Energy and Climate Change

What is missing?

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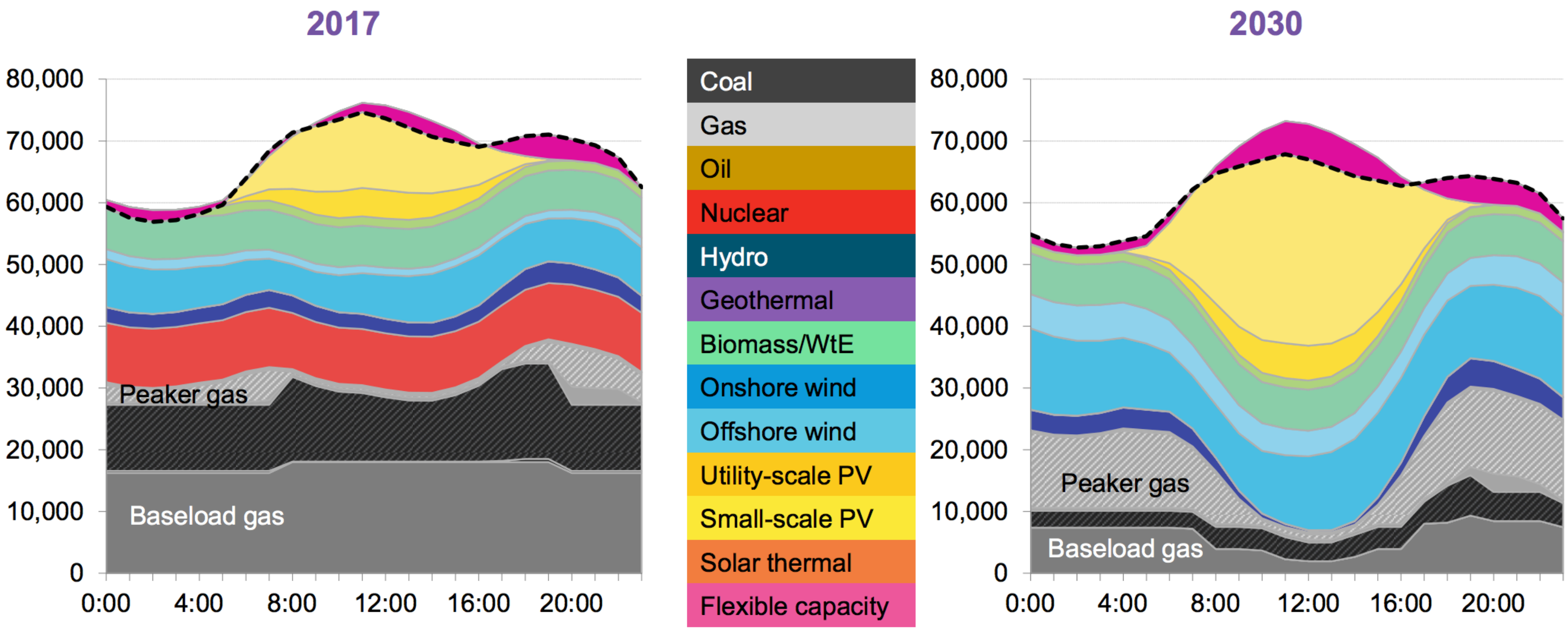
What is missing?

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
- Digital technologies for sustainable energy systems
- Artificial intelligence and big data for energy transition
- Public policies and smart regulation for sustainable and carbon neutral energy system
- Energy economics and markets
- Social aspects of energy transition
- (…)

- Energy storage

Germany hourly dispatch

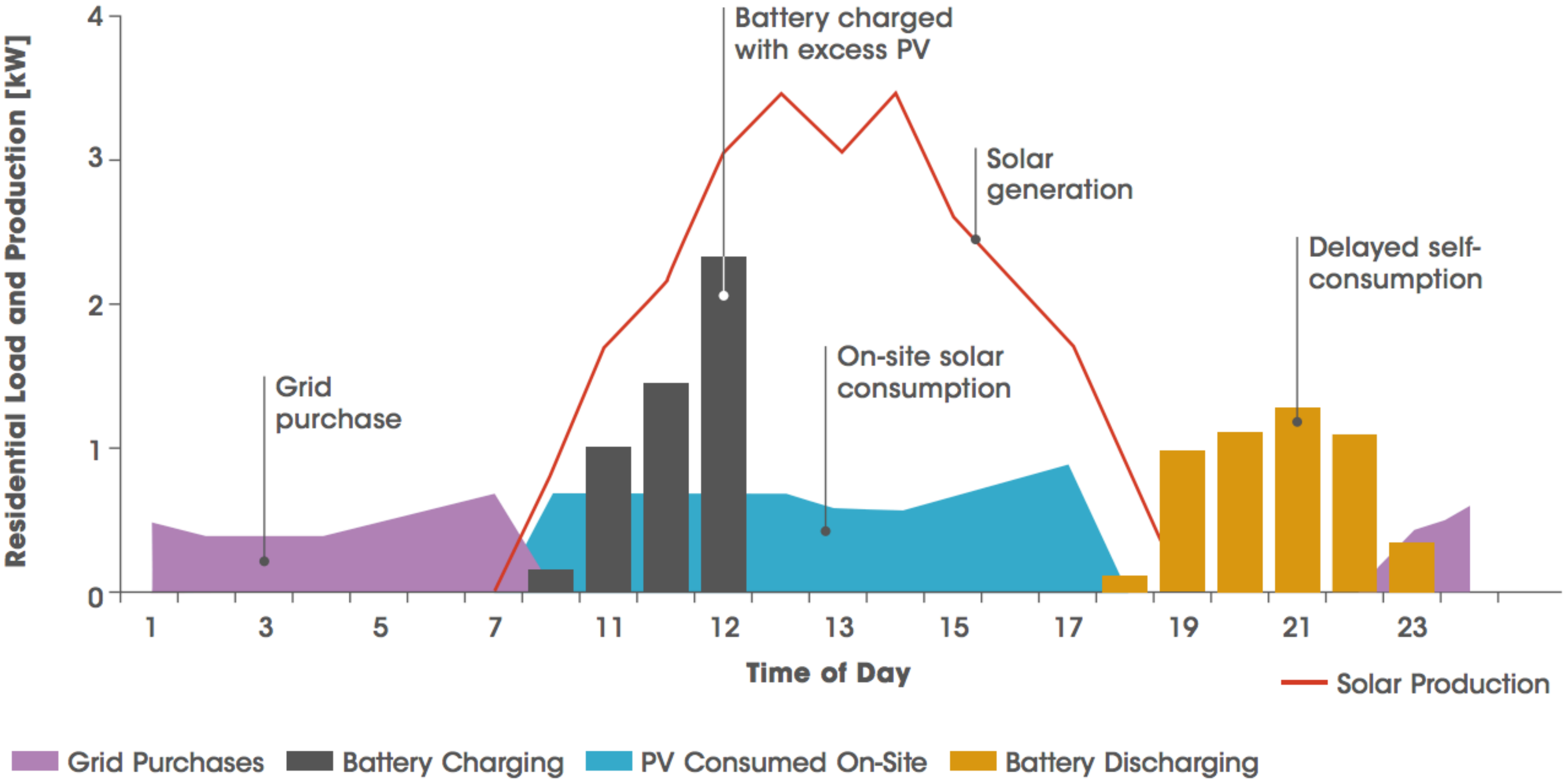


Source: Bloomberg New Energy Forecast

Source: Bloomberg New Energy Finance

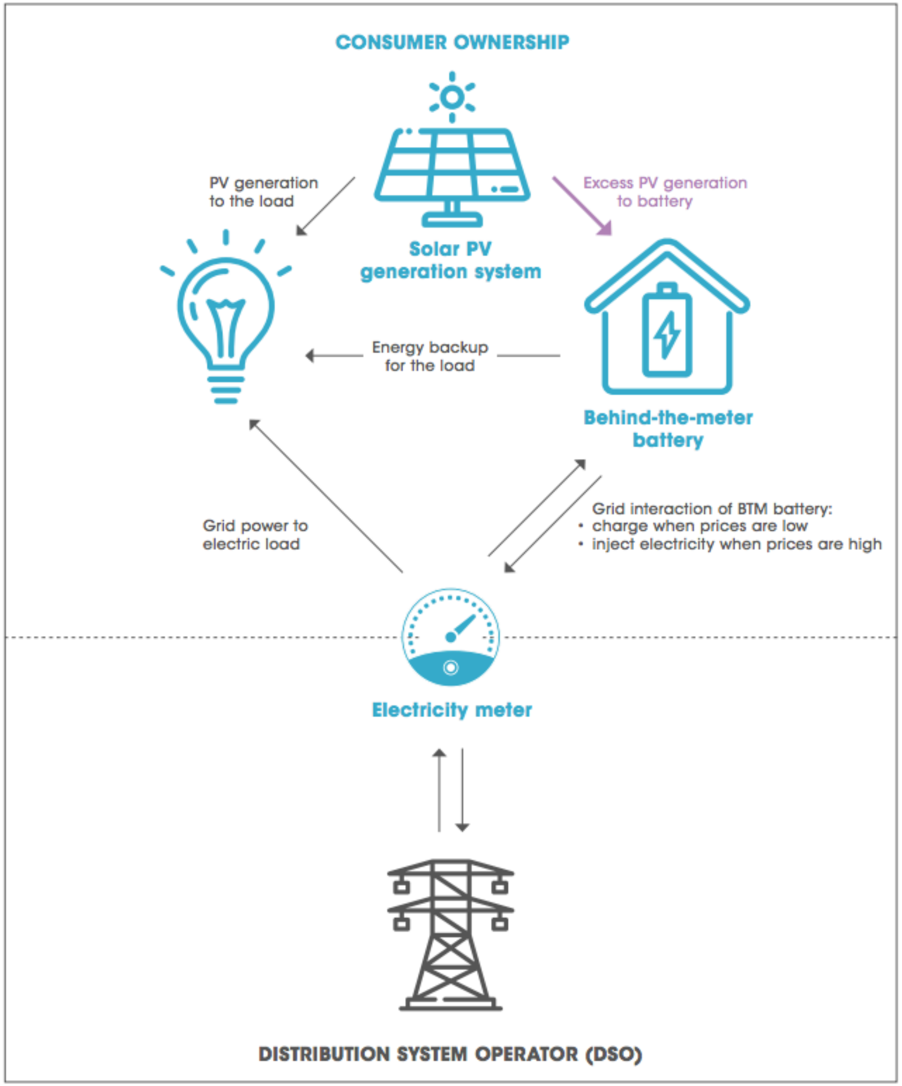
- Energy storage

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



Source: Fitzgerald et al., 2015

- Energy storage



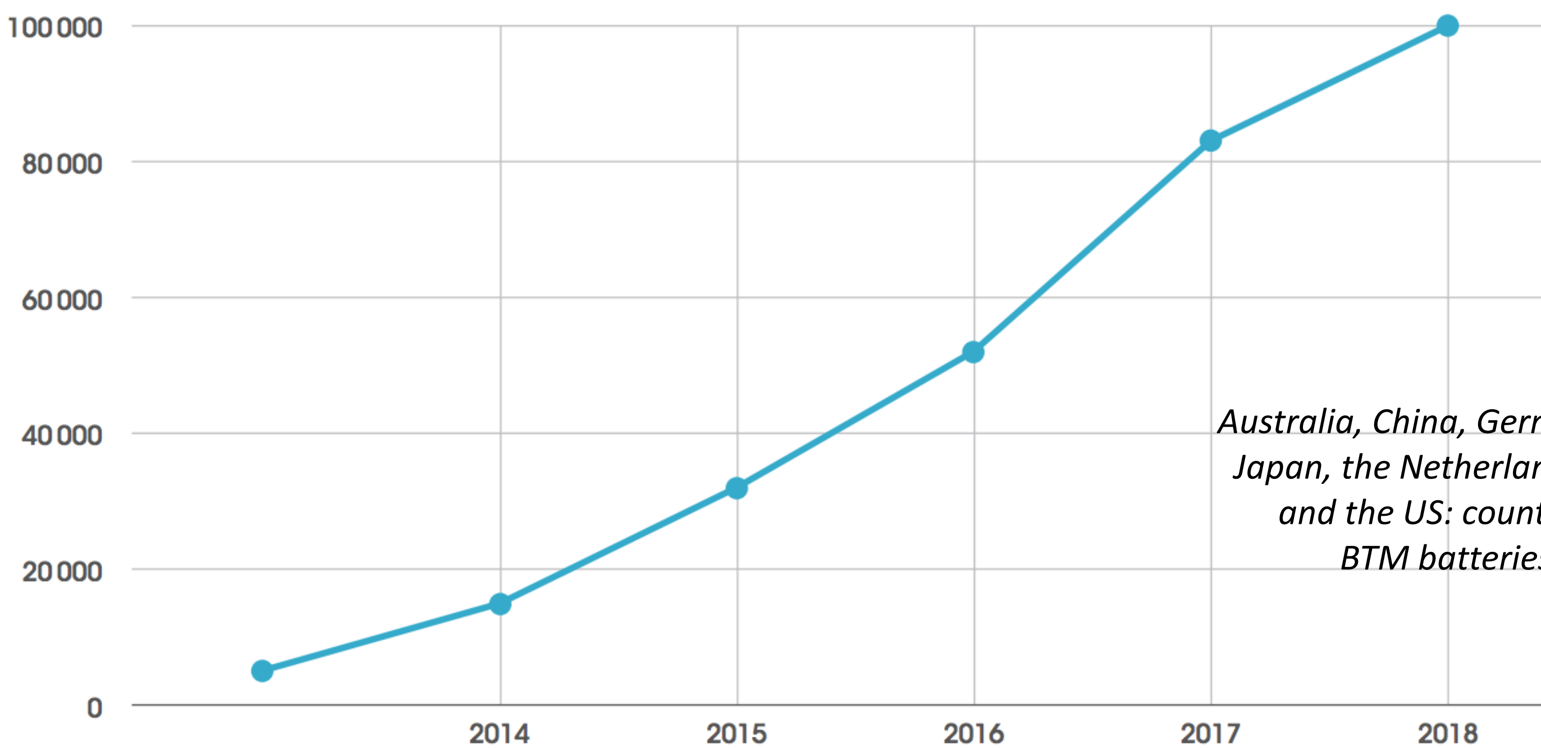
- Poway Unified School District in California installed a 6 MWh BTM storage system. The expected **savings of this project are around USD 1.4 million over 10 years**, and the main application is demand charge reduction (ENGIE Storage, 2018).
- Advanced Microgrid Solutions (AMS) completed a battery-based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

Behind-the-meter (BTM) batteries are 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.

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_BTM_Batteries_2019.pdf

- Energy storage

Figure 7: Household battery storage systems in Germany from 2013 to 2018



Australia, China, Germany, Italy, Japan, the Netherlands, the UK and the US: countries where BTM batteries are being deployed.

Source: Rathi, 2018

In Germany, around 100 000 commercial and residential solar PV with BTM storage systems had been implemented by summer 2018 (Rathi, 2018). This number is expected to double by 2020 (Parkin, 2018).

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_BTM_Batteries_2019.pdf

- Energy storage

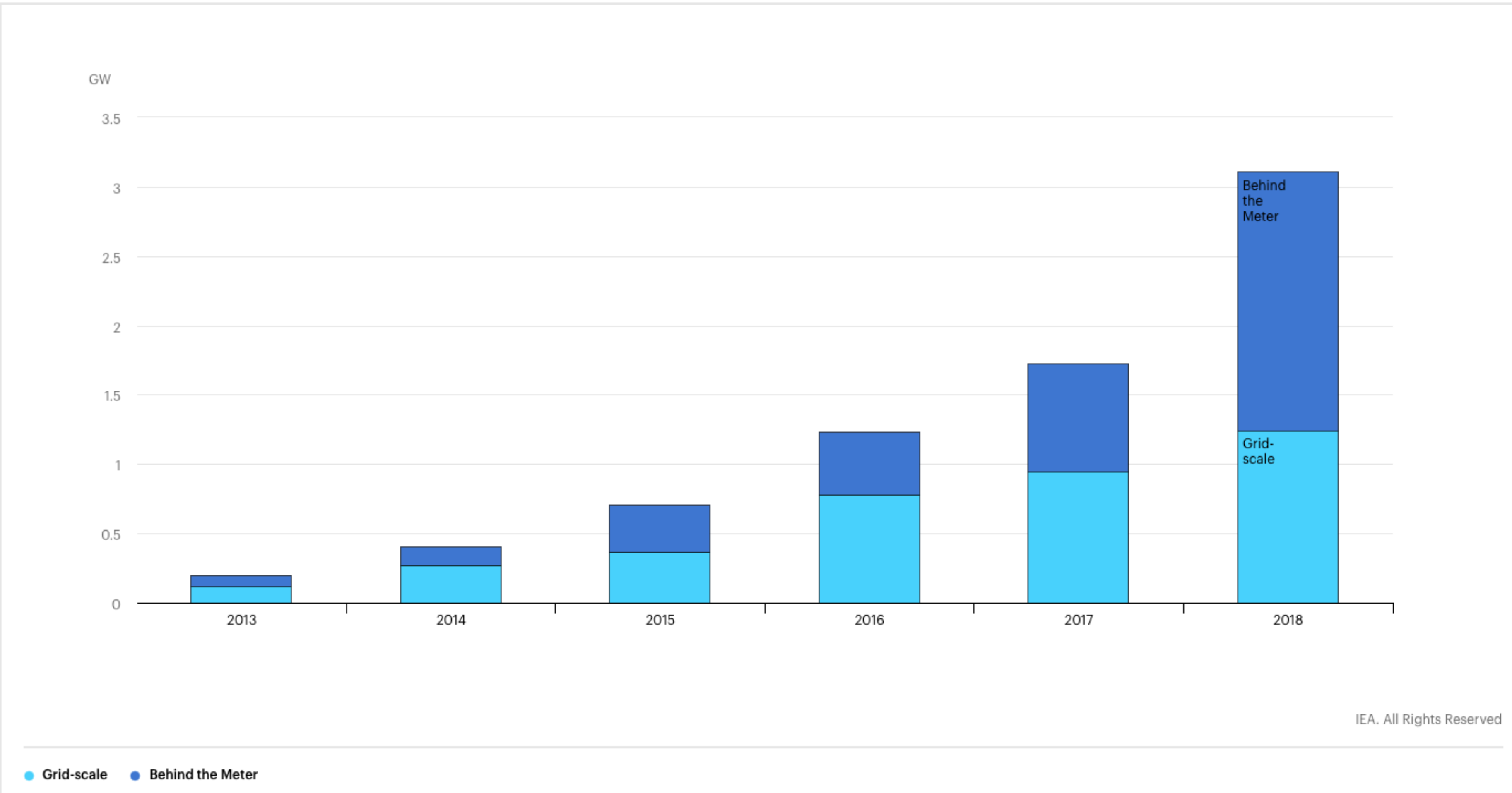
Stationary batteries (or grid scale) can be connected to distribution/transmission networks or power-generation assets. Utility-scale storage capacity ranges from several megawatt-hours to hundreds. Lithium-ion batteries are the most prevalent and mature type

- 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).

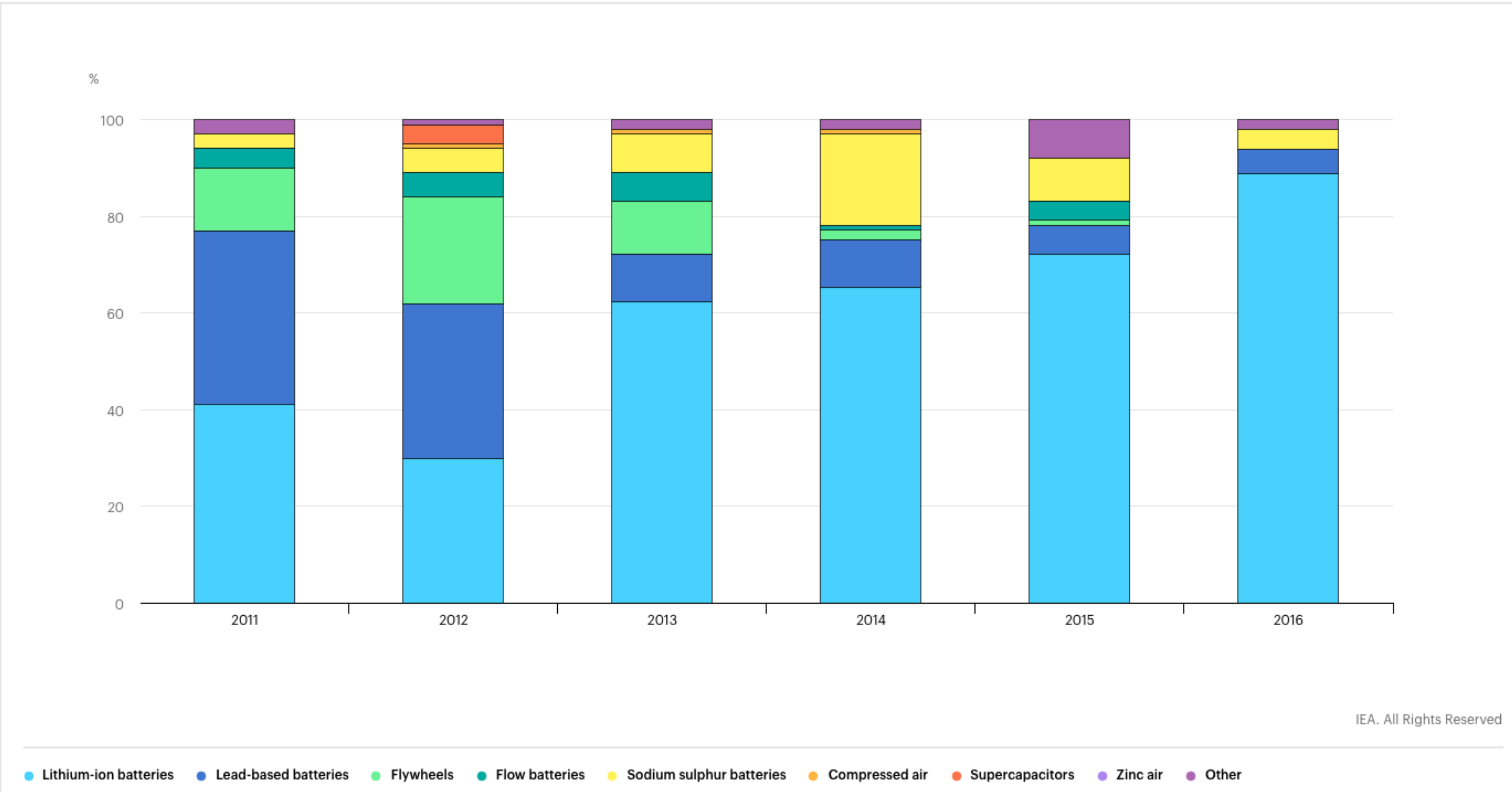
https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Utility-scale-batteries_2019.pdf

- Energy storage



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

- 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-and-statistics/charts/technology-mix-in-storage-installations-excluding-pumped-hydro-2011-2016

• Energy storage

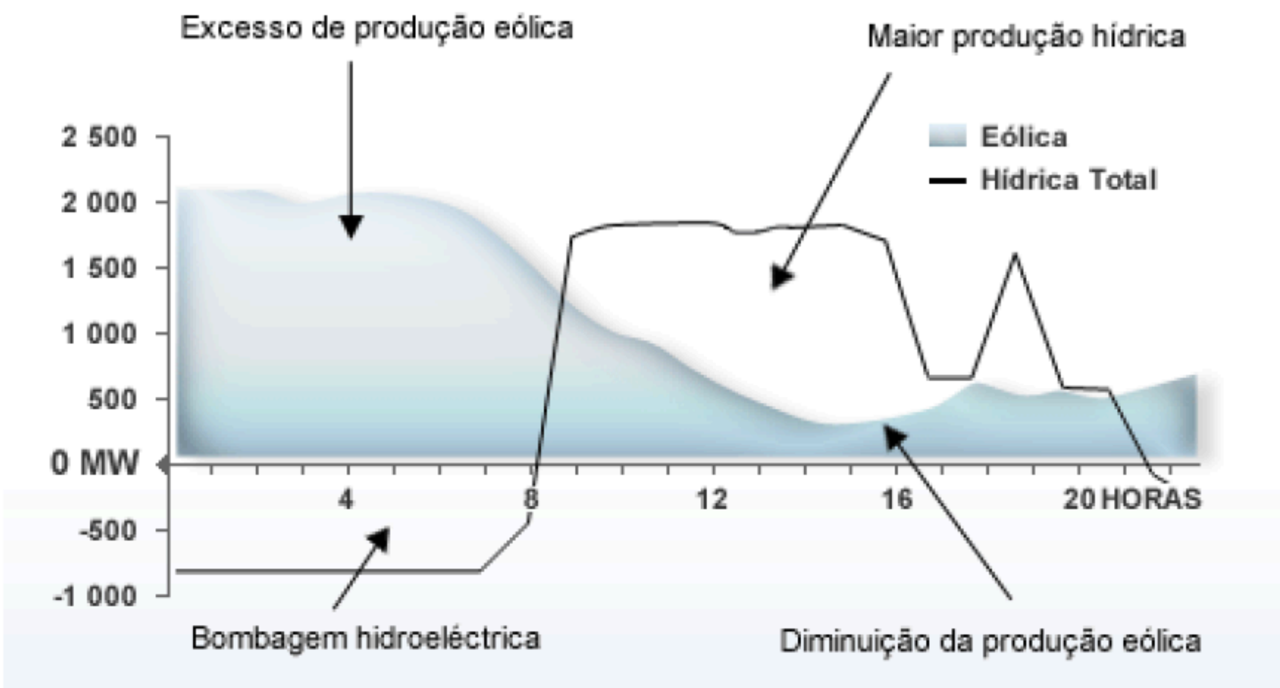


Figura 1 - Relação entre os gráficos de produção eólica e hidroeléctrica
(Fonte: www .a-nossa-energia.edp.pt)

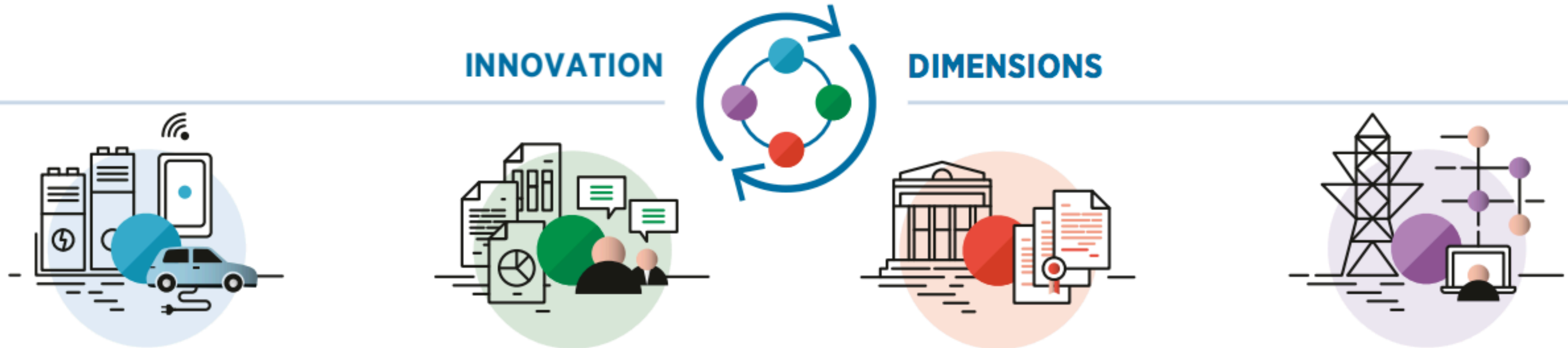
J. Marques (2015) Hidroelectricidade e Barragens Reversíveis: Panorama actual, FCUP

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.

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

- Energy storage

INNOVATION DIMENSIONS



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

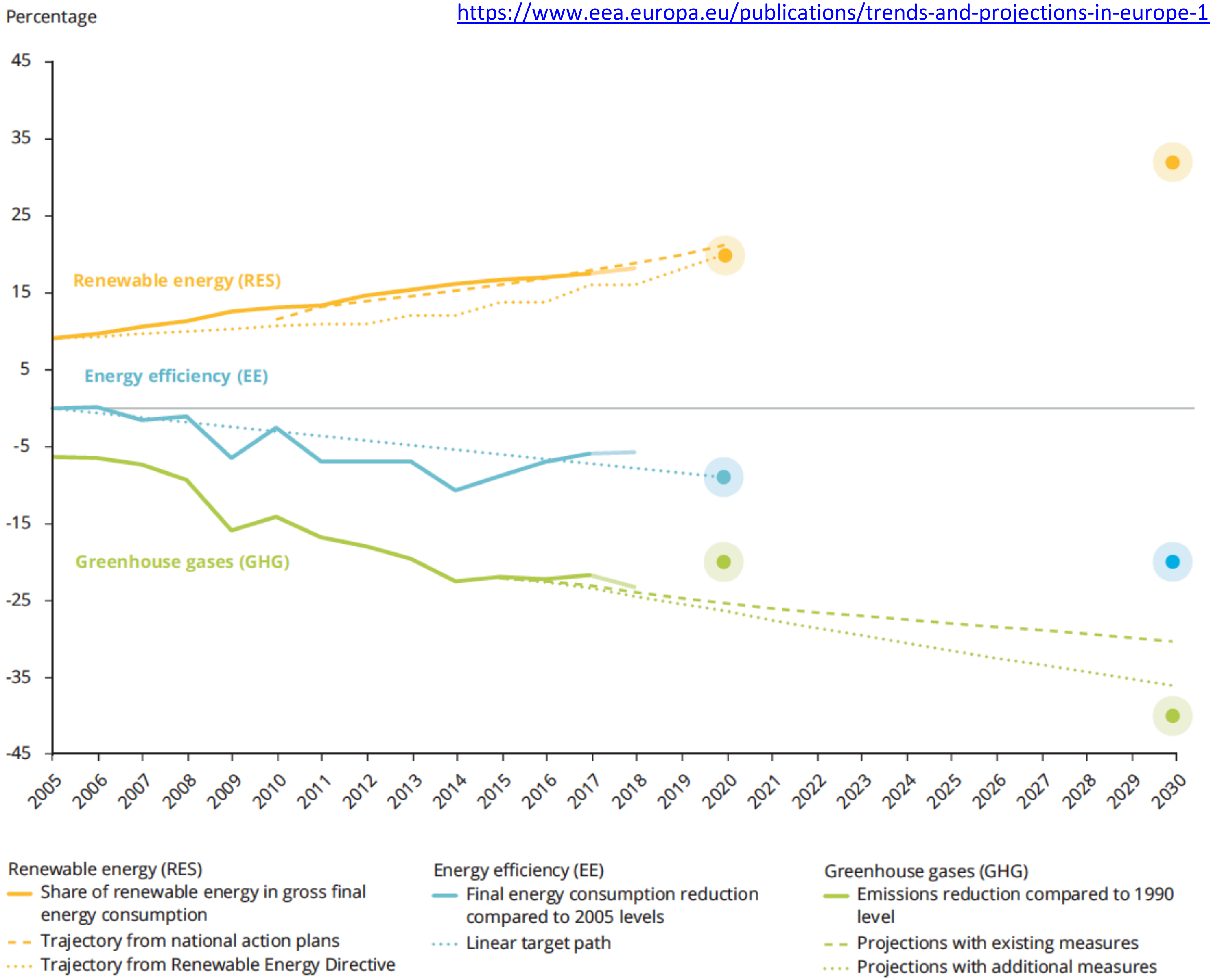
29 Virtual power lines
30 Dynamic line rating

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_BTM_Batteries_2019.pdf

- Energy efficiency

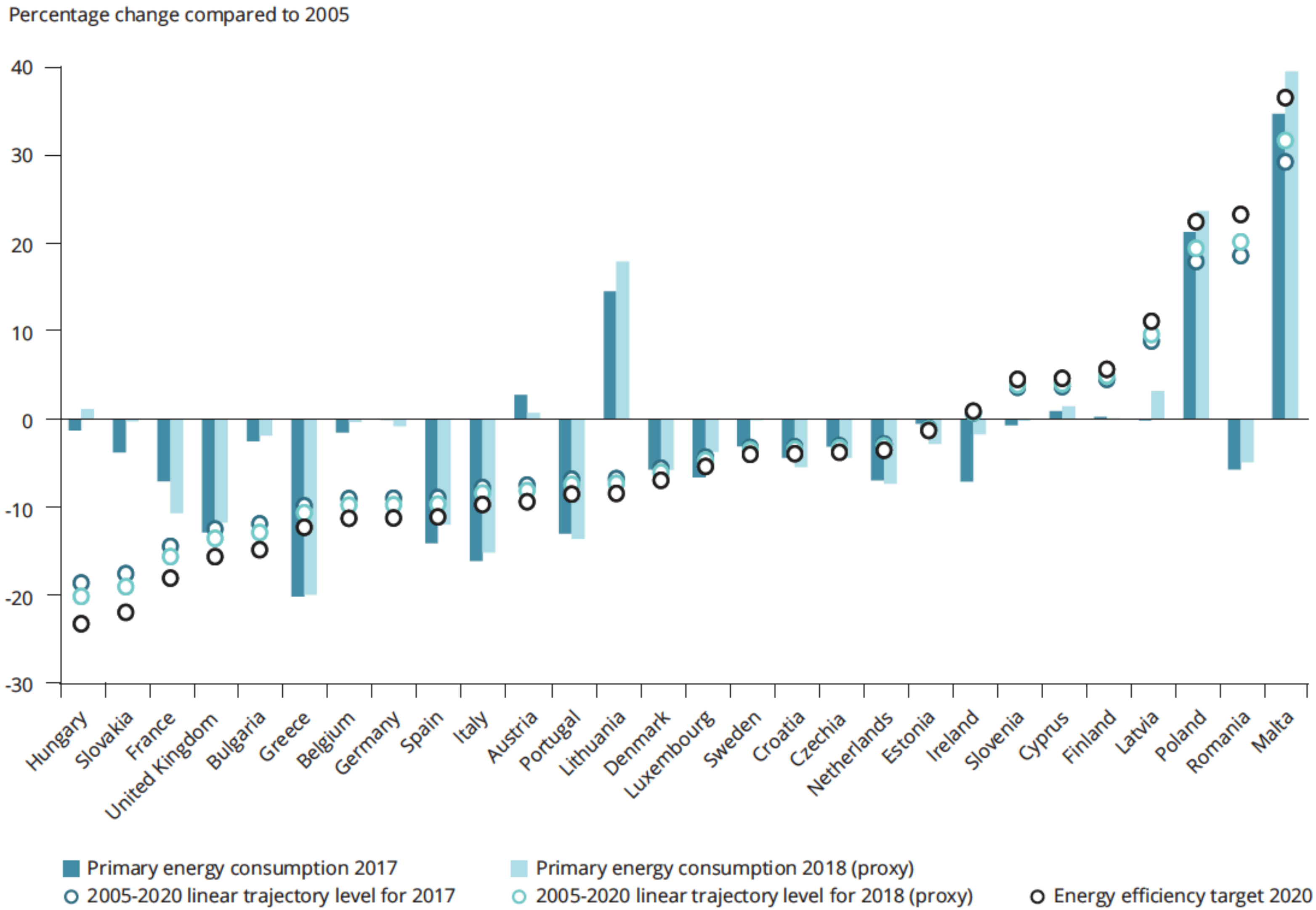
Figure ES.2 EU progress towards 2020 and 2030 targets on climate and energy

https://www.eea.europa.eu/publications/trends-and-projections-in-europe-1

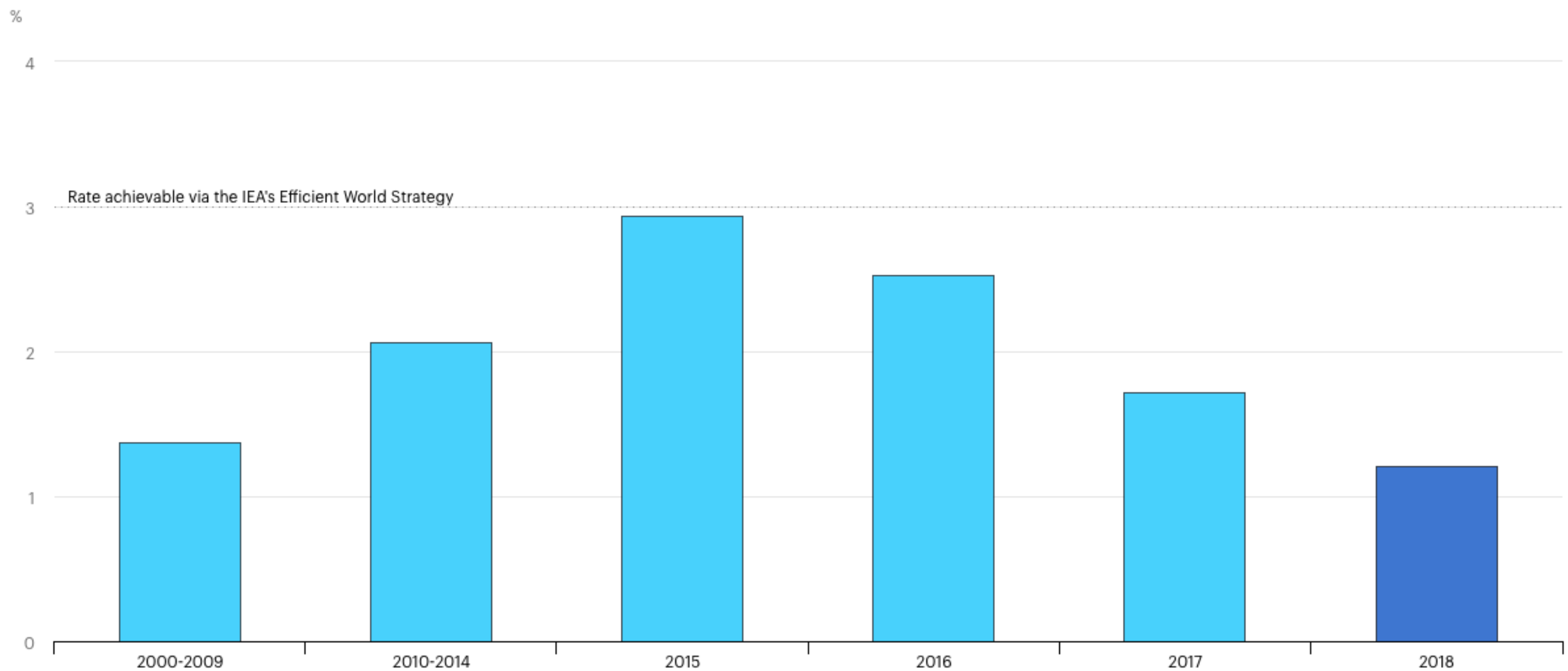


- Energy efficiency

Figure 4.2 Final energy consumption and linear trajectory levels to reach 2020 targets, 2017 and 2018



- Energy efficiency

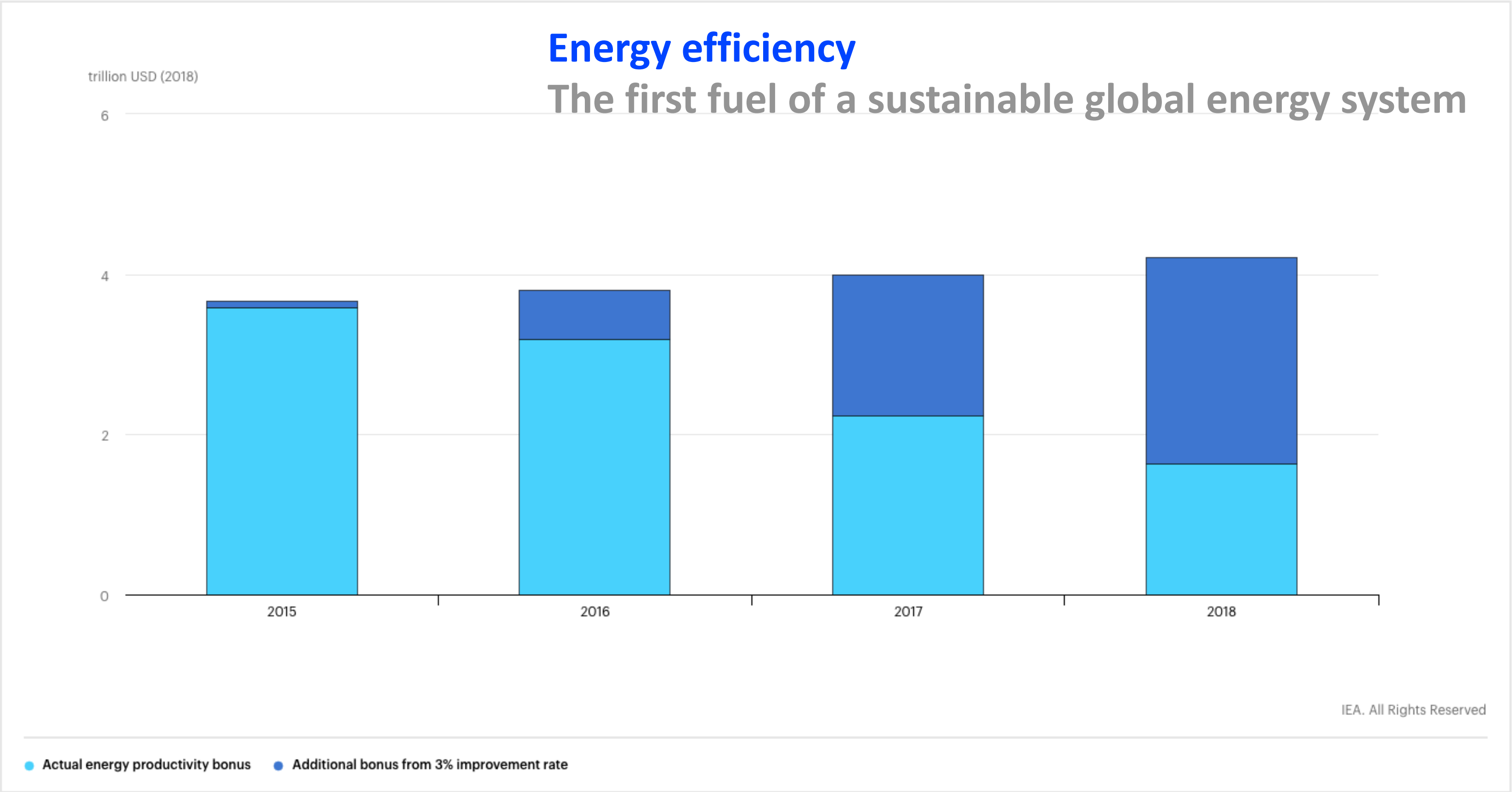


IEA, Global improvements in primary energy intensity, 2000-2018, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-improvements-in-primary-energy-intensity-2000-2018

Global energy efficiency improvements are slowing

In 2018, **primary energy intensity** - an important indicator of how much energy is used by the global economy - improved by just 1.2%, the slowest rate since 2010. This was significantly slower than the 1.7% improvement in 2017 and marked the third year in a row the rate has declined. It was also well below the average 3% improvement consistent with the IEA's Efficient World Strategy, first described in Energy Efficiency 2018.

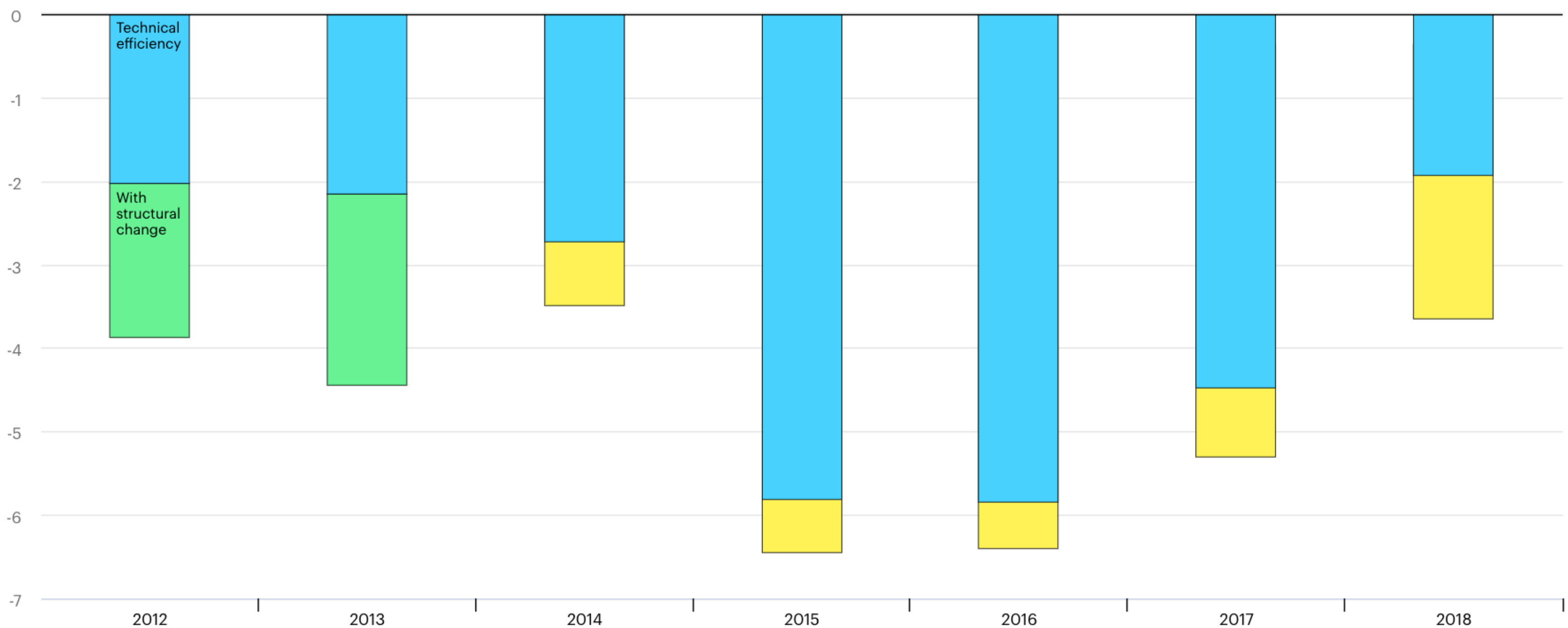
- Energy efficiency



IEA, Global energy productivity bonus, actual and if energy efficiency had improved at 3%, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-energy-productivity-bonus-actual-and-if-energy-efficiency-had-improved-at-3

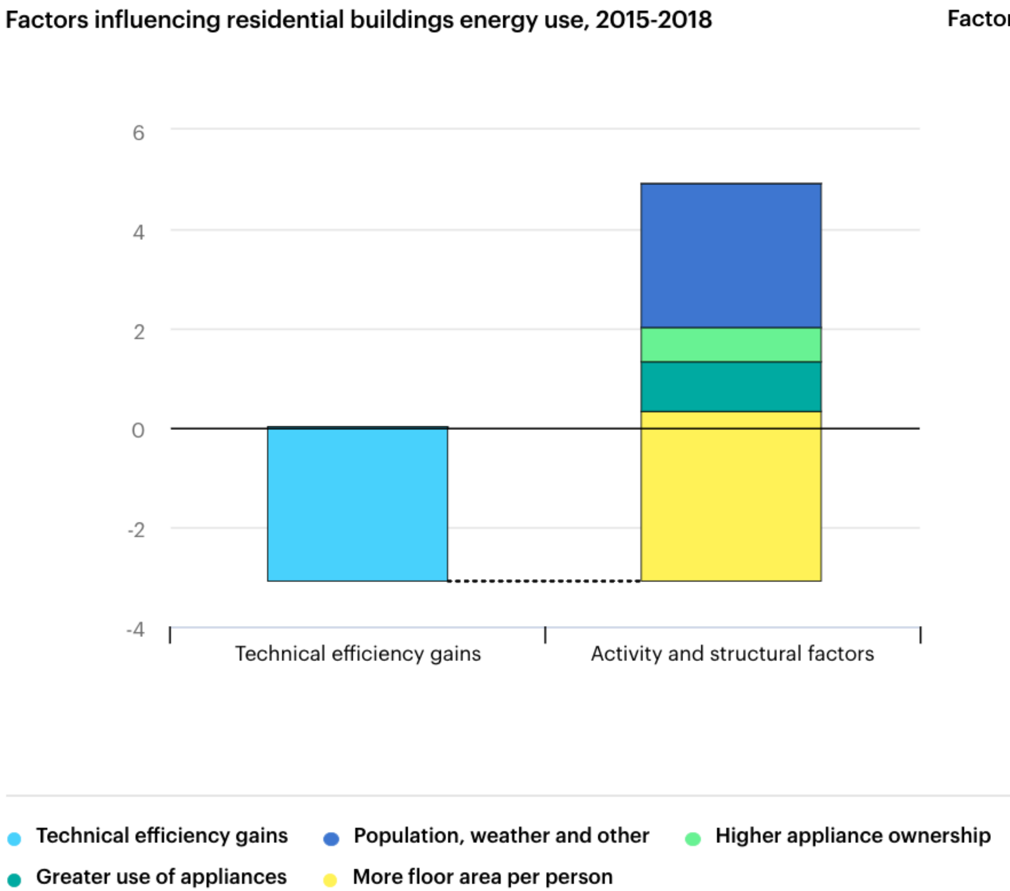
The 1.2% improvement in energy intensity equated to around $1.6 trillion more GDP for the amount of energy used compared to 2017.
However this figure could have been $4 trillion – an amount greater than the size of the German economy – had energy intensity improved at 3% every year since 2015.

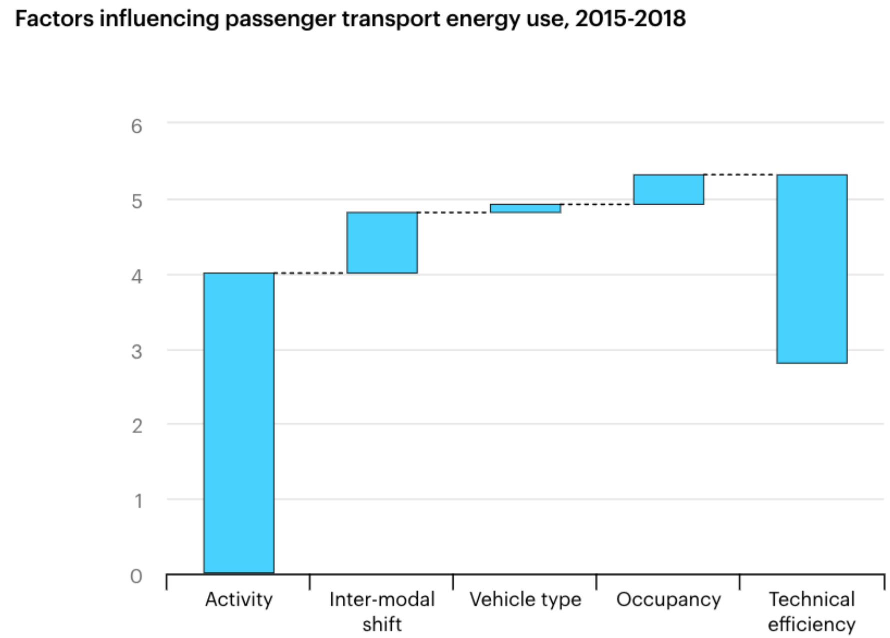
- Energy efficiency



Longer-term structural factors are also playing a part in the slowdown. While technologies and processes are becoming more efficient, structural factors, like changes in transport modes and more building floor area per person, are dampening the impact of these technical efficiency gains on energy demand, and slowing global energy intensity improvements.

- Energy efficiency

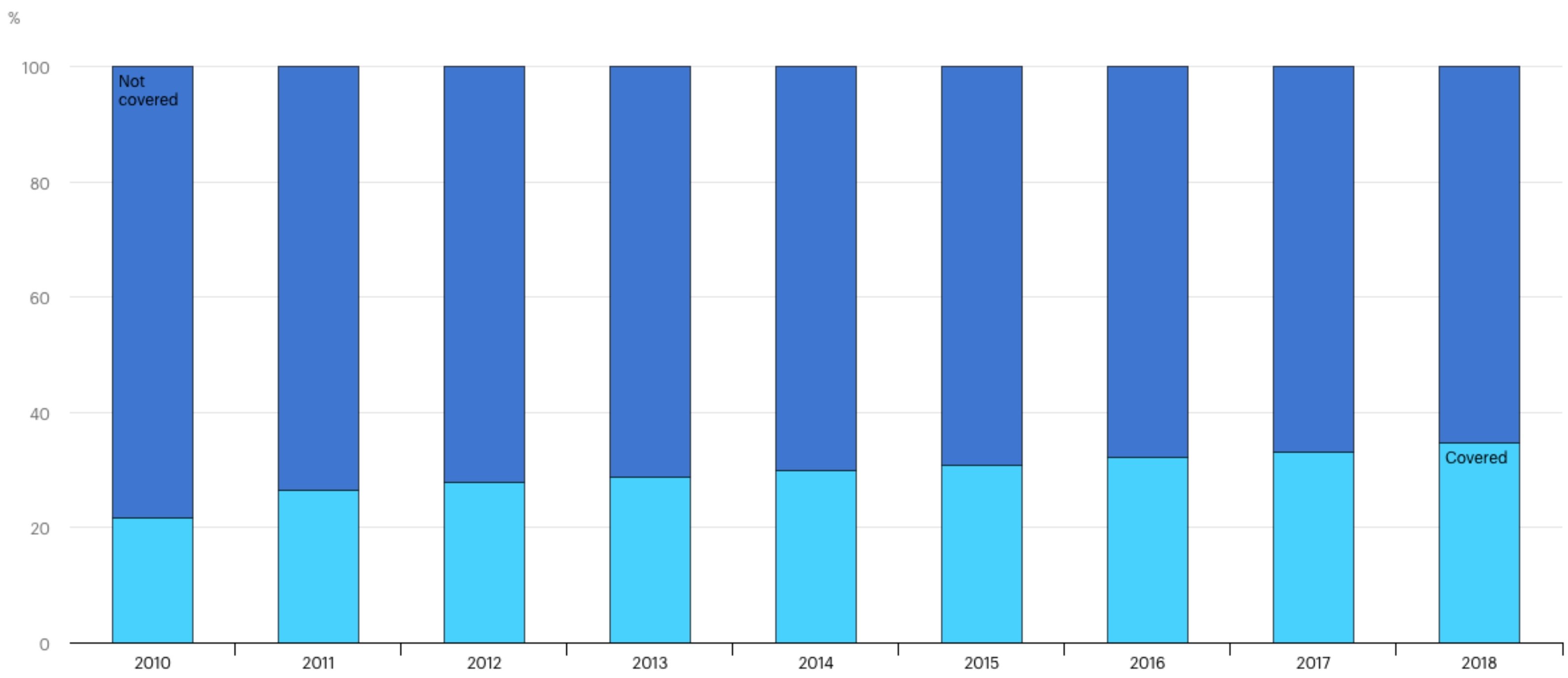




In residential buildings, structural changes have consistently matched or outpaced efficiency gains since 2014. These include increased device ownership and use and a significant growth in average per-capita residential floor area in all economies.

In transport, despite improvements in vehicle efficiency, energy use continues to grow. Amongst other factors, sales of new, more efficient vehicles have slowed, consumers prefer larger cars, and typical vehicle occupancy rates have fallen.

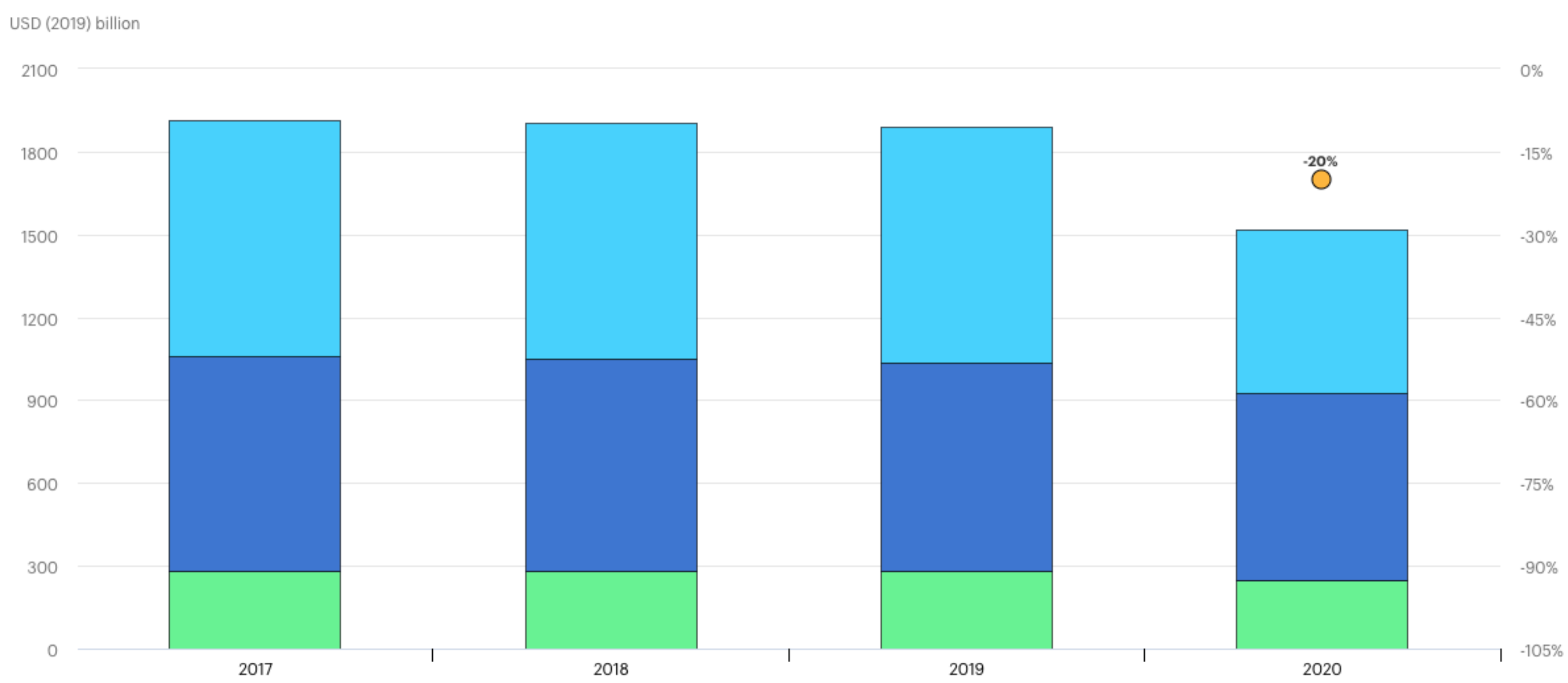
- Energy efficiency



IEA, Share of final energy use covered by mandatory efficiency policies, 2010-2018, IEA, Paris https://www.iea.org/data-and-statistics/charts/share-of-final-energy-use-covered-by-mandatory-efficiency-policies-2010-2018

The coverage of mandatory efficiency policies increased in 2018, but this was almost exclusively due to existing policies. Meanwhile the strength of mandatory policies increased by less than 0.5%, slightly higher than the previous two years, though still below the five-year historical average, indicating more can be done to ensure mandatory policies are effective. The coverage and strength of energy efficiency obligation programmes remained largely unchanged.

- Energy efficiency



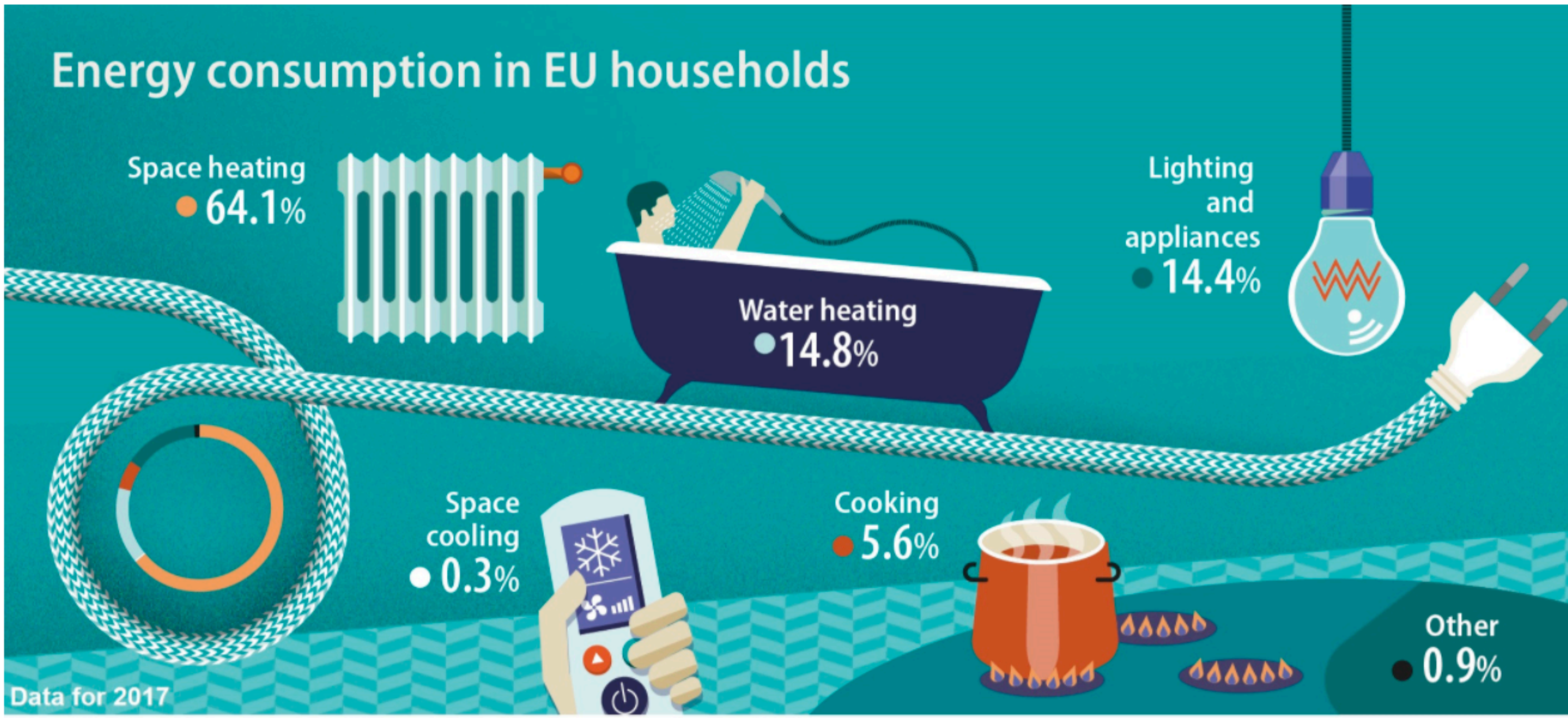
IEA, Total global energy investment, 2017-2020, IEA, Paris https://www.iea.org/data-and-statistics/charts/total-global-energy-investment-2017-2020

Energy investment is set to fall by one-fifth in 2020 due to the Covid-19 pandemic

- Energy efficiency

the case of 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.



ec.europa.eu/eurostat

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%)

- Energy efficiency
the case of 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)

- Energy efficiency: from the house to the district

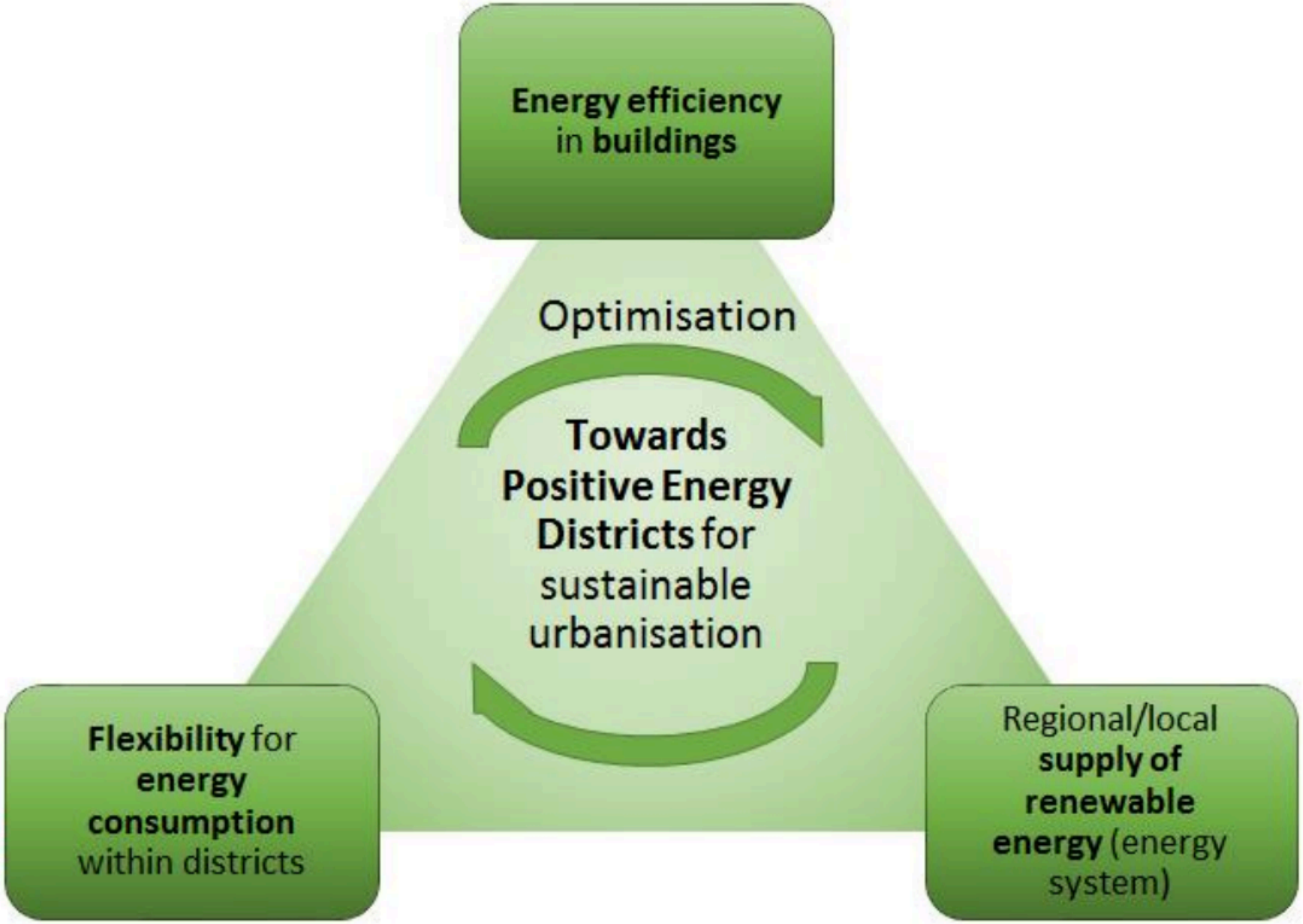


Figure 5: Definition of Positive Energy Districts

https://setis.ec.europa.eu/system/files/setplan_smartcities_implementationplan.pdf

- Energy efficiency: from the house to the district

Figure 6: Key challenges and needs for deploying PEDs

https://setis.ec.europa.eu/system/files/setplan_smartcities_implementationplan.pdf

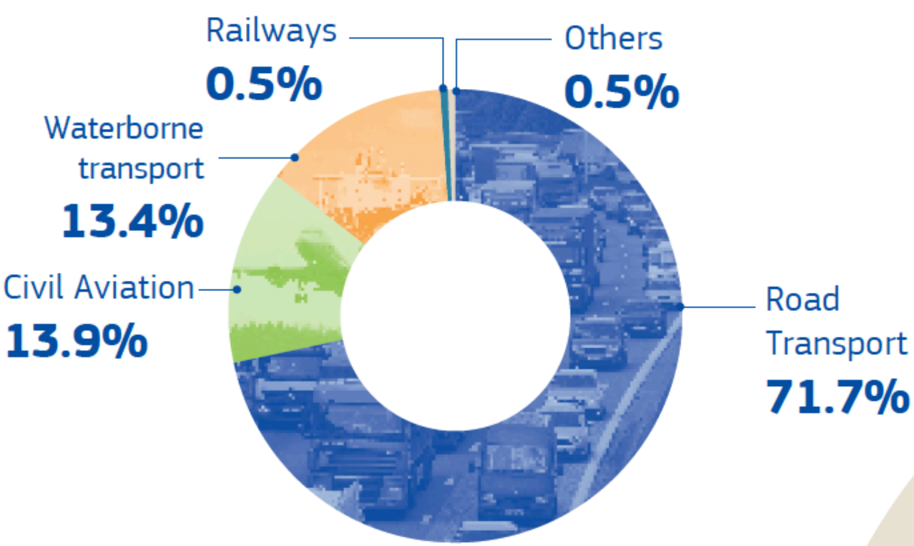
- Sustainable mobility

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

EU, Sustainable Mobility Factsheet (2020)

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.

- Sustainable mobility

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

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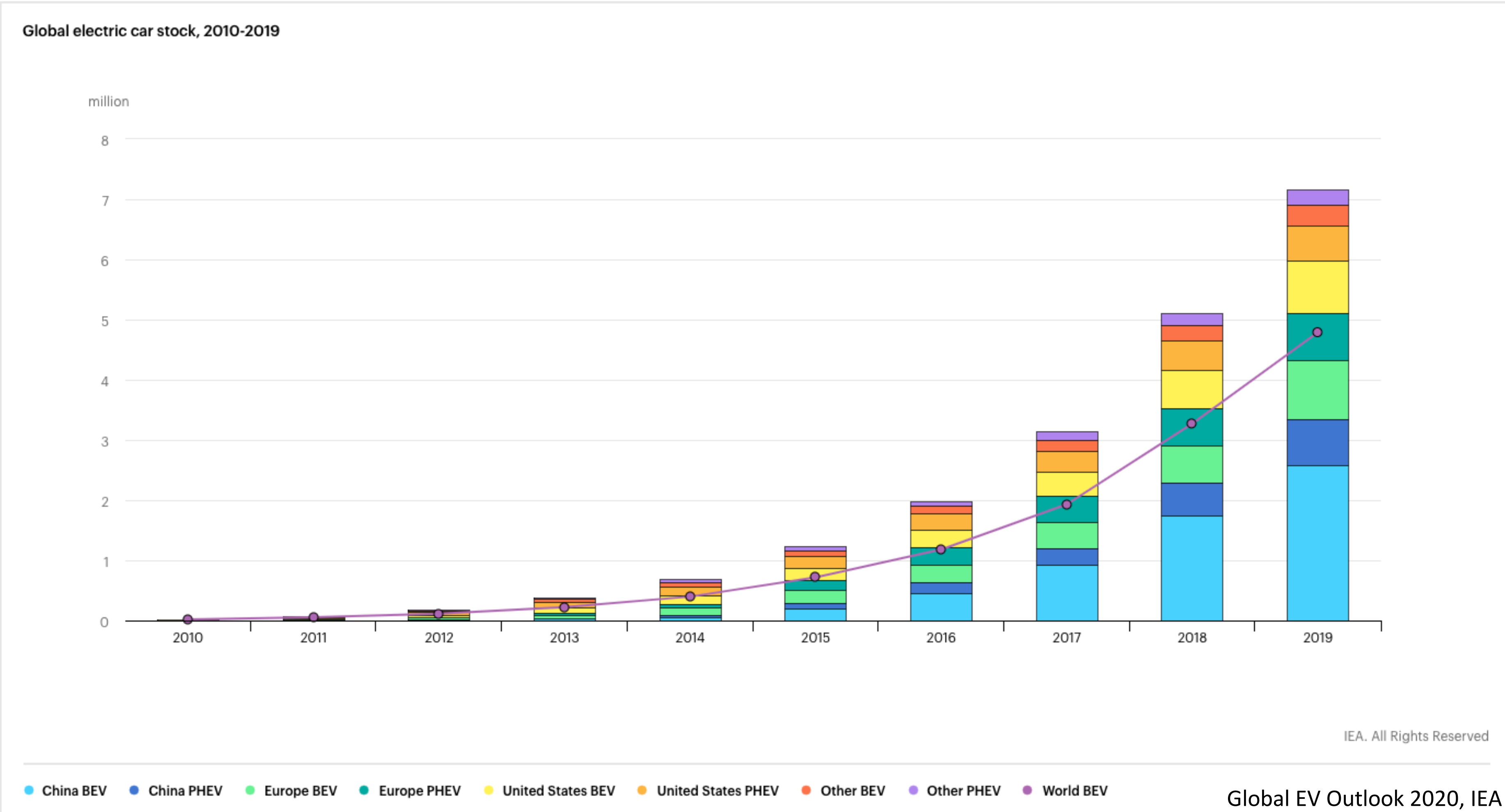
EU, Sustainable Mobility Factsheet (2020)

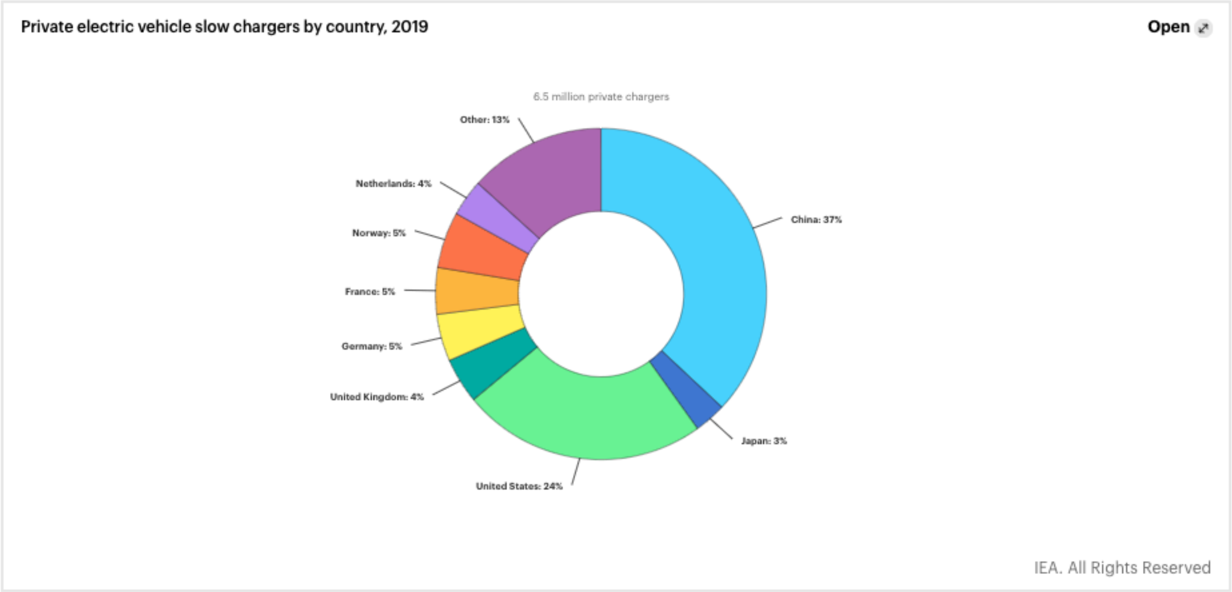
- Sustainable mobility



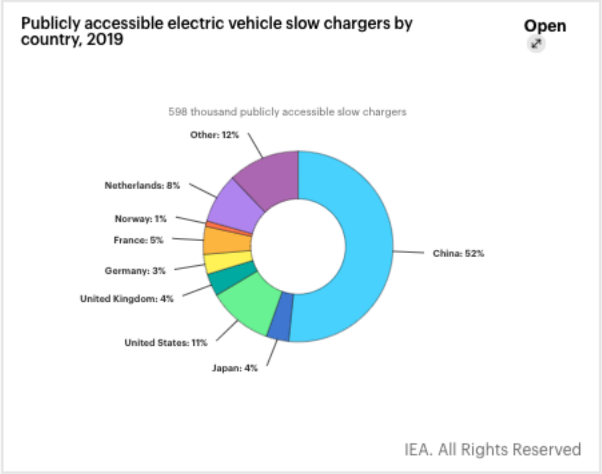
Global EV Outlook 2020, IEA

Sales of electric cars topped 2.1 million globally in 2019, surpassing 2018 – already a record year – to boost the stock to 7.2 million electric cars.1 Electric cars, which accounted for 2.6% of global car sales and about 1% of global car stock in 2019, registered a 40% year-on-year increase.

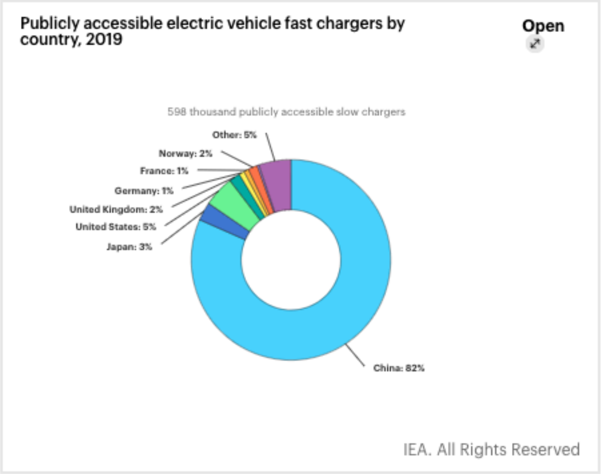
- Sustainable mobility



Private electric vehicle slow chargers by country, 2019



Publicly accessible electric vehicle slow chargers by country, 2019



Publicly accessible electric vehicle fast chargers by country, 2019

Global EV Outlook 2020, IEA

In 2019, there were about 7.3 million chargers worldwide, of which about 6.5 million were private, light-duty vehicle slow chargers in homes, multi-dwelling buildings and workplaces. Convenience, cost-effectiveness and a variety of support policies are the main drivers for the prevalence of private charging.

- Sustainable mobility: what will be the role of H2?

TRL: 8

- cerca de 10.000 veículos vendidos (2014-Out2019)

OUTROS FABRICANTES

Hyundai, Honda, Mercedes-Benz (ligeiros de mercadorias/vans), Ford (vans)

FONTE: Toyota, 2019

TRL: 7-8

- + de 10 M kms percorridos até Set2019

DIVERSOS FABRICANTES

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

FONTE: FuelCell Bus e CaetanoBus, 2019

- Sustainable mobility: what will be the role of H2?

TRL: 7

- Alstom ilint. opera desde 2018 na Alemanha em tráfego de passageiros regular

OUTROS FABRICANTES

CRRC TRC (Tangshan) produziu em 2017 um sistema ligeiro que opera nesta cidade chinesa

FONTE: Alstom e Ballard Power Systems, 2019

TRL: 5-6

- nesta fase apenas protótipos funcionais

OUTROS FABRICANTES

Boeing, Pipistrel, Zeroavia

LMG Marin and partner Westcon Power & Automation, Hydra

FONTE: Boeing e Norled, 2019

- Energy sustainability in cities (the right scale?)

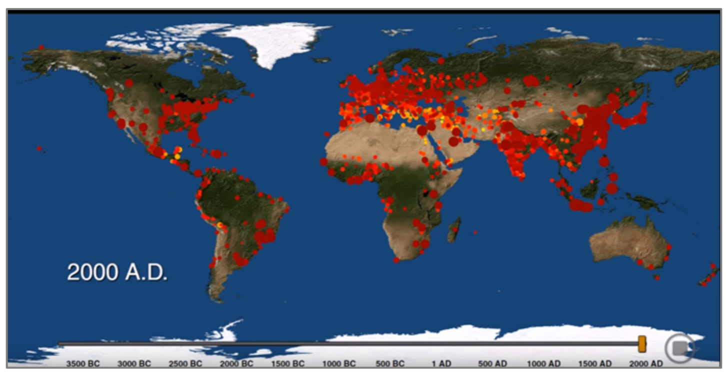
more than half of global population

70% in 2050

80% of the world's GDP in 2013

two-thirds of primary energy demand

70% of total energy-related CO2 emissions

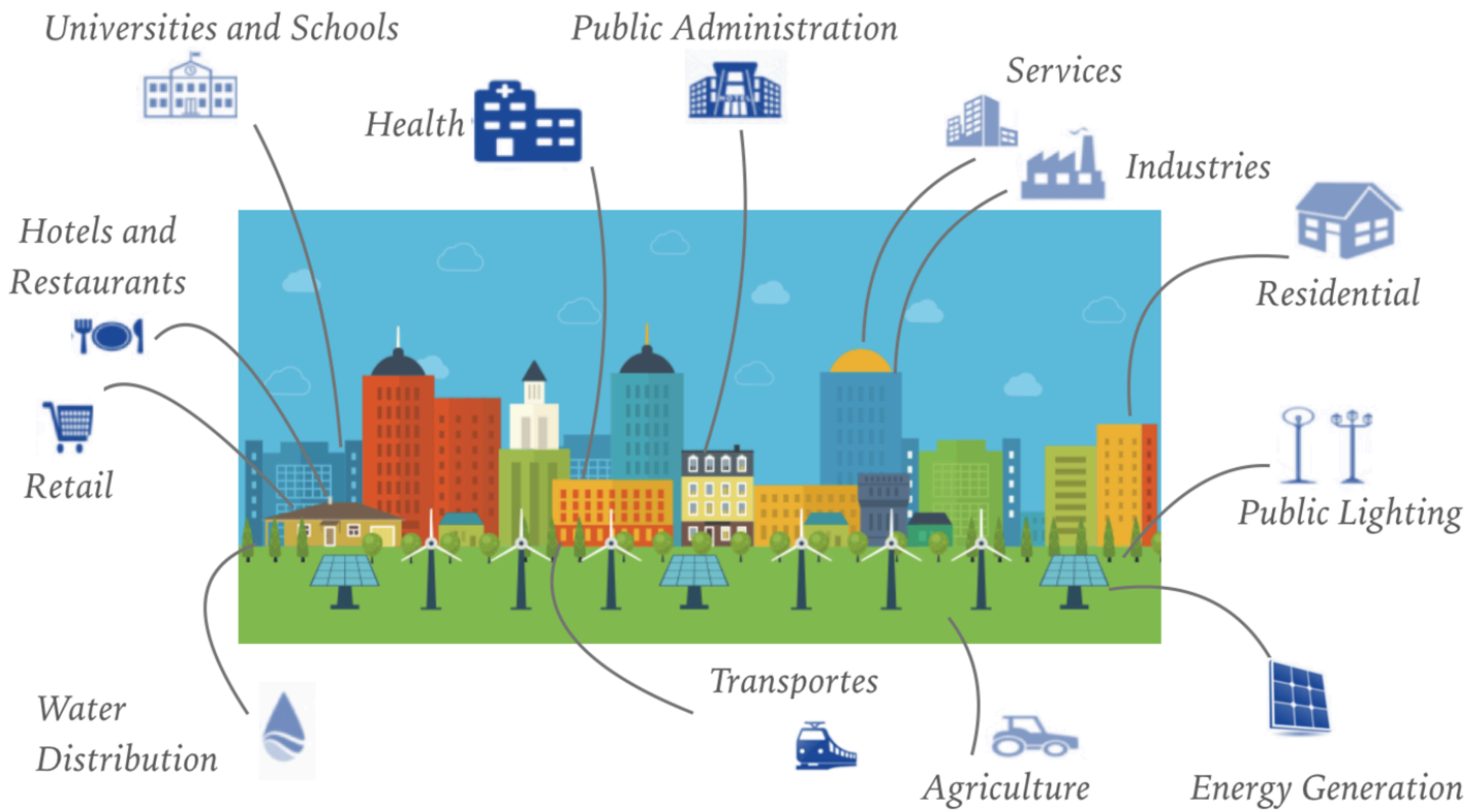


2050?
2100?

The History of Urbanization, 3700 BC - 2000 AD: https://www.youtube.com/watch?v=yKJYXujJ7sU

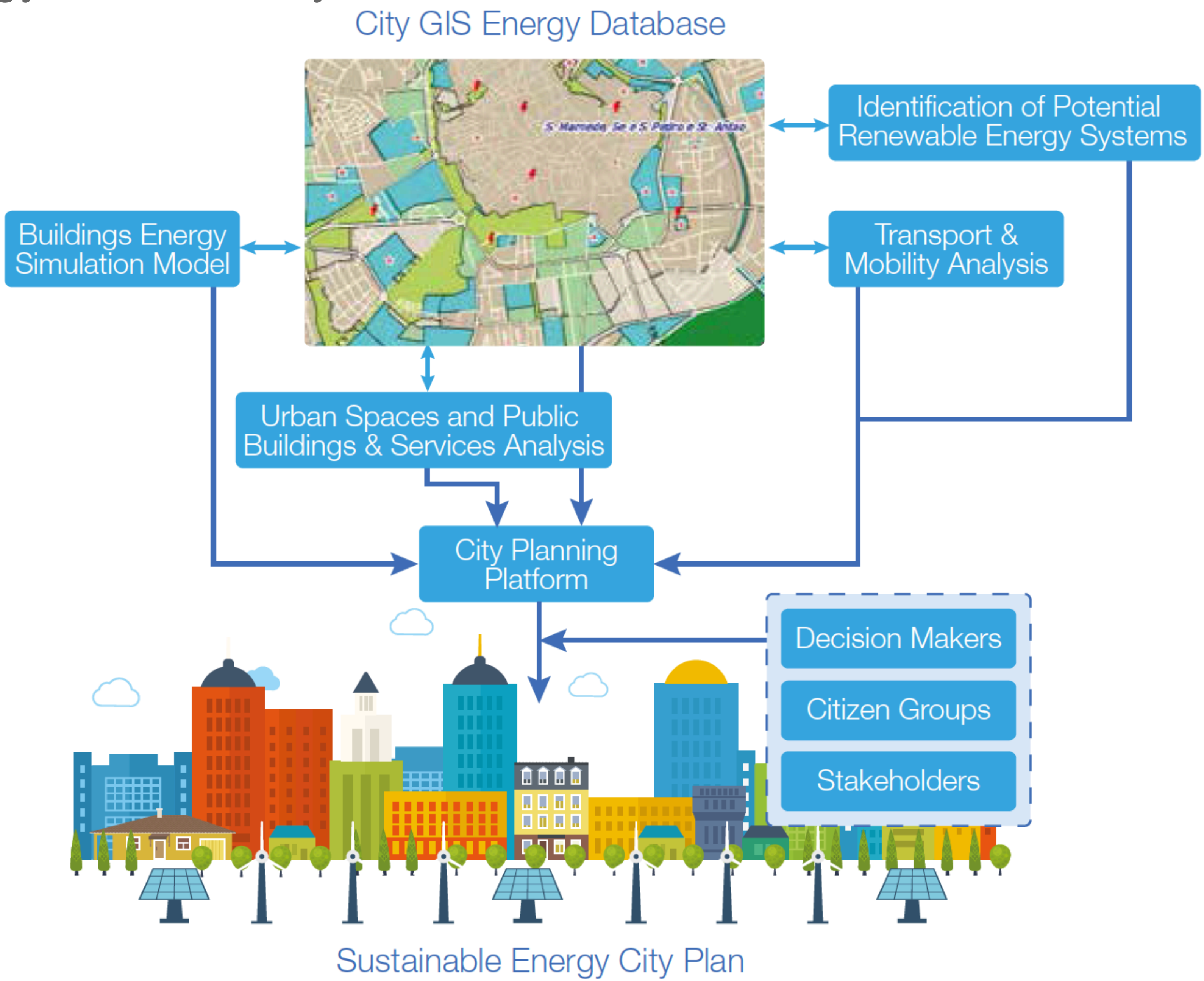
- Energy sustainability in cities

High resolution data integration



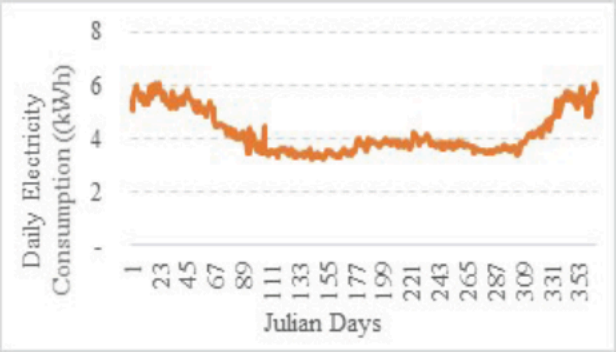
INSMART
Integrative Smart City Planning

- Energy sustainability in cities

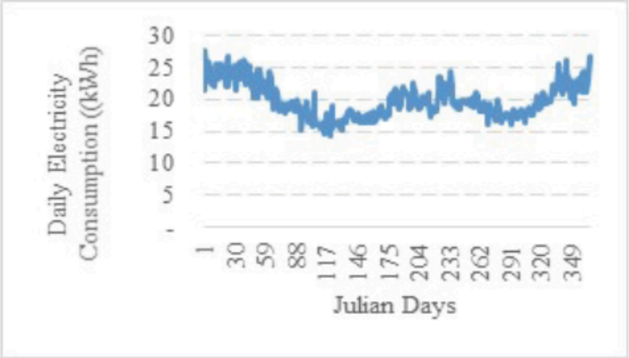


INSMART
www.insmartenergy.com

- 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.

CENSE center for environmental and sustainability research

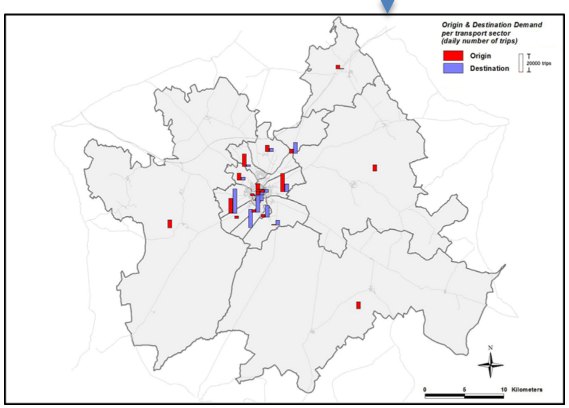
• Energy sustainability in cities

Equipments and energy services

Mobility

10 building typologies

- By type of fuel
- By age (Euro Norm)
- By **origin-destiny matrice**



4 city zones

- Energy sustainability in cities

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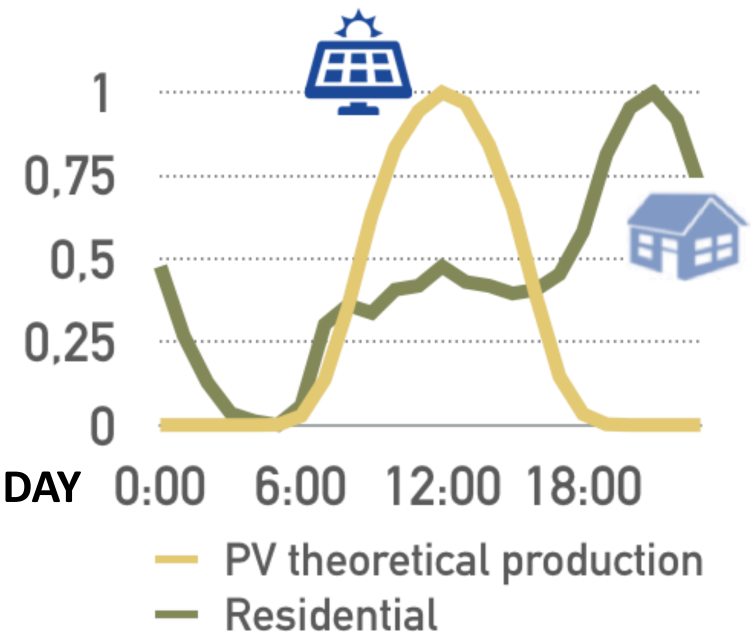
www.insmartenergy.com

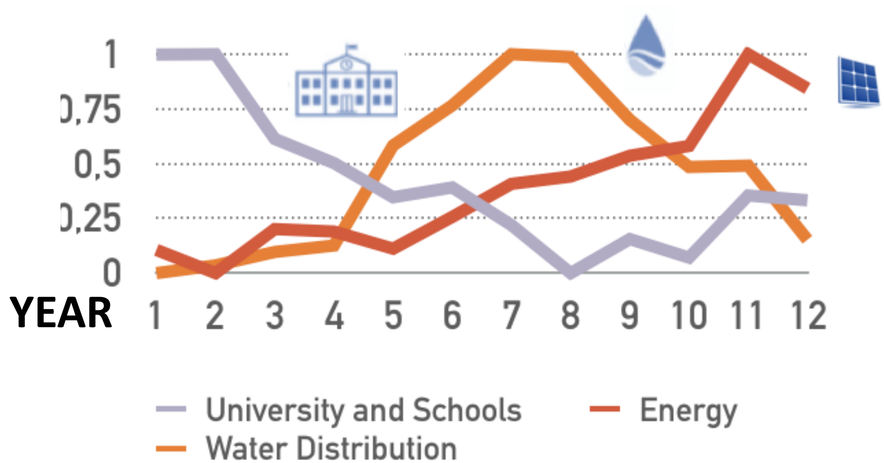
○ (Real) Time slices

Based on the quality of information that we had: **Big data -** 32 000 smart meter information on residential and avrious sectors electricity consumption at 15 minutes and also PV powerplants electricity production profiles;



<u>18 timeslices/year</u>

- Seasons: **Summer; Winter and interseasonal**
- **Week days** and **week ends**
- **Day, night** and **peak**



CENSE
center for environmental and sustainability research

• Energy integrated modelling tools

- **[TIMES (The Integrated MARKAL-EFOM System)](#)** model generator was developed as part of the **IEA-ETSAP** (Energy Technology Systems Analysis Program), which uses <u>long term energy scenarios to conduct in-depth energy and environmental analyses</u> (Loulou et al., 2004).
- **TIMES is a technology rich, bottom-up model generator**, which uses linear-programming to produce a least-cost energy system, **optimized according to a number of user constraints**, over medium to **long-term time horizons.** In a nutshell, TIMES is used for, "<u>the exploration of possible energy futures based on contrasted scenarios</u>" (Loulou et al., 2005).

Global

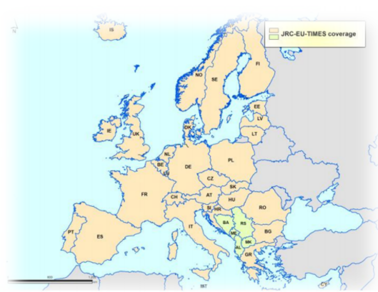
ETSAP-TIAM

15 regions

Regional

JRC-EU-TIMES model

28 European states



Available at: http://bookshop.europa.eu/en/the-jrc-eu-times-model-pbLDNA26292/?CatalogCategoryID=YysKABsty0YAAAEjqJEY4e5L

National

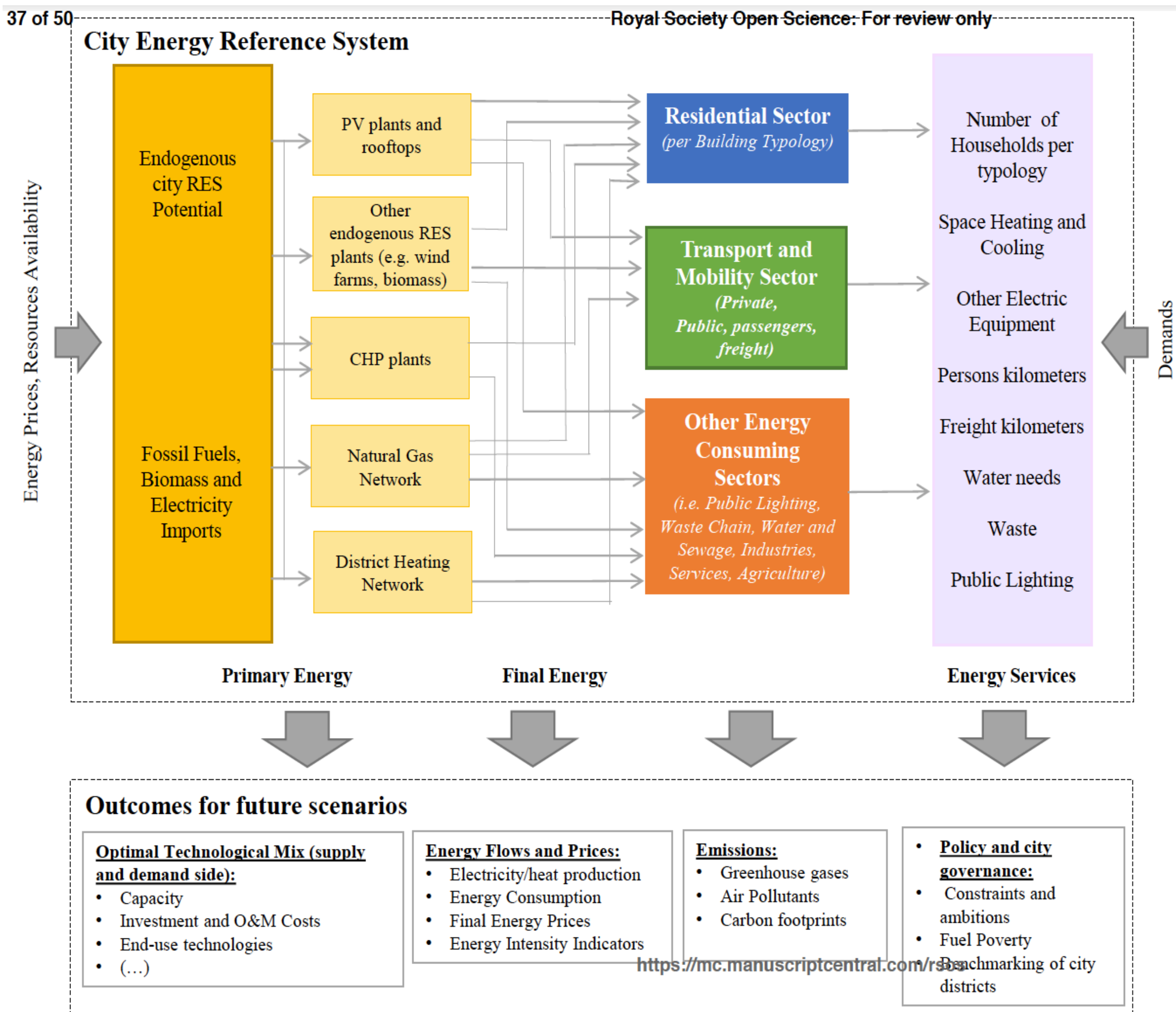
TIMES_PT

Local

TIMES_EVORA

More information at: http://www.iea-etsap.org/

- Energy integrated modelling tools



Integrated City Energy Planning framework and major outcomes

INSMART
Integrative Smart City Planning

- Energy integrated modelling tools

➔ **Generate Sustainable Future Energy (realistic) pathways**

by integrated city's energy system modeling [TIMES_city] to achieve the targets by 2030:

MOBILITY

- Expand the individual mobility soft-modes
- Prohibit cars in cities' historical centers
- Expand the use of electric vehicles (5-10% of vehicles)

HOUSEHOLDS

- 50% of households equipped with solar generation (PV and thermal)
- Smart-biomass heating systems (60% of fireplaces)
- Energy efficiency measures in 70% of households (double glazing, insulation, shadowing)

SERVICES BUILDINGS

- Reduce 30-50% of energy consumption & Demo on Zero Energy Building

PUBLIC SERVICES

- Reduce 30% waste generation
- Improve energy efficiency in waste water treatment plants
- Public lighting with 100% of LEDs

ENDOGENOUS POWER PRODUCTION

- 100% local power production

INSMART
Integrative Smart City Planning

- Local Stakeholders Participation for energy planning

1) Future technologies and measures towards low-carbon city by 2030 generated by integrated city's energy system modeling (TIMES)

2) Assessed through multi-criteria in 2 live-workshops with public bodies, private companies, NGOs and city planners and decision-makers.

➔ Priorities for development of Sustainable Energy Action Plan including financing possibilities

INSMART
Integrative Smart City Planning

- Local Stakeholders Participation for energy planning

  – **Results presented and classified according to each criterion weight**
  – **Stakeholders asked to review weights, if necessary**

Private sector		Public services		Local authoritues		Civil society	
Rank	**action**	**Rank**	**action**	**Rank**	**action**	**Rank**	**action**
1	Autocarros	**1**	Autocarros	**1**	Autocarros	**1**	Autocarros
2	Walls&Roof	**2**	Walls&Roof	**2**	Walls&Roof	**2**	Walls&Roof
3	Windows	**3**	Electric cars	**3**	Windows	**3**	Windows
4	PV 2030	**4**	Windows	**4**	Ciclovias	**4**	Electric cars
5	Electric cars	**5**	Redução velocidade	**5**	Electric cars	**5**	LED 2020
6	Shading	**6**	LED 2020	**6**	Shading	**6**	Ciclovias
7	Ciclovias	**6**	Aumento taxa	**7**	LED 2020	**7**	Shading
8	LED 2020	**8**	Shading	**8**	Decrease MSW	**8**	Aumento taxa
9	Aumento taxa	**9**	Ciclovias	**9**	Aumento taxa	**9**	Redução velocidade
10	Decrease MSW	**10**	PV 2030	**10**	PV 2030	**10**	Decrease MSW
11	Redução velocidade	**11**	Decrease MSW	**11**	Redução velocidade	**11**	PV 2030
12	Solar Th 2030	**12**	Transporte público	**12**	More recycling	**12**	Transporte público
13	LED 2030	**13**	LED 2030	**13**	Transporte público	**13**	LED 2030
14	Transporte público	**14**	Restrição tráfego	**14**	LED 2030	**14**	More recycling
15	More recycling	**15**	Solar Th 2030	**15**	Restrição tráfego	**15**	Restrição tráfego
16	Restrição tráfego	**16**	More recycling	**16**	Solar Th 2030	**16**	Solar Th 2030
17	Parques	**17**	Estacionamento	**17**	Parques	**17**	Parques
18	Estacionamento	**18**	Parques	**18**	Estacionamento	**18**	Estacionamento

What is the impact on natural resources use? And on materials use?

Mobility in Copenhagen