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Limiting Global Warming: Energy

Warming cannot be limited to well below 2°C without rapid and deep emissions reductions from the energy system and substantial changes over the next 30 years. This will involve a significant reduction in overall fossil fuel use, use of carbon capture and storage, low- or no-carbon energy systems, widespread electrification, use of alternative fuels such as hydrogen and sustainable biofuels, and improved energy efficiency.

THE BIG PICTURE

Emissions from fossil fuels:

34%
of all emissions come from the energy sector (2019)

Demand for energy continues to rise
with energy emissions growing by 2.7%

CH_4

18%
Overall, methane accounted for 18% of all emissions in 2019 – these are mainly fugitive emissions from oil, gas, and coal. That is, greenhouse gases released during the exploration, processing and delivery of fossil fuels to the point of final use.

Coal Gas Oil

7.5%
Growth in coal electricity capacity
Growth in building of new coal-fired power plants increased in some countries, offsetting the decline in others.

15%
increase in consumption of natural gas

5%
increase in consumption of oil and oil products

Low and zero carbon energy sources:

Fuels
37%
of global electricity (2019)

8-10%
Growth in low and zero carbon power

16%
Comes from hydroelectric power (2019)

10%
comes from nuclear

10%
of primary energy is from bioenergy

8%
of all electricity comes from solar and wind

WHAT HAS BEEN ACHIEVED?

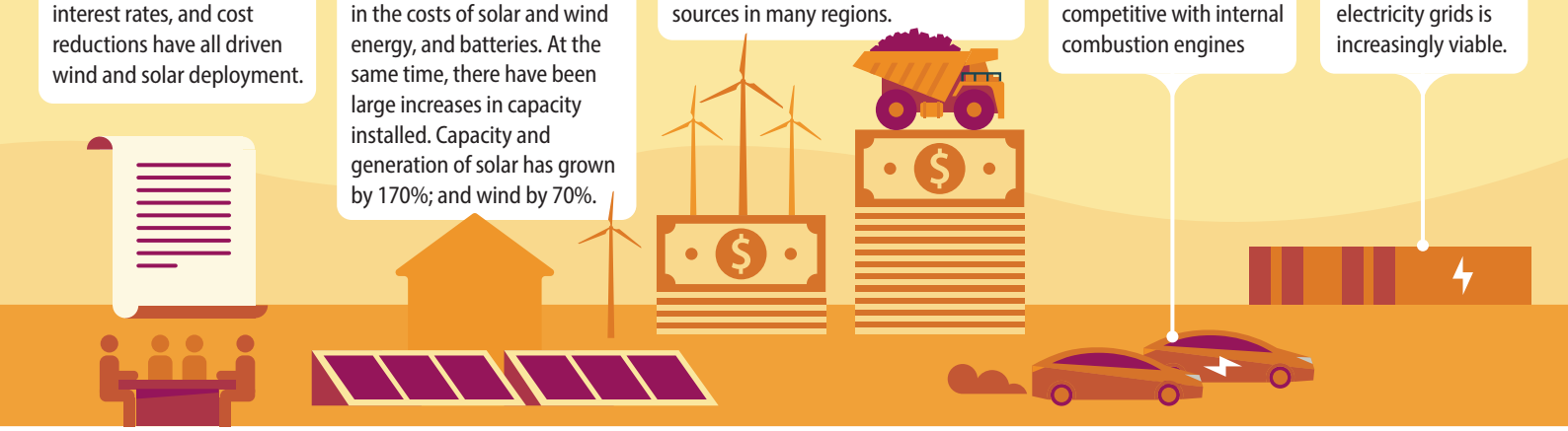
Policy, societal pressure to limit fossil generation, low interest rates, and cost reductions have all driven wind and solar deployment.

Since 2010, there have been sustained decreases of up to 85% in the costs of solar and wind energy, and batteries. At the same time, there have been large increases in capacity installed. Capacity and generation of solar has grown by 170%; and wind by 70%.

Electricity from solar and wind is now cheaper than electricity from fossil sources in many regions.

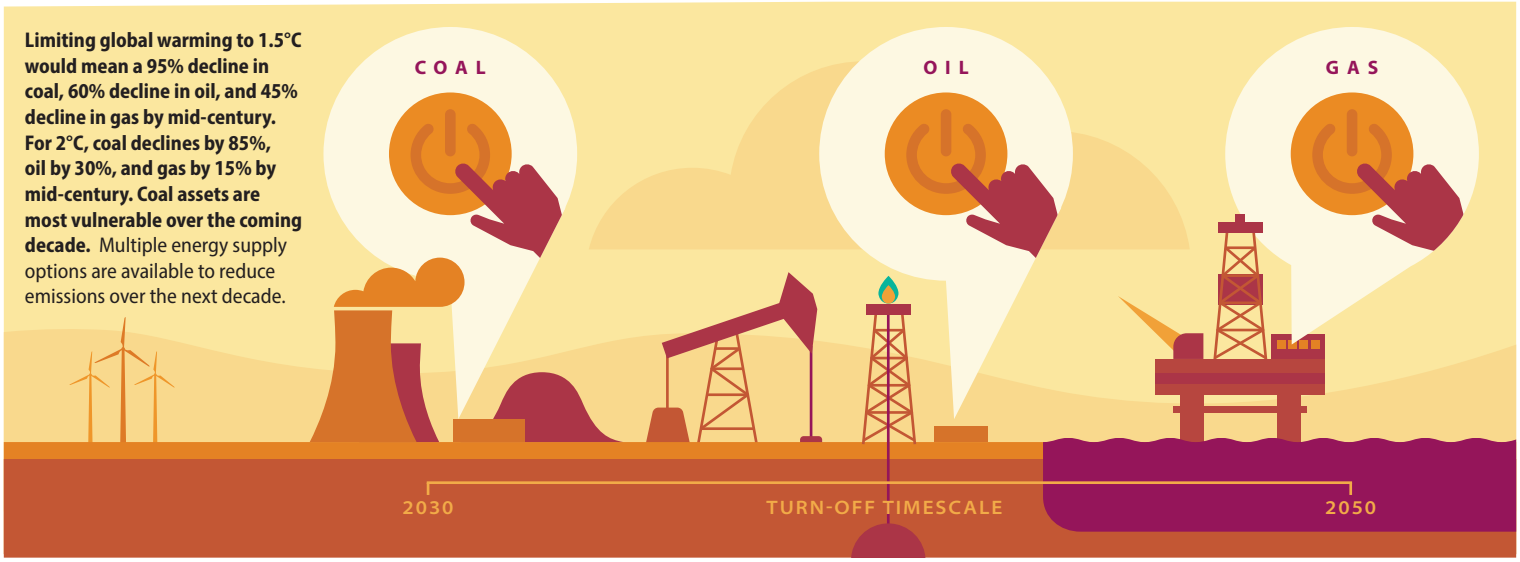
Electric vehicles are becoming increasingly competitive with internal combustion engines

Large-scale battery storage on electricity grids is increasingly viable.



WHAT THE FUTURE LOOKS LIKE

Limiting global warming to 1.5°C would mean a 95% decline in coal, 60% decline in oil, and 45% decline in gas by mid-century. For 2°C, coal declines by 85%, oil by 30%, and gas by 15% by mid-century. Coal assets are most vulnerable over the coming decade. Multiple energy supply options are available to reduce emissions over the next decade.



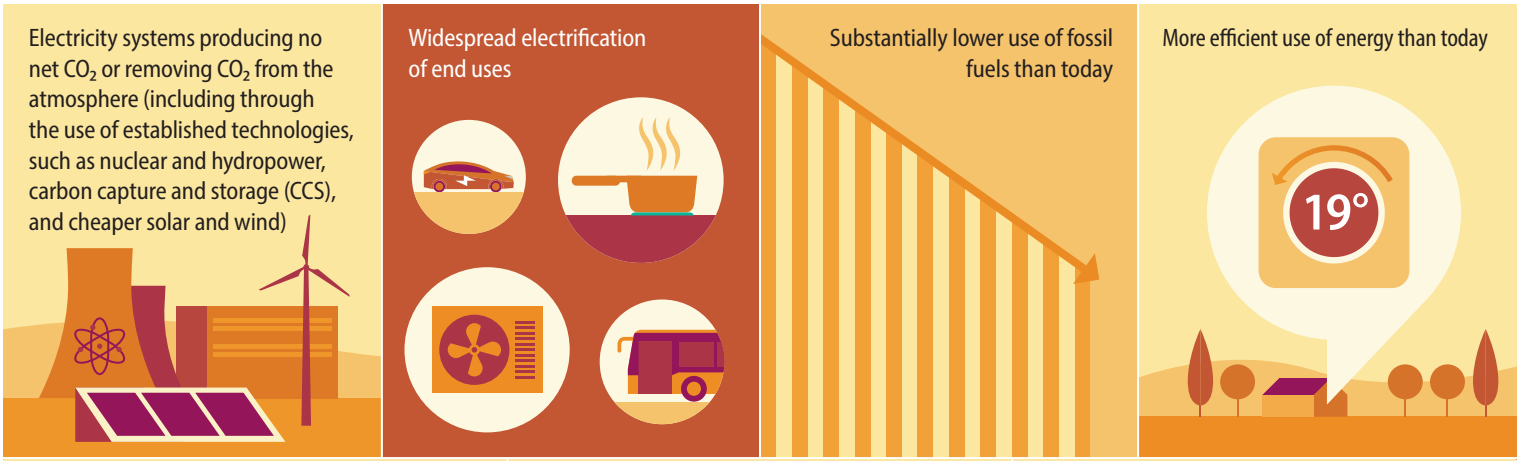
WHAT CAN BE DONE — NET ZERO ENERGY SYSTEMS

Electricity systems producing no net CO_2 or removing CO_2 from the atmosphere (including through the use of established technologies, such as nuclear and hydropower, carbon capture and storage (CCS), and cheaper solar and wind)

Widespread electrification of end uses

Substantially lower use of fossil fuels than today

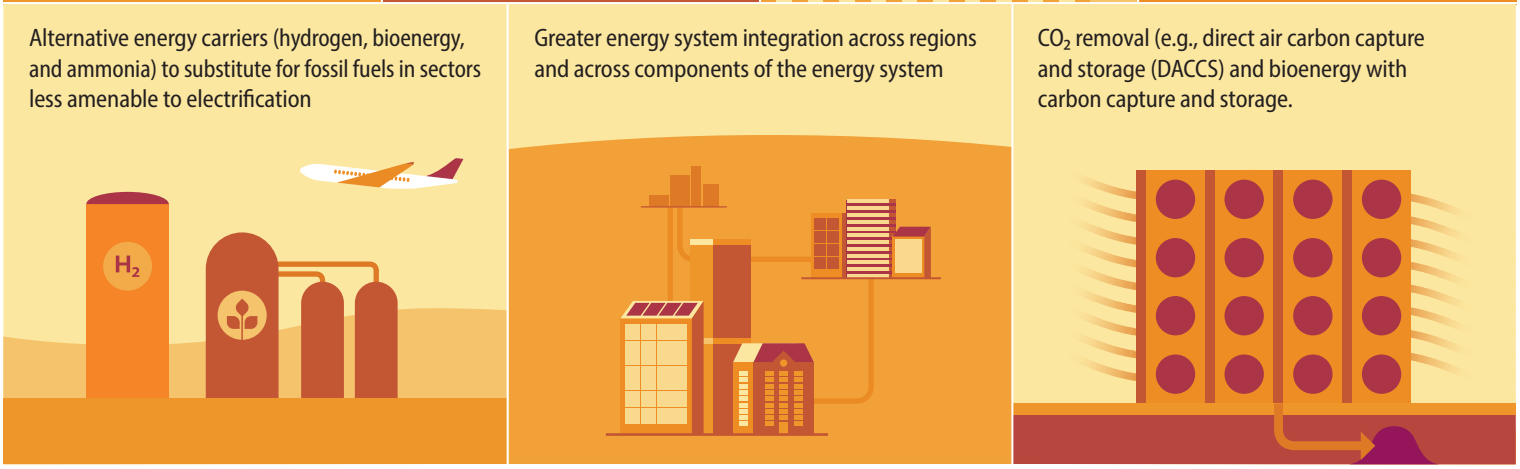
More efficient use of energy than today



Alternative energy carriers (hydrogen, bioenergy, and ammonia) to substitute for fossil fuels in sectors less amenable to electrification

Greater energy system integration across regions and across components of the energy system

CO_2 removal (e.g., direct air carbon capture and storage (DACCS) and bioenergy with carbon capture and storage.



ENABLERS, BENEFITS AND OPPORTUNITIES

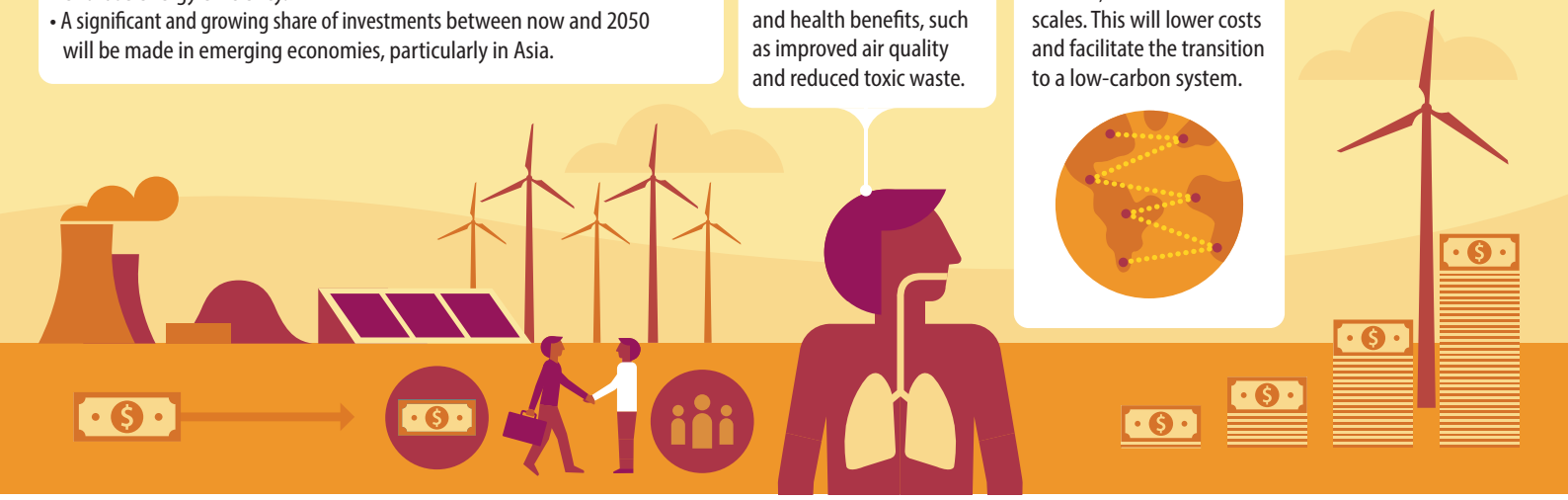
Finance and investment: A low-carbon energy transition will shift investment patterns and create **new economic opportunities.**

- To likely limit warming to 2°C or below, total **energy investment needs will rise,** relative to today, over the next decades.
- These increases will be far less pronounced than the reallocations of investment flows. Reallocations of investment will be away from fossil fuels (extraction, conversion, and electricity generation) without CCS and toward renewables, nuclear power, CCS, electricity networks and storage, and end-use energy efficiency.
- A significant and growing share of investments between now and 2050 will be made in emerging economies, particularly in Asia.

Several mitigation options are technically viable, are becoming increasingly cost effective, and are generally supported by the public. This enables deployment in many regions. Some options have other environmental and health benefits, such as improved air quality and reduced toxic waste.

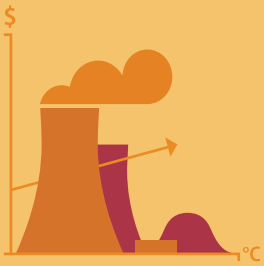
Greater integration between the electricity sector and end use sectors can facilitate integration of variable renewable energy (VRE) options. Energy systems can be integrated across district, regional, national, and international scales. This will lower costs and facilitate the transition to a low-carbon system.

The economic outcomes of low-carbon transitions in some sectors and regions may be on a par with, or superior to those of an emissions-intensive future.

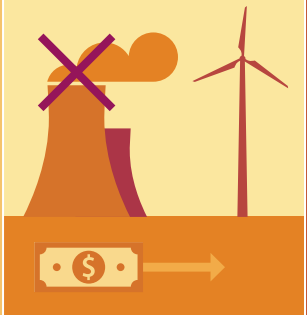


BARRIERS

If investments in coal and other fossil infrastructure continue, energy systems will be locked in to higher emissions, making it harder to limit warming to well below 2°C.



New investments in coal-fired electricity without CCS are inconsistent with limiting warming to well below 2°C.



Resistance or slow to change aspects of the energy system, e.g. physical infrastructure; institutions, laws, and regulations; and behaviour.

Environmental impacts associated with some mitigation options require managing, such as large scare use of battery storage.

Institutional barriers need to be addressed to enable application of mitigation options at scale.

CHALLENGES

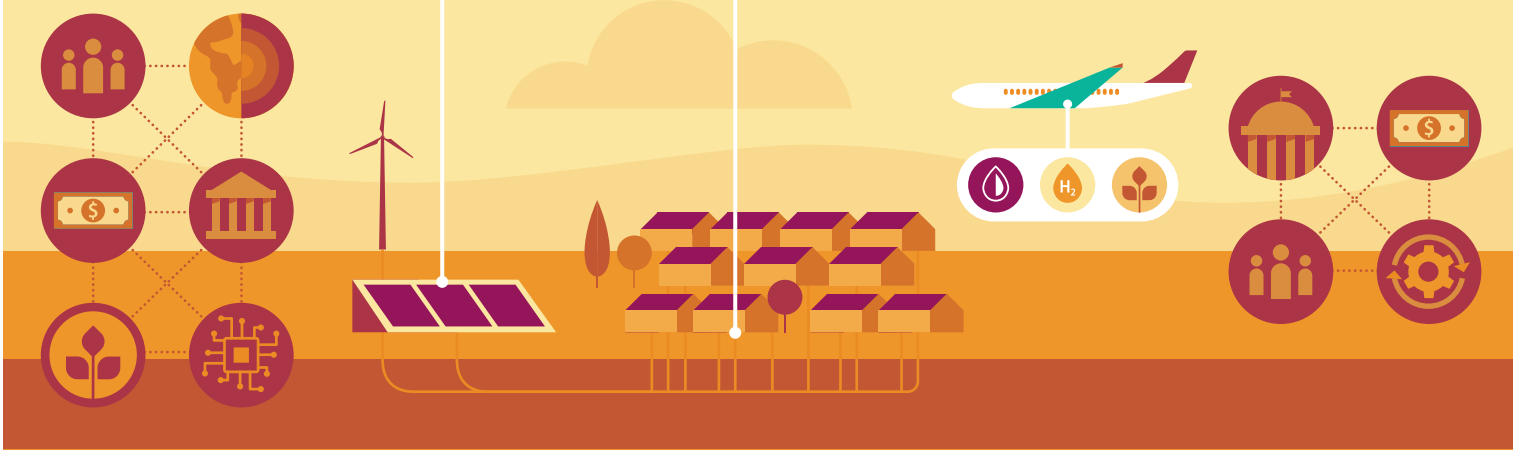
Need to address the geophysical, environmental-ecological, economic, technological, socio-cultural, and institutional factors that can facilitate or hinder implementation of low or no carbon options.

Electricity systems powered by renewables are becoming increasingly viable, but it will be challenging to supply the entire energy system in this way.

Majority of solar and wind power can be incorporated in electricity grids through batteries, hydrogen, and other forms of storage/transmission.

Since some applications (e.g., air travel) are not currently amenable to electrification, net zero energy systems would likely need to include alternative fuels such as hydrogen or biofuels.

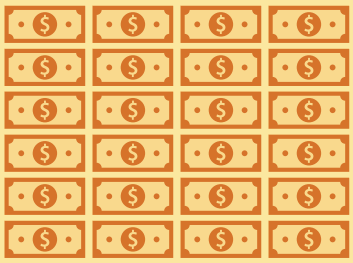
Higher shares of renewable electricity and energy are associated with increased economic, regulatory, social, and operational challenges. How to overcome all of these challenges in practice is not yet fully understood.



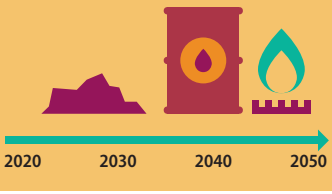
TRADE-OFFS

Limiting warming to well below 2°C will strand fossil-related assets, including fossil infrastructure and unburned fossil fuel resources.

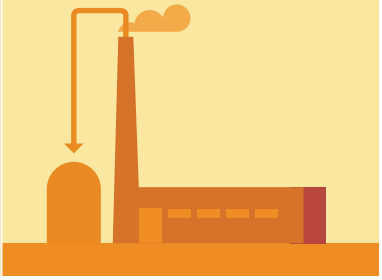
The economic impact of stranded assets could amount to trillions of dollars.



Coal assets are most vulnerable over the coming decade; oil and gas assets are more vulnerable toward mid-century.

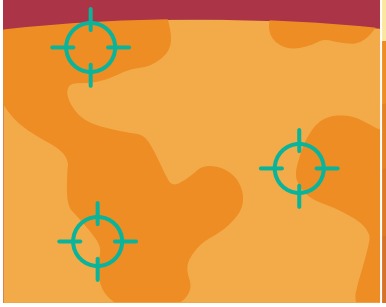


CCS can allow fossil fuels to be used longer, reducing potential stranded assets.

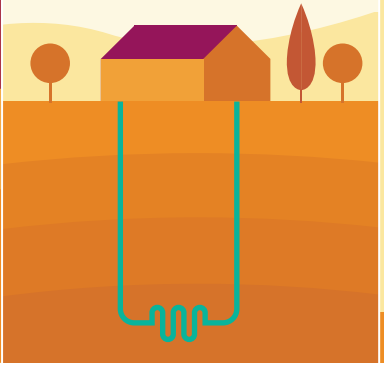


FEASIBILITY OF MITIGATION OPTIONS VARIES ACCORDING TO CONTEXT AND TIME

Feasibility of large-scale land-use changes varies across regions

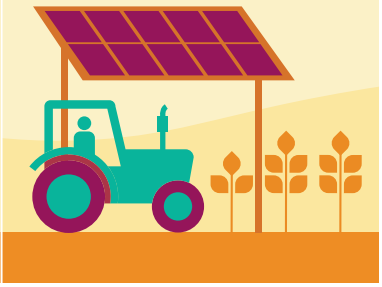


The potential of geothermal is site specific



Deployment of solar and wind energy has been assessed to become increasingly feasible over time

The feasibility of some options can increase when combined or integrated, e.g. using land for both agriculture and centralised solar production.



LINKAGES

International trade: A low-carbon energy sector transition is expected to reduce international trade in fossil fuels. There may be trade in other types of energy (such as hydrogen) and large-scale bioenergy production is likely to trigger global biomass trade.

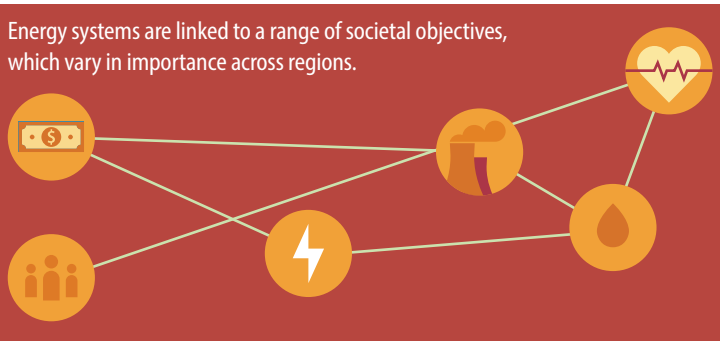
Transport: Electric vehicles powered by low-emissions electricity offer the largest decarbonisation potential for land-based transport, on a life cycle basis.

Buildings: 61% of emissions from buildings could be mitigated by 2050. 10% from **Sufficiency policies** (set of measures and daily practices that avoid demand for energy, materials, land and water while delivering human wellbeing for all within planetary boundaries); 42% from **energy efficiency** policies; 9% from **renewable energy** policies.

SUSTAINABLE DEVELOPMENT

The viable speed and scope of a low-carbon energy system transition will depend on how well it can support sustainable development goals and other societal objectives.

Energy systems are linked to a range of societal objectives, which vary in importance across regions.



Energy sector mitigation and efforts to achieve SDGs generally support one another, though there are important region-specific exceptions.

As an example, Electrification combined with low-GHG energy, and shifts to public transport can enhance health, employment, and can elicit energy security and deliver equity.

KNOWLEDGE GAPS AND ADVANCES REQUIRED

Long-term mitigation costs are not well understood and depend on policy design and implementation, and the future costs and availability of technologies.

Advances in low-carbon energy resources and carriers such as next-generation biofuels, hydrogen produced from electrolysis, synthetic fuels, and carbon-neutral ammonia would substantially improve the economics of net-zero energy systems.

To read full AR6 Working Group III report, please visit www.ipcc.ch/report/ar6/wg3

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