GRID EDGE TECHNOLOGIES:

CHANGING THE PARADIGMS TO PROMOTE THE 3D CONCEPT AND THE ENERGY TRANSITION

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Agenda

- ✓ Grid-edge technologies: definitions
- ✓ 3D concept
- ✓ Customer-side solutions
- ✓ Utility-side solutions
- ✓ Potential applications
- ✓ Emerging impacts
- ✓ Energy transition: a brief insight – challenges and opportunities
- ✓ Comments

Grid-edge technologies: definitions and contextualization

Greentech Media: *The grid edge comprises the **technologies**, **solutions** and **business models** advancing the transition toward a **decentralized** and **distributed** grid structure.*

World Economic Forum: *Three trends of the grid edge transformation: **electrification**, **decentralization** and **digitalization**.*

3D Concept

Decentralization

Decarbonization

Digitalization

Siemens: *Grid edge is where the **consumer**, **prosumer** and the **intelligent grid** interact. This transition is driven by **digitalization**, **decentralization** and a global call for **decarbonization**.*

ABB: *An ecosystem of **distributed energy capabilities**, **digital solution** and **services** to maximize customer value and retention.*

IEEE: *Grid edge is one of the **most exciting emerging technology transitions**… It will connect utilities, technology providers, policymakers, and key stakeholders worldwide to advance a **clean energy** future while preserving the grid's **reliability** and **affordability**…*

Grid-edge technologies: 3D concept

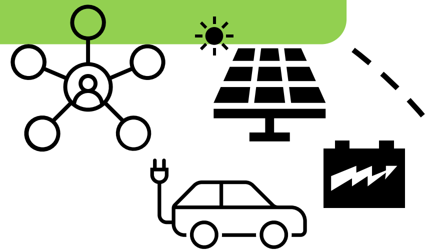
✓ **Business model:**
from SERVICE to MULTIPLATFORM

✓ **New regulatory framework**

NEW

3D Concept

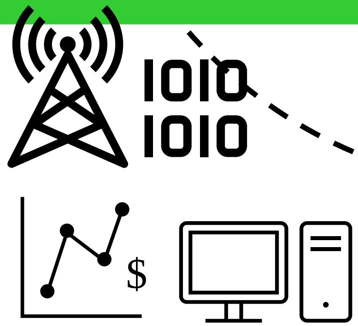
Decentralization



Key technologies/ solutions:
- ✓ Distributed energy resources
- ✓ Demand response
- ✓ Microgrids
- ✓ Transactive energy

Key players:
- ✓ Adaptive prosumers (active customers)
- ✓ Third-party integrators/service suppliers (nonregulated)

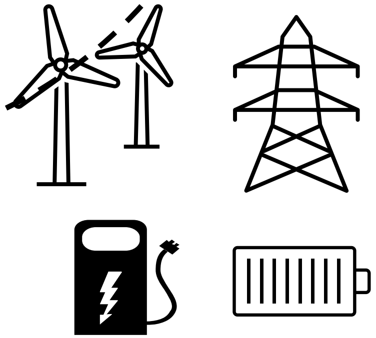
Digitalization



Key technologies/solutions:
- ✓ Smart meter
- ✓ Communication/computing (IoT)
- ✓ Automation, supervision, protection, and control
- ✓ Energy market

Key players:
- ✓ Third-party integrators/ service suppliers
- ✓ Software and solution developers

Decarbonization (Electrification)



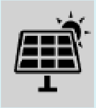
Key technologies/solutions:
- ✓ Electric mobility
- ✓ Electric heating/cooling systems
- ✓ Energy efficiency
- ✓ Renewable generators

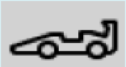
Key players:
- ✓ Third-party integrators/ service suppliers
- ✓ Independent Producers
- ✓ Utilities (Grid)

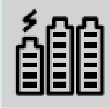
Grid-edge technologies: LV customer-side solutions

Low voltage residential customers


Smart meter


Rooftop PV generation


Regular EV charging


Energy storage


Inverter-based air conditioner

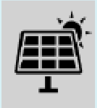

Induction cooker

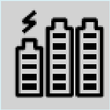

Inverter-based refrigerator

Energy efficient home appliances

Low voltage rural customers


Smart meter


PV generation


Energy storage


Motors with efficient drivers


Inverter-based air conditioner

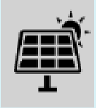

Induction cooker

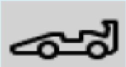
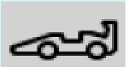

Inverter-based refrigerator

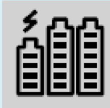
Energy efficient home appliances

Low voltage commercial customers


Smart meter


Rooftop PV generation



Semi-fast EV charging


Energy storage


Motors with efficient drivers


Efficient lighting system

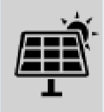

Inverter-based cooling system

Energy efficient appliances

Grid-edge technologies: MV customer-side solutions

Medium voltage commercial customers

Smart meter



PV generation

Energy storage

Motors with efficient drivers

Inverter-based refrigerator

Inverter-based cooling system

Parking lot with fast EV chargers

Efficient lighting system

Energy efficient appliances

Medium voltage industrial customers

Smart meter

PV farm

Energy storage

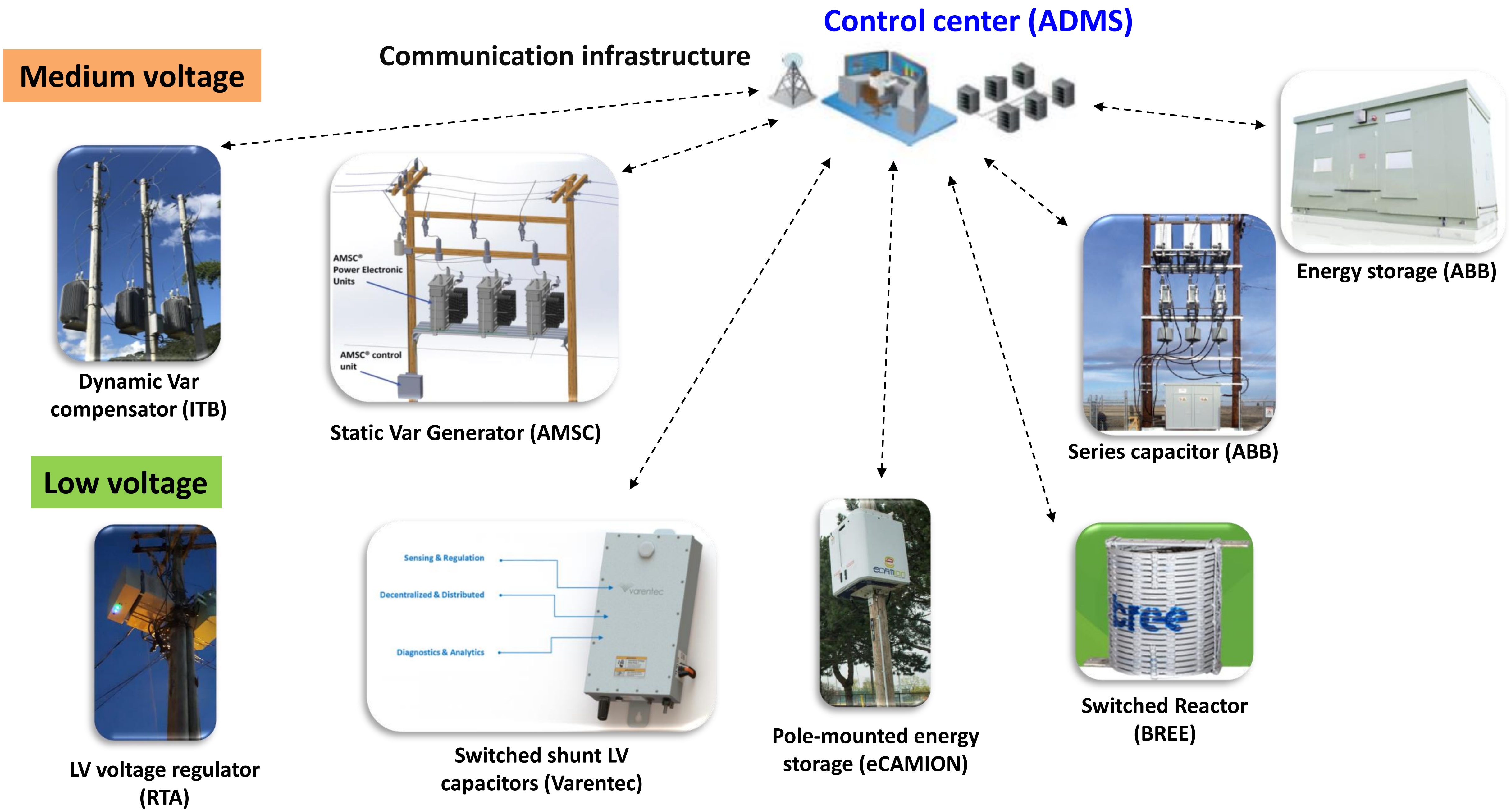
Efficient cooling system

EV fleet

Parking lot with fast EV chargers

Large motors with efficient drivers

Grid-edge technologies: utility-side solutions



Grid-edge technologies: emerging impacts

Emerging impacts on system planning

- Higher uncertainties and variabilities related to load-generation curves (need to move from deterministic approaches to **risk-based (optimal stochastic) planning** approaches)
- Higher complexity for asset management due to diversity (need to move from passive-deterministic approaches to **active-risk-based** approaches)
- Higher complexity to design the protection system due to several sources of short-circuit currents and more complex devices with unknow probability of failure or maloperation (need to combine traditional reactive approaches and **emerging predictive approaches**)
- More sophisticated customer irregular connections (need to develop more **robust methods** for non-technical losses detection and location)
- **Higher complexity** for losses management

Grid-edge technologies: emerging impacts

Emerging impacts on system power quality

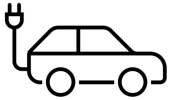
- Unbalance and **over/under voltage** caused by distributed energy resources (PV, EV)
- Voltage quality caused by cloud transients (PV)
- Temporary under (over) voltage due to tripping (reconnection) of distributed generators
- **Harmonic resonances** and instabilities on low voltage systems
- **Subsynchronous resonances** and instabilities on medium voltage systems
- **High frequency distortion** (supraharmonics) emission and propagation

Emerging impacts on system control/operation

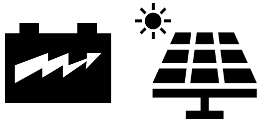
- **Unstable interactions between voltage control devices** on low voltage systems (voltage regulators, shunt capacitor banks, inverter-based generators)
- **Unstable interactions between voltage control devices** on medium voltage systems (voltage regulators, shunt capacitor banks, STATCOMs, inverter-based generators, large motor drivers)

R&D Vision: Emerging technologies + Enabling technologies + Applications = Benefits for society

Emerging technologies

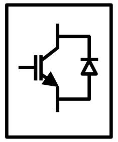


Electric mobility



Distributed Energy Resources

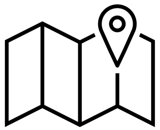
Sensors (smart meters)



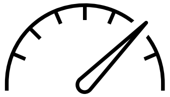
Smart inverters

Enabling technologies

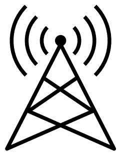
ADMS



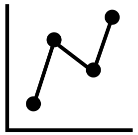
GIS/OMS



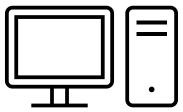
Sensor network



Communication



Data science



Distributed Computing

Applications (R)

- ✓ Non-technical loss detection
- ✓ Load disaggregation, modeling, monitoring (curve), short- and long-term forecast
- ✓ Database automatic correction
- ✓ MV/LV system load/phase balancing
- ✓ Volt/Var integration/optimization
- ✓ Fault anticipation and location
- ✓ Fast restoration (self-healing)
- ✓ Demand response/peak shaving
- ✓ Conservative voltage reduction
- ✓ Loss management
- ✓ Active management of renewable generators and electric vehicles
- ✓ Microgrid management
- ✓ Active equipment monitoring and management (maintenance/replacement)
- ✓ Transactive energy
- ✓ **New Services (energy conservation, security monitoring, planning data)**

Benefits for society (D)

- ✓ More efficient and reliable energy systems (energy cost reduction)
- ✓ Greenhouse emission reduction
- ✓ Better product (energy)
- ✓ New and better services (supply)
- ✓ **Electricity systems as a business platform for multiple services:**
  - ✓ **risk monitoring for public authorities (*e.g.*, civil defense)**
  - ✓ **data for public planning (*e.g.*, city land use, transit, infra investment)**
  - ✓ **security monitoring for public authorities and customers**
  - ✓ **efficiency coaching**
- ✓ New and more jobs/companies

Energy transition: definitions

- *"Energy transition refers to the global energy sector's shift from fossil-based systems of energy production and consumption — including oil, natural gas and coal — to renewable energy sources like wind and solar, as well as lithium-ion batteries."*

  storage systems

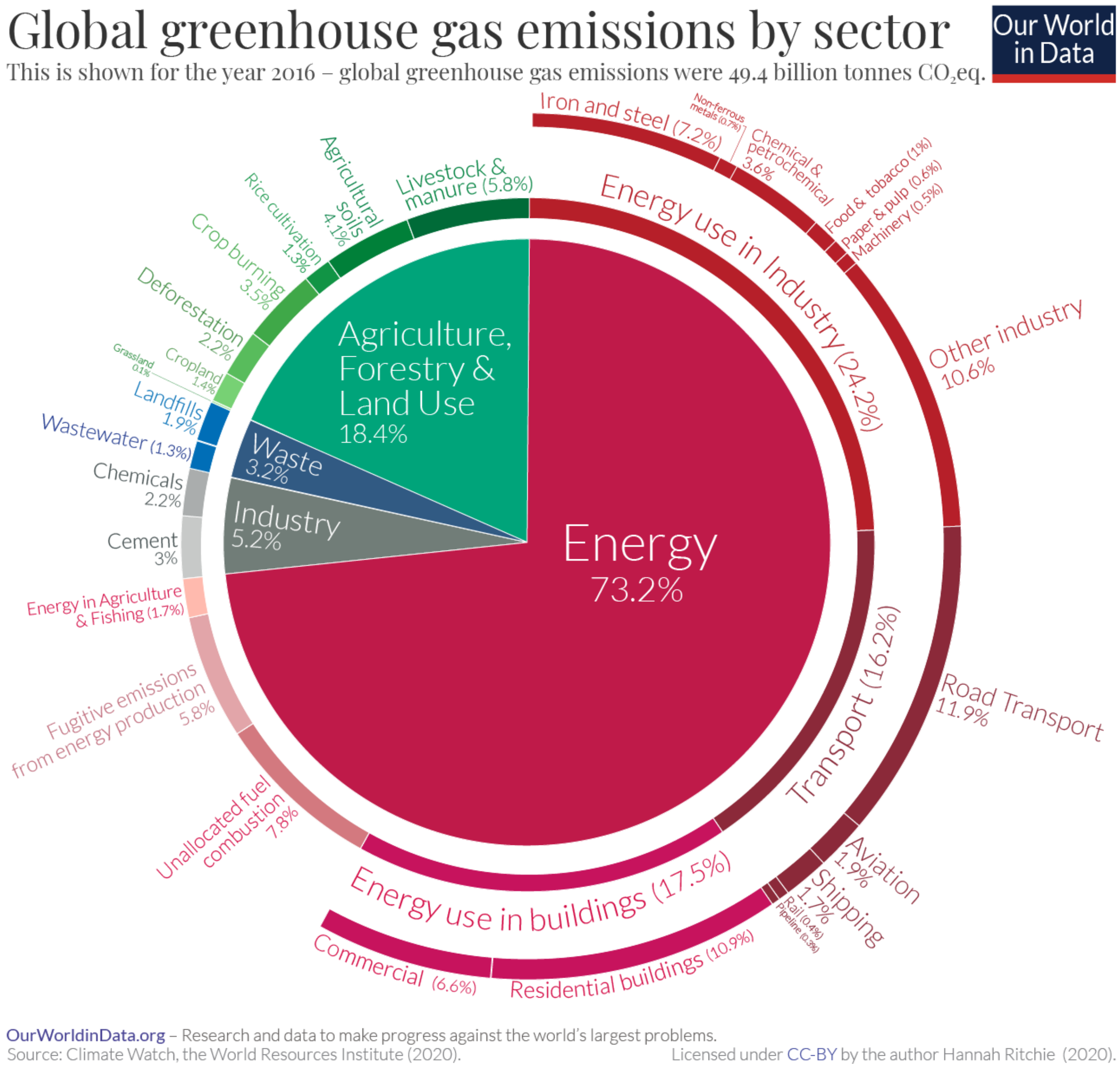
  Source: What is Energy Transition? S&P Global

- *"Replacing the current global energy system relying overwhelmingly on fossil fuels by biofuels and by electricity generated intermittently from renewable sources will be necessarily a prolonged, multidecadal process."*

  Source: Vaclav Smil, Examining energy transitions: A dozen insights based on performance, Energy Research & Social Science, 22, 2016

Energy transition is a vast, multidisciplinary theme/subject

Motivation: climate change mitigation

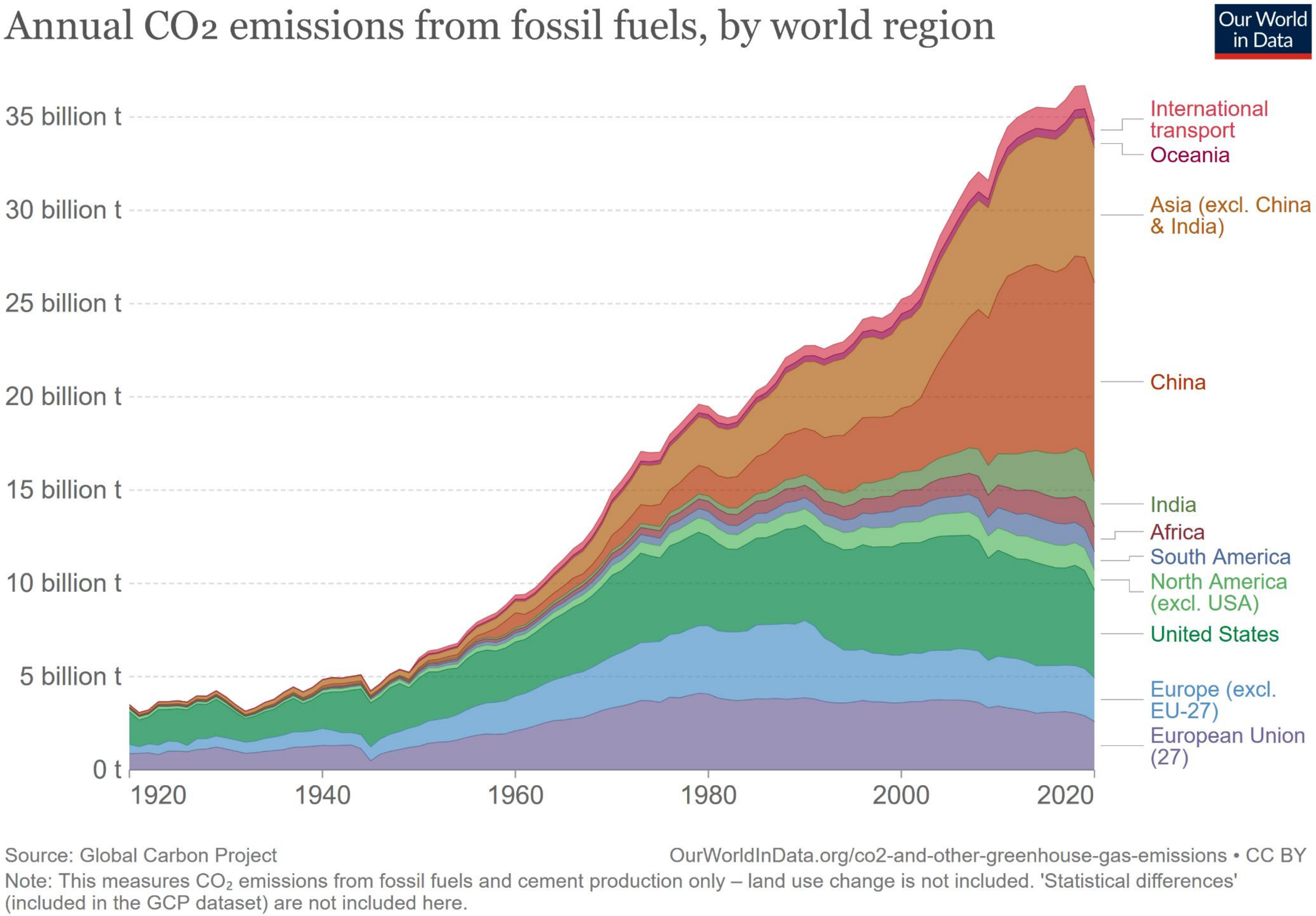


Energy use in:

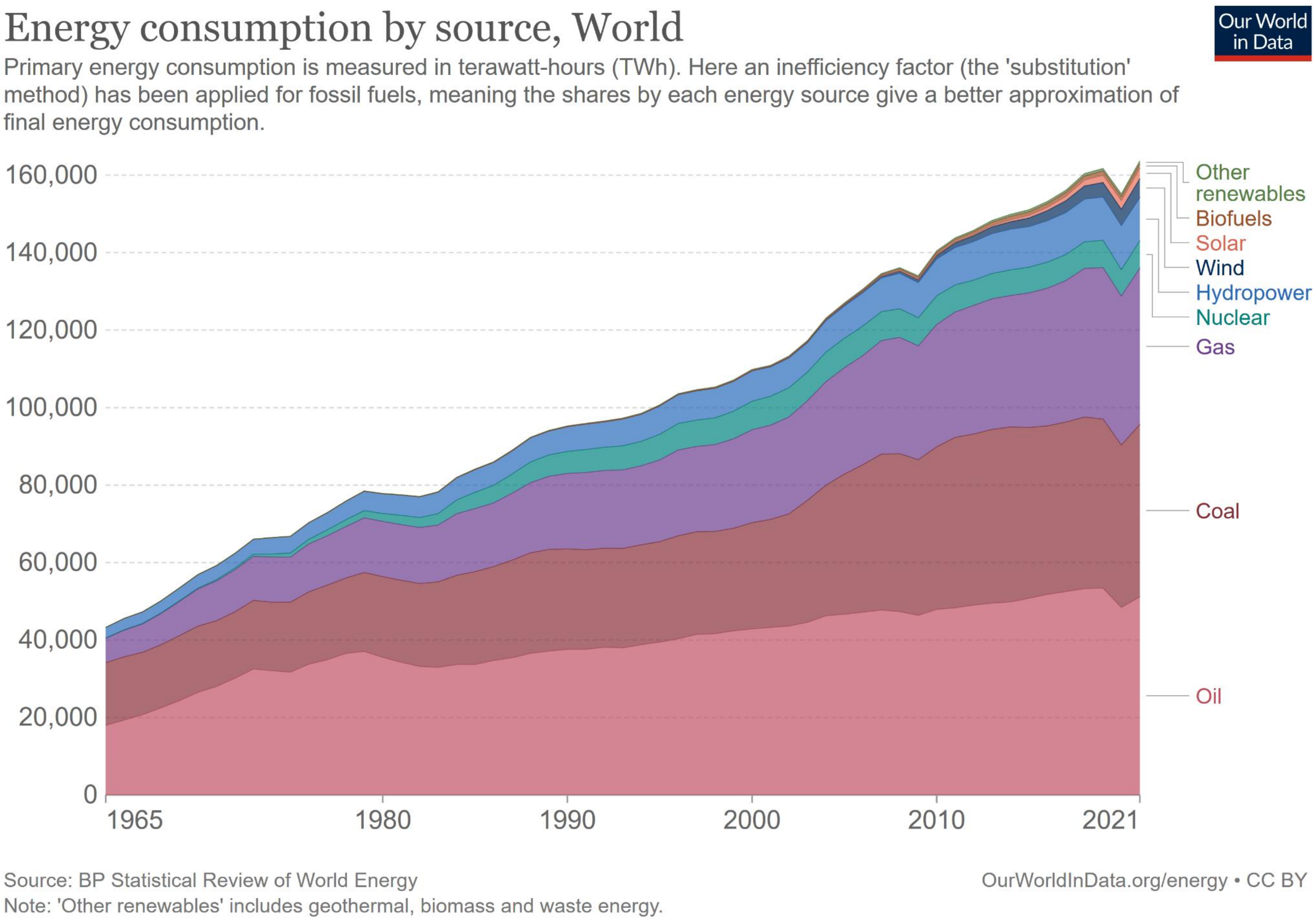
- ✓ Industry
- ✓ Transport
- ✓ Buildings

57.9%

Climate change mitigation: challenge



Energy transition: challenge – where are we?



Energy consumption increased 47.6% between 2001 and 2021

Dependency on fossil fuels

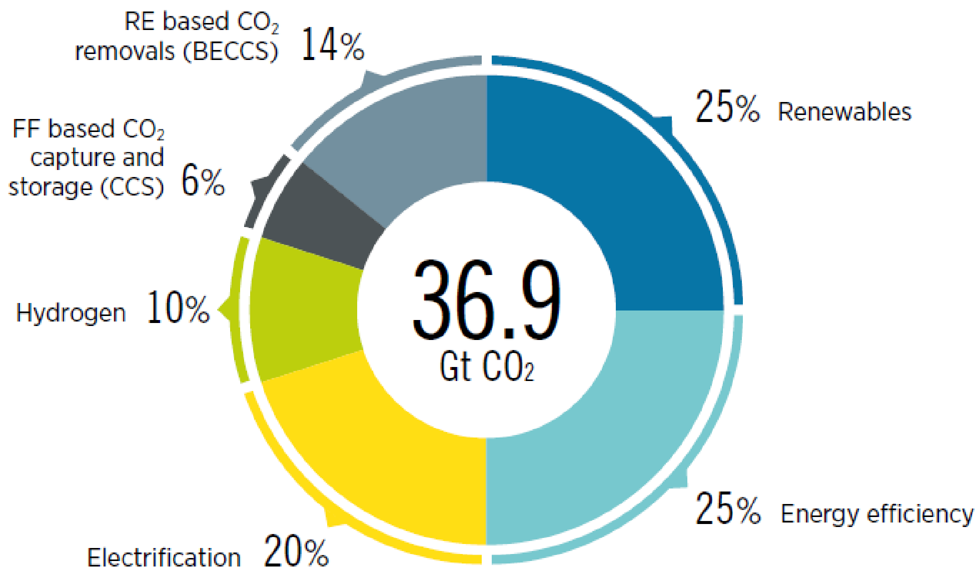
YEAR	%
2001	86.0
2011	86.7
2021	83.1

Potential solutions/technologies

Reducing the emission by 2050 through 5 technological avenues:

1. Renewables: significant increase in generation and direct use of renewable-based electricity
2. Energy efficiency: substantial improvement in energy efficiency
3. Electrification: the electrification of end-use sectors (*e.g.*, electric vehicles and heat pumps) and industry
4. Green hydrogen: clean hydrogen and its derivatives and associated (*e.g.*, ammonia)
5. Carbon capture and storage (CCS): carbon capture and storage from fossil fuel-based processes, mainly in industry, and bioenergy coupled with CCS in electricity, heat generation, and industry

FIGURE ES.1 Reducing emissions by 2050 through six technological avenues

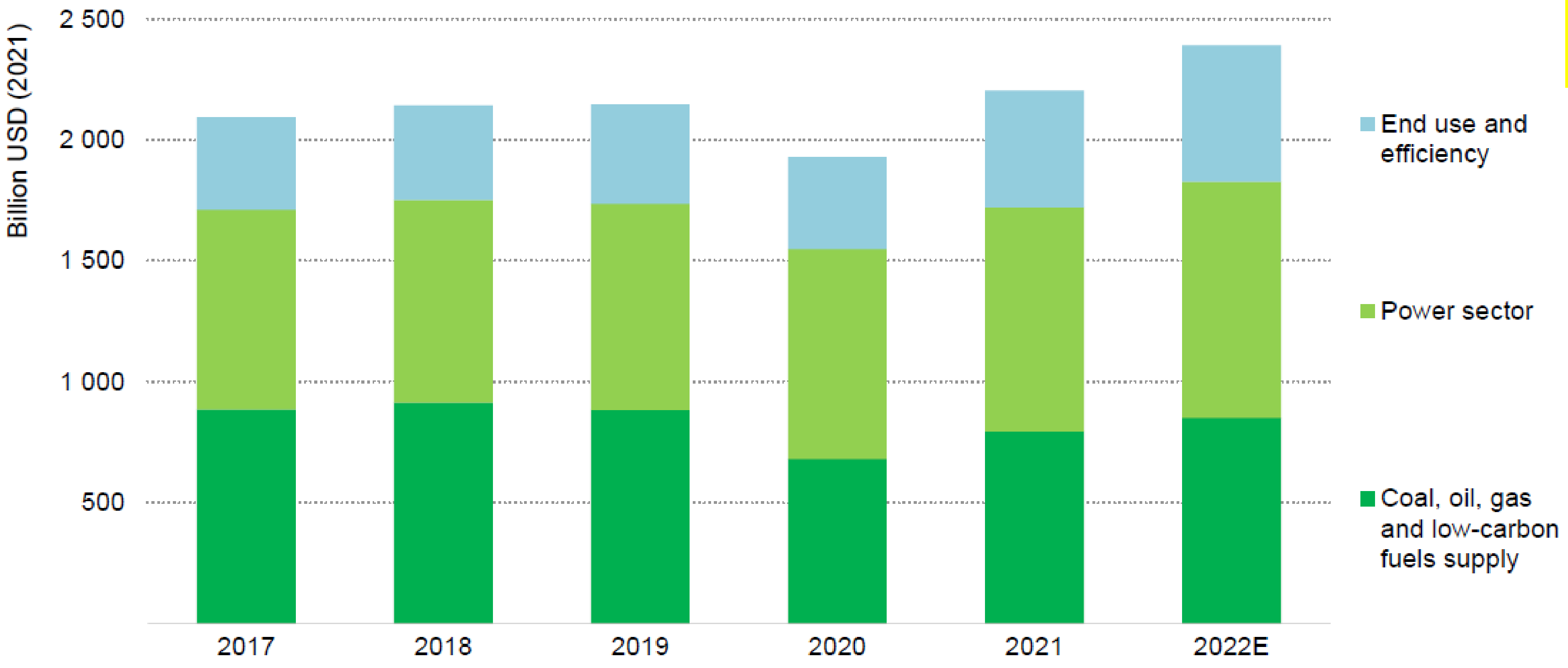


Source: World Energy Transition: Outlook 2022 – 1.5° C Pathway, IRENA (International Renewable Energy Agency)

Opportunities: energy investment

Energy investment is set to pick up by 8% in 2022 against the backdrop of the global energy crisis, but almost half of the increase in capital spending is linked to higher costs

Global energy investment



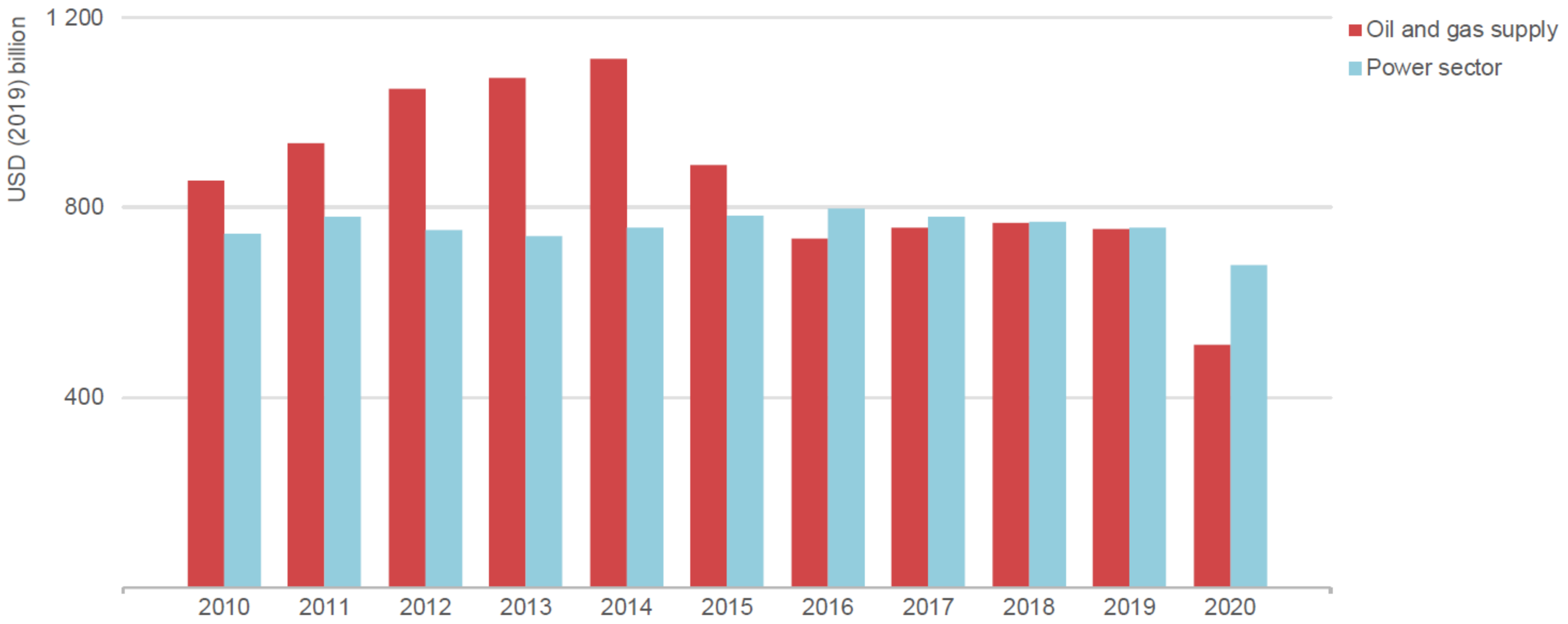
Brazilian GDP (2021): 1.6 Trillion US$

iea

Opportunities: energy investment

Over the last ten years, power sector spending has been relatively stable compared with the rollercoaster ride for oil and gas

Global investment in energy supply



Opportunities: energy investment

Diversification plans by oil and gas companies are more ambitious than the underlying clean energy investments

Current diversification options by selected international oil companies and NOCs

Company	Activity and investment in selected alternative businesses						
	Solar PV and wind generation	Geothermal	Electricity services	Bioenergy	CCUS	Low-carbon hydrogen	Nature-based solutions
BP	●	◉	●	●	◉	○	◉
Eni	●		●	●	◉	○	◉
Shell	●	○	●	●	●	○	◉
TotalEnergies	●		●	●	●	○	◉
Chevron		◉		●	●	○	
ExxonMobil				●	●	○	
ConocoPhillips					○		
Saudi Aramco	●				●	○	
ADNOC	●				●	○	
CNPC	○	◉		○	◉	○	○
Sinopec	○	●			◉	○	
CNOOC	○				○	○	

Notes: ● = growth supported by strategic investments (M&A), project FIDs and/or spending on commercial-scale activities; ◉ = announced strategy with minor investments, venture capital and/or R&D spending; ○ = announced strategy but with limited evidence of investment activity or no announced strategy but minimal investments. Electricity services include battery storage and EV charging. Bioenergy includes advanced biofuels and biomethane.

Sources: Company reported strategies, publicly disclosed investments and interviews with Chinese NOCs.

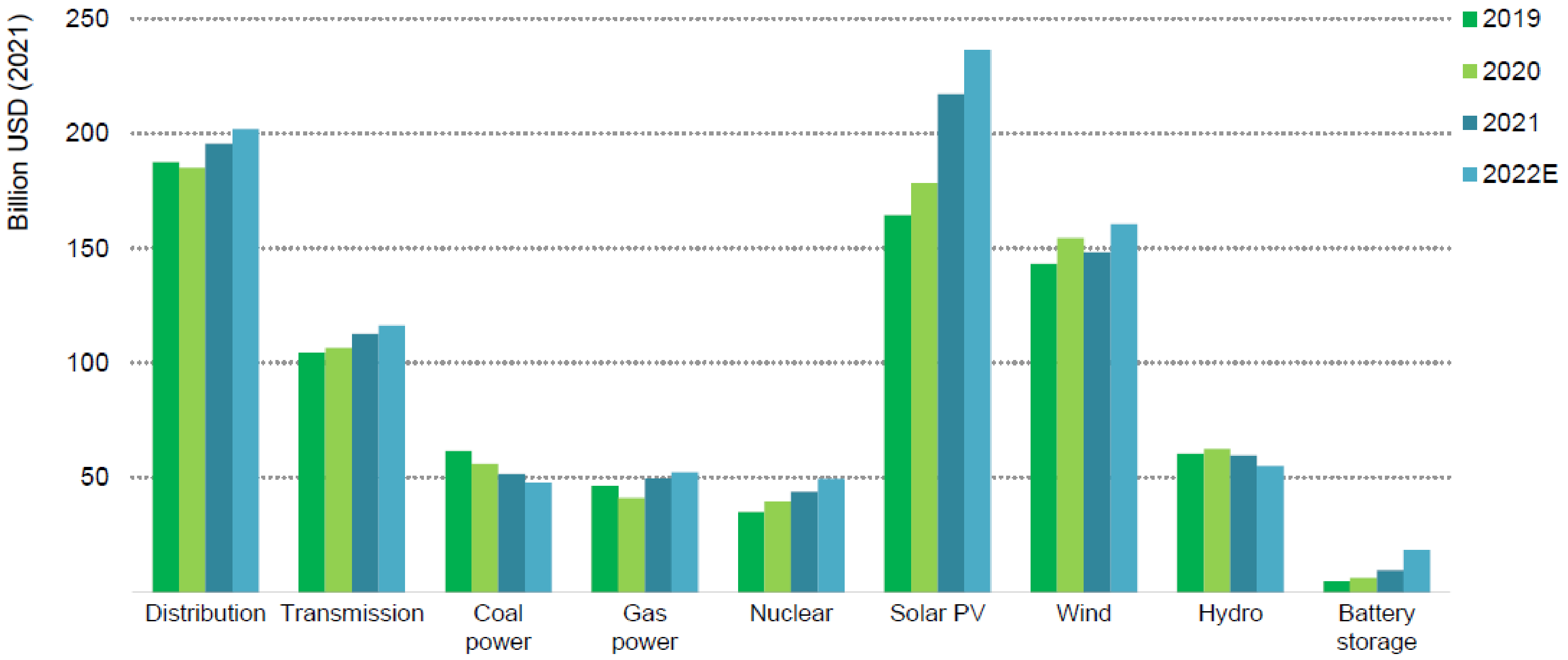
Shell aims to become world's largest electricity company

Source: Reuters Events

Opportunities: power sector investment

Solar PV is leading power sector investment, with positive signs for transmission and distribution networks and an acceleration in battery energy storage

Global annual investment in the power sector by technology, 2019-2022E



Notes: Gas-fired generation investment includes both large-scale plants and small-scale generating sets and engines; hydropower includes pumped-hydro storage.
Sources: IEA analysis based on calculations from IRENA (2022) and Platts (2022).

Total investment increased
from 800 to 1,000 billion US$/year

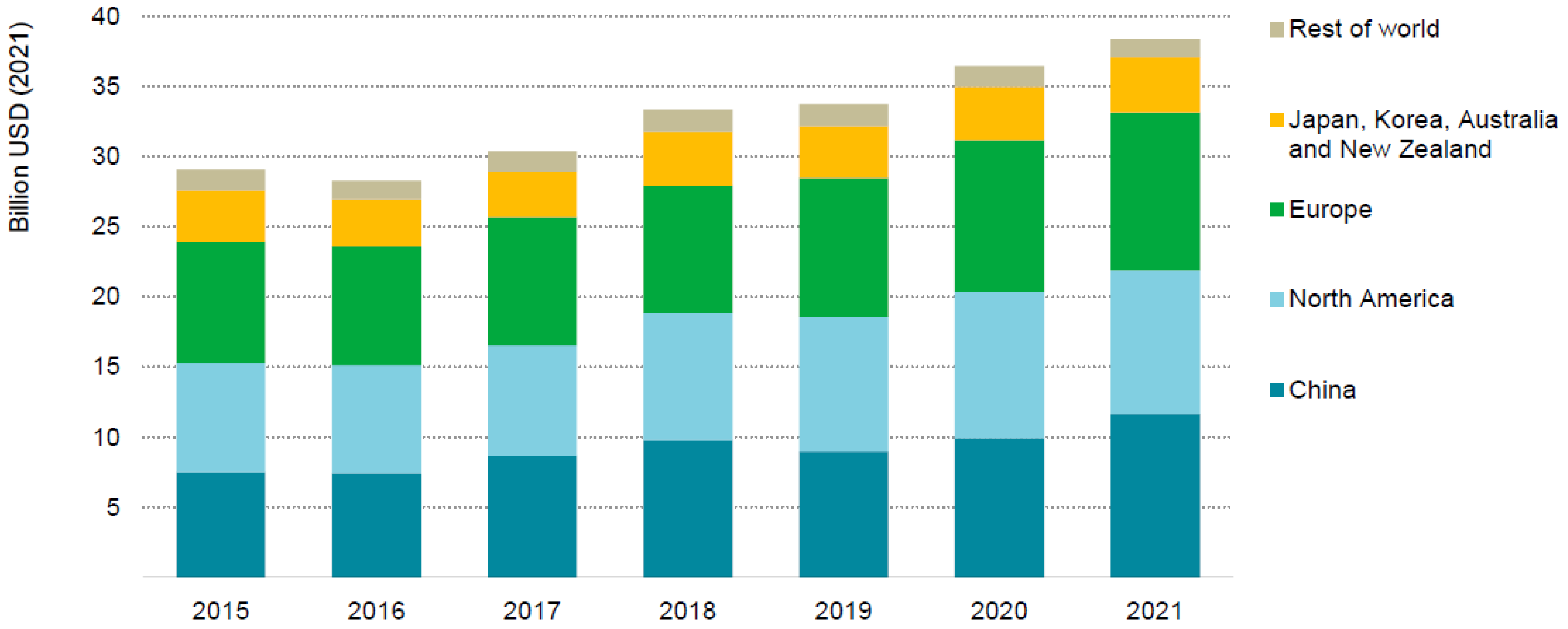
Opportunities: R&D investment – government

World Energy Investment 2022

R&D and technology innovation

Government spending on energy R&D increased in 2021, but Covid-19 uncertainties slowed growth

Government spending on energy R&D, 2015-2021



Notes: Includes spending on demonstration projects (i.e. RD&D) wherever reported by governments as defined in IEA documentation; 2021 is a preliminary estimate based on data available by mid-May 2022; state-owned enterprise funds comprise a significant share of the Chinese total, for which the 2021 estimate is based on reported company spending where available; the IEA Secretariat has estimated US data from public sources.

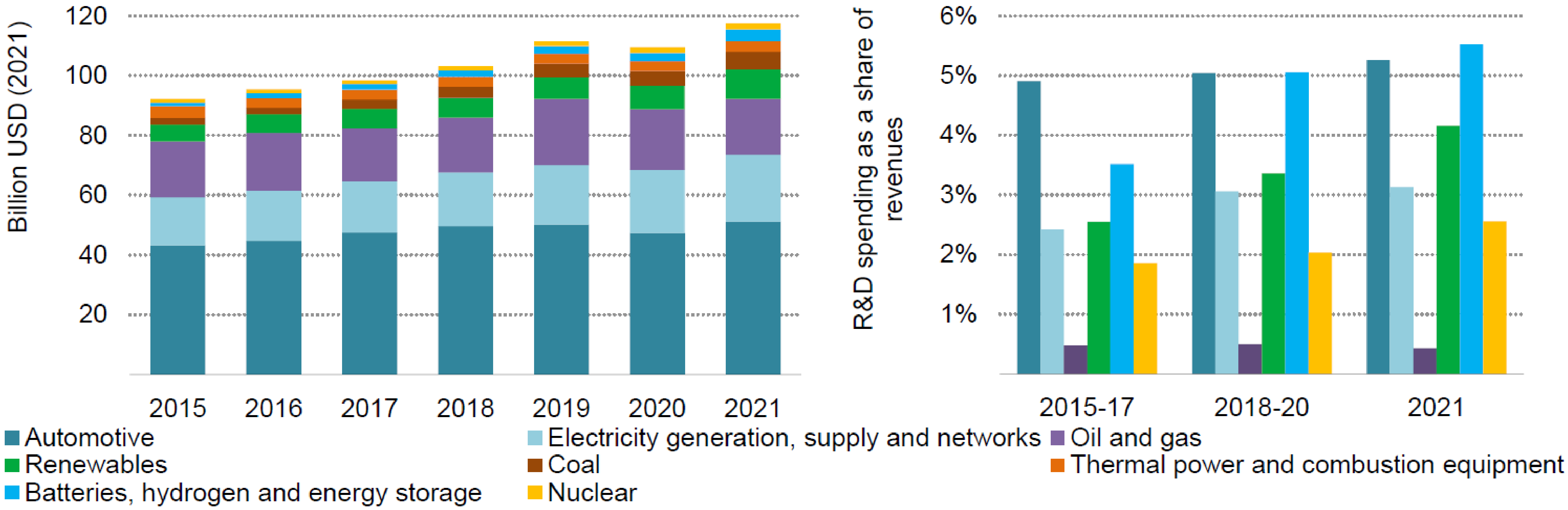
Source: IEA Energy Technology RD&D Budgets: Overview (forthcoming).

Opportunities: R&D investment – corporate

R&D and technology innovation

Corporate energy R&D spending returned to growth in 2021, with uplift in China and renewables compensating for tightened budgets elsewhere and among fossil fuel companies

Spending on energy R&D by listed companies (left) and R&D budgets as a share of revenues (right), by sector of activity, 2015-2021



Opportunities: green products/market

Electricity/energy intensive industry:

- Fertilizer industry: the fertilizer industry accounts for about 1.2% of world energy use, and more than 90% of this energy is used in the production of ammonia
- Primary metal industry: the primary metal manufacturing subsector consists of iron and steel mills, alumina and aluminum production and processing, foundries etc.
- Paper and pulp industry: the four largest paper-producing regions (the EU, the US, China, and Japan) account for 80% of the energy use and carbon dioxide emissions
- Cement industry: developing countries account for about 73% of the global cement production

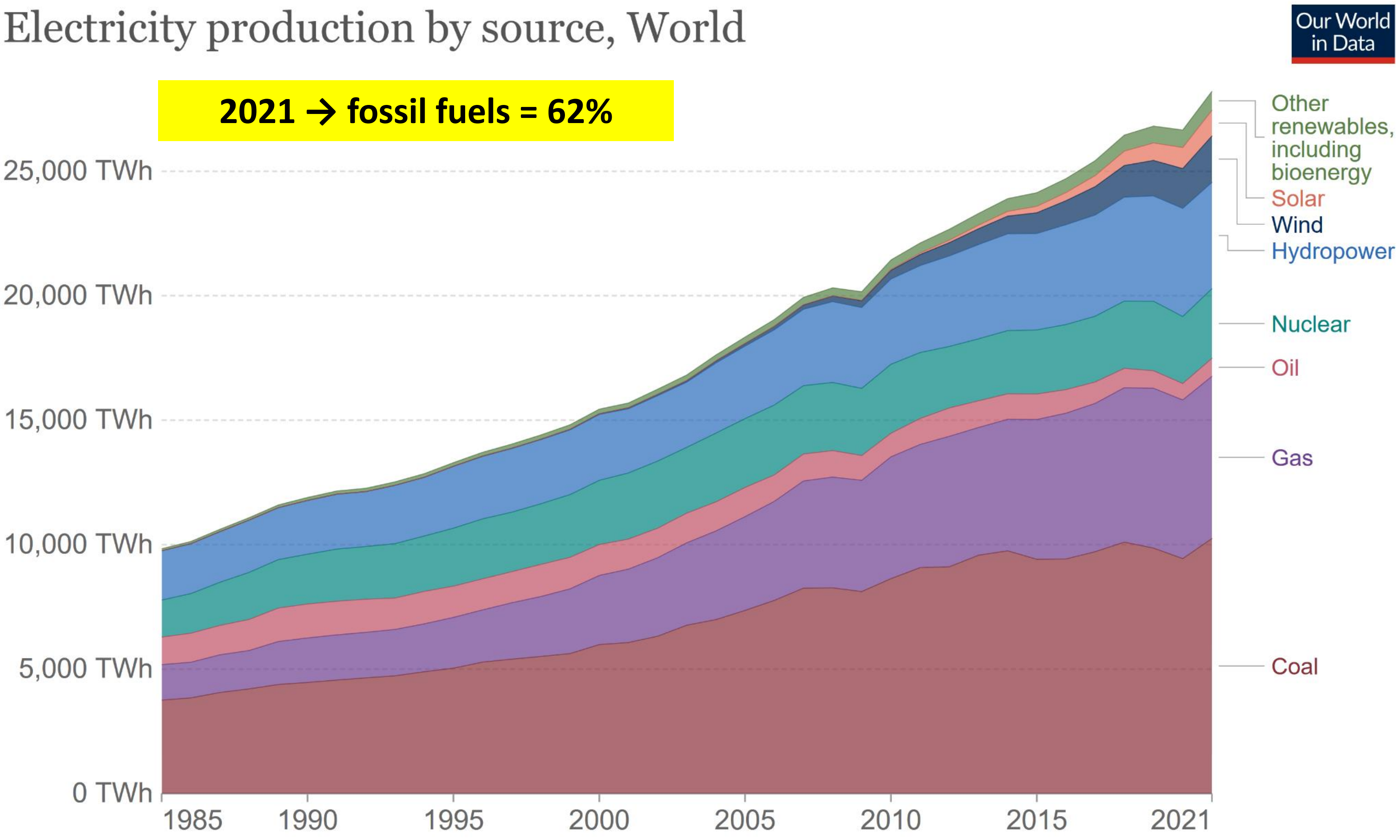
Brazil has a huge potential to produce and export green products with premium value

Sources:
https://consumerenergysolutions.com
https://goenergylink.com

"If a genie offered me one wish, a single breakthrough in just one activity that drives climate change, I'd pick making ***electricity****: It's going to play a big role in decarbonizing other parts of the physical economy."*

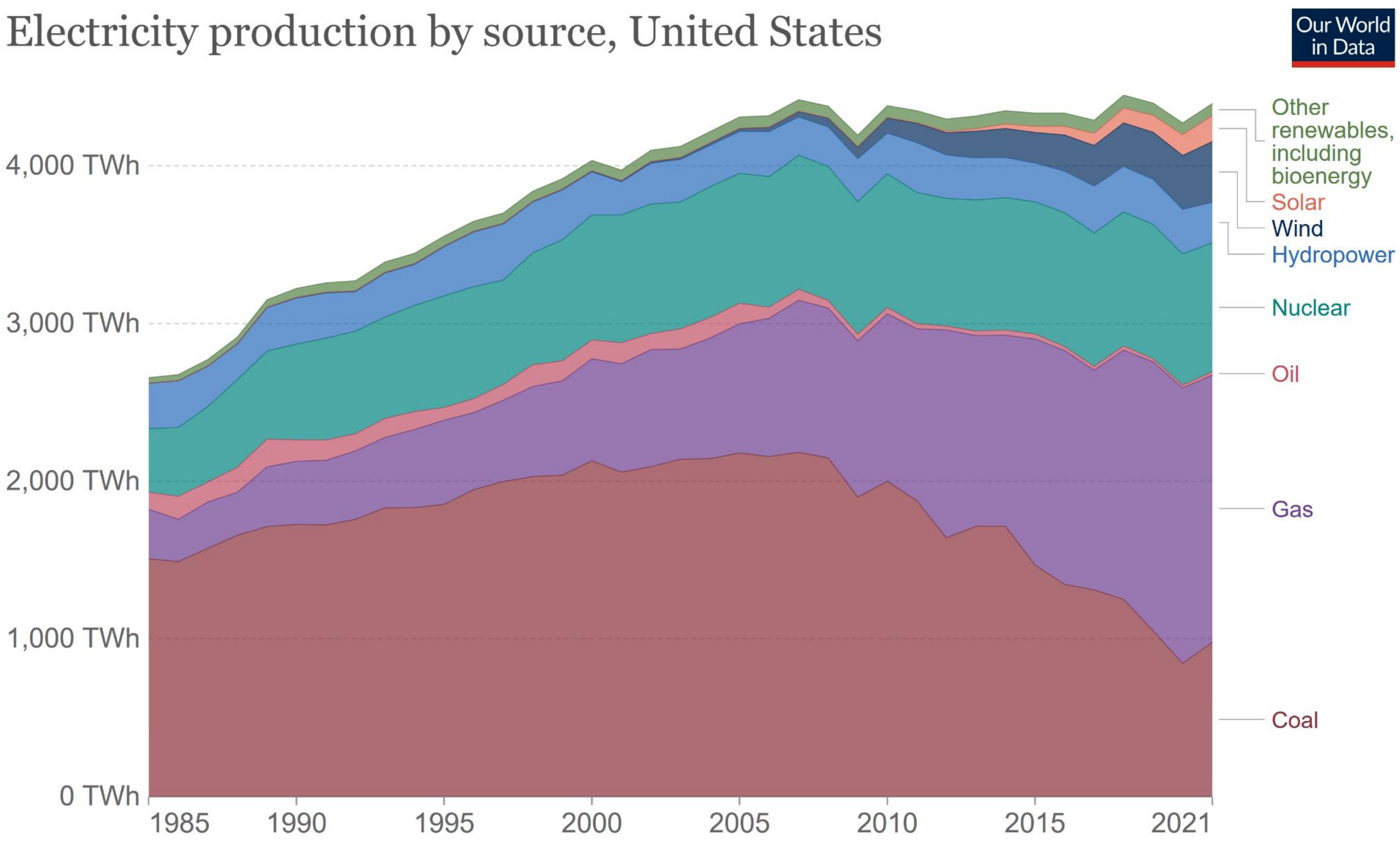
Bill Gates, on book "How to Avoid a Climate Disaster: The solutions we have and the breakthroughs we need" (2021)

Electricity sector



Source: Our World in Data based on BP Statistical Review of World Energy (2022); Our World in Data based on Ember's Global Electricity Review (2022); Our World in Data based on Ember's European Electricity Review (2022)
Note: 'Other renewables' includes biomass and waste, geothermal, wave and tidal.

Electricity sector



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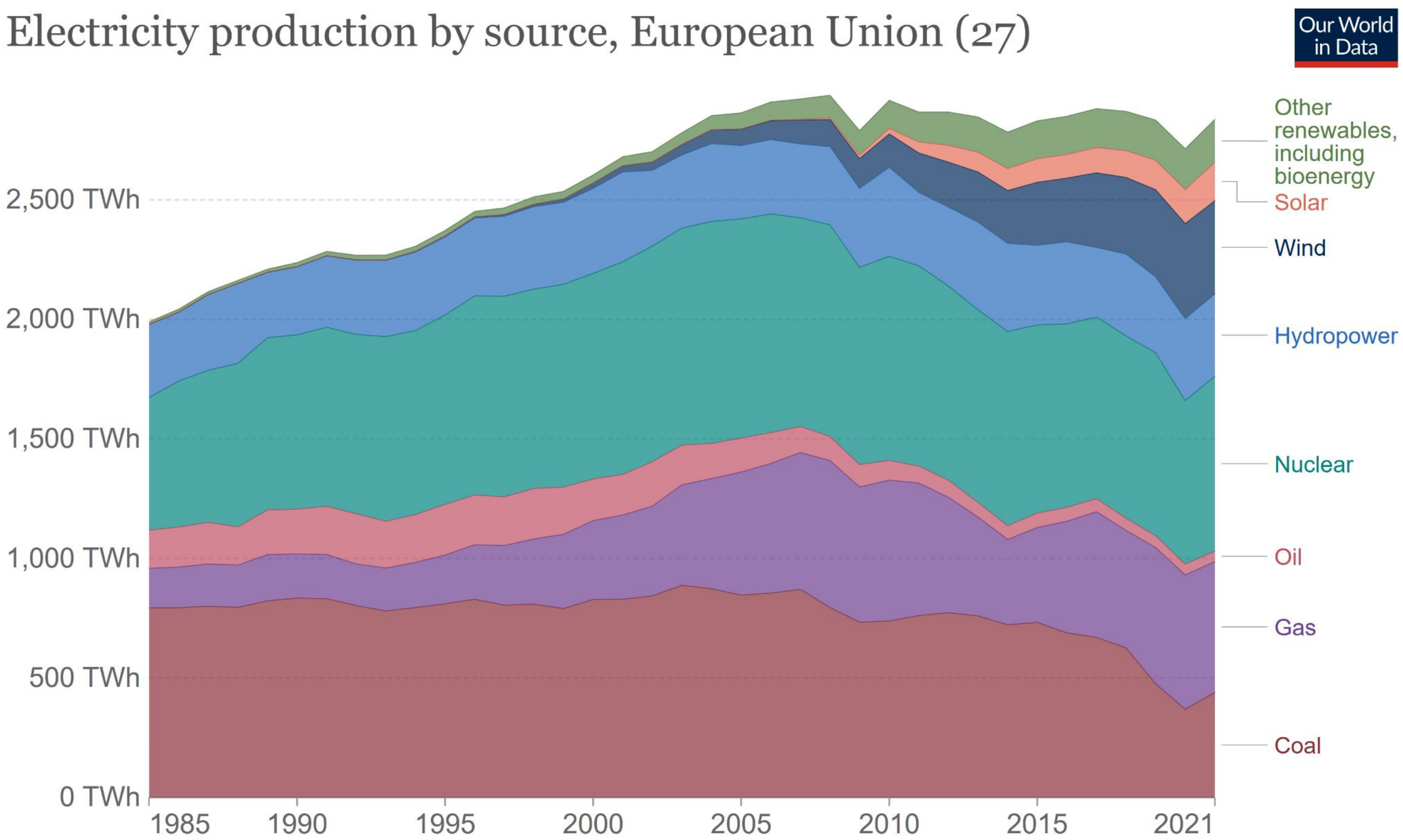
OurWorldInData.org/energy • CC BY

Electricity sector



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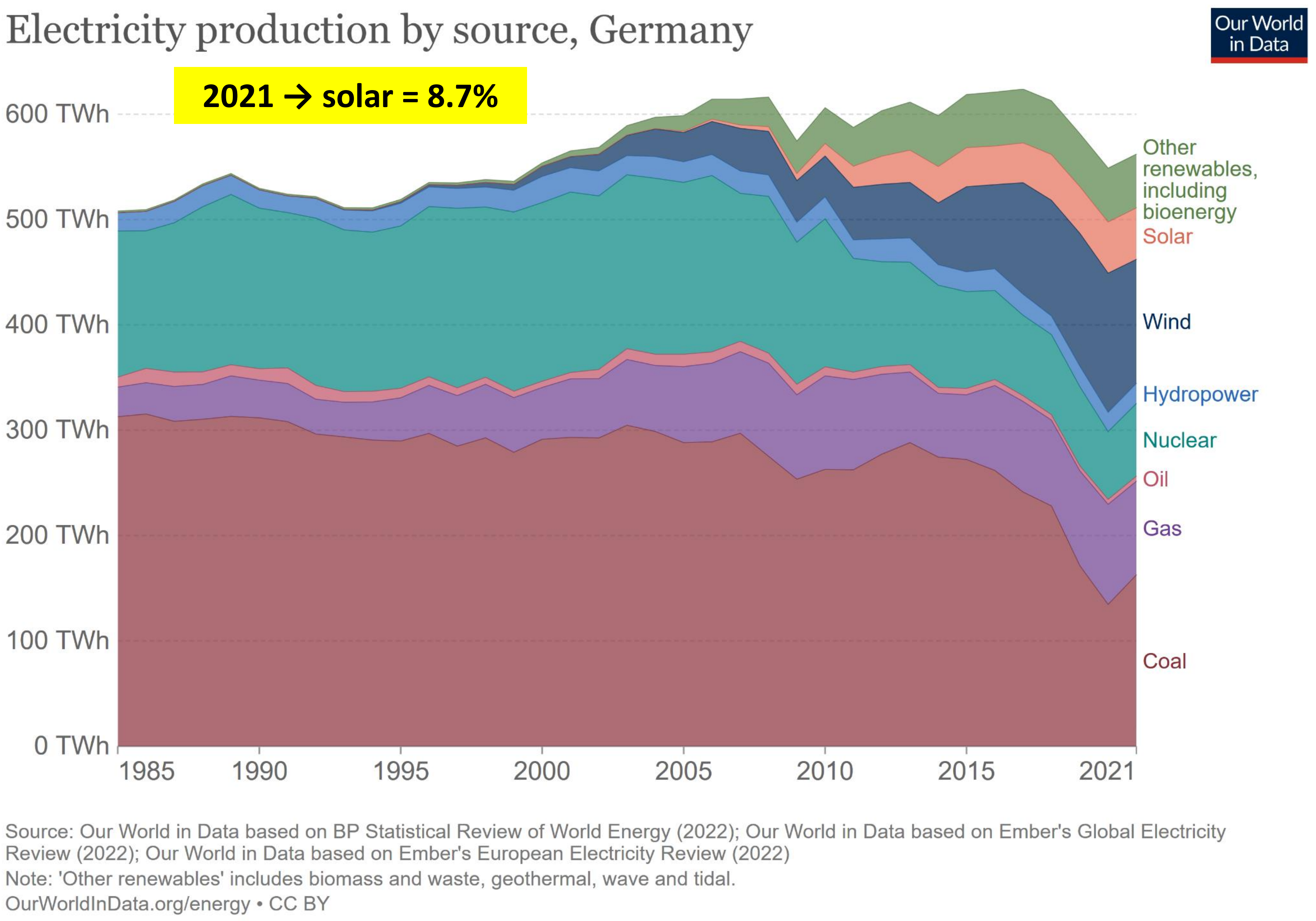
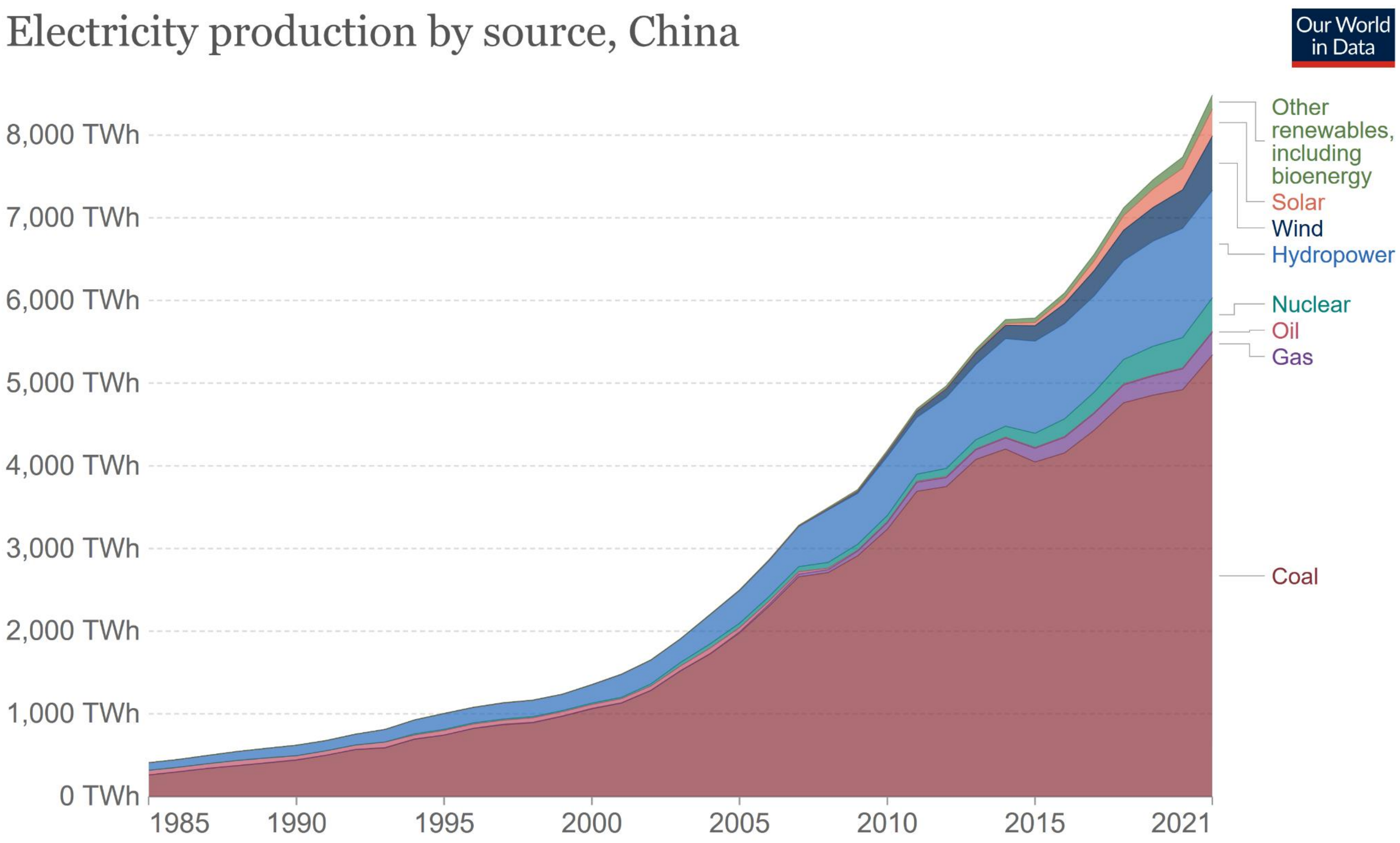
Electricity sector



Electricity sector



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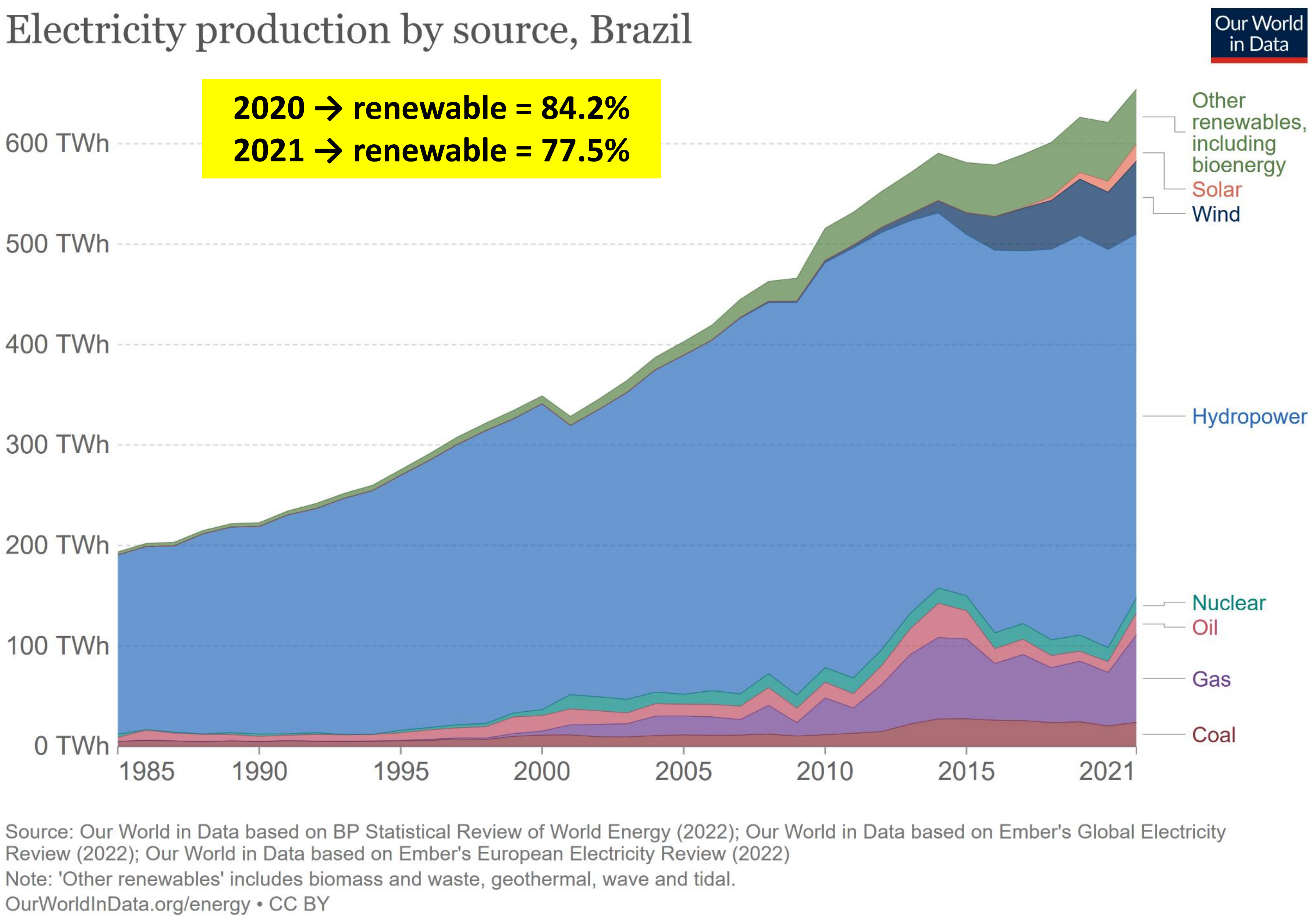
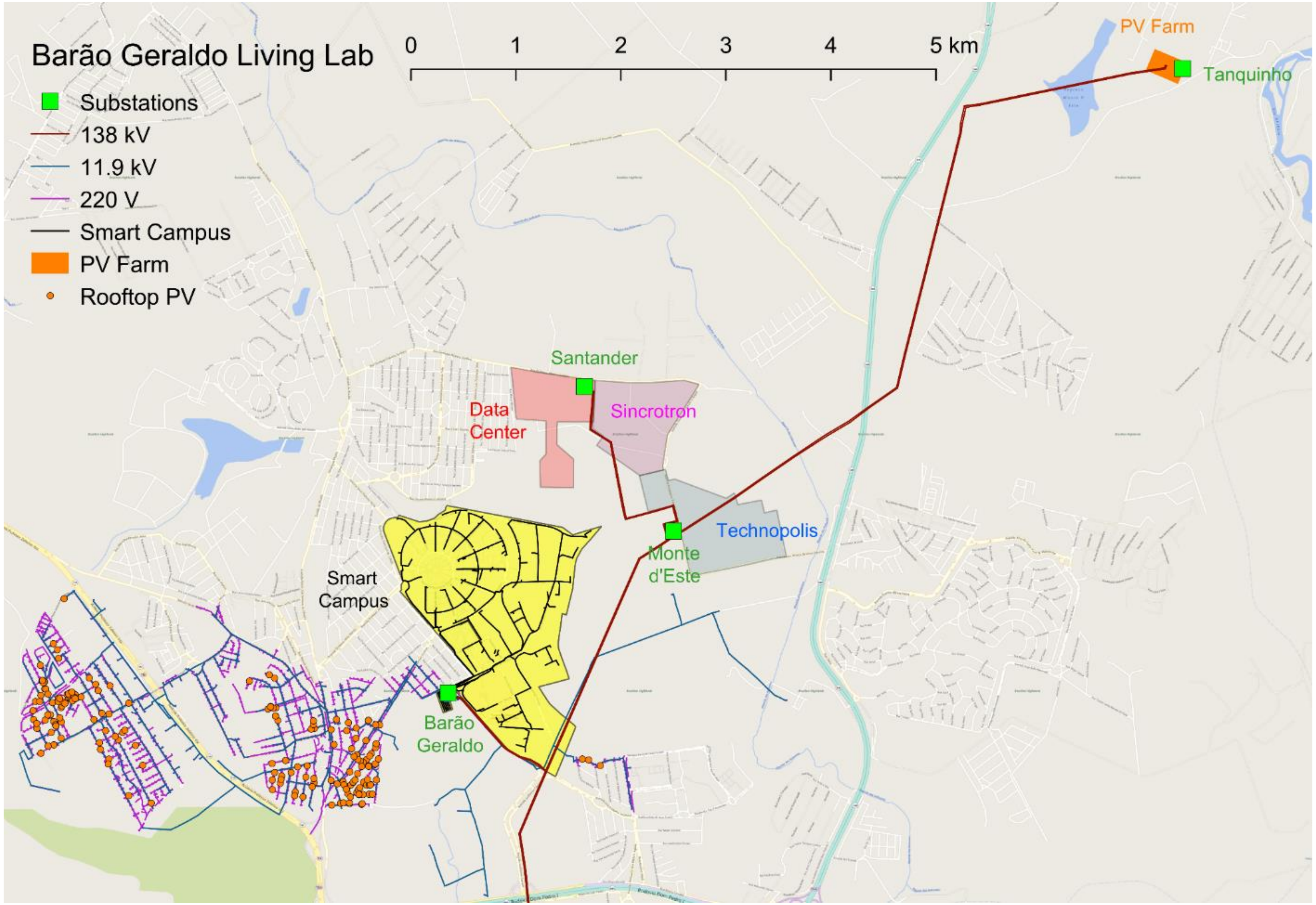
Electricity sector



A platform for smart grid technologies integration: one of the largest living labs in Latin America



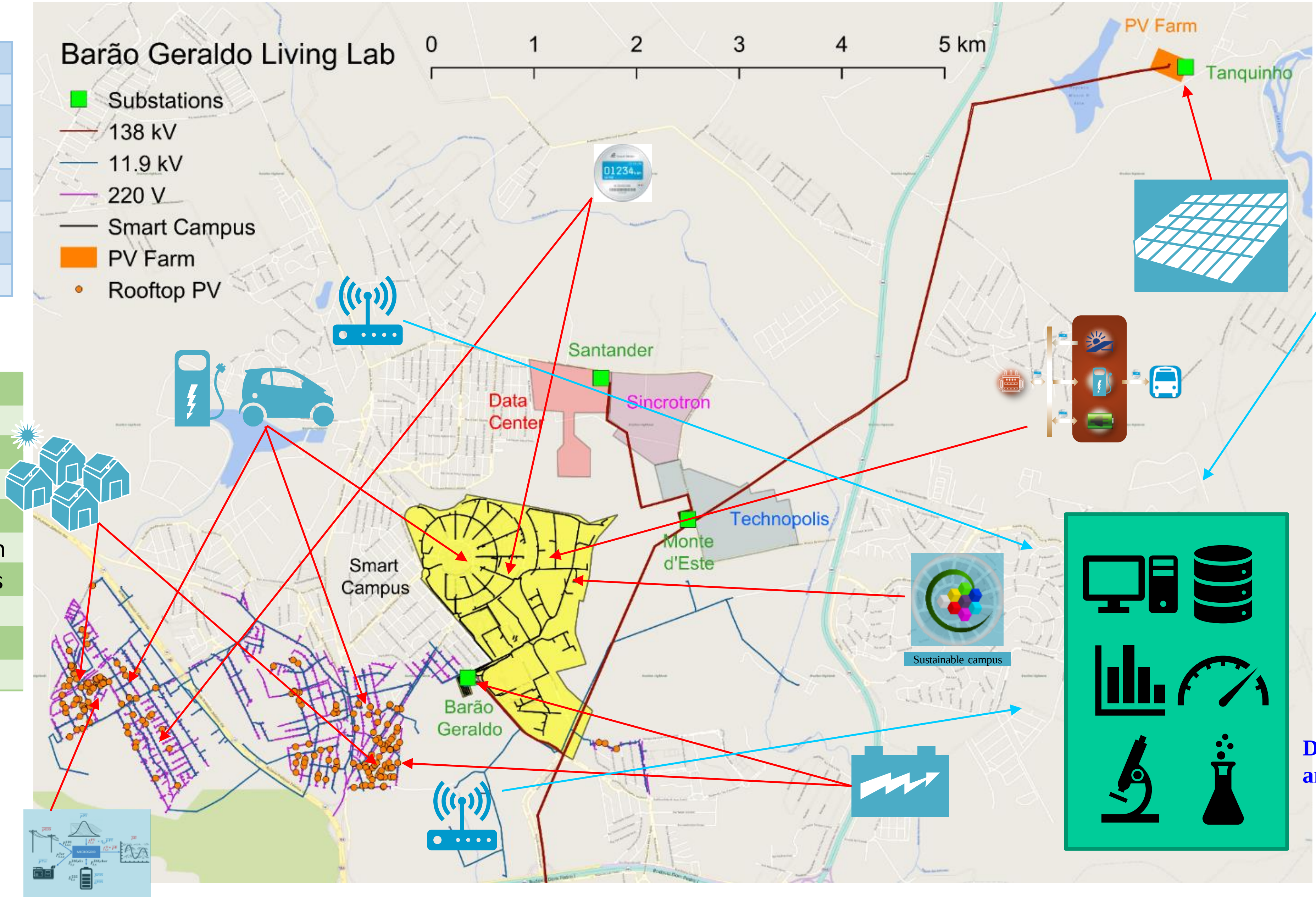
A Platform for smart grid technologies integration: one of the largest living labs in Latin America

Technologies

PV generators
Electrical vehicles
Storage systems
Smart meters
Electronic-based regulators
Microgrids
A-DMS
Data analytics / Big data

Projects

PA3012: PV rooftop
PA0060: Electric mobility
PA3018: Energy storage
PA3048: Technical losses
PA3047: Volt/var
PA2030: Load disaggregation
PA3032: Sustainable campus
PA3043: Electric bus
CS3060: Electromobility
PA3058: Microgrids



Investment:
~R$ 180 million

UNICAMP

Data science: data analytics / big data

CPTEn: São Paulo Center for Energy Transition Studies

CPTEn
Centro Paulista de Estudos da Transição Energética

FAPESP 60
SCIENCE, CULTURE AND DEVELOPMENT 1962 - 2022

R&D Themes

I **Artificial Intelligence and Data Science for Energy Management**	**II** **Regulatory Innovation and Models of Financing and Partnerships**	**III** **Public Politics and Governance**	**IV** **Economics Analysis of Prospection and Scenarios**
V **Education, HH formation, and capacitation for sustainable socioenvironment**	**VI** **Transition to Renewable Energy and Bioenergy**	**VII** **Transition to Digital Grids and Smart Consume**	**VIII** **Innovation for Smart Cities**

Program: Science Centers for Development

Home Institution:

- ✓ UNICAMP

Partners:

- ✓ CPFL ENERGIA
- ✓ ELETROBRAS/PROCEL
- ✓ SIMA-SP
- ✓ RADAZ

Associate Institutions:

- ✓ USP UNESP
- ✓ PUCMINAS
- ✓ CTI Renato Archer
- ✓ IFSP
- ✓ TUDELFT
- ✓ UFG
- ✓ UTFPR
- ✓ UPM
- ✓ LUT
- ✓ UNINOVE

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Comments

- Energy transition: it is not only a need, but also an opportunity
- Electricity produced by using renewable resources is one of the main vectors to support the transition
- Green products market should increase in the next years
- Brazil has a huge potential to fulfill this market (electrical sector is already green and there are resources to be deployed) – we cannot miss this opportunity
- Warning: it is a very slow process!

Comments

- National plan to:
  - ✓ strengthen the electricity sector
  - ✓ electrify the economy
  - ✓ increase the participation of renewables (wind, solar and hydro)
  - ✓ create products for green markets

Thank you

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