IRENA
International Renewable Energy Agency

Where will we get our biojet?

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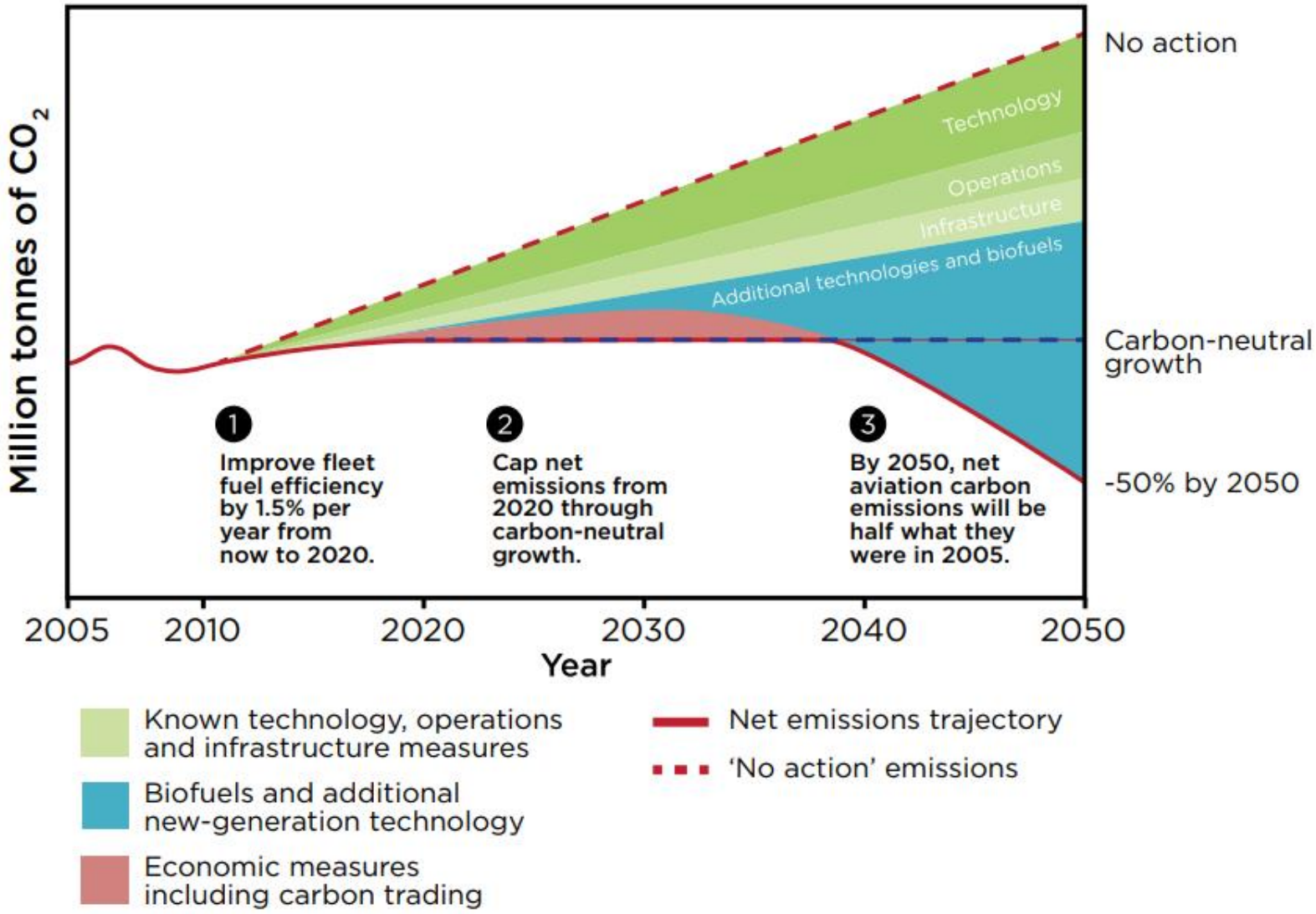
Ways to decarbonise aviation

- Improved efficiency through better aircraft design and operation to reduce fuel per person-km or tonne-km
  - Well advanced, low in cost or even cost-reducing
  - May be tough to reduce fuel use by more than half
- Sustainable Aviation Fuel (SAF) to reduce carbon emissions from fuel still used in more efficient aviation
  - Substantial life cycle emissions reductions per litre
  - If half as much fuel were needed and emissions were 80% less per liter, total emissions would decline 90%
  - Hard to compete with fossil fuels: must work to reduce conversion costs, organise feedstock logistics

Biojet to reduce carbon emissions



Source: Air Transport Action Group

Where will we get our biojet?

- Feedstocks and technologies to consider:
  - Oilseed crops on restored land (upgrade biodiesel)
    - Europe (rapeseed), China, Americas
    - FORBIO project – set aside land in EU
  - Wood residues (thermochemical routes)
    - Uncollected logging residue in Scandinavia
    - Unrealised forestry potential in SE Europe
  - Sugar/Energy cane (1G+2G ethanol plus conversion)
    - Brazil, Southern Africa, Caribbean
    - Economies from shared 1G/2G process steps
    - Future potential enhanced by high-yield energy cane

What biojet pathways are certified?

- **Certified technology pathways (end of 2018):**
  - Oilseed crops (oleochemical routes)
    - HEFA - ASTM D-7566 Annex A2 (2011)
  - Wood residues (thermochemical routes)
    - FT – ASTM D-7566 Annex A1 (2009)
  - Sugar/Energy cane (biochemical routes)
    - ATJ (Alcohol to Jet) – ASTM D-7566 Annex A5 (2018)
    - DSHC (Direct Sugar to Hydrocarbon) or SIP (Synthesised Iso-Paraffinic) Fuels – Annex A3
      - Much more costly than ATJ,
      - Farnesene has alternative uses
      - Brazil plant has shifted to higher-value products

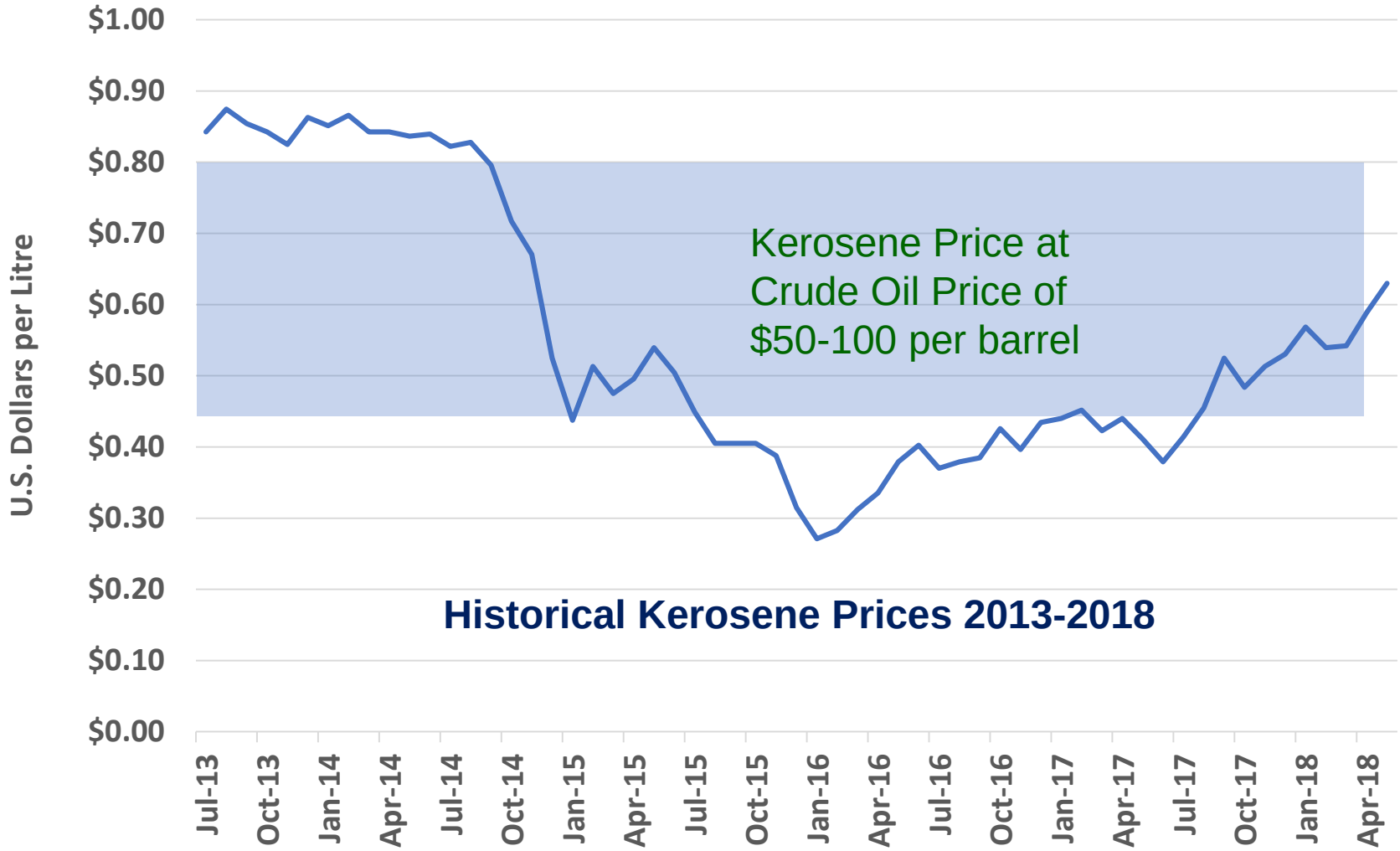
How ready are biojet technologies?

- **Technology Readiness Levels of biojet Pathways:**
  - Oilseed crops (oleochemical routes)
    - Hydro processed Esters & Fatty Acids (TRL = 6 to 9)
  - Wood residues (thermochemical routes)
    - Fischer-Tropsch (TRL = 7 to 8)
    - Pyrolysis (TRL = 4 to 6)
    - Hydro-Thermal Liquefaction (TRL = 1/3 - 4)
  - Sugar/Energy cane (biochemical routes)
    - Alcohol to Jet (TRL = 4 to 7)
    - DSHC / SIP (TRL = 5 to 7)

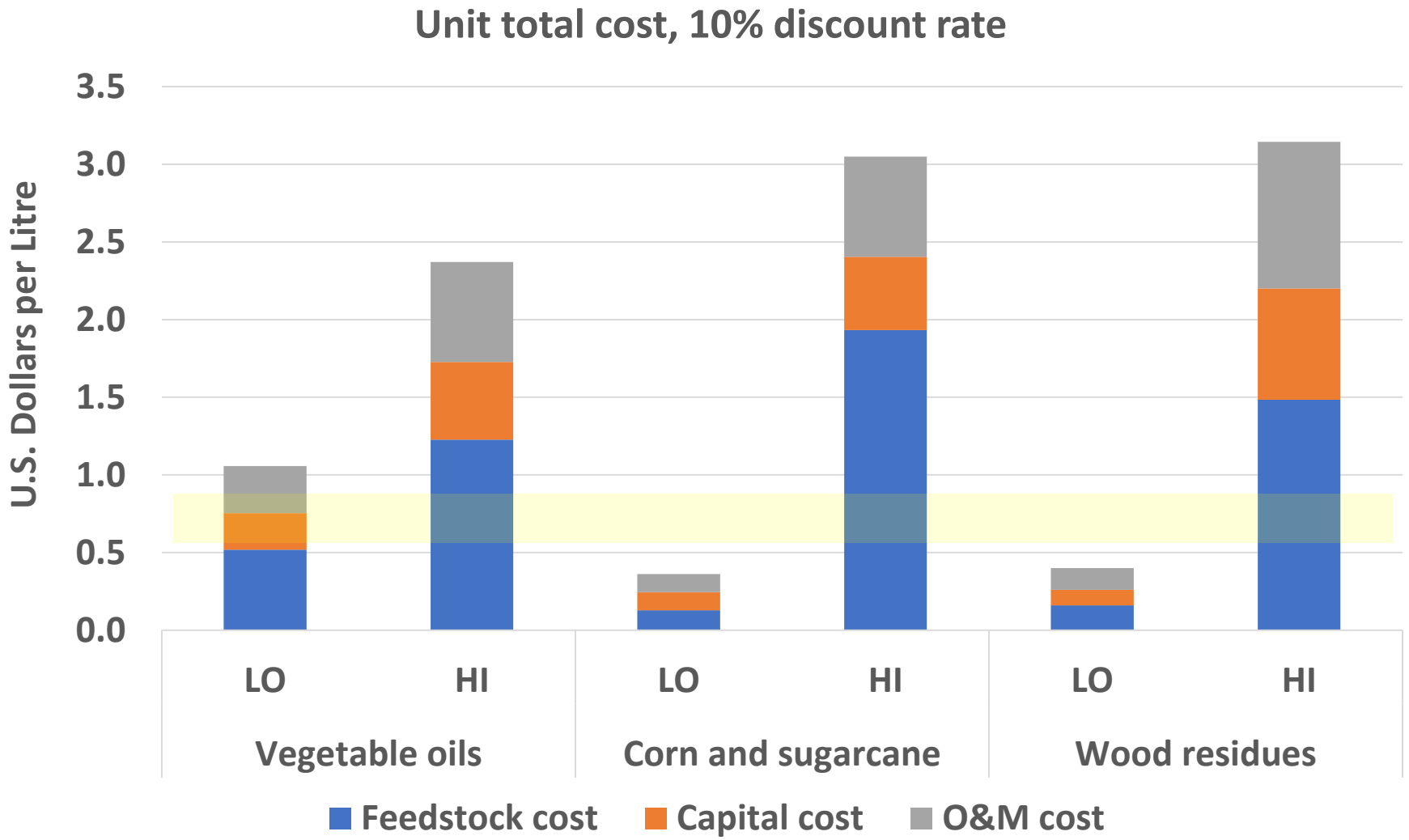
Select biojet pilot projects

- Oilseed crops (oleochemical routes)
  - Altair
  - Neste (vegetable oils, jatropha, camelina, animal fats)
- Wood residues (thermochemical routes)
  - Red Rock (wood residues)
  - Fulcrum (municipal solid waste)
- Sugar to Alcohol to Jet (biochemical routes)
  - Raizen (Sugarcane 1G/2G to ethanol)
  - Gevo (Maize to butanol)
  - Poet (Maize to ethanol)
  - Clariant (Maize 1G and stover 2G to ethanol)
  - Lanzatech (waste to ethanol)
  - Biogy (catalytic synthesis of alcohols to biojet)
  - PNNL – dehydration/oligomerization/hydrogenation

Costs of conventional fossil jet fuel



How do total costs for biojet compare?



How will we push for biojet?

- **Policy support to consider:**
  - RD&D support for pilot plants w lignocellulosic feedstock
  - Significant market value for carbon and methane
  - Volumetric renewable fuel mandates
  - Limits on jet fuel carbon per person-km, tonne-km
- **CORSIA – Carbon Offsetting and Reduction Scheme for International Aviation** – a model for domestic schemes?
  - 66 states (86% of traffic) joined at outset in 2016
  - MRV (monitoring, reporting and verification) system
  - Criteria for emissions units to be purchased by airlines
  - Linking with initiative for State Action Plans
  - Partnership with World Bank for capacity building
  - Support by Germany for pilot implementation project

A few concluding thoughts

- Advanced biojet fuel will be essential to the RE transition and full decarbonisation of energy supply since aviation cannot be completely electrified and efficiency improvements can only go so far
- Advanced biofuel conversion technologies are needed to diversify the range of feedstocks to include farm and forest residues and wood crops
- Advanced biofuels should become cost competitive given expected oil prices and carbon values, if investment is made to get to “nth” plants and efficient logistic chains are identified to utilise abundant feedstocks

Key questions

1) What are the main barriers to large-scale, commercial deployment of biojet?

2) Economic competitiveness with fossil fuels seem to be a major barrier today. Would cost reductions alone be sufficient to unleash the potential?

3) If cost reductions alone are not enough (or if costs will never be reduced to the extent needed to compete with fossil fuels), what else would be needed?

4) How relevant would national policies for domestic aviation be in comparison to international policies for international aviation? Should governments take the lead and deal with the issue at the domestic level (at least for domestic aviation), or should they wait and follow what the international consensus dictate?

5) Will the supply of biojet be dominated by a few technologies and feedstocks or will it be diverse, depending on the region?

6) Will supply be concentrated in a few countries/regions with the development of global trade or will it be distributed around the world?

7) How important is the support to the existing conventional biofuel industry to the development of the nascent biojet industry?

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