CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY
An Initiative of the Clean Energy Ministerial

INTERNATIONAL SOLAR ALLIANCE

International Solar Alliance Expert Training Course

In partnership with the Clean Energy Solutions Center (CESC)

Dr. David Jacobs

Session 31: Sector coupling - Using PV for the heating/cooling and transport sector

In partnership with the Clean Energy Solutions Center (CESC)

Dr. David Jacobs

Supporters of this Expert Training Series

International Energy Transition

INTERNATIONAL SOLAR ALLIANCE

CLEAN ENERGY SOLUTIONS CENTER

ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

IET – International Energy Transition GmbH

Dr. David Jacobs

- Founder and director of IET
- Focus on sustainable energy policy and market design
- 14+ years experience in renewable energy policies
- 60+ publications on energy and climate
- 40+ countries work experience (consulting and presentations)

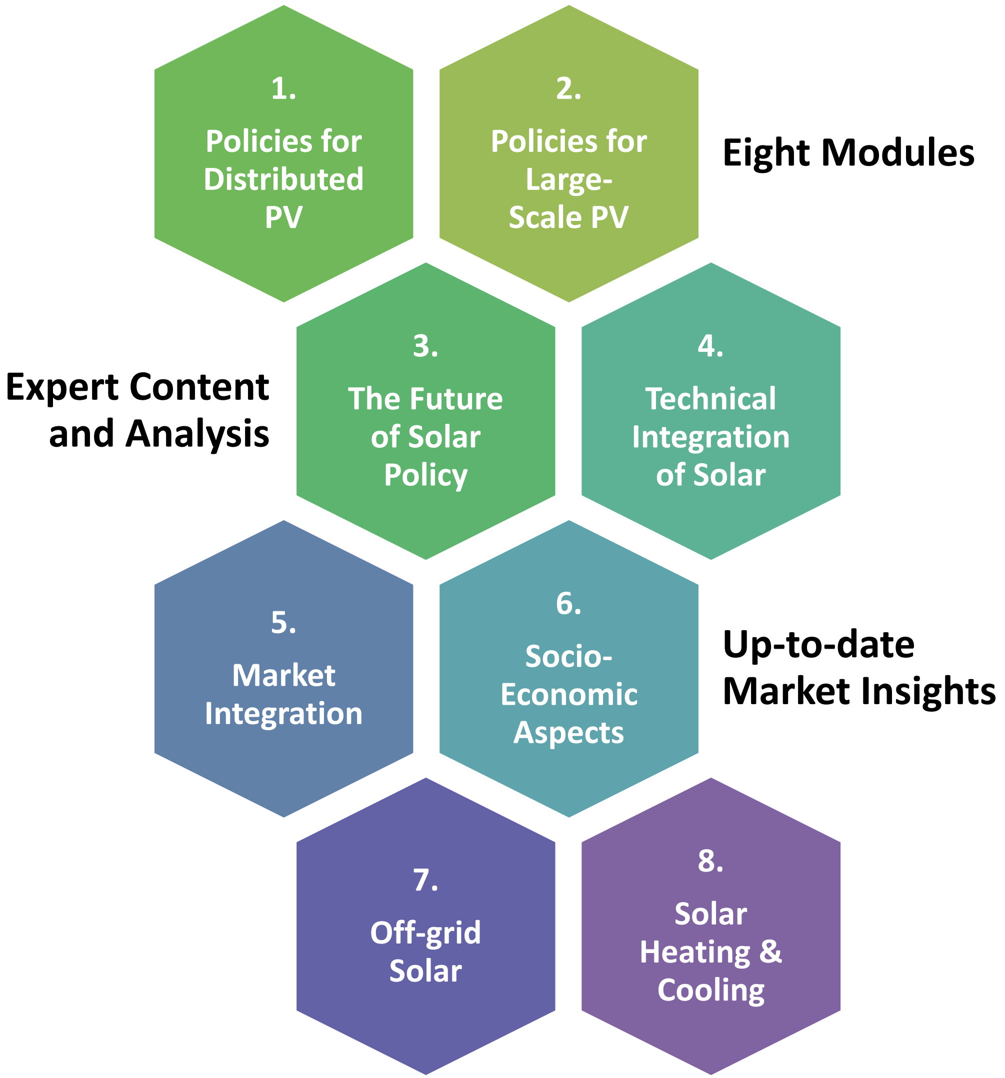
Training Course Material

International Energy Transition

This Training is part of Module 5, and focuses on System and Market Integration

<u>Related training units are:</u>

- ✓ 27. System integration of renewables in wholesale electricity markets
- ✓ 30. Solar PV and the Role of Storage
- ✓ 43. Solar Heating and Cooling: Challenges and Opportunities



Overview of the Training Session

1. Introduction: Learning Objective

2. Understanding opportunities and challenges of using solar PV in other sectors

3. Further Reading

4. Knowledge Check: Multiple-Choice Questions

Introduction:

Learning Objective

Learning Objective

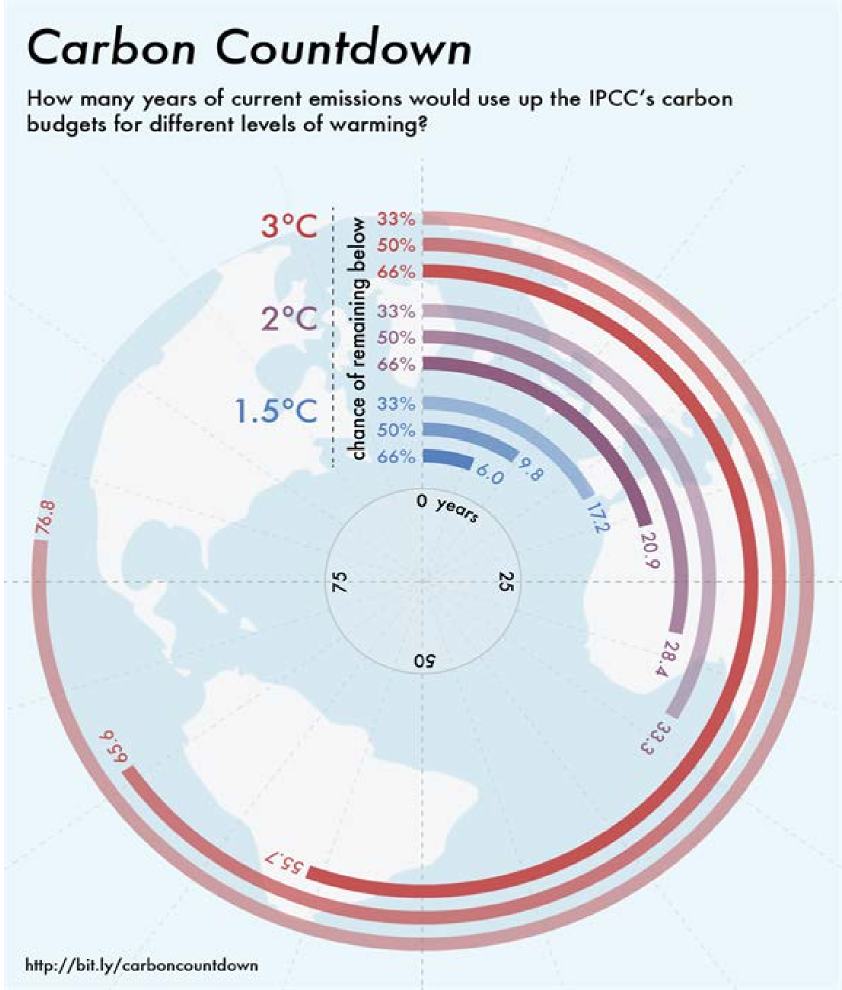
- Understand the role of sector coupling for a decarbonized energy sector
- Understand the basic framework conditions for successful sector coupling (infrastructure, market design/rate design; harmonized taxation)
- Learn about options for using solar PV in the transport sector
- Learn about options for using solar PV in the heating/cooling sector

Decarbonizing the energy sector:

The role of electrifying the transport and heating/cooling sector

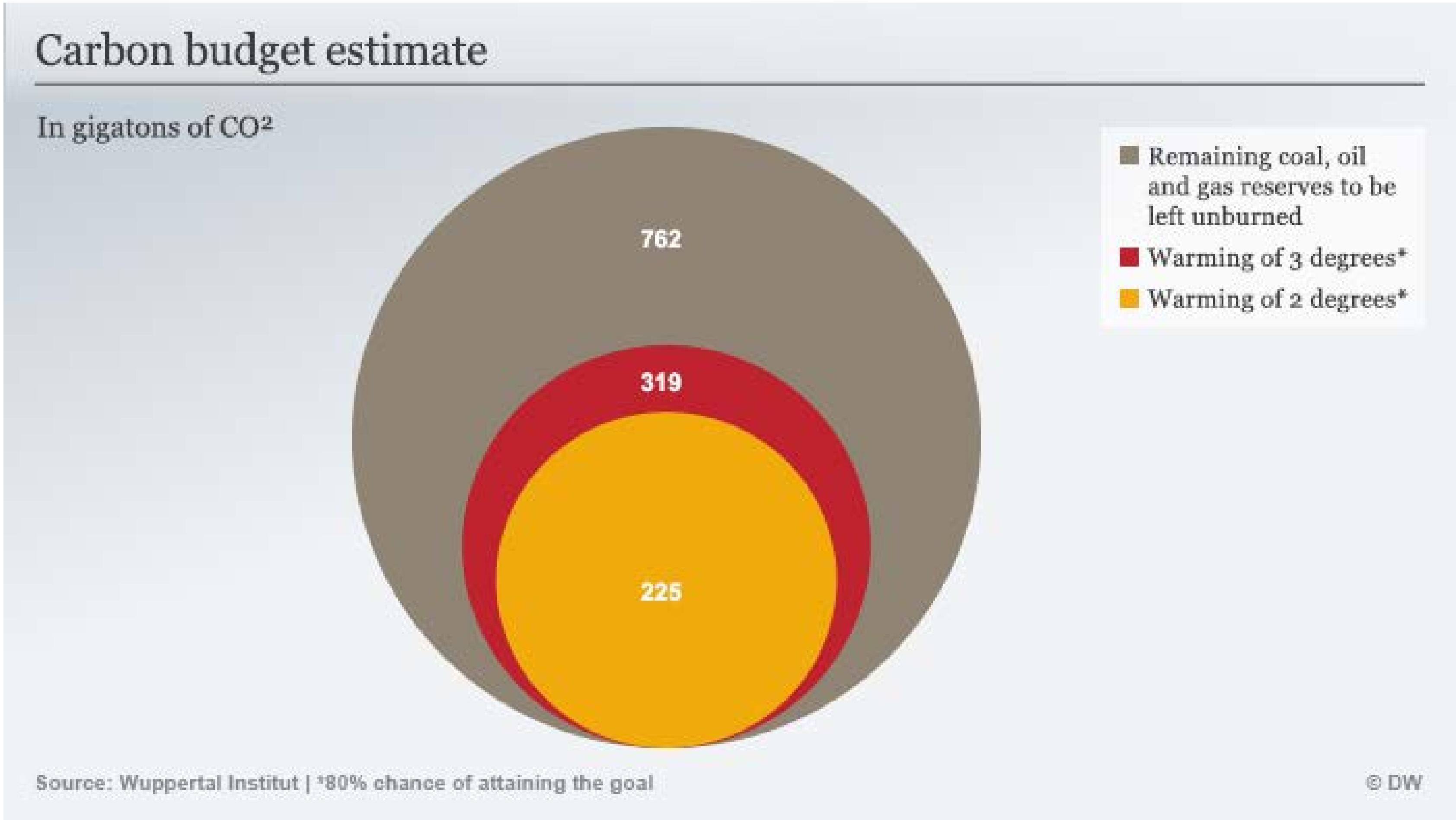
The Remaining Carbon Budget

- Remaining below 1.5°C at currently emissions:
  - 6 years (66% chance)
  - 10 years (50% chance)
  - 17 years (33% chance)



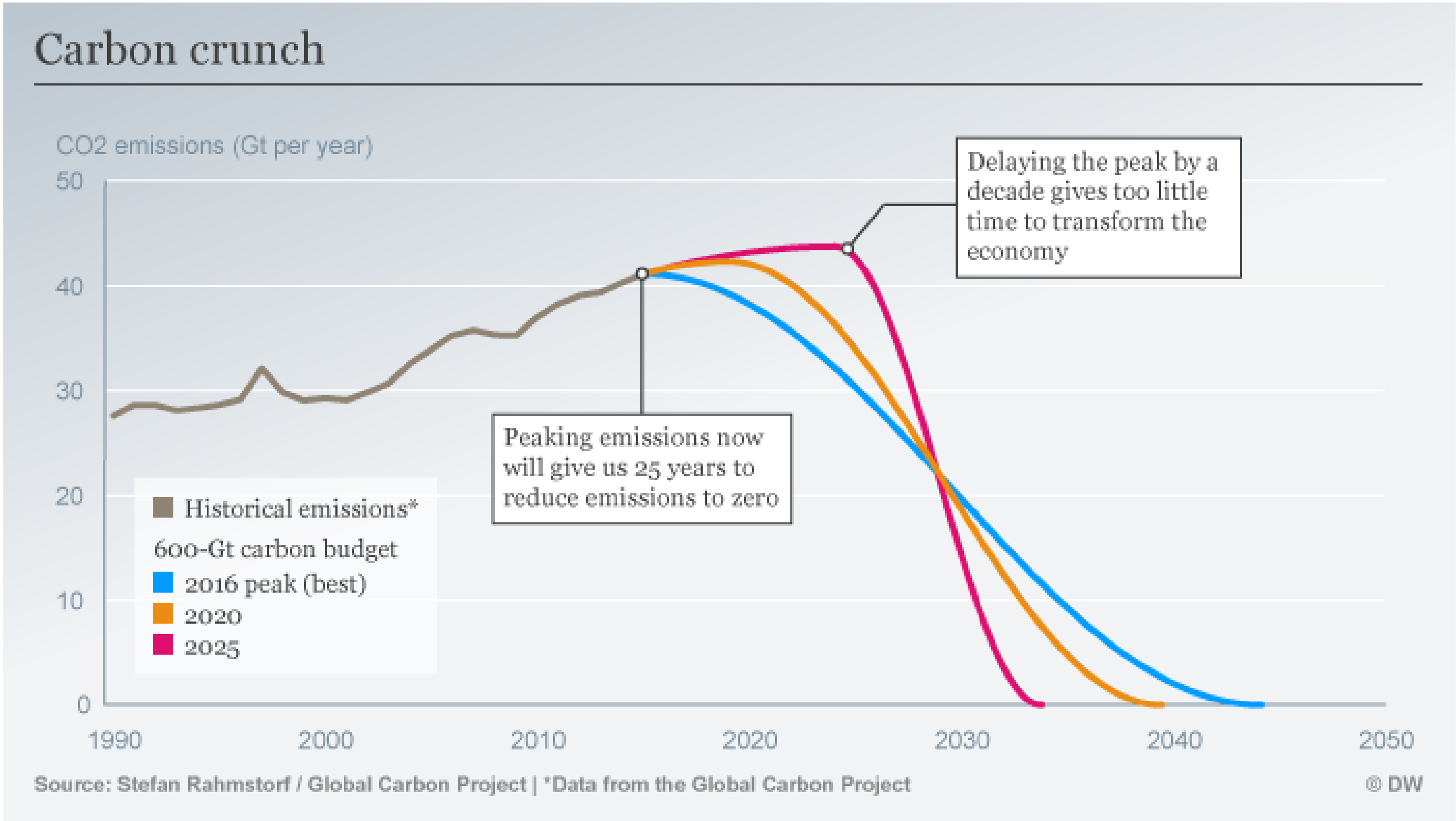
Source: Carbon Brief https://www.carbonbrief.org/six-years-worth-of-current-emissions-would-blow-the-carbon-budget-for-1-5-degrees

The Remaining Carbon Budget



Source: https://www.dw.com/en/have-we-already-blown-our-carbon-budget/a-39878925

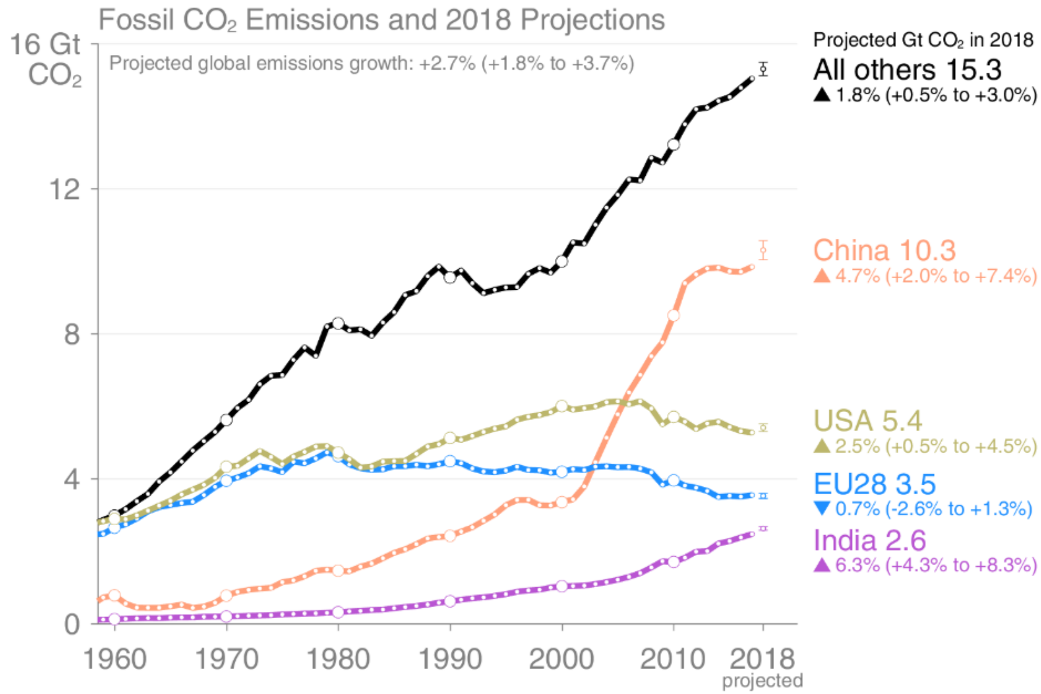
It‘s now or never…



Source: https://www.dw.com/en/have-we-already-blown-our-carbon-budget/a-39878925

Global Carbon Emissions are Still Rising

- Global fossil CO2 emissions rose by 2.7% in 2018
- The top four emitters in 2017 covered 58% of global emissions
- China (27%), United States (15%), EU28 (10%), India (7%)



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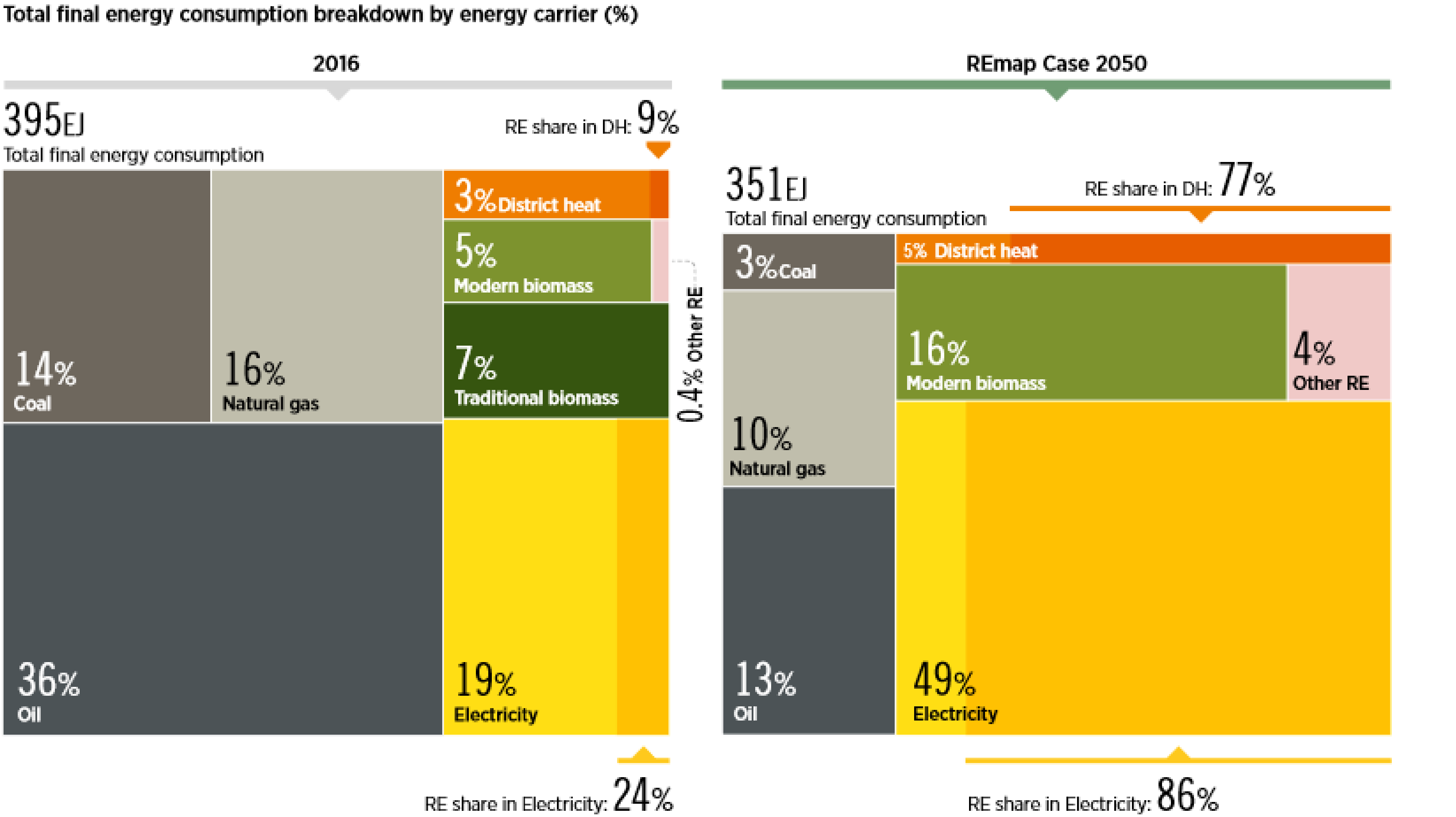
Electricity becomes the main energy source by 2050



Source: IRENA (2019a)

Electrification with Renewables

	2010	TODAY (2017/2018)	REMAP CASE 2030	REMAP CASE 2040	REMAP CASE 2050	ON/OFF TRACK	IMPLICATIONS
ELECTRIFICATION WITH RENEWABLES							
Share of electricity in final energy consumption (TFEC)	18%	20%	29%	38%	49%	Off track	Focus on electric mobility and electrifying heat in buildings and industry, and on synthetic fuels and feedstocks – see further recommendations below.
Renewable energy share in power generation	20%	25%	57%	75%	86%	Progress	Emphasise solar and wind deployment, but also maximise solid biomass and biogas in the niche applications where they make sense.
Annual solar PV additions	17 GW/yr	109 GW/yr	300 GW/yr	355 GW/yr	360 GW/yr	Progress	Accelerate solar deployment by reinforcing existing policy and market support.
Annual wind additions	31 GW/yr	54 GW/yr	200 GW/yr	210 GW/yr	240 GW/yr	Off track	Plan for wind industry and required logistics to enable accelerated deployment. Consider the large potential of offshore deployment.

Source: IRENA (2019)

Electrification with Renewables

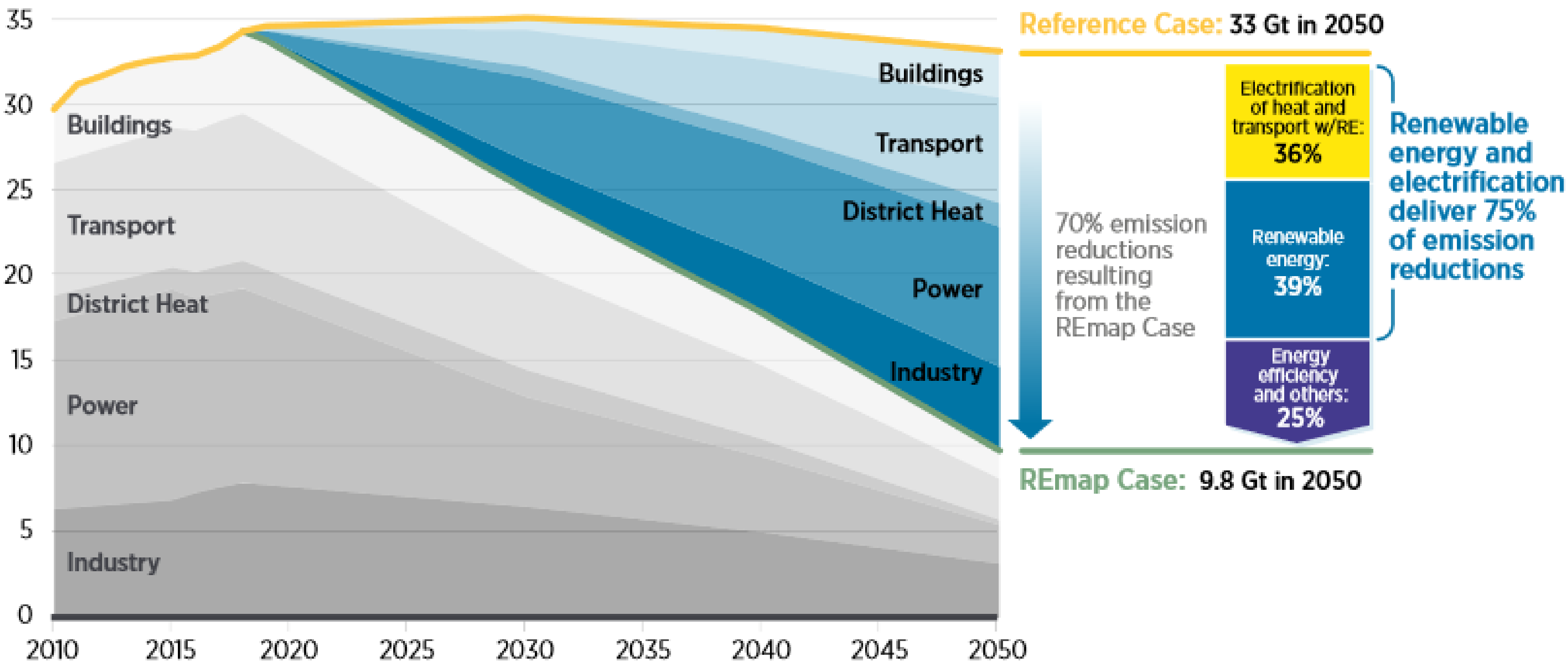
International Energy Transition

	2010	TODAY (2017/2018)	REMAP CASE 2030	REMAP CASE 2040	REMAP CASE 2050	ON/OFF TRACK	IMPLICATIONS
Passenger electric cars on the road	<0.5 mln	6 mln	157 mln	745 mln	1166 mln	Progress	Enact measures to support getting electric cars purchasing price down and invest heavily in charging infrastructure.
Heat pumps		20 mln	155 mln	259 mln	334 mln	Off track	Promote public awareness about the advantages of heat pumps and create special lines of finance to project developers that can disseminate the technology.
Hydrogen production with renewable electricity			3 EJ	8 EJ	19 EJ	Emerging	Find the niches where this makes sense today and support commercial-scale pilot projects.

Source: IRENA (2019)

Electricity of the transport and heating/cooling sector is crucial

Annual energy-related CO_2 emissions, 2010-2050 (Gt/yr)

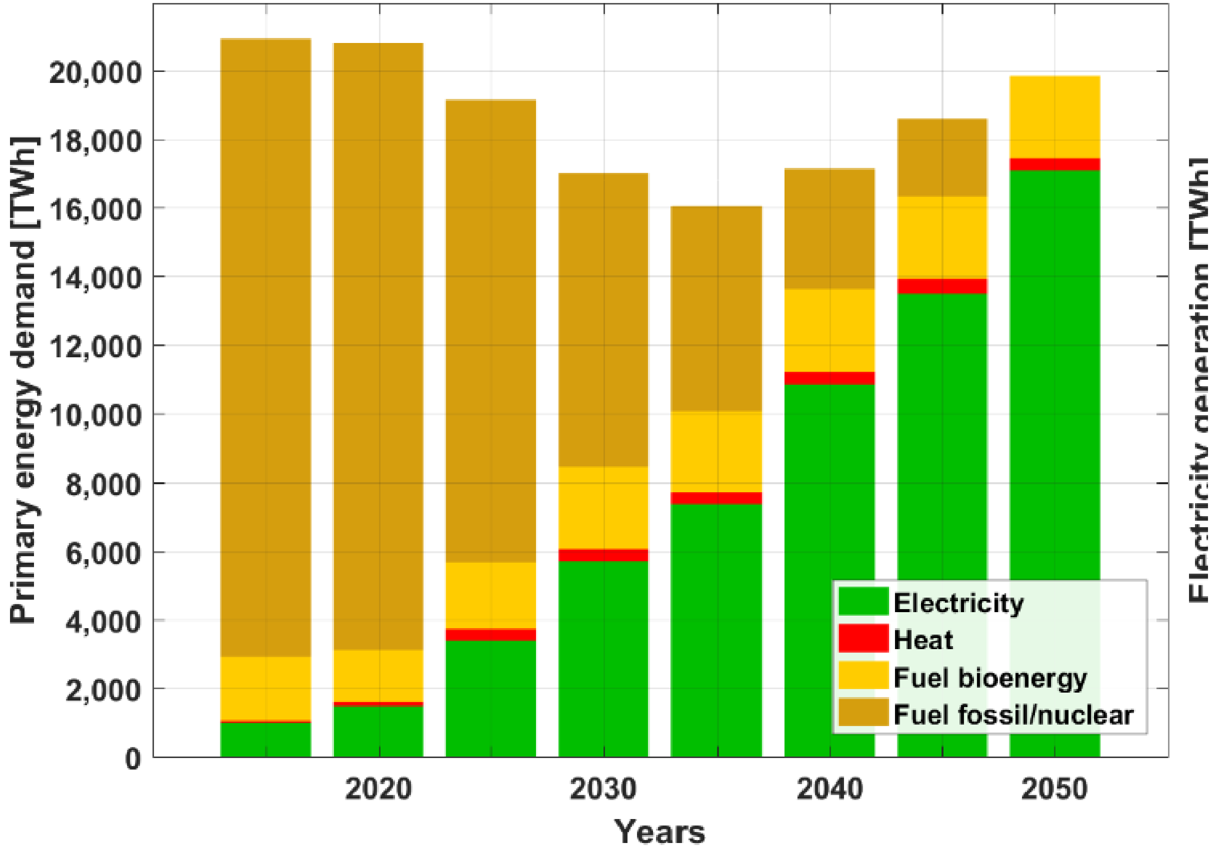


Source: IRENA (2019a)

Decarbonisation of the Energy Sector: Electrification

International Energy Transition

- Primary energy demand in a fully decarbonized European energy system

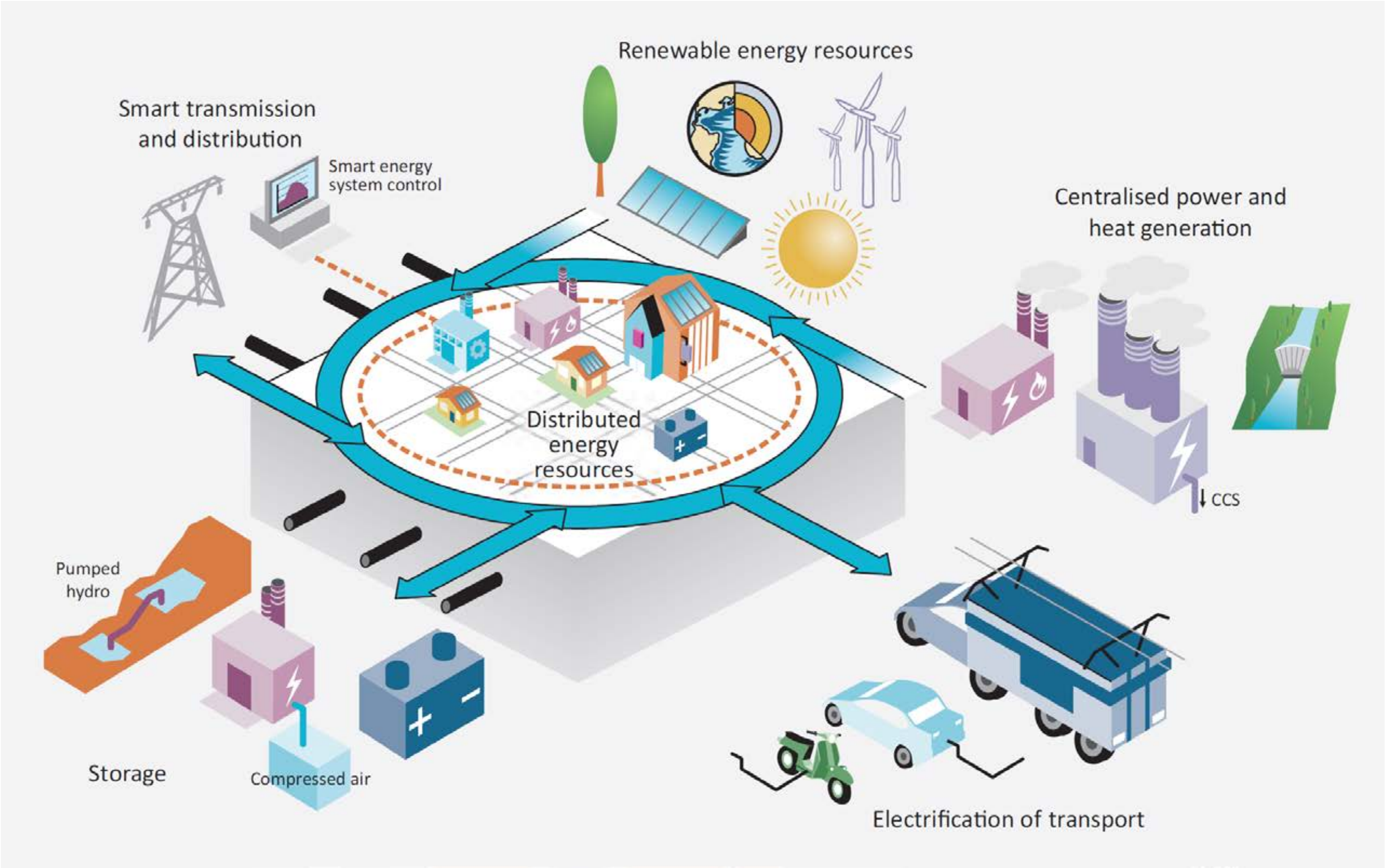


Source: EWG (2018)

Sector Coupling:

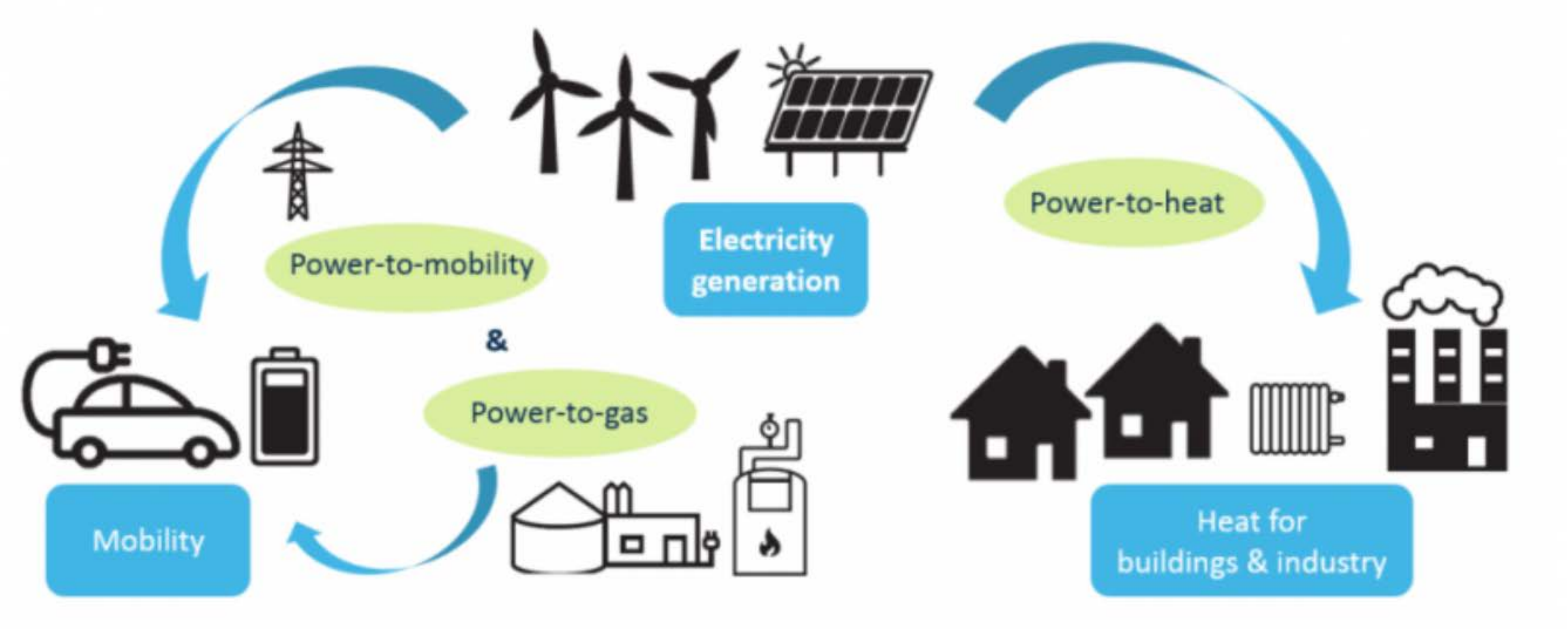
Using Solar Electricity for Other Sectors

The integrated and intelligent electricity system of the future



Source: (IEA 2014)

Using solar PV for other sectors



Source: https://www.cleanenergywire.org/factsheets/sector-coupling-shaping-integrated-renewable-power-system

Sector Coupling: Selected Analysis

International Energy Transition

Framework Conditions for Successful Sector Coupling

- Solar PV and EVs
- Solar PV and Heating/Cooling

Sector Coupling:

General Framework Conditions

General Framework Conditions for Sector Coupling

- Harmonization of taxation/subsides/levies for the different energy sectors
  - Are all sectors treated the same?
  - What are the regulated components of the electricity price in your jurisdiction (e.g. grid fees, taxes and levies)? Does this make electricity more expensive and therefore less attractive for use in other sectors?
  - Are there (remaining) subsidies (e.g. subsidies for fuels in the transport sector)?

Long-term Infrastructure Planning

- Long-term planning for electricity and gas infrastructure
- New electricity infrastructure (e.g. grid expansion, digitalization, charging infrastucture)
- New gas infrastructure (e.g. adopting existing network for green gases)
- Increasing interlinkages between electricity and gas infrastructure (also in planning processes).

Adopting electricity markets: Rate Design

Traditional rates	Smart rates
• Volumetric Charges	• Time-of-Use
• Fixed Charges	• Critical Peak Pricing
• Minimum bills	• Real-Time Pricing
• Demand Charges	• Locational Pricing
Can be implemented based on **existing meter technologies**	Require **advanced metering infrastructure (AMI)**

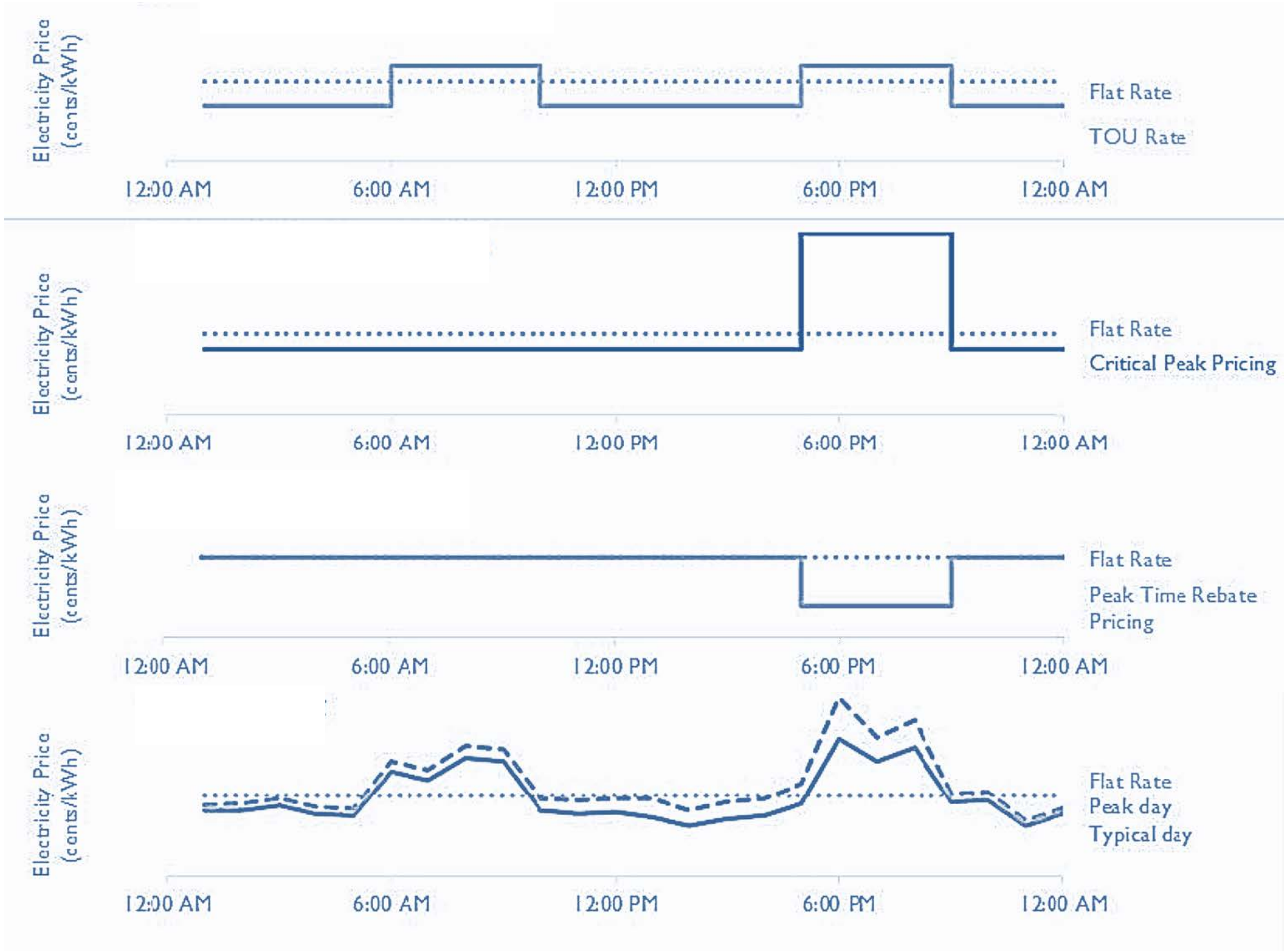
Overview of Time-Varying Rates

TOU rate

Critical Peak Pricing

Peak Time Rebate Pricing

Hourly / Real-Time Pricing



Source: Whited (2017)

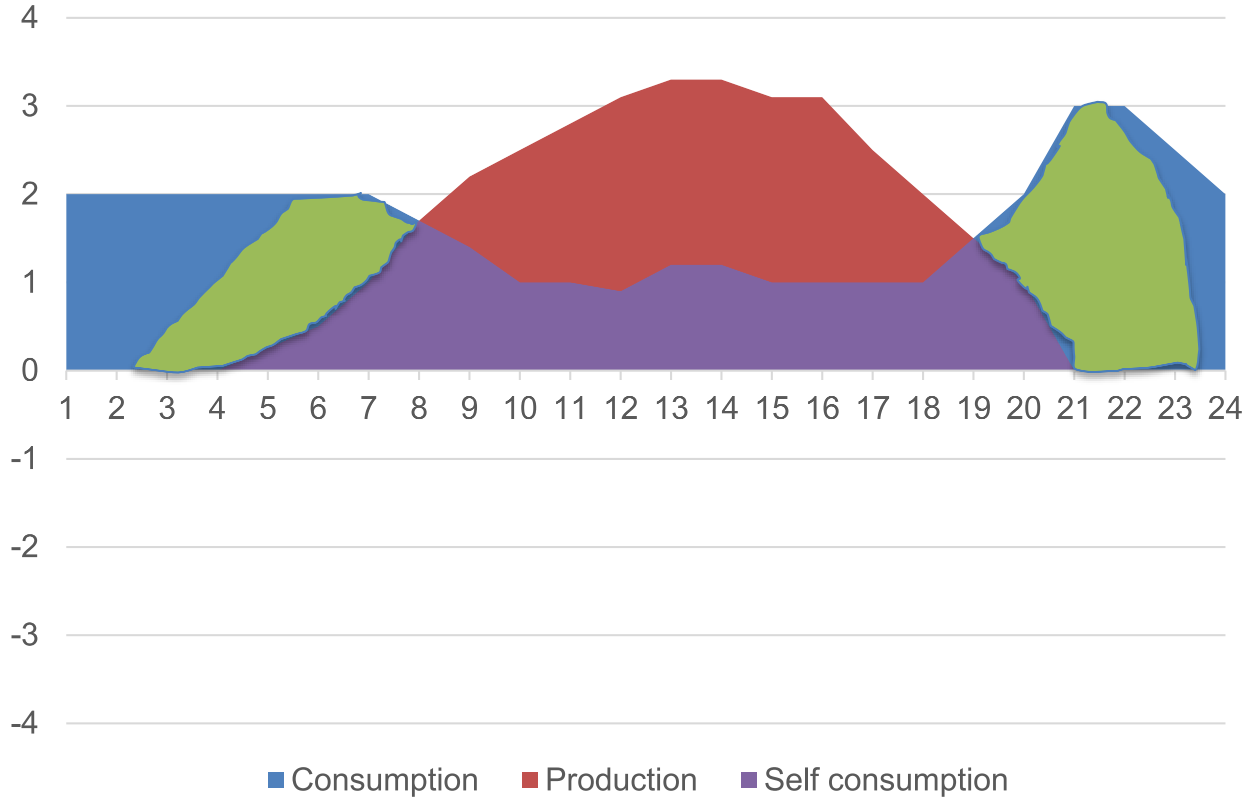
PV Self-Consumption

- PV self-consumption without storage/EVs (excess electricity is fed into the main grid)

Source: IET

PV Self-Consumption

- Increasing self-consumption with electricity storage or additional loads such as EVs (reducing influx of excess electricity into the grid)

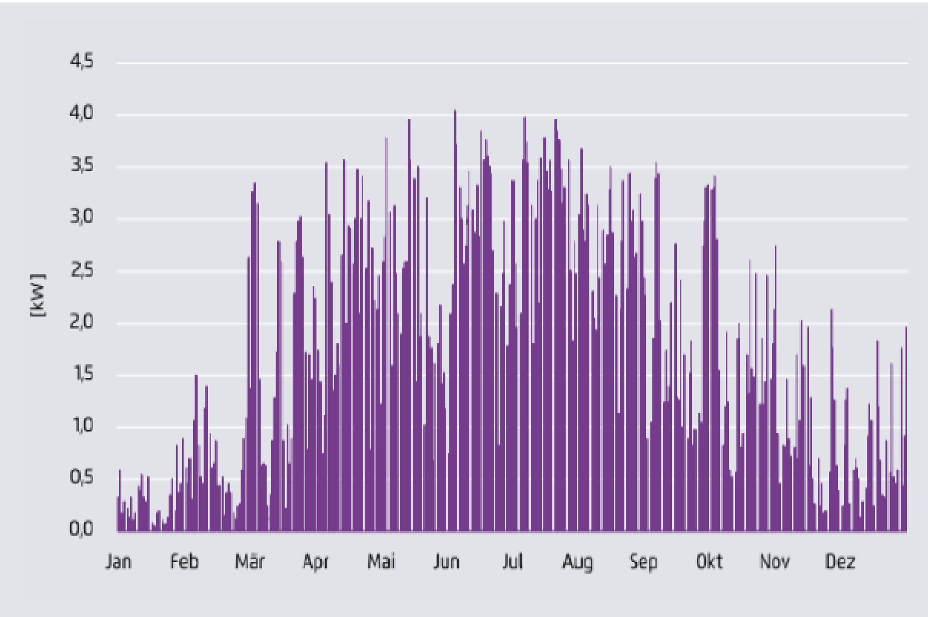


Source: IET

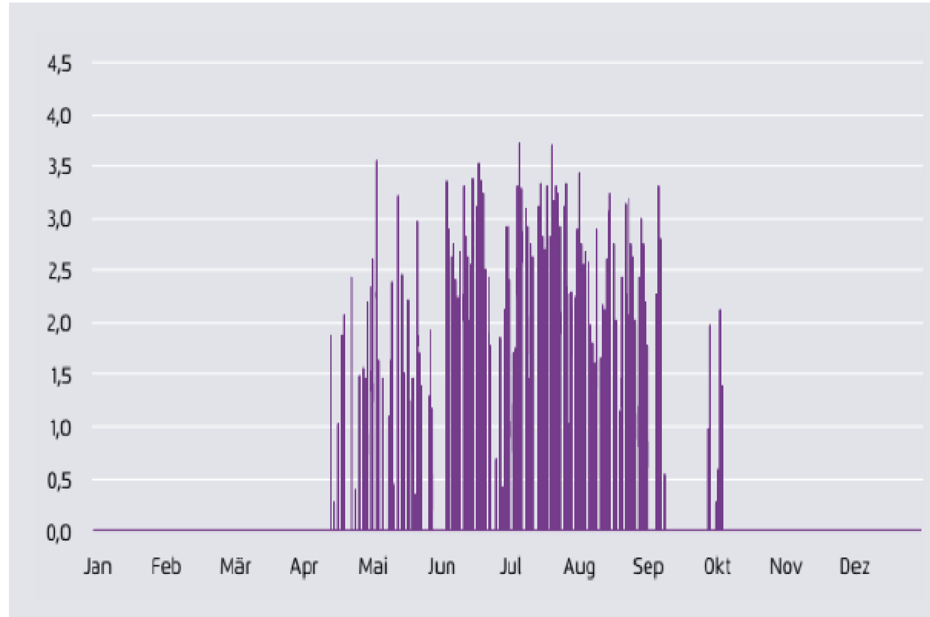
Batteries, EVs and heat pumps can help to increase self-consumption

- Case study Germany:
  - No more influx of solar PV during winter months; little changes during the summer months

Feed-in from PV system without storage in kW



Feed-in from PV system with battery storage and heat pump in kW



Prognos (2016)

* Assuming a PV expansion to 60 to 80 GW by 2035.

Source: Agora (2016)

Power to Mobility:

EVs and impact on electricity systems

Range of Services Provided by Storage in Power Systems

Bulk energy services	Ancillary services	Transmission infrastructure services	Distribution infrastructure services	Customer energy management services	Off-grid	Transport sector
Electric energy time shift (arbitrage)	Regulation	Transmission upgrade deferral	Distribution upgrade deferral	Power quality	Solar home systems	Electric 2/3 wheelers, buses, cars and commercial vehicles
Electric supply capacity	Spinning, non-spinning and supplemental reserves	Transmission congestion relief	Voltage support	Power rellability	Mini-grids: System stability services	
	Voltage support			Retail electric energy time shift	Mini-grids: Facilitating high share of VRE	
	Black start			Demand charge management		
				Increased self-consumption of solar PV		

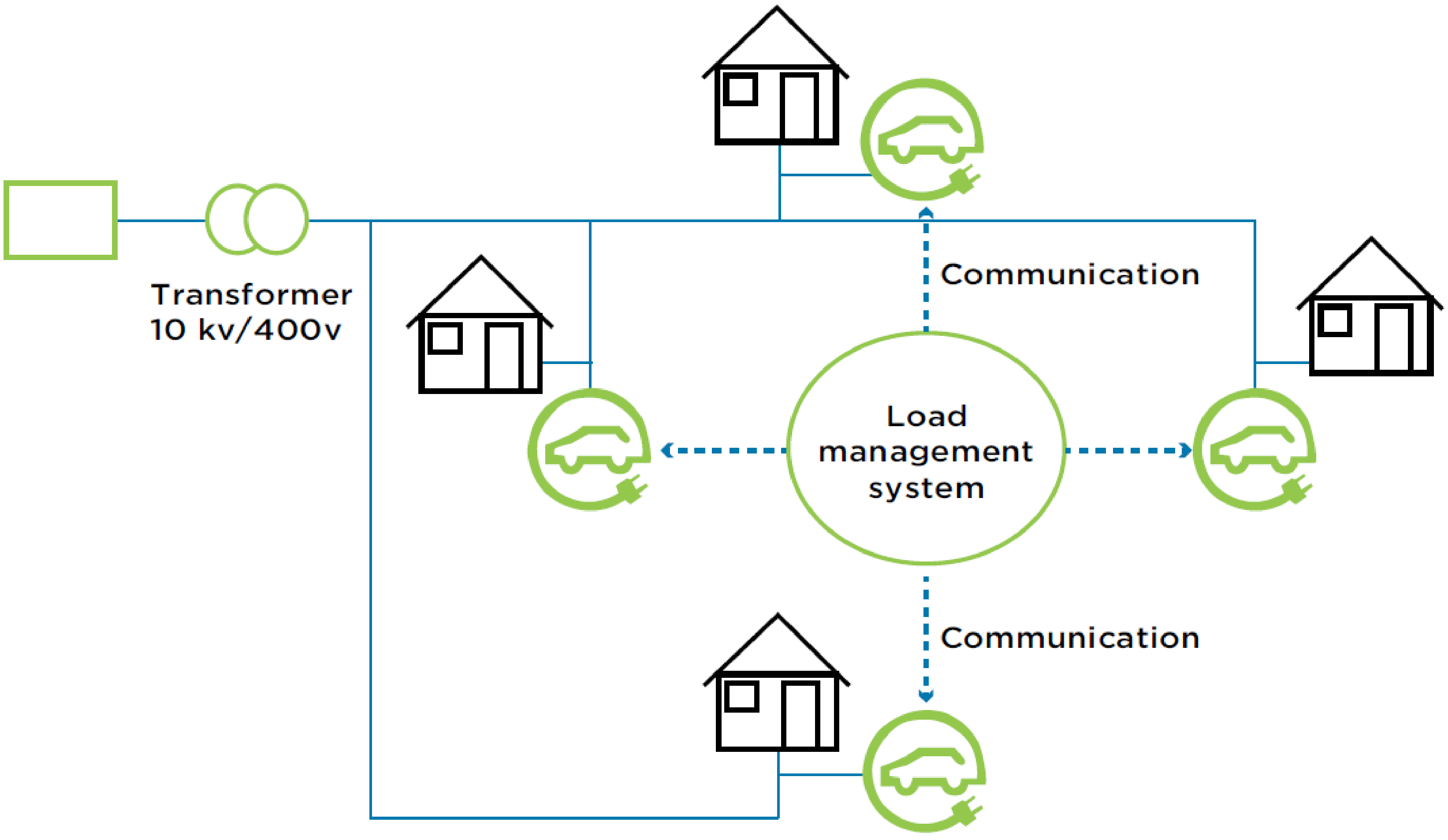
Boxes in red: Energy storage services directly supporting the integration of variable renewable energy

Source: IRENA (2017), Storage report

EV Charging

- EVs could cause peaks in electricity demand
- Rate design can give appropriate price signals to EV customers
- Alternatives:
  - The DSO communicates potential grid connections to EV customers (direct control over charging processes)
  - Aggregators are confronted with price signal and coordinate charging accordingly
  - Load management systems at distribution level

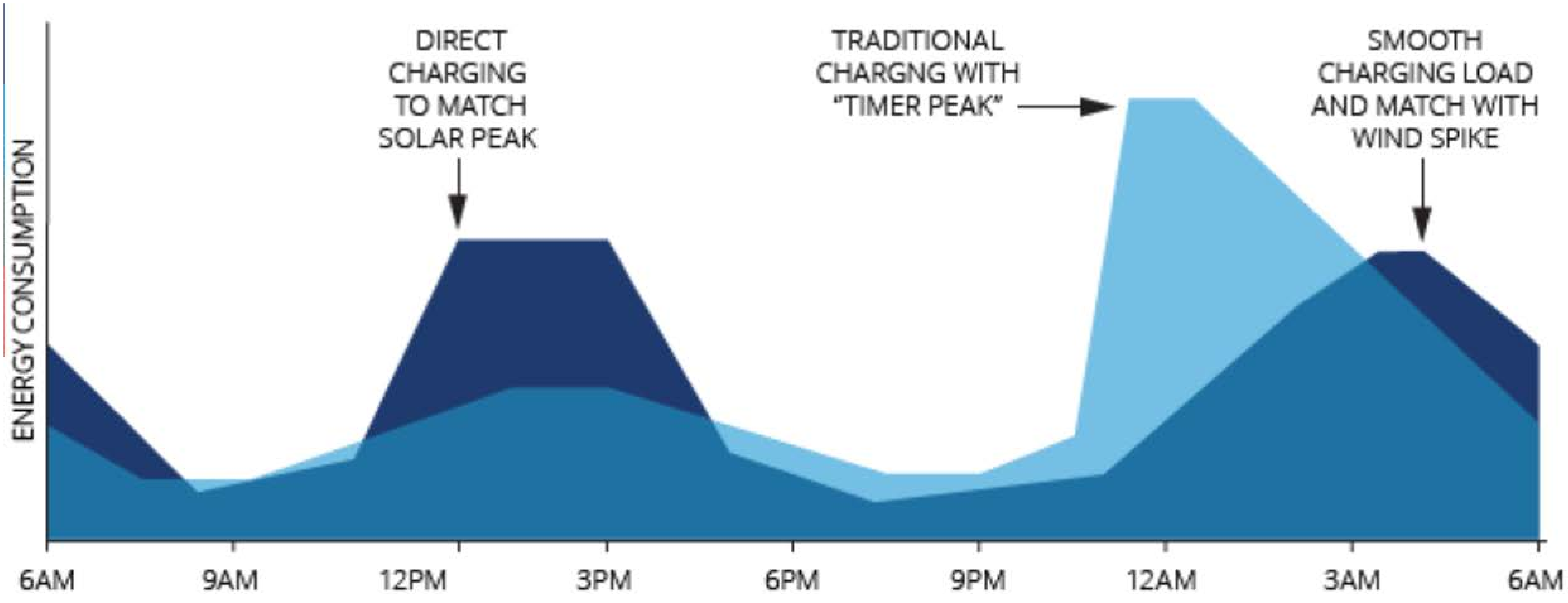
EV Charging



Source: IRENA (2017)

System Friendly EV Charging

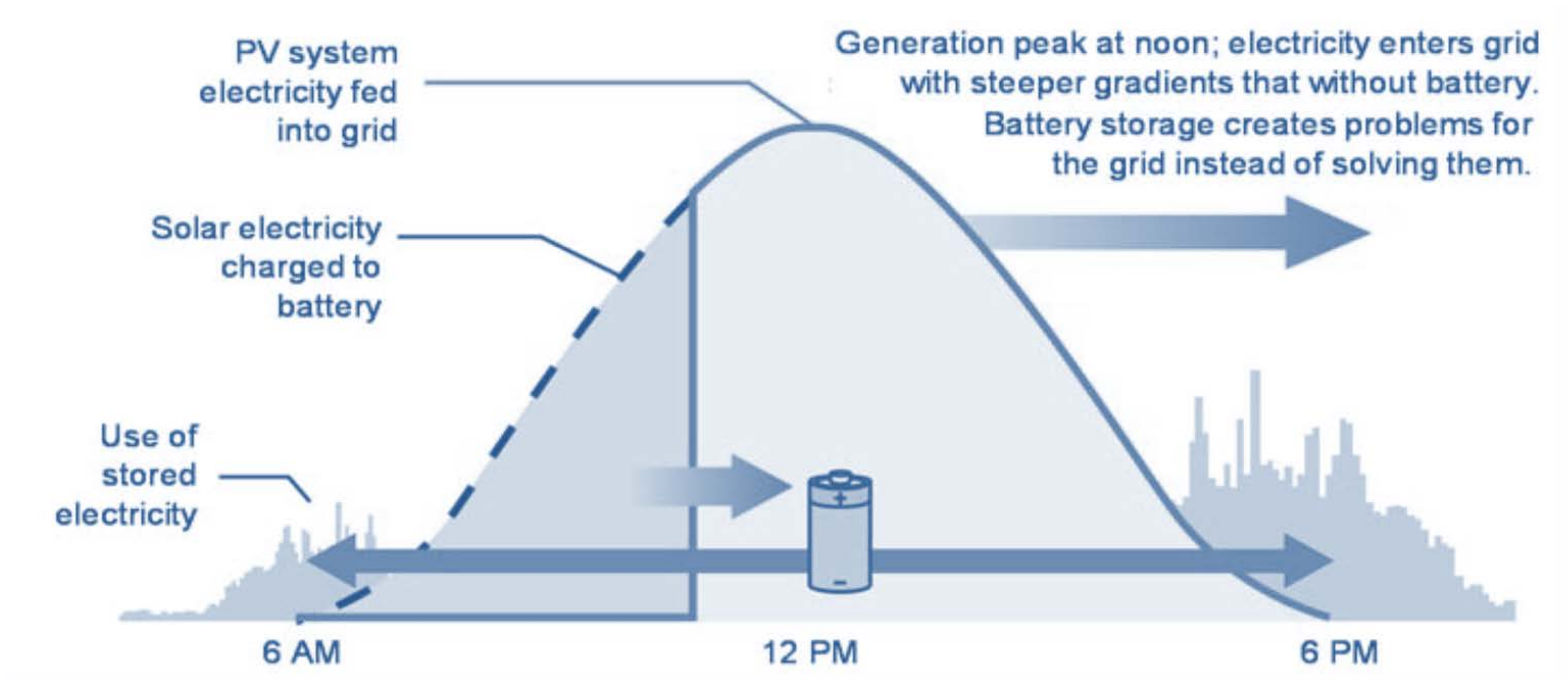
- Charging during solar peak periods or wind peaks



Source: https://energywatch-inc.com/increase-electric-powered-vehicles-will-grid-respond/

Storage can increase ramps in the power system

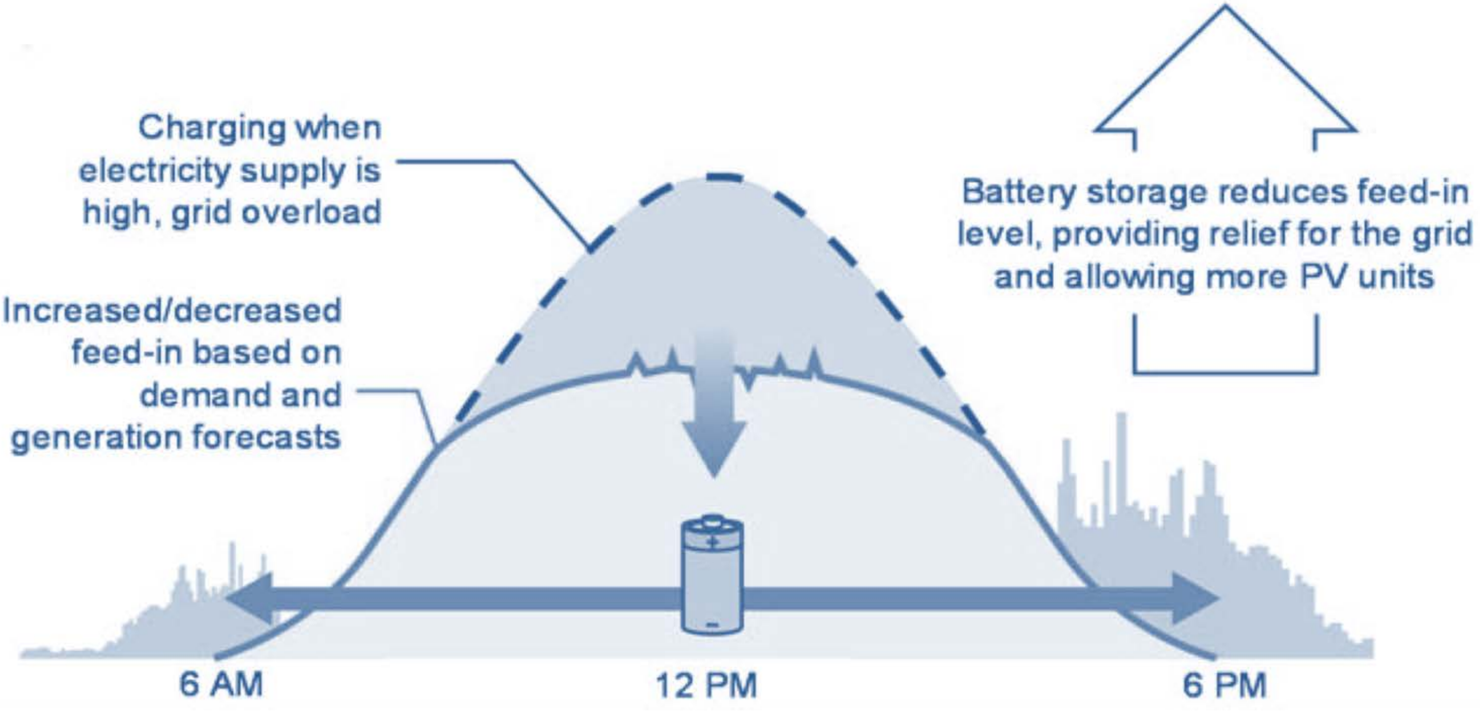
- Example of system unfriendly charging and discharging of batteries



Source: (Weniger, Bergner et al. 2015) (Deutsch and Graichen 2015, Sterner, Eckert et al. 2015)

Storage can smoothen the profile of PV influx

- Forecast-based charge and discharge of distributed battery storage to increase system stability and reduce grid expansion

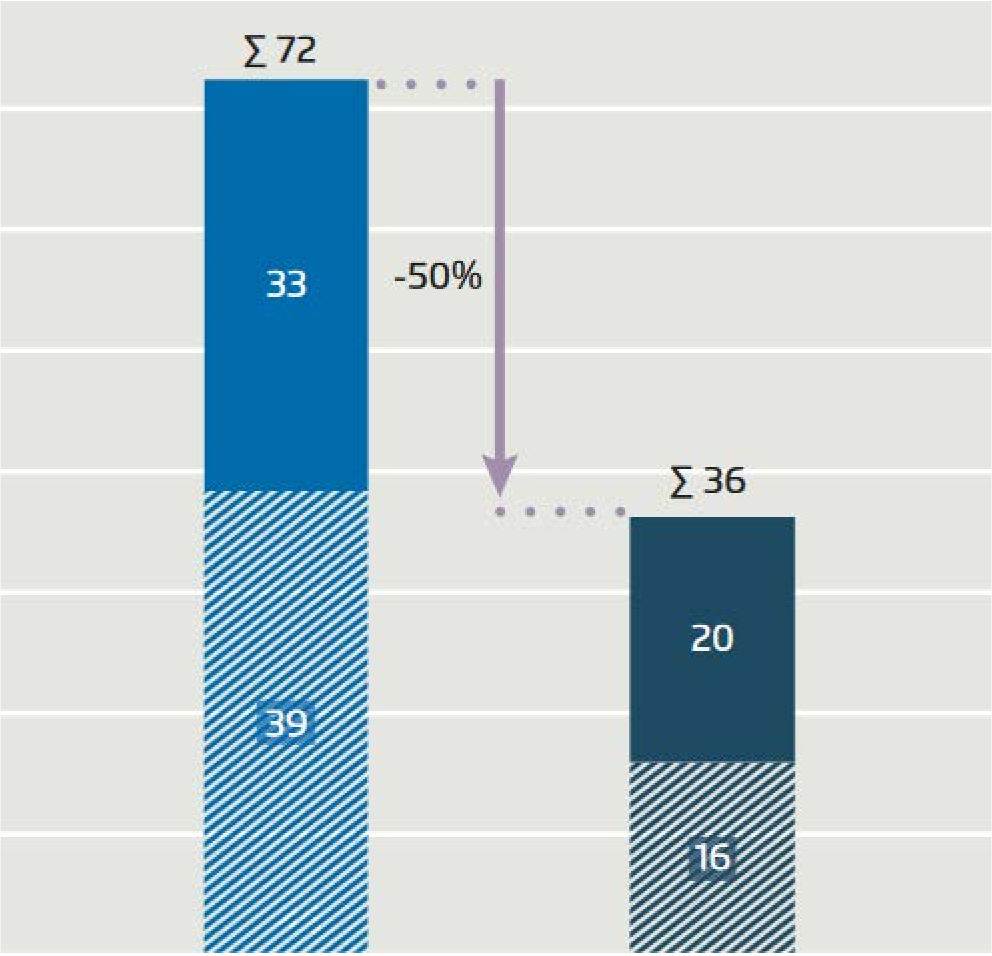


Source: (Weniger, Bergner et al. 2015) (Deutsch and Graichen 2015, Sterner, Eckert et al. 2015)

EV Charging: Reduction of Distribution Network Expansion

International Energy Transition

- Reduction of cummulative distribution network expansion costs in Germany until 2030
- € 33 billion can be saved



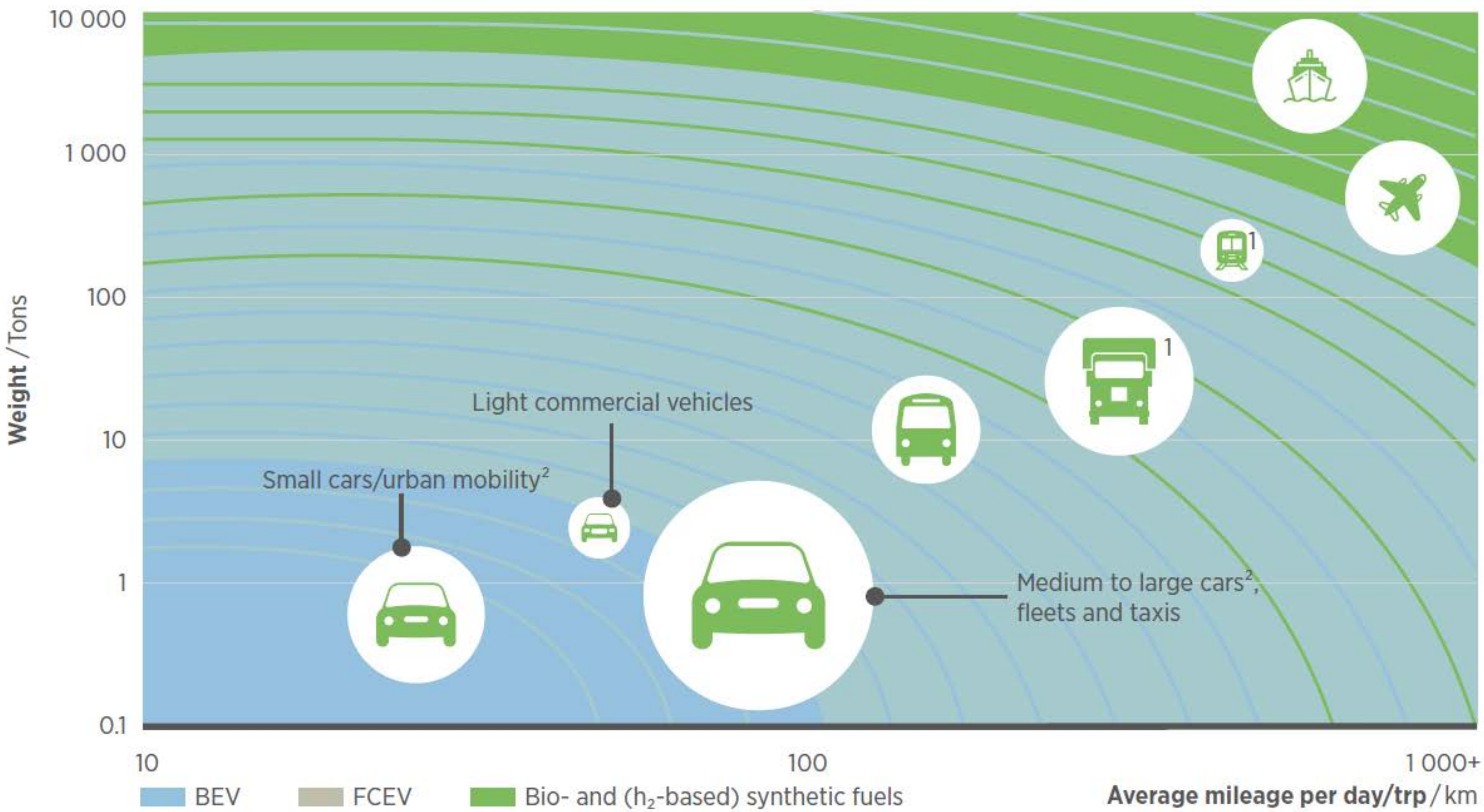
Power to Mobility:

Other Power-to-X Technologies

Options for Decarbonizing the Transport Sector

- Three major options for decarbonizing the transport sector:
  - Using solar PV electricity directly
  - Using liquids or gases converted from solar PV
  - Using biofuels with low greenhouse gas emissions

Options for Decarbonizing the Transport Sector

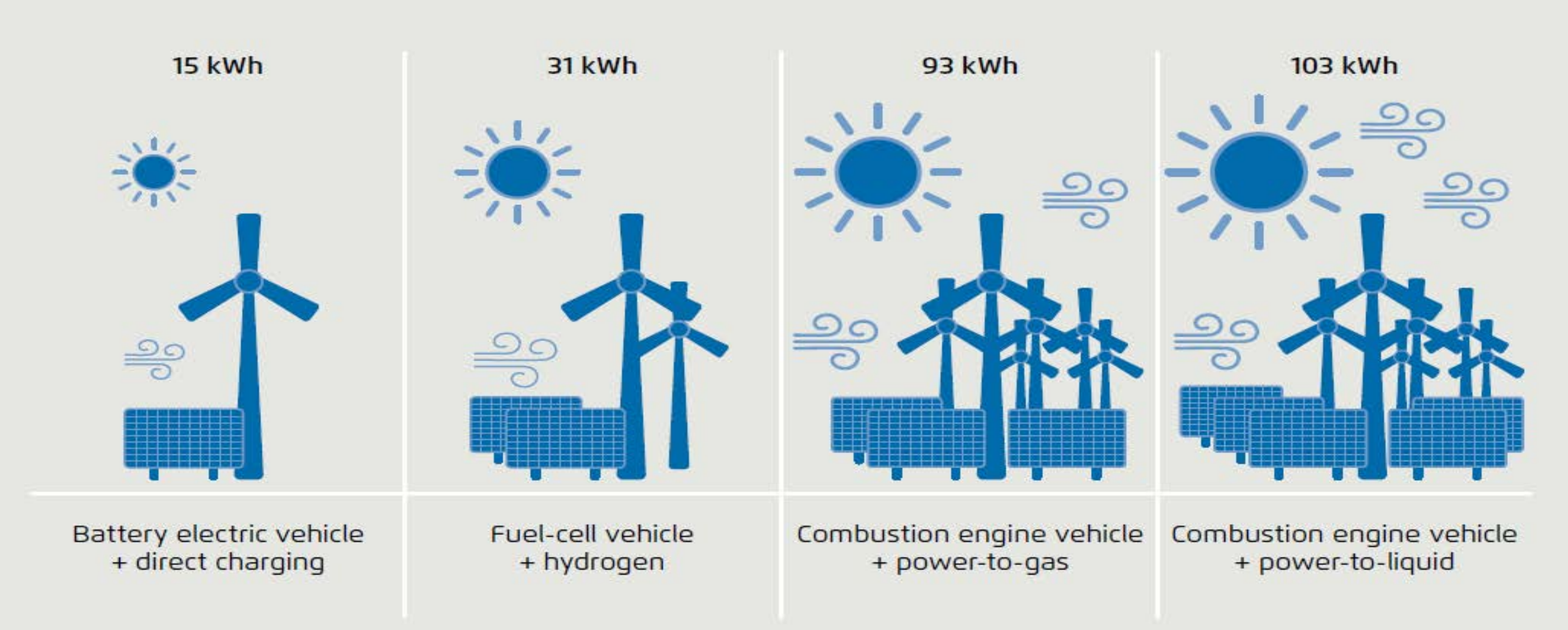


Source: IRENA (2018)

Efficiency Losses with Other Power-to-X solutions

- Direct use of electricity is by far the most efficient technology

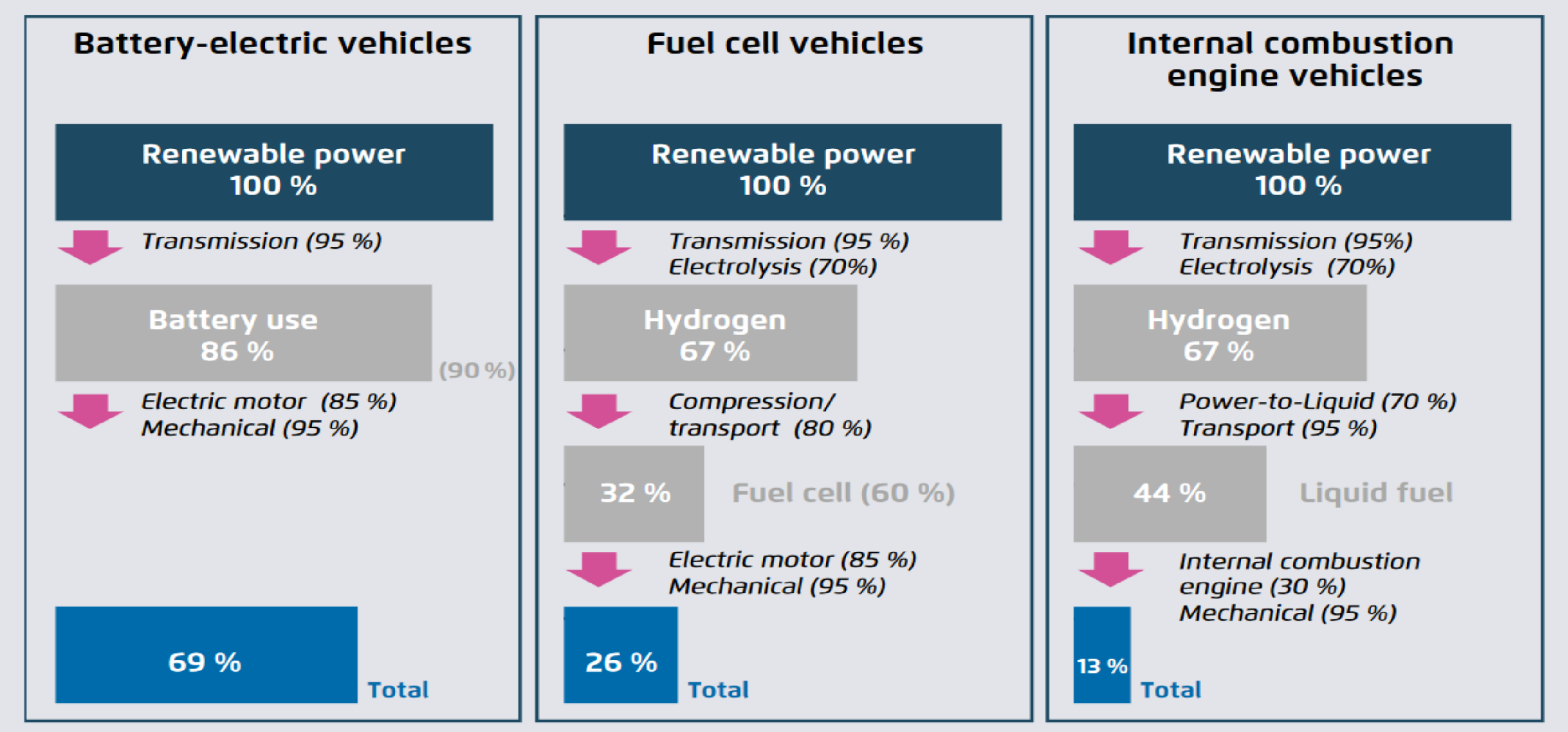
Figure: Amount of renewable energy required for various powertrain and fuel combinations (per 100 km)



Source: Agora Verkehrswende (2017)

Efficiency Losses with Other Vehicle Drive Technologies

Figure: Individual and overall efficiencies for cars with different vehicle drive technologies, starting from renewable electricity



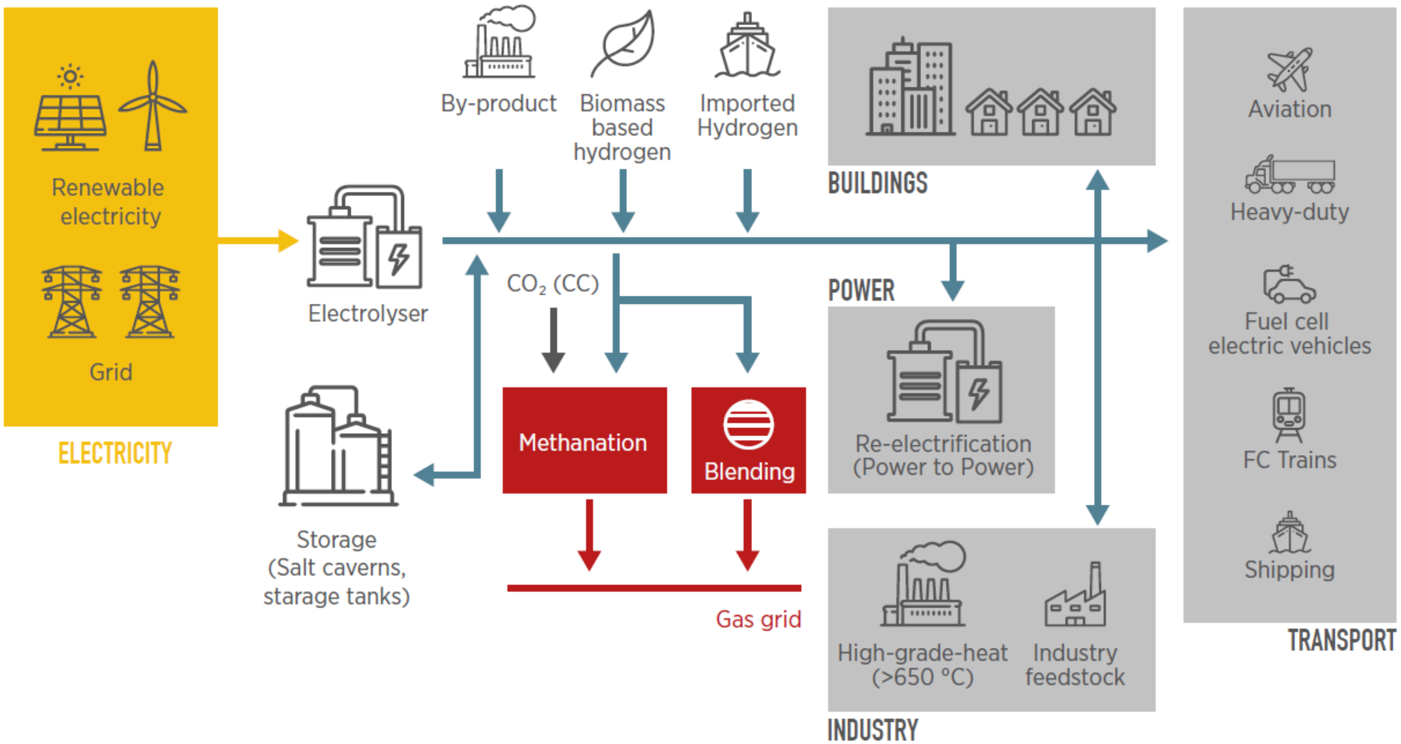
Source: Agora Verkehrswende (2017b)

Using Electricity for Trucks

Source: SIEMENS

Hydrogen

Integrating solar PV into end uses by means of hydrogen



Source: IRENA (2018)

Power to Heating:

Technical Solutions

Electricity Use in Buildings

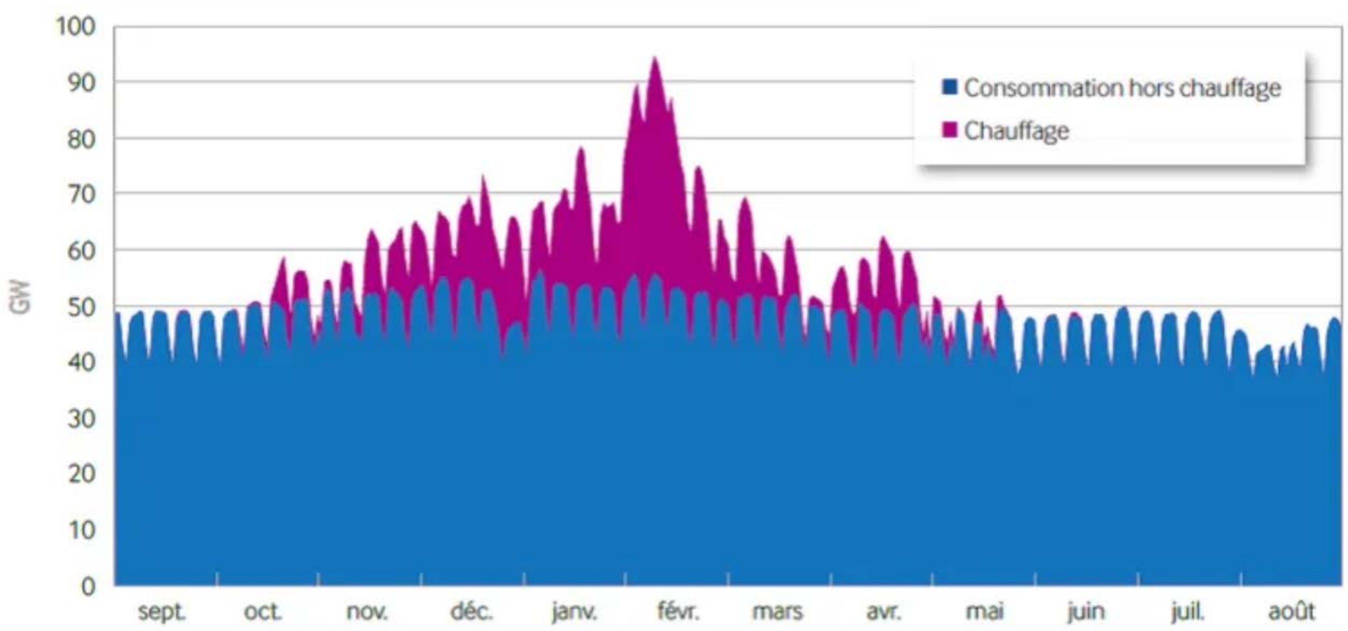
- Buildings use 30% of global final consumption
- Electricity supplies 24% of the energy used in residential and 51% for commercial and public buildings

Heat Pumps for space heating and hot water	Direct use of electricity for resistance heating in boilers and furnaces
• The share can be further increase by switching to heat-pumps for space heating and hot water • High efficiency • However, major retrofitting of buildings is required and they have high upfront capital costs.	• Heating water that is circulated for heating puposes and for space heaters • Relatively low efficiency • Suited for well-insulated houses or mild climates

Source: IRENA (2019b)

Case Study France: Electricity Demand from Heat

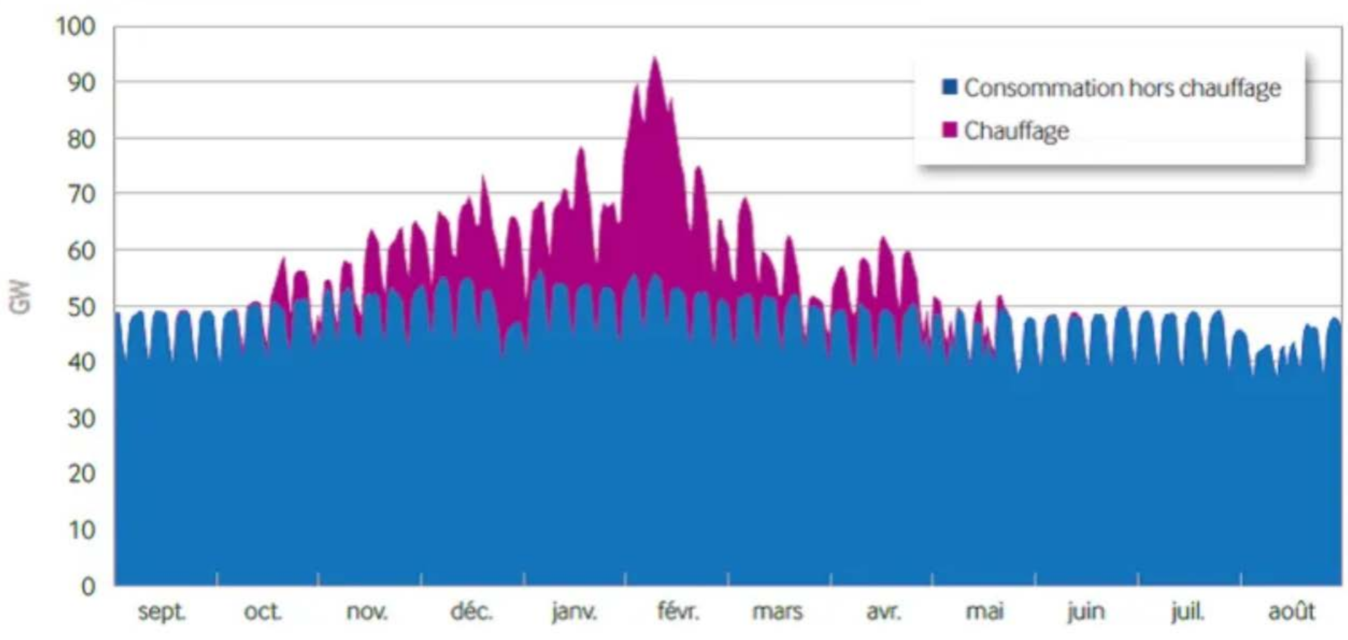
- Electricity demand related to heating doubled in the winter months (2012) – challenge for cold climates
- Low influx of solar PV during winter months
- Import of (coal-generated) electricity from Germany



Source: RTE

Synthetic Fuels – A Potential Solution?

- Solar PV electricity could be tranformed into synthetic fuels such as hydrogen or synthetic methane
- Existing (?) gas infrastructure can be used for distribution

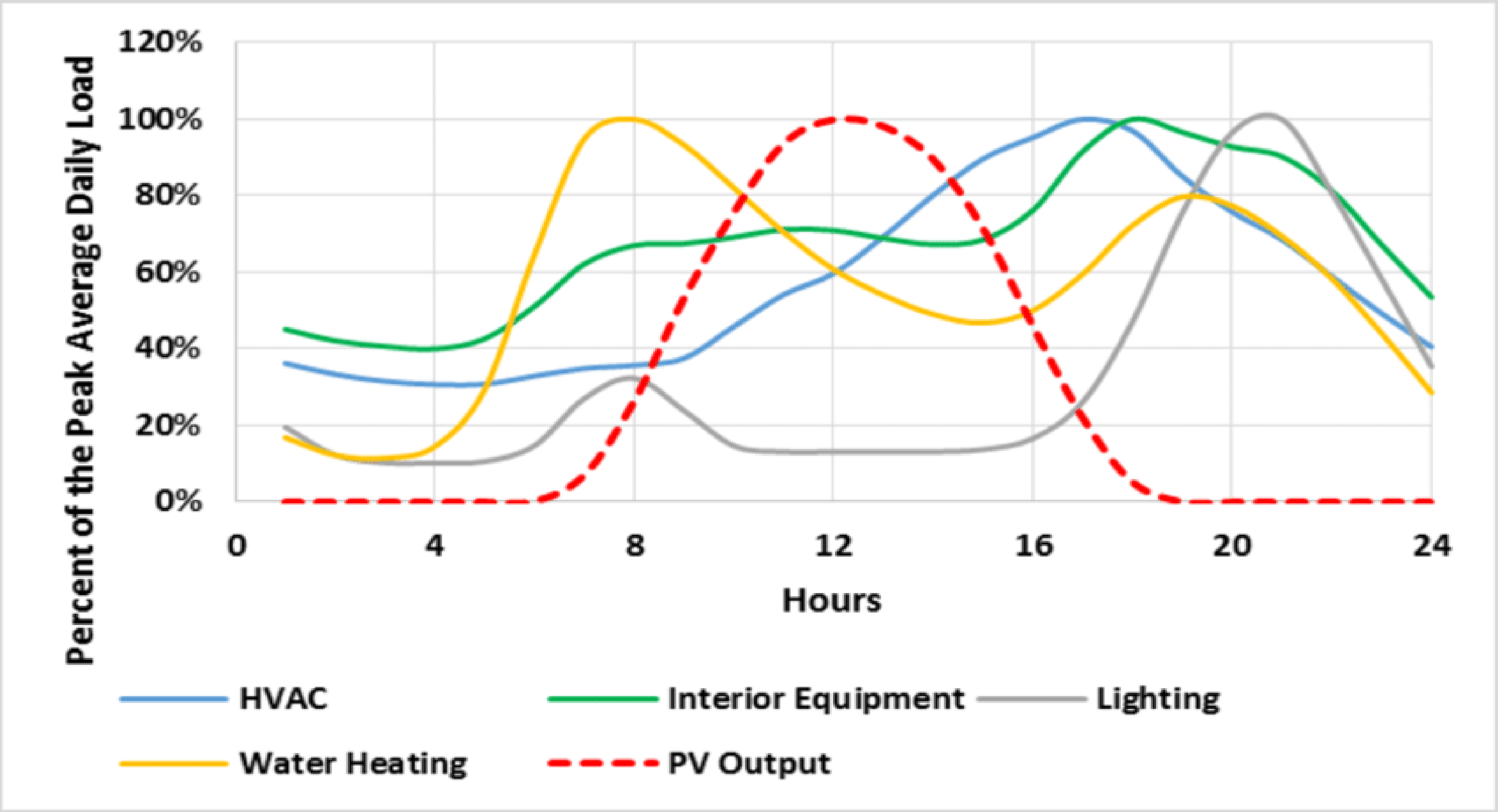


Source: RTE

Cooling with PV:

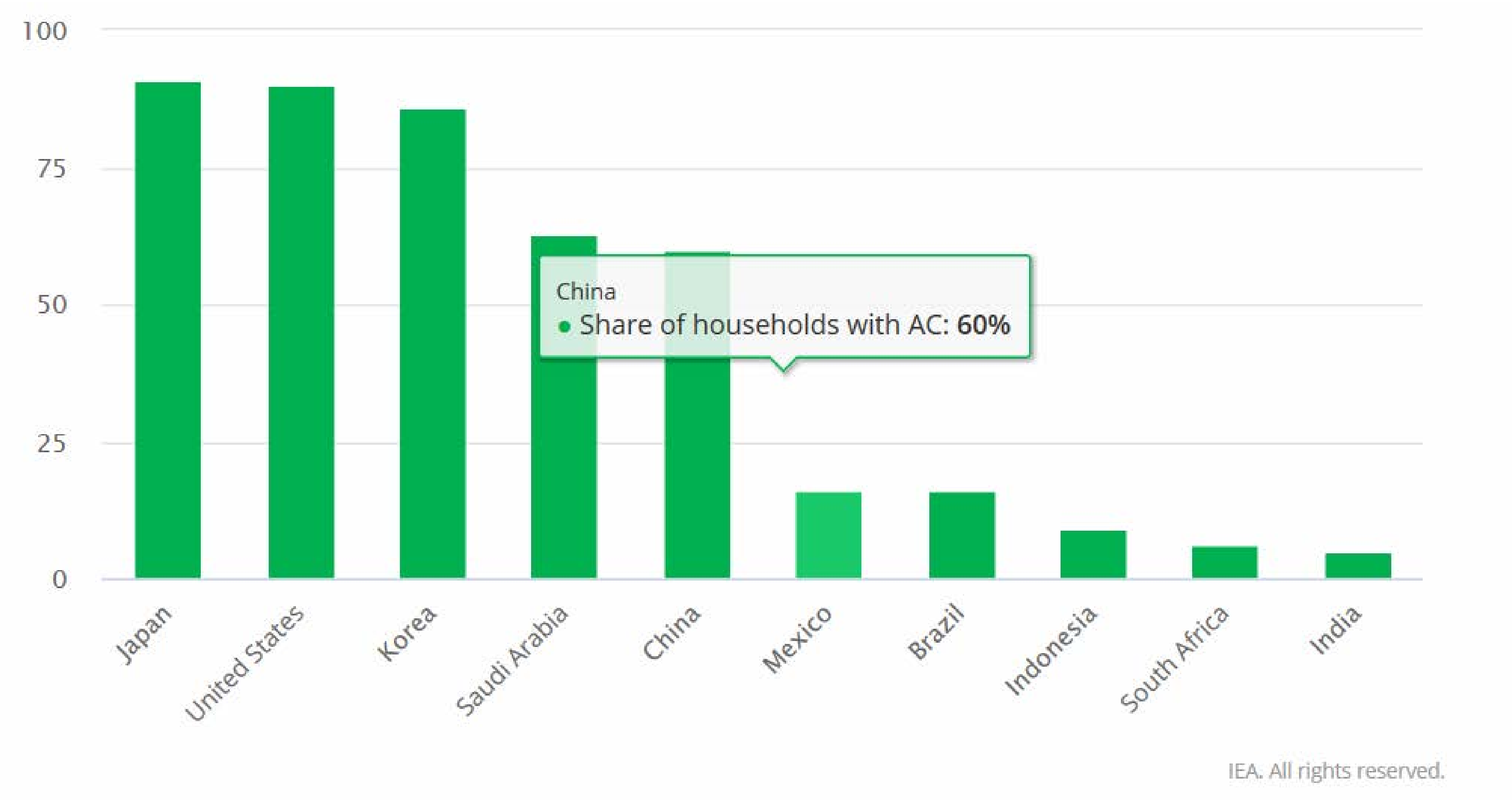
Solar Electric Cooling

Load Profile AC and solar PV



Source: https://eta.lbl.gov/sites/default/files/publications/lbnl-2001084.pdf

Percentage of Households with AC

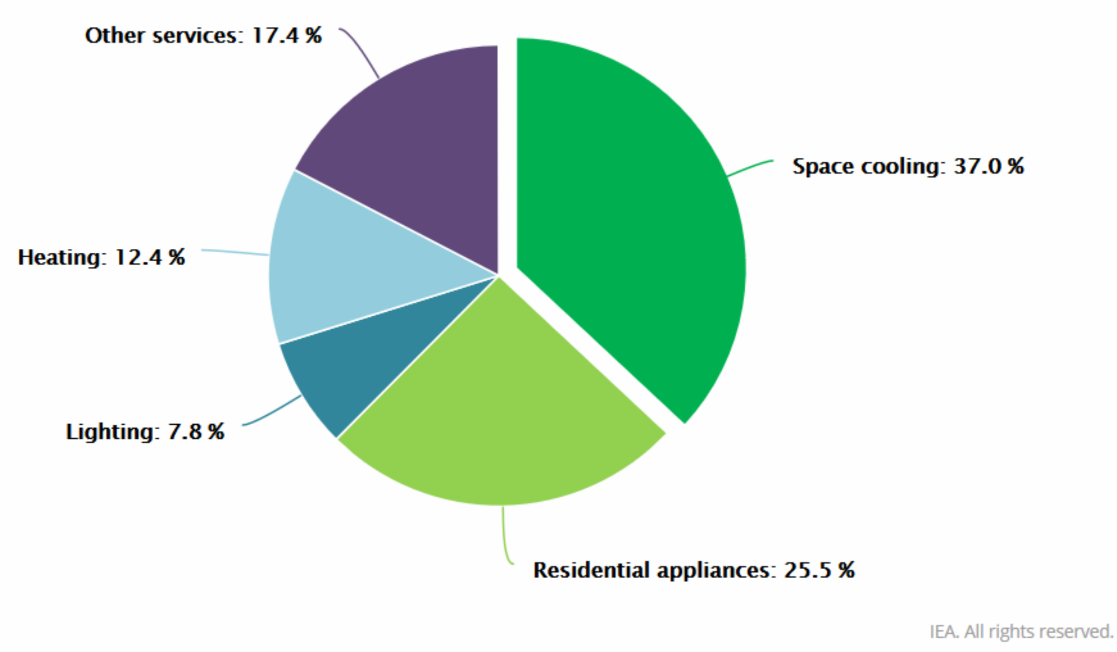


Source: https://www.iea.org/futureofcooling/

Rapid Growth of Cooling Needs

- Cooling is the fastest growing use of energy in buildings

Figure: Share of final electricity demand growth until 2050:

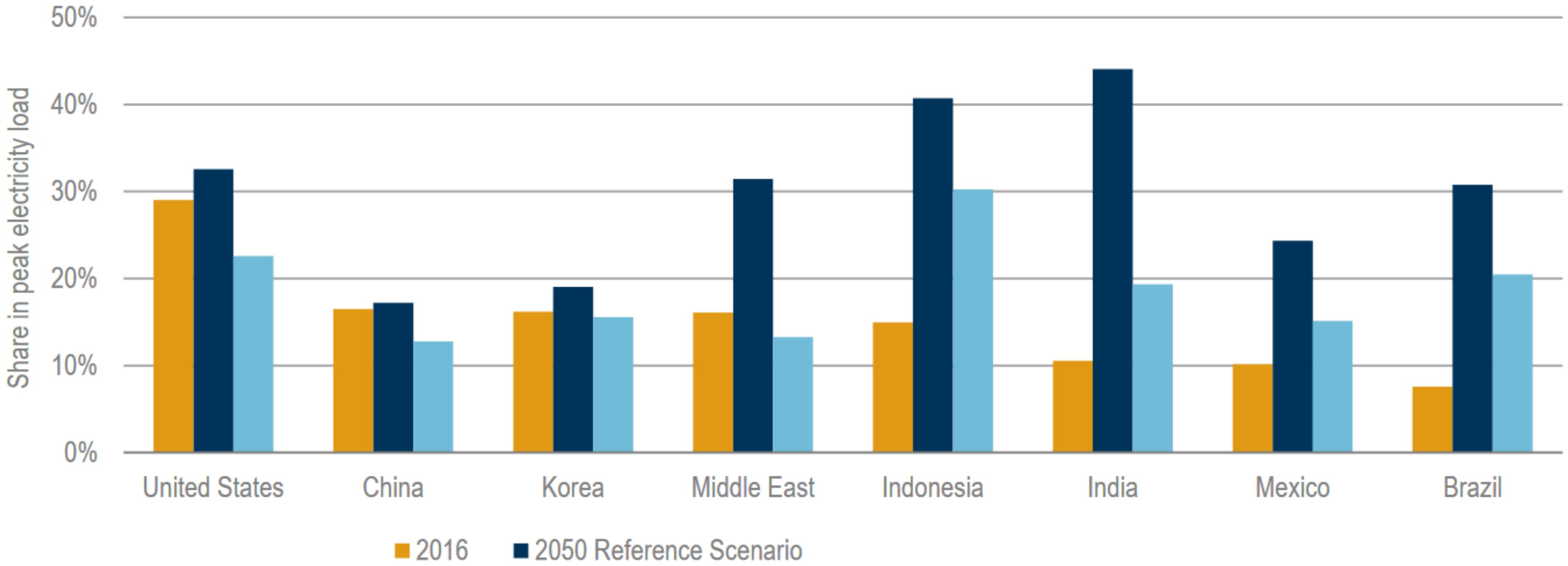


Source: https://www.iea.org/futureofcooling/

Rapid Growth of Cooling Needs

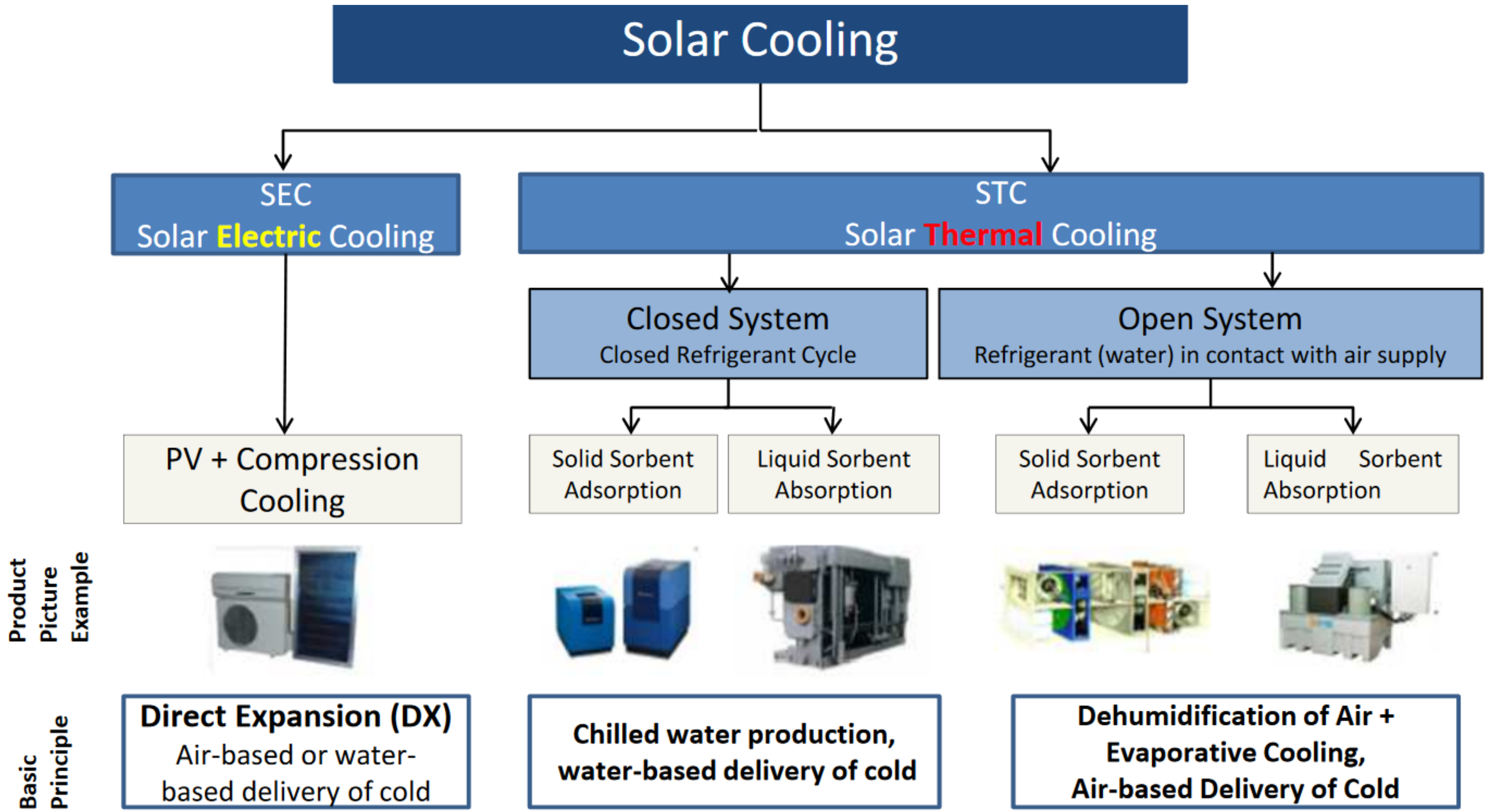
- Cooling will increase peak electricity demand

Share of cooling in electricity system peak loads



Source: https://www.iea.org/futureofcooling/

Options for Solar Cooling



Source:
https://www.ises.org/sites/default/files/webinars/Presentation%20Sonia%20Longo%20%2B%20Marco%20Beccali.pdf

Summary

Summary

- Sector coupling and the increasing electrification of the transport and heating/cooling sector is required for the decarbonization of the energy sector.

- A number of general framework conditions are crucial for successful sector coupling (e.g. infrastructure planning and coordination, harmonization of taxes/levies/subsidies, modifications to rate design).

- Consumers need to be confronted with the right price signals to reduce increases in peak electricity demand to a minimum;

Further Reading/List of References

Further Reading and List of References

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Thank you for your time!

E3 ANALYTICS

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Factor
Ideas for change

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ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

6. Knowledge Checkpoint: Multiple Choice Questions