Sixth Assessment Report
WORKING GROUP III – MITIGATION OF CLIMATE CHANGE

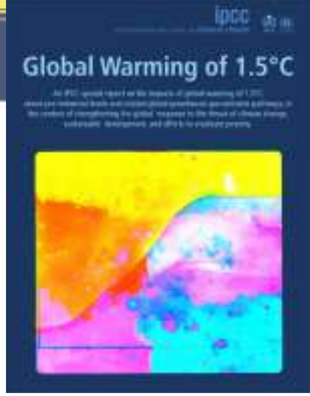
ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

<u>Climate Change 2022</u>

The role of energy demand and services in climate stabilization

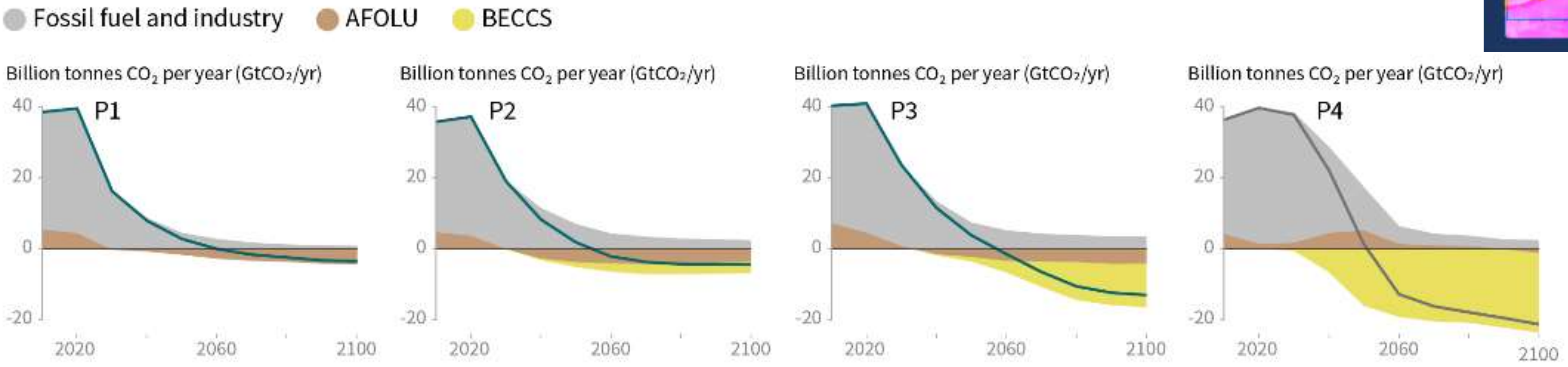
Based on the findings of the IPCC's Sixth Assessment Report

[Matt Bridgestock, Director and Architect at John Gilbert Architects]



Characteristics of four illustrative model pathways

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

There are options available **now** in every sector that can at least **halve** emissions by 2030

Demand and services

Energy

Land use

Industry

Urban

Buildings

Transport

C.4 Reducing GHG emissions across the full energy sector requires major transitions, including a substantial reduction in overall fossil fuel use, the deployment of low-emission energy sources, switching to alternative energy carriers, and energy efficiency and conservation. The contin… emissi…

C.5 Net-zero CO_2 emissions from the industrial sector are challenging but possible. Reducing industry emissions will entail coordinated action throughout value chains to promote all mitigation options, including demand management, energy and materials efficiency, circular … ction … the … and

C.6 Urban areas can create opportunities to increase resource efficiency and significantly reduce GHG emissions through the systemic transition of infrastructure and urban form through low-emission development pathways towards net-zero emissions. Ambitious mitigation efforts for established, rapidly growing and emerging cities will encompass 1) reducing or changing energy and material consumption, 2) electrification, and 3) enhancing carbon uptake and storage in the urban environment. Cities can achieve net-zero emissions, but only if emissions are reduced

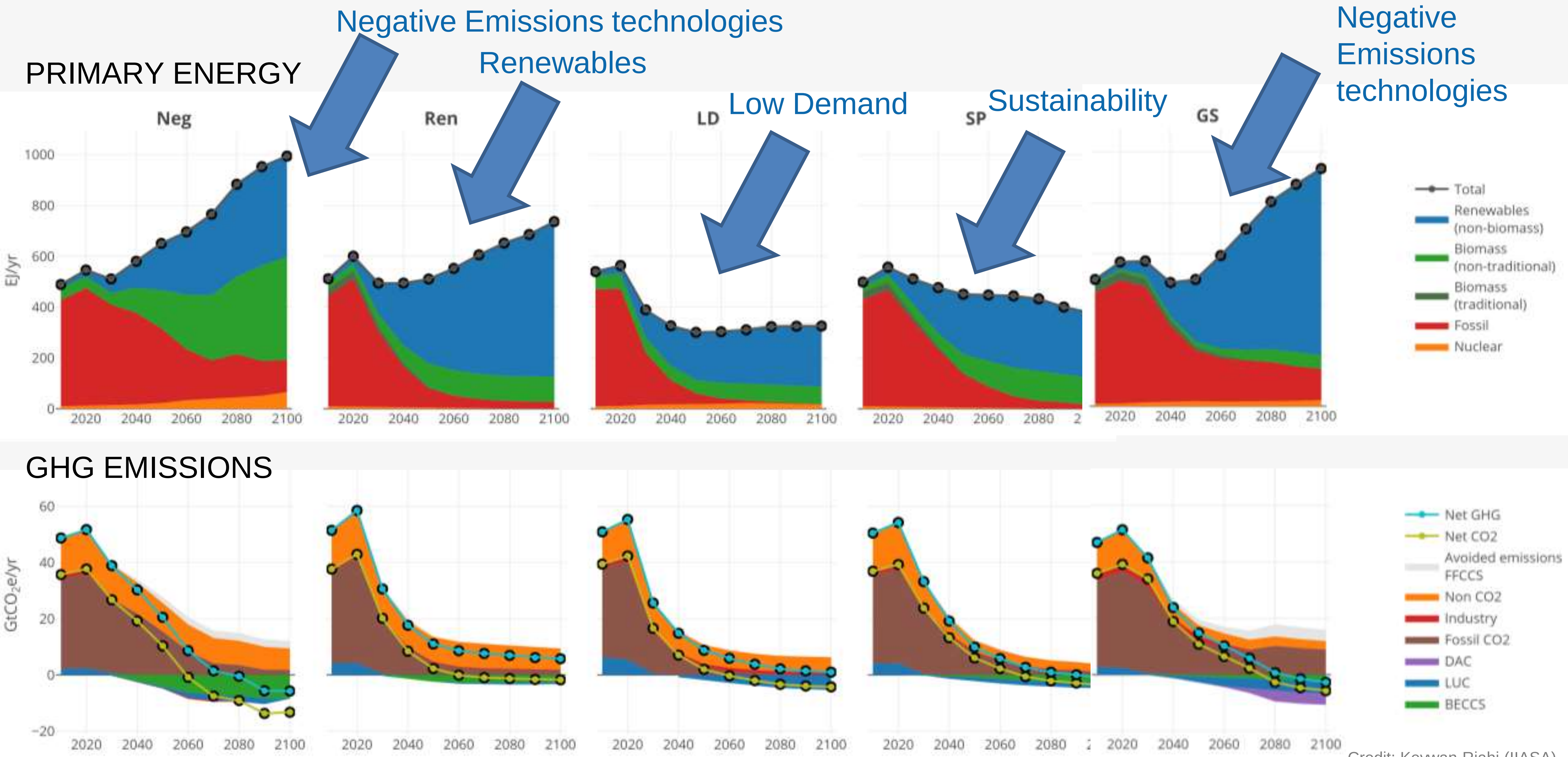
most regions. There are many sustainable options for demand management, materials efficiency, and circular material flows that can contribute to reduced emissions, but how these can be applied will vary across regions a… and wou… technolog… scenarios…

C.7. In modelled global scenarios, existing buildings, if retrofitted, and buildings yet to be built, are projected to approach net zero GHG emissions in 2050 if policy packages, which combine ambitious sufficiency, efficiency, and renewable energy measures, are effectively implemented and barriers to decarbonisation are removed. Low ambitious policies increase the

underestimated compared to bottom-up industry-specific models. (*high confidence*) {3.4, 5.3, Figure

Illustrative Mitigation Pathways (IMPs) =>

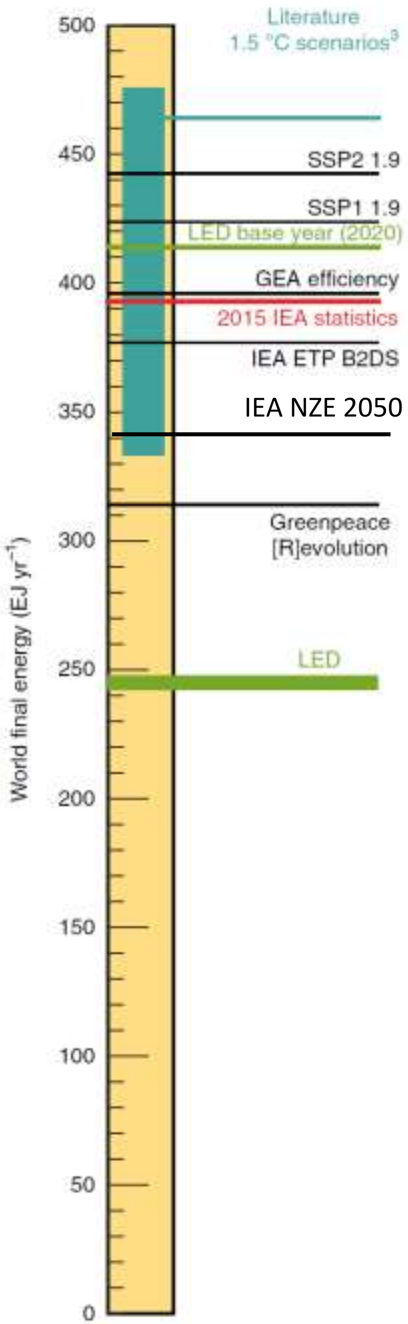
There are many ways to achieve net zero … with benefits and risks to each.

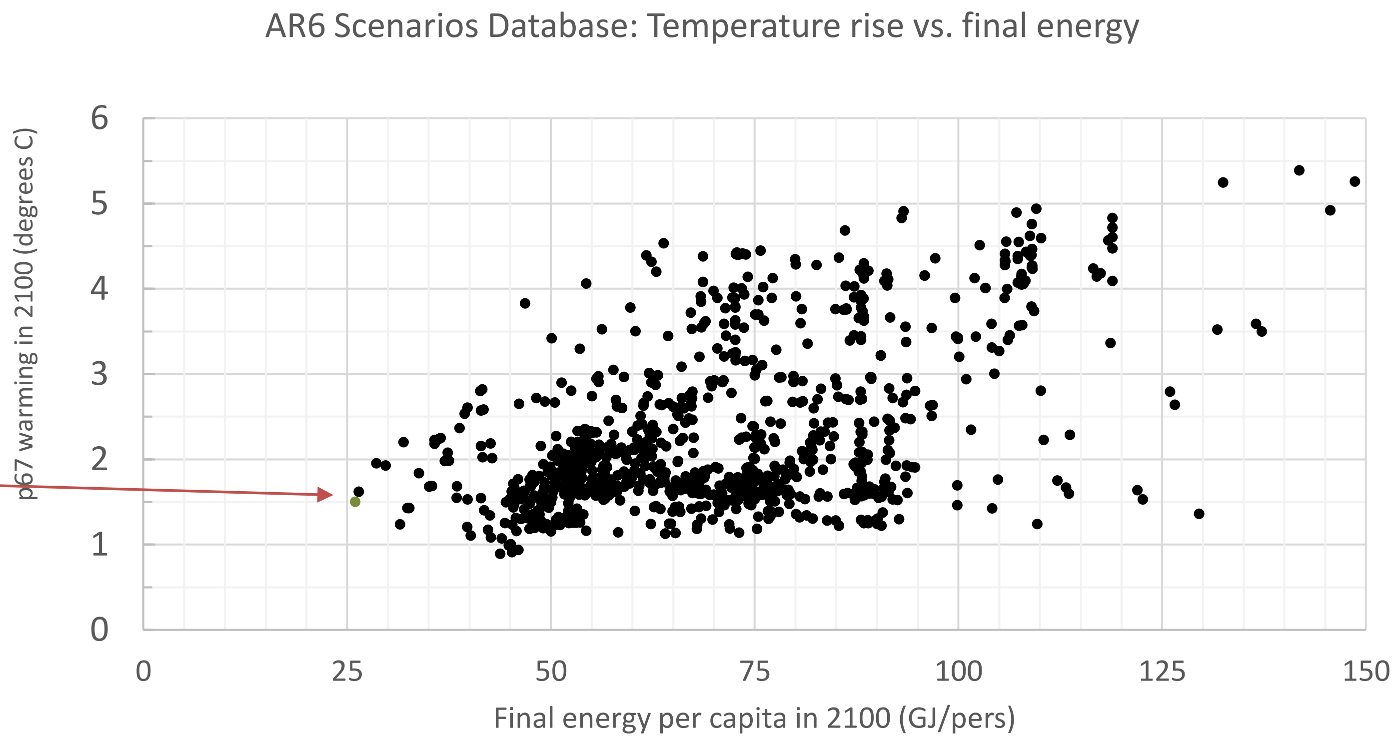


Credit: Keywan Riahi (IIASA)

Low-demand pathways: a key blind spot in decarbonization scenarios

Final energy demand in selected decarbonization scenarios





To better inform low demand policies, better datasets, models, and scenarios are needed on behavioral, infrastructural, and technological changes that minimize energy and resource demand, particularly at urban scales

Source: Grubler et al. (2018); IEA (2020a, 2020b); IPCC AR6 Scenarios Database

Granular technologies and decentralised energy end-use, characterised by modularity, small unit sizes and small unit costs, diffuse faster into markets and are associated with faster technological learning benefits, greater efficiency, more opportunities to escape technological lock-in, and greater employment

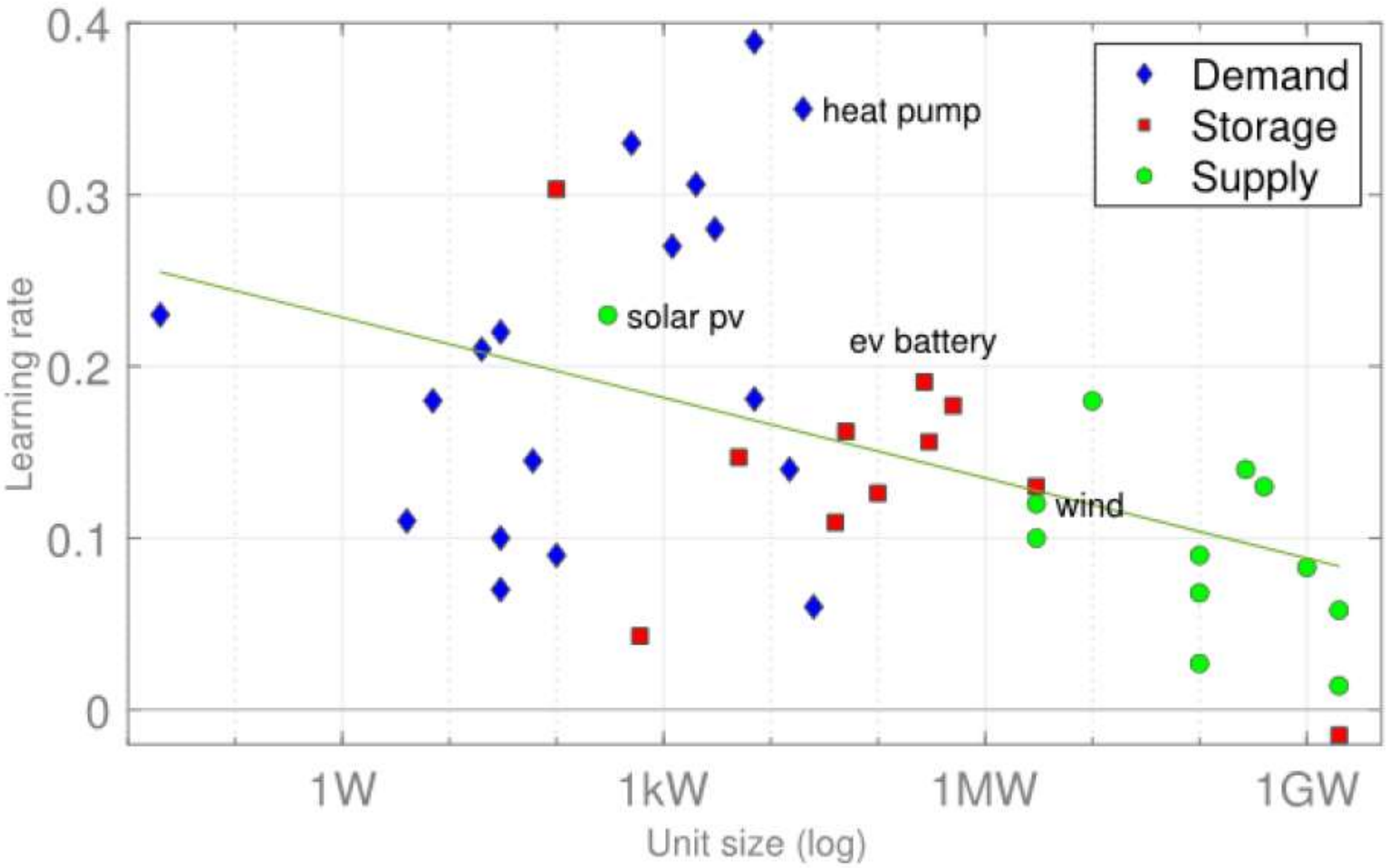
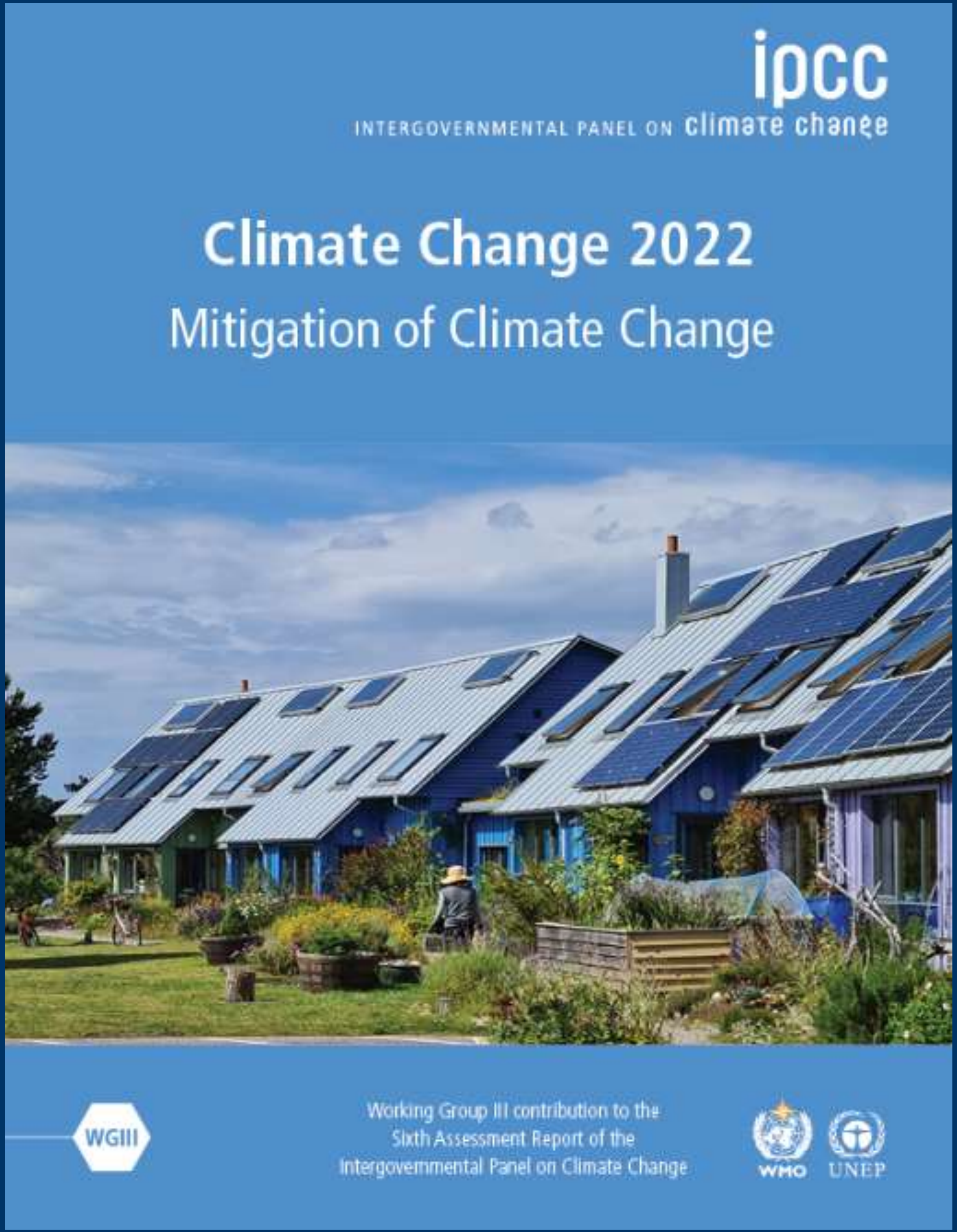


Figure 5.15 Demand technologies show high learning rates. Learning from small-scale granular technologies outperforms learning in larger supply side technologies. Line is linear fit of log unit size to learning rate for all 41 technologies plotted.



[Matt Bridgestock, Director and Architect at John Gilbert Architects]

Demand is especially important in developed countries

In developed countries, most technological, social, business (model) innovations are needed for **rethinking** and **restructuring** existing urban space, **repurposing**, **retrofitting** and **reusing existing** infrastructure, vehicle stocks and equipment rather having to build/produce new

Demand and services

- potential to **bring down** global **emissions** by **40-70%** by 2050
- walking and cycling, electrified transport, reducing air travel, and adapting houses make large contributions
- **lifestyle changes** require **systemic changes** across all of society
- **some** people require additional **housing**, **energy** and **resources** for human wellbeing

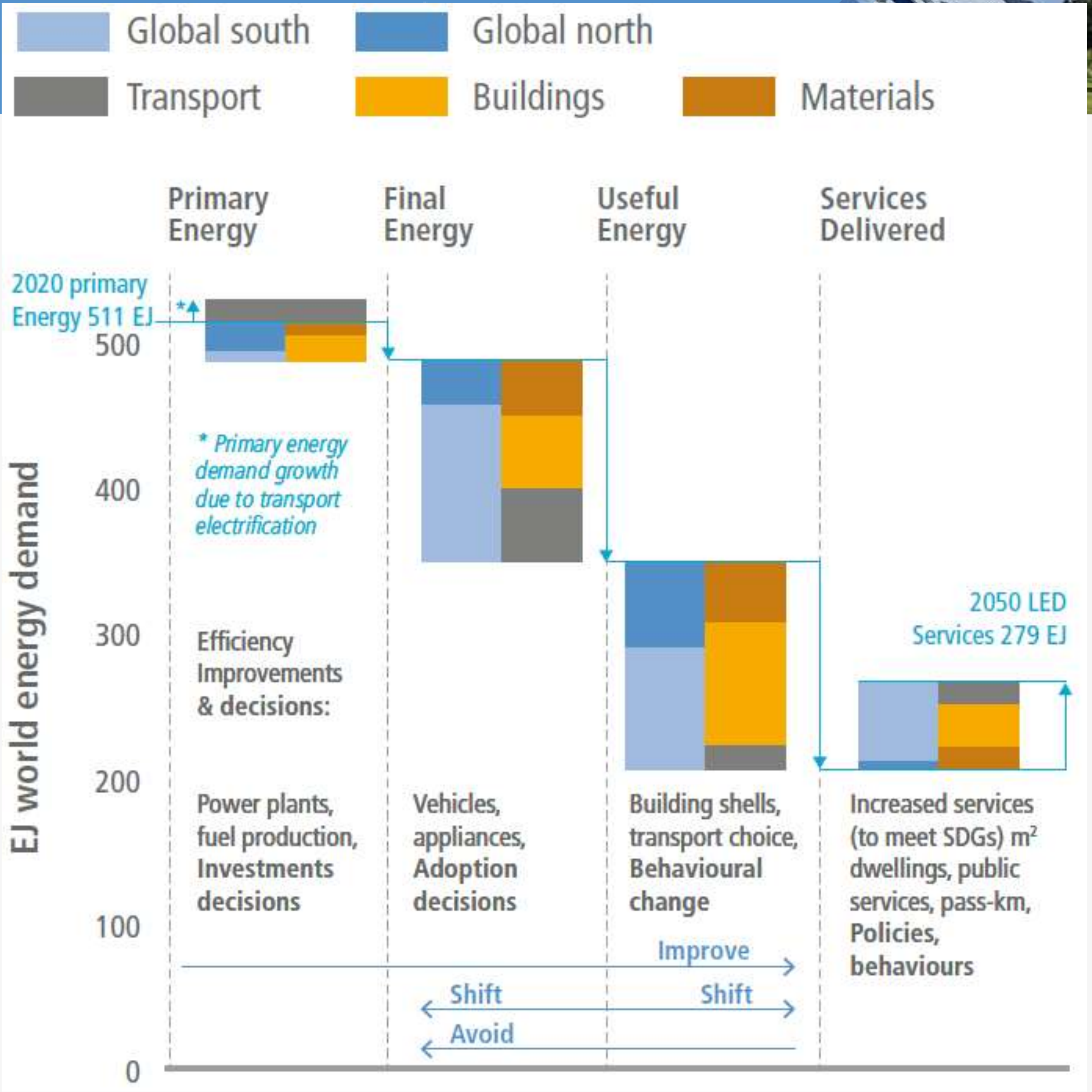
[Bosch, Unsplash/Yoav Aziz, Adam Bartoszewicz, Victor Hernandez]

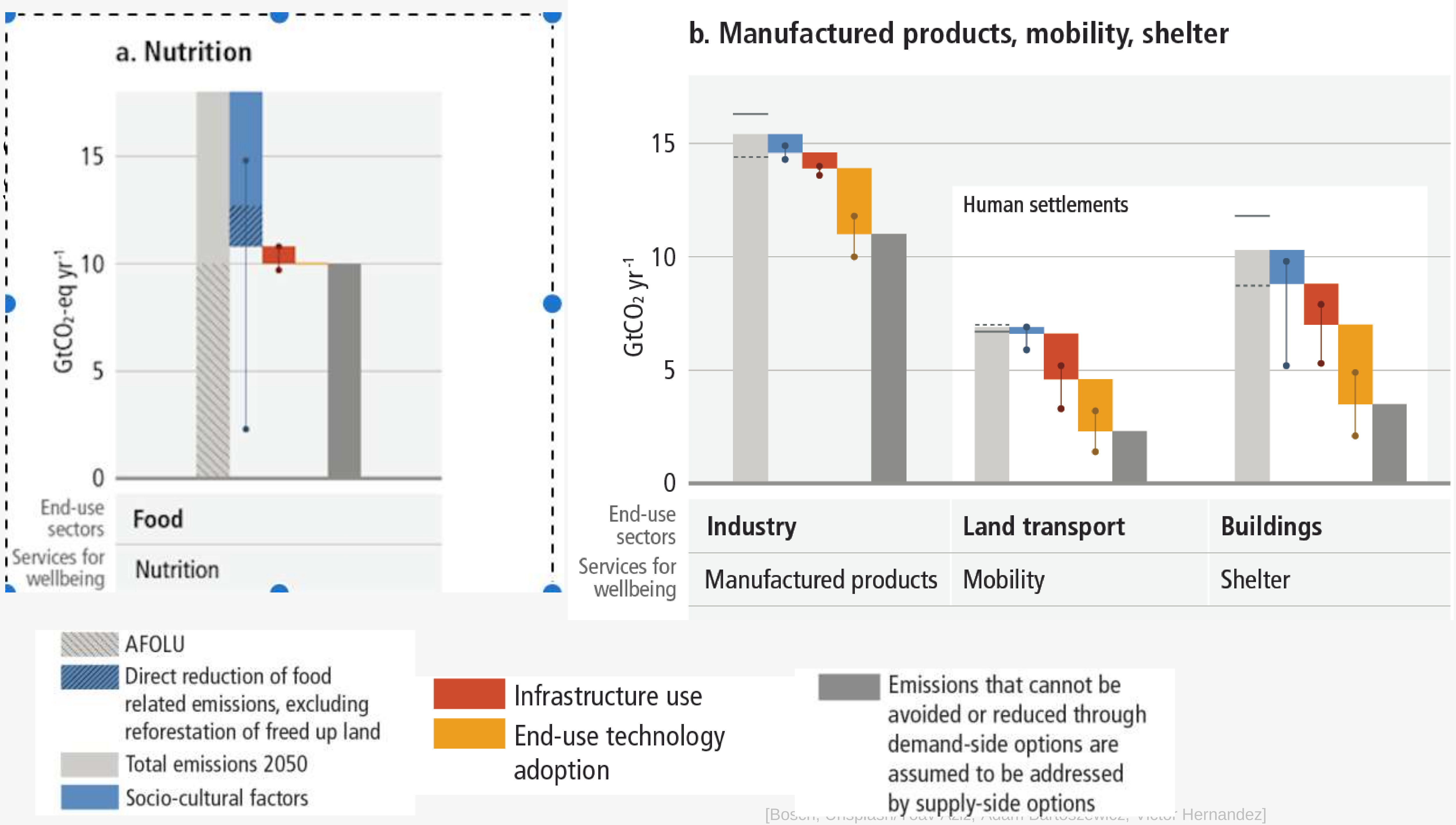
Demand and services

more efficient end-use energy conversion can improve services while reducing the need for upstream energy by 45% by 2050 compared to 2020

Demand-side mitigation encompasses changes in infrastructure, end-use technology adoption, service provision, and socio-cultural and behavioural change.

Lowest quartile of population **require additional** housing, nutrition, energy and resources for human wellbeing




a. Nutrition
15
10
5
0
GtCO2-eq yr-1
End-use sectors
Food
Services for wellbeing
Nutrition
b. Manufactured products, mobility, shelter
Human settlements
GtCO2 yr-1
Industry
Land transport
Buildings
Manufactured products
Mobility
Shelter
AFOLU
Direct reduction of food related emissions, excluding reforestation of freed up land
Total emissions 2050
Socio-cultural factors
Infrastructure use
End-use technology adoption
Emissions that cannot be avoided or reduced through demand-side options are assumed to be addressed by supply-side options

End-use sectors	Food	Industry	Aviation	Shipping	Land transport	Buildings	Electricity
Services for well-being	Nutrition	Manufactured products	Mobility			Shelter	
	Socio-cultural factors	Socio-cultural factors					Additional electrification (+60%)
	Dietary shift (shifting to balanced, sustainable healthy diets), avoidance of food waste and over-consumption	Shift in demand towards sustainable consumption, such as intensive use of longer-lived repairable products	Avoid long-haul flights; shift to trains wherever possible	Currently not applicable	Teleworking or telecommuting; active mobility through walking and cycling	Social practices resulting in energy saving; lifestyle and behavioural changes	Additional emissions from increased electricity generation to enable the end-use sectors' substitution of electricity for fossil fuels, e.g. via heat pumps and electric cars {Table SM5.3; 6.6}
	Infrastructure use	Infrastructure use					
	Choice architecture[1] and information to guide dietary choices; financial incentives; waste management; recycling infrastructure	Networks established for recycling, repurposing, remanufacturing and reuse of metals, plastics and glass; labelling low-emissions materials and products	Currently not applicable	Currently not applicable	Public transport; shared mobility; compact cities; spatial planning	Compact cities; rationalisation of living floor space; architectural design; urban planning (e.g., green roof, cool roof, urban green spaces etc.)	Industry Land transport Buildings Load management[2] **Demand-side measures −73%**
	End-use technology adoption	End-use technology adoption					
	Currently estimates are not available (for lab-based meat and similar options – no quantitative literature available, overall potential considered in socio-cultural factors)	Green procurement to access material-efficient products and services; access to energy-efficient and CO_2 neutral materials	Adoption of energy-efficient technologies; technologies with improved aerodynamics	Adoption of energy-efficient technology/ systems	Electric vehicles; shift to more efficient vehicles	Energy-efficient building envelopes and appliances; shift to renewables	Reduced emissions through demand-side mitigation options (in end-use sectors: buildings, industry and land transport) which has potential to reduce electricity demand[3]

The role of individuals 1

- Individual behavioural change is insufficient for climate change mitigation unless embedded in structural and cultural change and facilitated by right infrastructures and service provisioning systems
- **Wealthy individuals contribute disproportionately to higher emissions and have a high potential for emissions reductions**
- Individuals with high socio-economic status are capable of reducing their GHG emissions by becoming **role models** of low-carbon lifestyles, investing in low-carbon businesses, and advocating for stringent climate policies.
- Behavioural interventions, including information provision, education, **choice architectures** and nudges, work synergistically with price signals, making the combinations more effective
- Green **defaults**, such as automatic enrolment in ‘green energy’ provision, are highly effective.

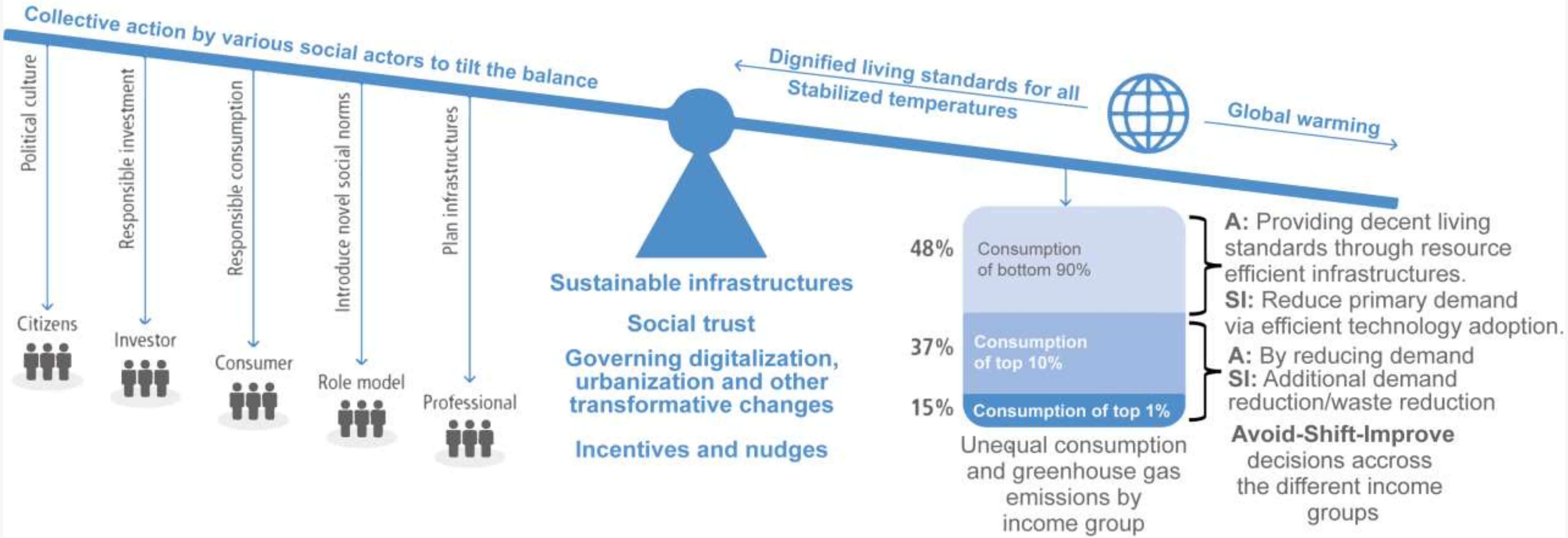
The role of individuals 2

- **Cultural change,** in combination with infrastructure, is necessary to enable and realise behavioural change
- Individuals contribute to climate change mitigation in their diverse capacities as **consumers, citizens, professionals, role models, investors, and policymakers**
- **Social influencers** and **thought leaders** can increase the adoption of low-carbon technologies, behaviours, and lifestyles
- Transition pathways and changes in social norms often start with pilot experiments led by **dedicated individuals** and **niche groups** (eg youth climate strikes)

Individuals are important, but people alone cannot bring in change: need infrastructure, technology access, incentives, equity

Demand side mitigation is about more than behavioural change. Reconfiguring the way services are provided while simultaneously changing social norms and preferences will help reduce emissions and access. Transformation happens through societal, technological and institutional changes.

Tilting the balance towards less resource intensive service provisioning



The role of corporations

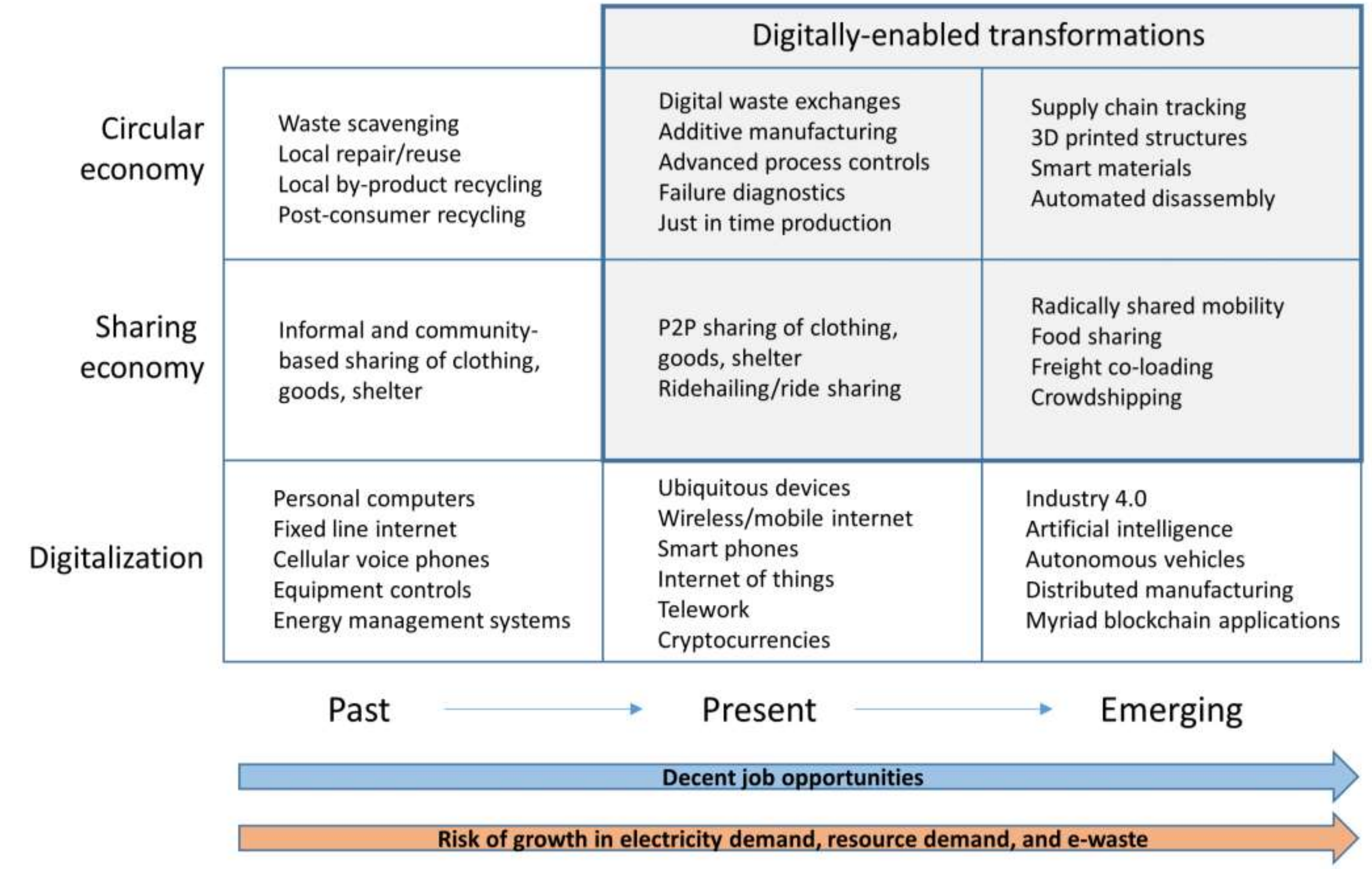
- **The current effects of climate change, as well as some mitigation strategies, are threatening the viability of existing business practices, while some corporate efforts also delay mitigation action**
- A good number of corporate agents have attempted to derail climate change mitigation by **targeted lobbying** and **doubt-inducing media strategies**
- Corporate advertisement and brand-building strategies may also attempt to deflect corporate responsibility to individuals or aim to appropriate climate-care sentiments in their own brand–building
- Corporate advertisement and brand building strategies also attempt to deflect corporate responsibility to individuals, and/or to appropriate climate care sentiments in their own brand building; climate change mitigation is uniquely framed through choice of products and consumption, avoiding the notion of corporate responsibility

The role of corporations

- Businesses and corporate organisations play a key role in mitigation through their own commitments to zero-carbon footprints, decisions to invest in researching and implementing new energy technologies and energy efficient measures, and the supply side interaction with changing consumer preferences and behaviours, e.g. via marketing.
- Business models and strategies work both as a barrier to and as accelerator of decarbonisation
- **strong sustainability business models** (SSBM) are characterised by identifying nature as the primary stakeholder, strong local anchorage, the creation of diversified income sources, and deliberate limitations on economic growth. However, SSBM are difficult to maintain if generally traditional business models prevail, requiring short-term accounting
- Companies, businesses and organisations might face liability claims for their contribution to climate change especially in the carbon intensive energy sector

Service provisioning, sharing economy, digitalization, circular economy

- **Alternative service provision systems, for example, those enabled through digitalisation, sharing economy initiatives and circular economy initiatives, have to date made a limited contribution to climate change mitigation**
- While digitalisation through specific new products and applications holds potential for improvement in service-level efficiencies, without public policies and regulations, it also has the potential to increase consumption and energy use.
- Claims on the benefits of the circular economy for sustainability and climate change mitigation have limited evidence

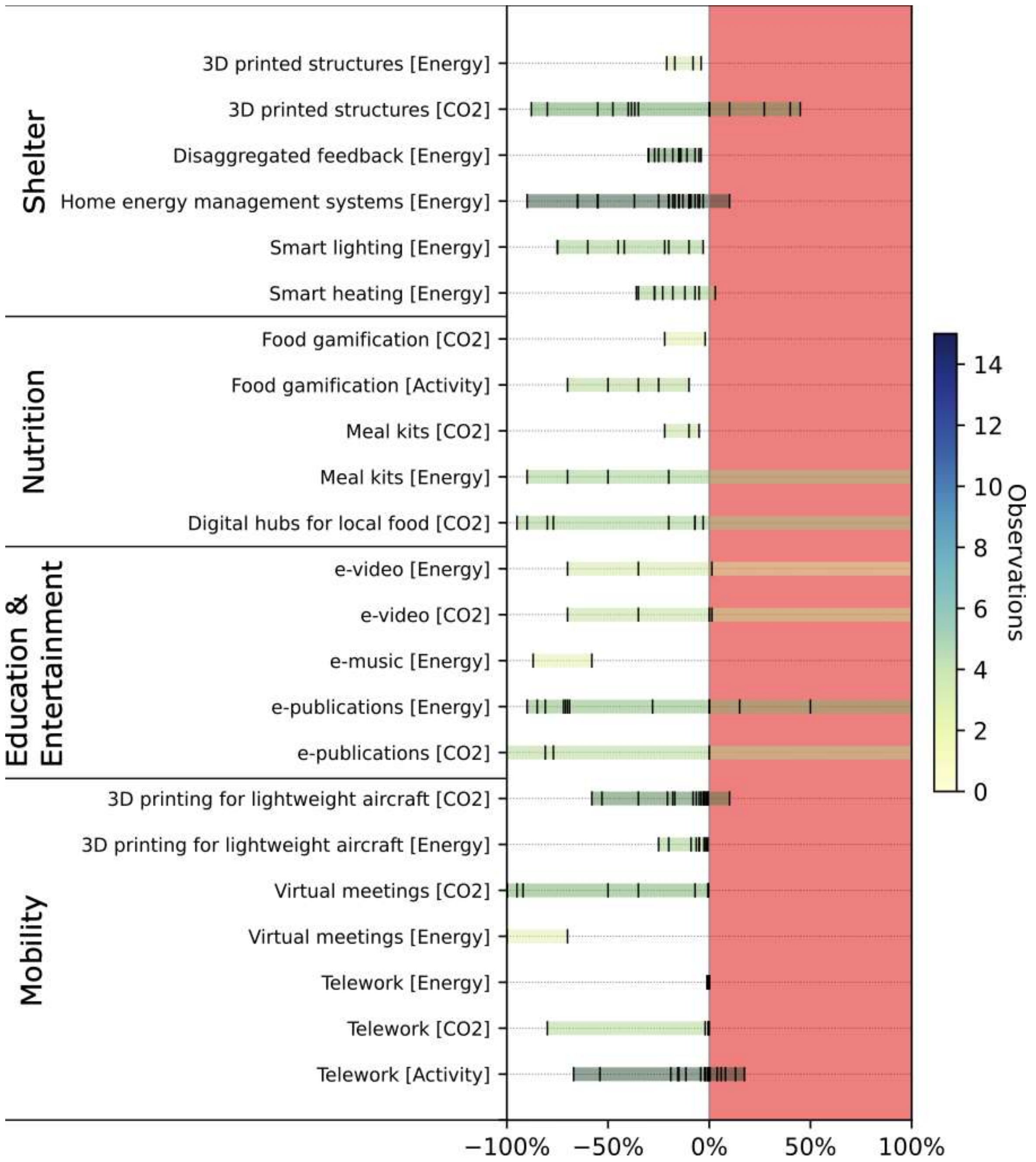


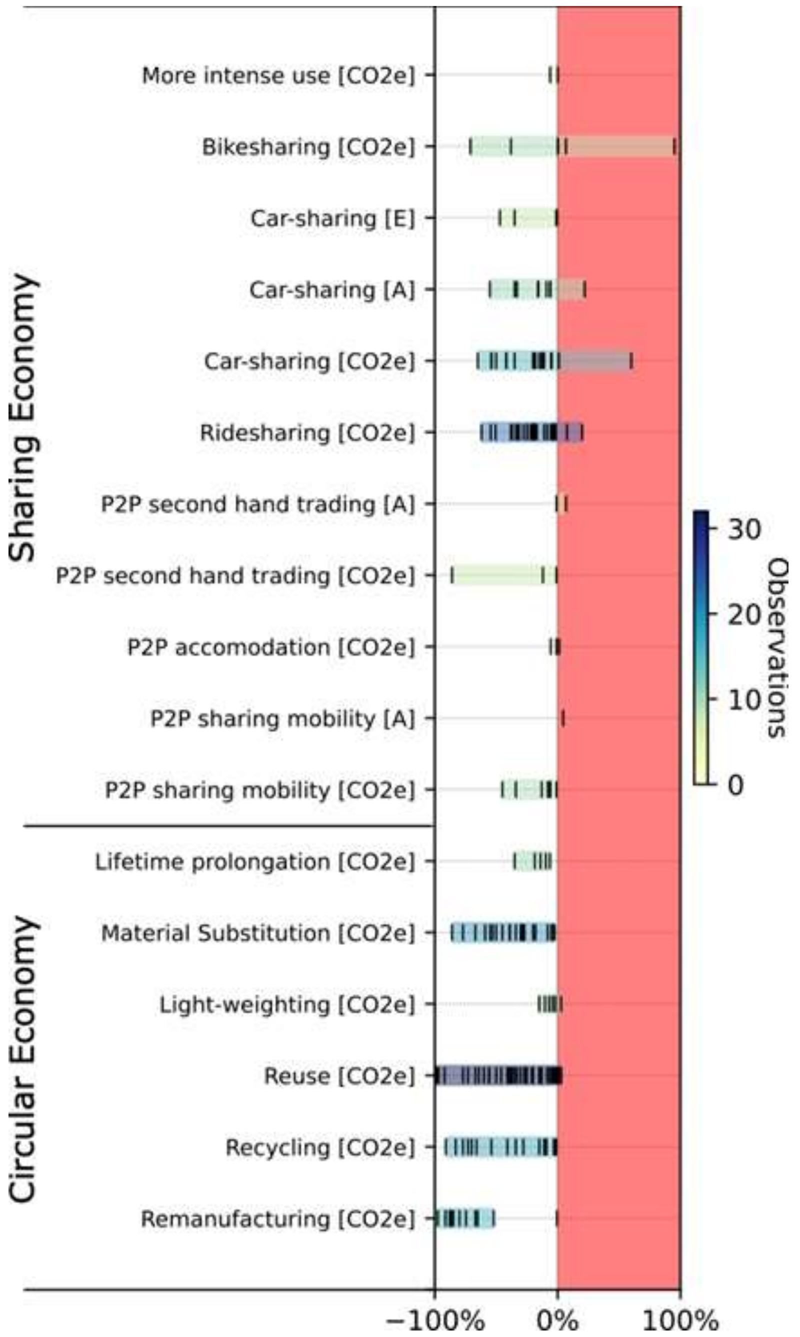
The growing nexus between digitalisation, the sharing economy, and the circular economy in service delivery systems.
Widespread digitalisation may lead to net increases in electricity use, demand for electronics manufacturing resources, and e-waste, all of which must be monitored and managed via targeted policies

Digitalisation

- Offers both opportunities and risks for emissions
- Digital platforms allow surplus resources to be identified, offered , shared, transacted and exchanged
- Real-time information flows on consumers' preferences and needs mean service provision can be personalised, differentiated, automated, and optimised
- Rapid innovation cycles and software upgrades drive continual improvements in performance and responsiveness to consumer behaviour
- The sustainability implications of digitalised services hinge on:
  - (1) the direct energy demands of connected devices and the digital infrastructures (i.e. data centres and communication networks) that provide necessary computing, storage, and communication services
  - (2) the systems-level energy and resource efficiencies that may be gained and energy and material demand that can be avoided through the provision of digital services
  - (3) the resource, material, and waste management requirements of the billions of ICT devices that comprise the world's digital systems
  - (4) the magnitude of potential rebound effects or induced energy demands that might unleash unintended and unsustainable demand growth, such as autonomous vehicles inducing more frequent and longer journeys due to reduced travel costs

Digitalization and sharing … help or hindrance?





Source: IPCC AR6 WGIII Chapter 5 https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter_05.pdf

Digitalisation 2

- quantitative estimates vary widely, with literature values suggesting that consumer devices, data centres, and data networks account for anywhere from **6% to 12% of global electricity use**
- there is growing concern that remaining energy efficiency improvements might be outpaced by rising demand for digital services, particularly as data-intensive technologies such as artificial intelligence, smart and connected energy systems, distributed manufacturing systems, and autonomous vehicles promise to increase demand for data services even further in the future
- net systems-level energy and resource efficiencies gained through the provision of digital services could play an important role in dealing with climate change and other environmental challenges
- evidence of potential negative outcomes due to rebound effects, induced demand, or life-cycle trade-offs can also be observed

Digitalisation 3

- automated vehicles reduce the costs of time, parking, and personnel, and therefore may dramatically increase vehicle mileage
- The energy requirements of cryptocurrencies is also a growing concern, although much uncertainty
- Initial estimates of the computational intensity of **artificial intelligence** algorithms suggest that energy requirements may be **enormous without concerted effort to improve efficiencies**
- **the net effects of digitalization is yet unknown, but there is *medium evidence* that digitalised consumer services can reduce overall emissions, energy use, and activity levels, but induced demand and rebound effects must be managed carefully to avoid negative outcomes**

Digitalisation 4: maximizing its mitigation potential

- Maximising the mitigation potential of digitalisation trends involves diligent monitoring and proactive management of both direct and indirect demand effects,
- Direct energy demand can be managed through continued improvements in the **energy efficiency of** data centres, networks, and end-use devices
- Shifts to low-carbon power are a particularly important strategy for data centres and networks where **data demands outpace hardware efficiency gains**, which **may be approaching limits in the near future**
- Most recently, data centres are being investigated as a potential resource for **demand response** and **load balancing** in renewable power grids, while a large bandwidth for improving **software efficiency** has been suggested for overcoming slowing hardware efficiency
- Ensuring efficiency benefits of digital services while avoiding potential rebound effects and will require **early and proactive public policies**

Circular economy

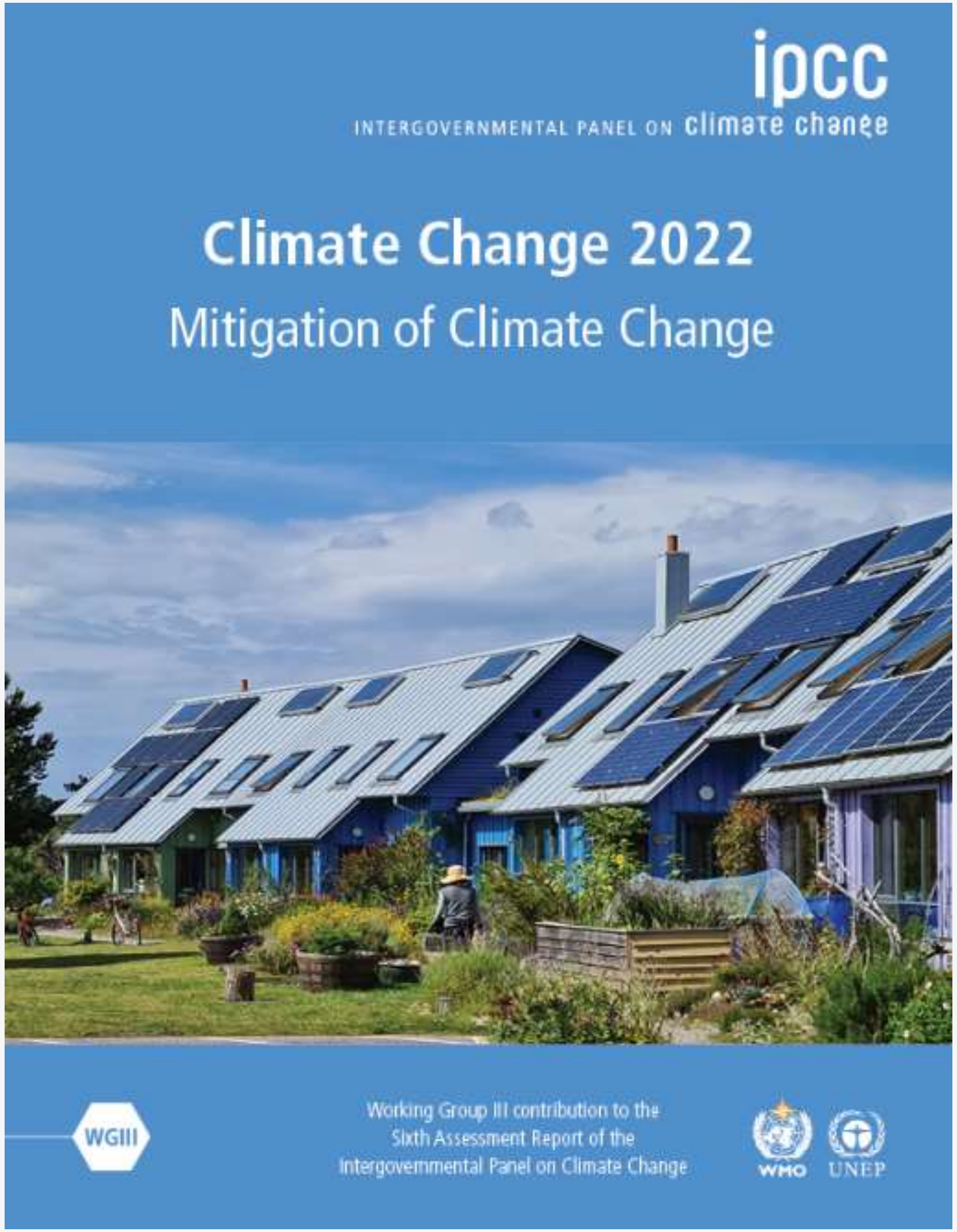
- Many publications, many of them non peer reviewed, eulogize the perceived benefits of the CE, but stop short of providing a quantitative assessment. Promotion of CE from this perspective has been criticised as a greenwashing attempt by industry
- **Most of the methodologically rigorous publications found only small potentials to reduce GHG emissions**

3 concerns related to the circular economy in the mitigation context

1. many proposals on CE insufficiently reflect on thermodynamic constraints that limit the potential of recycling from both mass conservation and material quality perspectives or ignore the considerable amount of energy needed so reuse materials
2. demand for materials and resources will outpace efficiency gains in supply chains, becoming a key driver of GHG emissions, rendering the CE alone an insufficient strategy to reduce emissions
    1. As long as long-lived material stocks (e.g., in buildings and infrastructure) continue to grow, strategies targeting end-of-pipe materials cannot keep pace with primary materials demand
    2. only 6.5% of all processed materials (4 Gt yr-1) globally originate from recycled sources
    3. Instead, a significant reduction of societal stock growth, and decisive eco-design is suggested to advance the CE
3. Third, cost-effectiveness underlying CE activities may 12 concurrently also increase energy intensity

Legend
- High positive impact [+3]
- Medium positive impact [+2]
- Low positive impact [+1]
- Overall Neutral
- No impact
- Low negative impact [-1]
- Medium negative impact [-2]
- ★ Confidence level

Sectors	Mitigation strategies / Wellbeing dimensions	Food	Water	Air	Health	Sanitation	Energy	Shelter	Mobility	Education	Communication	Social protection	Participation	Personal Security	Social cohesion	Political stability	Economic stability	Material provision	Supply side / incumbents
	SDGs	2	6	7,11	3	6	7	11	11	4		1,2,8,10	5,10,16	5,16	10,16	11,16	8	9,12	8,12
Building	Sufficiency	[+1] ★★★	[+2] ★★★★	[+2] ★★★★★	[+3] ★★★★★	[+1] ★	[+3] ★★★★	[+1] ★	[+1] ★★	[+1] ★★	[+2] ★★★	[+1] ★★	[+1] ★★		[+2] ★★★★★		[+2] ★★★★	[+2] ★★★★	[-2] ★★★
Building	Efficiency	[+2] ★	[+2] ★★★★	[+3/-1] ★★★★	[+3/-1] ★★★★★	[+1] ★	[+3] ★★★★	[+2] ★★★★		[+1] ★★★	[+1] ★★★		[+1] ★★★★	[+1] ★★★	[+2/-1] ★★★★		[+2] ★★★★★	[+2/-1] ★★★★	[+2/-2] ★★★
Building	Lower carbon and renewable energy	[+2/-1] ★★★	[+2/-1] ★★★★	[+3] ★★★★★	[+3] ★★★★★		[+3] ★★★★	[+1] ★★★	[+1] ★★★	[+1] ★★★	[+2] ★★★		[+1] ★★★	[+1] ★★★	[+2/-1] ★★★★		[+2/-1] ★★★★★	[+2] ★★★★	[+2/-2] ★★★
Food	Food waste	[+1] ★★★	[+2] ★★★★	[+2] ★★★★	[+2] ★★★	[+1] ★★	[+1] ★★★★				[+1] ★★	[-1/+1] ★★★	[+1] ★★★			[+1] ★	[+1] ★★		[-1] ★★★
Food	Over-consumption	[+1] ★	[+1/-1] ★	[+1/-1] ★	[+3] ★★★★		[+1/-1] ★						[+2] ★★★★			[+1] ★			[+1/-2] ★
Food	Animal free protein	[+2] ★★★	[+2] ★★★★	[+3] ★★★★★	[+3] ★★★						[-1] ★★★	[+3] ★★★★★	[+1] ★★★★		[-1] ★	[+2] ★			[-1] ★★★
Transport	Teleworking and online education system	[+1] ★★		[+3] ★★★★	[+2] ★★★★		[+2] ★★★★	[+1] ★★	[+2] ★★★★	[-1] ★★★	[+2] ★★★★	[+1] ★★★★	[+2] ★★★★	[+1/-1] ★★★★	[+2] ★★★★	[+2] ★★★	[+2] ★★★		[+1] ★★★★
Transport	Non-motorized transport	[+2] ★★	[+1] ★★	[+1] ★★★★★	[+3] ★★★★★		[+2] ★★★★		[+3] ★★★★★	[+1] ★★★★	[+3] ★★★	[+1] ★★★	[+1] ★★	[+2] ★★★★	[+2] ★★★	[+2] ★★	[+2] ★★★		[+1] ★★★
Transport	Shared mobility	[+1] ★★		[+3] ★★★	[+2] ★★★★		[+1] ★★★		[+2] ★★★★		[+1] ★★★	[+2] ★★★	[+1] ★★★	[+1/-1] ★★★	[+1/-1] ★★★★	[-1] ★★★★	[+2] ★★★★	[+2] ★★★★	[-1] ★★
Transport	Evs	[+1] ★★★		[+2] ★★★★	[+1] ★★★★	[+1] ★★★★	[+3 ★★★★		[+2] ★★★★			[+3] ★★★★★	[+2] ★★★				[+2] ★★★★	[-1] ★★	[+1] ★★★
Urabn	Compact city	[+2/-1] ★★★	[+1] ★★	[+2/-1] ★★★	[+3/-1] ★★★★	[+1] ★★	[+3/-1] ★★★★★	[-1] ★★★★★	[+3] ★★★★★	[+1] ★★★★★	[+1/-1] ★★★	[+2] ★★	[+1] ★★	[+1] ★★★★	[+1/-1] ★★★★★		[+1] ★★★★	[+1] ★★	[+1/-2] ★★★
Urabn	Circular and shared economy	[+2] ★★★★	[+1] ★★★	[+2] ★★★	[+2] ★★★		[+3] ★★★	[+2/-1] ★★★	[+3] ★★★★★	[+1] ★★★★	[+1] ★★★★	[+1] ★★★	[+1] ★★★	[+2] ★★★★	[+1] ★★	[+1] ★★	[+2] ★★	[+3] ★★★	[-1] ★★★★
Urabn	Systems approach in urban policy and practice	[+1] ★★★	[+2] ★★★	[+2] ★★★	[+3] ★★★	[+1] ★★★	[+3] ★★★	[+2] ★★★	[+3] ★★★		[+1] ★★	[-1] ★★	[+1] ★★★	[+2] ★	[+1] ★★		[+1] ★★	[+3] ★★★★★	[+2/-2] ★★
Urabn	Nature based solutions	[+2] ★★★	[+1/-1] ★★★★★	[+3/-1] ★★★★	[+3] ★★★★★	[+1] ★★★	[+3] ★★★	[+1/-1] ★★★	[+1] ★★★	[+2] ★★★★		[+2] ★★	[+3] ★★	[+1] ★★★	[+2/-2] ★★★		[+3] ★★★★	[+1] ★★	[+1] ★★
Industry	Using less material by design	[+2] ★★	[+2] ★★★	[+3] ★★★	[+2] ★★	[+2] ★★★	[+3] ★★★★	[+2] ★★★★	[+2] ★★★★	[+1] ★★	[+2] ★★★	[+1] ★★	[+1] ★★★	[+1] ★★	[+1] ★★	[+1] ★★	[+2] ★★★	[+3] ★★	[-2] ★★
Industry	Product life extension	[+2] ★★	[+2] ★★★	[+3] ★★★	[+2] ★★	[+2] ★★★	[+3] ★★★★	[+2] ★★★★	[+2] ★★★★	[+1] ★★	[+2] ★★★	[+1] ★★	[-1] ★★★★	[+1] ★★	[+1] ★★	[+1] ★★	[+2] ★★★	[+3] ★★	[-2] ★★
Industry	Energy Efficiency	[+2] ★★	[+2] ★★★	[+3] ★★★	[+1] ★★	[+2] ★★★	[+3] ★★★★	[+2] ★★★★	[+2] ★★★★	[+1] ★★	[+2] ★★★	[+2] ★★★★	[+2] ★★★	[+1] ★★		[+1] ★★	[+2] ★★★	[+2] ★★	[-2] ★★
Industry	Circular economy	[+2] ★★★	[+2] ★★★	[+3] ★★★	[+1] ★★	[+2] ★★★	[+3] ★★★★	[+2] ★★★★	[+2] ★★★★	[+1] ★★	[+2] ★★★	[+1] ★★	[+1] ★★★	[+2] ★★	[+1] ★★		[+2] ★★★	[+3] ★★	[-2] ★★



"the cleanest energy is the energy we never needed to produce"

Ürge-Vorsatz Diana

vorsatzd@ceu.edu

www.ipcc.ch

Twitter:

@DianaUrge

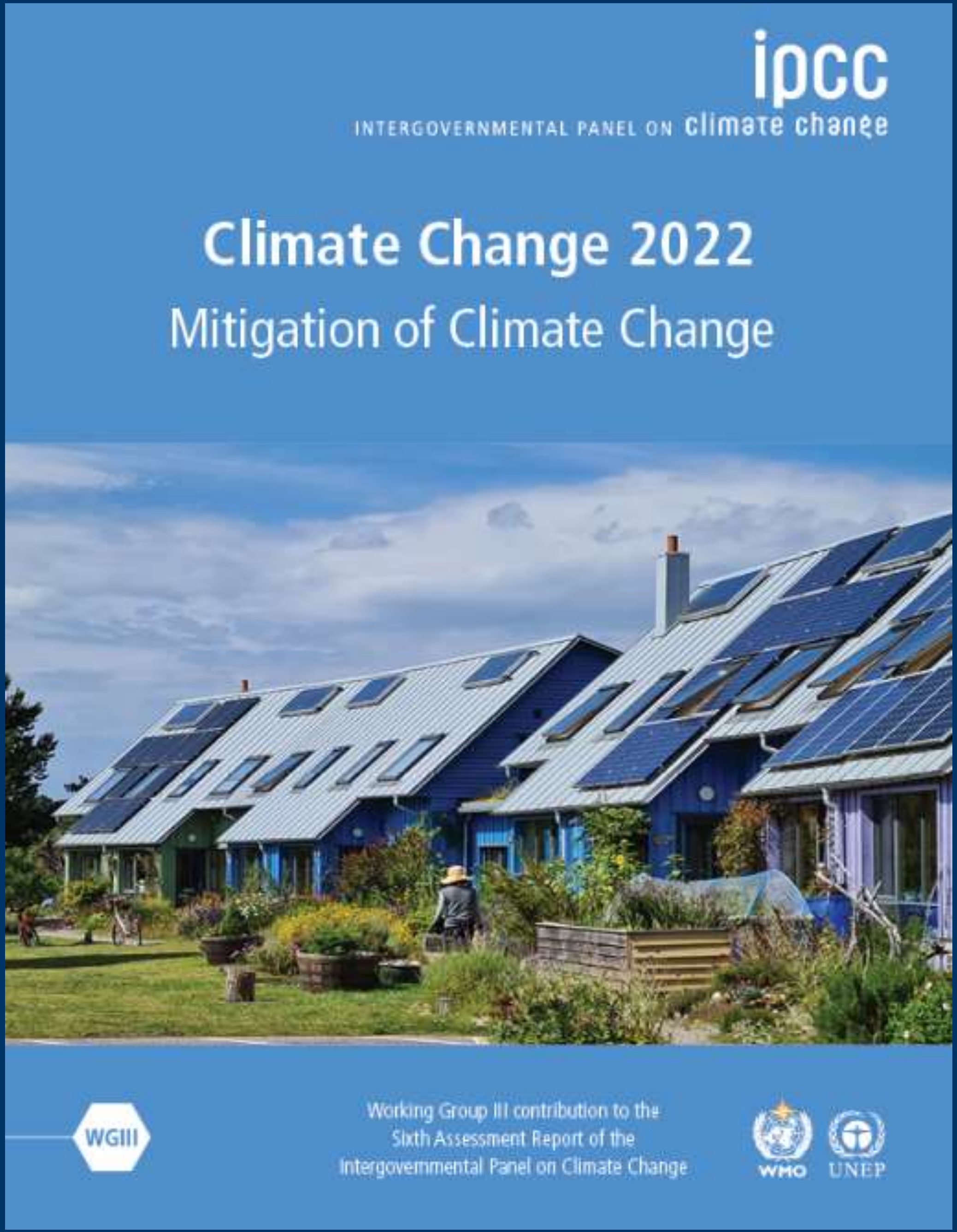
Instagram

dr_Diana_UrgeVorsatz

Diana Ürge-Vorsatz

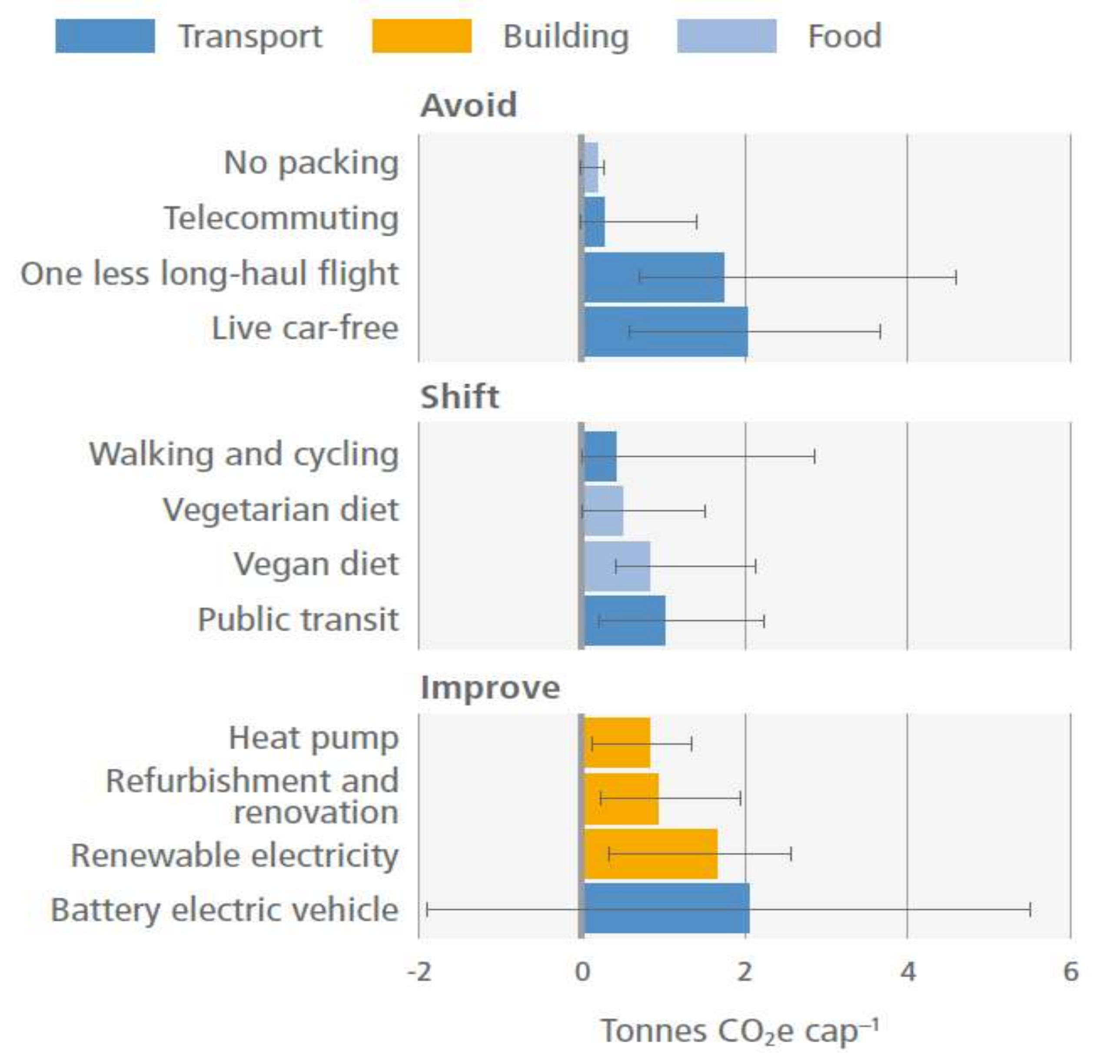
diana.urgevorsatz

Supplementary slides



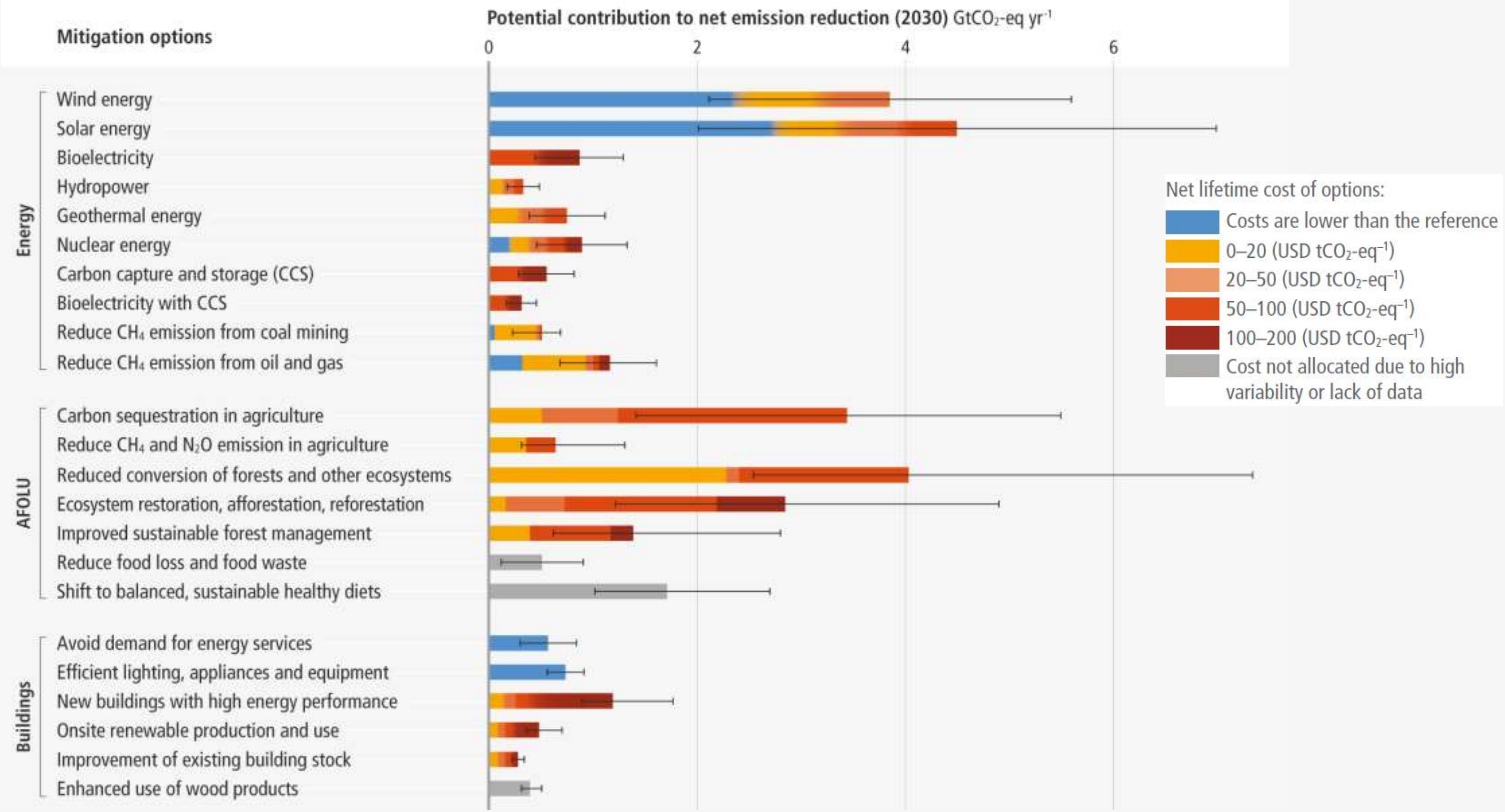
In developed country cities, most technological, social, business (model) innovations are needed for **rethinking** and **restructuring** existing urban space, **repurposing**, **retrofitting** and **reusing existing** infrastructure, vehicle stocks and equipment rather having to build/produce new

[Matt Bridgestock, Director and Architect at John Gilbert Architects]



The low-carbon lifestyle transition can be classified into Avoid, Shift, and Improve options

The total emission mitigation potential by 2030 is sufficient to reduce global greenhouse gas (GHG) emissions to half of the current level or less



Robust Insights Deriving from Low Demand Scenarios

1. Socio-cultural changes within transition pathways can offer Gigaton-scale CO_2 savings potential at the global level, and therefore represent a substantial overlooked strategy in traditional mitigation scenarios.
2. Deep demand reductions require parallel pursuit of behavioral change and advanced energy efficient technology deployment; neither is sufficient on its own.
3. Low demand scenarios can reduce both supply-side capacity additions and the need for carbon capture and removal technologies to reach emissions targets.
4. The costs of reaching mitigation targets may be lower when incorporating Avoid-Shift-Improve strategies for deep energy and resource demand reductions.
5. Achieving low demand requires combining innovations in several areas: technological, behavioral, institutional, and business model

Sources: IPCC WG III AR6 Ch. 5, and David Mc Collum

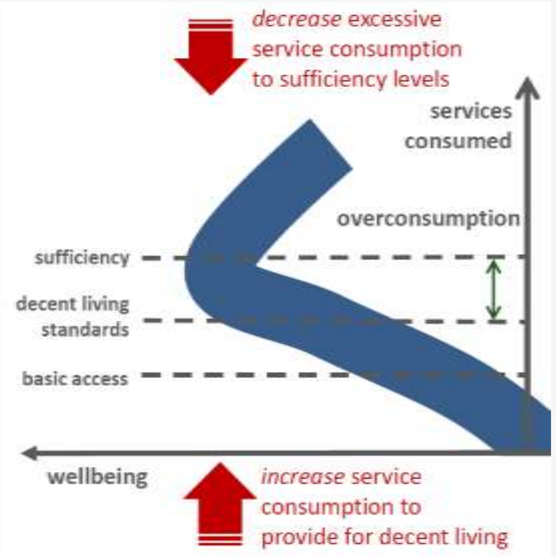
Low demand options for buildings

"Avoid"	"Shift"	"Improve"
Reduced dwelling size	Multi-family dwellings	Heat pumps
Building lifespan extension	Multi-use buildings	Efficient appliances
Materials-efficient designs	Shared services	LED lighting
Daylighting	Compact urban forms	Solar water heating
Temperature set points	…	Insulation and retrofits
Shading/orientation		Low carbon materials
…		…

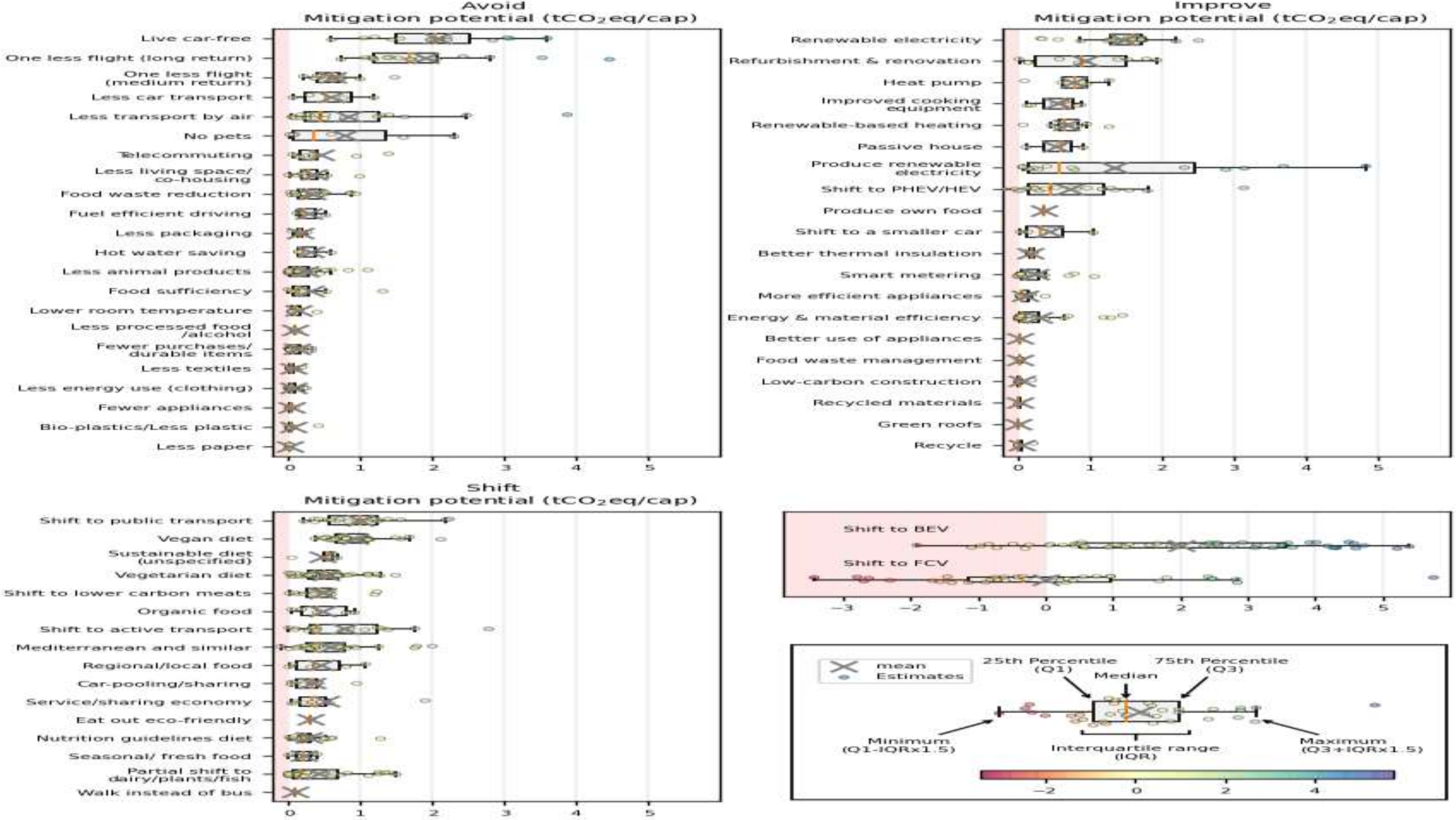
Source: IPCC AR6 WGIII Chapter 5
https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter_05.pdf

Characteristics of an Energy-Services Led Transformation

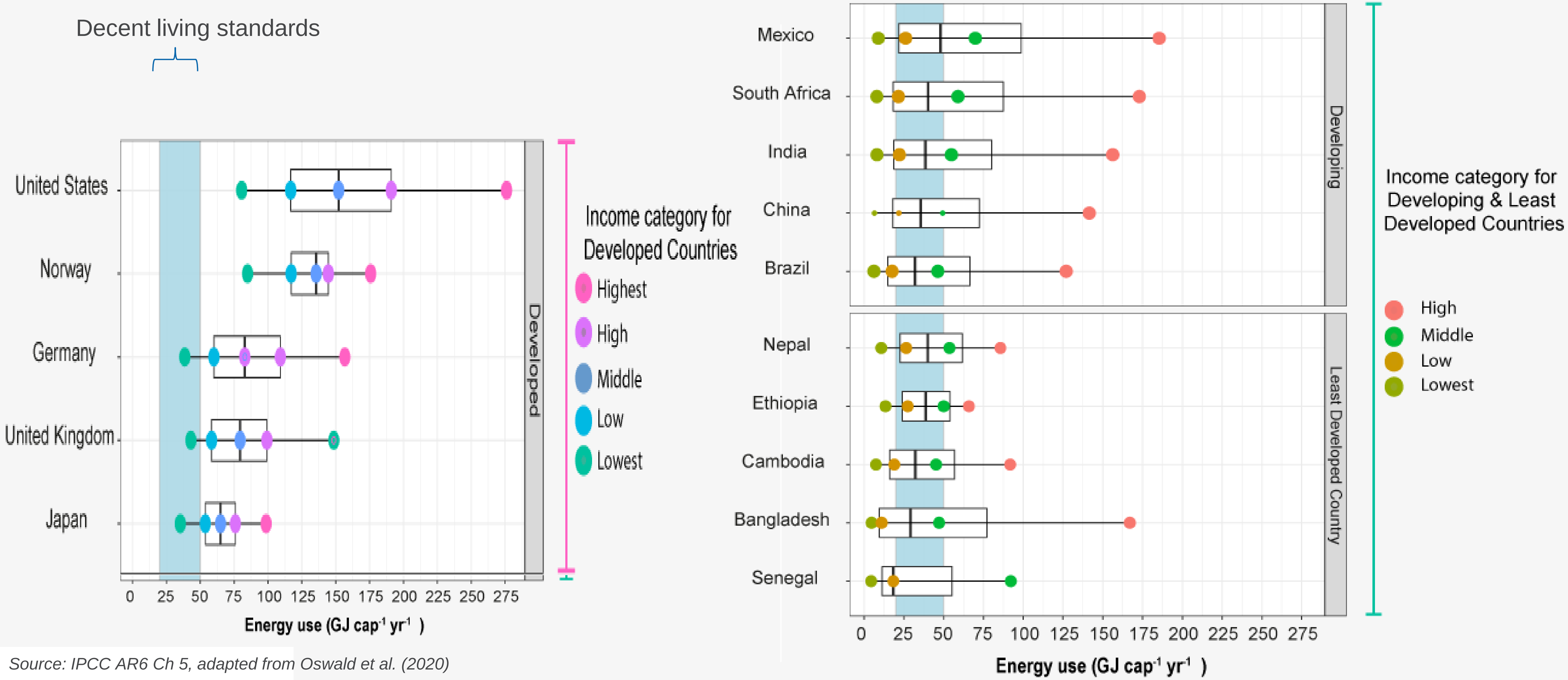
- Inclusive wellbeing = decent living standards for all (well above access and poverty thresholds)
- End-use transformations (efficiency, electrification) drive upstream decarbonization
- Low resource use (energy, materials, land, water, …)
- Significant SDG synergies = remain within planetary boundaries for climate, land-use, biodiversity, ...
- Key concept = *services* (i.e., amenities or functionalities like thermal comfort, mobility, or nutrition that constitute wellbeing)
  - focus on *outputs* and *outcomes*, instead of resource or economic *inputs*
- New Trends in Social and Technological Change
  - Changing consumer preferences (e.g., diets)
  - Generational change in materialism (access rather than ownership)
  - New business models (sharing & circular economy)
  - Pervasive digitalization and ICT convergence
  - Rapid innovation in granular technologies and integrated digital services



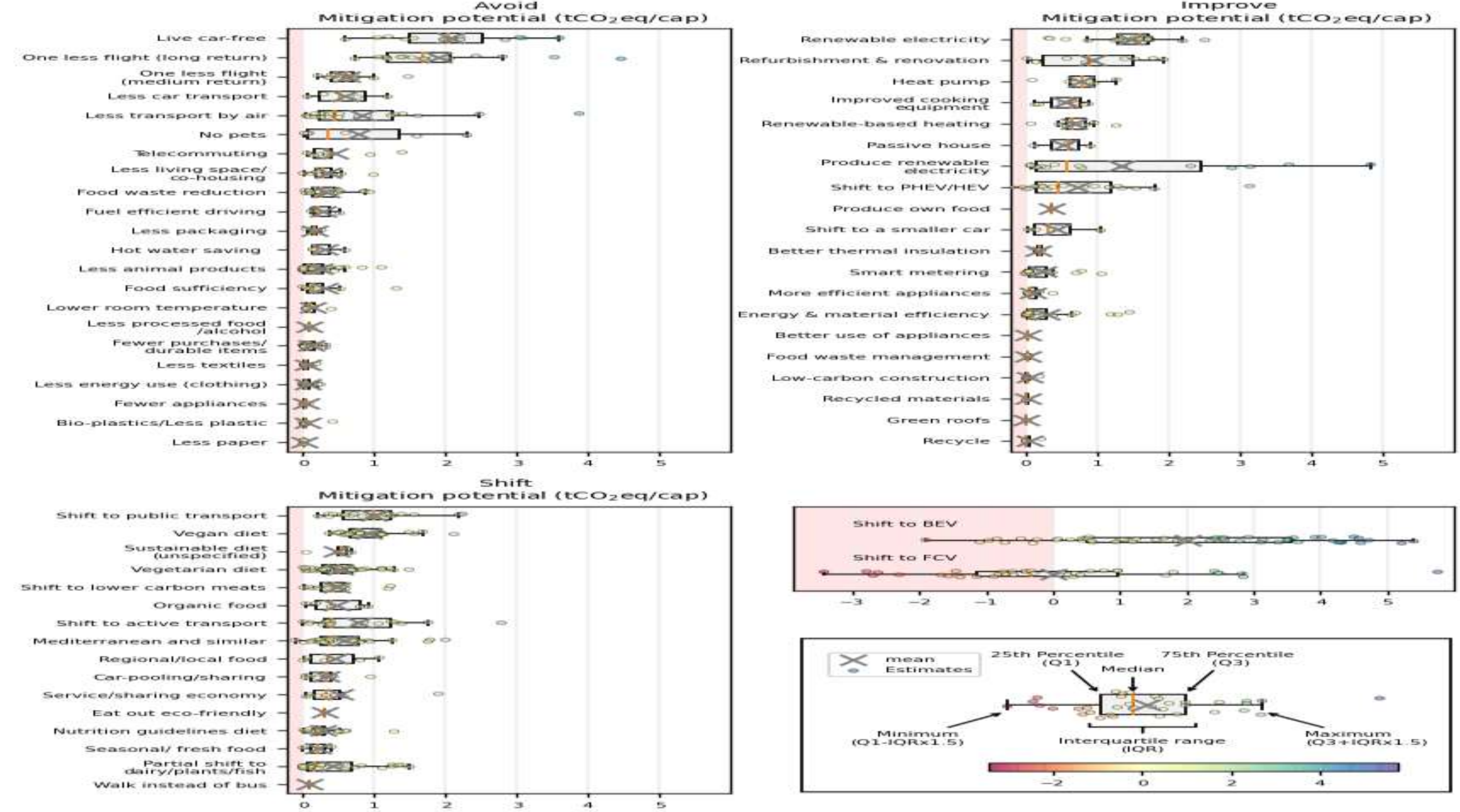
Source: Wilson, Grubler, and Zimm(2022). Energy-Services Led Transformation. In: Routledge Handbook of Energy Transitions(Ed: Araujo). Grubler et al. (2018).


Avoid
Mitigation potential (tCO₂eq/cap)
Live car-free
One less flight (long return)
One less flight (medium return)
Less car transport
Less transport by air
No pets
Telecommuting
Less living space/ co-housing
Food waste reduction
Fuel efficient driving
Less packaging
Hot water saving
Less animal products
Food sufficiency
Lower room temperature
Less processed food /alcohol
Fewer purchases/ durable items
Less textiles
Less energy use (clothing)
Fewer appliances
Bio-plastics/Less plastic
Less paper
Improve
Mitigation potential (tCO₂eq/cap)
Renewable electricity
Refurbishment & renovation
Heat pump
Improved cooking equipment
Renewable-based heating
Passive house
Produce renewable electricity
Shift to PHEV/HEV
Produce own food
Shift to a smaller car
Better thermal insulation
Smart metering
More efficient appliances
Energy & material efficiency
Better use of appliances
Food waste management
Low-carbon construction
Recycled materials
Green roofs
Recycle
Shift
Mitigation potential (tCO₂eq/cap)
Shift to public transport
Vegan diet
Sustainable diet (unspecified)
Vegetarian diet
Shift to lower carbon meats
Organic food
Shift to active transport
Mediterranean and similar
Regional/local food
Car-pooling/sharing
Service/sharing economy
Eat out eco-friendly
Nutrition guidelines diet
Seasonal/ fresh food
Partial shift to dairy/plants/fish
Walk instead of bus
Shift to BEV
Shift to FCV
mean
Estimates
25th Percentile (Q1)
Median
75th Percentile (Q3)
Minimum (Q1-IQRx1.5)
Interquartile range (IQR)
Maximum (Q3+IQRx1.5)

Low demand pathways vary by income and development stage



Source: IPCC AR6 Ch 5, adapted from Oswald et al. (2020)



Avoid
Mitigation potential (tCO₂eq/cap)
Live car-free
One less flight (long return)
One less flight (medium return)
Less car transport
Less transport by air
No pets
Telecommuting
Less living space/ co-housing
Food waste reduction
Fuel efficient driving
Less packaging
Hot water saving
Less animal products
Food sufficiency
Lower room temperature
Less processed food /alcohol
Fewer purchases/ durable items
Less textiles
Less energy use (clothing)
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Bio-plastics/Less plastic
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Heat pump
Improved cooking equipment
Renewable-based heating
Passive house
Produce renewable electricity
Shift to PHEV/HEV
Produce own food
Shift to a smaller car
Better thermal insulation
Smart metering
More efficient appliances
Energy & material efficiency
Better use of appliances
Food waste management
Low-carbon construction
Recycled materials
Green roofs
Recycle
Shift
Mitigation potential (tCO₂eq/cap)
Shift to public transport
Vegan diet
Sustainable diet (unspecified)
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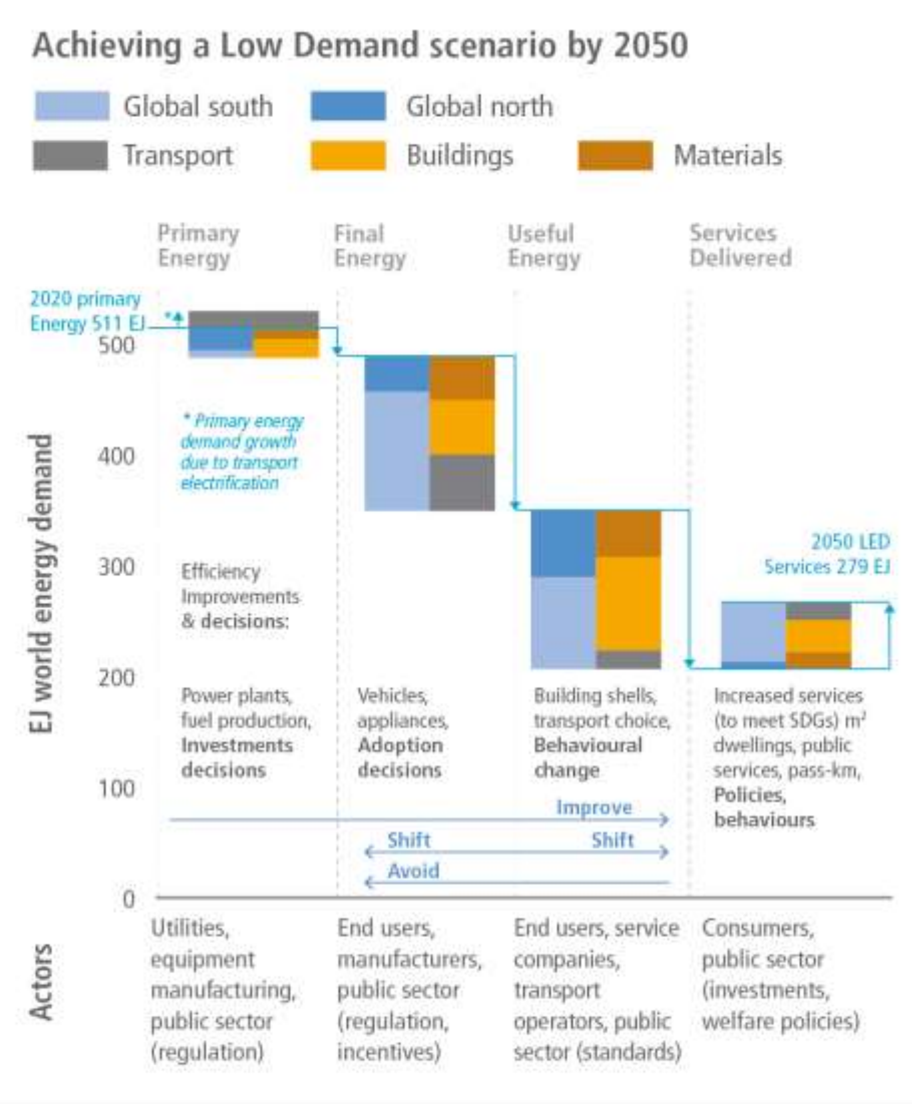
Partial shift to dairy/plants/fish
Walk instead of bus
Shift to BEV
Shift to FCV
mean
Estimates
25th Percentile (Q1)
Median
75th Percentile (Q3)
Minimum (Q1-IQRx1.5)
Interquartile range (IQR)
Maximum (Q3+IQRx1.5)

Demand and services

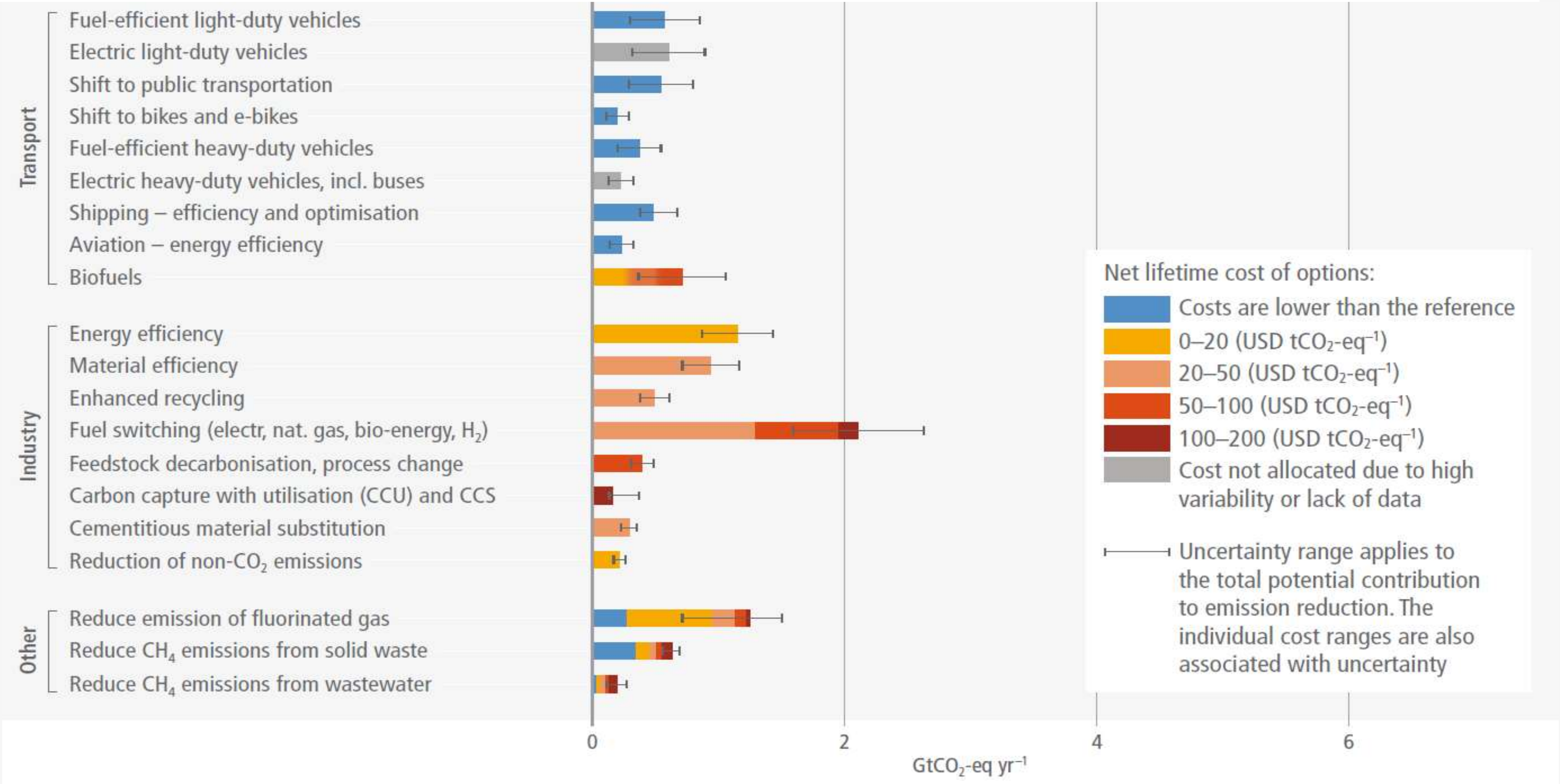
- Demand-side mitigation encompasses changes in infrastructure use, end-use technology adoption, and socio-cultural and behavioural change.
- more efficient end-use energy conversion can improve services while reducing the need for upstream energy by 45% by 2050 compared to 2020
- There are regional differences in potential
- Lowest quartile of population require additional housing, nutrition, energy and resources for human wellbeing



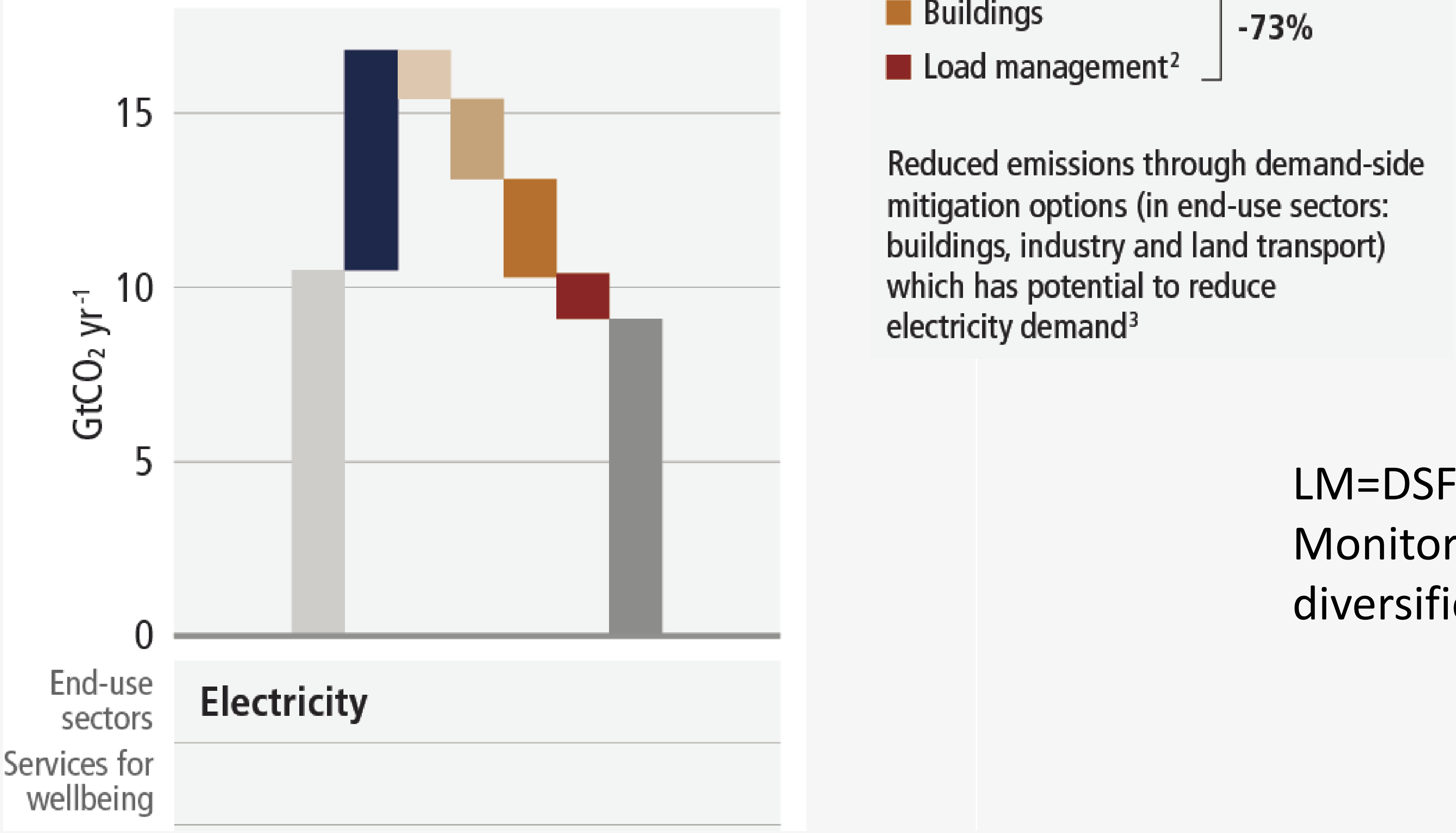
Improved service provisioning systems enable increases in service levels and at the same time a reduction in upstream energy demand by 45%.

[E

The total emission mitigation potential by 2030 is sufficient to reduce global greenhouse gas (GHG) emissions to half of the current level or less



c. Electricity: indicative impacts of change in service demand



Reduced emissions through demand-side mitigation options (in end-use sectors: buildings, industry and land transport) which has potential to reduce electricity demand[3]

LM=DSF through pricing, Monitoring, AI, storage diversification

[Bosch, Unsplash/Yoav Aziz, Adam Bartoszewicz, Victor Hernandez]

Combine behavioral interventions

- Social norms that recognize the social and planetary domain
- Taxes on positional goods/status consumption
- Street space rededication (1km bike lane increases bicycle modal share by 0.6% in average
- Choice architectures (feedback, social comparison, economic incentives, defaults, etc.) –help in presenting choices for better decision making by individuals

5-30% of global annual GHG emissions from end-use sectors are avoidable by 2050, compared to 2050 emissions projection of two scenarios consistent with policies announced by national governments until 2020:

through changes in the built environment, new and repurposed infrastructures and service provision through compact cities, co-location of jobs and housing, more efficient use of floor space and energy in buildings, and reallocation of street space for active mobility

Mitigation options in urban areas

Relation with Sustainable Development Goals

	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
Urban land use and spatial planning	+	•	+	+	+	+	+	+	+	•	+	•	•	•	+	
Electrification of the urban energy system	+	•	+	+	+	+	+	+	+	+	+	•	+	•	+	
District heating and cooling networks	+	−	+				+	+	+		+	+		+	+	
Urban green and blue infrastructure	+	+	+	+		+	+	+	+	•	+	+	+	+	+	
Waste prevention, minimization and management	+	+	•			+		•	+		+	•	+	+	+	
Integrating sectors, strategies and innovations	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Mitigation options in agriculture and forestry

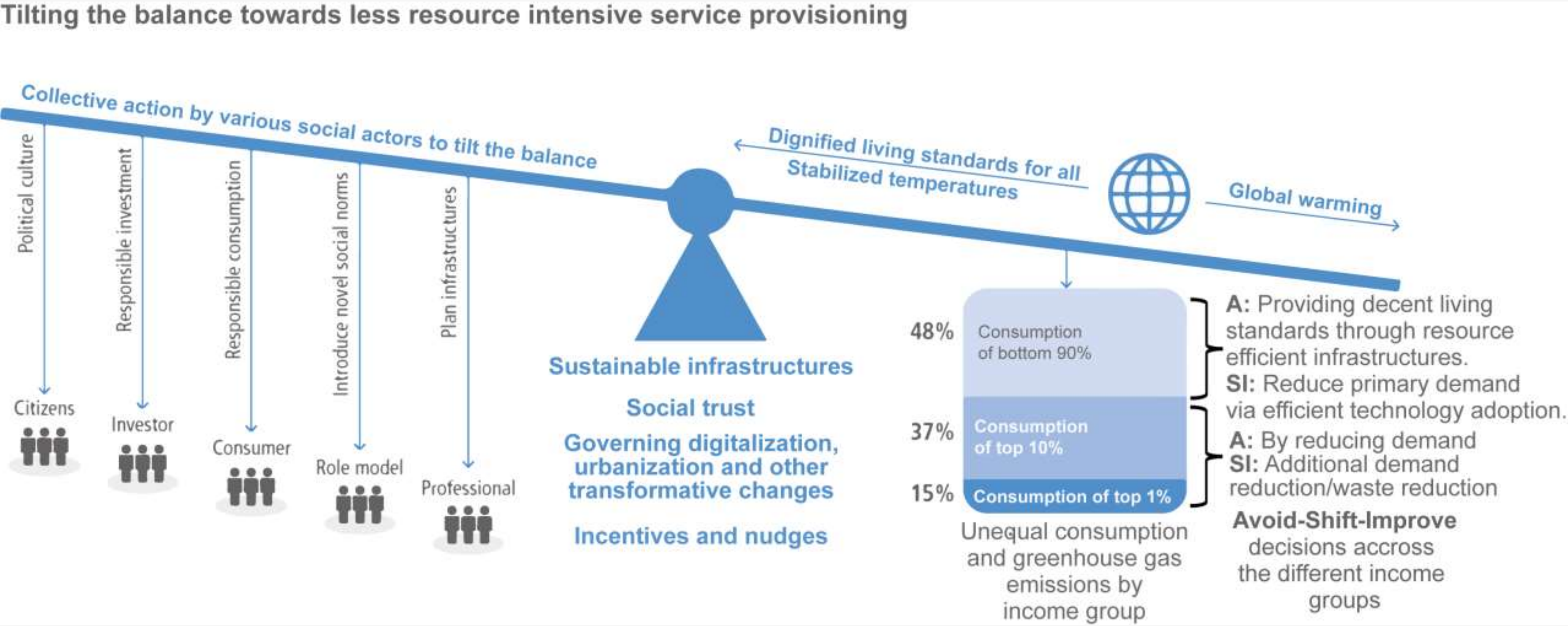
Relation with Sustainable Development Goals

	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17
Carbon sequestration in agriculture[1]	+	+	•			+		+				•	+	+	+	
Reduce CH_4 and N_2O emission in agriculture		•	+			•			•			+	+	+		
Reduced conversion of forests and other ecosystems[2]	•	−	+			+		•			•		+	+	•	•
Ecosystem restoration, reforestation, afforestation	+	•	+			•		−		•	+		+	+		
Improved sustainable forest management	+	•	+			+	•	+	+	•	•		+	+		
Reduce food loss and food waste	+	+	+			+	+			+	+	+	+	+	+	
Shift to balanced, sustainable healthy diets	•	+	+			+	+		•	+	+	+	+	+		
Renewables supply[3]	•	•	•			•	•	+	+				•	•		

Closing investment gaps

- financial flows: **3-6x lower** than levels needed **by 2030** to limit warming to below 1.5°C or 2°C
- there is **sufficient global capital** and liquidity to close investment gaps
- challenge of closing gaps is widest for developing countries

People matters



Accelerated climate action is critical to sustainable development

[Duy Pham/Unsplash]

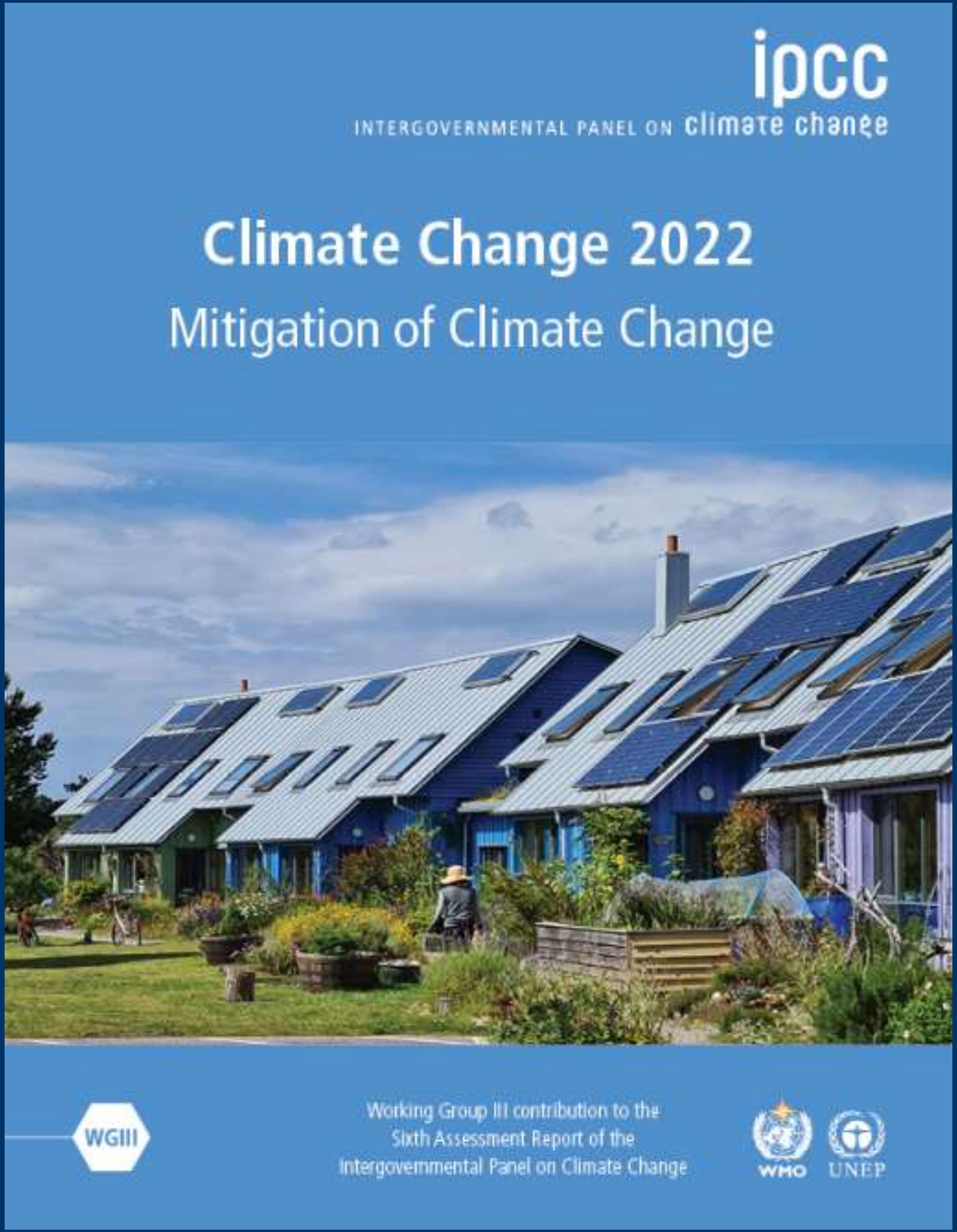
ew research needed to understand costs of demand-side options; The working of economic systems under a well-being-driven rather than GDP-driven paradigm requires better understanding

ually Policies that are aimed at behaviour and lifestyle changes come with political risks for policymakers-need better understanding

[Duy Pham/Unsplash]

“The evidence is clear:

The time for action is now



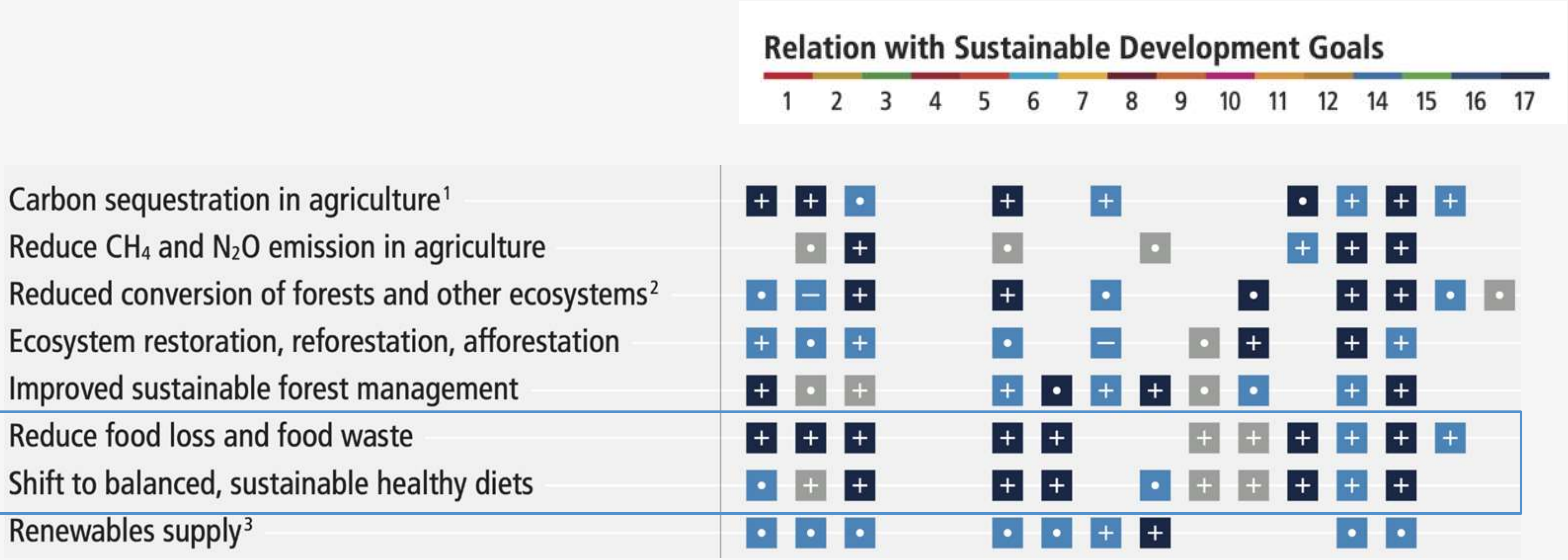
[Matt Bridgestock, Director and Architect at John Gilbert Architects]

•Demand side options improve wellbeing

Legend
- High positive impact [+3]
- Medium positive impact [+2]
- Low positive impact [+1]
- Overall Neutral
- No impact
- Low negative impact [-1]
- Medium negative impact [-2]
- ★ Confidence level

Sectors	SDGs	2	6	7,11	3	6	7	11	11	4		1,2,8,10	5,10,16	5,16	10,16	11,16	8	9,12	8,12
	Mitigation strategies / Wellbeing dimensions	Food	Water	Air	Health	Sanitation	Energy	Shelter	Mobility	Education	Communication	Social protection	Participation	Personal Security	Social cohesion	Political stability	Economic stability	Material provision	Supply side / incumbents
Building	Sufficiency	[+1] ★★★	[+2] ★★★★	[+2] ★★★★★	[+3] ★★★★★	[+1] ★	[+3] ★★★★	[+1] ★	[+1] ★★	[+1] ★★	[+2] ★★★	[+1] ★★	[+1] ★★		[+2] ★★★★★		[+2] ★★★★	[+2] ★★★★	[-2] ★★★
Building	Efficiency	[+2] ★	[+2] ★★★★	[+3/-1] ★★★★	[+3/-1] ★★★★★	[+1] ★	[+3] ★★★★	[+2] ★★★★		[+1] ★★★	[+1] ★★★		[+1] ★★★★	[+1] ★★★	[+2/-1] ★★★★		[+2] ★★★★★	[+2/-1] ★★★★	[+2/-2] ★★★
Building	Lower carbon and renewable energy	[+2/-1] ★★★	[+2/-1] ★★★★	[+3] ★★★★★	[+3] ★★★★★		[+3] ★★★★	[+1] ★★★	[+1] ★★★	[+1] ★★★	[+2] ★★★		[+1] ★★★	[+1] ★★★	[+2/-1] ★★★★		[+2/-1] ★★★★★	[+2] ★★★★	[+2/-2] ★★★
Food	Food waste	[+1] ★★★	[+2] ★★★★	[+2] ★★★★	[+2] ★★★	[+1] ★★	[+1] ★★★★				[+1] ★★	[-1/+1] ★★★	[+1] ★★★			[+1] ★	[+1] ★★		[-1] ★★★
Food	Over-consumption	[+1] ★	[+1/-1] ★	[+1/-1] ★	[+3] ★★★★		[+1/-1] ★						[+2] ★★★★			[+1] ★			[+1/-2] ★
Food	Animal free protein	[+2] ★★★	[+2] ★★★★	[+3] ★★★★★	[+3] ★★★						[-1] ★★★	[+3] ★★★★★	[+1] ★★★★		[-1] ★	[+2] ★			[-1] ★★★
Transport	Teleworking and online education system	[+1] ★★		[+3] ★★★★	[+2] ★★★★		[+2] ★★★★	[+1] ★★	[+2] ★★★★	[-1] ★★★	[+2] ★★★★	[+1] ★★★★	[+2] ★★★★	[+1/-1] ★★★★	[+2] ★★★★	[+2] ★★★	[+2] ★★★		[+1] ★★★★
Transport	Non-motorized transport	[+2] ★★	[+1] ★★	[+1] ★★★★★	[+3] ★★★★★		[+2] ★★★★		[+3] ★★★★★	[+1] ★★★★	[+3] ★★★	[+1] ★★★	[+1] ★★	[+2] ★★★★	[+2] ★★★	[+2] ★★	[+2] ★★★		[+1] ★★★
Transport	Shared mobility	[+1] ★★		[+3] ★★★	[+2] ★★★★		[+1] ★★★		[+2] ★★★★		[+1] ★★★	[+2] ★★★	[+1] ★★★	[+1/-1] ★★★	[+1/-1] ★★★★	[-1] ★★★★	[+2] ★★★★	[+2] ★★★★	[-1] ★★
Transport	Evs	[+1] ★★★		[+2] ★★★★	[+1] ★★★★	[+1] ★★★★	[+3 ★★★★		[+2] ★★★★			[+3] ★★★★★	[+2] ★★★				[+2] ★★★★	[-1] ★★	[+1] ★★★
Urabn	Compact city	[+2/-1] ★★★	[+1] ★★	[+2/-1] ★★★	[+3/-1] ★★★★	[+1] ★★	[+3/-1] ★★★★★	[-1] ★★★★★	[+3] ★★★★★	[+1] ★★★★★	[+1/-1] ★★★	[+2] ★★	[+1] ★★	[+1] ★★★★	[+1/-1] ★★★★★		[+1] ★★★★	[+1] ★★	[+1/-2] ★★★
Urabn	Circular and shared economy	[+2] ★★★★	[+1] ★★★	[+2] ★★★	[+2] ★★★		[+3] ★★★	[+2/-1] ★★★	[+3] ★★★★★	[+1] ★★★★	[+1] ★★★★	[+1] ★★★	[+1] ★★★	[+2] ★★★★	[+1] ★★	[+1] ★★	[+2] ★★	[+3] ★★★	[-1] ★★★★
Urabn	Systems approach in urban policy and practice	[+1] ★★★	[+2] ★★★	[+2] ★★★	[+3] ★★★	[+1] ★★★	[+3] ★★★	[+2] ★★★	[+3] ★★★		[+1] ★★	[-1] ★★	[+1] ★★★	[+2] ★	[+1] ★★		[+1] ★★	[+3] ★★★★★	[+2/-2] ★★
Urabn	Nature based solutions	[+2] ★★★	[+1/-1] ★★★★★	[+3/-1] ★★★★	[+3] ★★★★★	[+1] ★★★	[+3] ★★★	[+1/-1] ★★★	[+1] ★★★	[+2] ★★★★		[+2] ★★	[+3] ★★	[+1] ★★★	[+2/-2] ★★★		[+3] ★★★★	[+1] ★★	[+1] ★★
Industry	Using less material by design	[+2] ★★	[+2] ★★★	[+3] ★★★	[+2] ★★	[+2] ★★★	[+3] ★★★★	[+2] ★★★★	[+2] ★★★★	[+1] ★★	[+2] ★★★	[+1] ★★	[+1] ★★★	[+1] ★★	[+1] ★★	[+1] ★★	[+2] ★★★	[+3] ★★	[-2] ★★
Industry	Product life extension	[+2] ★★	[+2] ★★★	[+3] ★★★	[+2] ★★	[+2] ★★★	[+3] ★★★★	[+2] ★★★★	[+2] ★★★★	[+1] ★★	[+2] ★★★	[+1] ★★	[-1] ★★★★	[+1] ★★	[+1] ★★	[+1] ★★	[+2] ★★★	[+3] ★★	[-2] ★★
Industry	Energy Efficiency	[+2] ★★	[+2] ★★★	[+3] ★★★	[+1] ★★	[+2] ★★★	[+3] ★★★★	[+2] ★★★★	[+2] ★★★★	[+1] ★★	[+2] ★★★	[+2] ★★★★	[+2] ★★★	[+1] ★★		[+1] ★★	[+2] ★★★	[+2] ★★	[-2] ★★
Industry	Circular economy	[+2] ★★★	[+2] ★★★	[+3] ★★★	[+1] ★★	[+2] ★★★	[+3] ★★★★	[+2] ★★★★	[+2] ★★★★	[+1] ★★	[+2] ★★★	[+1] ★★	[+1] ★★★	[+2] ★★	[+1] ★★		[+2] ★★★	[+3] ★★	[-2] ★★

Mitigation options in agriculture and forestry



ew research needed to understand costs of demand side options; The working of economic systems under a well-being driven rather than GDP-driven paradigm requires better understanding

ually Policies that are aimed at behaviour and lifestyle changes come with political risks for policymakers-need better understanding

[Duy Pham/Unsplash]