Prospects for Green Transformation focusing on the energy demand-side

2023.3.6

Research Institute of Innovative Technology for the Earth（RITE)

Director-General

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1.

Wrap-up the symposium

2.

Condition of carbon-neutral energy system

Condition of carbon-neutral energy system

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- Annual energy balance

Carbon-free energy supply＝Energy demand

- Always keeping electricity supply/demand:

Supply of carbon-free electricity

＝Electricity demand

First equation

$$\text{Carbon free energy} = \frac{\text{energy demand}}{\text{service}} \times \frac{\text{service}}{\text{sufficiency}} \times \frac{sufficiency}{\text{population}} \times \text{population}$$

Renewable energy

Nuclear

Blue/green hydrogen/ammonia/e-fuels

Fossil Fuel Thermal with CCS

1st term : Inverse of energy efficiency

2nd term : Inverse of lifestyle efficiency

Service : thermal environment, brightness, information, etc.

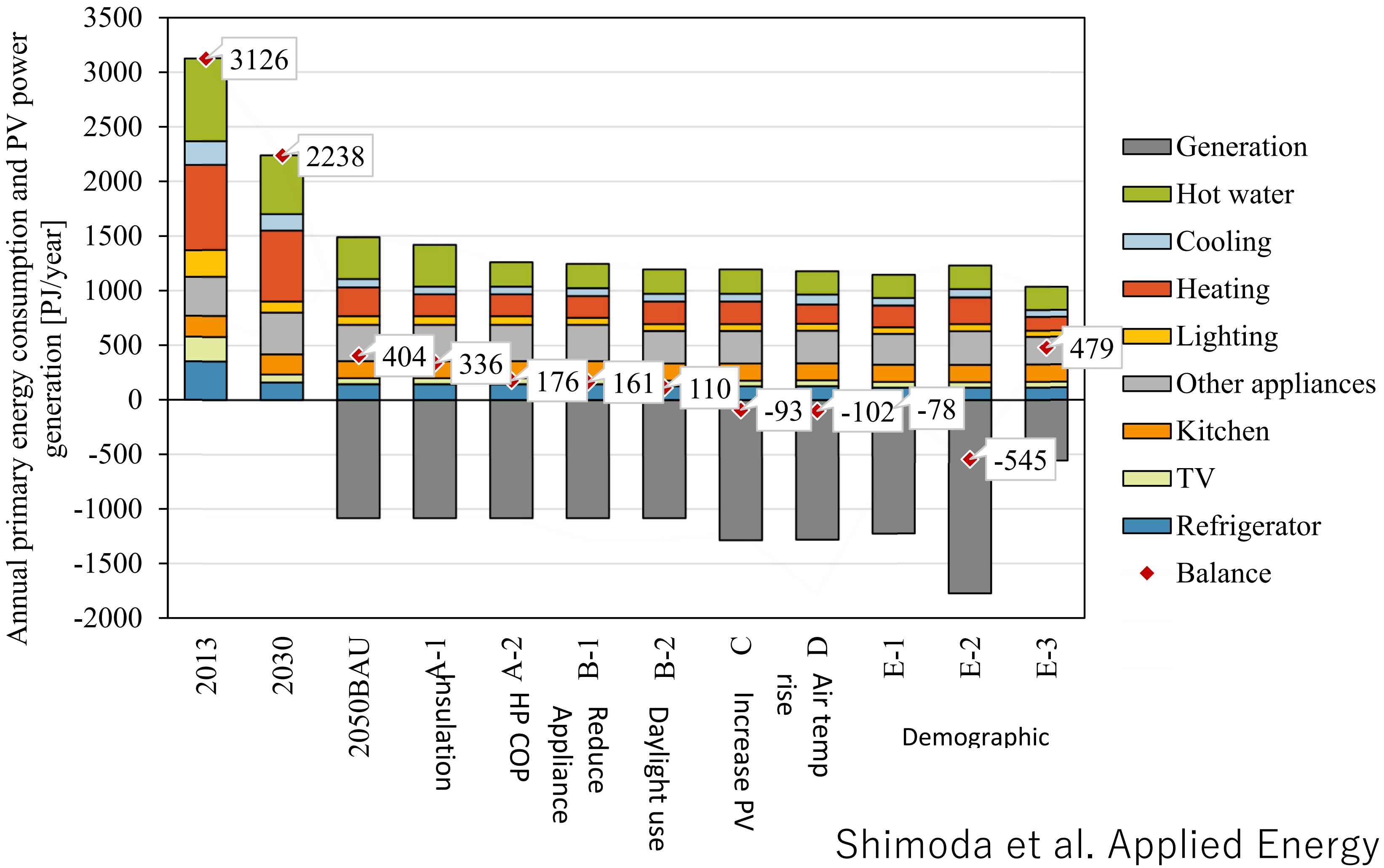
Sufficiency

- Present share of renewable electricity is 20%. In order to increase the renewable energy ratio to 80%, it is more realistic to reduce the power demand to 50% and double the renewable electricity power rather than quadrupling renewable electricity.

Shimoda, et al.: Renewable and Sustainable Energy Reviews 132 (2020), 115792

Is it possible to reduce electricity demand by 50%?

- Evaluation of Japanese residential sector's carbon-neutrality by 2050. More than 50% energy reduction is possible with currently available technology. BiPV can achieve positive energy.



Shimoda et al. Applied Energy (2021)

Second equation

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$$\text{Carbon free electricity} = \mathit{electricity\ demand}$$

Variable renewable electricity(PV, Wind)

Nuclear

Flexible renewable power (Hydro, Biomass)

Blue/green hydrogen /ammonia thermal power

Fossil fuel thermal power with CCS

⇔

Battery

Hydrogen

Thermal storage

DR

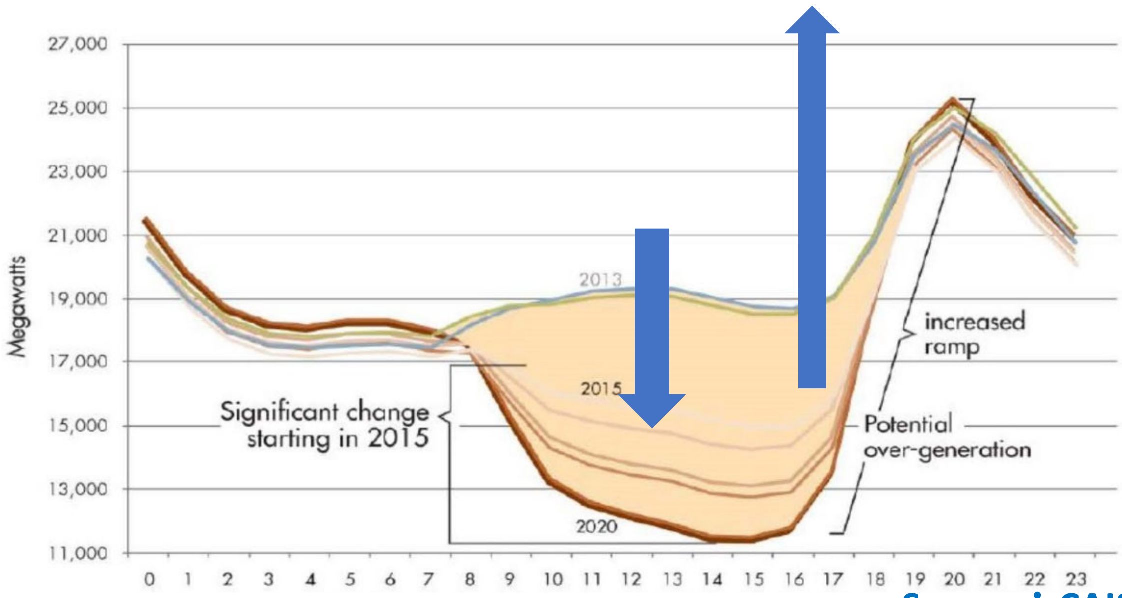
⇔

Fluctuating demand (buildings)

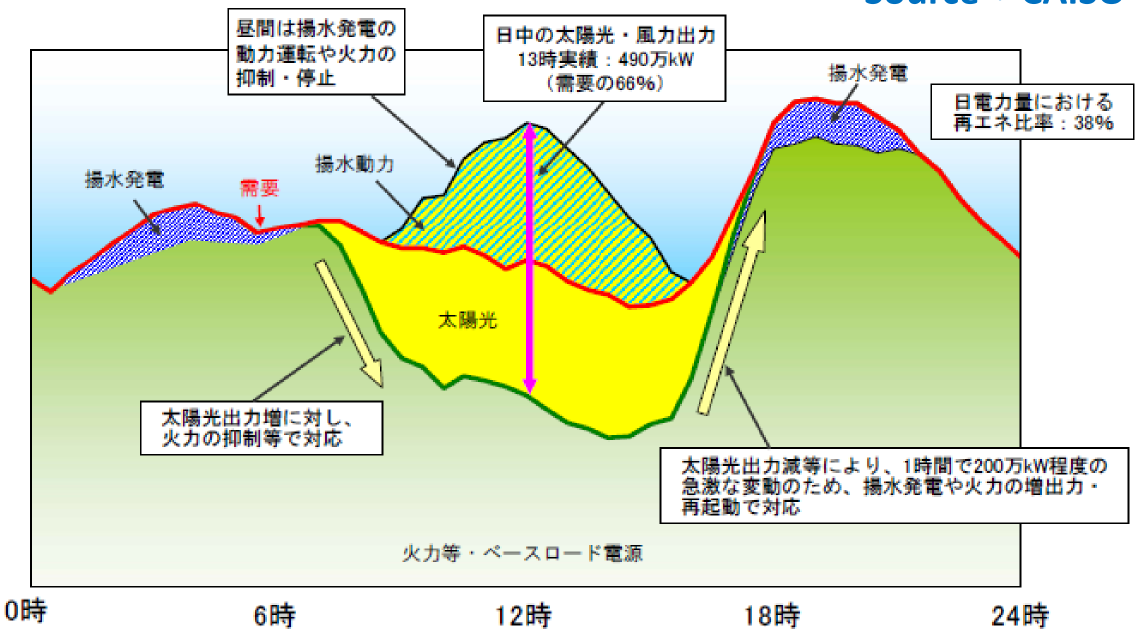
Constant demand (Factory, data center)

Pulse demand (EV charging)

Influence of PV dissemination



Source：CAISO



Electricity supply/demand balance in Kyushu（May 5, 2016）

Source : Kyushu Power company（Jul.2016）

'Duck carve' in California, US and Kyushu Japan. Steep increase of demand in evening. Planned blackout in August 2020. EV charging escalate the situation

Increase daytime demand by HP water heater etc.
Demand response.
Battery, Heat Storage
Smart charging of EV
Heat from Biomass and Solar

Unbalanced Seasonal supply/demand.

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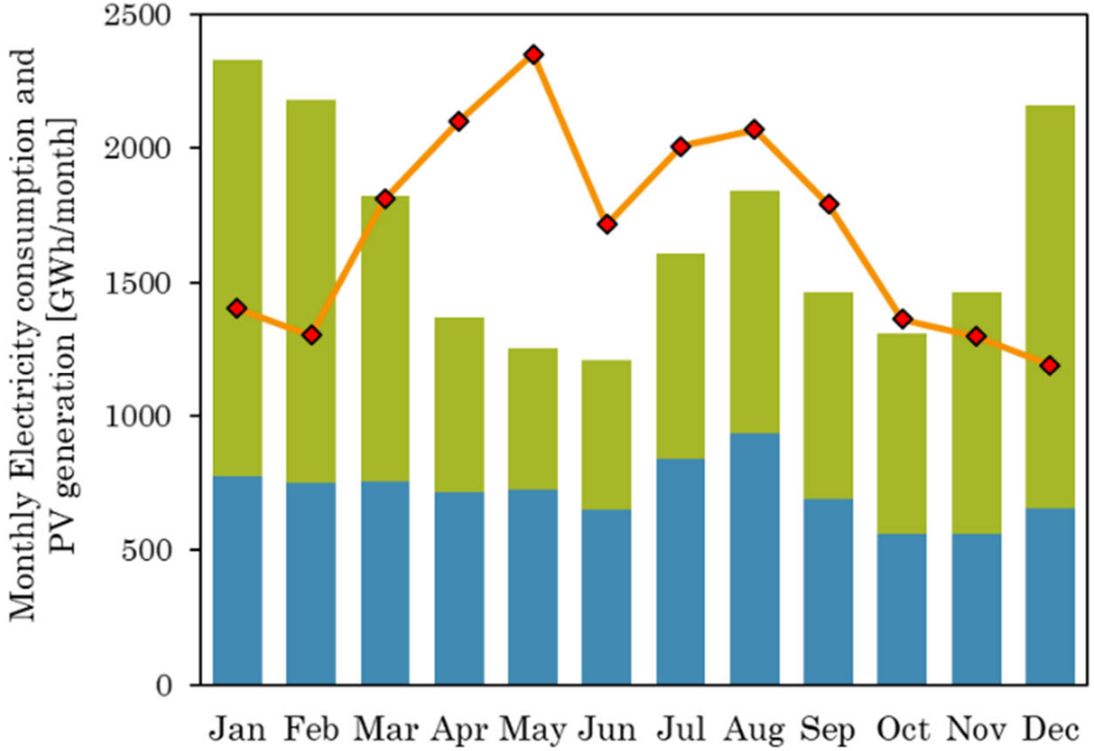
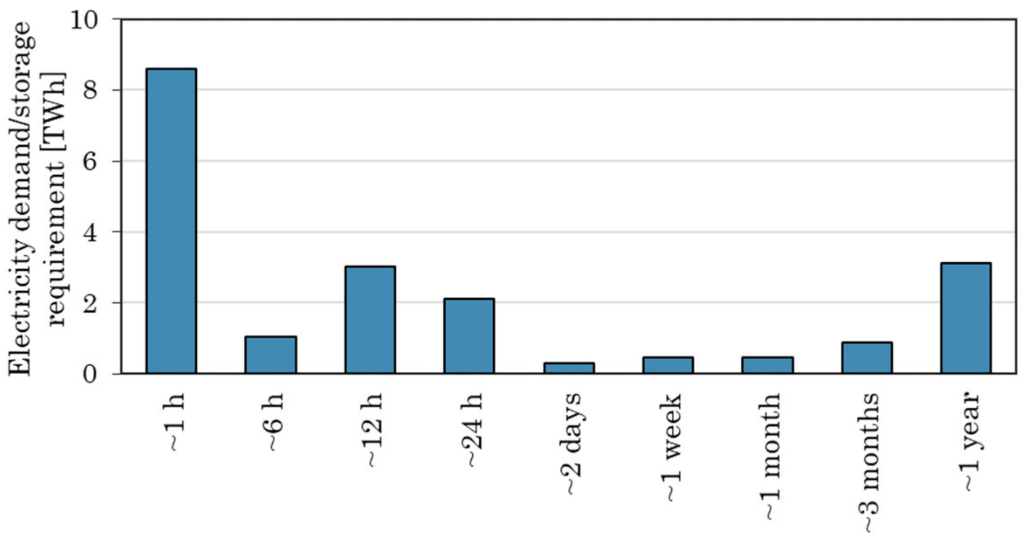


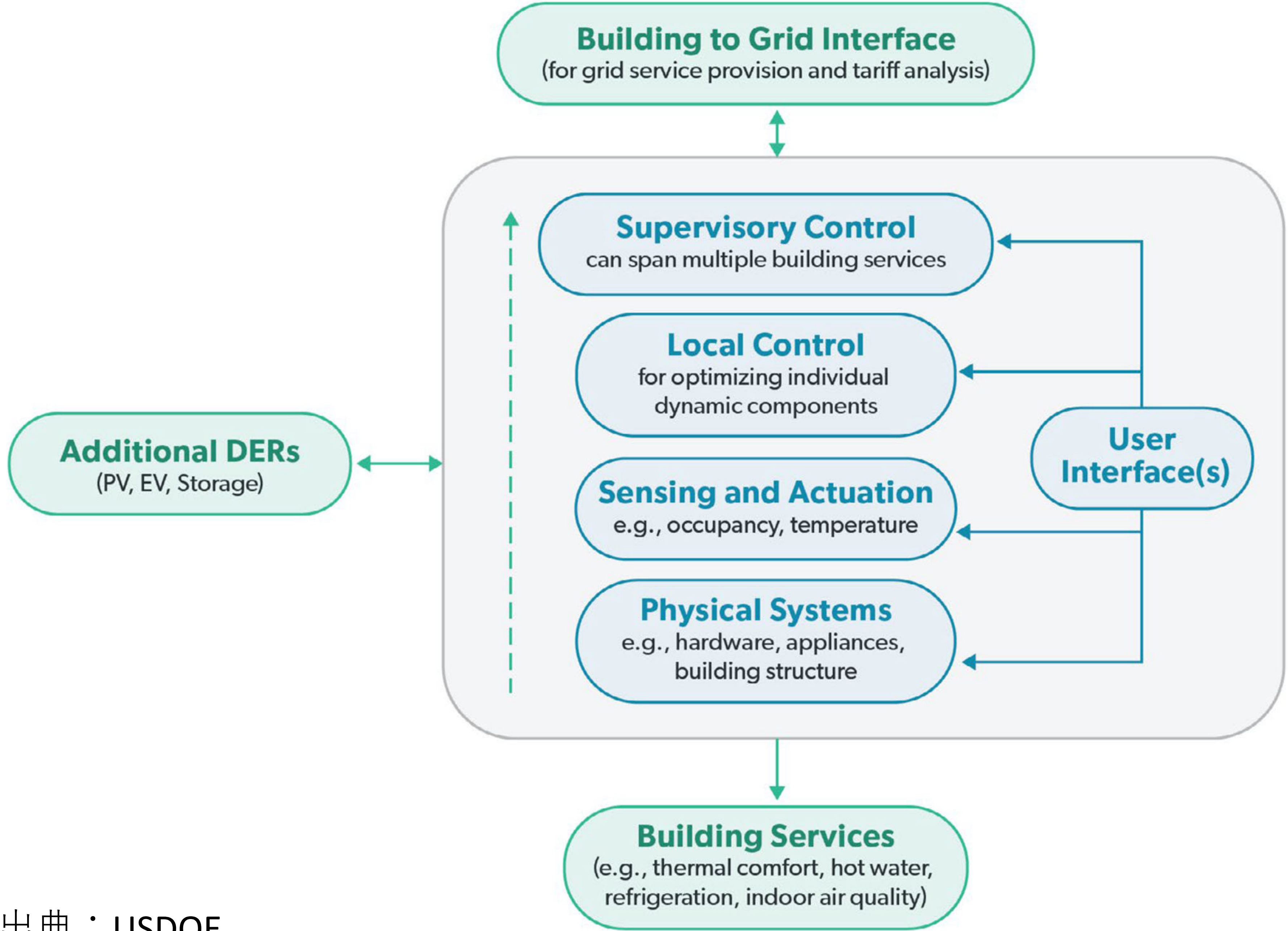
Monthly balance of PV supply and demand in Japanese residential sector in the state of achieving positive energy for the year



22% of electricity must be stored more than a week → Hydrogen is required for long-term energy storage.

Shimoda et al. Applied Energy (2021)

Grid-interactive efficient buildings



出典：USDOE

Herman Daly's word

- 1. Who is going to require the energy?
- 2. How much energy?
- 3. What kind of energy?
- 4. For what purpose?
- 5. For how long?

Source: Lovins "Soft Energy Path"

- Identifying each energy demand and classify them is the basis of energy management.

3.

Energy demand and service demand

Characteristics of energy demand

- Energy demand is “derivative demand”.
- We don’t consume energy directly, but service.

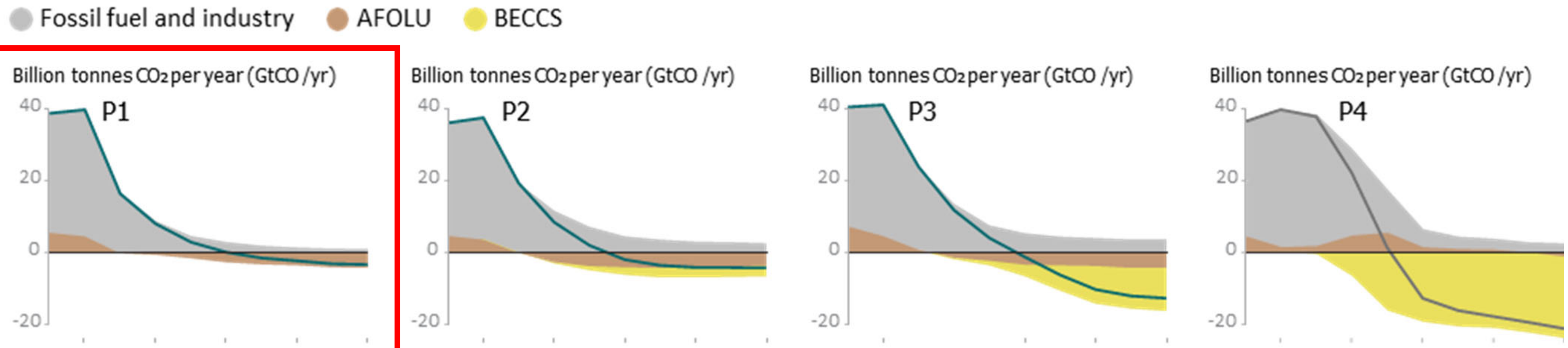
$$\text{Carbon free energy} = \frac{\text{energy demand}}{\text{service}} \times \frac{\text{service}}{\text{sufficiency}} \times \frac{sufficiency}{\text{population}} \times \text{population}$$

- A significant reduction in energy demand can be achieved by narrowing down the services necessary to provide sufficiency (Avoid), changing the system that supplies services (Shift), and supplying services with as little energy as possible (Improve).

(IPCC WG3 Chap5)

IPCC Special report on 1.5°C

Breakdown of contributions to global net CO2 emissions in four illustrative model pathways



Demand 32% down、RE 77% BECCS 0

Demand 2%up、 RE 81%, BECCS 151Gt

Demand21%up, RE 63%, BECCS 414Gt

Demand 44%up, RE 70% BECCS 1191Gt

LED Scenario (Low Energy Demand)

Other three pathways using negative emission technology

Source IPCC SR1.5 SPM

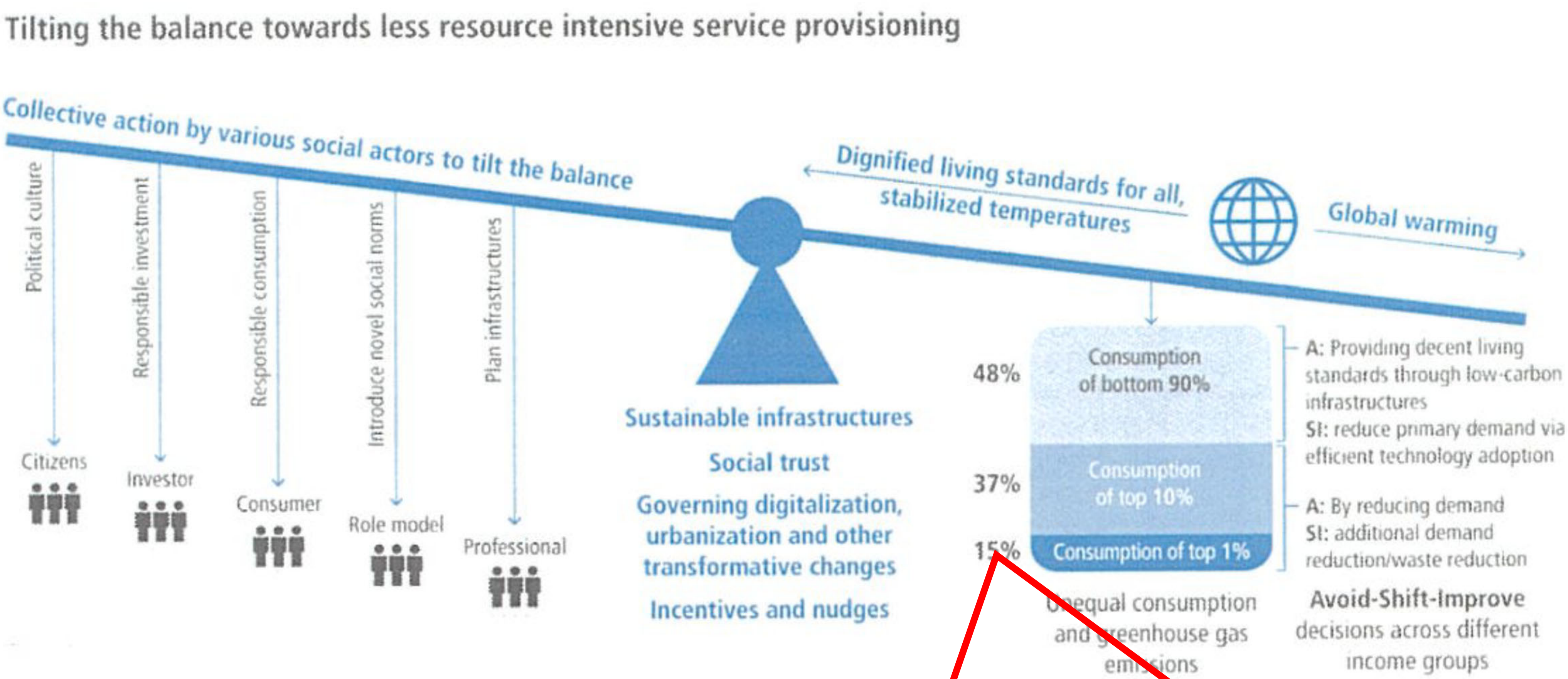
LED Scenario

- LED (Low Energy Demand) Scenario（Grubler et al. Nature energy, 2018）
- **Five main drivers of long-term change in energy end-use; Quality of Life, Urbanization, Novel energy services, End-user roles, Information innovation.**
- **Focusing the relationship between energy end-use and service.**
- Low energy demand will be brought by information innovation, sharing economy, and electrification.

Services and energy efficiencies in LED scenario

Service demand	Activity level （Global North)	Energy intensity
Thermal comfort	30㎡/capita	Decrease by 75% to 160-170MJ/㎡
Consumer goods	Increase by 2 to 42 device/capita	93→82kWh/device
Mobility	Decrease by 20%	Decrease by 70%
Food	Increase by 70～100%	Not quantified.
Commercial and public buildings	Increase by 43％ to 23㎡ /capita	Decrease by 76% to 139MJ/㎡
Industry	Decrease of material demand by 15％ to 6.4Gt(world)	Decrease by 1/5 to 16.7GJ/t
Freight transport	Increase by 20% to 64×10^{12}tkm	10% decrease in Truck transport to 0.5-0.7 MJ /tkm、10％ decrease in railway to 0.2MJ/tkm^{-1}

Unequal consumption of energy



Top 1% of the world population consume 15% of energy. Next 10% consume 37%.
Remaining 90% consume only 48% energy.

Source：IPCC AR6 WG3 chap. 5

Avoid-Shift-Improve Options

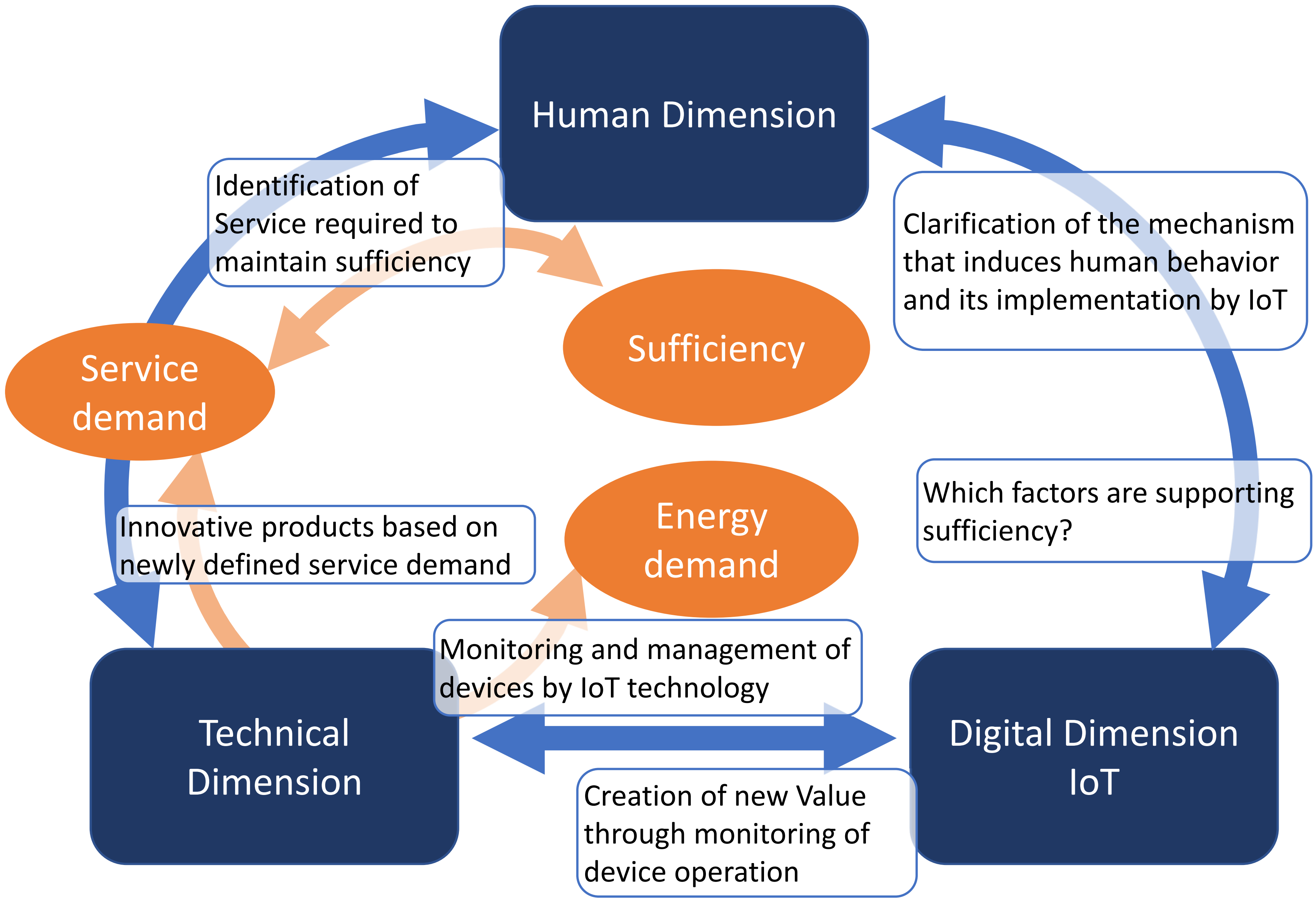
Service	Emission decomposition factors	Avoid	Shift	Improve
Mobility [passenger-km] *(Chapters 8, 10, 11, 16)*	$kgCO_2$ = (passenger km)* (MJ pkm^{-1})*($kgCO_2$ MJ^{-1})	**Innovative mobility to reduce passenger-km:** Integrate transport and land-use planning Smart logistics Teleworking Compact cities Fewer long-haul flights Local holidays	**Increased options for mobility MJ pkm^{-1}:** Modal shifts, from car to cycling, walking, or public transit Modal shift from air travel to high-speed rail	**Innovation in equipment design MJ pkm^{-1} and CO_2-eq MJ^{-1}:** Lightweight vehicles Hydrogen vehicles Electric vehicles Eco-driving
Shelter [square metres] *(Chapters 8, 9, 11)*	$kgCO_2$ = (square metres)* (tonnes material m^{-2})* (kg CO_2 tonne $material^{-1}$)	**Innovative dwellings to reduce square metres:** Smaller decent dwellings Shared common spaces Multigenerational housing	**Materials-efficient housing tonnes material m^{-2}:** Less material-intensive dwelling designs Shift from single-family to multi-family dwellings	**Low emission dwelling design $kgCO_2$ $tonne^{-1}$ material:** Use wood as material Use low-carbon production processes for building materials (e.g., cement and steel)
Thermal comfort [indoor temperature] *(Chapters 9, 16)*	$kgCO_2$ = (Δ°C m^3 to warm or cool) (MJ m^{-3})* ($kgCO_2$ MJ^{-1})	**Choice of healthy indoor temperature Δ°C m^3:** Reduce m^2 as above Change temperature set-points Change dress code Change working times	**Design options to reduce MJ Δ°C^{-1} m^{-3}:** Architectural design (shading, natural ventilation, etc.)	**New technologies to reduce MJ Δ°C^{-1} m^{-3} and $kgCO_2$ MJ^{-1}:** Solar thermal devices Improved insulation Heat pumps District heating
Goods [units] *(Chapters 11, 12)*	$kgCO_2$ = (product units)* (kg material $product^{-1}$)* ($kgCO_2$ kg $material^{-1}$)	**More service per product:** Reduce consumption quantities Long lasting fabric, appliances Sharing economy	**Innovative product design kg material $product^{-1}$:** Materials-efficient product designs	**Choice of new materials $kgCO_2$ kg $material^{-1}$:** Use of low-carbon materials New manufacturing processes and equipment use
Nutrition [calories consumed] *(Chapters 6, 12)*	$kgCO_2$-eq = (calories consumed)* (calories produced calories $consumed^{-1}$)* ($kgCO_2$-eq calorie $produced^{-1}$)	**Reduce calories produced/ calories consumed and optimise calories consumed:** Keep calories in line with daily needs and health guidelines Reduce waste in supply chain and after purchase	**Add more variety in food plate to reduce $kgCO_2$-eq cal^{-1} produced:** Dietary shifts from ruminant meat and dairy to other protein sources while maintaining nutritional quality	**Reduce $kgCO_2$-eq cal^{-1} produced:** Improved agricultural practices Energy efficient food processing
Lighting [lumens] *(Chapters 9, 16)*	$kgCO_2$ = lumens* (kWh $lumen^{-1}$)* ($kgCO_2$ kWh^{-1})	**Minimise artificial lumen demand:** Occupancy sensors Lighting controls	**Design options to increase natural lumen supply:** Architectural designs with maximal daylighting	**Demand innovation lighting technologies kWh $lumens^{-1}$ and power supply $kgCO_2$ kWh^{-1}:** LED lamps

Source：IPCC AR6 WG3 chap. 5

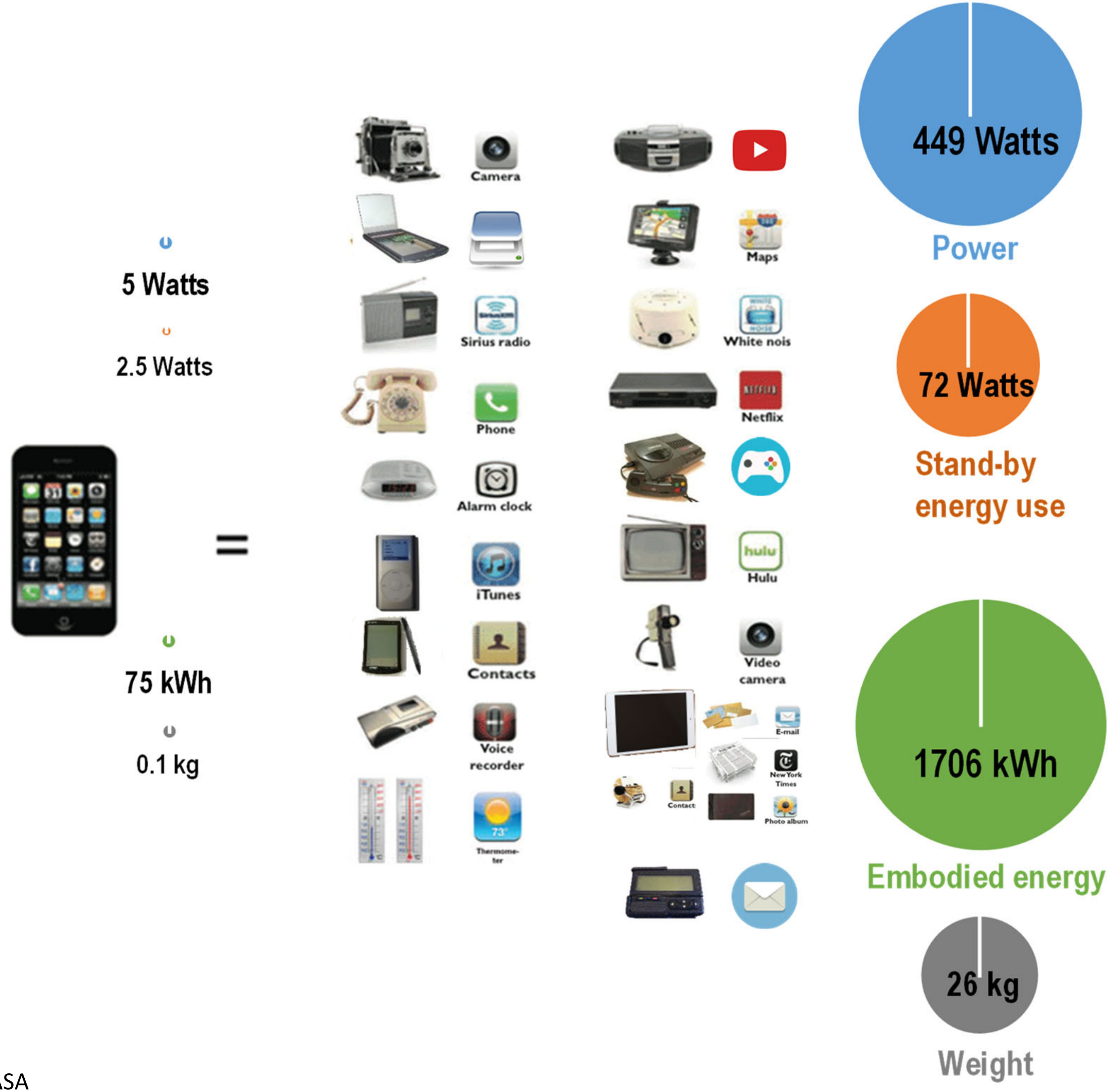
4.

Impact of digitalization on energy demand

Structure of energy demand science



Digital Convergence

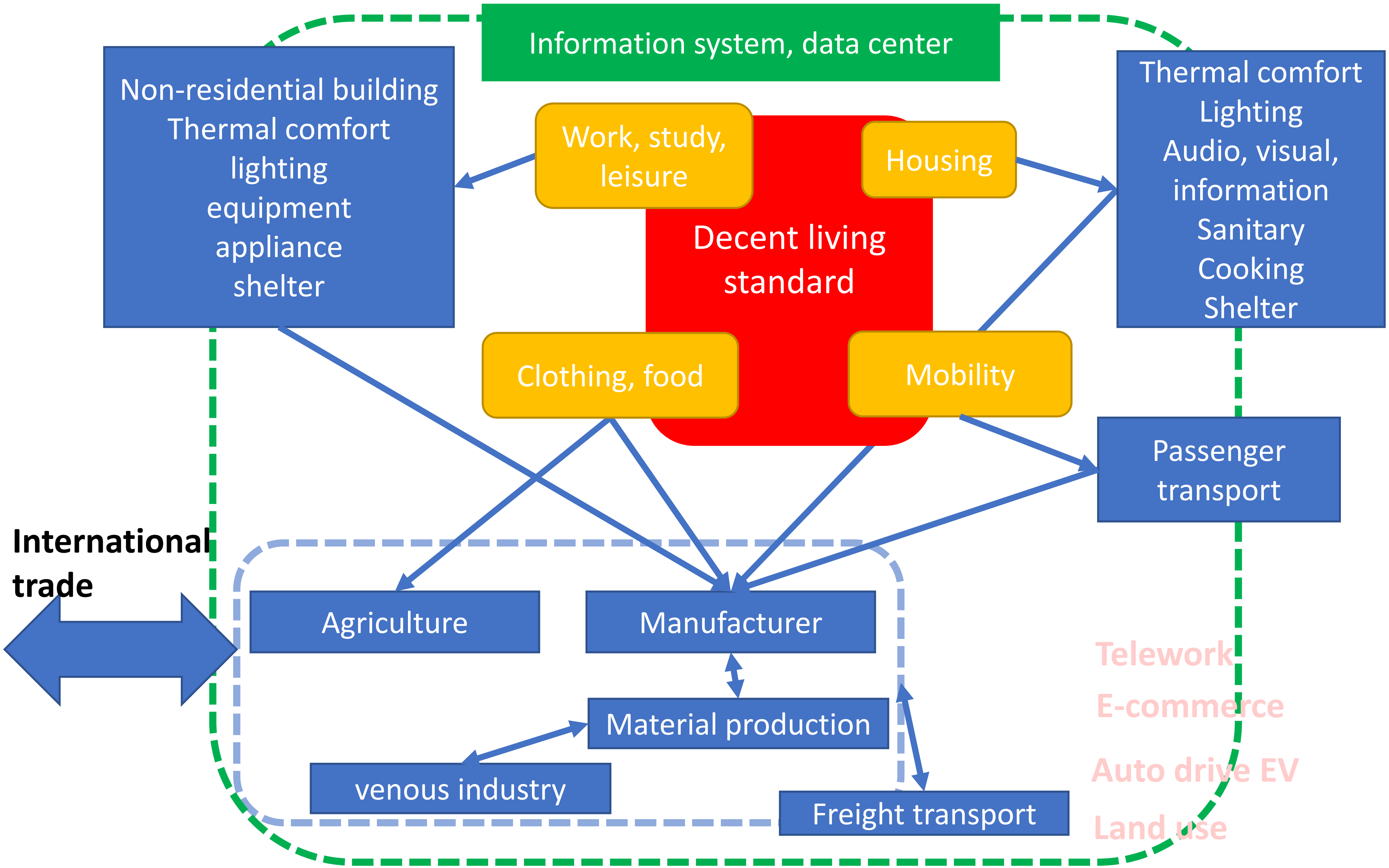


出典：IIASA

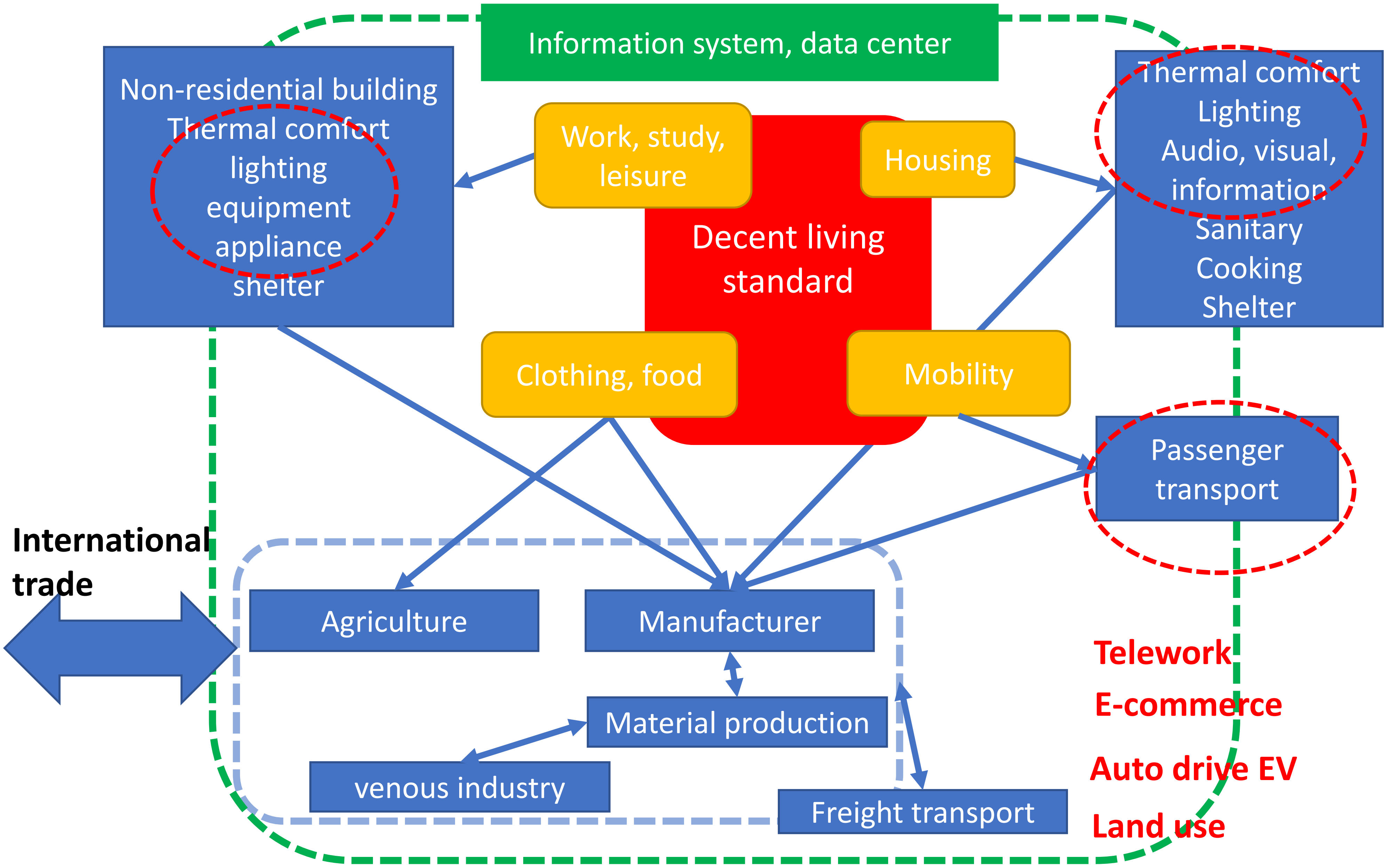
Discussion on Digital Convergence

- Smartphones have not been expanding their functions to energy efficiency. In advancement of digital technology, the expansion of the services provided by device has resulted in a reduction of energy use.
- While reducing device energy consumption, the following issues remain.
    - Many services such as GPS and car navigation functions process information in data centers located in remote locations. Is it really energy efficient when considering the energy consumption in data centers?
    - Each device before integration to smartphone has a longer life than a smartphone. Therefore, functional integration shortens the life of device and increases the ratio of embodied energy to the life cycle energy consumption, and making eco-design and recycling of device important.

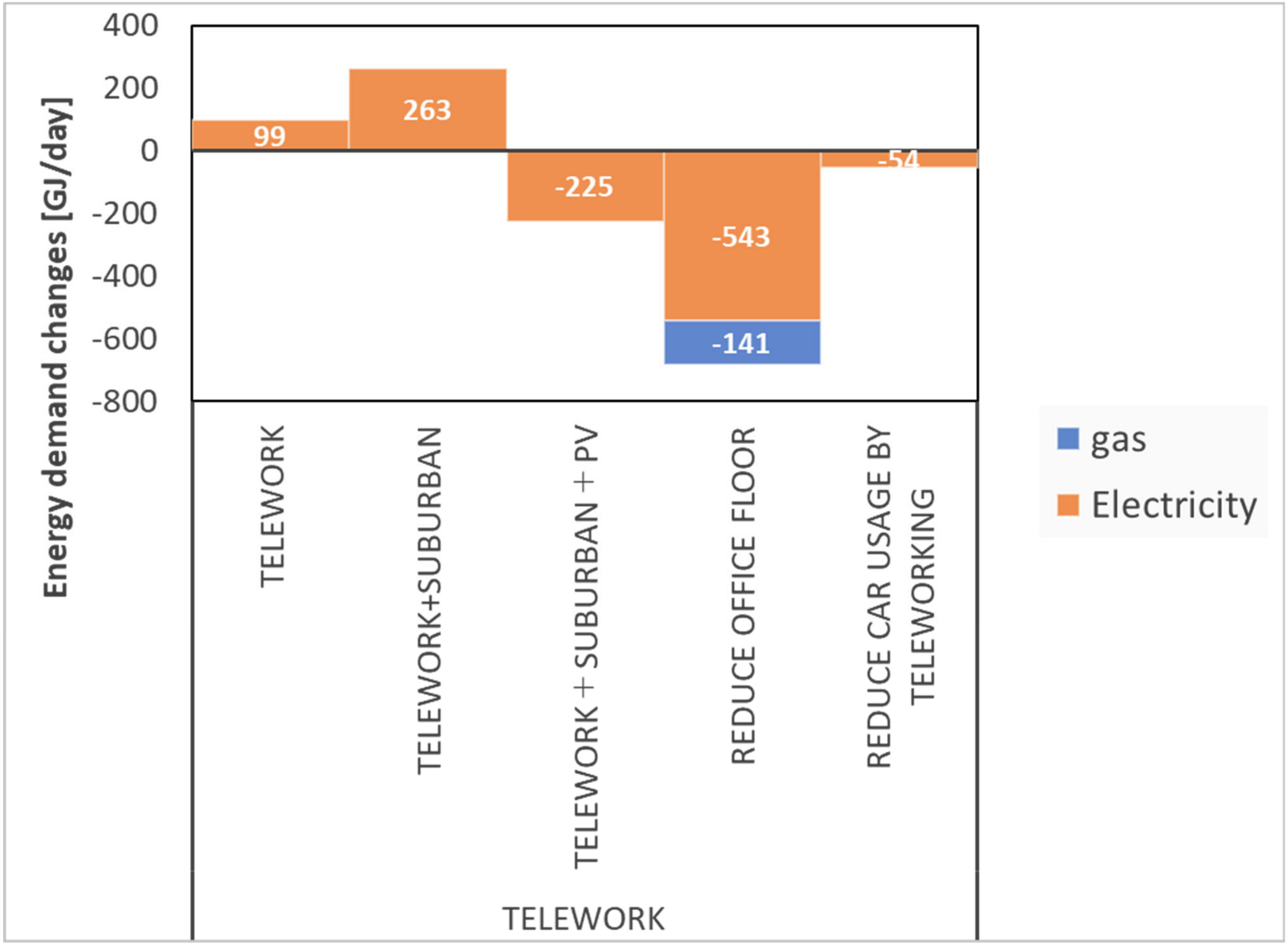
Digitization creates transformation across sectors



Digitization creates transformation across sectors



Energy demand changes by teleworking



Change in manufacturer

- De-materialization and Efficient material use
  - Servicizing [Rental]
  - Reuse/recycle, remanufacturing, sharing economy
  - Long-life, advanced maintenance
  - Weight saving, material efficiency through eco-design
- Efficiency and decarbonization of production
  - Energy efficient production and fossil fuel free production.
  - On-demand production
  - 3D printing
  - Advanced demand forecasting and supply chain (Industry 4.0)

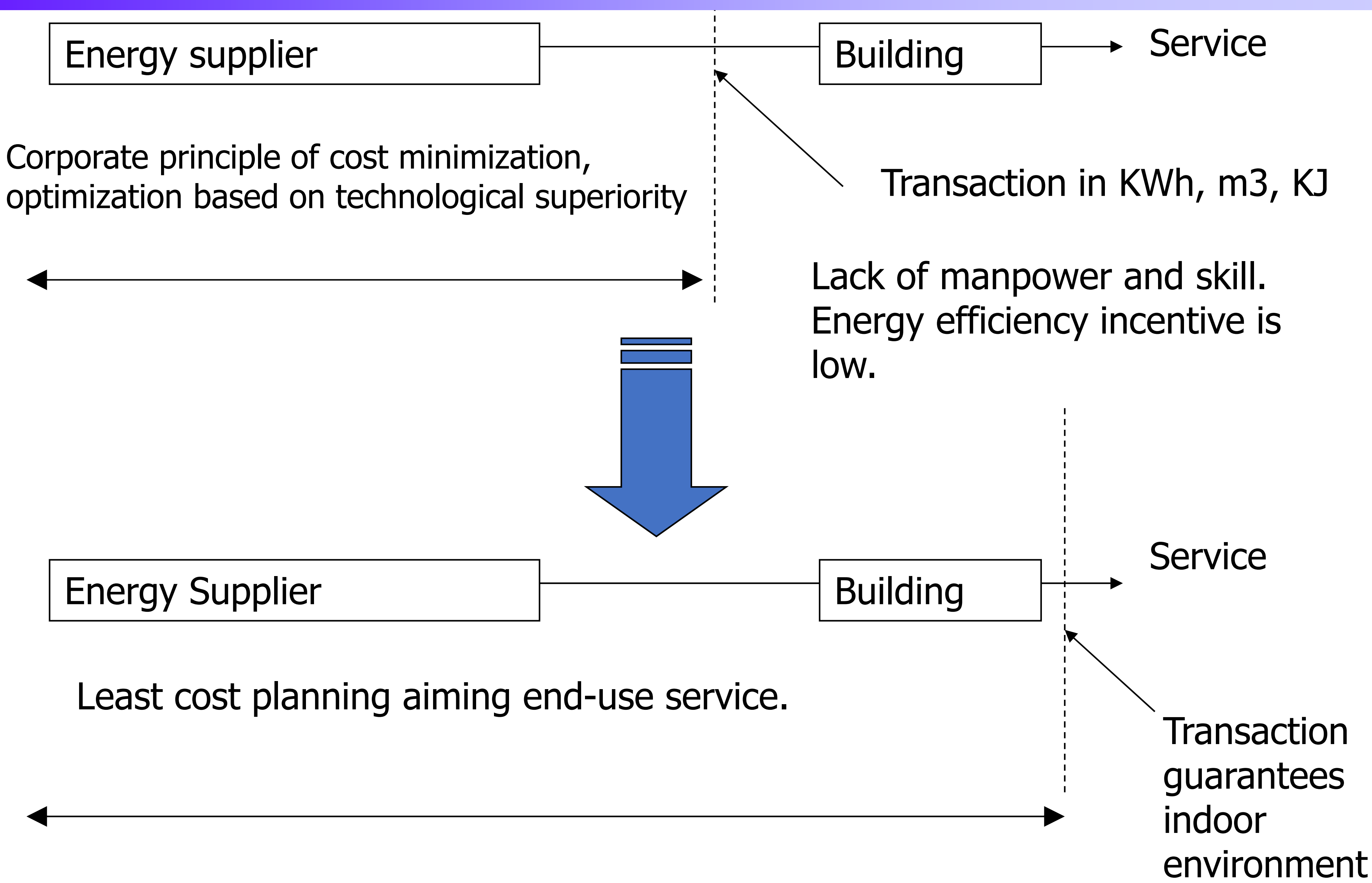
5.

How can we realize low energy demand and link to growth of competitive industries?

Servicizing

- A business that sells services rather than products.
- Producers change the way they provide product functionality to meet consumer needs.
- Since the ownership remains in the hands of the producer, efforts to reduce the environmental burden at the time of disposal are easy to work.
- Recently, the concept has expanded to transportation (Mobility as a Service) in addition to products.
- How is in energy business?

Climate Agreement (Gothenburg)



Granular technology, Granular stakeholder

- Granular technology
  - Part of the energy supply will be “granular technologies" such as PV.
  - Energy demand is also divided into device units, it is “granular technology".
  - The same device is operated differently due to user’s behavior.
  - Digitization enables management of group of technologies.
- Granular stakeholder
  - Families and small businesses.
  - Decisions depend not only the economical optimum.
  - Insufficient information.
  - It is difficult to make long-term investment.
- Needs to be aggregated and managed.

City/Community energy system.

- Housing, construction, home appliances, building equipment, car, urban infrastructure etc., which account for the majority of energy demand in the building sector and passenger transport sector, are fields in which Japan has a high level of technology and can contribute to the decarbonization of the world.
- In order to enhance the demand for these decarbonization technology, create further innovation, and contribute to decarbonization and green recovery, it is necessary to induce performance improvements through continuous and ambitious policies, and to encourage the public to disseminate them. In particular, it is important to spread these technology to all households in order to achieve decarbonization.
- In order to get participation of all households and small businesses, it is important not only the payback year, but also to appeal the attractivity of decarbonized society consist of these goods. In the future, city/community scale efforts will be important, since most of EV charging will be occur in house or building.

Japanese excellent decarbonization technologies

- Construction field.
  - Prefabricated house
  - Environmental symbiosis design aided by simulation
- Building equipment field
  - Package air conditioner
  - Refrigerator for HVAC
  - Heat pump water heater
  - Lighting (LED)
  - Cogeneration technology(Fuel cell)
  - Battery
  - New concept PV (Perovskite)

(Package air conditioner, Refrigerator for HVAC:) Important technology in the rapid growth of cooling demand in Asia and Africa

- Home electric appliances
- Battery EV, Hydrogen vehicle, Charging/filling-up equipment
- Power distribution, city-gas supply.
- Water and sewage systems, waste treatment, and integration of these infrastructure and urban energy system.
- Energy management system consists of these devices and IoT system

Challenges of Japanese city/community

- While Japan excels in technology of each equipment, following points should be improved.
  - Systematization that integrates and optimizes each element in the city/community
  - Considering not only decarbonization but also achievement to SDGs, design ability to create attractive city/community such as excellent landscapes.
- To disseminate decarbonization technology, it should be transformed from a "calorie table in restaurant menu (only GHG reduction performance" to a "menu" itself that attracts the people, with co-benefits.

Plan for Global Warming Countermeasures：Bottom-up of countermeasures and estimated effect.

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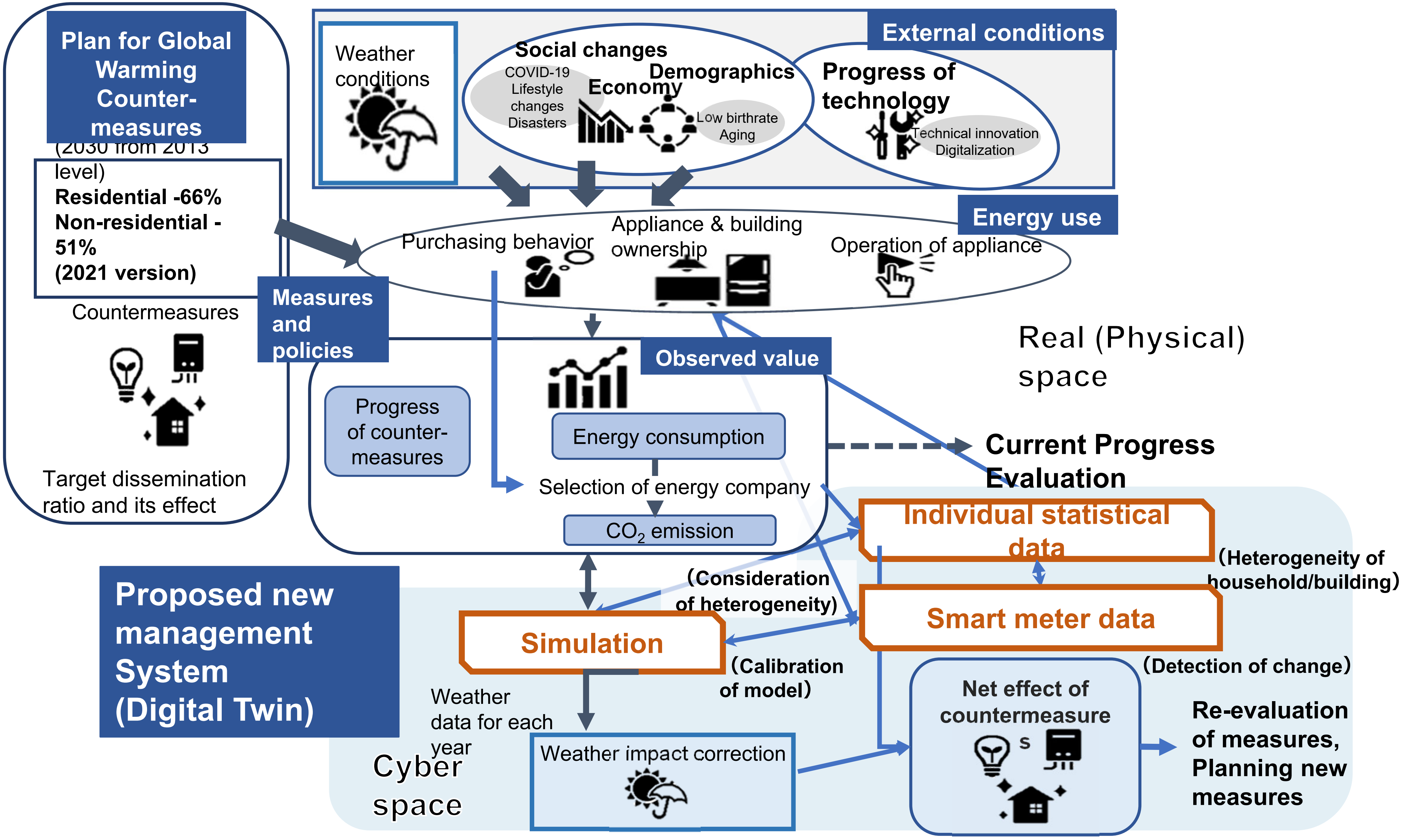
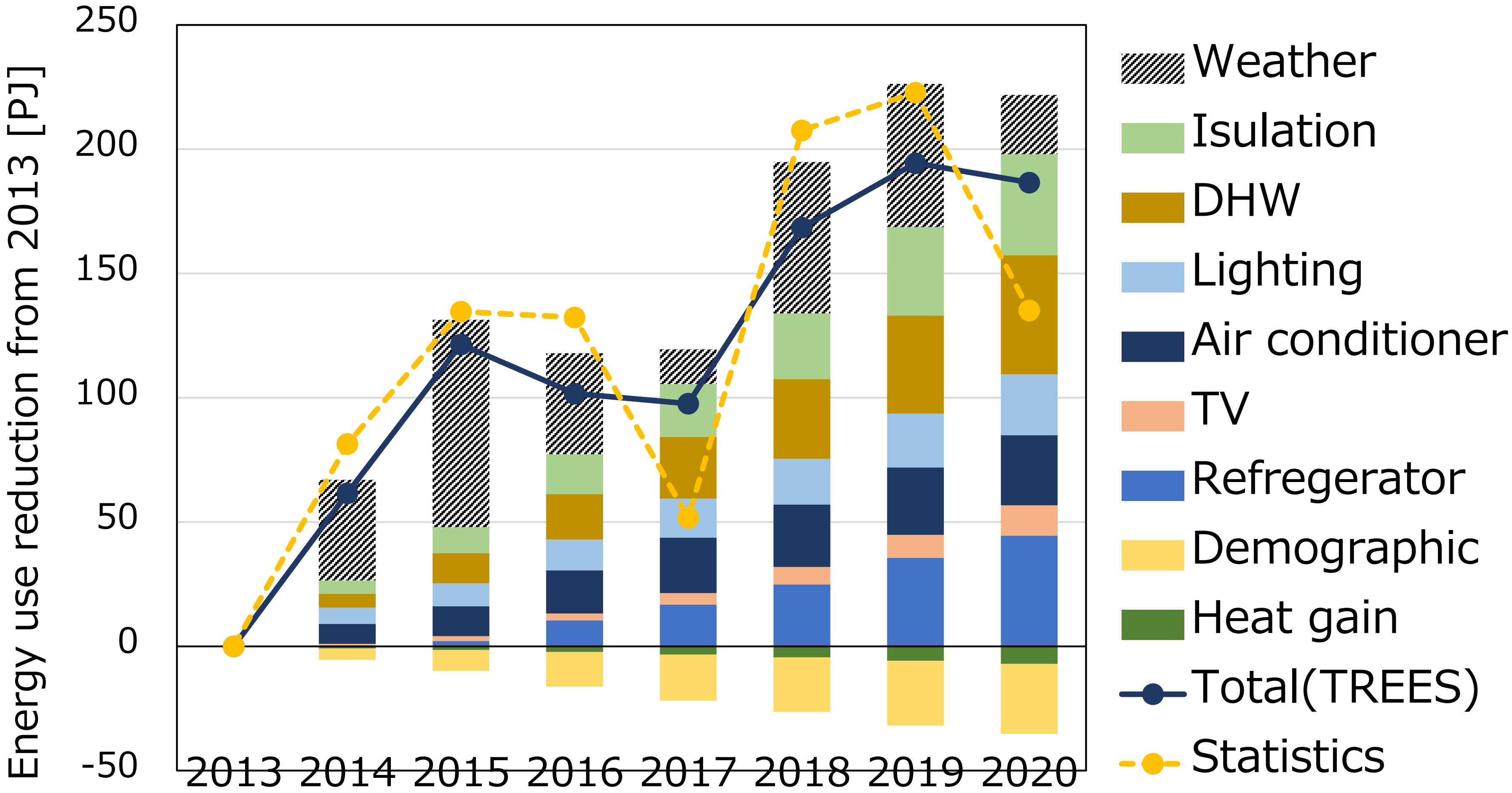
Countermeasures		2013	2030	Estimated Energy Demand Reduction [PJ]		
				Total	Electricity	Fuel
Energy saving standards for newly built houses		6%	30%	121.8	30.5	91.3
Insulation retrofitting of existing houses				16.5	4.3	12.2
Installation of high-efficiency water heaters [units]	Electric HP water heater	4,220,000	14,000,000	104.1	-10.2	114.3
	Condensing gas/oil water heater	4,480,000	27,000,000			
	Fuel cell cogeneration	55,000	5,300,000			
Installation of high-efficiency lighting devices		9%	Approximately 100%	77.9	77.9	0.0
Improvement in appliance energy efficiency by the top-runner Standard		–	–	51.7	40.6	11.1
Energy management by HEMS and smart meters		0.2%	Approximately 100%	69.1	69.1	0.0
Efforts by citizens (Cool Biz/Warm Biz [1 °C relaxation of set temperature] , promotion of appliance replacement, home energy auditing)		–	–	8.7	4.1	4.5
Total				449.8	216.4	238.5

Digital twin for carbon management



Shimoda et. al. eceee summer study 2022

Estimation result for Japanese Residential Sector



Energy conservation in the residential sector is about 10% behind the plan.

Fujiwara, Shimoda, Nakanishi, Proceedings of JSER (2022)

Thank you.