient.

The planning of priority objects

The European Commission stated in its report that, with regard to network development projects, member states should ensure that projects enjoy the status of the greatest possible national importance, with all the advantages that this entails. These projects must therefore be given priority in any administrative or legal proceedings. Spain has therefore created a "fast-track unit" for projects considered strategic

Tacit administrative authorizations as another legal tool

It sometimes happens that, despite efforts to simplify the procedures for granting permits or the use of external resources, these can be delayed when the responsible authorities do not give their response within the specified time. Administrative silence has therefore been introduced, which means that in the absence of a response from an authority that does not have a determining role, its approval can be bypassed. The Netherlands uses this system, in particular, in the case of cross-border projects, where only the opinion of the national authority (and not its formal approval) is taken into account to speed up the procedure.

Another example from the USA, on May 13, 2024, the Federal Energy Regulatory Commission approved the issue of permits for electricity transmission lines where the state regulatory authorities had not acted on an application to build the line for more than a year or had rejected the application.

The need to accelerate investment in Renewable Energy grids

An essential aspect of acceleration towards energy transition is investment in the development of renewable energy grids. The aim of these grids is to distribute electricity across the whole of the border and cross-border areas, particularly in zones where there are no wind or photovoltaic production sites. In France, electricity distribution companies such as Enedis have connected 90% of green energy production facilities (solar, wind) to meet 2050 targets, and are even experimenting with storage solutions to make this energy as available as possible. Enedis is now connecting more than one million of points every year, doubling year on year. However, while connection delays have been cut, but renewable producers or people asking for a new connection still consider the delay to be too long.

China is also planning to reform its electricity market to facilitate the transition. This reform involves the development of inter-regional electricity transfer grids projects in former fossil fuels producing areas. Wind and solar energy are being given priority in the distribution of electricity.



The use of New Technologies

The digitization of administrative procedures

The European Commission has pointed out that speeding up the licensing process will inevitably require a digital transformation. In fact, the revised RED directive stipulated that the necessary documents should be transmitted via a digital gateway by November 21, 2025. The use of digital communication platforms makes it possible to unify the various application processes and help the staff of the authorities responsible for issuing permits to process applications; it also forms the basis for monitoring and improving procedures. Digital transmission would make the progress of applications more transparent. The Netherlands, for example, has set up the "All in One Permit for Physical Aspects" platform for wind and photovoltaic projects. With the development of artificial intelligence, these platforms could become totally autonomous and manage the approval process without any external intervention from the government.

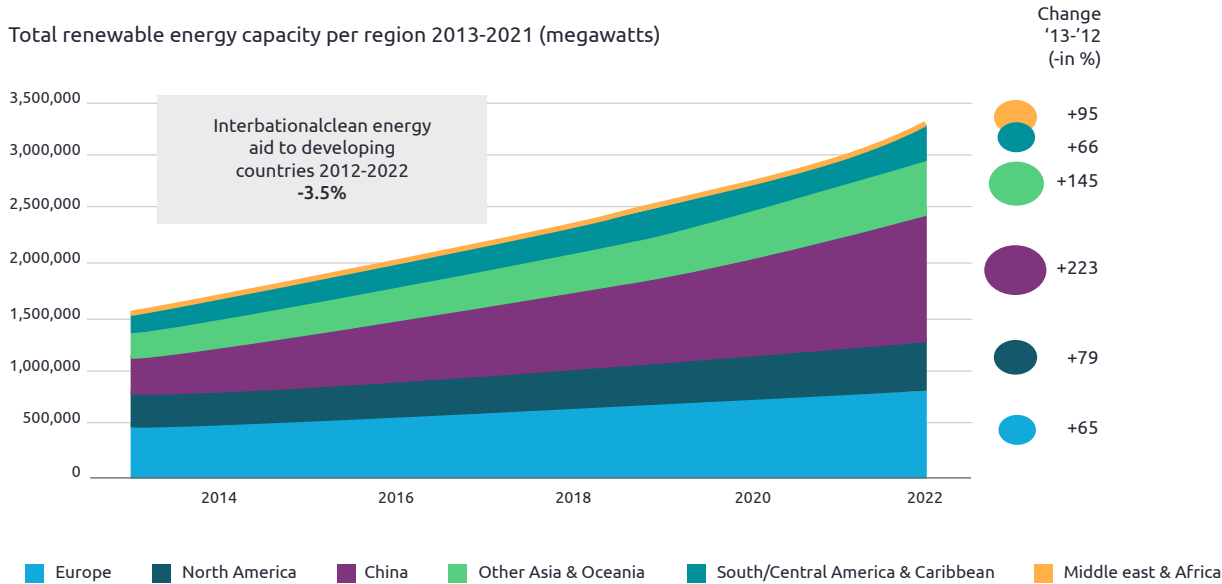
On the other hand, the United States has set up the Solar APP+ platform for rooftop solar installations. This platform digitizes the entire procedure and is free of charge for local authorities responsible for issuing permits. It automatically examines permit applications, instantly approving eligible systems.

To conclude on progress towards the energy transition

The energy transition has been underway since 2017. In fact, the increase in the world's consumption of renewable energy means an increase in their production. This increase in production is forcing a revolution in the use of administrative procedures

for project approvals. Since production has to meet demand, reducing the complexity of procedures and creating specific status for certain projects is effective, but not enough in the long term. From now on, it will be the technological resources and the investments made within them that will enable production needs to be met in the long term.

FIGURE 2
Where Renewable Energy Is Growing (And Where It Is Stalling)



Source: <https://fr.statista.com/infographie/14530/la-transition-energetique-en-marche/>



Our Convictions

- As shown by the guidelines provided by the European Commission, the countries of the European Union are good examples of what could be done to speed up approval procedures, including cross-border projects (i.e., tacit permits process, planning priority projects, such as the special status of national importance granted to some renewable energy projects).
- Outside the EU, other countries, such as the USA, are competing with them in terms of energy transition (e.g., the widespread use of one stop shop).
- The political effort to reduce the permitting delay is significant. However, if the approval procedures in some countries take several years, the implementation of some measures and good practices should help to reduce the permitting delay to one year.
- The digitization of procedures could be the first step to guaranteeing long-term development, as it provides transparency and centralizes the monitoring of permit applications.

14

IRA *impact*
and progress





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Striking IRA old while it’s still hot

1. The Inflation Reduction Act (IRA) has been effective in accelerating clean energy development. To keep up with this demand, the United States has accelerated policy development to expedite the expansion of clean electric generation and underlying transmission lines.
2. Revisions to tax incentives, including Direct Pay and Transferability, has allowed local governments, public utilities, and entities to ensure the advancement of planned and ongoing renewable energy projects.

Introduction

In 2022, the Biden Administration passed the Inflation Reduction Act (IRA), landmark legislation and largest investment towards reducing greenhouse gas emissions and the impacts of climate change in United States history. The legislation's goals being to decrease greenhouse gas emissions by 41% by 2030, compared to 2005, levels and to achieve 100% carbon-/pollution-free electricity by 2035.

In total, the IRA has earmarked \$142 billion, including \$37B for federal loans and loan guarantees, and \$105B for grants, awards, and other direct spending by federal agencies. In addition, the IRA has several tax credits which span across multiple areas, which include renewable energy, electric vehicles and infrastructure, and energy efficiency. The estimated value of total tax credits could be between \$780 billion to \$1.2 trillion over the IRA's 10-year life.

In the two years since the inception of the IRA, total American investment has been ~\$493 billion, with clean energy and transportation seeing the largest investments. Clean investments account for 5.5% of all investments, and account for more than half of all USA private investment growth. Clean energy production and industrial decarbonization is at \$161 billion, with a utility scale solar at a 56% increase compared to pre-IRA.



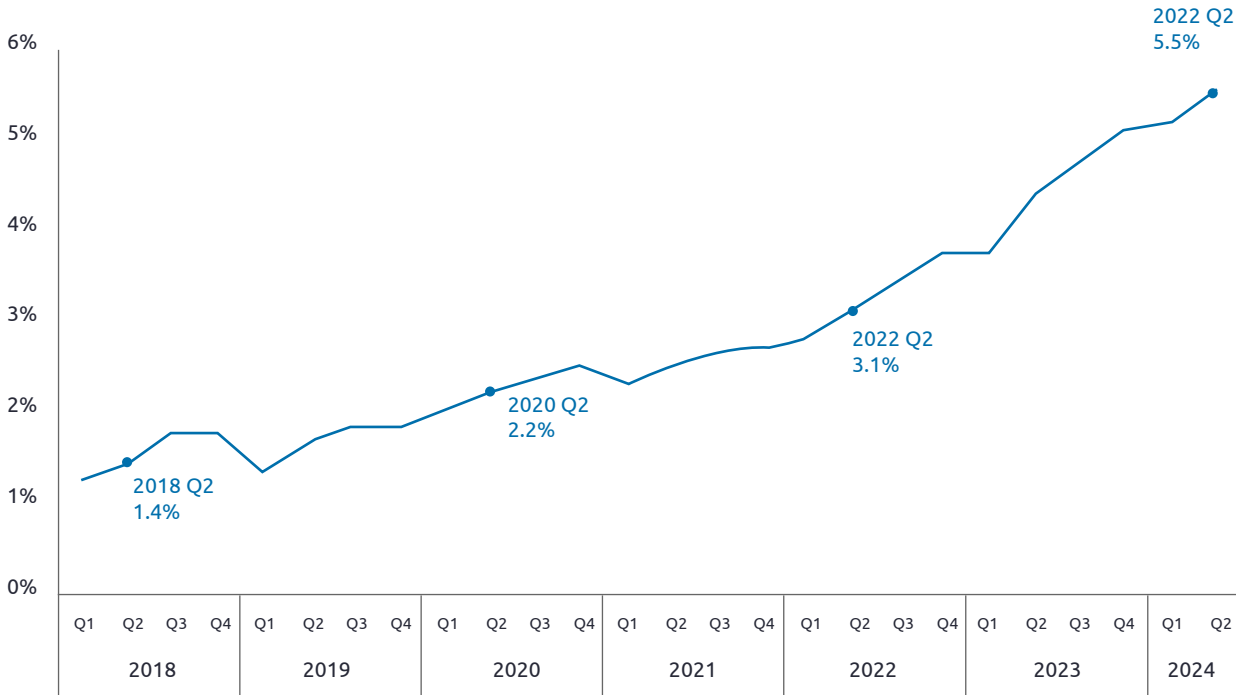
Clean tech investment growth

The USA economy has experienced double-digit growth, benefiting from clean technologies spanning from renewable energy, grid infrastructure, storage, alternative fuels, transportation, built environment, and have provided incentives in the creation of net-zero products impacting construction, pharmaceuticals, consumer goods, and aviation. The IRA incentive provides an accelerated advantage to boost and secure resources, capabilities, and infrastructure domestically.

FIGURE 1

Annualized basis, total private investment in all structures, equipment, and durable consumer goods

Actual clean investment as a share of total USA private investment



Source: Rhodium Group/ MIT-CEEPR Clean Investment Monitor



The IRA has catalyzed significant investments across manufacturing, clean energy, and transportation, doubling total USA private investments to 4.5% compared to 2.5% pre-IRA.

Manufacturing represents 18% of total clean investments at \$89 billion, a 305% increase from pre-IRA at \$22 billion.

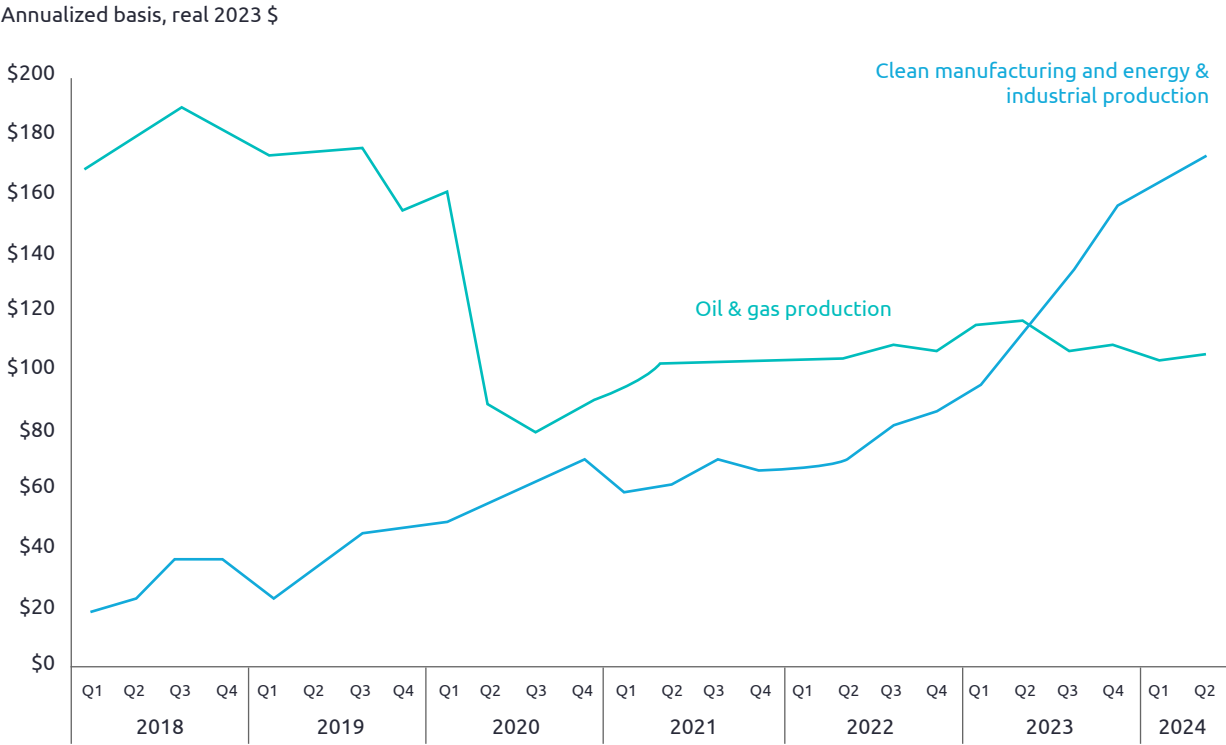
Energy represents 43% increase, totaling \$161 billion.

Overall, investments in manufacturing and energy combined, exceeded investments in oil and gas production with a 64% gap.

Clean Power Generation Sees Doubling in Private Investments

- There Department of Energy (DOE) has enabled more private-sector investment towards clean energy noting the need for public-private sector partnerships, estimating \$300 billion in private capital is needed annually, alongside government funding.
- In July 2024, the DOE saw market momentum with private-sector investments matching at a rate of 2 to 2.5 times. \$50 billion from the government is translating to \$100 to \$150 in private-sector commitment.

FIGURE 2
Actual investment in clean manufacturing and energy & industry compared to oil & gas production



Source: Rhodium Group/ MIT-CEEPR Clean Investment Monitor



Onshoring Surge in the EV and Solar Supply Chain

Battery has tripled in growth, while solar sees 10-fold growth Battery Manufacturing

- The demand for clean transportation and the IRA's enactment to onshore manufacturing has created 45% growth vs pre-IRA, being 65% of total manufacturing investment, totaling \$58 billion dollars.

- IRA incentives create more investment in the United States due its requirement of 60% of value components needing to be assembled in North America.
- Automakers and battery manufacturers have committed to invest \$112 billion in domestic cell and module manufacturing, totaling the annual capacity at 1,000 gigawatt-hours before 2030.

Solar Manufacturing

- During the two years since the inception of the IRA, solar manufacturing has grown to \$10 billion compared to pre-IRA at \$890 million. Grid-scale storage investment grew by 130% to \$37 billion, and utility-scale solar and battery storage investments for renewable energy, total \$108 billion.

FIGURE 3
Manufacturing investment by technology

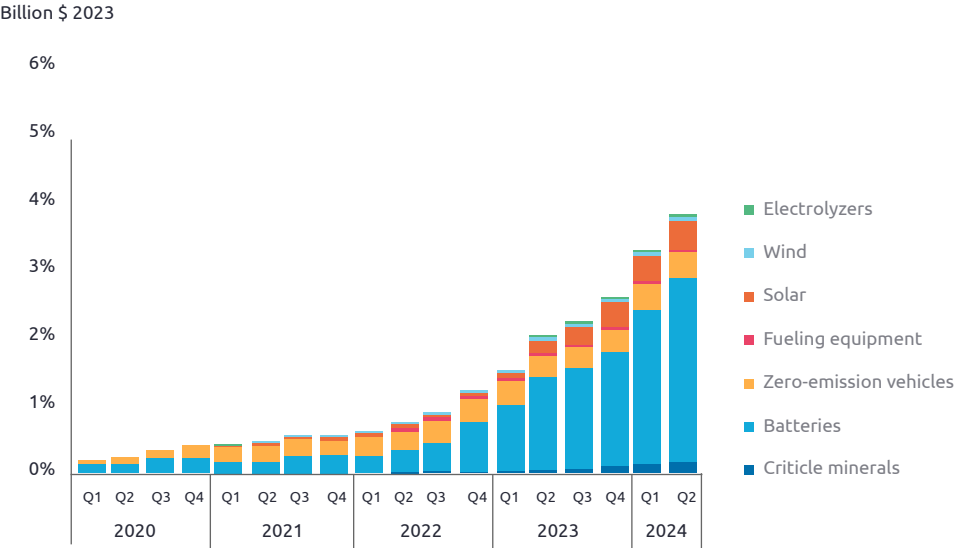
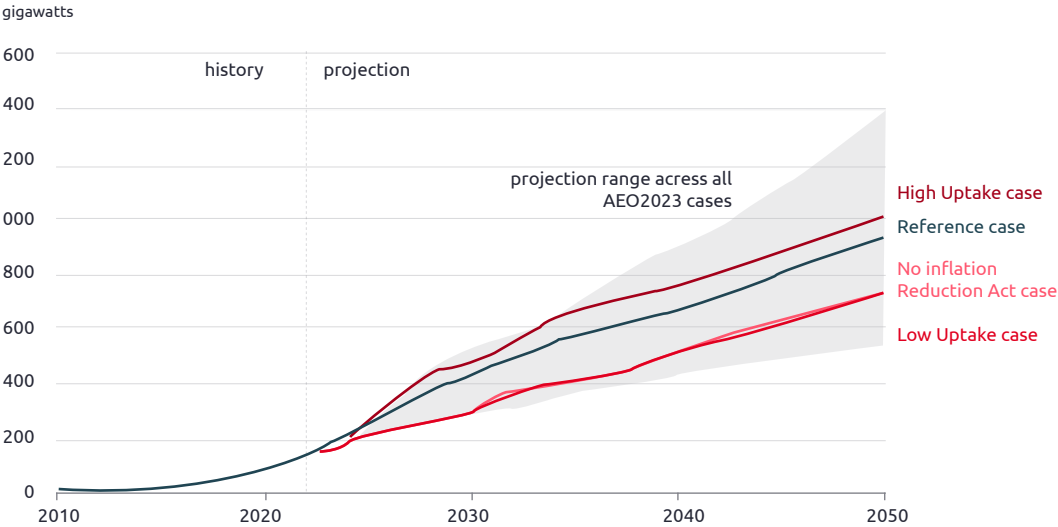


FIGURE 4
USA solar capacity, by Annual Energy Outlook 2023 (AEO2023) case (2010-2050)



Source: U.S. Energy Information Administration, Annual Energy Outlook 2023
Note: Does not include



Clean technology investment growth leads to 334,000 clean energy jobs within two years.

81% of total investment have gone to counties with below-average wages, with clean energy jobs paying 21% higher wages.

18% of total investment post-IRA towards Emerging Climate Technologies (ECT)

Strong demand for clean technology also means challenges across multi-jurisdictional state/local entities due to enablement of infrastructure, developing supply chains, and scarcity of resources.

To be noted after this investment acceleration, Nov. 5th presidential elections and related uncertainty are slowing down IRA investment, which have peaked in Q4 2023.

Emerging Climate Technologies

Significant Growth in Investment

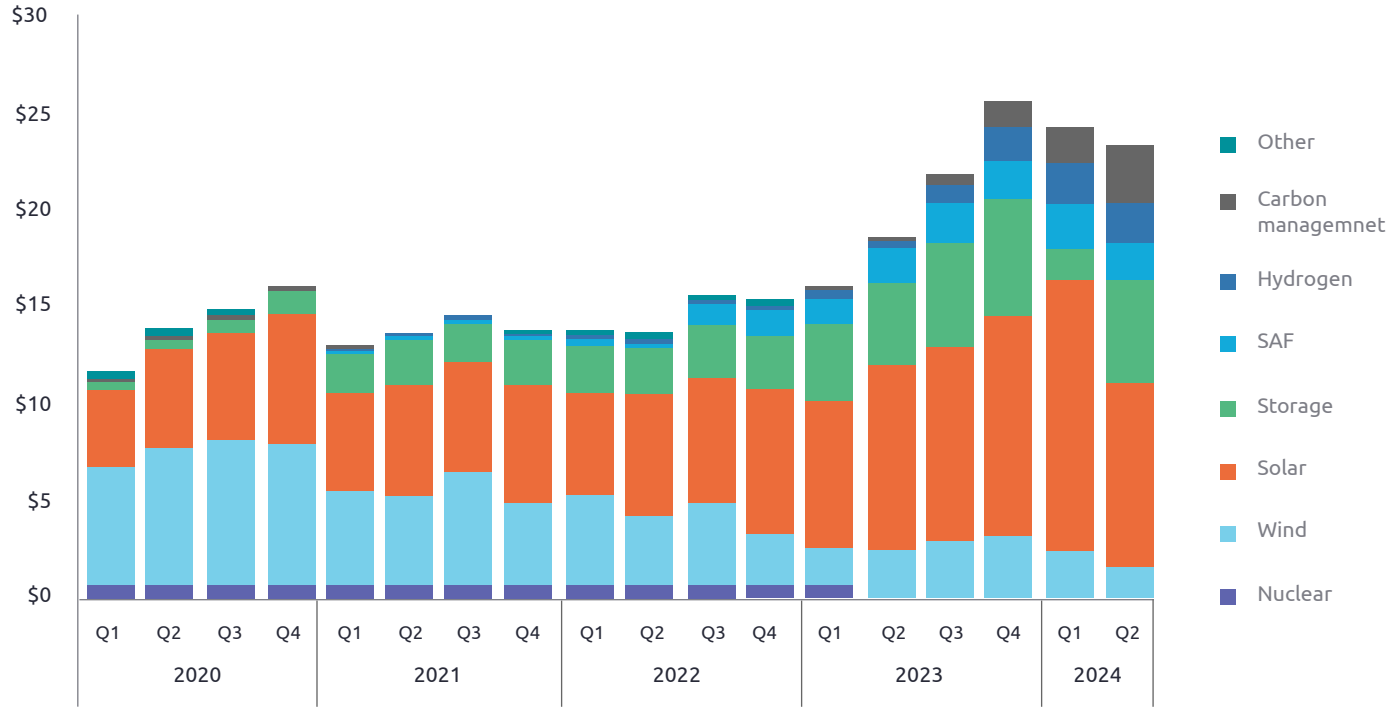
- Sustainable Aviation Fuels (SAF) 1655%, \$14 billion post-IRA.
- Carbon Management 6x, \$7 billion
- Hydrogen 14x, \$8 billion

Carbon capture technologies will play a critical role across industries to achieve emission reduction commitments. As technology continues to improve, the IRA has expanded tax credits for the development of carbon capture projects which

include technologies designed to capture, transport, and store carbon emissions to reduce emissions, especially for hard-to-abate industries like the power sector.

FIGURE 5
Energy & industry investment by technology

Billion \$ 2023



Source: Rhodium Group/ MIT-CEEPR Clean Investment Monitor



Near Term Obstacles Still Remain but States See the Need

As interconnection lines run across states with varying jurisdictions, permitting between multiple state/local government rules can block or delay infrastructure, and this is especially the case for emerging climate technologies.

The top needs to enable clean technology growth sources by renewable energy requires the build-out of utility-scale infrastructure and the tremendous need for new transmission line corridors. The Department of Energy has earmarked \$2.5 billion to develop new, large-scale, interregional transmission lines across six states, adding 3.5 GW of grid capacity—an additional \$14 billion for states, tribes, and utilities for grid-enhancing technologies and upgrades. Overall, the IRA has made clean energy investments cost-competitive, with barriers being primarily related to siting, permitting, backlogged interconnection queues, and supply chain constraints.

Navigating the state/local jurisdictions can often be challenging. States, independently, are also taking lead to ensure their communities are resilient and connected. States like California and New York are leading the charge by investing into their transmission systems and enhancing regulatory processes to meet the accelerated demand.

As the IRA accelerates clean energy projects, leveraging tax credits offers significant benefits for both sellers and buyers.

However, it is crucial to navigate the associated risks effectively to ensure sustainable growth and compliance.

These risks are associated with the sales and purchase of these tax credits and can take different forms like compliance risk, financial risk, project performance risk, etc.

Benefits of Purchasing a Tax Credit for a Buyer:

Tax credits offer significant value to issuers by providing crucial capital for low-carbon projects and improving cash flow, which helps secure financing. Buyers of these credits also benefit from:

Financial Savings: The primary benefit of purchasing a tax credit is the potential to receive a discount on the purchase price relative to the value of the credit. For example, buying a credit at 95 cents for a dollar's worth of credit results in a savings of five cents for every dollar. These credits can be utilized against quarterly estimated tax payments. Buyers need to understand these mechanics before they can recognize the financial benefit.

Support for Sustainable Technologies: Purchasing tax credits can also support investments in clean or low-carbon technologies, aligning with a company's sustainability goals.

Simplified Transactions: Compared to previous tax equity investments, transactions involving tax credits are straightforward and do not involve complex accounting. This simplicity requires performing thorough due diligence on the tax credit itself to ensure compliance and validity.

What are some of the risks we are seeing?

Identified Risks When Purchasing Tax Credits:

1. Disallowance and Recapture Risks:

- There is a risk that the IRS could invalidate claimed tax credits.
- For example, for investment tax credits that are subject to recapture, if the credited property ceases to operate within the recapture period, the IRS may reclaim those credits.

2. Creditworthiness of the Counterparty:

- Typically, the seller indemnifies the buyer for any losses, penalties, and interest associated with these tax credits.
- However, a significant risk arises if the seller lacks the financial stability to fulfill their indemnity obligations.

3. Audit Compliance:

- While audit compliance does not inherently pose a risk, it can create an administrative burden. The buyer is subject to audit, but it is the seller who must provide the documentation to substantiate the tax credits.
- Generally, the buyer's strategy is to shift financial risk to the seller through the indemnity agreement.



Green banks continue to leverage public capital to attract private investment, reducing risk and making clean energy projects more accessible.

Public-private partnerships enable co-financing of clean energy projects, allowing for scalability in underserved markets.

Federal loan programs offer low-interest financing for innovative clean energy projects. Government grants provide funding for various stages of project development, including grid modernization, and renewable energy storage.

Financing Options Beyond Tax Credits

While tax credits provide significant benefits for buyers and sellers in clean energy projects, additional financing mechanisms are available to further enhance the financial feasibility of projects.

Green Banks and Public-Private Partnerships

Green banks continue to play a crucial role in financing clean energy projects by leveraging public capital to attract private investment. These institutions help reduce risk and make clean energy investments more accessible, particularly for smaller developers or in underserved markets. Through public-private partnerships, green banks can co-finance projects alongside private lenders, enabling greater scalability of clean energy solutions.

A great example of such a project is the Solar for All Program in Washington, D.C., which is co-financed through a public-private partnership involving the D.C. Green Bank and private lenders. The D.C. Green Bank partnered with local developers and private investors to finance solar installations on residential properties. The D.C. Green Bank provided low-cost financing to smaller developers who typically would not have access to traditional financial institutions due to the high risk of these projects.

The Solar for All program aims to install 100 megawatts of solar capacity by 2032, which will benefit up to 100,000 low-income residents.

Loan Programs and Government Grants

Federal loan programs, such as the Department of Energy's Loan Programs Office (LPO), continue to provide low-interest financing to innovative clean energy projects. For example, the LPO has committed billions of dollars to support electric vehicle (EV) infrastructure and large-scale renewable energy projects. Additionally, companies like Tesla have benefited from these loans, receiving early support for manufacturing and scaling clean technologies. Similarly, government grants, such as those offered through the Infrastructure Investment and Jobs Act (IIJA), support various stages of project development, including feasibility studies,

storage solutions, and grid modernization. Not to forget sustainable financing options, like **green bonds** and **sustainability-linked bonds**, continue to gain popularity for funding large-scale renewable energy projects.

Introduction

The Inflation Reduction Act (IRA) has significantly accelerated the clean energy sector in the United States by fostering renewable energy projects and implementing supportive tax policies. Key achievements include a notable increase in renewable energy capacity and substantial investment in new clean energy projects.

Despite these successes, several challenges persist, including supply chain resiliency, the complexity of constructing new transmission lines, and the intricacies of managing tax credit risks.

Addressing these issues through innovative technologies and effective policy implementation is crucial to meeting the nation's ambitious clean energy goals.



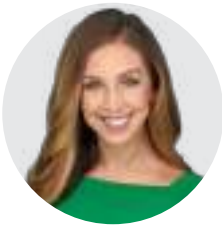
Conclusion

The continuous development and implementation of advanced technologies are essential to overcoming current obstacles in the clean energy transition. Investing in innovative solutions can enhance grid capacity, improve supply chain resilience, and streamline project implementation.

Collaboration among local governments, public utilities, and private entities is necessary to drive the expansion of electric generation and transmission lines.

Navigating the risks associated with tax credits is crucial for sustainable growth. Companies must focus on understanding compliance, financial, and performance risks to leverage tax credits effectively.

Partner Quote



Abby Massey, PE, LEED AP

VP of Energy Incentives, TaxTaker

email abby@taxtaker.com



How do you think the market is evolving with respect to implementing projects under the Inflation Reduction Act?

"Entities are eager to implement projects that will trigger the various tax incentives from the Inflation Reduction Act, but face challenges as we wait for continued IRS guidance on how best to comply with the new legislation.

There are many opportunities to increase the value of these powerful incentives, but the complexities of these requirements call for experience and feedback to ensure projects are meeting the intent of the legislation. For many, these 'gray zones' in the law provide risk when claiming and selling large credits.

Despite these uncertainties, engaging the right expertise early on the project allows organizations to navigate these risks while also maximizing the value of these incentives."

**We are *not on track* to meet the
Paris Agreement's objectives.
What should we do?**

About WEMO

The World Energy Markets Observatory (WEMO) is Capgemini's annual thought leadership and research report created in partnership with Hogan Lovells, Vaasa ETT and Enerdata, that tracks the development and transformation of Energy transition and Utilities across the globe. Now in its 26th edition, the report includes in-depth coverage of geopolitical impacts; climate change; money, markets and regulation; energy transition and related technologies; customers; renewables and net zero pathway.

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About Hogan Lovells

Hogan Lovells is an international law firm that delivers exceptional legal services in highly regulated sectors achieving results for their clients and society. With the combined talent of 2,800 lawyers spanning six continents, Hogan Lovells brings a world of relevant experience to every matter, and creates clarity from complexity, and forge deep, committed client relationships in the process.

Hogan Lovells has been established in Paris for over 30 years and now has over 180 lawyers, including 42 partners, working in all areas of business law. The law firm has also embarked on a strategy of specialisation by industrial sector, giving its lawyers in-depth knowledge of the sectors in which their clients operate.

Energy is a global strategic priority for Hogan Lovells. For this reason, the Paris office has strengthened its energy capabilities with the arrival in April 2024 of a new Energy Regulatory Law team to create the Energy Transition practice.

With leading experience in energy regulation, the team advises public and private companies operating in this sector, including integrated players in non-interconnected areas or in the regions, as well as the State and local authorities.

For more information about Hogan Lovells, the partners and their qualifications, see www.hoganlovells.com



About VaasaETT

VaasaETT is a leading retail energy consultancy, specialized in complex market issues in six continents and over 90 jurisdictions around the world. We support a global client base of energy companies, governments, regulators, innovators, investors and enterprise consumers, based on the most extensive insight and advanced market analytics.

VaasaETT assists clients with market assessments and entry, Innovate retail development and M&A support, backed by a close eye on consumers, sustainability and profitable business models.

More information at: www.vaasaett.com



About Enerdata

Enerdata is an independent research company that specialises in the analysis and forecasting of energy and climate issues, at a variety of different geographic and business / sector levels. The company is headquartered in Grenoble, France, where it was founded in 1991, and has a subsidiary in Singapore.

Leveraging its globally recognised databases, business intelligence processes, and prospective models, Enerdata assists clients – which include companies, investors, and public authorities around the world – in designing their policies, strategies, and business plans.



Glossary

ACER

Agency for the Cooperation of Energy Regulators, created under the EU Third Legislative Package, adopted in April 2009

ACORE

Stands for American Council on Renewable Energy, is a national non-profit organization that unites finance, policy and technology to accelerate the transition to a renewable energy economy.

AEMC

Set up by the Council of Australian Governments through the Ministerial Council on Energy in 2005, the Australian Energy Market Commission makes and amends the National Electricity Rules, National Gas Rules and National Energy Retail Rules, and also provides market development advice to governments.

AEMO

The Australian Energy Market Operator is responsible for operating Australia's largest gas and electricity markets and power systems, including the NEM and Wholesale Electricity Market (WEM) and power system in Western Australia.

AGA

American Gas Association Representing more than 200 local energy companies that deliver clean natural gas throughout the United States.

AMI

Stands for Advanced Metering Infrastructure, it is the collective term to describe the whole infrastructure from Smart Meter to two way-communication network to control center equipment and all the applications that enable the gathering and transfer of energy usage information in near real-time.

Asian Renewable Energy Hub

The Asian Renewable Energy Hub (AREH) is a proposal to create one of the world's largest renewable energy plant in the Pilbara region of Western Australia. It was first proposed in 2014, with plans for the project concept changing several times since then. As of June 2022, the project developers BP, Intercontinental Energy, CWP Global, Vestas and Pathway Investments were planning to build a mixture of wind power and solar energy power generators which would generate up to 26 gigawatts of power.

Backwardation/Contango

"Contango" means that long-term prices are more expensive than short-term prices, depicting a relaxed short-term market, whereas "backwardation" reveals more tension in the short-term reflected in higher short-term prices than in the long-term

Base load

The minimum amount of electricity delivered or required over a given period, at a constant rate

Battery of the Nation

The Battery of the Nation initiative is investigating and developing a pathway of future development opportunities for Tasmania to make a greater contribution to the NEM.

Bilateral contracts/OTC

A contractual system between a buyer and a seller agreed directly without using a third party (exchanges, etc.). Also named as OTC for Over The Counter

Black Certificates

Exchangeable or tradable CO₂ allowances or quotas within the European Trading Scheme and Kyoto protocol (see EUA)

CAISO

Stands for California Independent System Operator is the non-profit Independent System Operator serving California that oversees the operation of California's bulk electric power system, transmission lines, and electricity market generated and transmitted by its member utilities.

CAPEX

Capital Expenditure, funds used by a company to acquire or upgrade physical assets

Carbon Budget

Carbon budget' is the cumulative quantity of CO₂ emissions that are allowed in order to keep global warming below a certain warming threshold



Carbon Cost Coalition

A multi-state coalition of state legislators from 12 states of the USA, who are focused on reducing carbon emissions, ensuring equity in policy proposals, developing market based solutions, creating a resilient local economy and improving public health.

CCGT/Combined cycle power plant

Combined Cycle Gas Turbine. Thermal power plant, usually running on gas-fired turbines, where electricity is generated at two consecutive levels: firstly by gas combustion in the turbines, and secondly by using energy from the product of the gas combustion process in boilers, which supply heat to steam turbo-generators. This process provides high levels of thermal output (55 to 60%, compared with only 33 to 35% for conventional thermal power plants)

CCS

Carbon Capture and Storage. Technologies used for isolating carbon dioxide from fuel gas (at combustion plants) and storing it. This means that a significantly lower amount of CO₂ is emitted into the atmosphere

CDM

Clean Development Mechanisms, a mechanism under the Kyoto Protocol through which developed countries may finance greenhouse-gas emission reduction or removal projects in developing countries, and receive credits for doing so which they may apply towards meeting mandatory limits on their own emissions

CEER/ERGEG

Council of the European Energy Regulators and European Regulators Group for Electricity and Gas. ERGEG was dissolved with the creation of ACER, all ERGEG works are found in CEER website

CER

Certified Emission Reduction. Quotas issued for emission reductions from Clean Development Mechanism (CDM) project activities

CHP/Cogeneration

Combined Heat and Power. System of simultaneous generation of electricity and heat. The output from cogeneration plants is substantially better than it would be if they produced only electricity

Churn/Switch

Free (by choice) movement of a customer from one supplier to another

Clean Coal

New technologies and processes allowing electricity generation from coal while lowering CO₂ emissions

Clean Dark Spread/Clean Spark Spread

The Clean Dark Spread is the difference between electricity's spot market price and the cost of electricity produced with coal plus the price of related carbon dioxide allowances while the Clean Spark Spread is the same indicator but with electricity produced with natural gas

Climate Change

Climate change is any significant long-term change in the expected patterns of average weather of a region (or the whole Earth) over a significant period of time.

Climate Risk Index

Climate Risk Index is released by Germanwatch which analyses to what extent countries and regions have been affected by impacts of weather-related loss events (storms, floods, heat waves etc.)

Copenhagen Accord

A voluntary agreement between the United States, China, Japan, Canada, Mexico, Russia and hundreds more making up over 80% of the global population and over 85% of global emissions that is based on goodwill of each member country assuming that each country will live up to their part in saving the climate by reducing greenhouse gases.

CSIRO

Commonwealth Scientific and Industrial Research Organization is an independent Australian federal government agency responsible for scientific research.

Decentralized generation

Production of electricity near the point of use, irrespective of size and technology, capacity and energy sources



Demand response

Any program which communicates with the end-users regarding price changes in the energy market and encourages them to reduce or shift their consumption

Demand-side participation

Demand side participation (DSP) reflects the capability of demand side resources (customer load reductions or generation from customers' embedded generators) to reduce operational demand at times of high wholesale prices or emerging reliability issues

DER

Distributed Energy Resources refer to distribution level resources that produce electricity or actively manage consumer demand such as solar rooftop PVs, batteries; and demand response activities that manage hot water systems, pool pumps, smart appliances and air conditioning control.

Deregulated Market

A "deregulated electricity market" allows for the entrance of competitors to buy and sell electricity by permitting market participants to invest in power plants and transmission lines

Discom

Power Distribution Company of the state, responsible for distribution of electrical power in the region and associated activities.

DG Competition

European Union's Directorate General for Competition which role is to enforce the competition rules of the Community Treaties

DG TREN

European Union's Directorate General for Transport & Energy that develops EU policies in the energy and transport sectors

Distributed generation

Any technology that provides electricity closer to an enduser's site. It may involve a small on-site generating plant or fuel cell technology

Distribution System Loss

Distribution System Losses are losses pertaining to distribution of electricity. While technical losses are at times under the control of utilities, non-technical losses are external forces that impact the efficiency of the system and lead to revenue leakage

Dividend per share

Dividend per share (DPS) is the sum of declared dividends issued by a company for every ordinary share outstanding. The figure is calculated by dividing the total dividends paid out by a business, including interim dividends, over a period of time by the number of outstanding ordinary shares issued

DMO

Default market offers also known as the 'standing offers' are default, government-regulated energy offers which do not include any discount.

DOE (Philippines)

The Philippines' Department of Energy is the executive department of the Philippine Government responsible for preparing, integrating, manipulating, organizing, coordinating, supervising and controlling all plans, programs, projects and activities of the Government relative to energy exploration, development, utilization, distribution and conservation

Domestic consumers

Residential customers

Dual Monopoly

A situation wherein; two companies dominate the market. In other words two companies control production and supply of a product

EBIT

Earnings Before Interest and Taxes. EBIT may also be called operating income; i.e. the product of the company's industrial and commercial activities before its financing operations are taken into account. EBIT is a key ratio for gauging the financial performance of companies

EBITDA

Earnings Before Interest, Taxes, Depreciation and Amortization. EBITDA is a key ratio for gauging the cash flow of companies

Economic Regulation Authority

The ERA is Western Australia's independent economic regulator. The ERA's work ensures that Western Australian consumers and businesses have a fair, competitive and efficient environment.



EERS

Stands for Energy Efficiency Resource Standards establishes specific, long-term targets for energy savings that utilities or non-utility program administrators must meet through customer energy efficiency programs.

Electricity Tariffs

The amount of money frame by the supplier for the supply of electrical energy to various types of consumers in known as an electricity tariff

Eligible customer

Electricity or gas consumer authorized to turn to one or more electricity or gas suppliers of his choice

Energy Efficiency

Energy efficiency means using less energy to perform the same task

Energy Innovation and Carbon Dividend Act of 2019

The Energy Innovation and Carbon Dividend Act of 2019 is a bill in the United States House of Representatives that proposes a fee on carbon at the point of extraction to encourage market-driven innovation of clean energy technologies to reduce greenhouse gas emissions.

Energy Mix

Refers to the combination of the various primary energy sources used to meet energy needs in a given geographic region. It includes fossil fuels (oil, natural gas and coal), nuclear energy, non-renewable waste and the many sources of renewable energy (wood, biofuel,

hydro, wind, solar, geothermal, heat from heat pumps, renewable waste and biogas).

Energy Regulatory Commission

Power Generation in Philippines is regulated by Energy Regulatory Commission (ERC). It is an independent electric power industry regulator that equitably promotes and protects the interests of consumers and other stakeholders, to enable the delivery of long-term benefits that contribute to sustained economic growth and an improved quality of life

Energy Transition Index

The Energy Transition Index(ETI) benchmarks countries on the performance of their energy system, as well as their readiness for transition to a secure and sustainable energy future. The ETI aggregates indicators from 40 different energy, economic and environmental datasets in order to provide a comprehensive of the world's energy system

Energy Trilemma Index

The World Energy Trilemma Index is an annual comparative ranking of 125 countries on their ability to balance energy priorities Stands for El Niño-Southern Oscillation which is a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean, affecting the climate of much of the tropics and subtropics. The warming phase of the sea temperature is known as El Niño and the cooling phase as La Niña.

ENTSO-E

European Network of Transmission System Operators for Electricity. ENTSO-E, the unique association of all European TSOs, was created at the end of 2008 and is operational since July 1, 2009. All former TSOs associations such as UCTE or ETSO are now part of ENTSO-E

ENTSO-G

European Network of Transmission System Operators for Gas. ENTSO-G was created at the end of 2009 and comprises 32 gas TSOs from 22 European countries

EPIC

Stands for Energy Policy Institute at Chicago, it is an interdisciplinary research and training institute focused on the economic and social consequences of energy policies.

EPR

European Pressurized Reactor. Third generation of nuclear plant technology using advanced Pressurized Water Reactor (PWR)

ERU

European Reduction Unit. A unit referring to the reduction of greenhouse gases, particularly under the Joint Implementation where it represents one ton of CO₂ reduced

ETS

Emissions Trading Scheme. An administrative approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. The European Union Emissions Trading Scheme has been in operation since January 1, 2005



EUA

European Union Allowances. Quotas allocated by the National Allocation Plans in compliance with the European Trading Scheme

Eurelectric

Professional association which represents the common interests of the Electricity industry at pan-European level

European Commission (EC)

A governing body of the European Union that oversees the organization's treaties, recommends actions under the treaties, and issues independent decisions on EU matters

European Council

A body formed when the heads of state or government of European Union member states meet. Held at least twice a year, these meetings determine the major guidelines for the EU's future development

European Parliament (EP)

The assembly of the representatives of the Union citizens

European Union (EU)

The European Union (EU) is a group of 28 countries that operates as a cohesive economic and political block

EVs

Electric vehicles is an alternative fuel automobile that uses electric motors and motor controllers for propulsion, in place of more common propulsion methods such as the internal combustion engine (ICE).

EWEA

European Wind Energy Association

FERC

Stands for The Federal Energy Regulatory Commission, is the United States federal agency that regulates the transmission and wholesale sale of electricity and natural gas in interstate commerce and regulates the transportation of oil by pipeline in interstate commerce.

FID

Final Investment Decision

FLNG

Stands for Floating Liquefied Natural Gas, refers to waterbased liquefied natural gas (LNG) operations employing technologies designed to enable the development of offshore natural gas resources

Forwards

A standard contract agreement for delivery of a given quantity at a given price, for a given maturity (OTC markets)

Futures

A standard contract agreement for delivery of a given quantity at a given price, for a given maturity (organized exchanges). The maturities may differ across power exchanges (weekly, half-yearly, quarterly, monthly, annually). Maturity Y+1 corresponds to the calendar year after the current year

GCF

The Green Climate Fund is a global fund that was formed to support climate change vulnerable nations, especially the "Least Developed Countries" to fulfil their climate change goals and lower their GHG emissions.

GDP

Stands for Gross Domestic Product, is a monetary measure of the market value of all the final goods and services produced in a country over a specific time period, often annually.

GECF

Gas Exporting Countries Forum. GECF is a gathering of the world's leading gas producers

GIE

Gas Infrastructure Europe. GIE is the association representing gas transmission companies (GTE), storage system operators (GSE) and LNG terminal operators (GLE) in Europe

Green Bond

A green bond is a bond specifically earmarked to be used for climate and environmental projects. These bonds are typically asset-linked and backed by the issuer's balance sheet, and are also referred to as climate bonds

Green Certificates

A Guarantee of Origin certificate associated with renewable targets fixed by national governments. Green Certificates are often tradable



Greenhouse effect

The warming of the atmosphere caused by the build up of 'greenhouse' gases, which allow sunlight to heat the earth while absorbing the infrared radiation returning to space, preventing the heat from escaping. Excessive human emissions including carbon dioxide, methane and other gases contribute to climate change

Grid

An electrical grid, electric grid or power grid, is an interconnected network for delivering electricity from producers to consumers.

Grid 2.0

Grid 2.0 refers to the grid system which will transform how gas, solar and thermal energy is managed into a single intelligent network efficiently. This builds on Singapore's past investments in smart meters, grid storage, solar photovoltaics, as well as various energy efficiency and demand management solutions to address Singapore's unique energy challenges, and also grow the base of capabilities.

Guarantee of Origin

A certificate stating a volume of electricity that was generated from renewable sources. In this way the quality of the electricity is decoupled from the actual physical volume. It can be used within feed in tariffs or Green Certificate systems

HHI

Herfindahl-Hirschman Index, a commonly accepted measure of market concentration. It is calculated by squaring the market share of each firm competing in a market, and then summing the resulting numbers. The HHI number can range from close to zero to 10,000

Hub (gas)

Physical or virtual entry/exit points for natural Gas

Hub (retail)

Inter Company Data Exchange platform primarily enabling Suppliers and Distribution companies to exchange client related data and making supplier's switching more reliable

ICPT Mechanism

The ICPT is a mechanism approved by the Government and implemented by ST since 1 January 2014 as part of a wider regulatory reform called the Incentive Based Regulation ("IBR"). ICPT mechanism allows TNB to reflect changes in fuel and generation costs in consumer's electricity tariff every six months. This mechanism is implemented according to Section 26 of Electricity Supply Act 1990 [Act 447]. The impact of ICPT implementation is neutral on TNB and will not have any effect to its business operations and financial position

IED

Industrial Emissions Directive, a European Union Directive that sets strict limits on the pollutants that industrial installations are allowed to spew into the air, water and soil. Installations have until 2016 to comply with the limits

Incentive Based Regulation

An incentive-based regulatory approach aims to reduce environmentally-harmful pollutants by offering inducements to polluters who limit their emissions

Installed capacity

The installed capacity represents the maximum potential net generating capacity of electric utility companies and autoproducers in the countries concerned

International Energy Consultants

IEC is a Perth-based consulting firm which specializes in providing power market advisory services to companies operating in and associated with the IPP sector within the Asia-Pacific region

Investment Tax Credits

A tax related incentive that allows individuals or entities to deduct a certain percentage of specific investment related costs from their tax liability apart from usual allowances for depreciation.



Market Liberalization

The process of removing government control and opening up the markets to private companies

Merit order

The merit order is a way of ranking available sources of energy, especially electrical generation, in ascending order of their short-run marginal costs of production, so that those with the lowest marginal costs are the first ones to be brought online to meet demand, and the plants with the highest marginal costs are the last to be brought online

MESI 2.0

The Malaysian Electricity Supply Industry (MESI) under the MESI 2.0 initiative, has three key aims, which are to increase industry efficiency, future-proof the industry, and empower consumers

Metering

Measurement of the various characteristics of electricity or gas in order to determine the amount of energy produced or consumed

MyPower

MyPower, (which is a part of Malaysian Energy Supply Industry-MESI) stands for Malaysia Programme Office for Power Electricity Reform, will design and drive the implementation of energy reform over the next three years

MSCI ACWI IMI

MSCI (Morgan Stanley Capital Index) ACWI (All Country World Index) IMI (Investable Market Index) captures large, mid, and small cap representation across 23 Developed Markets (DM) and 24 Emerging Markets (EM) countries

NAP

National Allocation Plan. List of selected industrial and power installations with their specific emissions allowance (under the ETS system)

Natural Gas

Mixture of gases which are rich in hydrocarbons. Gases such as methane, nitrogen, carbon dioxide etc. are naturally found in atmosphere. Natural gas reserves are deep inside the earth near other solid & liquid hydrocarbons beds like coal and crude oil.

NDC

Stands for the Nationally Determined Contributions, it implies the achievement of long-term goals made under the Paris Agreement which embodies efforts by each country to reduce national emissions and adapt to the impacts of climate change.

NEEAPs

National Energy Efficient Action Plans, plans providing detailed roadmaps of how each Member State expects to reach its energy efficiency target by 2020

NEG

National Energy Guarantee was an energy policy proposed by the Turnbull government in late 2017 to deal with rising energy prices in Australia and lack of clarity for energy companies to invest in energy infrastructure.

NEM

The National Electricity Market of Australia interconnects five regional market jurisdictions – Queensland, New South Wales (including the Australian Capital Territory), Victoria, South Australia, and Tasmania.

Nomination

A request for a physical quantity of gas under a specific purchase or transportation agreement

Non-Domestic Consumers

Commercial and industrial customers, and others

NREAPs

National Renewable Energy Action Plans, plans providing detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption

NTC

Net Transfer Capacity. NTC is the expected maximal electrical generation power that can be transported through the tie lines of two systems without any bottlenecks appearing in any system



IPCC

Intergovernmental Panel on Climate Change, the leading body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences

IUS

Stands for the Integrated Utility Services, developed by Rocky Mountain Institute wherein utility companies could seamlessly blend an array of products, services and financing tools that have not previously been integrated.

JI

Joint Implementation, a mechanism under the Kyoto Protocol allowing industrialised countries with a greenhouse gas reduction commitment to invest in emission reducing projects in another industrialised country as an alternative to emission reductions in their own countries

Kyoto Protocol

The United Nations regulatory frame for greenhouse gases management, adopted in December 1997 and entered into force in February 2005. It encompasses 6 greenhouse gases: CO₂, CH₄, N₂O, HFC, PFC, SF₆ LCOE (levelized cost of energy) LCOE is the cost of electricity produced by a generator calculated by accounting for all of a system's expected lifetime costs (including construction, financing, fuel, maintenance, taxes,

insurance and incentives), which are then divided by the system's lifetime expected power output (kWh).

LCOS (levelized cost of storage)

It quantifies the discounted cost per unit of discharged electricity for a specific storage technology and application.

LCPD

Large Combustion Plant Directive, a European Union Directive that aims to reduce acidification, ground level ozone and particulates by controlling the emissions of sulphur dioxide, oxides of nitrogen and dust from large combustion plant. All combustion plant built after 1987 must comply with the emission limits in LCPD. Those power stations in operation before 1987 are defined as 'existing plant'. Existing plant can either comply with the LCPD through installing emission abatement (Flue Gas Desulphurization) equipment or 'opt-out' of the directive. An existing plant that chooses to 'opt-out' is restricted in its operation after 2007 and must close by the end of 2015

LNG

Liquefied Natural Gas. Natural gas that has been subjected to high pressure and very low temperatures and stored in a liquid state. It is returned to a gaseous state by the reverse process and is mainly used as a peaking fuel

LNG Netback Price

A measure of an export parity price that a gas supplier can expect to receive for exporting its gas.

Load balancing

Maintaining system integrity through measures which equalize pipeline (shipper) receipt volumes with delivery volumes during periods of high system usage. Withdrawal and injection operations into underground storage facilities are often used to balance load on a short-term basis

Load factor

Ratio of average daily deliveries to peak-day deliveries over a given time period

LTIFR: Lost Time Injury Frequency Rate

LTIFR refers to Lost Time Injury Frequency Rate, the number of lost time injuries occurring in a workplace per 1 million man-hours worked.

LULUCF

Referred to as Forestry and other land use defined as the greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human induced land use such as settlements and commercial uses, land-use change, and forestry activities.

Market coupling

Market coupling links together separate markets in a region, whereas market splitting divides a regional market into prices zones. Market coupling minimizes prices differences and makes them converge wherever transmission capacity is sufficient. Cross-border market coupling also drives better use of interconnection capacity



Off-peak

Off-peak energy is the electric energy supplied during periods of relatively low system demand as specified by the supplier

On-peak

On-peak energy is electric energy supplied during periods of relatively high system demand as specified by the supplier

Optimal development path

The ODP comprises a range of projects classified as either actionable, committed and anticipated, or future. Together, these projects entail the development of 10,000 km of new transmission lines by 2050 under the Step Change and Progressive scenarios.

OPEC

Organization of the Petroleum Exporting Countries

Open season

A period (often 1 month) when a pipeline operator accepts offering bids from shippers and others for potential new transportation capacity. Bidders may or may not have to provide “earnest” money, depending upon the type of open season. If enough interest is shown in the announced new capacity, the pipeline operator will refine the proposal and prepare an application for construction before the appropriate regulatory body for approval

OPEX

Operational Expenditure, expenditures that a business incurs as a result of performing its normal business operations

P/E

Price / Earning ratio. The ratio of the share price to the Earning per share (EPS). P/E ratio is one of the tools most commonly used for valuing a company share

Paris Agreement

The Paris Agreement is an agreement within the United Nations Framework Convention on Climate Change, dealing with greenhouse-gas-emissions mitigation, adaptation, and finance, signed in 2016.

Peak load

The highest electrical level of demand within a particular period of time

Peak shaving

Reduction of peak demand for natural gas or electricity

PPA

Stands for Power Purchase Agreements that freezes a price and a notional energy volume for both the buyer and seller of electricity for a specific period of time. This price agreement acts as the final agreed price for a development project that is either achieving financial close or remaining on the shelf. The agreement also includes reference to cases of failure to meet the contract terms and conditions including, the payment of liquidated damages.

PPU

(Programmations pluriannuelles de l'énergie) Multi-year Energy Programming, a tool for planning and steering national energy policy, which defines the priorities for actions and the specific objectives to be achieved over the period 2016-2023, targeting all energy sources, in order to achieve the national objectives set by the LTE

REBA

Stands for Renewable Energy Buyers Alliance, is a membership association of large clean energy buyers, energy providers, and service providers that, together with NGO partners, are committed to unlocking the marketplace for all nonresidential energy buyers to lead a rapid transition to a cleaner, prosperous, zero-carbon energy future.

Regulated Market

A regulated electricity market contains utilities that own and operate all electricity

Retailer of Last Resort

The Retailer of Last Resort (RoLR) scheme was created under the energy laws to protect electricity and gas supply consumers if a retailer is no longer able to operate, ensuring your energy supply is not disrupted.

RES

Renewable Energy Sources. Energy (electricity or heat) produced using wind, sun, wood, biomass, hydro and geothermal. Their exploitation generates little or no waste or pollutant emissions



RGGI

Stands for Regional Greenhouse Gas Initiative, which is the first mandatory market based program in the United States to reduce greenhouse gas emissions is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont to cap and reduce carbon dioxide (CO₂) emissions from the power sector.

Rhodium Group

Rhodium Group is an independent research provider combining economic data and policy insight to analyze global trends.

South Australia Power Networks (SAPN)

SA Power Networks is the sole electricity distributor in the state of South Australia

SAIDI

Stands for System Average Interruption Duration Index that measures the average outage duration for each customer served in units of time, often minutes or hours.

SGIG

NA

Shippers

The party who contracts with a pipeline operator for transportation service. A shipper has the obligation to confirm that the volume of gas delivered to the transporter is consistent

with nominations. The shipper is obligated to confirm that differences between the volume delivered in the pipeline and the volume delivered by the pipeline back to the shipper is brought into balance as quickly as possible

SLCP

Stands for Short-lived Climate Pollutants that identifies black carbon, methane, tropospheric ozone, and fluorinated gases. Currently, fluorinated gases (HFCs, perfluorocarbons (PFCs), SF₆, and NF₃) account for 3 percent of domestic greenhouse gas emissions in terms of carbon dioxide equivalency (CO₂e)

Smart Grid

An electricity supply network that uses digital communications technology to detect and react to local changes in usage.

Solar Power Europe

European Photovoltaic Industry Association. The association that represents the photovoltaic (PV) industry towards political institutions at European and international level.

Spot contract

Short-term contract, generally a day ahead

State Ownership

State ownership is the ownership of an industry, asset, or enterprise by the state or a public body representing a community as opposed to an individual or private party

Super Pollutants

Methane and black carbon identified as the Super Pollutants being some of the most aggressive contributors to global warming.

System Loss

System losses occur when 100% efficiency isn't achieved in either conversion or transport of energy. System losses are of two types: 1. Technical Loss, driven by the characteristics for the equipment and materials 2. Non-technical Loss, driven by theft, meter readings, pilferage etc.

Take-or-pay contract

Contract whereby the agreed consumption has to be paid for, irrespective of whether the consumption has actually taken place

TCI

Stands for Transportation and Climate Initiative, it is a regional collaboration of 12 Northeast and Mid-Atlantic states and the District of Columbia that seeks to improve transportation, develop the clean energy economy and reduce carbon emissions from the transportation sector.

Third Energy Package

Third Energy Package. A legislative package proposed on September 19, 2007 by the EC in order to pursue the liberalization of the electricity and gas markets



TPA

Third Party Access. Recognized right of each user (eligible customer, distributor, and producer) to access in a non discriminatory and efficient manner transmission or distribution systems in exchange for payment of access rights

UFC

Federal Union of Consumers

Unbundling

Separation of roles according to the value chain segment (generation, transmission, distribution, retail) required by European Directives for enabling fair competition rules

UNEP

United Nations Environment Program

U.S. Climate Alliance

The United States Climate Alliance is a bipartisan coalition of governors committed to reducing greenhouse gas emissions consistent with the goals of the Paris Agreement

U.S. Energy Information Administration

The U.S. Energy Information Administration (EIA) is a principal agency of the U.S. Federal Statistical System responsible for collecting, analyzing, and disseminating energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment.

Utility Death Spiral

In 2013, the Edison Electric Institute (EEI) released a report positing that an eroding revenue stream, declining profits, rising costs, and ever-weakening credit metrics would diminish the ability of electric utilities to survive in an increasingly off-the-grid world.

Victorian Default Offer

The Victorian Default Offer is a simple and trusted electricity price that is set by us, not energy companies.

Vehicle-to-grid

V2G technology refers to the process of feeding the electricity contained in an electric car's batteries back into the electrical grid while it is parked.

White Certificate

A certificate stating a volume of engaged energy savings (electricity, gas, fuel, ...) at end-users' site, like a home or a business. They are tradable or not

Wholesale Electricity Market

The wholesale market is where electricity is traded (bought and sold) before being delivered to end consumers (individuals, households or businesses) via the grid





List of Acronyms

- AACCC: Australia Competition and Consumer Commission
- ACEEE: American Council for an Energy Efficient Economy
- ACORE: American Council on Renewable Energy
- ACT: Australian Capital Territory
- ADIT: Accumulated Deferred Income Tax
- AEMC: Australian Energy Market Commission
- AEMO: Australian Energy Market Operator
- AER: Australian Energy Regulator
- AGA: Advanced Grid Analytics
- AGD: Ausgrid
- AMI: Advanced Metering Infrastructure
- APEC: Asia-Pacific Economic Cooperation
- APGCC: ASEAN Power Grid Consultative Committee
- APRA: Australian Prudential Regulation Authority
- APS: Announced Pledges Scenario
- AREH: Asian Renewable Energy Hub
- ARENA: Australian Renewable Energy Agency
- ARFVTP: Alternative and Renewable Fuel and Vehicle Technology Program
- ARRA: American Recovery and Reinvestment Act
- ASEAN: Association of Southeast Asian Nations
- ASEP: Access to Sustainable Energy Program
- ASIC: Australian Securities & Investments Commission
- ATF: Aviation Turbine Fuel
- B2C: Business-to-Consumer
- BAU: Business-as-usual
- Bcm: Billion cubic meters
- BESS: Battery Energy Storage System
- BEV: Battery Electric Vehicle
- Bloomberg NEF: Bloomberg New Energy Finance
- BNEF: Bloomberg New Energy Finance
- BoM: Bureau of Meteorology
- CAFD: Cash Available for Distribution
- CAFÉ: Corporate Average Fuel Economy
- CAGR: Compound Annual Growth Rate
- CAISO: California Independent System Operator
- CapEx: Capital Expenditure
- CARC: Customer Acquisition and Retention Costs
- CAT: Climate Action Tracker
- CC: Contestable Consumers
- CCA: Climate Council Authority
- CCC: Climate Change Commission
- CCGT: Combined Cycle Gas Turbine
- CCPI: Climate Change Performance Index
- CCS: Carbon Capture and Storage
- CCUS: Carbon Capture, Usage and Storage
- CEFC: Clean Energy Finance Corporation
- CER: Clean Energy Regulator
- CEVS: Carbon Emissions-Based Vehicle Scheme
- CFD: Contract for Difference
- CO₂: Carbon dioxide
- CO₂e: Carbon dioxide Equivalent
- COAG: Council of Australian Governments
- COP22: 22nd Conference of the Parties
- COP26: Conference of the Parties - 26th United Nations Climate Change conference
- CPI: Consumer Price Index
- CPP: Clean Power Plan
- CPPA: Corporate Power Purchase Agreement
- CREZ: Competitive Renewable Energy Zones
- CRI: Climate Risk Index
- CRM: Customer relationship management
- CSI: California Solar Initiative

- CSI: Customer Satisfaction Index
- CSIRO: Commonwealth Scientific and Industrial Research Organization
- CSP: Competitive Selection Process
- CSRD: Corporate Sustainability Reporting Directive
- CSS: Customer self-service
- CST: Concentrated Solar Thermal
- CTA: Cost to Acquire
- CTS: Costs to Serve
- DEE: Department of Environment and Energy
- DER: Distributed Energy Resource
- DES: Distributed Electricity and Storage
- DfE: Design for Efficiency
- DILG: Department of the Interior and Local Government
- DMIRS: Department of Mines, Industry Regulation and Safety
- DMO: Default Market Offer (aka 'standing offers')
- DMO: Distribution Market Operator
- DNSP: Distribution Network Service providers
- DoE: Department of Energy
- DPPA: Direct Power Purchase Agreement
- DREAMS: Development for Renewable Energy Applications Mainstreaming and Market Sustainability
- DSL: Distribution System Loss
- DSM: Demand-side Management
- DSO: Distribution System Operator
- DSP: Demand-side participation
- DU: Distribution Utilities
- EASe: Energy Efficiency Improvement Assistance Scheme
- EBA: European Battery Alliance
- EBITA: Earnings before Interest, Taxes, and Amortization
- EBITDA: Earnings before Interest, Tax, Depreciation and Amortization
- EBSS: Efficiency Benefit Sharing Scheme
- EC: Energy Commission
- eceee: European Council for an Energy Efficient Economy
- ECF: Equity Crowd Funding
- EE: Energy Efficiency
- EERS: Energy Efficiency Resource Standards
- EIA: Energy Information Administration
- EMA: Electricity Market Authority
- EMC: Energy Market Company
- EMS: Energy Management System
- END: Endeavour Energy
- ENSO: El Niño-Southern Oscillation
- ENTR: Electricity Network Transformation Roadmap
- ENX: Energex
- EPA: Environmental Protection Agency
- EPBC: Environment Protection and Biodiversity Conservation
- EPIC: Energy Policy Institute at University of Chicago
- EPS: Earnings per Share
- ERA: Economic Regulation Authority
- ERC: Energy Regulatory Commission
- ERCOT: The Electric Reliability Council of Texas
- ERF: Emissions Reduction Fund
- ERG: Ergon
- ERP: Enterprise resource planning
- ESB: Energy Security Board
- ESCO: Energy Service Company
- ESOO: Electricity Statement of Opportunities
- ESS: Essential Energy
- ETI: Energy Transition Index
- ETS: Emissions Trading Scheme
- EV: Electric Vehicle
- EVN: Vietnam Electricity Company
- FERC: The Federal Energy Regulatory Commission
- FFO: Funds from Operation



- FFR: Fast Frequency Response
- FIT: Feed-in-Tariffs
- FLNG: Floating liquefied natural gas
- FMRS: Faster More Reliable Switching
- FPA: Federal Power Act
- FPSS: Future Power System Security
- FRC: Full Retail Contestability
- FUM: Forecast Uncertainty Measure
- GCF: Green Climate Fund
- GDP: Gross Domestic Product
- GEOP: Green Energy Option Program
- GHG: Greenhouse Gas
- GIS: Geographic Information System
- GJ: Gigajoules
- GMI: Grid Modernization Initiative
- GMLC: Grid Modernization Lab Consortium
- GMRG: Gas Market Reform Group
- GREET: Grant for Energy Efficient Technologies
- GSOO: Gas Statement of Opportunities
- GSSF: Grid Scale Storage Fund
- GTFS: Green Technology Financing Scheme
- GW: Gigawatt
- GWh: Gigawatt-hours
- HDB: Housing and Development Board
- HEV: Hybrid Electric Vehicle
- HFCs: Hydrofluorocarbons
- HGL: Hydrocarbon Gas Liquids
- HK Electric: Hongkong Electric Company
- HKSAR: Hong Kong Special Administrative Region
- HVAC: Heating, Cooling & Ventilation
- IA: Investment Allowance
- IBR: Incentive Based Regulation
- ICE: Internal combustion engine
- ICPT: Imbalance Cost Pass-Through
- ICT: Information and Communication Technologies
- IEA: International Energy Agency
- IEC: International Energy Consultants
- IEMOP: Independent Electricity Market Operator of the Philippines
- IEP: International Environmental Partnership
- IFC: The International Finance Corp
- INDC: Intended Nationally Determined Contribution
- IoT: Internet of Things
- IOUs: Investor-owned Utilities
- IPCC: Intergovernmental Panel on Climate Change
- IPP: Independent Power Producer
- IPv6: Internet Protocol version 6
- IRS: Internal Revenue Service
- ISEM: Institute for Superconducting and Electronic Materials
- ISO: International Organization for Standardization
- ISP: Integrated System Plan
- ITC: Investment Tax Credits
- IUS: Integrated Utility Services
- IVR: Interactive Voice Response
- kgoe: Kilograms of oil equivalent
- KV: Kilovolt
- KW: Kilowatt
- kWh: Kilowatt-hours
- LCOE: Levelized Cost of Energy/Electricity
- LDC: Least Developed Countries
- LDV: Light Duty Vehicle
- LED: Light Emitting Diode
- LNG: Liquefied Natural Gas
- LPE: Local Planning Energy
- LPG: Liquefied Petroleum Gas
- LRET: Large-scale Renewable Energy Target



- LSS: Large Solar Scale
- LTIFR: Lost Time Injury Frequency Rate
- LULUCF: Land Use, Land Use Change and Forestry
- M&A: Merger and Acquisition
- M2M: Machine to Machine
- MDB: Multilateral development banks
- MDM: Meter Data Management
- MENA: Middle East and North Africa region
- MESI: Malaysian Energy Supply Industry
- MESTECC: Minister of Energy, Science, Technology, Environment and Climate Change
- MIDA: Malaysian Investment Development Authority
- MIT: Massachusetts Institute of Technology
- MMBTU: Million Metric British Thermal Units
- MMHS: Market-wide Half Hourly Settlement
- MMT: Million Metric Tonnes
- MMTPA: Million Metric Tonnes Per Annum
- MNCAA: The Mayors National Climate Action Agenda
- MOEA: Ministry of Economic Affairs
- MOIT: Ministry of Industry and Trade
- MoT: Ministry of Transport
- MOU: Memorandum of Understanding
- MSCI: Morgan Stanley Capital International
- Mt: Million Tonnes
- MtCO₂-e: Million Tonnes of Carbon Dioxide Equivalent
- Mtoe: Million Tonnes of Oil Equivalent
- MW: Megawatt
- MWe: Mega Watt Electrical
- MWh: Megawatt-hours
- MWp: Mega Watt Peak
- NAFTA: North American Free Trade Agreement
- NAPCC: National Action Plan on Climate Change
- NCOS: National Carbon Offset Standard
- NDC: Nationally Determined Contributions
- NEA: National Environment Agency
- NEA: Nuclear Energy Agency
- NEB: National Energy Board
- NECF: National Energy Customer Framework
- NEM: National Electricity Market
- NEM: Net Energy Metering
- NEMEMF: National Electricity Market Emergency Management Forum
- NEMS: National Energy Modeling System
- NEPA: National Environmental Policy Act
- NEV: New Energy Vehicle
- NGERAC: National Gas Emergency Response Advisory Committee
- NGV: Natural Gas Vehicle
- NIA: National Irrigation Administration
- NIC: Network Interface Card
- NOAA: National Oceanic and Atmospheric Administration
- NOL: Net Operating Loss
- NREP: National Renewable Energy Program
- NSP: Network Service Providers
- NSPS: New Source Performance Standards
- NSW: New South Wales
- NT: Northern Territory
- NWIS: Northwest Interconnected System
- NZE: Net Zero Emissions
- OBPS: Output Based Pricing System
- OCBC: Oversea-Chinese Banking Corporation
- ODP: Optimal development path
- OECD: Organization for Economic Co-operation and Development
- OEM: Open Electricity Market
- OWZ: Offshore Wind Zones



- PACE: Property Assessed Clean Energy
- PAG: Providence Asset Group
- PASA: Projected Assessment of System Adequacy
- PBR: Performance-Based Ratemaking
- PDP: Power Development Plan
- PEV: Plug-in Electric Vehicle
- PHES: Pumped Heat Electrical Storage
- PHEV: Plug-in Hybrid Electric Vehicle
- PJ: Petajoule
- PLI: Production Linked Incentive
- PNOC: Philippine National Oil Company
- PPAs: Power Purchasing Agreements
- PPI: Producer Price Index
- PPM: Parts per million
- PPP: Public Private Partnership
- PSA: Power Supply Agreements
- PV: Photovoltaic
- PVN: PetroVietnam
- QLD: Queensland
- R&D: Research and Development
- RAB: Regulated Asset Base
- RE: Renewable Energy
- REBA: Renewable Energy Buyers Alliance
- REC: Renewable Energy Certificate
- REDD+: Reduce Emissions from Deforestation and Forest Degradation
- REJI: Renewable Energy (Jobs and Investment)
- REP: Retail Electric Provider
- REPI: Retail Electricity Pricing Inquiry
- REPPA: Renewable Energy Power Purchase Agreement
- RERT: Reliability and Emergency Reserve Trader
- RES: Renewable Energy Sources
- RET: Renewable Energy Target
- RETF: Renewable Energy Trust Fund
- RETR: Renewable Energy Transition Roadmap
- REZ: Renewable Energy Zones
- RGGI: Regional Greenhouse Gas Initiative
- RIT-T: Regulatory Investment Test for Transmission
- ROLR: Retailer of Last Resort
- RPS: Renewable Portfolio Standards
- RRO: Regional Reliability Organizations
- RTO: Regional Transmission Organization
- S&P: Standard & Poor's
- SA: Southern Australia
- SAIDI: System Average Interruption Duration Index
- SAIFI: System Average Interruption Frequency Index
- SAPN: South Australia Power Networks
- SARE: Supply Agreement for Renewable Energy
- SCA: Scheme of Control Agreement
- SCADA: Supervisory Control and Data Acquisition
- SCC: Social Cost of Carbon
- SCEM: Singapore Certified Energy Manager
- SDS: Sustainable Development Scenario
- SEA: Southeast Asia
- SGER: Specified Gas Emitters Regulation
- SGIG: Smart Grid Investment Matching Grant
- SLCP: Short-lived Climate Pollutants
- SMOC: Streaming Media Online Charging System
- SMR: Small Modular Reactors
- SoC: Scheme of Control
- SRES: Small-scale Renewable Energy Scheme
- SSR: Summer Saver Rebate
- STEPS: Stated Policies Scenario
- SWIS: Southwest Interconnected System
- T&D: Transmission and Distribution
- TAITRA: Taiwan External Trade Development Council



- TAS: Tasmania
- TCF: Trillion cubic feet
- TCI: Transportation and Climate Initiative
- TNB: Tenaga Nasional Berhad
- TNSP: Transmission Network Service Providers
- ToU: Time-of-Use
- TWh: Terawatt-hours
- UNCED: United Nations' Conference on Environment and Development
- UNEP: United Nations Environment Programme
- UNFCCC: United Nations Framework Convention on Climate Change
- UOB: United Overseas Bank
- US EIA: United States Energy Information Administration
- USAID: United States Agency for International Development
- USTDA: United States Trade and Development Agency
- UTP: Uniform Tariff Policy
- V2G: vehicle-to-grid
- VDO: Victorian Default Offer
- VES: Vehicular Emissions Scheme
- VIC: Victoria
- V-LEEP: Vietnam Low Emission Energy Program
- VPP: Virtual Power Plant
- VRE: Variable Renewable Electricity
- VRET: Victorian Renewable Energy Target
- VWEM: Vietnam Competitive Wholesale Electricity Market
- WA: Western Australia
- WEM: Wholesale Electricity Market
- WESM: Wholesale Electricity Spot Market
- WPI: Wholesale Price Index
- WSD: Water Supplies Department
- WTE: Waste-to-Energy
- WTO: The World Trade Organization
- WWII: World War II
- YTD: Year to date
- ZEV: Zero-Emission Vehicle
- NCI: Non-controlling interest
- BEE: Bundesverband Erneuerbare Energien
- EFET: European Federation of Energy Traders
- BDI: Bundesverband der Deutschen Industrie
- BDEW: Bundesverband der Energie- und Wasserwirtschaft
- EIB: European Investment Bank
- WECC: Western Electricity Coordinating Council
- TSO: Transmission system operators
- EEG: Renewable Energy Sources Act or Erneuerbare-Energien-Gesetz
- OFGEM: Office of Gas and Electricity Markets
- CRE: French Energy Regulatory Commission
- REE: Red Eléctrica de España
- WERA: Water and Electricity Regulatory Authority
- IRA: Inflation Reduction Act
- SEN: Sistema Eléctrico Nacional
- MER: Market Exchange Rate
- EMDE: Emerging Market and Developing Economies
- RTE: Réseau de Transport d'Électricité in France
- EMD: Electricity Market Design
- REMIT: Regulation On Wholesale Energy Market Integrity And Transparency
- RED: Renewable Energy Directive
- CBAM: Carbon Border Adjustment Mechanism
- SEIA: Solar Energy Industries Association
- ACSI: American Customer Satisfaction Index
- EPAH: Energy Poverty Advisory Hub



Country Abbreviations and Energy Authorities

Countries Abbreviation Regulators Ministries or authorities for energy-related topics Utility Death Spiral

Austria AT E-Control Ministry of Agriculture, Forestry, Environment and Water Management: www.bmlfuw.gv.at/
Environment Agency: www.umweltbundesamt.at/
Competition Authority: <http://www.bwb.gv.at/>

Belgium BE CREG (national)

BRUGEL (Brussels)

CWAPE (Walloon)

VREG (Flanders)

Ministry of Economic Affairs: <http://economie.fgov.be/>

Bulgaria BG DKER Ministry of Economy and Energy: www.mi.government.bg/

Canada CA NEB National Energy Board: www.neb-one.gc.ca

Ministry of Energy: <http://www.energy.gov.on.ca>

Croatia HR HERA Ministry of Economy, Labour and Entrepreneurship: www.mingo.hr/

Czech Republic CZ ERU Ministry of Industry and Trade: www.mpo.cz/

Competition Office: www.compet.cz/

Denmark DK DERA

NordREG

Energy Agency: www.ens.dk/

Ministry of Economic and Business Affairs: www.evm.dk/

Ministry of Environment: www.mim.dk/

Estonia EE ETI Ministry of Economic Affairs: www.mkm.ee/

Competition Authority: www.konkurentsiamet.ee/

Finland FI EMV

NordREG

Ministry of Employment and the Economy: www.tem.fi/

Ministry of Environment: www.ymparisto.fi/

Competition Authority: www.kilpailuvirasto.fi/

France FR CRE Ministry of Ecology, Sustainable Development and Energy: www.developpement-durable.gouv.fr/

Réseau de Transport d'Électricité (<https://www.rte-france.com/>)

Germany DE BNetzA

German Renewable Energy Federation ([Bundesverband Erneuerbare Energien](http://BundesverbandErneuerbareEnergien.org) or BEE)

UNFCCC

Federal Environment Ministry: www.bmu.de/

Energy Agency: www.dena.de/

United Nations Framework Convention on Climate Change <https://unfccc.int/>

Competition Authority: www.bundeskartellamt.de/

Greece GR RAE Ministry of Development: www.mindev.gov.gr/el/

Ministry of Environment, Energy and Climate Change: www.ypeka.gr/

Competition Commission: www.epant.gr/

Hungary HU MEH Energy Office: www.mekh.hu/

Hong-Kong HK EMSD

HKSAR

Electrical and Mechanical Services Department: www.emsd.gov.hk

Hong Kong Special Administrative Region

Environment Bureau: <http://www.enb.gov.hk/en/>

Ireland IE CER (Republic of Ireland)

Department of Communications, Energy & Natural Resources: www.dcenr.gov.ie/Energy/

NIAUR (Northern Ireland)

Italy IT AEEG Ministry of Environment: www.minambiente.it/

Ministry of Economic Development: www.sviluppoeconomico.gov.it/

Competition Authority: www.agcm.it/

Latvia LV SRPK Ministry of Economy: www.em.gov.lv/

Competition Council: www.kp.gov.lv/

Lithuania LT REGULA Ministry of Economy: www.ukmin.lt/

Luxemburg LU ILR Ministry of Economic Affairs: www.eco.public.lu/

Malaysia MY ST

MESTECC

MoT

MESI

Energy Commission : www.st.gov.my

Minister of Energy, Science, Technology, Environment and Climate Change <https://www.mestecc.gov.my/web/en/>

Ministry of Transport



Malaysian Energy Supply Industry

Mexico MX SENER Secretaría de Energía de México: www.gob.mx, SEN (<https://www.coordinador.cl/sistema-electrico/>)

Comisión Federal de Electricidad: <http://www.cfe.gob.mx>

Netherlands NL DTe Ministry of Economic Affairs: www.rijksoverheid.nl/

Energy Council: www.algemene-energieraad.nl/

Competition Authority: www.nmanet.nl/

Norway NO NVE

NordREG

Oil and Energy Ministry: www.regjeringen.no/

Competition Authority: www.konkurransetilsynet.no/

Philippines PH ERC

DILG

ERC

IEMOP

DOE

Energy Regulatory Commission: www.erc.gov.ph

Department of the Interior and Local Government <https://www.dilg.gov.ph/>

Energy Regulatory Commission <https://www.erc.gov.ph/>

Independent Electricity Market Operator of the Philippines <http://www.iemop.ph/>

Department of Energy <https://www.doe.gov.ph/>

Poland PL URE Ministry of Economy: www.me.gov.pl

Portugal PT ERSE Ministry of Economy: www.min-economia.pt/

Directorate General for Energy and Geology: www.dgeg.pt/

Romania RO ANRE Ministry of Energy and Resources: www.minind.ro/

Singapore SG EMA

HDB

EDB

Energy Market Authority: www.ema.gov.sg

Housing and Development Board <https://www.hdb.gov.sg/cs/infoweb/homepage>

The Singapore Economic Development Board <https://www.edb.gov.sg/>

Slovakia SK URSO Ministry of Economy: www.economy.gov.sk/

Ministry of Environment: www.enviro.sk/

Slovenia SI AGEN Ministry of Infrastructure: www.mzip.gov.si/

Spain ES CNMC Ministry of Industry, Energy and Tourism: www.minetur.gob.es/

Ministry of Agriculture, Fishing & Food: www.mapa.gob.es/

Ministry of Ecologic Transition: www.miteco.gob.es/

Sweden SE EI

NordREG

Ministry of Energy: www.regeringen.se/

Competition Authority: www.kkv.se/

Switzerland CH BFE

IPCC

Federal Department of Environment, Transport, Energy and Communications: www.uvek.admin.ch/

Intergovernmental Panel on Climate Change <http://www.ipcc.ch/>

Competition Authority: www.weko.admin.ch/

Taiwan TW BOE

TAITRA

MOEA

Bureau of Energy, Ministry of Economic Affairs: www.moeaboe.gov.tw

Taiwan External Trade Development Council <https://en.taitra.org.tw/>

Ministry of Economic Affairs <https://www.moea.gov.tw/Mns/english/home/English.aspx>

United Kingdom UK OFGEM Department of Energy and Climate Change: www.decc.gov.uk/

Competition Authority: www.gov.uk/government/organisations/competition-and-markets-authority

United States of

America

USA DoE

EIA

U.S. Climate Alliance

FERC

U.S. Department of Energy: <https://www.energy.gov/>

U.S. Energy Information Administration: <https://www.eia.gov/>

<https://www.usclimatealliance.org/>

Federal Energy Regulatory Commission (FERC): <https://www.ferc.gov/>

Vietnam VN MOIT Ministry of Industry and Trade: www.moit.gov.vn

Australia AUS ACCC



AEMO
AEMC
AER
APRA
CSIRO
COAG
ARENA
CER
DEE
Australian Competition and Consumer Commission [https://
www.accc.gov.au/](https://www.accc.gov.au/)
Australian Energy Market Operator [https://www.aemo.com.
au/](https://www.aemo.com.au/)
Australian Energy Market Commission [https://www.aemc.
gov.au/](https://www.aemc.gov.au/)
Australian Energy Regulator <https://www.aer.gov.au/>
Australian Prudential Regulation Authority [https://www.
apra.gov.au/](https://www.apra.gov.au/)
Commonwealth Scientific and Industrial Research
Organisation <https://www.csiro.au/>
Council of Australian Governments Energy Council [http://
coagenergycouncil.gov.au/](http://coagenergycouncil.gov.au/)
Australian Renewable Energy Agency <https://arena.gov.au/>
Clean Energy Regulator [http://www.cleanenergyregulator.
gov.au/](http://www.cleanenergyregulator.gov.au/)
Department of the Environment and Energy [http://www.
environment.gov.au/](http://www.environment.gov.au/)



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01. How to make money from renewables?

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02. The Realistic case of Gen AI

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03. The Business Case for Batteries needs to be clearer

Peter King, Global Energy and Utilities Leader, Vice President, Capgemini Invent

04. Which net zero Pathway are we on?

Elfije Lemaitre, Head of Resources & Energy Transition, Capgemini Americas

05. Primary energy demand is an outdated concept

James Forrest, EVP: Global Industry Leader for Energy Transition & Utilities

06. The need for a Demand Side Energy Transition

Hariharan Krishnamurthy, Global Head of ET&U, Capgemini Engineering

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07. The need for a Demand Side Energy Transition

Benoît Calatayud, Director, Energy Transition & Utilities, Capgemini Invent

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Florent Andrillon, Sustainability Services and Group Head of Climate Tech

08. IT needs to accelerate data center decarbonisation

Caroline Vateau, Sustainable IT Director. Capgemini Invent

09. SMRs are part of the answer

Paul Shoemaker, North American Nuclear Transformation Director

10. Electricity Consumption is not rising as predicted in Europe

Colette Lewiner, Senior advisor to Capgemini

11. Geopolitical impacts will maintain uncertainty in energy markets

Philippe Vié, Senior advisor to Capgemini

12. Industrial Heat is in the blind spot of energy transition

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13. Permitting is still not fast enough and is slowing down the energy transition

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14. Striking IRA gold while it's still hot

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Market Data

01. Physical Energy Flows

02. Money, Markets and Regulation

03. Data and Digital

04. Customers

05. Climate

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Energy in the Regions and Countries

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North America card

Middle East card

Africa card

South East Asia card

Germany

UK

France

Italy

Netherlands

Switzerland

Poland

Turkey

Spain

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Belgium

Norway

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