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# Beyond the Stocktake (Part II):

## Clean Energy Technologies

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**Abstract**

Ever since its inception, the G20 Energy Transitions Working Group (ETWG) has covered a wide range of priority areas broadly spanning across clean energy, energy access and energy security. Specifically, with respect to clean energy technologies, while there exist some legacy topics such as energy efficiency, renewable energy, nuclear energy, phasing out inefficient fossil fuel subsidies etc. that are included year after year, every successive presidency has attempted to introduce new elements. This policy brief aims to chart out the future course of action *Beyond the Stocktake*, highlighting aspects that can be carried forward by the presidencies that follow India. It delves into the progress made at the G20 with respect to select clean technologies with the idea of gauging how much has been covered and what remains to be done for accelerating energy transitions. In particular, the paper tables a few promising ideas for guiding the engagement structure of G20 ETWG negotiations and attempts to build a case for adopting strategies tailor made for technologies in different stages of development.

***Keywords:*** *Clean energy, Energy transition, G20*

***JEL Classification:*** *Q54, Q55, Q56*

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# Beyond the Stocktake (Part II): Clean Energy Technologies

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## 1. Introduction

With the G20 countries contributing towards 85 per cent of the global gross domestic product (GDP), representing 75 per cent[3] of the energy demand, and accounting for 75 per cent of global greenhouse gas (GHG) emissions, the group has considerable bearing on shaping the international energy and climate agenda. Since its inception in 2013, the Energy Sustainability Working Group (ESWG)[4] has covered a wide range of priority areas. What started off with a narrow focus on clean energy, energy access and energy security has over the years evolved to comprise of a diverse range of topics, including but not being limited to energy data transparency, market stability, financial flows for meeting Paris agreement targets, technology innovation etc. Specifically with respect to clean energy technologies, while there exist some legacy topics such as energy efficiency, renewable energy, nuclear energy, phasing out inefficient fossil fuel subsidies etc. that are included year after year, every successive presidency has attempted to introduce new elements. For instance, energy storage was mentioned for the first time during the Chinese Presidency; hydrogen was introduced during the Japanese round; Italy included offshore renewables within its priority areas and so on.

The recently released Stocktake on Access, Technology and Finance Report (2022)[5] aims to monitor the progress with respect to energy access, clean energy technology and clean energy financing and investments, which is in turn expected to facilitate the identification of critical priorities for collaborating and forging partnerships amongst G20 member countries.

This policy brief aims to chart out the future course of action beyond the stocktake, highlighting elements that can be carried forward by the presidencies that follow India. Throughout the course of the past G20 negotiations, India has emerged as a strong leader voicing the concerns of developing countries while largely embracing ideas put forth by preceding presidencies. With the G20 being consecutively led by developing countries for four years in a row (starting with the Indonesian round), it provides an opportune time to ensure that common priorities lie at the heart of the discussions. This policy brief tables a few promising ideas for guiding the engagement structure of G20 Energy Transition Working Group (ETWG) negotiations.

The structure of this paper is as follows. While Section I introduces the topic and discusses the premise for the same, Section II delves into the progress made in G20 ETWG deliberations as

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3 Available at: https://www.g20-insights.org/2022/02/28/g20-needs-to-provide-inclusive-energy-system-to-accelerate-global-energy-transition/. Accessed on 10 November, 2022
4 Hereafter referred to as the Energy Transition Working Group (ETWG)
5 Available at: https://g20.org/wp-content/uploads/2022/09/Stock_Take_on_Access_Technology_and_Finance_compressed.pdf. Accessed on 7 November, 2022.

regards some of the prominent clean energy technologies. This is followed by Section III that focuses on the stages of technology development and classifies select technologies into the same with respect to G20 developing countries. Finally, Section IV discusses the nature of G20 interventions and its role in furthering the agenda of clean energy technologies.

## 2. Progress at G20

This section provides an overview of some the key clean energy technologies that have been included as part of previous ETWG negotiations, have been identified as 'emerging' by the Bali Stocktake Report and/or are of strategic importance for India. For each of the technologies, this section tracks the discussions that have unfolded so far as part of the ETWG deliberations. The basic idea is to gauge how much has already been covered and what remains to be done in order to accelerate clean energy transitions.

- Energy Efficiency

Energy efficiency has been a long-standing priority area for G20 members. Since 2014, member countries have participated in voluntary frameworks working towards improving energy efficiency. For instance, the 'G20 Energy Efficiency Action Plan' (2014) that encouraged international collaboration in key areas such as buildings, industrial energy management, electricity generation, transport etc. Similarly, the 'G20 Energy Efficiency Leading Programme (EELP)' of 2016 represents one of G20's first long-term frameworks endorsing energy efficiency co-operation till 2030. This was followed by the 'G20 Energy Efficiency Investment Toolkit' of 2017 that highlighted voluntary options for scaling up investments in energy efficiency. Under the Japanese Presidency, the dialogue was extended to explore energy efficiency in key sectors such as buildings, heating and cooling. As part of the Circular Carbon Economy (CCE) Guide prepared under the Saudi Arabian Presidency, the pivotal role played by energy efficiency or the 'reduce' component was highlighted with regard to building a circular carbon economy, that paved the way for effective implementation of the remaining 3 R's. In 2021, the Italian Presidency expressed its intent to enhance existing multilateral initiatives such as the EELP and the Energy Efficiency Hub. Similarly, the Indonesian Presidency emphasized on the principle of energy efficiency as the 'first fuel' for driving cost effectiveness.

- Non-Biomass Renewables: Solar and Wind

Renewable energy has frequently featured as a priority area under the G20 agenda and efforts have been made to facilitate accelerated deployment of the same in member countries. Almost 81 percent of the installed capacity of renewable power generation in the world is hosted in G20 countries and, as per IRENA estimates, these countries possess 75 per cent of the deployment potential between 2010 and 2030 (IRENA, 2018). Over the years, the group has come together to endorse and adopt a variety of outcomes. For instance, the 'G20 Toolkit of Voluntary Options for Renewable Energy Deployment', which provided options to member countries to scale up their renewables. Similarly, the 'G20 Voluntary Action Plan on Renewable Energy' that was put forth by the Chinese Presidency for augmenting the share of renewables by 2030 and simultaneously advancing the implementation of the toolkit. As part of the CCE Guide released by the Saudi Arabian Presidency, a guide for the ‘reduce’ component covering non-biomass renewables was prepared by IRENA that highlighted the role of renewable energy technologies in the post pandemic recovery phase. Further, it recognized the importance of targets, supporting policies, capacity building and innovation as being the corner stones of policy engagement for G20 member countries (IRENA, 2020). Pushing the envelope further, the Italian Presidency included offshore renewables such as floating solar PV, offshore wind and ocean energy within their agenda. In addition, member countries expressed interest in further investing in critical low emission technologies that would help in achieving SDG 7 and the Paris Agreement targets. This was followed by the Indonesian round wherein emphasis was laid upon scaling up (both existing and innovative) technology solutions. In particular the focus was on the affordability aspect of technologies that play a deterministic role with regard to technology deployment, specifically in the developing and emerging economies.

- Renewable Energy: Biofuels and Bioenergy

The G20 rounds of 2016, 2017 and 2018 acknowledged the importance of developing and deploying modern bioenergy including 2$^{nd}$ generation and advanced biofuels for accelerating energy transitions and reducing emissions. All three rounds highlighted the need for moving beyond the power sector and making concerted efforts in other end use sectors. The Japanese Presidency (2019) went one step ahead and called for increased cooperation for sustainable biofuels and bioenergy by leveraging existing initiatives such as the Bio-future Platform. This was followed by the Saudi Arabian round wherein the cross-cutting nature of modern bioenergy and biofuels across the 4 R’s of Reduce, Reuse, Recycle and Remove was highlighted. While the Italian round failed to include biofuels within its priority area, it encouraged continued investment for integration of renewable energy including bioenergy for maintaining system stability.

- Hydrogen

The versatility of hydrogen in terms of an energy carrier, means of chemical storage and industrial production feedstock, is among the primary reasons for the growing interest in this energy source. Hydrogen has been a very recent addition to the G20 Dialogue and was included as part of G20 discussions during the Japanese Presidency in 2019. Energy Ministers recognised hydrogen as a promising alternative form of energy carrier and storage and committed to step up existing international efforts to unlock its potential as a clean, reliable and secure source of energy. The need for greater co-operation in research and development and evaluation of the economic and technical potential and the need to address various challenges were also highlighted. This was followed by the Riyadh Summit, wherein the potential of hydrogen as a source of clean energy was acknowledged along with the recognition of its applicability across the 4 R’s. The energy ministers pledged to strengthen international collaboration for furthering its development and deployment.[6] Under the Italian Presidency (2021), the need for advancing technologies and augmenting commercialization of the same was recognized particularly in the case of low emission hydrogen with specific reference to the hard to abate sectors. Additionally, the role of international trade with respect to hydrogen was also highlighted.[7] The Indonesian round drew focus on the need to plan and build the requisite supportive infrastructure for scaling up hydrogen technologies and unlocking their decarbonization potential.

- <u>Storage Technologies</u>

Concerns regarding energy security loom over most nations today. As countries grapple to ensure uninterrupted energy supply while catering to sustainable development goals, the role of energy storage systems becomes more pronounced. It was under the Chinese Presidency (2016) that the G20 acknowledged the challenge of maintaining power system flexibility in light of the increasing share of variable renewable energy. Member countries were thus encouraged to promote technical development and deployment of storage technologies to ensure stability of the grid. While the subsequent rounds in Germany (2017), Argentina (2018), Japan (2019) and Italy (2021) have laid emphasis on this technology, limited ground has been at the G20 in this regard. The Indonesian round emphasized on the need for international cooperation for ensuring that these technologies are accessible and affordable.

- <u>Electric Mobility</u>

Electric Vehicles (EVs) found mention for the first time in the G20 discourse during the Chinese Presidency (2016) wherein technical development of technologies such as energy storage, EVs and modern bioenergy was promoted. Following a momentary pause, discussions resumed during the Japanese round in 2019, wherein energy leaders acknowledged the potential of electricity use for avoiding emissions in end use sectors through technologies such as electrified mobility. Further, they discussed the need for minimizing risk of malicious use of technologies such as ICT, EVs, flexible power plants etc. Under the Italian Presidency (2021) the focus was on collaborating efforts for deploying low emission vehicles and fuels while also working towards accelerated deployment of zero emissions vehicles.

- <u>Smart Grids</u>

The discussion on smart grids was included as part of the G20 agenda under the Chinese Presidency. It recognized the role of such technologies in reducing emissions and enhancing resilience of power systems. Cooperation with regard to common standards for accelerating smart grid deployment was also encouraged. In the summits led by the German and the Japanese Presidencies, smart grid technologies were mentioned in passing with specific reference to their role in integration of variable renewable energy and ensuring power systems

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[6] Available at: https://www.jodidata.org/_resources/files/events/jodi-inter-secretariat-meeting---december-2020/g20-energy-ministerial-communique--27-28-september-2020.pdf. Accessed on 10 November, 2022.

[7] Available at: http://www.g20.utoronto.ca/2021/2021_G20-Energy-Climate-joint-Ministerial-Communique.pdf. Accessed on 10 November, 2022.

flexibility. This was followed by the Italian Presidency encouraging investments and use of digital technologies such as smart grids for maintaining stability of the system and for smoother coordination between power sources, grids, load and storage.

- Carbon Capture Utilization and Storage (CCUS)

While the importance of CCUS has been acknowledged in passing under the G20 Presidencies of Germany and Argentina, it was only during the Japanese round that concerted efforts were made towards recognising opportunities offered by these technologies. In particular, special emphasis was laid upon carbon recycling and emissions to value. The 'CCE Guide' released during the Saudi Arabian round went on to provide an overview of the concept of a circular carbon economy and detailed out the different options available under the 4 R's. With specific reference to the 'reuse' and 'remove' component, it highlighted the importance of CCU and CCS technologies in closing the carbon loop. Taking note of the dominant role of fossil fuels in the energy mix, the Italian Presidency emphasized on the need for investing in advanced technologies such as CCUS and carbon recycling that would facilitate in abating emissions from the same. The focus under the Indonesian round was on making CCUS technologies affordable specifically for the developing countries. Further, the need for developing value chain networks and CCUS hubs for accelerated deployment were also discussed.

- Nuclear Energy

Ever since its inclusion in the G20 discourse under the Chinese Presidency, the essence of the text in the ETWG communiques pertaining to nuclear energy has remained broadly the same. It has been recognized in terms of its contribution in the energy mix of a few countries and in terms of its role in reducing GHG emissions. Additionally, member countries have been cautioned to ensure the highest safety and security standards when dealing with the same. Under the 2019 Japanese Presidency, the scope was expanded to acknowledge the role of nuclear energy in contributing towards energy security and providing baseload power as well. Further, the need for safe disposal of radioactive waste and the need for promotion of technical cooperation for safety improvement were highlighted.

## 3. Stages of technology development and clean energy

It is important to be cognizant of the fact that the stage of technology dictates the form of support that will be required for it to develop further. The financial support aspect of technology development has been dealt with in detail by Goldar, Jain & Bhattacharya (2023). This section focuses more on what the nature of G20 interventions should be with respect to clean energy technologies. This policy brief divides the stages of technology development into four categories namely- (a) Research & Development (R&D), (b) Demonstration & Deployment, (c) Initial and limited diffusion and (d) Commercialization. Combining and suitably modifying the definition provided by numerous sources, the authors have arrived at the following:

a) **Research & Development (R&D)**: Refers to the conception of a new idea of technology being developed into a prototype, or an existing technology being experimented for a new component. This stage may also be accompanied by feasibility studies being undertaken to gauge the scope and potential of developing the technology in question.[8]

**b) Demonstration and Deployment**: Refers to the stage wherein a new technology is introduced in the market for the first time, on an experimental basis for further development and refinement. It is produced by a limited number of commercial units and this stage is typically more risky and costly than the previous stage.[9]

**c) Initial and limited diffusion**: Refers to the stage wherein a technology becomes available for limited use in relevant applications through adoption by a few. Though the innovation is a part of the mainstream market (i.e., with respect to its market share), its extent is fairly limited.[10]

**d) Commercialization**: Refers to the final stage wherein the technology becomes a part of the mainstream market, available for mass scale usage/adoption.[11]

Using the above definition, the technologies identified in the previous section have been placed into relevant stages for the set of developing countries within the G20. The motivation behind focussing on this set stems from the fact that for the first time, the G20 presidency will be consecutively held by developing countries (i.e., Indonesia, India, Brazil and South Africa), thereby providing them the opportunity to steer discussions towards priority areas that they have in common. For the purpose of this paper, G20 developing countries have been selected based on the categorization provided by the report titled *World Economic Situation and Prospects (2020)*, by the United Nations Department of Economic and Social Affairs. The set of countries includes Argentina, Brazil, China, India, Indonesia, Mexico, Saudi Arabia, South Africa, South Korea and Turkey. The basis for the categorization into technology stages can be gleaned from the Annexure Tables A.1 – A.8 that provide details regarding the total primary energy supply, electricity generation mix, renewable energy installed capacity, transport energy mix, projects and programs launched by countries for various technologies and so on. The data for the same has been collated for the year 2021 from individual country profiles provided by the Climate Transparency Report (2022).

While there is some degree of heterogeneity amongst the countries, Table 1 provides a broad classification of the stage of technology development. For instance, in the case of biofuels their share in the transport energy mix (presented in Annexure Table A.7) indicates that for countries like Brazil and Indonesia it has reached the commercialization stage, whereas for the remaining the shares are relatively modest. Thus, this technology has been placed under both diffusion and commercialization stages. Similarly, in the case of CCUS, countries are currently

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8 Adapted from "Energy Technology Perspectives 2020: Special Report on Clean Energy Innovation" (IEA,2020)

9 Adapted from "Net Zero by 2050: The need for net zero demonstration projects" (IEA, 2022)

10 Adapted from "Technology Innovation, Development and Diffusion" (OECD & IEA, 2003)

11 Authors' judgement

conducting feasibility studies and carrying out demonstration projects which indicates that this technology is presently somewhere between the first two stages of technology development.

**Table 1: Stage of Technology development in G20 Developing Countries**[12]

| Technology | R&D | Demonstration & Deployment/Pilot | Diffusion | Commercialization |
|---|---|---|---|---|
| Solar & Wind | | | | • |
| Biofuels | | | • | • |
| Low carbon hydrogen | | • | | |
| Energy Efficiency | | | | • |
| Battery Storage | | • | • | |
| Electric Mobility | | | • | |
| CCUS | • | • | | |
| Nuclear | | | | • |

(Authors' Construction)

In the section that follows, an attempt has been made by the authors to make use of the above classification to suggest possible G20 interventions for the technologies in question.

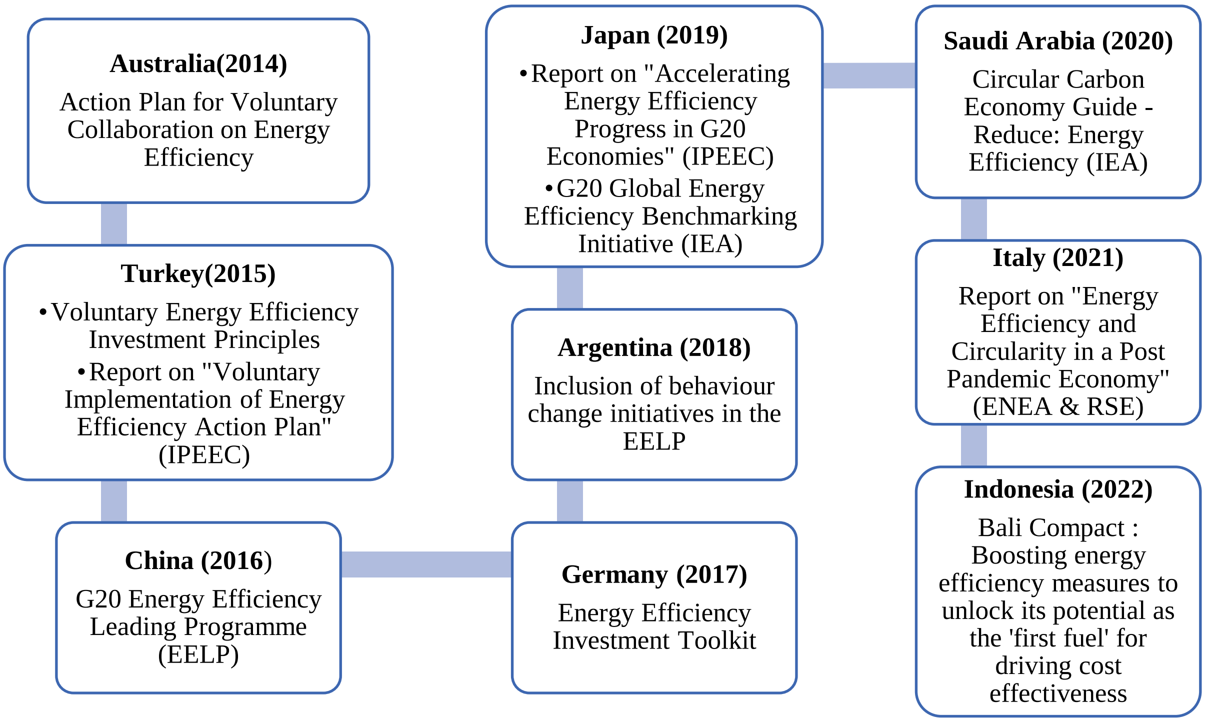
## 4. Taking the clean energy technologies agenda forward: Recommendations and the Role of G20

At the G20, interventions have typically taken the form of an action plan or roadmap, compilation of best practices, developing a toolkit, or adopting a declaration. These play a complementary role to individual country level actions that will ultimately contribute towards the common goal of limiting temperature increase within 1.5°C. However, in order for the intervention to be effective, it is critical to tailor the outcome to each technology depending on its stage of development.

There is precedence for providing targeted support to technologies at the G20 as is evident in the case of energy efficiency (Figure 1).

[12] Smart grids have not been included here as they represent a very broad concept that encompasses a wide range of elements such as smart meters, Supervisory Control and Data Acquisition (SCADA), Distributed Energy Resources (DER), substation & distribution automation, distribution transformer monitoring systems and much more. Since each country is at a different stage of development in so far as smart grids are concerned, it is not possible to compare the status of each country vis-a-vis the others. For any meaningful comparison each component of the smart grid prevalent in a country would have to be compared with the similar component, which may or may not be present in another country.

**Figure 1: Progress of G20 interventions with respect to energy efficiency**




For technologies in the **R&D stage**, action plans for collaboration or platforms for knowledge exchange will be a suitable intervention. The Research and Development 20 (RD20) is one such example of an initiative launched during the Japanese Presidency for facilitating joint international research by premier institutes across the G20 member countries. At present the RD20 has in place taskforces dealing with solar energy, hydrogen and energy management systems. Outcomes from such an engagement platform can perhaps be bolstered by preparing a catalogue of research institutes and universities engaged in clean energy innovation so as to widen the pool of prospective participants and encourage cross country collaboration. Such an exercise has precedence as can be seen from India's BRICS Presidency of 2021 wherein an Energy Research Directory was formally released as part of the outcome documents, that listed out organizations and institutions along with their areas of work and contact details of concerned personnel overseeing the same.

Similarly, for technologies in the **demonstration & deployment stage** releasing a compendium of best practices and case studies is likely to provide the necessary guidance. However, it is important to note here that the capability of indigenization would differ based on country specific circumstances and resource endowments. For example, in the case of CCUS, application of this technology will be contingent upon availability of suitable carbon storage sites, well developed transportation infrastructure between the source and site of use and so on. Similarly in the case of battery storage technologies, availability of critical raw minerals such as lithium, nickel, cobalt etc. will be a determining factor.

With respect to accelerating **diffusion**, declarations and policy roadmaps for scaling up would be useful for charting the future course of action. These may be strengthened by leveraging off of the efforts carried out by international platforms such as the Clean Energy Ministerial (CEM) that happens to focus on a number of overlapping priority areas. A case in point is the ongoing work involving biofuels and electric mobility by way of its bio-future platform and campaign and electric vehicle initiative. Given that the CEM represents one of the largest agglomeration of countries, companies and experts dealing with clean energy technologies and is guided by the mandate of hastening the pace and scale of clean energy adoption, joining forces with the same may prove to be fruitful.

Finally, for technologies in the **commercialization** stage the role of the private sector through G20 engagement groups such as the B20 becomes pronounced. A case could also be made for the eventual graduation of a technology out of the G20 agenda once it reaches maturity. Additionally, the G20 may consider constituting a 'Green Technology Clearing House Exchange' that would serve as a medium for promoting technologies in countries that may not a part of the G20 but face institutional or non-institutional constraints in developing such technology solutions. This may take the form of information exchange and showcasing of mature green technologies through setting up of pilot projects in these countries.

While each G20 Presidency is strategic with respect to the choice of topics that cover not only their own interests but also resonate with other member countries; there is also (to some extent) a degree of continuity of priority areas across different rounds. That being said, there is merit in following such a technology mapping approach to prepare outcome documents that are best suited for technologies in different stages of development. However, there are significant learnings from previous G20 rounds that if properly distilled will provide clear insights into possible outcomes that can be envisaged from the negotiation process.

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# Annexure

## Table A.1: Country Profile for CCUS Projects

| G20 Countries | CCUS |
|---|---|
| Argentina | No regulatory framework or roadmap has been developed so far for CCS application in the short, medium or long term. However, a few **techno-economic studies** to gauge the theoretical potential and possible challenges for CCS in the country have been carried out (NewClimate Institute and Climate Analytics, 2019). |
| Brazil | The release of the Brazilian atlas of $CO_2$ capture and geological storage in 2015 marked a milestone in terms of development of this technology in the country. At Brazil has one large scale installation in operation headed by Petrobras, which is currently progressing towards meeting its 2025 target of injecting 40 million tonnes of $CO_2$ (GCCSI, 2022). |
| China | CCUS has been identified as a critical technology in numerous government documents for meeting the country's climate goals and the 14$^{th}$ Five Year Plan specifies the goal of deploying large scale CCUS demonstration plants particularly in coal producing areas. As of 2021, China has roughly 50 CCUS projects (**demonstration and commercial scale**) at different stages of development (IEA, 2022). |
| India | The establishment of the Indian $CO_2$ Sequestration Applied Research Network, under the leadership of the Department of Science and Technology (DST) in 2007, marked the country's first engagement with CCUS. However, except for a few mentions of this technology in the National Action Plan on Climate Change, the Second National Communication and the 2$^{nd}$ and 3$^{rd}$ Biennial Update Reports, India has not devised any dedicated policy action in this regard. While the importance and relevance of this technology lever is recognized, the uptake of CCUS has been somewhat sluggish in the country. Nevertheless, a few projects have been initiated with **techno-economic feasibility** studies being carried out for some. For example, the Dalmia Cement's 5,00,000 tonne carbon capture **demonstration** plant in Tamil Nadu; the ONGC and IOCL joint venture to reduce emissions using CCUS at the Koyali refinery in Gujarat[13]; NTPC's $CO_2$ capturing from flue gas for methanol conversion at the Vindhyachal Super Thermal Power Station[14] etc. The policy discussion at the national level has been somewhat reignited with the release of the Draft 2030 Roadmap for CCUS for Upstream E&P Companies (2021) that outlines guidelines for oil and gas companies in India for developing and scaling up CCS/CCUS techniques. As of February 2022, two national centres of excellence in CCU have been set up in Bombay and Bengaluru for the purpose of mapping research and development innovation activities and for developing networks with key stakeholders in the field. It is expected that the centres will function as design development and capacity building hubs for application-based initiatives involving CCU. |
| Indonesia | The setting up of the National Centre of Excellence on CCS/CCUS in 2017 for promoting collaborative research and development marked the beginning of CCUS development in Indonesia. Currently there exist a number of **pilot projects** and **feasibility** studies that are being undertaken.[15] Additionally, as of 2021, the country has established a taskforce for drafting regulations for CCUS which is expected to be released by the end of 2022.[16] |
| Mexico | Mexico released a $CO_2$ geological storage atlas in 2012 for evaluating the country's storage capacity. Shortly after, a ten-year technology roadmap was issued in 2014 comprising of overlapping stages cutting across research, capacity building, designing regulations, promoting private investment, developing pilot projects and finally commissioning large |

13 Available at: https://www.dailypioneer.com/2019/state-editions/ongc-signs-mou-with-iocl-for-eor.html. Accessed on 2 November, 2022.

14 Available at: https://www.powermag.com/carbon-capture-begins-at-indias-largest-coal-power-plant/. Accessed on 2 November, 2022.

15 Available at: https://thediplomat.com/2021/09/carbon-capture-is-the-key-to-indonesias-net-zero-emissions-future/. Accessed on 20 November, 2022.

16 Available at: https://status22.globalccsinstitute.com/2022-status-report/regional-overview/. Accessed on 20 November 2022.

| | |
|---|---|
| | scale demonstration and commercial CCUS projects (IEA, 2017). With the help of funding from the World Bank CCS Trust Fund, two CCS **pilot projects**, i.e., $CO_2$ Capture Pilot Project (CCPP) and the $CO_2$ EOR and Storage Pilot Project (CESP) are underway in Mexico.[17] |
| Republic of Korea | There exist limited CCS or CCUS facilities in South Korea, most of which are in the development phases. The Boryeong KoSol $CO_2$ Capture Test Site and the Hadong Dry Sorbent Capture Test Site represent two completed **pilot and demonstration projects** of the country involving thermal power capture processes. Additionally, two other CCS **test sites** are also being developed. With respect to DAC and BECCS, limited activity is taking place, mostly in the form of **experimental testing**.[18] |
| Saudi Arabia | There exist two CCUS operational projects in Saudi Arabia, namely Aramco's Uthmaniyah **demonstration** project that involves enhanced oil recovery (EOR) injection and the SABIC carbon utilization plant involved in chemical production (OGCI, 2021). The two have a capture rate of 0.8 and 0.5 mtpa respectively.[19] Further, the country also endeavours to build one of the world's largest CCUS hubs with a capacity to capture 44 million tonnes of $CO_2$ by 2035.[20] |
| South Africa | The country prepared a five stage CCS Roadmap in 2004 that was designed to guide CCS development in the country. Based on the roadmap, a preliminary study had been conducted to determine the theoretical potential of CCS in the country which was followed by the preparation of a $CO_2$ geological storage atlas. The country has identified locations for storing 150 giga tonnes of $CO_2$ (Surridge , et al., 2021). South Africa is currently implementing the third stage of the roadmap which involves conducting **pilot projects** that will act as a proof of concept for storing $CO_2$ in geological formations.[21] |
| Turkey | There exist no R&D or demonstration projects for CCS in the country (IEA, 2021) |

*Source: Authors' construction*

[17] Available at: https://www.cslforum.org/cslf/sites/default/files/documents/7thMinUAE2017/PG-World%20BankCSLF-FinancingCCSDevelopingCountries.pdf. Accessed on 26 November, 2022.

[18] Available at: https://carbon180.medium.com/a-tour-of-south-koreas-efforts-to-capitalize-on-carbon-257b49d38f04. Accessed on, 19 November, 2022.

[19] Available at: https://www.unescwa.org/sites/default/files/event/materials/ccus_in_gcc-_economic_institutional_drivers_and_potential_development_paths_post_cop22_.pdf. Accessed on 19 November, 2022.

[20] Available at: https://www.zawya.com/en/business/energy/saudi-arabia-to-build-largest-ccs-hub-in-jubail-maohi6k5. Accessed on 19 November, 2022.

[21] Available at: https://south-africa-platform.vizzuality.com/mitigation/flagship-programmes/the-carbon-capture-and-sequestration-flagship-program. Accessed on 19 November 2022.

## Table A.2: Country Profile for Low Carbon Hydrogen Projects

| G20 Countries | Low Carbon Hydrogen |
|---|---|
| Argentina | The country is currently preparing its National Hydrogen Strategy that is expected to be released this year. Hychico represents one of the few private initiatives involved in hydrogen production in Argentina. Located in Chubut Province, the plant produces hydrogen from wind energy and has been in operation since 2009. It is currently in the process of testing transportation and storage of hydrogen. A few other small scale **pilot projects** are being carried out by the Institute for Hydrogen Technology and Sustainable Energies and the Institute for Energy and Sustainable Development wherein the former is producing hydrogen derived from biomass and the latter is dealing with production of hydrogen using nuclear energy (pink hydrogen) and blending of hydrogen with compressed natural gas (Gomes, et al., 2021). |
| Brazil | The National Hydrogen Program was launched in 2021 for establishing a legal and regulatory framework with respect to use of hydrogen as a source of energy. The country is currently conducting **pilot projects** and **feasibility studies**. For example, Unigel (fertilizer producer) has commenced construction of Phase I of its integrated green hydrogen and green ammonia plants in Bahia. It is expected to have a capacity of producing 10,000 tonnes of green hydrogen and 60,000 tonnes of green ammonia per year, once production begins by the end of 2023.[22] Another example is that of "Base one" project in Ceará that was launched by an Australian energy company for producing green hydrogen in Pecém, is currently in the feasibility study stage and is expected to be operational from 2025 (Gomes, et al., 2021). As of August 2022, the country has also set up a secretariat to facilitate the production of green hydrogen by ensuring supply of low-cost clean energy for production, coordinating with key market stakeholders, entrepreneurs, energy associations etc. [23] |
| China | The country recently released its "Medium and Long-Term Plan for Development of Hydrogen Energy Industry" that spans across 2021-2035. The plan is expected to serve as a guide for all stages of the value chain with specific focus on low carbon hydrogen production, storage and transportation. As per the targets specified in the plan, China will work towards producing 1,00,000-2,00,000 metric tonnes of green hydrogen per year and roll out 50,000 fuel cell EVs and by 2025. Further the plan also seeks to increase the share of green hydrogen in the final energy consumption by 2035.[24] In addition to the national targets, subnational development plans have also been prepared at the provincial level. For instance, inner Mongolia set the target of producing 5,00,000 tons of green hydrogen by 2025. At present majority of the hydrogen produced by China is using fossil fuels, with green hydrogen representing a meagre one percent of the production. Currently most of the green hydrogen projects are in the **experimental stage** being led by state owned enterprises. The country has more than 120 green hydrogen projects at varying stages of development and it is expected that green hydrogen would reach the commercialization stage within the next decade (Brown & Grünberg, 2022). |
| India | The country has been actively exploring hydrogen as a potential source of energy and aims to emerge as a global manufacturing hub for hydrogen as well as fuel cell technologies. India has set a target to produce 5 million tonnes of green hydrogen by 2030 and in 2021, announced its National Hydrogen Energy Mission (NHM). The Mission aims to draw up a road map for hydrogen use as an energy source with strategies for the short (4 years) and |

22 Available at: https://globuc.com/news/construction-begins-on-worlds-largest-integrated-green-hydrogen-ammonia-plant/. Accessed on 22 November 2022.

23 Available at: https://www.pv-magazine.com/2022/08/09/brazil-sets-up-secretariat-to-develop-green-hydrogen/. Accessed on 22 November, 2022.

24 Available at: https://www.spglobal.com/commodityinsights/en/ci/research-analysis/china-issues-first-nationallevel-hydrogen-development-plan.html#:~:text=By%202030%2C%20the%20Plan%20aims,its%20peak%20carbon%20emissions%20goal.. Accessed on 23 November, 2022.

| | |
|---|---|
| | long term (10 years).[25] The NHM focuses on generation of green hydrogen and aims at leveraging the country's growing renewable capacity for producing the same. Further, the Green Hydrogen Policy released earlier this year proposes setting up of manufacturing zones for green hydrogen and green ammonia, amongst other provisions. Some of the other notable initiatives introduced by India include the "Hydrogen and Fuel Cell Program" and the "Advanced Hydrogen and Fuel Cell Program". While the former aims to develop technologies that deliver reduction in cost of hydrogen production, storage and distribution, enhancing power system flexibility and reduce emissions, the latter focuses on developing new and existing materials such as membranes, catalysts, fuel cell components etc. As of April 2022, Oil India Limited has commissioned the country's first pure green hydrogen **pilot** plant in Assam, that is expected to produce 10-30 kgs of green hydrogen a day.[26] Similarly, an MoU has been signed between Ladakh and the National Hydroelectric Power Corporation Limited for building two green hydrogen plants that will be powered via green energy sources.[27] Limited amount of green hydrogen is produced by the country at present, most of which is via **pilot** projects.[28] |
| Indonesia | In light of its underutilized renewable energy capacity, the country has recently announced its plans of producing blue and green hydrogen as a part of its 2030 emissions reduction target.[29] Though Indonesia does not have any dedicated national hydrogen strategy at the moment, a few **pilot projects** are being developed for advancing this technology lever.[30] For example, Pertamina is conducting trials for producing green hydrogen using geothermal energy in Ulubelu and targets setting up a pilot project with a daily production capacity of 100 kgs to begin operations in 2023 (Lo, Chu, Cheung, & Yip, 2022). |
| Mexico | The country does not have any national hydrogen strategy as of now and at present produces only grey hydrogen. However, there are a few **pilot projects** that are being carried out for exploring low carbon alternatives as well. For instance, a fertilizer company by the name of Tarafert has launched two projects. One that deals with blue ammonia and urea production (commercial operations scheduled to commence by 2026) and the other that deals with green hydrogen production using solar energy and electrolysis.[31] Similarly, as of January 2022, the Federal Electricity Commission has also launched a pilot project for green hydrogen production.[32] |
| Republic of Korea | South Korea released its Hydrogen Economy Roadmap in 2019 and identified energy and mobility as the priority sectors. The country targets manufacturing 6.2 million fuel cell EVs, setting up 1200 refuelling stations and designating 15 GW of fuel cells for generating electricity by 2040.[33] The formation of the Hydrogen Economy Committee, launch of the "Hydrogen Powered Cities Initiative" and the passing of the Hydrogen Economic Promotion and Hydrogen Safety Management Law represent some of the efforts by the government for supporting the development of hydrogen as an energy source (Lo, Chu, Cheung, & Yip, 2022). South Korea has adopted the strategy of first setting up a cost- |

25 Available at: https://pib.gov.in/PressReleasePage.aspx?PRID=1696498. Accessed on 1 November, 2022.
26 Available at: https://pib.gov.in/PressReleasePage.aspx?PRID=1818482. Accessed on 26 December 2022.
27 Available at: https://ladakh.nic.in/ladakh-to-get-2-pilot-green-hydrogen-projects-mou-signed-between-ladakh-admin-and-nhpcl/. Accessed on 26 December, 2022.
28 Available at: https://economictimes.indiatimes.com/industry/renewables/india-may-soon-export-green-hydrogen/articleshow/95418550.cms?from=mdr. Accessed on 26 December 2022.
29 Available at: https://www.hydrogen-indonesia.id/green-hydrogen/in-indonesia/overview. Accessed on 22 November, 2022.
30 Available at: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/102622-indonesia-tightens-emissions-goals-ahead-of-cop27-deploys-green-hydrogen-pilots#:~:text=Hydrogen%20and%20carbon,according%20to%20the%20ministry's%20estimates. Accessed on 22 November, 2022.
31 Available at: https://theenergyyear.com/articles/mexicos-hydrogen-roadmap/#:~:text=The%20country%20does%20not%20have,or%20roadmap%20like%20other%20countries. Accessed on 24 November, 2022.
32 Available at: https://newenergyevents.com/mexicos-federal-electricity-commission-cfe-launches-pilot-project-for-green-hydrogen-production/. Accessed on 24 November, 2022.
33 Available at: https://www.powermag.com/countries-roll-out-green-hydrogen-strategies-electrolyzer-targets/. Accessed on November 23, 2022.

| | |
|---|---|
| | effective hydrogen infrastructure (initially focus on producing grey and blue hydrogen) and in the medium to long term, gradually moving towards the production of green hydrogen (Australian Trade and Investment Commission, 2022). As of September 2022, a 12.5 MW green hydrogen **demonstration project** in Jeju that is deemed to be the country's largest, has begun its operations and is expected to run till 2026.[34] The country is in the process of developing a new clean hydrogen certification system that would be implemented from 2024. It will be used to determine whether the hydrogen produced is in fact 'low carbon' on the basis of its carbon emissions.[35] |
| Saudi Arabia | Owing to its abundant supply of renewable energy and natural gas reserves, Saudi Arabia is well positioned to develop both green and blue hydrogen. The country has set the target of producing clean hydrogen with 2.9 million tonnes per year by 2030 and 4 million tonnes per year by 2035.[36] On the basis of the geographical distribution of its resources, it is expected that the eastern region would engage in producing and exporting blue hydrogen, while green hydrogen production would be managed by the western region (Hasan & Shabaneh, 2021). The country's first green hydrogen project in Neom is in the process of being developed and is expected to be completed by 2026. The project has a capacity to produce 650 million tonnes of green hydrogen via water electrolysis and generate 1.2 million tonnes of green ammonia annually.[37] With respect to blue hydrogen, in 2020 Saudi Aramco, an oil and gas company successfully **demonstrated** the world's first shipment of blue ammonia to Japan. Both the aforementioned projects reflect the country's resolve of building a hydrogen economy as the country aims to emerge as a global hub for carbon neutral hydrogen. |
| South Africa | According to the Hydrogen Society Roadmap released in February 2022, South Africa targets deploying 10 GW of electrolysis capacity by 2030 and producing 500 kilotons of hydrogen per year by 2030.[38] As a part of the roadmap, four large scale projects are in the process of being developed for supporting green hydrogen and ammonia production in the country. These include the (a) Platinum Valley Initiative, (b) Coal$CO_2$-X Project, (c) Boegoebaai Green Hydrogen Development Project and the Sustainable Aviation Fuels Project (Department of Science and Innovation, 2021). Moreover, a **feasibility study** carried out by the national government has identified three locations for being developed as a hydrogen valley, namely – Johannesburg, Durban and Mogalakwena. Additionally, nine **pilot projects** involving hydrogen across the industry, building and mobility sectors (Department of Science and Innovation, 2021). |
| Turkey | The country is yet to release its national hydrogen strategy and announced its plans of building its first green hydrogen plant earlier this year.[39] |

*Source: Authors' construction*

[34] Available at: https://energynews.biz/south-koreas-largest-green-hydrogen-demonstration-project-starts. Accessed on 23 November, 2022.

[35] Available at: https://www.koreaherald.com/view.php?ud=20220720000816. Accessed on November 23, 2022.

[36] Available at: https://www.argusmedia.com/en/news/2267651-saudi-aramco-plans-new-green-hydrogen-ammonia-project. Accessed on 24 November, 2022.

[37] Available at: https://www.power-technology.com/comment/neom-hydrogen-scheme/. Accessed on 24 November, 2022.

[38] Available at: https://www.csis.org/analysis/south-africas-hydrogen-strategy. Accessed on 22 November, 2022.

[39] Available at: https://www.dailysabah.com/business/energy/turkey-to-establish-1st-green-hydrogen-power-plant-in-balikesir. Accessed on 24 November, 2022.

**Table A.3: Country Profile for Battery Storage**

| G20 Countries | Battery Storage |
|---|---|
| Argentina | Houses two pumped hydro storage facilities having a joint capacity of 1 GW that are operational since the 1980s (Graham et al, 2021). Despite being a part of the 'lithium triangle' and accounting for 21 per cent[40] of the global reserves, Argentina at present does not have any battery storage projects being carried out in the country. |
| Brazil | Batteries for behind-the-meter applications in case of consumer storage solutions are competitive in multiple states of Brazil.[41] However, the country lags behind with respect to utility scale battery storage systems. In 2016 the Brazilian Electricity Regulatory Agency initiated a three-year **R&D** program for exploring grid connected storage solutions and approved **pilot** studies for 23 proposals.[42] One such project was undertaken by Cemig which developed three storage systems with one having a capacity of 1.36MWh and the combined capacity of the remaining two totalling 225 KWh.[43] |
| China | The country has one of the largest battery energy storage markets in the world.[44] According to the 14th Five Year Plan, China aims at building 30 GW of new non-hydro based storage capacity by 2025 and also achieve a 30 per cent reduction in the per unit cost of energy storage to ensure commercial viability bereft of subsidies. By 2030, the aim is to build domestic capabilities across all major forms of storage technologies for supporting the power sector.[45] In addition to the national targets, several provinces have also announced their energy storage targets for 2025.[46] After having launched several pilot and demonstration projects over the years, the development of energy storage technologies in China have come a long way and the 14th FYP is expected to provide a launchpad for promoting large scale commercialization.[47] |
| India | Grid scale energy storage solutions in the country are primarily in the form of pumped hydro storage plants having a capacity of 4.8 GW. The installation of the first pilot project for frequency regulation by the POWERGRID in 2017 marked the beginning of large-scale battery energy storage deployment of projects in India (ISGF & IESA, 2019). However, the rising share of renewables in India's energy mix, particularly with the target of reaching 500 GW of non-fossil fuel-based capacity and meeting 50 per |

40 Available at: https://time.com/6200372/lithium-mining-technology-argentina-gold/. Accessed on 25 November, 2022.

41 Available at: https://www.pv-magazine.com/2022/07/19/storage-for-load-shifting-viable-in-several-brazilian-states/#:~:text=From%20pv%20magazine%20Brazil,applications%20in%20several%20Brazilian%20states. . Accessed on 24 November, 2022.

42 Available at: https://www.smart-energy.com/features-analysis/battery-energy-storage-systems-brazil-analysis/. Accessed on 25 November, 2022.

43 Available at: https://www.smart-energy.com/storage/brazils-cemig-pilots-energy-storage-with-distributed-generation/. Accessed on 24 November, 2022.

44 Available at: https://www.china-briefing.com/news/chinas-energy-storage-sector-policies-and-investment-opportunities/. Accessed on 27 November, 2022.

45 Available at: https://www.china-briefing.com/news/chinas-energy-storage-sector-policies-and-investment-opportunities/. Accessed on 27 November, 2022.

46 Available at: https://www.infolink-group.com/energy-article/Supportive-policies-to-accelerate-energy-storage-in-China. Accessed on 27 November, 2022.

47 Available at: http://en.cnesa.org/latest-news/2021/1/29/2020-china-energy-storage-policy-review-entering-a-new-stage-of-development-in-the-14th-five-year-plan-period. Accessed on 27 November, 2022.

| | |
|---|---|
| | cent of energy requirements from renewables by 2030, has the country gearing towards building the necessary infrastructure to support the targets. This is evident from the expression of interest sought by the Indian government for setting up a 1000 MWh battery energy storage system **pilot project**, which is 2.5 times larger than the highest installed capacity (400 GWh) in the world today.[48,49] In addition to a 13 GWh plant in Ladakh, it has also announced plans of building a 14 GWh grid scale storage system in Kutch (Gujarat), which happens to house one of the world's largest renewable energy plants. As of July 2022, India has included an Energy Storage Obligation (ESO) to its Renewable Purchase Obligation (RPO) that specifies a storage requirement of 1 per cent of energy consumption starting from 2023-24 that gradually increases to 4 per cent by 2029-2030.[50] |
| Indonesia | As the country gears towards moving away from diesel generated power, a **pilot project** for a 5 MW battery energy storage system has been launched by PT PNL (a state-owned utility).[51] |
| Mexico | While Mexico has limited battery storage facilities, the country has developed hybrid plants that have solar energy generating capacity and are equipped with batteries. [52] The Aura III Solar Plant in La Paz is one such example. It is the country's **first utility scale solar plus storage facility** that has been in operation since 2018. With a storage capacity of 10 MW, it provides frequency regulation services to the Baja California Sur grid (Graham, Malagón, Viscidi, & Yé, 2021). |
| Republic of Korea | Over the years, the country has exhibited remarkable growth with respect to its battery storage industry, being driven primarily by government support. In 2011, an energy storage technology development and industrialization strategy was released to improve the competitive edge of Korean batteries. The strategy in turn provided a basis for extending incentives and developing regulations such as increasing the weights assigned to renewable energy certificates for solar and wind connected storage systems; making ESS installations mandatory in public buildings and so on. The Korea Electric Power Corporation has been instrumental to the growth process with its frequency regulation energy storage **demonstration** projects. Private entities have also played a role in developing the market through their active involvement in **R&D** and **demonstration** projects. Korea is home to some of the leading developers and distributors of lithium-ion battery (LiB) storage systems in the world and some of the leading suppliers of LiBs namely – LG Chem, Samsung SDI and SK Innovation (Hwang & Jung, 2020). While the growth spurt came to a temporary halt when instances of LiB fires were recorded in 2018 which led to the government suspending operations,[53] production was restarted following the conclusion of the investigation. |

48 Available at: https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1763883. Accessed on 4 November, 2022.

49 Available at: https://ornatesolar.com/news/in-kutch-the-government-is-considering-a-14-gwh-battery-storage-system. Accessed on 4 November, 2022.

50 Available at: https://powermin.gov.in/sites/default/files/Renewable_Purchase_Obligation_and_Energy_Storage_Obligation_Trajectory_till_2029_30.pdf. Accessed on 13 November, 2022.

51 Available at: https://www.energy-storage.news/indonesia-government-launching-5mw-pilot-bess/. Accessed on 24 November, 2022.

52 Available at: https://mexicoenergyllc.com.mx/blogs/mexico-energy-insights/strong-fundamentals-for-energy-storage-in-mexico. Accessed on 24 November, 2022.

53 Available at: https://www.spglobal.com/commodityinsights/en/ci/research-analysis/aggressive-loadshifting-could-increase-battery-fire-risk-inves.html. Accessed on 27 November 2022.

| | |
|---|---|
| Saudi Arabia | Saudi Arabia has announced its plan of building one of the largest battery facilities in the world with a capacity of 1200-1300 MWh, to power fifty hotels and an airport as part of the Red Sea project.[54] Phase I of the project is expected to be completed by the end of 2023.[55] |
| South Africa | As of July 2022, Eskom (primary supplier of electricity) has announced its plans for deployment of battery storage in the country for managing peak demand and ensuring grid stability. The project is the first of its kind in South Africa and is expected to serve as a proof of concept for integrating renewable energy. It is scheduled to be rolled out in two phases with Phase I expected to commence from June 2023 with a capacity of 199 MW (with a 2MW solar PV) spread across 8 sites and Phase II commissioned from December 2024 with a capacity of 144 MW (with a 58 MW solar PV) spread across 4 sites.[56,57] |
| Turkey | In 2021, Aggreko commissioned the country's first battery storage project with a 500kw capacity for grid stabilization. Inovat is another company that has set up 4 **pilot projects** so far in Turkey with capacities ranging between 336 kwh-448 kwh [58] |

*Source: Authors' construction*

### Table A.4: Total Primary Energy Supply (2021)

| G20 Countries | TPES (2021) | | | | | |
|---|---|---|---|---|---|---|
| | **Coal** | **Oil** | **Fossil Gas** | **Nuclear** | **Renewables** | **Other** |
| Argentina | 2% | 32% | 52% | 4% | 9% | 2% |
| Brazil | 6% | 35% | 12% | 1% | 44% | 3% |
| China | 60% | 19% | 8% | 3% | 8% | 2% |
| India | 44% | 24% | 6% | 1% | 13% | 11% |
| Indonesia | 29% | 30% | 11% | | 23% | 6% |
| Mexico | 3% | 44% | 38% | 2% | 8% | 4% |
| Republic of Korea | 24% | 35% | 18% | 14% | 9% | |
| Saudi Arabia | | 60% | 40% | | | |
| South Africa | 74% | 15% | 3% | 2% | 4% | 2% |
| Turkey | 27% | 27% | 30% | | 14% | 1% |

*Source: Climate Transparency Report (2022)*

Note 1. For Argentina, the share of renewables includes large hydro (3%)

54 Available at: https://www.energy-storage.news/financial-close-red-sea-project-worlds-largest-off-grid-bess-1300gwh-huawei/. Accessed on 24 November, 2022.

55 Available at: https://www.powerengineeringint.com/gas-oil-fired/saudis-red-sea-project-secures-supply-with-man-biofuel-gensets/. Accessed on 24 November, 2022.

56 Available at: https://www.news24.com/fin24/economy/sas-first-battery-storage-project-gains-ground-as-eskom-appoints-suppliers-20220729. Accessed on 24 November, 2022.

57 Available at: https://www.energy-storage.news/south-africas-eskom-confirms-contract-awards-for-1440mwh-battery-storage/. Accessed on 24 November, 2022.

58 Available at: https://etn.news/energy-storage/aggreko-commissions-turkey-s-first. Accessed on 24 November, 2022.

### Table A.5: Renewable Energy Supply (as % of TPES) (2021)

| G20 Countries | RES (as a share of TPES) | | | | |
|---|---|---|---|---|---|
| | Biomass (excluding traditional biomass) | Small hydro | Wind | Solar | Geothermal |
| Argentina | 4.34% | 0.14% | 1.67% | 0.25% | |
| Brazil | 29.96% | | 2.02% | 0.39% | |
| China | 1.39% | | 1.51% | 0.83% | |
| India | 10.34% | | 0.80% | 0.47% | |
| Indonesia | 10% | | | | 12% |
| Mexico | 2.12% | | 1.09% | 0.74% | 1.36% |
| Republic of Korea | 7.58% | | 0.09% | 0.69% | |
| Saudi Arabia | | | | 0.10% | |
| South Africa | 3.33% | | 0.52% | 0.41% | |
| Turkey | 1.68% | | 1.65% | 0.69% | 5.75% |

*Source: Climate Transparency Report (2022)*

### Table A.6: Installed Capacity of Renewable Energy

| G20 Countries | RES Installed Capacity 2021 (MW) | | | |
|---|---|---|---|---|
| | Hydro Power | Wind Energy | Solar Energy | Bio Energy |
| Argentina | 11350 | 3292 | 1071 | 288 |
| Brazil | 109426 | 21161 | 13055 | 16300 |
| China | 390920 | 328973 | 306973 | 29753 |
| India | 51565 | 40067 | 49684 | 10592 |
| Indonesia | 6602 | 154 | 211 | 1912 |
| Mexico | 12671 | 7692 | 7040 | 1064 |
| Republic of Korea | 6541 | 1708 | 18161 | 2400 |
| Saudi Arabia | | 3 | 439 | |
| South Africa | 3484 | 2956 | 6221 | 265 |
| Turkey | 31493 | 10607 | 7817 | 1641 |

*Source: IRENA (2022)*

### Table A.7: Installed Capacity of Renewable Energy

| G20 Countries | Transport Energy Mix | | | |
|---|---|---|---|---|
| | Oil | Fossil Gas | Electricity | Biofuels |
| Argentina | 82% | 12% | 0.30% | 5.50% |
| Brazil | 75% | 2% | | 22% |
| China | 86% | 9% | 5% | 1% |
| India | 94% | 3% | 2% | 1% |
| Indonesia | 86% | | | 14% |
| Mexico | 99.70% | 0.10% | 0.20% | |
| Republic of Korea | 94% | 3% | 1% | 2% |
| Saudi Arabia | 100% | | | |
| South Africa | 99% | | 1% | |
| Turkey | 99% | 0.20% | 0.40% | 0.40% |

*Source: Climate Transparency Report (2022)*

**Table A.8: Electricity Generation Mix (2021)**

| G20 Countries | Electricity Generation Mix | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Coal** | **Oil** | **Fossil Gas** | **Nuclear** | **Hydro** | **Solar** | **Wind onshore** | **Biomass& Waste** | **Geothermal** |
| Argentina | 1% | 9% | 54% | 7% | 18% | 1.60% | 9.60% | 0.80% | |
| Brazil | 4% | 3% | 12% | 2% | 57.70% | 2% | 10.60% | 8.40% | |
| China | 63% | | 3% | 5% | 15.70% | 4.10% | 7.50% | 1.60% | |
| India | 72% | | 4% | 3% | 10% | 3.10% | 5.10% | 2.20% | |
| Indonesia | 62% | 2% | 18% | | 8% | 0.10% | 0.10% | 5.30% | 5.10% |
| Mexico | 3% | 8% | 62% | 4% | 10.30% | 4.30% | 6.30% | 0.60% | 1.30% |
| Republic of Korea | 35% | 1% | 28% | 27% | 1.10% | 4% | 0.50% | 3.20% | |
| Saudi Arabia | | 41% | 59% | | | 0.50% | | | |
| South Africa | 87% | | | 3% | 2.90% | 2.70% | 3.40% | 0.20% | |
| Turkey | 32% | | 32% | | 16.80% | 3.90% | 9.40% | 1.90% | 3.30% |

*Source: Climate Transparency Report (2022)*

Note 1: For Argentina, share of Hydro power includes plants over 50 MW and small hydro share (0.9%)

Note 2: For China, onshore wind share includes offshore wind (0.5%)

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