T20
SAUDI ARABIA 2020
THINK

VISION PAPER

FIT-FOR-PURPOSE ENERGY TRANSITION STRATEGIES: CASE STUDIES FROM G20 MEMBERS

Task Force 10

SUSTAINABLE ENERGY, WATER, AND FOOD SYSTEMS

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ورقة رؤية

استراتيجيات تحولات الطاقة "المصممة بعناية ودقة": دراسات حالة من الدول الأعضاء بمجموعة العشرين

فريق العمل العاشر

نُظم الطاقة المستدامة والمياه والغذاء

المؤلفون

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ABSTRACT

While the G7 is responsible for most anthropogenic climate change, the global climate challenge is being exacerbated as large populations in Asia and Africa move toward universal electricity and energy access that use large amounts of high carbon-emitting fossil fuels. It is important to identify policy directions that are appropriate for each country's market structure, governance regime, and resource base to develop fit-for-purpose energy transition strategies. Integrated planning across the energy value-stream, managing costs and the availability of low emission energy sources, designing transition strategies reflecting local conditions and aspirations, and managing emissions in energy production are some of the common elements of such interventions. In the context of the Group of Twenty (G20), multinational co-operation can promote co-learning among all actors involved in energy ecosystems.

على الرغم من أن مجموعة الدول الصناعية السبع مسؤولة عن مُعظم التغير المناخي من سنع البشر، تتفاقم مع توجه العديد من القطاعات السكانية الكبيرة في آسيا وأفريقيا نحو الكهرباء العمومية، والاعتماد على الطاقة التي تستهلك كميات كبيرة من الوقود الأحفوري ذي الانبعاث الكربوني المرتفع. ومن الأهمية بمكان تحديد اتجاهات السياسة التي تتناسب مع كل بلد من حيث هيكل التسويق ونظام الحوكمة وقاعدة الموارد بهدف وضع استراتيجيات تحول في الطاقة المصممة بعناية ودقة.

يُعد التخطيط المتكامل على مستوى تيار قيمة الطاقة، وإدارة التكاليف، وتوافر مصادر الطاقة منخفضة الانبعاثات، وتصميم استراتيجيات تحول تعكس الظروف والتطلعات المحلية وإدارة الانبعاثات في إنتاج الطاقة، من الأهداف المنشودة لمثل هذه التدخلات. وفي سياق مجموعة العشرين، يمكن أن يؤدي التعاون المشترك إلى تعزيز التعلم بين جميع الفاعلين المنخرطين في نُظم الطاقة البيئية كما تبرزه هذه الحالات التي تستعرضها هذه الورقة.

CHALLENGE

The Sustainable Development Goals of access to affordable, clean, and efficient energy, and aggressive action to mitigate emissions from energy use, are often perceived as contradicting goals in global policy discourses. Achieving even the Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change, in some cases, could compromise the ability of countries to grow rapidly and address poverty at the same time. The challenge is exacerbated in large populations in Asia and Africa, including G20 countries that are yet to ensure full electricity and energy access. Subsequently, there is growing concern that as these populations enter the energy mainstream, their effect on climate would be severe.

In high-income countries, where energy demand is not expected to rise, economic development will continue to lead to urbanization, along with an aging society. There are changes in living standards and lifestyles that may cause increased and new forms of energy demands. Managing this transition is crucial for global energy sustainability. Energy systems must be adapted to societies of all stages of development, and policies must provide and promote innovative opportunities.

Another layer of complexity arises from the diversity in the state of development of various countries, their resource base, and national priorities. It is important to have broadly consistent transition strategies to promote available and accessible sustainable technologies and investments. Meanwhile, the menu of available options should be adaptable to the different starting points for each country.

PROPOSAL

Ensuring economic development anchored in energy access and achieving climate neutrality requires balancing global economic and social equity with sustainability. If managed well, the energy transition path implied for such a development strategy would consist of increasing the share of low-carbon fuels such as natural gas, nuclear, and renewables in the energy mix. The objective of this brief is to identify the policy directions that can promote progressive energy transitions, especially in low-income countries (LICs), and lead to lower emissions outcomes. A menu of such policy and market transition strategies would help nations achieve the dual objectives of increasing access to clean and efficient energy as well as reducing the growth of emissions by switching from inefficient high carbon-emitting energy use. Lessons from case studies in China, India, Japan, the European Union (EU), and Saudi Arabia have helped identify transition strategies that consider the global diversity in the energy resources and the market conditions in these countries.

China

The rapid falling costs and rising share of variable renewable energy (VRE)—namely, wind and solar—have created the growing need to improve the flexibility of power systems. Unlocking flexibility across power systems and restructuring the market design becomes critical for achieving a cost-effective energy transition in the longer run.

Therefore, China launched an energy revolution to develop a clean, low-carbon, safe, and efficient energy system by 2050 during the 13th five-year-plan period. Since then, there has been progress in several areas:

- Non-fossil energy consumption accounted for 14.3% of total energy consumption in 2018, implying that China's 2020 target of 15% of total energy consumption as non-fossil energy will likely be achieved ahead of schedule.

- China remained the world's largest energy investment market in 2018. About 70% of the $120 billion investment in the power sector was spent on renewable energy (International Energy Agency 2019).

- China's carbon intensity dropped by 45.8% in 2018 compared with 2005, which indicates that China has achieved its carbon reduction commitment: 40–45% reduction of carbon intensity by 2020 based on its 2005 emission levels (Ministry of Ecology and Environment 2019).

• In China's 74 key cities, the PM2.5, PM10, NO2, and SO2 concentrations dropped by 34%, 30%, 8%, and 56%, respectively, from 2013 to 2017 (Natural Resources Defense Council 2018).

Renewable energy has a key role to play in this energy revolution strategy. The enforcement of the Renewable Energy Law in 2006, establishment of the pilot carbon market in 2011, launch of the green certificate in 2017, and continued power system reforms since 2002, as significant policy and institutional changes, have significantly stimulated the deployment of VRE in China. Additionally, the total installed capacity increased 70-fold for wind power and 20-fold for solar photovoltaic from 2006 to 2018.

However, high-level curtailments of power generation have also been reported in China in parallel with rapid VRE deployment over the past decade. For example, the wind and solar curtailment reached 17% and 11% of the highest levels, respectively, in 2016. The lack of economic incentives for grid companies and the rigidness of the highly regulated power market have created barriers to accommodate a higher level of VRE in the power system.

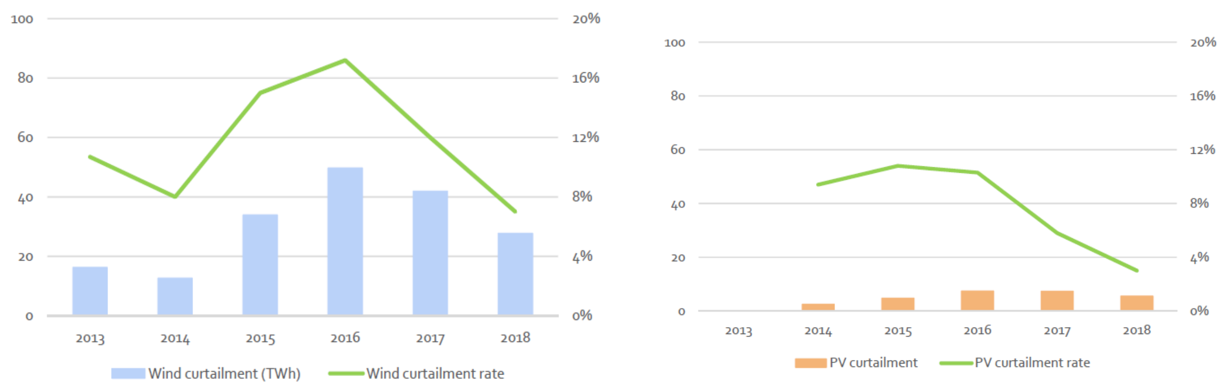

Figure 1. **Curtailment of Wind and Solar in China.**
Source: **Energy Research Institute and China National Renewable Energy Centre (2019), China National Energy Administration Statistics**

To deal with this challenge, China has moved from a directive-based static framework to a more flexible and market-orientated approach. This includes increasing the flexibility of coal power plants by retrofitting old technology and offsetting revenue losses from lower operating hours, establishing reserve sharing mechanisms for regional power grids, and prioritizing the dispatch to VRE projects. These practices have led to a significant drop in the curtailment of wind and solar energy to 7% and 3%, respectively, in 2018.

Some measures that China is now experimenting with will become essential for building long-term flexibility for the entire power system—these include ongoing reform for a mature spot market, stimulating cross-region and cross-province power trading, increasing the flexibility of thermal power plants, and building the dynamic integration of industrial load flexibilities. This requires further integrated planning across power market segments, including a multitude of different technical solutions coupled with appropriate market design and economic incentive structures.

Japan

The energy transition in Japan is being managed by meeting the NDC targets of reducing greenhouse gas (GHG) emissions, while increasing the share of nuclear and natural gas into the energy mix, together with research and development strategies for renewable energy sources. Japan is among the top G20 countries that are projected to meet their unconditional NDC targets even with their current energy policies. Additionally, Japan has begun to focus on a future zero-carbon society, and it aims to derive 44% of its required power from renewable and nuclear power by 2030 (Agency for Natural Resources and Energy 2018a). This target will result in a 20–30% reduction in GHG emissions. The key policy levers, especially after the Fukushima Nuclear disaster, are reducing electricity consumption and the introduction of a feed-in tariff system for low-carbon electricity. By 2050, Japan attempts to cut GHG emissions by 80%; this is in accordance with the Paris Agreement. This strategy should increase the energy security and self-sufficiency rate by adopting a hydrogen-based society, developing innovative technologies for highly efficient water electrolysis for hydrogen production, and realizing low-cost hydrogen energy.

In the Basic Hydrogen Strategy issued in 2017, a roadmap for technology and infrastructure development was introduced, and specific plans for 2030 were formulated to achieve the widespread use of hydrogen by 2050. It is expected to be used as a backup and output adjustment of the power supply when using unstable renewable energy as well as fuel supplied to fuel cells to expand application in mobility.

The use of solar and wind has been growing rapidly in Japan, but it still accounts for only 7.6% of the total energy mix (Agency for Natural Resources and Energy 2018a). Japan has favorable sites for geothermal power, although it has been hard to develop these resources extensively. However, Japan has restarted nine nuclear reactors since the nuclear disaster in 2011 (Agency for Natural Resources and Energy, 2018b). The government's new energy policy aims for nuclear power to provide 20–22% of electricity by 2030 (30% in 2011 (5th Strategic Energy Plan, 2018). This is conditional upon reactors passing the new safety and maintenance standards introduced by the Nuclear Regulation Agency, which is now responsible for approving restarts. The total costs of implementing the government-mandated safety measures, maintaining facilities, and decommissioning commercially operated nuclear power plants in Japan are extremely high. Considering these costs, the nuclear economy has become less competitive, and subsequently, Japan published a long-term national strategy in June 2019 to use zero-carbon power sources of mainly renewable energy. In the hydrogen strategy mentioned above, the main focus is on cost reduction. Cost is the most important factor in determining whether renewable and nuclear energy will become the main power supply source, and the Japanese government must curb the cost burden as much as possible.

India

Gas consumption in India has grown slower than overall energy consumption, leading to a loss of the market share in sharp contrast to the targets laid out in various policy statements that called for an increase in gas to meet India's rapidly rising energy demand efficiently and sustainably (NITI Aayog 2017). Indian data from 2008 to 2013 provide insight into the impact of domestic regulatory and fiscal policies on the energy mix and, hence, on energy intensity and emissions (Deb 2015). Coal remains the dominant fuel in India, both in volume as well as growth terms, and its share of the energy mix as of 2013 was the highest in fifteen years (BP 2019). Oil has the second-largest share, with natural gas and non-fossil fuels (nuclear, hydro, and renewables) far behind.

This five-year average, however, masks the significant shift in India's energy mix that took place in the middle of this period. Gas, which had steadily begun to gain market share, lost that momentum because of a fall in domestic production from 2011 onward. However, the growth in coal consumption that had slowed down from 2008 to 2011 began to pick up after 2011 to compensate for the falling gas consumption. Coal consumption rose by 7.63% in 2013 alone, the second-largest volumetric increase on record. This trend can be traced to the dramatic rise in gas production from 2008 to 2011, and its subsequent fall. New gas discoveries were brought online from 2008 to

2011. Subsequently, gas production started to fall from 2011, with the new fields starting to decline much faster than expected and no new investment in the sector having been seen in the previous years. The lack of a viable pricing policy and commercial flexibility was the key constraint to growth in this sector.

All this had a direct impact on energy intensity and emissions from energy use in India. The rapid decline in energy intensity during the early 2000s slowed down from 2008 to 2013 as the gains in energy efficiency that were made during 2008–2011 were offset by losses during 2011–2013. In line with these changes in energy intensity, the rate of growth of CO2 emissions from energy consumption has also fluctuated. With the rising share of gas in the energy mix from 2008 to 2011, CO2 emissions increased more slowly. However, the subsequent increase in the share of coal in the energy mix raised the growth rate of CO2 emissions from 2011 to 2013.

This assessment of India's energy landscape from 2008 to 2013 demonstrates that Indian coal consumption responded relatively quickly to the changes in energy production, and the natural gas market supply responded more to regulatory policies. Perhaps the most significant implication of this is the impact on CO2 emissions. Going forward, India's emissions of CO2 will be dependent on the relative proportions of cleaner fuels in primary energy. Most importantly, assured and affordable supply of low-carbon energy sources is key to the transition to a low-carbon energy system.

European Union

The electricity sector is both the starting point and lies at the heart of the EU's decarbonization strategy. The strategy was predicated on the reasoning that the decarbonization of electricity in the EU (and generally speaking) would bring about the largest absolute reduction in CO2 emissions, as seen in Table 1. Indeed, in countries such as the United Kingdom, the electricity sector has, following this strategy, experienced a 60% reduction in its power sector emissions over the last decade. This reduction has primarily been brought about through a redesign of the electricity market, which, by extension, lies at the core of the EU's decarbonization strategy. As the electricity sector continues to decarbonize, the EU strategy has been to progressively electrify different sectors of the economy, focusing on transport, heating, and the construction sector. To draw lessons from the experience of the EU, it is imperative to understand the role of the electricity market design that was at the heart of the EU's decarbonization strategy, such that other countries may avoid the policy pitfalls experienced in the EU.

Table 1. Per Capita Emissions by Sector, 2010 (per kg of CO2 per capita)

	Electricity and Heat Production	Other Energy Industry Own Use	Manufacturing Industries and Construction	Transport	Residential	Other	Total CO_2 Emissions from Fuel Combustion
OECD	4,007	558	1,423	2,699	797	1,408	10,096
UK	2,873	519	822	1,919	1,325	1,643	7,776
USA	7,448	845	1,893	5,229	1,038	1,897	17,312
India	748	52	342	138	64	108	1,388
China	2,659	205	1,734	382	225	416	5,395
Brazil	230	129	585	852	87	194	1,989
Africa	414	39	138	215	56	104	910
Middle East	2,715	786	1,577	1,651	623	829	7,559

Source: **Sen (2014)**

European countries are among the pioneers of the OECD model of power sector reforms of the 1980s, namely, unbundling the sector from a state-owned, vertically integrated monopoly into its functional components—generation, transmission, distribution, and retail supply—and introducing competition in generation and retail supply (for example, through wholesale markets, retail competition, and privatization). This is arguably the blueprint on which many LICs, particularly in non-OECD Asia, have based their reform processes. Experience in Europe holds three big lessons for these countries (Poudineh, Fattouh, and Sen 2018a):

- First, prices in energy-only markets are set according to the system marginal cost, relying on market price signals to organize both short-term coordination for dispatching and long-term coordination for investment in generation capacity. The OECD model ignores market imperfections around short- versus long-term coordination, as participants in the retail market (Roques and Finon 2017). The retail competition allows consumers to switch electricity suppliers at short notice; even if this does not happen, it constrains retail companies' ability to sign contracts with generators exceeding the duration of their contracts with customers. Thus, the interests of market participants are not aligned, weakening their incentive to contract forward and share risk (Poudineh, Fattouh, and Sen 2018b).

- Second, power sector decarbonization (a major objective in OECD countries) has exposed the weaknesses in the wholesale market model around its compatibility with the intermittency of renewables. Marginal cost-based price formation in energy-only markets has little relevance for renewable generation technologies. This is because renewable plants (in a dispatch market) are distinct in their location and ability to provide flexibility and balancing services, rather than their marginal costs, which are close to zero (Keay 2016). Zero marginal cost renewables in energy-only markets have led to price volatility (and sometimes to zero or negative prices in many European countries).

- Third, it is increasingly evident that moving toward an economy-wide net zero-carbon target will require moving away from a silo-based approach to power sector operation and reform. This target effectively implies that emissions reductions in one economic sector cannot be exceeded by emissions increases elsewhere. Further, it is required to move toward a systems approach in terms of economics, regulation, and markets for end-user sectors, such as transport and heating/cooling. This requires harmonizing regulatory and fiscal policies for energy to optimize the operation of the energy system as a whole, for example, by enabling sector coupling (e.g., between gas and electricity). A systems approach is one where policy changes made in one part of the energy sector do not have an unintended adverse impact on other parts.

A final point to note is that the power sector itself is undergoing a radical structural change, driven by a combination of technologies that enable decentralization and government policies promoting decarbonization. This effectively implies that a future electricity system could be based on matching demand with supply (rather than solely on supply with demand). It would have a more active consumer side (Keay 2020), varying according to consumer preferences and consumers' interface with the system in specific markets. Collectively, these lessons imply that the OECD model no longer serves as a blueprint, but as a general guideline for countries that are at an early stage of market-oriented reform. LICs should therefore avoid replicating the OECD model and instead, adopt a model of electricity market reform that tailors the transition toward a decarbonized energy sector to their unique contexts.

Saudi Arabia

Gas is envisaged as the fuel of choice in the power sector and the ideal transition toward clean, sustainable, and affordable energy access. As vital as gas is for electricity generation as well as the petrochemical industry, transportation sector, and heating, many oil operators either flare or vent associated gas, a by-product of oil extraction, at the wellhead or gathering stations. Thus, they release GHGs into the atmosphere for various reasons including the lack of financial incentives to capture and process gas, poor regulatory frameworks, institutional capacities, or binding contractual rights.

The World Bank estimated the amount of flared natural gas in the oil and gas industry reached 5.1 trillion ft3 (tcf) in 2018 (World Bank 2018). The amount of energy lost because of flaring or venting this gas is equivalent to more than 770 billion kW·h, and it releases more than 310 million tonnes of carbon equivalent. Because of these troubling statistics, many countries and oil operators have managed to mitigate gas flaring and venting across their oil and gas value chains.

The Kingdom of Saudi Arabia's gas flaring mitigation process emerges as a successful case study of how governments and oil operators can collaborate toward monetizing gas during times when gas is not viewed as a valuable commodity.

In the mid-1980s, Saudi Arabia managed to capture the associated gas production from its oil fields and established flourishing petrochemical, cement, iron, and steel industries, and generate electricity using the captured gas substituting 40 billion ft3 of crude from being burned every day (equivalent to 80 million tons of CO2 from being emitted into the atmosphere every year); this is depicted in Figures 2 and 3 (Al-Ghamdi 2018). The Saudi government requested Aramco, by then well on the way to nationalization, to undertake the responsibility of building the master gas system—a network of gas-gathering facilities and pipelines—to capture, process, and utilize gas as fuel and feedstock for petrochemical plants. By the fall of 1982, key components of the master gas system—gas-gathering and processing facilities and the pipeline—were fully operational (Robins 2002).

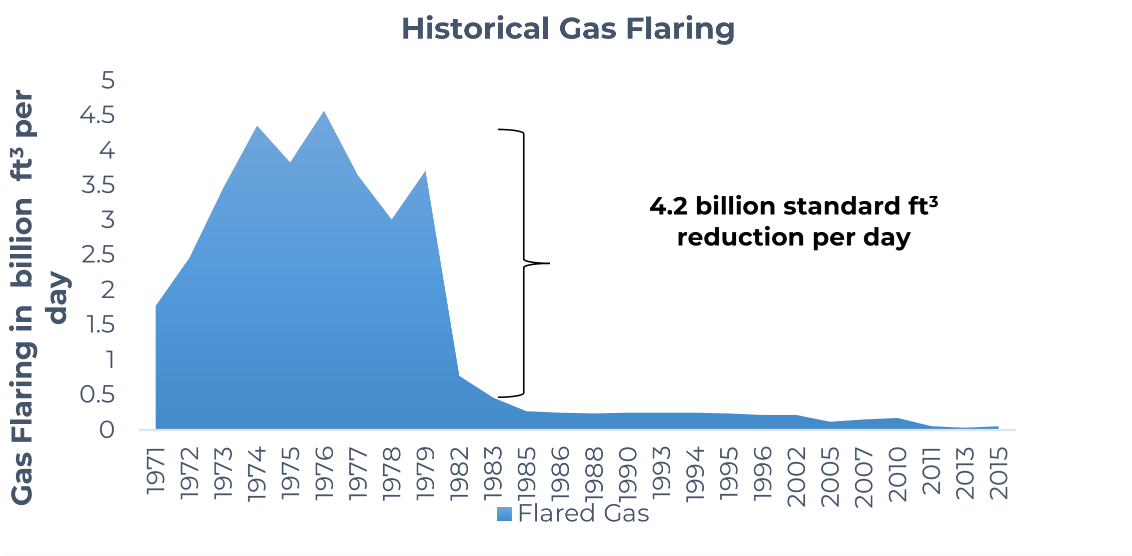

Figure 2. **Gas Flaring in Saudi Arabia.**

Source: **https://ksa-climate.com/wp-content/uploads/2018/12/Adel-Al-Ghamdi-Flaring-Minimization-Program.pdf.**

With domestic gas demand on the rise, particularly in the past two decades, mainly in the petrochemical and power sectors, Saudi Aramco sought out solutions to meet demand by placing on-stream and new non-associated gas fields as well as extending technologies to curb further gas flaring in its oil operations. As a result, it succeeded in lowering gas flaring in its exploration and production activities by performing facility upgrades and extending innovative technology solutions. Flaring at wellheads has been gradually phased out, and routine gas flaring at processing facilities was reduced to 2.3 billion m3 in 2018, positing the Kingdom to become the fourth lowest emitter in terms of gas flaring intensity in its oil and gas industries compared with other G20 countries, as illustrated in Figure 3.

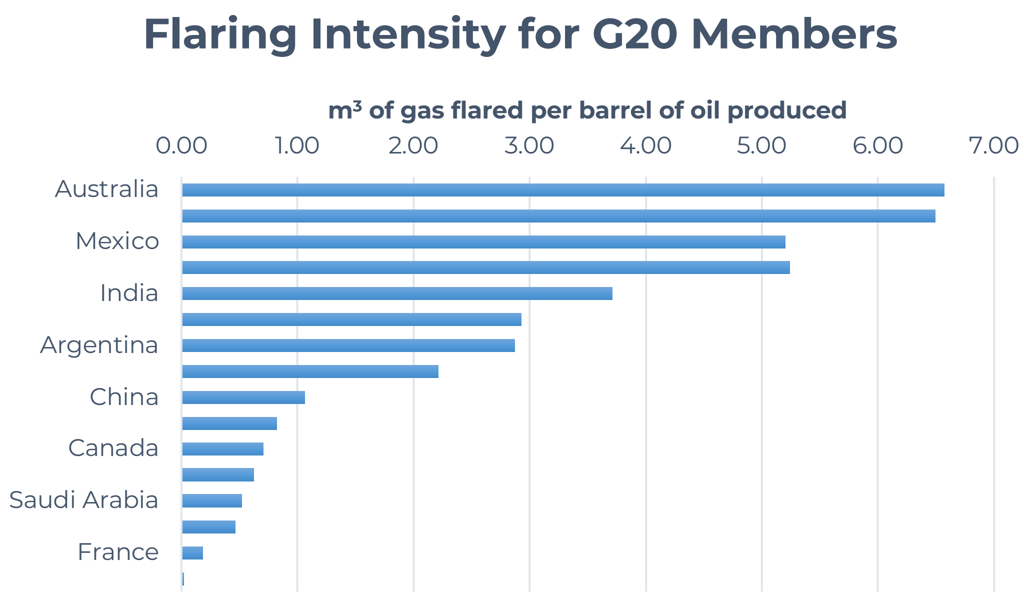

Figure 3. **Flaring Intensity for G20 Countries*.**
Source: **https://dataviz.worldbank.org/t/DECDG/views/OilProduction/FlaringIntensity?iframeSizedToWindow=true&%3Aembed=y&%3AshowAppBanner=false&%3Adisplay_count=no&%3AshowVizHome=no.**
***No Flaring Data Figures were posted for South Africa, Germany, and Japan**
***South Korea does not produce crude oil domestically**

Recently, Saudi Aramco joined the World Bank initiative "zero routine flaring by 2030" to eliminate flaring in its upstream sector (World Bank n.d.). Using innovative technologies including zero discharge applications in its exploration and production sector as well as deploying flare gas recovery systems in its gas-oil-separator plants and crude and gas processing complexes, the company managed to lower the flaring percentage of its operations from 2.3% to less than 0.5%.

The success in reducing flaring in the Saudi oil and gas industry is attributed to many factors including the government and oil company partnership; monetizing gas as a valuable commodity; and providing a legal, regulatory, investment, and operating environment conducive to upstream investments and the development of viable markets for utilization of the gas. The key developments in Saudi Arabia that facilitated this transition can be summarized as follows:

- Governments must create efficient technical regulations and develop competitive mid and downstream markets to improve the economics of associated gas and create suitable opportunities for operators to use gas rather than flare or vent.

- Governments, oil companies, and development institutions can benefit from multilateral initiatives such as the Zero Routine Flaring by 2030 Initiative by the World Bank and the Oil and Gas Climate Initiative to reduce the collective average methane intensity in exploration and production operations to below 0.25% by 2025.

- Governments should mandate measures for oil companies and extend fit-for-purpose technology solutions across their oil and gas supply chains to reach near-zero flaring targets.

Policy directions and next steps

The paths chosen to achieve universal access to energy and climate goals, such as in the NDCs to the United Nations Framework Convention on Climate Change, have varied considerably across the G20 members depending on their state of development, resource base, and national priorities. To achieve a zero-carbon society with economic development, it is necessary to develop and apply stable, broadly available, and accessible sustainable energy systems/technologies. Further, efficient investment decisions should be promoted based on quantitative technological and economic evaluations in consideration with social change.

The role of governments in supporting the transition to cleaner fuels through a variety of policy measures and across sectors remains crucial. As observed in the case studies of Japan and India, consistent government support is necessary to increase the share of low-carbon fuels in the energy mix, especially as traditional fuels that usually have a higher carbon content are available in mature markets that respond quickly to demand and supply signals. In contrast, low-carbon fuels still considerably depend on government support.

Additionally, the choice of appropriate policy instruments would depend on the market structure and governance regimes of each country and region. For example, the OECD model of electricity sector reform is embedded in the separation of monopoly infrastructure from service delivery, and as noted above, its applicability for each case must be assessed. However, Saudi Arabia was successful in reducing methane emissions to record levels. It succeeded in its gas transition because of the nature of the relationship with Saudi Aramco. However, governments around the world can scale-up many of the lessons learned in mitigating gas flaring while maintaining the freedom-to-operate rights of oil companies.

To identify appropriate policy instruments, governments should support research on the decarbonization of society and use the output of think tanks in the context of each country's circumstances. Governments must increase investment in energy research and development that will strengthen their role and responsibilities. The co-learning possible also creates opportunities for bilateral and group-level cooperation between civil society actors, private actors, and national governments in the G20 in policy and market reforms to achieve universal access to clean energy sources for sustainable development. Moreover, G20 countries can work together to strengthen the power network, increase energy storage, and use hydrocarbons based on biomass-derived or post-emission carbon capture and storage/ direct air capture to decarbonize the energy mix.

Disclaimer

This policy brief was developed and written by the authors and has undergone a peer review process. The views and opinions expressed in this policy brief are those of the authors and do not necessarily reflect the official policy or position of the authors' organizations or the T20 Secretariat.

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