CLIMATE ACTION PATHWAY

Energy

Executive Summary

2020

Global Climate Action
United Nations Climate Change

Marrakech Partnership

VISION STATEMENT

It is 2050 and energy systems worldwide have been decarbonized thanks to a range of innovative solutions, investments and policy choices that set us on the pathway decades earlier. The response to the COVID-19 pandemic was a milestone in the shift to a decarbonized and resilient energy system due to behavioural changes and investments in a green recovery. Institutional, legal and regulatory frameworks have been put in place in decarbonized energy sectors, including electricity, transport, heating and cooling. 100 million people work in the energy sector in well-paid, stable jobs that rely on sustainable and indigenous resources.

The energy we use is primarily electric and at least 80 per cent of our electricity is being generated from renewable energy sources, and 100 per cent from zero-carbon sources. Energy intensity has been dramatically reduced. The energy infrastructure now in place is more resilient to market shocks and the impacts of climate change than the heavily centralized fossil- and nuclear-fuelled systems of the past. The global energy system has been democratized, with the participation of millions of people who produce, trade and consume energy in market structures that are fit for purpose.

There is now universal access to energy services, enabled by affordable, reliable, sustainable and modern energy sources. While the early phases of the transition were somewhat tumultuous, ultimately a fair and just transition was achieved. Societies are thriving as a result.

The future beyond 2050 looks bright, despite the challenges of our changing climate. The global energy system is decarbonized, resilient and efficient, providing the necessary services for further economic development for inclusive societies. Human welfare has improved, most notably health outcomes as air pollution from fossil fuel combustion has dramatically decreased.

SYSTEM TRANSFORMATION SUMMARY

In energy, decarbonization occurs through aggressive efficiency measures, a mass expansion of renewables, electrification of end-use sectors and a shift from fossil to zero emission liquid and gaseous fuels. Ensuring the resilience of energy systems is also a key priority. Decarbonization of the power system is already occurring in most locations due to the shift to a renewables-based power system, but this must accelerate. End-use sectors see greater electrification as the primary decarbonization route, for example in road transport and heating/cooling, with a supplementary role for green hydrogen and other zero emission technologies. Structural change occurs within the fossil fuel industries. Coal power is being phased out and there are drastic reductions in oil and gas use, with replacement by zero-emission fuels, for example in long-haul, heavy-duty transport.

For decarbonized power, the pathway to zero is clear. A mass expansion of renewable power enables increased electrification of end use sectors. Increased integration of high proportions of renewables is enabled by greater grid flexibility through technology and market solutions, along with investment in infrastructure and continuous innovation. The sector is critical for the energy transition - in 2019, emissions from power were 14Gt CO2, making up 40 per cent of global carbon emissions[1].

Progress is under way in the transition to renewable power – renewables have made up the majority of capacity additions for the last eight years[2]. Many renewable energy technologies are mature and costs have tumbled with increased deployment in the last decade. Renewables are now cheaper to build than fossil fuel power plants in 85 per cent of the world[3]. But renewables deployment needs to accelerate further, by a factor of five to six, on latest estimates[4]. The exponential rate of change seen in wind and solar technologies shows that this is possible; growth in generation from these technologies is already on Paris-compliant trajectories[5] (see "S curves" in facts & figures below).

In **finance**, renewable energy projects are now mainstream, but project pipelines need to be scaled up and financial flows need to increase, including to developing countries. **Policy** measures to facilitate renewables must be further improved, including by setting clear and ambitious targets for deployment, implementing "investment grade" enabling frameworks to facilitate access to markets (including renewable power auctions for mature technologies) and enabling enhanced grid flexibility and investment. **Technology providers** should continue to innovate to reduce the cost and environmental footprint of key renewable technologies. **Businesses** can increase demand for renewables by committing to source 100 per cent renewable energy and set targets for reduced intensity of their operations. **Civil society** can support deployment through advocacy efforts and raising public awareness of the benefits of renewable energy.

1 IEA, "World Energy Outlook 2020"
2 IRENA, "Global Renewables Outlook 2020"
3 Bloomberg New Energy Finance, "Scale-up of Solar and Wind Puts Existing Coal, Gas at Risk"
4 Energy Transition Commission, "Making Mission Possible"
5 Grub et al, "Shape & Pace of Change in The Electricity Transition: Sectoral Dynamics & Indicators of Progress"

By 2030, the industry should aim to **achieve at least 60 per cent renewable energy share in power generation**[6], up from 26 per cent in 2019. Within the decade, the tipping point to an entirely decarbonized power system must be passed and the next 10 years should focus on increased deployment towards achieving a global decarbonized power system in the 2040s.

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°C; 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 can reach 60 per cent by 2050, driven by 2030 milestones of 20 per cent in passenger vehicles, 50 per cent in buildings, and 30 per cent in industry and heavy transport.[7]

Progress remains too slow to achieve these milestones; mass deployment of new and smarter end-use technologies – like smart water heaters, high-efficiency pumps, and electric vehicles – must be accompanied by investment in enabling infrastructure and improved **policy**. **Electricity system regulators** at regional and national levels bear responsibility for rapidly evolving market designs to support resilient, smart, renewables-electrified economies.

Green hydrogen produced from renewable electricity and its derivatives must meet the bulk of the remaining needs 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 and learning by doing that builds on a foundation of state-funded innovation. The same will be true in hydrogen - but in 10 years, not 30 - by harnessing the resulting cost reduction "learning" curves to realize exponential growth. Public and private procurement processes, consumer-demanded commodities transparency, businesses' appetite for market growth, national strategies for industrial development, labour unions' pursuit of high-quality job opportunities, and citizens' preferences for clean air drive accelerated information, skills, and technology diffusion to support such critical scale-up of green hydrogen markets.

By 2030, responding to those demands, businesses, investors, civil society and international policymakers must work together to rapidly **expand green hydrogen deployment.** This means over the next five to six years, at least 25 Gigawatts (GW) capacity and USD 100 billion should be deployed, leveraging concessional funding and catalytic subsidies**;** pre-competitive collaboration to industrialize supply chains, develop business and financial models, expand infrastructure, align technical and safety standards, and inform integrated market structures; and the rapid transmission of policy best practices between regions and countries. This will enable market development in the

[6] IRENA, "Global Renewables Outlook 2020", IEA, "World Energy Outlook 2020"
[7] Rocky Mountain Institute, "Seven Challenges for Energy Transformation"

order of **300 GW deployment, USD 600 billion investment, and 500,000 jobs by 2030 to be on a climate-aligned pathway**.[8]

For the fossil fuel industry, structural change is needed to address the decarbonization challenge, and progress to date has been limited. CO2 emissions from fossil fuels totalled 33Gt in 2019. Alternatives to fossil fuels already exist in some areas (e.g. renewables for coal power, electric vehicles for internal combustion engines), for which deployment needs to be increased. However, further research and development or demonstration is needed in other areas (e.g. sustainable aviation and shipping fuels, industrial heat). Oil and gas sectors are challenging to decarbonize, given widespread use, and require cross-value chain collaboration in hard to abate sectors. Fossil fuel production needs to decrease and business models of fossil fuel firms needs to change – operational efficiency measures can reduce emissions, but new technologies and business models are needed for full decarbonization.

Policy must support decarbonization of the fossil fuel sector, by halting investment in new fossil fuel exploration and development, setting carbon pricing, phasing out fossil fuel subsidies, reducing fossil fuel demand (e.g. coal power and international combustion engine phase out dates), restricting fossil fuel infrastructure, planning for and supporting economic diversification in producing countries and supporting a just transition for workers and communities. In **business,** no new unabated coal-fired power plants should be built after 2020. Oil and gas end users must signal the desire to transition from fossil fuels to sustainable alternatives, encouraging oil and gas companies to make commitments to net zero and transitioning to low-carbon business models. Within the **financial community,** investors must make commitments to invest in energy transition assets and infrastructure and reallocate capital and bank lending to 1.5°C trajectories, given the risks of high-carbon investments, including stranded assets. **Civil society** has a role in advocating for decarbonization and ensuring a just transition for workers and communities.

By 2030, developed countries should have **phased out coal power** and **oil and gas companies should have made significant progress in their zero-carbon transitions**, with oil and gas production down by 25-40 per cent compared to 2019[9].

This pathway should be read in conjunction with other relevant thematic pathways, such as transport, human settlements, oceans, water and industry.

[8] Hydrogen Council, "Path to Hydrogen Competitiveness"; Energy Transitions Commission, "Making Mission Possible"; and IRENA, "Hydrogen from Renewable Power"; and IEA, "Sustainable Recovery".
[9] Carbon Tracker, "Breaking The Habit"

MILESTONES TOWARDS 2050

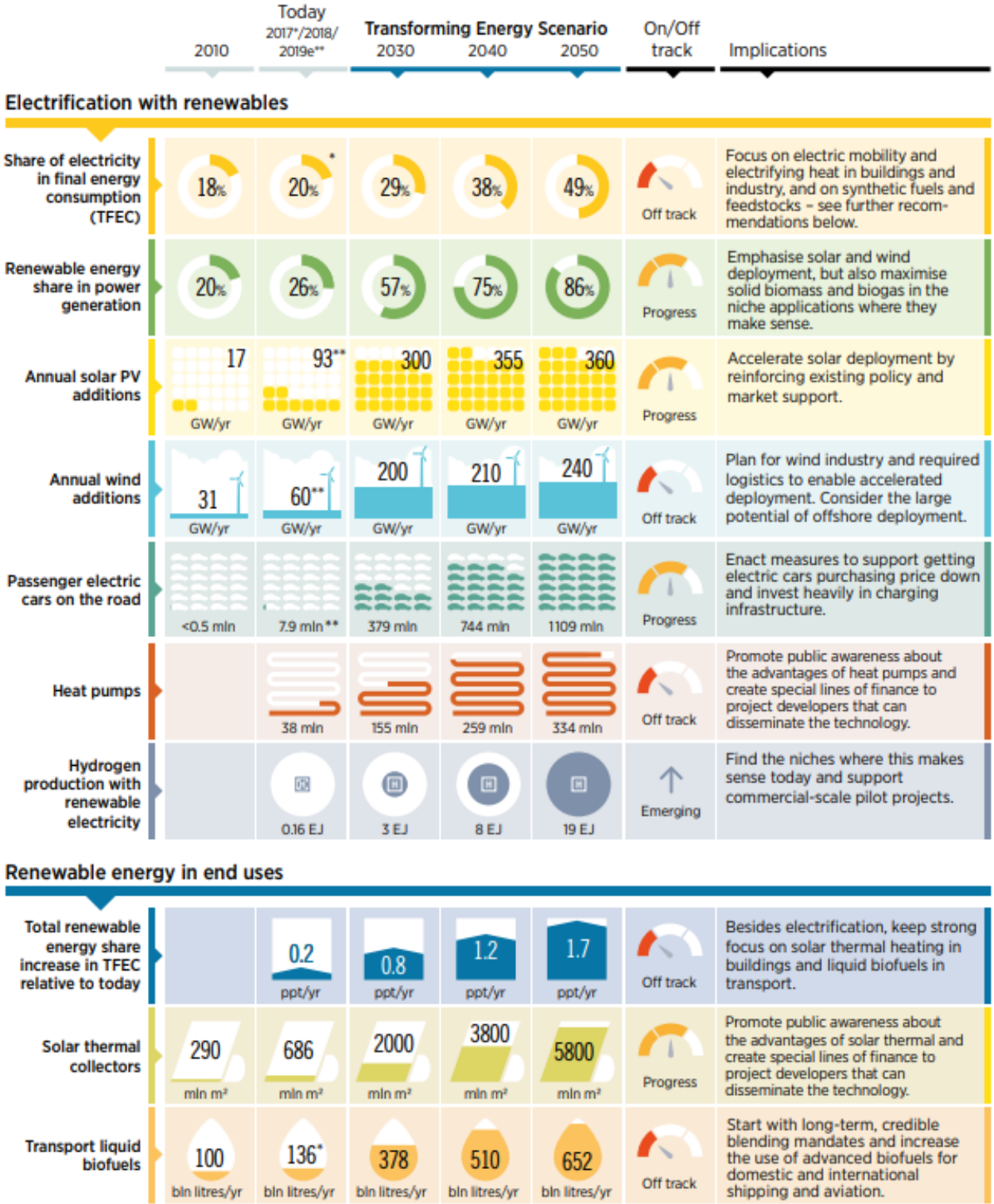
	By 2021	By 2025	By 2030	By 2040
Decarbonized Power	• 90 utilities and developers adopt verified net-zero commitments aligned to 1.5°C	• 100 countries have targets for 100% clean power	• At least 60 per cent global renewable energy share in power generation • All people have access to affordable, reliable, sustainable electricity	• Global decarbonized power system in the 2040s
Sectoral Integration	• Majority of new COVID-19 recovery funding supports efficiency, demonstration and deployment of smart technologies	• Green hydrogen 25 GW capacity under construction, achieving $1.5/kg, with investment of at least USD 100 billion	• Green hydrogen deployment of 200 GW capacity, achieving <$1.5/kg and cumulative investment of USD 1 trillion • All people have access to affordable, reliable, sustainable and modern energy	• Green hydrogen and innovative production routes are mature and mainstreamed
Fossil Fuel Structural Change	• No new coal power plants are being approved anywhere in the world • 8 major oil and gas companies adopt verified net-zero commitments aligned to 1.5°C	• The world's coal pipeline has dried out because of lack of economic competitiveness • All major oil and gas companies have verified net-zero commitments	• All OECD countries have successfully phased out coal in their power sectors and emerging economies are well advanced in their phase out plans • Oil and gas companies have made significant progress in their transition strategies	• Major emitters have phased out coal power • Other developing countries are well advanced in their coal phase out strategies and have started to implement just transition strategies

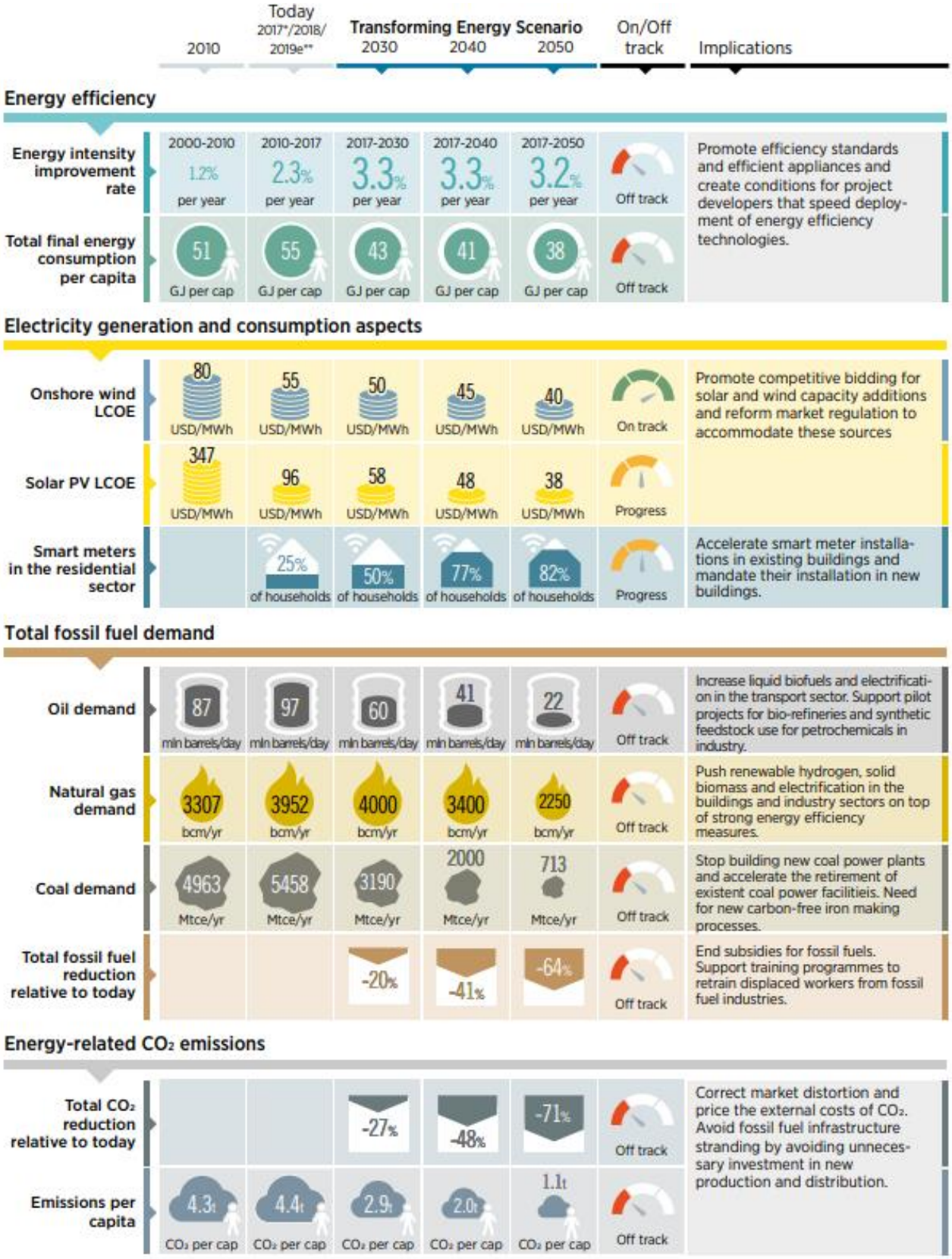
PROGRESS

Overall, the energy transition to a decarbonized system has begun, but much greater progress must be made to get on track for a 1.5°C pathway. The infographic below provides a visual representation of progress, based on key elements of IRENA's "Transforming Energy Scenario".

Progress has been made in recent years in decarbonizing power through renewable energy deployment, with increased capacity additions and significant cost reductions. Greater progress must be made in end-use sectors, including via energy efficiency, direct renewable energy use, electrification and deployment of technologies such as heat pumps and electric vehicles. Structural change is needed in the fossil fuel sector, including development and deployment of alternative

technologies to meet demand, and retirement/avoidance of fossil fuel infrastructure, such as coal power plants.



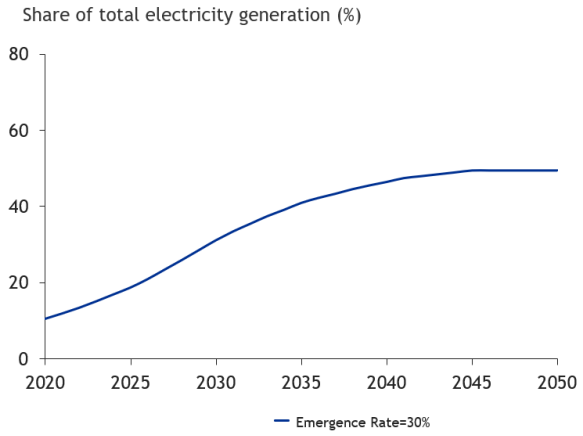

2010
Today 2017*/2018/ 2019e**
Transforming Energy Scenario 2030 2040 2050
On/Off track
Implications
Energy efficiency
Energy intensity improvement rate
2000-2010 1.2% per year
2010-2017 2.3% per year
2017-2030 3.3% per year
2017-2040 3.3% per year
2017-2050 3.2% per year
Off track
Total final energy consumption per capita
51 GJ per cap
55 GJ per cap
43 GJ per cap
41 GJ per cap
38 GJ per cap
Off track
Promote efficiency standards and efficient appliances and create conditions for project developers that speed deployment of energy efficiency technologies.
Electricity generation and consumption aspects
Onshore wind LCOE
80 USD/MWh
55 USD/MWh
50 USD/MWh
45 USD/MWh
40 USD/MWh
On track
Solar PV LCOE
347 USD/MWh
96 USD/MWh
58 USD/MWh
48 USD/MWh
38 USD/MWh
Progress
Promote competitive bidding for solar and wind capacity additions and reform market regulation to accommodate these sources
Smart meters in the residential sector
25% of households
50% of households
77% of households
82% of households
Progress
Accelerate smart meter installations in existing buildings and mandate their installation in new buildings.
Total fossil fuel demand
Oil demand
87 mln barrels/day
97 mln barrels/day
60 mln barrels/day
41 mln barrels/day
22 mln barrels/day
Off track
Increase liquid biofuels and electrification in the transport sector. Support pilot projects for bio-refineries and synthetic feedstock use for petrochemicals in industry.
Natural gas demand
3307 bcm/yr
3952 bcm/yr
4000 bcm/yr
3400 bcm/yr
2250 bcm/yr
Off track
Push renewable hydrogen, solid biomass and electrification in the buildings and industry sectors on top of strong energy efficiency measures.
Coal demand
4963 Mtce/yr
5458 Mtce/yr
3190 Mtce/yr
2000 Mtce/yr
713 Mtce/yr
Off track
Stop building new coal power plants and accelerate the retirement of existent coal power facilitieis. Need for new carbon-free iron making processes.
Total fossil fuel reduction relative to today
-20%
-41%
-64%
Off track
End subsidies for fossil fuels. Support training programmes to retrain displaced workers from fossil fuel industries.
Energy-related CO2 emissions
Total CO2 reduction relative to today
-27%
-48%
-71%
Off track
Emissions per capita
4.3t CO2 per cap
4.4t CO2 per cap
2.9t CO2 per cap
2.0t CO2 per cap
1.1t CO2 per cap
Off track
Correct market distortion and price the external costs of CO2. Avoid fossil fuel infrastructure stranding by avoiding unnecessary investment in new production and distribution.

FACTS & FIGURES

History has shown that sectoral transformations, whether they be horse-and-cart to automobile, coal power to gas or adoption of telecommunication technologies, do not occur linearly, but rather slowly in an emergence phase, and then exponentially in a diffusion phase. This dynamic process can be captured in an "S-curve". S-curves in green hydrogen and renewable electricity are presented below and covered in further detail in the respective Action Tables.

Wind & Solar PV electricity generation

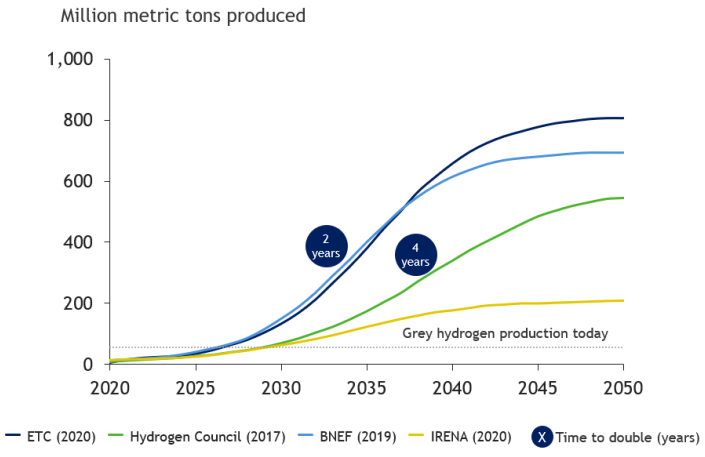
For alignment with a 1.5-degree trajectory, 30% share of solar and wind in electricity required by 2030, or 60% share of all renewables



Note: Based on a smoothed sigmoid curve forced to 100% at the end given the starting point.
Source: High Level Champions 2020, based on Grub et al, 'The Shape and Pace of Change in The Electricity Transitions' 2020

Green hydrogen global production

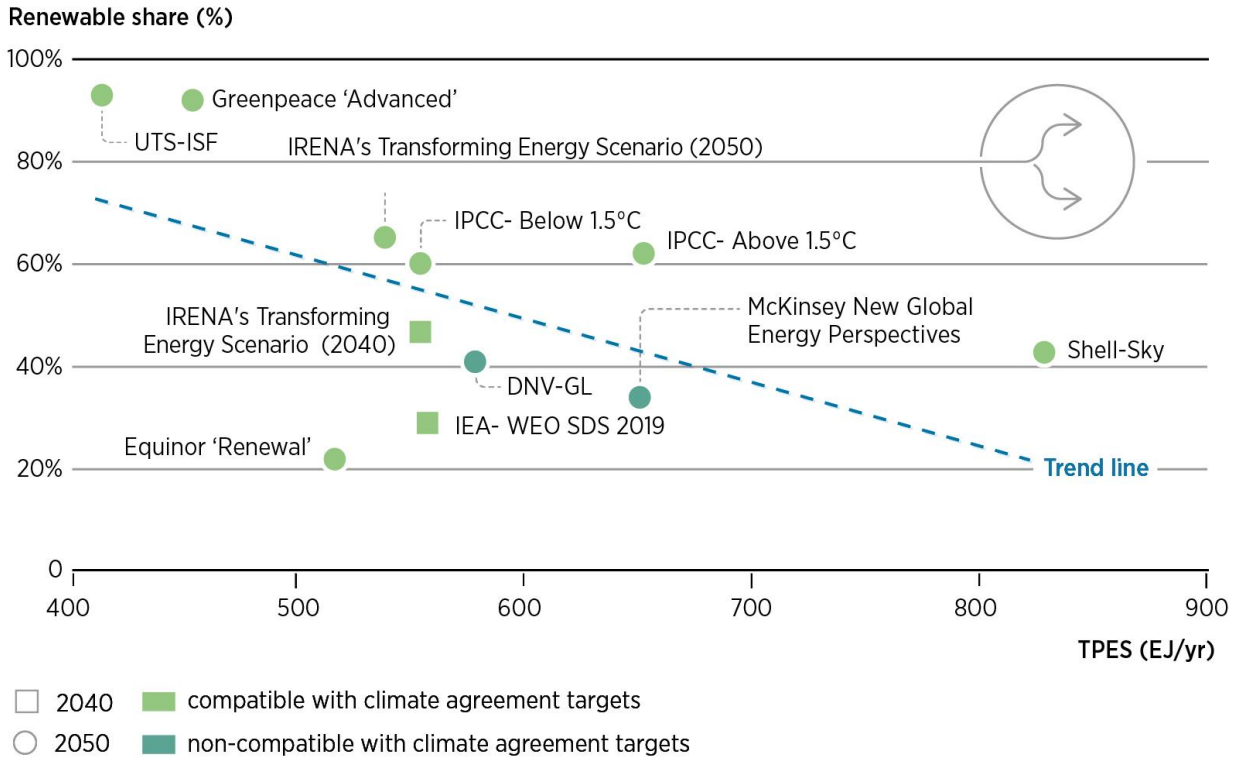
For alignment with a 1.5-degree trajectory of 200-800 million tons by 2050, at least 300 GW of green hydrogen production capacity needs to be deployed by 2030



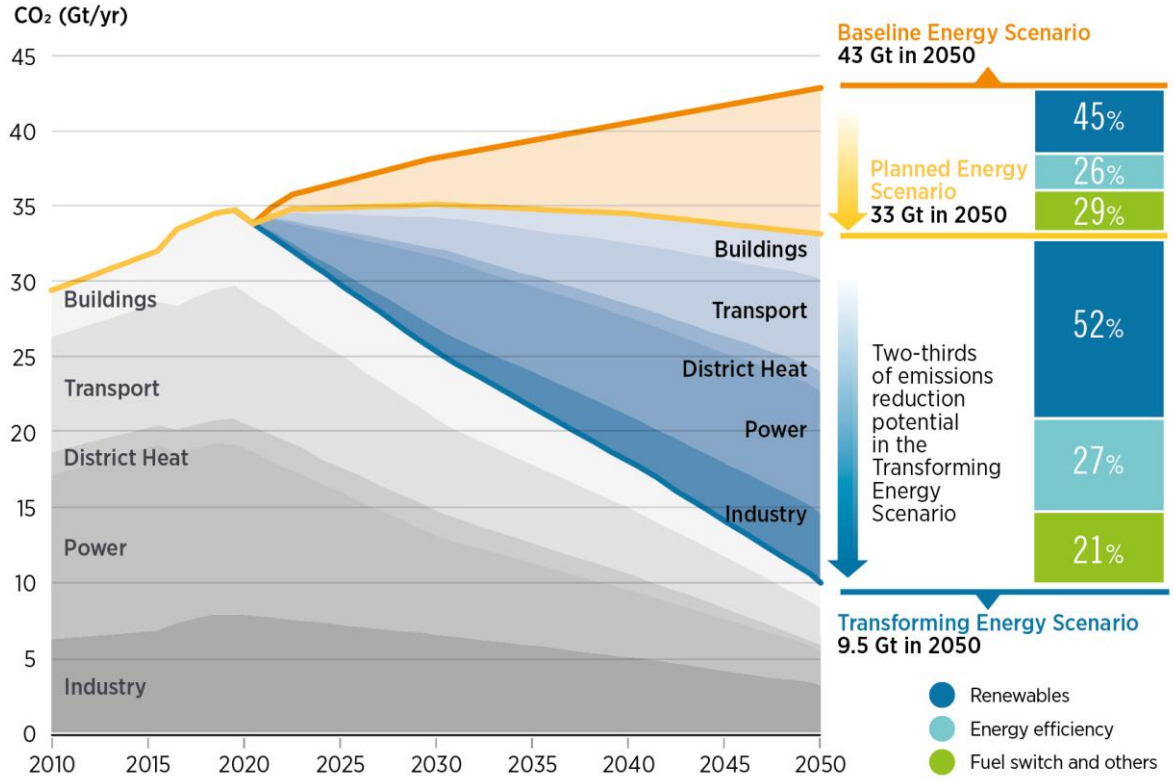
Note: Based on a smoothed sigmoid curve forced to 100% at the end given the starting point.
Source: High Level Champions, 2020

EMERGING CONSENSUS ON THE ROLE OF RENEWABLE POWER (IRENA, GLOBAL RENEWABLES OUTLOOK: ENERGY TRANSFORMATION 2050)

SHARES OF RENEWABLES IN TOTAL PRIMARY ENERGY IN 2040 AND 2050 IN VARIOUS CLIMATE SCENARIOS



THE BULK OF EMISSION REDUCTIONS: RENEWABLES AND EFFICIENCY (IRENA, GLOBAL RENEWABLES OUTLOOK: ENERGY TRANSFORMATION 2050)



KNOWLEDGE BASE

The key sources listed below were used to inform the present document:

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- Rocky Mountain Institute, Seven Challenges for Energy Transformation (2019).

CLIMATE ACTION TABLE - STRUCTURE

This executive summary should be read together with the more detailed Energy Action Tables. The tables outline, across key milestones of 2021, 2025, 2030 and 2040, the actions key actors should take in order to achieve an energy transition consistent with 1.5°C.

The diagram below shows the structure of the Energy Action Tables, which are split into three sub-sectors (dark blue boxes) and five impact areas (light blue boxes).