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DEPARTMENT OF

INDUSTRIAL ENGINEERING

Renewable Energy Conversion Systems

Lecture 20

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MSc Degree in Mechatronic Engineering,

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*Department of Information
Engineering*



Lecture 20: Outline

Main topic:

Electrification based on renewable energies

- The concept of electrification and its purpose
- Electrification in different sectors
 - Buildings
 - Industry
 - Transport
 - Power generation
- Potential risks of electrification

Lecture background



Higher Energy Demand



Urbanization, Megacities



Scarcity of Natural Resources



Environmental Awareness



Open Power Markets



Increased Use of Distributed Generation and Renewable Energy Resources



Capacity Increase and Bulk Power Transmission over long Distances



Power Distribution within congested Areas and Megacities



Goal: flexible, efficient and secure Grids

An ambitious goal



UN target: 2° (preferably 1.5°) global temperature rise not to be breached compared to pre-industrial levels

The EU aims to be **climate neutral** in 2050 by:

- investing in **environmentally-friendly technology**
- supporting **industry** to innovate
- rolling out cleaner forms of **transport**
- decarbonising the **energy sector**
- ensuring higher **buildings' energy efficiency**
- improve global environmental standards



The European Green Deal

- The **EU Green Deal** is a strategy for growth, aimed at making Europe climate-neutral and protecting its natural habitat

The EU will:



Become
climate-neutral
by 2050



Protect human life,
animals and plants,
by cutting pollution



Help companies
become world leaders
in clean products and
technologies

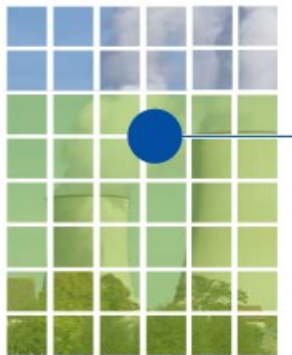


Help ensure a
just and inclusive
transition



The European Green Deal

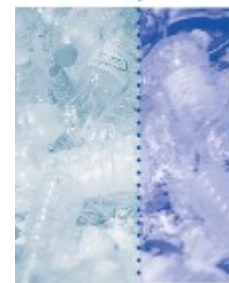
Carbon Neutrality moves from being a political commitment to being a **legal obligation** by being included in the **European Climate Law**



**Decarbonise the
energy sector**



**Renovate
buildings**



**Support industry
to become global
leaders in the
green economy**



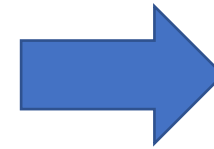
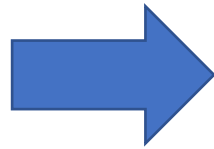
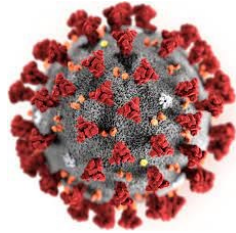
**Roll-out cleaner
forms of public
and private
transport**



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RePower EU



May 2022

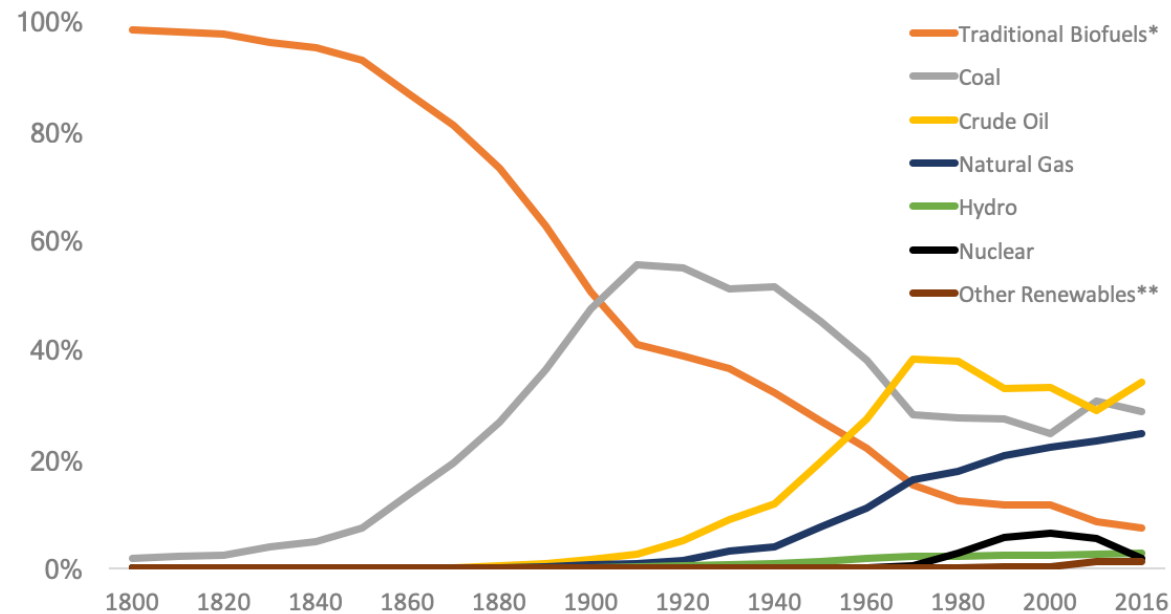
As a consequence of the invasion of Ukraine, EU has to revise its energy strategy to reduce and end its dependency on Russia

It relies on 4 measures: saving energy, producing clean energy, diversifying our energy supplies, backed by financial and legal measures



Energy transformation

Share of Global Primary Energy Mix



Data Source: Vaclav Smil (2017), *Energy Transitions: Global and National Perspectives*

Notes: *Burning wood and other organic matter

**Wind, solar and modern biofuels



Source: Crystol.com



Source: United Nations



Energy transformation goal

To achieve sustainability and climate goals we need a new energy system transformation underpinned by:

- Large expansion of renewable energy generation
- Huge increase in the number of products & processes relying on electricity (including transport)
- A flexible and smarter electricity grid

These are the pillars or “*RE-Electrification*” (Electrification with renewables)



What is the «Electrification»?

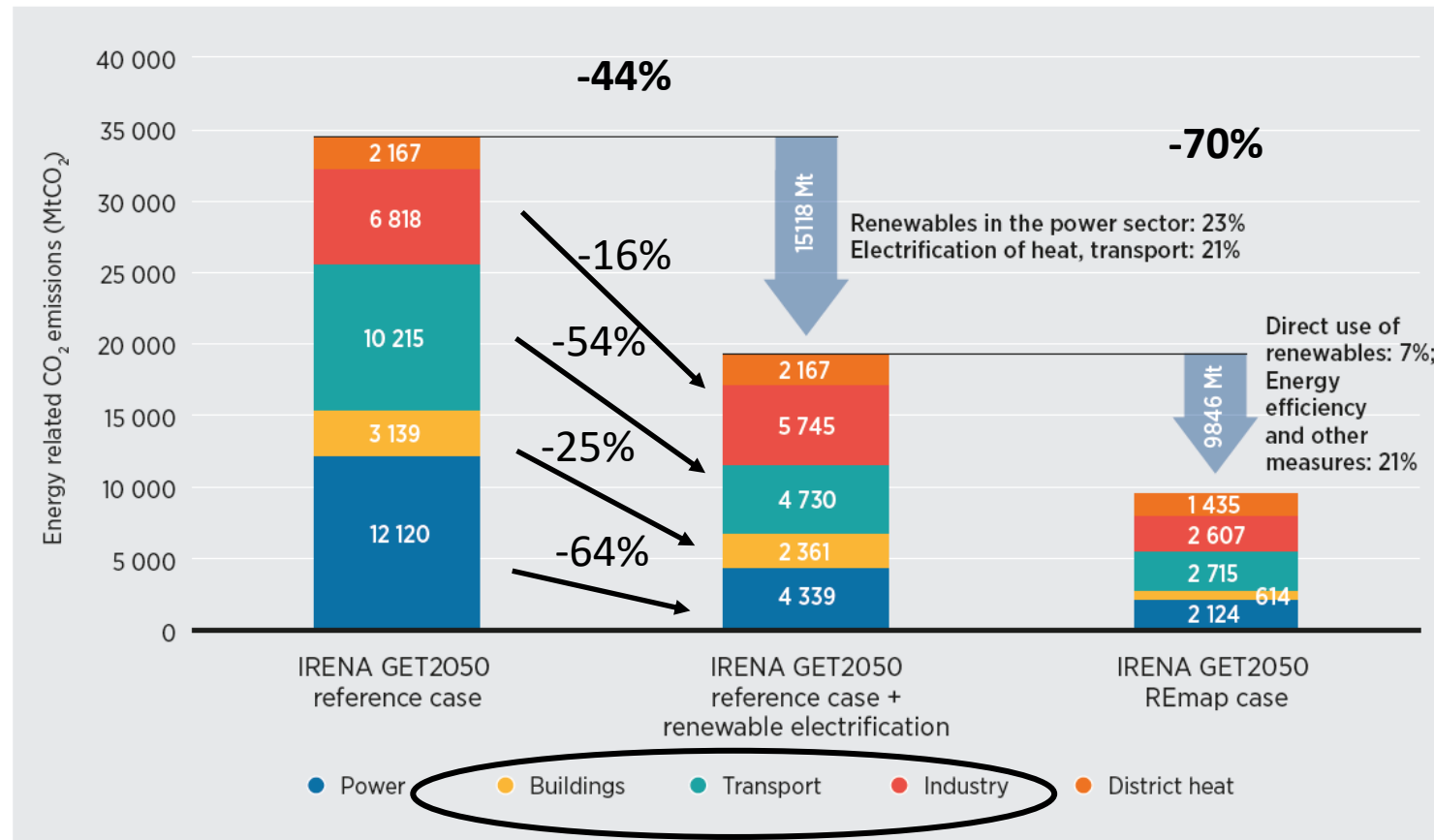
- **Electrification** is the process of powering by electricity and, in many contexts, the introduction of such power by changing over from an earlier power source
(Wikipedia)
- In other words, **electrification** is defined as the substitution of electricity for direct combustion of non-electricity-based fuels used to provide similar services
(National Renewable Energy Lab - NREL)



Usefulness of electrification

- **Electrification can enable a more sustainable energy supply, i.e. through grid integration of renewable energy sources**
- **Electrification can contribute to making industrial processes and energy use more efficient**

Electrification for decarbonization

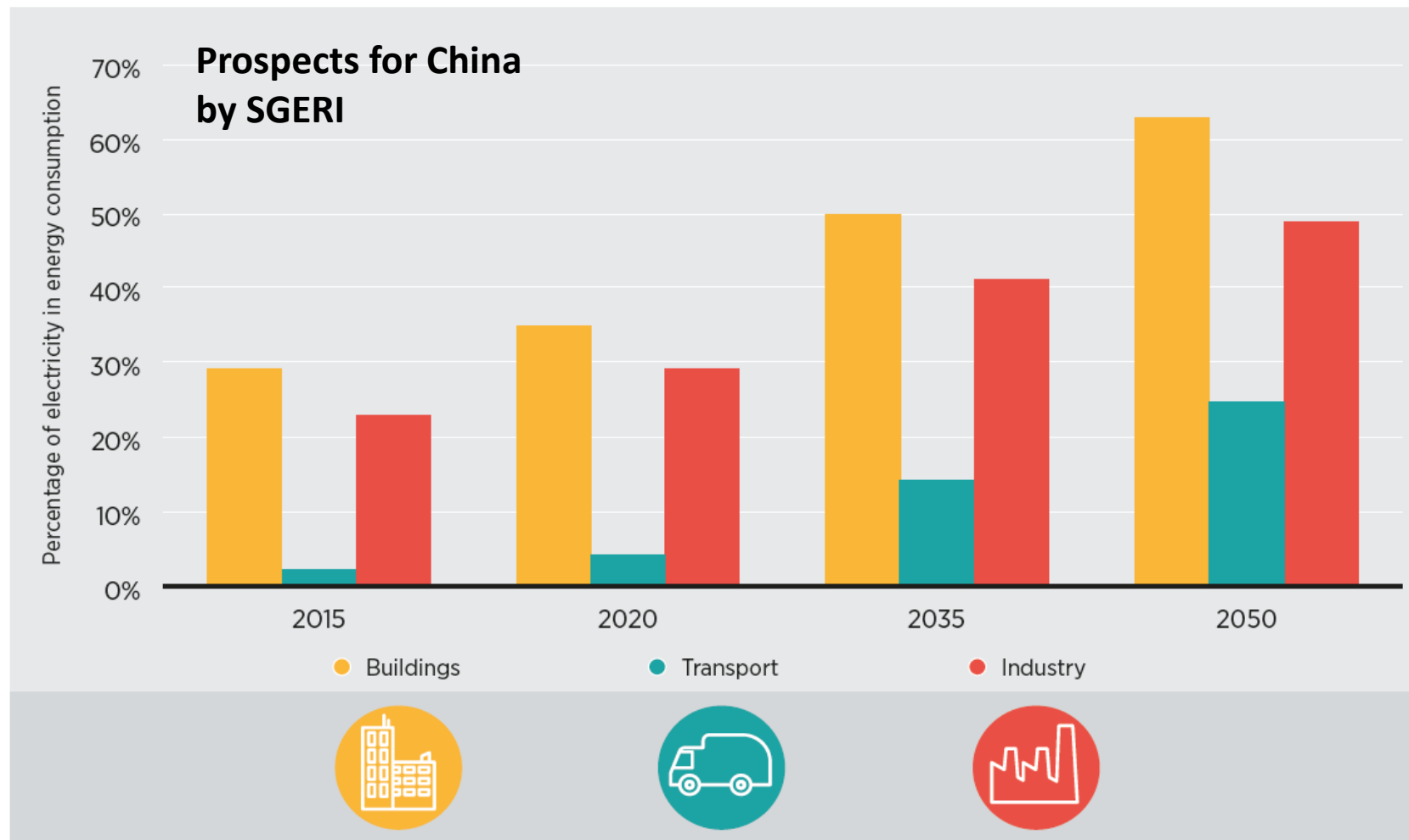


Notes: CO₂ = carbon dioxide; MtCO₂ = million tonnes of carbon dioxide.

Source: IRENA's own analysis based on IRENA (2018a)

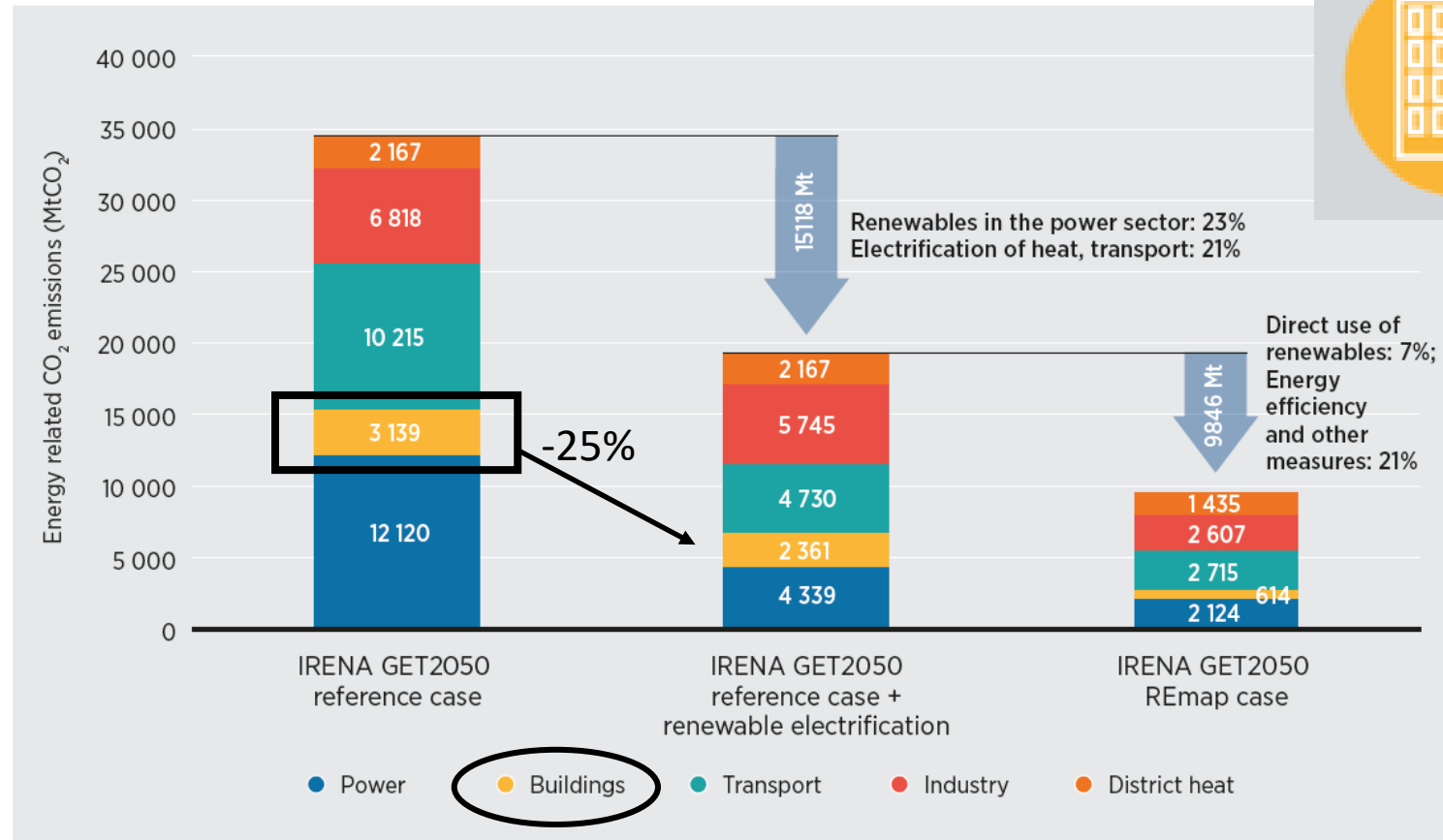


Electrification for decarbonization



Source: SGERI's own analysis

Electrification in buildings



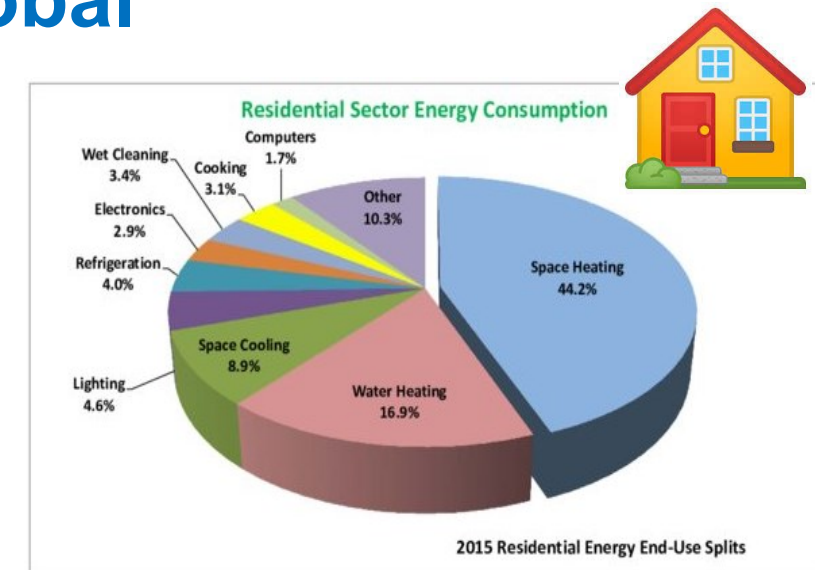
Notes: CO₂ = carbon dioxide; MtCO₂ = million tonnes of carbon dioxide.

Source: IRENA's own analysis based on IRENA (2018a)

Electrification of buildings

- Buildings now use about 120 exajoules (EJ) of energy globally per year, about 30% of global final consumption (IEA, 2018)
- More than half of that energy is supplied by natural gas, oil, coal, or biomass.

Homes and other residences consume about 70% of buildings energy, while commercial and government buildings use the rest



Over 50% of energy consumption is related to HVAC systems

Electrification of buildings

Perspectives for increasing electrification:

Improve Heating, Ventilation and Air Conditioning (HVAC)

- Switch to heat pumps for space heating and hot water
- Use electricity directly for resistance heating in boilers and furnaces
- Increase the use of Variable Speed Drives



Electrification of buildings

HVAC systems are normally sized for peak load conditions

- Chillers, air handlers and heat pumps can be coupled to **variable frequency drives** which can adapt the speed of fans, pumps and compressors to the actual need of the building
- **Example of a public building**

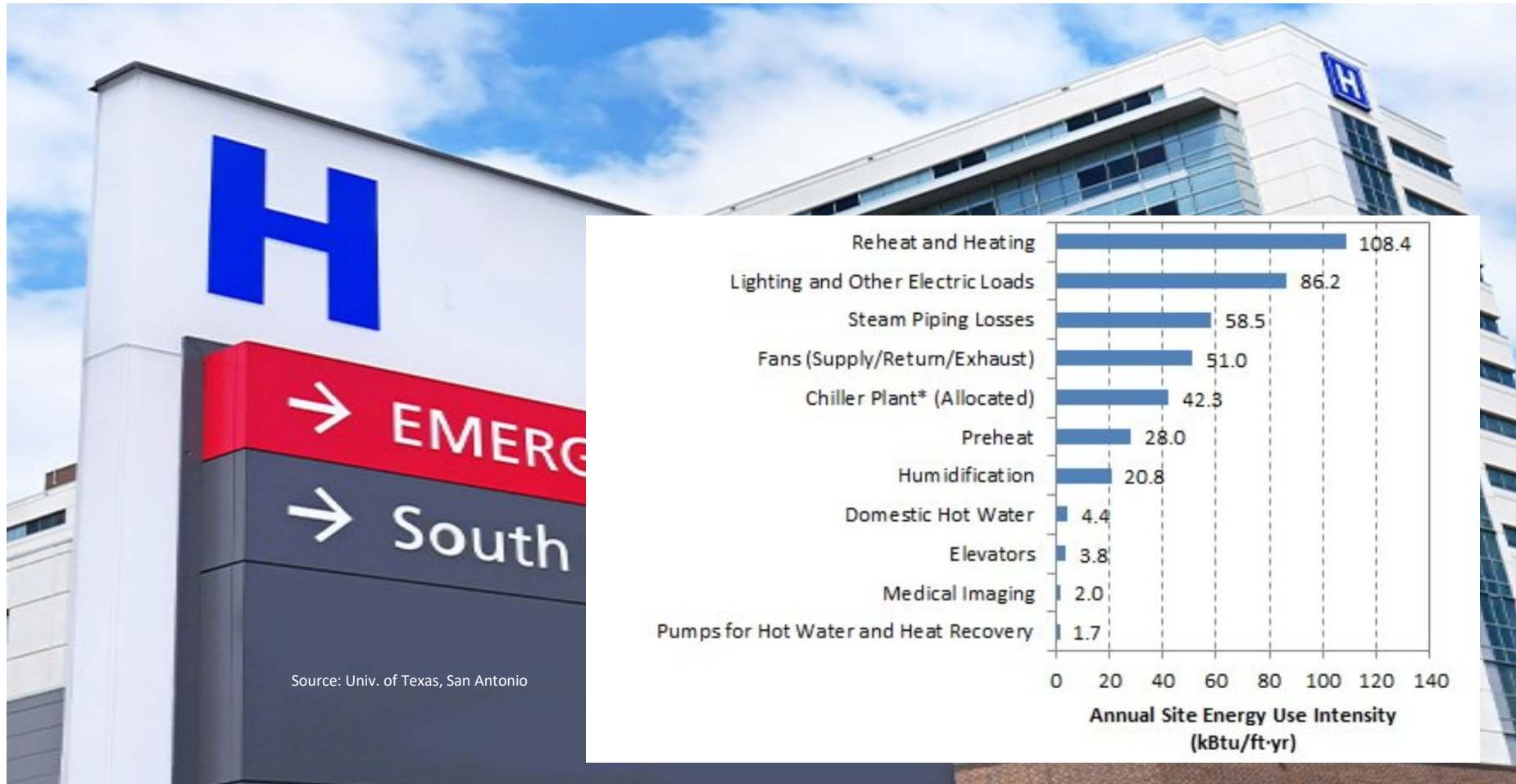


Source: Schibuola et al. (2018)

Electricity savings up to 39% vs. fixed speed solutions are achieved

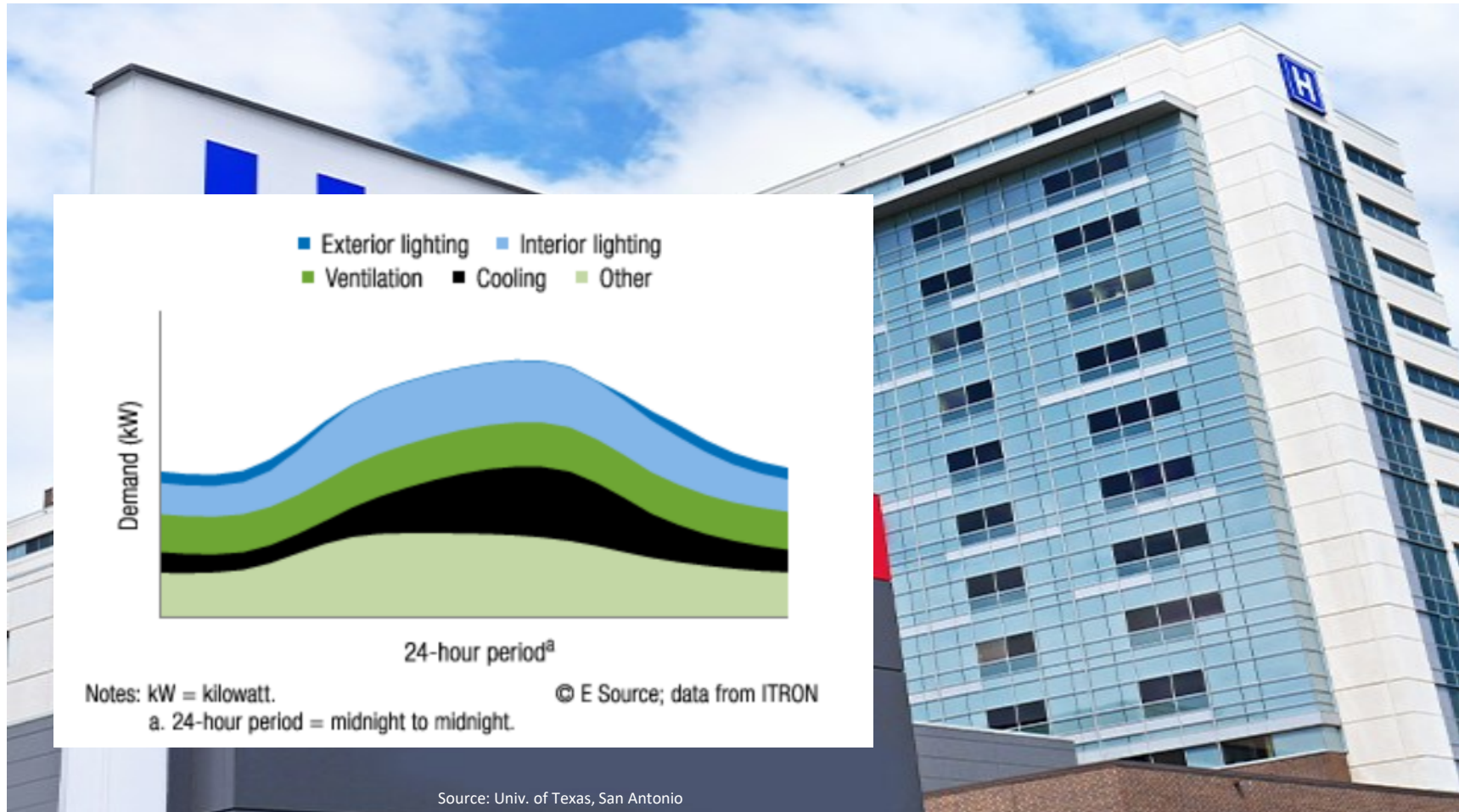


Electrification of mission critical applications: hospitals





Electrification of mission critical applications: hospitals



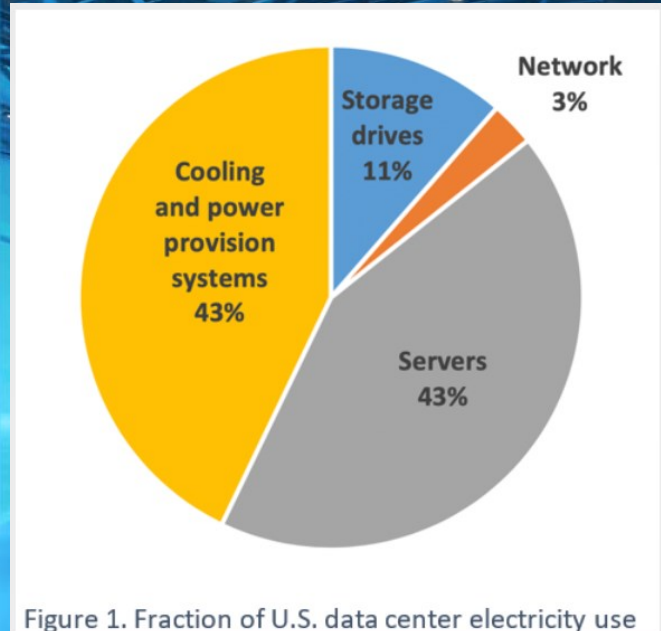
- Hospitals use three to five times as much energy as a five-star hotel when it comes to heating, ventilation and air conditioning (HVAC),

Controllers can save 25% to 50% of total Roof Top Units energy consumption for single-zone cooling (with a capacity of 5 tons or greater)

Variable speed drives save the most energy in spaces with lower ventilation requirements, and they can decrease the power used by fans by up to 50%.

Electrification of mission critical applications: data centers

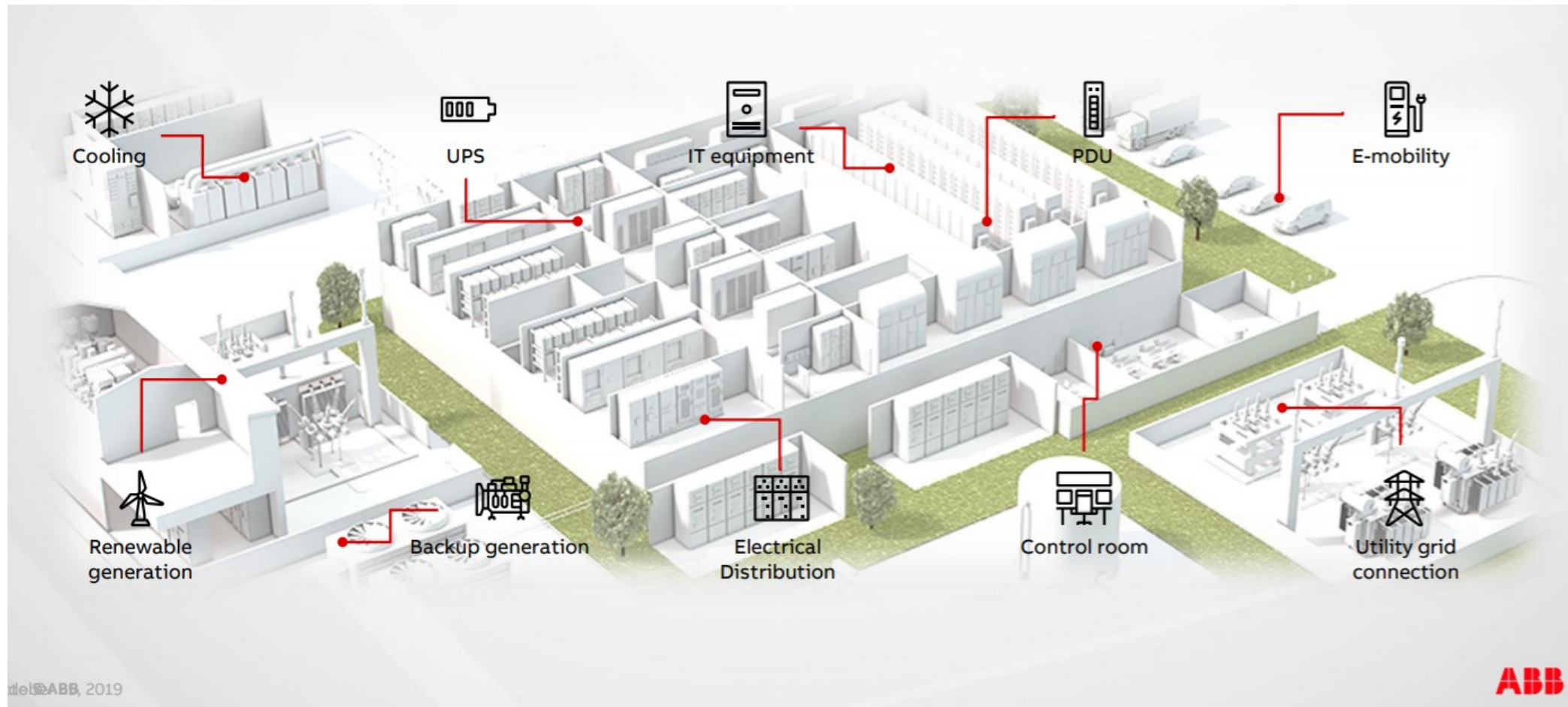
The largest data centers can require more than 100 MW of power capacity



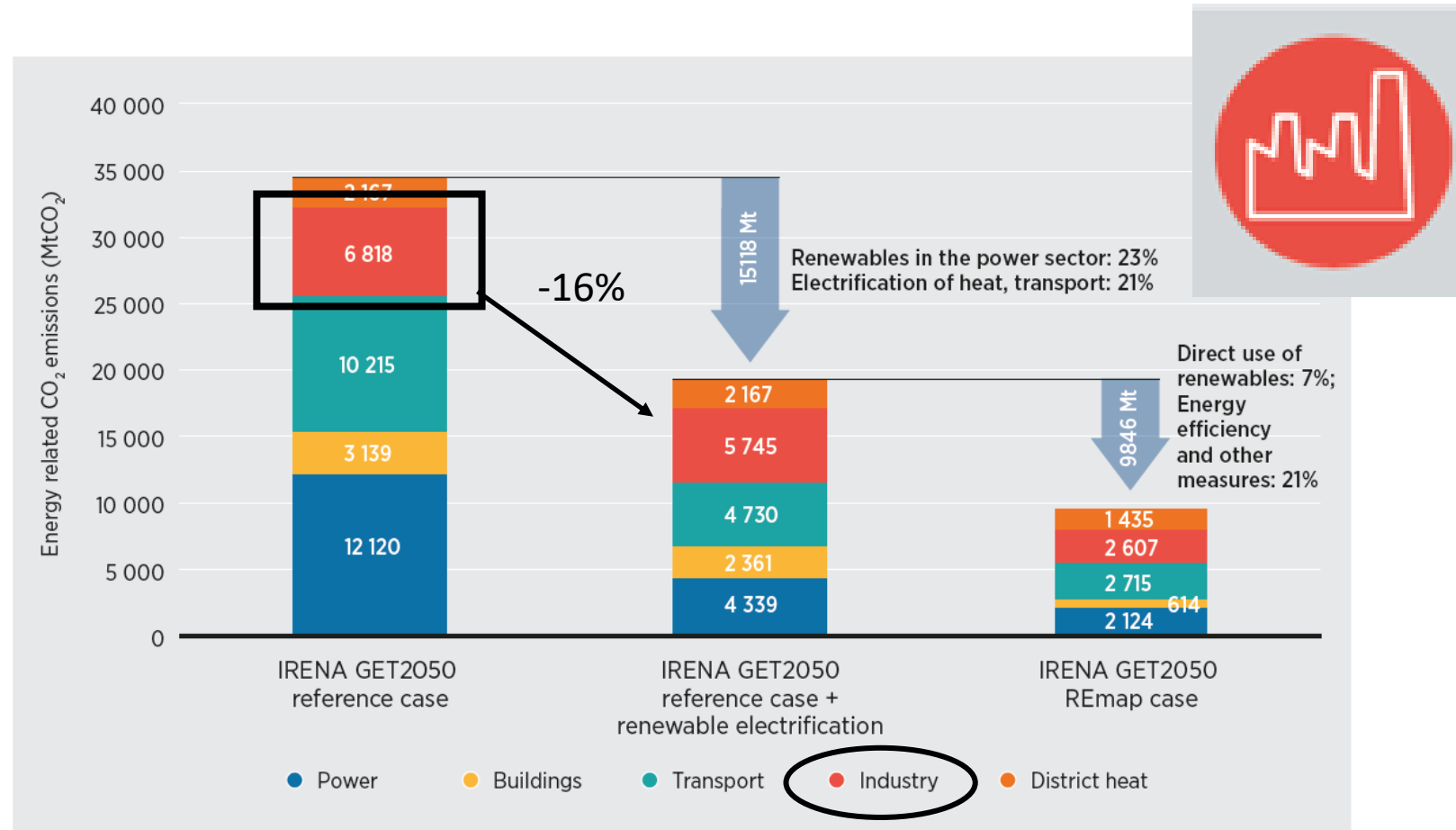
According to the study, in 2018, the world's data centers consumed 205 terawatt-hours of electricity, or about 1% of all electricity consumed that year worldwide.



Electrification of mission critical applications: data centers



Electrification in the industrial sector



Notes: CO₂ = carbon dioxide; MtCO₂ = million tonnes of carbon dioxide.

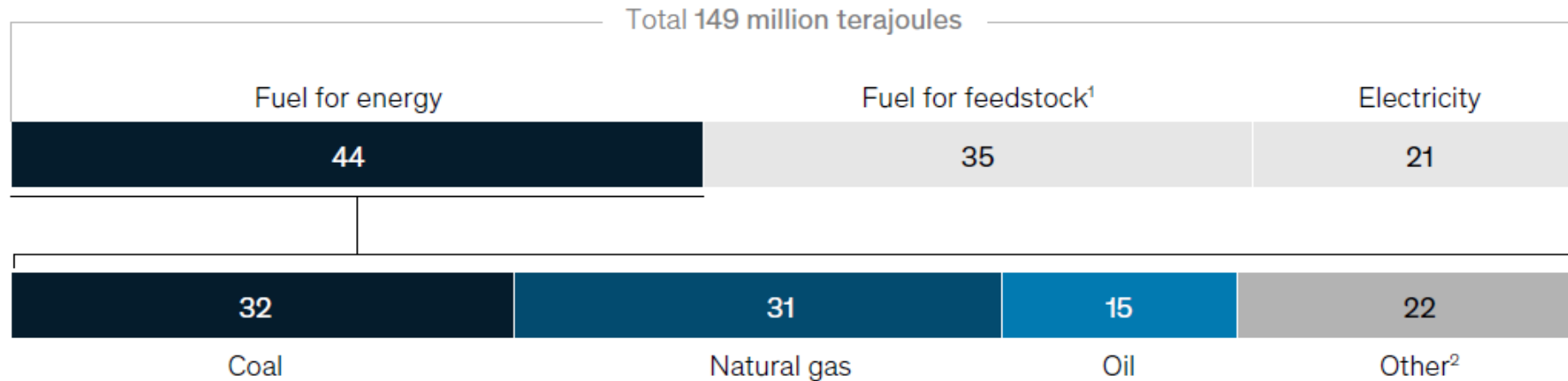
Source: IRENA's own analysis based on IRENA (2018a)



Electrification in the industrial sector: Heating, ventilation and air conditioning

Share of total estimated industrial energy consumption, 2017, %

Source: McKinsey



- 44% of energy consumption in industry is fuel consumed for energy. This includes the generation of heat for processes such as drying, melting, and cracking.
- It is technologically possible to **electrify up to half of the industrial fuel consumption today**
- Electrically driven industrial equipment is slightly **more energy efficient** than the conventional option, but it has **lower maintenance** costs, and, in the case of the industrial boiler, the **investment cost** of the electrical equipment is lower.



Electrification in the industrial sector: Heating, ventilation and air conditioning



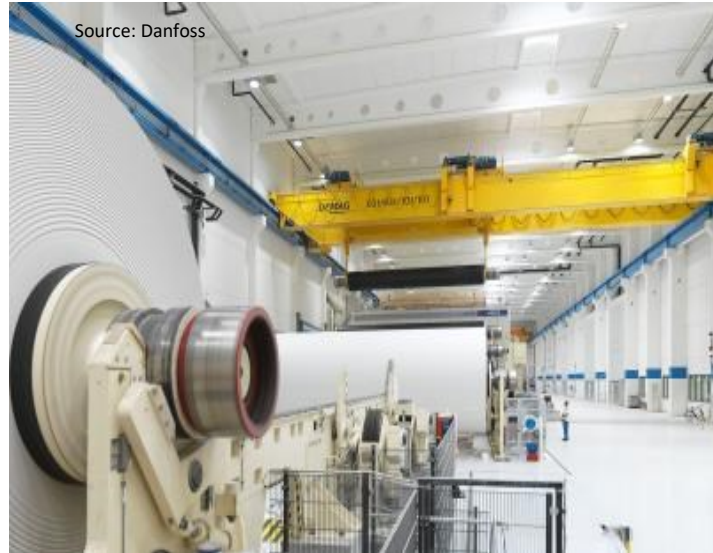
- Required processes are related to heating, cooling, drying and circulating air.
- They imply taking the extra heat out of the building or providing additional heat energy to the building
- Use of an electric drive to control the fan or pump output avoids using dampers, vanes, valves or on/off control



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Electrification in the industrial sector: paper, steel & process industry



Hoists and rollers are used in the paper and steel industry

Agitators, pumps, fans & compressors are common in process industry


Electrification permits quick and substantial reductions in industry's carbon emissions as the bulk of energy use is in just a few energy-intensive industries, such as metals and chemicals

Electrification in the industrial sector

Perspectives for increasing electrification

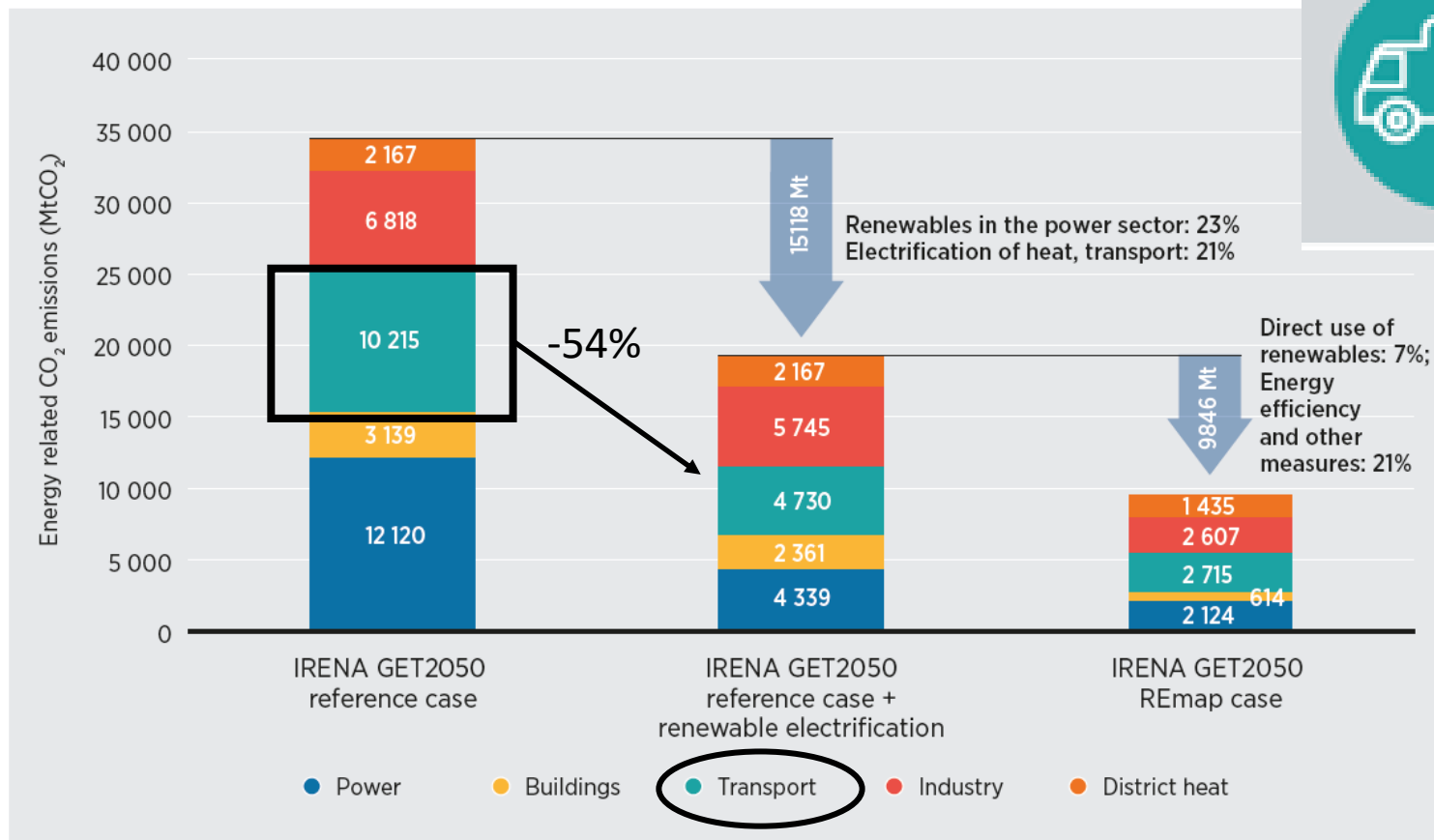
Improve Heating, Ventilation and Air Conditioning

- Increase the use of efficient heat pumps for low temperature heat
- Adopt electric boilers or hybrid boilers that can switch instantly between electricity and natural gas
- Replace natural gas fuel and feedstocks with hydrogen or its derivatives produced with renewable power



Electrifying new plants is easier than refurbishing old ones

Electrification in the transport sector



Notes: CO₂ = carbon dioxide; MtCO₂ = million tonnes of carbon dioxide.

Source: IRENA's own analysis based on IRENA (2018a)



Electrification in the transport sector

Currently, only about **1% of total energy use in transport** (including passenger & cargo transport by road, rail, maritime shipping and aviation) is supplied by **electricity**

More than two-thirds of that is used for rail transport globally, and much of the rest is used by tram and subways

Electrification in the transport sector

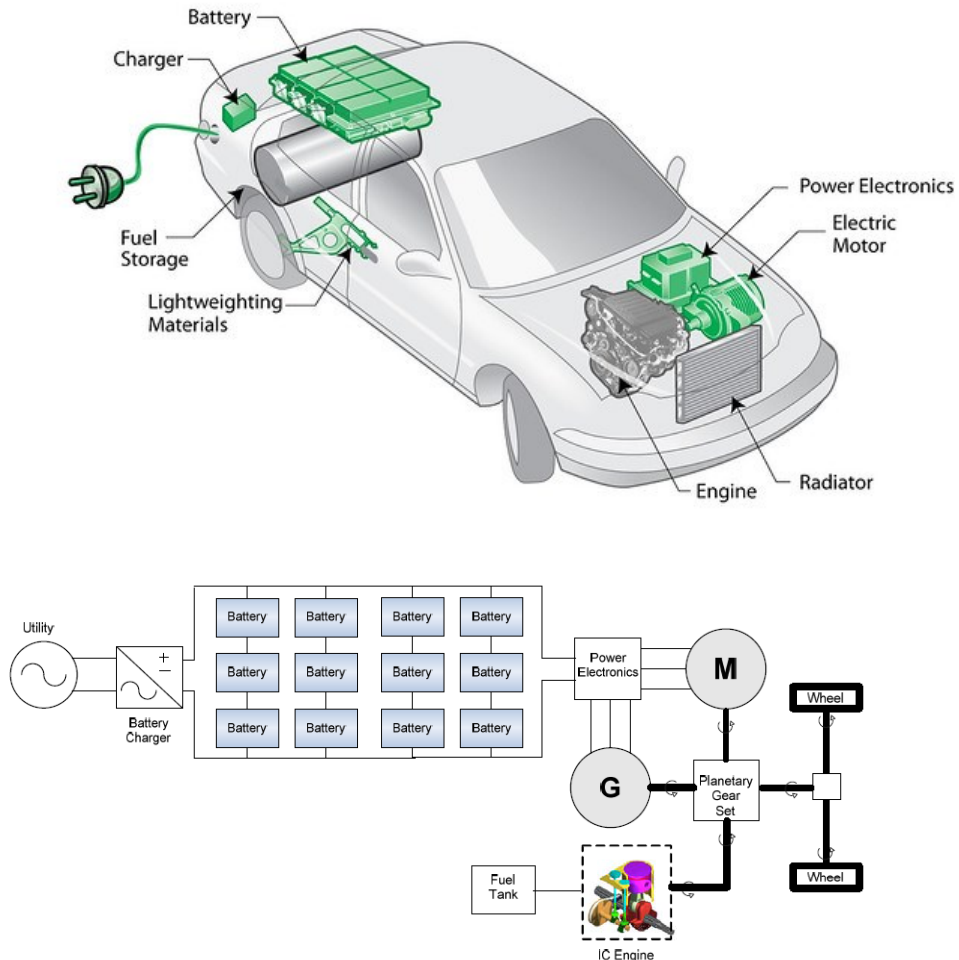
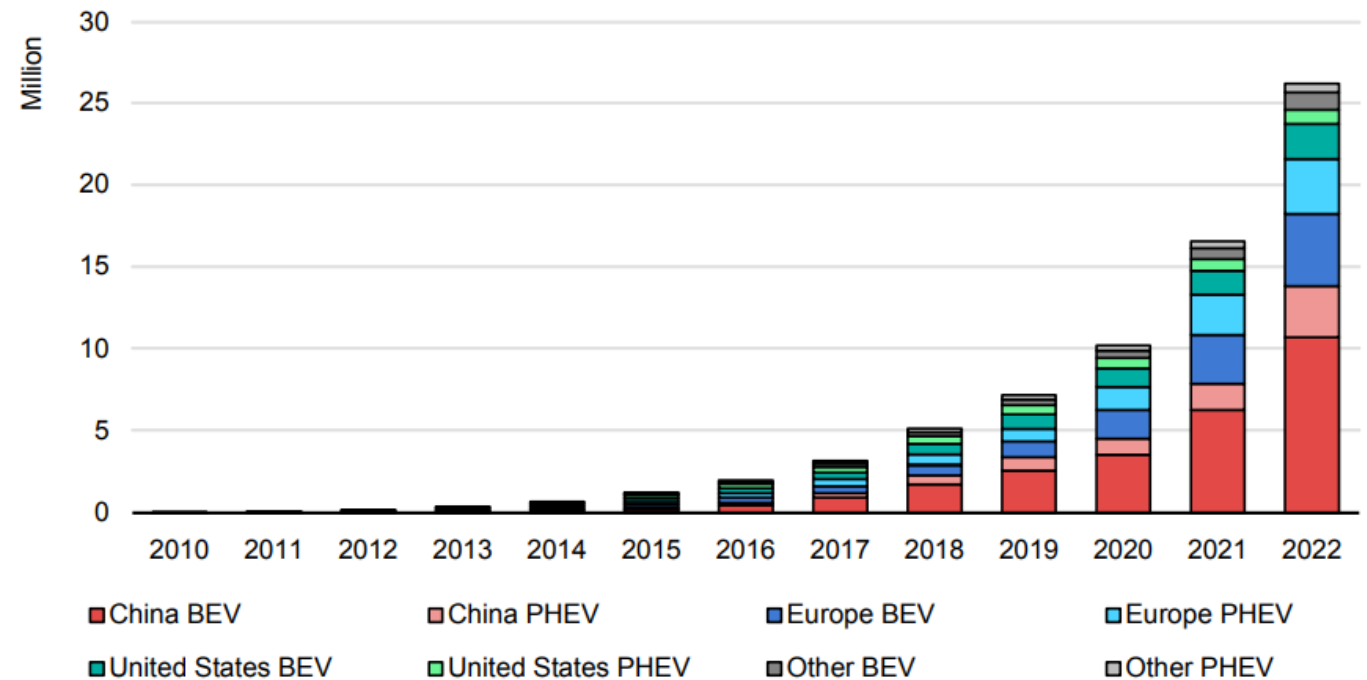


Figure 1.1 Global electric car stock in selected regions, 2010-2022





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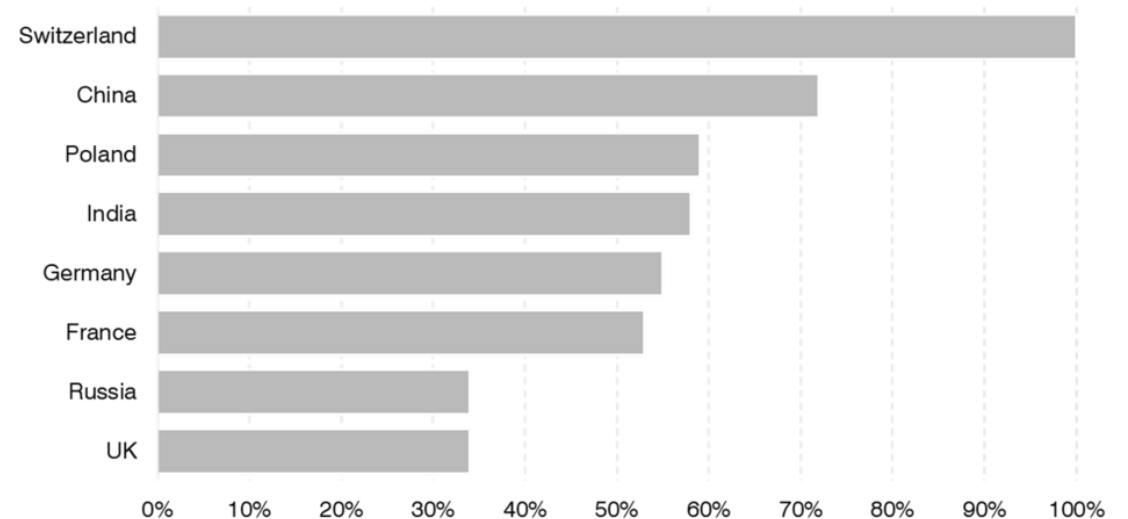
Electrification in the transport sector



Electrification in the transport sector



Electrification grade railway in selected countries including private railways [%]



© SCI Verkehr

Of about 1.3 million km of track worldwide, about 375,000 km are electrified, bringing the total volume to just under 30%. In the individual market regions, the degree of electrification varies between 1% in North America and 57% in the Western Europe. The degree of electrification in Asia has risen sharply in recent years. In 2013 it was 34%, four years later 47% and in 2020 already 55%



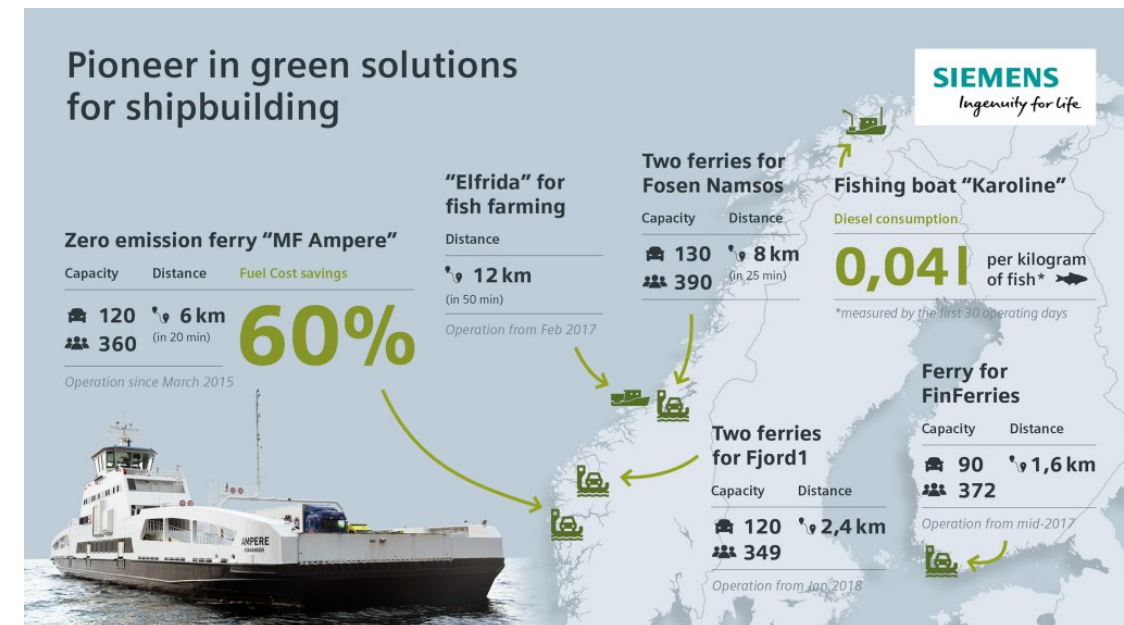
Electrification in the transport sector



Worldwide, maritime transport is responsible for almost 2.5% of total GHG emissions

One single large ship emits as much CO₂ as 70,000 cars, as much nitrogen oxide as 2 million cars

By 2050, the 173 member states of the UN organization want to at least halve CO₂ emissions from ships compared to 2008





Electrification in the transport sector

Nearly 3% of total greenhouse gases produced globally are from aviation sector

Another reason favoring the electrification of the aviation sector is cost of operation: electric planes have a **low cost of operation due to low maintenance cost and secondly, they could use renewable energy resources (cheaper than jet fuel)**

Aircraft electrification can also overcome 'noise-problem'





Electrification in the transport sector

Perspectives for increasing electrification:

- Increase EVs' share on the roads
- Supply heavy-vehicles and trains with green hydrogen for long distance transport
- Use of synthetic gas or oil (hydrogen derivatives) to replace fossil-based transport fuels (beyond road transport)

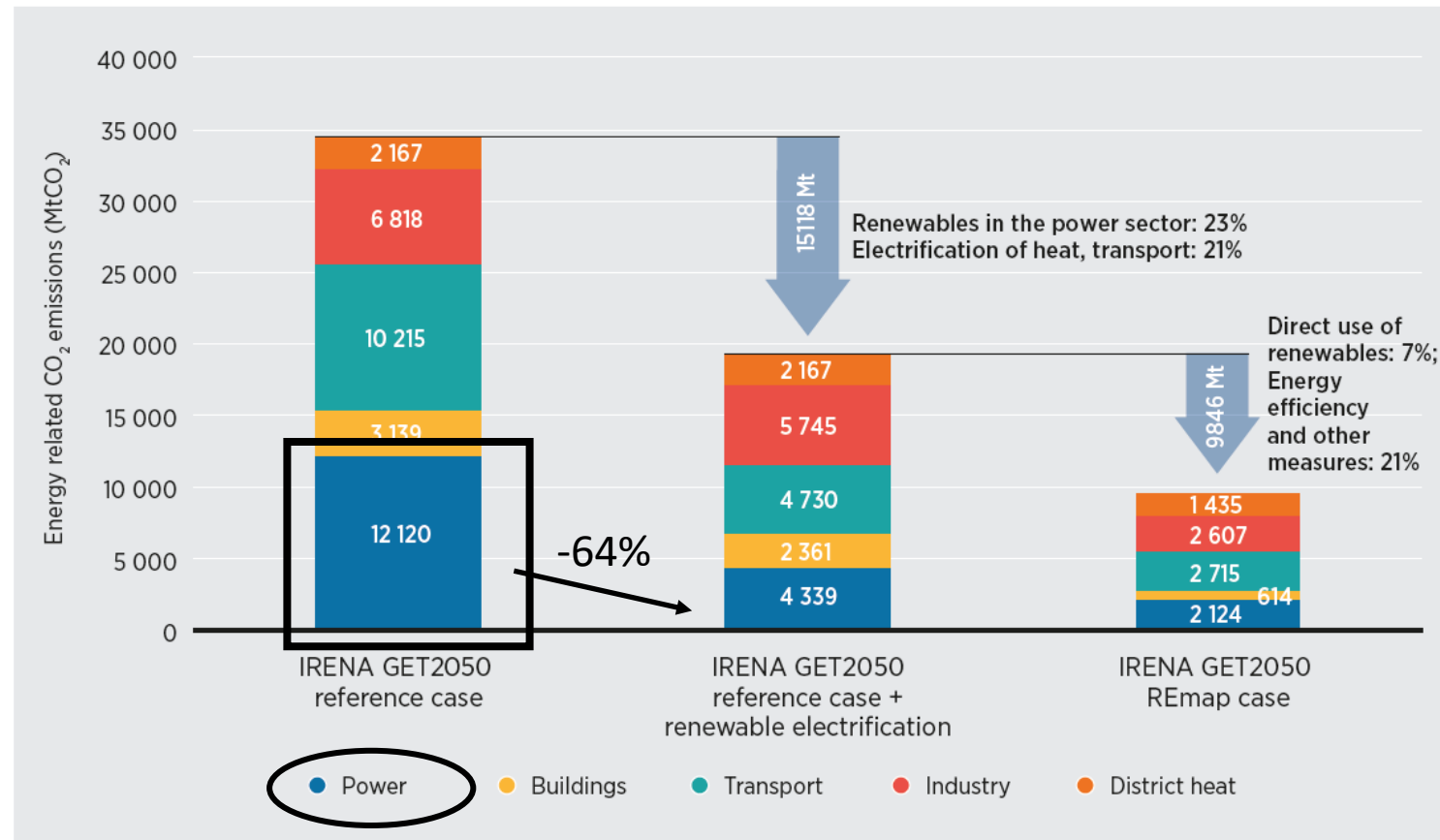


Electrification in the transport sector

- The **electrification of transport** is ideal for **use of renewable power**, given the intermittency of natural resources such as solar and wind and the fact that road vehicles are parked about 90% of the time.
- This provides the required **flexibility** to match their charge/discharge schedule to match the variability of the renewable generation



Electrification in the power sector

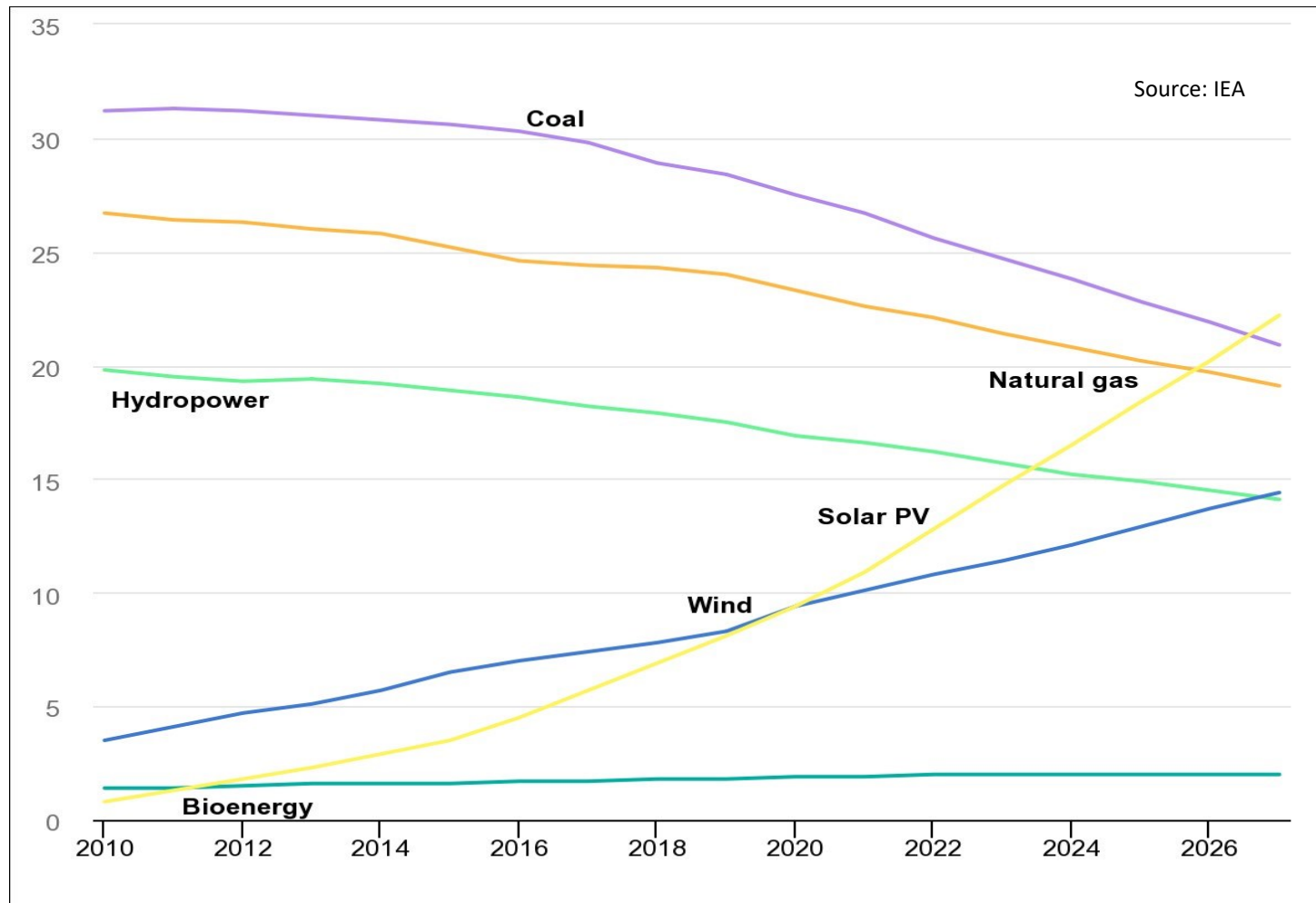


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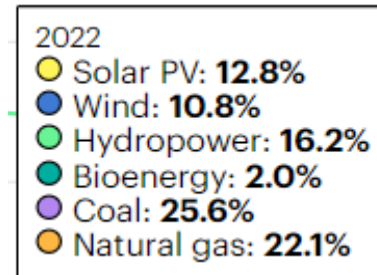
Source: IRENA's own analysis based on IRENA (2018a)



Electrification in the power sector

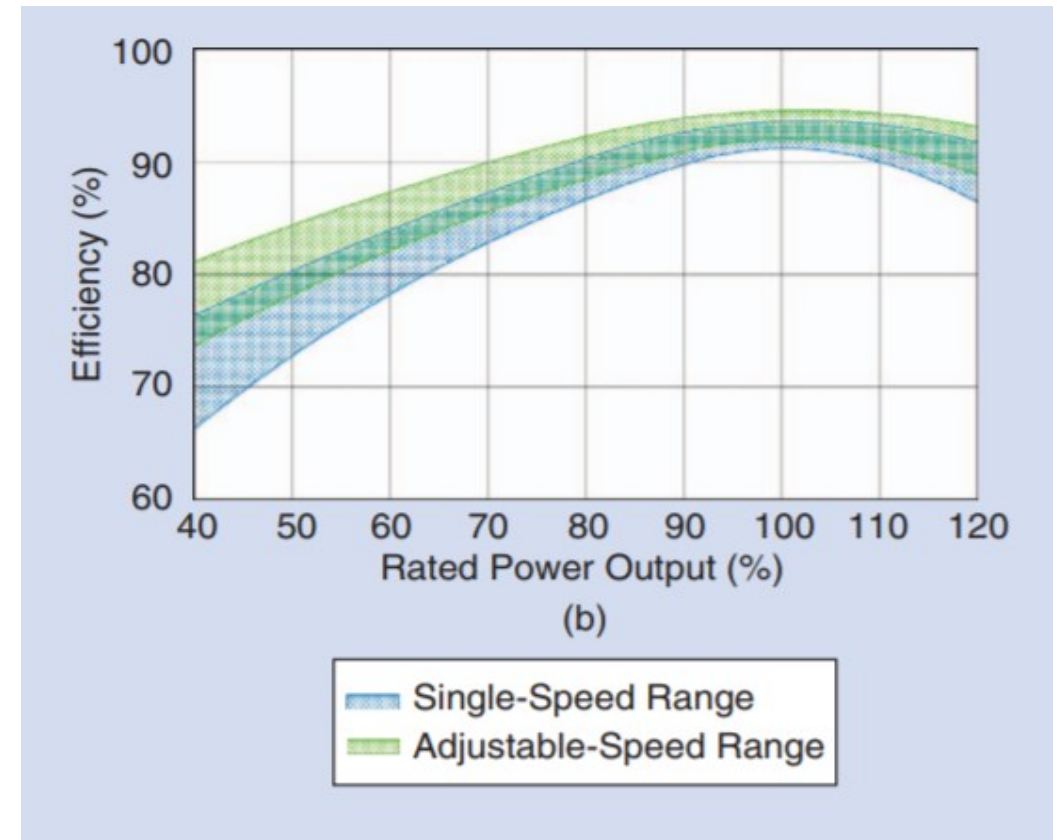


Growth in the renewable energy use



Share of cumulative power capacity by technology, 2010-2027

Electrification in the power sector



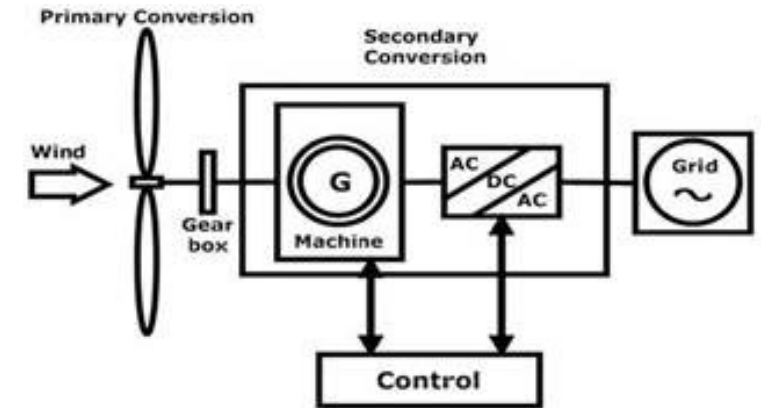
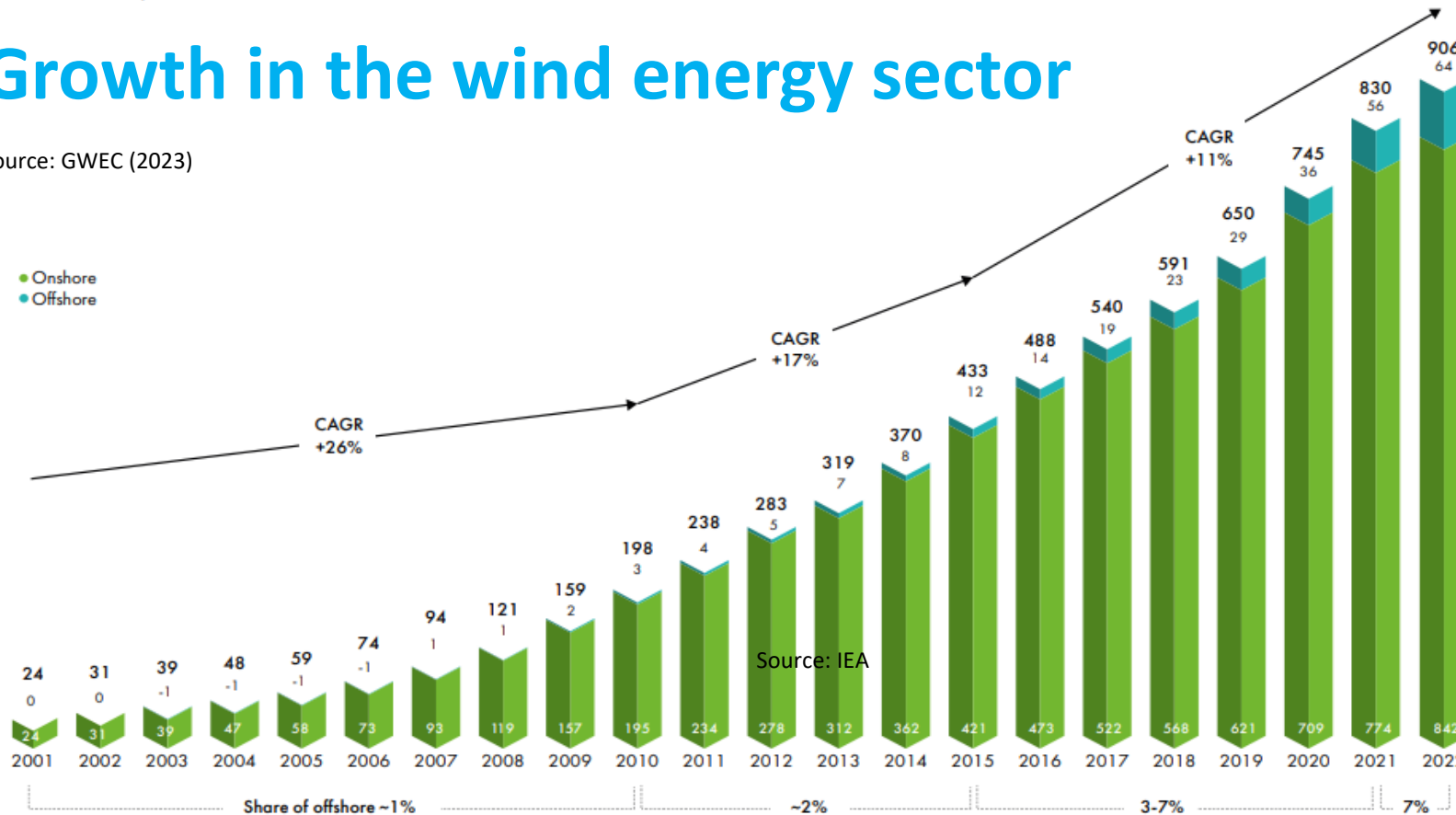
Source: M. Valavi, A. Nysveen

Electrification in the power sector

Historic development of total installations (GW)

Growth in the wind energy sector

Source: GWEC (2023)



Source: Blaabjerg et al.



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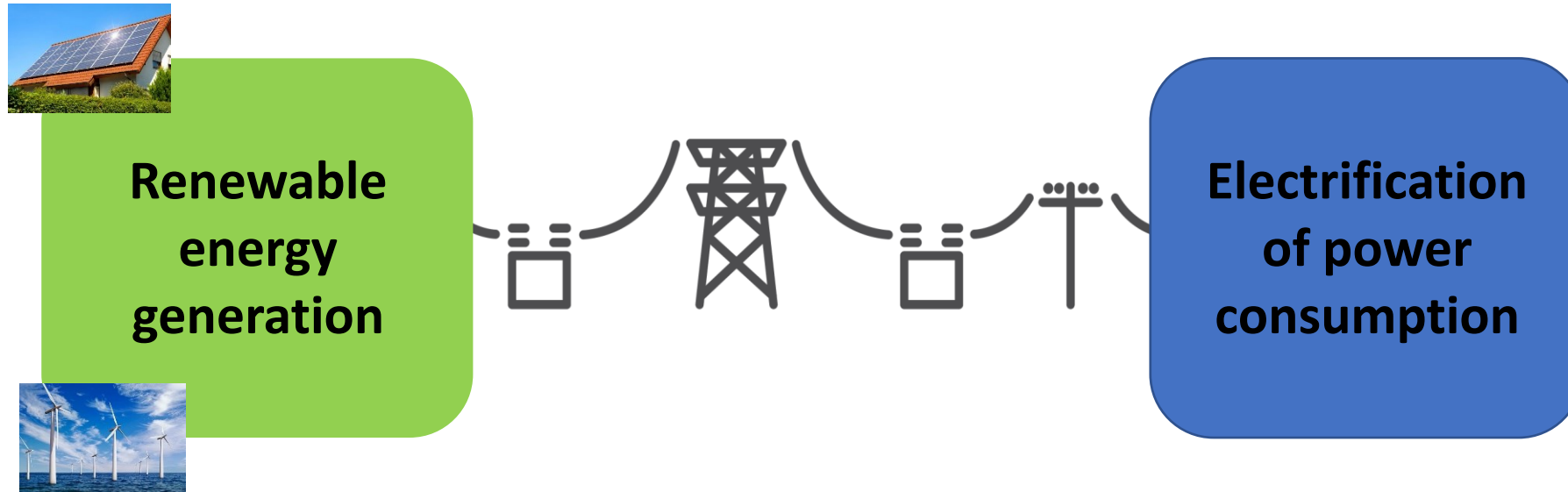
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Electrification in the power sector



Power electronics is a key enabling technology
at the core of the electrification process

Electrification in the power sector



To implement **electrification** at scale, it will be necessary to invest in buildings or to upgrade critical **infrastructures**



Risks of electrification

Increased **electrification** could **negatively impact** the power system by increasing the peak power demand with respect to the average demand

As the grid infrastructure needs to be rated for the peak demand, **costly upgrades** may be required



Risks of electrification and solutions

The risk of congestions in the grid can be addressed:

- **by smart demand management (e.g. smart charging of EVs, V2G functionality etc.)**
- **combining and operating distributed energy resources as Virtual Power Plants**
- **co-locating generation and consumption where possible**
- **deploying energy storage**
- **exploiting synergies of multi-energy systems**



Electrification based on renewables

RE-electrification is a particularly powerful strategy because it takes advantage of potential synergies between electrification and renewable energy, and between sectors of the economy.

At the same time, however, it is a very complex undertaking, since steps taken in one sector can have major impacts on other sectors and their infrastructure requirements



Electrification based on renewables

Application side - Goal: Increase the efficiency, sustainability and flexibility on the energy use

Generation side - Goal: Increase the sustainability of the energy mix by more and efficient renewables

Grid side - Goal: Optimize the energy infrastructure to enable the electrification of society



References

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