Characteristics of emission pathways to achieve the Paris Agreement goals

Paris Agreement [1]

Article 2

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

[...]

Paris Agreement

Article 3

As nationally determined contributions [NDCs] to the global response to climate change, all Parties are to undertake and communicate ambitious efforts as defined in Articles 4, 7, 9, 10, 11 and 13 with the view to achieving the purpose of this Agreement as set out in Article 2. The efforts of all Parties will represent a progression over time, while recognizing the need to support developing country Parties for the effective implementation of this Agreement.

[...]

The IPCC Special Report [2]

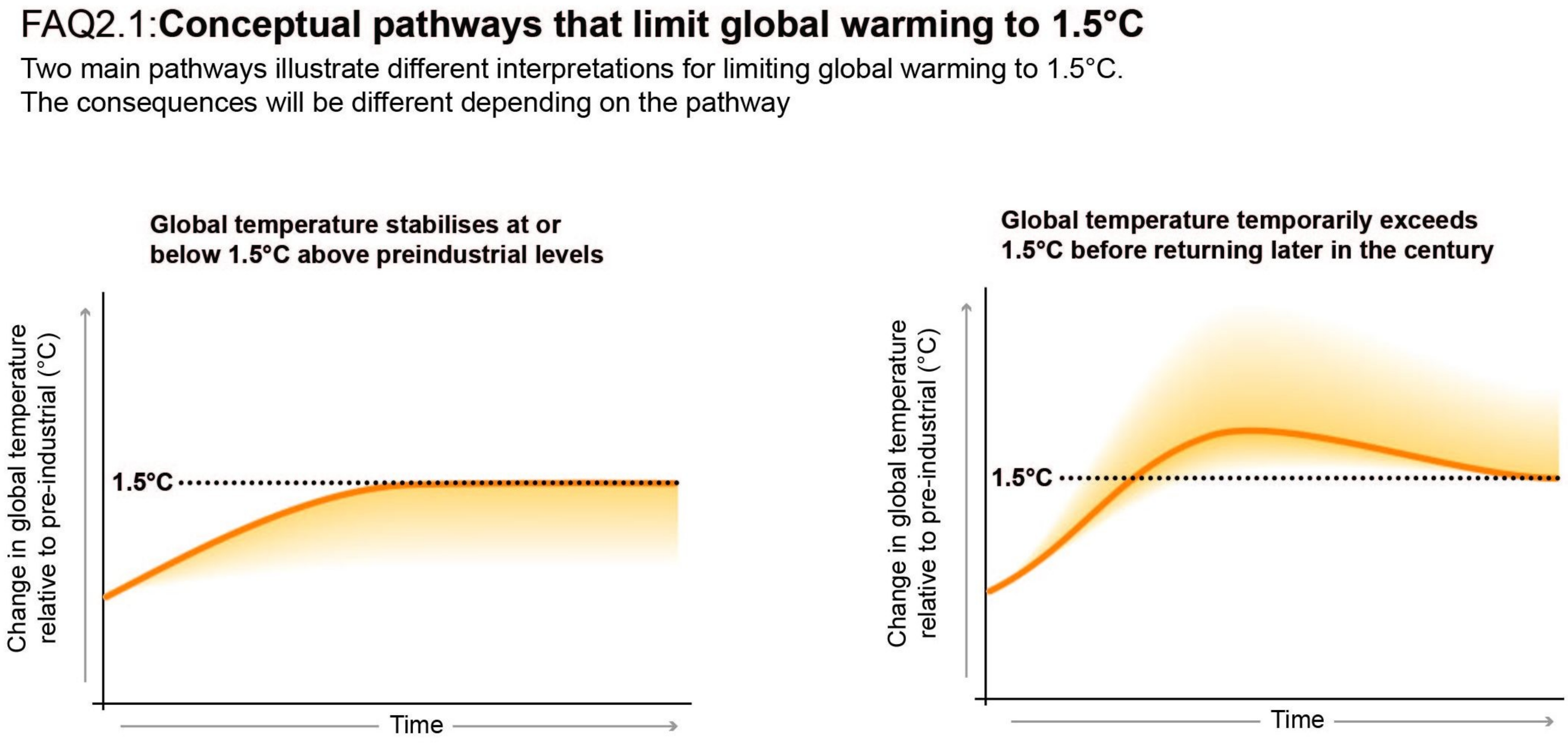
“ Under emissions in line with current pledges under the Paris Agreement (known as Nationally Determined Contributions, or NDCs), global warming is expected to <u>surpass</u> 1.5°C above pre-industrial levels, even if these pledges are supplemented with very challenging increases in the scale and ambition of mitigation after 2030 (high confidence). “

(SR15 p. 95)

Content

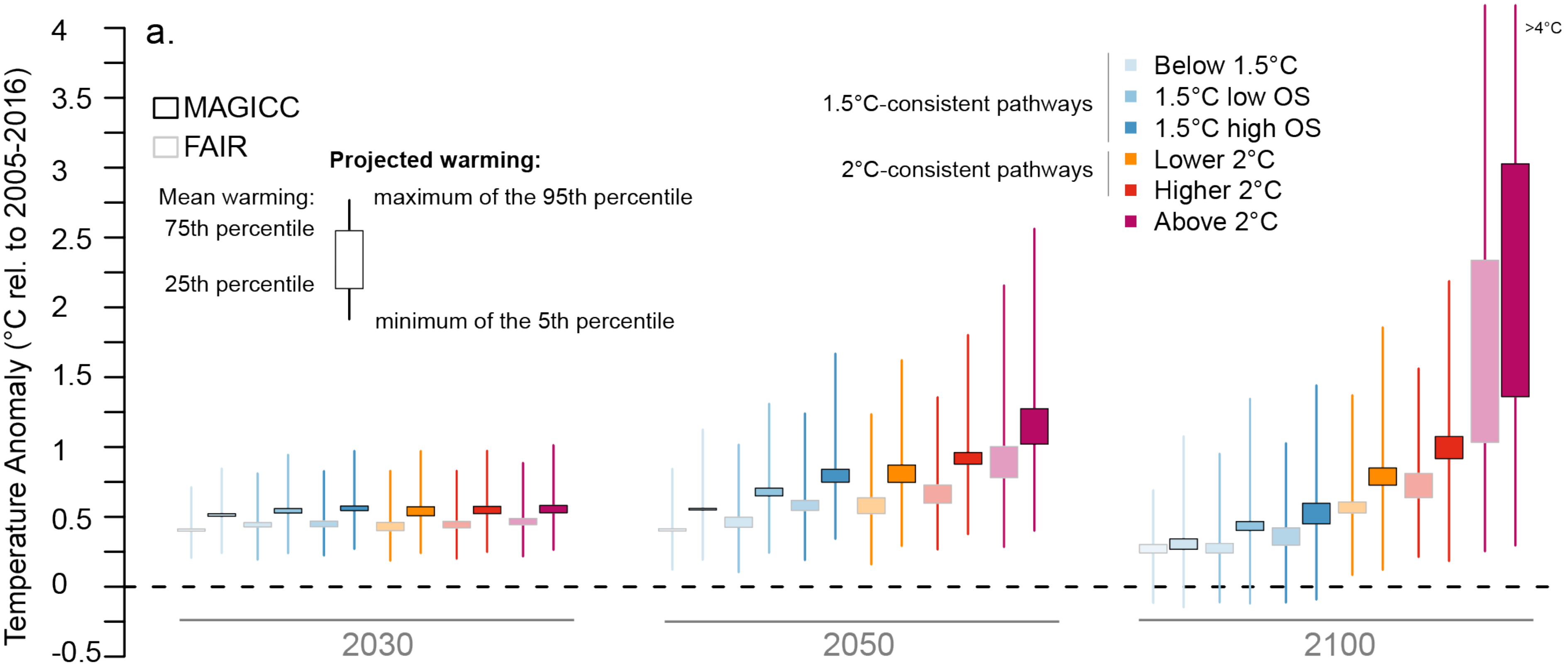
- Assess core characteristics of 1.5 scenarios based on the Archetype framework
- Negative emissions and Carbon Dioxide Removal technologies
- Near-term emissions reductions up to 2030
- Demand-side and energy efficiency

What is “1.5°C consistent”?



[SR15 IPCC]

Pathways with no, low or high Overshoot (OS)



Overshoot scenarios increase uncertainty, because earth system feedbacks are hard to predict

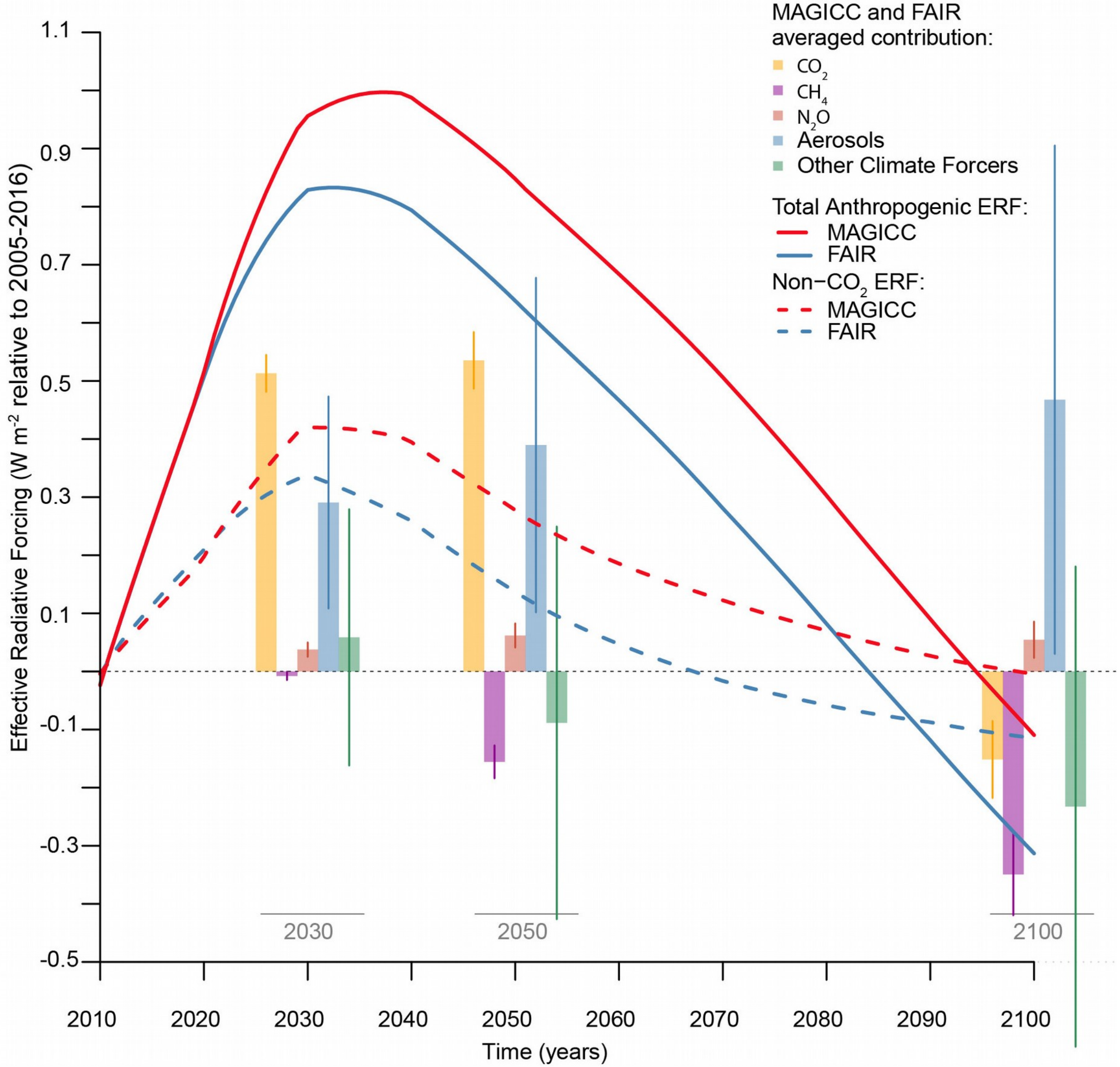
[SR15 IPCC]

Exemplary use of two climate models

- **MAGICC**
  - ‘Model for the Assessment of Greenhouse Gas-Induced Climate Change’
- **FAIRv1.3**
  - ‘Finite Amplitude Impulse Response’ model

- Scenarios classified based on simulations using these two reduced-complexity (e.g. no permafrost or non-CO_2 feedbacks) carbon cycle, atmospheric composition, and climate models
- Variation between models due to inclusion/exclusion of specific Earth system feedbacks, assumed climate sensitivity etc.

Changes and uncertainties in effective radiative forcings (ERF) for one 1.5°C-consistent pathway (SSP2-19) as estimated by MAGICC and FAIR



[SR15 IPCC]

- **Non-CO_2 forcers exhibit greater geographical variation**
- **Difference between the models gives idea of uncertainties but should not be interpreted as a true statistical deviation**

Intermission: Exploring IAMC 1.5°C Database

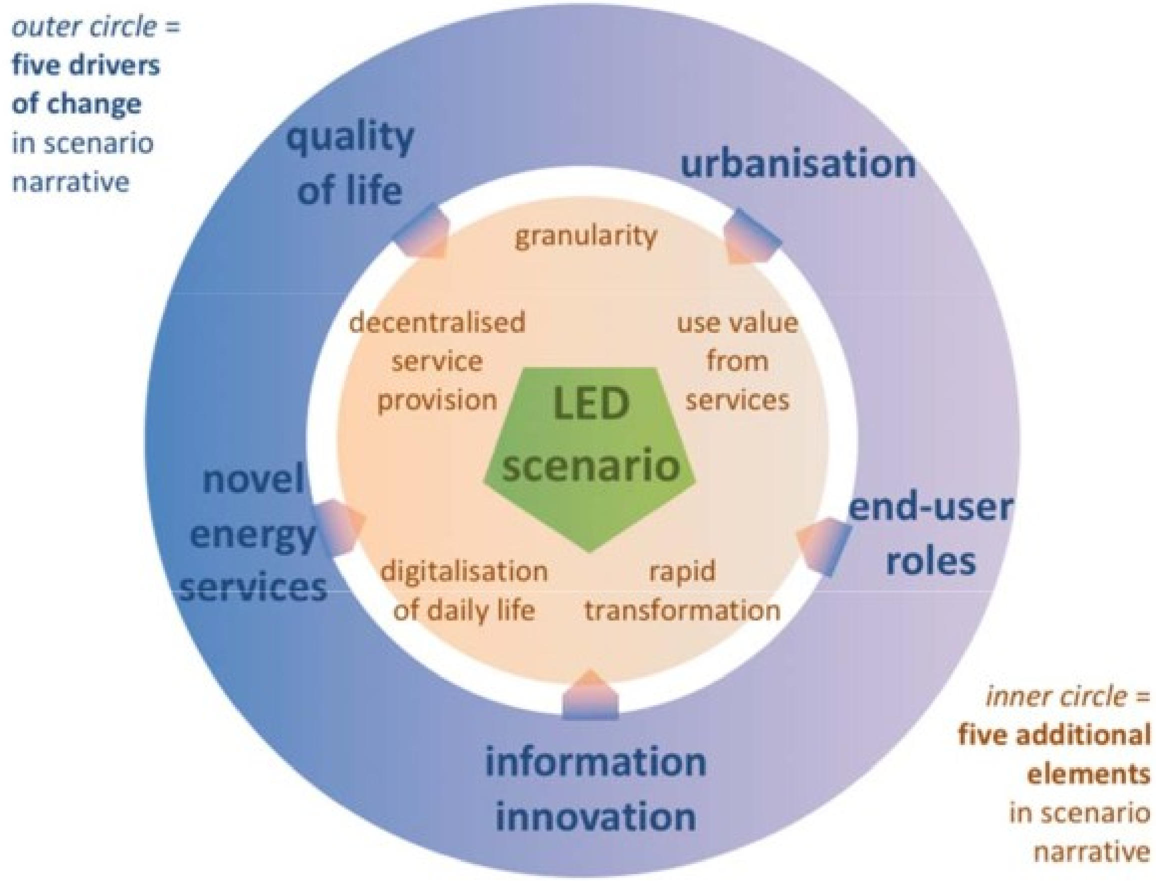
- https://data.ene.iiasa.ac.at/iamc-1.5c-explorer/#/workspaces/3183

- Compare pathways with no, low or high OS regarding predictions about food production, population, energy demand etc.

Revision: Five Shared Socio-Economic Pathways

Socio-Economic Challenges to Mitigation	Socio-Economic Challenges to Adaptation		
	Low	Medium	High
High	**SSP5: Fossil-fuelled development** • low population • very high economic growth per capita • high human development • high technological progress • ample fossil fuel resources • very resource intensive lifestyles • high energy and food demand per capita • economic convergence and global cooperation		**SSP3: Regional rivalry** • high population • low economic growth per capita • low human development • low technological progress • resource-intensive lifestyles • resource-constrained energy and food demand per capita • focus on regional food and energy security • regionalization and lack of global cooperation
Medium		**SSP2: Middle of the road** • medium population • medium and uneven economic growth • medium and uneven human development • medium and uneven technological progress • resource-intensive lifestyles • medium and uneven energy and food demand per capita • limited global cooperation and economic convergence	
Low	**SSP1: Sustainable development** • low population • high economic growth per capita • high human development • high technological progress • environmentally oriented technological and behavioural change • resource-efficient lifestyles • low energy and food demand per capita • economic convergence and global cooperation		**SSP4: Inequality** • Medium to high population • Unequal low to medium economic growth per capita • Unequal low to medium human development • unequal technological progress: high in globalized high-tech sectors, slow in domestic sectors • unequal lifestyles and energy /food consumption: resource intensity depending on income • Globally connected elite, disconnected domestic work forces

Demand-side and energy efficiency: The Low-Energy-Demand (LED) Scenario [3]



Supplementary Figure 2. Schematic representation of the LED scenario narrative. *Outer circle shows LED narrative drivers, inner circle lists LED scenario additional features.*

[Grubler et al., 2018]

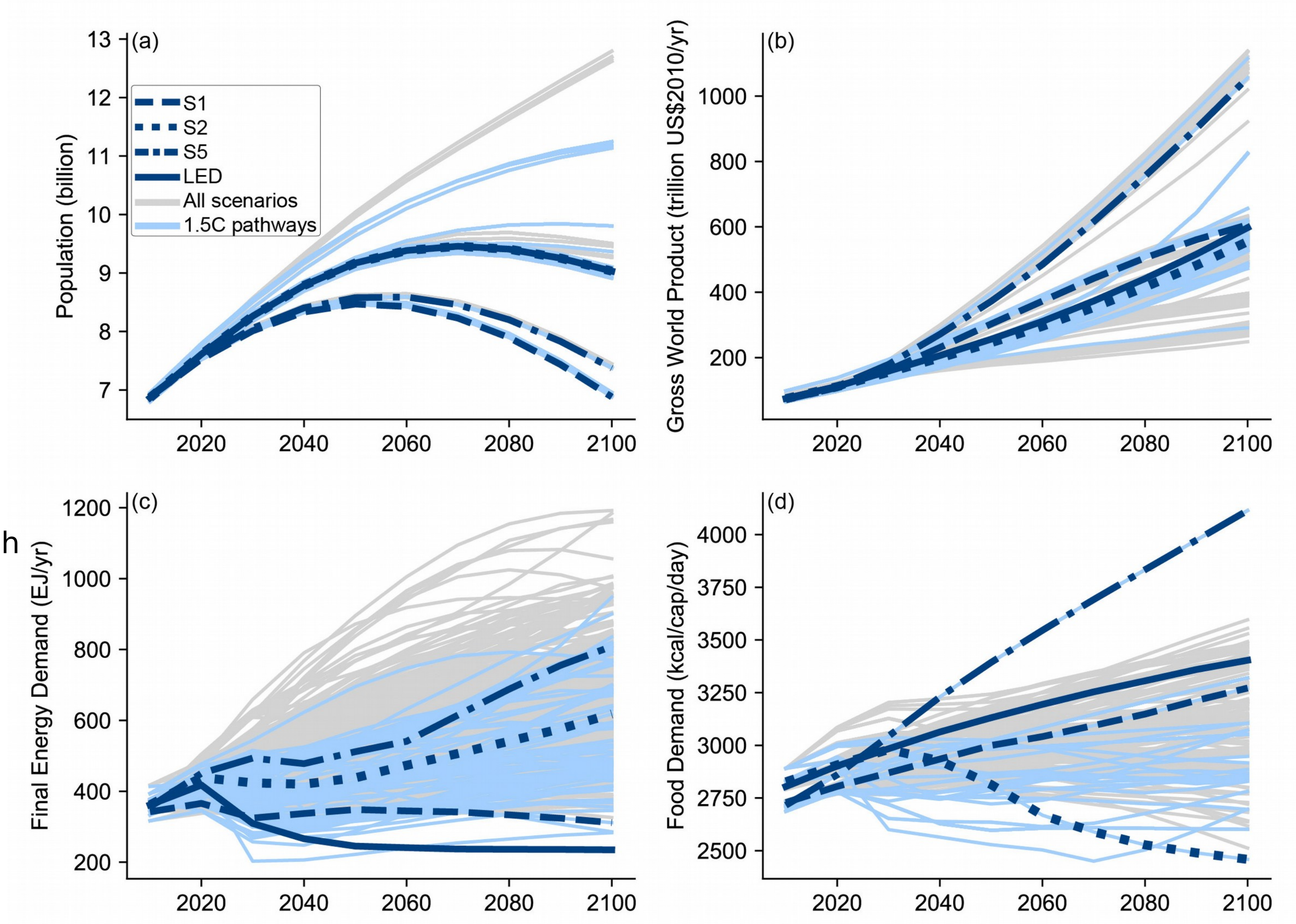
Four exemplary Archetypes of 1.5°C pathways

S1: Sustainable development
(Low mitigation and adaptation costs)

S2: Middle of the road
(Medium mitigation and adaptation costs)

S5: Fossil fuel development
(Low mitigation, high adaptation costs)

LED: Low Energy Demand
(Low mitigation, medium to high adaptation costs)
[personal assessment]



The remaining carbon budget

- Common property in all pathways: reduction of carbon emissions to net zero or so-called “negative” emissions
- Disagreement on remaining carbon budget and peak-level emission time frame
- “This assessment suggests a remaining budget of about 420 $GtCO_2$ for a twothirds chance of limiting warming to 1.5°C, and of about 580$GtCO_2$ for an even chance (medium confidence)”
- → approximately 100Gt lower to account for permafrost thawing & potential methane release from wetlands
- → additional geophysical uncertainty of at least ±400 GtCO2, related to non-CO2 response and TCRE [transient climate response to cumulative carbon emissions] distribution

Discussion Part 1

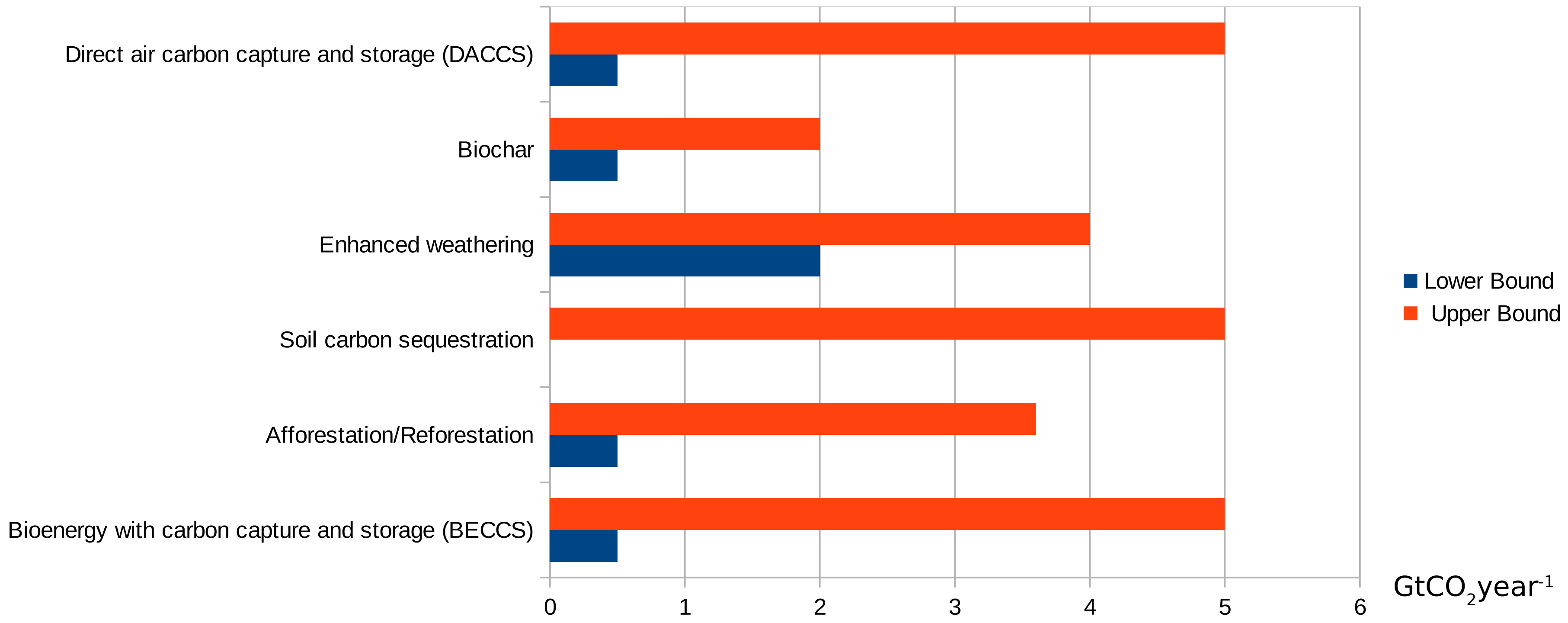
- **(Anonymous Poll)**
- **Do you think uncertainties should be communicated differently in the media?**
- **How has learning about uncertainties affected your outlook on combating climate change? (hopeful, pessimistic, indifferent…)**
- **Vote: https://www.survey-maker.com/QDCJ4WTZ**

Negative emissions

- Look at CO_2 emissions of agriculture, forestry and other land-use (AFOLU) sectors
- Some scenarios predict negative emissions – how can this be?

Carbon Dioxide Removal (CDR) technologies

- **Sustainable global NET potentials [4]**



[adapted from Fuss et. al]

Bioenergy with carbon capture and storage (BECCS)

- Biomass is converted into bioenergy (electricity, heat, biofuel…)
- During the process the carbon from the biomass is captured, then transported and stored:
- → Geological storage: injecting CO_2 in supercritical form directly into oil fields, gas fields, other geological formations
- → Degradation using bacteria/algae
- → Mineral storage (exothermal reaction with metal oxides)

Bioenergy with carbon capture and storage (BECCS)

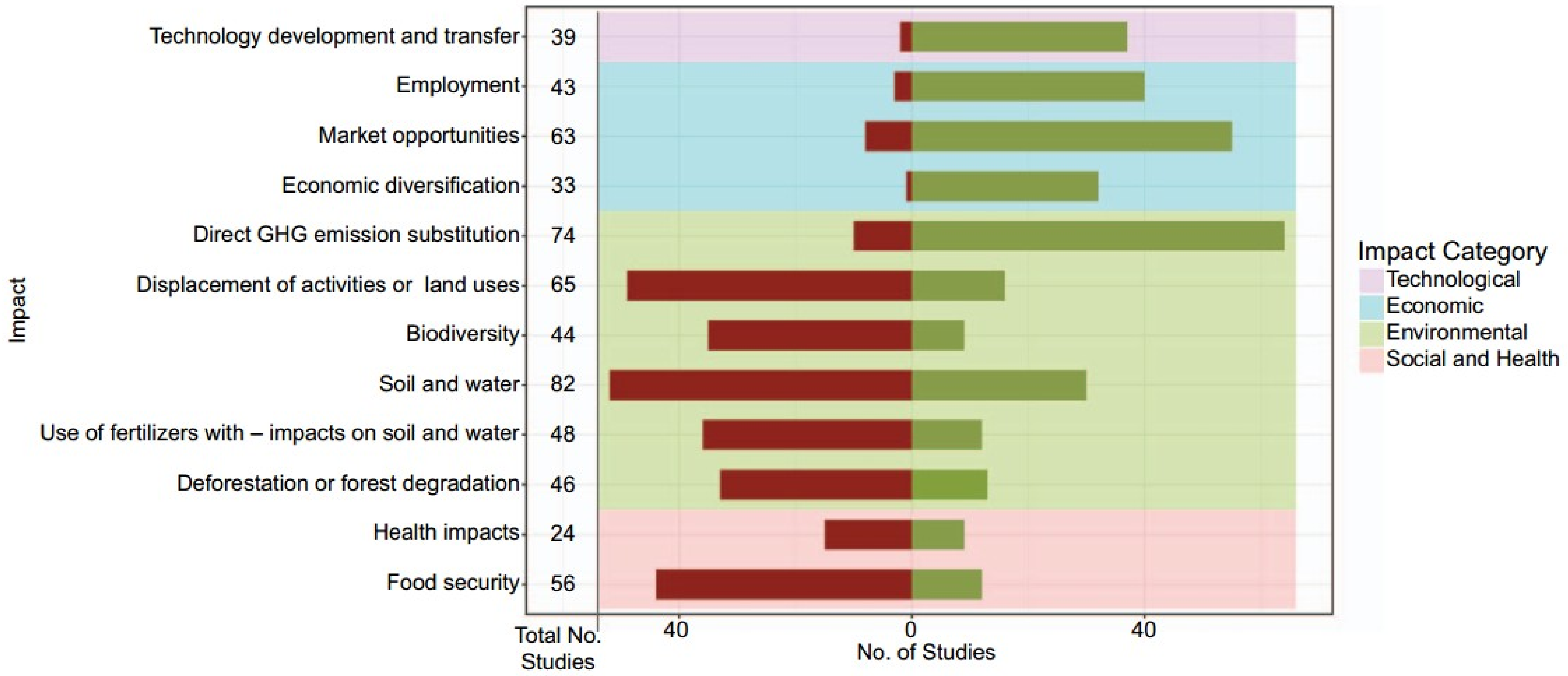


Figure 7. Distribution studies discussing negative and positive impacts for key side-effects. Adapted from Robledo-Abad *et al* (2017).

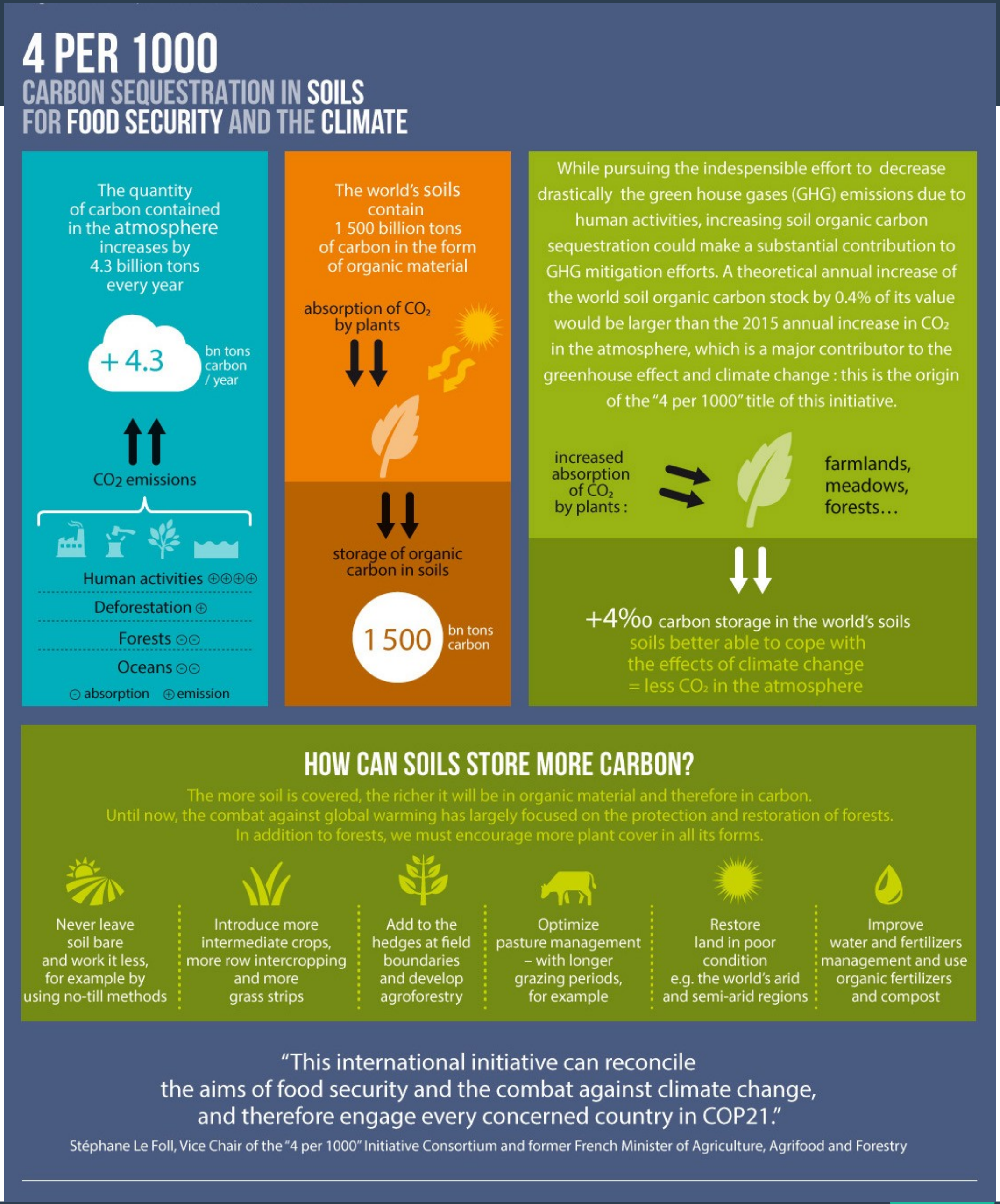
Stretching the "sustainable" limit of 5GtCO_2/year would require global land governance in order to handle land use concerns appropriately[4]

Afforestation/Reforestation

- Afforestation: on land that has not (recently) been covered by forest
- Reforestation: Replanting on deforested land
- Constrained to tropics by albedo (low for boreal forests)
- Land use conflict with agriculture
- Either using only unproductive land or reforesting grasslands after dietary shifts away from beef
- Stored carbon can return to atmosphere by forest fires/pests

Carbon sequestration in soils [5]

- **Land management change increases soil organic carbon content through well understood practices**
- **Drawbacks: sink saturation, non-permanence (soil degradation)**
- **Less side effects compared to other CDR technologies**



Negative emissions and Carbon Dioxide Removal (CDR)

- **“CDR deployed at scale is unproven, and reliance on such technology is a major risk in the ability to limit warming to 1.5°C.“**[2]

Near-term emissions reductions up to 2030: Energy supply

- **Growing share of electricity from low-carbon-emitting sources (renewables, nuclear, fossil fuels with CCS) while the share of fossil fuels without CCS declines**
- **Reduction in carbon intensity of final energy other than electricity (e.g. fuel etc.)**
- **Increasing use of CCS applied to fossil and biomass carbon**

Now it’s your turn

- Look at different methods of energy supply in the four pathway archetypes: https://data.ene.iiasa.ac.at/iamc-1.5c-explorer/#/login → Guest Login
- → Please click on the third workspace: “The energy system in the four illustrative pathways”
- 1) Which source of energy dominates in each pathway in 2020, 2060 and 2100?
- 2) What can you say about the role of nuclear energy for each pathway? What constraints/restrictions could apply in certain narratives?
- 3) How heavily does each scenario rely on Carbon Capture and Storage (CCS). How do you think emissions leading up to 2050 influence the reliance on CCS?

Results

- 1) 2020: All Scenarios Fossil Fuel w/o CCS
- LED 2060, 2100: Solar Energy
- S2&S5 2060, 2100: Biomass
- 2) first increase and then decrease in all pathways
- technology how to manage nuclear waste (other sustainability implications besides climate), scenario narrative might rely on other more “reliable” scenarios
- Issue: investment cycle for nuclear spans a very long time (~100 years) so this trend is worrying
- also political implications (weapon-grade plutonium as nuclear waste)
- very high costs in comparison to renewables (not feasible)

Primary Energy

- Nuclear energy: increases in most pathways but decreases in some, constrained by "societal preferences assumed in narratives underlying the pathways"
- Pathways with higher use of coal and gas tend to deploy CCS to control their carbon emissions
- Transitions of up to 100% renewable energy have been analyzed but were not included here (underlying assumptions have been challenged)

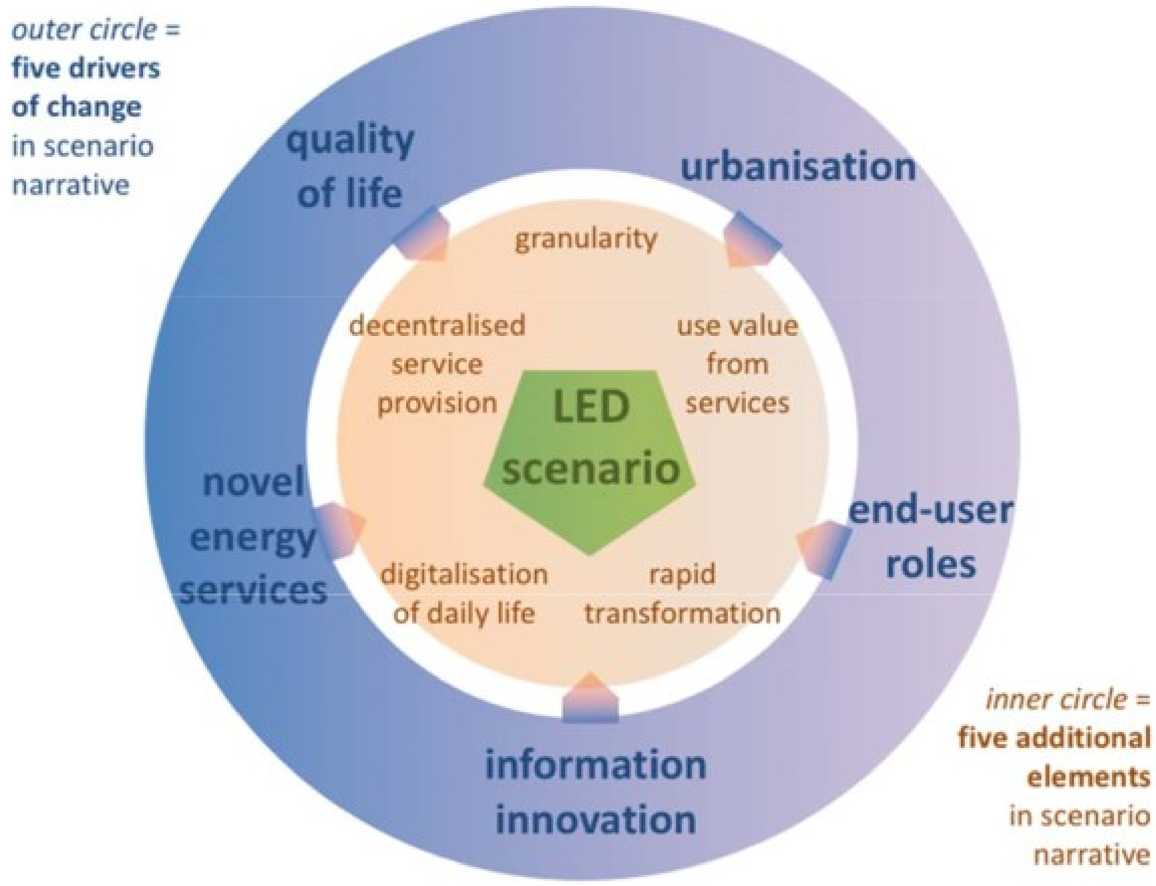
Secondary (final) Energy

- “Energy end-use is the least efficient part of the global energy system and has the largest improvement potential.“ [3]
- Increase share of electricity (as opposed to fuel and gas)
- Decreasing carbon intensity in electricity
- Decrease demand
- Increase efficiency

Reducing demand, increasing efficiency [2]

- Industry largest end-use sector (final energy demand and GHG emissions)
- Material industry: close to 66% of FED and 72% direct industry-induced emissions
- Reduction in the use of industrial materials, or improving the quality of products could help to reduce energy demand and overall system-level CO_2 emissions
- Strategies include using materials more intensively, extending product lifetimes, increasing recycling, and increasing inter-industry material synergies

Demand-side and energy efficiency: The Low-Energy-Demand (LED) Scenario



Supplementary Figure 2. Schematic representation of the LED scenario narrative. *Outer circle shows LED narrative drivers, inner circle lists LED scenario additional features.*

[Grubler et al., 2018]

Example

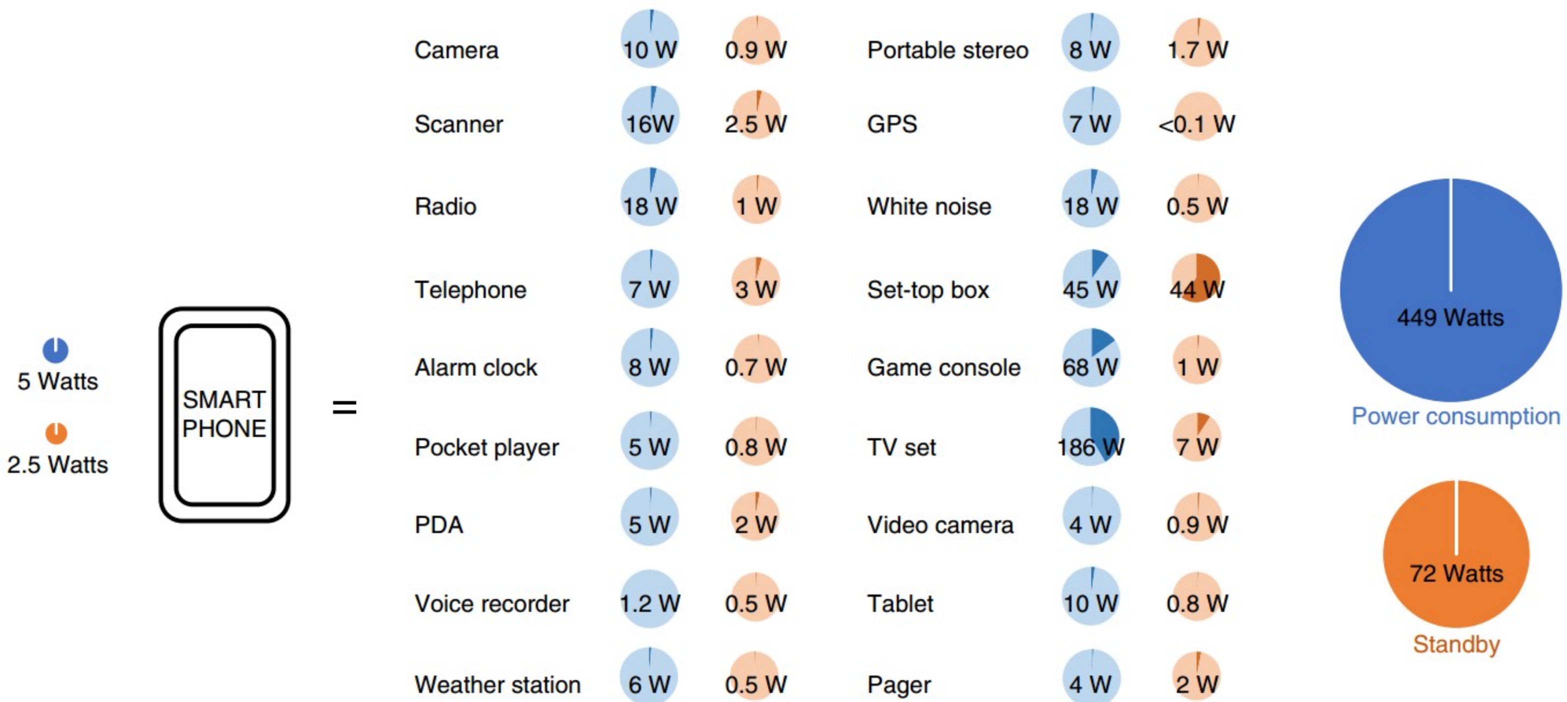


Fig. 2 | Example of reduced energy demand through digitalization and device convergence. A smartphone with 5 W of power and 2.5 W of standby-energy use provides a single integrated digital platform, which potentially substitutes for over 15 different end-use devices. The reductions in power that result (load (blue)) are close to a factor of 100, and reductions in standby-energy use (orange) are close to a factor of 30 (Supplementary Table 4). The wedges in each graph represent the share of the respective device in total power consumption (blue) and in total standby power (orange); for example, the load of 186 W for a TV set is over a third of the estimated total power consumption of substituted devices (449 W). Tupy[59] gives a pictorial representation. PDA, personal digital assistant; GPS, global positioning system, a navigation system that substitutes a map.

[Grubler et al., 2018]

Discussion Part 3

- **Which path to take?**
- **Survey:**
- **http://www.survey-maker.com/QK1WXOBX**

Take-home messages

- <u>Reliance on CDR poses major risk in limiting warming</u>
- Near term emission reduction by:
- <u>Low-emission/carbon-free technologies</u>
- <u>Electrification of transport and industry</u>
- <u>Energy demand reduction</u>
- <u>Reduction of land-use change</u>
- Possible driver: carbon pricing
- "Policies reflecting a high price on emissions are necessary in models to achieve cost-effective 1.5°C pathways (high confidence)." [2]

References

- [1] United Nations. Paris Agreement. Online at https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf [06/05/2020].
- [2] Rogelj, J., D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, and M.V. Vilariño, 2018: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press.
- [3] Grubler, Arnulf, et al. "A low energy demand scenario for meeting the 1.5 C target and sustainable development goals without negative emission technologies." Nature energy 3.6 (2018): 515-527.
- [4] Fuss, Sabine, et al. "Negative emissions—Part 2: Costs, potentials and side effects." Environmental Research Letters 13.6 (2018): 063002.
- [5] Le Foll, Stephane et al. “4p100 Initiative”. Online at https://www.4p1000.org/ [06/05/2020].