IRENA QUARTERLY
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TRANSPORT OFFERS OPENING FOR DECARBONISATION

In the next two decades, vehicle ownership is expected to reach two billion worldwide

Around one million oil and natural gas wells are in operation around the globe today. These feed a huge global supply chain, which covers over 95% of the energy demand from road vehicles, ships, aircraft and other means of transport.

Switching to mainly renewable fuels and power sources is going to be an enormous challenge, according to a joint study by the International Renewable Energy Agency (IRENA) and the International Energy Agency (IEA). But it will save lives – and money – in the long run.

The Intergovernmental Panel on Climate Change (IPCC) calls for transport to be transformed to help cut carbon dioxide (CO_2) emissions, which contribute significantly to global warming. The sector accounted for just over one-fifth of energy-related CO_2 emissions in 2015. Of the emissions from transport, four-fifths came from passenger and freight vehicles, while aviation accounted for one-tenth. Shipping made up most of the rest.

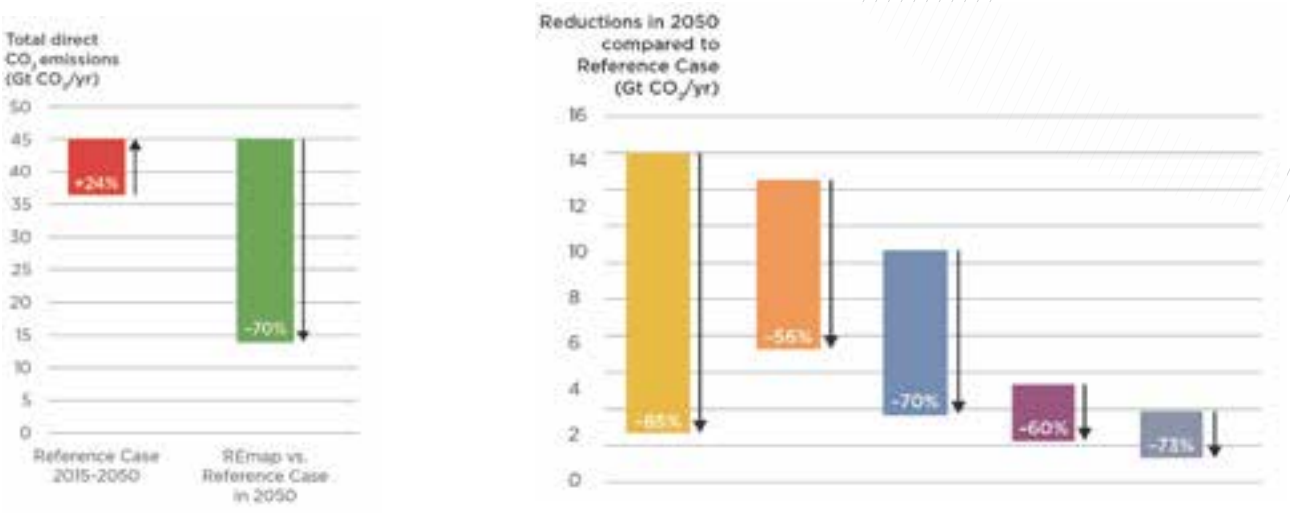
Aviation alone contributes about 2-3% of total global CO_2 emissions and demand for long-distance passenger flights is set to keep rising, the IEA and IRENA notes.

Without decisive action on decarbonisation soon, average global temperatures could rise to and beyond 2 degrees centigrade (2°C) — the level described by the IPCC as the tipping point for catastrophic climate change — by the second half of this century. At the Paris climate conference in 2015, governments worldwide agreed to limit the global temperature rise to well below 2°C. In order to reach this aim the IPCC calls for decarbonisation to occur across all sectors, including in transport.

Transport has to be transformed to help cut carbon dioxide (CO_2) emissions

Around two-thirds of global greenhouse gas emissions can be attributed to the fossil fuels used for energy. While energy efficiency and renewables are widely recognised as the primary drivers for deep, worldwide decarbonisation, the key role of the transport sector is often overlooked.

Figure: Carbon-dioxide emissions by sector, 2015-2050, with accelerated uptake of renewables compared to current policies



Notes: CO_2 emissions include energy-related emissions (fossil fuel, waste, gas flaring) and process emissions from industry. If only fossil fuel emissions were displayed in this figure, CO_2 emissions would start from 33 gigatonnes (Gt) in 2015 and would reach 40.5 Gt and 9.5 Gt per year in 2050 in the Reference Case and REmap, respectively.

Transport emissions can be tackled with options that include:

- Electric cars, charged via a renewable-based power grid.
- Advanced biofuels, particular in transport modes such as in shipping or heavy freight, and in importantly also jet aircraft.

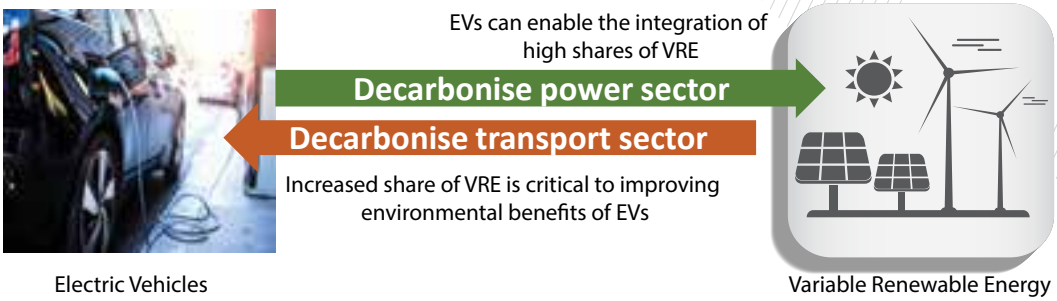
People can also make a difference with a so-called 'modal shift' — by taking public buses, trains and riding bicycles.

Oil wells and mines have started being replaced with renewable energy sources. Decentralised, flexible grids can help with the energy transition to cleaner energy. Such grids enhance the efficiency of vehicle re-charging.

The global energy transition will take decades. Emissions must be reduced without undermining economic growth, the IEA and IRENA report emphasises.

However, if policies and measures were put in place now to scale up renewables faster, emissions from transport could be 70% less in 2050 than with the path set by current plans and policies (see figure). Importantly, the mitigation options in transport are affordable in broad economic terms.

For more information on decarbonisation and transport, see **Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System.**



Electric cars key to power transformation

Operating power grids with a high share of variable generation, like from solar and wind energy, requires flexibility. Electric vehicles (EVs) are one of the key technologies to provide this flexibility. Their batteries, by storing excess electricity, can provide ancillary services to the grid, such as frequency regulation, shaving peak demand, and boosting reserve capacity.

Even emission-free vehicles, after all, can still pollute the air or contribute to carbon dioxide emission indirectly by drawing on power produced from fossil fuels. But increased integration of more renewable energy into national power grids would maximise the renewable energy environmental benefits of electric cars, buses or trucks and help achieve crucial decarbonisation in the transport sector.

EVs spend hours each day parked, on top of their grid-to-vehicle (G2V) recharging needs. This idle time also allows for vehicle-to-grid (V2G) discharge of power to the grid, which includes boosting grid capacity.

Integration of variable renewable energy into the power system can be enhanced in multiple ways:

- use of vehicle batteries as mobile power storage systems;
- use of old batteries in a "second life" role as stationary storage systems;
- widespread deployment of charging technologies and infrastructure; and
- development of smart charging schemes and engagement with consumers.

The emerging combination of EVs with smart grids gives vehicle owners more control and lets them make well informed decisions about their electricity consumption. However, charging, aggregating and operating EVs in the optimal manner may require active engagement by owners and drivers.

Successful EV deployment depends on, two main factors, initial government support and then popularity with the customers.

EVs are already known to offer a good driving experience, while the range they can drive is steadily increasing. Policy support will be needed for at least another five to ten years to reduce upfront costs of EVs, provide better road or parking access or lower fees. With the initial hurdles cleared, rapid sales growth can follow.

German carmakers – BMW Group, Daimler AG, Volkswagen Group and Ford – have signed a memorandum to establish Europe's biggest fast-charging network. This outlines targets for deployment; such as 400 fast-charging stations for EVs by the end of this year and several thousand by 2020. Government plans call for another 400 fast charging stations, which would bring to total to 800 this year. German utilities E.ON and Innogy, also aim to develop and expand Europe's charging infrastructure.

The global stock of EVs reached 1 million in 2015 and exceeded 2 million by the end of 2016. Yet faster growth is needed for EVs to fulfil their role in the global energy transition, both through lowering vehicle emissions and boosting renewable energy use.

IRENA's **Electical Vehicles** *technology brief outlines the technological and policy advances still needed for EVs to help drive the transition to a sustainable global energy future.*

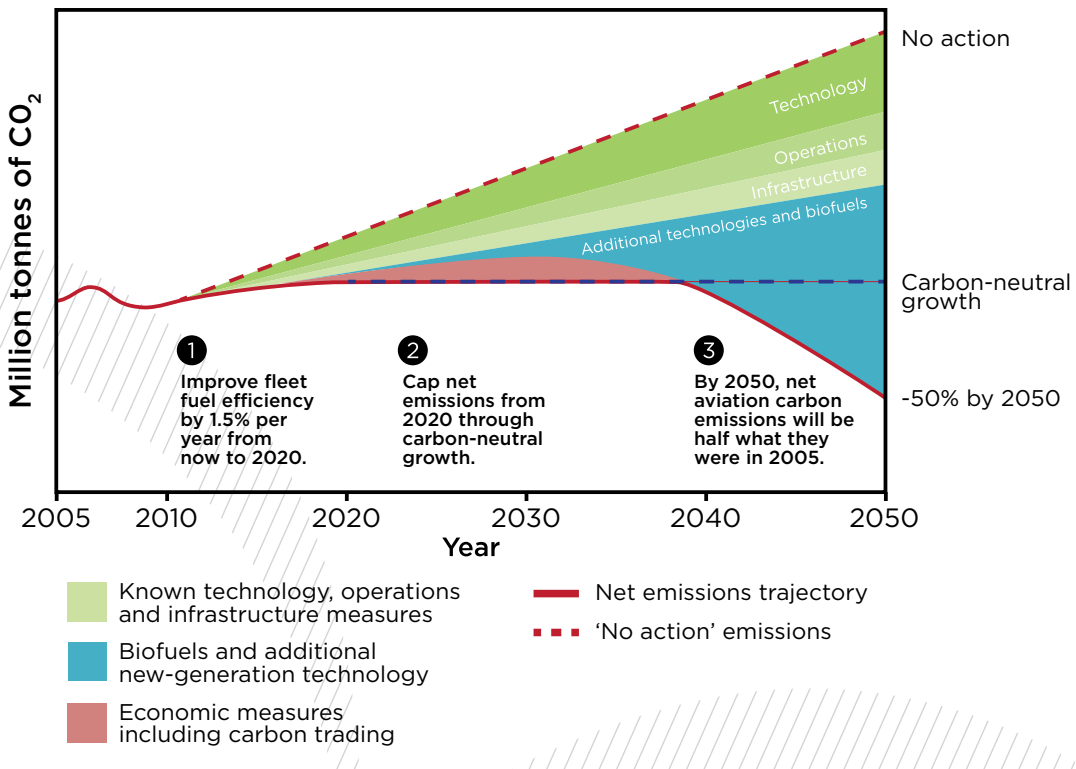
Co-operation needed to decarbonise air transport

The aviation sector emits 2% of the world's human-induced greenhouse gases. Many airlines, aircraft manufacturers and industry associations have set voluntary targets, aiming for carbon-neutral growth by 2020 and to halve emissions by 2050 (relative to 2005 levels). The number of commercial flights using biofuels for jet aircraft, or "bio-jet" fuels, has already grown as a result, and a downstream supply chain has developed in some places (see figure).

Pioneering airports, such as Oslo's Gardermoen airport, have incorporated bio-jet fuel into their refuelling systems. The proposed construction of several new facilities, will help to further spread the use of bio-jet.

However, biofuel adoption needs to happen much faster in order to contribute meaningfully to meeting international climate goals. National policies combined with international agreements

Figure: Emissions from aviation in the absence of any action, and emissions-reduction goals set by the industry



Source: Air Transport Action Group

can accelerate this vital transition in several ways:

- Bridge the price gap between bio-jet and conventional jet fuel by following successful models from the automotive biofuel sector;
- Create bio-jet demand by mandating use to develop markets for biofuels;
- Support bio-jet commercialisation by helping investors during the commercialisation stage of the technology;
- Develop the supply chain and ensure an adequate framework from feedstock to bio-jet distribution.

With trips by jet increasing, the International Civil Aviation Organization (ICAO) has forecast emissions of carbon dioxide (CO_2) in the sector ranging between 682 mega tonnes (Mt) and 755 Mt by 2020, and as high as 2 700 Mt by 2050 if no action is taken. Curbing aviation emissions, therefore, is crucial to meet the climate goals set in the 2015 Paris Agreement.

Sustainable, clean propulsion technologies are in development. Yet options such as electric- or solar-powered aircraft and the use of cryogenic hydrogen are unlikely to be ready for commercial use until well after 2050.

Biofuels offer a realistic way to cut aviation emissions starting nownow. Derived from sustainable sources like vegetable oils and animal fats, bio-jet fuels can be used in existing, unmodified jet engines. Life-cycle analysis of bio-jet fuels shows they can reduce emissions by at least 50%, and by as much as 95% compared with fossil jet fuel.

Growth of the bio-jet market, is limited by high costs, technical challenges and inadequate policy support, however, when oil prices in recent times were close to their peak, bio-jet was still at least twice as costly as fossil-derived jet fuel.

With trips by jet increasing, carbon dioxide emissions are forecast to rise

Countries struggle to regulate bio-jet on their own, partly because fuel for international flights is not usually taxed. While the ICAO regulates emissions, comprehensive and novel policies are needed both nationally and internationally. Dutch airline KLM and the Fly Green Fund, a company aiming to develop Nordic countries into a pioneering bio-jet region, encourage corporate customers to cover the price premium for bio-jet fuel.

To learn more, see the IRENA technology brief, **Biofuels for Aviation**.

IRENA at EXPO 2017 World's Fair

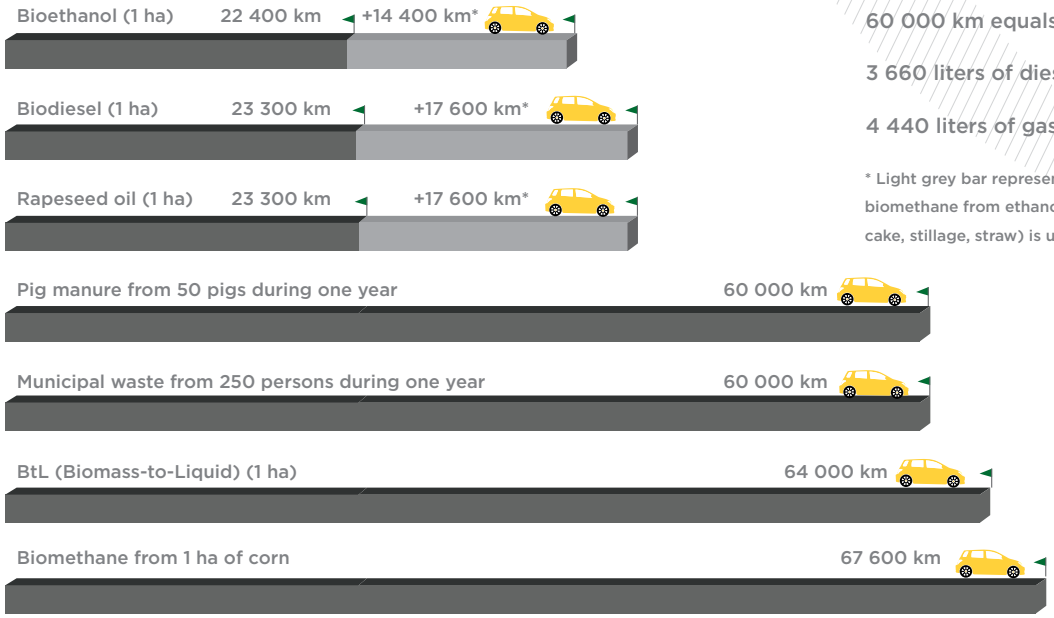
JUNE - SEPTEMBER 2017

EXPO 2017 ASTANA FUTURE ENERGY

EVENTS CONTINUE

REmap: Global Renewable Energy Outlook — part of the World Scientific and Engineering Congress	20 June	9:00 - 13:00	Congress Center
IRENA booth — part of the Joint Pavilion of International Organizations	Until 10 Sept	10:00 - 20:00 (Daily)	Pavilion of International Organizations

Average distance of passenger cars driven with different biofuels



60 000 km equals a consumption of:

3 660 liters of diesel (6.1 L/ 100 km)

4 440 liters of gasoline (7.4 L/ 100 km)

* Light grey bar represents the additional range if biomethane from ethanol by-products (rapeseed cake, stillage, straw) is used as transport fuel

Sources: FNR (2016); Hoornweg (2012)

Refined biogas hits the road running

While the world watches electric car prices fall and waits for new breakthrough technologies, one renewable transport fuel is already viable, compatible and increasingly affordable with existing engines. Raw biogas and upgraded biogas — also known as biomethane — are increasingly available worldwide.

With production mainly concentrated in Europe, especially Sweden, Switzerland, the Netherlands and Germany, upgraded biogas is still relatively costly compared to fossil fuels. However, it is recognised as a "green substitute", providing reductions in greenhouse gas emissions of 60-80% compared to gasoline, while also producing less nitrogen oxides (NO_x), fine dust and noise.

Conveniently upgraded biogas can go directly into natural gas powered vehicles, making this renewable fuel easy to adopt and economically viable. Switching not only averts ecological damage, it helps make use of waste and residues. Upgraded biogas production facilities can also make organic fertiliser, replace fuel imports and create jobs and local income.

For long distance road trips, upgraded biogas offers excellent mileage (see figure). The municipal organic waste production by 250 people in a year, or the annual manure of 50 pigs, support around 60 000 km of travel, which is the same as 3 660 litres of diesel or 4 440 litres of gasoline.

Biogas production, purification and upgrading technologies are reliable and mature. An estimated 500 plants produce biogas and upgrade it to natural gas quality, which is equivalent to about 50 petajoules per year.

Different countries have worked to establish a biogas-as-fuel market. Sweden has city buses running on biogas and has established the first biogas-powered train in the world. A pilot programme in Kolkata, India, has a bus fuelled by biogas, from animal and human waste, put on a regular 17 kilometre route. Brazil's Dois Arcos Project, in Rio de Janeiro, produces upgraded biogas from landfill gas and uses it to fuel cars and a local garbage-collection truck.

Still, upgraded biogas needs substantial investment and political support, to take hold in more countries. Technological research and innovation could continue to reduce costs by 30-40%, making it more attractive for public use.

For more about biogas as a fuel for road vehicles, see **Biogas for Road Transport**, *part of the IRENA Technology Brief series.*

(Picture Source: FNR (2016), *http://biogas.fnr.de/daten-und-fakten/faustzahlen/*; Hoornweg and Bhada-Tata (2012), *https://openknowledge.worldbank.org/handle/10986/17388*).

Solar plane spawns breakthrough technologies

Since the historic round-the-world flight of Solar Impulse 2, in 2015 and 2016, technologies from the innovative aircraft have already made an impact beyond aviation.

Solar Impulse's parts and components involved the co-operation and support of a large number of private firms. Innovations by these companies during the development of the plane are now being applied to cars, elevators, escalators and more.

Engineers have suggested that the plane's specially developed battery binders could be used to upgrade electric car batteries and grid storage systems. Conventional cars, too, could benefit from the additive in Solar Impulse's motor lubricant, which makes any kind of engine more resistant to wear and rust.

Solar Impulse's motors are rated at a record 96% efficiency, due to smart sensors. If applied to all industrial electric motors, such sensors could save the world 616 billion kilowatt-hours (kWh) of electricity per year, says ABB Group, a global technology company.

The plane also used special ultra-light solar cells, which achieved roughly 23% efficiency, opening a range of new applications in the aerospace sector and beyond.

"Solar Impulse has been able to both raise awareness about the tremendous promise of renewable energy and push technological boundaries forward," said Adnan Z. Amin, Director-General of IRENA. "Innovative solutions can unlock even more potential in the future."

Solar impulse weighed only 2.3 tonnes and its cockpit had room for just one pilot. The sun-powered craft has a wingspan of 72 metres, similar to the 400-tonne A380 jet airliner. An array of photovoltaic cells fed enough power into efficient engines for the plane to reach 29 500 feet (9 000 metres) — the height it climbed to before gliding down to 5 000 feet (1 500 metres) when the sun faded.

Even so, solar transport is only in its infancy. Solar Impulse 2 took more than 16 months, of which over 500 hours were spent in the air, to complete its around the world trip.

The remarkable plane travelled at an average speed of only 75 kilometres per hour. But what Solar Impulse lacked in speed it made up for in ingenuity. Its four propellers and batteries were charged by approximately 17 000 solar panels. Over the course of the journey these produced over 10 000 kilowatt-hours (kWh) of solar energy, close to a typical US household's annual power consumption about 11 700 kWh.

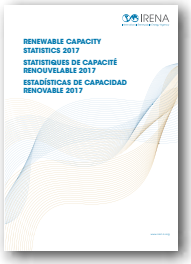
Beyond engineering and design feats, the plane provided a tangible demonstration that renewable technologies can really power our planet.

The solar plane broke eight world records and travelled 42 000 kilometres without using a single drop of fuel. The final leg of the journey, from Cairo to Abu Dhabi, was delayed by wind and seasonal weather over the Arabian Peninsula. In the end, the plane covered its last 2 700 kilometres in a little under 49 hours.

Recent publications

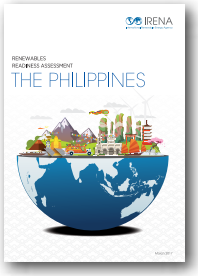
Perspectives for the energy transition: Investment needs for a low-carbon energy system

This study looks at the potential for decarbonisation in the energy sector in G20 countries and around the world. Decarbonisation of the energy sector requires urgent action on a global scale. Chapter 3, *Global Energy Transition Prospects and the Role of Renewables*, highlights findings from IRENA.



Renewable Capacity Statistics 2017

This publication presents renewable power generation capacity statistics for t he last decade (2007-2016) in trilingual tables (English, French and Spanish). For most countries and tec hnologies, the data reflects the capacity installed and connected at the end of the calendar year.



Renewables Readiness Assessment: The Philippines

The Philippines faces twin challenges of population growth and rising energy demand. This report identifies barriers and proposes key actions to strengthen the policy, regulatory and institutional framework in order to accelerate renewable energy deployment.

Renewable Energy Prospects for the Russian Federation (REmap working paper)

The Russian Federation has set out to increase and diversify its use of renewables. Accelerated deployment could boost Russia's renewable energy share and according to this country analysis forms part of REmap REmap working paper.

www.irena.org/publications

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.