

**Course: Global Energy Transitions and Climate Policy**

## **lecture 3 Energy Transitions: Technological Perspectives**

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# The Agenda Today

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## Energy transitions: technological perspectives

- Solar PV as a successful example (?)
- Challenges in energy transitions
- Electric vehicles
- Energy storage systems

## Reflection on the Workshop

- Four stakeholder groups: consumers, government, industry, energy producers
- Four different learning methods: role play, group work, gallery walk, presentation

# Energy Transitions (reminder)

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- Definition of “Energy Transition”: structural changes in the **energy system over time**

Examples:

- Switching between fuels at large scale (renewables instead of fossil fuel)
- Phase-in and phase-out of technologies (phase-in of nuclear in France, wind energy in Denmark, nuclear phase-out in Japan, electric vehicles)
- Changing the energy use pattern (vehicles in 20<sup>th</sup> Century, digitalization)
- At the country level, regional, and global.
- Linked with other changes (transitions) in the society, such as industrialization, human development, etc.
- Happens over time, e.g., over 20-30 years, transition ≠ transformation
- Different aspects: technological, societal, behavioural, political, economic, etc.
- Involves different actors/agents: consumer, producer, regulator, etc.
- Usually difficult: energy path dependency, investment needs, phase-in vs. phase-out

# Energy Transitions: Technological Perspective

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- Condorcet paradox:  $a > b > c > a$ ?  
Renewables vs. nuclear: more stable baseload  
Nuclear vs. coal: less expensive  
Coal vs. renewables: less environmental impact
- Reliability, security of supply
- Economics, affordability
- Availability
- Self-sufficiency, independency



<https://www.setis.europa.eu>

# Solar PV

- Small-scale: household
- Large scale: solar PV farms
- Modular, quick, no water needs, maintenance-free
- Distributed and off-grid generation
- Often peak-demand following
- Economically competitive:

In many places in the world, the cheapest option for new capacity

**Globally 707 GW installed by 2020**

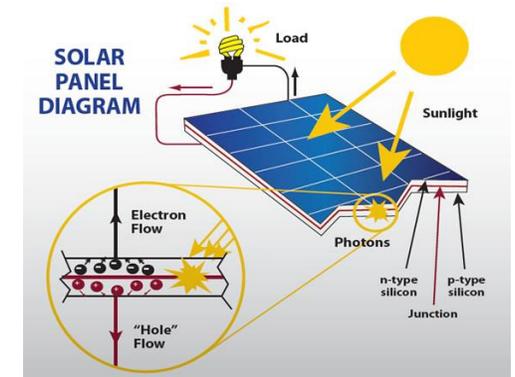
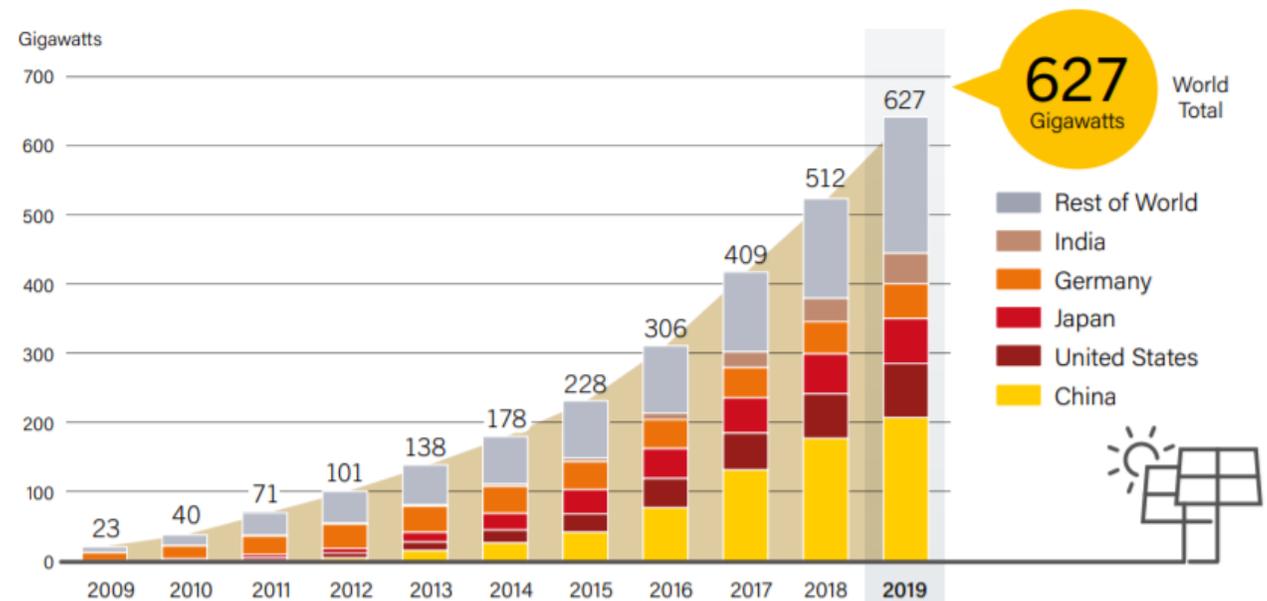


FIGURE 29. Solar PV Global Capacity, by Country and Region, 2009-2019



Images: <http://dosolar.com.au> above and <https://ren21.net>

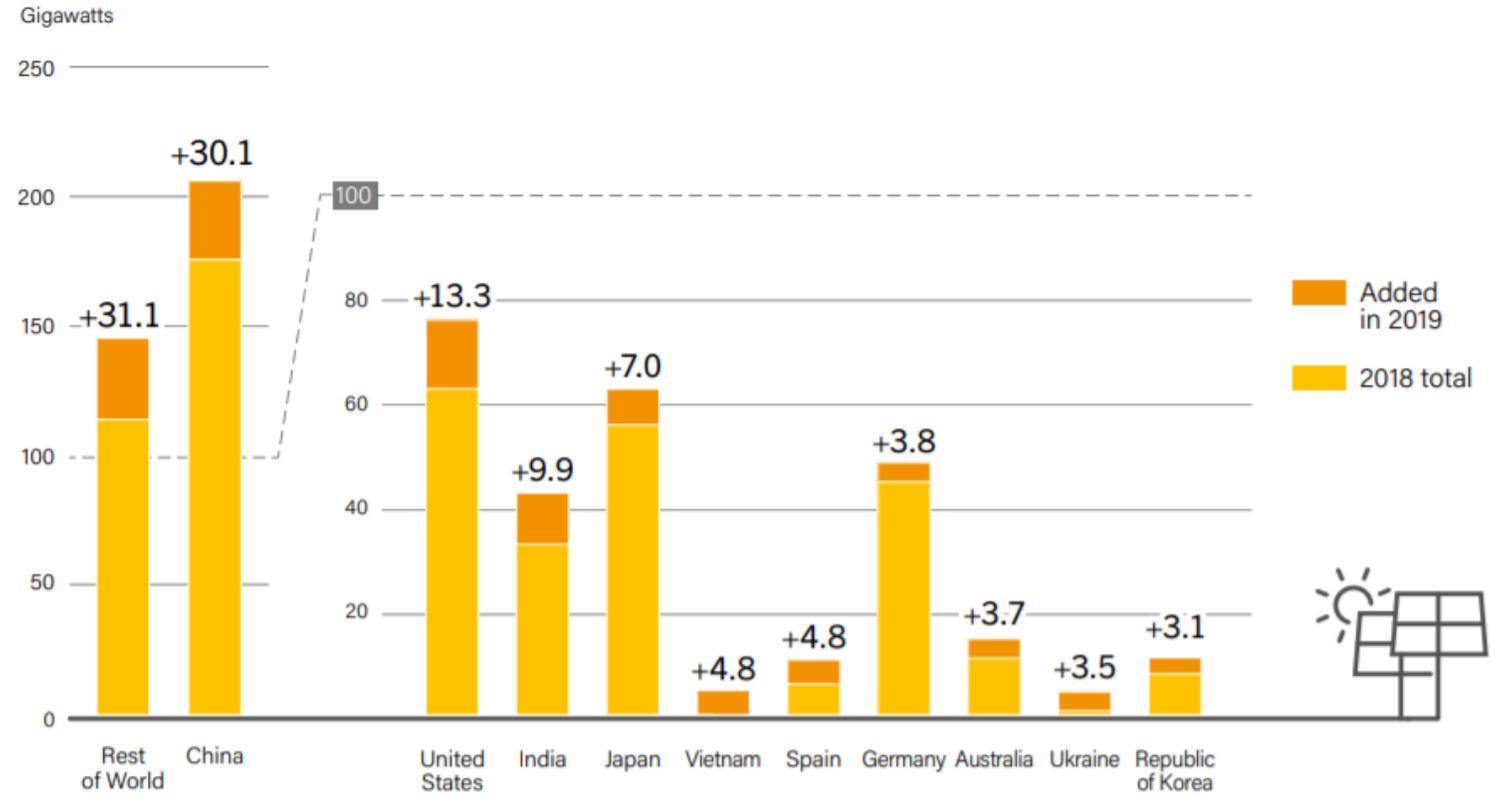
# Solar PV Capacity Additions

- As cheap as 0.014 \$/kWh: a choice also for developing countries

## Rooftop solar PV :

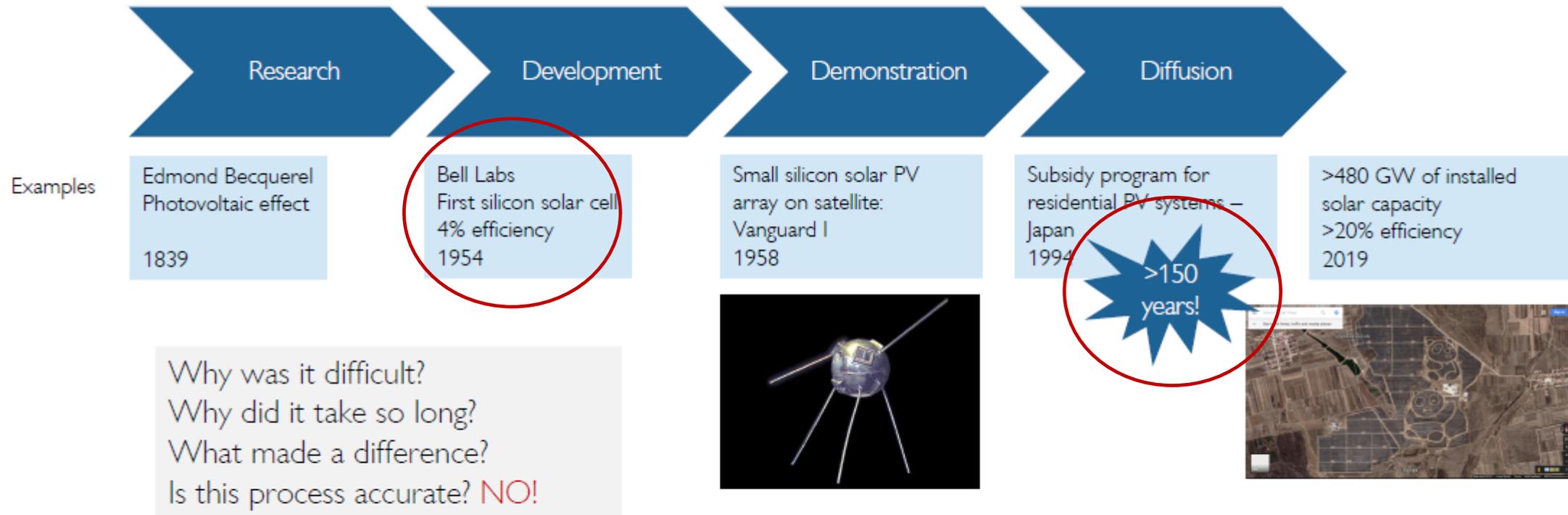
- Grid independence  
(off-grid areas)
- Energy communities  
(decentralized generation)
- Energy democracy  
(competing with utility companies)

FIGURE 30. Solar PV Capacity and Additions, Top 10 Countries for Capacity Added, 2019



# Energy Transitions (example of solar PV)

Solar PV one of the renewable technology with rapid growth in the past decade



DOE – EERE - The History of Solar

[https://www1.eere.energy.gov/solar/pdfs/solar\\_timeline.pdf](https://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf)

Also see: <https://gizmodo.com/60-years-ago-today-bell-labs-unveiled-the-solar-cell-1567543841>

Slide courtesy of Dr. Kavita Saruna

# Rate of Transition in Energy Systems

- Rapid cost decline of solar PV
- But energy innovation is slower than other sectors (Many actors are involved in energy transitions)

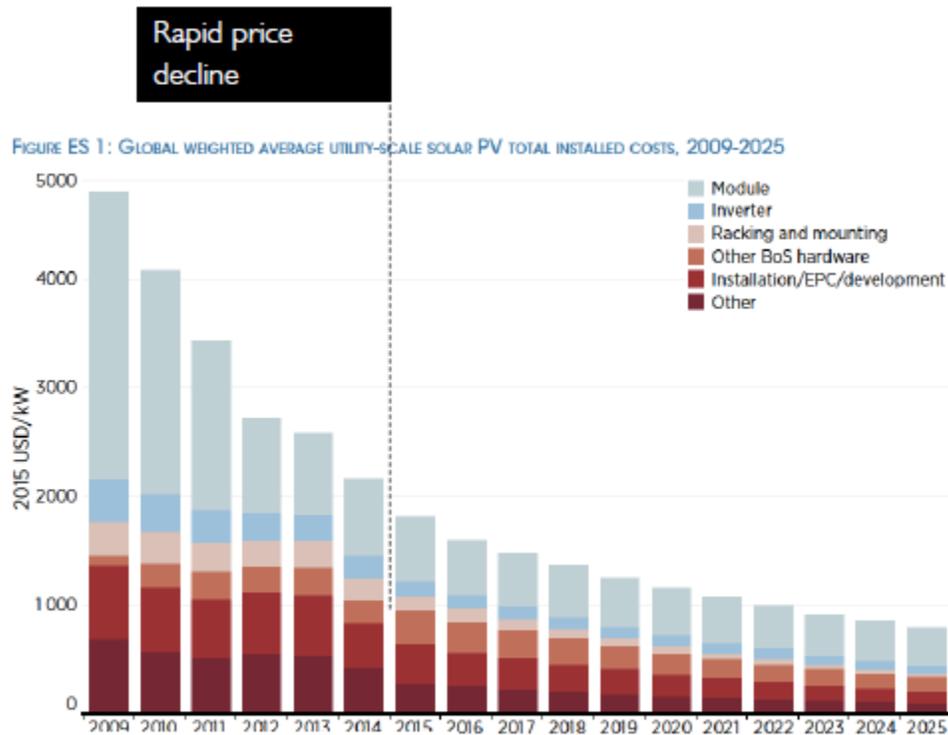
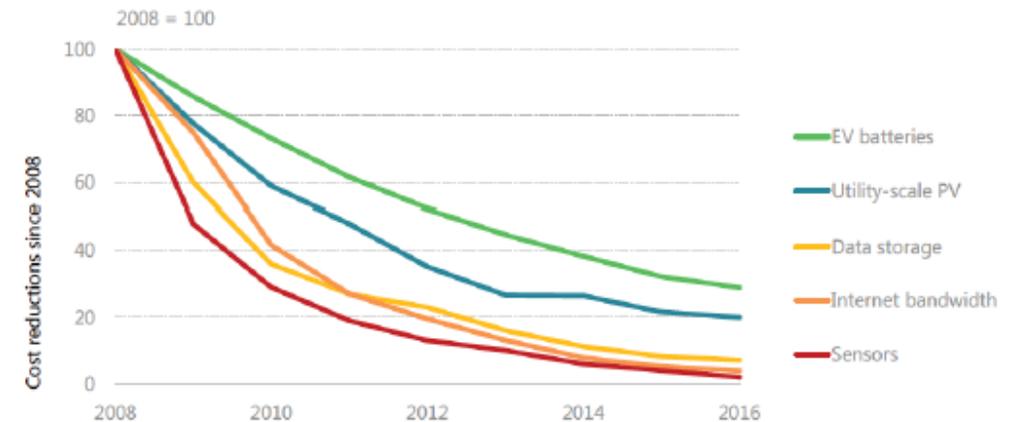


Figure 6. Speed of cost reductions in key energy sector technologies, against those in the digital sector



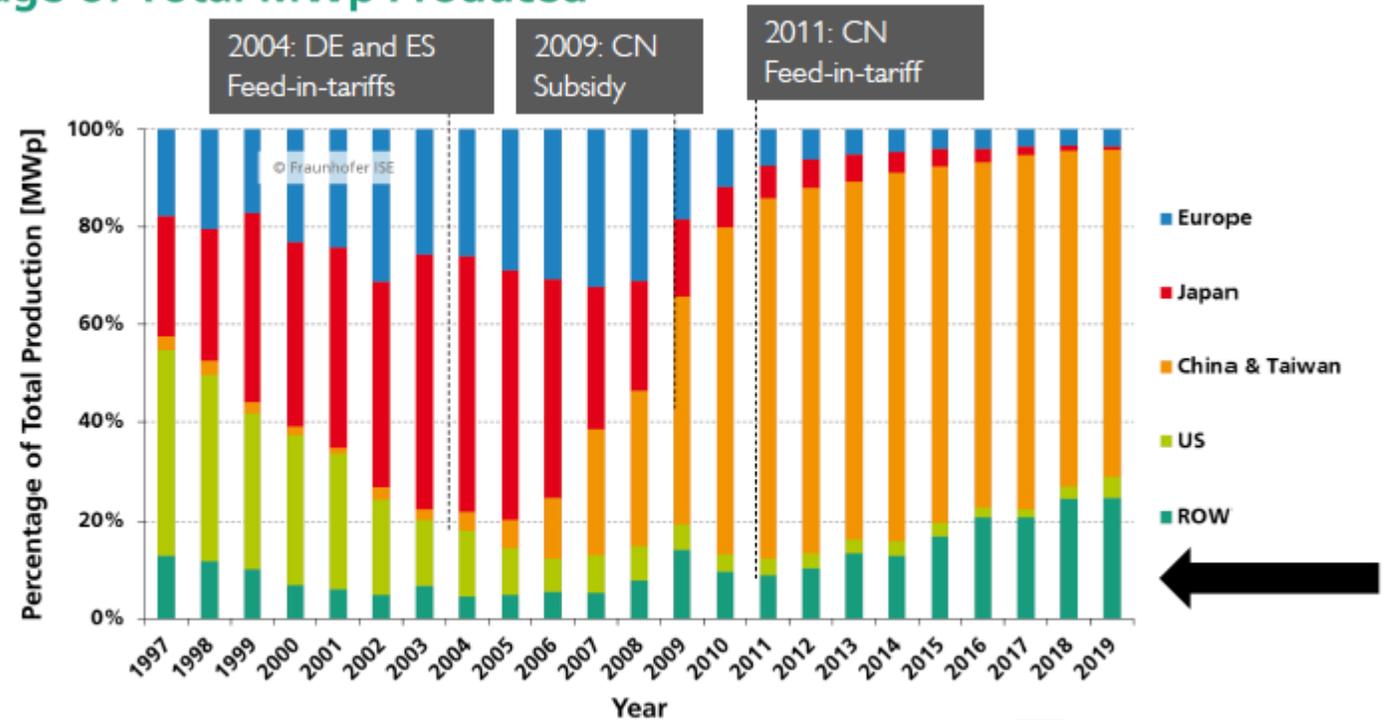
Note: EV = electric vehicle.

Source: Based on BNEF (2017), *Utilities, Smart Thermostats and the Connected Home Opportunity*; Holdowsky et al. (2015), *Inside the Internet of Things*; IEA (2017), *Renewables; Tracking Clean Energy Progress; World Energy Investment*, Navigant Research (2017), *Market Data: Demand response. Global Capacity, Sites, Spending and Revenue Forecasts*.

# Solar PV: Demand and Manufacturing

- Chinese manufacturing initially supplied the EU markets, later domestic market

**PV Module Production by Region 1997-2019**  
Percentage of Total MWp Produced



Data: Up to 2009: Navigant Consulting; since 2010: IHS Markit. Graph: PSE Projects GmbH 2020



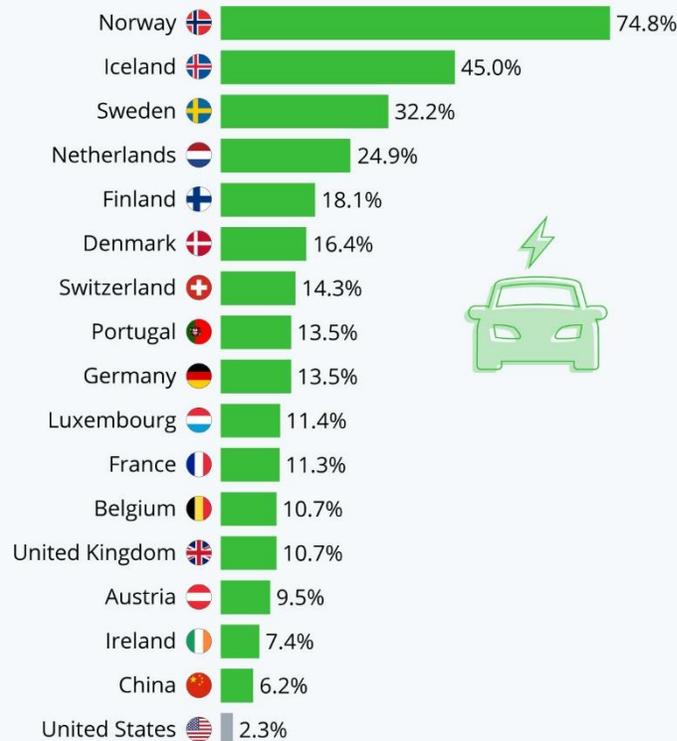
- Economies of scale
- Incentives for installation
- Incentives for manufacturing
- Learning by doing

# Electric Vehicles: 2021 a breakout year

- While light vehicles sold 4.6% more in 2021, EV sales grew by 108% from 2020
- 17% of new vehicles sold in EU are EVs
- China overtook EU in EV sales in 2021, with 3.4 million cars (~ triple growth from 1.2 m cars in 2020)
- EV sales in China alone more than the rest of the world

## Electric Mobility: Europe Races Ahead

Countries with the highest share of plug-in electric vehicles in new passenger car sales in 2020\*



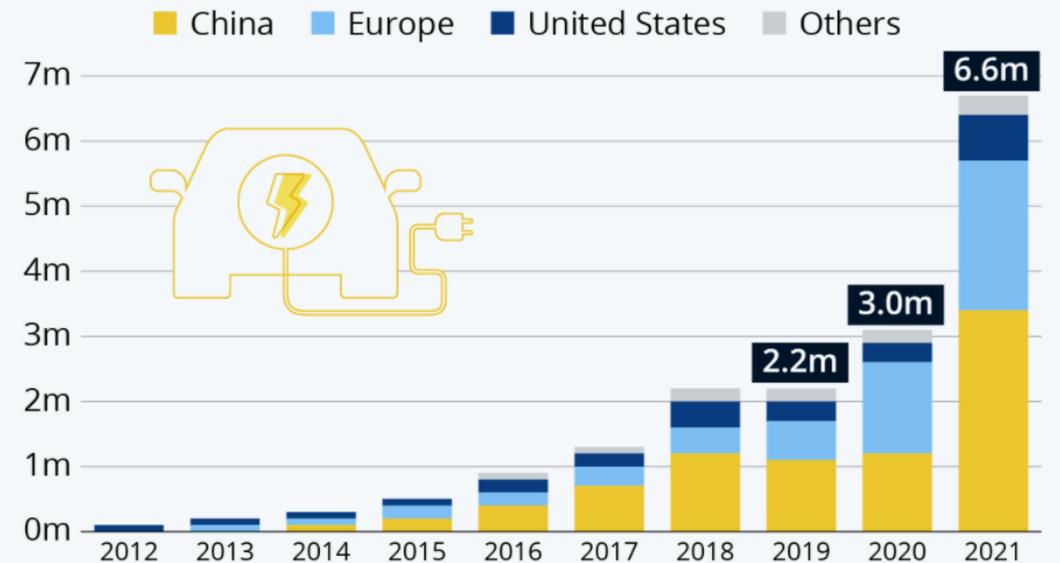
\* including plug-in hybrids and light vehicles, excluding commercial vehicles  
Sources: ACEA, CAAM, EV-Volumes



statista

## Global Electric Car Sales Doubled in 2021

Global registrations of electric vehicles (incl. plug-in hybrids), by region\*



\* incl. passenger cars and light commercial vehicles (vans, light trucks)

Source: EV-volumes.com via IEA



statista

# EV's Battery Supply Chain: Dominated by China

## Raw material:

- Australia and Chile (Li) >75% of Lithium, Congo (DRC) >50% of cobalt, China 65% of Graphite
- 70% of the cobalt mining sector in Congo is dominated by Chinese companies

## Chemical Refining:

- Chinese refineries supplied 85% of the world's battery-ready cobalt in 2020

## Battery cells:

- China manufactures >83% of anode and >60% of cathode globally

## Battery pack:

- China 75% of Li-ion batteries globally

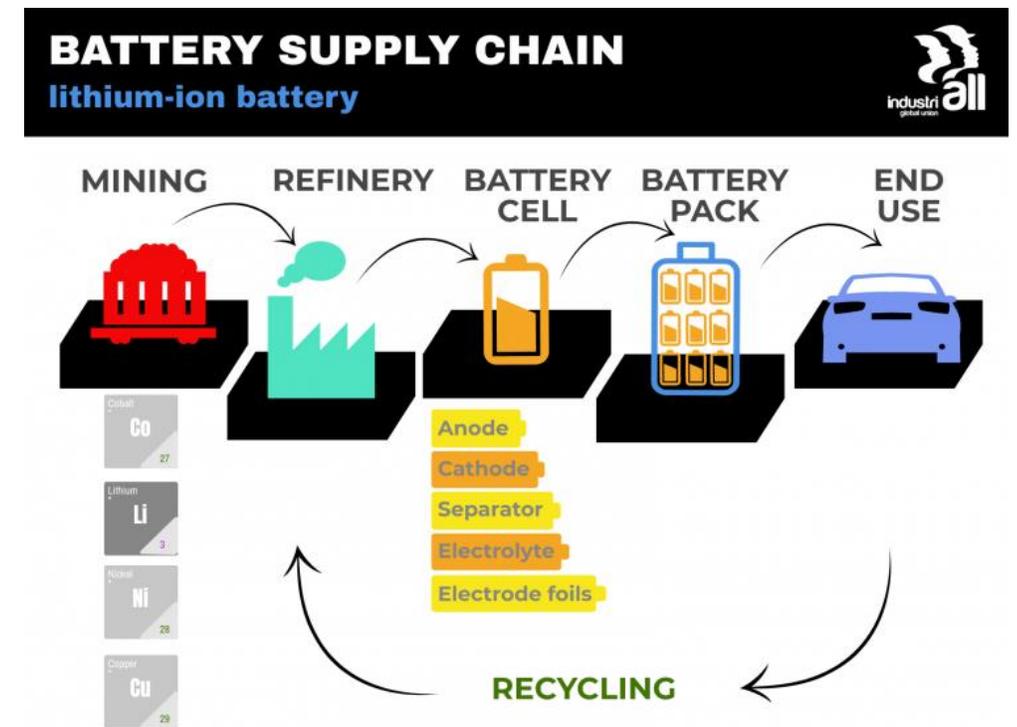


Image: <https://www.industriall-union.org/>

# EV's Battery Supply Chain: Outlook

- EU has plans to increase its share in battery manufacturing
- Market share of China will decline yet dominant
- Human rights in small-scale mining in Congo



Image: <https://www.mining.com/>

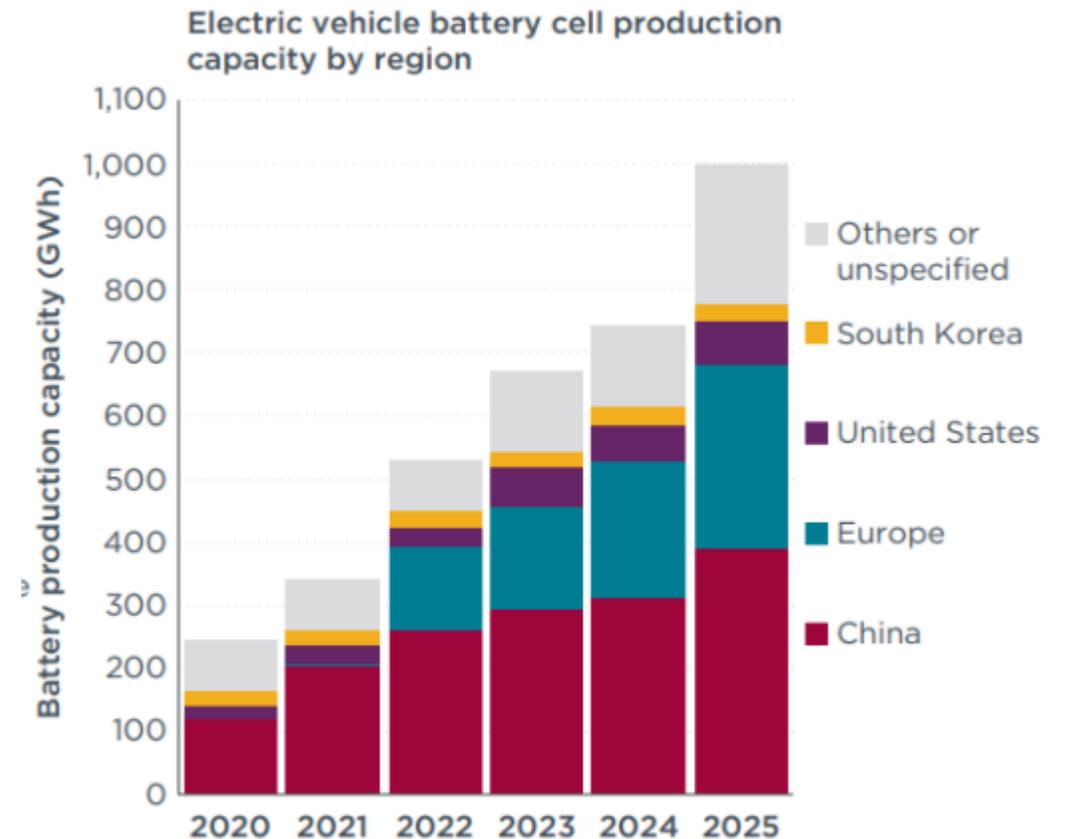


Image: <https://www.atlasevhub.com/>

# Technological Challenges in Energy Transitions

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## *Why was the innovation process (for solar PV) difficult?*

- **New technologies** are imperfect: High performance / novel ability to do a task but expensive, e.g., solar vs. coal power generation
- **Niche markets** initially needed with less price sensitive customers (e.g., for satellites, solar calculators, off-grid and rural electrification)
- Over **time**, established end-use markets with users/ consumers residential, utilities, others
- **Technology lock-in** or path dependency (difficult to replace others)
- Dominant technological regime establishes interrelated technologies, business models, etc. that new technologies may need to displace (e.g., coal power plants, fossil fuel-based infrastructures, past investments)

# Question

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*How is technological change related to your stakeholder role? How can you have an impact on it or how will you be affected by that?*

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- Thank you for your attention!