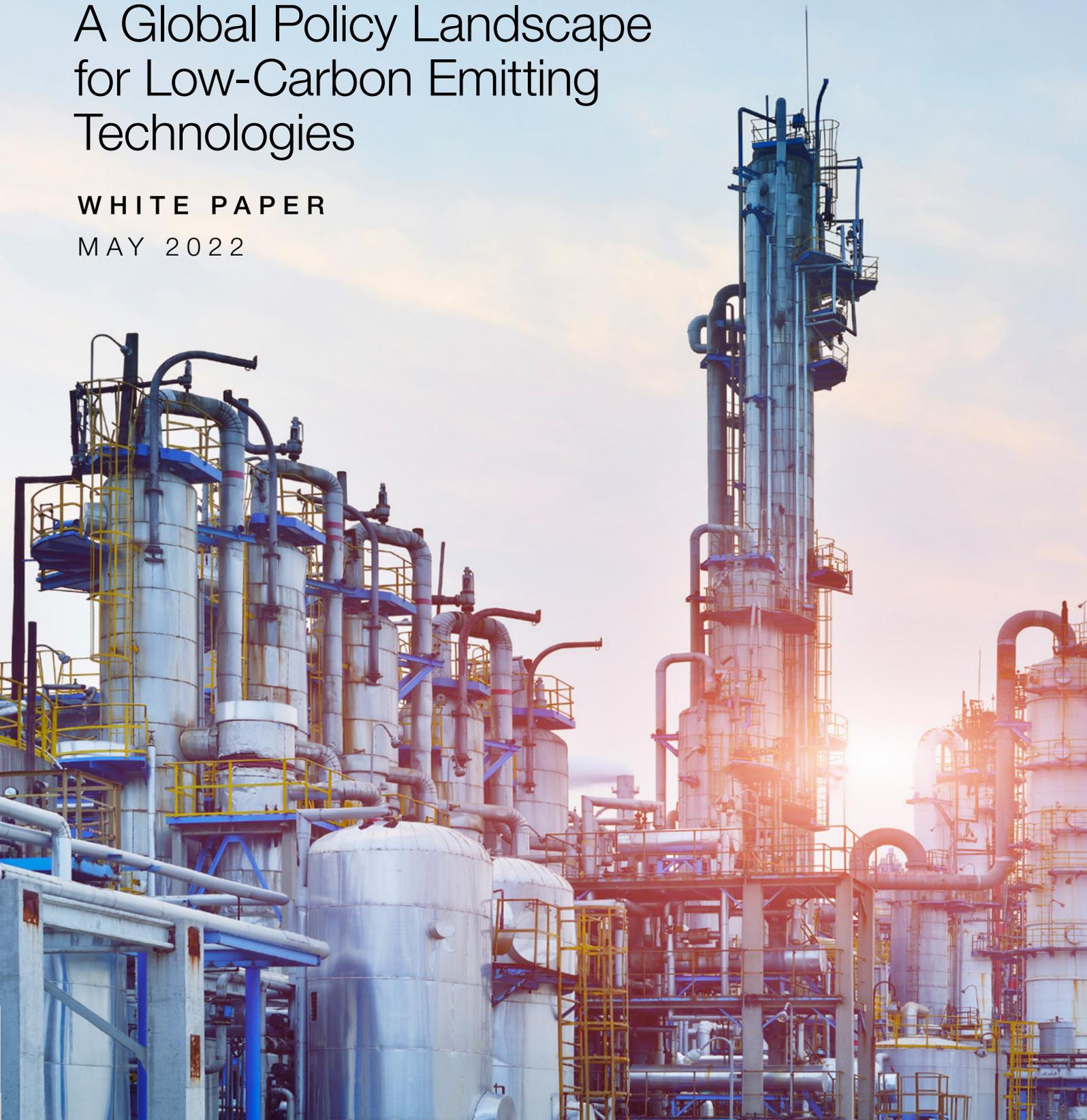


In collaboration with Accenture

Towards a Net-Zero Chemical Industry: A Global Policy Landscape for Low-Carbon Emitting Technologies

WHITE PAPER

MAY 2022



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Foreword



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As the world moves towards a net-zero chemical industry, the World Economic Forum's initiative on low-carbon emitting technologies (LCETs) stands out for its scope and ambition. Accenture's commitment to a sustainable future and its long-standing industry expertise made us natural partners in this important endeavour.

Essential as LCETs will be for the chemical industry of the future, to date they face challenges that require collaborative efforts – including from industry players, organizations for public-private dialogue and knowledge partners.

Focusing on the political and legal environment affecting the development and upscaling of LCETs, we conducted an in-depth policy



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assessment across seven jurisdictions, five technology areas and six policy clusters.

Qualitative and quantitative data was gathered through more than 20 expert interviews and Accenture research, and was made comparable and assessed by a bespoke policy model, which – to the best of our knowledge – is unique in this field. A selection of results and insights drawn from this model are presented in this paper.

Our hope is that this policy landscape paper will find many interested readers. It should also provide support for strategic decision-making and lay a foundation for continuing public-private dialogue towards a net-zero chemical industry.

Executive summary

The chemical industry has a vital role in the transition towards a global net-zero society.

As a cornerstone of the global economy, the chemical industry is tightly interconnected in a complex web of value chains, contributing to all goods-producing industrial sectors, and plays a vital role in the transition towards a global net-zero society. The so-called low-carbon emitting technologies (LCETs) are important building blocks in the chemical industry's net-zero endeavour. To propel LCETs forward, the World Economic Forum and major chemical-sector companies founded the Low-Carbon Emitting Technologies Initiative. While offering significant decarbonization opportunities to all industrial value chains, LCETs still face various challenges.

The development and upscaling of LCETs depend strongly on favourable policy environments, ranging from monetary incentives to demand-side policies.

Analyses of seven jurisdictions covering about 50% of global greenhouse gas (GHG) emissions¹ (China, the European Union, Japan, Saudi Arabia, the United Arab Emirates, the United Kingdom and the United States) across five key LCET areas (biomass utilization, carbon capture and utilization, electrification, alternative hydrogen production and waste processing) revealed the following insights about existing policy support:

- Hydrogen receives the most attention and policy support among LCET areas
- Carbon capture is on a par with hydrogen production in the United States

- Electrification of processes is on a par with hydrogen production in the European Union
- Biomass utilization and waste processing will both likely see additional policy support in the near future, moving away from fossil feed and fuel
- Besides increased incentives and climate targets, on average, technology and infrastructure policies are strengthened in all analysed jurisdictions
- Supportive measures, e.g. funding schemes, vary significantly between countries, but are emerging or maturing across the globe
- While on the rise in some countries and across borders, policies stimulating demand for sustainably produced goods are not yet a focus

Increased policy ambitions supporting the development and upscaling of LCETs are influenced by a number of globally emerging themes, alongside national or regional approaches, reflecting political and legal traditions as well as strategic considerations.

This work intends to give a high-level overview of the current policy landscape across the jurisdictions and LCET areas mentioned above. It should lay a foundation for further analysis, industry decision-making aimed at real-life projects, and public-private dialogues for the continued development of a decarbonization-promoting policy landscape.

1

Introduction

Innovative solutions are being implemented by the chemical industry and its value chains to tackle the net-zero challenge.

1.1 The chemical industry in the context of net zero

To reduce global anthropogenic emissions of greenhouse gases (GHGs), amounting to almost 50Gt carbon dioxide equivalents (CO₂eq) in 2018,² countries are committing to moving towards net zero by 2050.³ Additionally, balancing emissions from CO₂ sources and removing CO₂ through carbon sinks, described in the Paris Agreement, is a cornerstone of limiting global warming and achieving the agreement's long-term temperature goals.⁴

The chemical industry plays an important double role in this endeavour. Having relied extensively on fossil resources over the past century, for both fuel and feedstock, this industry currently contributes 5–6% of global GHG emissions (Scope 1 and 2 emissions).⁵

Simultaneously, the chemical industry supplies materials and solutions used in various applications such as automotive, healthcare, agriculture,

electronics and fast-moving consumer goods – providing essential products for technologies that help reduce anthropogenic GHG emissions.⁶

While it is clear that the chemical industry must contribute towards reaching net zero, it has become apparent that optimizing existing processes will be insufficient on its own. The industry is facing a drastic material demand increase by 2050, and innovative solutions will be essential to tackle the net-zero challenge.

Various decarbonization solutions for the chemical industry and associated value chains are being explored. This study focuses on a subset, as defined by the scope of the Low-Carbon Emitting Technologies Initiative below. Considering the brevity of this work, the presented outcomes constitute only a selection of findings.



1.2 The Low-Carbon Emitting Technologies Initiative as a catalyst towards net zero

The Low-Carbon Emitting Technologies Initiative aims to accelerate the chemical industry's journey towards net zero by 2050. The chief executive officer-led initiative of major chemical companies centres on: a) collaboration within and beyond the industry to ultimately increase the maturity of chosen LCETs; and b) exploration of opportunities to implement real-life projects in accordance with five focus areas:⁷

- **Biomass utilization:** Fossil fuels and feedstocks can be substituted with, ideally, sustainably produced biomass from agricultural and forestry waste and by-products. In combination with carbon capture, a carbon sink could evolve.
- **Carbon capture and utilization (CCU):** CCU can be a valuable solution to reduce emissions by complementing other LCETs via capturing CO₂ streams from industrial processes and using the carbon as raw material in valuable products or as an energy/hydrogen carrier. While this initiative focuses on utilization, it is acknowledged that carbon capture and storage (CCS) can be a valuable transition technology.
- **Electrification:** Assuming low-carbon electricity generation,⁸ the substitution of fossil fuel with electrically heated chemical processes can contribute significantly to reducing emissions. While several factors play a role, electrification of processes is closely linked to the availability and affordability of low-carbon electricity.
- **Alternative hydrogen production:** Hydrogen has the potential to substitute fossil fuels for various applications and consequently reduce emissions, assuming that it is produced in a low-carbon emitting fashion, e.g. blue or green hydrogen. The former combines conventional production with carbon capture and the latter uses renewable electricity-driven electrolysis. In the long term, green hydrogen is the preferred solution.
- **Waste processing:** Waste processing or recycling of plastic waste should reduce the required amount of fossil feedstock to produce plastics as well as avoiding emissions-intensive end-of-life product incineration.

1.3 The importance of public policy for the implementation of LCETs

The chemical industry strongly relies on capital-intensive and long-lived assets and requires significant investment to change its business models and operations.⁹ Any structural changes to be in place by 2050 require action soon – preferably now.

The development, deployment and upscaling of LCETs depend largely on an enabling political and

regulatory environment; however, different countries have different ambitions and even within one country disparities can loom large.¹⁰

This paper attempts to provide insights, guidance and support for strategic decision-making and future policy-making in this complex environment without suggesting a particular stance.

Methodology

Seven jurisdictions and six policy clusters were identified as key to this analysis.

Selection of jurisdictions

Based on the following set of criteria, seven jurisdictions were selected to be covered in the analysis:

- Economic significance (large economy with significant chemical industry)
- Proximity to feedstock and/or availability of required infrastructure
- Current availability or future development of renewable energy/hydrogen infrastructure/other enablers for LCET projects
- Progressive decarbonization efforts and targets

In addition, the number of jurisdictions was constrained to a maximum of 10 in order to focus the scope of the analysis.

This resulted in the selection of the following jurisdictions: China, the European Union, Japan, Saudi Arabia, the United Arab Emirates, the United Kingdom and the United States.

Data acquisition

Data was acquired through expert interviews and desk research. Twenty-four interviews were conducted with industry experts, policy-makers, NGO representatives, academics and legal practitioners. Additional information was collected from public sources and Accenture internal research.

Policy model

The acquired data was quantified by a model based on an assessment matrix (structured questionnaire) with a set of more than 80 questions across all policy clusters (see below). To each question, four possible answers were assigned, linked with a numerical value representing the degree of policy support for either one or more LCETs. Below the policy clusters, more specific policy areas were identified, and even more specific policy issues.

Calculating the scoring was conducted from the bottom up, from policy issues to policy areas, policy clusters and LCET areas, with weighting factors adjusting for the varying impact of items within these categories with regard to the deployment of LCETs.

Six key policy clusters affect the deployment of LCETs

Enabling the transition requires a complex set of policies facilitating change across the value chain and in various stakeholder behaviours and decisions. Six policy clusters have been identified that can significantly affect the development and upscaling of LCETs.

1. **Incentives and Targets:** Setting climate targets and the right incentives are major drivers towards a net-zero chemical industry. This analysis considers energy- and GHG-specific regulations, voluntary carbon markets, fossil fuel pricing, the volume of lawsuits for increased climate action, and carbon-pricing mechanisms. In addition, taking a macro view, the creation of a level playing field and avoidance of carbon leakage (the process of companies relocating operations into jurisdictions with less stringent carbon pricing, while incentivizing investments) is a major challenge.
2. **Technologies and Infrastructure:** Key enablers for the development, upscaling and deployment of LCETs are technology- and infrastructure-related, which is captured in this work by analysing: a) regulatory actions that inhibit the move towards low-carbon alternatives such as a lack of clearly defined criteria for classification of biomass as sustainable; and b) the availability of required physical infrastructure such as pipelines, power transmission networks and renewable energy supplies.
3. **Supporting and Enabling:** Transforming the chemical industry from using conventional technologies to LCETs requires significant investment in the form of capital expenditure (capex). Additionally, operating LCETs will often come at a higher cost – operating expenditure (opex) – as well, temporarily leading to less competitive products and thus decreasing

the attractiveness of the project in the eyes of potential investors. Policy-makers can actively affect investment attractiveness. This support type is captured in this work by analysing: a) direct support for LCET projects (capex impact); b) indirect support via tax incentives for low-carbon production (bottom-line impact); and c) sustainable financing guidelines and GHG emissions-related reporting standards and regulations.

4. **Markets and Demand:** Since low-carbon products will temporarily have higher opex in comparison to their conventional counterparts, creating and growing markets for green products is vital for sustainable LCET deployment. This research considered, among others, private procurement actions such as a market pull for non-fossil plastics, public procurement actions such as governmental car fleets requiring large shares of non-fossil materials, and legislation ensuring companies use minimum shares of green materials in their product portfolio.

5. **Collaboration and Innovation:** The technical and financial challenges that need to be overcome to deploy LCETs require innovation-supporting policies and strong collaboration among industry players and the public and private sectors. Here, the existence of public-private platforms, IP protection and competition-law aspects are analysed.

6. **Caveats and Inhibitors:** Potential roadblocks for LCET deployment, beyond missing policy enablers, must also be considered. Hence, this work assesses, for example, the risk of court cases posing a threat to LCET deployment, and public opinion as well as protest movements that might constitute a hindrance to LCET and related projects, such as CO₂ pipelines or new wind parks.



The LCET-deployment matrix: a high-level tool for decision-makers

To facilitate strategic decision-making, the LCET-deployment matrix was developed. It supports initial thinking by putting the level of policy support and the burden of stranded assets in relation to one another. The level of policy support is categorized as low or high, depending on the outcome of this analysis. Policy support will be considered low for a score below 60 out of 100 and high if the score is equal to or above 60 out of 100.¹¹ The policy model and the results discussed in this paper address this dimension only.

The other axis of the matrix considers the net present value of a certain asset (facility). Assets will lose value in case of operations relocation and potentially require asset adjustments via capex. The burden of stranded assets is categorized as low or high, with net present value (NPV) being positive and negative, respectively. Put simply, the NPV of an asset will be negative if the sum of the discounted cash flows is below 0.

FIGURE 1 **LCET-deployment matrix provides initial orientation on where to develop and what kind of low-carbon project**

		Policy support	
		Low	High
Burden of stranded assets	Low	<p>Collaborate: Engage with policy-makers ~</p> <hr/> <p>Collaborate in joint ventures, e.g. to mitigate suboptimal policy environment</p> <hr/> <p>Engage with policy-makers to discuss enabling policy measures</p>	<p>Deploy at scale now +</p> <hr/> <p>Conduct in-depth policy and market analysis</p> <hr/> <p>Investigate business case</p> <hr/> <p>Create financing structure tailored to low-carbon projects</p>
	High	<p>Postpone: Engage with policy-makers —</p> <hr/> <p>Postpone new project and use current assets until end of their lifetime</p> <hr/> <p>Engage with policy-makers to discuss enabling policy measures</p>	<p>Conduct pilot project now and learn ~</p> <hr/> <p>Make use of favourable policies as a first mover</p> <hr/> <p>Scale up to replace current assets later</p> <hr/> <p>Use learnings in further navigating and shaping the policy landscape</p>

Disclaimer

- Out of necessity, this work represents only a snapshot of the policy environment at a given point in time. While the policy landscape is dynamic, it was not possible to factor in changes that occurred after 31 January 2022.
- Unless clearly noted otherwise, when speaking of the position or trend of a particular LCET area, this refers only to its policy support.
- Besides the objective and quantified scoring of policy support for LCETs, the differently characterized political spheres of the analysed jurisdictions play important roles – e.g. the topic's sustainability vs. (energy) security, and different legal traditions and available policy tools.
- The investigation of causal relationships between concrete policy measures and an uptake in real-life deployment of LCETs was outside the scope of this study. Further research in this area could improve the understanding and sharing of best practices within and among jurisdictions.

3 LCET policy analysis by jurisdiction

The main policy features supporting key LCETs in the seven jurisdictions selected for this paper are detailed below.



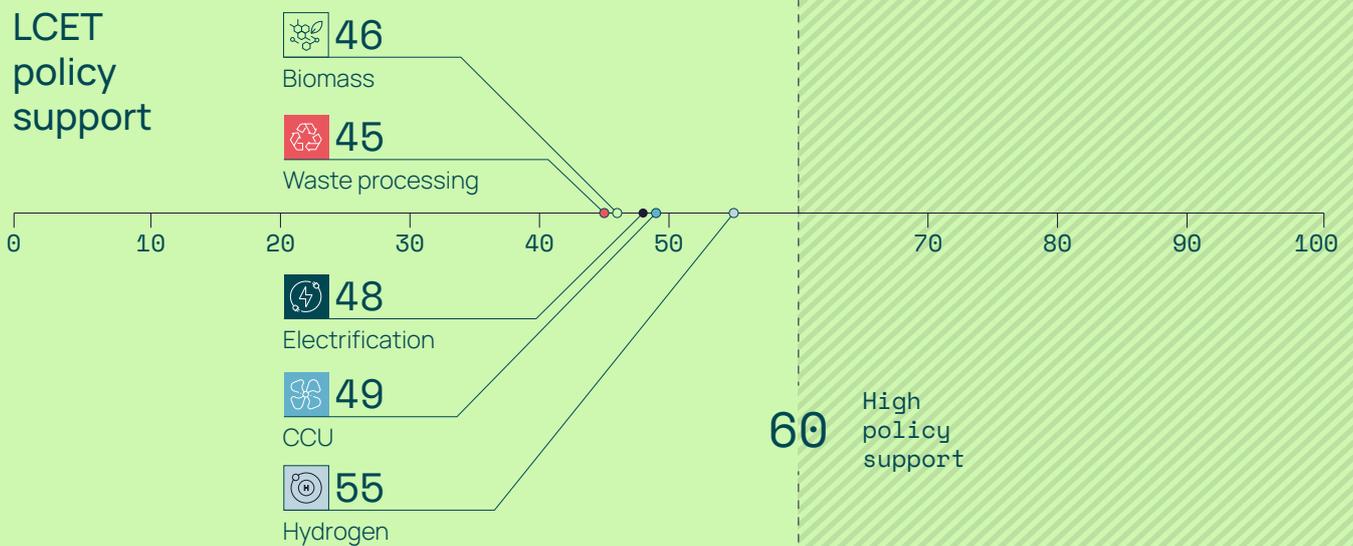
Status quo*

GHG emissions per year [MtCO ₂ eq]	12,355
% of global emissions	26.9
GHG emissions/GDP real [MtCO ₂ eq/bn \$]	0.93
Population [M]	1,428
GDP real/capita [k \$]	9.4
Chemical industry's revenue [bn \$]	1,801

Goals set

Carbon peak before 2030	Net zero by 2060
Solar and wind capacity of at least 1,200GW by 2030	Reduction in carbon intensity of 65% by 2030 compared to 2005 levels

LCET policy support



Policy priorities per LCET

Policy clusters	LCETs					
	Average	Biomass	CCU	Electrification	Hydrogen	Waste processing
		46	49	48	55	45
Incentives and Targets	34	32	34	34	36	33
Technologies and Infrastructure	49	42	52	42	67	42
Supporting and Enabling	59	58	67	58	67	48
Markets and Demand	28	31	24	24	31	31
Collaboration and Innovation	48	36	49	49	56	49
Caveats and Inhibitors	11	0	19	0	19	19

LCETs listed in alphabetical order

* Reference year 2018 for all measures

Sources: GHG emissions: World Bank, "Total Greenhouse Gas Emissions (kt of CO₂ equivalent)": <https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE>; Other: Oxford Economics; GDP real based on 2015 prices

Since China's GDP and with it its appetite for goods will keep growing, becoming carbon neutral is a particular challenge for this major economy.¹²

A more ambitious updated nationally determined contribution (NDC) was submitted in late 2021 outlining the country's path towards its main climate targets (see above).

Notably, during COP26, the EU and China aligned on common ground regarding the definition of green investments¹³ – a type of classification that has become known as (sustainable or green) taxonomy.



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Biomass

Biomass utilization receives below-average scorings for most policy clusters, despite its large potential in China. The Circular Economy Promotion Law encourages the use of waste biomass for the use of biogas and biomass energies.¹⁴ However, dedicated policies aligning the use of biomass with farmland and implementing monetary support mechanisms still require elaboration.



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CCU

CCU ranks as the second most prioritized LCET in China, scoring high in Technologies and Infrastructure and Supporting and Enabling. Given the high dependency on coal-based electricity generation, carbon capture has great potential; however, large investments in research and development (R&D) and dedicated funding mechanisms for companies will be required.



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Electrification

Electrification plays a major role in China's LCET space, with two noticeable developments: a) the renewables capacity is increasing at a high rate, while nuclear will be a part of the energy mix and is supported by the introduction of the national emissions trading system (ETS) in 2021, which currently applies to the power sector only; and b) tight regulation on energy consumption to balance supply and ever-increasing demand. Two policies are important: double-control, which regulates existing operations' energy intensity and consumption; and double-high, which regulates new projects' energy intensity and GHG emissions. Additionally, the Energy Conservation Law promotes energy saving for chemical and other industries.



55 /100

Hydrogen

Besides having strong support in Technologies and Infrastructure (carbon peak action plan)¹⁵ and funding opportunities, alternative hydrogen production is emphasized by multiple industries and benefits from above-average Collaboration and Innovation support. Additionally, China is dependent on expensive natural gas imports to produce hydrogen using conventional methods.



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Waste processing

Promoting the circular economy to reduce emissions is one of the key tasks for China's action plan towards peak emissions. China aims to "push industrial parks to develop in a circular manner" and "refine systems for resource recycling."¹⁶

While reusing and recycling products is also one of the central issues in China's Circular Economy Promotion Law, waste processing is yet to receive more attention and policy support from the government.

Progress to date

- Commitment to carbon peak before 2030 and the launch of an action plan system for various sectors (1+N action plan system) promote upscaling of all LCETs
- Hydrogen and carbon capture, utilization and storage (CCUS) are likely to lead post-2025, given their potential to deliver lower emissions in the face of concerns about energy security
- Introduction of national ETS for the power sector as an important step towards lowering emissions, supporting electrification in the long run

Changes tomorrow

- Clarity regarding the development of China's carbon market (extension of ETS and relaunch of CCER) could support the move towards LCETs
- Public-private dialogues regarding LCET funding models and green finance opportunities could facilitate increased access to capital for green projects
- Concrete legislation implementing high-level action plans (1+N) could deliver planning certainty for industry

Status quo*

GHG emissions per year [MtCO ₂ eq]	3,115
% of global emissions	6.8
GHG emissions/GDP real [MtCO ₂ eq/bn \$]	0.21
Population [M]	447
GDP real/capita [k \$]	32.5
Chemical industry's revenue [bn \$]	706

Goals set

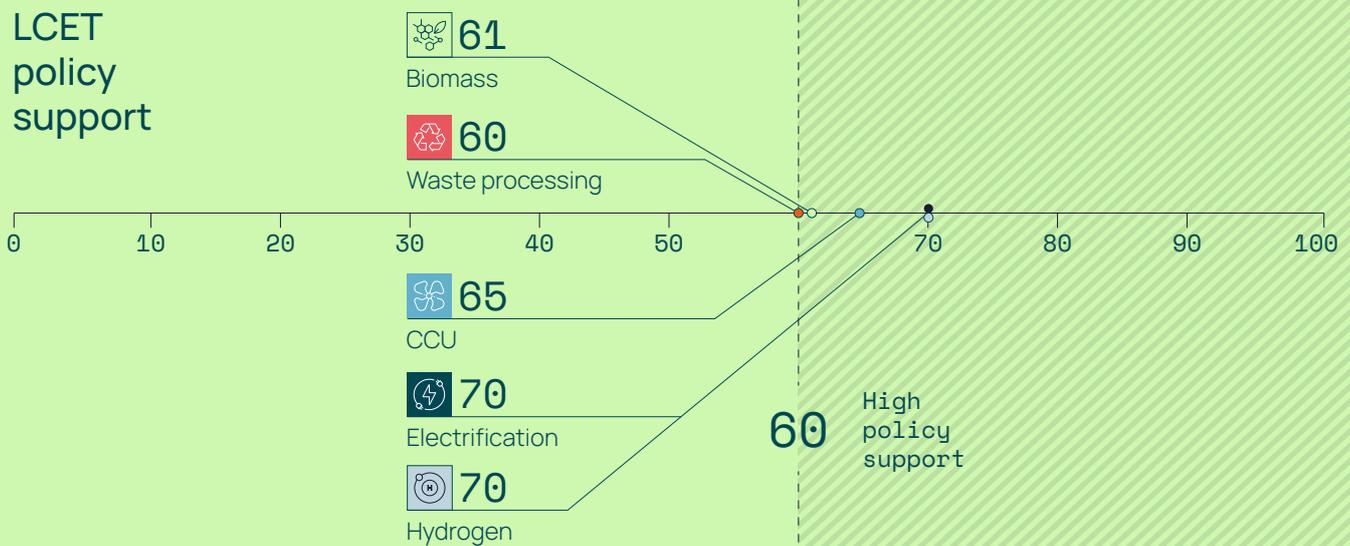
Net zero by 2050

At least 40GW electrolyzer capacity by 2030

38–40% renewable energy of final energy consumption by 2030

-55% GHG emissions by 2030 compared to 1990 levels

LCET policy support



Policy clusters	LCETs					
	Average	Biomass	CCU	Electrification	Hydrogen	Waste processing
		61	65	70	70	60
Incentives and Targets	78	76	80	80	80	74
Technologies and Infrastructure	73	73	67	85	85	58
Supporting and Enabling	56	58	58	58	58	48
Markets and Demand	42	42	42	42	42	42
Collaboration and Innovation	67	56	69	75	75	62
Caveats and Inhibitors	37	52	33	33	33	33

LCETs listed in alphabetical order

* Reference year 2018 for all measures

Sources: GHG emissions: World Bank, "Total Greenhouse Gas Emissions (kt of CO₂ equivalent)": <https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE>; Other: Oxford Economics; GDP real based on 2015 prices

With the European Green Deal, the EU laid out a comprehensive climate action plan.

It aims to reduce GHG emissions to net zero by 2050 while ensuring economic growth decoupled from resource use,

and a socially acceptable transition, leaving “no person and no place” behind.¹⁷ In July 2021, the Commission presented a proposal package towards implementation of the European Green Deal, the so-called Fit for 55 package,¹⁸ which is currently being negotiated among legislative actors and other stakeholders.



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Biomass

EU climate regulations and policies support biomass utilization. The proposed revision of the second Renewable Energy Directive (REDII)¹⁹ raises the 2030 targets for renewable energy and encourages the use of bioenergy and sustainable biofuels. The revisions would also mandate member states to set up support schemes in accordance with the biomass hierarchy. Yet they also push for a more sustainable use of biomass, prohibiting the use of all biomass from “primary and highly biodiverse forests”. This might lead to supply shortages once industry demand for biomass feedstock increases – this is expected post-2030. Furthermore, biomass utilization faces noticeable public opposition.



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CCU

Looking forward, incentives to deploy CCU projects might be strengthened by the revision of both the EU ETS directives and REDII, as well as initiatives proposed in the European Commission’s communication on sustainable carbon cycles.²⁰ Previously, CCS has been treated favourably by the ETS. The new proposed revision intends to recognize CO₂ bound permanently by CCU as negative emissions, boosting this technology.

The ETS Innovation Fund and the Connecting Europe Facility (CEF) are major funding instruments. The emerging scale-up of these technologies might also be supported by future requirements to use a certain share of non-fossil feedstock in the production of chemicals, as proposed in a recent European Commission communication.²¹



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Electrification

As some 75% of total anthropogenic GHG emissions in the EU stem from energy use,²² moving towards renewable energy can be seen as the number one priority, supported by the ambitious revision of REDII. Receiving good scores for Incentives and Targets as well as Technologies and Infrastructure, electrification will lead the way pre-2030. The quick upscaling of renewable capacity and transmission infrastructure remains challenging, not least due to some public resistance to large infrastructure projects.



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Hydrogen

The use of hydrogen as renewable fuel currently has momentum as a result of the revised REDII and the EU Hydrogen Strategy, which aims at electrolyser capacities of 10Mt per year by 2030.²³

The Energy System Integration Strategy, together with the Hydrogen Strategy, is one of the EU’s high-level initiatives addressing energy infrastructure improvement. The EU hydrogen network aims to connect cost-effective hydrogen production with off-takers.²⁴ Creating a market for hydrogen is a priority driven by the new framework to decarbonize gas markets, together with the EU’s Hydrogen Strategy.²⁵



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Waste processing

Plastic waste processing, in particular chemical recycling, still faces significant uncertainty at a policy level; however, it is expected to play a larger role post-2030. Many required policies are not yet in place or laid out at a member state level. At the EU level, the major legislative act is the Waste Framework Directive,²⁶ which is supported by the circular economy action plan.²⁷ Despite a clear trend towards recycling, dedicated funding opportunities are yet to be improved and policies for mechanical and chemical recycling are still to be fully developed.

Progress to date

- Electrification and hydrogen leading the way due to strong targets (REDII) and strategies (Hydrogen Strategy), aligned industry agenda and public acceptance
- Coherent programme of climate action legislation would support all LCET areas (Fit for 55 proposals)
- Wide range of funding opportunities at EU and member state level for LCETs to enable demonstration projects

Changes tomorrow

- Taxonomy regulation would benefit from adjustment towards capturing chemical industry’s complexity
- Demand for green/circular products could be strengthened for LCETs, e.g. by defining green labels/setting green (public) procurement targets
- Funding landscape could be enriched by opex support mechanisms, e.g. carbon contracts for difference (CCfDs)

Status quo*

GHG emissions per year [MtCO ₂ eq]	1,187
% of global emissions	2.6
GHG emissions/GDP real [MtCO ₂ eq/bn \$]	0.26
Population [M]	127
GDP real/capita [k \$]	36.0
Chemical industry's revenue [bn \$]	267

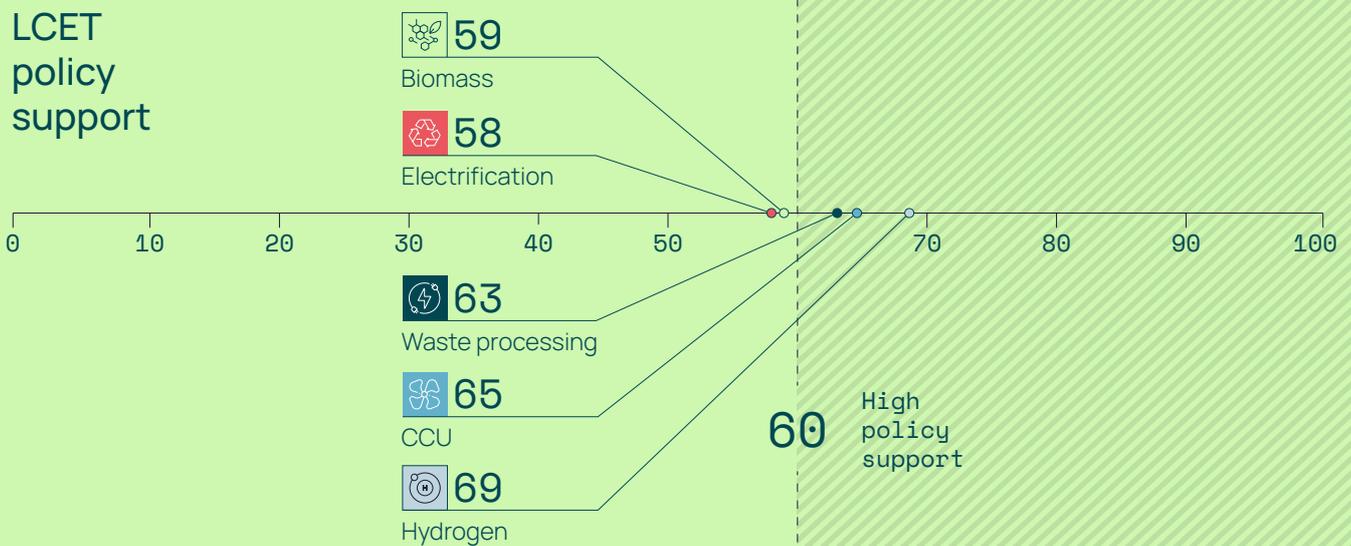
Goals set

Net zero by 2050

GHG emissions reduction by 46% by 2030 (from 2013 levels)

36–38% renewables in electricity mix by 2030

LCET policy support



Policy priorities per LCET

Policy clusters	LCETs					
	Average	Biomass	CCU	Electrification	Hydrogen	Waste processing
		59	65	58	69	63
Incentives and Targets	65	65	69	63	67	62
Technologies and Infrastructure	67	52	76	67	76	67
Supporting and Enabling	48	39	58	39	58	48
Markets and Demand	38	50	28	28	35	50
Collaboration and Innovation	72	72	72	65	78	72
Caveats and Inhibitors	15	19	19	19	0	19

LCETs listed in alphabetical order

* Reference year 2018 for all measures

Sources: GHG emissions: World Bank, "Total Greenhouse Gas Emissions (kt of CO₂ equivalent)": <https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE>; Other: Oxford Economics; GDP real based on 2015 prices

An island state with few natural resources but with extensive industry, Japan faces various challenges in reducing emissions.

Its net-zero goal, announced in 2020, and an ambitious NDC, updated in 2021, is to be reached through a set of initiatives: the Green Growth Strategy,²⁸ aiming at combining emissions reduction with growth in 14 sectors, the Basic Hydrogen Strategy, and the sixth Strategic Energy Plan²⁹ will be central to Japan's transition.



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Biomass

Biomass utilization in Japan benefits from the overall high level of ambition reflected in its Incentives and Targets. Bioenergy contributes about 2.5% to the total energy supply.³⁰ The Green Growth Strategy stresses the use of biomass as future feedstock for plastics. One challenge for Japanese biomass is its limited domestic supply, leading to a high level of imports.



65 /100

CCU

Carbon capture, utilization and storage (also known as carbon recycling in Japan) is a key technology in the country's journey to net zero. It places considerable emphasis on the development of CCU/CCS technology, targeting further cost reductions by 2030 and a leading role in the growing carbon capture market by 2050.³¹



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Electrification

Japan targets an ambitious future electricity mix of 36–38% of renewables by 2030. Together, nuclear and thermal electricity generation (fossil-based) combined with CCUS might increase to 30–40% by 2050. Currently, a carbon tax of about \$3/tCO₂ (climate change mitigation tax)³² and a fossil fuel tax incentivize decarbonization. Still, Japan experiences electrification of processes as a difficult challenge, given its high electricity prices due to limited domestic resources.



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Hydrogen

The Basic Hydrogen Strategy aims to position Japan as a leader in this space, aspiring to be a hydrogen-based society. Given that producing green hydrogen within Japan and importing it are both still too expensive, the current focus lies on importing blue hydrogen from Australia and the Middle East, especially Saudi Arabia. Japan is also experimenting with large-scale power generation using hydrogen as an energy vector. Current policies already boost Japan's hydrogen scoring – particularly in Technologies and Infrastructure and Collaboration and Innovation. Yet full implementation of the hydrogen strategy in legislation and concrete measures will likely take until 2030.



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Waste processing

Plastic waste processing is already a focus area for Japan's chemical industry in the feedstock transition – ahead of biomass utilization. A decade from now, the share of recycled feedstock could be 10–20%. Waste processing scores particularly well in Collaboration and Innovation. In 2021, a major Japanese chemical company announced the construction of a chemical recycling plant with a capacity of 20,000t of plastic waste per year.³³ The government invests in supporting infrastructure, while incentives and funding opportunities show room for improvement.

Progress to date

- High level of ambition in NDC and Green Growth Strategy with a focus on 14 growth sectors support transition towards lower emissions
- Hydrogen is clearly leading the way due to a dedicated hydrogen strategy and the government's commitment towards a hydrogen-based society
- The Ministry of Economy, Trade and Industry (METI) announced plans to start a demonstrative carbon credit market in the fiscal year 2022/2023,³⁴ which could realize additional incentives for LCETs

Changes tomorrow

- Implementing a clearer carbon price signal (beyond a climate change mitigation tax) could further incentivize investment in LCETs
- Given the challenges Japan faces as an island state, finding a bespoke solution in terms of a reliable low-carbon energy supply will be vital
- Benefiting from favourable policy environments, facilitating and engaging in dialogues regarding opex support for LCETs might strengthen Japan's position

Status quo*

GHG emissions per year [MtCO ₂ eq]	638
% of global emissions	1.4
GHG emissions/GDP real [MtCO ₂ eq/bn \$]	0.94
Population [M]	33
GDP real/capita [k \$]	20.3
Chemical industry's revenue [bn \$]	75

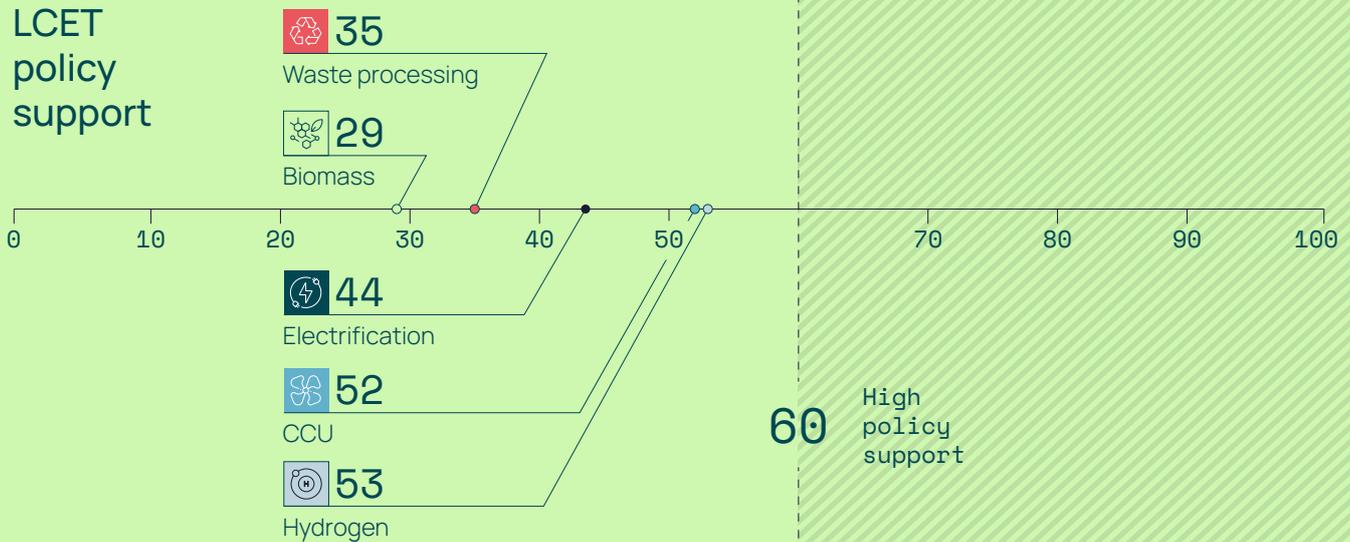
Goals set

Net zero by 2060
(dependent on economy)

GHG emissions reduction of 278Mt CO₂eq/a by 2030 compared to 2019

50% renewables in electricity mix by 2030 (58.7GW of installed capacity)

LCET policy support



Policy priorities per LCET

Policy clusters	LCETs					
	Average	Biomass	CCU	Electrification	Hydrogen	Waste processing
Incentives and Targets	23	24	21	25	27	20
Technologies and Infrastructure	63	27	85	67	85	52
Supporting and Enabling	48	30	67	48	67	30
Markets and Demand	22	14	28	28	28	14
Collaboration and Innovation	32	17	43	30	43	30
Caveats and Inhibitors	19	19	19	19	19	19

LCETs listed in alphabetical order

* Reference year 2018 for all measures

Sources: GHG emissions: World Bank, "Total Greenhouse Gas Emissions (kt of CO₂ equivalent)": <https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE>; Other: Oxford Economics; GDP real based on 2015 prices

For the past half-century, the Kingdom of Saudi Arabia has been very much dependent on fossil fuels.

Vision 2030, launched in 2016, is the grand strategy to not only diversify the economy but also privatize it, increase foreign investments and transform society.³⁵

Outlining its climate targets, Saudi Arabia submitted an updated NDC in 2021. While both the NDC and Vision 2030 rely on revenues from the continued export of fossil fuels, the climate targets are indeed ambitious compared to the country's economic traditions and environmental circumstances.³⁶



29 /100

Biomass

Biomass utilization receives little-to-no specific policy support while, on the practical side, little activity regarding bio-energy applications is noticeable. Very limited biomass potential³⁷ for the country overall creates a different focus.



52 /100

CCU

CCUS is one of the leading LCET areas in Saudi Arabia. With carbon capture being a priority, infrastructure developments are being pushed in the cities of Jubail and Yanbu, which are to become CCUS hubs. Plans to establish an investment fund to enhance deployment of CCU/CCS were announced in autumn 2021.³⁸ Besides its use in the production of blue hydrogen, carbon capture is used for enhanced oil recovery (EOR) and captured carbon is used as feedstock, with one of the largest CCU plants being located in Saudi Arabia.³⁹



53 /100

Hydrogen

Saudi Arabia aims to market itself as a frontrunner in the hydrogen space – both blue and green – and is very actively promoting the deployment of large-scale plants. The most prominent of these is the Helios project,⁴¹ part of the NEOM giga-project,⁴² which will be powered by 4GW of renewable energy from solar and wind. Its production capacity should reach 650t of hydrogen per day and 1.2Mt of green ammonia per year.

In the future, green hydrogen will play a large role in western parts of the country, once the share of renewables is sufficient. However, Saudi Arabia is currently scaling up blue hydrogen production in eastern parts of the country by focusing on CCU and CCS in combination with conventional hydrogen production processes. Notably, a memorandum of understanding outlines the setting up of a Saudi-German innovation fund for the promotion of clean hydrogen.⁴³



35 /100

Waste processing

Plastic waste processing is becoming more important in Saudi Arabia, with a new Waste Management Law having been enacted in 2021⁴⁴ and the launch of the Circular Carbon Economy National Program.⁴⁵ Yet it is still in its early stages and, with concrete policy support towards recycling still to be developed, it is not a priority LCET at this time.



44 /100

Electrification

High ambitions and heavy reliance on fossil fuels make an interesting future for the electrification of processes in Saudi Arabia. The National Renewable Energy Program (part of Vision 2030) aims to boost the share of renewables in the electricity mix to 50% by 2030, which will come in large part from solar photovoltaic (sPV) (two-thirds), wind (one-third) and concentrated solar power.⁴⁰

Progress to date

- Taking the lead in alternative hydrogen production is a priority – with large-scale green hydrogen plants as lighthouse projects
- Existing infrastructure combined with a commitment to drastically reduce emissions within the country boosts CCUS deployment in industrial hubs
- Vision to massively increase capacity of renewables will support electrification in the long run

Changes tomorrow

- Given the existing industrial hubs, policies specifically supporting waste processing could encourage cooperation between industrial consortiums
- Demand-side policies for both public and private actors could facilitate the transition to a vibrant society, as envisaged in Vision 2030
- Implementation of dedicated monetary support mechanisms could facilitate more private investment, especially by foreign companies

Status quo*

GHG emissions per year [MtCO ₂ eq]	263
% of global emissions	0.6
GHG emissions/GDP real [MtCO ₂ eq/bn \$]	0.69
Population [M]	9.6
GDP real/capita [k \$]	39.6
Chemical industry's revenue [bn \$]	14

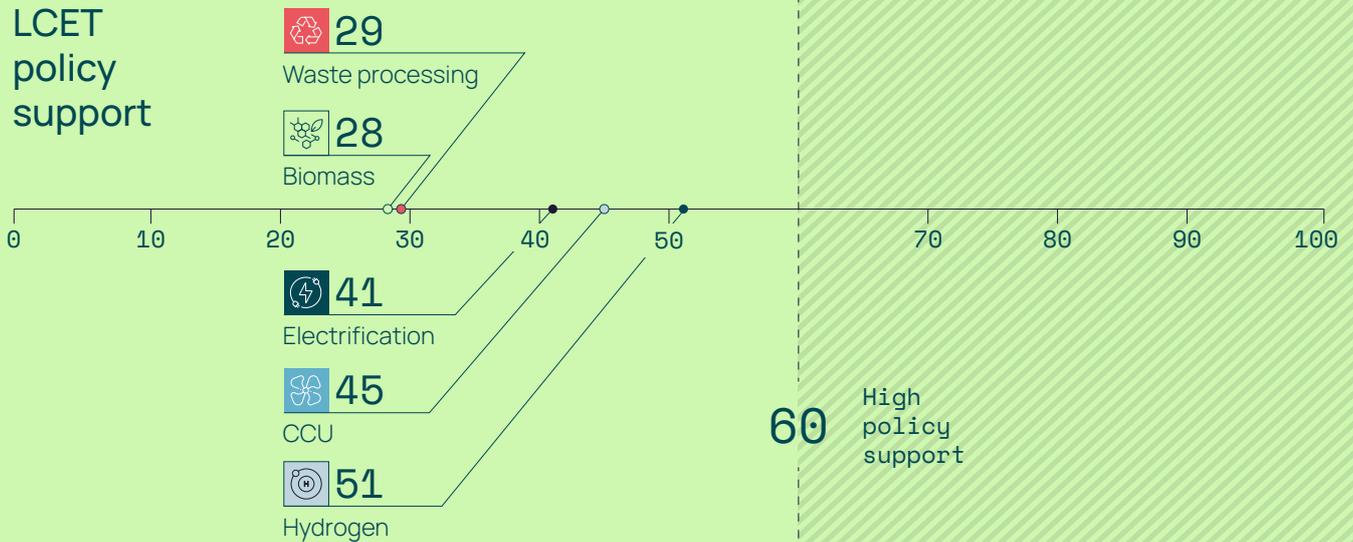
Goals set

44% clean energy in energy mix by 2050

Net zero by 2050

Emission reduction of 23.5% by 2030 (compared to BAU-scenario)

LCET policy support



Policy priorities per LCET

Policy clusters	LCETs					
	Average	Biomass	CCU	Electrification	Hydrogen	Waste processing
Incentives and Targets	36	36	35	38	40	34
Technologies and Infrastructure	39	9	58	42	67	18
Supporting and Enabling	26	15	33	33	33	15
Markets and Demand	27	22	28	28	35	22
Collaboration and Innovation	37	24	43	37	56	24
Caveats and Inhibitors	19	19	19	19	19	19

LCETs listed in alphabetical order

* Reference year 2018 for all measures

Sources: GHG emissions: World Bank, "Total Greenhouse Gas Emissions (kt of CO₂ equivalent)": <https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE>; Other: Oxford Economics; GDP real based on 2015 prices

The United Arab Emirates (UAE), a heavy user and producer of fossil fuels, has been trying to shift its economic focus to other industries and push for deployment of certain LCETs.

Hitherto, no legally binding climate regulations at the federal level exist, except for international treaties.



28 /100

Biomass

Biomass utilization plays a minor role in the UAE in terms of both bioenergy and biomass as feedstock alternative. Limited availability of biomass in the region corresponds to a small amount of activity within the policy space.



45 /100

CCU

Besides hydrogen, carbon capture technologies are among the focus LCETs in the UAE. CCUS benefits from above-average scoring in Technologies and Infrastructure and Collaboration and Innovation – thanks to political and industry interest in that field. The UAE plans to expand its carbon capture capacity, building on the experience with the Al Reyadah project capturing CO₂ for EOR.⁴⁶



41 /100

Electrification

The UAE Energy Strategy 2050 targets an energy mix that includes 44% clean energy, 38% gas, 12% clean coal and 6% nuclear.⁴⁷ Securing its energy supply and diversifying energy sources, the UAE announced investment of AED 600 billion (~\$160 billion), but detailed policies are yet to be implemented.

Renewable energy projects are usually based on power purchase agreements. As part of the Dubai Clean Energy Strategy, the UAE is aiming to set up a large solar park with a capacity of 5GW by 2030.⁴⁸



51 /100

Hydrogen

Hydrogen, both blue and green, is clearly the focus LCET within the UAE. While many strategies are yet to be followed by more concrete policies and funding opportunities, the UAE markets itself as a hub for hydrogen. Pushing forward with green ammonia, the UAE will build a \$1 billion green ammonia facility in the Khalifa Industrial Zone Abu Dhabi (KIZAD), which is to be powered by an 800MW solar plant.⁴⁹



29 /100

Waste processing

Not a priority LCET solution for the UAE yet, waste processing will likely be more important than biomass in the feedstock transition in the decades to come. To date, the UAE recognizes the need to move towards a circular economy, having established a federal public-private partnership – the Circle Coalition (Coalition of Innovation in Recycling towards a Closed Loop Economy) – in 2019.⁵⁰

Progress to date

- Production of blue and green hydrogen is leading in the UAE due to experience with carbon capture and the scaling-up of renewables
- Competition between emirates is likely to speed up implementation of concrete policies and funding opportunities
- The municipality of Ras Al Khaimah has launched a green public procurement programme recently – paving a new path within the UAE

Changes tomorrow

- Balancing competition between emirates and harmonizing binding climate regulation on a federal level could facilitate LCET transition
- Introducing a carbon price signal could support efforts to move towards more sustainable investments
- Demand-side policies and dedicated funding opportunities at a federal level could boost LCET deployment

Status quo*

GHG emissions per year [MtCO ₂ eq]	452
% of global emissions	1.0
GHG emissions/GDP real [MtCO ₂ eq/bn \$]	0.14
Population [M]	66
GDP real/capita [k \$]	47.2
Chemical industry's revenue [bn \$]	46

Goals set

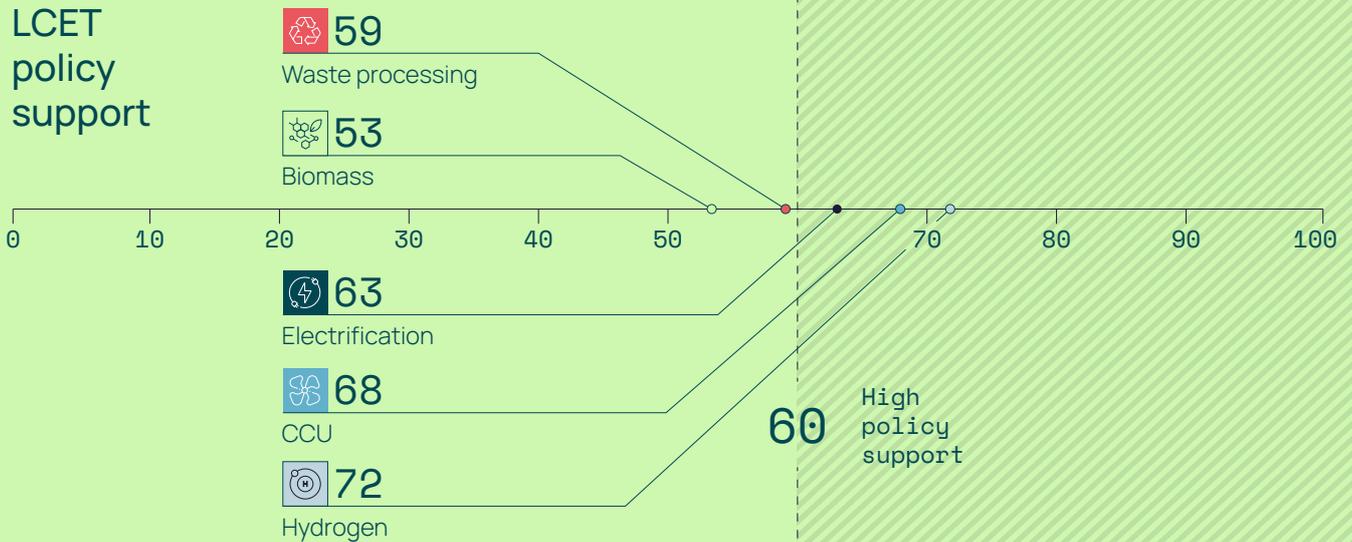
Low-carbon hydrogen production capacity to reach 5GW by 2030

GHG emissions reduction of 68% by 2030 and 78% by 2035 (from 1990 levels)

Decarbonized power system by 2035

Net zero by 2050

LCET policy support



Policy priorities per LCET

Policy clusters	LCETs					
	Average	Biomass	CCU	Electrification	Hydrogen	Waste processing
		53	68	63	72	59
Incentives and Targets	58	56	59	57	59	56
Technologies and Infrastructure	74	52	76	76	100	67
Supporting and Enabling	72	58	85	67	85	67
Markets and Demand	40	35	42	42	42	35
Collaboration and Innovation	65	53	73	66	73	60
Caveats and Inhibitors	33	33	33	33	33	33

LCETs listed in alphabetical order

* Reference year 2018 for all measures

Sources: GHG emissions: World Bank, "Total Greenhouse Gas Emissions (kt of CO₂ equivalent)": <https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE>; Other: Oxford Economics; GDP real based on 2015 prices

The United Kingdom (UK) has put forward a collection of strategies that lay out a comprehensive framework for the decarbonization of the industry and the country as a whole, with the Net Zero Strategy⁵¹ as the central piece.

It is accompanied by a set of approaches tailored to individual sectors and technologies (e.g. the Industrial Decarbonization Strategy, the Hydrogen Strategy). The Ten Point Plan for a Green Industrial Revolution presented in November 2020 focuses on low-carbon electricity⁵² and low-carbon hydrogen across several policy clusters.



63 /100

Electrification

To meet the starkly increasing demand for electricity, the UK strategy emphasizes the upscaling of offshore wind, the capacity of which should be quadrupled by 2030 up to 40GW.⁵⁶ However, due to high electricity prices, electrifying industry processes is challenging. The Energy-Intensive Industries Compensation Scheme alleviates this effect by partially exempting heavy industry. Retrofitting and R&D for switching from fossil fuel to a renewable carbon alternative are supported by the Industrial Fuel Switching Competition (IFSC).⁵⁷



53 /100

Biomass

In the UK, biomass is seen as a transitional technology pre-2030. While the focus lies on bioenergy (often as bioenergy with carbon capture and storage – BECCS), it will also play a role in feedstock replacement for the chemical industry. Compared to other LCETs, biomass is lacking solid support in terms of Technologies and Infrastructure as well as Collaboration and Innovation. This is intended to change, however, with a biomass strategy to be released in the fourth quarter of 2022 and the Biomass Feedstocks Innovation Programme gaining traction.⁵³



68 /100

CCU

Carbon capture technologies are clearly among the long-term focus areas, facing a favourable policy environment. Currently, CCS seems to be favoured over CCU as the government sees greater potential for the former. Attempting to establish CCUS in four industrial clusters (SuperPlaces) by 2030, capturing up to 10Mt CO₂ annually, the UK plans to invest up to £1 billion (\$1.3 billion).⁵⁴ In order to make carbon capture economically feasible, the UK set up several business models with similar effects as carbon contracts for difference (CCfDs).⁵⁵



72 /100

Hydrogen

Boosted by a dedicated strategy,⁵⁸ the Net Zero Hydrogen Fund and a supportive regulatory environment, hydrogen is set to lead the UK LCET space in the long term. By 2030, low-carbon hydrogen production should be scaled up to a capacity of 5GW.⁵⁹



59 /100

Waste processing

The UK's central policy document on waste treatment, the Resources and Waste Strategy, lays out the path towards more resource efficiency and a circular economy. Details regarding reuse and recycling are yet to be defined in a chemicals strategy.⁶⁰

Progress to date

- Post-2030, hydrogen and CCUS are likely to be dominant due to dedicated strategies and funding opportunities (both capex and opex) as well as collaboration in industry clusters
- UK ETS, now decoupled from the EU ETS, sends an important carbon price signal for the industry
- Ambitious GHG reduction and energy goals push towards swift deployment of renewables

Changes tomorrow

- Biomass and waste processing policies could be strengthened by dedicated strategies and bespoke support mechanisms (as for CCUS)
- Matching the high activity in pushing LCETs by targets, incentives and funding opportunities with demand-side policies could unlock their full potential
- Increasing green public procurement could trigger more private demand for green products

Status quo*

GHG emissions per year [MtCO ₂ eq]	6,024
% of global emissions	13.1
GHG emissions/GDP real [MtCO ₂ eq/bn \$]	0.31
Population [M]	328
GDP real/capita [k \$]	59.3
Chemical industry's revenue [bn \$]	491

Goals set

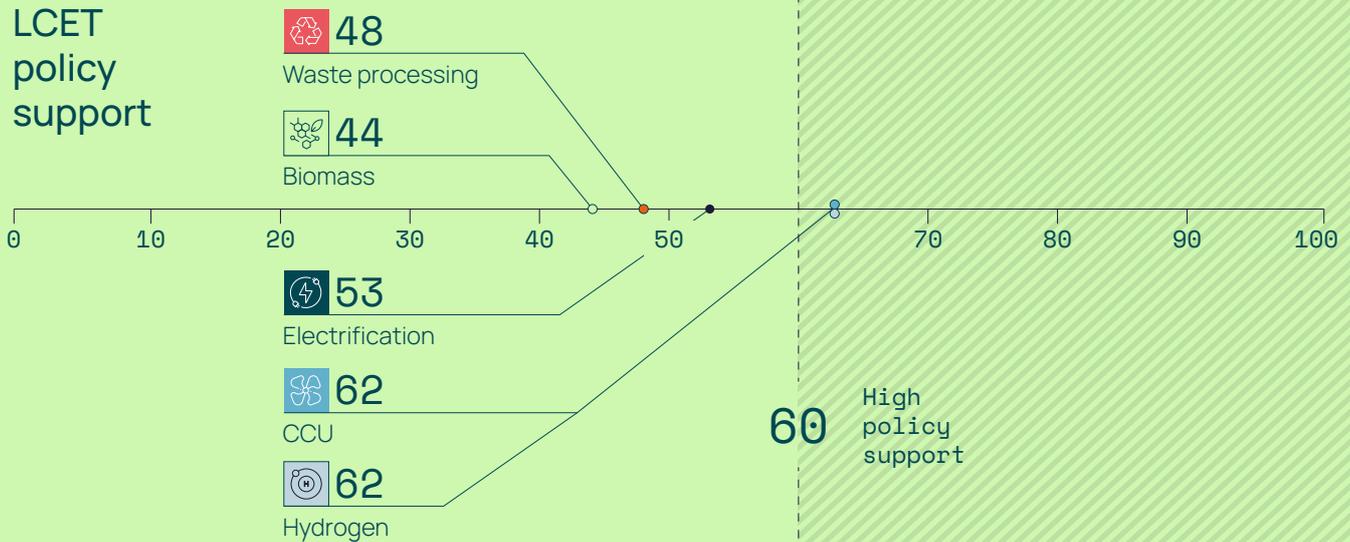
GHG reduction of 50% by 2030 compared to 2005 levels (NDC)

Net zero by 2050 (non-binding)

California: net zero by 2045

Pennsylvania: 80% GHG reduction by 2050

LCET policy support



Policy priorities per LCET

Policy clusters	LCETs	Biomass	CCU	Electrification	Hydrogen	Waste processing
	Average	44	62	53	62	48
Incentives and Targets	52	49	59	51	52	49
Technologies and Infrastructure	67	42	85	67	85	58
Supporting and Enabling	44	33	61	33	61	33
Markets and Demand	38	35	38	38	42	35
Collaboration and Innovation	74	61	87	68	81	74
Caveats and Inhibitors	67	63	81	44	63	81

LCETs listed in alphabetical order

* Reference year 2018 for all measures

Sources: GHG emissions: World Bank, "Total Greenhouse Gas Emissions (kt of CO₂ equivalent)": <https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE>; Other: Oxford Economics; GDP real based on 2015 prices

The United States has been lacking a consistent climate strategy so far, with significant variability between states.

Trying to stabilize the course on climate action, the current administration has proposed two major bills touching upon climate change mitigation and low-carbon technologies: the Infrastructure Bill and the Reconciliation Bill (Build Back Better Bill). While the \$1 trillion Infrastructure Bill was enacted in November 2021,⁶¹ the fate of the larger Reconciliation Bill⁶² is highly uncertain. Parts of it – including the climate policies – might be passed in 2022.



44 /100

Biomass

Bio-based feedstock alternatives have appeared on the radar of the chemical industry in the US but are not top of the agenda. Due to the US being self-sufficient with regard to fossil hydrocarbons, use of biomass as feedstock has yet to pick up speed. However, bioenergy – e.g. bio-ethanol-based fuel – has been supported by several federal incentive schemes.⁶³



62 /100

CCU

Carbon capture technologies are leading the US LCET space – on a par with hydrogen. CCUS is being supported by a tax credit per tonne of carbon oxide sequestered (referred to as 45Q).⁶⁴ While previously 45Q applied only to CCS and EOR, it now also includes other qualified uses of captured carbon.⁶⁵ Additionally, experts expect more bioenergy with carbon capture and storage (BECCS) to contribute to lower-carbon energy production in the future.



53 /100

Electrification

In 2021, the US announced its target of a carbon pollution-free power sector by 2035. An extremely ambitious goal, this is intended to stimulate supportive policy measures and boost the electrification of processes. Renewing and expanding grid infrastructure – also making it fit for more renewable energy – is expected to be driven by proposed tax credits⁶⁶ for electricity transmission investments and \$65 billion from the Infrastructure Bill. Trying to catch up regarding renewable energy, the future energy mix will likely include more offshore wind power, some geothermal energy – in some states – and BECCS. Existing nuclear plants would be supported by the Reconciliation Bill, while small modular (nuclear) reactors might gain the interest of the chemical industry in the future. Recently, the establishment of a new Office of Clean Energy Demonstrations has been announced that will support green energy projects, distributing some \$20 billion.⁶⁷



62 /100

Hydrogen

While hydrogen is a strong trend across the US, the colour varies depending on the state – as a function of its infrastructure and level of climate action ambition. A range of funding opportunities support the hydrogen trend, ranging from grants for regional clean hydrogen hubs (Infrastructure Bill)⁶⁸ to a proposed hydrogen production tax credit (PTC) (Reconciliation Bill).⁶⁹



48 /100

Waste processing

Waste processing is viewed as an important technology for the future of the chemical industry. However, it is not considered primarily as a contributor to climate change mitigation due to its ambiguous lifetime assessment. The latter leads to noticeable opposition from NGOs, challenging the upscaling of plastic recycling technologies.

Progress to date

- The First Mover Coalition⁷⁰ stands out as an initiative on the demand side and is set to include chemicals and carbon removal from 2022 onwards
- The newly established Buy Clean Task Force aims to support the creation of markets for low-carbon materials⁷¹
- Low-carbon solutions and ambitions differ by state, given the variability in resources and predominant industry

Changes tomorrow

- Harmonization of climate action on a federal level could avoid interstate carbon leakage and reduce compliance complexity for industry players
- A clear carbon price signal could enable industry to make more sustainable and feasible investment decisions in the absence of coherent federal regulation
- Adjustments in electricity regulations could facilitate cross-border trade and electrification in line with ambitious 2035 target

4

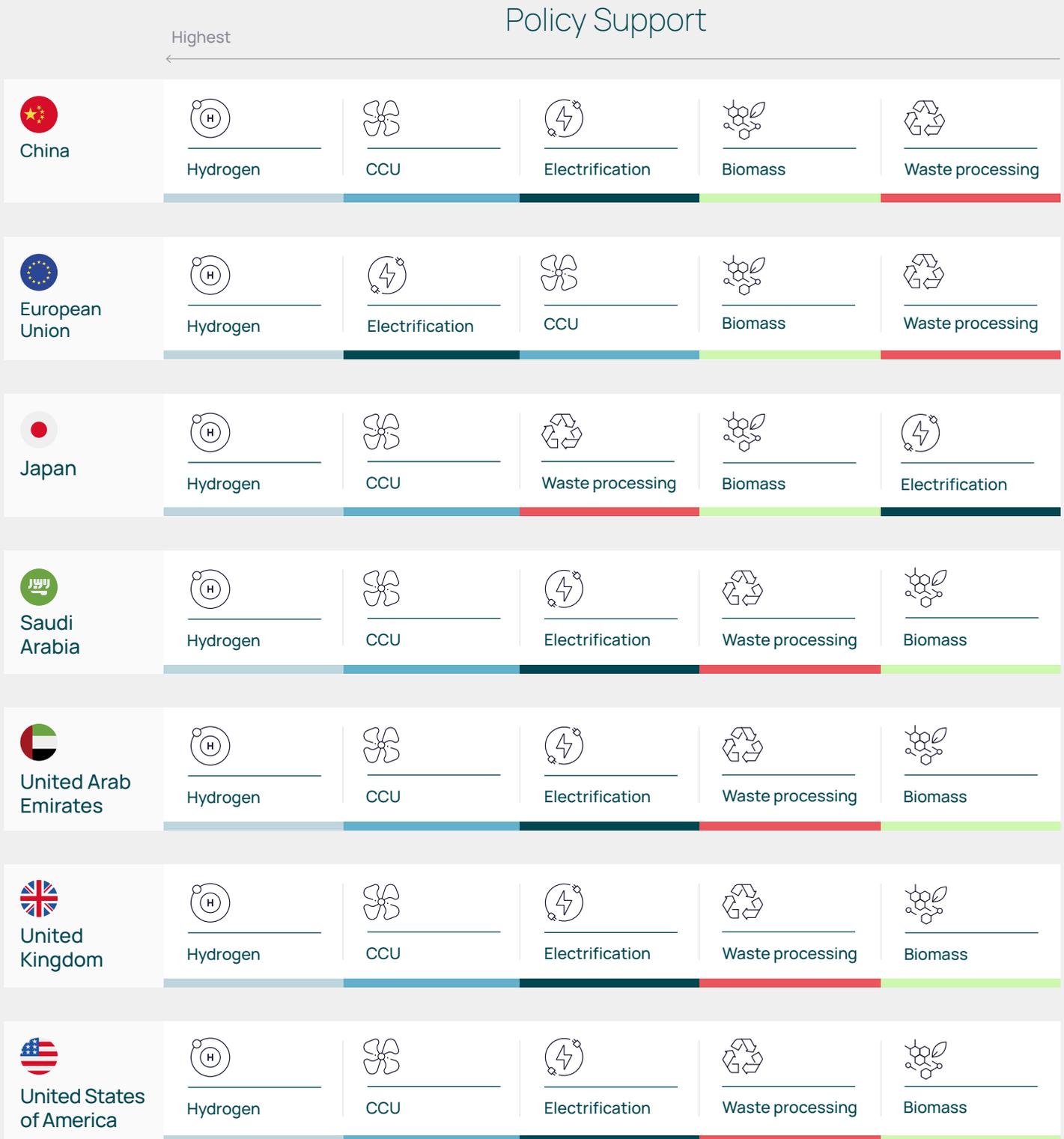
At a glance: the current state of LCET support

On a global level, increased policy ambition, trends in sustainable financing and funding opportunities are supporting the development and upscaling of LCETs.



The policy landscape

FIGURE 2 Overview of policy support for LCETs in selected jurisdictions



Global trends

Hydrogen is the leading LCET area in five out of seven jurisdictions

Biomass utilization receives the least policy support across jurisdictions – usually just behind (occasionally in front of) waste processing

Hydrogen is on a par with electrification in the EU and with CCU in the US

FIGURE 3 Decarbonization-promoting finance and funding dynamics

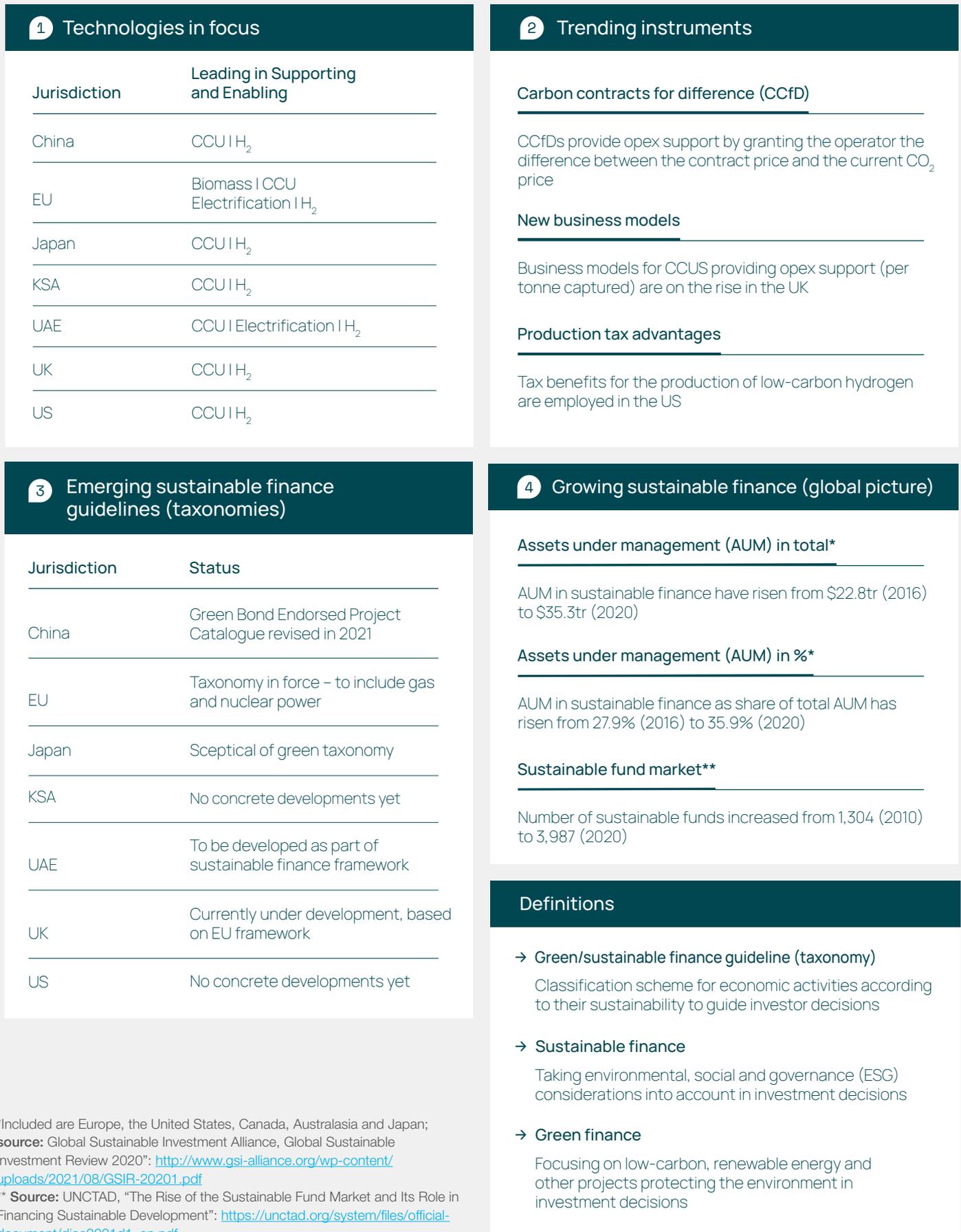


TABLE 1 | Non-exhaustive selection of funding opportunities across jurisdictions

Jurisdiction	LCET area	Programme	Description	Volume	Timeline
China	Electrification		Funding facility to support development of green energy by Chinese Industry and Merchant Bank and National Energy Administration	RMB 3tr (\$470bn)	Tbd
China	Biomass; CCU; electrification; hydrogen; waste processing	Carbon Emission Reduction Facility	Structural monetary policy instrument providing low-cost funds to financial institutions, aimed at carbon reduction projects mobilizing more social capital	Tbd	Tbd
China	Biomass; CCU; electrification; hydrogen; waste processing	China Clean Development Mechanism Fund	National climate fund supporting low-carbon growth and climate resilience in China; revolving fund that receives regular capital injections from levies collected by the government on clean development mechanism (CDM) projects in China	RMB 495m (\$78m) since 2008	In force
EU	Biomass; CCU; electrification; hydrogen; waste processing	Recovery and Resilience Facility	COVID-19 recovery facility; more than 50% to be spent on modernization (climate and digital); implemented by member states with dedicated plans; member states file request for funding with Commission	€723.8bn (\$800bn)	In force since February 2021; covering investments from 2020 to 2026
EU	Biomass; CCU; electrification; hydrogen; waste processing	Horizon Europe	Most prominent programme for research and innovation, focusing on climate change; budget directly distributed to researchers/research institutions in member states by Commission	€95.5bn (\$105bn) – Of which €5.4bn (\$5.9bn) from RRF – Of which €15bn (\$16.5bn) each to digital/industry/space and climate/energy/mobility	Active from 2021 to 2027
EU	CCU; electrification; hydrogen	ETS Innovation Fund	Supporting commercial demonstration of low-carbon projects in Europe over the period 2020–2030 through sales of ETS allowances. Focus on CCU/CCS and low-carbon processes in industry	€25bn (\$27.6bn) – Of which €1.3–1.5bn (\$1.4–1.6bn) in current call	Second large call (€1.5bn) to close in March 2022
Japan	Electrification	Feed-in tariffs (FIT)	Requires electric utilities to purchase electricity generated from renewable energy sources (solar PV, wind power, hydraulic power, geothermal and biomass) based on a fixed-period contract with fixed price	>11 JPY/kWh for solar PV >17 JPY/kWh for wind	Started in 2012; ongoing

TABLE 1 | Non-exhaustive selection of funding opportunities across jurisdictions continued

Jurisdiction	LCET area	Programme	Description	Volume	Timeline
Japan	Hydrogen; CCU; waste processing	Green Innovation Fund	Fund supporting R&D/demonstration projects/ social implementation of the outcomes	JPY 2tr (\$17bn)	Established 2021 – for a 10-year period
Saudi Arabia	CCU	Investment fund for carbon capture and clean cooking fuel programme	Fund to support carbon capture and back a plan to provide clean cooking fuels for people; Saudi Arabia is to contribute 15%; details yet to be announced	SAR 39bn (\$10.4bn)	Tbd
UAE	CCU; electrification; hydrogen; waste processing	Dubai Green Fund	Investment fund focusing on sustainable/ green projects across a range of sectors.	n/a	Ongoing
UK	Biomass; CCU; electrification; hydrogen; waste processing	Industrial Energy Transformation Fund (IETF)	Supporting energy efficiency projects and LCETs	£315m (\$415m)	Tbd
UK	Hydrogen	Net-Zero Hydrogen Fund	Kickstarting green and blue hydrogen in the UK	£240m (\$315m)	
UK	CCU	CCS Infrastructure Fund	UK government fund to support CCUS infrastructure	£1bn (\$1.3bn)	Budget confirmed in 2020
US	Hydrogen	Hydrogen production tax credit (PTC) (Reconciliation Bill – uncertain)	Opex support for the production of both green and blue hydrogen	up to \$3/kg depending on carbon intensity	10-year period/still uncertain
US	Hydrogen	Grants for green hydrogen demonstration projects (Infrastructure Bill)	Research and pilot-scale demonstrations to improve efficiency, durability and competitiveness Targeting costs of < \$2/kg by 2026	\$1bn	Tbd
US	CCU	45Q tax credit	Tax credit per tonne of carbon oxide sequestered, stored, used in EOR or used in qualified ways; credit realized for 12 years after facility placed in service.	Up to \$50/t	Project to commence construction by 1 January 2026

Conclusion

Work to decarbonize heavy industry, including the chemical sector, is being undertaken with an increased sense of urgency in all analysed jurisdictions, and commonalities can be observed across the globe. However, noticeable differences in ambition and focus are found. Taking a concluding global view of the policy landscape,⁷² it can be seen that:

- On average, alternative hydrogen production is leading the way, followed by CCU and electrification, while waste processing and biomass are lagging
- Hydrogen represents the leading LCET area for five out of seven jurisdictions, while in the EU it is on a par with electrification and with CCU in the US
- Biomass utilization currently receives the least policy support across all jurisdictions – usually just behind (occasionally in front of), waste processing. However, both are likely to receive additional policy support in the future, moving away from fossil feed and fuel
- Even though there is great leeway for more ambitious policies in all policy clusters, Technologies and Infrastructure and Collaboration and Innovation are being strengthened in most jurisdictions
- Creating and stimulating an appropriate marketplace for more sustainably produced goods appears to be the area with more room for improvement on a global scale (Markets and Demand)
- Caveats and Inhibitors – as defined in the methodology section – are generally modest, but with significant variability among jurisdictions

Several emerging topics that might play an important role in the continued development of the LCET policy landscape can be observed:

1. Scaling up low-carbon energy supply further could be critical, since most LCETs are energy-intensive

2. Guiding investment towards sustainable economic activities through appropriate and jurisdiction-specific policy instruments – e.g. carbon pricing or sustainable finance guidelines – might encourage the deployment of LCETs
3. Private and public initiatives to support nascent markets for sustainable products have the potential to encourage the economics of LCETs – e.g. the First Movers Coalition⁷³/ Germany's support for green lead markets⁷⁴
4. Though contentious and potentially having far-reaching effects, carbon border adjustment mechanisms are gaining prominence in discussions across jurisdictions
5. Public funding mechanisms – in terms of both capex and opex – and increased private financing could improve the development and upscaling of LCETs until they reach economic maturity

As the organization for public-private cooperation and host of the industry-led Low-Carbon Emitting Technologies Initiative, the World Economic Forum is uniquely positioned to strengthen collaboration between government actors and the chemical industry. Cultivating synergies between these stakeholders can promote the development, deployment and upscaling of LCETs as real decarbonization solutions. To this end, policy-makers are invited to engage with the initiative within a collaborative ecosystem by:

- Participating in the regional private-public dialogue series on reducing GHG emissions in the materials sector
- Catalysing public-private cooperation for the implementation of the industry-backed Sector Transition Strategies⁷⁵ to reach net-zero emissions
- Updating and expanding the global policy landscape for LCETs through a consultative process led by the Low-Carbon Emitting Technologies Initiative

Appendix: Abbreviations

BECCS	Bioenergy with carbon capture and storage
capex	Capital expenditures
CCER	Chinese-certified emissions reductions
CCfD	Carbon contract for difference
CCS	Carbon capture and storage
CCU	Carbon capture and utilization
CCUS	Carbon capture, utilization and storage
CO₂eq	Carbon dioxide equivalents
EOR	Enhanced oil recovery
ETS	Emissions trading system
GDP	Gross domestic product
GHG emissions	Greenhouse gas emissions
KSA	(Kingdom of) Saudi Arabia
LCET	Low-carbon emitting technology (initiative)
Mt	Million metric tonnes
NDC	Nationally determined contribution
NPV	Net present value
opex	Operating expenditures
PV	Photovoltaic
RED(II)	(Revised) renewable energy directive
sPV	Solar photovoltaic
t	Metric tonnes
UAE	United Arab Emirates

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Endnotes

1. World Bank, "Total Greenhouse Gas Emissions (Kt of CO₂ Equivalent) | Data": <https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE>.
2. Hannah Ritchie and Max Roser, "CO₂ and Greenhouse Gas Emissions", Our World in Data: <https://ourworldindata.org/emissions-by-sector>.
3. IEA, "Net Zero by 2050 – A Roadmap for the Global Energy Sector", 2021, 33: https://iea.blob.core.windows.net/assets/deebef5d-0c34-4539-9d0c-10b13d840027/NetZeroBy2050-ARoadmapfortheGlobalEnergySector_CORR.pdf.
4. United Nations, "Paris Agreement to the United Nations Framework Convention on Climate Change", 2015, Article 4: https://unfccc.int/sites/default/files/english_paris_agreement.pdf.
5. Ritchie and Roser, "CO₂ and Greenhouse Gas Emissions", Our World in Data, August 2020: <https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions>.
6. International Council of Chemical Associations (ICCA), "Sustainable Development Goals: Goal 8: Decent Work and Economic Growth" ["More than 96 percent of manufactured goods [...] are touched by chemistry"], n.d.: <https://icca-chem.org/focus/sustainability/sdg/goal-8-decent-work-and-economic-growth/>.
7. World Economic Forum, "Implementing Low Carbon Emitting Technologies in the Chemical Industry", 2021: https://www3.weforum.org/docs/WEF_Implementing_Low_Carbon_Emitting_Technologies_in_the_Chemical_Industry_A_Way_Forward_2021.pdf.
8. Renewables or nuclear energy.
9. IEA, "Net Zero by 2050 – A Roadmap for the Global Energy Sector", 123: <https://www.iea.org/events/net-zero-by-2050-a-roadmap-for-the-global-energy-system>.
10. Ibid., 32 et. seq.
11. The 60% threshold was chosen to reflect the policy model's scoring scheme with four possible answers (the second-highest rating would mean 75 out of 100) and the ambitious nature of the forward-looking assessment.
12. Hannah Ritchie and Max Roser, "China: CO₂ Country Profile", Our World in Data, 11 May 2020, 2: <https://ourworldindata.org/co2/country/china>.
13. Stefano F. Verde et al., "The EU ETS and Its Companion Policies: Any Insight for China's ETS?", Environment and Development Economics 26, no. 3 (June 2021): 302–320: <https://doi.org/10.1017/S1355770X20000595>.
14. World Bank, "Circular Economy Law": https://ppp.worldbank.org/public-private-partnership/sites/ppp.worldbank.org/files/documents/China_CircularEconomyLawEnglish.pdf.
15. National Development and Reform Commission, People's Republic of China (NDRC), "Action Plan for Carbon Dioxide Peaking before 2030": https://en.ndrc.gov.cn/policies/202110/t20211027_1301020.html.
16. Ibid.
17. European Commission, "A European Green Deal": https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.
18. European Commission, "Fit for 55 (COM (2021) 550 Final)", 2021: <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52021DC0550&from=EN>.
19. European Parliament, "Renewable Energy Directive – Revisions": <https://www.europarl.europa.eu/legislative-train>.
20. European Commission, "Sustainable Carbon Cycles (COM (2021) 800 Final)", 2021.
21. European Commission, "European Green Deal: Commission Proposals to Remove, Recycle and Sustainably Store Carbon" ["At least 20% of the carbon used in the chemical and plastic products should be from sustainable non-fossil sources by 2030"], 15 December 2021: https://ec.europa.eu/commission/presscorner/detail/en/ip_21_6687.
22. Eurostat, "CO₂ Emissions from Energy Use Clearly Decreased in the EU in 2020": <https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210507-1>.
23. European Commission, "EU Hydrogen Strategy (COM (2020) 301 Final)", 2020, 3.
24. European Commission, "Hydrogen and Decarbonised Gas Package": https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_6685.
25. European Commission, "New EU Framework to Decarbonise Gas Markets": https://ec.europa.eu/commission/presscorner/detail/en/IP_21_6682.
26. European Parliament, "Waste Framework Directive": <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02008L0098-20180705&from=EN>.
27. European Commission, "A New Circular Economy Action Plan (COM (2020) 98 Final)", 2020, 20.
28. Japanese Ministry of Economy, Trade and Industry, "Green Growth Strategy through Achieving Carbon Neutrality in 2050": https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/index.html.

29. Japanese Ministry of Economy, Trade and Industry, "6th Strategic Energy Plan", 2021: https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/6th_outline.pdf.
30. IEA Bioenergy, "Implementation of Bioenergy in Japan – 2021 update": https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_Japan_final.pdf.
31. Japanese Ministry of Economy, Trade and Industry, "Green Growth Strategy": https://www.meti.go.jp/english/press/2020/pdf/1225_001b.pdf.
32. Japanese Ministry of the Environment, "Tax for Climate Change Mitigation": https://www.env.go.jp/en/policy/tax/env-tax/20121001a_dct.pdf.
33. S&P Global, "Mitsubishi Announces Chemical Recycling Project with Mura Technology, KBR": <https://www.spglobal.com/platts/en/market-insights/latest-news/petrochemicals/081221-mitsubishi-announces-chemical-recycling-project-with-mura-technology-kbr>.
34. Takeo Kumagai, "Japan's METI Aims to Start Demonstrative Carbon Credit Market in FY 2022-23", S&P Global: <https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/080521-japans-meti-aims-to-start-demonstrative-carbon-credit-market-in-fy-2022-23>.
35. Daniel Yergin, The New Map: Energy, Climate and the Clash of Nations (New York: Penguin Press, 2020), 302 et. seq.; Kingdom of Saudi Arabia, "Vision 2030": https://www.vision2030.gov.sa/media/rc0b5oy1/saudi_vision203.pdf.
36. Kingdom of Saudi Arabia, "KSA NDC 2021 Submission to UNFCCC": <https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Saudi%20Arabia%20First/KSA%20NDC%202021%20FINAL%20v24%20Submitted%20to%20UNFCCC.pdf>.
37. International Renewable Energy Agency (IRENA), "Energy Profile: Saudi Arabia": https://www.irena.org/IRENADocuments/Statistical_Profiles/Middle%20East/Saudi%20Arabia_Middle%20East_RE_SP.pdf.
38. Al Jazeera, "Saudi Arabia to Set up Investment Fund for Carbon Capture": <https://www.aljazeera.com/economy/2021/10/25/saudi-arabia-to-set-up-investment-fund-for-carbon-capture>.
39. SABIC, "Creating the World's Largest Carbon Capture and Utilization Plant": <https://www.sabic.com/en/newsandmedia/stories/our-world/creating-the-worlds-largest-carbon-capture-and-utilization-plant>.
40. Abeer Abdulkareem and Amgad Ellaboudy, "Climate Policy Recommendation: Strengthen Saudi Arabia's Renewable Energy Program", Climate Scorecard: <https://www.climatescorecard.org/2021/03/climate-policy-recommendation-strengthen-saudi-arabias-renewable-energy-program/>.
41. Vivian Nereim, "Saudi Arabia to Start Building Green Hydrogen Plant in Neom", Bloomberg Green, 17 March 2022: <https://www.bloomberg.com/news/articles/2022-03-17/saudi-arabia-to-start-building-green-hydrogen-plant-in-neom#:~:text=The%20Neom%20project%2C%20called%20Helios,to%20split%20hydrogen%20from%20waterx>
42. Vision 2030: "Neom": <https://www.vision2030.gov.sa/v2030/v2030-projects/neom/>.
43. KSA Ministry of Energy, "HRH Minister of Energy Signs a Saudi-Germany MOU on the Production of Hydrogen": <http://www.moenergy.gov.sa/en/MediaCenter/News/Pages/27071442.aspx>.
44. KSA, "Waste Management Law" [in Arabic]: <https://laws.boe.gov.sa/BoeLaws/Laws/LawDetails/4d5bda56-cc0d-4b16-a025-ad9d00b281ab/1>.
45. KSA, "Circular Carbon Economy National Program": <https://www.cce.org.sa/>.
46. UAE, "Second Nationally Determined Contribution of the United Arab Emirates": <https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/United%20Arab%20Emirates%20Second/UAE%20Second%20NDC%20-%20UNFCCC%20Submission%20-%20English%20-%20FINAL.pdf>.
47. The Official Portal of the UAE Government, "UAE Energy Strategy 2050": <https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/uae-energy-strategy-2050>.
48. The Official Portal of the UAE Government, "Dubai Clean Energy Strategy": <https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/local-governments-strategies-and-plans/dubai-clean-energy-strategy>.
49. Dania Saadi, "UAE to Build \$1 Billion Green Ammonia Facility in Clean Energy Push", S&P Global, 26 May 2021: <https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/052621-uae-to-build-1-billion-green-ammonia-facility-in-clean-energy-push>.
50. GPCA, "Newly Launched Coalition Signs Pledge with UAE Ministry of Climate Change and Environment", 24 April 2019: <https://www.gpca.org.ae/2019/04/24/newly-launched-coalition-signs-pledge-with-uae-ministry-of-climate-change-and-environment/>.
51. UK Government, "Net Zero Strategy: Build Back Greener", 2021: <https://www.gov.uk/government/publications/net-zero-strategy>.
52. Renewables and advanced nuclear power.
53. UK Department for Business, Energy and Industrial Strategy, "Biomass Feedstocks Innovation Programme": <https://www.gov.uk/government/publications/apply-for-the-biomass-feedstocks-innovation-programme>.
54. UK Government, Policy Paper, "The Ten Point Plan for a Green Industrial Revolution": <https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution/title>.
55. UK Department for Business, Energy and Industrial Strategy, "Carbon Capture, Usage and Storage (CCUS): Business Models": <https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-ccus-business-models>.

56. UK Government, Policy Paper: “The Ten Point Plan for a Green Industrial Revolution”.
57. UK Department for Business, Energy and Industrial Strategy, “Industrial Fuel Switching Competition”: <https://www.gov.uk/government/publications/industrial-fuel-switching-competition>.
58. UK Government, “UK Hydrogen Strategy”, 2021: <https://www.gov.uk/government/publications/uk-hydrogen-strategy>.
59. UK Government, Policy Paper, “The Ten Point Plan for a Green Industrial Revolution”.
60. UK Department for Environment, Food and Rural Affairs, “Resources and Waste Strategy: At a Glance”: <https://www.gov.uk/government/publications/resources-and-waste-strategy-for-england/resources-and-waste-strategy-at-a-glance>.
61. US Rep. Peter A. DeFazio, “Actions – H.R.3684 – 117th Congress (2021–2022): Infrastructure Investment and Jobs Act”, legislation, 15 November 2021, 2021/2022: <https://www.congress.gov/bill/117th-congress/house-bill/3684/actions>.
62. Volume has been reduced from an initially proposed \$3.5 trillion.
63. Wood Energy, “Federal Policies and Incentives Promoting Woody Biomass Production and Utilization”: <https://wood-energy.extension.org/federal-policies-and-incentives-promoting-woody-biomass-production-and-utilization/>.
64. Angela C. Jones and Molly F. Sherlock, “The Tax Credit for Carbon Sequestration (Section 45Q)”, 8 June 2021: <https://sgp.fas.org/crs/misc/IF11455.pdf>.
65. Global CCS Institute, “45Q: The ‘Most Progressive CCS-Specific Incentive Globally’ Is Now Open for Business”: <https://www.globalccsinstitute.com/news-media/insights/45q-the-most-progressive-ccs-specific-incentive-globally-is-now-open-for-business/>.
66. As part of the Reconciliation Bill.
67. US Department of Energy, “DOE Establishes New Office of Clean Energy Demonstrations Under the Bipartisan Infrastructure Law”, Energy.gov: <https://www.energy.gov/articles/doe-establishes-new-office-clean-energy-demonstrations-under-bipartisan-infrastructure-law>.
68. Norton Rose Fulbright Project Finance, “Hydrogen Funding and Tax Credits”: <https://www.projectfinance.law/publications/2021/december/hydrogen-funding-and-tax-credits/>.
69. S&P Global, “Hydrogen Tax Credit Would Support Both Green, Blue Production”: <https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/hydrogen-tax-credit-would-support-both-green-blue-production-67404374>.
70. World Economic Forum, “First Movers Coalition”: <https://www.weforum.org/first-movers-coalition>.
71. David Shepardson, “Biden to Launch ‘Buy Clean’ US Government Task Force”, Reuters, 15 February 2022: <https://www.reuters.com/business/sustainable-business/biden-launch-buy-clean-us-government-task-force-2022-02-15/>.
72. As mentioned in the methodology chapter, the analysis and insights refer to the policy aspects only (not considering technical or economic factors). For simplicity, succinct wording has been used.
73. World Economic Forum, “First Movers Coalition”: <https://www.weforum.org/first-movers-coalition>.
74. German Federal Ministry of Finance, “Immediate Climate Action Programme for 2022”: https://www.bundesfinanzministerium.de/Content/EN/Downloads/Climate-Action/immediate-climate-action-programme-for-2022.pdf?__blob=publicationFile&v=3.
75. Mission Possible Partnership, “Sector Transition Strategies”: <https://missionpossiblepartnership.org/our-approach/sector-transition-strategies/>.



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