Doutoramento em Alterações Climáticas e Políticas de Desenvolvimento Sustentável

SEMINAR ENERGY & CLIMATE CHANGE

Missing energy topics you must be aware

Júlia Seixas
mjs@fct.unl.pt

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

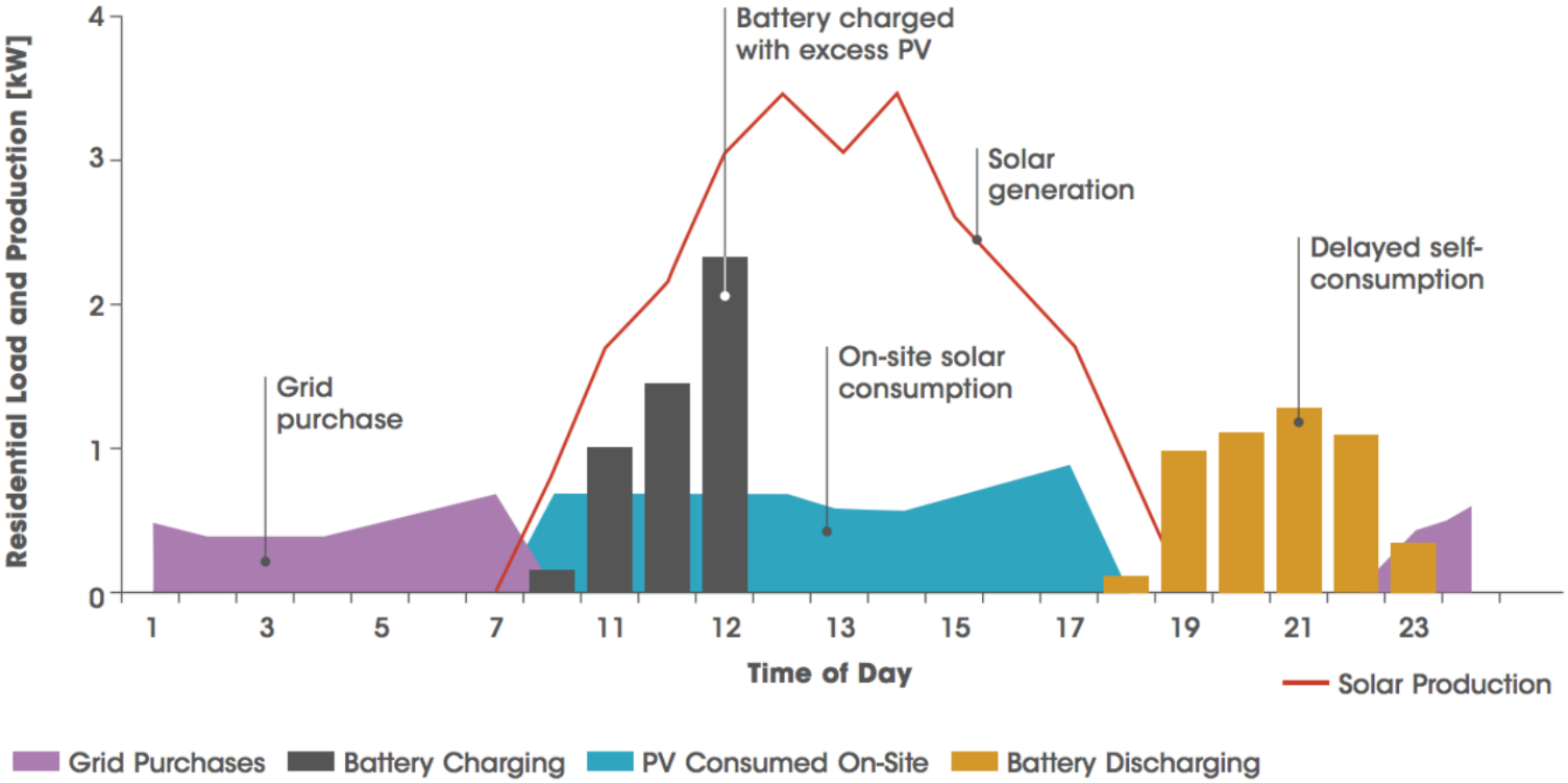
CENSE center for environmental and sustainability research

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

Aspects related with energy and climate change/sustainability not presented?

- **Energy storage**
- Energy security
- Energy-efficient and sustainable buildings
- Energy efficiency in industry
- **Sustainable mobility**
- Energy systems modelling tools
- Energy systems resilience to climate change
- Energy communities and prosumers
- Energy sustainability in cities, including supply chain
- **Natural resources and materials for energy systems**
- Environmental impacts of energy systems
- Digitalization of energy systems
- Artificial intelligence and big data for energy transition
- Energy markets
- Social aspects of energy transition
- (…)

Figure 5: Typical solar PV production and battery charging/discharging schedule



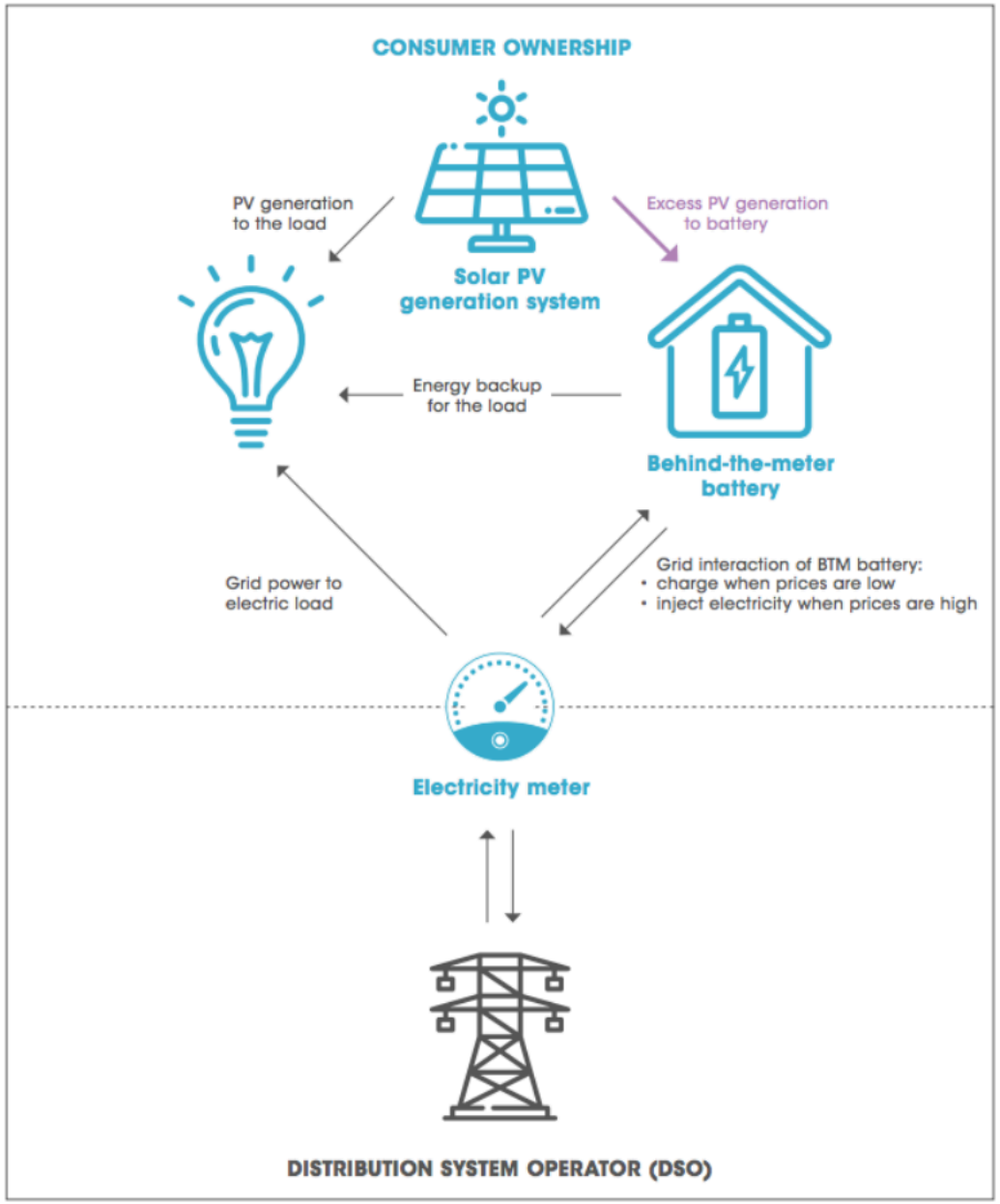
Source: Fitzgerald et al., 2015

Behind-the-meter (BTM) batteries

connected through electricity meters for commercial, industrial and residential customers. BTM batteries range in size from 3 kilowatts to 5 megawatts and are typically installed with rooftop solar PV

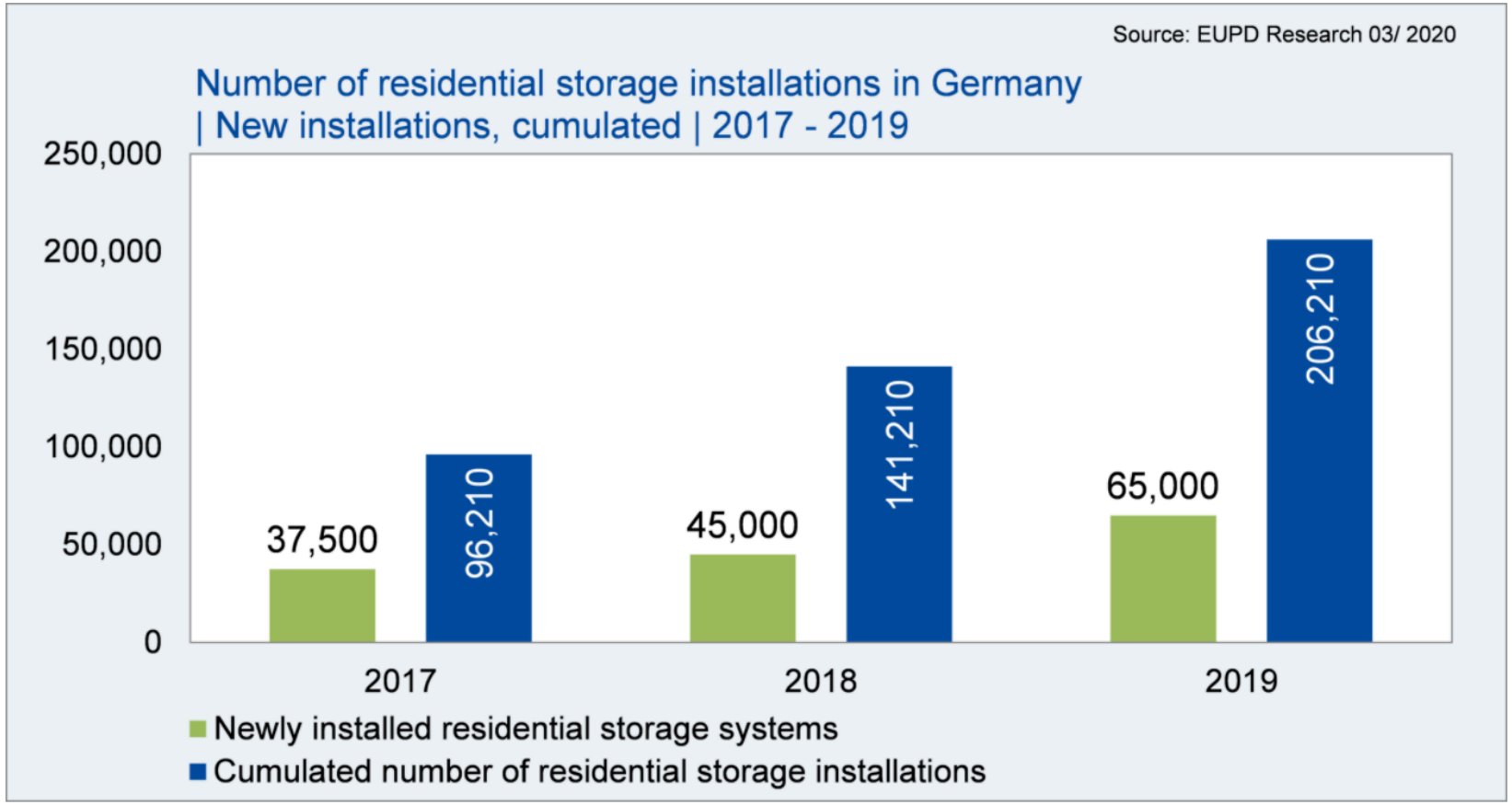
- Poway Unified School District in California installed a 6 MWh BTM storage system. The expected **savings of this project are around USD 1.4 million over 10 years**, and the main application is demand charge reduction (ENGIE Storage, 2018).

- Advanced Microgrid Solutions (AMS) completed a battery-based storage project for Morgan Stanley in the US, which resulted in a **20% peak demand reduction**, using 500 kW / 1 000 kWh Tesla Powerpack batteries. Peak demand charges for commercial and industrial consumers in the US can constitute up to 50% of their bill. This system is integrated into the existing building management system (Colthorpe, 2017b).



To know more about BTM batteries, read here (IRENA)

Behind-the-meter (BTM) batteries



How BTM may look like!

The average size of a residential energy storage system in Germany is about 4 kW, so the country installed about 260 MW of total capacity in 2019.
The total installed capacity of residential energy storage in the country is about 700 MW.

Stationary batteries (or grid scale)

Stationary batteries (or grid scale) can be connected to distribution/ transmission networks or power-generation assets. Utility-scale storage capacity ranges from several megawatthours to hundreds. Lithium-ion batteries are the most prevalent and mature type.

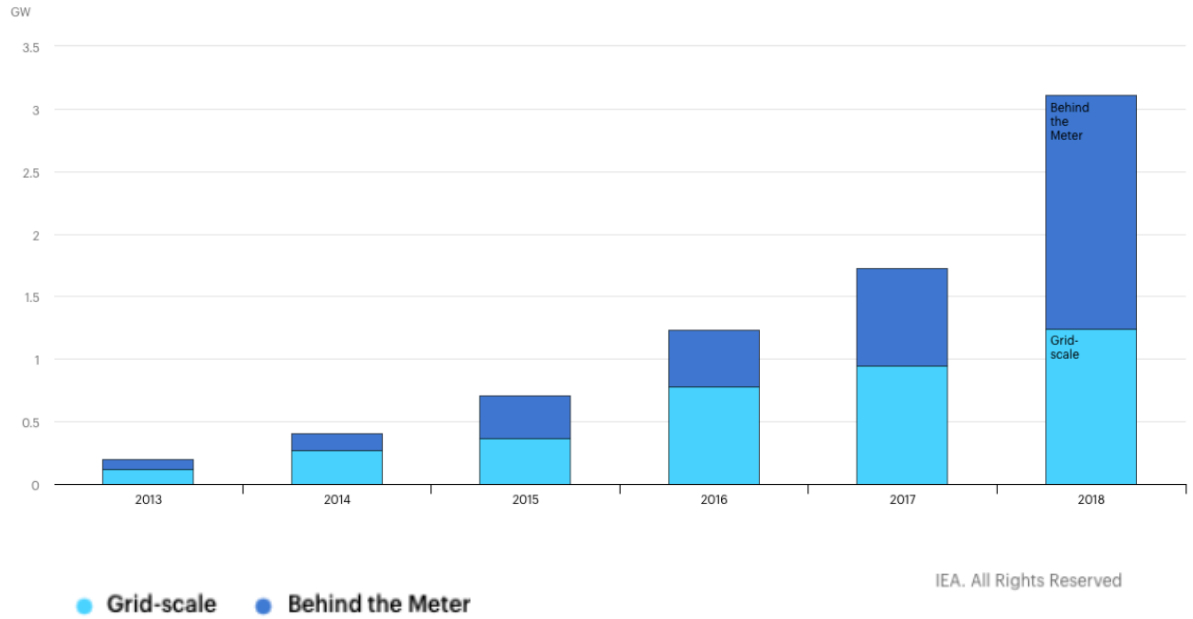
- A draft study commissioned by the State of New York estimated over **USD 22 billion in savings** if the state deployed about 11 500 MW of energy storage in lieu of traditional grid solutions by 2025 (NYSERDA, 2018).

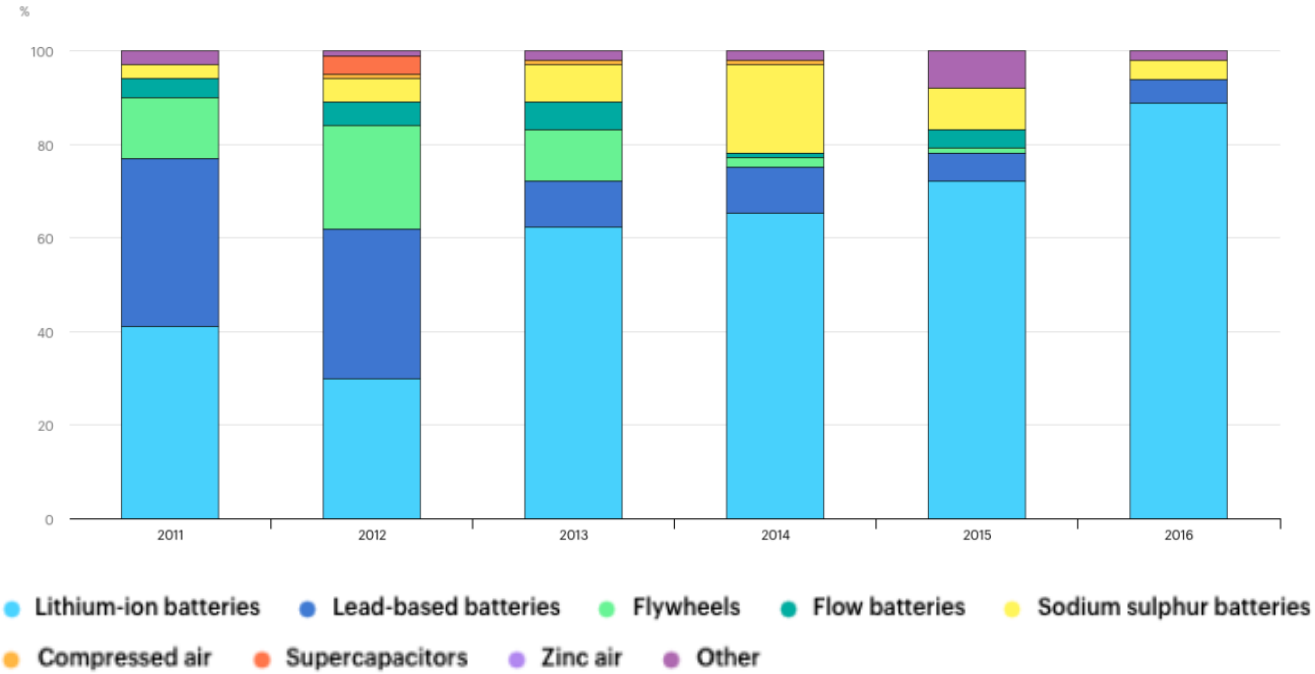
- In Martinique, the output of a solar PV farm will be supported by a 2 MWh energy storage unit, so that electricity will be injected into the grid at constant power, limited to 40% of the rated PV power. This will establish **solar PV as a predictable and reliable part of the island's energy mix**, with no need for additional back-up generation to compensate for the intermittent nature of renewable energy sources (DOE Global Energy Storage Database, 2019).

To know more about utility scale batteries, read here (IRENA)

Energy storage

Manufacturing capacity for lithium-ion batteries is expected to increase threefold by 2022, driven by the booming the EV market.





IEA, Technology mix in storage installations excluding pumped hydro, 2011-2016, IEA, Paris
https://www.iea.org/data-andstatistics/charts/technology-mix-in-storage-installations-excluding-pumped-hydro-2011-2016

Pumping storage

When there is excess capacity to produce electricity in periods of low consumption, this solution is used to transfer electricity from one period to another, by pumping water from a lower reservoir to another located at a higher height.

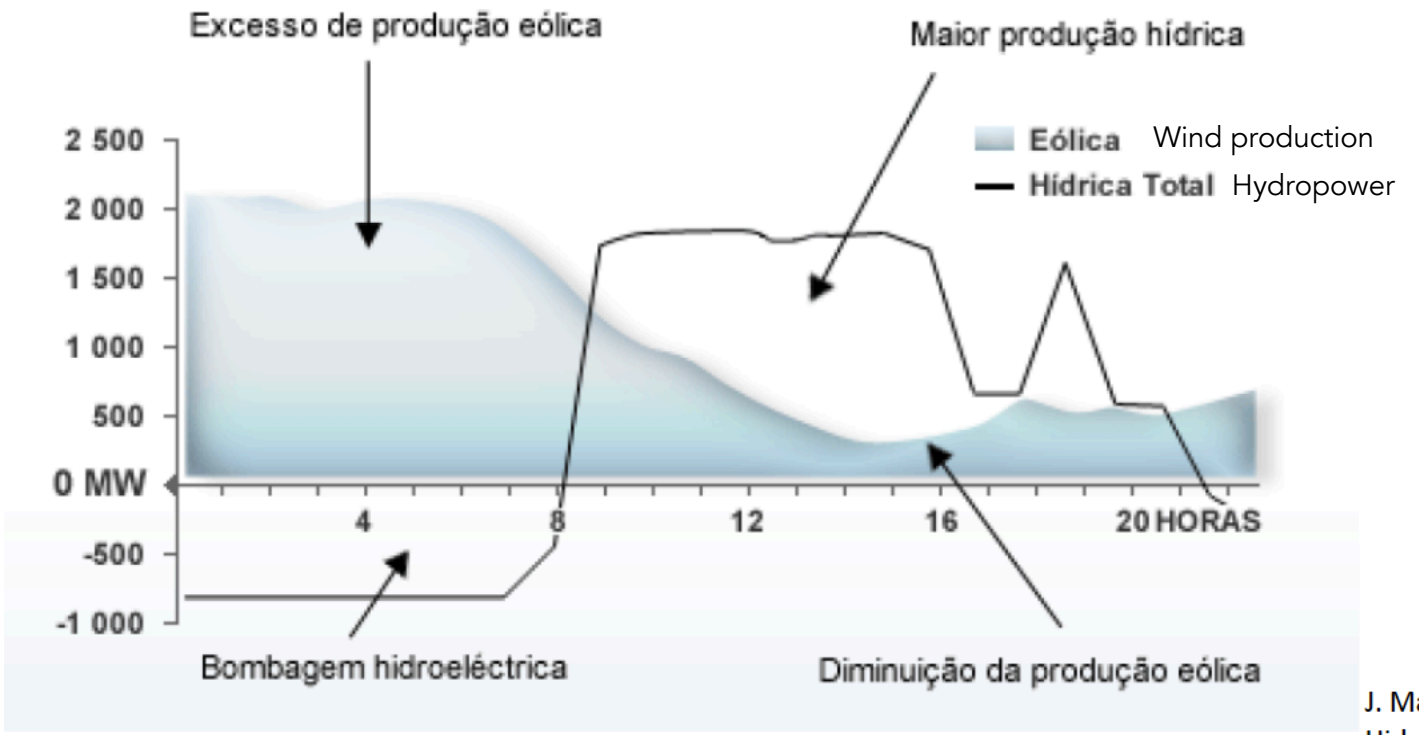
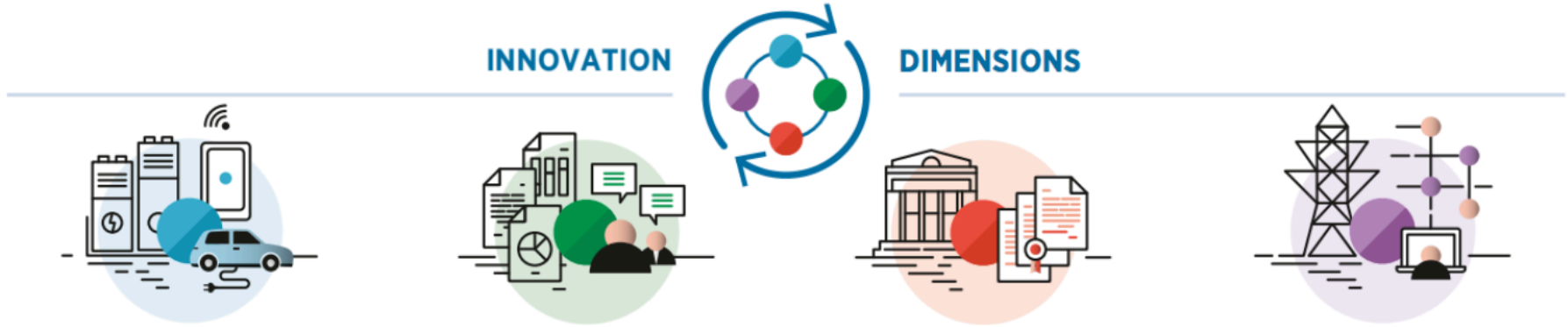


Figura 1 - Relação entre os gráficos de produção eólica e hidroeléctrica
(Fonte: www .a-nossa-energia.edp.pt)

J. Marques (2015) Hidroelectricidade e Barragens Reversíveis: Panorama actual, FCUP

Portugal: around 2,5 GW [2020: 2,7 GW | 2030: 3,6 – 4,1 GW, PNEC 2019]

Energy storage



ENABLING TECHNOLOGIES

1	Utility scale batteries
2	Behind-the-meter batteries
3	Electric-vehicle smart charging
4	Renewable power-to-heat
5	Renewable power-to-hydrogen
6	Internet of Things
7	Artificial intelligence and big data
8	Blockchain
9	Renewable mini-grids
10	Supergrids
11	Flexibility in conventional power plants

BUSINESS MODELS

12	Aggregators
13	Peer-to-peer electricity trading
14	Energy-as-a-service
15	Community-ownership models
16	Pay-as-you-go models

MARKET DESIGN

17	Increasing time granularity in electricity markets
18	Increasing space granularity in electricity markets
19	Innovative ancillary services
20	Re-designing capacity markets
21	Regional markets
22	Time-of-use tariffs
23	Market integration of distributed energy resources
24	Net billing schemes

SYSTEM OPERATION

25	Future role of distribution system operators
26	Co-operation between transmission and distribution system operators
27	Advanced forecasting of variable renewable power generation
28	Innovative operation of pumped hydropower storage
29	Virtual power lines
30	Dynamic line rating

IRENA, 2019

Energy efficiency means using less energy to get the same energy service.

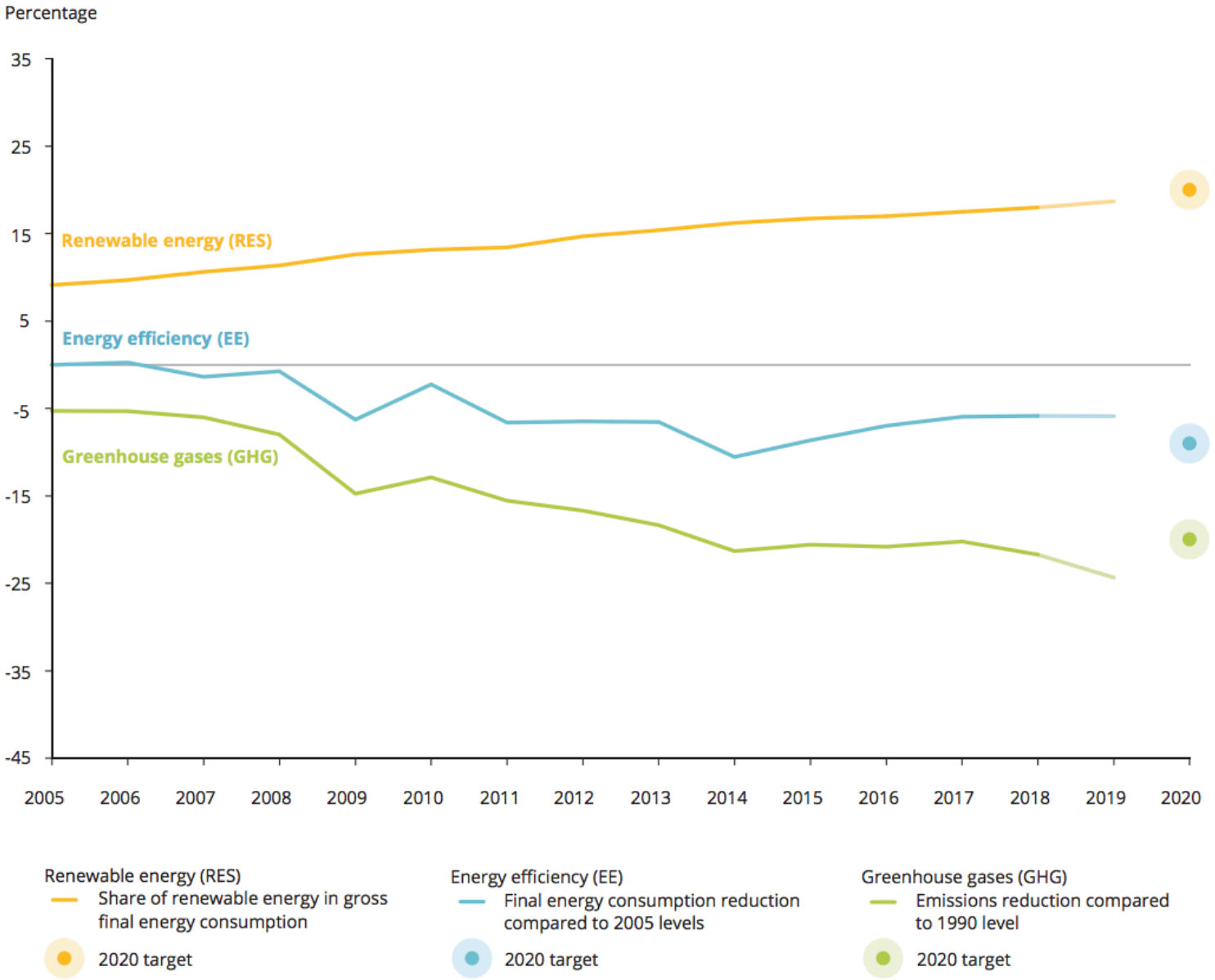
It is a technology based concept.

- **Light bulbs:** An LED light bulb uses 70-90% less energy than an incandescent light bulb, while providing the same illumination.
- **Windows:** Energy-efficient windows are made with materials that reduce heat exchange and air leaks, which means you don't need as much energy to heat or cool a space.
- **Insulation:** Adding more insulation to an attic keeps the warm air inside from escaping in the winter. In the summer, it keeps hot air out. With good insulation, you won't need to use as much energy to keep your house warm in the winter or cool in the summer.
- **Smart thermostats:** Smart thermostats are Wi-Fi enabled devices that control heating and cooling in your home by learning your temperature preferences and schedule to automatically adjust to energy-saving temperatures when you are asleep or away. They can help you lower your energy bills by not spending money to heat or cool an empty house.
- **Computer power management:** Computers can be set to automatically enter a low-power "sleep" mode when not in use.
- **Efficient equipment** (e.g. A+++) provide the same refrigeration, cooling or heating service levels with less energy consumption than less-efficient equipment.

Turning the lights off is not a measure of energy efficiency.

Energy efficiency

Figure ES1.2 Historical trends and progress to 2020 and 2030 targets of the EU-28



Target 2020 Europe
20% improvement
in energy efficiency
compared with BAU
(business as usual)

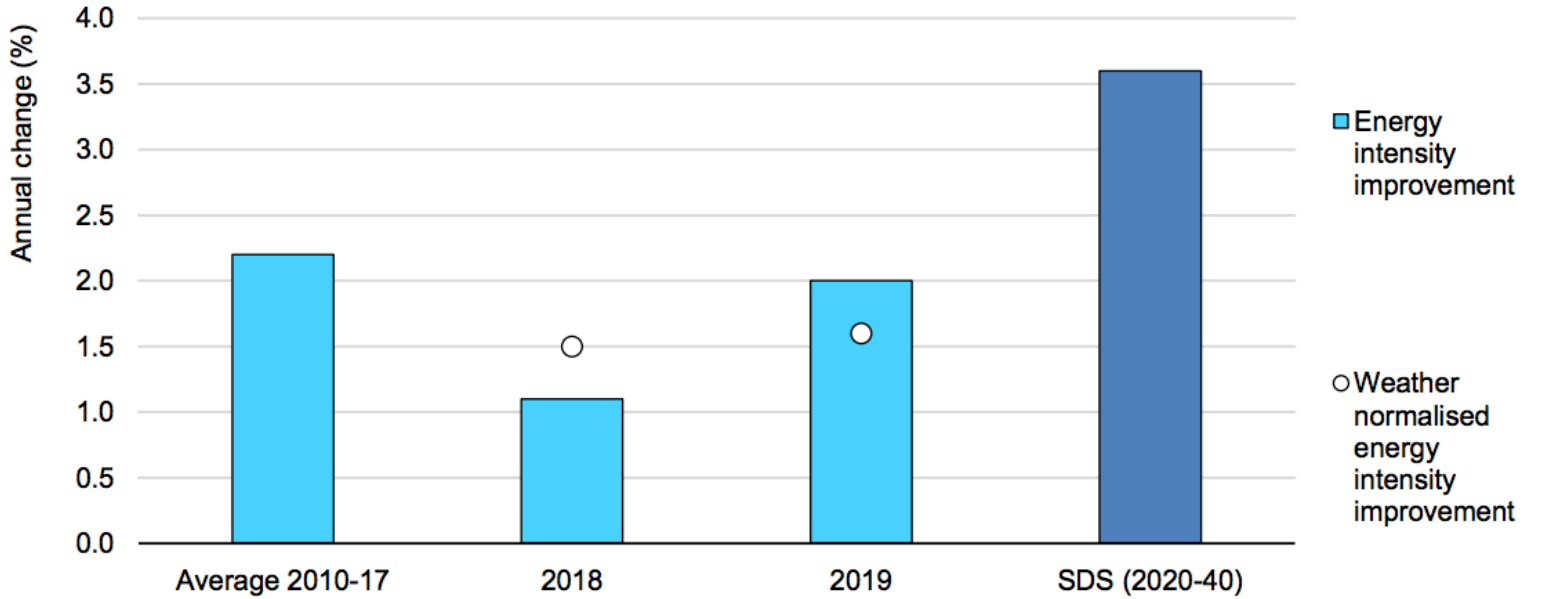
Target 2030 Europe
32,5 % improvement

Energy efficiency

Global primary energy intensity improved by 2% in 2019, compared with 1.1% in 2018.

Energy intensity is the ratio between energy consumption and GDP.

Figure 1.1 Average annual change in primary energy intensity improvement, historically and in the IEA Sustainable Development Scenario



Note: SDS = IEA Sustainable Development Scenario.

Source: IEA, Global Energy Review 2019.

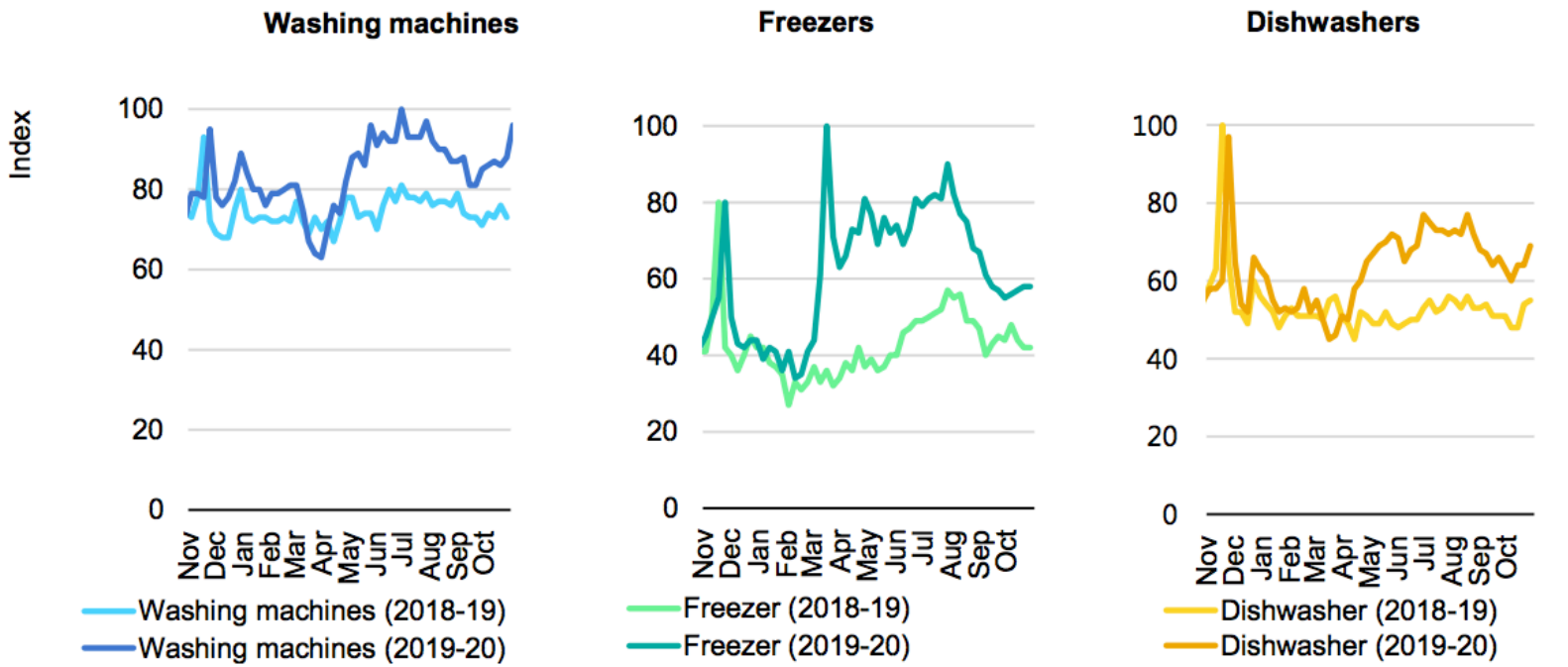
1 - **Technical energy efficiency improvements** were crucial, offsetting almost half of the potential increase in global energy demand that would have occurred due to economic growth.
2 - **Global economic growth itself was significantly lower** in 2019, at 2.9% compared with 3.6% in 2018.
3 - **More temperate weather** in key parts of the world reduced the need for coal, gas and electricity for heating and cooling, which so energy demand was over 10% lower than would have been expected from economic activity.

In the short term, the Covid-19 pandemic is likely to have improved the technical efficiency of the appliance stock, as increased time spent at home appears to have boosted purchases of new appliances, which tend to be more efficient than older models.

Read more here

Lockdowns spur purchases of new appliances in the short term, which could bolster technical efficiency

Figure 3.2 Worldwide weekly online shopping search indices for selected whitegoods, 2018-19 and 2019-20



Notes: Worldwide searches within the Shopping category for the following topics: washing machine, freezer, dishwasher. Figures are indexed to the highest value. "Worldwide" refers to all countries where the Google search engine is available, and therefore excludes China.

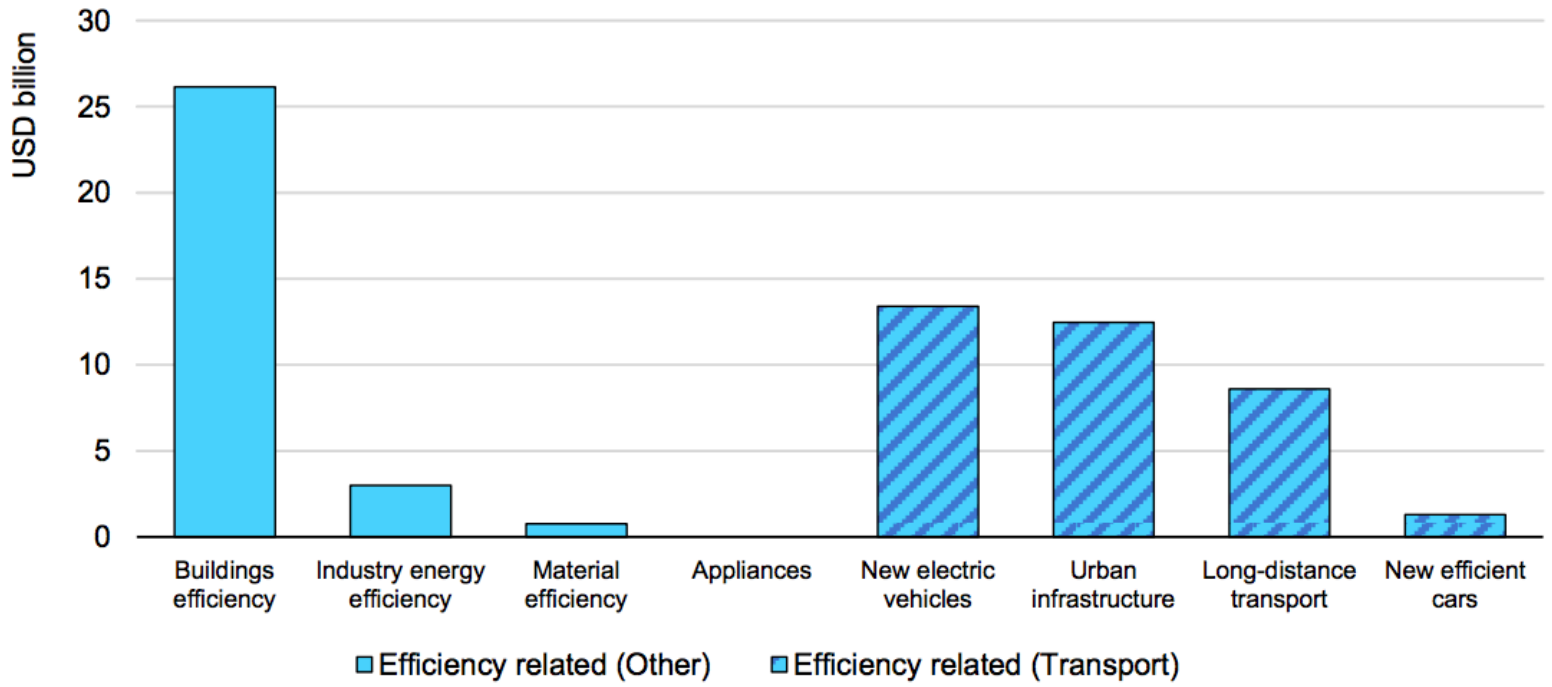
Source: Google Trends.

Energy efficiency

Spending on efficiency is becoming a large part of governments' clean energy stimulus spending (USD 114 billion of public spending in the energy sector).

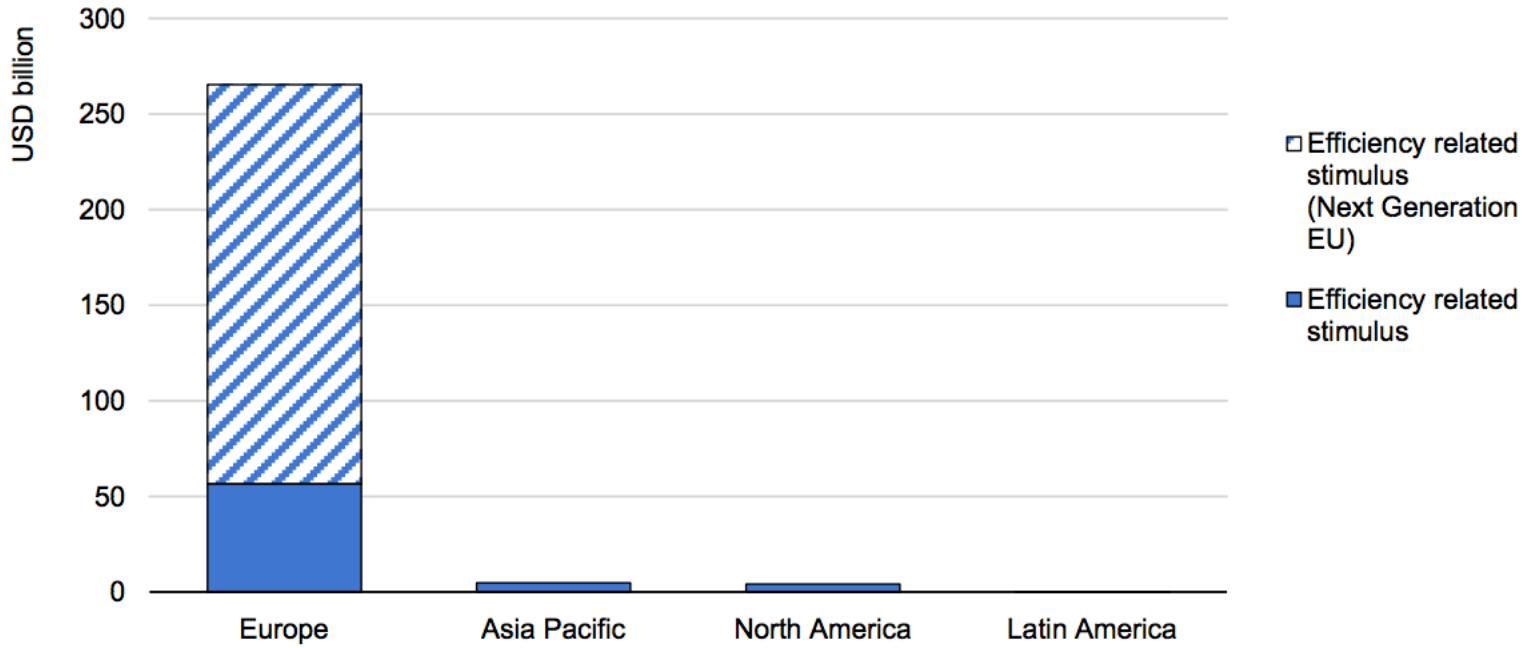
Around **58% of public clean energy stimulus** spending announced to the end of October 2020, totalling USD 66 billion, has been allocated to **energy efficiency related measures**. The announced efficiency-related stimulus has the potential to create 5 million energy efficiency job-years, when factoring in leveraged private investment.

Figure 7.3 Announced public efficiency-related stimulus funding by measure, to end of October 2020



Energy efficiency

Figure 7.4 Announced public energy efficiency stimulus funding by region, to end of October 2020

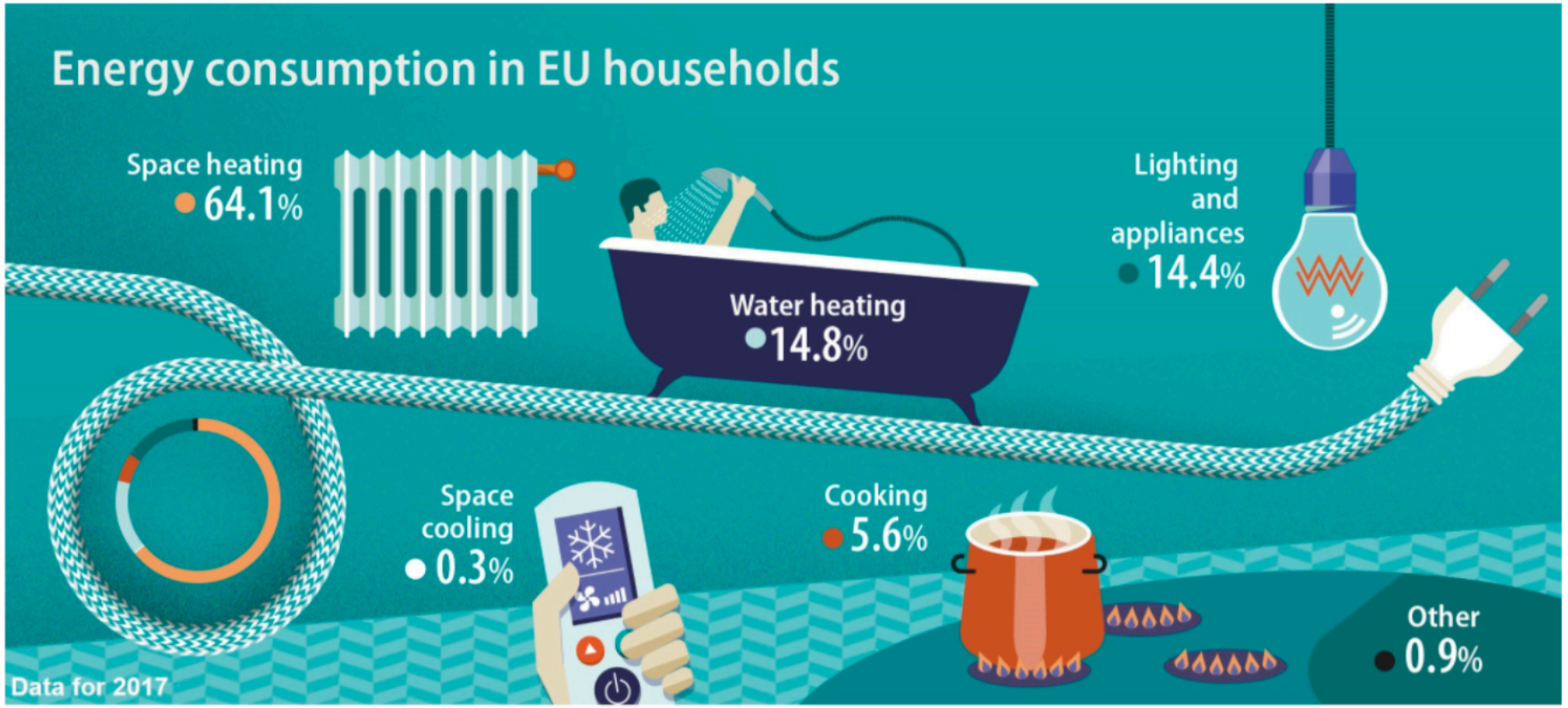


Note: Next Generation EU funds are estimates because at the time of writing, details on spending are yet to be finalised. Estimated spending has been calculated based on funding patterns observed in past EU programmes.

European governments have been the most active in announcing support for efficiency-related measures. Around USD 57 billion of spending proposals (or 86% of global stimulus announcements for efficiency) has been announced by European governments to the end of October, with the remaining 14% split between Asia Pacific and North America. Of European announcements, the largest are from France, Germany and Italy.

Buildings

In EU roughly 75% of the building stock is energy inefficient, yet almost 80% of today's buildings will still be in use in 2050.



Households: 27.2% of final energy consumption in the EU (2017).
natural gas (36.0%) | electricity (24.1%) | Renewables (17.5%) | oil products (11.2%) and derived heat (7.6%) | coal products (3.3%)

Buildings

Several measures in place:

- Energy Efficiency Directive
- Renovation (rehabilitation)
- Energy Performance Certificates
- Smart meters (really smart)
- Mobilise retail consumers (through dedicated Apps: www.cloogy.pt/)
- Funding schemes
- Energy performance contracting schemes (EPCs) offered by Energy Service Companies (ESCO),
- Green bonds
- State-aid funds (Fundo para a Eficiência Energética, PT)
- Signal Prices (pay as you consume)

Buildings

Positive Energy District

Positive Energy Districts and Neighbourhoods are an integral part of comprehensive approaches towards sustainable urbanisation including technology, spatial, regulatory, financial, legal, social and economic perspectives.

Read more here

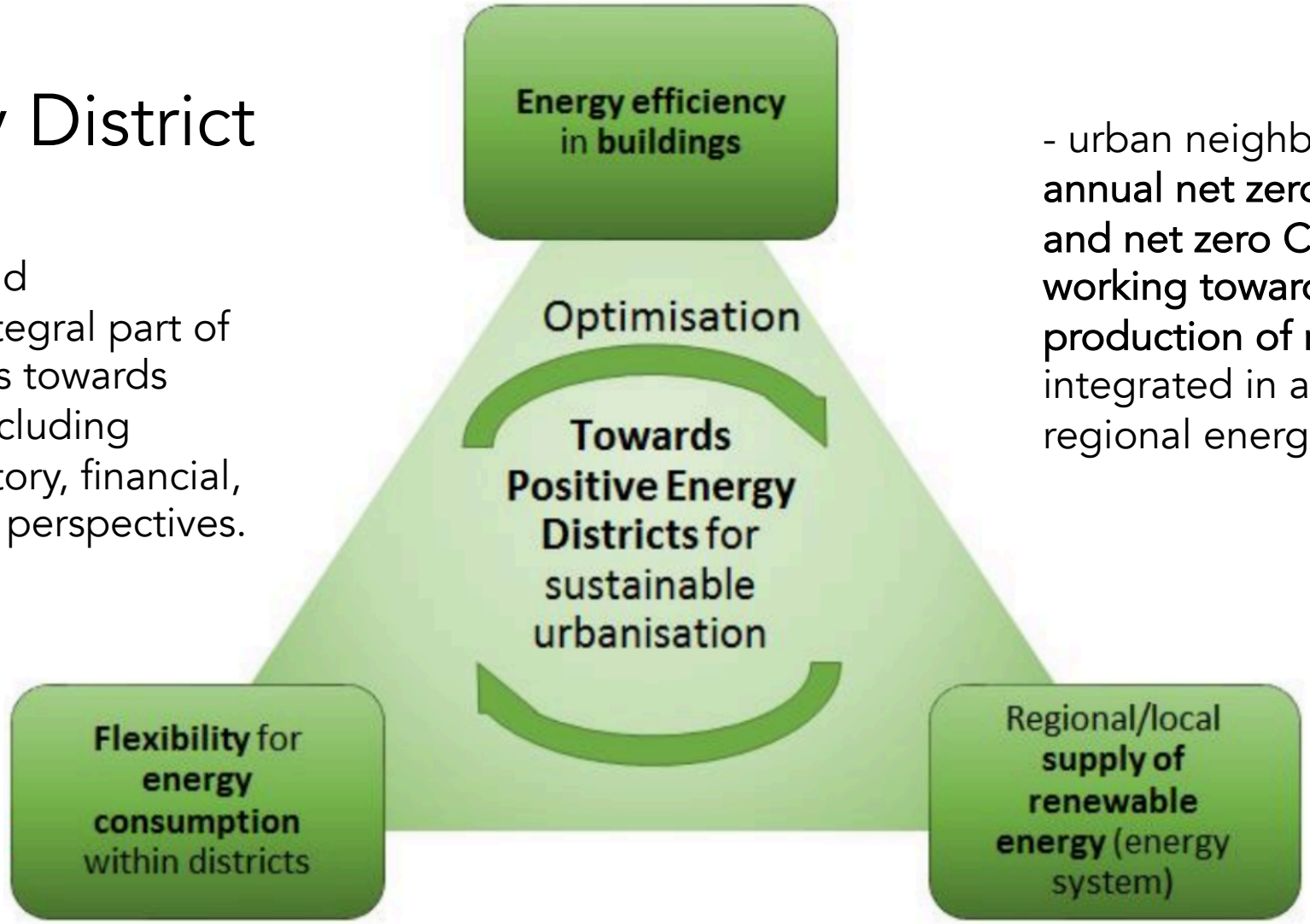


Figure 5: Definition of Positive Energy Districts

- urban neighbourhood with **annual net zero energy import and net zero CO_2 emissions working towards a surplus production of renewable energy**, integrated in an urban and regional energy system.

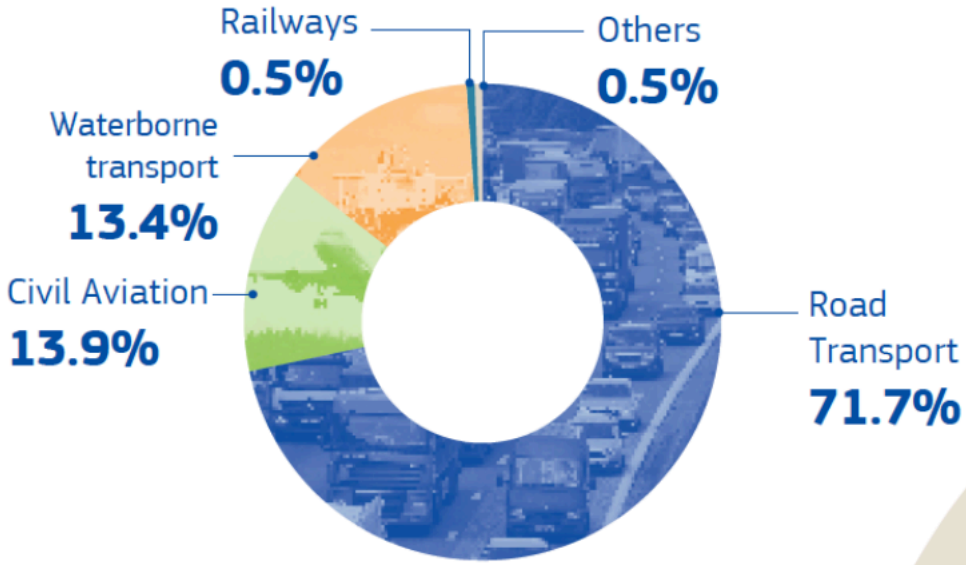
NOVA SCHOOL OF SCIENCE & TECHNOLOGY

Europe must reduce emissions from transport further and faster.

Transport accounts for a quarter of the Union's greenhouse gas emissions and these continue to grow. The Green Deal seeks a **90%** reduction in these emissions by **2050**.

90% reduction greenhouse gas emissions in transport by 2050

Share of Greenhouse Gas Emissions by Mode of Transport (2017)



Source: Statistical pocketbook 2019

Go digital

- **Automated mobility and smart traffic management systems** will make transport more efficient and cleaner.
- **Smart applications** and **'Mobility as a Service'** solutions will be developed.

EU, Sustainable Mobility Factsheet (2020)

Use different modes of transport

More freight should be transported by rail or water. And the **Single European Sky** should significantly reduce aviation emissions at zero cost to consumers and companies.

Single European Sky reform will help to cut up to **10%** of air transport emissions.

Prices that reflect impact on environment

Ending subsidies for fossil-fuel

Extending emissions trading to the maritime sector

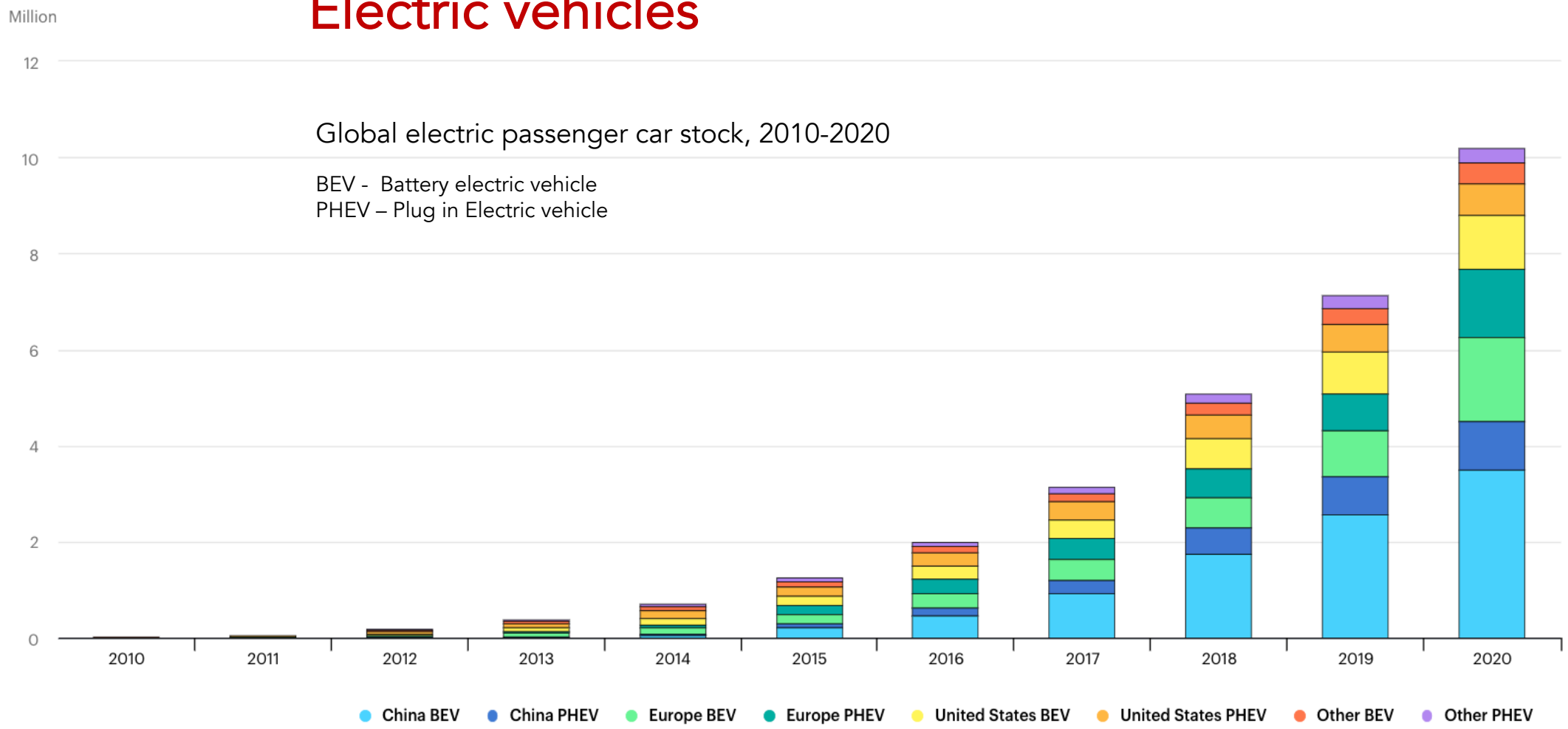
Effective road pricing in the EU

Reducing free allowances to airlines under emissions trading

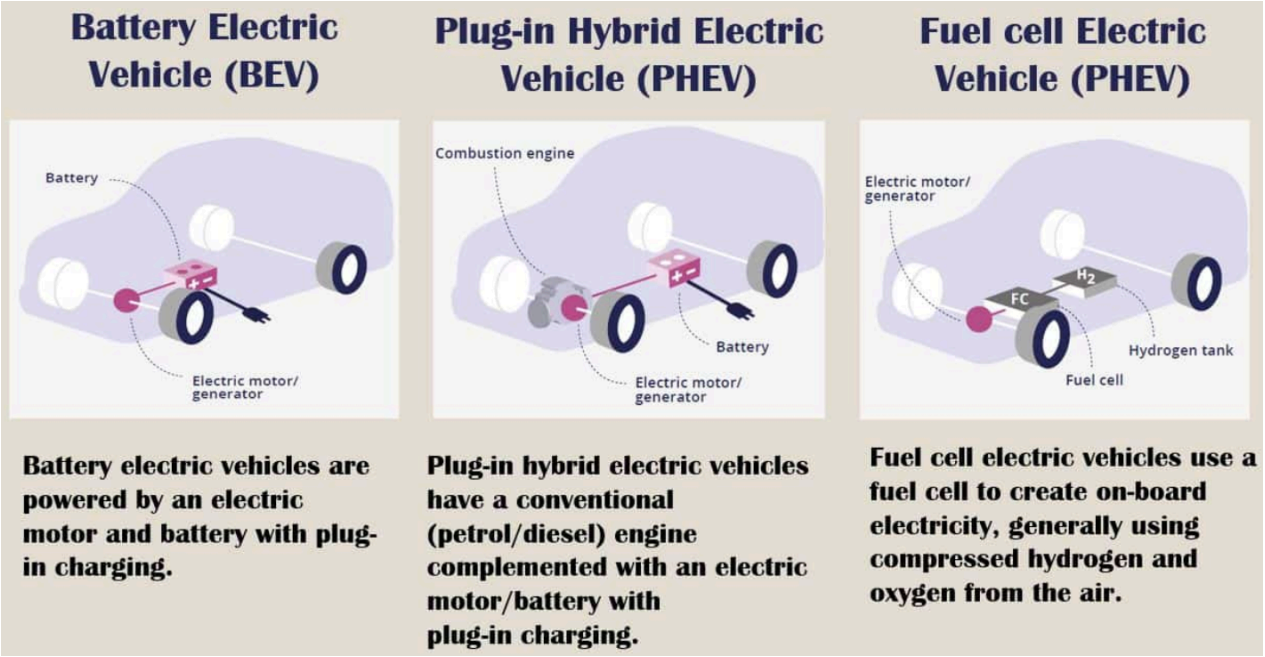
NA-02-19-958-EN-C
NA-02-19-958-EN-N

EU, Sustainable Mobility Factsheet (2020)

Electric vehicles



More than 10 million electric cars were on the world's roads in 2020 with battery electric models driving the expansion
Electric cars had a record year in 2020, with Europe overtaking China as the biggest market



what will be the role of H2?

TRL: 8

around 10.000 vehicles sold (2014-2019)
Car manufacturers:
Toyota, Hyundai, Honda, Mercedes-Benz (light duty vehicles/vans), Ford (vans)

what will be the role of H2?

TRL: 7-8

+ de 10 M kms up to 2019

Daimler (fuel cell da Ballard Power Systems), Thor Industries e Irisbus (fuel cell from UTC Power), Caetano Bus (fuel cell Toyota)

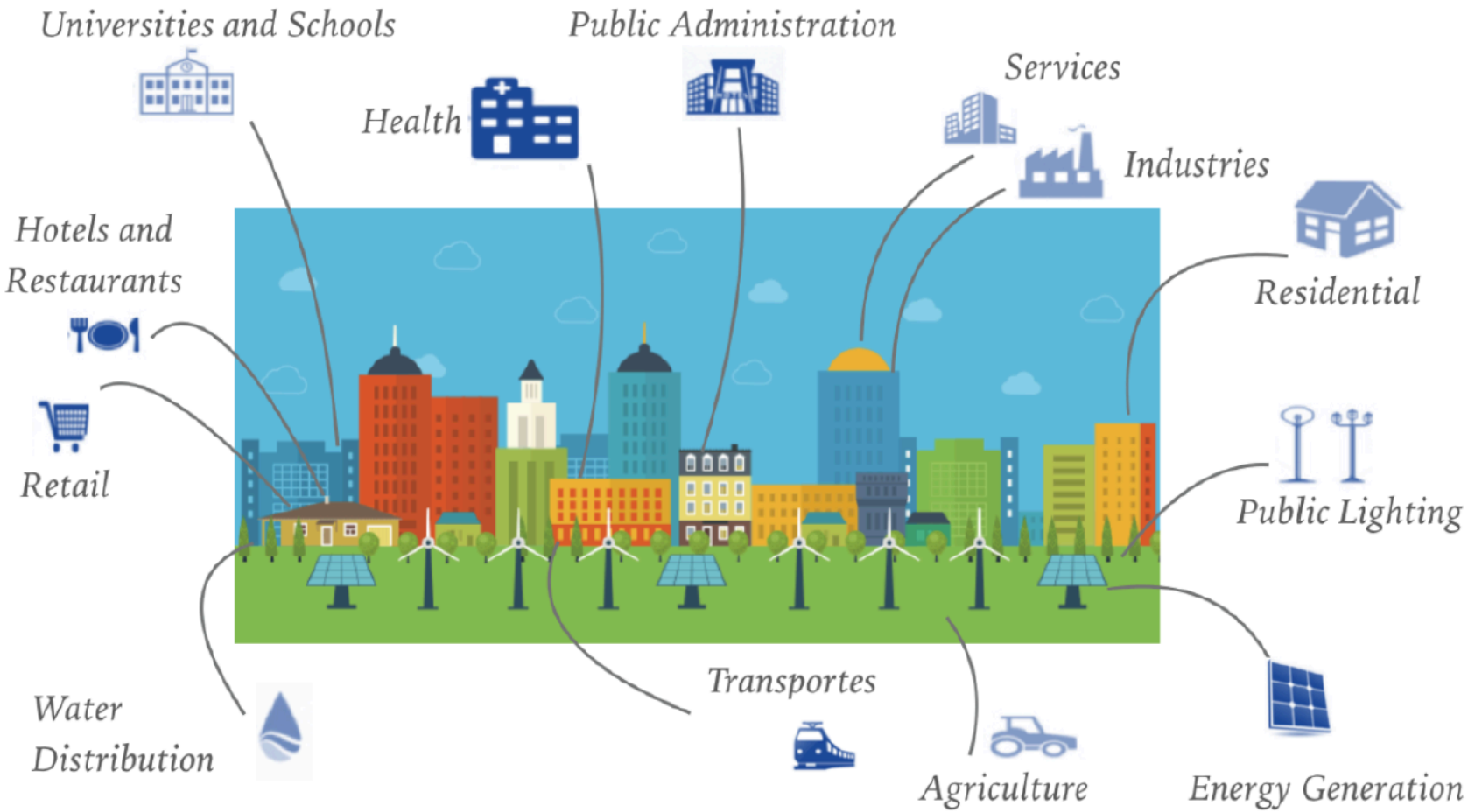
TRL: 7

Alstom iLint. since 2018 in Germany in regular passenger trains
Other manufacturers:
CRRC TRC (Tangshan) produced in 2017 a passenger light train system running in that chinese city

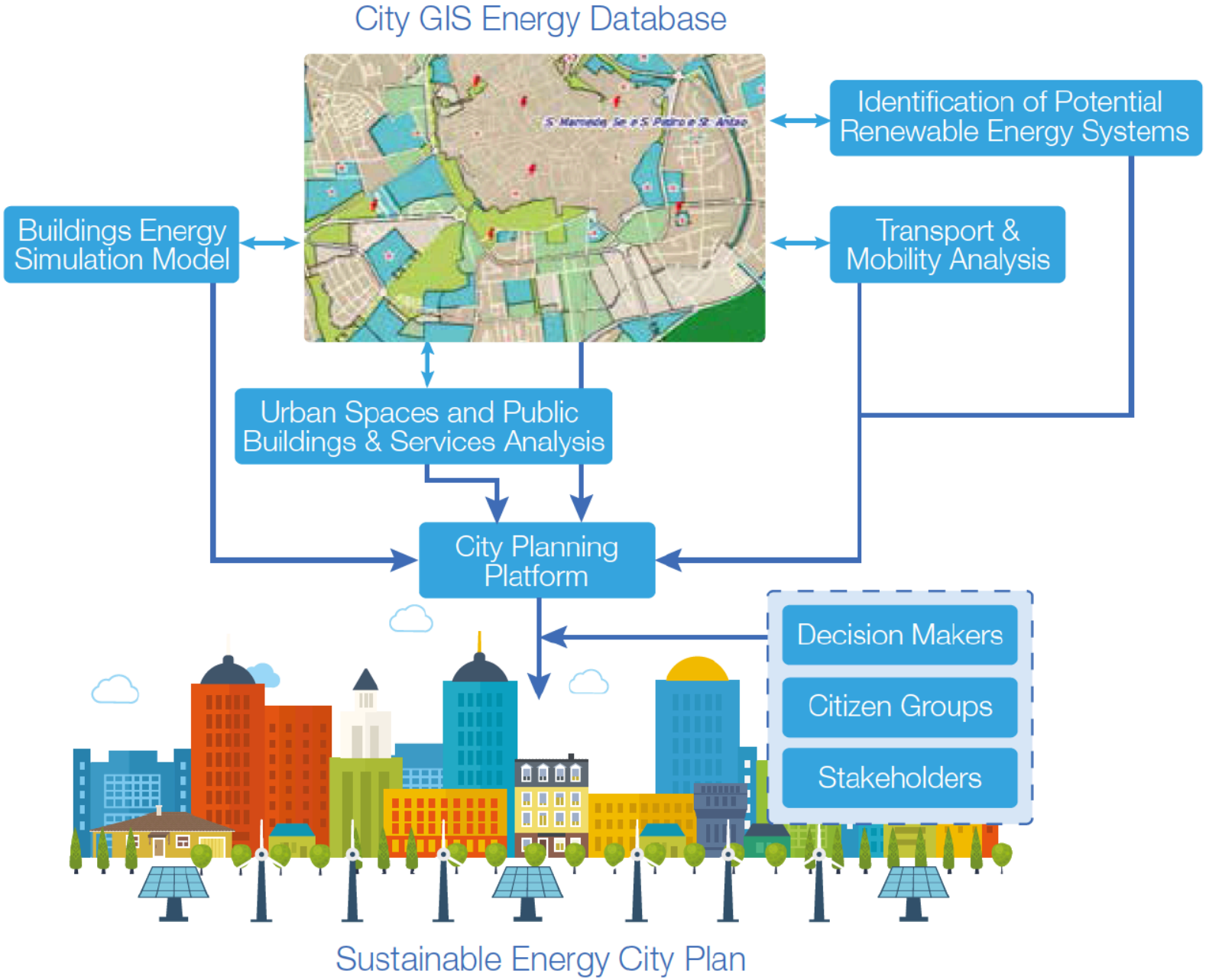
TRL: 5-6

Only functional prototypes manufacturers:
Boeing, Pipistrel, Zeroavia
LMG Marin and partner Westcon Power & Automation, Hydra

High resolution data integration

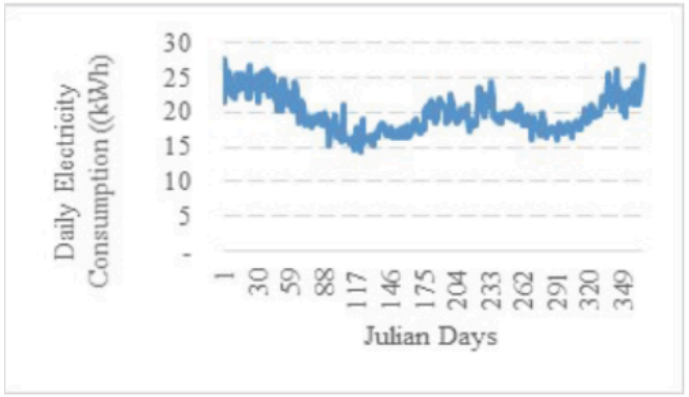


Energy sustainability in cities

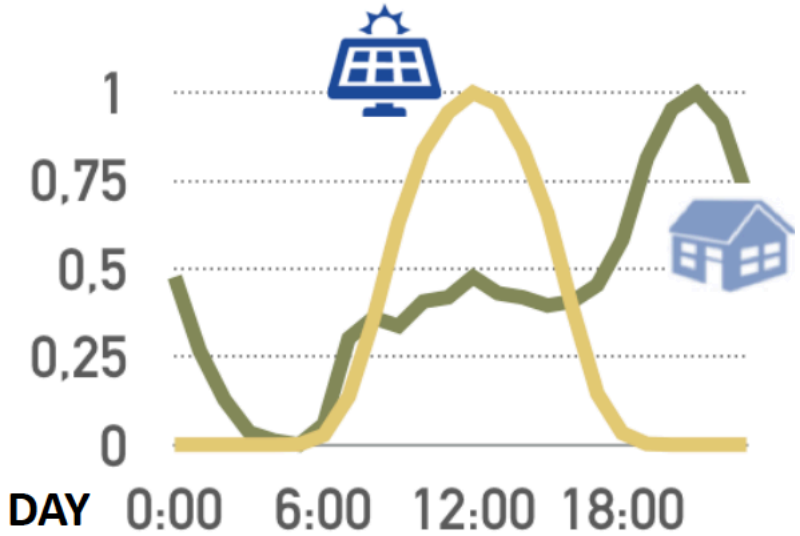


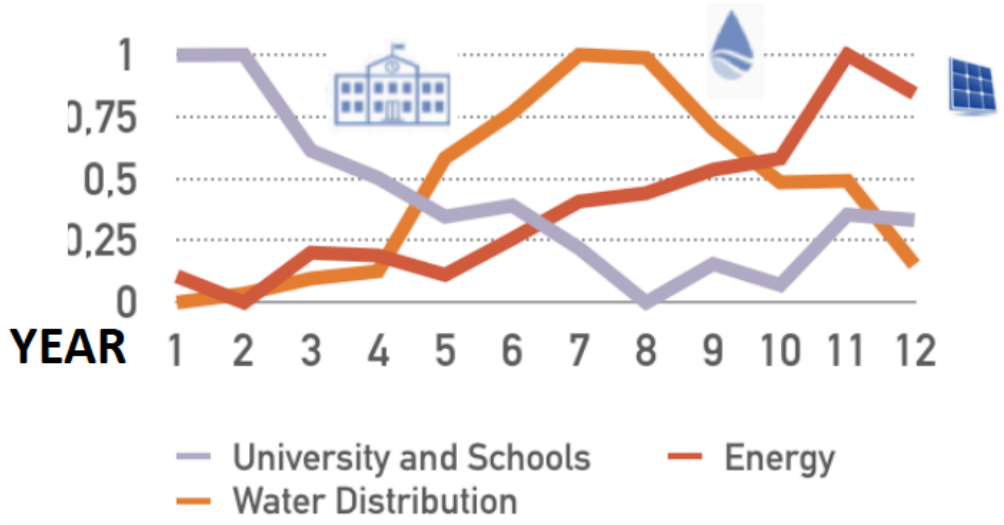
Energy sustainability in cities

U profile (soft): Fuel Poverty
Small houses (< 90m²)
Single glazing, rented houses
2 pax/house, > 65 years old,
low education level
Average income < 750€ monthly



W profile: 'Fat Energy' households
Rural very recent houses (>160 m²)
Double glazing
4 pax/house; 60% with 18-49 years old
50% with income > 2500€
Medium-high class





Gouveia, J.P., Seixas, J. (2016). Unraveling electricity consumption profiles in households through clusters: Combining smart meters and door-to-door surveys. Energy and Buildings. 116, 666–676.

Impacts on Sustainability: land use

Biggest solar farm in the world: Bhadla Solar Park, Rajasthan, India:
total installed capacity of 2,245 MW, spread over a total area of 5,700 ha

PV systems required, on average considering various technologies, a total area between **2.5 and 3.3 ha / MW**. (Ong et al, 2013; NREL)

Total area: all the land bounded by the project on site, including land directly occupied by solar panels, access roads, substations, service buildings and other infrastructures.

Worldwide | 2030
4000 GW (IEA) - 13 million ha
(1300 times the area of the city of Lisbon!)

Impacts on Sustainability: land use

Iberdrola has commissioned the largest PV plant in Europe – the 500 MW Núñez de Balboa project (Badajoz)

Potential assessment of solar production in **Europe (NUTS2)** GIS-based land-restriction scenarios: irradiation data, available area for solar applications. (Ruiz, 2019)[1]

Total EU potential solar power capacity and production in such a scenario amounts to 10,000 GW, covering **1,4% of the total EU area**.

[1]ENSPRESO - an open, EU-28 wide, transparent and coherent database of wind, solar and biomass energy potentials. https://doi.org/10.1016/j.esr.2019.100379

Impacts on Sustainability: land use

Country	Total share of area available for ground mounted	Land-use category with largest share
AT	30%	Pastures (11%)
BE	49%	other arable (21%)
BG	50%	other arable (28%)
CY	46%	other arable (38%)
CZ	49%	other arable (22%)
DE	44%	cereals (14%)
DK	63%	other arable (29%)
EE	23%	other arable (14%)
EL	43%	other arable (20%)
ES	48%	other arable (21%)
FI	3%	cereals (3%)
FR	53%	other arable (19%)
HR	17%	cereals (10%)
HU	63%	other arable (24%)
IE	60%	Pastures (44%)
IT	49%	other arable (26%)
LT	54%	other arable (33%)
LU	36%	Abandoned (15%)
LV	28%	other arable (12%)
MT	39%	other arable (21%)
NL	53%	Pastures (21%)
PL	50%	cereals (21%)
PT	35%	other arable (19%)
RO	59%	other arable (19%)
SE	5%	other arable (3%)
SI	30%	other arable (16%)
SK	43%	other arable (22%)

(Ruiz et al, 2019)

Total shares of available area for ground-mounted solar per country (based on exclusion criteria from Ruiz et al, 2019) and the land-use category providing the highest contribution to the total share.

Other arables the most frequent land use category
Then, cereals and pastures!

Cost of opportunity of land use (PV 25 years at least!)

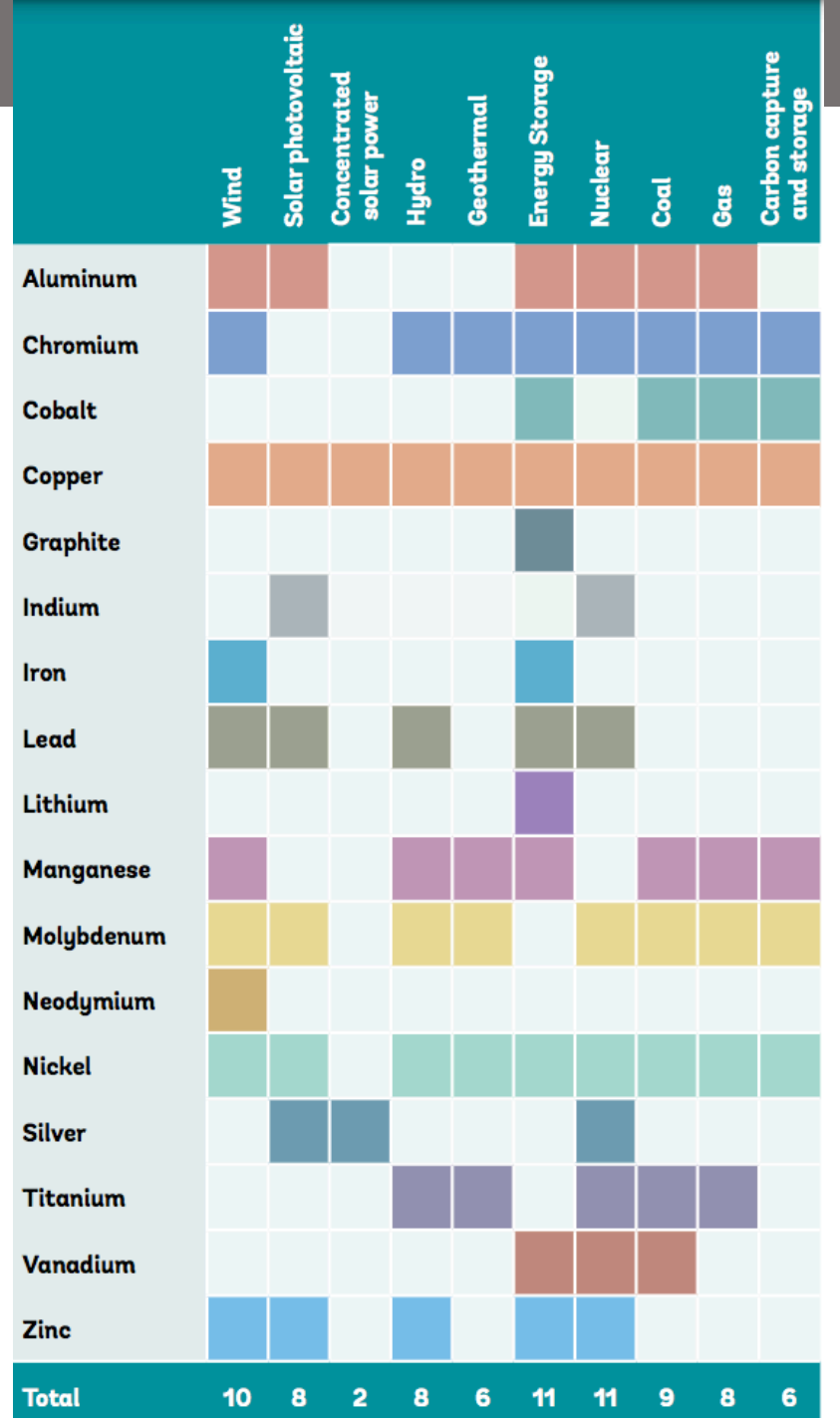
Fragmentation of ecosystems – Impact on Biodiversity

Impacts on Sustainability: mineral extraction

Table 1
Minerals required for green energy technologies

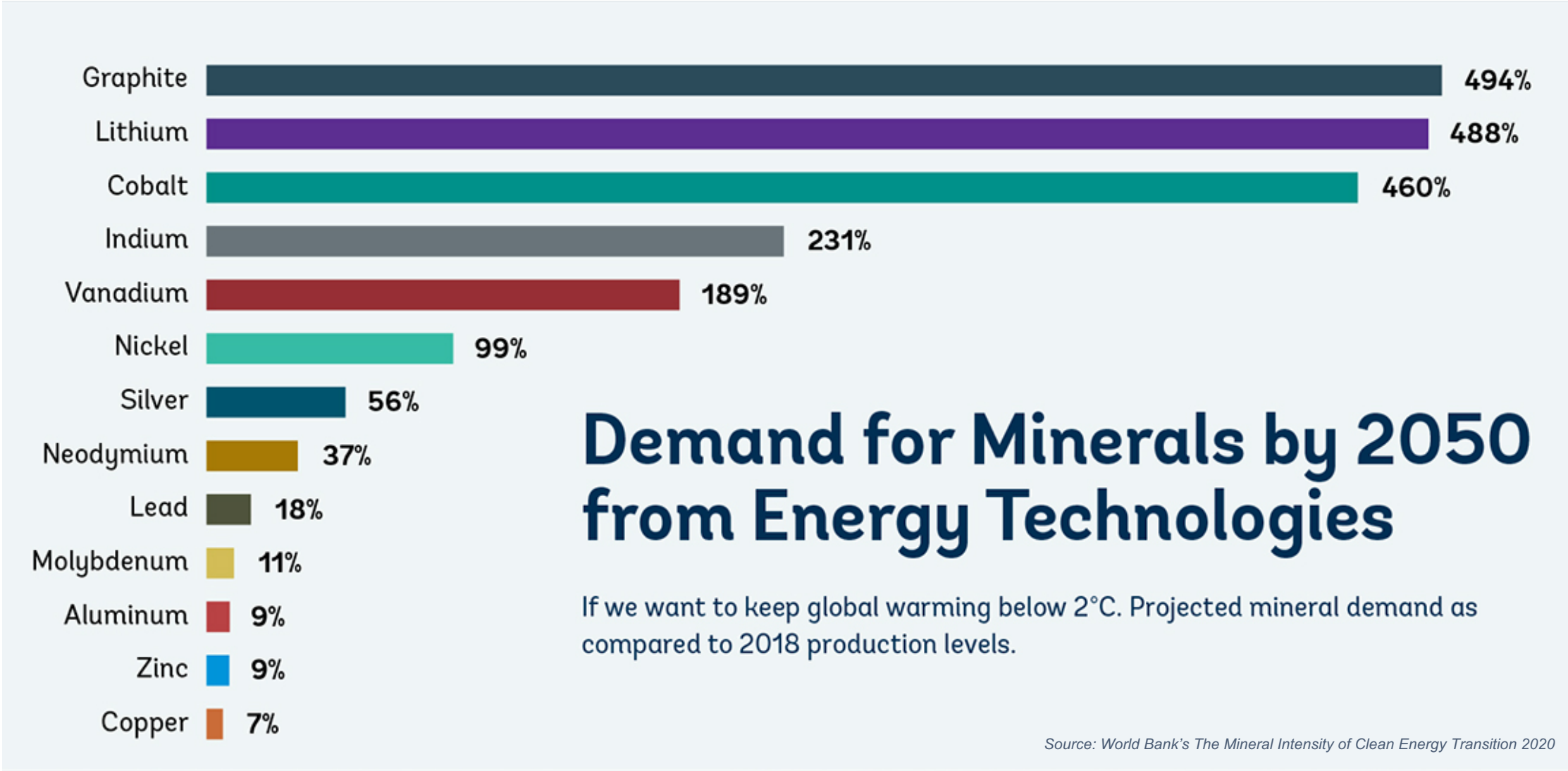
Green energy technology	Minerals required
Solar	Bauxite & Alumina, Cadmium, Copper, Gallium, Germanium, Indium, Iron, Lead, Nickel, Selenium, Silicon, Silver, Tellurium, Tin, Zinc
Wind	Bauxite & Alumina, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Molybdenum, Rare Earths, Zinc
Electric vehicles and energy storage	Bauxite & Alumina, Cobalt, Copper, Graphite, Iron, Lead, Lithium, Manganese, Nickel, Rare Earths, Silicon, Titanium

Source Data primarily from the World Bank (2017), Levin Sources (2017a, b), USGS (2017), Bloomberg New Energy Finance (2018) and the American Exploration & Mining Association (2013)



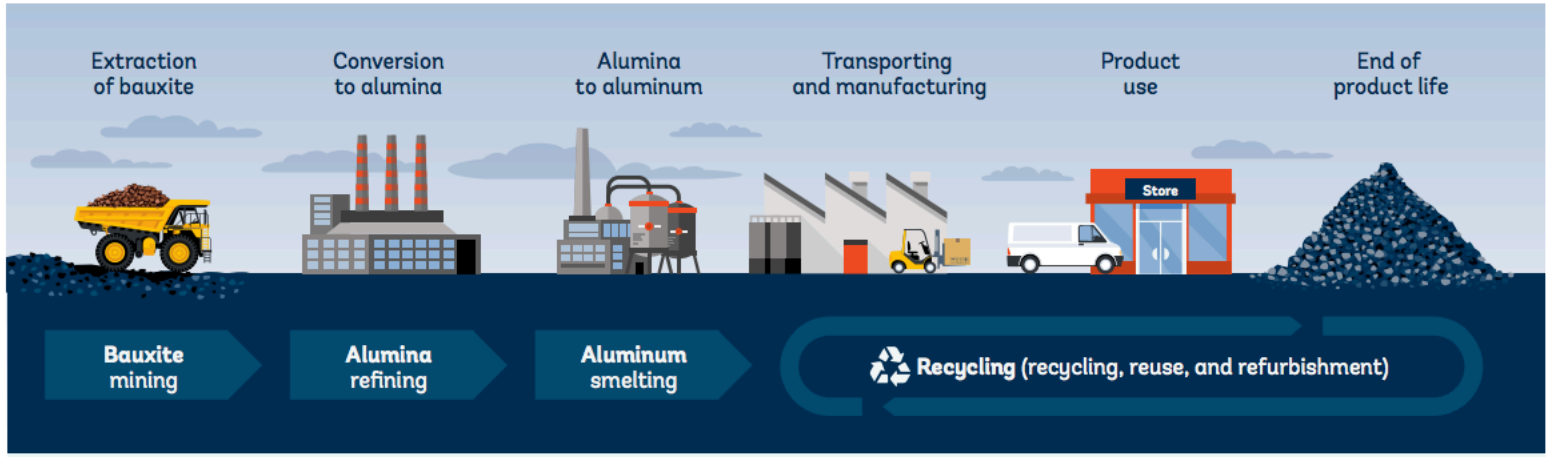
Minerals for Climate Action, World Bank (2020)

Impacts on Sustainability: mineral extraction



Minerals for Climate Action, World Bank (2020)

Impacts on Sustainability: mineral extraction



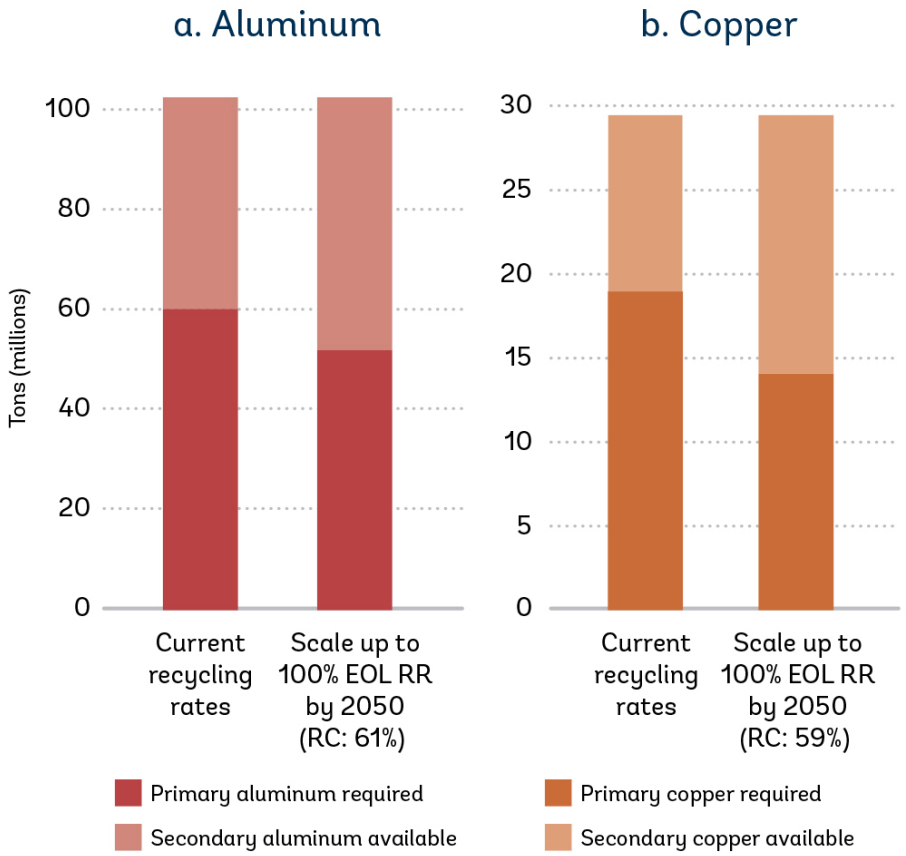
Minerals for Climate Action, World Bank (2020)

Extraction activities have impacts on:

- Energy consumption
- Water consumption
- Emissions
- Land use change
- Ecosystem fragmentation
- Biodiversity loss

A former rare earth mining site in Longnan county, Jiangxi province. MICHAEL STANDAERT/YALE E360

Impacts on Sustainability: mineral extraction



- End of life (EOL): The percentage of material that is recovered at the end of a products life and recycled into new material
- Recycled content (RC): The percentage of a new product that is made using secondary (recycled) material

RECYCLING

IF **aluminum** & **copper** are recovered at 100% at EOL from all products in the world

Aluminum RC rates would increase to 61% from current 35%

Copper RC rates would increase to 59% from current 28.5%

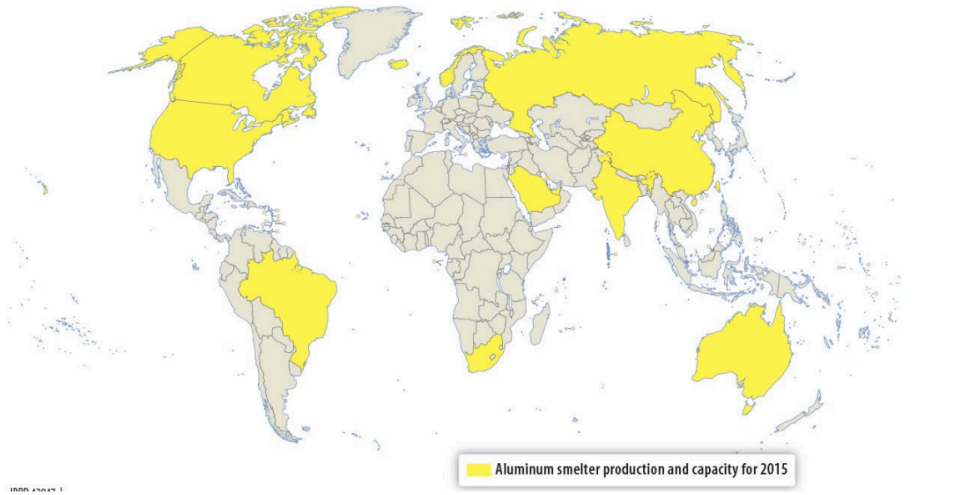
Results show it still wouldn't be enough to meet **mineral demand** from energy technologies under **2DS**

While **recycled minerals** (secondary minerals) can help meet demand in 2050, **mined minerals** (primary minerals) will still be needed

Minerals for Climate Action, World Bank (2020)

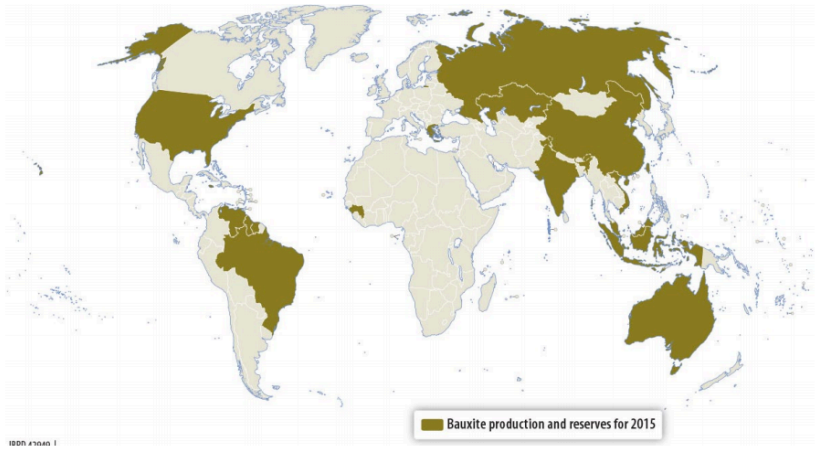
Impacts on Sustainability: mineral extraction

FIGURE 3.1 Aluminum Production



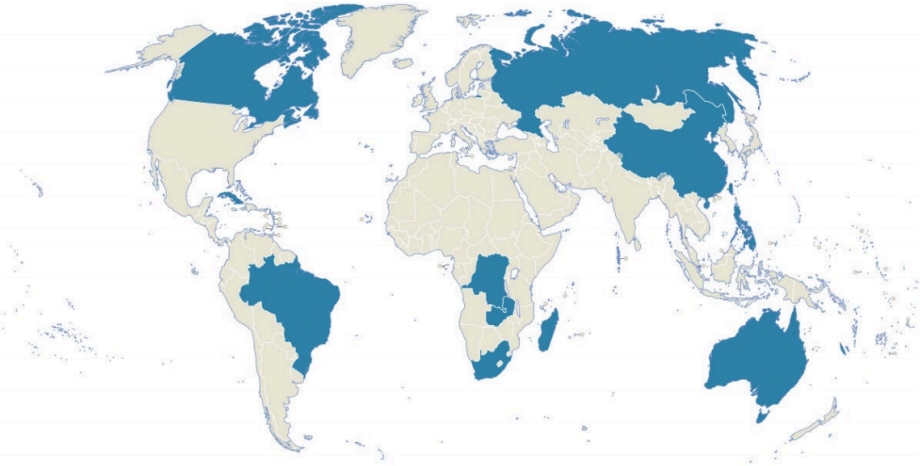
Source: USGS 2016, 23.

FIGURE 3.3 Bauxite Production and Reserves



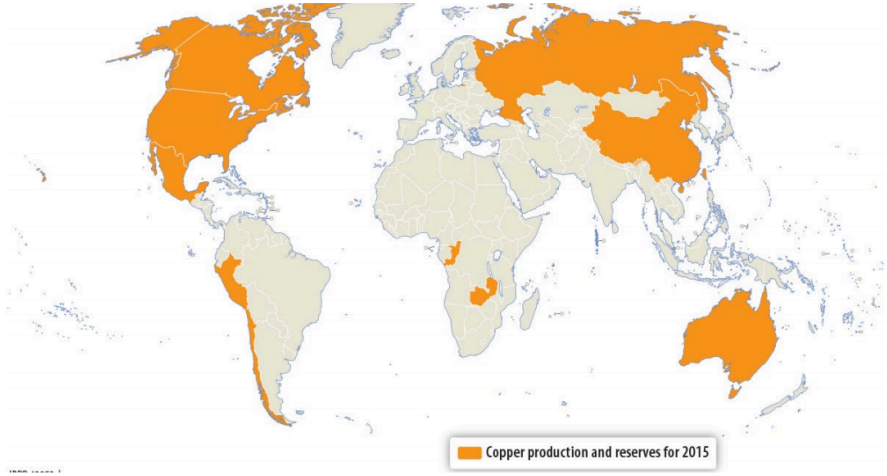
Source: USGS 2016, 33.

FIGURE 3.6 Cobalt Production and Reserves



Source: USGS 2016, 52.

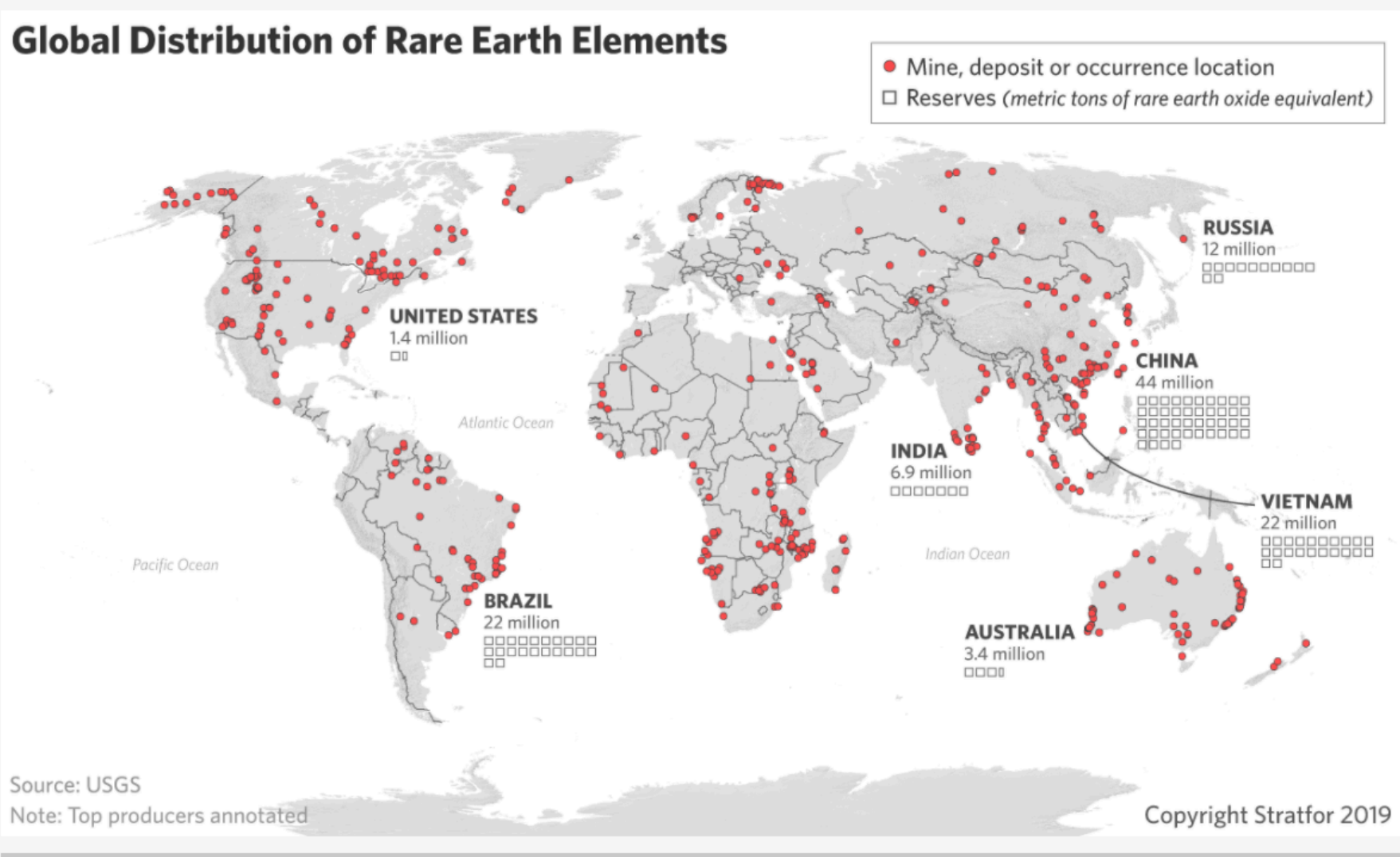
FIGURE 3.7 Copper Production and Reserves



Source: USGS 2016, 55.

(Arrobas et al, 2017; World Bank)

Impacts on Sustainability: mineral extraction



Argentina, Bolivia and Chile boast the world's largest reserves of lithium

Economic projections indicate that by 2025, 45% of the world's appetite for lithium will be fed by water-intensive mining operations adjacent to fragile eco-hydrological systems in the Atacama—the world's driest desert and one of the busiest mining districts on the planet.

Salar de Atacama Basin:
infrequent rains and highest solar radiation in the planet => high-quality lithium at a low cost
Lithium-rich brines are being unsustainably pumped from underneath the salty plains.

Fragile wetlands and lagoons are drying, protected Andean flamingo populations are declining, and drinking water sources that have sustained local communities for millennia are dwindling.

LIVING PLANET REPORT 2020

THIS REPORT HAS BEEN PRODUCED IN COLLABORATION WITH: WWF, ZSL LET'S WORK FOR WILDLIFE

Between 1970 and 2016:

- 68% decline in the population of mammals, birds, amphibians, reptiles and fish
- 94% decline in Living Planet Index in tropical sub-regions of the Americas, the biggest drop observed anywhere in the world.

Regional threats to populations in the LPI

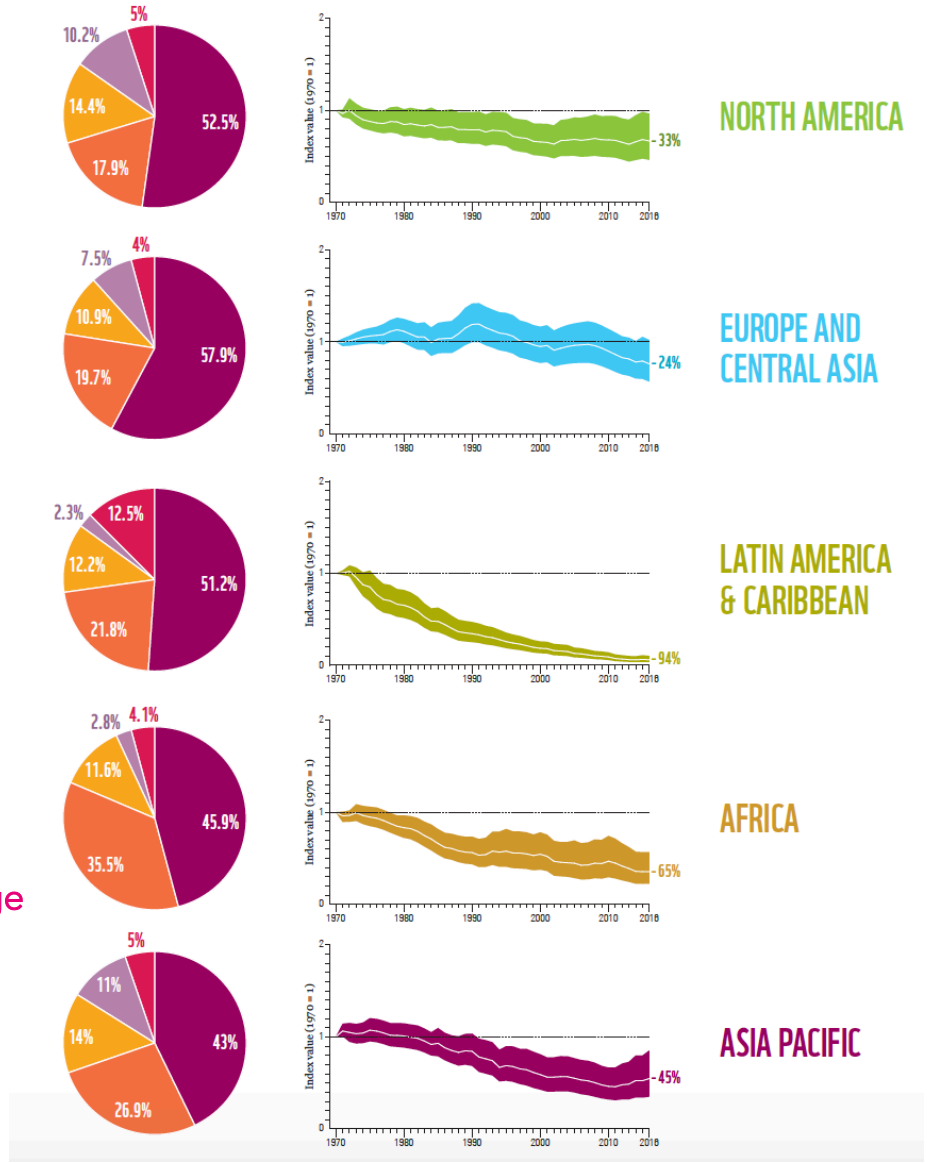
Changes in land and sea use, including habitat loss and degradation

Species overexploitation

Invasive species and diseases

Pollution

Climate Change



What does it mean 'sustainable energy'?

+ 2.2 bi persons by 2050 (UN, 2019)

ACCESS TO THE RESOURCES WILL KEEP THE SAME MODEL ACROSS DEVELOPED AND DEVELOPING COUNTRIES?

what needs to be changed? who are the actors of change?

HOW TO REQUIRE AND IMPLEMENT ENVIRONMENTAL AND SOCIAL STANDARDS IN THE DEVELOPING COUNTRIES?

Carbon neutral Energy System will not assure EQUITY and SUSTAINABILITY if new provisions/policies are not taken!