ESMAP
Energy Sector Management Assistance Program

The Economics of Clean Hydrogen Mobility for Road Transportation

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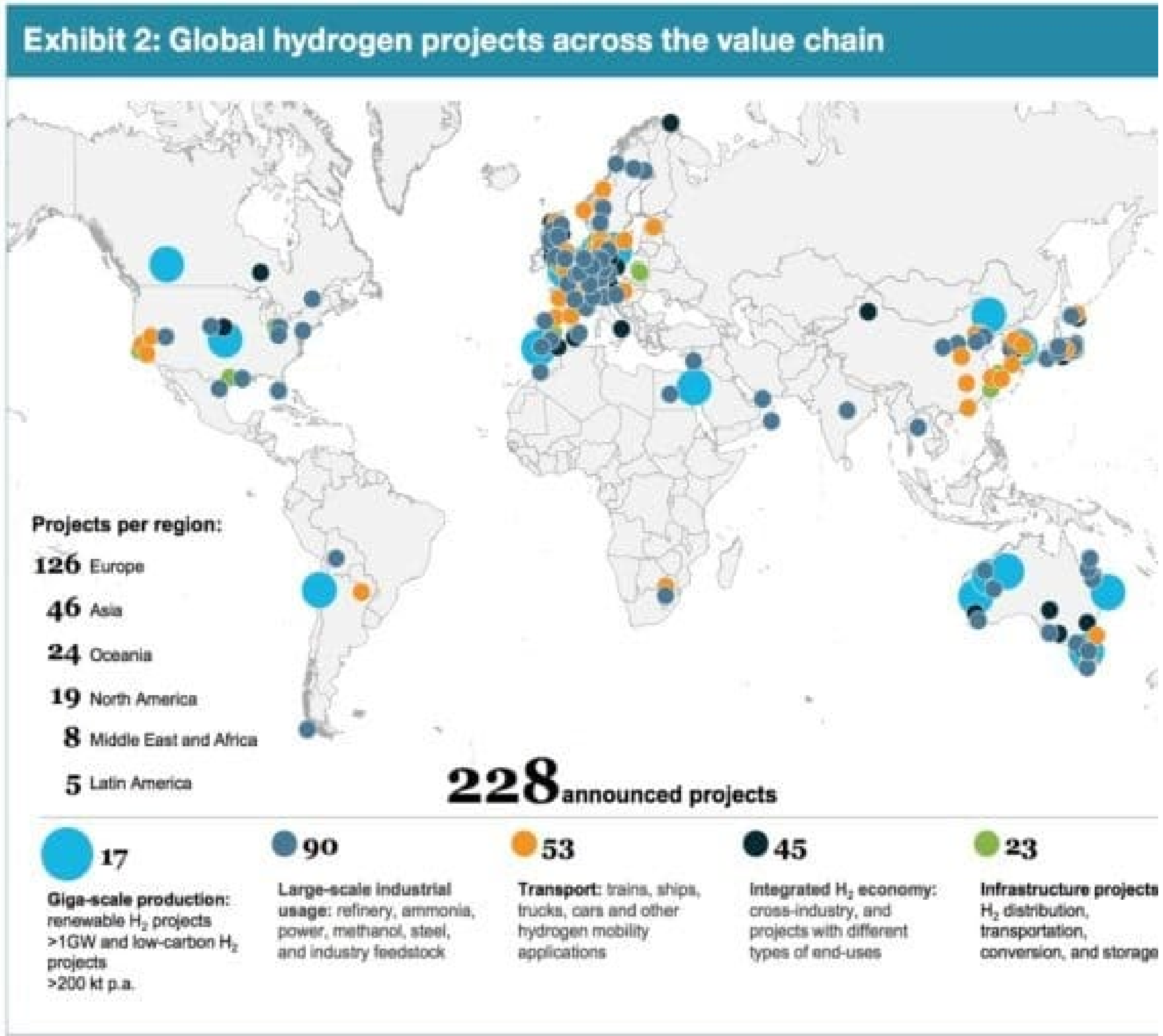
Clean Hydrogen is an essential component for Green Energy Transition

Hydrogen- an alternative to fossil fuel, has zero or low emission from production and tailpipe.

- Enhance energy security by reducing reliance on imported fossil fuels.
- Improve local air quality.
- Decarbonizing hard-to-abate sectors (steel, cement, chemicals)
- Drive economic growth and job creation for countries with abundant renewable energy resources through green hydrogen production, while for those with natural gas reserves through blue hydrogen production.

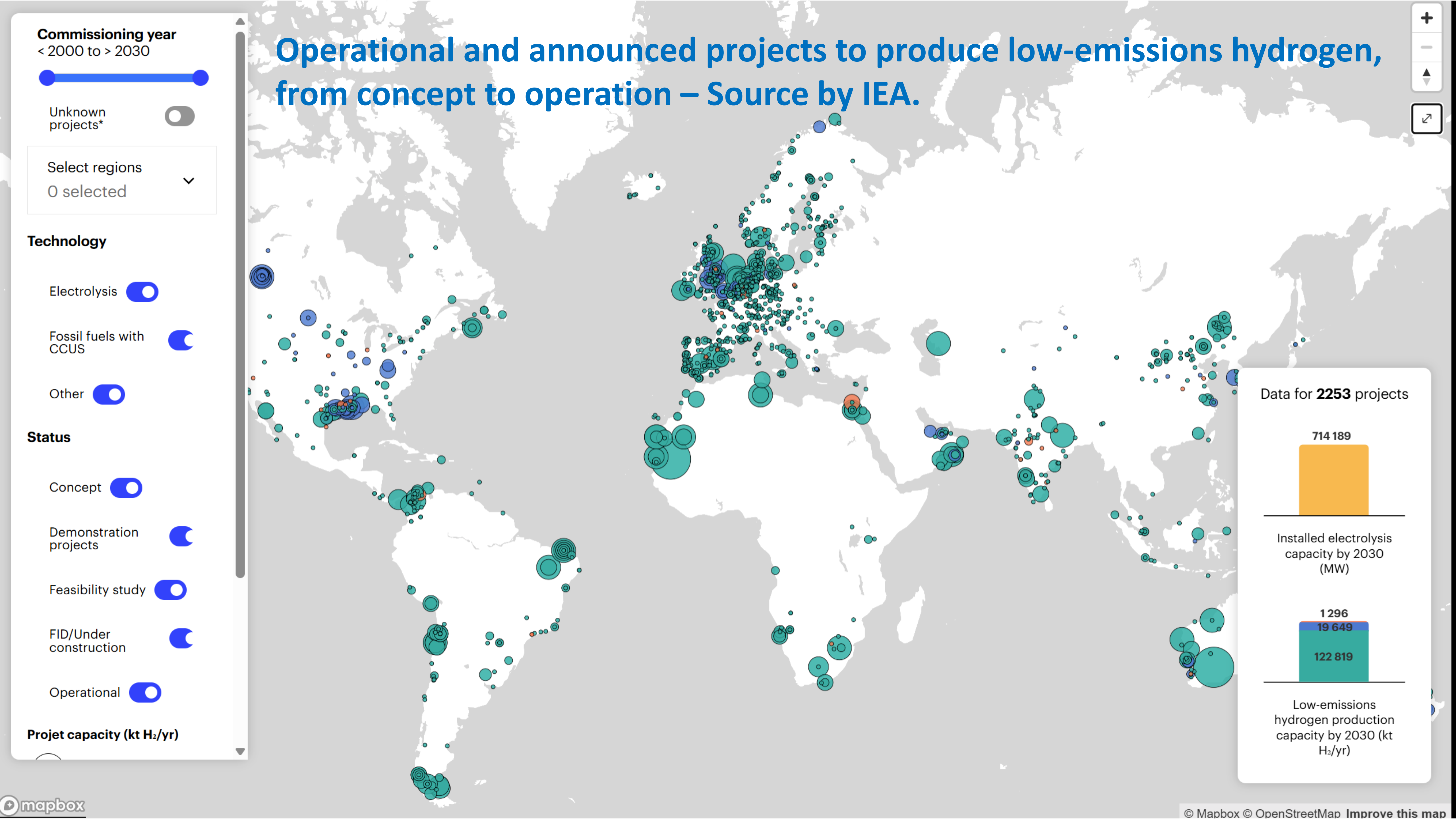
30+ countries announced commitment to clean hydrogen development

Global hydrogen project pipeline expected to exceed $300 billion by 2030

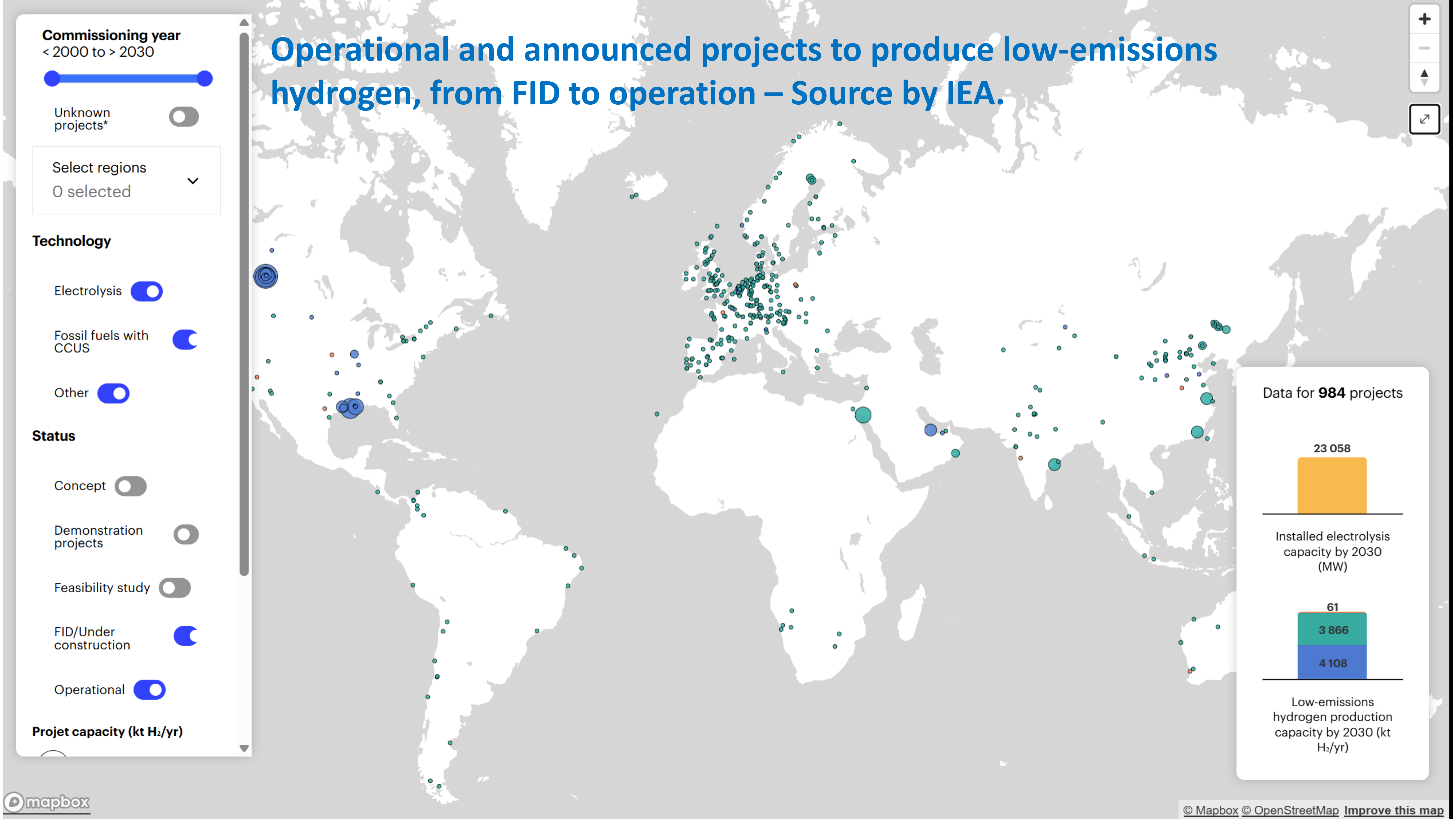


Source: Hydrogen Council and McKinsey, 2021

Operational and announced projects to produce low-emissions hydrogen, from concept to operation – Source by IEA.



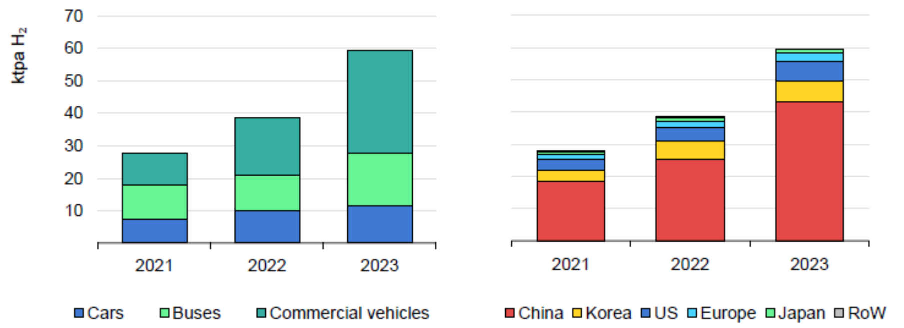
Operational and announced projects to produce low-emissions hydrogen, from FID to operation – Source by IEA.



Hydrogen in Transport

- Shipping: in short-sea shipping and ferries, replacing traditional bunker fuels.
- Aviation: short-haul flights and as a feedstock for sustainable aviation fuel.
- Rail: in non-electrified rail networks.
- Road: 60 kilotons in 2023 – an increased 55% over previous year but remain small fraction of total demand– driven mainly by heavy duty **trucks and buses**.

Figure 2.8 Hydrogen consumption in road transport by vehicle segment and region, 2021-2023



IEA. CC BY 4.0.

Notes: RoW = Rest of World; US = United States. Commercial vehicles include light commercial vehicles and medium- and heavy-duty trucks. Assumptions on annual mileage and fuel economy come from the IEA Global Energy and Climate Model.

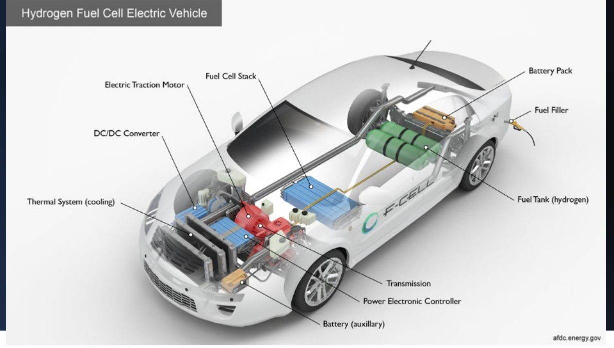
Hydrogen use in road transport increased by around 55% in 2023, with heavy-duty vehicles accounting for almost 85% of this growth.

Hydrogen Fueling Station

Hydrogen Bus

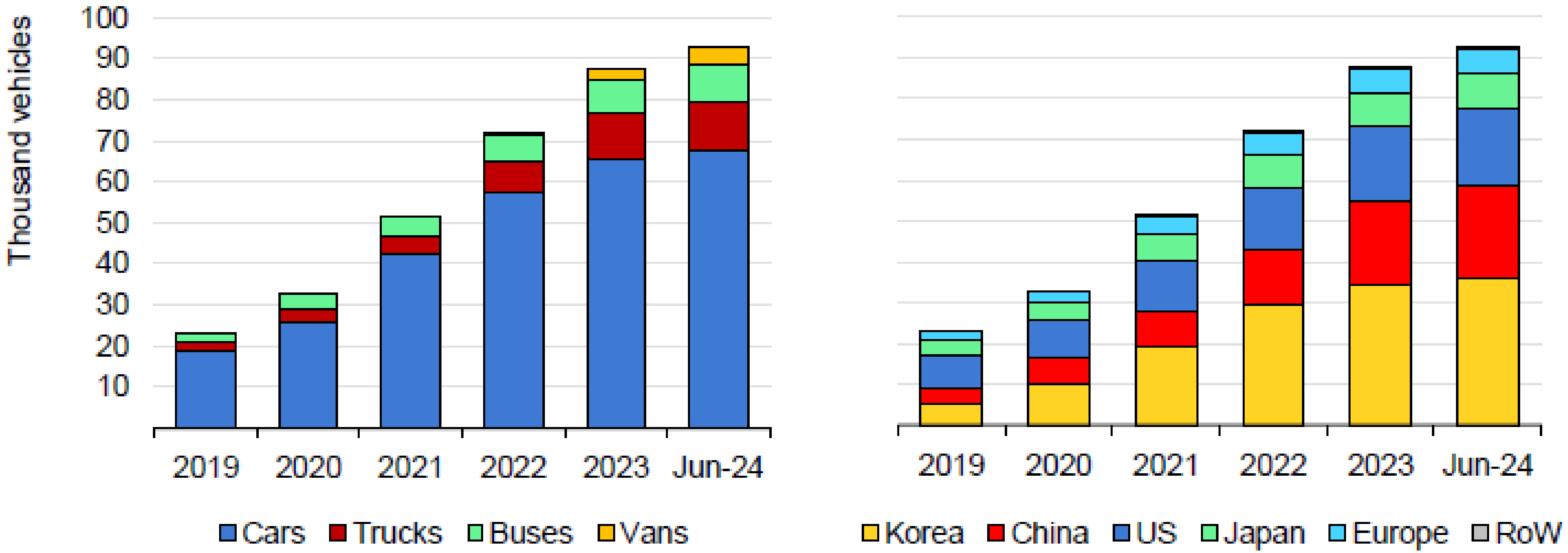
Forklifts for material handling

Fuel Cell Electric Vehicle (FCEV)



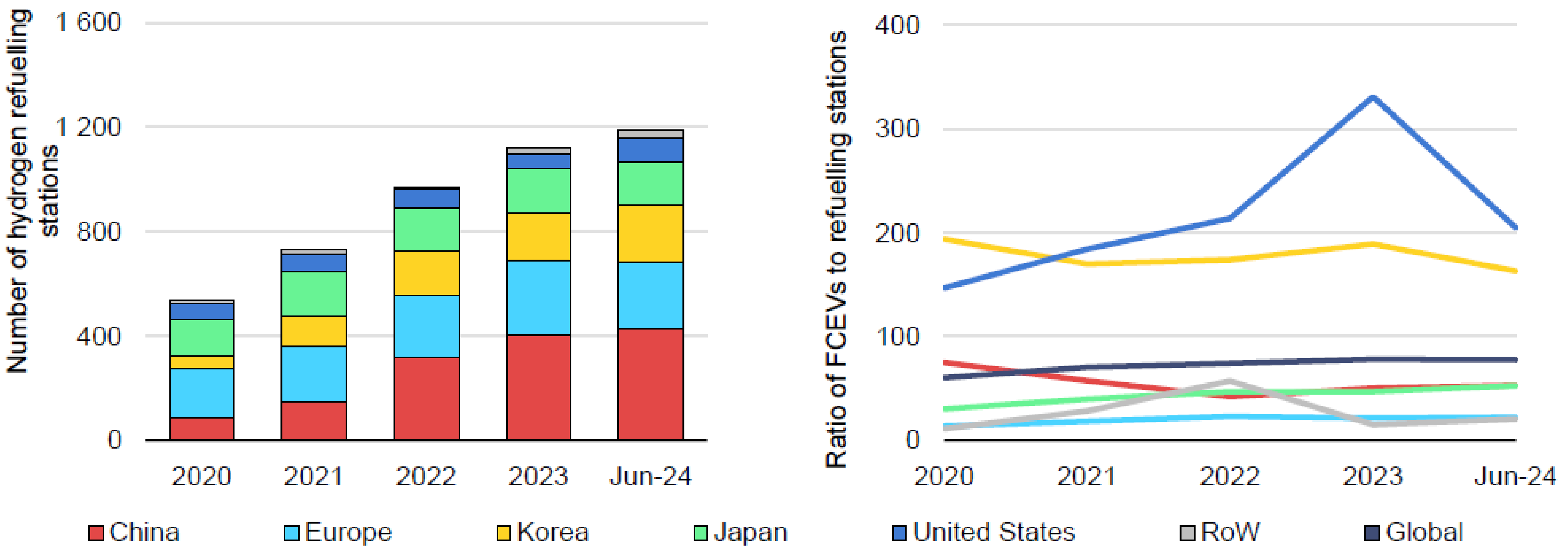
- FCEVs use on-board fuel-cell stacks to convert hydrogen to electricity to power the vehicle motors.
- By 2024, global FCEVs stock is at **93,000**, compared to **40 Million** BEVs on road.(Source: **IEA**)

Figure 2.9 Fuel cell electric vehicle stock by segment and region, 2019-2024



Global stock of Hydrogen Refueling Stations increased in 2023, driven by growth in China and Europe

Figure 2.11 Hydrogen refuelling stations by region and ratio of fuel cell electric vehicles to refuelling stations, 2020-2024



Notes: FCEV = fuel cell electric vehicle; RoW = rest of world. The number of hydrogen refuelling stations refers to both public (retail) and private stations. 2024 includes data until June 2024.

Sources: IEA analysis based on data from Advanced Fuel Cells Technology Collaboration Programme, H2stations.org by LBST, International Partnership for Hydrogen and Fuel Cells in the Economy and Clean Energy Ministerial Hydrogen Initiative country surveys.

Is hydrogen vehicle a relevant solution for the developing countries?

- Hydrogen powered vehicles are expensive: do they make economic sense for developing countries?
- Which categories of FCEV are the most relevant for developing countries?
- Does hydrogen-mobility make sense environmentally if blue hydrogen is used?
- How important are local environment benefits verses global ones?
- What are the investment needs if FCEV is adopted as one of the mobility solutions?

Study Scope and Methodology – country specific economic assessment

- The economic case of ZEVs depends on various country-specific factors: energy sources and prices, fleet composition, vehicle price, and valuation of environmental benefits of local air pollutant and CO2 reduction.
- For the first time, we undertakes a detailed economic analysis of the adoption of FCEVs across major passenger and freight vehicle segments in five countries: Brazil, Chile, India, South Africa, and Korea, based on a scoping tool.
- Two policy scenarios: BAU, “30 by 30”
- Three types of powertrains: ICE, BEV and FCEV.
- Four vehicle segments: cars, LCVs, buses, and HDVs.
- Key cost components: vehicle capital, fuel, maintenance, refueling/charging infrastructure, and environmental benefits from carbon emission and local air pollutants reduction, over the vehicle lifetime under different policy scenarios.

Highlights from research findings

Key Cost Drivers:

(1) vehicle capital costs

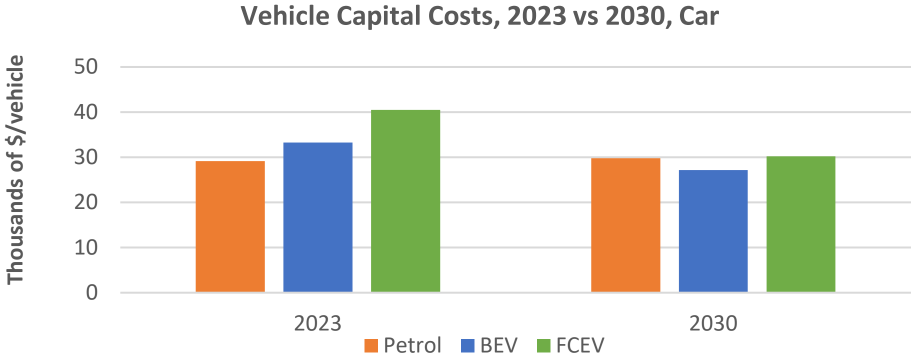
(2) fuel costs

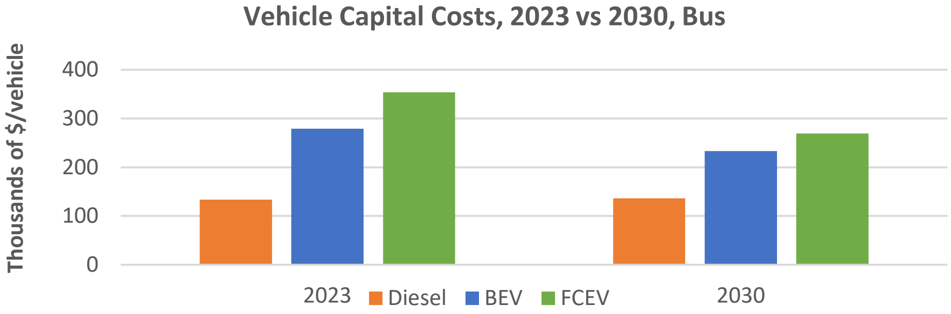
(3) environment benefits

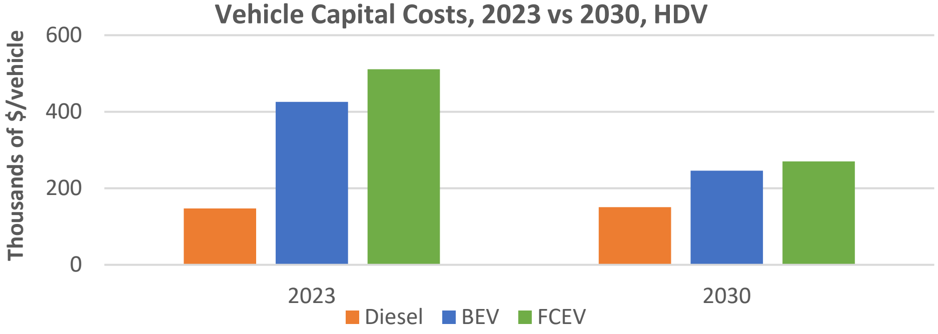
1. FCEVs currently face high costs, primarily due to the expensive hydrogen fuel and elevated vehicle capital costs.
2. FCEV buses and HDVs could emerge as viable clean fuel alternatives to ICE vehicles by 2030, in densely populated countries (India and Korea) – higher environment benefits to offset the cost disadvantages.
3. BEVs outperform FCEVs economically in all vehicle segment across all country studies.
4. FCEVs have some operational advantages not captured in economic analysis but can enable their use in niche markets, especially for bus and HDV.

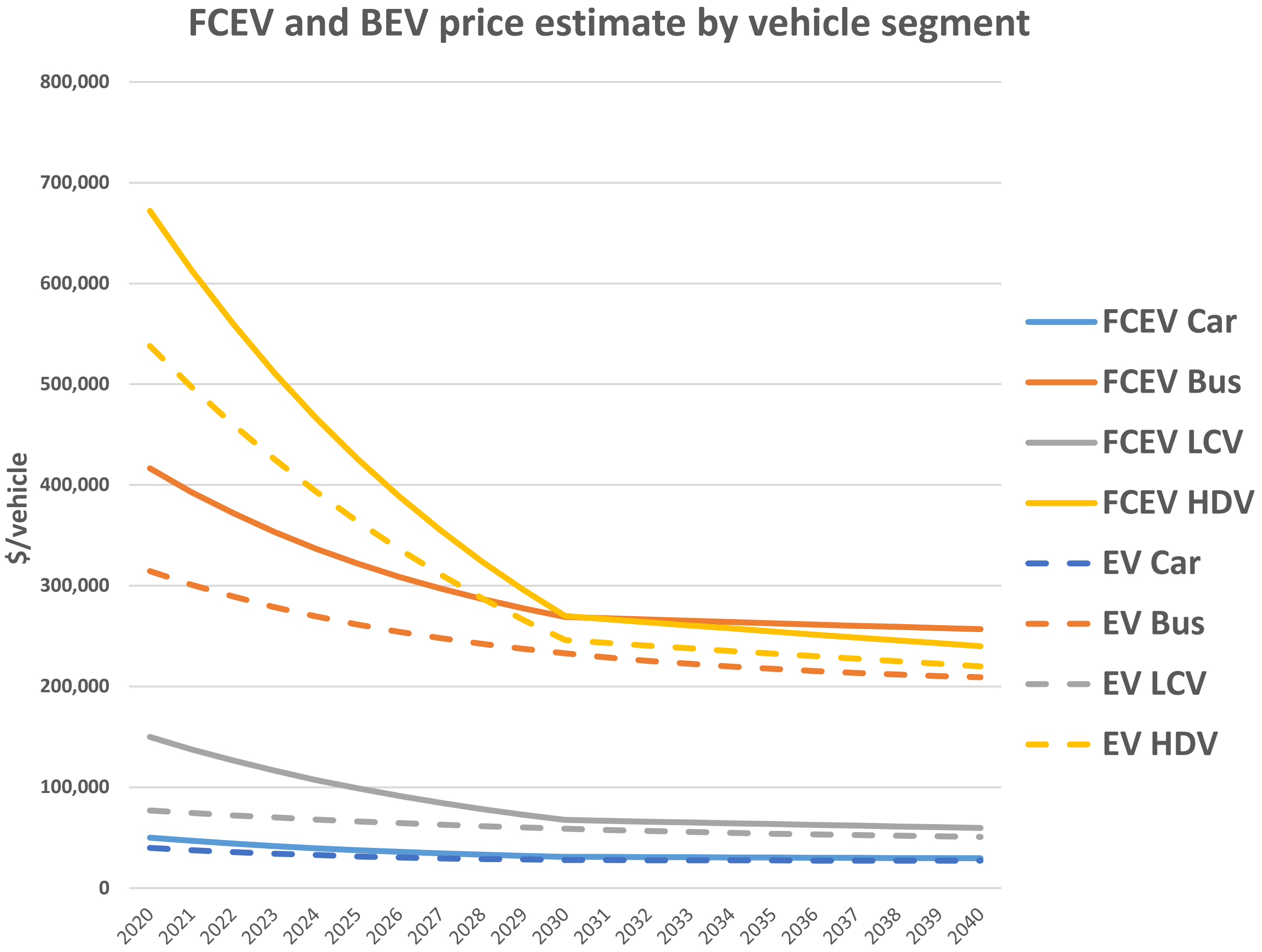
1. Vehicle Capital Cost

FCEV capital cost premium is substantial, but gradually declining; BEVs have a lower capital cost than FCEVs



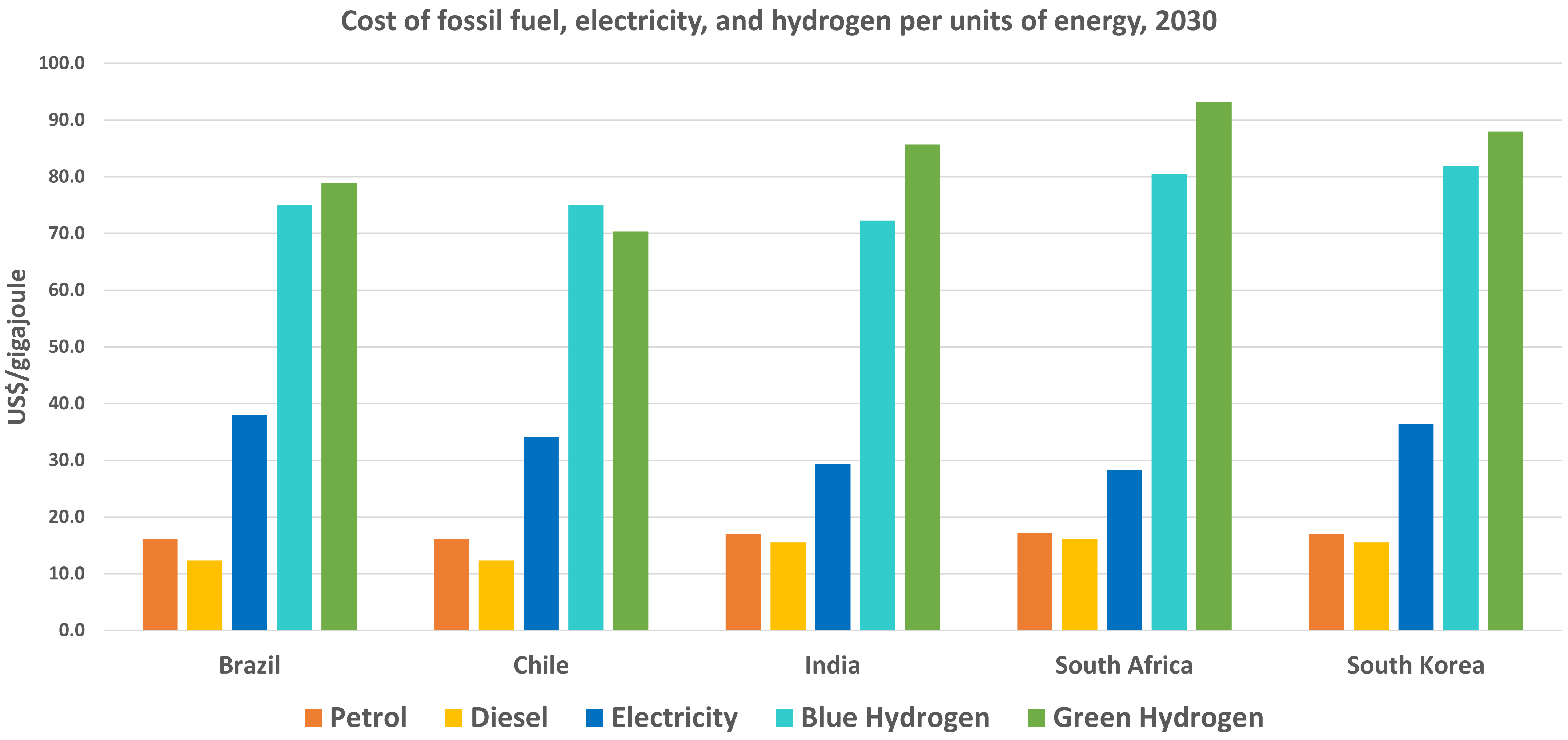






2. Vehicle Fuel Cost

Clean hydrogen as a fuel is expensive compared to fossil fuels and electricity, on per unit of energy basis - 4 times compared to fossil fuel and 2 times over electricity

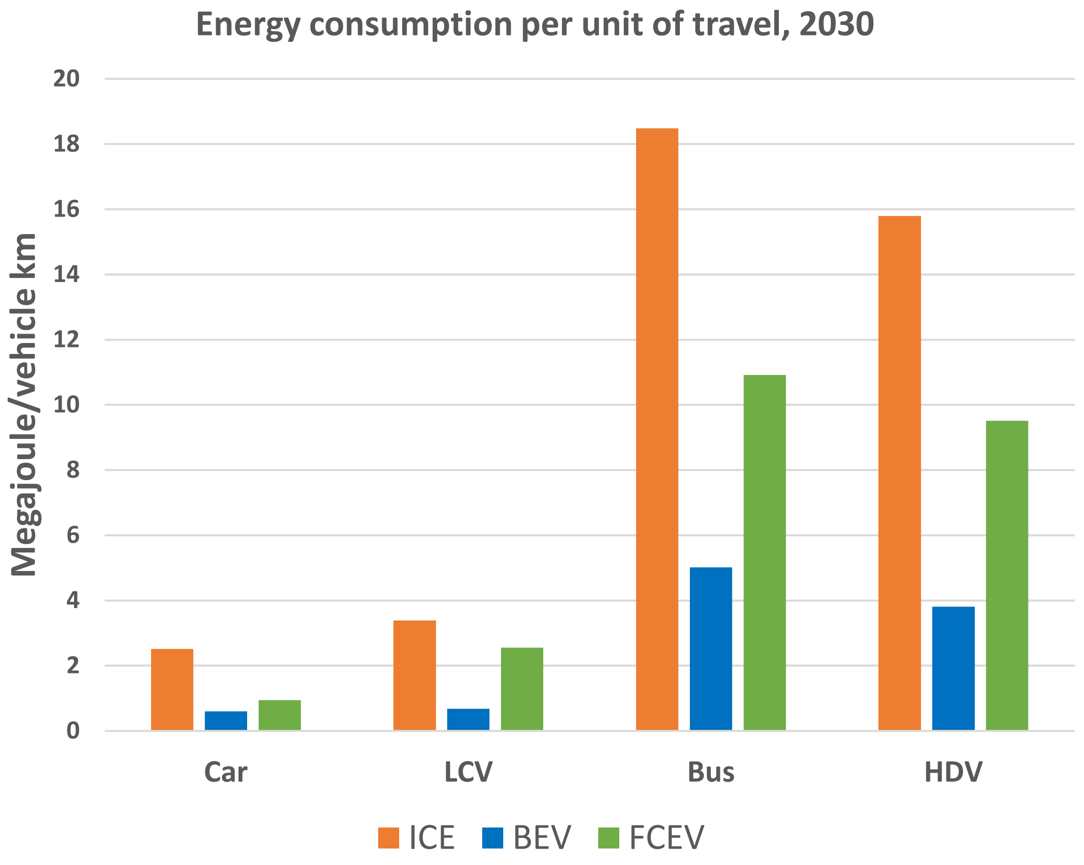


3. Vehicle Energy Efficiency

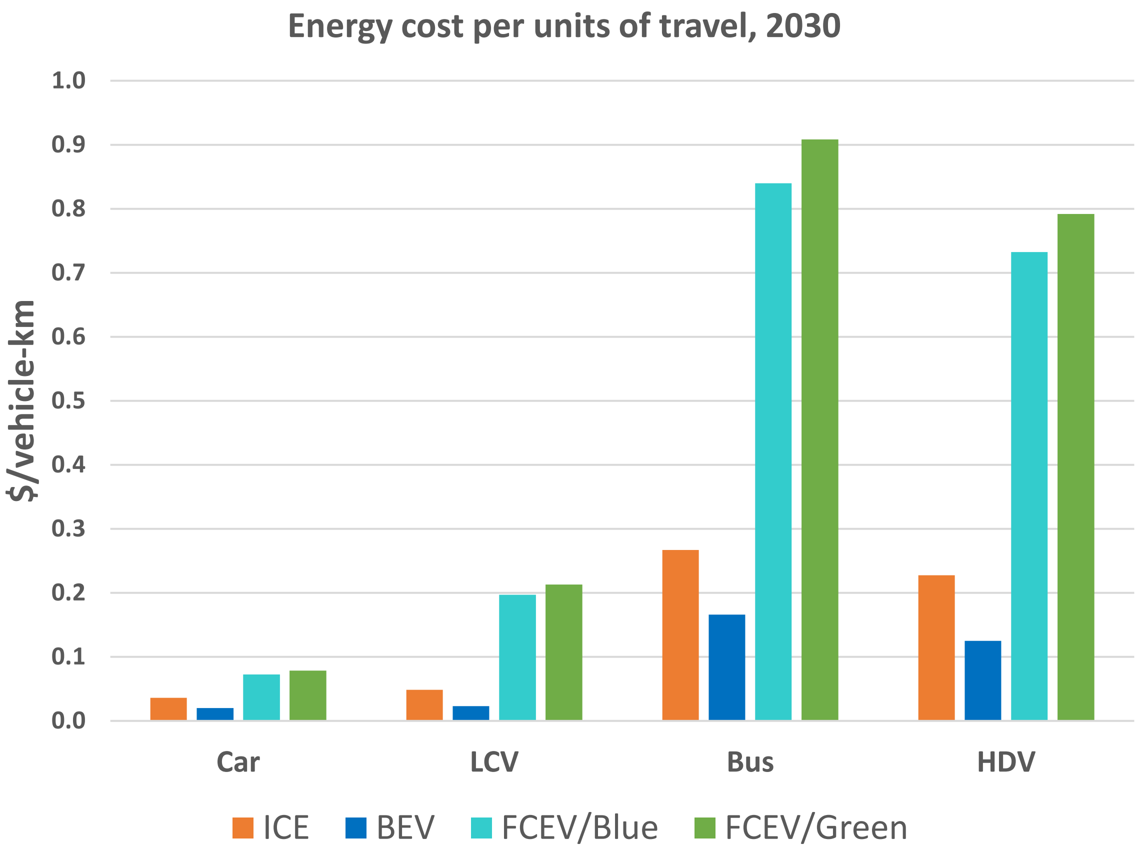
FCEVs are more energy efficient than ICEs (heat loss), but less efficient than BEVs

- Energy loss from converting hydrogen to electricity to power the motor
- FCEVs clean fuel cost can be 4 times higher than ICEs, 8 times higher than BEVs

Energy **consumption** ***per km traveled basis***

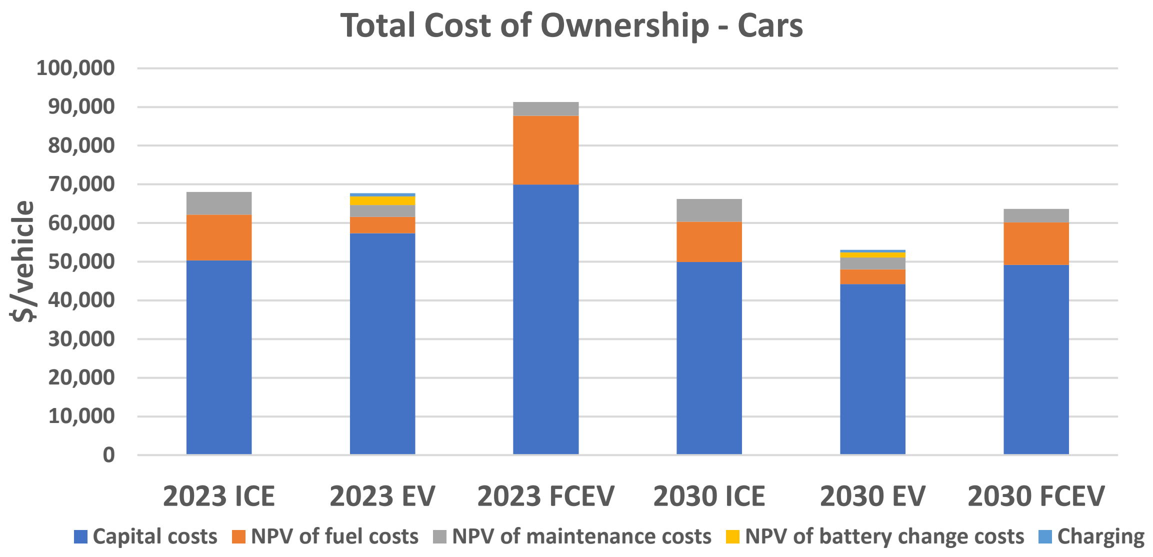


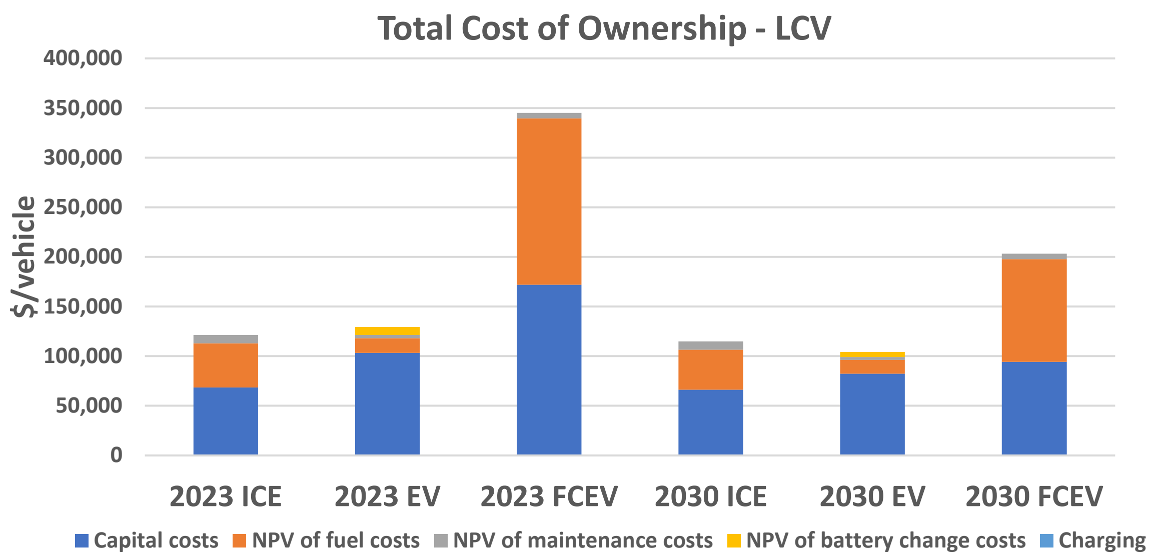
Energy **cost** ***per km traveled basis***

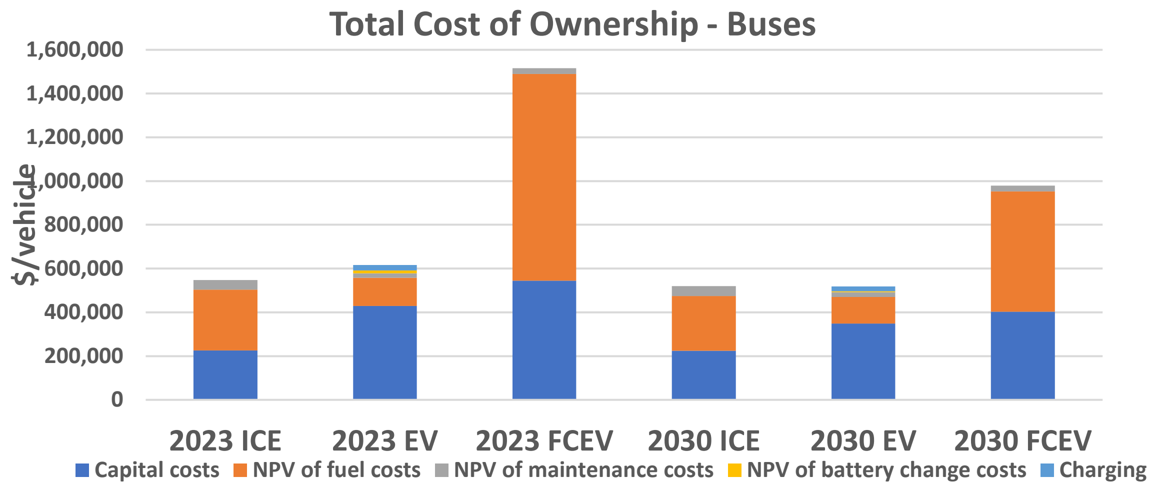


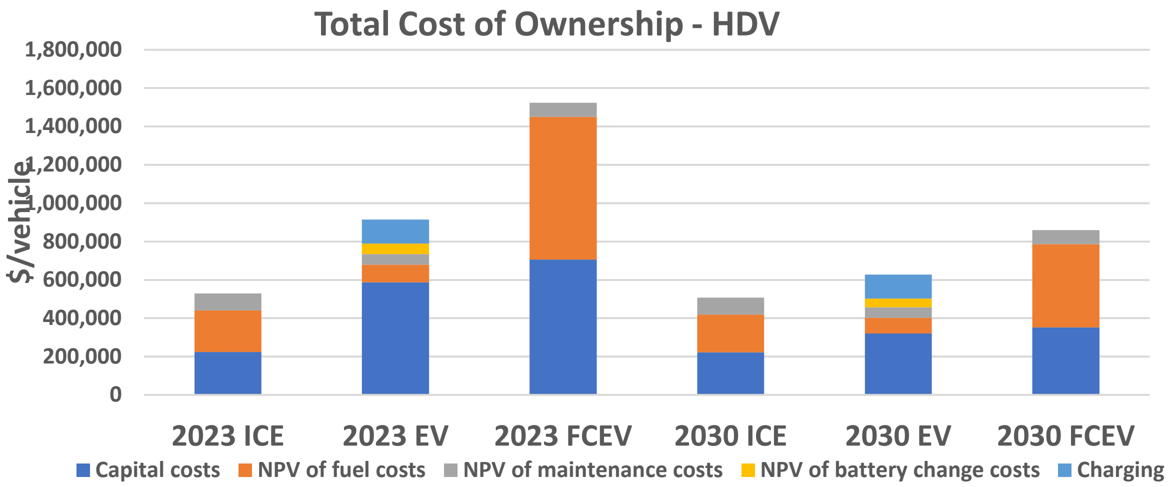
4. Total Cost of Ownership (TCO)

FCEVs TCO remain higher than ICEs and BEVs by 2030, but gap is narrowing







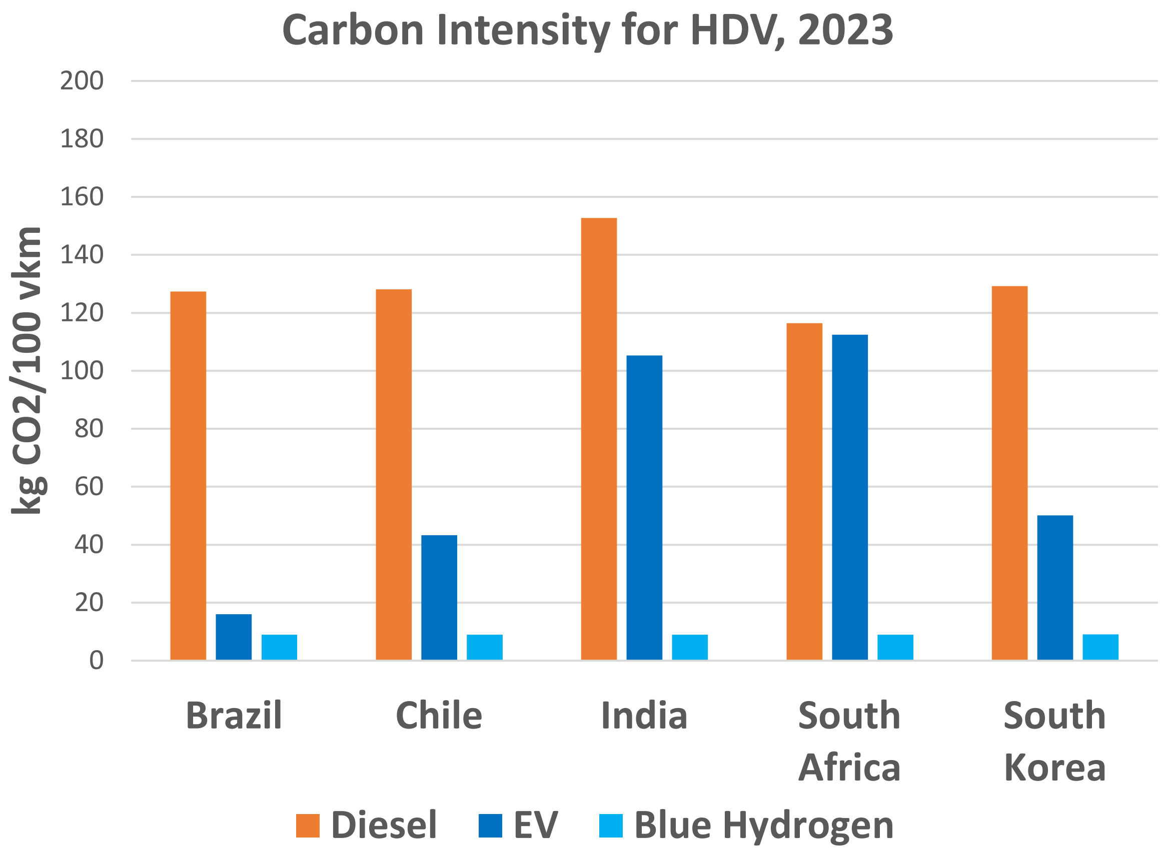


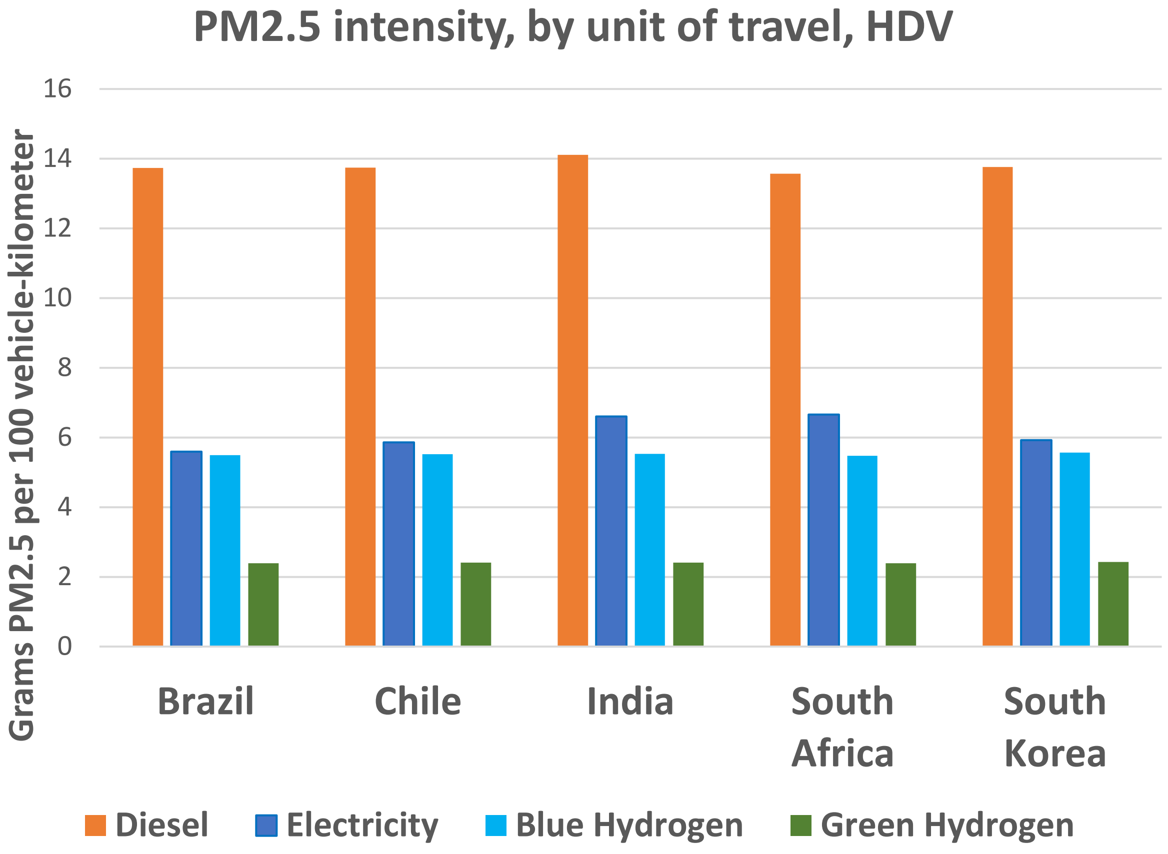
5. Environmental benefits–improve air quality and reduce carbon emission

--Less emission than ICE and BEV (gap narrows if power grid shifts to more renewables)

CO_2: zero emission from tailpipe (both FCEV&BEV)
Production: zero emission for green hydrogen using renewables, low emission for blue hydrogen using natural gas with CCS

Local air pollutants (PM2.5, NOx, SOx):
Mainly from energy production process for FCEV and BEVs



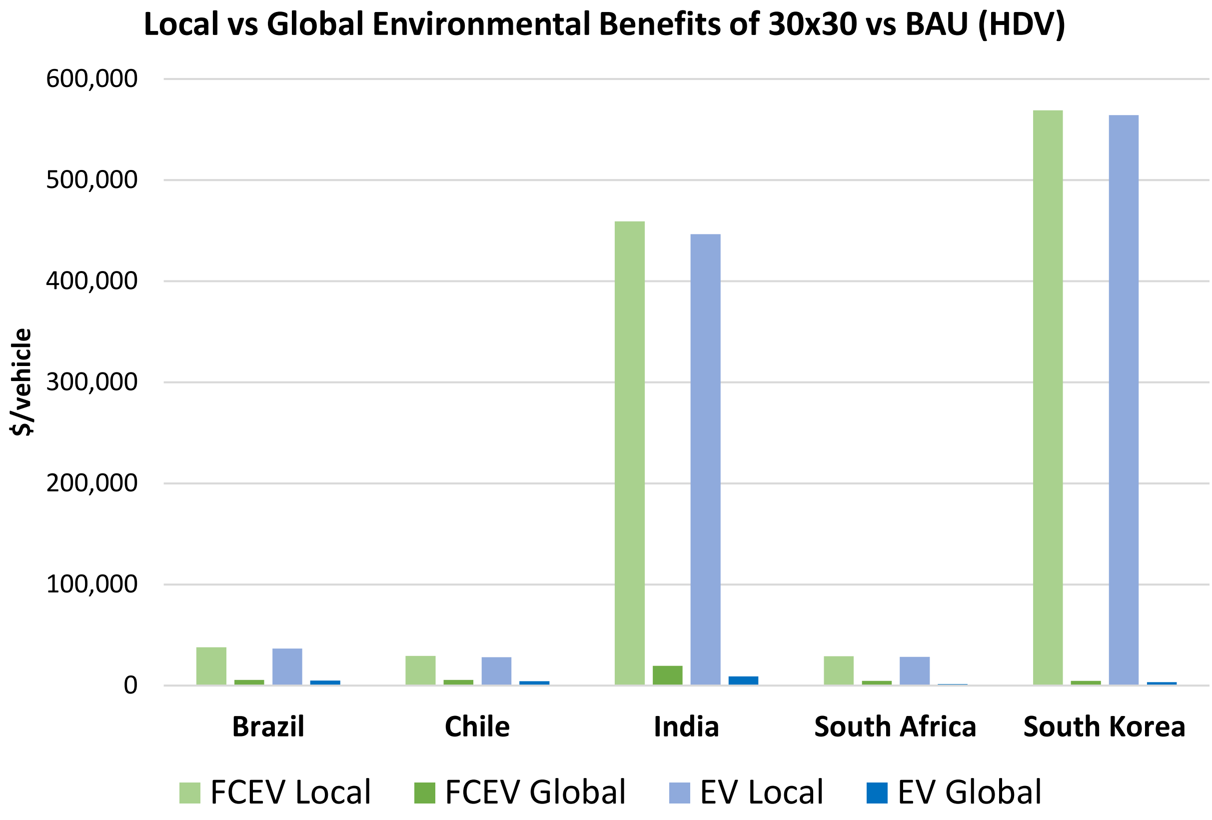


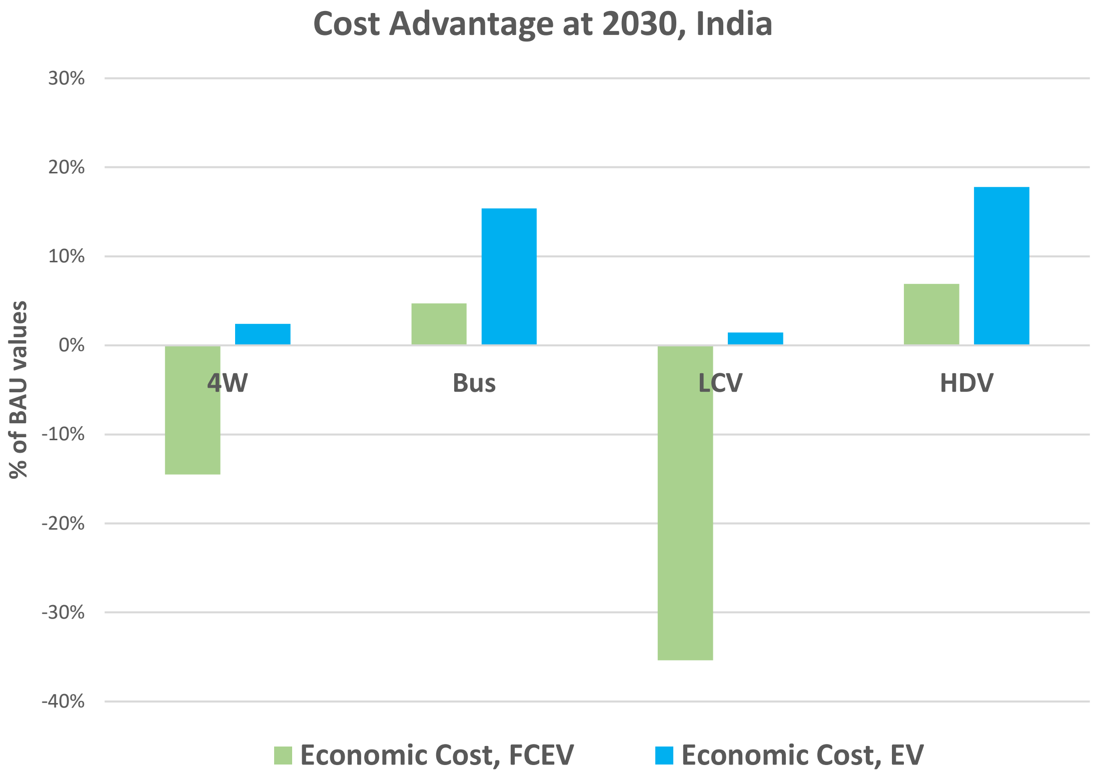
6. Aggregated Cost Advantage

Environment benefits can outweigh cost premium in some cases in bus and HDV segment in favor of FCEV compared to ICEs.

FCEVs reduce local air pollutants (PM2.5, NOx, and SOx). Significant benefits in countries with densely populated urban areas where economic value of air quality improvement is substantial.

FCEV show cost advantage in the bus and HDV segment in India, while BEVs outperform FCEVs economically across all vehicle segments





7. FCEVs offer distinct operational advantages that could make them competitive in certain niche markets

FCEV operational advantages not reflected in economic analysis

- **Longer driving range** - typically 300-350 miles compared to 175-200 miles for BEV buses - due to hydrogen's higher energy density per unit of weight.
- **Faster refueling** - refueled in just 5-15 minutes, compared to several hours for BEV charging - more suitable for operations requiring minimal downtime.
- **Lighter weights higher payload** - hydrogen storage tanks are generally lighter (2 tons) than large battery packs in HDV trucks - higher cargo payloads and reduced road wear.

FCEVs as a viable alternative in niche markets where BEVs face limitations

- **Hilly region -** FCEVs can sustain peak power output over longer distances, whereas BEV experience significant range losses on steep grades.
- **Cold weather -** impacts BEVs more severely, with range reductions of up to 37.8% in temperatures between 22-32°F, compared to 23.1% for FCEVs.
- **Logistics and high-utilization fleet operations -** requiring continuous, long-hour operation with minimal downtime.

Recommendations

- Promote a Clean Hydrogen Economy for **Energy Security and Job Creation.**
- Integrate Clean Hydrogen Pilot Projects into the Green Energy Transition, prioritizing **Hard-to-Abate sectors**.
- Target FCEV Deployment in **High-Impact Niche Markets** driven by its operational advantages.
- Develop Enabling **Policies and Regulations** for a Clean Hydrogen Economy.
- Adopt a Coherent Strategy for **Hydrogen Mobility in the Green Energy Transition**.
- Conducting **Country-specific Economic Assessments** for hydrogen mobility to guide investment and policy decision.

Thank You !

Albert Schweitzer:

"I am looking at the future with concern, but with good hope."

Like many transitions, while the trajectory is uncertain, the ultimate destination is clear.