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Highlights

Dr. Birol Warns of Deepening Dependency on Fossil Fuels due to Current Energy Crises

Nearly 2,500 world leaders met in Davos, Switzerland, at the World Economic Forum's (WEF) Annual Meeting from May 22-26, 2022, to address the world's most pressing concerns including the current global pandemic, the ongoing conflict in Ukraine, geo-economic shocks, and climate change. It has been more than two years since the WEF held its Annual Meeting in person.[1]

Speaking at the press conference of the WEF 22 Annual Meeting,[2] the Executive Director of the IEA, Dr. Fatih Birol emphasized the twin global challenges of energy security and a clean energy transition. "Energy security is becoming a key issue on many countries' agendas. It is important that the response we give to the Russia's invasion of Ukraine and the resulting energy questions do not lock in our energy future in a way that our chances to limit the temperature increase to 1.5ºC is damaged." [3]

"The First Global Energy Crisis"

Dr. Birol defined the situation as the first global energy crisis, one that is far different than the oil crisis of the 1970s. "In the seventies, it was the oil crisis but now we have an oil crisis, a natural gas crisis, and a coal crisis. All prices are skyrocketing, and energy security is a priority for many governments, if not all. We are in the middle of the first global energy crisis," Dr. Birol stated. [4]

[1] https://www.weforum.org/agenda/2022/05/davos-2022-whos-coming-and-everything-else-you-need-to-know/
[2] https://www.weforum.org/events/world-economic-forum-annual-meeting-2022
[3] https://www.weforum.org/events/world-economic-forum-annual-meeting-2022/sessions/speeding-up-on-the-road-to-net-zero
[4] https://www.weforum.org/agenda/2022/05/first-global-energy-crisis-how-to-fix-davos-2022/

Dr. Birol also stressed the importance of avoiding further reliance on fossil fuels because of the current challenges surrounding energy security. Urging on world leaders, Dr. Birol emphasized the negative outcomes that could arise from any new wave of fossil fuel-based investments. “Some people may well use Russia’s invasion of Ukraine as an excuse for a new wave of fossil fuel investments, it will forever close the door to reaching our climate targets.” [5] The IEA Executive Director instead underlined the importance of more investment on solar, wind, hydrogen, and other clean energy choices.

Dr. Birol urged the leaders not to choose between energy shortages and climate change. “There was an overwhelming consensus that the appropriate measures to handle the global energy problem could also get us closer to achieving our goals in terms of the environment. We need fossil fuels in the short term, but let’s not lock in our future by using the current situation as an excuse to justify some of the investments being done; timewise it does not work and morally in my view it does not work as well.” [6] The IEA Executive Director told delegates in Davos: “We don’t need to choose between an energy crisis and a climate crisis – we can solve both of them with the right investment.” During the WEF, Dr. Birol delivered keynote speeches and other remarks at several high-profile sessions on topics including energy security, energy transitions, and many others. He also held various bilateral meetings with a wide range of leaders from government and industry.

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IICEC Energy Market Newsletter Issue: 26 presents emerging developments on energy security with a holistic perspective on oil, natural gas, electricity, and clean energy technologies. (Click here to view IICEC NL 26).

[5] https://edition.cnn.com/2022/05/23/business/davos-global-economy-imf/index.html

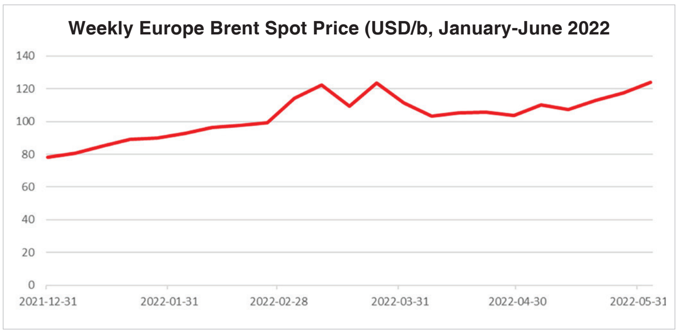
[6] https://www.business-standard.com/article/international/wef-2022-net-zero-by-2050-commitment-clearly-visible-in-davos-122052301439_1.html

"China oil demand must remain weak or we will have big trouble in oil markets." [7]

Referring to the present challenges in global oil markets, Dr. Fatih Birol presented a "tough picture" during the WEF 22 events, citing the price of oil as being "very high." [8] The price of Brent crude stands roughly USD 120/b in early-mid June, up approximately 50% from late December 2021, due to ongoing supply and demand mismatches and geopolitical tensions following Russia's invasion of Ukraine (Figure 1). Reminding the audience that while oil demand in **China** has decreased in recent months due to a number of strict lockdowns enforced by China in an effort to contain the spread of Covid-19, Dr. Birol highlighted the substantial impact that China's demand may have over the coming months. Speaking to Bloomberg at Davos, Dr. Birol warned that if oil producers do not assist in keeping prices in check, the world might experience a global recession.[9] "I very much hope that the oil production increase coming from the United States, Brazil, and Canada this year will be accompanied by similar increases from key producers in the Middle East and elsewhere. Otherwise, we can only hope that we do not have big trouble in oil markets this summer." [10]

Focus: Recent Developments in Oil Markets

Figure 1. *Brent Price Movement since the Beginning of 2022 (US$/b)*



Source: *US DOE EIA. Reproduced by IICEC*

A Rebalance ?

In its June 2022 Oil Market Report [11] (OMR), the IEA underlined that, in addition to the volatility in the oil market, slowing demand growth and a rise in world oil supply through the end of the year should alter the supply demand balances in the market. "After seven consecutive quarters of hefty inventory draws, slowing demand growth and a rise in world oil supply through the end of the year should help world oil markets rebalance. This situation might prove short-lived, however, as tougher sanctions on Russia come into full force, oil demand in China recovers from Covid-lockdowns, if sharper Libyan losses persist and the OPEC+ spare production capacity cushion erodes." the OMR noted.

The report estimates that supply side growth will be mainly driven by non-OPEC 4 in 2022 and 2023 (+1.9 mb/d and +1.8 mb/d, respectively), while demand growth prospects remain weak due to global economic outlook and high prices.

70% Increase since June 2021

Regarding the benchmark prices, the report notes "since 6 June, WTI and Brent futures have averaged over USD 120/b and North Sea Dated hit USD 127.9/b on 13 June". The OMR noted that ICE Brent prices have increased by 70% y-o-y.

[7] Ibid

[8] https://www.cnbc.com/2022/05/23/china-oil-demand-must-remain-weak-or-we-will-have-tough-summer-iea.html

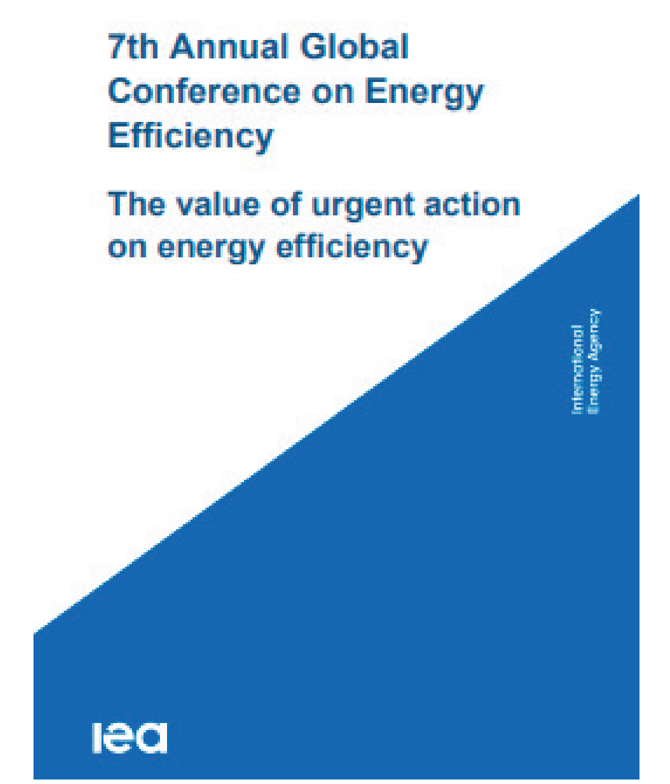
[9] https://www.bloomberg.com/news/articles/2022-05-24/lagarde-sanchez-hamers-among-day-two-highlights-davos-update

[10] https://www.cnbc.com/2022/05/23/china-oil-demand-must-remain-weak-or-we-will-have-tough-summer-iea.html

[11] https://www.iea.org/reports/oil-market-report-june-2022

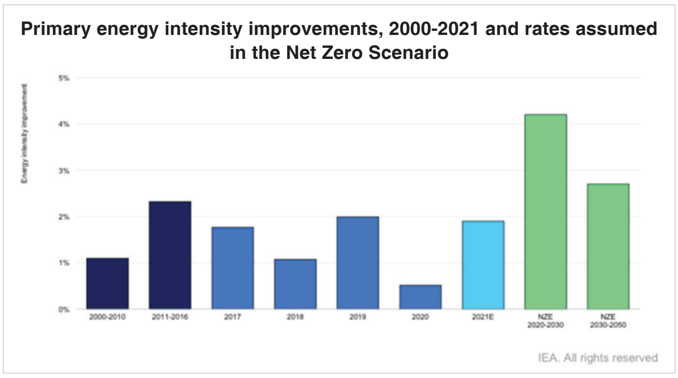
OPEC Secretary-General Mohammad Sanusi Barkindo visited with IEA Executive Director Dr. Fatih Birol at the IEA's office in Paris in May.[12] During the exchanges, Dr. Birol praised Mr. Barkindo for his efforts over the past several years to promote an open and candid dialogue between energy producers and consumers with the goal of enhancing oil market stability. The current developments in global oil markets were the topic of discussion at the meeting, including dynamics of oil supply and demand and their implications for the global economy, especially for emerging and developing economies. Two major shocks to the oil markets were of significance: "an unprecedented drop in oil demand due to the Covid-19 pandemic" and "the disruptions to supply caused by the impacts of Russia's invasion of Ukraine."

Energy Efficiency: The First Fuel that Requires Urgent Action for Multiple Benefits



The IEA released its detailed findings on the benefits of energy efficiency to support the **7th Annual Global Conference on Energy Efficiency.** The report, **The Value of Urgent Action on Energy Efficiency,** sheds light on recent energy intensity improvements and presents the benefits of how doubling past performance to 2030 can help achieve a more secure and clean energy future.

Figure 2. *Primary Energy Intensity Improvements (2000-2021 actual vs. NZE Scenario)*



Source: *IEA, 2022*

- The IEA analysis highlights massive opportunities for energy efficiency improvements in the global economy. Most of these involve readily available technologies. Thus, they would completely payoff thanks to lower operational costs, especially in the current environment of high energy prices, the IEA noted.
- The analyses show that doubling the current rate of energy intensity improvements (from 2%/yr to over 4%/yr) could result in a 5% reduction in energy demand by 2030 while serving a global economy that is 40% larger than it is presently (Figure 2).
- By 2030, around one-third of the energy demand that could be eliminated through improved energy efficiency would stem from deploying more efficient equipment, including air conditioners, other appliances, cars, and many others.

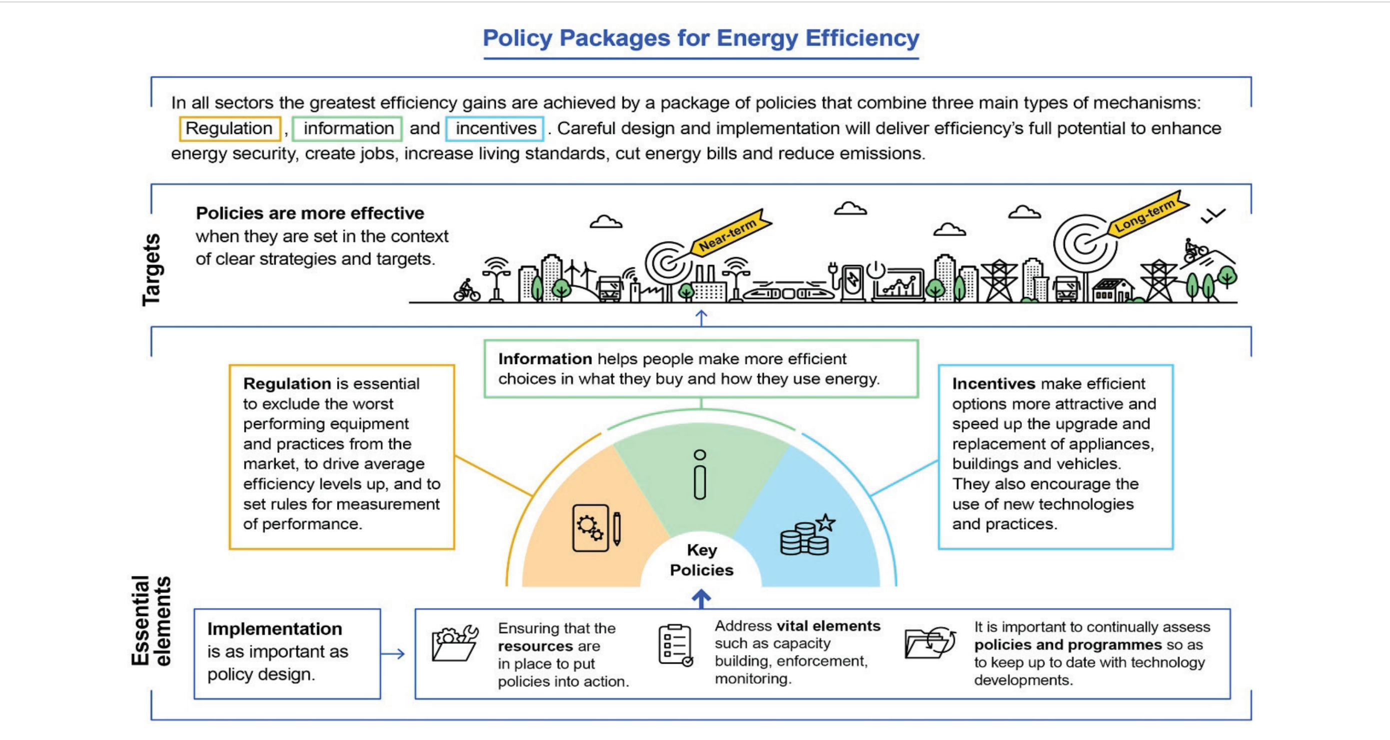
[12] https://www.iea.org/news/opec-secretary-general-makes-official-visit-to-paris-to-meet-with-iea-executive-director

- Electrification of end-use sectors is another key improvement area, as around one-fifth of the eliminated energy demand would come from various electrification benefits for energy efficiency, notably by switching to heat pumps for heating demand and more widely deploying electric cars in transportation. Last but not the least, digitalization, behavioral changes as well as a more efficient use of materials across industries can also provide strong energy efficiency benefits for economies and societies.

- The analyses show that doubling the current rate of energy intensity improvements could help avoid an extra 5 Gt/yr of emissions by 2030 when compared with a scenario with no additional policy push over current policies. This provides around one-third of total emission reductions in the IEA NZE Scenario and stands as a key enabler for a clean energy transition together with a wider use of renewables.

- The IEA also presents a model for successful policy packages to utilize vast energy efficiency potential across the energy supply and demand value chain (Figure 3). It recommends clear targets and strategies in combination with three pillars: regulation, information, and incentives. The role of incentives to enforce the use of new and more efficient technologies is highlighted, but regulation is also critical in order to exclude the "worst performing" equipment and practices from the market and thus improve average efficiency levels.

Figure 3. *Policy Packages for Energy Efficiency*



Source: *IEA, 2022*

- "The oil shocks of the 1970s set in motion major advances in efficiency, and it is utterly essential that efficiency is at the heart of the response to today's global energy crisis."

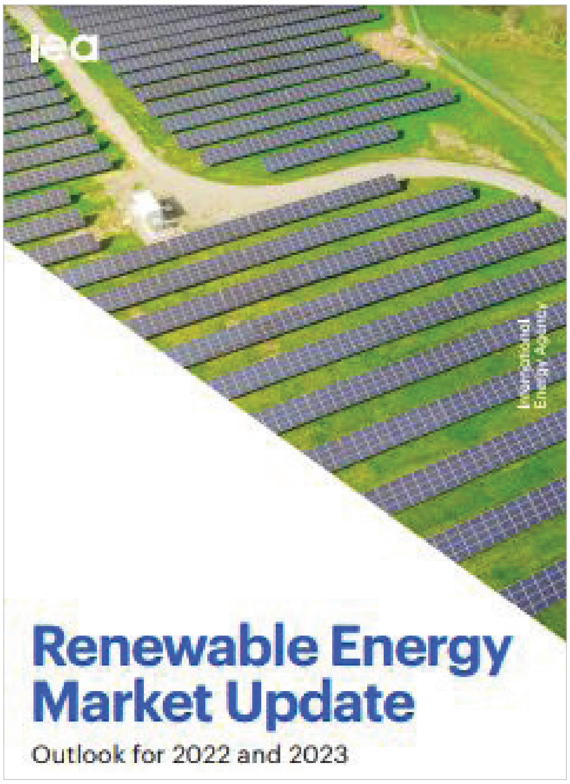
- "I do not know any other solution than energy efficiency that can simultaneously address our economic crisis, energy crisis, and climate crisis simultaneously."

- "Energy efficiency is a critical solution to so many of the world's most urgent challenges. But inexplicably, government and business leaders are failing to sufficiently act on this."

For further reading:

https://www.iea.org/events/7th-annual-global-conference-on-energy-efficiency-welcome-remarks-and-opening-plenary

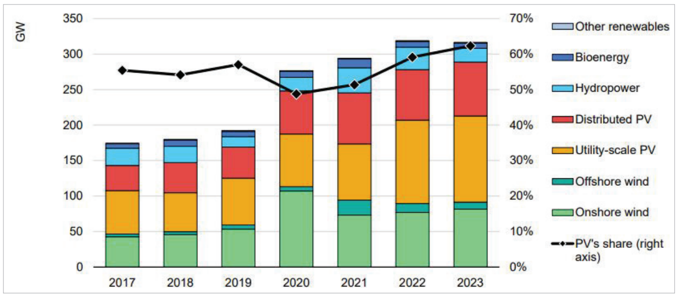
Renewables-Based Electricity Capacity Additions on Track for another Record in 2022



Renewable power is on track to shatter another record in 2022 despite the challenges posed by increasing prices and supply chain constraints, according to the IEA's recent renewable energy market update.[13] The IEA predicts renewable capacity will grow by over 8% in 2022. This would lead to breaking the 300 GW milestone for the first time (Figure 4).

- Solar PV is expected to lead this strong expansion in capacity. With the commissioning of 190 GW (or a 25% increase over 2021), solar PV is projected to account for 60% of the worldwide renewable capacity expansion in 2022. According to the report, two-thirds of global PV expansions in 2022 will come from utility-scale projects, mostly because of favorable legislative environments in China and the EU that encourage accelerated solar PV deployment. It is also projected that new onshore wind deployments will reach approximately 80 GW in 2022 globally. Following a four-fold increase in offshore wind growth in 2021, the global market is anticipated to shrink by 40% in 2022.
- In 2023, solar PV is expected to achieve a new record with nearly 200 GW of new capacity, while wind and bioenergy are expected to expand at the same rate as in 2022. Meanwhile, hydro expansions in China are expected to decline because of a reduction in the hydropower project pipeline. The report demonstrates that global annual renewable capacity addition would stay relatively unchanged in 2023 compared to 2022 unless new policies are put into place.

Figure 4. *Net Renewable Capacity Additions by Technology (GW, 2017-2023)*



Source: *IEA, 2022*

"Energy market developments in recent months – especially in Europe – have proven once again the essential role of renewables in improving energy security, in addition to their well-established effectiveness at reducing emissions."

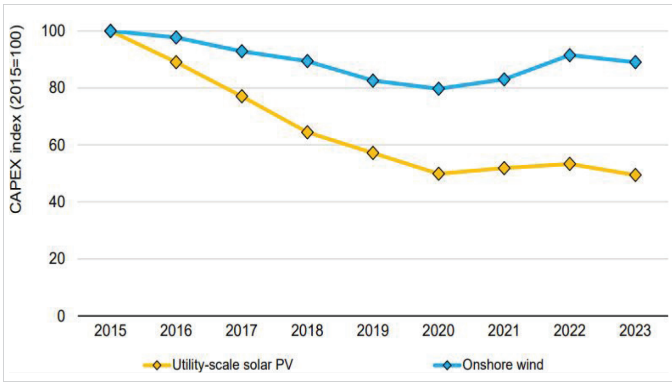
"Cutting red tape, accelerating permitting, and providing the right incentives for faster deployment of renewables are some of the most important actions that governments can take to address today's energy security and market challenges, while keeping alive the possibility of reaching our international climate goals."[14] Dr. Fatih Birol

[13] https://www.iea.org/reports/renewable-energy-market-update-may-2022

[14] https://www.iea.org/news/renewable-power-is-set-to-break-another-global-record-in-2022-despite-headwinds-from-higher-costs-and-supply-chain-bottlenecks

- **Cost dimension:** According to the report, throughout 2022 and 2023 the costs of solar PV and wind will continue to rise, but without a threat to the competitiveness of the industry. New utility-scale PV and onshore wind power facilities are expected to cost 15% to 25% more to build in 2022 compared to 2020 (Figure 5). Onshore wind prices have risen significantly due to rising freight costs. For solar PV, the effects of higher prices for freight, polysilicon, and metals are spread out more evenly. Despite these developments, the competitiveness of renewables-based electricity continues to improve due to drastic increases in fossil fuel prices, mainly coal and natural gas.

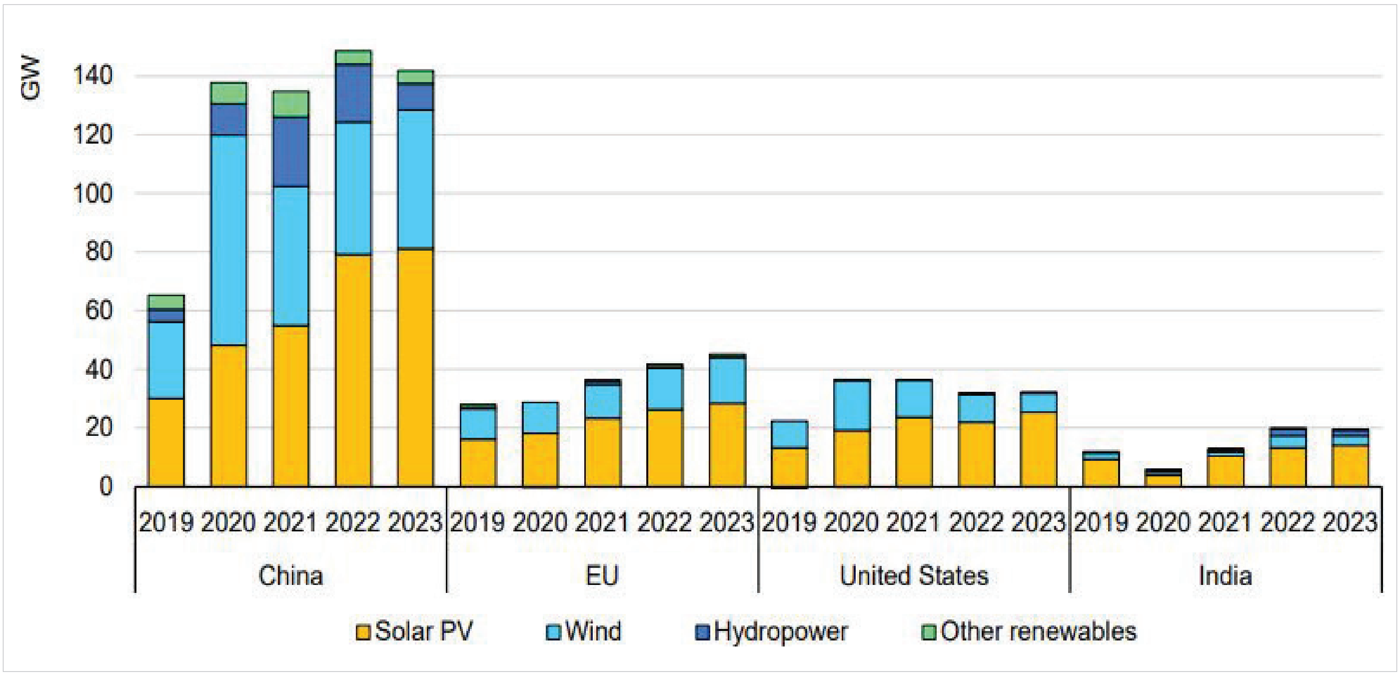
Figure 5. *Solar PV and Onshore Wind Investment Cost Estimates for New Contracted Projects under High Commodity Prices (CAPEX Index, 2015=100)*



Source: *IEA, 2022*

Regional variations: In 2022 and 2023, China will account for 45% of worldwide renewable capacity increases, with an average annual commissioning of over 140 GW that is driven mostly by large-scale solar PV deployment. Annual additions in China are expected to stay slightly higher than in 2020 and 2021, when the country had multiple rushes to deploy new renewable capacity because incentives for onshore wind, utility-scale PV, and residential PV were set to expire in 2020 and 2021, respectively. The **EU's** execution of its previously declared robust policy objectives and recently awarded auctions, along with continued incentives for distributed solar PV, is driving the growth. Residential and business PV installations are expected to grow the quickest with positive effects on power costs, as they allow users to benefit from self-generation models. The emerging focus on energy security across Europe is also supporting momentum towards policy initiatives that may further accelerate renewable energy improvements together with energy efficiency objectives. In the **United States**, it is anticipated that annual capacity increases would decelerate during the same time horizon due to long term uncertainties surrounding future incentive schemes as well as trade measures that may impact equipment availability and installations. The current production of PV modules in the US can meet less than 20% of annual domestic demand. **India** as an emerging energy economy is set to break new records for renewable capacity increases in 2022 and 2023, largely driven by solar energy (Figure 6).

Figure 6. *Renewable Capacity Additions by Major Regions (GW, 2019-2023)*



Source: *IEA, 2022*

Viewpoint: "Turkey's QR Code in Energy and Role of Renewables" [15]

Bora Şekip Güray, IICEC Director

The energy security paradigm, including continuity and reliability in energy supplies, energy costs, and prices, has reminded the world of its importance with the latest geopolitical developments. At the same time, we are in an era of addressing the climate security paradigm, which emphasizes the net-zero emissions perspective by the mid-century and puts environmental sustainability at the center of macro objectives. I think it would be appropriate to evaluate the important factors for Turkey vis-à-vis these **twin global challenges**' perspective under four inter-related dimensions. These four aspects can be considered as the **QR Code** of the Turkish energy system.

First, Turkey is **an emerging energy economy** with energy consumption standing at less than half of OECD and EU averages. Turkey's energy demand will continue to rise in the foreseeable future supported by drivers such as population growth, a relatively young population, urbanization, rising mobility demand, and industrial growth dynamics.Realizing this growth in the most efficient way should be a major factor for long-term success.

This dimension is strongly linked to the second one: **energy intensity** as a measure of how efficiently and productively energy is utilized across the economy. Turkey has a strong potential to improve energy intensity based on two pillars: a) advancing a more efficient energy system along the energy supply and demand chain and b) structurally transforming industry (i.e. from energy-intensive to less-energy intensive and at the same time more value-added industries and businesses).

The third dimension defines **the structure of the primary energy supply** by fuel and technology. Since almost three-quarters of primary energy demand is still met by imported fuels, it will be critical to reduce this to minimize impacts on the country's energy-import bill and its exposure to the fluctuations in the global and regional commodity markets, which have adverse effects on Turkey's current account balances. While the natural gas discovery in the Black Sea is expected to help improve this significantly, it is also important to accelerate the orientation toward market mechanisms and relevant technologies that can transform the heavy weighting of fossil fuel imports in the supply portfolio into a more diverse and sustainable mix that supports the efficient growth of the Turkish energy economy.

The fourth dimension refers to **the GHG emissions inventory** of the growing energy sector. Reducing **carbon intensity** through a wide set of clean energy solutions will be one of the most critical success factors to remain in line with major global and regional trends and assure sustainable growth and competitiveness of the Turkish energy sector as well as all energy-consuming industries.

Renewables Across Four Dimensions

Renewables are one of a few energy vectors that could contribute to all four dimensions. As indigenous resources, they can improve the long-term sustainability of the energy supply mix when accompanied by efforts to decrease the amount of imported primary energy supplies. They directly lower the carbon footprint of the electricity generation as well as the wider energy system via *beyond-electricity* applications such as direct use of renewable energy in various demand services, including but not limited to heating, agriculture, and some industries. Coupling renewable energy solutions with energy efficiency measures and technologies, for example, in energy-dense industrial regions, growing urban centers, and rural areas, can advance a more efficient and resilient energy supply and demand balance with enhanced environmental sustainability.

Renewables now provide over half of the installed power capacity and more than 40% of total electricity generation. They represent one-sixth of the total primary energy supply and about 5% of total final energy consumption. Turkey has a vast potential for renewable energy sources as well as a growing energy market over the past 20 years. Turning this significant potential into higher performance, i.e. larger utilization of renewable energy, will bring multiple energy security and environmental sustainability benefits. This will improve the QR code of the Turkish energy sector in response to the twin energy and climate challenges. More renewables can turn both these challenges into significant opportunities for Turkey to support a more secure and clean energy future.

[15] A shorter and Turkish version of this article was published in "Ekonomist Dergi / Enerji Eki" in June 2022.
https://iicec.sabanciuniv.edu/sites/iicec.sabanciuniv.edu/files/2022-06/Ekonomist-Bora%20%C5%9Eekip%20G%C3%BCray.pdf

"IICEC TURKEY RENEWABLE ENERGY OUTLOOK Stakeholders Meeting"

IICEC hosted industry and private sector leaders and experts on June 4 as part of its ongoing research on the Turkish renewable energy sector.

During the meeting, key aspects of Turkey's renewable energy sector were widely discussed together with future perspectives and priority areas that would support a wider deployment and larger contribution of renewable energy to Turkey's energy balances.

The exchanges and outcomes of the meeting provided valuable inputs to IICEC's ongoing research towards publishing this year's flagship publication: **Turkey Renewable Energy Outlook (TREO)**. TREO will be the third in IICEC's analytical outlook series, following Turkey Energy Outlook (TEO) in 2020 and Turkey Electric Vehicles Outlook (TEVO) in 2021. Similar to TEO and TEVO, TREO reflects a holistic approach including a long-term perspective based on detailed modeling and supporting analyses, and will present solid recommendations to support a more secure and clean energy future for Turkey.

Turkey Aims to Ramp up Solar PV Installed Capacity by Fast Installations

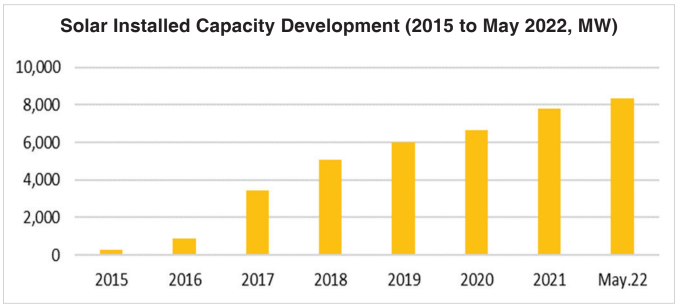
Turkey's solar PV installed capacity reached 8.4 GW as of the end of May 2022 (Table 1). This represents a 30-fold increase since the beginning of 2016 (Figure 7). Solar was second only after wind in terms of annual capacity additions by source in 2021 (1.2 GW). Solar PV now corresponds to about 8% of total installed capacity, up from less than 1% in 2015.

Table 1. *Installed Capacity by Source in Turkey (as of the end of May 2022, GW, %)*

Source	Installed Capacity (GW)	Share in total Installed Capacity (%)
Hydro	31,6	31%
Natural Gas	25,3	25%
Wind	10,9	11%
Local Coal	10,1	10%
Imported Coal	9,1	9%
Solar	8,4	8%
Biomass and Waste Heat	2,2	2%
Geothermal	1,7	2%
Liquid Fuels	1,0	1%
Asphaltite	0,4	0%

Source: *TEİAŞ, 2022*

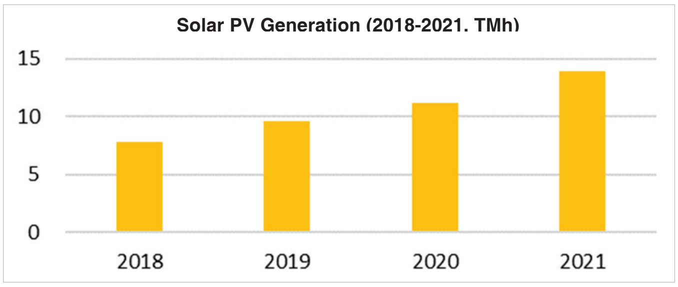
Figure 7. *Solar Installed Capacity Development (2015 to May 2022, MW)*



Source: *TEİAŞ, 2022*

Annual generation from solar has nearly doubled since 2018, realizing over 20% growth in 2021 compared to a roughly 9% increase in total gross generation in Turkey during the same period. In 2021, solar power generation of 13.4 TWh represented around 4% of Turkey's annual gross generation (Figure 8). Backed by capacity additions in 2022, especially in May, solar power plants provide almost 6% of gross power generation at present.

Figure 8. *Solar PV Generation (2018-2021, TWh)*

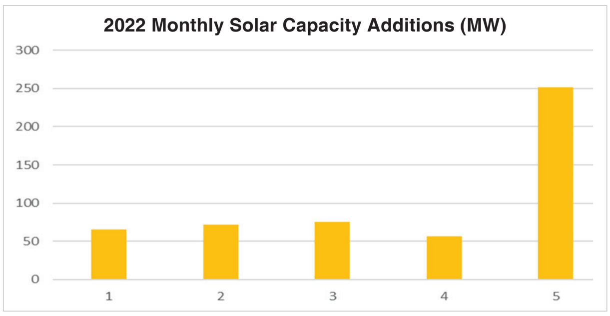


Source: *TEİAŞ, 2020*

Towards the 10-GW Milestone in 2022?

Despite a roughly 2.5 times increase in capacity since 2017, compared to the favorable solar irradiation features, Turkey is still not on track to reflect its vast potential to achieve faster growth in solar PV expansion that would advance multiple energy security, environmental sustainability and economic development benefits for the overall energy economy. However, growing post-pandemic power demand, the recent sharp increases in electricity prices, and physical supply-security challenges have triggered a focus on investing in solar PV installations. A set of regulations are now either in place or under discussion to facilitate the wider and faster deployment of solar PV units, in particular linked to growing power demand and costs for industrial facilities. Solar PV capacity has increased by 520 MW (or 7%) since the beginning of 2022, and the pace of investments in the next months will determine when Turkey achieves the 10-GW milestone in solar power (Figure 9).

Figure 9. *2022 Monthly Solar Capacity Additions (MW)*



Source: *TEİAŞ*

Turkish Wind Power: 11 GW of Installed Capacity with Strong Manufacturing Capabilities

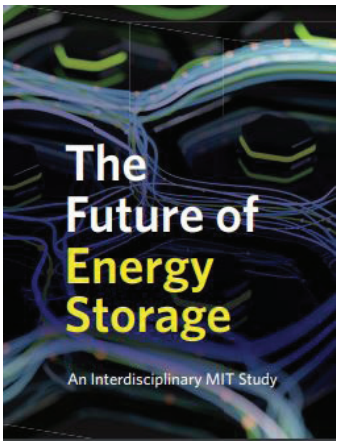
Turkey's wind power reached an installed capacity of 11 GW with an increase of nearly 1.4 GW year-over-year. Wind has become the third largest contributor to Turkey's total installed capacity base after hydro (31.6 GW) and natural gas (25.3 GW). It is important to note that installed wind capacity is now higher than both local coal and imported coal capacities (Table 1). Wind now contributes to around 10% of gross electricity generation with a similar share in total installed capacity. Together with increasing solar contribution, intermittent renewables (wind and solar PV) represent about one-sixth of the country's total power generation output, up from less than a few percentage points in early 2010s.

"The supply crisis in the global wind industry can turn into an opportunity for Turkey"

TÜREB President İbrahim Erden

TÜREB President İbrahim Erden noted that, according to their forecasts, approximately 3 GW of the existing project stock will be operational within the next three years. The total investment of the projects to be commissioned in the next four to five years will reach USD 3.5 billion, Erden informed. Erden also emphasized that the ongoing global supply chain crisis has opened a very important window of opportunity for Turkey's wind energy industry. The TÜREB President stressed that, in order to seize this significant potential, minimum 3 GW of new wind capacity should be provided annually in order to sustain and strengthen country's supply diversity and advancing domestic industrial capabilities, underlining that this organic growth of the industry is critical for overall sustainability. (Turkey installed 1.8 GW of wind power in 2021). Erden also noted the organization's vision for a wind industry that deepens along the wind energy value chain. Reminding that according to the study that TÜREB carried out two years ago, the Turkish wind industry reached a turnover of EUR 1 billion, of which 80% was for exports, he now predicts turnover to exceed EUR 1.5 billion by the end of 2022, with the data currently being updated.[17]

"The Future of Energy Storage": A MITei Study



The MIT Energy Initiative (MITei) published a new report titled **The Future of Energy Storage**[18] that provides a detailed understanding of different energy storage solutions in support of clean energy transitions. It particularly focuses on approaches to efficiently achieving decarbonized electricity systems by 2050 by relying heavily on variable renewable energy sources (VRE), namely wind and solar.

Evolving electricity supply and demand dynamics: The study predicts that there will be significantly more hours of both very low prices and high prices compared to current wholesale markets. Therefore, the research suggests that energy systems favor pricing and load management options that reward customers for moving their power use away from times when high wholesale prices indicate scarcity and toward times when low wholesale prices signal abundance.

16 https://www.aa.com.tr/tr/ekonomi/tureb-baskani-erden-batili-ruzgar-devleri-tedarik-zincirini-turkiyeye-tasimak-istiyor/2592057

17 https://yesilekonomi.com/tedarik-krizini-ruzgarda-firsata-cevirebiliriz/?utm_source=newsletter&utm_medium=email&utm_campaign=tedarik_krizini_ruezgarda_firsata_cevirebiliriz_guenluek_buelten&utm_term=2022-05-23

18 https://energy.mit.edu/research/future-of-energy-storage/#download

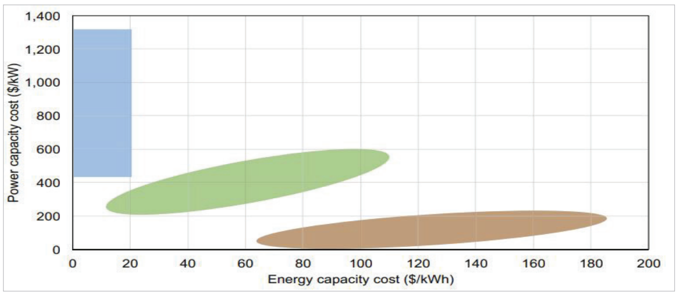
Importance of analytical tools and modeling: The interdisciplinary report recommends that decision makers invest in advanced analytical tools for planning, management, and regulation of electricity systems. In the future, storage technologies will be vital to the design, operation, and regulation of electricity systems because they may substitute or complement almost all other components of a power system: generation, grids, and demand side.

MITEI Director Robert Armstrong

"Fossil fuel power plant operators have traditionally responded to demand for electricity — in any given moment — by adjusting the supply of electricity flowing into the grid. But VRE resources such as wind and solar depend on daily and seasonal variations as well as weather fluctuations; they aren't always available to be dispatched to meet electricity demand. Our study finds that energy storage can help VRE-dominated electricity systems balance electricity supply and demand while maintaining reliability in a cost-effective manner — that in turn can support the electrification of many end-use activities beyond the electricity sector." **MITei Director Robert Armstrong, Chevron Professor of Chemical Engineering and chair of the Future of Energy Storage study.**

Thermal, chemical (e.g. hydrogen), metal-air battery, and pumped-hydro storage technologies are within the blue zone representing high power-capacity and low energy-capacity costs. They can provide long-duration storage. Fly batteries and some other technologies with intermediate capacities are shown in the green zone with moderate power-capacity and energy-capacity costs. Lithium-ion batteries (Li-ion) typically fall in the brown zone (high energy-capacity and low power-capacity costs) and are better suited to applications with shorter durations (a few hours) and more frequent cycling. (Figure 10).

Figure 10. *Storage Technologies Based on Power-Capacity and Energy-Capacity Costs ($/kW)*



Source: *MITei, 2022*

Some storage technologies have been tested extensively and are already available for commercial use. For example, overall Li-ion battery prices have plummeted in tandem with the rise in the use of VRE generation. The report recommends that policy makers focus research and development (R&D) efforts on other storage technologies. One particular technology domain is to improve alternative electrochemical storage technologies that use materials that are easy to find in response to addressing supply chain related difficulties.

According to the study, several decommissioned power stations may be transformed into energy-storage facilities by replacing their fossil fuel boilers with thermal storage and new steam generators. This retrofit may be accomplished with commercially available technologies and may be appealing to plant owners, as it makes use of assets that would otherwise be abandoned when power networks aim at wider decarbonization. The study notes that over the medium and long term, investing in VRE combined with energy storage is preferable to investing in new coal generation for countries such as India; however, existing coal plants may continue to operate unless they are compelled to do so by policy measures such as carbon pricing.

The report acknowledges the potential role of conventional hydropower systems with storage reservoirs in balancing power supply and demand in systems with large shares of VRE generation. The study also suggests that chemical energy storage offers certain advantages over electrochemical and thermal energy storage: low costs relative to energy capacity and very low self-discharge of energy stored over extended periods of time.[19] The ability to scale power and storage capacities independently supports chemical systems' suitability for long-duration energy-storage needs. Besides these advantages, in contrast to electrochemical energy storage, the report notes that chemical storage offers additional avenues for stored chemicals beyond the electricity system: use of stored as fuels or feedstocks in the transport sector and in industrial applications." (Gençer and Agrawal 2016; Gençer, Al-musleh, et al. 2014).[20]

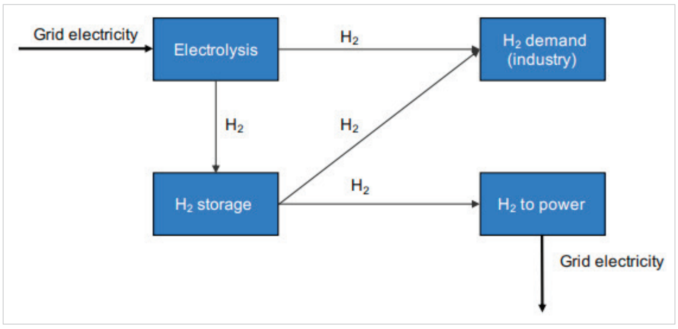
[19] MITei, pg.147
[20] Ibid.

Hydrogen Storage

The study also examines hydrogen storage options in detail and finds that their utilization will largely depend on how much hydrogen is utilized in the overall energy economy. According to the report, the widespread use of hydrogen will be determined by the future costs of producing, transporting, and storing it. The rate of innovation in applications that enable wider use of hydrogen will also be a critical determinant.

Hydrogen in Coupling of Industrial Energy Needs and Electricity Generation Dynamics: The report demonstrates that hydrogen can be employed as both a low-carbon fuel for industry and for power generation during periods when wind and/or solar power production is low (Figure 11). The use of electrolyzer technologies as a dispatchable load for the power system could also reduce the costs of decarbonizing the system by increasing the capacity utilization of VRE resources.

Figure 11. *Illustration of Power-Industry Coupling of Hydrogen*



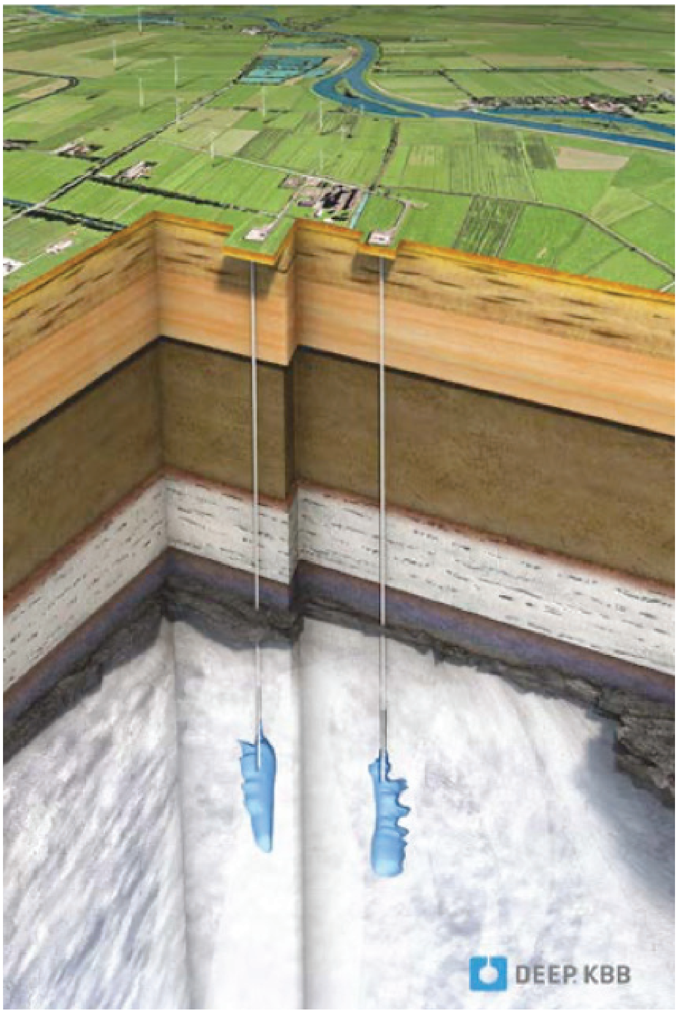
Source: *MITei, 2022*

Above-ground Hydrogen Storage vs. Underground Hydrogen Storage: At present, like other industrial gases, hydrogen is commercially stored in above-ground tanks or in underground geologic storage facilities (Figure 12 and Figure 13). Both technologies have achieved technological maturity. Above-ground storage is not bound by geological constraints, and hydrogen can be stored either in compressed (or gaseous) or refrigerated (or liquid) forms. Underground (or geologic) storage of hydrogen is also commercially viable and has been deployed at scale. Many locations around the world currently have hydrogen stored in underground caverns. Underground storage facilities have the capacity to store hydrogen on a much higher order-of-magnitude on an energy basis and are much larger than above-ground facilities,[21] but with a limitation: it requires suitable geology and locations with salt caverns. It is important to note that natural gas can stored in depleted oil and gas reservoirs, aquifers, and hard rock caverns, but due to its physical and chemical properties, hydrogen can only be stored in salt caverns[22].

Figure 12. *A Pressurized Hydrogen-Storage Tank*

Source: *Image courtesy of Linde plc. in MITei, 2022*

Figure 13. *Representation of an Underground Salt Cavern*



Source: *Image copyright DEEP.KBB GmbH. in MITei, 2022*

[21] MITei, 2022, pg. 151
[22] Ibid.

Europe Puts Forward Ambitious Targets to Boost Electrolyzer Manufacturing Capacities until 2025

On May 5, the EU Commissioner for the Internal Market along with 20 European electrolyzer manufacturers signed a Joint Declaration[23] committing the industry to a *ten-fold increase* in its electrolyser manufacturing capacities by 2025. This would make it possible for the EU to reach the goal of producing 10 million tons of renewable hydrogen annually by 2030, a key objective within the REPowerEU[24] Communication in March 2022. On May 18, the EU Commission revealed its REPowerEU Plan, which included EUR 200 million of funding for hydrogen project research.[25] The European Commission estimates that between EUR 34 billion and EUR 49 billion must be invested in hydrogen infrastructure to implement its REPowerEU plan.[26]

Photo Source: *Euractiv.com*

"Clean hydrogen is indispensable for reducing industrial carbon emissions and contributing to our energy independence from Russia. We have no time to lose, which is why this European electrolyser summit is so opportune. Today, the industry agreed to a ten-fold increase in electrolyser-manufacturing capacities in Europe. The Commission will support this important industrial upscaling which gives Europe an industrial leadership in the clean energy technologies of the future." [27] Thierry Breton, Commissioner for Internal Market, The European Commission

[23] https://hydrogeneurope.eu/wp-content/uploads/2022/05/2022.05.05-EU-ELY-Summit_joint-declaration_signed-c70ff98b5001f55b76b50cf0221c895f.pdf
[24] https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131
[25] https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131
[26] https://www.h2-view.com/story/repowereu-e34-49bn-needed-for-hydrogen-infrastructure/
[27] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2829

500 TWh of electricity input equivalent of a ten-fold increase in electrolyzer manufacturing capacities

- Electrolyzer manufacturers in Europe have agreed to boost their production capacity to 17.5 GW/yr.
- This corresponds to around 500 TWh of renewable-based electricity.
- The declaration notes that delivering large quantities of hydrogen from production sites to consumers would require important infrastructure upgrades for hydrogen transmission, distribution, and storage. It also underlines the importance of long-term storage to manage hydrogen demand and supply fluctuations.
- The joint declaration also defines necessary efforts by the EU Commission to establish:
  - a supportive regulatory environment,
  - simplified access to financing,
  - and more efficient supply chains.
- In terms of a supportive ***regulatory environment***, the European Commission will make it a priority to ensure that the regulations that govern the production of renewable hydrogen, including those that address the availability of renewable electricity to projects that produce renewable hydrogen, are both justified and proportionate, and that they provide support for a rapid and cost-effective ramp-up of the market for renewable hydrogen and its production in the continent.
- With regard to ***access to financing,*** the European Commission will support the development of hydrogen technology and applications through a variety of EU programs and grants. The Commission has designed a Hydrogen Public Funding Compass to assist stakeholders in identifying the best suitable program or fund to support their projects. The EU Innovation Fund is intended to promote highly creative low-carbon technology initiatives, such as the production of zero- and low-carbon equipment such as electrolyzers.
- With respect to the ***development of supply chains,*** the European Clean Hydrogen Alliance is helping to foster the development of integrated value chains across Europe. This would result in the formation of supply chains that are more effective and resilient.

President of the European Commission Ursula von der Leyen

"The European Commission, in its new plan, REPowerEU,[28] has doubled the EU's hydrogen targets for 2030 to 10 million tons of renewable hydrogen produced annually in the EU by 2030 and another 10 million tons in annual imports. We must complete the construction of the European hydrogen economy so that we offer your industry the conditions to move faster. As a result of the recent increase in the cost of gas, green hydrogen may already be more affordable than gray hydrogen. Our goal is to lower its price per kilogram substantially below 1.8 euros by 2030, and this objective is not out of reach." President of the European Commission Ursula von der Leyen at the opening of the European Hydrogen Energy Conference 2022." [29]

Von der Leyen underlined the following steps for a rapid boost for the role of hydrogen in the EU energy mix[30] :

- Increasing the amount of investment from the public sector in order to encourage more investment from the private sector,
- Working with industry to speed up projects and innovation,
- Making it easier for businesses to budget and plan ahead,
- Developing a European hydrogen industry that can compete on a worldwide scale.

Key role of R&D&I

The Joint Declaration emphasized the need for continuous research, development, and innovation (R&D&I), as the current upscaling and early industrial deployments of large-scale electrolyzers pose challenges. In this regard, the manufacturers are committing to channel investment into R&D&I privately, jointly with other companies as well as via partnerships with academia based on research programs. (Please see Figure 14 for a recent assessment on the technology levels of different electrolyser options.)

[28] https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131
[29] https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_22_3185
[30] https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_22_3185

Global Deployment Status for Electrolyzers

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- "Electrolysers are a relatively mature technology that has been long used in certain industrial processes, such as the production of chlorine in the chlor-alkali process (in which hydrogen is produced as a by-product). However, its use for dedicated hydrogen production has not yet been widely adopted. Current dedicated production of hydrogen from electrolysis is 30 kt per year, accounting for ~0.03% of all hydrogen produced.
- The level is low because the production cost of electrolytic hydrogen (USD 3-8/kg H2) is high compared with from unabated fossil fuels (USD 0.5-1.7/kg H2). Closing this gap will require a drop in electrolyser costs and more importantly in the price of low-carbon electricity, as well as an increase in load factors.
- Electrolysers have reached enough maturity to scale up manufacturing and deployment to significantly reduce costs, which is reflected in three consecutive years of record capacity deployment in 2018, 2019 and 2020. Despite the impact of the Covid 19 pandemic, which has delayed a significant number of projects, close to 70 MW of electrolysis became operational in 2020, bringing total installed capacity to almost 300 MW.
- Europe has 40% of global installed capacity and will remain the dominant region thanks to the stimulus of policy support from numerous hydrogen strategies adopted in the last year and the prominence of electrolytic hydrogen in the Covid 19 recovery packages of countries such as Germany, France and Spain.
- Continuous innovation is essential to reduce costs and increase the competitiveness of hydrogen technologies.
- Unlocking the full potential demand for hydrogen will require strong demonstration efforts over the next decade.
- Larger R&D budgets and support for demonstration projects are urgently needed to ensure that key hydrogen technologies reach the commercialisation phase as soon as possible."

For further reading:
https://www.iea.org/reports/hydrogen

Figure 14. *Technology Readiness Levels for Hydrogen Production via Electrolysis*

Readiness level ?	Sector	Technology	Step in value chain	↓ Importance for net-zero emissions
9	Energy transformation > **Hydrogen**	**Production** > **Electrolysis** > Polymer electrolyte membrane	**Production**	Very high
9	Energy transformation > **Hydrogen**	**Production** > **Electrolysis** > Alkaline	**Production**	Very high
3	Energy transformation > **Hydrogen**	**Production** > **Electrolysis** > Seawater electrolysis	**Production**	Moderate
7	Energy transformation > **Hydrogen**	**Production** > **Electrolysis** > Solid oxide electrolyser cell	**Production**	Moderate

For further reading: https://www.iea.org/articles/etp-clean-energy-technology-guide

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