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A people-centred approach to limiting global warming to 1.5°C

How Low Can We Go?

The purpose of the global energy system is to provide useful services to end users. End-use demand determines the size of the energy system and so the challenges of mitigating climate change. Rising energy demand pushes an ever larger burden of emission reduction onto supply-side decarbonisation. Global mitigation scenarios tend to focus on supply-side solutions. Available emission budgets for 1.5°C warming create demand for large-scale negative emission technologies that have been critically assessed in terms of limitations and uncertainty.

We show how abundant, available, and actionable energy end-use options can reduce emissions rapidly and pervasively while improving quality of life in the global North and South. A future scenario focusing on low energy demand which is consistent with 1.5°C climate mitigation, without relying on controversial negative emission technologies is described. The scenario is constructed from major trends clearly observable today which can lead to dramatic decreases in global energy demand to 2050.

The Low Energy Demand (LED) Scenario Narrative

The Low Energy Demand, in short 'LED', scenario narrative has five main drivers of long-term change in energy end-use. These five drivers are clearly observable today as major trends currently shaping energy-related developments.

- *Quality of Life*: continued push for higher living standards, clean local environments, and widely accessible services and end-use technologies.
- *Urbanisation*: continued rapid urbanisation particularly in mid-size cities in developing countries.
- *Novel Energy Services*: continued historical trend of end users demanding novel, more accessible, more convenient, cleaner, and higher quality energy services.
- *End-User Roles*: continued diversification of end-user roles in the energy system away from passive consumption and towards engagement as consumer, producer, citizen, designer and community member.
- *Information Innovation:* continued rapid improvements in cost and performance of information and communication technologies (ICTs) supporting widespread diffusion and digitalisation.

These five drivers of change interact to generate five additional elements of the LED scenario narrative. Each element is constituted by social, technological and institutional changes in how energy services are provided and consumed.

- *Granularity*: proliferation of small scale, low unit cost technologies enabling experimentation, rapid learning and equitable access.
- *Decentralised Service Provision*: decentralisation and localisation of energy generation, distribution and end-use, with piecewise expansion or adaptation of centralised infrastructure.

- *Use Value from Services*: move away from ownership of single purpose goods to 'usership' with flexible, multi-purpose services delivered through digital platforms or sharing economies.
- *Digitalisation of Daily Life*: integration of sensors, processors, wireless communication, and control functionality into energy-using technologies and daily routines.
- *Rapid Transformation*: acceleration in the changing form and quality of energy-service provision demanded by end users as incomes and aspirations rise.

In light of the above, three important characteristics of the LED scenario should be highlighted. First, LED describes rapid rates of change enabled by interacting social, technological and institutional innovations. Second, LED is strongly focused on energy end-use and energy services (thermal comfort, consumer goods, mobility, food). Third, downstream change in LED in turn drives structural change in intermediate (commercial, manufacturing, freight) and upstream sectors (energy supply and land use).

LED Scenario Quantification

The LED scenario development methodology involved the following steps:

1) bottom-up assessment of energy demand by major end-use service and upstream sector;
2) quantification of corresponding supply-side transformation in energy and land-use systems using the MESSAGE*ix*-GLOBIOM integrated assessment modeling framework; and
3) evaluation of LED scenario outcomes against quantitative indicators of a range of global Sustainable Development Goals (SDGs).

More specifically, a bottom-up assessment of activity, intensity, and energy demand for four end-use services (thermal comfort, consumer goods, mobility, food) and five intermediate and upstream sectors (public and commercial buildings, industry, freight transport, energy supply, agriculture/land-use) was carried out. In addition, it was examined how high levels of energy services could be provided with lower energy (and material) inputs compared to previous, more technically-focused efficiency scenarios such as those developed as part of the Global Energy Assessment (GEA). The LED scenario narrative also emphasises social, institutional and infrastructural changes leading to improved energy-service efficiencies, including through new forms of service provision (e.g. granular, decentralised energy systems), new business models (e.g. sharing economy, use value from services), economies of scope (e.g. device convergence), and digitalisation (e.g. smart appliances, homes and grids).

The LED scenario narrative maps onto changes from 2020 to 2050 in the activity levels and intensities of four main end-use services. Changes in the type and quantity of energy services consumed by end users then have knock-on effects on energy use in commercial buildings, industry (including manufacturing and construction), and freight transportation. LED has been designed to match, and in most cases, to far exceed the activity levels or amount of energy services provided in comparable scenarios, but with drastically reduced energy inputs.

LED describes a major transformation in the quantity and quality of energy services provided. Higher levels of energy services in absolute terms are provided with improved service efficiencies (e.g. higher asset utilisation), improved physical capital stock (e.g. efficient building designs and retrofits), and granular end-use technologies with diverse applications or economies of scope (e.g. batteries or fuel cells in vehicles, homes and grids). This demand-side transformation requires energy carriers with high versatility or exergy (ability to do work). As a result, LED sees strong electrification of energy end-use (Figure 1), consistent with the narrative of pervasive digitalisation and more versatile end-use technologies, which are non-polluting at the point of use. Over the longer term, hydrogen also increases its share of final energy demand (in addition to its role for energy storage).

Changes in energy end-use therefore drive supply-side transformation, as has been the case historically. Consistent with the LED scenario narrative, granular energy-supply technologies like heat pumps, fuel cells, and solar PV proliferate. Granularity, decentralisation and intermittent renewables pose significant challenges for system management and balancing addressed via 'smart' transformation of physical networks and control systems and scaled-up storage and load management options.

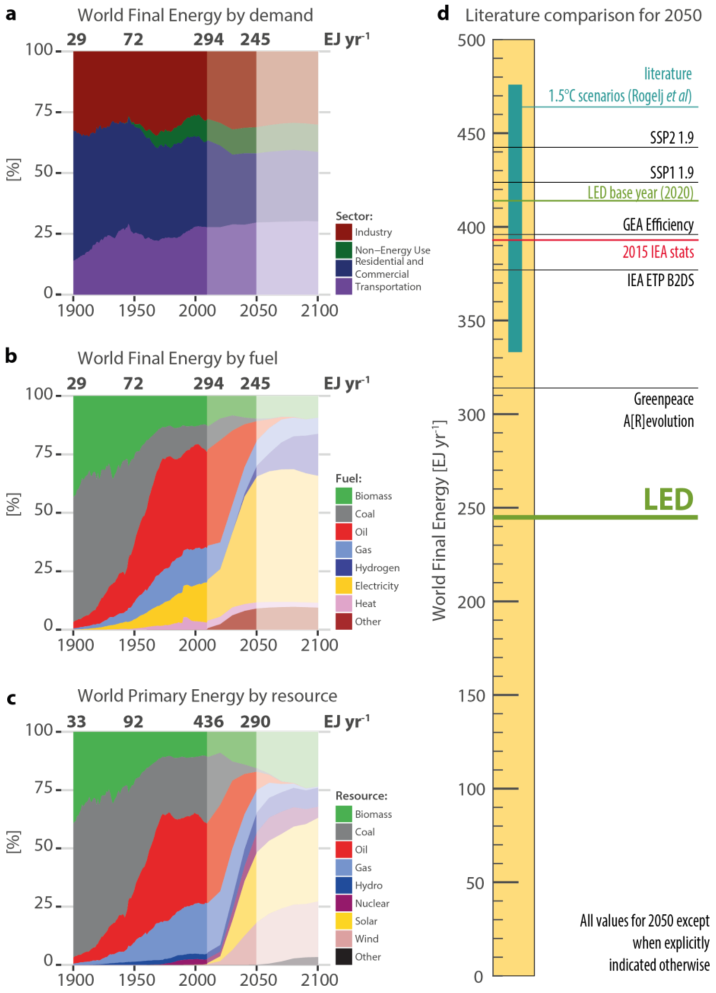

Figure 1. LED scenario in historical context and in comparison to the literature, World. Structural change in final energy shares by sector (**panel a**), final energy shares by fuel (**panel b**), and primary energy shares (**panel c**), historical data (to 2014), LED scenario to 2050 (light shade) and simplified scenario extension post 2050 (lightest shade) used for calculating climate change outcomes. For information, absolute levels of historical final and primary energy are indicated for key years on top of panels a, b, and c. **Panel d:** LED 2050 final energy demand (in EJ) compared to 2015 statistics, LED 2020 base year, and comparable scenarios with stringent climate mitigation for the year 2050.
Note: primary energy of non-combustible energy carriers counted as the direct equivalent of secondary energy output.

The global integrated assessment modelling framework, MESSAGE*ix*-GLOBIOM, was used to analyse quantitative pathways for LED demonstrating how changing energy end-use drives structural change in the energy supply. Figure 1 shows global final energy demand by end-use sector and by energy carrier, and the implications this has for primary energy supply. Results are shown to 2100 to illustrate long-term dynamics although LED is primarily concerned with the period to 2050. Final energy demand is shown in absolute terms for key years on top of each panel, and compared to other modelling projections for 2050 on the ruler.

Final energy demand of 245 EJ by 2050 in LED is significantly below current values and also significantly below comparable scenarios in the mitigation literature. It is also below global demand in the Greenpeace A[R]evolution, a historic landmark efficiency scenario (313 EJ in 2050 including energy for feedstock use), and below the lowest scenario of all those reviewed in IPCC AR5 (274 EJ in 2050).

However, from a long-term historical perspective this structural change in LED is 'dynamics as usual'. There is a historically consistent dynamic of substitution from carbon to hydrogen to electrons in final energy, as energy resources and carriers shifted from fuelwood to coal, to oil, to gas, to electricity over the past 70 or so years. This dynamic has stalled over the past two decades; LED sees it restarted and continued out to 2050.

Link to the Sustainable Development Goals

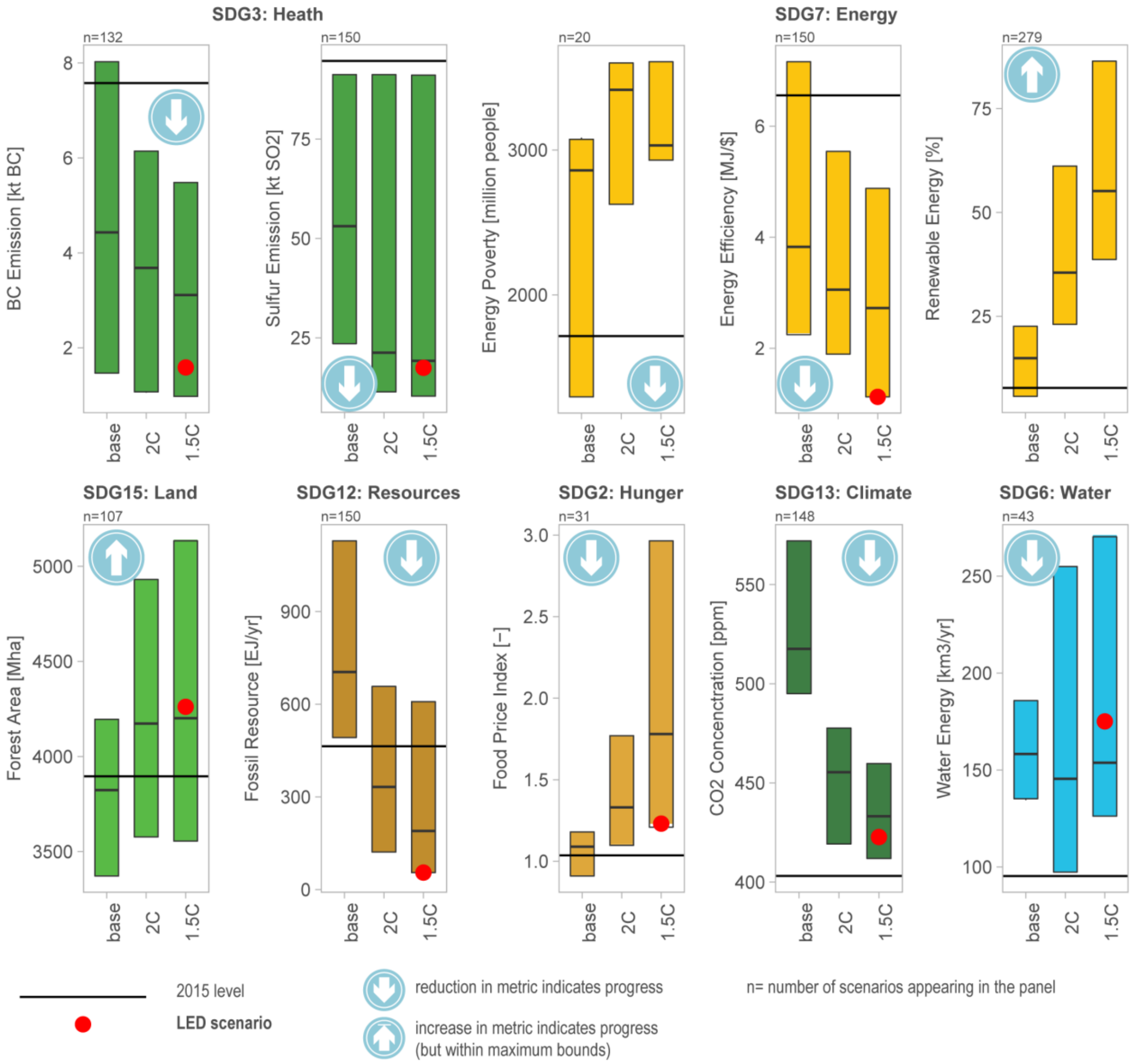

Figure 2. SDG benefits of the LED scenario in comparison to baseline, 2°C and 1.5°C scenarios assessed in the IPCC Special Report on Global Warming of 1.5°C (adapted from Figure 5.3a). Illustration of the multiple benefits of the LED scenario for achieving Sustainable Development Goals (SDGs) by 2050 globally. Progress towards SDG goals achievement (indicator in-/decrease) is denoted by arrow symbols. 2015 values or other target levels are shown for comparison as well.

LED outcomes translate into important benefits for many of the 17 UN Sustainable Development Goals (SDGs) especially when compared to other scenarios. The SDGs involve multiple indicators and targets, and have important distributional aspects, which we could not analyse in detail. Nonetheless Figure 2 demonstrates important positive effects of LED on SDG2 (Hunger), SDG3 (Health), SDG6 (Water), SDG7 (Energy), SDG12 (Resources), SDG13 (Climate) and SDG15 (Land).

Publication on which this policy brief is based:

Grubler A, Wilson C, Bento N, Boza-Kiss B, Krey V, McCollum DL, Rao ND, Riahi K, Rogelj J, De Stercke S, Cullen J, Frank S, Fricko O, Guo F, Gidden M, Havlík P, Huppmann D, Kiesewetter G, Rafaj P, Schoepp W, Valin H (2018). "A low energy demand scenario for meeting the 1.5 °C target and sustainable development goals without negative emission technologies." Nature Energy ***3****:515-527. DOI: 10.1038/s41560-018-0172-6*

Other references:

Intergovernmental Panel on Climate Change (2018) "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." https://www.ipcc.ch/report/sr15/

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The overall objective of the Energy (ENE) and Transitions-to-New-Technologies (TNT) Programs is to understand the nature of alternative future energy and technology transitions, their implications for human well-being and the environment, and how they might be shaped and directed by current and future decision makers.

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