

# On Electrons and Molecules

Lux Research's short vision on the future of energy and chemicals

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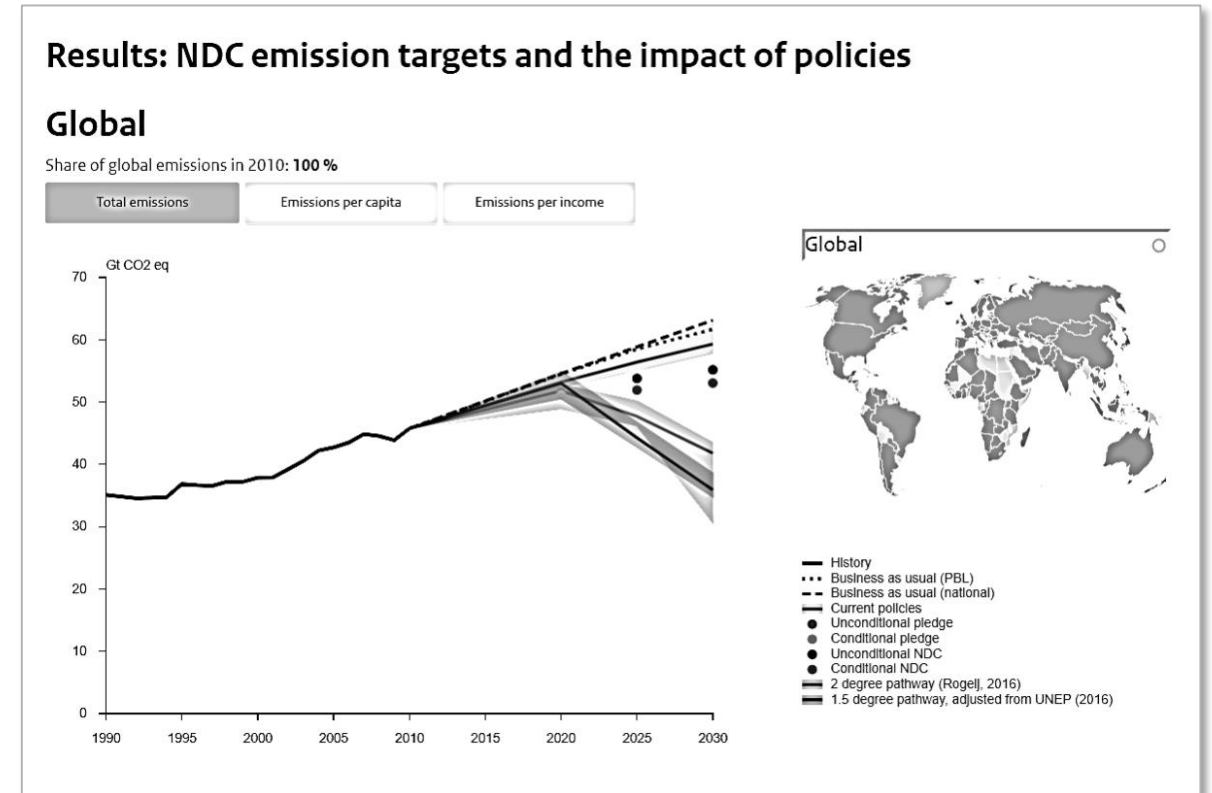
# As NDC's of COP-21 materialize, the roadmap takes shape

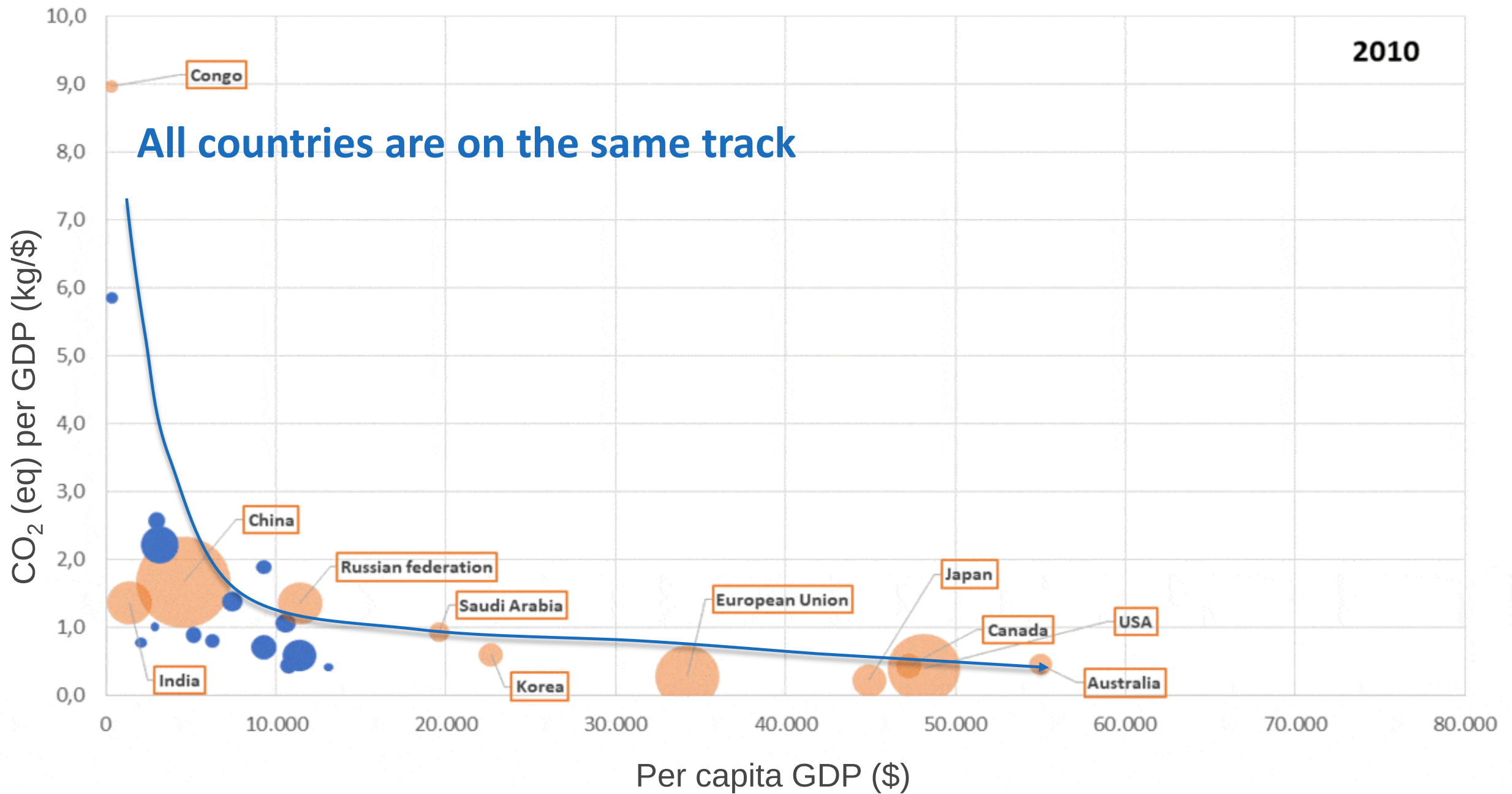
## How COP-21 works

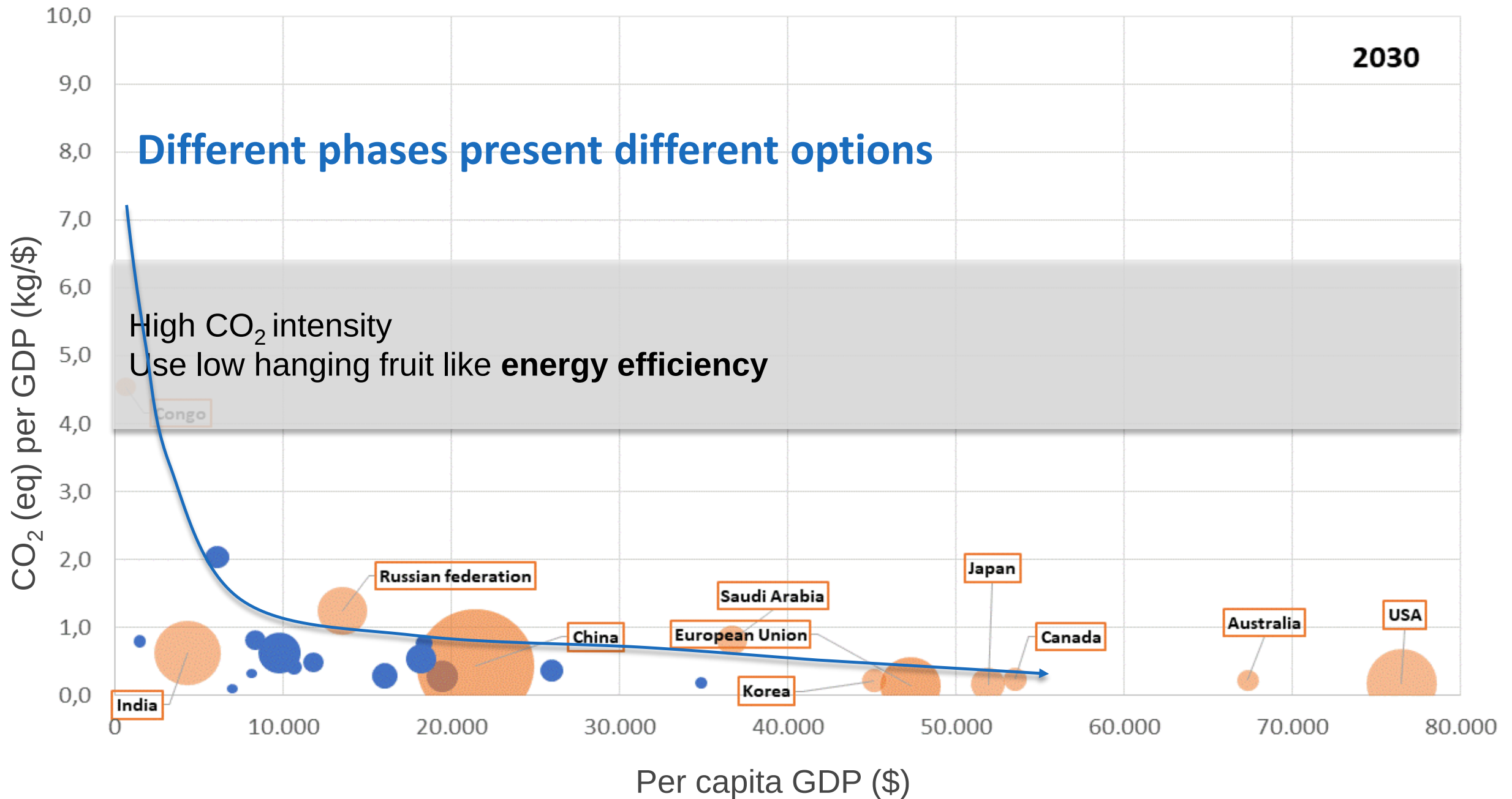
- Countries need to submit plans
- NDC: **N**ationally **D**efined **C**ontribution
- Most plans are in now, at least until 2030
- Acceleration will need to happen post 2030

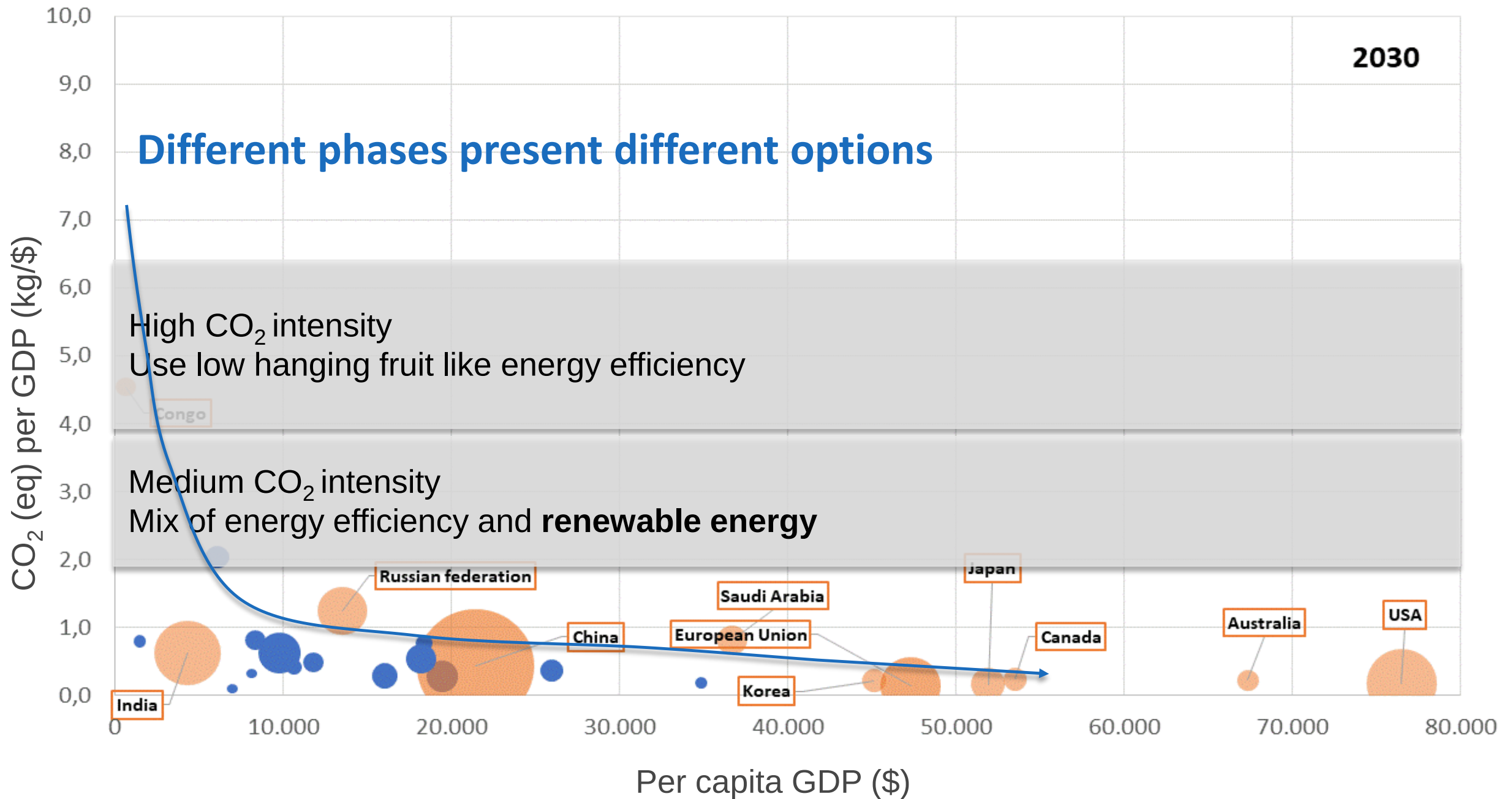
Take a look yourself, these people keep track:

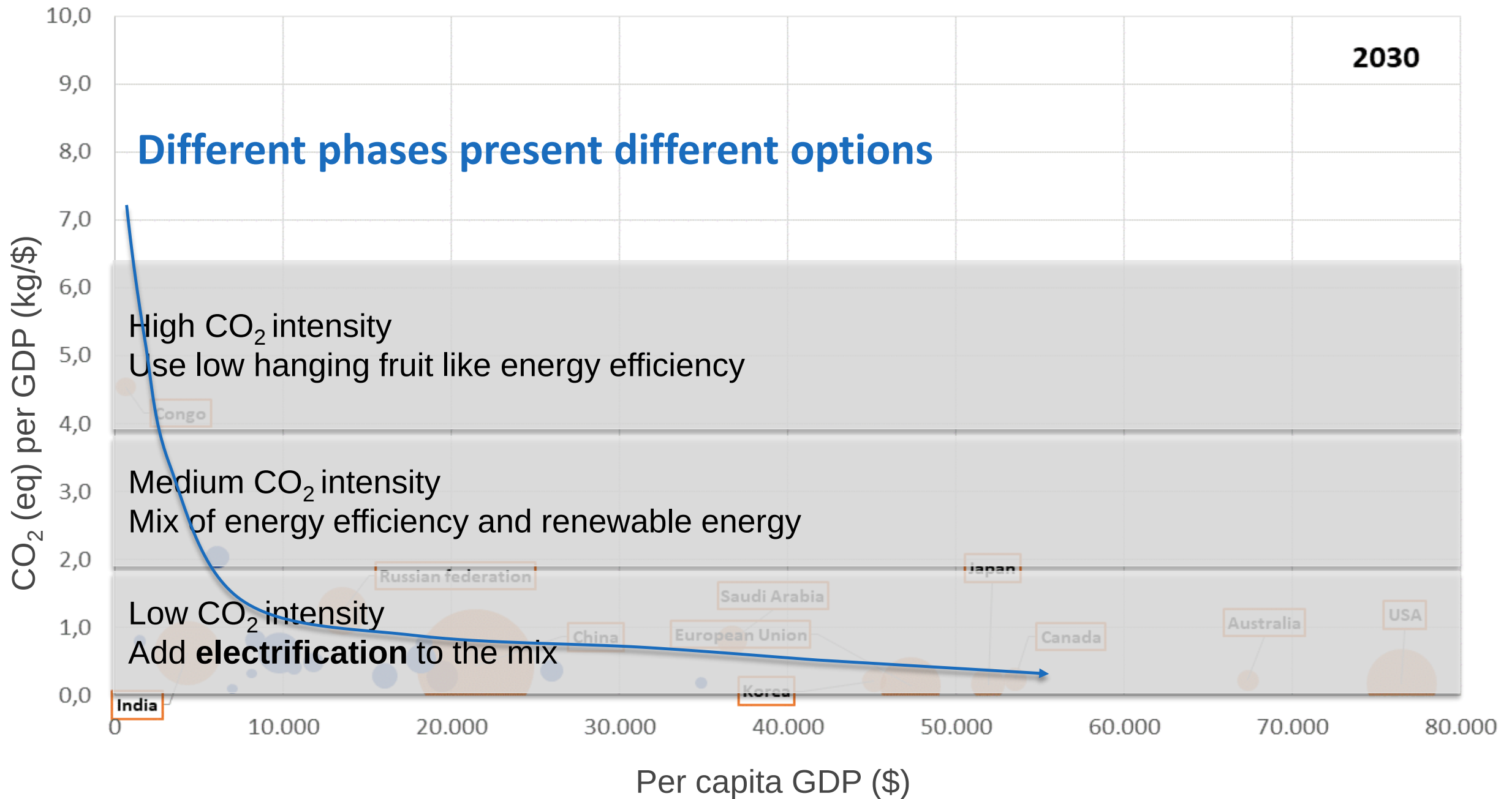
<http://themasites.pbl.nl/climate-ndc-policies-tool/>



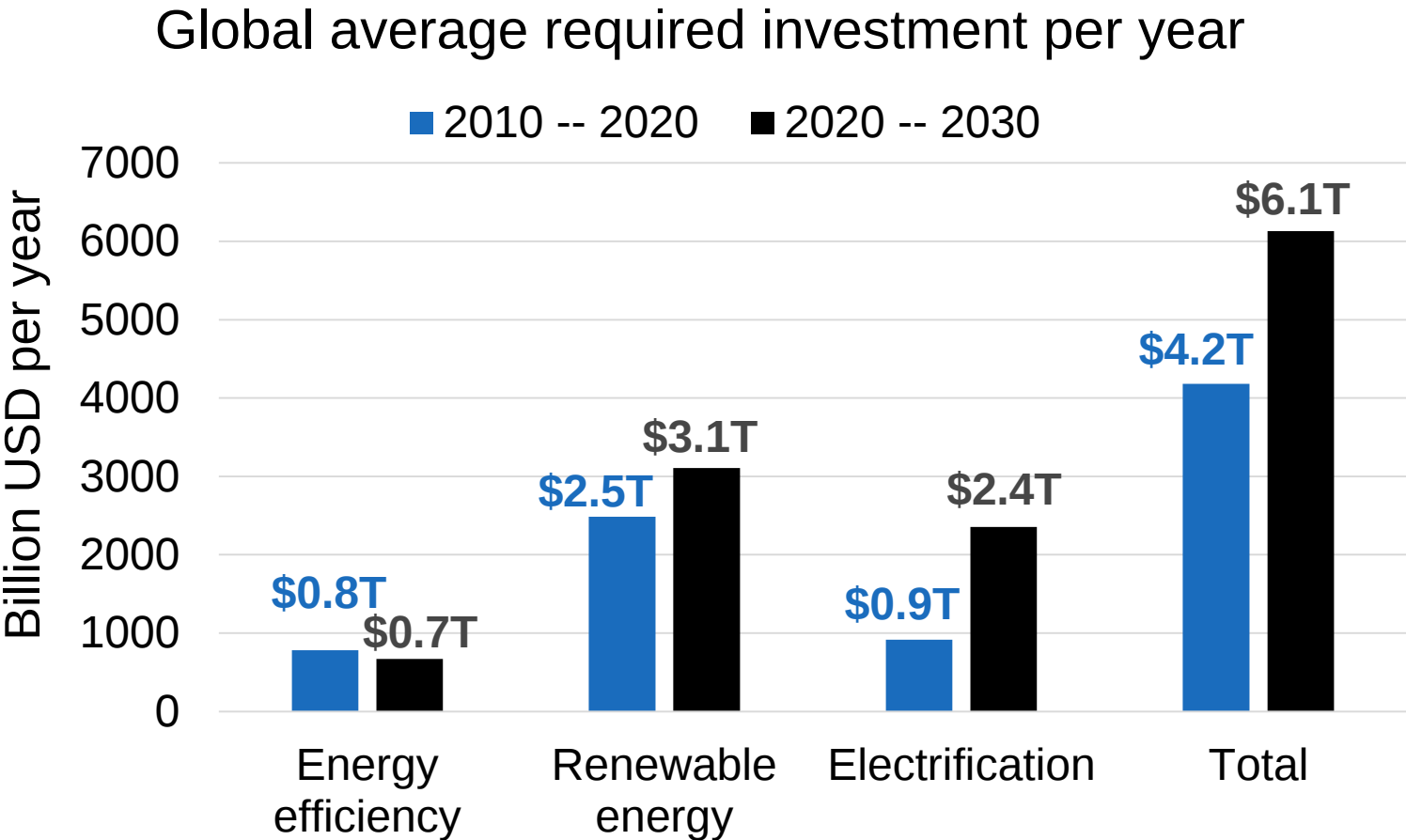








# The roadmap defines a multi-trillion dollar market



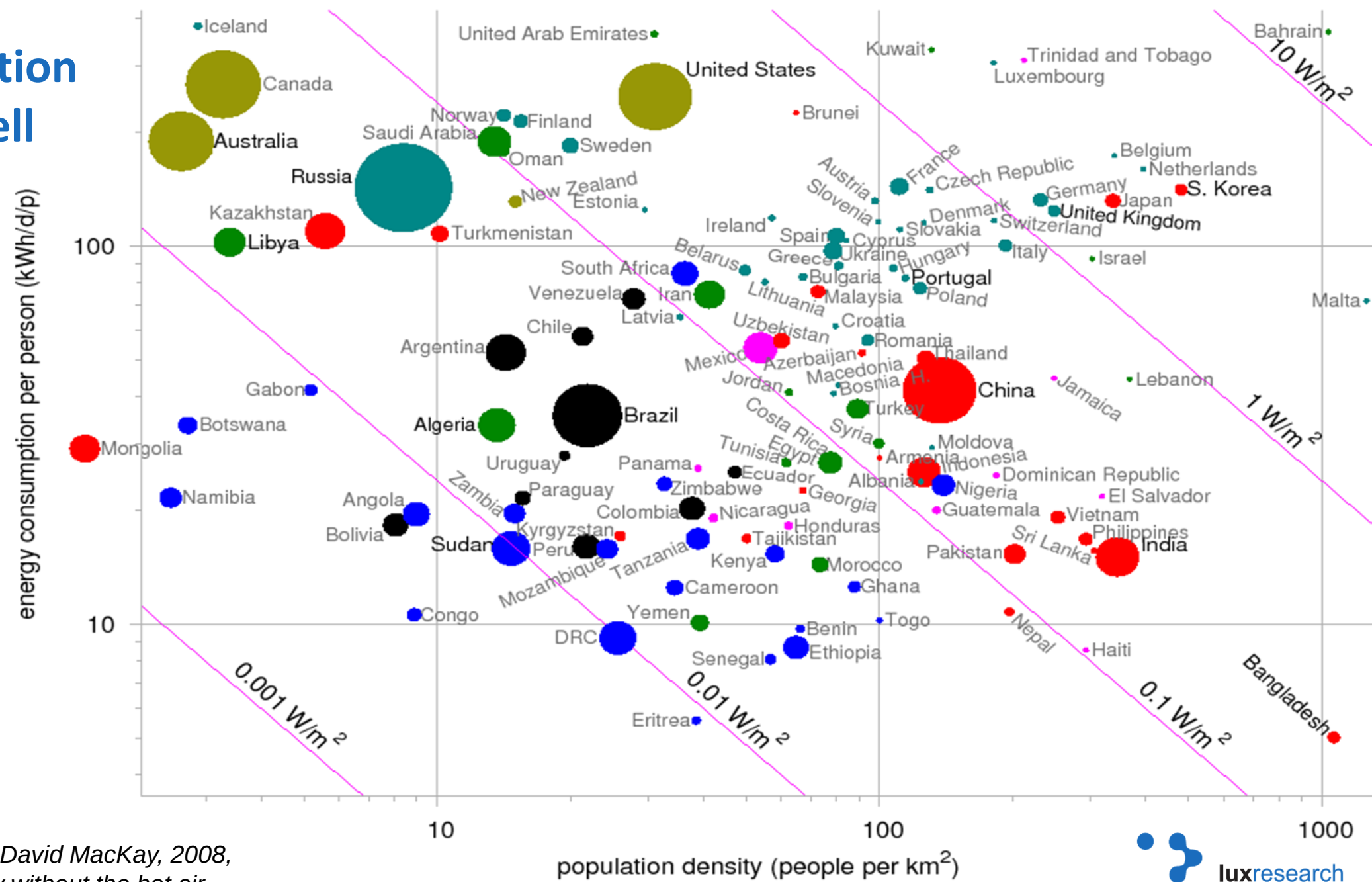
About 3% of global GDP

Varies by country; between 0.5% and 13% of GDP

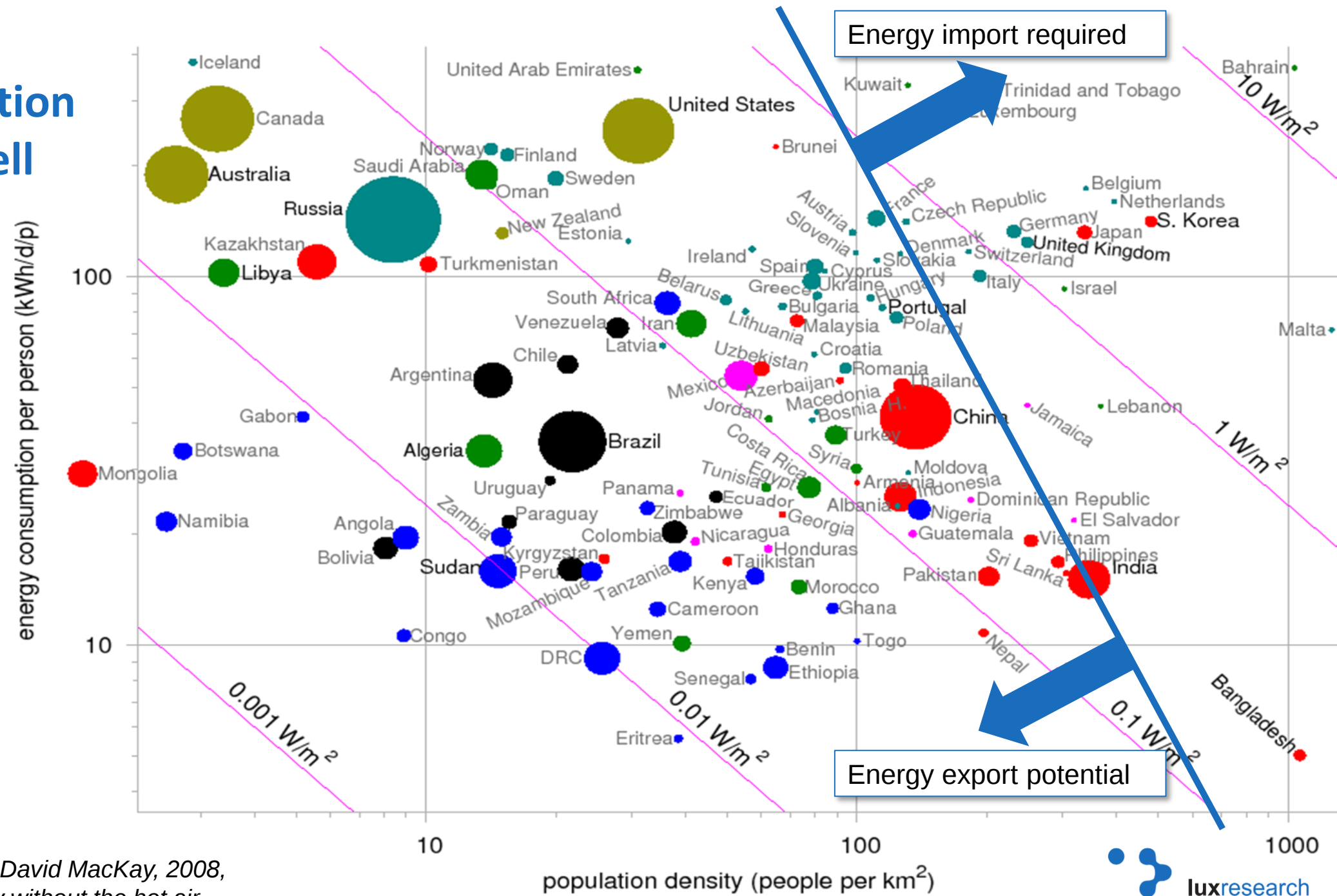
Based on the most aggressive promised reduction

Still a conservative estimate; **the most aggressive plans are not enough yet**

There is a  
transportation  
issue as well



There is a transportation issue as well



# The long-range energy transportation options



## LNG:

- Clean
- Existing infrastructure
- High energy density
- Available today
- Still CO<sub>2</sub>



## Electrolyte:

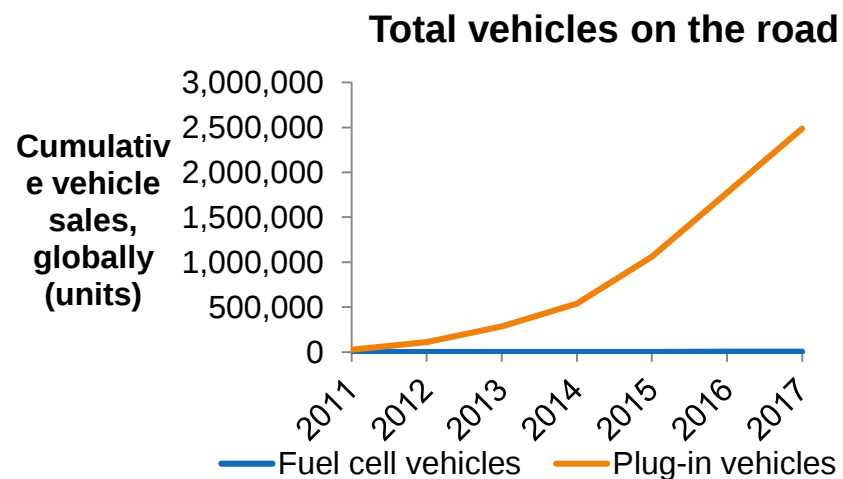
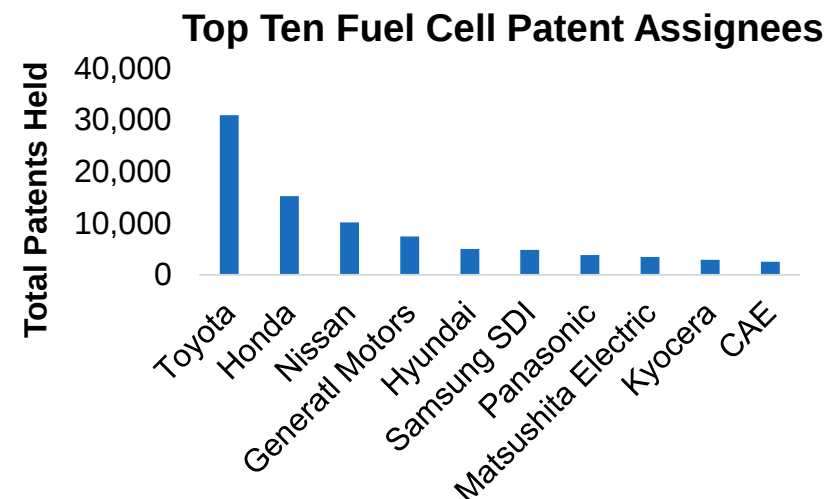
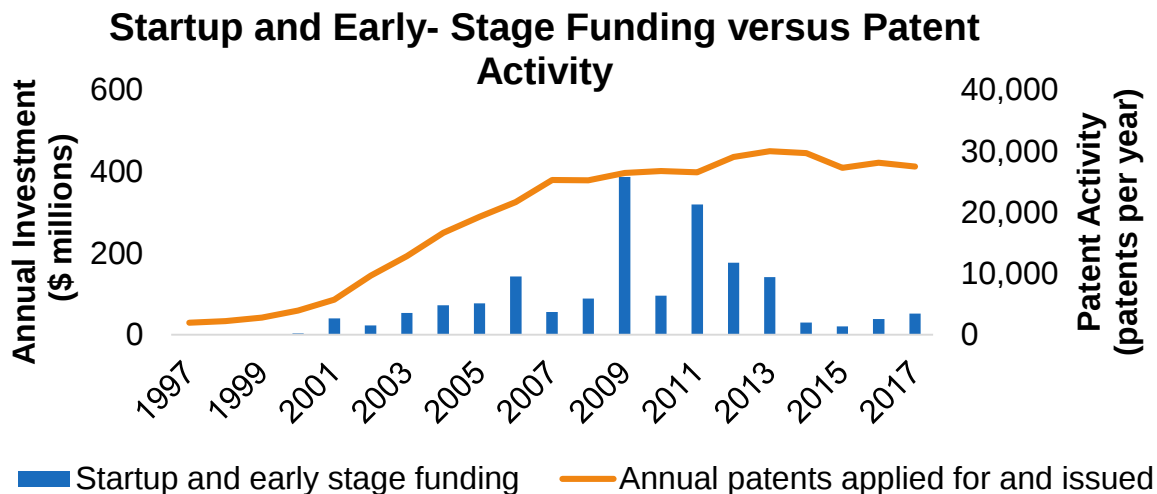
- Upcoming infrastructure
- New system
- Low energy density
- Electricity only



## Hydrogen:

- Expensive infrastructure
- Versatile
- High energy density
- In development

# Hydrogen is the most versatile option, but difficult to deploy



↑ Lots of activity

← Not a lot of result (yet?)

# Hydrogen is *almost* competitive for high-utilization vehicles



Ballard fuel cell bus in Vancouver

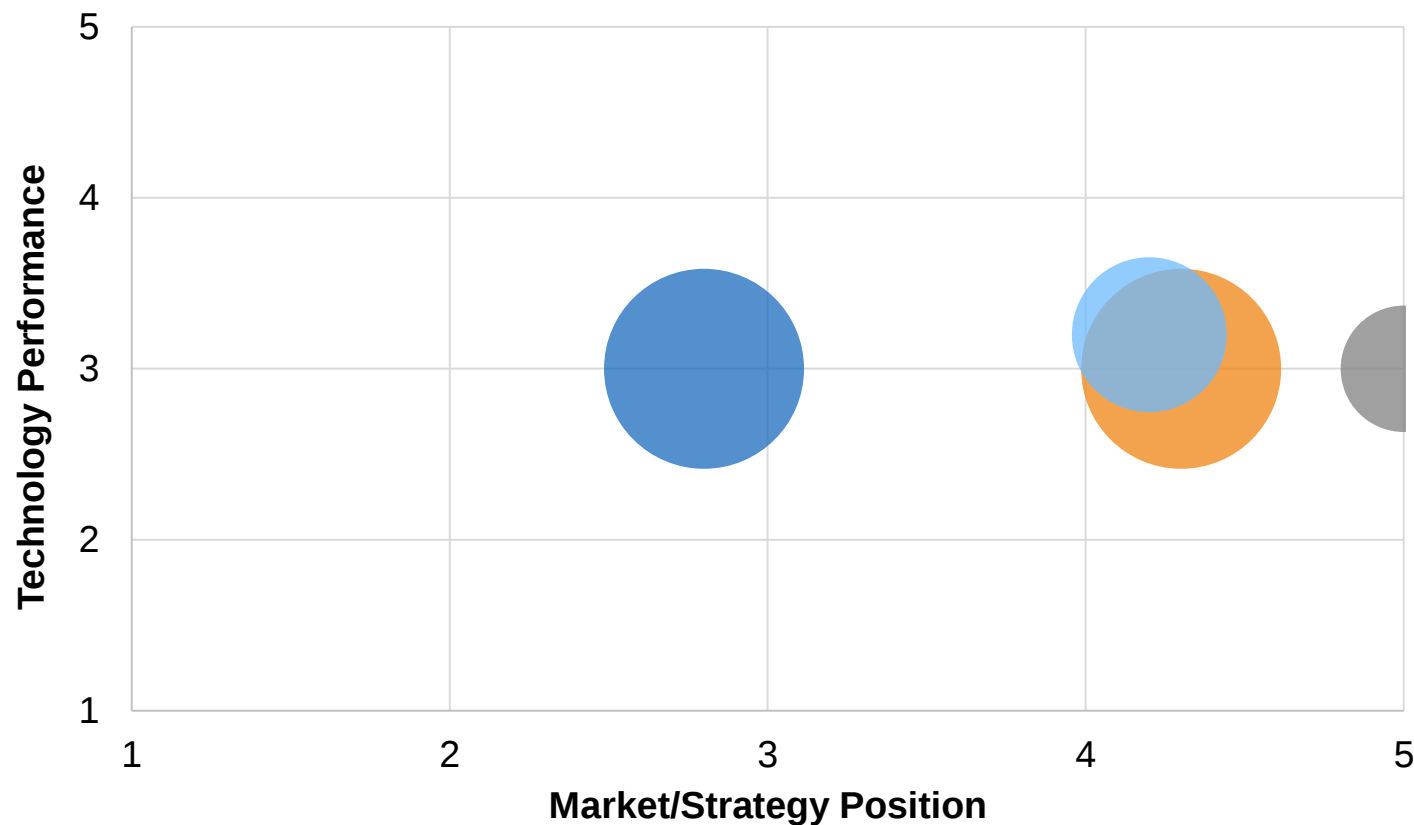
Source: Ballard



Proterra electric bus

Source: Proterra

Intra-City Bus Powertrain Competitive Matrix



● Diesel-hybrid ● Compressed natural gas ● Fuel cell ● Li-ion

# CO<sub>2</sub> utilization is the other driver for hydrogen

|           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Concrete  |                                                                                                                                                                                                                                                           |
| Chemicals |          |
| Fuels     |                                                                                                                                                                             |
| Polymers  |                                                                                      |
|           | <div>Laboratory</div> <div>Development</div> <div>Commercial</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

# Only a coordinated approach will build a hydrogen economy

- Every application of hydrogen on its own merits is too expensive
- When there is a hydrogen commodity market and infrastructure, this picture changes
- All hydrogen applications must mature in the same timeframe
- Coordination (governments) is essential

**Harshit Sharma**  
Alternative Fuels | More...  
April 16, 2018

**Shell and Anglo American invest in Hydrogen startup HyET Hydrogen** Edit

Shell Technology Ventures and Anglo American have each acquired a minority stake in Dutch startup HyET Hydrogen, who is developing an electrochemical solution for hydrogen compression and purification. The interest in a hydrogen-based economy has long garnered interest in Asian countries such as Japan, with oil companies such as Indian Oil and JXTG Nippon already exhibiting a gradual push for hydrogen this year. However, clients should also take note of Anglo American's involvement in this space, which is a sign of the first hydrogen of a mining player investing in a Hydrogen start-up positioning fuel cells as a future market opportunity here.

**Anthony Schiavo**  
Accelerating Materials Innovation | More...  
February 3, 2018

**SSAB invests \$250 million in CO<sub>2</sub>-free steel production** Edit

SSAB is set to become the first major steelmaker to build a hydrogen reduction steel plant – a technique for primary steel production that releases no CO<sub>2</sub>. This plant will cost between \$125 million and \$250 million to build and will be a key demonstration of the potential of CO<sub>2</sub> free steelmaking methods. Clients should monitor this effort closely, but be aware that this technique relies on many underdeveloped technologies and pieces of infrastructure – such as low-cost, widely available hydrogen – that mean it will take decades to transform steelmaking even if it works.

For the original news article, [click here](#).

**Chloe Holzinger**  
Energy Storage | More...  
July 12, 2018

**Germany approves the world's first train powered by hydrogen fuel cells** Edit

Two pilots of the approved train, Alstom's Coadia iLint, are set to operate in Germany and start carrying passengers by the end of the summer. Since compressed hydrogen has a greater volumetric energy density than Li-Ion batteries, hydrogen fuel cells have a growing value proposition for trains traveling relatively short routes in countries with some existing hydrogen infrastructure, such as Germany. Clients should expect to see more activity to provide 14 hydrogen fuel cell locomotive works is currently

**Chloe Holzinger**  
Alternative Fuels | More...  
June 25, 2018

**South Korea to invest \$2.3 billion in hydrogen fuel cell vehicle ecosystem by 2023** Edit

Through public-private partnerships, South Korea is looking to install 310 hydrogen refueling stations to support 16,000 fuel cell electric vehicles by 2023. The funds will also go toward building plants for mass-producing fuel cell stacks, refueling stations, and hydrogen through CNG reformers. Although South Korea has invested heavily in fuel cells in the past, the country has not enjoyed as much success in the space as Japan, which has invested about \$1.2 billion in its hydrogen vision since 2014 and has made hydrogen infrastructure a cornerstone of its Olympic bid. Clients should still consider Japan to be leading the hydrogen innovation race, but also recognize South Korea and Germany as strong players in the fuel cell industry.

**Runeel Daliah**  
Alternative Fuels | More...  
November 8, 2017

**Audi renews commitment to CO<sub>2</sub>-fuels by announcing second e-diesel facility** Edit

Last week, Audi announced plans for a second CO<sub>2</sub>-to-diesel facility together with INERATEC and Energiedienst Holding due for 2019 in Switzerland. The 105,000 gallons per year (GPY) diesel facility will use a combined reverse water gas shift and Fischer Tropsch (RWGS/FT) process to produce diesel from CO<sub>2</sub> and renewable hydrogen. Audi's first project in the space, a 15,000 GPY facility built with Sunfire and Climecworks in Germany, only produced 85 gallons of diesel as of May 2017. While groundbreaking, CO<sub>2</sub>-to-diesel remains far too expensive for commercialization; based on our estimates and rumors in the industry, the production cost of diesel using RWGS/FT exceeds \$22/gallon.

For the original news article, [click here](#).

**Max Halik**  
Energy Storage | More...  
September 15, 2017

**A power-to-gas project from Sunpower and Nel is unlikely to breathe life into hydrogen's deflating prospects** Edit

Creation of hydrogen electrolyzer facility in California of this plant, but intends to use

**Anthony Schiavo**  
Alternative Fuels | More...  
October 19, 2018

**Nouryon, Tata Steel, and Port of Amsterdam collaborate on feasibility study of 100 MW hydrogen production facility** Edit

This announcement is notable for multiple reasons: It is the biggest proposed PEM electrolysis facility, and it is Nouryon's (formerly AkzoNobel Specialty Chemical) first major announcement since its rebranding. This announcement is a step in the right direction, as it seeks to tackle the cost of electrolysis by scaling up the process and involves major stakeholders in the steel and chemical industries. Clients should recognize that while this is only a feasibility study and commercialization remains distant, it represents an important step toward large-scale, low-cost production of hydrogen.

For the original news article, [click here](#).

**Further reading from Lux Research:** Vattenfall, SSAB

**Further reading from Lux Research:** South Korea Ministry of Trade, Industry and Energy (MOTIE)

**Further reading from Lux Research:** Audi, Climecworks, Sunfire, INERATEC

**Further reading from Lux Research:** Tata Steel, Nouryon



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