CLIMATE ACTION PATHWAY

ENERGY

Action Table

2020

Global Climate Action
United Nations Climate Change

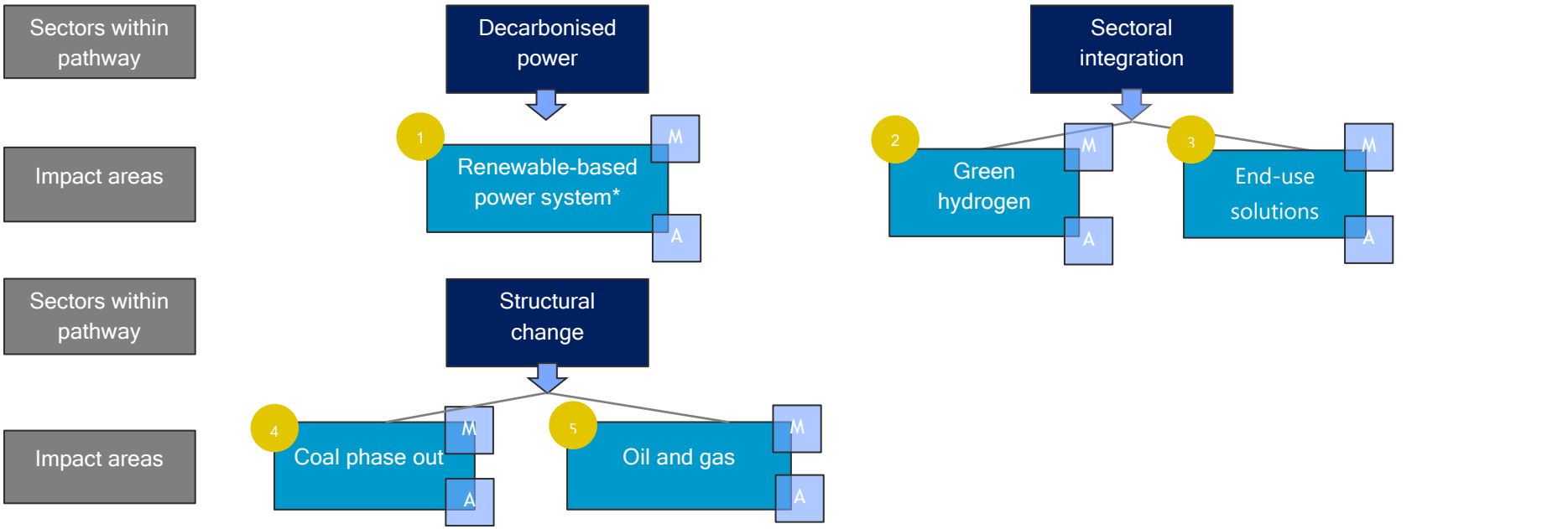
Marrakech Partnership
Global Climate Action

ACTION TABLE STRUCTURE AND APPROACH

The purpose of this Energy Action Table document is to highlight specific, promotable, and time-bound actions with a sector-based approach, to deliver the 2050 energy vision outlined in the Executive Summary. This Action Table is structured into three sub-sectors, each containing respective impact areas, represented in separate tables. "Decarbonized power" covers a path to a renewables-based power system; "Sectoral integration" provides technology options and the link between energy supply and end-use sectors; and "Structural change" covers a transition from fossil fuels. The impact area tables include recommended time-bound actions for selected actors[1] to take by 2021, 2025, 2030, and 2040 to achieve a 1.5°C outcome by 2050. Where relevant, "systems maps" show an indicative outline of the key actors in a sub-sector, and how they interact. In addition, "S-curves" for renewable power and green hydrogen show the potential for exponential growth, leading to sectoral transformation.

Given the use and impact of energy across sectors, this Pathway has synergies with the majority of the other sectoral Pathways, particularly transport, human settlements and industry. While not explicitly represented in pathways, energy also intersects with health, water, and gender, and is critically linked to the efforts to advance a just transition.

[1] Policymakers (national, subnational, local levels); Financial Institutions; Technology Providers and Innovators; Business and Service Providers; Civil Society


Sectors within pathway
Impact areas
Sectors within pathway
Impact areas
Decarbonised power
1
Renewable-based power system*
M
A
Sectoral integration
2
Green hydrogen
3
End-use solutions
Structural change
4
Coal phase out
5
Oil and gas
Heading
Sector
IAs with both Mitigation and Adaptation/Resilience components
M=Mitigation component
A=Adaptation/Resilience component

DECARBONISED POWER CHANGE LEVERS

Around two-thirds of global greenhouse gas emissions stem from energy production and use, which are at the core of efforts to combat climate change. To reach the Paris Agreement goal of limiting global temperature rise to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, energy transitions must be accelerated. While transitions were gaining momentum in recent years, the COVID-19 pandemic in 2020 halted many. Response measures, including widespread lockdowns, have disrupted production and supply chains, shrunk demand for goods and services, depressed commodity prices, and caused a massive economic contraction around the world. Alongside the health crisis, hundreds of millions of people have lost their jobs or seen their livelihoods threatened. Further, as per the latest Sustainable Development Goal (SDG)-7 2020, about 800 million people do not have electricity access. Some 2.8 billion do not have access to clean cooking, with a resulting cost in the form of poor health and safety – especially for women, as well as lost productivity. The pandemic has compounded the burden on these populations and the challenges for government to close the gap. Sustainable energy solutions based on renewable energy are critical to accelerating recovery, ensuring resilience, and delivering universal access to energy.

When incorporated into COVID-19 stimulus and recovery plans, the energy transition can represent a far-sighted investment in a future aligned with global climate goals. An investment package focused on the energy transition can help to overcome the economic slump and create much-needed jobs, for the short-term and beyond. Renewables would account for 2.46 million of these additional jobs, energy efficiency for 2.91 million, and grids and energy system flexibility for 0.12 million. In contrast, these gains far outweigh the loss of 1.07 million jobs in the fossil fuel and nuclear sectors.

Recovery measures over the next three years can either trigger a decisive shift toward resilient energy systems or ensure an enduring lock-in with unsustainable practices. A holistic policy approach – rooted in the climate-safe energy development, yet also focused on short-term imperatives – would reap multiple benefits and help set the stage for a just transition. Social equity considerations, in particular gender dimensions and climate justice, must be integrated into policy and programme design, in order to fully tap societal potential and to ensure that no one is left behind.

Decarbonising power must be underpinned by aggressive efficiency measures and ambitious deployment of renewable technologies and related infrastructure. Renewable power projects – including existing utility-scale plants and those under construction, distributed generation investments

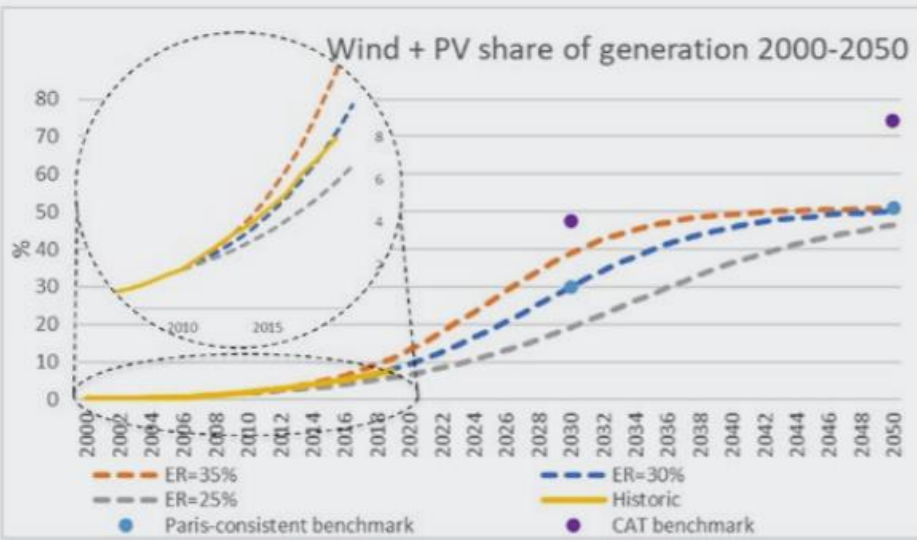
and renewables-ready network infrastructure – must be safeguarded during the ongoing economic downturn. Alongside renewable power generation, measures could stimulate supply industries, enabling infrastructure, energy-efficiency projects and increased electrification of end uses which would not only reduce emissions but enhance resilience to the impacts of climate change.

Energy investments undertaken as a short-term response to the pandemic's effects must support increasingly ambitious longer-term targets for renewables and efficiency in all sectors, as well as reinforce enhanced climate pledges. Short-term measures can also drive the energy transition in end uses like heat and transport that account for a large share of total energy demand. The post-COVID-19 stimulus package could advance sectoral integration in new and innovative ways. For instance, links can be made between energy, transport and buildings, along with measures to promote circular systems. Renewable-based heating and cooling systems combined with energy-efficiency measures in buildings, electromobility based on renewable power sources, and transport fuels based on sustainable bioenergy or green hydrogen, can facilitate such approaches. Increased electrification of end-use infrastructure, including via electric vehicle charging and electrolysis for hydrogen production, are deployment-ready solutions for a decarbonized system.

Policy measures and investments for stimulus and recovery can drive a wider structural shift, fostering national and regional energy transition strategies as a decisive step in building resilient economies and societies. The energy sector must be viewed as an integral part of the broader economy to fully understand the impact of the transition and ensure that it is timely and just.

DECARBONIZED POWER S-CURVE: WIND AND SOLAR PV

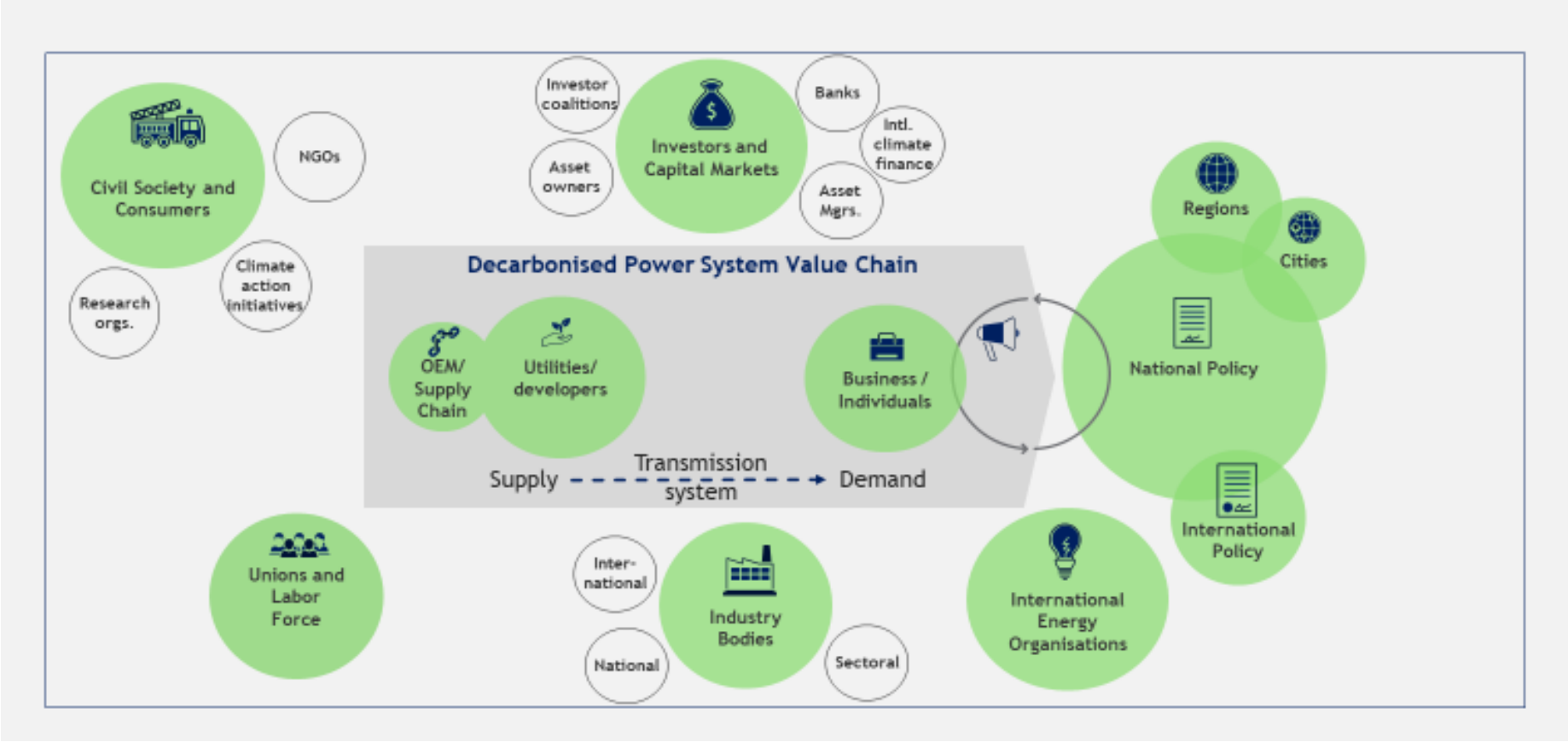
S-curves capture exponential dynamics usually seen in systems transformations. The S-curve below for wind and solar PV shows recent exponential generation growth in these technologies. With this growth these technologies *are already on 1.5°C compliant trajectories*. If such progress is maintained, solar and wind power would reach a 50% share of electricity generation in the 2040s. A 30% share of solar and wind power in 2030 would be aligned with that trajectory. The chart shows wind and solar PV historic share of total electricity generation, plus S-curve projections towards 2050 1.5°C consistent benchmarks. The Emergence Rate (or ER) is the annual rate of growth of solar and wind generation. For comparison, wind generation grew 22% per year between 2000 and 2019 and solar PV 41% per year.



Source: Grub et al. (2020), The Shape and Pace of Change in The Electricity Transition: Sectoral Dynamics and Indicators of Progress. CAT – Climate Action Tracker.

Note: Wind and solar generation shares in 2030 and 2050 are median values of Paris-consistent scenarios from the database of scenarios for the IPCC Special Report on 1.5°C (2018)

DECARBONISED POWER SYSTEM MAP



Impact 1

RENEWABLES-BASED POWER SYSTEM

Decarbonised power

MITIGATION &/OR ADAPTATION /RESILIENCE

NEXUS

	By 2021	By 2025	By 2030	By 2040
Policymakers (national, subnational, local levels)	• Power components of Nationally Determined Contributions (NDCs) are revised and are compatible with the 1.5°C pathway. Implementation is supported via consistent long-term energy plans and COVID-19 stimulus packages. • 35 countries have targets for 100% renewable energy (RE)-based power	• 100 countries have targets for 100% RE-based power. • Additional procurement of RE capacity is secured as part of stimulus measures, and short- and medium-term RE targets are increased to account for this. • Regulations are in place to correct power markets to ensure stable long-term signals to renewable generators and reward short-term flexibility.	• All countries have targets for 100% RE-based power. • SDG7 has been achieved with universal access to affordable, reliable, sustainable and modern energy by significantly increasing the deployment of renewable energy and doubling the share of efficiency. • Infrastructure and RE-based power are in place to support electric mobility.	• In the 2040s, power systems are decarbonized and resilient. • Universal access to sustainable power is maintained and continuously improved for social and economic development.

- Clear and ambitious energy efficiency and renewable power policies are adopted and aligned with targets at national, state/regional, and local levels.
- An enabling environment is being created, together with performance standards and financing/investment strategies.
- Local government energy planners are being empowered to increase deployment of decentralized power solutions.
- Governments establish "investment grade" enabling frameworks to: facilitate access to renewable electricity markets (including renewable power auctions for mature technologies), direct investment in renewable power by corporate customers, and develop and deploy grid and decentralized electricity solutions (including mini-grid and off-grid), accelerating the pace of electrification, particularly for underserved areas.
- Digitalized and integrated grids, including regulations on data and cybersecurity, are in place.
- Reliable access to electricity is ensured through support of vulnerable communities.
- Integrated energy planning (using grid, mini-grid, and off-grid technologies and taking into account of energy-water-land-use nexus) are fully utilized to advance universal energy access.
- Infrastructure and markets have been comprehensively re-designed to create and incentivize grid flexibility for integration of high-share renewable technologies to increase system resilience.
- Participatory processes and transparency through regular reviews and consultations are giving adequate voice to citizens and communities, helping to ensure public buy-in.
- Holistic policies drive outcomes toward sustainability and resilience, are aligned with NDCs and RE targets, and include the use of public funds to direct investment.
- 57% renewable share in electricity generation and electrification share of final energy has increased and is on a track compatible with the 1.5°C pathway.
- Supportive environment has led to widespread deployment of storage technologies (including static storage, EVs and hydro) and other flexibility solutions and is on a track compatible with the 1.5°C pathway.
- Enabling policies are stimulating a circular economy and maximizing opportunities for more efficient use of energy and other resources.
- Underserved populations have access to sustainable and resilient energy systems.
- Cross-sectoral linkages such as in health, clean water and agriculture are fully tapped into to improve livelihoods in rural and remote areas.
- Renewable energy solutions contribute to adaptation strategies for other sectors, such as water and land-use.
- Climate risks have been reduced through integrated planning (e.g., energy-water-land-use nexus).

- Policies increasingly in place to enable enhanced grid flexibility (storage, demand response, power-to-X, interconnection) to accommodate rising shares of renewables
- Fossil fuel subsidies are reformed and funds redirected toward energy transitions.
- Dedicated programmes are put in place to ensure modern energy access in critical public infrastructure including schools, health care facilities (including testing centres, laboratories and cold supply chains), water and sanitation services, and community centres.
- Preparations for a digitalized and integrated grid, including regulations on data and cybersecurity, are underway.
- Institutional capacity-building is helping to identify and manage climate risks.
- Governments and stakeholders have identified opportunities for improved integration, interconnectivity and efficiency of systems.
- RE supply chains for energy transition technologies are expanded, diversified and regionalised, thereby fostering global resilience to exogenous shocks.
- The expansion of the workforce in energy transition-related fields is supported by identifying required occupations, leveraging of existing skills, and developing training and education programmes in coordination with industry needs to minimize skills gaps.
- Social protection programmes, as well as education and skills training, minimise discrepancies between winners and losers of the energy transition, securing longer-term benefits of an investment-driven recovery and transition strategy.
- Real-time monitoring and early warning system are helping citizens prepare in the face of a range of climate impacts; contingency plans are available to the public.
- Cumulative investments in the energy system, including infrastructure and efficiency, would reach USD 60 trillion

- Clear policies are in place, including planning, labour market, social protection, industrial capacity, skill-training and environmental elements, to attract transition-related investment for power sector and ensure a just transition.
- Cities are increasingly committing to 100% RE targets.
- Building codes are integrating solar roofs, making them part of the energy infrastructure
- Mini grids are becoming an interesting district option

Economic recovery

- Energy transitions are at the centre of stimulus and recovery measures. Public financing is mobilised in enabling infrastructure and guiding strategic decision-making, and policy measures are designed to mobilise additional private capital.
- Energy-health-water nexus is an integral part of the recovery measures.

- Measures are in place to safeguard RE facilities already in operation or under construction and maintain investment in planned projects.
- Recovery measures encourage investment in green assets, and condition bailouts of fossil fuel and other non-sustainable sectors on further investment in the energy transition and measurable climate action.
- Governments match skills demand and supply through labour market and undertake industrial policies to build viable supply chains in support of an accelerated recovery and energy transition.
- Social protection measures are in place to minimise social and economic dislocation and provide support to affected energy sector workers, supply chains and communities.
- All energy transition measures have been developed based on the principles for a just, socially balanced and fair transition.

	• Fiscal reforms, including of government budgets, are enabling decarbonization of the electricity system.			
Financial Institutions	• The price of electricity from onshore wind could fall to USD 0.043/kWh by 2021, down 18% from 2019. • The price of electricity from offshore wind could fall 29% from 2019 values. • The price of electricity from CSP could fall 59% from 2019 values. • Annual investments in low-carbon power technologies and energy efficiency increase by roughly a factor of 6 compared to 2015. • Public finance, including by multilateral and international institutions, is being shifted away from fossil fuels towards power transition-related investment. • Investment is being steered into necessary infrastructure, aligned with long-term plans, such as grid enhancement and upgrades, distributed RE generation technologies, and R&D.	• Investment at scale in renewable energy is ongoing due to the pipeline of bankable projects. • Established sustainability requirements, restrictions and mandates for investors guide investments (e.g. climate risk analysis and disclosure). • There is greater use of green bonds, which have established standards in line with global climate objectives. • Significant and appropriate levels of finance are disbursed and committed to accelerate renewables-based access to energy.	• Global energy transitions related investments have reached USD 4.5 trillion per year, and are on track to fulfil the goal of achieving an annual average of USD 3.2 trillion per year to 2050.	• Cumulative USD 18.6 trillion of the planned energy investment has been shifted from fossil fuels to low-carbon technologies. • USD 110 trillion has been invested in energy transitions since 2018. • There is continued investment in resilient power systems.

- Investors, international financial institutions, philanthropists and impact investors are committing technical assistance and finance to urgently scale-up funding for energy access in line with the USD 51 billion required on an annual basis to achieve Sustainable Development Goal (SDG) 7.
- The lending decisions of national governments are taking into consideration the land-water-energy nexus thereby promoting a holistic approach to NDC implementation.
- Corporate demand for, and long-term commitment to purchasing renewable electricity is reducing risks for developers and lenders.
- Institutional capacity is being developed in financial institutions to identify and manage climate risks.
- Flexibility in new infrastructure design is becoming the norm;
- Finance institutions and banks have agreed to disclose investment in renewables and energy efficiency projects.

	• Project life-cycles are being included in analyses of technologies. *Economic recovery* • Public investment leverages private investment of a magnitude up to four times larger. • Financial assistance and international co-operation are flowing to developing countries to respond to the crisis and develop resilience. • International public flows in RE scaled up to countries so they have the infrastructure they need to accelerate the energy transition and achieve sustainable development.			
Technology Providers and Innovators	• Governments are providing enabling frameworks and resources for investment in innovation and a range of R&D solutions. • Utilities and distributors are accelerating innovative solutions in renewable power system operation and flexibility options, as well as digitalization and cyber security.	• Further cost reductions in onshore wind and solar make building those technologies lower cost than new fossil fuel plants in all countries, up from 85% (by generation) in 2020. • Electricity grid is modernized to enable it to handle growing amounts of variable renewable energy and related technologies in all regions to enable equitable access.	• Further cost reductions in onshore wind and solar make building those technologies lower cost than operating existing fossil fuel plants in nearly all countries. • Real-time hydro-meteorological monitoring and early warning systems have been put in place.	• Innovation for efficient and resilient electricity systems is continuing. • Electricity installations are decentralized and resilient to ever-increasing climate impacts.

- Network development plans include deployment targets for RE in mid- and long-term.
- Private sector innovation and investment is being increased in a range of R&D solutions, business models and system solutions for renewable power technology and digitalization.
- Modelling and information management systems aligned with 1.5C pathways are being developed by international organizations.

- Flexibility options have been developed and are being deployed in all regions, available to users equitably including grids, hydro, smart meters, batteries and other storage technologies.
- R&D has been expanded and emerging renewable technologies supported.
- A breadth of R&D initiatives is well funded that are led by, identify, and aim to address the needs of women, indigenous peoples, local communities, and those most affected by climate change in all regions.
- R&D support fostered for women, indigenous and minorities -- to balance the STEM imbalance – with the aim to support energy innovation from and for the communities which need them most.

- Innovation in energy-intensive processing industries for 1.5ºC-compatible trajectories are being stimulated, including maximum electrification, shifts to other low-emission energy carriers such as hydrogen or biomass, integration of carbon capture and storage and innovations for carbon capture and utilization.
- New design standards, planning processes and evaluation techniques have been developed to accommodate climate change-related risks.
- Innovative solutions to managing a low-carbon power system under conditions of resource scarcity (i.e. limitations on water, material and land use) have been found.
- New technologies have been developed to enable the integration of high-share renewable technologies to increase system resilience.
- Technologies and system for flexible systems, including market and storage solutions, are mainstreamed

Business and Service Providers

- New utility business models are serving as demand aggregators for the corporate sourcing of renewables for small and medium-sized enterprises.
- At least90 utilities and developers have committed to net zero/science-based targets.
- The private sector and others are collaborating around 1.5°C implementation strategies, especially the deployment of renewable power and flexibility.
- Local banks and stakeholders are being supported and capacitated to actively contribute to improve access to electricity in developing and emerging economies through locally available resources and technologies.
- Institutional capacity is in place in business to manage climate risks to existing assets and operations.
- Number of energy companies reporting on ESG risks is increasing.
- Deployment of renewable power and grid flexibility services is accelerating.
- 300 utilities and developers have committed to net zero/science-based targets.
- Corporations are delivering efficiency strategies and ambitious renewable power targets are widespread. 1000 businesses have committed to procure 100% of their power from renewables.
- Corporations have a systems-approach to renewable power procurement, using demand shifting and flexibility services.
- Local industries are being developed, supported by improved access to finance, learning and skill development programmes, and industry clusters as well as incubators for enterprises in energy transition-related technologies.
- Utility commitments to net zero, and wider corporate commitment to 100% renewable power use, is the global norm and is accelerating decarbonization.
- Efficient solutions have dramatically reduced energy intensity in hard-to-abate sectors.
- Targets for the share of renewable energy in buildings by 2030 have been met, including with the significant contribution by the private sector.
- Private sector action and investment has been a key driver of decarbonization of global power system.

- Stakeholder engagement has led to the identification of improved integration, interconnectivity and efficiency opportunities.
- Corporations are adopting efficiency strategies and ambitious renewable power targets 400 businesses have committed to procure 100% of their power from renewables. Leading businesses are encouraging their supply chain to also adopt such targets.
- Corporations are sharing best practice experiences on the procurement of electricity from renewable sources and the improvement of energy productivity.
- Asset conditions are being monitored and maintenance activities are prioritized to maximize adaptive capacity.
- Renewable electricity developers ensure human rights throughout their supply chain, particularly for materials extraction.

Civil society

- Civil society effectively influences policy making and action, including at the local level.
- Civil society at all levels is being supported in its advocacy efforts and raising public awareness of renewable energy deployment and benefits.
- Civil society and citizens are enabled to participate in the energy transition, including by developing community electricity systems, becoming prosumers, transitioning to renewable electricity, and purchasing energy efficient appliances.
- Misconceptions around renewables, particularly in terms of their costs and reliability, have been laid to rest.
- The public is engaged in decisions concerning resilient electricity infrastructure, due to a growing number of 'prosumers'
- No-regret/ win-win opportunities have been identified and acted upon.

- Civil society effectively influences policy making and action, including at the local level.
- Citizens are agents of change, articulating preferences and needs, and influencing decision-making in a tangible way.
- Citizens' participation in the energy transition has increased as prosumers and as drivers of behavioural changes.
- Renewable energy and climate topics are fully integrated into curricula.

- Civil society actively contributes to policy making and action, including at the local level.
- The public continues to be made fully aware of disaster recovery and other contingency plans.
- Civil society is helping people make the right choices in their energy management, production, consumption.

- Civil society continues to actively contribute to the shaping of electricity policies and strategies.

EXISTING INITIATIVES

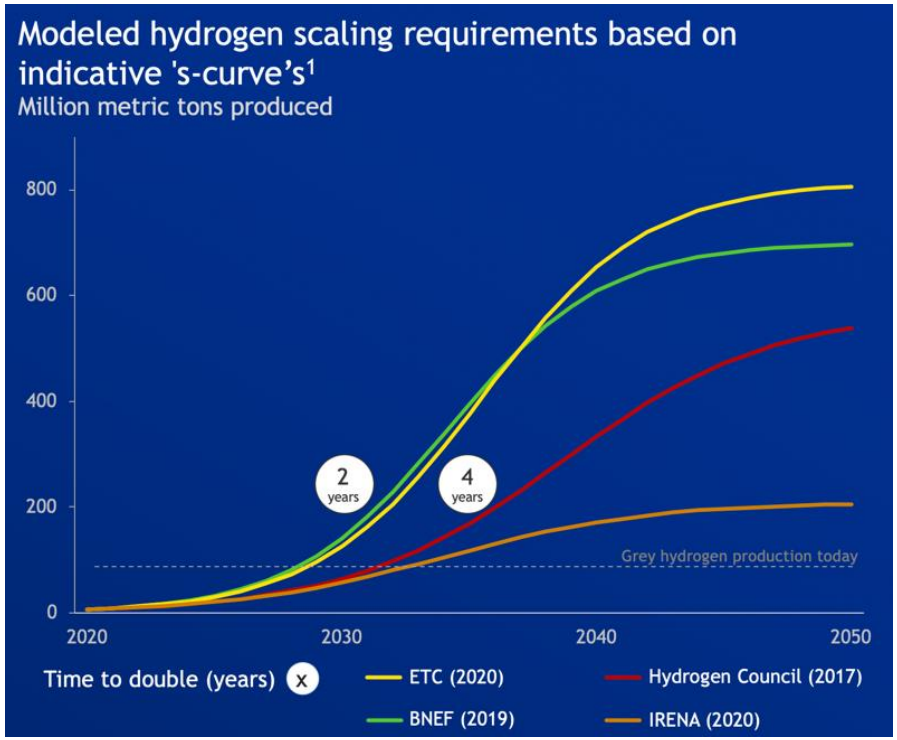
Energy Transition Commission	a global coalition of leaders from across the energy landscape committed to achieving net-zero emissions by mid-century, in line with the Paris climate objective of limiting global warming to well below 2°C and ideally to 1.5°C.

SECTORAL INTEGRATION CHANGE LEVERS

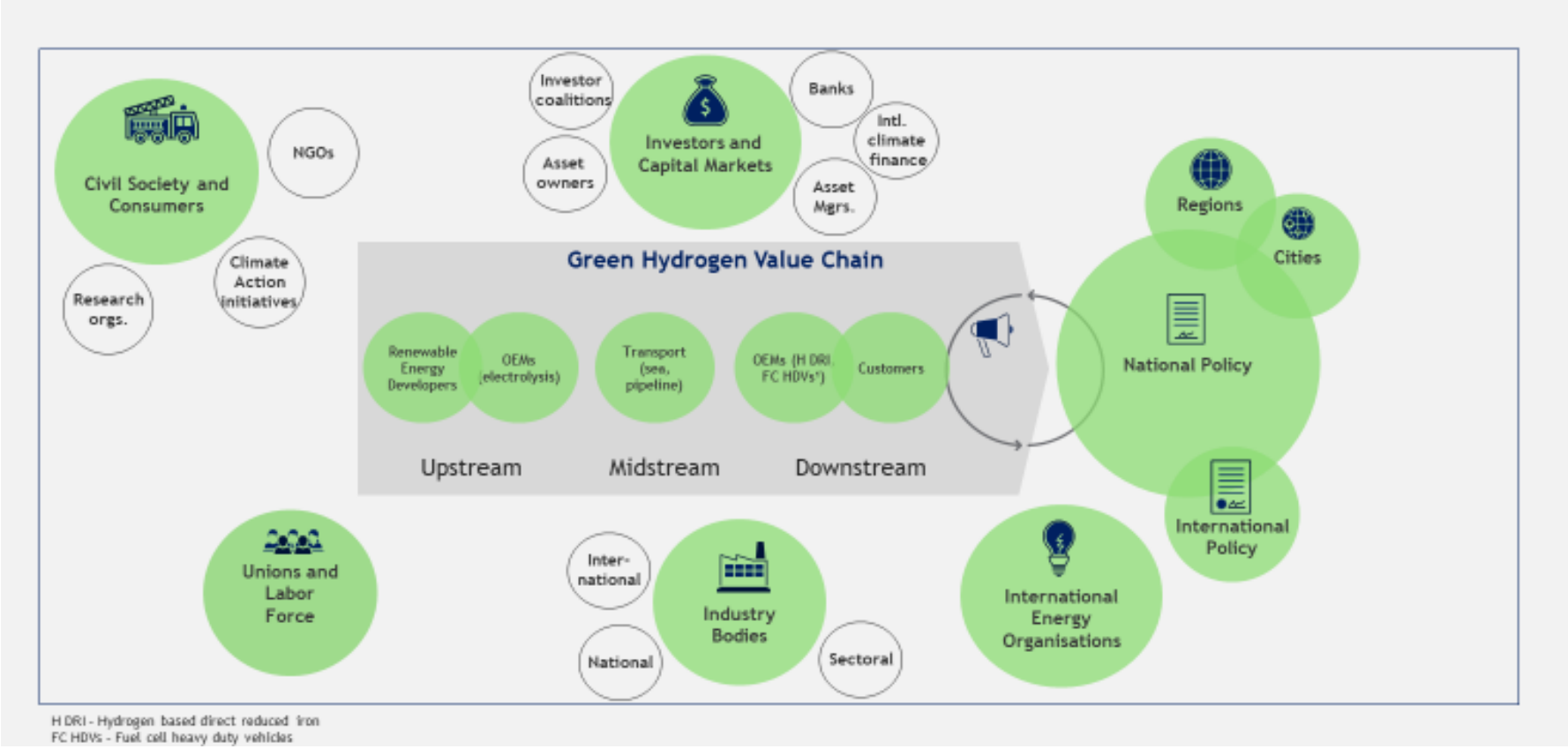
For sectoral integration across energy, industry, built environment, and transport, a low-cost, reliable, resilient, and zero carbon energy system is possible and necessary before 2050. First, tripling energy productivity gains relative to improvements over the last decade is crucial to achieving an efficient path to resilience and 1.5℃; the less energy required, the less needs to be decarbonized and integrated. To set off on an exponential rate of improvement, policymakers, businesses, and consumers must channel COVID-19 recovery spending to key energy efficiency measures (see other Thematic Pathways for end-use sectors). Exponential growth in electrification of remaining end-use sector demand – which will drive some of those efficiency gains – can reach 60% by 2050. Mass deployment of new and smarter end-use technologies – like smart water heaters, high efficiency pumps, and electric vehicles – must be accompanied by improved policy and regulation – for example electricity market design that offers equal access to supply and demand-side resources through transparent, all-source procurement practices, competitive wholesale power market mechanisms, and point-of-use and time-granular pricing tools. Electricity system regulators and stakeholders at regional and national levels bear responsibility for quickly evolving market designs and regulated business models to support smart, renewables-electrified economies.

Green hydrogen produced from renewable electricity and its derivatives can meet the remaining decarbonization opportunity where direct electrification of end-use is limited - particularly, heavy transport and high temperature industry - or local renewable energy supply is otherwise constrained. As was the case with solar and wind, corporate-led technology innovation and rapid cost reduction are a function of scaled-up deployment, building on a foundation of state-funded innovation. The same will be true of hydrogen - but in 10 years, not 30 - by harnessing cost-reduction "learning" curves to realize exponential growth. The levers that can enable that growth are manifold: public and private procurement processes, Research, Development and Deployment (RD&D) funding support, concessional and multilateral capital investment, consumer-demanded commodity emission transparency, businesses' appetite for market growth, labour unions' pursuit of high-quality job opportunities, and citizens' preferences for clean air. These levers can drive accelerated information, skills, and technology diffusion to support such critical scale up of green hydrogen markets.

SECTORAL INTEGRATION S-CURVES: HYDROGEN



SECTORAL INTEGRATION SYSTEMS MAP: GREEN HYDROGEN



Global Climate Action
United Nations Climate Change

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Impact 2

GREEN HYDROGEN

Sectoral integration

MITIGATION &/OR ADAPTATION /RESILIENCE

NEXUS

	By 2021	By 2025	By 2030	By 2040
Policymakers (national, subnational, local levels)	• Leverage post-COVID stimulus and recovery packages to kick-start solutions at an early stage of deployment such as green hydrogen. • Coordinate regulations, codes and standards along the hydrogen supply chain. • Include hydrogen in the revision of Nationally Determined Contributions (NDCs) (i.e. Chile).	• Include hydrogen in revised Nationally Determined Contributions (NDCs). • Set mandatory targets for sustainable hydrogen production. • Expand policy frameworks, regulatory models, procurement processes, funding support to new geographies for green hydrogen deployment. • Further support R&D activities to reduce production and infrastructure costs for green hydrogen.	• Set mandatory requirements for blending shares with natural gas. • Implement a renewable energy directive to promote the use of hydrogen in the transport sector, where relevant. • Introducing mandates and fiscal incentives for the use of hydrogen and hydrogen-derived synthetic fuels.	• Maintain mandates for the use of hydrogen, depending on each country context. • Maintain international certification systems to ensure that any future hydrogen supply is carbon-free. • Phase down upfront subsidies as green hydrogen technologies come down in cost.

	• Set comprehensive hydrogen strategies, including legal frameworks, short- and medium-term deployment targets, RD&D support, subsidies and funding instruments, procurement guidelines, and support for industry clusters around captive uses (ammonia, steel, refining) and key transport applications (heavy trucking, long distance shipping)	• Facilitate strategic public private partnerships, for example between regulators, Transmission System Operators (TSOs), gas industry and others. • Evaluate trade opportunities and barriers for a hydrogen international market. • Continue mapping natural clean hydrogen storage opportunities globally, such as salt caverns and aquifers. • Align guarantees of origin frameworks by developing certifications systems and standards at the international level. • Continue promoting investment into electrolysers and innovative zero-carbon process technologies for industry and other hard-to abate sectors. • Coordinate on clear criteria for carbon content of hydrogen and hydrogen-related fuels and feedstocks.	• Refine international certification systems to ensure that any future hydrogen supply is carbon-free. • Agree to international criteria for carbon content of hydrogen and hydrogen-related fuels and feedstocks.	
Financial Institutions	• Explore technology, market, attributes and select project and supply chain investment opportunities (i.e. public markets, private placements).	• Share knowledge, best practices, vetted models and contracts for mass-scale deployments to speed learning across community.	• Aggregate and re-finance project receivables in developed markets.	• Standardize due diligence and investment processes for efficiency.

	• Collaborate across the finance value chain with leading businesses to design and share viable corporate and project-financing solutions, i.e. offtake agreements, to support supply chain scale up. • Co-design innovative and leveraged contractual arrangements and/or concessional capital facilities to mitigate early stage deployment risks.	• Begin to standardize project and corporate finance contracts, instruments and models to broaden uptake. • Co-design and launch dedicated green hydrogen funding models and instruments in key resource-rich and policy-enabled geographies for mass-scale deployment, on the order of cumulative USD 100 billion invested in 25 GW deployed (double policy commitments to date).	• Financial markets and analysts are well-versed in green hydrogen project and corporate structures, cross-value chain investment opportunities, facilitating ready access to balance sheet and project capital on the order of cumulative USD 1 trillion invested in 300 GW deployed.	• Scale up risk management practices, i.e. renewable resource performance estimates underlying H_2 production.
Technology Providers and Innovators	• Accelerate scale up of electrolysis production facilities – in overall and modular scale – to meet nonlinear demand growth in existing and soon to be announced gigafactories. • By a factor of 10x, boost investments in RD&D of hydrogen and green molecules production, storage technologies (i.e. photocatalysis, carbon fiber storage, next generation membranes).	• Advance hydrogen and green molecules solutions (i.e. electrolyser size, efficiency) with integrated commercialization ecosystem to address key barriers to deployment. • National labs and corporates share emerging results of R&D and demonstration projects using hydrogen and derivatives. • Broaden assessments of gas TSOs natural gas grids readiness and retrofit / invest where necessary. • New end-use designs emerge to support hydrogen use, i.e. cryoplanes.	• Assessment of technological maturity of demonstration technologies, i.e. hydrogen DRI for primary steel production. End-use innovations enter deployment phase. • Upstream and midstream supply chain development achieved through significant scale of deployment in initial markets. • Technology providers expand geographic and market footprints.	• Electrolyser manufacturing growth slows to steady state as deployment reaches long-term targets of ~2000 GW. • Next generation production, storage and utilization technologies begin to emerge at scale.

	• Solve for commercialization barriers and challenges through public subsidies, accelerator–venture capital partnerships, and other collaboration models.			
Business and Service Providers	• Private sector associations and individual businesses set targets for the deployment of electrolysers and hydrogen infrastructure aligned with required scale of >25 GW by 2025. • Leaders prove business case for (additional) gigafactories and midstream supply chain technologies with significant capital raises and announcements. • Mass-scale deployment planning undertaken with customers, policy and finance partners. • Sector leaders identify critical demand pools and launch collaboration facilitate deployment. • Additional demonstration projects launched at captive-use sites.	• Leading companies transfer project learnings and best practices supporting definitive shift from demonstration to mass-scale projects to achieve 25GW deployed by 2025, triggering virtuous cycle of cost reduction through deployment. • Cross-sectoral and -value chain consortia models proliferate – illustrating the value pools underlying necessary scale, validating focused policy support protocols (i.e. IPCEI in Europe) and supporting further innovation in funding models. • Demand-creation consortia reach critical mass within industry sectors as cost reduction trajectory becomes clear.	• Fast followers catch up to first movers as cumulative deployment reaches at least 300 GW. • A dozen global leaders emerge as value accreting business models reach commercial scale in select geographies and sectors.	• Green hydrogen plays a critical role as solution for heavy industry and transport sectors.

	• Companies share emerging learnings, vetted contracts and models for adoption by fast followers.			
Civil society	• Supportive cross-sectoral and cross-value chain collaboration to identify and act on emerging value pools, informing critical path to scale • Develop and launch models for social dialogues including all stakeholders where significant near-term labour and land transition challenges are expected to prepare for re-skilling and labour transitions.	• Broadening awareness of value sharing opportunity – jobs, parcel fees, taxes – drives exponential support in communities	• Transition from captive uses to integration with heavy transport, gas networks etc supported by communities as safety and standards protocols, health outcomes are proven	• Civil society continues to actively contribute to shaping policy and strategies

EXISTING INITIATIVES

Green Hydrogen Catapult	The "Green Hydrogen Catapult" initiative will see green hydrogen industry leaders, including ACWA Power, CWP Renewables, Envision, Iberdrola, Ørsted, Snam, and Yara, target the deployment of 25 gigawatts through 2026 of renewables-based hydrogen production, with a view to halve the current cost of hydrogen to below US$2 per kilogram.
IRENA's Collaborative Framework on Green Hydrogen	IRENA's CF on Green Hydrogen is an initiative to provide a platform for IRENA Members and other partners of the Framework (incl. private sector) to have a dialogue, collaborate, and share information and best practices on green hydrogen deployment.

International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)	IPHE is an inter-governmental organization with a membership of 20 Member-Countries focused on bringing together governments to advance worldwide progress in hydrogen and fuel cells.
International Energy Agency's Hydrogen Technology Collaboration Program (IEA TCP)	IEA Hydrogen has facilitated and managed research, development and demonstration activities on hydrogen.
Clean Energy Ministerial – Hydrogen Initiative (CEM)	CEM is a global forum to promote policies and programs, to share lessons learned and best practices towards the transition to a global clean energy economy.
Mission Innovation	Mission Innovation is a global initiative of 24 countries and the European Commission. working to accelerate clean energy innovation. Innovation Challenge 8 (IC8)'s goal is identifying and overcoming key technology barriers to the production, distribution, storage, and use of hydrogen at gigawatt scale.
Fuel Cells and Hydrogen Joint Undertaking of the European Commission (FCH-JU)	The FCH-JU is a public private partnership supporting research, technological development and demonstration activities in fuel cell and hydrogen energy technologies in Europe. The three members of the FCH JU are the European Commission, the Hydrogen Europe and the Hydrogen Europe Research.
Hydrogen Council	The Hydrogen Council represents 81 energy, transport and industry companies with a united vision and long-term ambition of acknowledging hydrogen relevance for the energy transition and supporting its development.
European Clean Hydrogen Alliance	The European Clean Hydrogen Alliance aims at an ambitious deployment of hydrogen technologies by 2030, bringing together renewable and low-carbon hydrogen production, demand in industry, mobility and other sectors, and hydrogen transmission and distribution. With the alliance, the EU wants to build its global leadership in this domain, to support the EU's commitment to reach carbon neutrality by 2050.

FURTHER REFERENCES

Hydrogen: A Renewable Energy Perspective (IRENA, 2019)	The Future of Hydrogen (IEA, 2019)

Hydrogen from renewable power: Technology outlook for the energy transition (IRENA, 2018)	The Post-COVID Recovery - An agenda for resilience, development and equality (IRENA, 2020a)
Global Renewables Outlook: Energy transformation 2050 (IRENA, 2020b)	Path to Hydrogen Competitiveness - A Cost Perspective (HC, 2020)
Energy Technology Perspectives 2020 (IEA, 2020)	Decarbonising end uses: Focus on Hydrogen (IRENA, forthcoming)

Global Climate Action
United Nations Climate Change

Marrakech Partnership

Impact 3

ENERGY END-USE SECTORS

MITIGATION &/OR ADAPTATION /RESILIENCE

NEXUS

	By 2021	By 2025	By 2030	By 2040
Policymakers (national, subnational, local levels)	*Cross-cutting* • Governments introduce stepped carbon pricing mechanisms that begin to provide advantages for renewable technologies in all sectors. • Ambitious, progressive targets are set for share of renewable energy in all end-use sectors.	*Cross-cutting* • Carbon pricing mechanisms have increased, further reducing the competitiveness of fossil fuel technologies. • Phase 1 of target is achieved and possibly revised upward. • Policies implemented to optimize energy efficiency and demand response in appliances and buildings.	*Cross-cutting* • Carbon pricing mechanisms have increased again, pricing fossil fuel technologies out of the market. • Phase 2 of target is achieved and possibly revised upward. *Buildings* • Fossil fuel-based heating and cooling systems are banned for all new buildings in all countries.	*Cross-cutting* • Carbon pricing mechanisms continue to be in place. • Targets for renewables in final energy consumption have been achieved in all end-use sectors. *Buildings* • Fossil fuel-based heating and cooling systems are banned for all new and existing buildings.

Buildings

- Bans on some types of fossil fuels for new buildings are implemented in certain cities and countries.
- Net-zero building energy codes are introduced by some local and national governments.
- Many city governments introduce policies to supply all new municipal buildings with renewable energy.
- A targeted existing building energy efficiency renovation rate of 3% per year is established in some countries.
- Governments introduce mandates for renewable energy (including heat pumps) in all new buildings.
- Greenhouse gas emissions caps for new buildings are enforced.
- Targets for expansion of district heating and cooling are set in suitable countries.

Buildings

- Fossil fuel-based heating and cooling systems are banned for all new and some existing buildings in certain cities and countries.
- Net-zero building energy codes are adopted in most cities and countries.
- Most city governments have introduced policies to supply all new municipal buildings with renewable energy. Some governments are targeting existing buildings as well.
- A renovation rate of 3% per year has been established in many countries.
- Greenhouse gas emissions caps for new buildings are enforced.
- Most power systems have flexible tariffs that encourage buildings to consume and store heat at off-peak hours.

Industry

- Set progressive targets for share of renewable energy in all industrial sectors. Targets are achieved in sectors such as pulp and paper.

- Net-zero building energy codes are adopted in all cities and countries.
- All countries are achieving a renovation rate of 3% per year.
- Governments have introduced mandates for renewable energy in all new and existing buildings.
- District heating and cooling networks are fully established in many urban areas and provide low-cost, low-carbon heat to consumers.

Industry

- Targets for share of renewable energy are achieved in most industrial sectors.
- Industrial energy efficiency targets are achieved in all sectors.

Transport

- Fossil fuel bans and low-emission zones are established in all cities and countries.
- Scale up alternative transport solutions such as public, shared and on-demand transport services.

- All new and existing buildings are net-zero energy.
- All city governments have introduced policies to supply all new and existing municipal buildings with renewable energy. Some governments are targeting existing buildings as well.

Industry

- All industrial sectors are fully decarbonized.

Transport

- Road transport is fully decarbonized.

- Awareness campaigns on transitional residential and commercial heating and cooling systems to renewable energy (including heat pumps).

Industry

- Progressive targets are set for share of renewable energy in some industrial sectors.
- Industrial energy efficiency targets are set.
- Innovation funds are established for low-carbon technology demonstrations in energy-intensive industries.

Transport

- Fossil fuel bans and low-emission zones are established in some cities and countries.
- Set biofuel blending mandates (10% and increasing)
- Financial incentives are implemented for production and use of biofuels.
- Funding for biofuel blending and distribution infrastructure.

- Industrial energy efficiency targets are achieved in some sectors.
- Create supportive institutional, legal and regulatory frameworks to promote industry decarbonization.
- Further funding for technology development for energy-intensive industries.

Transport

- Fossil fuel bans and low-emission zones are established in most cities and countries.
- Policies integrating electric vehicles and renewable electricity have been adopted at a wide scale.
- Public procurement of electric vehicles.
- Zero-emissions zones implemented in most cities.

- Zero-emissions zones implemented in all cities.

	• Funding for biogas digesters and distribution infrastructure. • Vehicle emissions standards. • Incentives for electric vehicles such as congestion charging, free parking and preferred access are used to encourage EV adoption.			
Financial Institutions	*Cross-cutting* • International financial institutions and governments commit on harmonizing low- or net-zero emission investment taxonomies. • Finance and investment flows data are available and consolidated across energy end-use sectors. *Buildings* • Governments are providing enabling frameworks for investment in innovation and a range of R&D solutions for renewable heating and cooling in buildings. • Government investment for innovation targeting cost reductions in (low-temperature) district heating and cooling networks.	*Cross-cutting* • International financial institutions and governments have endorsed harmonized low- or net zero emission investment taxonomies. *Buildings* • Dedicated national funding plans channelled toward net zero emission buildings, renovation, energy efficiency & renewable energy in buildings. *Industry* • Pipeline of commercially viable near-zero emissions technology projects exists for investment at scale. • Increased conditional funding for hydrogen projects based on renewable energy production.	*Cross-cutting* • Mandatory disclosure for any financial institution on their portfolio. compliance/alignment with standardized low- or net zero emission investment taxonomies.	*Cross-cutting* • 100% of energy end-use sector finance and investment flows is aligned with standardized low- or net zero emission investment taxonomies.

- National end-customers fiscal incentive schemes for zero carbon / net zero energy buildings, renovation, energy efficiency and renewable energy in buildings.
- Multiply by ten public finance (compared to 2017) into clean cooking fuels and facilities, to reach USD 1 billion[2] (across High Impact Countries).

Industry

- Increased support for R&D and a series of early-stage near-zero emissions technology demonstration projects, particularly in steel, cement and chemical sectors.

Transport

- National fiscal incentive schemes for electric mobility (vehicles, charging infrastructures, etc.) that are linked to renewable energy production.

Transport

- Pipeline of commercially viable near-zero emissions technology projects exists for investment at scale.
- Increased conditional funding for electric mobility projects (fleets, charging infrastructures) that are linked to renewable energy production.

[2] Energising finance 2019, Executive Summary, p. 11

	• Increased support R&D and a series of early-stage near-zero emissions technology demonstration projects, particularly in maritime transport, aviation and road freight.			
Technology Providers and Innovators	*Buildings* • Smart technologies under development to intelligently manage power consumption in buildings and couple it with heating and cooling demand. • Cost reductions in electric heat pump technologies and high efficiency, climate friendly cooling equipment for buildings. • Research and development in building envelope. • Innovations in thermal energy storage for low-cost storage of heat and cold. *Industry* • Cost reductions in hydrogen electrolysis with renewable electricity leads to development of robust, global supply chain.	*Buildings* • Further cost reductions in district heating and cooling networks and development of innovative low-temperature networks that optimize cost for energy producers and consumers. • Innovation in low-carbon building materials for reductions in embedded emissions. • Product innovation in pre-fabricated building components. • R&I funds towards SME in construction sector to stimulate innovation. • Further innovations in building envelope to reduce energy demand. • Further significant cost reductions in high efficiency. climate friendly cooling equipment for buildings.	*Buildings* • Further innovation in pre-fabricated building components. • Building envelopes are optimized to reduce energy demand. *Industry* • Cost reductions lead to hydrogen production, distribution and use in industry being cheaper than fossil fuels. • Decarbonisation of industrial processes now widespread with renewable hydrogen. • High-temperature heat pumps powered by renewable electricity are commonplace in industrial processes.	*Buildings* • Buildings are net-zero and constructed with low-carbon materials. • Heating and cooling in all buildings supplied by renewable technologies (solar, geothermal, bioenergy, renewable electricity for heat/cold). *Industry* • Industry has been fully decarbonised with renewable hydrogen, renewable electricity, bioenergy, solar thermal heat and geothermal heat. *Transport* • Trucking, shipping and aviation are now fully decarbonised.

- Pilot projects (such as the Hybrit initiative for steelmaking) are demonstrating low-carbon industrial processes with hydrogen.
- High-temp heat pumps powered by renewable electricity are being used in more industrial processes to power electric arc furnaces.
- Waste heat usage is increasingly valorized and being delivered to district energy networks to meet heating loads in nearby settlements urban areas.

Transport

- Cost reductions in electric vehicles (powered by renewable electricity) more widespread and increasing annual market share of EVs.
- Higher blends of biofuels achieved through innovations in production and supply chain.
- Innovation for smart charging of EVs allows for sector coupling between power sector and transport sector.

- Further cost reductions in thermal energy storage technologies, both for district energy networks as well as individual residential/ commercial storage units.
- Fossil gas pipelines are being retrofitted to distribute biogas.
- Further cost reductions in electric heat pump, solar thermal and geothermal technologies make these technologies cheaper than fossil gas or prevailing fossil fuel-based heating technology in many countries.
- Innovations in supply chain of bioenergy for increased sustainability.

Industry

- Further cost reductions in hydrogen electrolysis has created a hydrogen production industry in several countries, leading to the increased use of hydrogen in industry.
- More industries demonstrating use of renewable hydrogen in manufacturing.

- Further cost reductions in bioenergy, solar thermal and geothermal heat technologies and high efficiency, climate friendly cooling technologies.
- Usage of waste heat has been completely optimized and recycled within industry.

Transport

- Due to cost reductions, passenger electric vehicles are now cheaper than all models of conventional internal combustion engine vehicles. They account for all of the world's annual passenger vehicle sales. The global stock is more than 50% electric.
- Renewable hydrogen use in trucking, shipping and aviation is now widespread due to cost reductions from innovation.
- The world's EV fleet is being operated via smart charging devices, integrating efficiently with the power sector.

- All annual passenger vehicle sales are EVs and the global passenger vehicle stock is >90% electric.

- Related to industry sector, hydrogen supply chain under development and used for segments of the transport sector, including long-haul trucking, shipping and aviation.
- Cost reductions in drop-in biofuels.

- High-temperature heat pumps powered by renewable electricity are commonplace in industrial processes.
- Bioenergy and solar thermal cost reductions lead to their replacing fossil fuels in many low-temperature applications such as pulp and paper, and food processing.
- Usage of waste heat has been further optimized and recycled within industry, while also being delivered to district energy networks.

Transport

- Due to cost reductions, electric vehicles now account for the majority of annual vehicle sales worldwide. The global stock is increasingly electric.
- Further innovation of renewable hydrogen use in trucking, shipping and aviation leads to the development of commercial activity in this sector.
- Smart charging technologies are now widespread and being used to control charging patterns of the majority of the world's EV fleet.

Business and Service Providers

Cross-cutting

- Governments step up the regulatory frameworks for the business sector and have set up targets for certifications and compliance.
- Regulations set up to improve the responsible business management of companies with sectors with a high environmental and social impact.
- Governments set up incentives for the business sector to adhere to environmental practices and international initiatives (e.g. UN Global Compact [UNGC]).
- Governments set up incentives for Universities to adhere to the UNPRME principles.
- Governments set up mandatory environmental impact and social assessments for all businesses to get into force in different phases.
- Governments create enabling frameworks to allow the transformation of business towards circular economy.

Cross-cutting

- New (or more stringent) regulations and standards have entered into force which means governments will begin the compliance and enforcement measures for the business sector.
- The majority of companies have adhered to international certifications or initiatives (e.g. UNGC).
- All business and Industry associations require their members to adhere to environmental/social certifications or international initiatives.

Buildings

- All companies in this industry are required to comply with environmental and social standards.
- At least 50% of the industry has shifted to environmentally friendly designs, construction and maintenance.

Cross-cutting

- The majority of governments have improved their capacity for compliance and enforcement of regulations and standards and there are no longer gaps in this sense.
- All companies have been certified and have adhered to international initiatives.

Buildings

- All companies comply with environmental and social regulations and standards.
- At least 80% of the industry has shifted to environmentally friendly designs, construction and maintenance.
- It is now cheaper to construct with new materials and methods that are environmentally friendly than ever before.

Industry

- Governments have a strong enabling framework that allows that at least 80% of the industry to be immersed in the circular economy.

Cross-cutting

- All governments have enough capacity to ensure the compliance and enforcement of the regulations and standards.

Buildings

- The building industry has been fully decarbonized.

Industry

- The industry has completely shifted towards circular economy models.

Transport

- The transportation industry (design, manufacturing, and transportation) has been fully decarbonized.

Buildings

- Regulations set up to improve the environmental and social impact of this industry.
- Targets are defined to make the industry shift towards environmentally friendly design, construction, and maintenance.

Industry

- Governments place stringent regulations on industry to phase out the use of fossil fuels and reduce their GHG emissions and environmental and social impact.
- Governments create enabling frameworks to allow the transformation of business towards circular economy.
- Governments determine a series of targets for the reduction of the environmental impact and GHG emissions of the industry.
- The falling costs of new materials make it a business case for the building industry to move towards its decarbonisation.

Industry

- The industry has begun a transformation towards circular economy with help from national and local governments.
- Governments provide fiscal and financial incentives for SMEs to improve their sustainable business approach.

Transport

- All the big players in the transportation industry (design, manufacturing and transportation industries) have pledged to reduce their environmental footprint and have been certified.
- Governments have established enabling frameworks for business development that support the sustainable transportation industries.
- It is now cheaper to produce EVs than other types of vehicles.

	Transport • Governments begin providing financial support for customers to buy EVs. • Governments place stringent regulations on industry to phase out the use fossil fuels incentivizing the transition towards EV's. • Governments create new mechanisms to support sustainable transportation modes.			
Civil society	*Cross-cutting* • Civil society is considered as a key element to achieve the energy transition in all end-use sectors; this is reflected in policy-making. • Civil society, including trade unions, are included as key stakeholders in developing plans on just transition for workers and communities. • Civil society is included in the energy transition and is encouraged to do so via participatory governance processes.	*Cross-cutting* • Civil society effectively influences policy making and action in most jurisdiction around the world, including at the local level. • Participatory governance in energy topics is the norm for most. • Misconceptions around renewables, particularly in terms of their costs, reliability and their job potential, have been laid to rest.	*Cross-cutting* • Civil society effectively influences policy making and action in all jurisdiction around the world, including at the local level. *Buildings* • Civil society participation, in the form of prosumerism is possible in all jurisdiction around the world, including at local level.	*Cross-cutting* • Civil society continues to actively contribute to shaping policy and strategies in all jurisdictions around the world, including at the local level. *Buildings* • Civil society participation, in the form of prosumerism continues to be a key element in all jurisdictions around the world.

- Citizens are agents of change, articulating preferences and needs, and influencing decision-making in a tangible way.

- Civil society at all levels is being supported in its advocacy efforts and raising public awareness of renewable energy deployment and benefits; public campaign to tackle the misconceptions around renewables.

Buildings

- Civil society and citizens are enabled to participate in the energy transition in buildings, including by developing community electricity systems, becoming prosumers, transitioning to renewable electricity, and purchasing energy efficient appliances.

Industry

- Civil society actors support the reskilling of workers.

Buildings

- Civil society participation, in the form of prosumerism is possible in most jurisdiction around the world, including at local level.

Industry

- Reskilling of workers to renewable energy jobs is happening actively in most jurisdictions around the world.
- Engagement of civil society to hold industry accountable for transition metrics and product emission thresholds.

Transport

- Awareness raising campaigns have contributed to a decrease in cars on the road worldwide.
- Improved and safe bike infrastructure, walkable cities and fossil-fuel free public transport is available in most cities around the world.

Industry

- Reskilling of workers to renewable energy jobs is happening actively in all jurisdictions around the world.

Transport

- Improved and safe bike infrastructure, walkable cities and fossil-fuel free public transport is available in all cities around the world.

- Civil society initiatives are leading to improved data on company emissions. benchmarks, transition metrics and product emission thresholds, enabling heightened transparency.

Transport

- Awareness raising campaign to support civil society to shift from private vehicles to public transport.
- Civil society is enabled to participate in alternatives mode of transport by promoting bike infrastructure, improving walkability of cities, expanding public transport and shifting public transport away from fossil fuels.

FURTHER REFERENCES

Reaching Zero with renewables (IRENA 2020)	

STRUCTURAL CHANGE LEVERS

Structural change is needed in fossil fuel production and consumption. In recent years, coal for power generation has become widely uneconomic compared to renewable power. This has been reinforced by government policy in some jurisdictions, which have set coal phase out dates and implemented carbon pricing. To achieve net zero energy systems, this trend needs to increase, with all OECD countries phasing out coal power by 2030, and elsewhere by 2040. No new unabated coal-fired power plants should be built after 2020. Oil and gas will prove to be more challenging to decarbonise, due to widespread use across transport, industry and power sectors. Government policies addressing both demand- and supply-side aspects of reductions in fuel use will need to go hand in hand with action by both upstream producers and downstream consumers to set ambitious net-zero targets and find sustainable alternatives to current fuels, as well as transitioning entire companies to sustainable business models. Improving energy efficiency will help to reduce the costs of decarbonizing power generation and achieve an ambitious phase out time frame. The financial community will continue to play an increasingly important role in the low carbon transition, with investors advocating for more ambitious company responses and reallocating capital, and banks aligning lending to 1.5°C trajectories, given the risk from high-carbon investments, including stranded assets, and the ever-increasing opportunities in low carbon. Feedback loops between government policy, company action and financial sector influence will accelerate momentum. Across the transition from fossil fuels, it will be key to mainstream the concept of a just transition and quickly move from rhetoric, to plans to implementation, so that affected workers and communities have the opportunity to engage in the process and transition successfully to alternative livelihoods.

Global Climate Action
United Nations Climate Change

Marrakech Partnership

Impact 4

COAL PHASE OUT

Structural change

MITIGATION &/OR ADAPTATION /RESILIENCE

NEXUS

	By 2021	By 2025	By 2030	By 2040
Policymakers (national, subnational, local levels)	• No new coal plants are being approved in the world. • Policies in place to ensure role filled by coal in electricity systems can be filled by other technologies. • Policies for a just transition can facilitate the process of retaining fossil fuel workers at risk. Reskilling needs of fossil fuel workers must be evaluated so that financial support can be provided to help them acquire new skills.	• Countries are implementing their just transition strategies and have a clear coal phase out plan. • Countries are investing in grid adaptation and alternative ways of managing electricity demand. • Coal power production is widely seen as uneconomic and hazardous for human health and the environment.	• Coal power generation declines by 75% compared to 2019. • Structural dependencies for producers and exporters (export revenues; supply chains) and importers (operating infrastructure and assets) are addressed through social protections, educational and re-training, industrial policies, utilizing spillovers. • OECD countries have phased out coal power.	• All countries have phased out coal power.

	• End subsidies to coal assets. • Existing policies are developed and strengthened further i.e. air pollution regulation, and policies addressing other negative externalities of coal such as soil pollution, competition for land and water resources at the local level; policies related to limiting import quantities in key geographies. • Economic Recovery - COVID-19 recovery measures promote just transition and secure livelihoods and secure alternative job opportunities for coal workers. • Impose strict performance requirements on local suppliers in exchange for government support (such as subsidies and tax breaks) with regards to their energy sourcing.	• Countries are designing strategies to minimize stranded assets related to coal production and use for electricity generation.	• Developing countries have clear coal phase out strategies and have started to implement just transition strategies. • Carbon pricing and supportive emission standards are universal. • Supportive policy environment has led to widespread adoption of increased grid flexibility.	
Financial Institutions	• Investors with previous coal exit announcements with exceptions revise them to have no exceptions at all. • Donor countries announce a stop to all financing of fossil fuel related projects abroad.	• The world's coal pipeline has dried out because of the realization that investing in coal is bad business. • Financing for RE and EE projects is streamlined and prioritized above potential stranded assets such as coal plants.	• Green finance is fully mainstreamed and considered the norm.	• Green finance is fully mainstreamed and considered the norm. • Global power system has been decarbonized.

	• Investments are moving from fossil fuel to renewables. 100 investors and banks commit to end coal funding. Investors have influenced utilities transition plans through Science Based Targets Initiative (SBTI) and clean power engagement.			
Technology Providers and Innovators	• Efficient coal plants equipped with Carbon Capture, Use and Storage (CCUS) facilitates earlier retirement of less efficient coal plants.	• New technologies and systems for storage emerge.	• New technologies and systems for storage are mainstream. • People manage their electricity production and consumption at a household level and are integral parts of the energy system.	• Global power system has been decarbonized.
Business and Service Providers	• At least 90 utilities/developers committed to net zero targets and 10 new utilities committed to phase out coal.	• Most utilities/developers in developed countries have net zero targets for 2030 and from developing countries by 2040 or 2050.	• Utility commitment to net zero is the global norm and is accelerating decarbonization.	• Global power system has been decarbonized.
Civil society	• Civil society demands their country, province/state, city, utility have ambitious decarbonization targets.	• Civil society is effectively influencing policy making and action.	• Civil society is pressuring remaining countries with coal to accelerate phase out.	

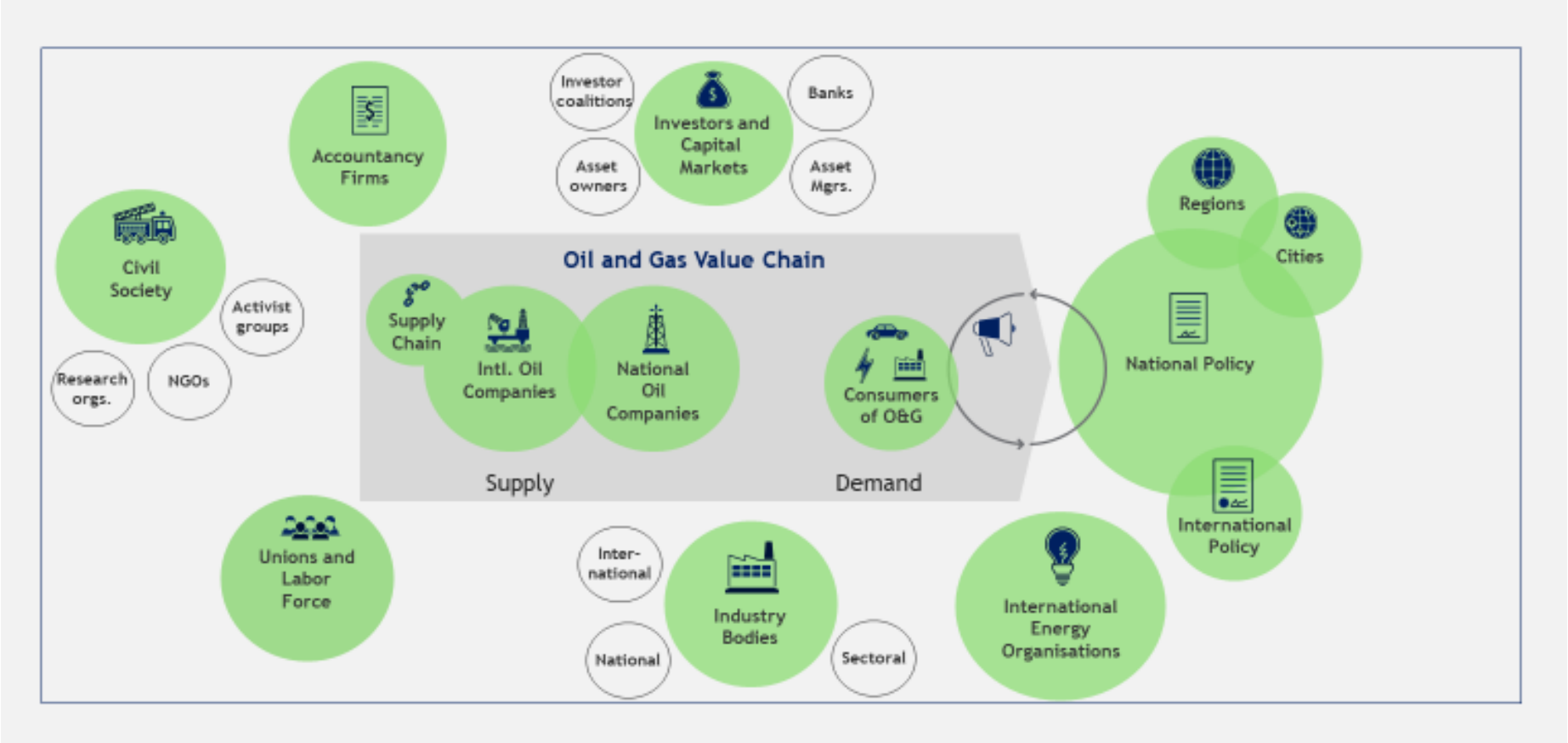
EXISTING INITIATIVES

Powering Past Coal Alliance	The members of the Powering Past Coal Alliance work together to share real-world examples and best practices to support the phase-out of unabated coal, including through climate finance, and to adopt practical initiatives to support this transition, including through developing clean energy plans and targets. The commitment is to work together is informed by science-based benchmarks that show that EU and OECD countries must phase out unabated coal-fired electricity generation no later than 2030, with the rest of the world no later than 2050 to limit global warming and the impacts of climate change.
Clean Air Fund	Call for all relevant organizations, MDBs, philanthropies, donor countries to increase financing for resilient health systems and air quality. The Clean Air Fund with 50 million dollars raised towards their USD 100 million target was launched. Donors include IKEA Foundation, Children's Investment Fund Foundation, Bernard Van Leer Foundation, Oak Foundation, Saint Thomas Charity and FIA Foundation.

FURTHER REFERENCES

Measuring the socio-economics of transition: Focus on jobs (IRENA, 2020)	Special Report on Global Warming of 1.5°C (IPCC 2018)
World Energy Outlook (IEA 2020)	Production Gap Report (UNEP 2019)
Clean Energy Innovation (IEA 2020)	Innovation landscape for a renewable-powered future (IRENA 2019)
IRENA Innovation Toolbox	

STRUCTURAL CHANGE SYSTEM MAP: OIL AND GAS



Impact 5

OIL AND GAS

Structural change

MITIGATION &/OR ADAPTATION /RESILIENCE

NEXUS

	By 2021	By 2025	By 2030	By 2040
Policymakers (national, subnational, local levels)	• Long term energy plans are in place, compatible with 1.5°C pathway, including clear targets for transition from fossil fuels. • COVID-19 recovery packages drive shift from grey to green economy. Bailout support is used to shift business models towards net zero with conditionalities applied. • Oil and Gas (O&G) subsidies are reduced from 2020 levels. Carbon pricing is being increasingly adopted globally.	• Comprehensive policies are in place to enable the transition away from O&G. Policies have enabled markets in zero carbon fuels. • Policies on fuel imports (methane or carbon border tax) related to carbon/methane intensity in place. • O&G subsidies phased out. Carbon pricing in most markets. Supportive emission standards have been established.	• Strong emphasis on phasing out fossil fuel technologies. Bans on O&G use in key sectors (transport, heating) have entered into force in many countries and cities. • Policies restricting introduction of new O&G infrastructure are gaining further traction and encouraging options to use the infrastructure for low to zero-carbon forms of energy (e.g. biofuels, biomethane, hydrogen).	• Comprehensive and clear policy action has enabled structural shift away from oil and gas use and towards sustainable alternatives, en route to net zero by 2050.

- Future policies to reduce O&G demand are increasingly being announced at national (e.g. internal combustion engine phase out dates) and local (e.g. bans on such vehicles in city centres) levels
- Several countries introducing policies restricting new O&G infrastructure, which can be used for low-carbon energy sources.
- Strategies are developed for just transition from fossil fuels to minimise impact on individuals and communities.
- Just transition strategies in place to address social and economic impacts of O&G transition, including support for developing countries.
- Increasing number of announcements on ban on fossil fuel use in key sectors (transport, heating).
- Enhanced regulation of O&G supply to decrease methane venting and leakage, including standards, performance targets (e.g. intensity targets), and/or economic incentives.

- Future policies to reduce O&G demand (e.g. internal combustion engine/gas domestic heating phase out dates) have been announced in most key markets and have entered into force in some.
- Policies restricting introduction of new O&G infrastructure gaining further traction.
- Fossil fuel dependent economies progressing diversification. Comprehensive border adjustment taxes may be in place if countries are not taking climate action.
- Government adaptation policies and plans are encouraging mainstreaming of adaptation considerations in sectoral physical infrastructure.
- Jurisdictions at all levels adopt and implement measures for transparency and integrity in lobbying and decision-making processes, following international, national and local best practices.

- Carbon pricing and emissions standards are universal.

	• New exploration is banned in international and national protected areas, including UNESCO World Heritage sites, Marine Protected Areas, and the Arctic. • Institutional capacity building is helping officials identify and manage sectoral climate risks (e.g. extreme weather impacts on O&G installations offshore).			
Financial Institutions	• Multilateral public financing of O&G is phased out. • Active divestment for fossil fuel companies by private companies, pension funds, and others. • Banks are increasingly measuring the climate impact of their lending to the O&G sector and are beginning to shift to lending aligned with 1.5°C trajectory. • Investors, led by asset owners, are strongly influencing O&G company low carbon transition strategies via direct engagement. Metrics developed for re-orientating investment portfolios to align with 1.5°C trajectory.	• All public financing of O&G has been phased out. • Private investments in O&G infrastructure have dropped significantly. Leading investors have re-orientated their investment portfolios to align with 1.5°C trajectory. • Many banks have stopped financing new oil and gas infrastructure, instead shifting portfolio to more sustainable alternatives. • All O&G company capital investment fully aligned with 1.5°C trajectory, with little to no space for new field developments.	• All investors and banks have stopped financing new oil and gas infrastructure, instead shifting portfolio to more sustainable alternatives. • Insurance underwriters accurately integrate climate risks in their assessments, ensure affordable coverage without market distortion and do not disincentivize government climate strategies nor resiliency planning.	• Financial sector has been re-configured, including in respect to O&G industry, to support low carbon transition and net zero by 2050.

	• O&G companies starting to align capital investment towards 1.5°C trajectory, including by transitioning to clean energy business models. • O&G companies are implementing TCFD recommendations and accounting firms are aligning audit treatment of O&G firms with 1.5°C trajectory • Insurance underwriters begin to accurately integrate climate risks in their assessments, and work with governments at all levels to ensure affordable coverage without market distortion or disincentivizing governmental climate strategies or resiliency planning.			
Technology Providers and Innovators	• Private sector innovation and investment is being increased in a range of RD&D solutions and business models for reducing emissions from O&G production in the short term and transitioning to sustainable alternatives in the long term.	• Innovation in energy intensive industries for 1.5°C trajectory has been stimulated. Therefore, industrial sectors are increasingly using renewables driven electrification, sustainable bioenergy, green hydrogen or Carbon Capture, Use and Storage (CCUS) instead of unabated gas.	• Innovation in energy intensive industries for 1.5°C trajectory is advanced. Therefore, industrial sectors are mostly using renewables driven electrification, sustainable bioenergy, green hydrogen or CCUS instead of unabated gas.	• Innovation for efficient and resilient energy systems is continuing.

		• Innovation in transport for 1.5°C trajectories has been stimulated. Oil products in transport are therefore increasingly being displaced by EVs and starting to be displaced by sustainable aviation/ shipping fuels. • Improved methane monitoring, including by space-based and airborne technologies, enables targeted action on leakage. • Continued deployment of safe and environmentally responsible CCUS facilities to enable technology scale up in industrial sectors in future.	• Innovation in transport for 1.5°C trajectories is advanced. Oil products in transport are therefore being significantly displaced by EVs and increasingly being displaced by sustainable aviation/ shipping fuels. -	
Business and Service Providers	• Oil and gas end users and other stakeholders, such as investors, NGOs, academia and owners, are increasingly signalling desire to transition from fossil fuels to sustainable alternatives and oil and gas companies committing to support them in this journey. • Oil and gas companies representing at least 30 percent of the operated global production are systematically monitoring, disclosing and reducing operational emissions	• Oil and gas end users are increasingly acting to transition from fossil fuels to sustainable alternatives in partnership with oil and gas companies. • Oil and gas production have reduced by at least 10-20% compared to 2019. • All major oil and gas companies have verified science based 2050 net zero targets, including scope 3 emissions, and have made detailed plans to transition to low carbon business models.	• Oil and gas end users consistently acting to transition from fossil fuels to sustainable alternatives in partnership with oil and gas companies. • All major oil and gas companies have verified science based 2050 net zero targets, including scope 3 emissions, and have made detailed plans to transition to low carbon business models. • Oil and gas companies have made significant progress in their zero carbon transitions.	• Deep partnership between end users and companies traditionally producing oil & gas leading to comprehensive sectoral decarbonisation progress, en route to net zero by 2050. • Oil and gas production have reduced by at least 45-65% compared to 2019, progressing towards sectoral net zero emissions by 2050.

- At least 8 major oil and gas companies have verified science based 2050 net zero targets, including scope 3 emissions, and have made detailed plans to transition to low carbon business models, for example expanding renewable energy generation
- Focus increasing on tackling methane flaring and leakage.
- Global oil and gas consumption have peaked
- High environmental and social safeguards are committed to on all operations by leading companies, including to engage indigenous peoples and local communities in alignment with the recommendations of IPIECA's oil and gas industry guidance on voluntary sustainability reporting
- Several O&G companies are seeing that moving to renewables is a strategic business decision that will help them keep their business going and growing to new markets

- Achievement of maximum 0.2% methane intensity via updated equipment and processes by majority of industry.
- Industry standard is transparent reporting of methane leakage and flaring, with aim to reach near zero (accidental) leakage and zero routine flaring by 2030.
- All oil and gas companies implement TCFD or similar recommendation to transparently disclose climate-related financial risks.
- Industry standard is to systematically monitor, disclose and reduce operational emissions
- Industry standard is to follow high environmental and social safeguards on all operations, including to engage indigenous peoples and local communities in alignment with the recommendations of IPIECA's oil and gas industry guidance on voluntary sustainability reporting

- Oil and gas production have reduced by at least 25-40% compared to 2019
- Achievement of zero routine gas flaring and near zero methane leakage complemented by transparent reporting and third-party verification

Civil society	• Civil society, including trade unions, are included as key stakeholders in developing plans on just transition for workers and communities. • Civil society is showcasing public desire for transition away from fossil fuels due to high demand for reskilling and green job creation, local campaigns for cleaner air, and COVID-19 induced desire for energy supply security and national self-reliance. • Civil society initiatives are leading to improved data on company emissions benchmarks, transition metrics and product emission thresholds, enabling heightened transparency.	• Civil society is continuing to effectively influence policy making and action.	• Civil society actively contributes to shaping policy and strategies.	• Civil society continues to actively contribute to shaping policy and strategies.

EXISTING INITIATIVES

Science Based Targets Initiative for Oil and Gas	The Science Based Targets Initiative encourages companies to set targets for their carbon reductions based on scientific evidence and aligned with 1.5°C trajectories. A methodology for the oil and gas sector is in development (at time of publication in December 2020).
Mineral Methane Initiative	The Mineral Methane Initiative by the UNEP led Climate and Clean Air Coalition promotes deep cuts in methane from the oil and gas sector, focusing on transparency, science and policy

OGCI	The Oil and Gas Climate Initiative supports emissions reductions in the oil and gas sector. OGCI aims to increase the ambition, speed and scale of initiatives of individual companies to reduce the greenhouse gas footprint of the core oil and gas business – and to explore new businesses and technologies.
Clean Cooking Alliance	The Clean Cooking Alliance works with a global network of partners to build an inclusive industry that makes clean cooking accessible to the three billion people who live each day without it. Established in 2010, the Alliance is driving consumer demand, mobilizing investment to build a pipeline of scalable businesses, and fostering an enabling environment that allows the sector to thrive. Clean cooking transforms lives by improving health, protecting the climate and environment, empowering women, and helping consumers save time and money.
Climate and Clean Air Coalition	The Climate and Clean Air Coalition is a voluntary partnership of governments, intergovernmental organizations, businesses, scientific institutions and civil society organizations committed to protecting the climate and improving air quality through actions to reduce short-lived climate pollutants.
The World Bank's Global Gas Flaring Reduction Initiative	The World Bank's Global Gas Flaring Reduction Partnership (GGFR) is a Multi-Donor Trust Fund composed of governments, oil companies, and multilateral organizations working to end routine gas flaring at oil production sites across the world. The Partnership helps identify solutions to the many technical and regulatory barriers to flaring reduction by developing country-specific flaring reduction programs, conducting research, sharing best practices, raising awareness, increasing the global commitments to end routine flaring, and advancing flare measurements and reporting.
Global Methane Alliance	The Global Alliance to Significantly Reduce Methane Emissions in the Oil and Gas Sector by 2030 or Global Methane Alliance brings together governments, financing institutions, international organizations and NGOs, and industry to support ambitious methane reduction targets from the oil and gas industry.

FURTHER REFERENCES

IEA – The Oil and Gas Industry in Energy Transitions (2020)	Exponential Roadmap – Scaling 36 solutions to halve emissions by 2030 (2020)
Carbon Tracker – Breaking the Habit (2019)	Production Gap Report (2019)
Methane Tracker 2020 (IEA 2020)	Methane Guiding Principles
Carbon Tracker – Breaking the Habit (2019)	