IRENA
International Renewable Energy Agency

REACHING ZERO WITH RENEWABLES

Eliminating CO_2 emissions in industry and transport

PREVIEW

REACHING ZERO WITH RENEWABLES:

Eliminating CO_2 emissions in industry and transport

Limiting the global average temperature rise to 1.5-degrees-C will require all sectors of the economy to reach zero carbon dioxide (CO_2) emissions early in the second half of this century. Doing so will be very challenging, particularly in some key industry and transport sectors. Options that deliver only partial emission reductions will not be sufficient; the focus of policy makers and industry investors must unerringly be on a pathway that progressively scales up those few options that are consistent with reaching the zero-emission goal. Most of those options rely on renewable.

Four of the most energy-intensive industries and three key transport sectors stand out as the hardest to decarbonise. Together, those seven sectors could account for 38% of energy and process emissions and 29% of final energy use by 2050 unless major policy changes are pursued now.

Energy-intensive industrial sectors

Iron and steel

In 2017:

- Consumed 32 exajoules (EJ) of energy
- Only 4% was from renewables
- Emitted 3.1 gigatonnes (Gt) of CO_2

Chemicals and petro-chemicals

In 2017:

- Consumed 46.8 EJ of energy
- Only 3% was from renewables
- Emitted 1.7 Gt of CO_2

Cement and lime

In 2017:

- Consumed 15.6 EJ of energy
- Only 6% was from renewables
- Emitted 2.5 Gt of CO_2

Aluminium

In 2017:

- Consumed 4.5 EJ of energy
- 16% was from renewables
- Emitted 0.4 Gt of CO_2

Energy-intensive freight & long-haul transport sectors

Road freight

In 2017:

- Consumed 32.3 EJ of energy
- Only 1.5% was from renewables
- Emitted 2.3 Gt of CO_2

Aviation

In 2017:

- Consumed 13.5 EJ of energy
- A negligible share was from renewables
- Emitted 0.9 Gt of CO_2

Shipping

In 2017:

- Consumed 11.3 EJ of energy
- A negligible share was from renewables
- Emitted 0.9 Gt of CO_2

IRENA's *Reaching zero with renewables report* has a twin focus: examining how the world could achieve zero emissions in key industry and transport sectors by around 2060, and assessing the potential role of renewables-based technologies in doing so. This report will serve as a starting point for the more comprehensive and informed discussions that are needed among policy makers, industry investors and other stakeholders.

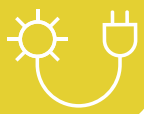
Progress in these sectors has been limited to date, but in recent years two things have changed that should allow for far more rapid reductions in emissions. Firstly, there is strong and widening societal recognition, and increasing political consensus, on the need for all sectors to make deep cuts in carbon emissions, despite the challenges in doing so. Secondly, the rapid decline in the costs of renewables over the past decade, and the future potential for further cost reductions and scaling, opens up options for the use of renewable energy that were previously dismissed. Renewable energy, and some enabling technologies such as batteries, are now proven and increasingly affordable options in all countries and in many applications. As this report shows there is a high potential for renewables use, much more than previous analysis has identified. The use of renewables both for energy and for feedstocks will therefore be central to the pathway to zero emissions.

Renewables together with demand reduction and energy efficiency could account for over 80% of the CO_2 emission reductions needed across seven key industry and transport sectors.

A small number of solutions are available for each of these sectors (as summarised on pages 3 and 4 and explored in full in the main report). These are built around five key emission reduction measures.

Reduced demand and improved energy efficiency

Direct use of clean electricity – predominantly produced from renewable sources

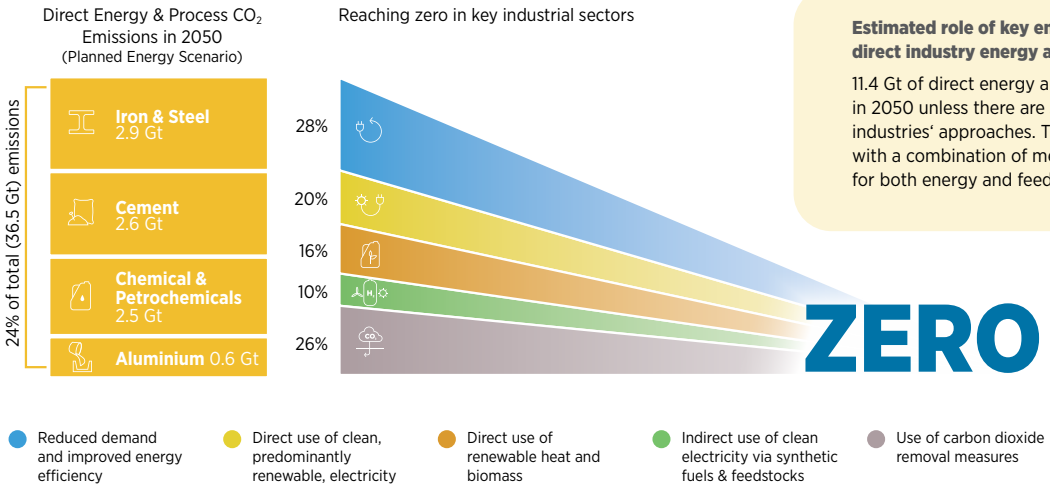


Direct use of renewable heat and biomass – including solar thermal, geothermal, biofuels and bio-feedstocks

Indirect use of clean electricity via synthetic fuels and feedstocks – predominantly using renewable electricity

Use of carbon dioxide removal measures – including carbon capture, utilisation and/or storage (CCUS)

Energy-intensive industries: Options for reaching zero



Estimated role of key emission reduction measures to reduce direct industry energy and process emissions to zero

11.4 Gt of direct energy and process emissions will be produced in 2050 unless there are significant changes in policies and in the industries' approaches. Those emissions can be reduced to zero with a combination of measures – most of which utilise renewables for both energy and feedstocks.

2 options compatible with reaching zero emissions for iron and steel

Hydrogen-based direct reduction of iron and electric arc furnace-based steel production

- Produce iron via the direct reduction process using clean, preferably green, hydrogen as a reducing agent.
- Produce steel using electric arc furnaces.
- Source all heat and electricity inputs from renewables.

Capturing and storing process and waste emissions, and using renewables for energy

- Apply CCUS to existing iron and steel production processes.
- Source all heat and electricity inputs from renewables.

3 options compatible with reaching zero emissions for chemicals and petrochemicals

Using biomass for feedstocks and renewables for energy

- Source all heat and electricity inputs from renewables.
- Use biomass for chemical feedstocks – replacing primary petrochemicals with bio-based chemicals or replacing fossil fuel-derived polymers (particularly plastics) with alternatives produced from biomass.

Using synthetic hydrocarbons for feedstocks and renewables for energy

- Source all heat and electricity inputs from renewables.
- Use synthetic hydrocarbons – produced from green hydrogen and clean CO_2 sources – for chemical feedstocks.

Capturing and storing process and waste emissions, and using renewables for energy

- Apply CCUS to existing production processes.
- Source all heat and electricity inputs from renewables.
- Apply measures for the permanent storage of the carbon in products – e.g., a highly efficient circular economy, the long-term storage of waste products or CCUS applied to end-of-life combustion.

4 options compatible with reaching zero emissions for cement and lime production

Reducing clinker use

- Partially substitute clinker with alternative binders, e.g., blast furnace slag or fly ash.
- Reducing demand for conventional cement
- Use alternative construction techniques to reduce cement use, and/or use renewable building materials, such as wood, instead of cement.
- Avoid clinker emissions by using alternative cement formulations.

Fuel switching to renewables

- Use direct electrification or the use of biomass and waste for process energy.

Capturing and storing CO_2 emissions

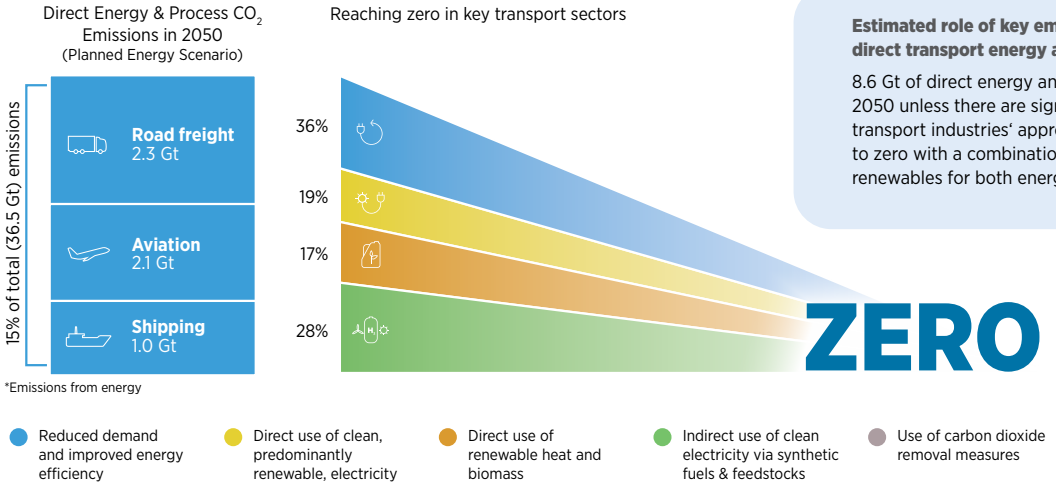
- Apply CCUS to abate remaining energy and process emissions.
- Use biomass with CCS (BECCS) to produce negative emissions that can offset some uncaptured clinker emissions.

1 option compatible with reaching zero emissions for aluminium

Renewable power and inert anodes

- Source all heat and electricity inputs from renewables.
- Switch to the use of inert anodes.

Freight transport: Options for reaching zero



Estimated role of key emission reduction measures to reduce direct transport energy and process emissions to zero

8.6 Gt of direct energy and process emissions will be produced in 2050 unless there are significant changes in policies and in the transport industries' approaches. Those emissions can be reduced to zero with a combination of measures – most of which utilise renewables for both energy and feedstocks.

3 options compatible with reaching zero emissions for road freight

Battery electric vehicles

- Use electric motors powered by a battery pack, charged with renewable electricity.

Fuel cell electric vehicles

- Use electricity produced by fuel cells powered by compressed (green) hydrogen.

Advanced biofuels

- Use biomass-based fuel substitutes, such as biodiesels and renewable diesels.

3 options compatible with reaching zero emissions for aviation

Biojet fuel

- Use fuels produced from sustainable sourced biomass.

E-fuels

- Use synthetic fuels produced from cleanly sourced CO_2 and green hydrogen.

Battery-powered aircraft

- Use propulsion systems powered by batteries charged with renewable electricity.

2 options compatible with reaching zero emissions for shipping

Advanced biofuels

- Use biomass-based fuels such as biodiesel, renewable diesel, bio-methanol, bio-fuel oil and liquefied biogas.

E-fuels

- Use green hydrogen or synthetic fuels such as green methanol, ammonia and methane.

Realising a renewables-based strategy for reaching zero

None of the options outlined in the *Reaching zero with renewables report* are commercially mature and ready for wide adoption; many uncertainties remain about their potential and optimum use, and none will be easy to scale-up. The reasons are varied and complex but include: the high costs of new technologies and processes; the need for enabling infrastructure ahead of demand; highly integrated operations and long-established practices; uneven, large and long-term investment needs; gaps in carbon accounting; and competitiveness and carbon leakage risks for first-movers. Addressing these challenges needs to be the focus of far more attention and creativity than is currently being applied. Sector-specific actions are explored in the report, but at the higher level there are a number of cross-cutting actions that should be addressed with urgency.

The world has made remarkable progress in the last decade in developing renewable energy sources, with major steps taken in decarbonising power systems. Collectively it must now seek to make comparable progress in addressing carbon emissions in end-use sectors. That 40-year transition has barely begun, but it warrants far greater attention, planning ingenuity and resources now if progress is to be made fast enough. Significant challenges lie ahead, but promising options exist – particularly based on low-cost and abundant renewable energy resources. With the right plans and sufficient support, the goal of reaching zero emissions in key transport and industry sectors is achievable.

Look out for the full report, *Reaching zero with renewables* on http://www.irena.org/industrytransport.

For more insights and to engage in discussions on these topics join IRENA's virtual Innovation Week 2020 (5-8 October) which will explore "Renewable Solutions for Industry & Transport". Register or view the recordings at: http://innovationweek.irena.org.

For more information or to be sent the full report when published e-mail us at: innovationweek@irena.org.

Recommendations for industry and governments to begin the transition to zero emissions

1	**Pursue a renewables-based strategy for end-use sectors with an end goal of zero emissions.**	This involves developing linked sectoral strategies at the local, national and international levels built on the five technology pillars of demand reduction / energy efficiency, renewable electricity, renewable heat and biofuels, green hydrogen and e-fuels, and carbon removal technologies.
2	**Develop a shared vision and strategy and co-develop practical roadmaps involving all major players.**	To ensure engagement, national and international visions and roadmaps for the sector must be supported by all key actors – across political parties, across competing companies, by consumers and by the wider public. International and inter-governmental bodies and initiatives can assist in building consensus.
3	**Build confidence and knowledge among decision makers.**	Decision makers need to better understand the risks. Many more demonstration and lighthouse projects are needed. Those who can must lead – that is, developed countries, major economies, major companies, and public and private sector "coalitions of the willing" need to step up and show what is possible.
4	**Plan and deploy enabling infrastructure early on.**	New approaches will require substantial new infrastructure – to produce and deliver large amounts of renewable power, biofuels and e-fuels. Infrastructure investment needs to come ahead of the demand. Carefully co-ordinated planning coupled with targeted incentives will be needed.
5	**Foster early demand for green products and services.**	Creating early sources of demand for green fuels, materials, products and services – through public procurement, corporate sourcing, regulated minimum percent requirements, etc. – will help build the scale of production needed and help reduce costs. There are some good and bad examples of this that can be learned from.
6	**Develop tailored approaches to ensure access to finance.**	Considering the specificities of these sectors – i.e., high CAPEX, long payback periods, etc. – tailored financial instruments along the whole innovation cycle are needed. Co-operation between public and private financial institutions can help.
7	**Collaborate across borders.**	This is a global challenge, and the solutions needed are complex and expensive. Countries working alone will not be able to explore all options in the necessary depth. International collaboration can help countries share the burden.
8	**Think globally, utilise national strengths.**	Relocating industrial production to places with better access to low-cost renewable energy could reduce costs and create new trade opportunities. Countries with large or expanding production should be supported in getting on the right (zero-carbon-compatible) track early on.
9	**Establish pathways for evolving regulation and international standards.**	Regulations and standards are key enablers of change but can also be barriers – they require careful planning to ensure that they shift at the same pace as the technological changes.
10	**Support RD&D and systemic innovation.**	Large gaps in capability and large cost differences between new renewables and established fossil fuel options still remain. Investment in research, development and deployment (RD&D) is needed across a range of technologies to reduce costs, improve performance and broaden applicability. Innovation must be systemic – that is, technology innovation needs to go hand-in-hand with innovation in business models, in market design, in system operations and in regulation.