WORLD ENERGY COUNCIL

INNOVATION INSIGHTS BRIEFING

HYDROGEN ON THE HORIZON: READY, ALMOST SET, GO?

World Energy Council, in collaboration with EPRI and PwC

ABOUT

WORLD ENERGY COUNCIL

The World Energy Council has been at the heart of global, regional and national energy debates for nearly a century, developing new thinking and driving effective action around the world to achieve the benefits of sustainable energy for all.

Comprised of over 3,000 member organisations in nearly 90 countries, drawn from governments, private and state corporations, academia and new and wider system shapers stakeholders, the Council is the world's first and only truly global member-based energy network.

The Council works dynamically across the whole energy sector as a global energy transitions platform, pulling together intelligent leadership to catalyse and inform the world's energy policy dialogue, create impact and drive practical action.

The Council does not advocate for any country, company, technology or source of energy. The World Energy Council remains thoroughly committed to the challenge of being both impartial and impactful.

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INNOVATION INSIGHTS BRIEFING

This Innovation Insights Briefing on hydrogen is part of a series of publications by the World Energy Council focused on Innovation. It was developed in collaboration with the Electric Power Research Institute (EPRI) and PwC.

EPRI and Gas Technology Institute (GTI) have created the Low-Carbon Resources Initiative (LCRI) to address the challenges and gaps in achieving deep carbon reductions across the energy economy. LCRI is focused on the value chain of alternative energy carriers (AECs) and low-carbon fuels—such as hydrogen, ammonia, biofuels (including renewable natural gas [RNG]), and synthetic fuels—and research, development, and demonstration (RD&D) to enable their production, storage, delivery, and use across the energy economy. These energy carriers/fuels are needed to enable affordable pathways to economy-wide decarbonization by mid-century. This five-year, global collaborative will identify and accelerate fundamental development of promising technologies; demonstrate and assess the performance of key technologies and processes, identifying pathways to possible improvements; and inform key stakeholders and the public about technology options and potential pathways to a low-carbon future.

PwC is a network of firms in 155 countries with over 284,000 people committed to delivering quality in assurance, advisory and tax services, including more than 20,000 professionals engaged in the energy, utilities and resources sectors. With its global strategy, The New Equation, PwC is responding to the challenges shaping the world today, with a focus on building trust and delivering sustained outcomes that create value for organisations, their stakeholders and broader society. Climate change is one of the world's most pressing problems, and PwC has committed to reach net zero greenhouse gas emissions by 2030 and is working with organisations to accelerate their own climate-based transformation. PwC and the World Energy Council have a common goal of promoting energy transition and sustainability by engaging with policymakers and leading industry players. Our shared view is that energy transition and sustainability are achieved through the interaction of robust policy frameworks and a strong, competitive energy industry.
Learn more about PwC

In a fast-paced era of disruptive changes, this briefing aims at facilitating strategic sharing of knowledge between the Council's members and the other energy stakeholders and policy shapers and contribute to a global dialogue on hydrogen's role in energy transitions.

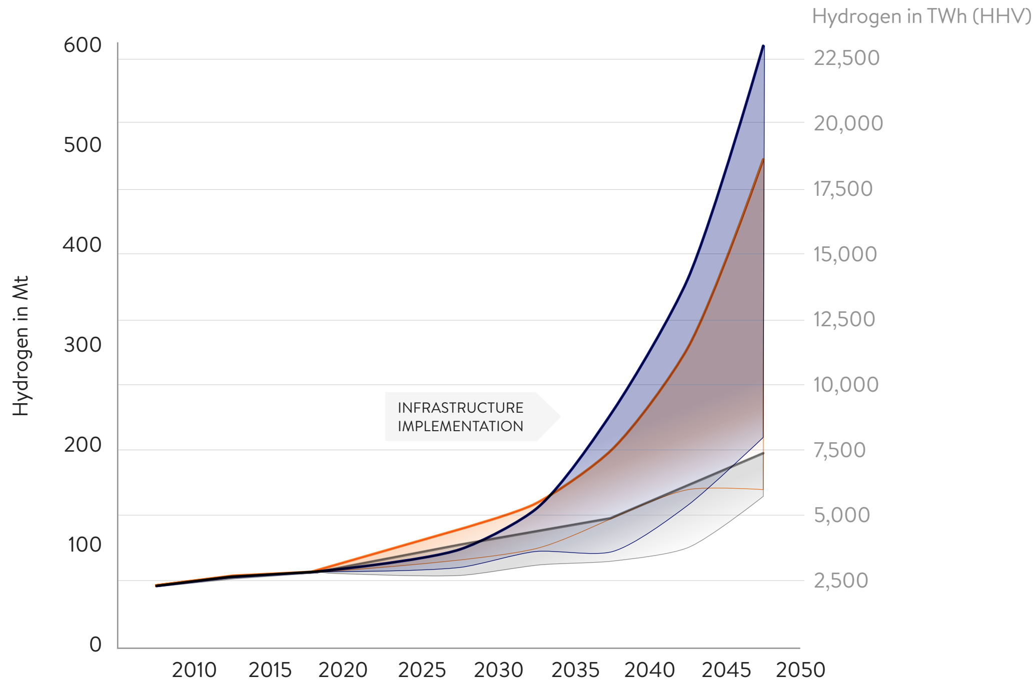
This briefing builds upon earlier work by the Council and involved extensive research on national strategy developments and interviews with 38 experts from 23 countries, reflecting 61 % of the global Total Primary Energy Supply – TPES (2018 data, OECD) and 70% of global GDP (2019 data, WB).

Conversations about Energy Transitions frequently overlook the role of clean molecules and heat. Combined with deeper electrification, clean molecules (e.g., hydrogen-based fuels, natural gas with CCUS, biofuels, etc.) can play a major role to decarbonise further areas and uses, in a more circular carbon economy. COP26 is reinforcing the ambition for many countries and companies to become climate neutral and achieve net-zero. It is in this context that interest in clean hydrogen as an energy vector is surging across the globe as countries and companies seek to explore its potential to decarbonise the hard-to-abate sectors and uses, provide flexible storage for an increasing amount of renewables. While hydrogen's true potential within future energy systems remains unclear, there are increasing ambitions for new economic and social opportunities, particularly to support the post-COVID19 recovery. At present, hydrogen demand is broadly concentrated in the petrochemical industry with its potential in other areas beginning to be explored in low volume pilot studies that seek to prove viability and reduce the substantive costs of low-carbon hydrogen and its distribution. With increasing interest and support, there is a pressing need to untangle the differing underlying drivers and actual opportunities to understand better the real potential of clean hydrogen in energy systems and in energy transitions.

The World Energy Council's **Humanising Energy** agenda notably stresses the need to move beyond traditional supply-centric energy perspectives to focus more on the demand-side and the role of consumers, given their increasing potential for disruptive innovation. Better understanding hydrogen demand has proved particularly challenging at this embryonic stage of its development.

A comparative assessment of existing hydrogen demand estimates to 2050 (see annex 1) shows significant variation with limited but steady growth of hydrogen demand until 2030 as infrastructure is developed. By 2050, the estimates vary significantly between an equivalent of 6 to 25% of total final energy consumption dependent on underlying assumptions.

Graph 1. Range Of Hydrogen Demand Assessment By 2050



< 1.8°C

Acil Allen Report - High
BP Energy Outlook 2020 - Net Zero
IEA Energy Technology Perspectives 2020 - SDS
Shell - Sky Scenario
Powerfuels in a Renewables World
Hydrogen Economy Outlook - Strong Policy

1.8 - 2.3°C

Acil Allen Report - Medium
BP Energy Outlook 2020 - Rapid
Hydrogen Council - 2DS
World Energy Council - Unfinished Symphony

> 2.3°C

Acil Allen Report - Low
World Energy Council - Modern Jazz
Hydrogen Economy Outlook - Weak Policy

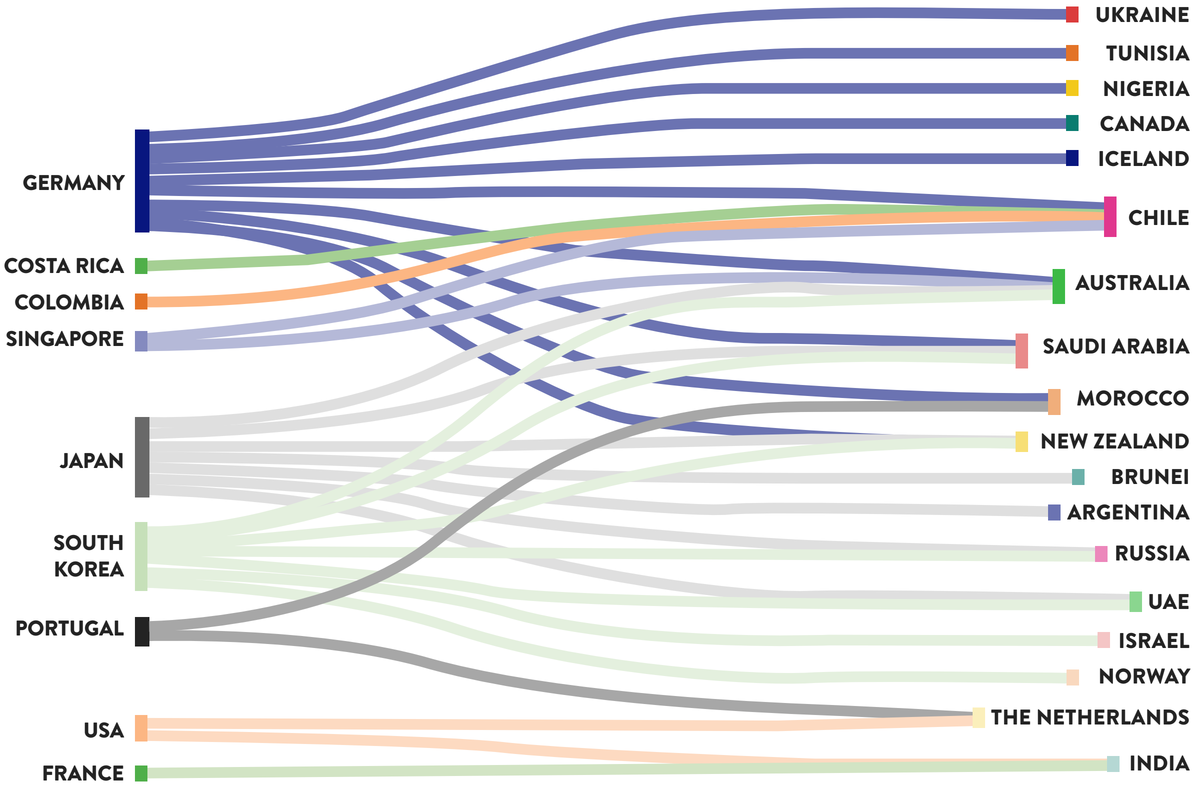
Source: PwC

Scaling hydrogen up within the energy system faces **significant challenges.** First, low-carbon hydrogen is currently not cost competitive with other energy supplies in most applications and locations and is likely to remain so without significant support to bridge the price gap - which raises the question of who should fund this support. However, environmental and political drivers are sending encouraging signals to the market and prompting the current growing interest. With the appropriate policies and technologies to enable hydrogen scale up, some projections suggest that it could be cost competitive with other solutions as soon as 2030. Secondly, as the "hydrogen economy" is at an embryonic stage of development, it faces the "chicken and egg problem" between supply and demand, both lacking secure volumes from the other to help establish the value chain. Thirdly, the numerous hydrogen technologies are at different levels of maturity, contributing to a complex landscape with multiple paths being explored and few approaches as yet being fully eliminated.

Countries view hydrogen's potential role in energy transitions differently with national hydrogen strategies showing significant **divergences emerging across countries and regions (see annex 2). Asia and Europe currently seem more demand focused while the Middle East and North Africa focus on supply.** Asia shows a greater focus on hydrogen as a liquid fuel in the form of ammonia and as a transport fuel for shipping and road transport. Japan has been actively seeking to establish international supply chains, while Korea has focused on new technologies such as hydrogen fuel cell vehicles. In contrast, Europe is more focused on using hydrogen to decarbonise the hard-to-abate sectors in industry and transport (heavy duty – for example, buses and lorries). The Americas (North and South) are considering production for their own consumption and export.

Those countries exploring hydrogen seem to favour significant direct public support to increase clean hydrogen volumes, reduce prices and encourage its uptake in the end-use sectors. At this early stage, countries are considering different policy tools to facilitate hydrogen's scale-up with direct investment in hydrogen projects along the value chain being common across countries. Any regulatory action primarily focuses on "quick wins" to simplify or clarify existing frameworks, and reduce potential barriers to project development. Regulation remains limited at this stage to allow innovation and enable the differing technologies to be explored. Outside national territories, some countries are actively developing bilateral partnerships to help form global hydrogen supply chains and secure clean hydrogen supply.

FIGURE 1: BILATERAL PARTNERSHIPS [1]



Source: World Energy Council, modified from German Member Committee map, 2021 [2]

Several national strategies highlight **jobs** as an important driver behind hydrogen development, either to safeguard existing jobs through re-purposing current hydrocarbon infrastructure or capturing carbon emissions, or create new jobs in the new hydrogen economy. For many, the **post-COVID recovery** offers scope to invest in the hydrogen economy for jobs and economic growth to build forward together. These hydrogen job ambitions need further analysis to understand their real implications and the actual impacts in different regions. Beyond the jobs perspective, hydrogen's social licence could help its role as a clean molecule vector and further encourage its uptake with suitable societal understanding and support.

While hydrogen has previously faced cycles of optimism and scepticism about its potential, this current interest does differ due to environmental, economic, and political factors, with countries setting more ambitious and binding climate targets, cheaper renewable energy, and technological advancements (e.g. electrolysis technologies reducing costs).

[1] *Methodology: The bilateral partnerships are exclusively government-to-government agreements that can encompass trade relations around hydrogen (import/export of hydrogen fuel and/or technologies), demonstrations projects, and Memorandums of Understandings. Based on information available on 27th May 2021.*
[2] *Global Overview on Activities Towards H2 Strategies - H2 partnerships globally*

There is a clear need for **more dialogue** to better understand hydrogen's true potential in energy systems targeting net-zero, to explore the supply-demand potential within regions and how different hydrogen strategies and initiatives could complement each other, and to learn from and with each other. Within the World Energy Council's community, there is significant appetite for broader, multi-stakeholder conversations at the regional and global levels to increase knowledge sharing and experience learning within the community and across regions, and particularly explore demand and value-chains development and identify the barriers and enablers to hydrogen development at a large scale.

Our analysis has particularly highlighted one priority topic with the energy+ community and that is to clarify the **"hydrogen colour" debate.** Colour has been used to simplify the conversation about the carbon footprint of hydrogen production, but it has become more complex with no universally agreed colours for specific technologies and some disagreement as to which colour matches which supply. Most notably, there seems to be no agreed colour for hydrogen produced from nuclear and differing shades of blue for hydrogen supplied from various fossil fuels with carbon capture. The colour debate needs clarity as it could risk prematurely excluding some technological routes that could be more cost and carbon effective. There is an emerging sense that the discussion should perhaps think about moving beyond colour and instead focus on carbon equivalence. The Council's global community would be keen to work to explore the colour discussion and how it might shape hydrogen's role in energy transitions. The geopolitics of hydrogen are still evolving and being shaped by how countries want to produce and consume clean hydrogen within their energy systems. The carbon equivalence of the hydrogen production and competition over electrolyser technologies are likely to be key areas where there needs to be further dialogue.

The World Energy Council, in collaboration with EPRI and PwC, aims to provide a better understanding of hydrogen development worldwide for the energy community, building on the expertise and experience of its global network. **This Innovation Insights Briefing aims to start a multi-stakeholder, multi-level community dialogue on hydrogen's role in energy transitions.**

Our work has identified the following 4 areas for further discussion:

1. **Significant divergences are emerging across countries and regions,** as national hydrogen strategies reveal varying attitudes towards hydrogen's role in energy transitions. This signals a need to embrace diversity – eliminating a one size fits all mindset – and enable differing technologies and use cases to be explored.

2. **Confusion over 'colours' is stifling innovation,** with over-simplification and colour prejudice risking the premature exclusion of some technological routes that could potentially be more cost- and carbon-effective. There is a need for further dialogue which looks beyond colour to instead explore carbon equivalence.

3. **Demand-centric hydrogen perspectives are needed to advance the Humanising Energy and demand-driven agendas.** The current hydrogen conversation focuses heavily on supply, ignoring the role of hydrogen users. Discussions must explore what's needed to trigger demand, with a specific focus on the development of hydrogen infrastructure and a global supply chain.

4. **The hydrogen economy could stimulate job creation and economic growth,** potentially helping to fulfil 'build forward together' ambitions post-COVID-19. Several national hydrogen strategies highlight jobs as an important driver of hydrogen development, with opportunities to reskill the existing workforce and upskill a new workforce.

A short series of detailed Innovation Insights Briefing will be released to help inform the dialogue on these 4 topics. Together with our community, we expect to bring greater insights for discussion at the 25th World Energy Congress in St. Petersburg in October 2022.

HUMANISING ENERGY IMPERATIVE

Humanising Energy promotes the benefits of looking beyond the dominant supply centric mindset in energy. It enables a shift to a customer-centric perspective which is essential to better anticipate new and shifting patterns of demand. It directs leadership attention to questions of 'pace' and societal resilience (such as full costs, affordability, justice agenda). It is a way to reframe the conversation and address the current people-centric blind-spots - new uses/demand shifts and the role of human behaviours - in energy systems transitions and transformations.

In 2019, the Council launched Hydrogen Global to establish a customer-centric, demand aggregation platform and as means to build middle ground and avoid colour-polarised debates.

The World Energy Council will continue to build a unique independent global dialogue platform complementary to other supply-centric, technology advocacy platforms. We will develop new and deeper understanding on how hydrogen demand differs between and within regions and sectors. We will enable a customer-centric leadership perspective on the role of hydrogen as a flexible, 'clean molecules' energy vector in energy system transition and transformation.

The World Energy Council will humanise the role of hydrogen in energy transitions agendas by addressing blind-spots and better anticipating the role of new demand, shifting uses and changing human behaviours.

HYDROGEN DEMAND SCENARIOS

	Acil Allen Report	BP Energy Outlook 2020	Hydrogen Economy Outlook	Hydrogen Council – 2DS	IEA	Powerfuels in a Renewables World	Shell – Sky scenario	World Energy Council
Total hydrogen demand estimates (Mt)	**High:** - 2030: 93 - 2040: 161 - 2050: 401 **Medium:** - 2030: 84 - 2040: 113 - 2050: 213 **Low:** - 2030: 77 - 2040: 94 - 2050: 148	**Net Zero:** - 2030: 104 - 2040: 282 - 2050: 560 **Rapid:** - 2030: 102 - 2040: 173 - 2050: 284	**Strong policy:** - 2030: N/A - 2040: N/A - 2050: 696 **Weak policy:** - 2030: N/A - 2040: N/A - 2050: 187	- 2030: 111 - 2040: 201 - 2050: 567	**Energy Technology Perspectives (ETP) 2020 - SDS:** - 2030: 90 - 2040: 135 - 2050: 290 **Net Zero Scenario:** - 2030: 212 - 2040: 391 - 2050: 528	- 2030: 86 - 2040: 164 - 2050: 346	- 2030: 80 - 2040: 94 - 2050: 149	**Unfinished symphony:** - 2030: 117 - 2040: 164 - 2050: 228 **Modern Jazz:** - 2030: 99 - 2040: 125 - 2050: 185
Hydrogen production route		Green, Blue, Grey hydrogen			**ETP 2020:** Electricity, Fossil w CCUS, Refining CNR, Fossil w/o CCUS **Net Zero Scenario:** Fossil fuels, Refining CNR, With CCUS, Electricity, Biomass	Green hydrogen		
Projected demand by application	Transport, Space heating and cooling, Power sector	Power, Buildings, Transport, Industry	Buildings, Power, Industry, Transport	Buildings, Power, Industry, Transport, Energy system	Net Zero Scenario: Transport (shipping, road, aviation), Iron and steel, Chemicals		Industry (heavy, light), Transport (road, air, ship)	
Ambition to limit global warming	**High:** a 50% chance of limiting the peak in global temperature (temp.) to between 1.5-2°C **Medium:** a 50% chance of limiting the peak in global temp. to 2°C **Low:** 50% chance of limiting the peak in global temp. between 2-4°C	**Net Zero:** limiting temp. rise to 1.5°C above pre-industrial levels **Rapid:** limiting temp. rise to well below 2°C above pre-industrial levels	**Strong policy:** H2 supply 27EJ of energy in global economy, meeting 4% of projected final energy needs in 2050 or 7% in 1.5°C scenario **Weak policy:** H2 supply 99EJ of energy in global economy, meeting 15% of projected final energy needs in 2050 or 24% in 1.5°C scenario	Limit global warming to 2°C	**ETP 2020:** hold the temp. rise to below 1.8°C with a 66% probability without reliance on global net-negative CO2 emissions **Net Zero Scenario:** a 50% chance of limiting the temp. rise to 1.5°C	Achieve the goals of the Paris Agreement of achieving zero GHG emissions from the energy sector by 2050	Limiting the global average temp. rise to well below 2°C from pre-industrial levels	**Unfinished symphony:** <2.3°C confirmed with study authors **Modern Jazz:** >2.3°C confirmed with study authors

Source: PwC

ANNEX 2

SUMMARY OVERVIEW OF THE NATIONAL HYDROGEN STRATEGIES[3]

CATEGORY	ASIA			EUROPE								LAC	NORTH AMERICA
	Australia	Japan	South Korea	EU	France	Germany	Hungary	Netherlands	Norway	Portugal	Spain	Chile	Canada
Strategy contains timeline for market development with targets	Detailed	Detailed	Detailed	Detailed	Mentioned	Detailed	Mentioned	Mentioned	Not seen	Mentioned	Detailed	Detailed	Detailed
Strategy contains hydrogen cost targets	Mentioned	Detailed	Detailed	Not seen	Not seen	Not seen	Not seen	Not seen	Not seen	Not seen	Not seen	Mentioned	Mentioned
Strategy includes measures to support H2 development													
Direct investments	Detailed	Detailed	Detailed	Detailed	Detailed	Detailed	Not seen	Mentioned	Detailed	Detailed	Mentioned	Mentioned	Mentioned
Other economic and financial mechanisms	Detailed	Mentioned	Detailed	Detailed	Detailed	Detailed	Mentioned	Detailed	Detailed	Detailed	Mentioned	Mentioned	Mentioned
Legislative and regulatory measures	Detailed	Mentioned	Detailed	Detailed	Mentioned	Detailed	Mentioned	Detailed	Mentioned	Detailed	Detailed	Detailed	Mentioned
Standardisation strategy and priorities	Detailed	Detailed	Detailed	Mentioned	Mentioned	Detailed	Mentioned	Mentioned	Detailed	Detailed	Detailed	Mentioned	Detailed
Research & development initiatives	Detailed	Detailed	Detailed	Mentioned	Detailed	Detailed	Detailed	Detailed	Detailed	Detailed	Detailed	Mentioned	Detailed
International strategy	Detailed	Detailed	Mentioned	Mentioned	Mentioned	Detailed	Detailed	Detailed	Mentioned	Detailed	Detailed	Mentioned	Mentioned
Strategy addresses social issues for H2 development	Detailed	Detailed	Detailed	Not seen	Detailed	Mentioned	Not seen	Mentioned	Mentioned	Detailed	Detailed	Detailed	Detailed
Strategy includes review and update	Mentioned	Not seen	Not seen	Not seen	Not seen	Detailed	Not seen	Not seen	Mentioned	Mentioned	Detailed	Mentioned	Not seen
Strategy's H2 target source by 2030	Clean	Fossil-based with CCS	From natural gas	Low carbon	Low-carbon & fossil based	Carbon-free	Low carbon & carbon free	Blue & Green	Clean	Green	Renewable	Green	Low carbon intensity
Strategy's H2 target source by 2050	Clean	CO_2-free	Eco-friendly CO_2-free	Clean / Renewable	Low-carbon	Renewable	Low carbon & carbon free	Green	Clean	Green	Renewable	Green	Low carbon intensity
Import / Self-reliance / Export	Export; Self-reliance	Import	Import; Export (tech)	Depends on Member States	Export	Import; Export (tech)	Self-reliance	Import to export H2 (EU hub)	Self-reliance	Self-reliance; Export	Self-reliance; Export	Self-reliance; Export	Self-reliance; Export
MAIN GOALS / DRIVERS													
Decarbonisation	Lower	Immediate	Lower	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate
Diversify energy supply	Lower	Immediate	Long term	Lower	Lower	Immediate	Immediate	Immediate	Lower	Immediate	Immediate	Lower	Immediate
Foster economic growth	Immediate	Immediate	Immediate	Lower	Immediate	Immediate	Lower	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate
Integration of renewables	Lower	Lower	Long term	Immediate	Lower	Immediate	Lower	Immediate	Lower	Immediate	Immediate	Immediate	Immediate
SECTORAL PRIORITIES													
Heating	Immediate	Immediate	Lower	Lower	Lower	Lower	Immediate	Immediate	Lower	Immediate	Lower	Immediate	Immediate
Industry													
Iron and Steel	Long term	Lower	Lower	Long term	Immediate	Immediate	Long term	Immediate	Lower	Immediate	Lower	Not seen	Immediate
Chemical feedstock	Immediate	Lower	Not seen	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate
Refining	Not seen	Lower	Not seen	Immediate	Immediate	Immediate	Immediate	Immediate	Lower	Immediate	Immediate	Immediate	Immediate
Others (cement, etc.)	Not seen	Not seen	Not seen	Not seen	Immediate	Lower	Long term	Lower	Not seen	Immediate	Lower	Not seen	Immediate
Power													
Power generation	Lower	Immediate	Immediate	Lower	Not seen	Not seen	Lower	Lower	Not seen	Lower	Lower	Not seen	Lower
Back-up services	Lower	Lower	Lower	Lower	Not seen	Not seen	Long term	Lower	Not seen	Lower	Lower	Not seen	Lower
Transport													
Passenger vehicles	Lower	Immediate	Immediate	Lower	Lower	Lower	Long term	Immediate	Lower	Lower	Lower	Long term	Immediate
Medium and heavy duty	Immediate	Long term	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Lower	Immediate	Lower	Immediate	Immediate
Buses	Immediate	Long term	Immediate	Immediate	Immediate	Immediate	Immediate	Immediate	Lower	Immediate	Lower	Immediate	Immediate
Rail	Lower	Lower	Lower	Immediate	Immediate	Immediate	Lower	Immediate	Not seen	Immediate	Lower	Not seen	Long term
Maritime	Long term	Lower	Lower	Long term	Lower	Long term	Lower	Lower	Immediate	Long term	Lower	Long term	Long term
Aviation	Lower	Lower	Not seen	Long term	Immediate	Long term	Not seen	Lower	Lower	Long term	Lower	Long term	Long term

Source: World Energy Council

[3] *Methodology: National strategies published until 30th May 2021.*

Strategies content: Detailed · Mentioned · Not seen

Goals and sector priorities: Immediate priority · Long term priority · Lower priority · Not seen

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