ENERGY TRANSITIONS COMMISSION

Achieving zero-emissions in aviation: technologies, costs and policies

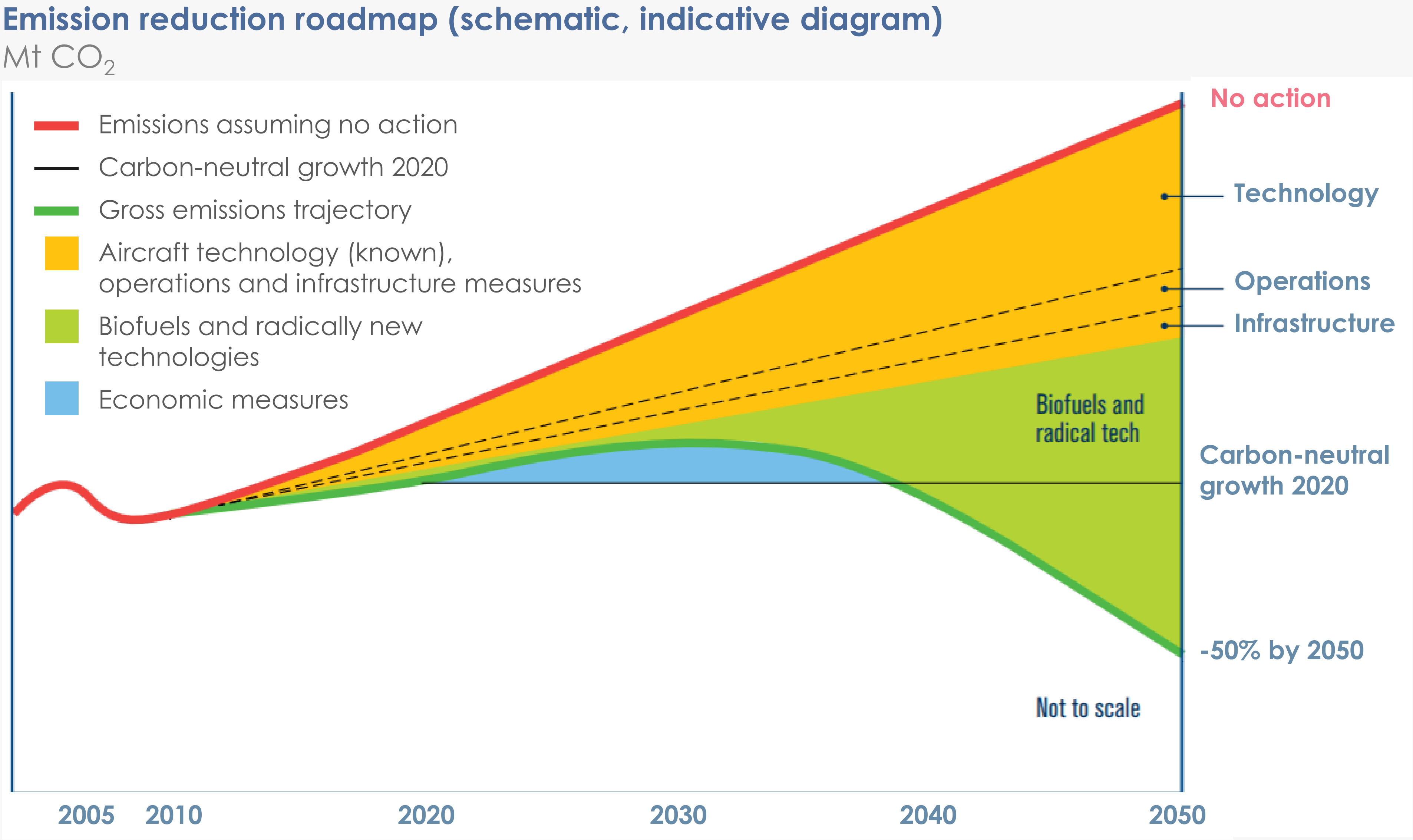
Adair Turner

Chairman, Energy Transitions Commission

Greener by Design Annual Conference

Royal Aeronautical Society, London, 7th November 2019

The International Air Transport Association (IATA) has set global goals for the reduction of aviation's emissions

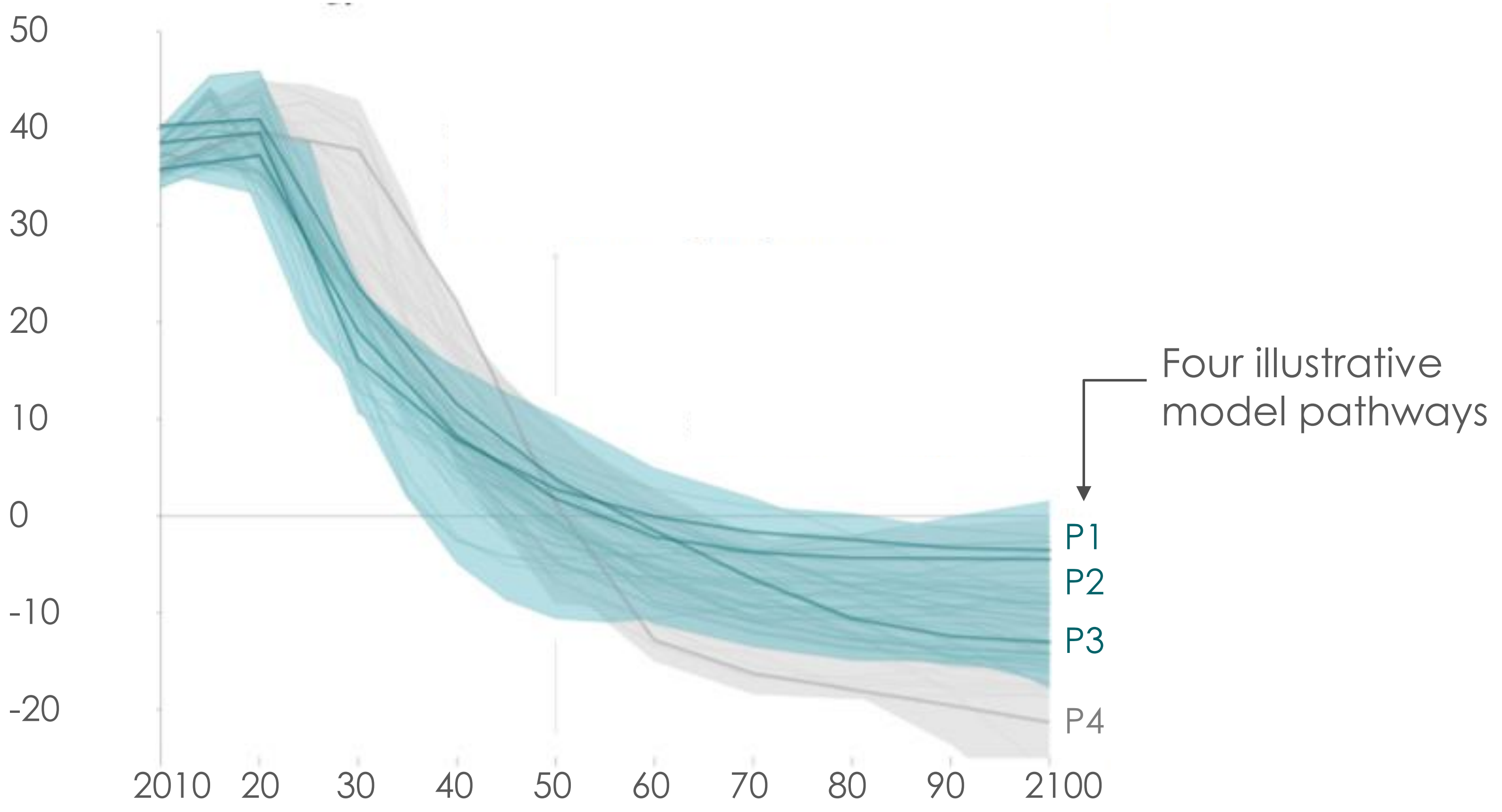


Source: IATA (2013), *IATA Technology Roadmap, 4th edition*

To limit global warming to 1.5˚C global CO_2 emissions must fall to net zero by around 2050

Global emissions pathways in the IPCC 1.5˚C report

Gt CO_2/year



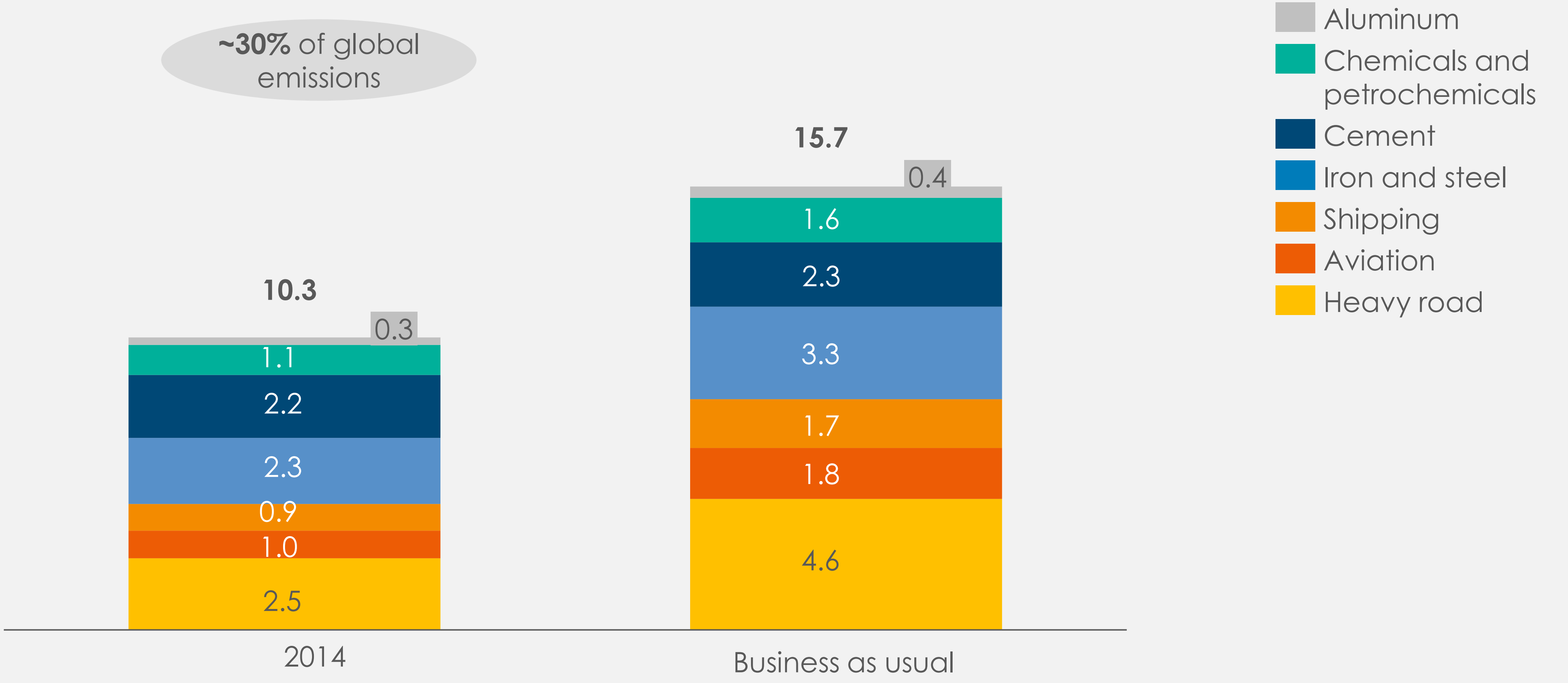
Source: IPCC (2018), *Global Warming of 1.5˚C*

It is technically and economically feasible for the global economy to reach by 2050 net-zero carbon emissions from the energy and industrial systems without relying on offsets from land use

Without forceful action emissions from harder-to-abate sectors could reach 60% of the total by mid-century

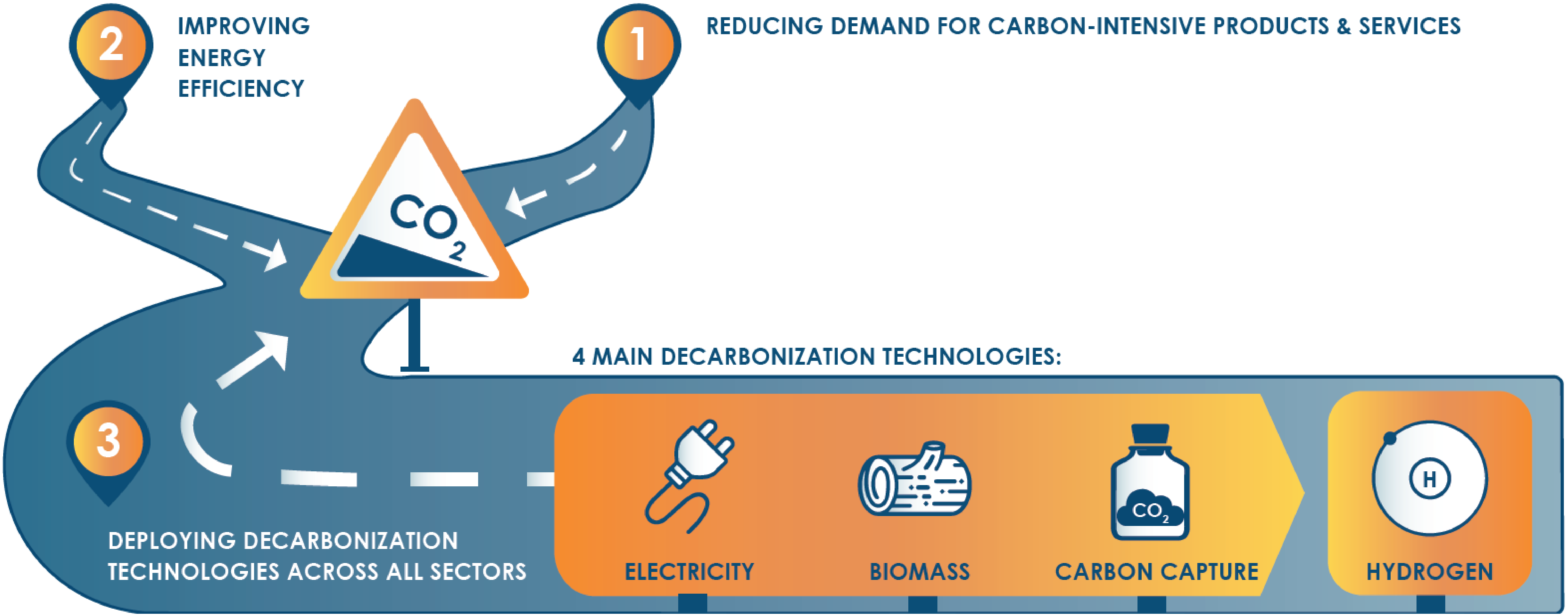
Direct and process emissions from the harder-to-abate sectors

Gt CO_2

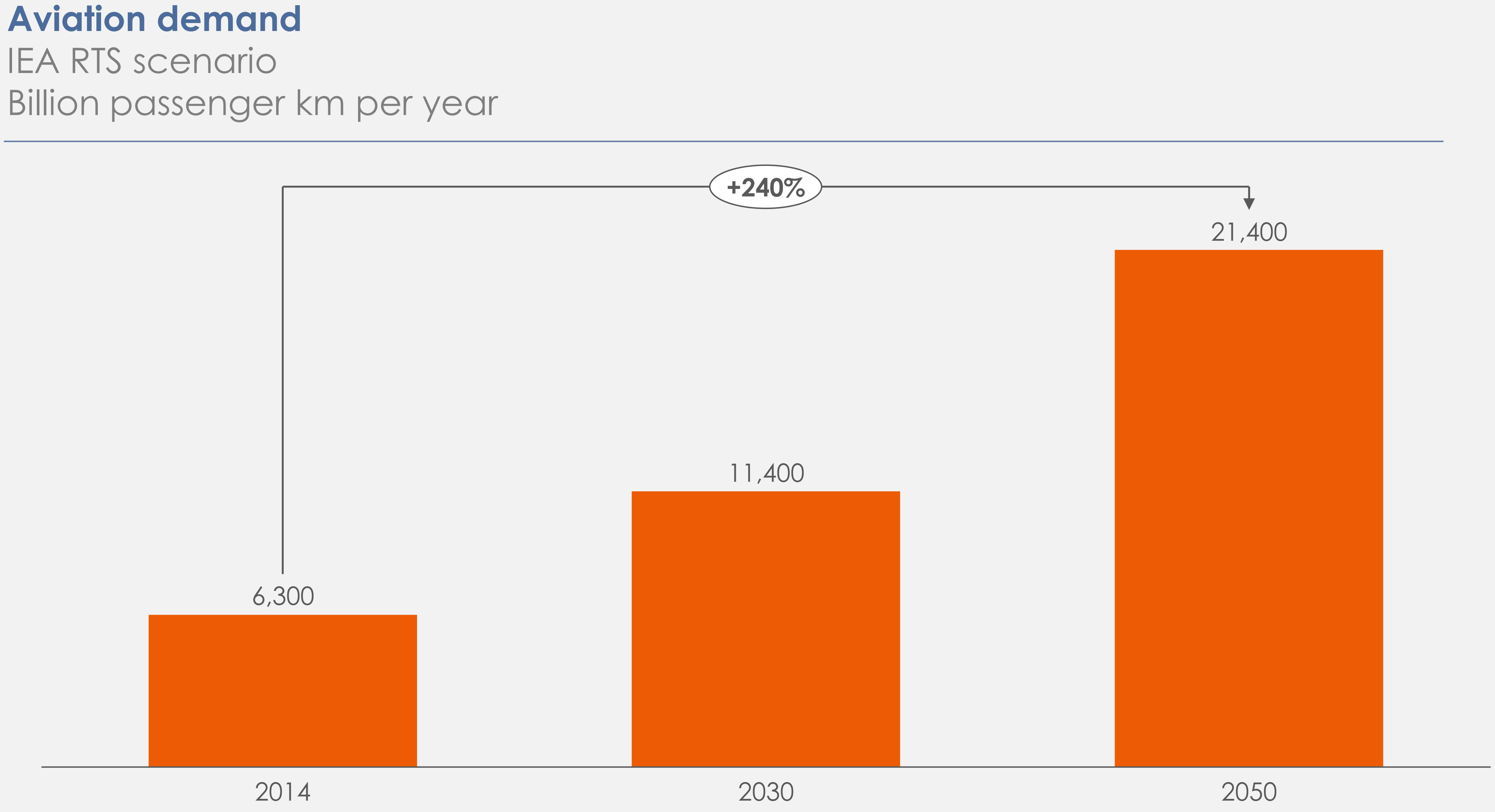


Source: IEA (2017), *Energy Technology Perspectives*

Three routes to net-zero carbon emissions

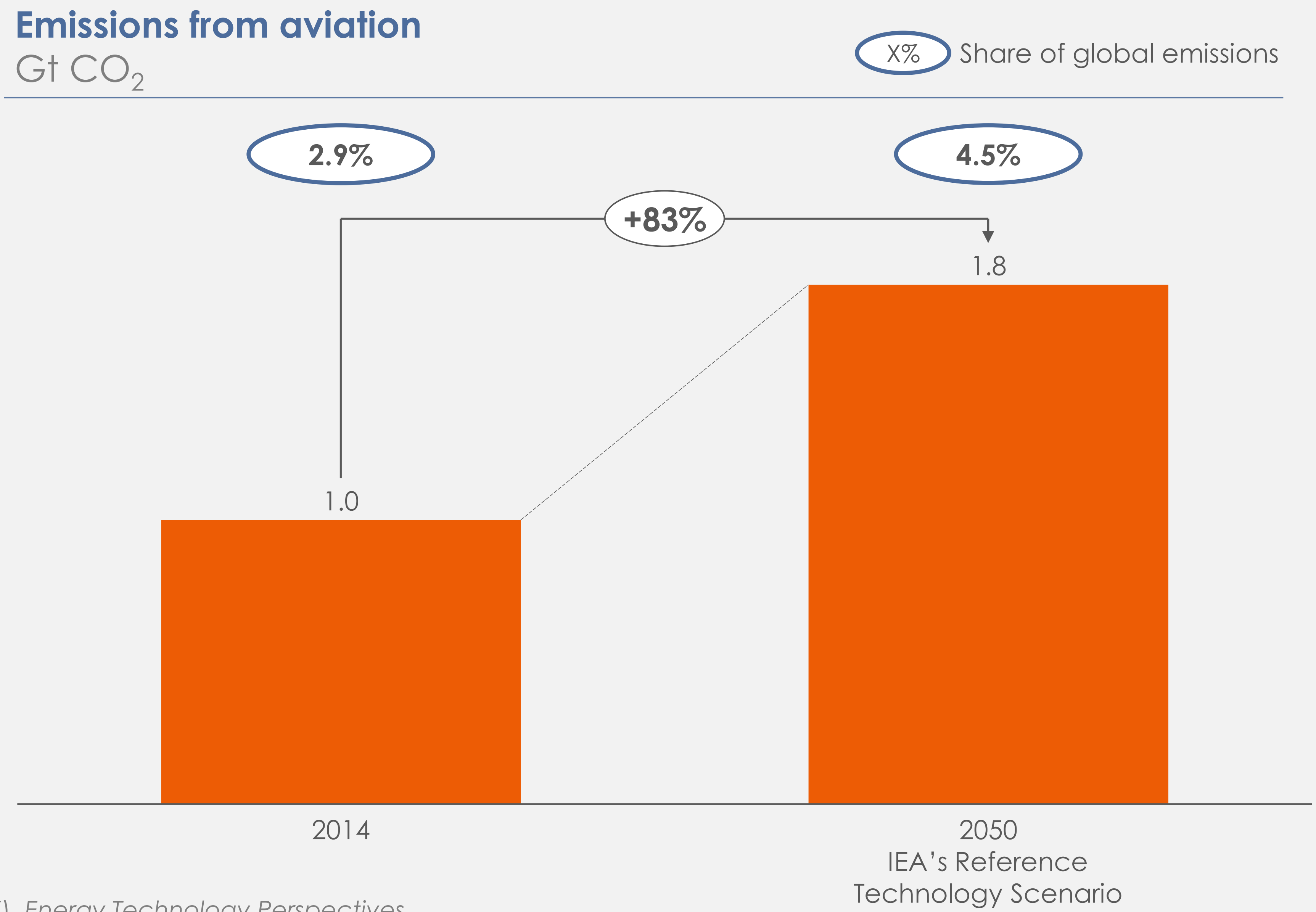


Aviation demand is expected to increase significantly by mid-century



Source: IEA (2017), *Energy Technology Perspectives;* OECD (2017), *IFT Transport Outlook 2017*

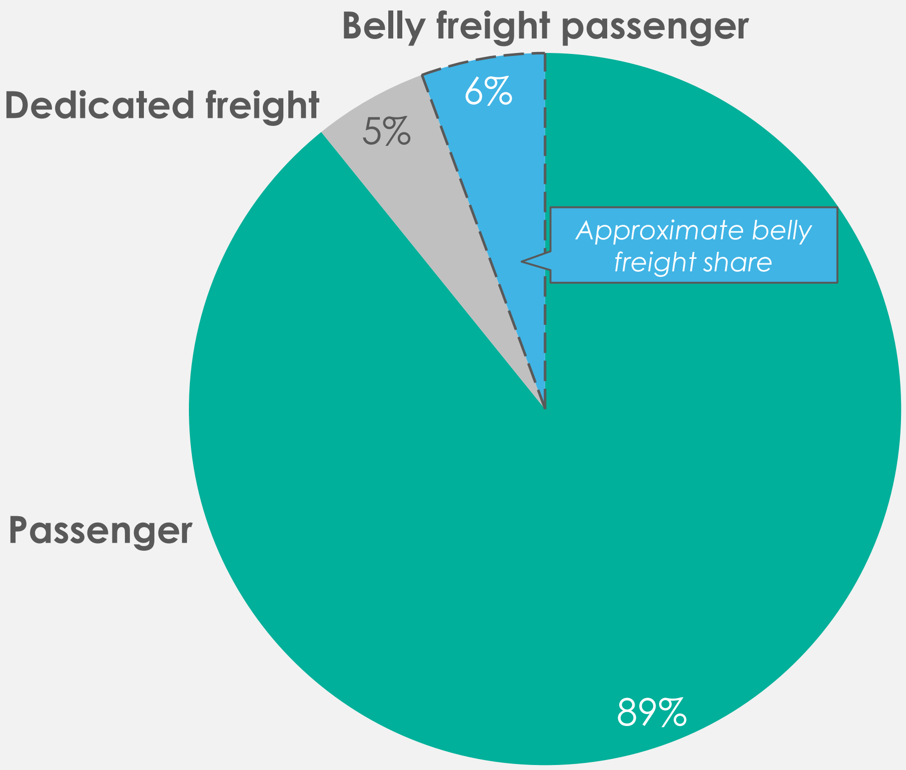
Carbon emissions from aviation could increase by 83% by 2050 in a business-as-usual scenario



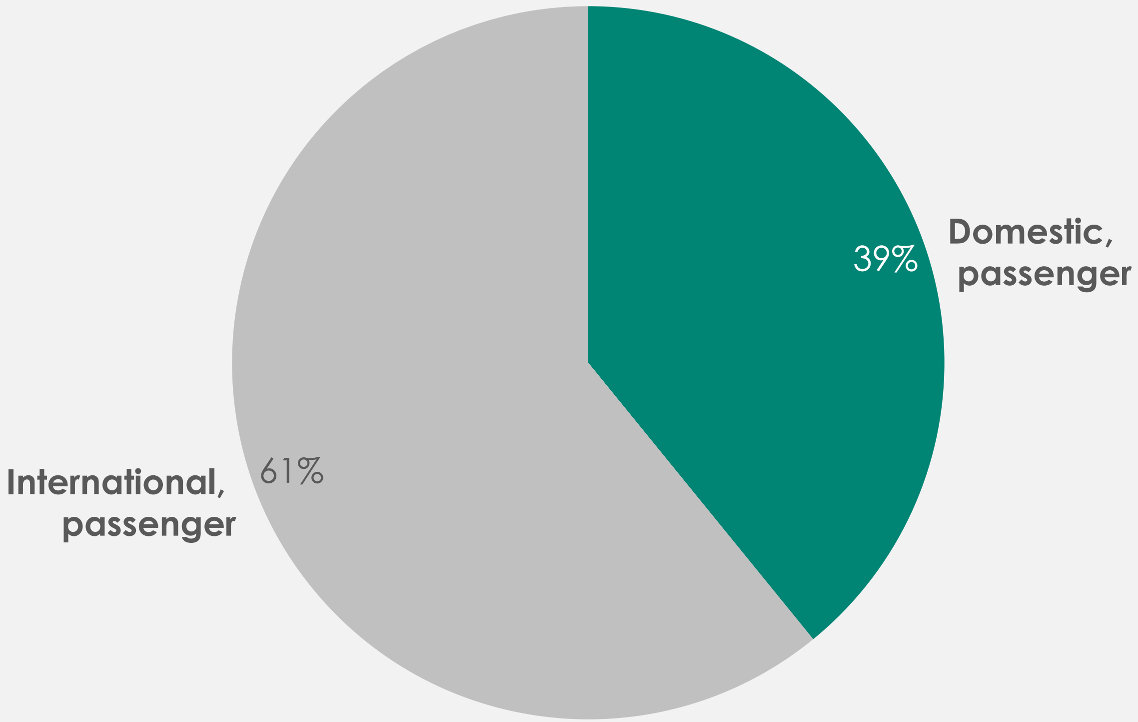
Source: IEA (2017), *Energy Technology Perspectives*

The largest share of aviation CO_2 emissions comes from international passenger travel

Breakdown of CO_2 emissions from the aviation sector
Passenger and freight, % of total



Emissions from passenger aviation
% of total

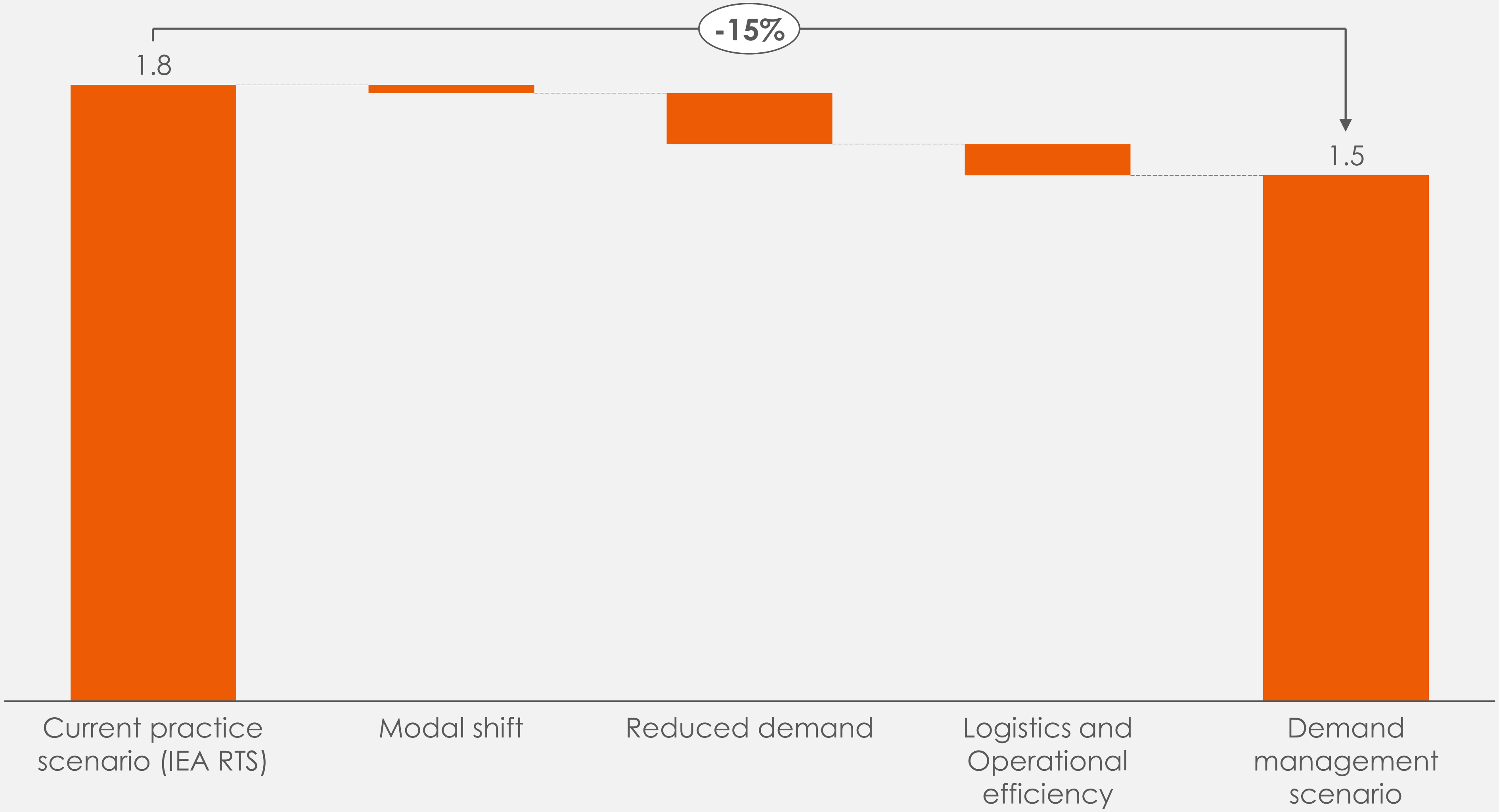


Source: ITF Transport Outlook (2017)

Demand management of the aviation sector can cut sector emissions by 15% by 2050

Global emissions reductions potential from demand management

Gt CO_2 per year, 2050



Source: SYSTEMIQ analysis for the Energy Transitions Commission (2018)

Energy efficiency improvement potential

Early 2020s	2030	Beyond 2030
• Improved engines and composite structural components	• Laminator flow control • Open rotor	• Blended wing bodies • Fundamental airframe redesigns to allow hydrogen storage • Electric engines (+generators) • Multiple hybrid options
+10 – 20%	**+30-40%**	**Still larger potential**

Aircraft lifetime: 25-30 years → long lead time for radical fleet improvement

There are technically feasible options to decarbonise the long distance and heavy duty transport sectors

Most probable options

	Short haul	Long haul
Heavy-road transport	Battery electric vehicles	Battery electric vehicles (with or without catenary wiring) or Fuel-cell electric vehicles
Shipping	Battery electric or Fuel-cell electric vessels	Ammonia or Hydrogen Biofuels or Synfuels
Aviation	Battery electric or Fuel-cell electric planes	Biofuels or Synfuels

Sustainable biofuels and priority use

Estimates of sustainable bioenergy vary greatly

- Minimum 50 EJ
- Reasonable 100 EJ? Optimists 150 EJ

Total potential 2050 demands greatly exceeded sustainable supply		Priority
Trucking	~ 50 EJ	Low – electrification alternative
Aviation	~ 40 EJ	High but cannot meet all demand
Shipping	~ 40 EJ	Low/moderate – ammonia alternative
10% of power generation	~ 30 EJ	Role must be limited to peak generation only
Petrochemical energy and feedstock	> 90 EJ	Low for energy High for feed stock

Implications for aviation:

- High priority sector
- But must maximise energy efficiency, electricity and hydrogen at short distance, and develop synfuels as well
- Cannot rely on auto/trucking to drive economy of scale and learning curve effects

Implications of biofuel / synfuel cost penalty

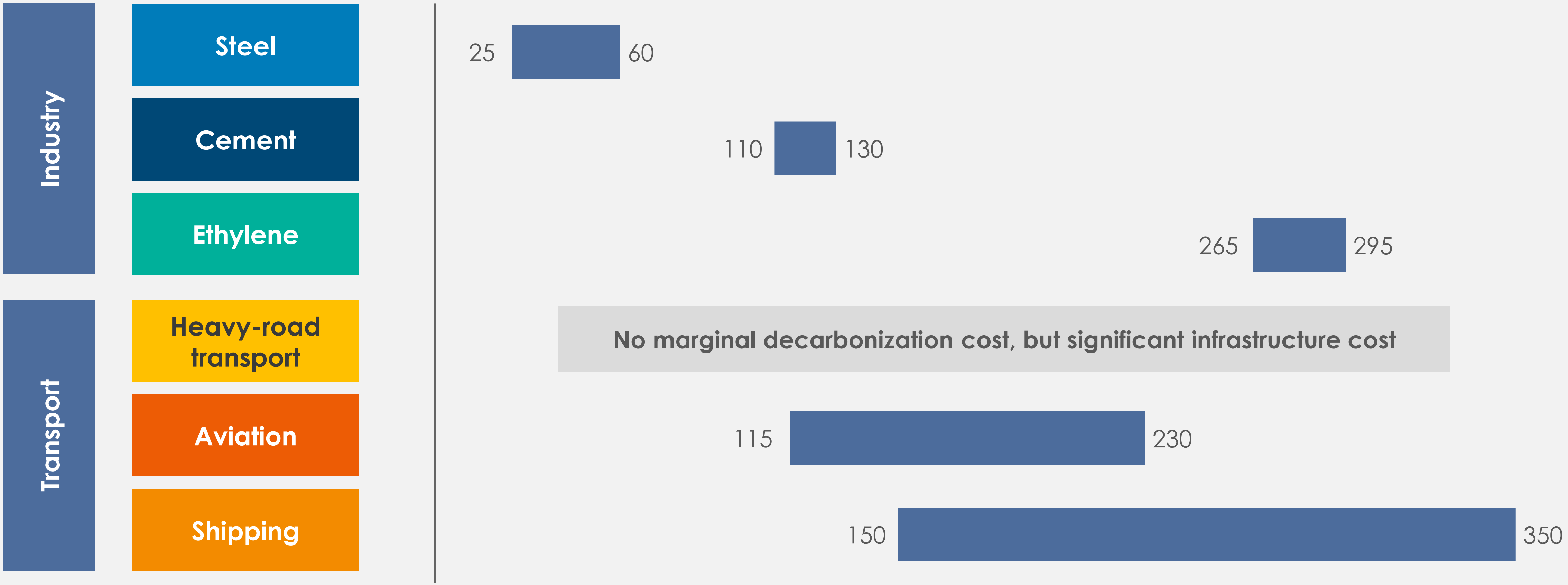
Illustrative cost penalty of biofuels / synfuels vs. jet fuel *(US$ per litre)*	Kg CO_2 per litre of jet fuel *(kg)*	CO_2 per tonne price to make cost equivalent *(US$)*	Cost penalty on 6500km journey per passenger *(US$)*
0.25	**2.57**	**97**	**40**
0.5	**2.57**	**194**	**80**
0.75	**2.57**	**291**	**120**

Source: SYSTEMIQ analysis (2018)

Costs of supply-side decarbonization vary greatly by sectors

Supply-side abatement cost in a low-cost and high-cost scenarios

US$/tonne CO_2



Source: Industry: McKinsey & Company (2018), *Decarbonization of industrial sectors: the next frontier* / Shipping: UMAS analysis for the Energy Transitions Commission (2018) / Other transport sectors: SYSTEMIQ analysis for the Energy Transitions Commission (2018)

In some cases there could be a significant impact on intermediate product costs …

Impact on intermediate product cost
US$ / % price increase

Industry	Cement	+$100 per tonne of cement (+$30 per tonne of concrete)	+100% (+30%)
Industry	Steel	+$120 per tonne of steel	+20%
Industry	Plastics	+$500 per tonne of ethylene	+50%*
Transport	Heavy-road transport	No price impact	None
Transport	Shipping	+$4 million on typical bulk carrier voyage call per annum	+110%
Transport	Aviation	+$0.3-0.6 per liter of jet fuel equivalent	+50-100%

*Assuming an initial price of US$1000/tonne for ethylene, although the price of ethylene is very volatile.
Source: SYSTEMIQ analysis for the Energy Transitions Commission (2018)

…but with a minimal impact on most end consumer prices…

Sector	Segment	Impact on final product cost US$ / % price increase	
Industry	Plastics	+$0.01 on a bottle of soda	<1%
Industry	Steel	+$180 on the price of a car	+1%
Industry	Cement	+$15,000 on a $500,000 house	+3%
Transport	Heavy-road transport	No price impact	None
Transport	Shipping	+$0.03 per kilogram of imported sugar	<1%
Transport	Aviation	+$40-80 on a 6,500-km economy class flight	+10-20%

Source: SYSTEMIQ analysis for the Energy Transitions Commission (2018)

Three ways of thinking about cost impact

Additional ticket cost relative to no action alternative:

- **+ 10% to 20%?**

Additional ticket cost relative to today:

- **negative if fuel efficiency improved by more than 20%-25%?**

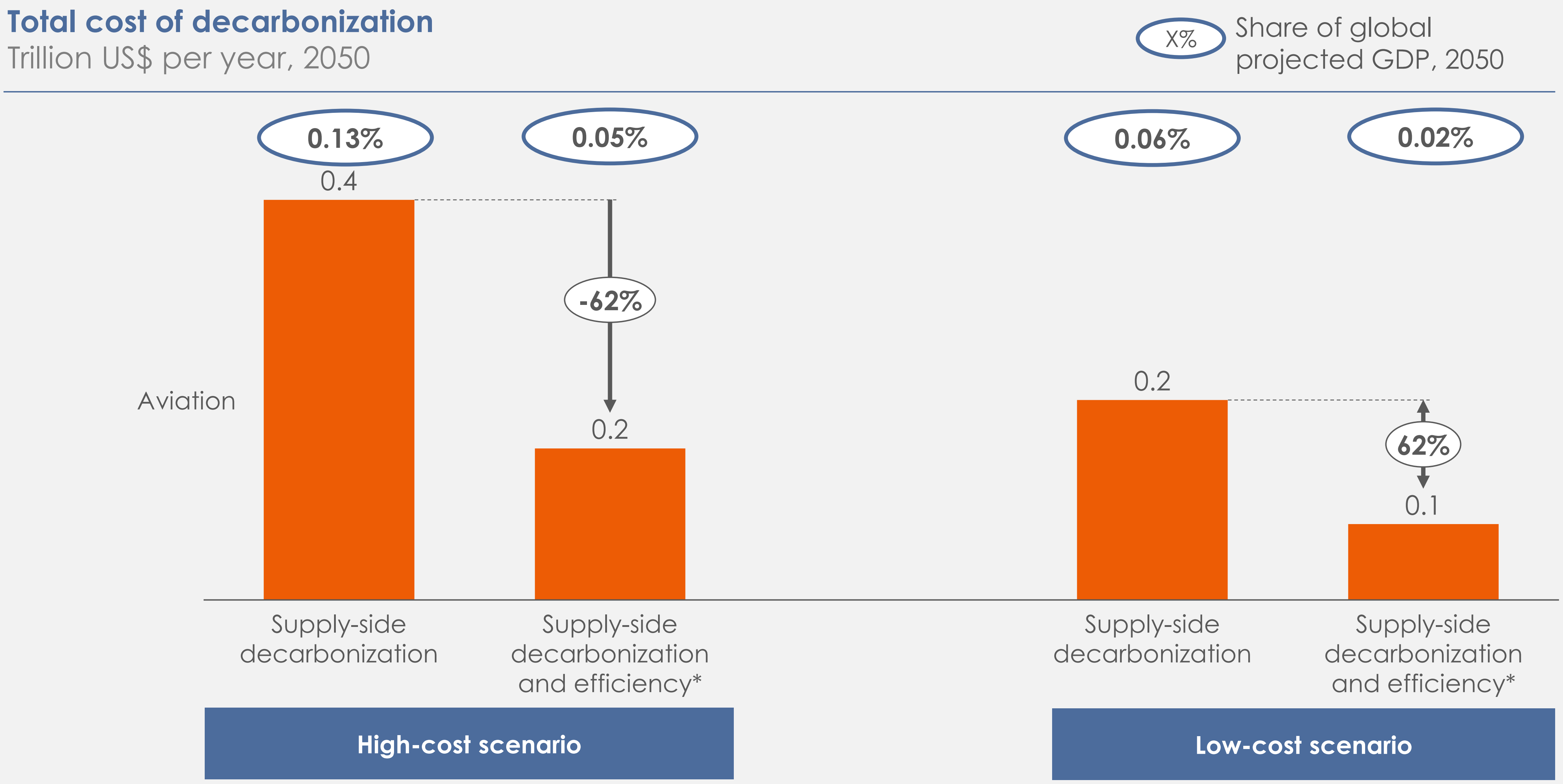
Impact on total consumer budget:

- **trivial since air travel about 3% of median consumer expenditure**

Achieving zero carbon: impact on consumer living standards

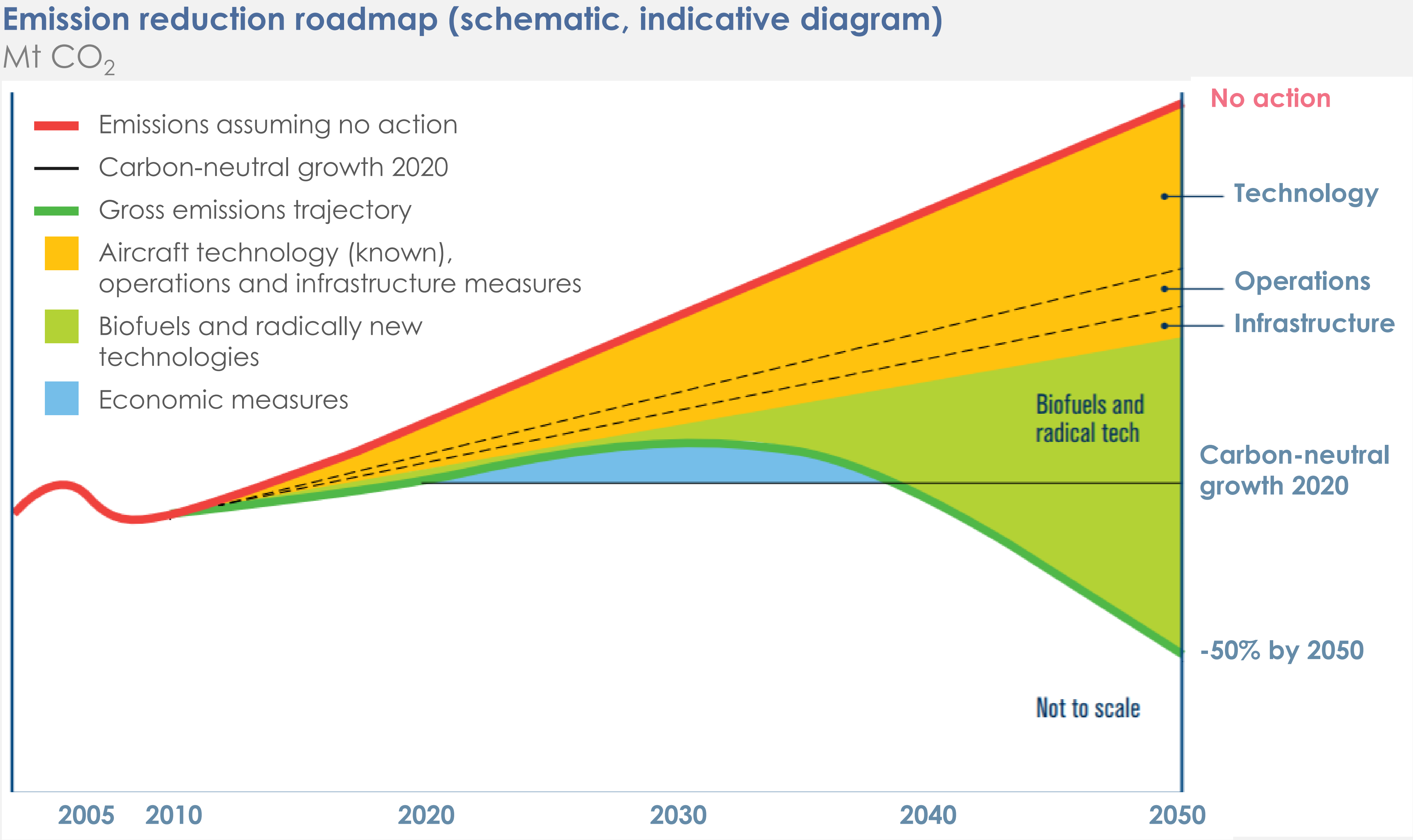
	Short-term	Long-term		
Non energy intensive services (e.g. healthcare)	Nil	Nil	←	Large and growing % of economy
Surface passenger transport	Moderately negative	Significantly positive		
Manufactured goods (reflecting production and freight costs)	Very small negative impact		←	Key issue is international competitiveness
Residential heat	Significant for low income households due to capital costs of insulation and heat pump installation		←	Fuel = 12% of lower income household expenditure
Air travel	Significant cost increase but very small as % of consumer expenditure			

Decarbonizing aviation would cost less than 0.15% of global GDP, and significantly less if pursuing energy efficiency improvement and demand management opportunities



Note: The term "efficiency" covers demand management
Source: SYSTEMIQ analysis for the Energy Transitions Commission (2018)

The International Air Transport Association (IATA) has set global goals for the reduction of aviation's emissions



Source: IATA (2013), *IATA Technology Roadmap, 4th edition*

The case for zero aviation emissions by 2050

Necessary

If we are serious about the IPCC 1.5C objective, the whole world needs to reach net zero emissions by 2050.

If all sectors are at net zero, no sector can buy offsets from other sectors.

Land use offsets are a one-off transitional option – a fully mature forest is carbon neutral.

If aviation is not zero carbon – it will probably be politically demand constrained.

Technically and economically possible

100% biofuel or synthetic fuel mix technically possible today

Extra costs to consumers

- Significant ticket price impact relative to no action alternative - but real prices may still be lower than today
- Very small as % of total consumer budgets

Opportunity and challenge

- Costs of biofuels/synfuels will fall with scale and learning curve effects
- Good case for aviation to be priority sector for use of limited sustainable biofuels
- But cannot piggy back on road transport biofuel developments
- Needs to overcome "chicken and egg" problem of supply and demand

Industry and policy response?

- Commit to 2050 zero emissions objective
- Foster short-term demand for premium priced bio/synfuels among major business users
- Introduce seriously priced offset systems – voluntary and then compulsory
- Introduce fuel duty standards to require zero carbon fuel use
  - 10% by 2025?
  - 100% by 2050