CCS in Achieving Negative Emissions

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Mitigation Measures

More efficient use of energy

Greater use of low-carbon and no-carbon energy

- Many of these technologies exist today

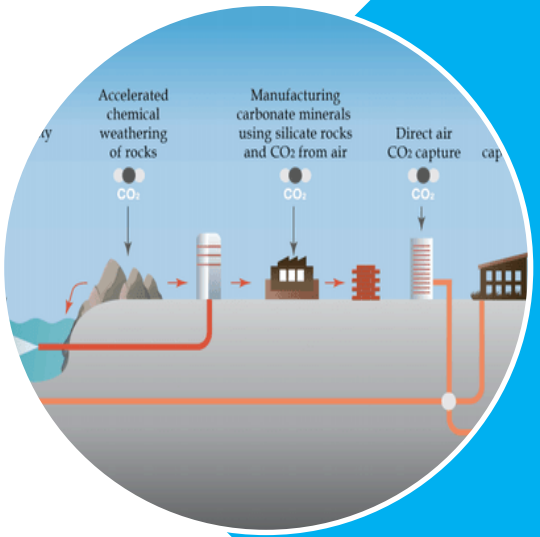
Improved carbon sinks

- Reduced deforestation and improved forest management and planting of new forests
- Bio-energy with carbon capture and storage

Lifestyle and behavioural changes

AR5 WGIII SPM

What are NETs?

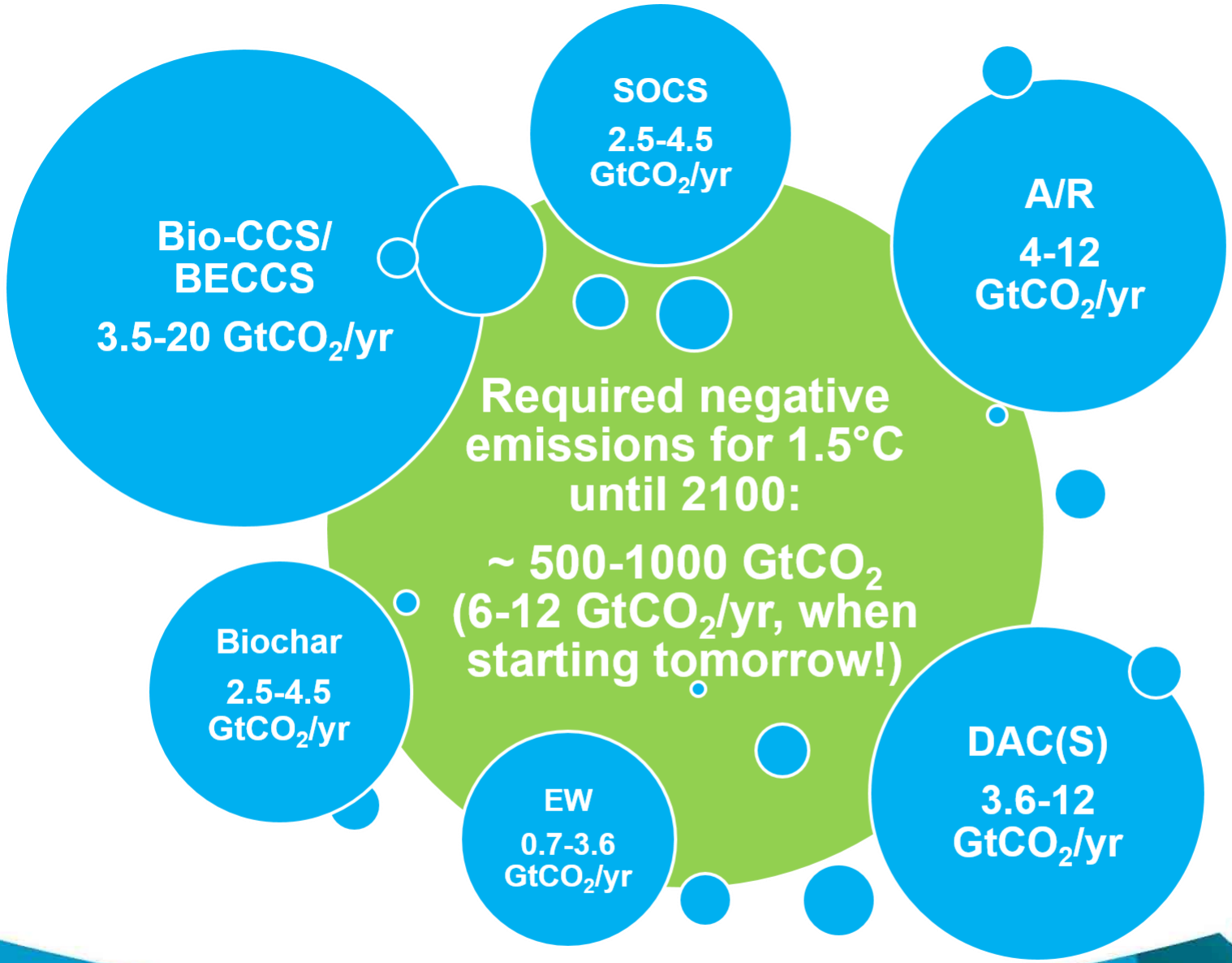


Virgin Earth Challenge

NETs (negative emission technologies)

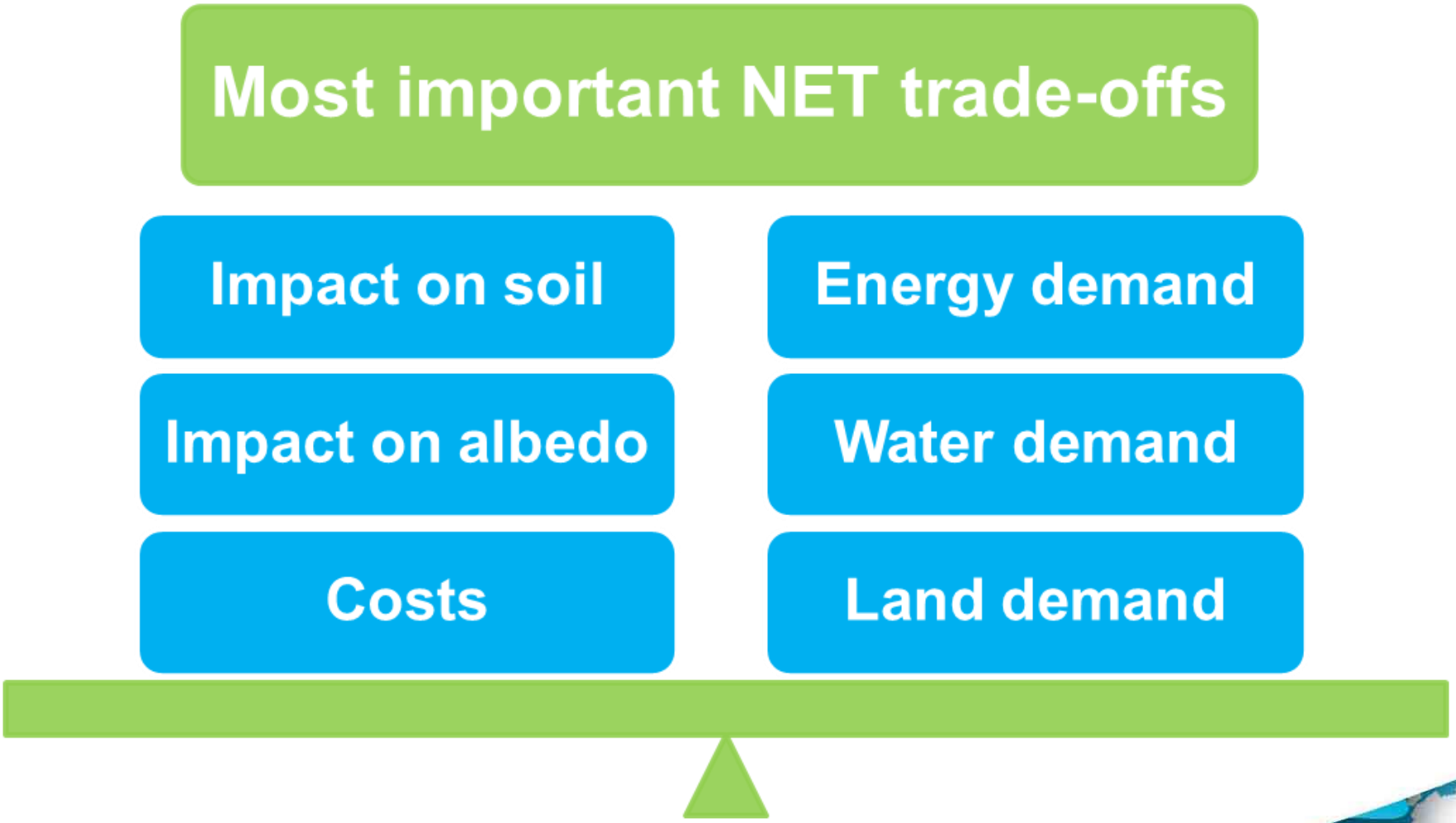
- **Bio-CCS/BECCS (bioenergy with CCS)** – using biomass that has previously taken up CO_2 during growth to produce power/heat/fuels, then capturing and storing the emitted CO_2
- **A/R (afforestation/reforestation)** – planting trees where previously (a) there were none or (b) they have been cut down
- **DAC(S) (direct air CCS)** – capturing CO_2 directly from air
- **EW/MC (enhanced weathering/mineral carbonation)** – spreading pulverised rock on land/water to take up CO_2 and form bicarbonate
- **SOCS (soil organic carbon sequestration)** – storing CO_2 in soil through advanced farming methods, restoration and land creation
- **Biochar** – adding burnt/torrefied biomass to soil for long term storage
- **Ocean fertilisation** – adding Fe or N to accelerate CO_2 uptake by microorganisms for photosynthesis
- **Cloud/ocean treatment** – (a) using alkalis to wash CO_2 out of the atmosphere, (b) using lime to absorb CO_2 from the oceans

NET potentials



Based on Smith et al. 2016

NET potentials



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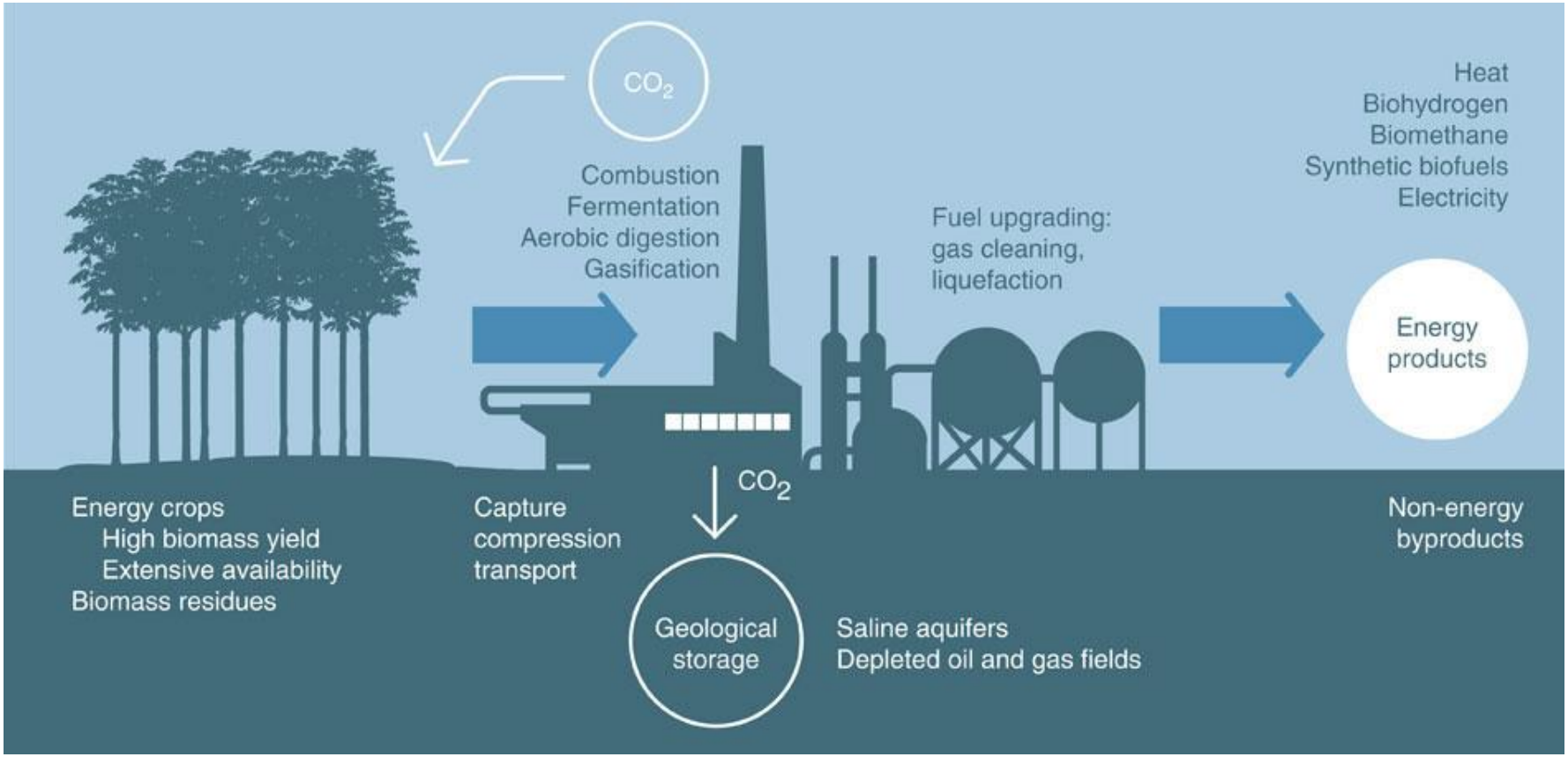
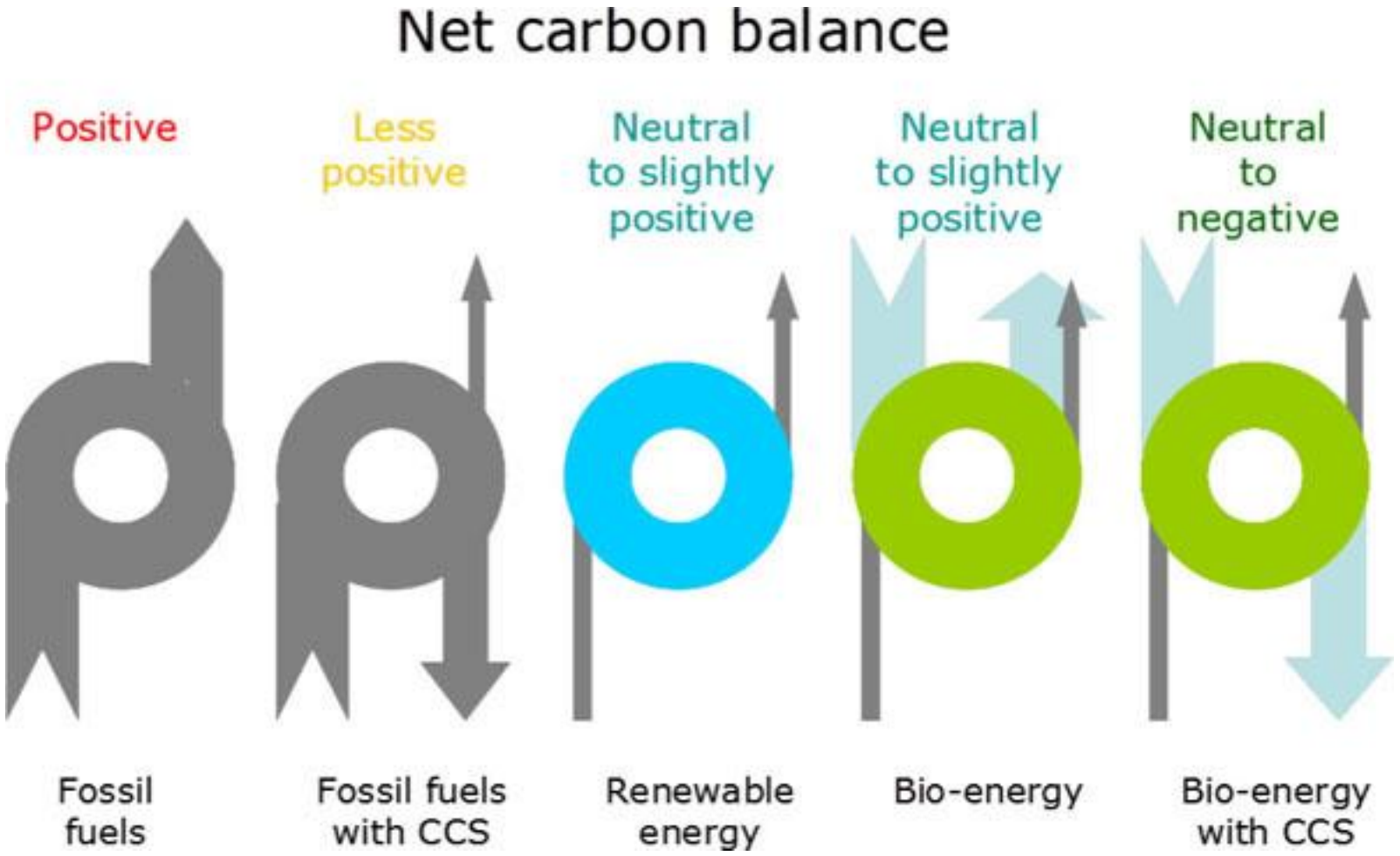
Concept of Bio-CCS



Sanchez et al. 2014, courtesy of Nature

C balance of energy systems



IEAGHG/Ecofys 2011, adapted from ecofriendlymag.com; grey denotes carbon of fossil origin, blue denotes carbon of biogenic origin)

Bio-CCS – brief status summary

Many studies conclude: Bio-CCS, incl. its CCS components, technically feasible as of today (TRL 3-7) [except microalgal biomass]

Perceived „double benefit“: heat/power + negative emissions

5 operating Bio-CCS projects 0.1-1 $MtCO_2$/yr (all EtOH, 3 for EOR, 4 in US, 1 rather Bio-CCU), several more underway

GHG accounting: only 2006 IPCC GLs, CDM/JI, Ca LCFS and EU RED/FQD cover Bio-CCS

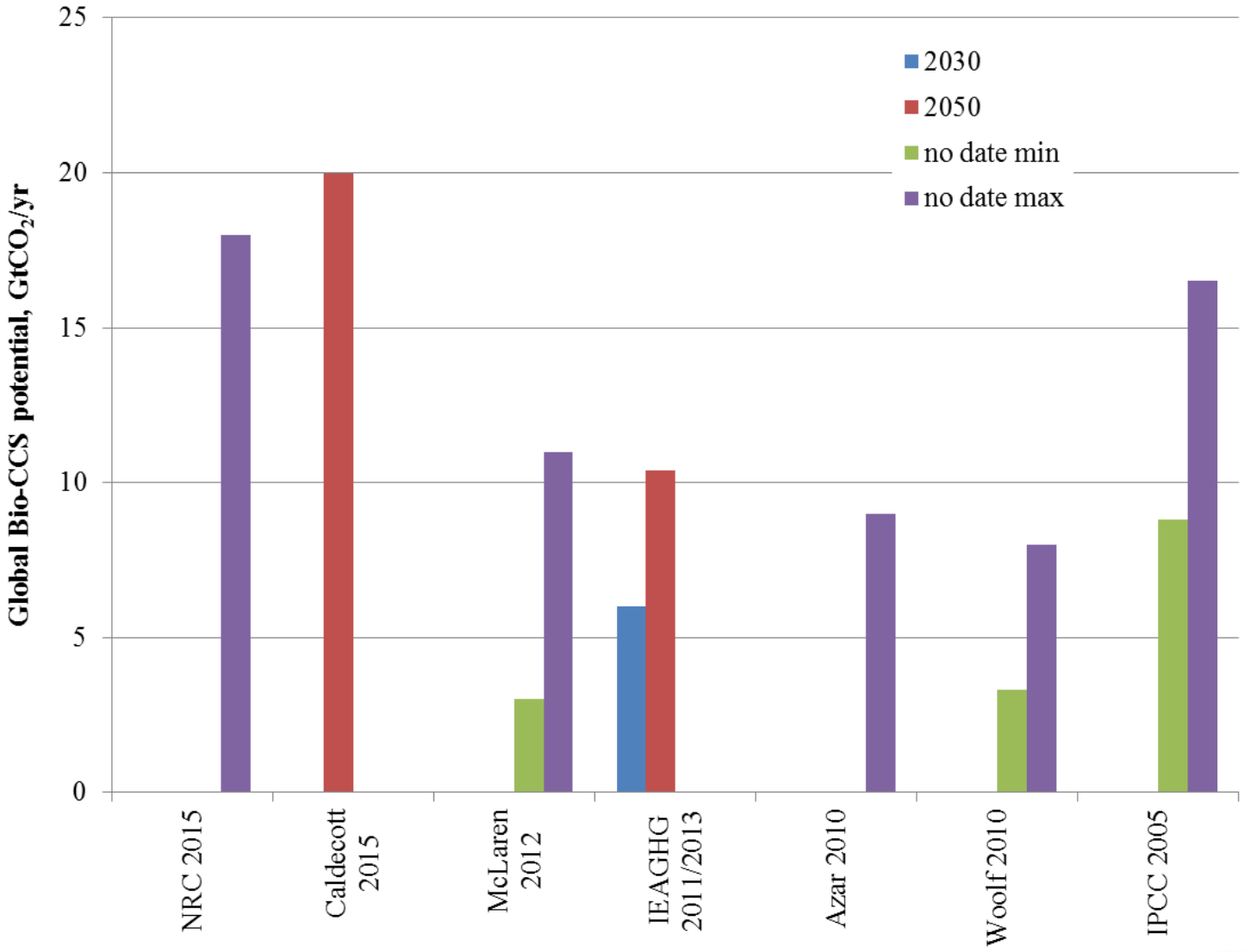
Plenty of research on public perception of CCS but very limited and contradictory on Bio-CCS

- Bio-CCS generally has lower profile than Fossil-CCS

Main drivers/barriers for Bio-CCS:

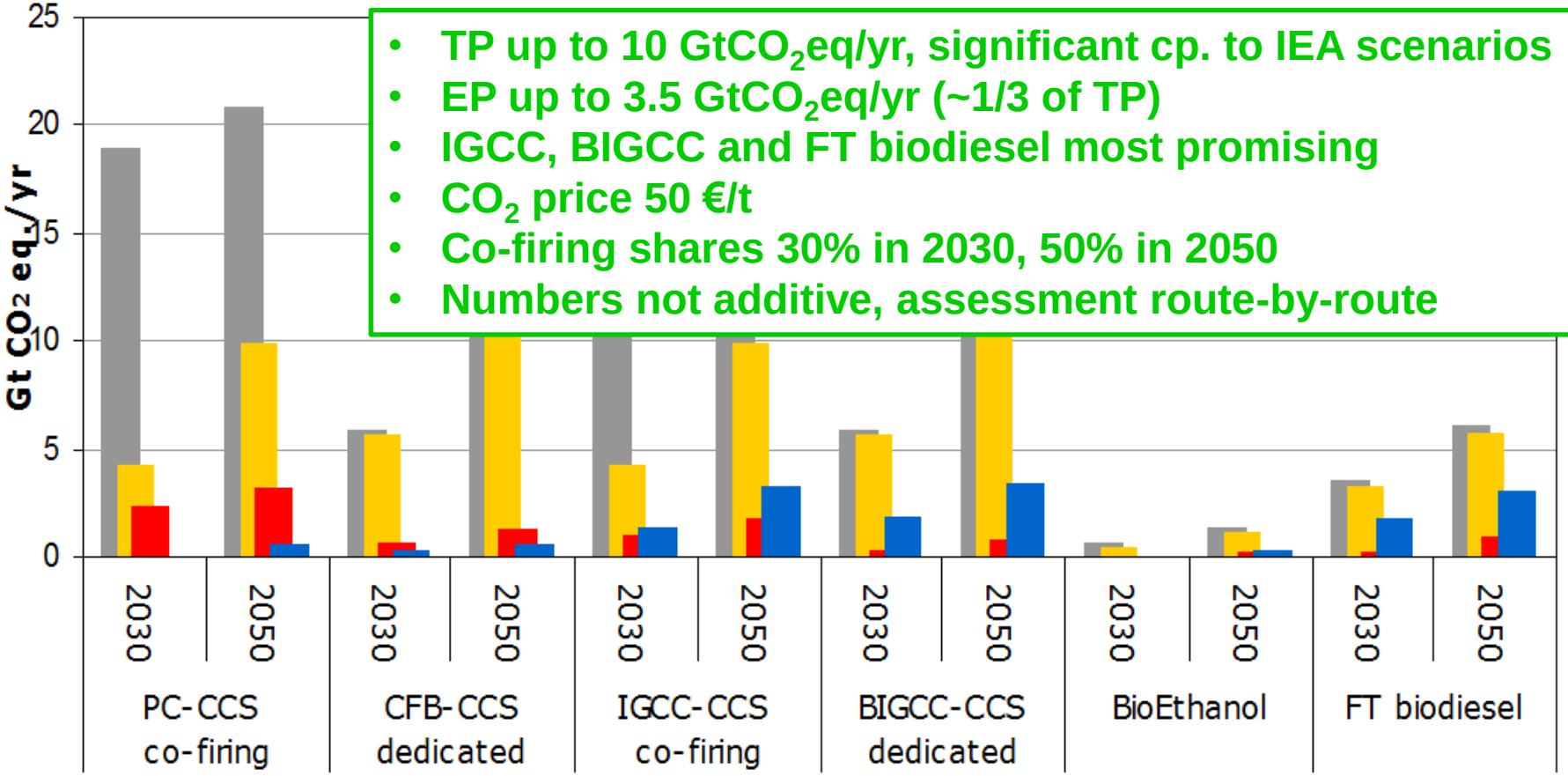
- CO_2/NG price, infrastructure/clusters, sustainable feedstocks, public perception

Global Bio-CCS potential



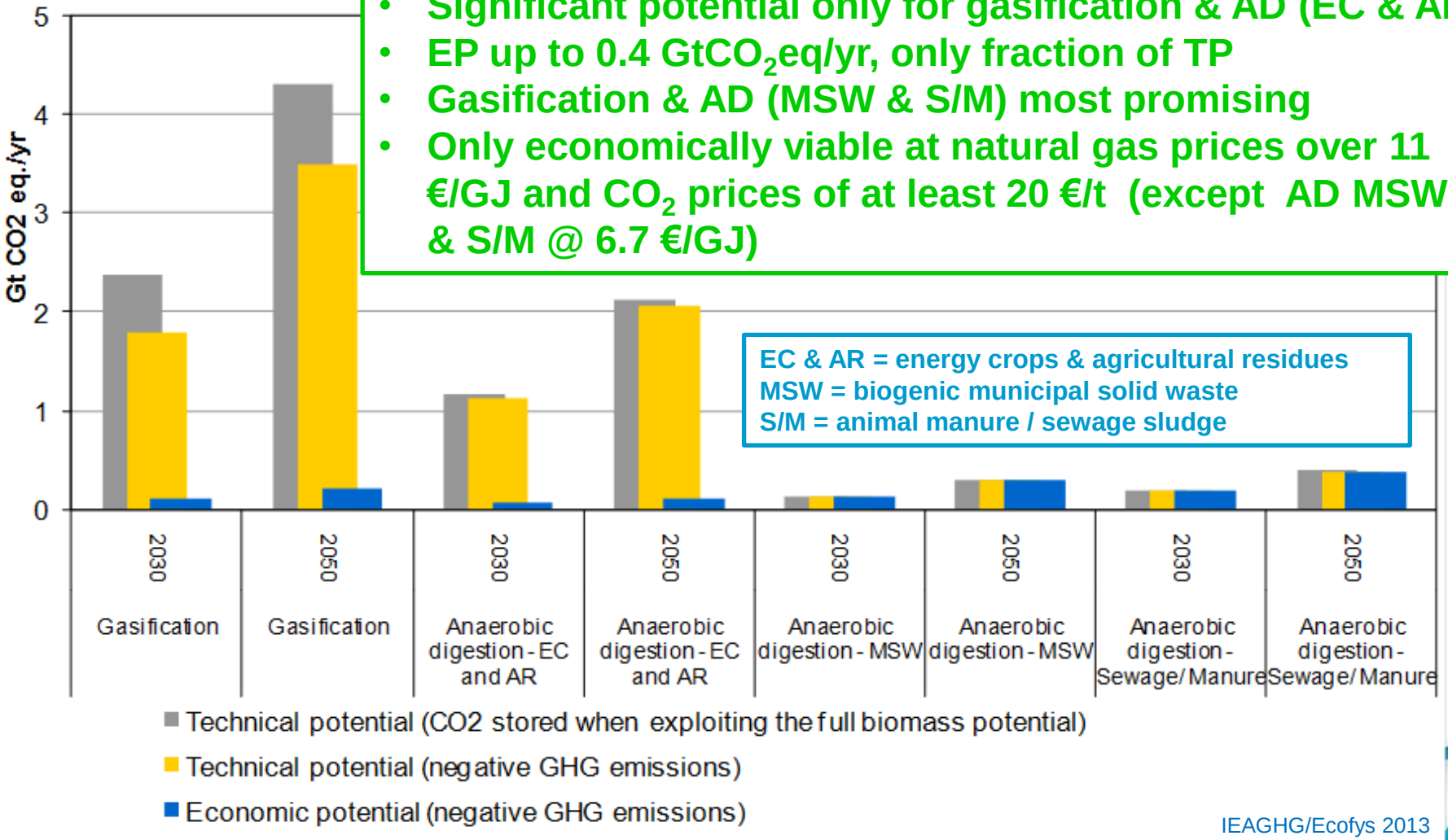
Negative emissions potential for Bio-CCS

- TP up to 10 $GtCO_2eq/yr$, significant cp. to IEA scenarios
- EP up to 3.5 $GtCO_2eq/yr$ (~1/3 of TP)
- IGCC, BIGCC and FT biodiesel most promising
- CO_2 price 50 €/t
- Co-firing shares 30% in 2030, 50% in 2050
- Numbers not additive, assessment route-by-route



Negative emissions potential for biomethane routes

- TP up to 3.5 $GtCO_2eq/yr$, smaller than previous routes
- Significant potential only for gasification & AD (EC & AR)
- EP up to 0.4 $GtCO_2eq/yr$, only fraction of TP
- Gasification & AD (MSW & S/M) most promising
- Only economically viable at natural gas prices over 11 €/GJ and CO_2 prices of at least 20 €/t (except AD MSW & S/M @ 6.7 €/GJ)



IEAGHG/Ecofys 2013

Accounting frameworks

Scheme	CCS	Biomass growth/ harvesting/ combustion/ processing	dLUC/iLUC	Life cycle emissions	Negative emissions
2006 IPCC GLs	✓	✓	✓	✓	✓
EU ETS	✓	✓	✗	✗	✗
EU RED/FQD	✓	✓	✓	✓	✓
US GHGRP	✓	✓	✗	✗	✓
California ETS	✗	✓	✗	✗	✓
California LCFS	✓	✓	✓	✓	✓
Australia CPM[#]	✓	✗	✗	✗	✗
UNFCCC KP's CDM/JI	✓	✓	✓	✓	✓

Note that the Australian Senate repealed the CPM on 17th July 2014, taking effect from 1st July 2014. The repeal has no effect on entities' reporting obligations under the NGER.

Bio-CCS in energy / water / food nexus

- Competition between food and bioenergy crops
- Shift of GHG/CO_2 emissions from one sector to another ("carbon leakage")
- Impact of large-scale biomass infrastructure, trade, and supply chains
- Impact of climate change on crop yields
- Water footprint of Bio-CCS systems
- Effects of increased fertiliser use
- Land availability and lock-in
- Land use change (LUC) impacts
- Biomass sustainability

Main nexus concerns

Conclusions

- Ability of Bio-CCS to deliver negative emissions important to achieve climate mitigation targets
- Majority of research suggests bioenergy potential of ~100 EJ/yr and Bio-CCS potential of ~10 $GtCO_2$/yr
- Costs of Bio-CCS comparable to Fossil-CCS, in the region of 60 – 250 $/t$CO_2$
- Several projects underway but lots more needed to build up confidence
- Policy, regulations and financial instruments for Bio-CCS need development
- Bio-CCS deployment will hinge on case-specific details, with sustainable biomass supply likely to be the linchpin
- Nexus-approach required due to complex sustainability issues

Thank you, any questions?

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