nature climate change

SUPPLEMENTARY INFORMATION

https://doi.org/10.1038/s41558-018-0119-8

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Alternative pathways to the 1.5 °C target reduce the need for negative emission technologies

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Table 1: Key assumptions made in the various scenarios. Further explanations are given in the text below.

Scenario	Implementation	Key references
Baseline (SSP2)	Standard IMAGE implementation of the SSP2 scenario. In the SSP2 scenario, that forms part of the overall SSP set, median assumptions have been made for all key model assumptions	[1,2]
Default (DEF)	In the default mitigation scenarios climate policy is introduced by a global price on CO_2-equivalent emissions.	[1-3]
Lifestyle change (LiStCh)	*Diet and food water*. • Introduction of so-called Willett diet[4] (i.e. 10.4 kcal/cap/day of cattle, 16.0 of pork, 32.3 of eggs, 33.2 of poultry and 13.0 kcal/cap/day of fish and seafood) with substitution of meat by pulses/oilcrops (mostly soy), and correcting staples/luxuries to keep total calories as in baseline (following earlier work)[5]. The diet is introduced from 2020, reaching a 100% in 2050. • Household food waste as fraction of food demand is reduced: 10% less avoidable waste per year starting in 2011, reaching 98% reduction in 2050. • Food waste as fraction of demand is also reduced in storage and distribution systems: 5% less waste per year starting in 2011, reaching 86% in 2050. • Note that the absolute amount of food waste will decrease less quickly than this waste fraction, since total demand increases with population size and affluence. *Transport*[6,7] • Mode shift towards more mass transit and non-motorized movement • Demand reduction (reduced vehicle use through car sharing and a reduction in the travel time) *Residential*[6] • Lower appliance ownership than in baseline by capping future ownership to 2010 ownership in high-income countries and phasing out tumbling dryers. • Energy in standby mode deduced for appliances in the residential sector • Best available technology (BAT) energy use for appliances to reflect more efficient use • 1°C difference in base temperature used for calculating heating and cooling demand • Reduced shower time (reduced water heating demand) Non-energy • Reduced demand for non-energy products (bulk chemicals)	[5,6,8]
Renewable electrification (RenElec)	*Electricity system* • Transmission and distribution costs for renewable technologies set equal to other technologies • Increased foresight in the power sector to 20 years • Reduced power sector early retirement delay • Use of relaxed integration constraints for intermittent renewable energy options (assuming further development of storage technology or load management systems) Hydrogen • Forced hydrogen module to only use electricity as an energy source *Energy Demand* • Heat electricity demand ratio shifted towards electricity *Transport*	[9,10]

	• Optimistic technology development for new vehicle technologies (electric, fuel cell, plug-in hybrid, or other hybrid-electric vehicles).
	• Transition from 2020 to 2025 in OECD and 2030 in Rest of the World (ROW)
	  o Passenger cars: sales fully to electric vehicles
	  o Heavy freight trucks: almost fully to hydrogen 2030 in OECD; 2040 ROW
	  o Airplanes: moving towards hydrogen planes from 2050 onwards
	Steel and Cement
	• Introduced subsidies for electric produced steel.
	Residential sector
	• Disable solid and liquid fuels after 2030 for cooking and heating in the residential
	• No natural gas use from 2050 onwards.	

Efficiency (Eff)	*Electricity production* • Best-available-technologies in all power plants • Reduced distribution losses *Transport* • Only efficient passenger road and air vehicles are sold after 2025 • Regions transition to the most efficient regional practice (e.g. to smaller cars) and technologies follow an optimistic development pathway. *Steel and Cement* • Best-available-technologies from 2025 and continued efficiency improvements • Cement to clinker ratio in reduce to 60-70% in 2025 and 55 % in 2050 • Increased recycling of obsolete steel (80% in 2025) • Less cement and steel demand (30% reduction w.r.t. baseline in 2050) *Service sector* • Energy efficiency measures lead to 25% less energy use in 2050 w.r.t. baseline (transition from 2025) *Residential sector* • Best-available technologies used for all energy end uses (i.e. heating, cooling, appliances, lighting) *Other industry and other demand sectors* • Energy and material efficiency measures lead to 35% less energy use in 2050 w.r.t. baseline (transition from 2025) • Increased recycling of waste in non-energy uses	[11,12]

Low Non-CO_2
 	
(LoNCO2)
	• Assumed increased non-CO_2 abatement, increasing towards maximum abatement in the year 2050 continuing till 2100. In 2030, half of the maximum reduction is achieved. Max reductions: Methane from: Gas/oil production 100%, Coal production 90%, Enteric fermentation in ruminants 73%, Sewage 95%, Landfills 100%, Animal waste / manure 100% and N_2O from: Fertilizer use 80%, Animal waste / manure 75%, Transportation/Adipic and nitric acid production/plant residues 100% Fluorinated-gases 97%);
	• Reduced inertia in implementing reduction measures (No explicit assumptions on delay)
	• Lower emission factors Black Carbon (based on maximum feasible reduction)[13]
	• Cultivated meat (product) production
	  o 80% of meat-like products (including eggs) are replaced by cultivated meat, which is grown from mostly corn and small amounts of soy. Conversion factors based on literature [14,15]
	  o Dairy products are produced "naturally" by the remaining 20% of animals still used for meat (product) production.
	  o Transition: 0% in 2035, 100% in 2050, 100% in 2100, linear interpolation.
	  o Fish are left as-is, because this is not modeled in IMAGE, due to negligible greenhouse gas emissions.	

Agricultural intensification (IntAgr)	• SSP1 livestock efficiency; convergence to most efficient livestock system globally by 60% in 2050 and by 80% in 2100 • Yields increase by implementing the highest regional management factors of SSP1 or SSP5, achieved by 70% in 2050 and by 100% in 2100	[16]
Population (LowPop)	• The standard SSP2 population scenario is replaced by the SSP1 population scenario, reducing the global population size from 9.2 to 8.4 billion in 2050 and from 9 to 6.9 billion in 2100.	[17]

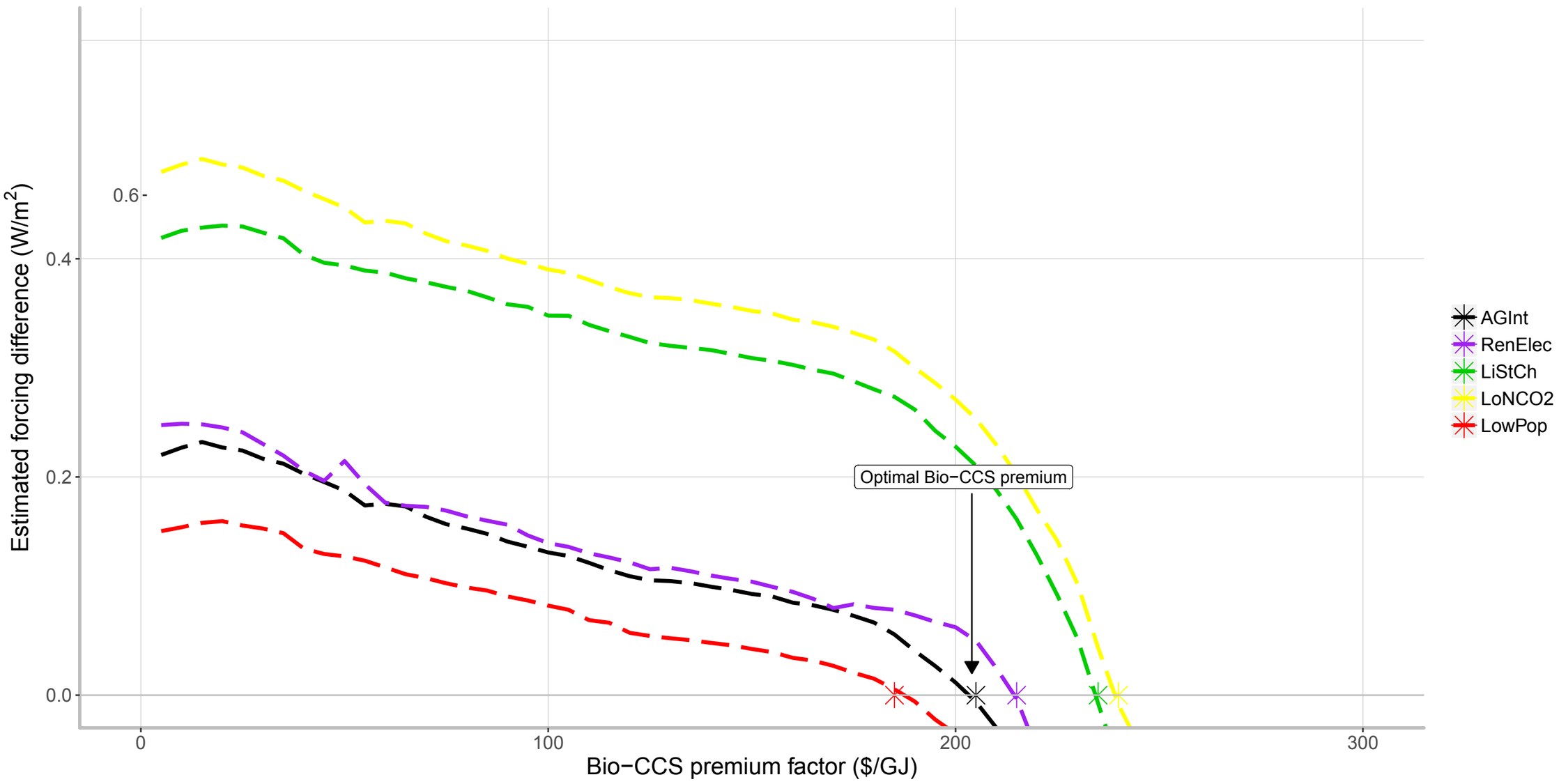

Figure S1: Calibration of the BECCS premium factor in the alternative scenarios

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