NEGEM key results on environmental impacts of CDR methods

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POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

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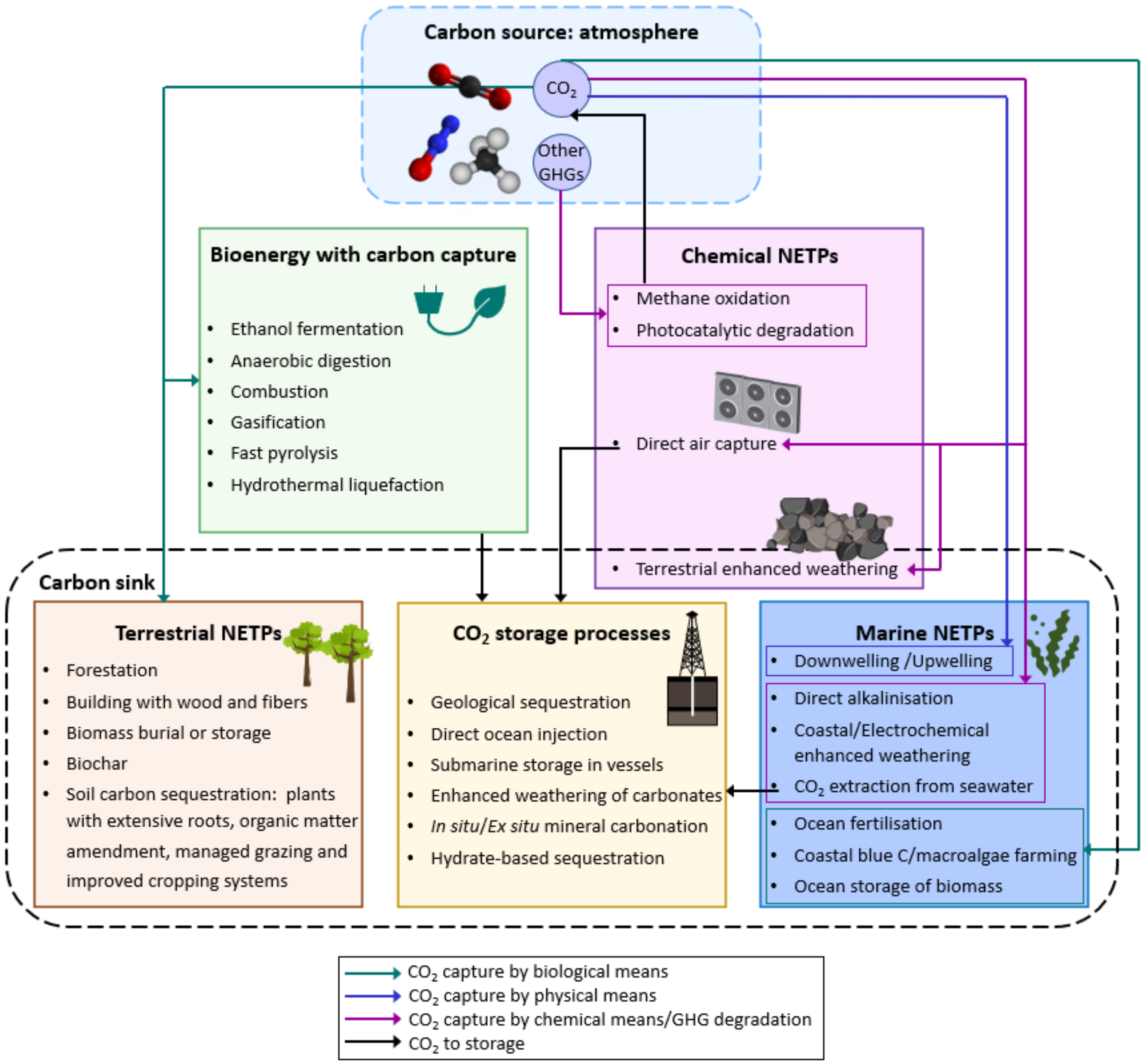

NETP impact assessment with Life Cycle Assessment (LCA)

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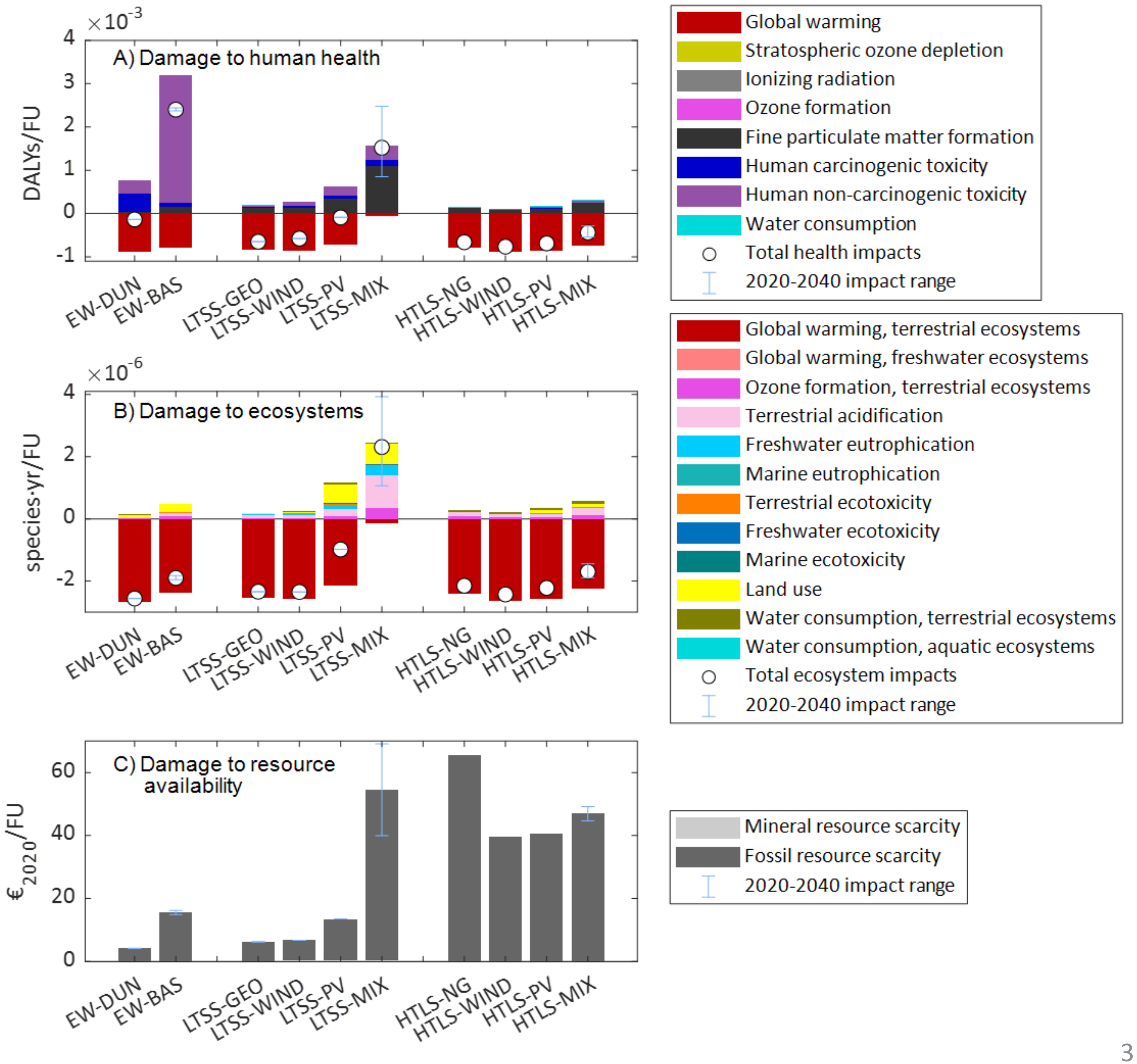
Damage associated with NETP resource consumption and emissions

	NETPs	TRL	Max CDR Gtonne·yr[-1]	Cost (2019€) €·tonne[-1] CO_2	Score [-3, 3]
TERRESTRIAL	Wood burial or storage	1-2[44]	1-3[33]	7-51[33]	0
	Biochar amendment	4-6[33]	0.5-2[25]	28-112[25]	0
	Afforestation/reforestation	8-9[159]	0.5-3.6[25]	5-47[5]	2
	Soil carbon sequestration	6-7[33]	2-5[25]	0-93[25]	2
	Building with wood	8-9[33]	0.5-1[33]	Negligible[33]	2
MARINE	Downwelling	1-2[b]	0.035[a,55]	228-5142[55]	-3
	Upwelling	1-3[b]	0.059[a,58]	n/a	-2
	Ocean fertilization (Fe)	1-4[33]	3.6[83]	459[82]	-2
	CO_2 extraction from seawater	2-3[b]	[c]	347-562[78]	-1
	Ocean storage of terrestrial biomass	1-2[b]	6.75[d,91]	104[91]	-1
	Ocean alkalinization	2-3[b]	8.43-12.15[e,62,63]	3-160[69,75]	0
	Coastal blue carbon	5-6[33]	0.13-0.80[f,8]	9[8]	0
	Ocean fertilization (N and P)	2-3[33]	5.5[84]	21[81]	1
	Direct injection[1]*	*1-2[b]*	*12.5[g,53]*	*14-19[88]*	*1*
	Submarine storage in vessels[1]*	*1-2[b]*	[c]	*16[89]*	*1*
BECCS	Hydrothermal liquefaction	5[160]	0.5-5[25]	210-294[h,131]	-1
	Algal BECCS	1-2[b]	53[i,161]	n/a	0
	Anaerobic digestion	8[b]	2.8[162]	139-313[j,163]	0
	Chemical looping combustion	4[164]	0.5-5[25]	n/a	0
	Oxy-combustion	5[164]	0.5-5[25]	136[j,165]	0
	Combustion	4-6[33]	0.5-5[25]	116[j,131]	0
	Pyrolysis	7[166]	0.5-5[25]	136-387[j,131]	0
	Gasification	3-5[167]	0.5-5[25]	160-182[j,131]	0
	Ethanol fermentation	7[b]	0.5-5[25]	19-163[j,25]	1
CHEMICAL	Degradation of non-CO_2 GHG	1-3[b]	n/a	n/a	-1
	Terrestrial enhanced weathering	3-5[168]	4.9-95[105]	25-591[111]	0
	Ex situ mineral carbonation[1*]	*3-4[b]*	[c]	*60[125]*	*1*
	Direct air capture (LTSS, MSA)[2]*	*3-4[b]*	[c]	*97[144]*	*1*
	Direct air capture (LTSS, TSA)[2*]	*7[93]*	[c]	*≈ 600[k]*	*1*
	Direct air capture (HTLS)[2*]	*7[93]*	[c]	*88-216[135]*	*2*
	In situ mineral carbonation[1*]	*7[166]*	[c]	*17[121]*	*3*

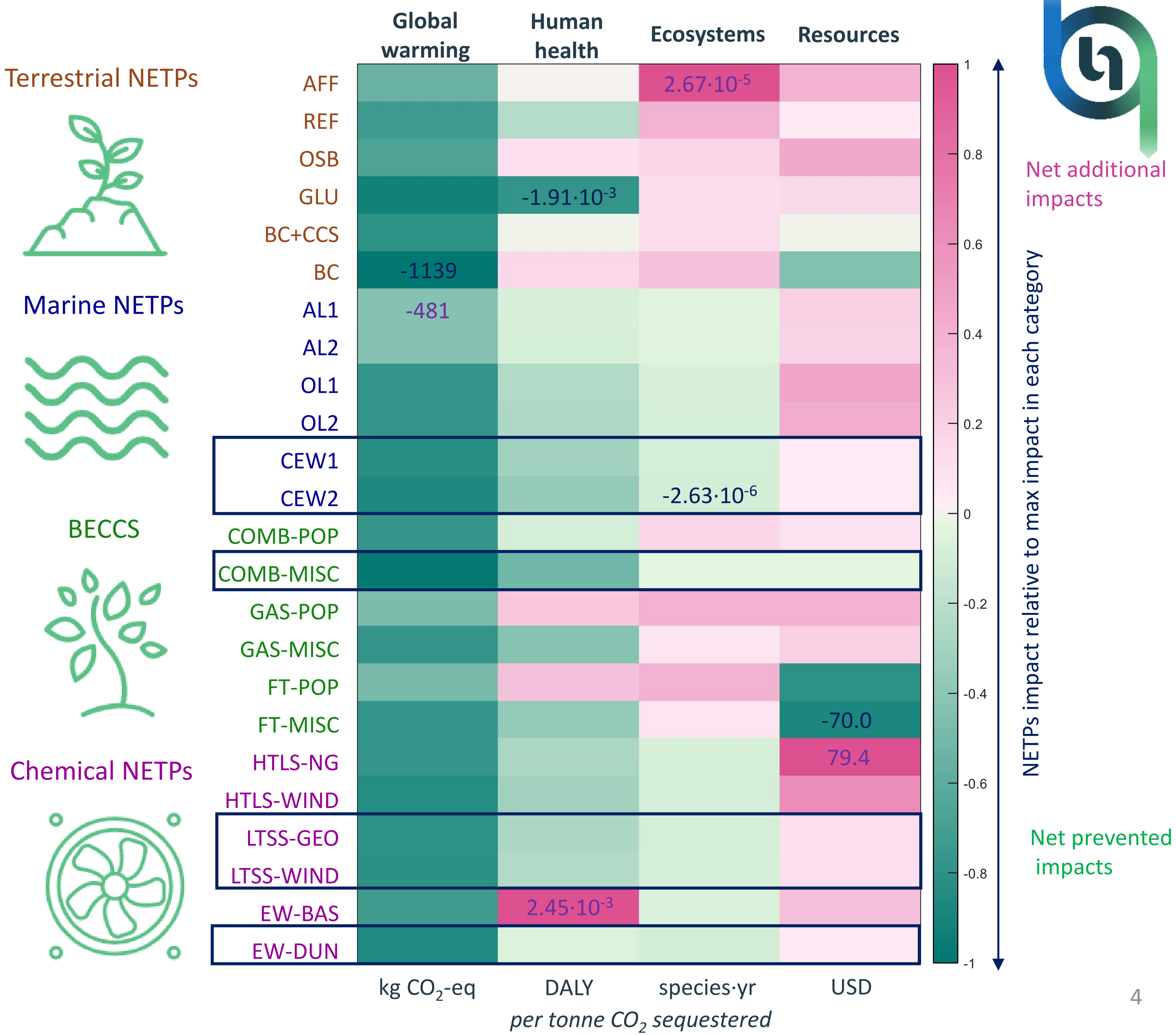


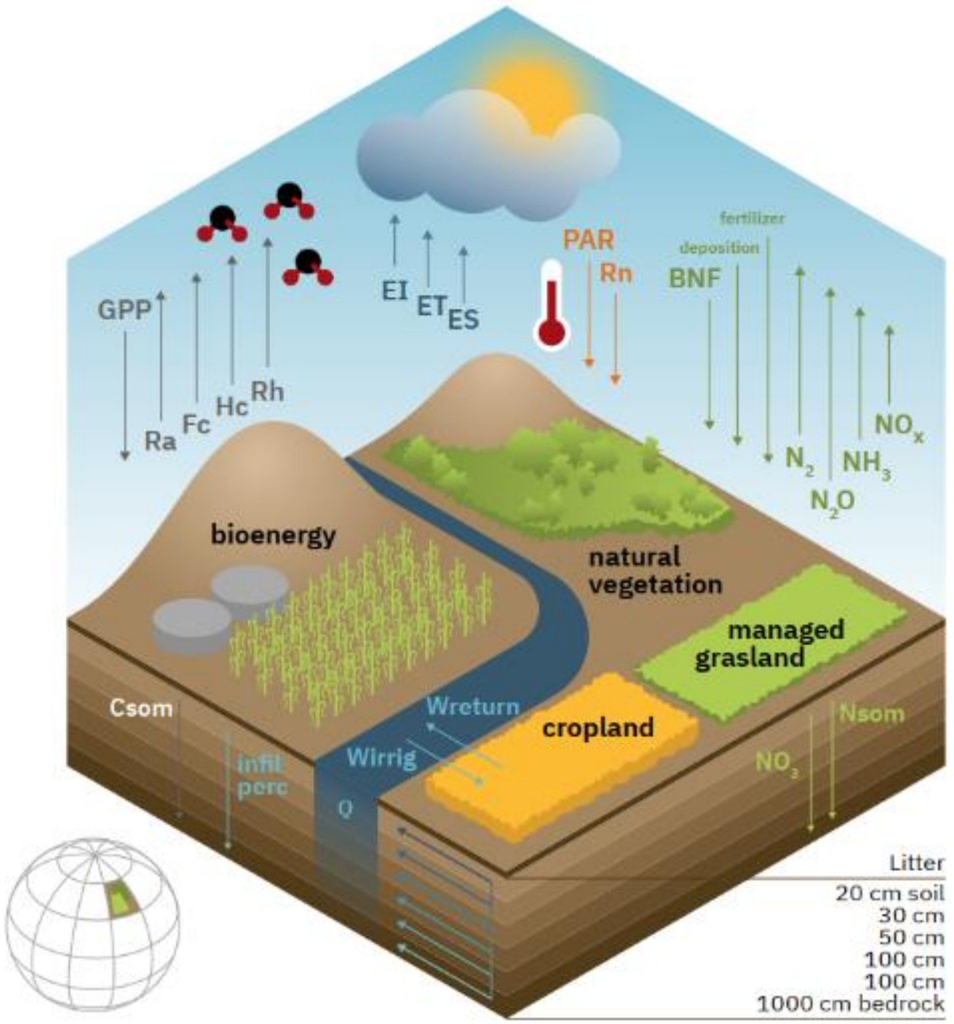
No silver bullet:

none of the assessed NETPs performs better than all the others in all assessed impact dimensions

→ Recomendation: portfolio of NETPs

- enhanced weathering & LTSS-DACCS = promising NETPs (generating net health and ecosystems co-benefits & low damage to resource availability)
- NETPS relying on terrestrial biomass generate net detrimental ecosystems impacts, mainly due to land use requirements → possible solution: use of forest and agricultural residues
- Not addressed: impacts from stressors not related to resource use and emissions





NETP impact assessment with the biosphere model LPJmL

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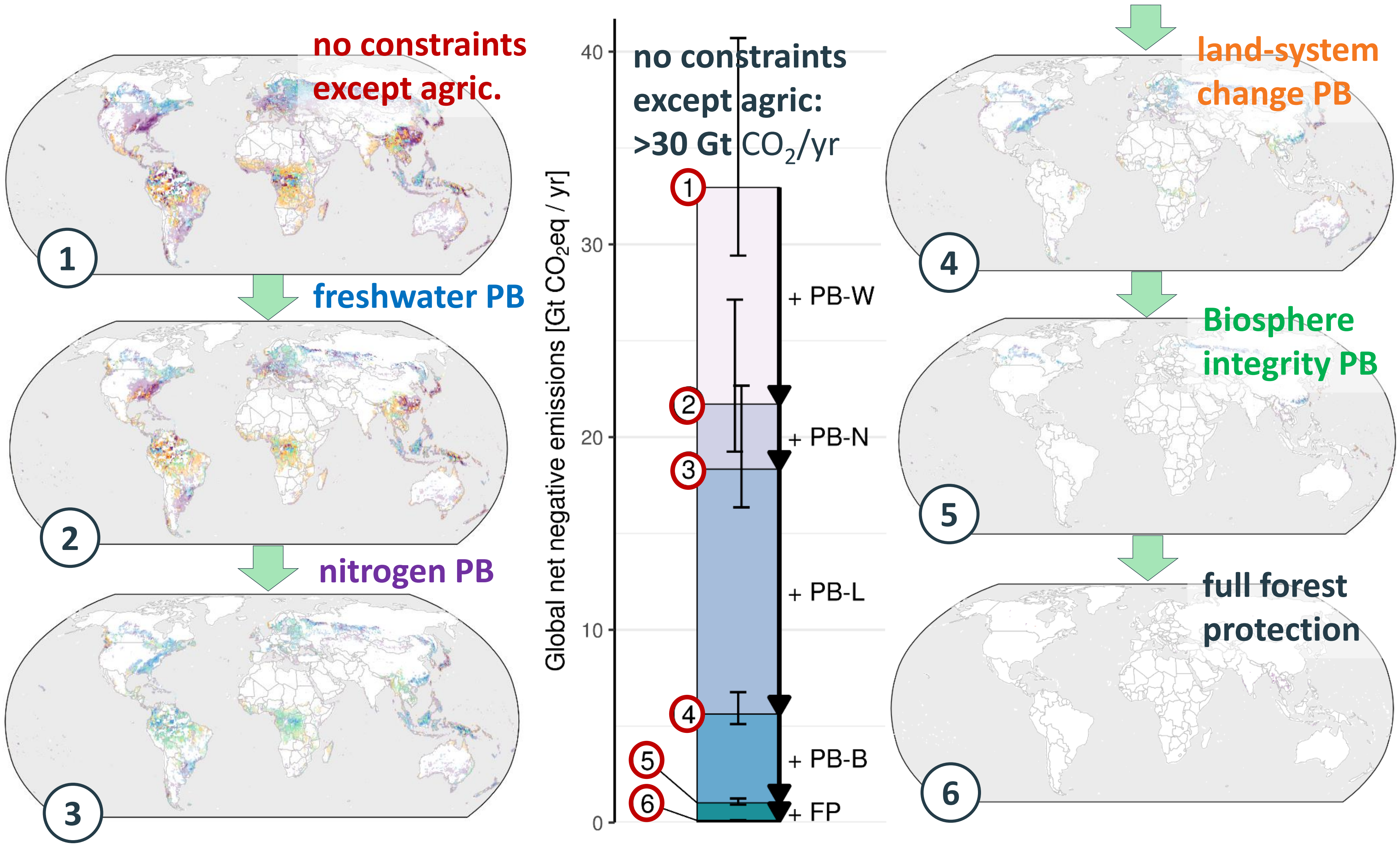
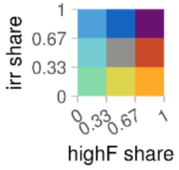
No potential of BECCS outside agricultural areas without further transgressions of planetary boundaries and with full forest protection



BECCS potentials constrained by planetary boundaries:
>30 → 1 (→ 0) Gt CO_2/yr

Note:
- Study on energy crops, residual biomass potential not included
- Global, not local study

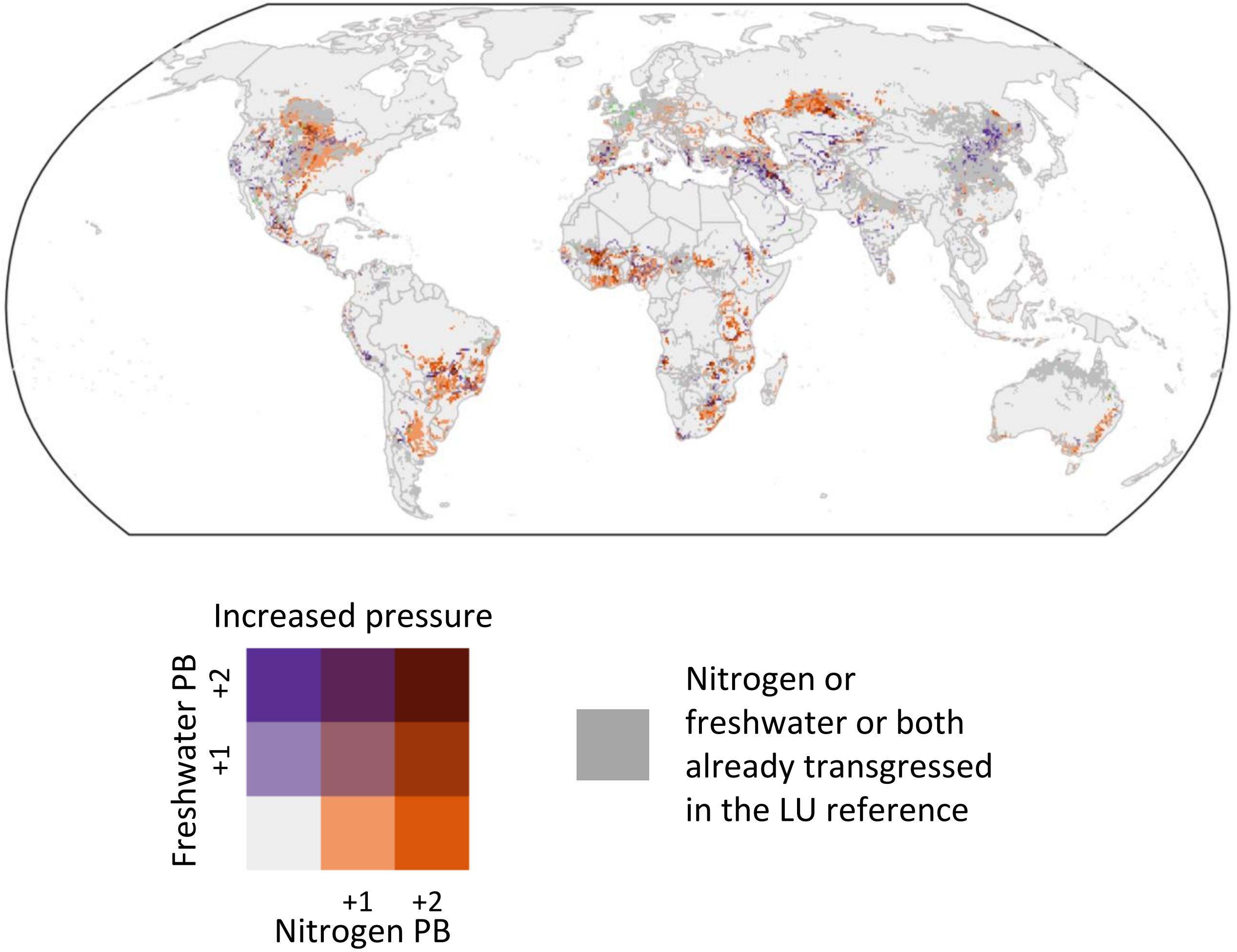


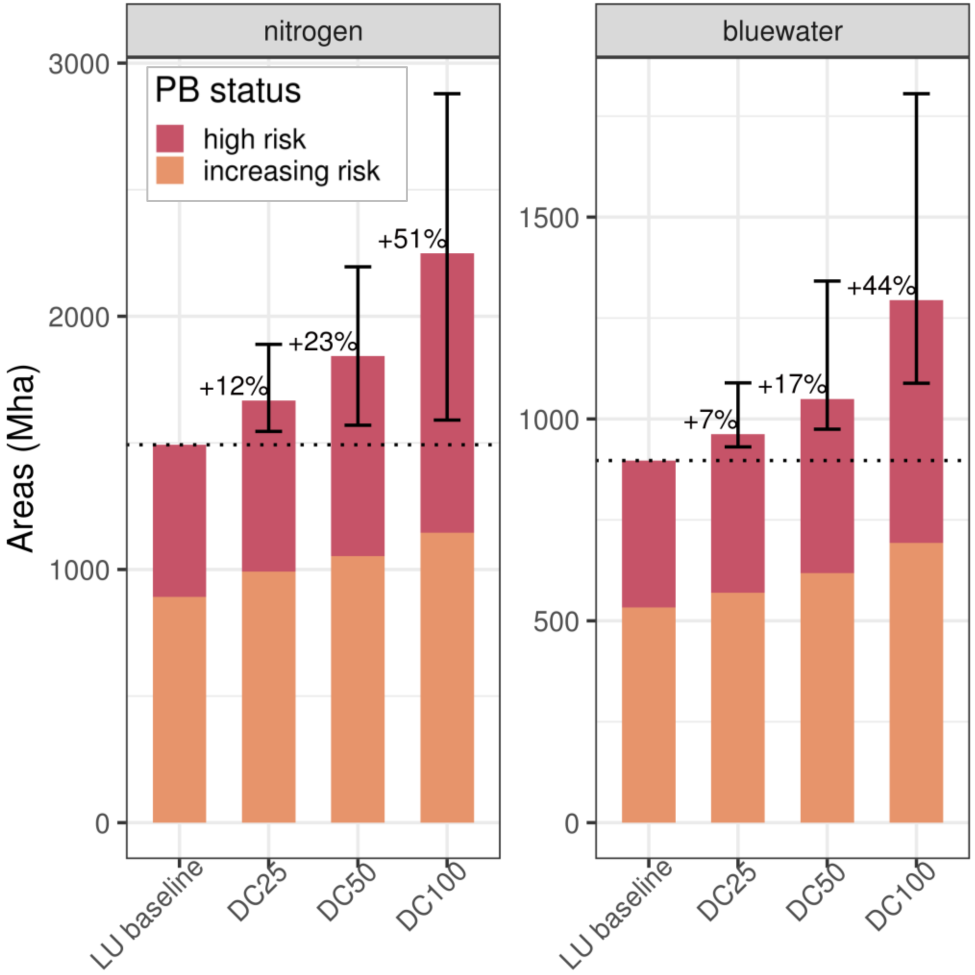
highF = high fertilization
irr = irrigation

Option for land-based CDR within currently used areas: diet change

Releasing pastures for BECCS increases pressure on planetary boundaries

Full transition to EAT Lancet planetary health diet



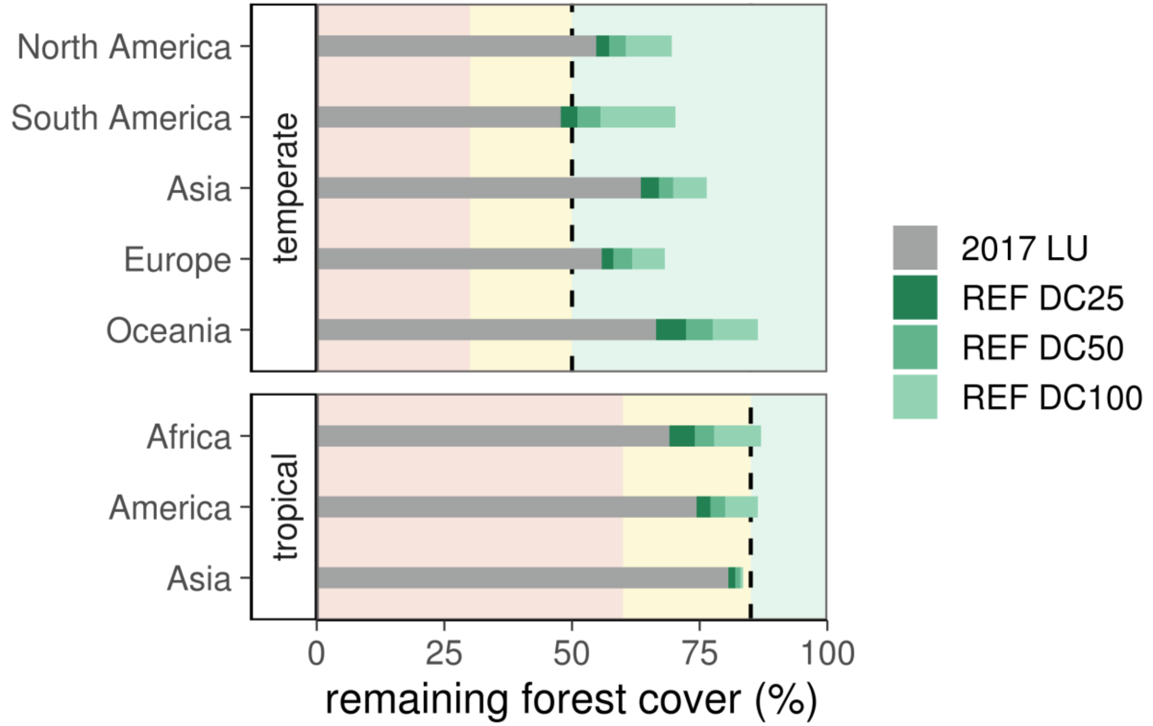


Option for land-based CDR within currently used areas: diet change

Releasing pastures for reforestation releases pressure on planetary boundaries

Reforestation

Land-system change

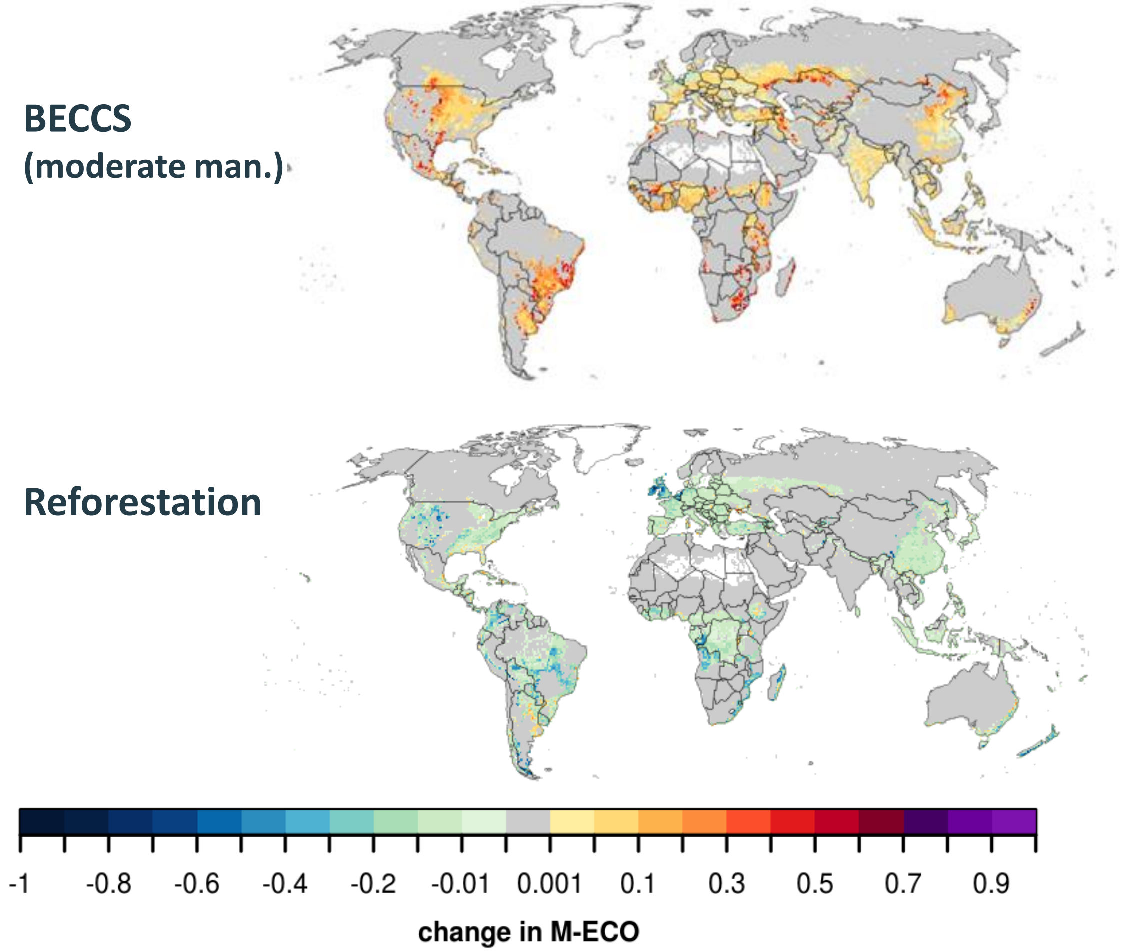


DC100 = 100% transition to EAT Lancet planetary health diet
DC50 = 50%
DC25 = 25%

DC100

BECCS (moderate man.)

Reforestation



closer to natural state ← → further away from natural state

Conclusions from NEGEM impact assessment (1/2)

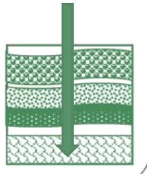
There is **no NETP without negative effects** identified in at least one impact dimension

Forest restoration = NETP with most **co-benefits** (LPJmL analyses/LCA/literature review)

- contribution to international targets of nature restoration (e.g. the Kunming-Montreal Biodiversity Framework)
- strongly depends on large-scale food system transformations, e.g. reduced meat consumption

All assessed **biomass-based NETPs** (wood products, biochar, BECCS) can have particularly **critical impacts** on the biosphere if based on feedstock production on large-scale and intensively managed plantations

Conclusions from NEGEM impact assessment (2/2)



CCS-based NETPs have the potential to become a crucial approach for effectively counterbalancing residual emissions, primarily due to their **permanent and reliable** carbon storage, while sourcing sustainable biomass for BECCS and clean energy for DACCS prevail as **limiting factors**

CDR from **reforestation** and natural climate solutions is saturable and **reversible** and thus not reliable for compensation of residual fossil emissions

but their role in restoring, fostering and protecting the natural carbon sink as well as the multiple co-benefits remain indispensable for **Earth system stability**

The effects of individual stressors from specific NETPs can be mitigated by diversifying the **NETP portfolio** (optimized portfolios of NETPs will be needed, while research efforts should focus on a range of NETPs)

- considering their multidimensional constraints and critical impacts
- accounting for differences in the reliability of long-term CO_2 storage

NEGEM

Thank you!

Project Partners

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