A Low Energy Demand Scenario for Meeting the 1.5°C Target and Sustainable Development Goals without Negative Emissions.

A. Grubler, C. Wilson, N. Bento, B. Boza-Kiss, V. Krey, et al., 2018.

Nature Energy **3**, 515-527

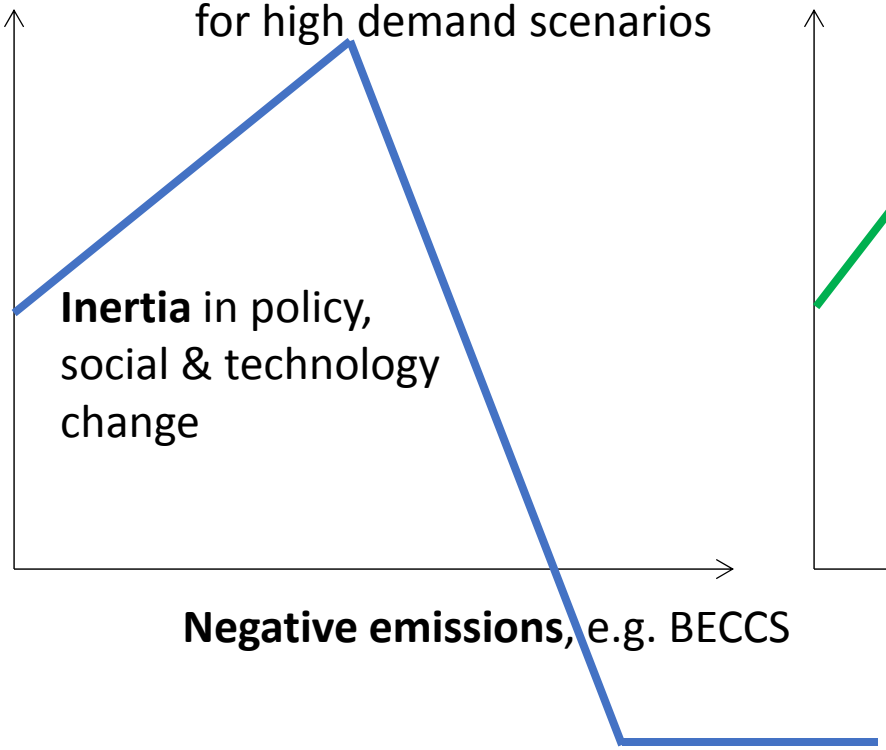
Article + SI
online LED DB:
https://db1.ene.iiasa.ac.at/LEDDB/dsd?Action=htmlpage&page=10

The LED (Low Energy Demand Scenario) Motivation and Main Features

- Scenario of rapid transitions:
  End-use, efficiency and granularity focus
- End-use change leverages and drives upstream transformation
- SDGs as overarching narrative and driver:
  Climate mitigation integrated in SDGs, but no longer singular objective (with SDG co-benefits)

2 Perspectives on Meeting 1.5 °C
GHG Emissions Profiles

Overshoot as
supply-side options
scale slowly, but need massive
long-term deployment
for high demand scenarios

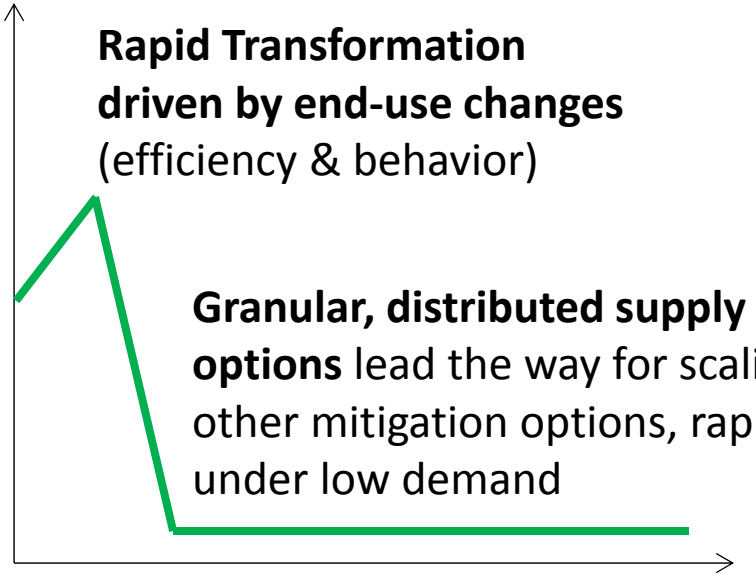


Inertia in policy,
social & technology
change

Negative emissions, e.g. BECCS

Conventional wisdom 1.5 IAM model run

Rapid Transformation
driven by end-use changes
(efficiency & behavior)

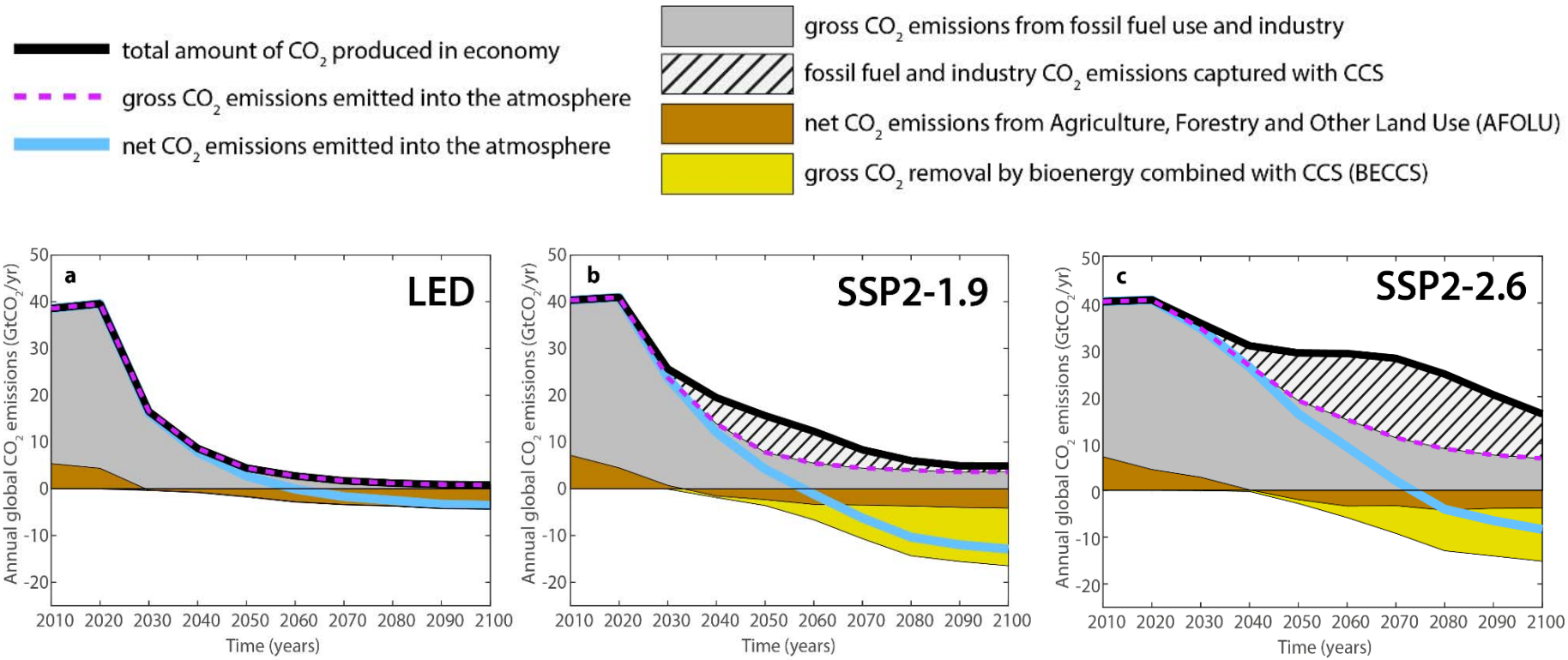


Granular, distributed supply side options lead the way for scaling other mitigation options, rapid change under low demand

"Grand Restoration"
sink enhancement via
returning land to nature

LED Scenario narrative and IAM run

Prototype 2° and 1.5° Scenarios



Integration of SDGs via Goal 12 Addresses 12 SDGs

Responsible Consumption & Production:
End poverty, reduce overconsumption,
minimize waste, and environmental impacts

LED

LED Scenario Methodology

- LED: Scenario theme (SDGs, DSL, rapid transitions) → scenario narrative → demand quantifications → supply quantifications → SDG impacts assessment
- Bottom-up assessment of end-use demands:
  Thermal comfort (residential bldgs.), consumer goods, passenger transport
- Bottom-up assessment of upstream demand implications:
  Commercial buildings, goods transport, industry
- Starting point: GEA Efficiency Scenario updated with recent sectorial studies
- Novel features: sharing economy; digital convergence; granular, distributed systems, "grand restoration": freeing land for Nature
- Normative assumptions:
  -- Decent Standards of Living for all
  -- meeting 1.5 ˚C (cum CO2 budget: 390 Gt)
  -- no CCS, BECCS or geoengineering
- Supply-side implications assessed with IIASA MESSAGE-GLOBIOM IAM framework
- Climate, air pollution health impacts assessed with MAGICC & GAINS
- Focus on 2020-2050, post 2050 stylized scenario only

PROCESS

scenario narrative → bottom-up quantification of activity and energy intensity → integrated modelling of system consequences

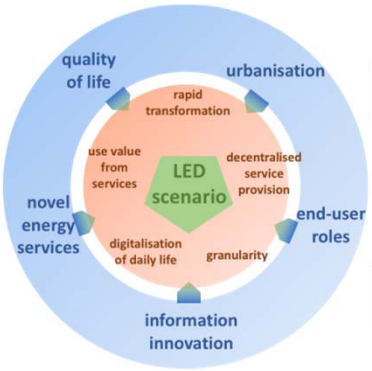
drivers of change

downstream … then upstream

energy supply & land-use

climate & health

METHOD & TOOLS



thermal comfort → commercial buildings

consumer goods → industry & manufacturing

mobility → freight transport

food

MESSAGE (energy-system model)

GLOBIOM (land-use model)

GAINS (air pollution)

MAGICC (climate)

ASSUMPTIONS

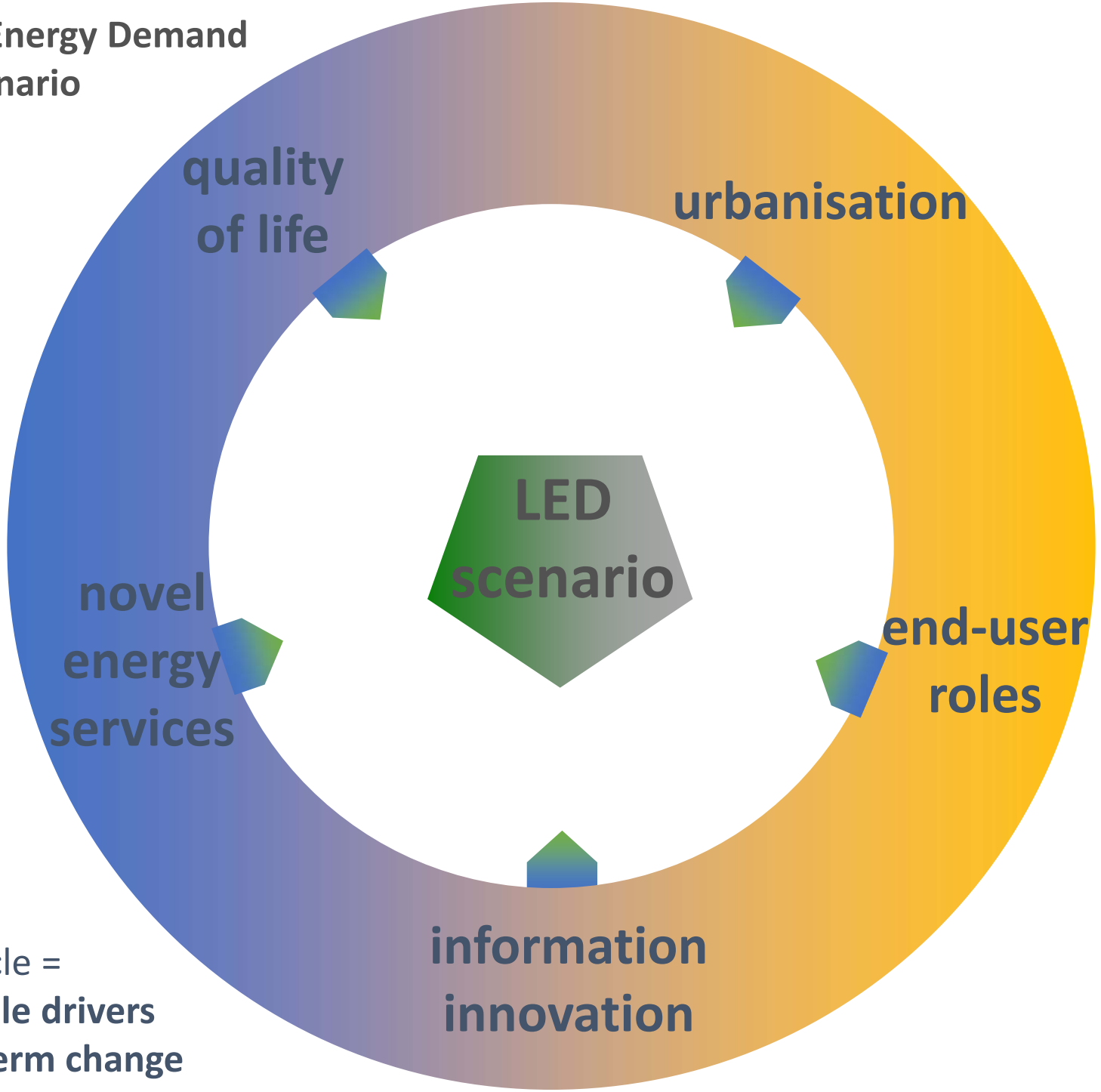
- digitalisation -
- end-use diversity -
- efficiency standards -

- activity levels -
- energy intensities -
- global North vs South -

- discount rate -
- technology costs -
- CCS constraints –
- cum. emission budget -

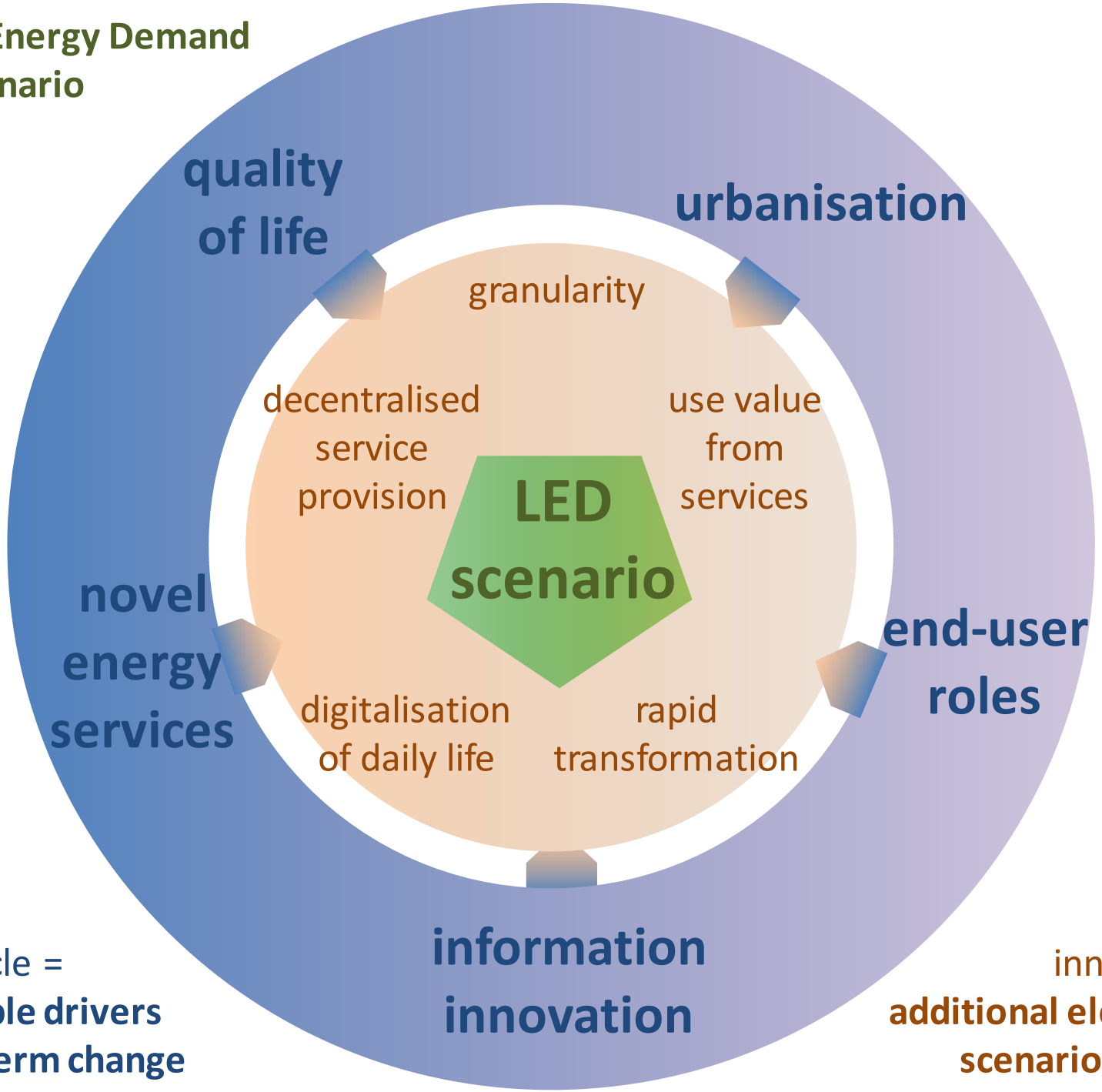
- probabilistic climate sensitivity -

the Low Energy Demand (LED) Scenario



outer circle =
observable drivers of long-term change

the Low Energy Demand (LED) Scenario



outer circle =
observable drivers of long-term change

inner circle =
additional elements in scenario narrative

LED Highlights

- Higher levels of energy services than even GEA High
- Assuring "decent standards of living" for all (well above access and poverty thresholds)
- (technological & service) efficiency driven "Peak" Energy
- Lowest demand scenario (<250 EJ FE by 2050) ever published
- End-use transformations (efficiency, electrification) drive upstream decarbonization
- Stays below 1.5 with no negative emission technologies
- Significant SDG synergies (>6 SDGs)

SDG 12: Decent Standards of Living (DSL)

DSL Indicator	**Minimum DSL**	**LED by 2050**
Food intake, cal/day/capita	**2500**	**>3000**
Shelter (residential), m^2/capita	**10**	**~30**
Consumer goods, # of devices/Household *GJ/capita*	**A/C, clean cooking, refrigeration, washing, TV, phone: >6** ***3.5-4.1***	**>27** ***3.7-8.2***
Mobility, pass-km/yr/capita	**7000**	**>7600**
Total DSL Final Energy inputs, *GJ/capita*	***12-26*** **(today's technology, range India-Brazil)**	***>27*** **(future technology: more service output per input)**

DSL requirements ensure that people have the means to pursue a decent life, and avoid harm to their basic interests (Rao & Min, 2017). DSL requirements include amenities that ensure good health, quality of life, and those that enable people to engage with society. DSL energy requirements include "upstream" infrastructure and ancillary services (education, culture, materials, goods transport, etc.)

New Trends in Social and Technological Change

- Changing consumer preferences (e.g. diets)
- Generational change in materialism
  (service rather than ownership)
- New business models
  (sharing & circular economy)
- Pervasive digitalization and ICT convergence (Society 5.0)
- Rapid innovation in granular technologies
  and integrated digital services

Social Change:
Change in Car Driving Licenses Held by Young
Trends: near-term: <50%, long-term: ~0?

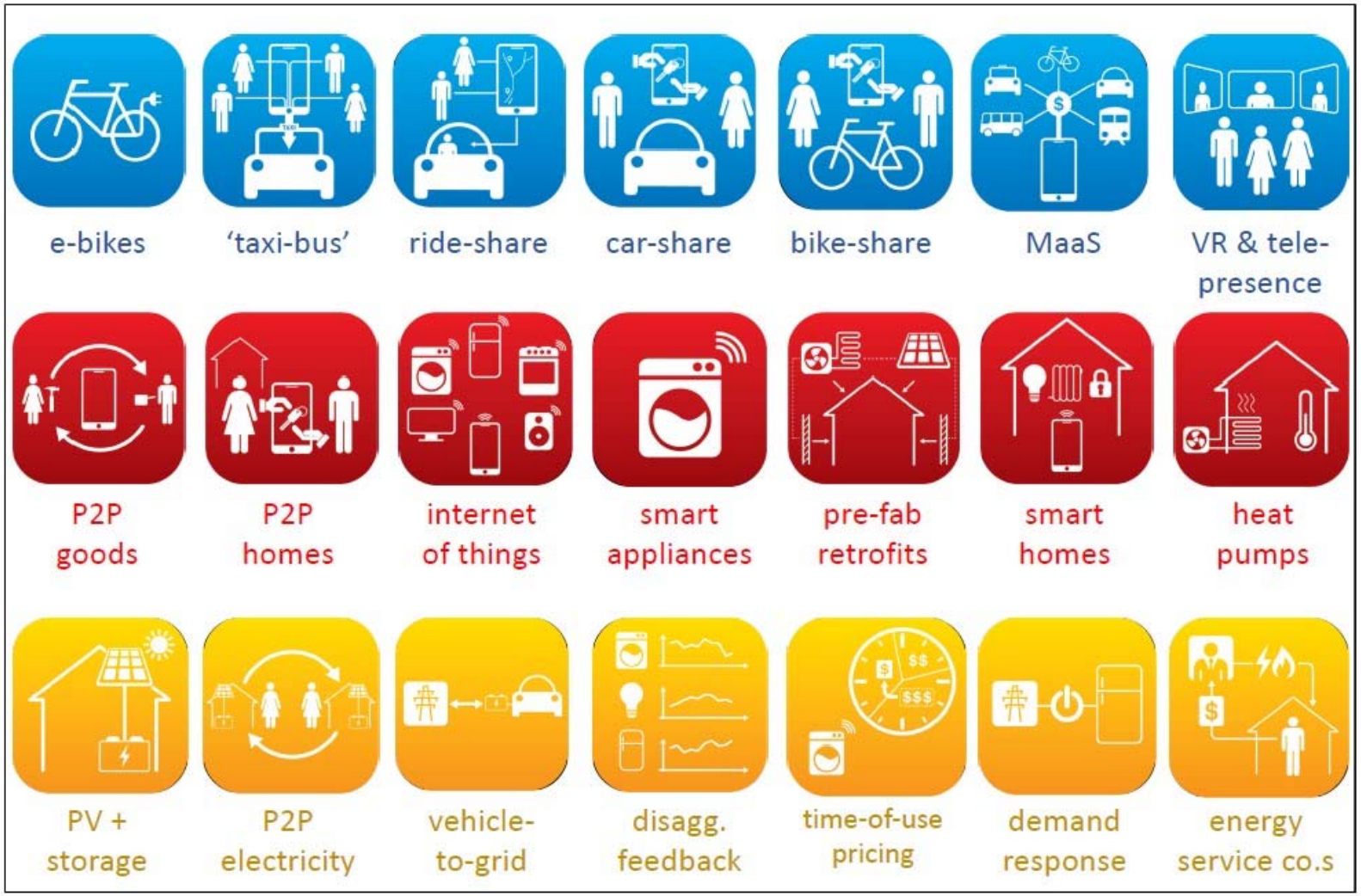
Location	year a	year b	age group	% of age group with drivers license		change
				year a	year b	%-points
Austria 2	2010	2015	17-18	39	28	-11
Germany	2008	2017	18-24	71	66	-5
Great Britain	1995	2008	17-20	43	36	-7
Great Britain	1995	2008	21-29	74	63	-11
Israel 2	2005	2015	17-18	34	30	-4
Israel 2	2009	2016	19-24	65	64	-1
Japan	2001	2009	16-19	19	17	-2
Japan	2001	2009	20-24	79	75	-4
Norway	1991	2009	19	74	55	-19
Norway	1991	2009	20-24	85	67	-18
Sweden	1983	2008	19	70	49	-21
Sweden	1983	2008	20-24	78	63	-15
Switzerland	1994	2015	18-24	71	61	-10
USA	1983	2014	18	80	60	-20
USA	1983	2014	19	86	69	-17
USA	1983	2014	20-24	91	77	-14

Location	year a	year b	age group	% of age group with drivers license		change
				year a	year b	%-points
Austria 1	2006	2010	17-18	32	39	7
Finland	1983	2008	18-19	37	68	31
Finland	1983	2008	20-29	51	82	31
Israel 1	1983	2008	19-24	42	64	22
Israel 1	1983	2008	25-34	62	78	16
Netherlands	1985	2008	18-19	25	45	20
Netherlands	1985	2008	20-24	64	64	0
Spain	1999	2009	15-24	37	50	13

Note in particular much larger prevalence of declining driving license ownership
and shift from growth to decline trends in Austria and Israel around 2008/2010
(for Finland, Netherlands, Spain no more recent data available to uncover similar trend breaks)

Data sources: Sivak & Schottle, 2011; Delbosc & Currie, 2013; Nat.Stats, 2017 for Austria, Germany, Israel, Switzerland

Disruptive End-user Innovations



(1) From ownership to usership – (2) Sharing Economy – (3) From atomized to connected

Source: Charlie Wilson

lumpy
large unit size
high unit cost
indivisible
high risk

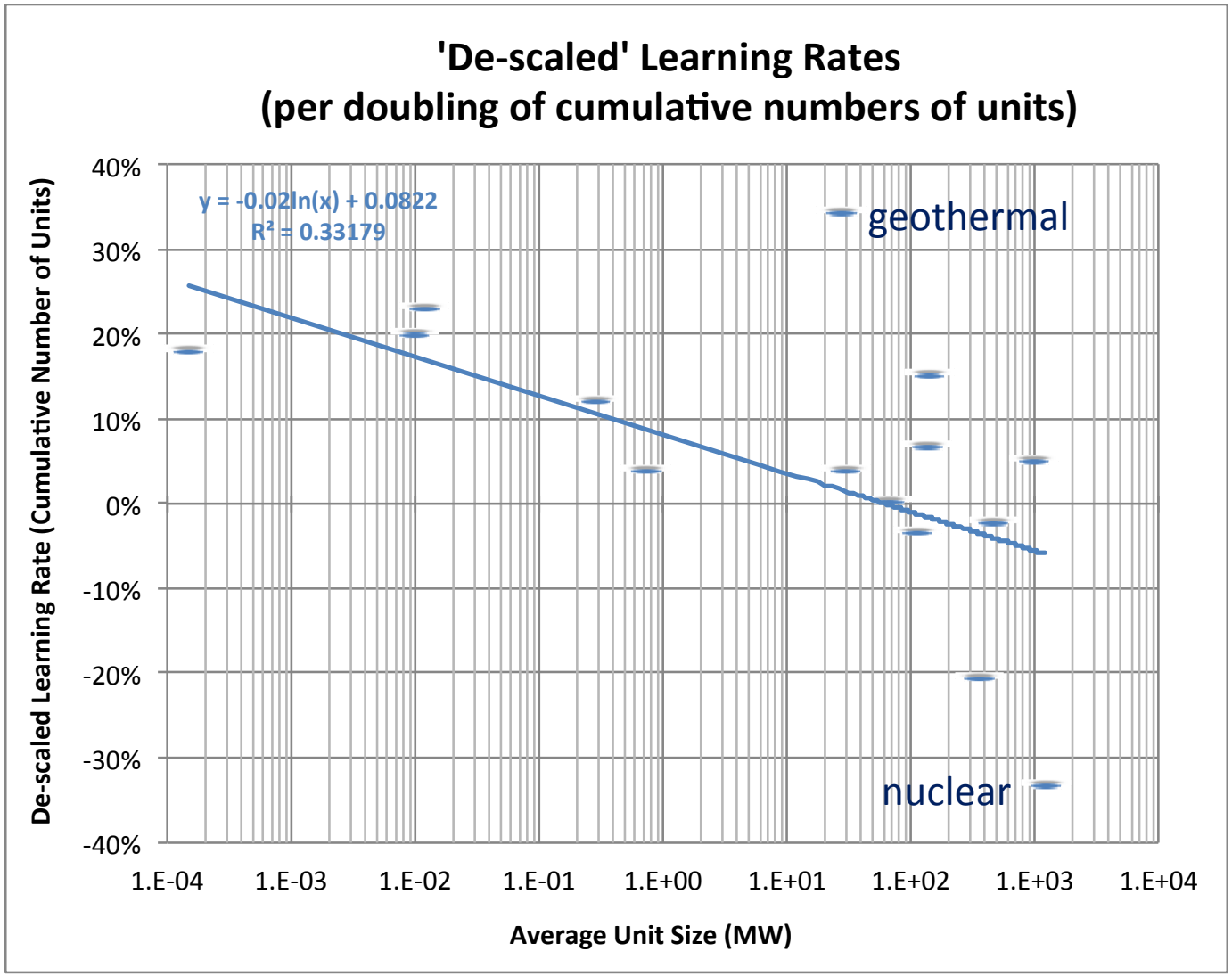
Technology
Unit Size

granular
small unit size
low unit cost
modular
low risk

Source: Grubler
ESA class material

Granularity Benefits

Higher Learning with Smaller Unit Scale After Accounting for Economies of Scale



smaller units

-> more units

-> more opportunities to experiment

-> more learning

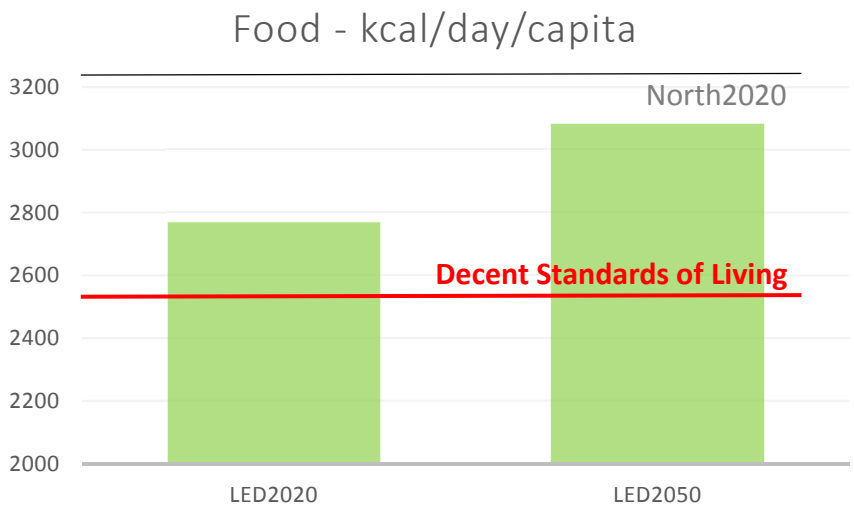
Healey, S. (2015). Separating Economies of Scale and Learning Effects in Technology Cost Improvements. IR-15-009. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

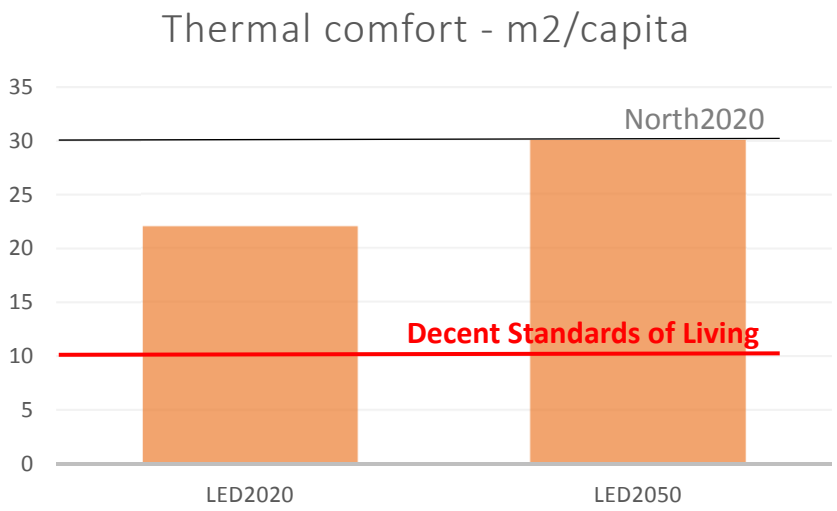
Granularity (1): faster learning -> LED exogenous cost assumptions in MESSAGE

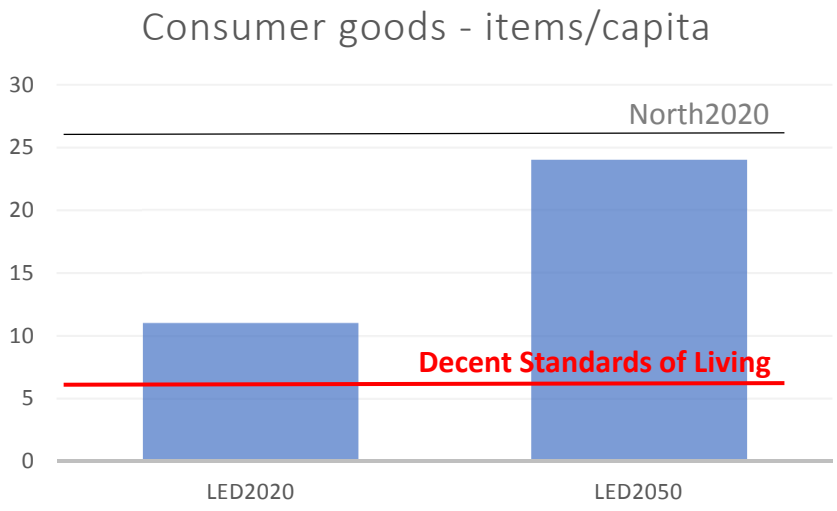
LED-scenario specific cost assumptions for granular technologies for MESSAGE supply-side transformation analysis (specific investment costs in US$2010 per kW installed).

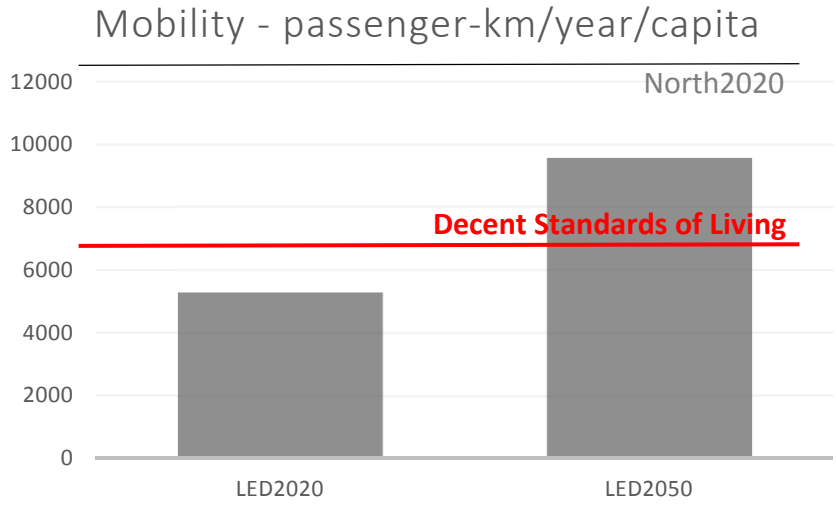
technology	short-term ca. 2030	medium-term ca. 2050	long-term post 2050
solar PV	500	120	50
batteries (transport & storage)	300	100	50
fuel cells	750	300	100
electrolytic hydrogen	300	200	100
solar direct heat industry	300	100	100

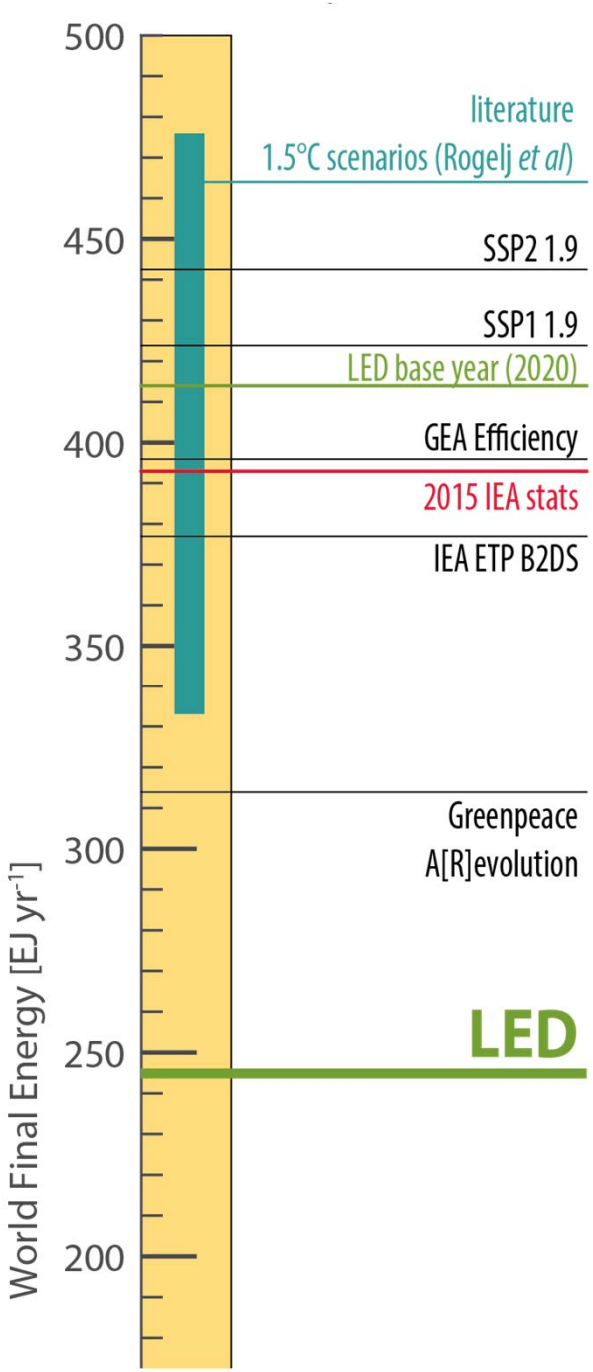
Granularity (3): equal distribution -> LED per capita energy services in the global South











LED
Final Energy Demand Compared for 2050:

Scenarios with comparable climate outcomes:

IPCC Shared Socioeconomic Pathway 2 (SSP2)
max. 1.9 W/m2 radiative forcing

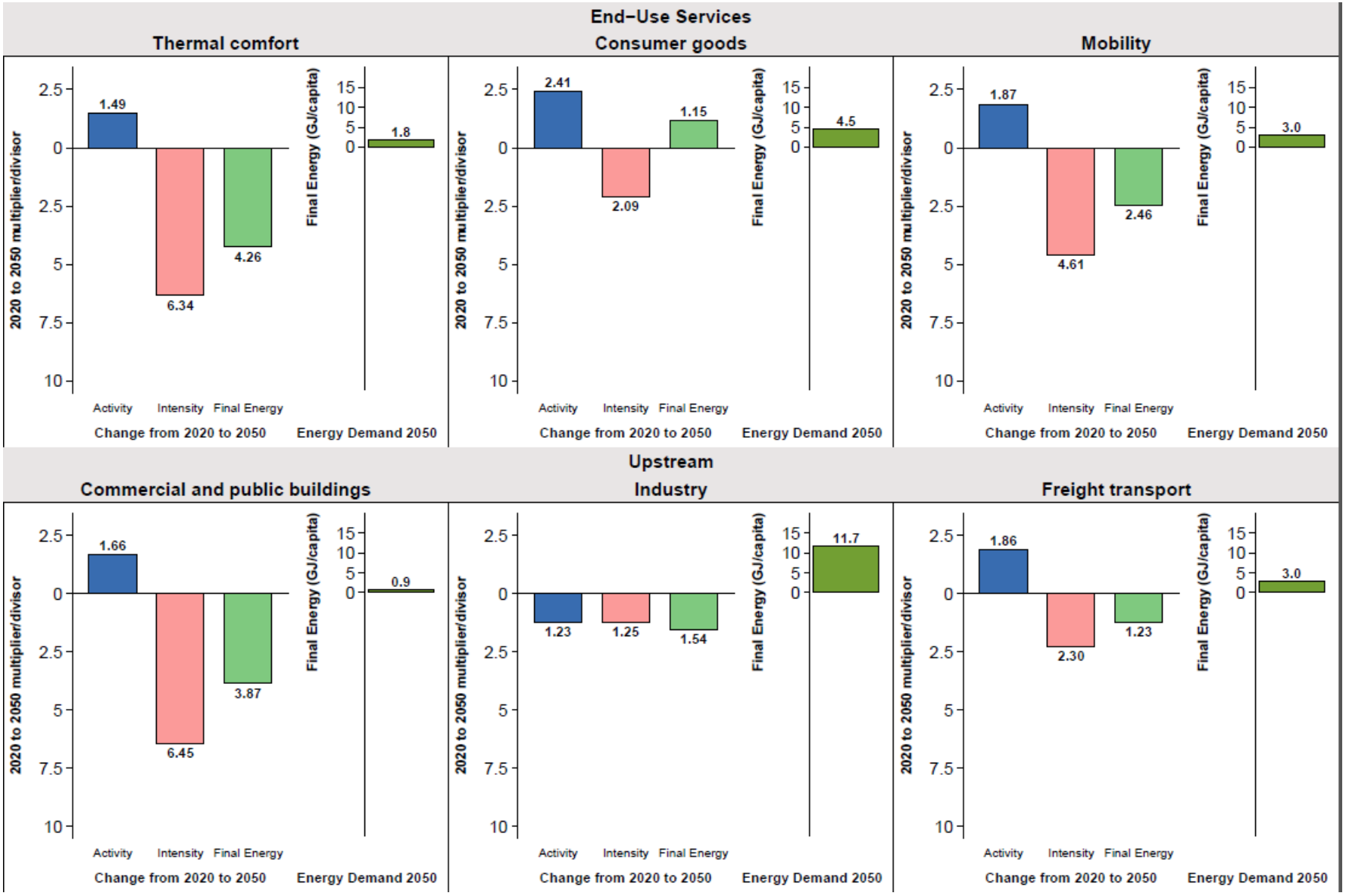
Global Energy Assessment (GEA) Efficiency scenario

International Energy Agency (IEA)
Below 2 Degrees Scenario (B2DS)

Greenpeace A[R]evolution scenario

LED: Factors of Change 2050/2020 Global:

More services & amenities: Less resource inputs



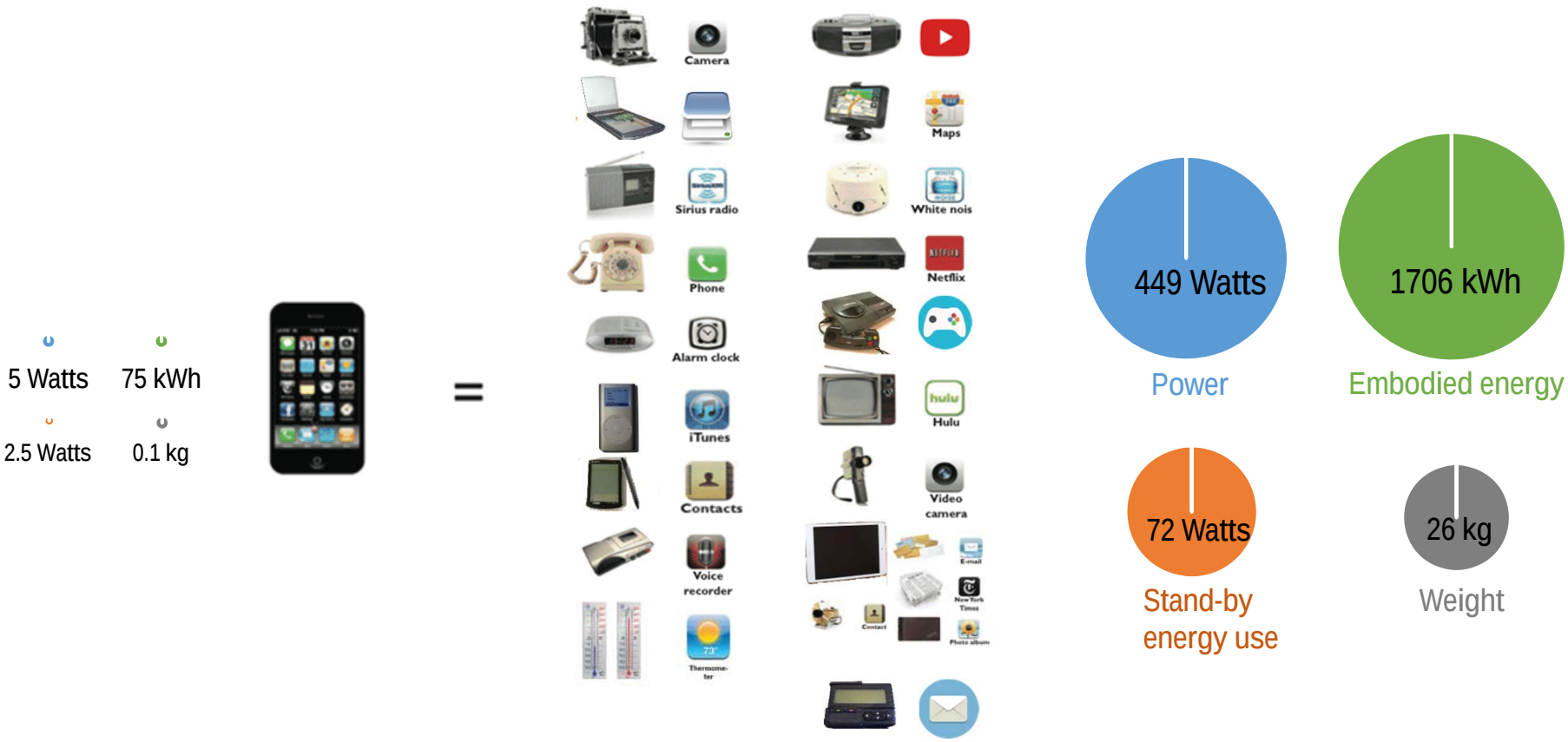
LED Global (compared to 2020) Thermal Comfort: Activity x 1.5, Intensity ÷ 6.3, Energy ÷ 6.3

Mexico: NAMA
low energy social housing projects

Netherlands: Energiesprong
prefabricated thermal retrofits, net-zero housing

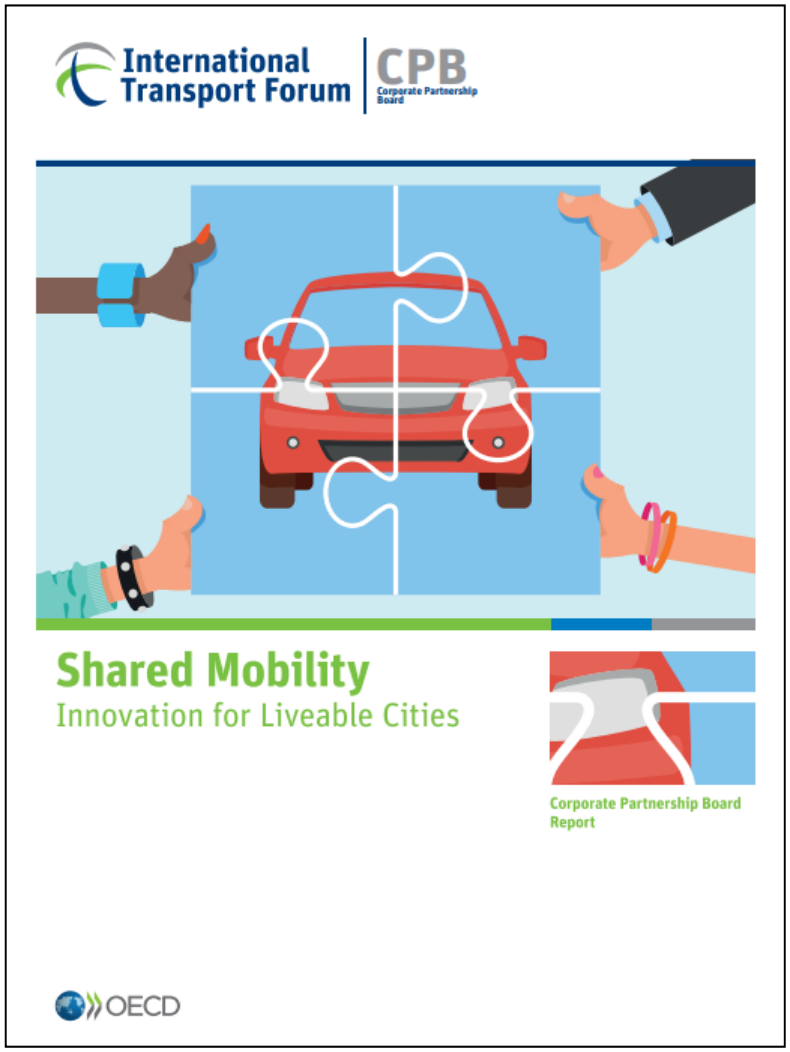
Austria: Raiffeisen
First Passivhausstandard office tower & retrofit

Resource Impacts of Digital Convergence



LED Global (compared to 2020) Consumer Goods:
Activity x 2.4, Intensity ÷ 62.1, Energy ÷ 1.2

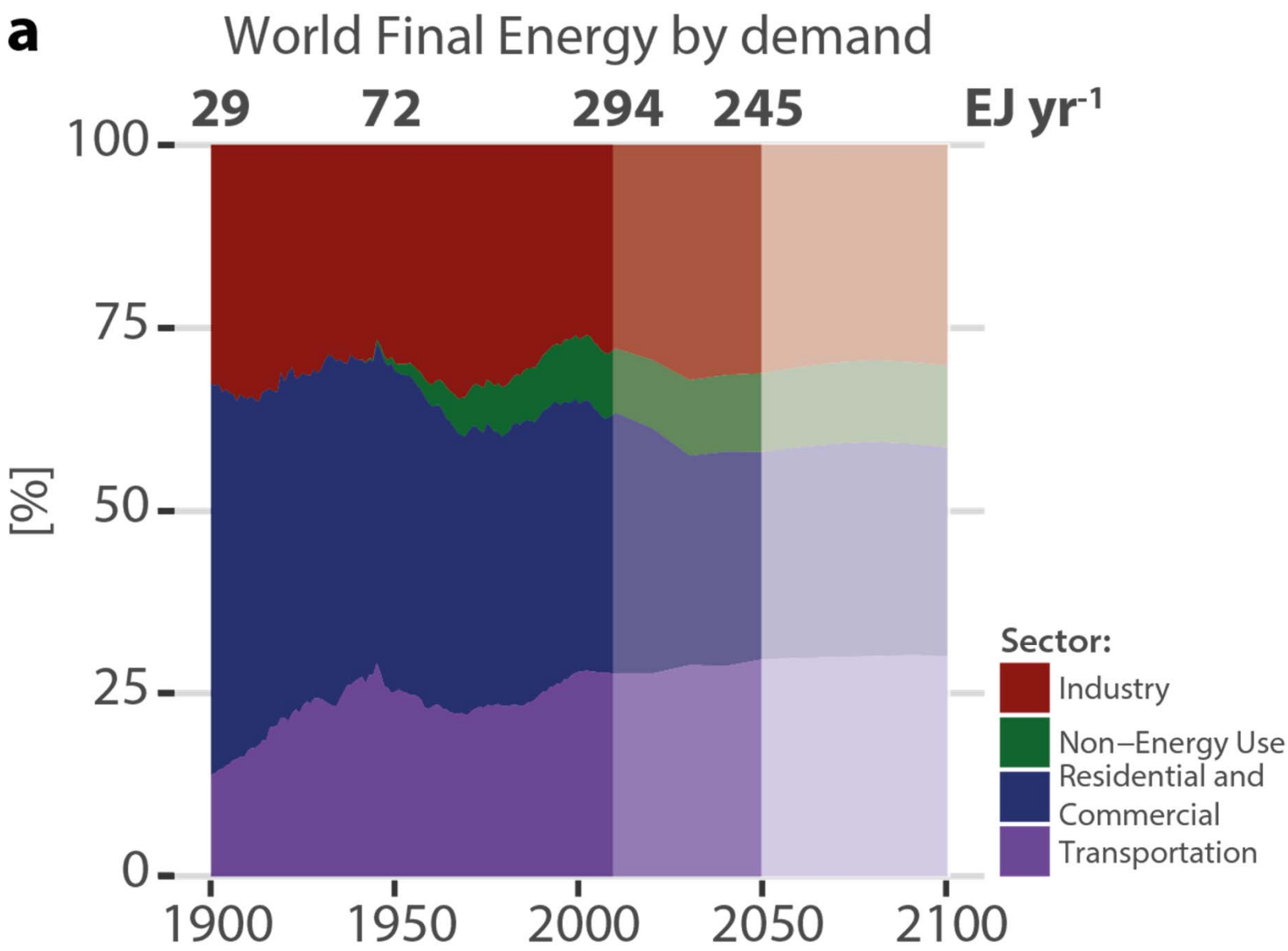
The “Sharing Economy”: A Mobility Case Study

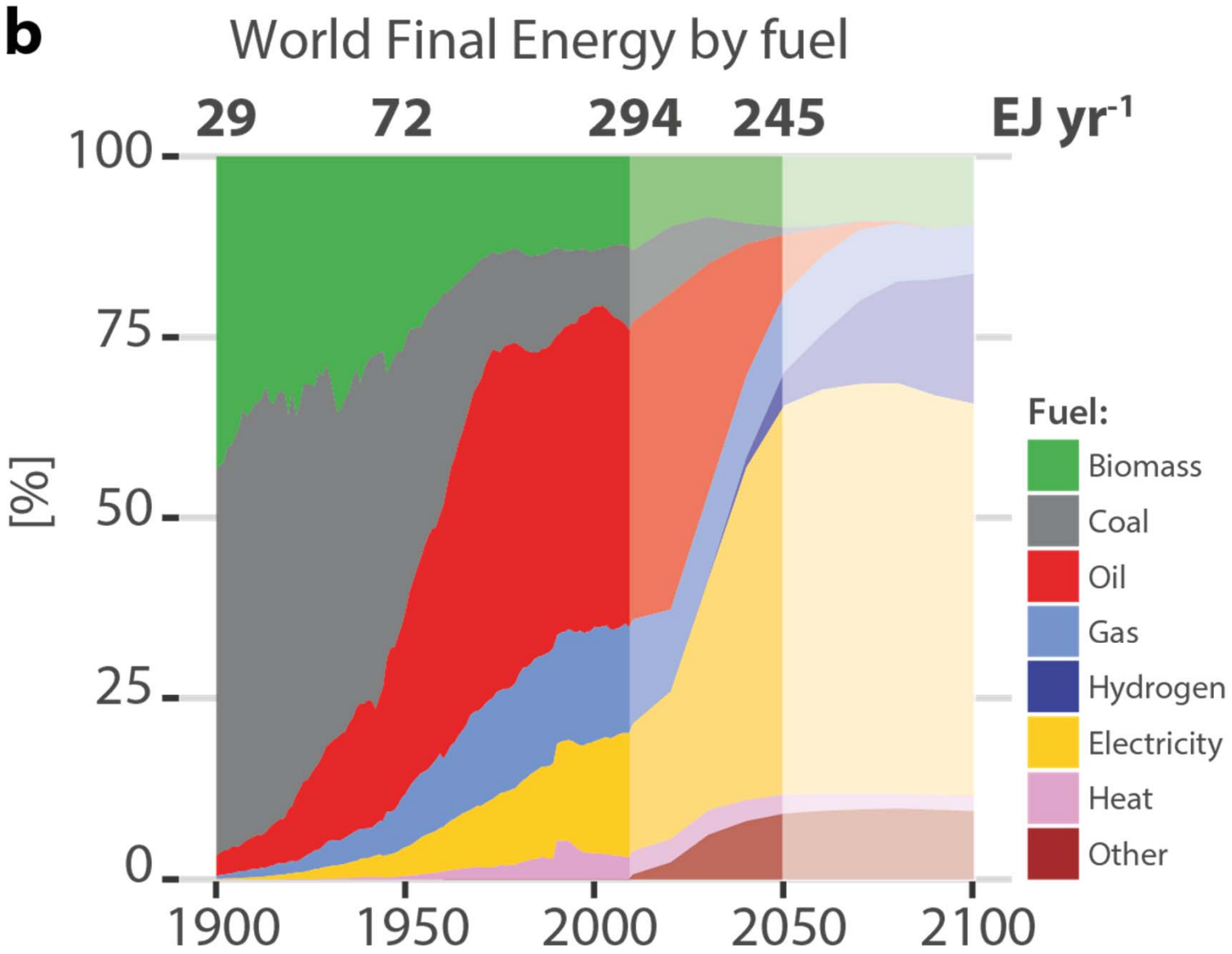


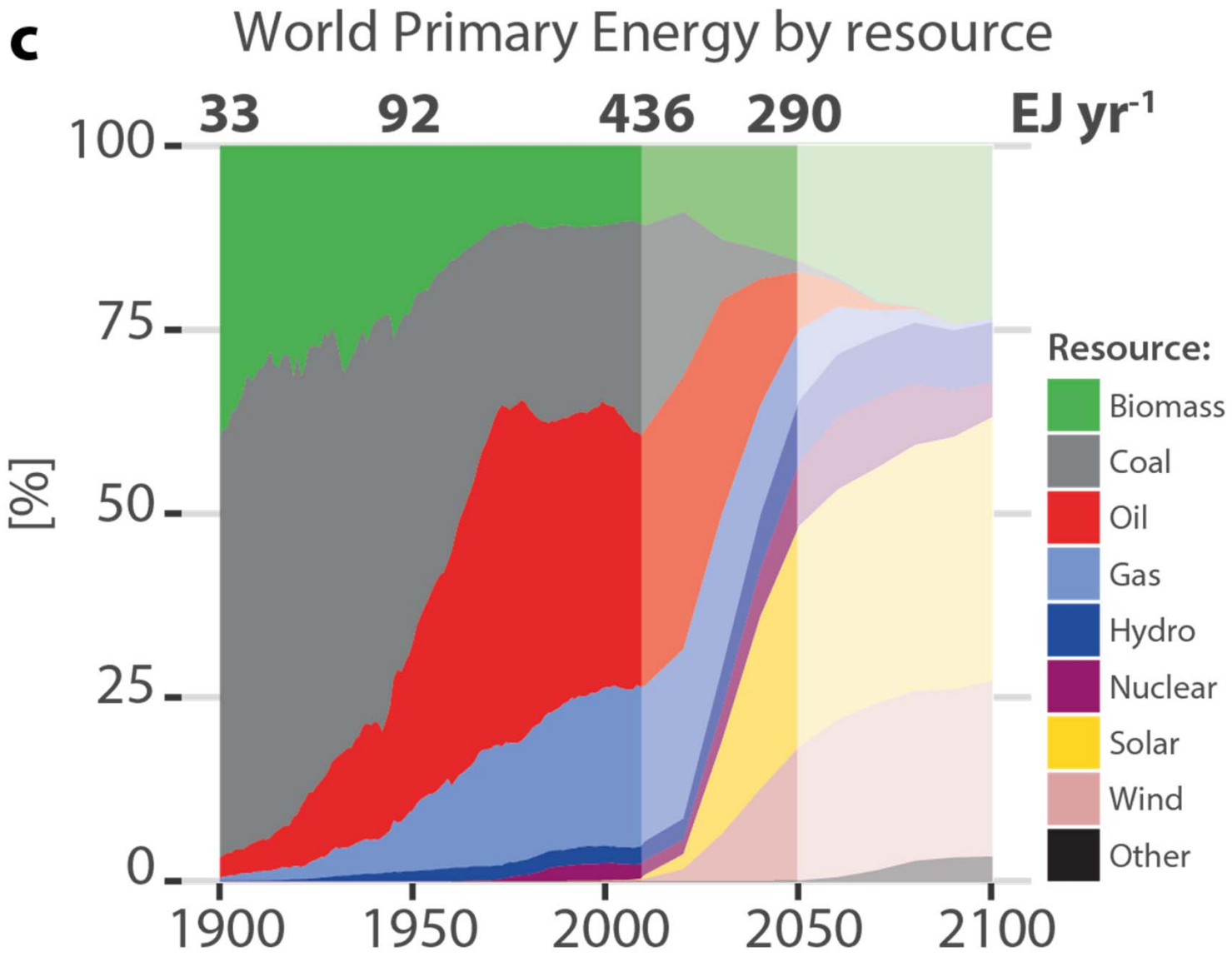
OECD ITF Case Study Lissabon:
„Shared“ Car-Taxi-Bus system

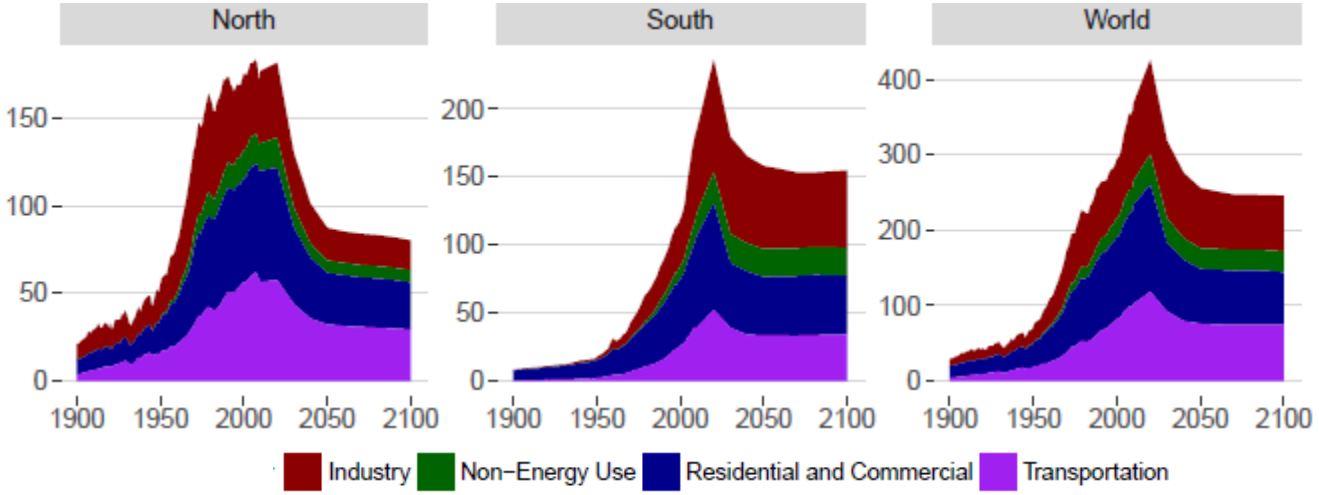
- Same level of motorized mobility, with 3% of vehicles
- Congestion: 0
- Fuel use and CO_2:
  - 30% (conventional IC vehicles)
  - >60% (electric vehicles)
- Parking spaces: - 95%
- Mobilty costs: - 50%

LED Global (compared to 2020) Mobility:
Activity x 1.9, Intensity ÷ 4.6, Energy ÷ 2.5

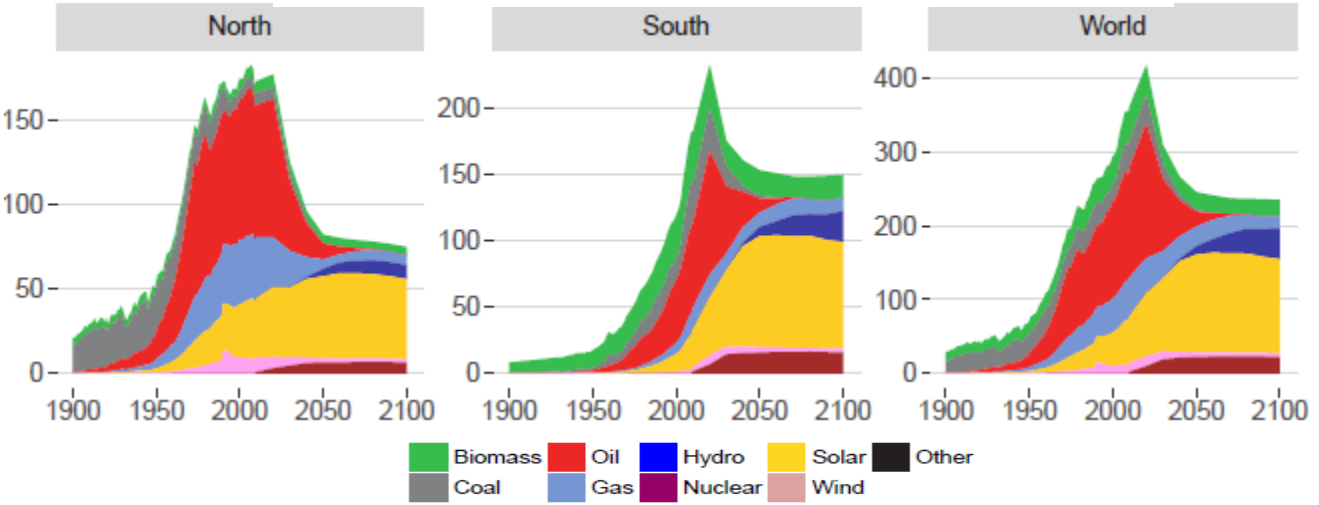

a
World Final Energy by demand
29
72
294
245
EJ yr-1
100
75
50
25
0
[%]
1900
1950
2000
2050
2100
Sector:
Industry
Non–Energy Use
Residential and
Commercial
Transportation


b
World Final Energy by fuel
29
72
294
245
EJ yr-1
100
75
50
25
0
[%]
1900
1950
2000
2050
2100
Fuel:
Biomass
Coal
Oil
Gas
Hydrogen
Electricity
Heat
Other

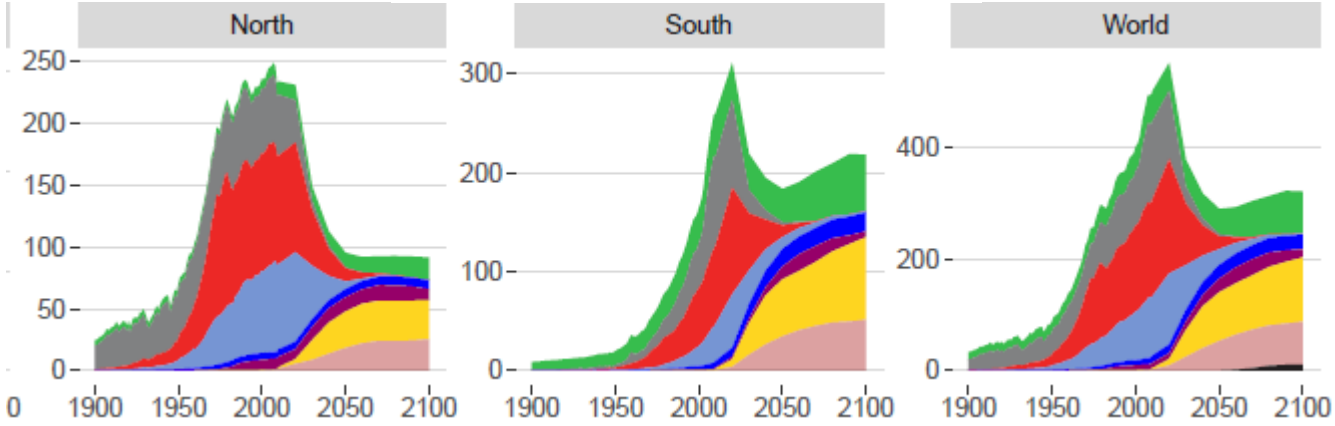

c
World Primary Energy by resource
33
92
436
290
EJ yr-1
100
75
50
25
0
[%]
1900
1950
2000
2050
2100
Resource:
Biomass
Coal
Oil
Gas
Hydro
Nuclear
Solar
Wind
Other



LED EJ Final Energy

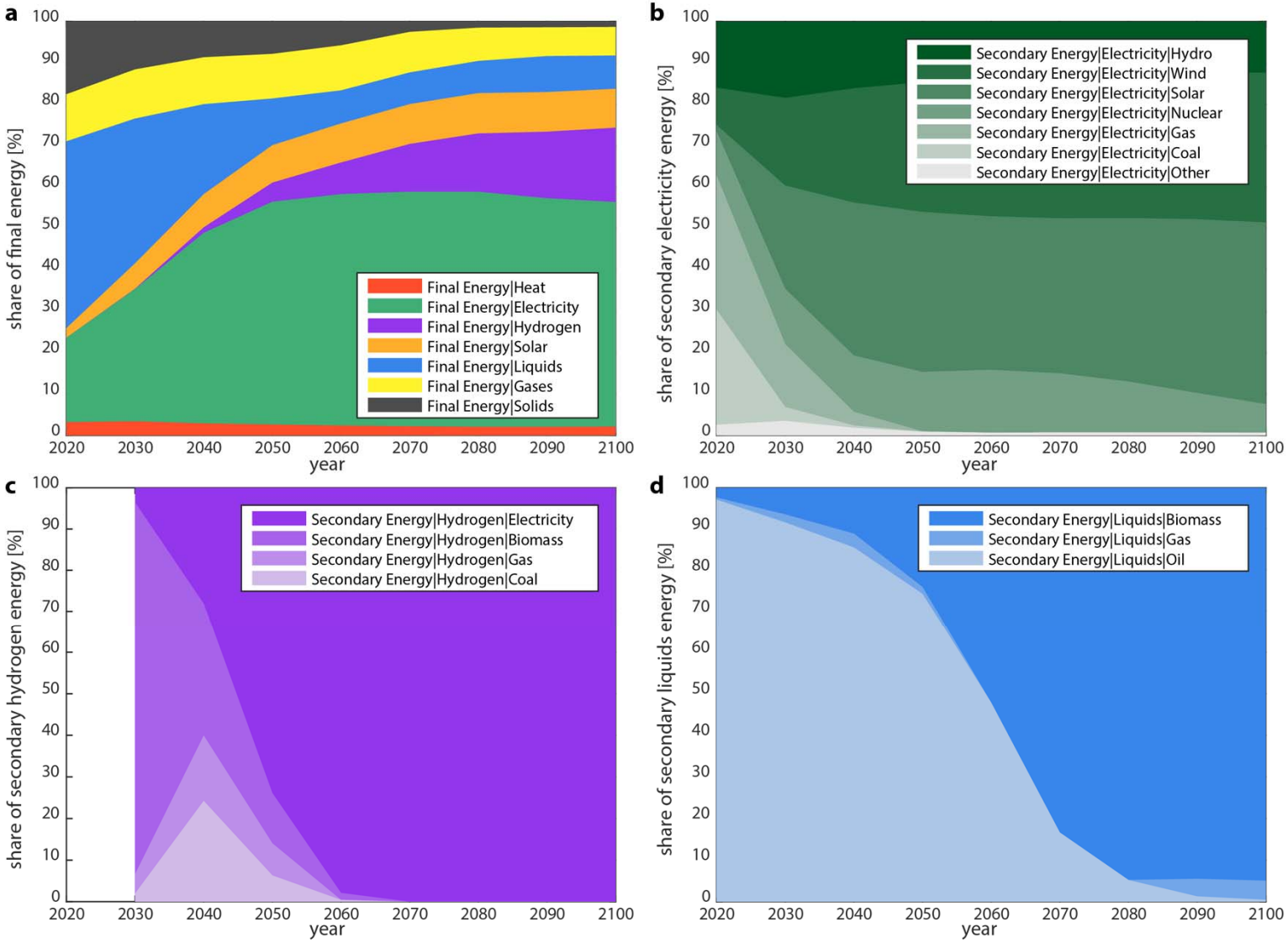


LED EJ Final Energy

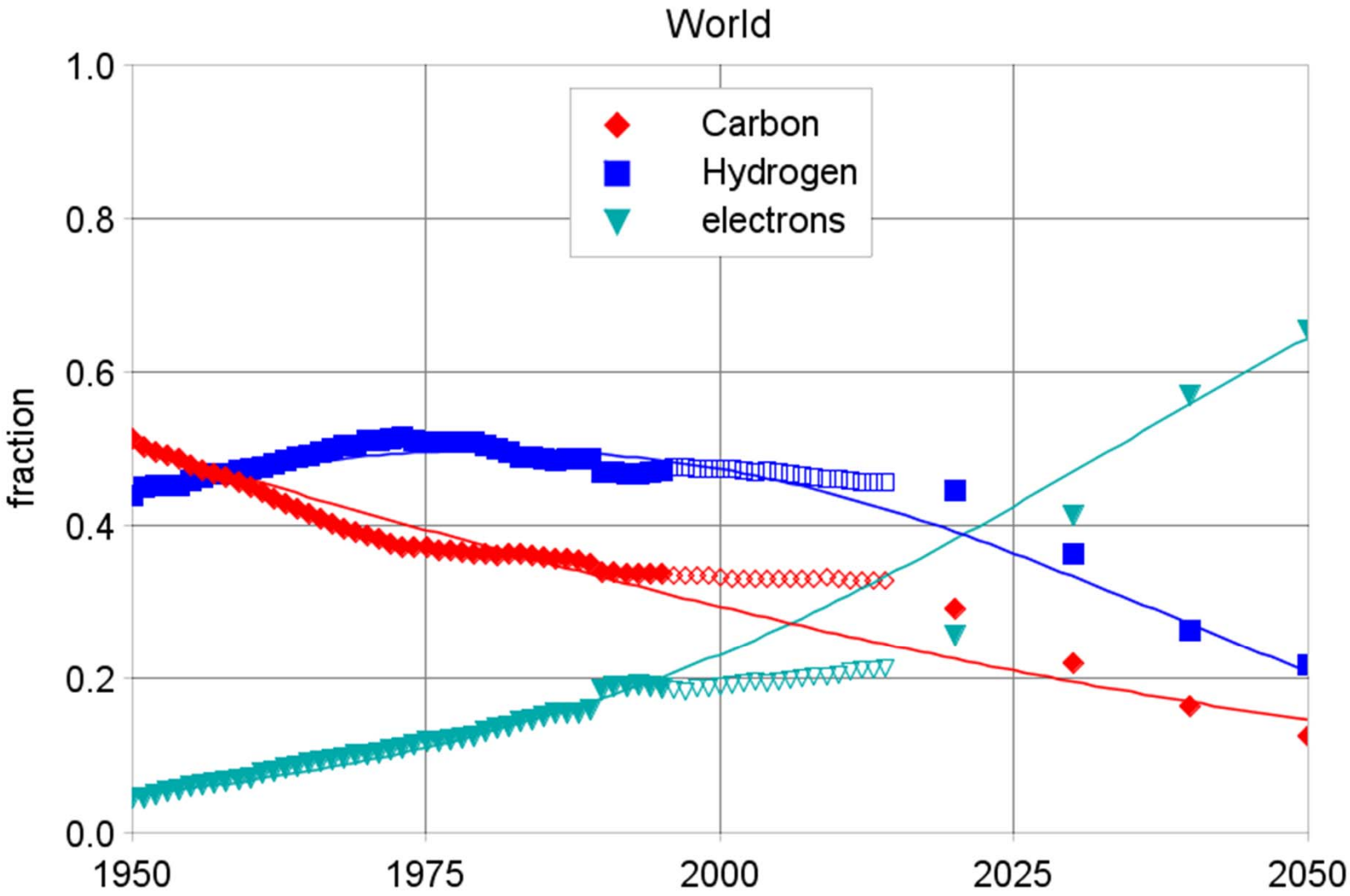


LED EJ Primary Energy

LED: Transformations in Final Energy Use (a) and Upstream Secondary Energy Transitions (b, c, d)



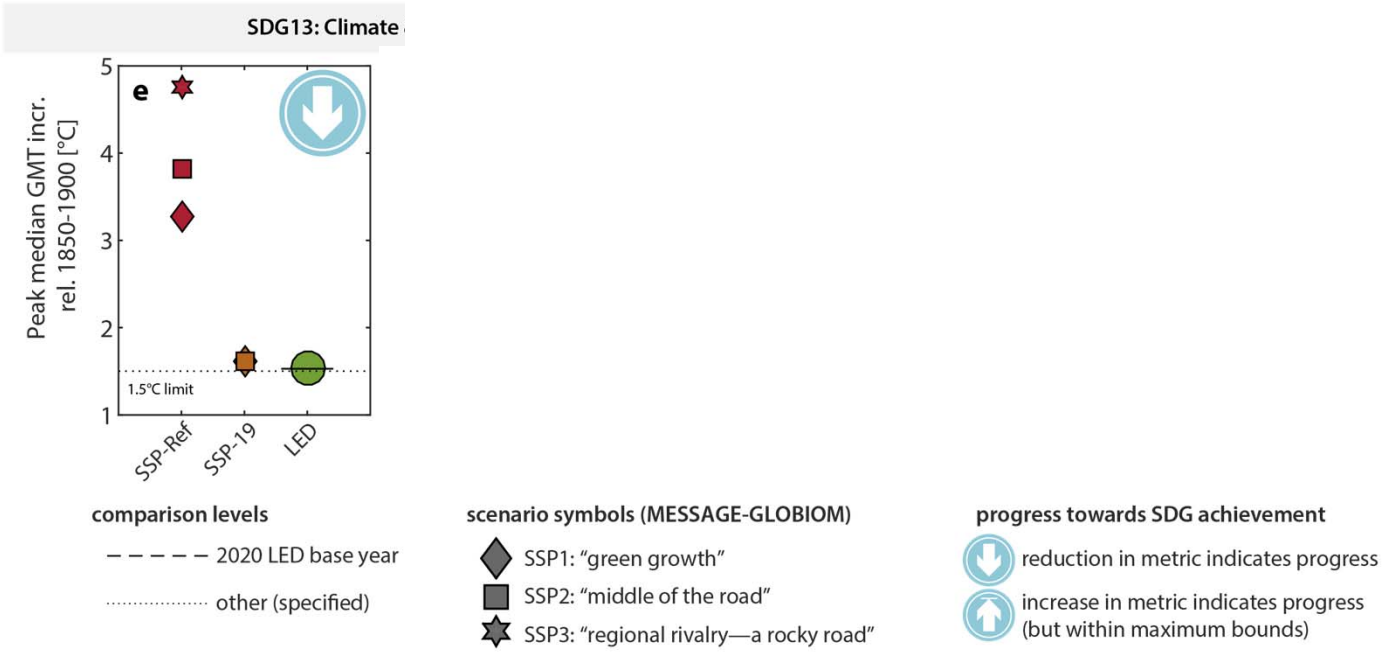
Transitions in Final Energy Use: LED *aka* "dynamics as usual"



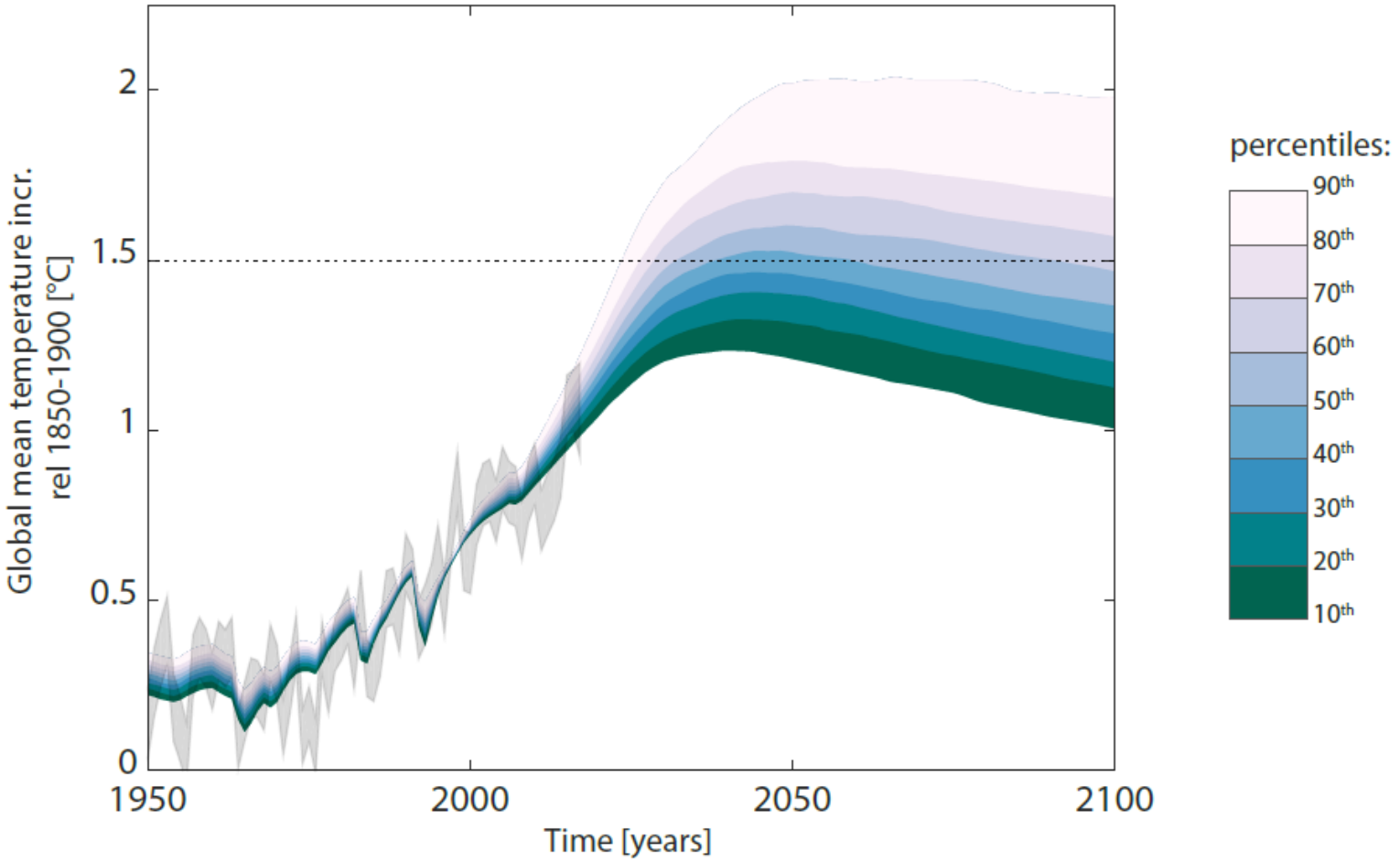
Main Characteristics of Transitions

- Scaled-down demand allows faster systems transitions:
  - faster electrification
  - higher market share of renewables:
    8% (2020), 32% (2030), 60% (2050)
  - with lower rates of absolute capacity additions
    up to 91%/yr historically, 15% (2020-2030)
    <5% (>2050)
  - With no CCS, BECCS, or geoengineering
- Outperforming all other scenarios on 7 SDG dimensions

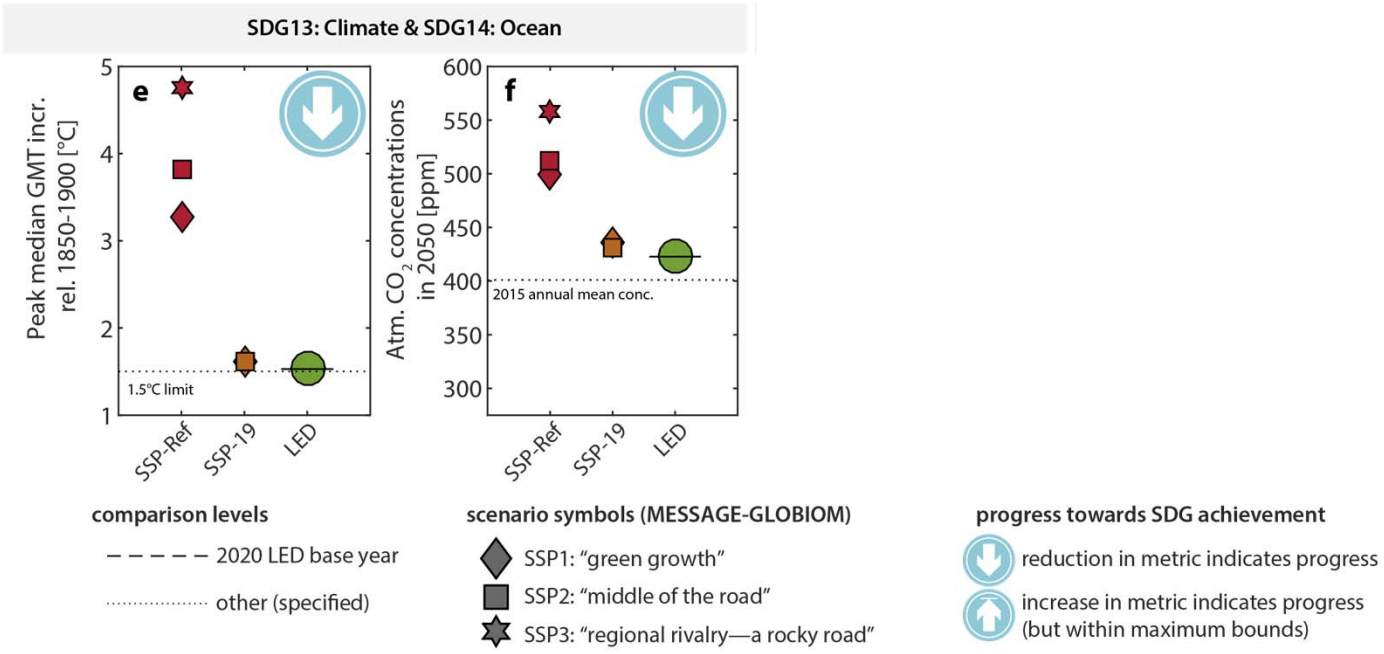
SDG Implications: SDG13



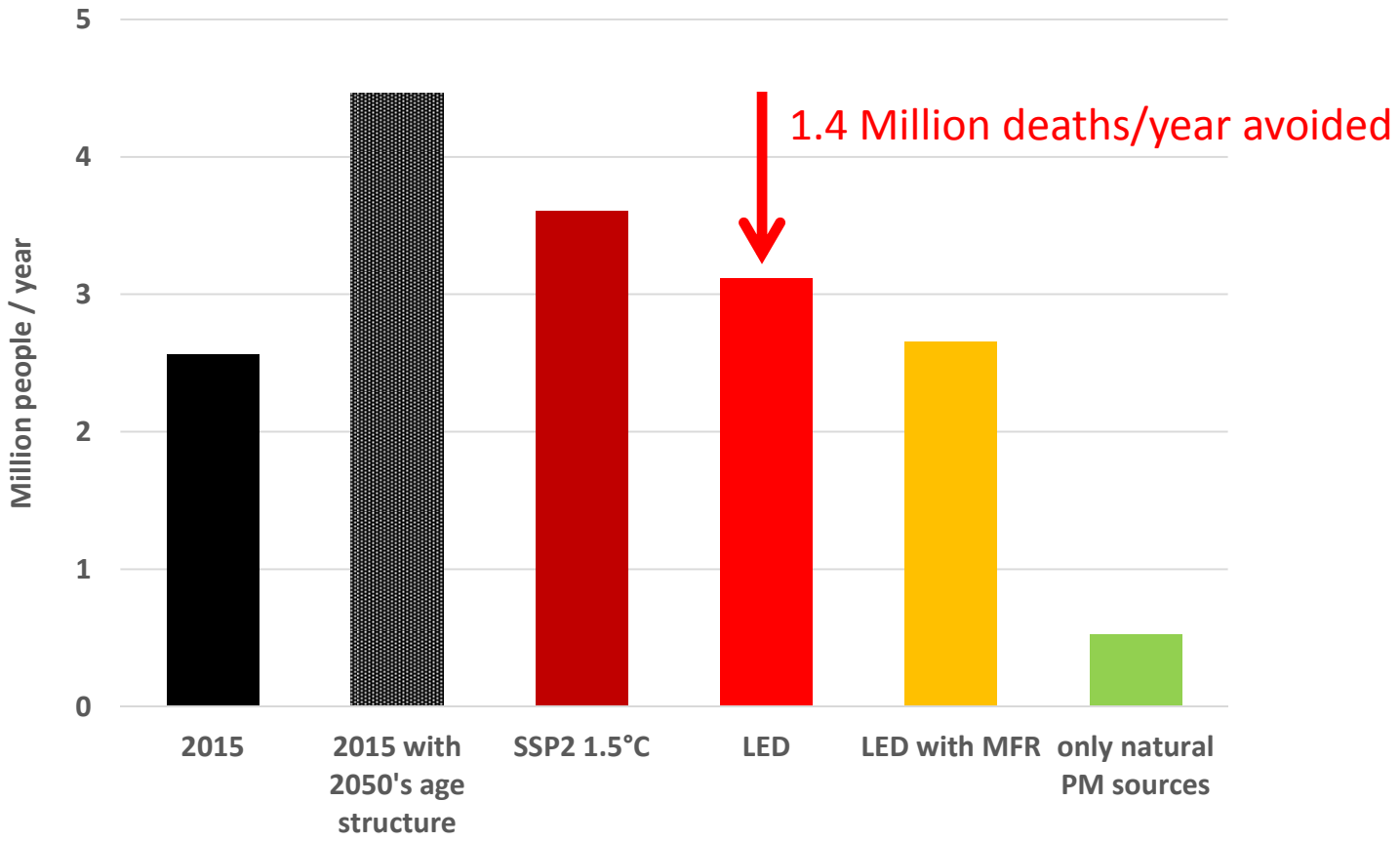
LED: Global Mean Temperature Change
Probabilistic MAGICC Results



SDG Implications: SDG13, SDG14

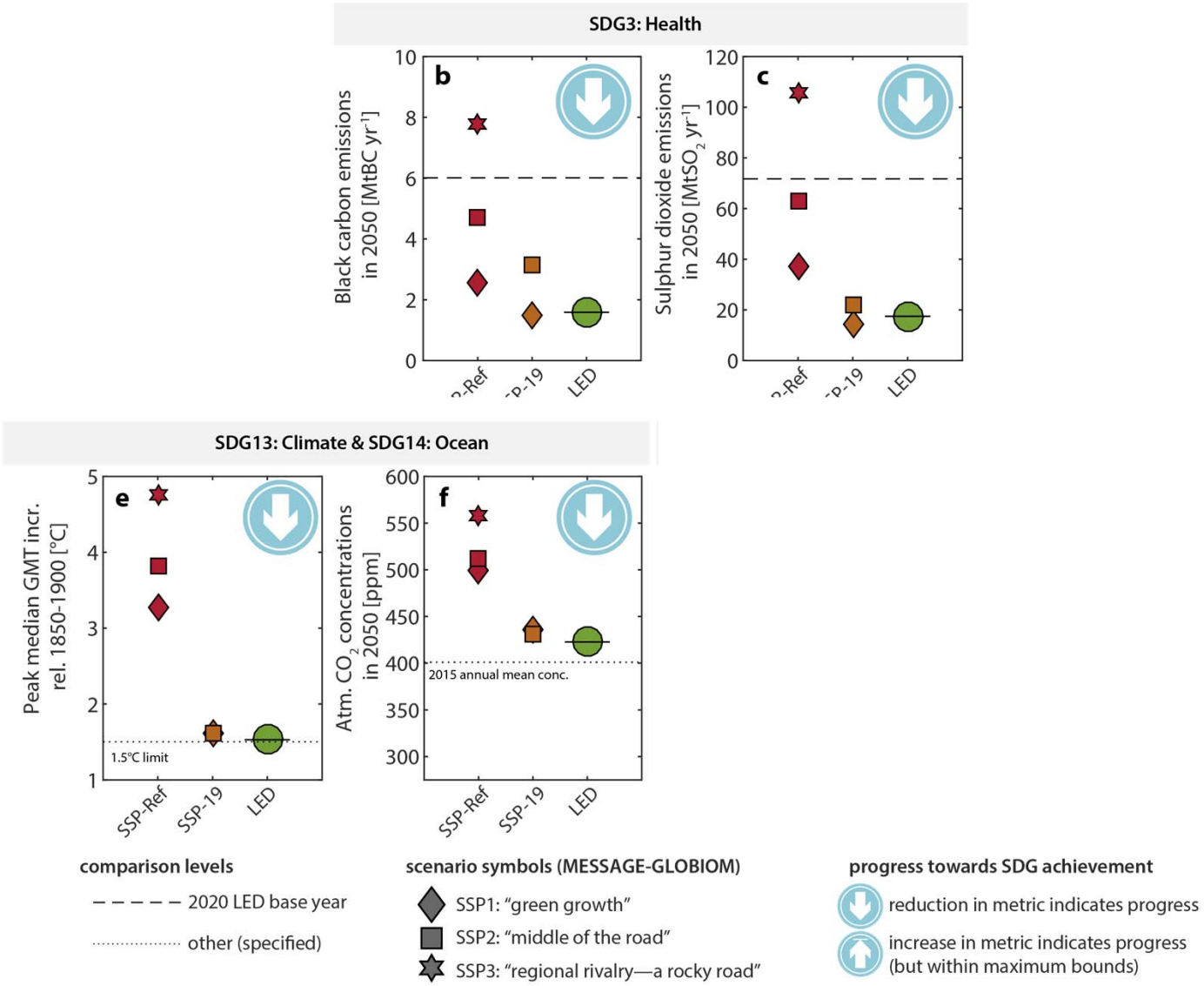


Pre-mature Deaths from Air Pollution



MFR= maximum feasible emissions reductions (near-term technology)

SDG Implications: SDG13, SDG 14, SDG3



Land Use Difference in Two 1.5° Scenarios

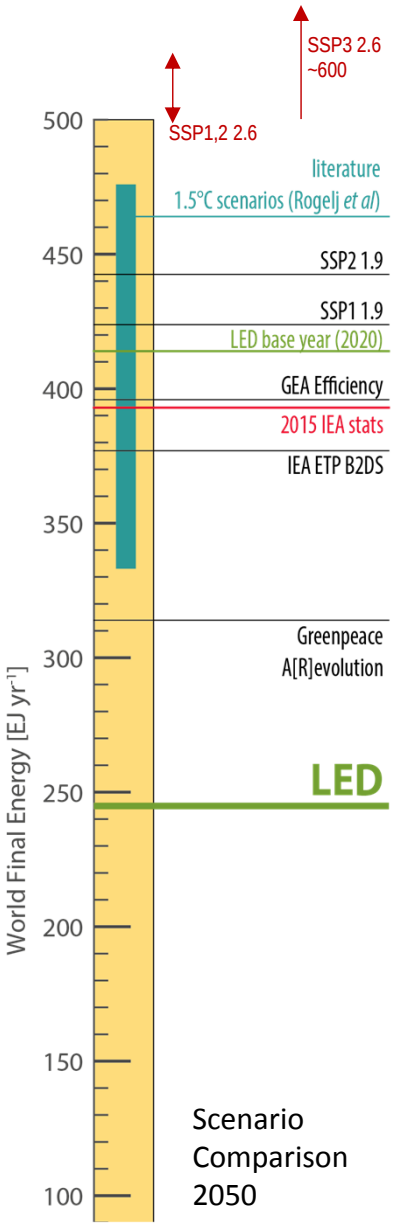
LED scenario -- SSP2-RCP1.9 scenario

Land use change (Mha)

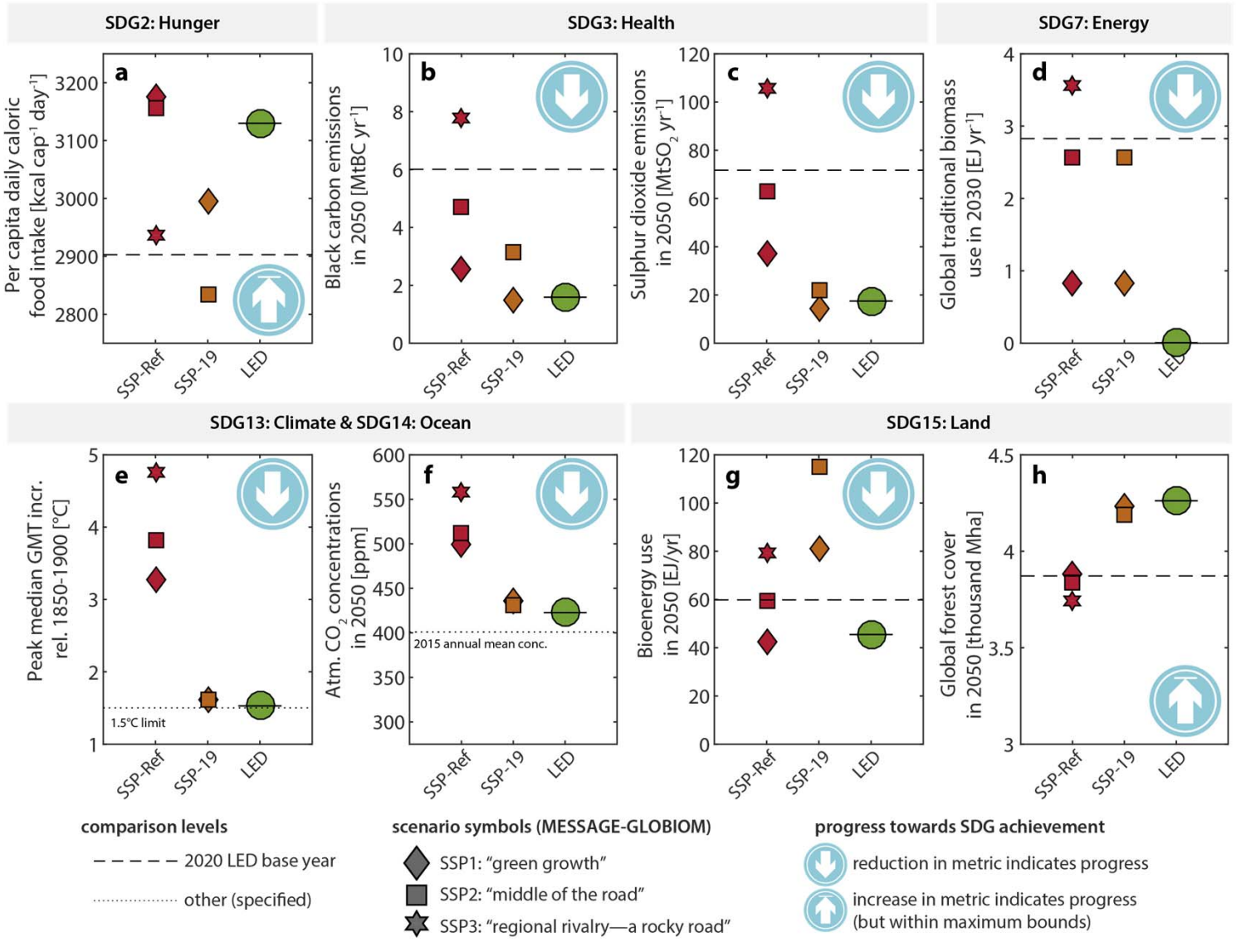
	2050	2100
Cropland -energy crops	-112	-446
Forest managed	-523	-1662
Natural forest	535	1736
Afforestation and reforestation	5	48
Pasture	5	114
Other natural land	48	107

SDG 2, 3, 7, 13, 14, 15 Implications

LED *vs* IPCC SSPs (SSP1-3Ref & 1.9) Scenarios



Scenario Comparison 2050



Conclusion

- Demand (technological and service efficiency) key for SDGs and 1.5
- Transition acceleration possible with end-use & granularity focus
- First global scenario quantification (LED), informed by recent trends and advances in transition modeling
- Implications for Policy Makers: Forget global climate policy architecture, actor coalitions with urban citizens and farmers, challenge: systemic incentives (land-use, transport, infrastructure)
- Implications for Business: New opportunities with service-oriented business models, building efficiency, granular end-use technology innovation

Escaping Lock-in with Rapid Transitions in “well-below 2°C” Scenarios

- Efficiency improvements in existing systems
- Change in end-use technologies & services
- Granular & distributed options
- Maximize SDGs benefits
- Low- and Zero-C-Development: SDG12: “responsible production & consumption”

vs traditional

- BAU demand and consumption growth
- Large-scale supply side options
- Climate-only “fixes” (negative emissions)