

Decarbonisation Levers

Annex 1

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Aviation decarbonisation levers

Decarbonisation lever	Efficiency	Drop-in Sustainable Aviation Fuel (SAF)		
		HEFA	Alcohol to Jet and Gasification/FT	Power-to-Liquid
Description	Upgrading aircrafts, using the most fuel-efficient jets, or improving fuel efficiency by optimising routes and other operational practices	SAF produced from waste and residue lipids, such as from cooking oil	SAF production from agricultural/ forestry residues, municipal solid waste and/or cellulosic energy crops	Alternative fuel produced from renewable energy sources, e.g. green hydrogen and carbon dioxide.
Technology maturity	Various	8-9	7-8	5-8
% life cycle reduction potential vs fossil incumbent	-15-40%	-73-84%	-85-94%	-99%

Note a range of other measures, such as modal shift and novel production aircraft are also expected to play a key role in decarbonisation of the aviation sector. Further details of these and other levers are set out in [Making Net Zero Aviation Possible](#). This analysis focuses on in sector decarbonisation levers that we expect to be most impactful before 2030.

Maritime decarbonisation levers

Decarbonisation lever	Efficiency	Novel propulsion ships	
		Ammonia-fuelled ships	Methanol-fuelled ships
Description	Optimising the speed, size and the technological specifications of vessels to drive energy efficiency	Vessels that are fuelled by using ammonia derived from clean hydrogen	Vessels that are fuelled by methanol, particularly those made from renewable sources: (1) bio-methanol, produced from biomass, and (2) green e-methanol, produced from bioenergy with carbon capture and storage (BECCS) or direct air capture (DAC), and green hydrogen.
Technology maturity	Various	TRL 7-9	TRL 9
% lifecycle reduction potential vs fossil incumbent	-25-30% ¹	Up to -100% ¹	Up to -100% ¹

1: High emissions reductions can be achieved if ammonia and methanol are produced using green hydrogen and in the case of methanol, using carbon dioxide that is carbon neutral (e.g. utilising direct air capture or carbon dioxide from a biological source). Otherwise, emissions reductions are typically much lower.

Ammonia decarbonisation levers

Decarbonisation lever	Demand efficiency	Blue ammonia	Green ammonia	Methane pyrolysis	Biomass-based ammonia
Description	Levers decreasing the amount of ammonia needed per output (e.g. improved nutrient use efficiency, dietary shifts)	Use of blue hydrogen (produced from fossil fuels with CCUS) to synthesise ammonia.	Use of green hydrogen (produced via electrolysis and renewable electricity) to synthesise ammonia.	Methane pyrolysis produces solid carbon and “turquoise” hydrogen from which ammonia is synthesized.	Biomethane and hydrogen are produced via biomass digestion or gasification. Resulting gas is fed to a reformer.
Technology maturity	Various	TRL 7-9	TRL 7-8	TL 6-7	TRL 3-7 ²
% lifecycle reduction potential vs fossil incumbent	-4% (indicative)	Up to -90% to -95% (scope 1) ¹	-100% (scope 1)	-100% (scope 1) ¹	-100% (scope 1)

1: Note that upstream emissions resulting from fossil fuel extraction and processing are left unmitigated with the blue ammonia or methane pyrolysis route. In 2020, these were estimated to approximately 25% of the global scope 1 emissions of ammonia production.
2: the TRL of biomass-based ammonia technologies refers to the maturity of producing biogas from digestion or gasification process integrated with a reformer and ammonia synthesis plant. The direct use of biomethane in substitution of fossil methane is not a technical challenge in itself and would be considered TRL 9.

Methanol decarbonisation levers

Decarbonisation lever	Blue methanol	E-Methanol with green electricity	Methane pyrolysis	Biomethanol
Description	CO ₂ generated during the synthesis of fossil-based methanol is captured and either stored or used.	Use of green hydrogen produced from renewables and an external source of CO ₂ to synthesise methanol.	Methane pyrolysis produces solid carbon and "turquoise" hydrogen from which methanol is synthetised with CO ₂ .	Biomass feedstock (e.g. biomethane, waste gasification) is converted into syngas used for methanol synthesis
Technology maturity	TRL 7-9	TRL 8-9	TRL 7	TRL 8
% lifecycle reduction potential vs fossil incumbent ¹	-20% ²	-37% (fossil CO ₂) -100% (biogenic CO ₂)	-21% (fossil CO ₂) -84% (biogenic CO ₂)	-70% to -100% (depending on biomass)

1: the life cycle perimeter considered here accounts for the feedstock production (e.g. natural gas extraction and processing), synthesis and combustion of methanol. Note that the carbon contained in methanol is not necessarily released shortly after production in the form of CO₂ and can have longer retention time depending on the final application of the product (e.g. fuels, plastics, textiles, coatings).
2: Assuming 95% CO₂ capture rate.

Steel decarbonisation levers

Decarbonisation lever	Material efficiency	Steel recycling	Primary steel production		
			H ₂ -DRI	Steel with CCUS	Direct electrolysis
Description	Levers decreasing the amount of steel needed per product (e.g. vehicle lightweighting, 3D printing).	Use of steel scrap in an Electric Arc Furnace (EAF) instead of primary steel produced in a blast furnace.	New primary steelmaking route based on the reduction of iron ores with 100% green hydrogen instead of coal.	Primary steelmaking route (including BF-BOF, DRI-EAF, DRI-Melt-BOF and Smelting) retrofitted with CO ₂ capture.	Direct electrolysis and electrowinning of iron ores are novel ironmaking technologies not yet available
Technology maturity	Various	TRL 9	TRL 5-7	TL 5-8	TRL 5-6
% lifecycle reduction potential vs fossil incumbent	-23% (based on the steel demand it can reduce)	-93% ¹	-97% to -98% (if based on low-carbon electricity)	-50% to -90% ²	-97% (if based on low-carbon electricity)

1: this emission reduction potential represents the switch from a BF-BOF to a 100% scrap-based EAF process. The figure does not account for constraints that may arise from the limited supply of scrap or the demand for higher grades of steel which is difficult to produce using 100% scrap.

2: for BF-BOF retrofitted with CCUS, emission reduction typically ranges between 50 and 70% depending on capture configuration. Although further emission reductions can be achieved in theory, the number of CO2 sources and variable flue gas compositions on an integrated steel plant makes it economically unattractive and technically challenging to capture 100% of CO2 emissions. Studies that have investigated carbon capture on a BF-BOF steel plant tend to focus on main emissions sources and preferably with higher CO2 concentration (e.g. coke oven, hot stoves, onsite power plant), leaving behind more diffuse and unstable sources (e.g. sintering, flares, ladle metallurgy). For DRI equipped with CCUS, expected emission reductions compared to conventional BF-BOF are typically higher (up to 90%). This is because the DRI route uses natural gas which is less emission-intensive than coal but also because CO2 is inherently easier to capture in a DRI furnace.

Aluminium decarbonisation levers

Decarbonisation lever	Material and resource efficiency	Recycling of Aluminium	Primary aluminium production		
			Low carbon electricity	Inert anodes	Low carbon refining
Description	Levers decreasing the amount of aluminium demand (e.g. lightweighting, reduced losses, increased lifetime).	Use of aluminium scrap in melting and casting instead of primary aluminium produced in a smelter.	Primary aluminium smelters running on 100% low carbon electricity (e.g. green Power Purchase Agreements (PPAs), CCS retrofit).	Replacement of conventional carbon anodes with innovative inert anode technology to cut process CO ₂ emissions.	Technologies to decarbonise alumina refining (e.g. Mechanical Vapour Recompression, electric boilers and hydrogen calcination).
Technology maturity	Various	TRL 9	TRL 8-9	TRL7	TRL 4-9 ⁴
% lifecycle reduction potential vs fossil incumbent ¹	-22%	-97% ²	-65%	-16% ³ (-95% direct emissions for a smelter)	Up to -16% (if low-carbon electricity)

1: except from recycling, the values presented are within the global aluminium value chain i.e. including bauxite mining, alumina refining and scope 2 emissions from electricity consumption.
2: this emission reduction potential represents the switch from a primary aluminium producer to a 100% aluminium recycling process. The figure does not account for constraints that may arise from the limited supply of scrap or the demand for high quality aluminium alloys which can be difficult to produce using 100% scrap.
3: from the perspective of a conventional aluminium smelter with on-site anode production, switching to inert anodes would reduce direct scope 1 emissions by approximately 95%.
4: electric and hydrogen calcination are at TRL 4-5, Mechanical Vapour Recompression (MVR) is at TRL 7, and electric and hydrogen boilers for digestion are at TRL 8-9.

Cement decarbonisation levers

Decarbonisation lever	More efficient use of concrete	Reduction of clinker content	Fuel switching to waste and biomass	Kiln electrification/ hydrogen	CCUS
Description	Reduction in concrete demand through optimisation measures (e.g. improved design, precast concrete).	Substitution of clinker (i.e. the CO ₂ bearing material) by use of Supplementary Cementitious Materials (SCMs).	Partial or full substitution of fossil fuels (typically coal and petcoke) by fuels derived from waste and biomass.	High temperature heat provided by electricity (e.g. plasma torch, resistance) or hydrogen combustion instead of fossil fuels.	Cement plant retrofitted with carbon capture, utilisation and storage.
Technology maturity	Various	TRL 9 (for most SCMs)	TRL 9	TRL 5-6	TRL 6-9
% lifecycle reduction potential vs fossil incumbent	-22% (indicative)	Up to -73% (depending on SCM) ¹	Up to -35% (if fuel is 100% biogenic)	Up to -35% (if low-carbon electricity)	Up to -95% (depending on capture rate)

1: compared an Ordinary Portland Cement (OPC) that contains 95% clinker. Some few cement types with very high substitution rates (i.e. more than 50%) generally incorporate high proportions of Ground Granulated Blast Furnace Slag (GGBFS) but most common blends (with e.g. GGBFS, fly ash, limestone, calcined clay, pozzolanas) achieve a clinker substitution rate in the order of 10 to 40%.