



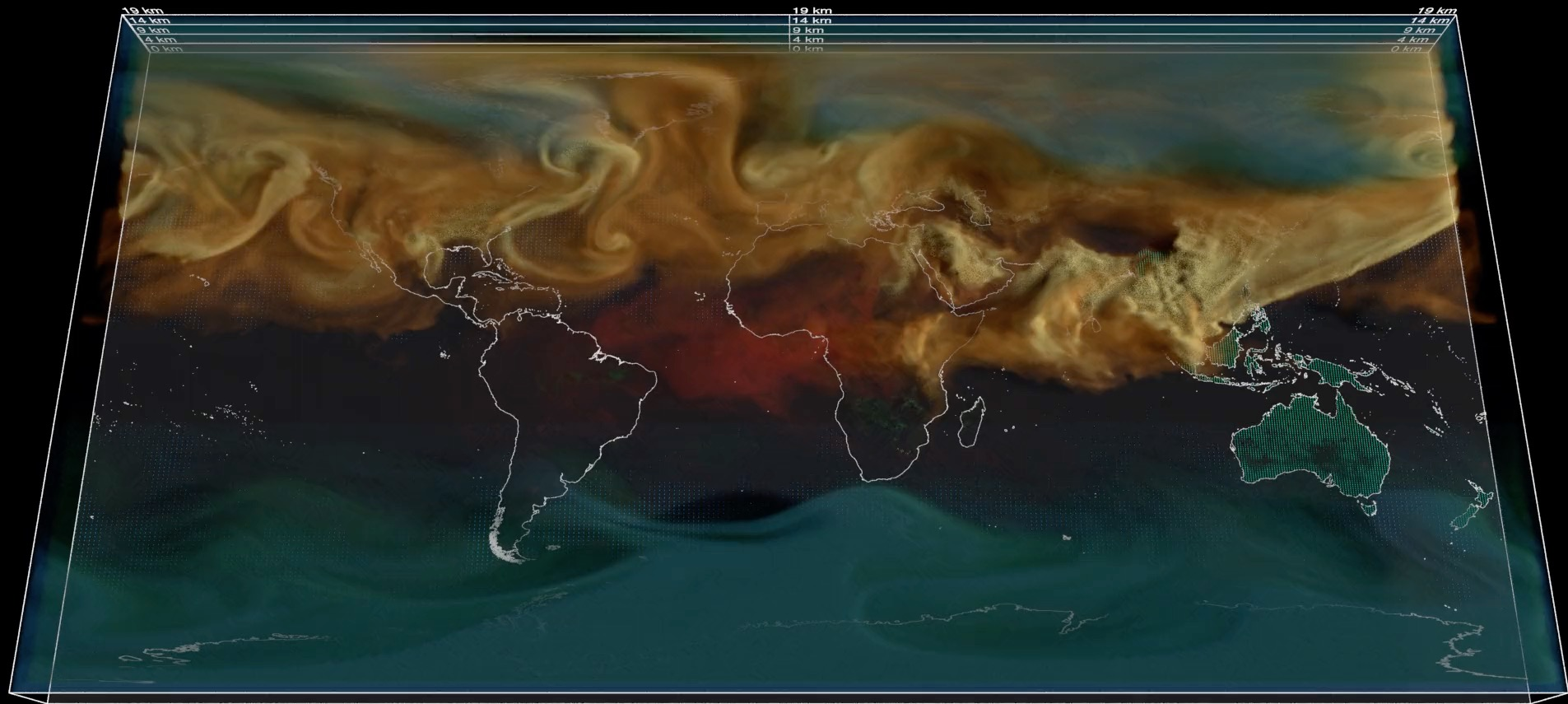
Cours « Conversion d'énergie » Partie I

The “Big Energy” challenge

**Génie Electrique et Electronique
2025-2026
Bachelor semestre 5**

**Prof. Mario Paolone
Laboratoire de Systèmes Electriques Distribués l'EPFL**

Drivers – The CO₂ emissions



Source: NASA Goddard Space Flight Center - <https://svs.gsfc.nasa.gov/5110>

Drivers – The global warming

B-ROLL FOR JULY 2023 TEMPERATURE UPDATE LIVE SHOTS

TRT - 3:16

Source: NASA Scientific Visualization Studio - <https://svs.gsfc.nasa.gov/14396/>

Drivers – Arctic ocean ice coverage



Source: NASA Visualization Explorer

<https://science.nasa.gov/resource/video-annual-arctic-sea-ice-minimum-1979-2022-with-area-graph/>



Global greenhouse emissions by sector in 2016

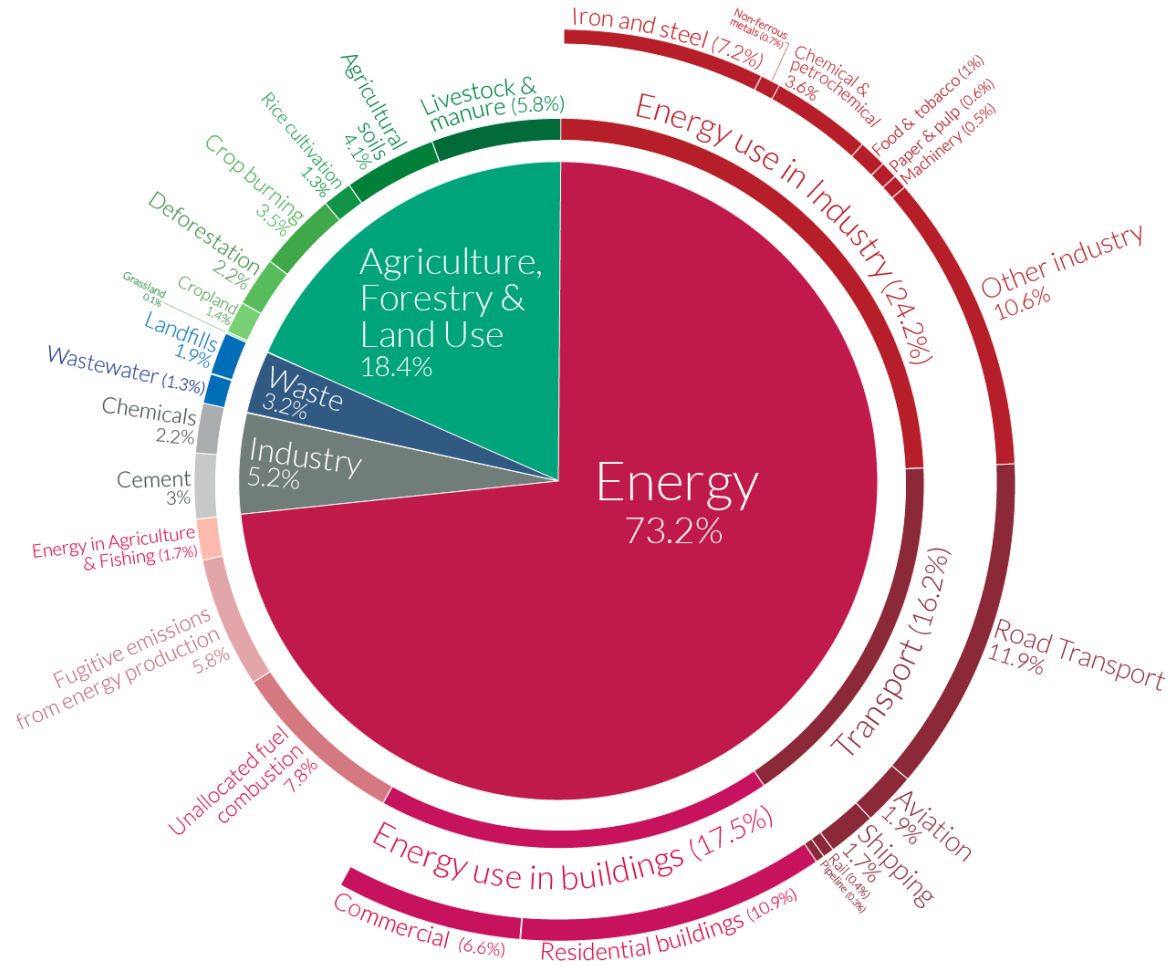


Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO₂eq.

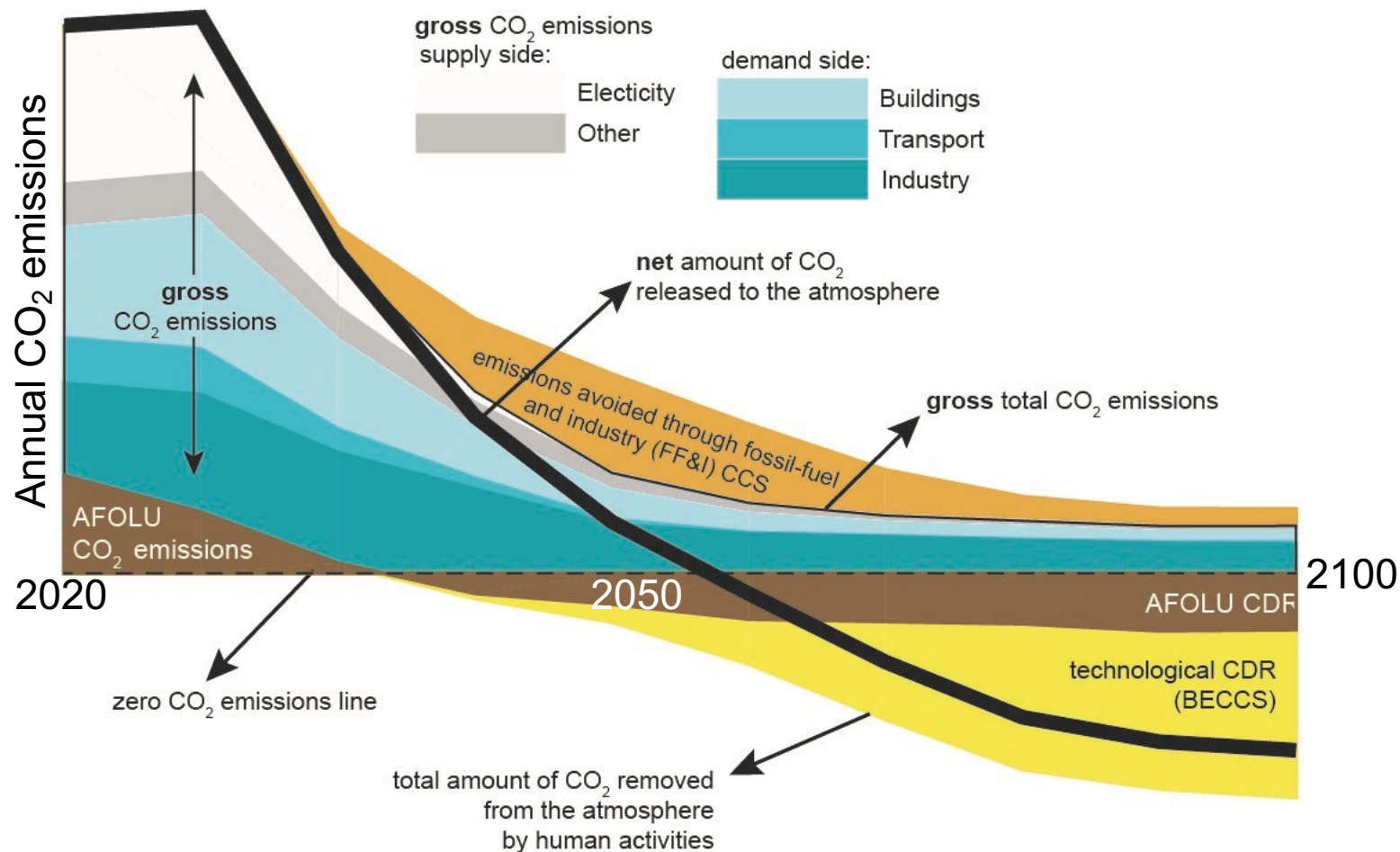
Source:

<https://github.com/owid/co2-data>



OurWorldinData.org – Research and data to make progress against the world's largest problems.
 Source: Climate Watch, the World Resources Institute (2020). Licensed under CC-BY by the author Hannah Ritchie (2020).

Evolution and break down of global anthropogenic CO₂ emissions until 2100



Source: IPCC Special report "Global warming of 1.5 degC"

<https://www.ipcc.ch/site/assets/uploads/sites/2/2019/01/Figure-2.5.jpg>

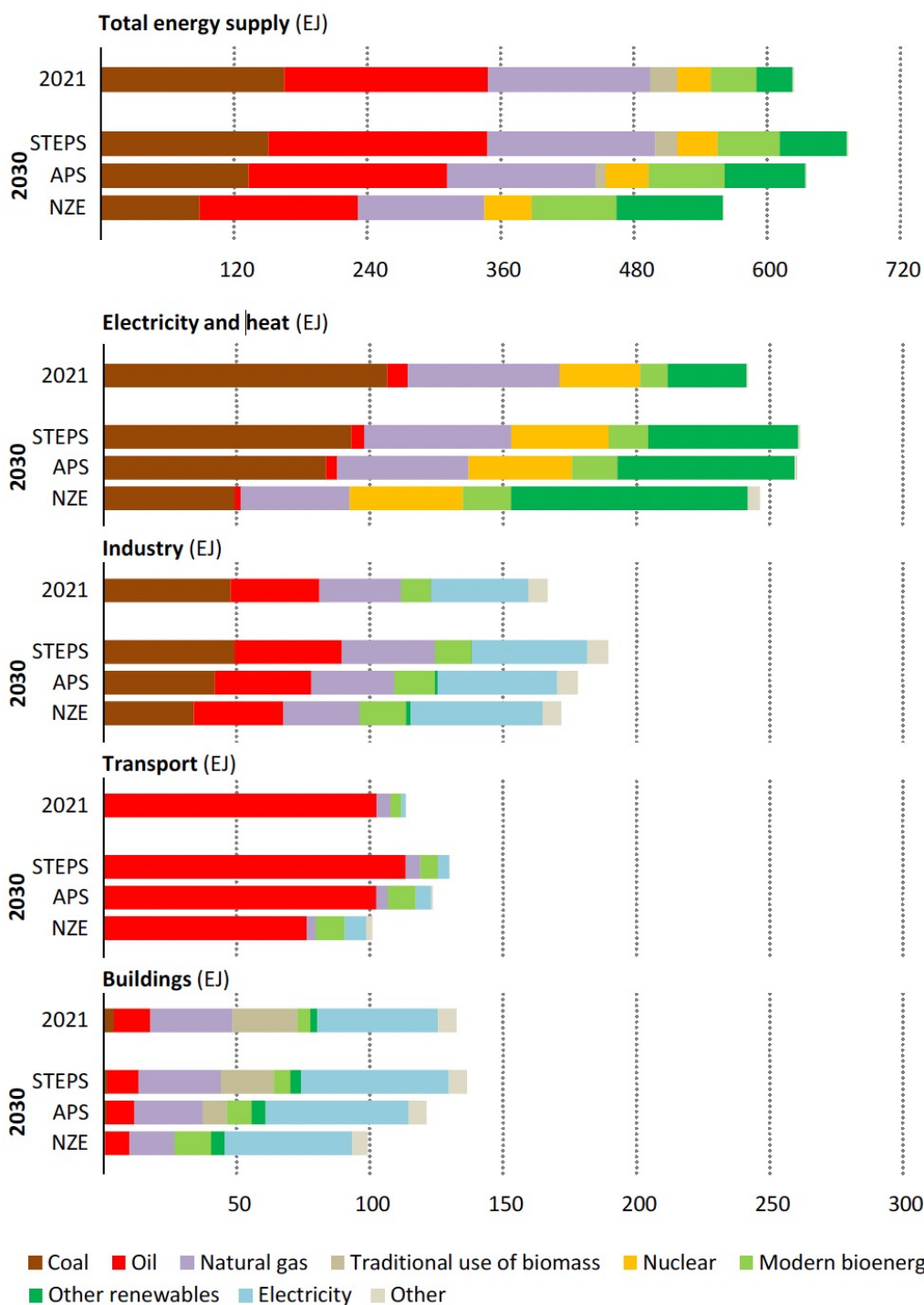
The IPCC is the Intergovernmental Panel on Climate Change (IPCC) of the United Nations (body in charge for assessing science-related aspects to climate change).

Global energy supply and demand by sector, scenario and fuel

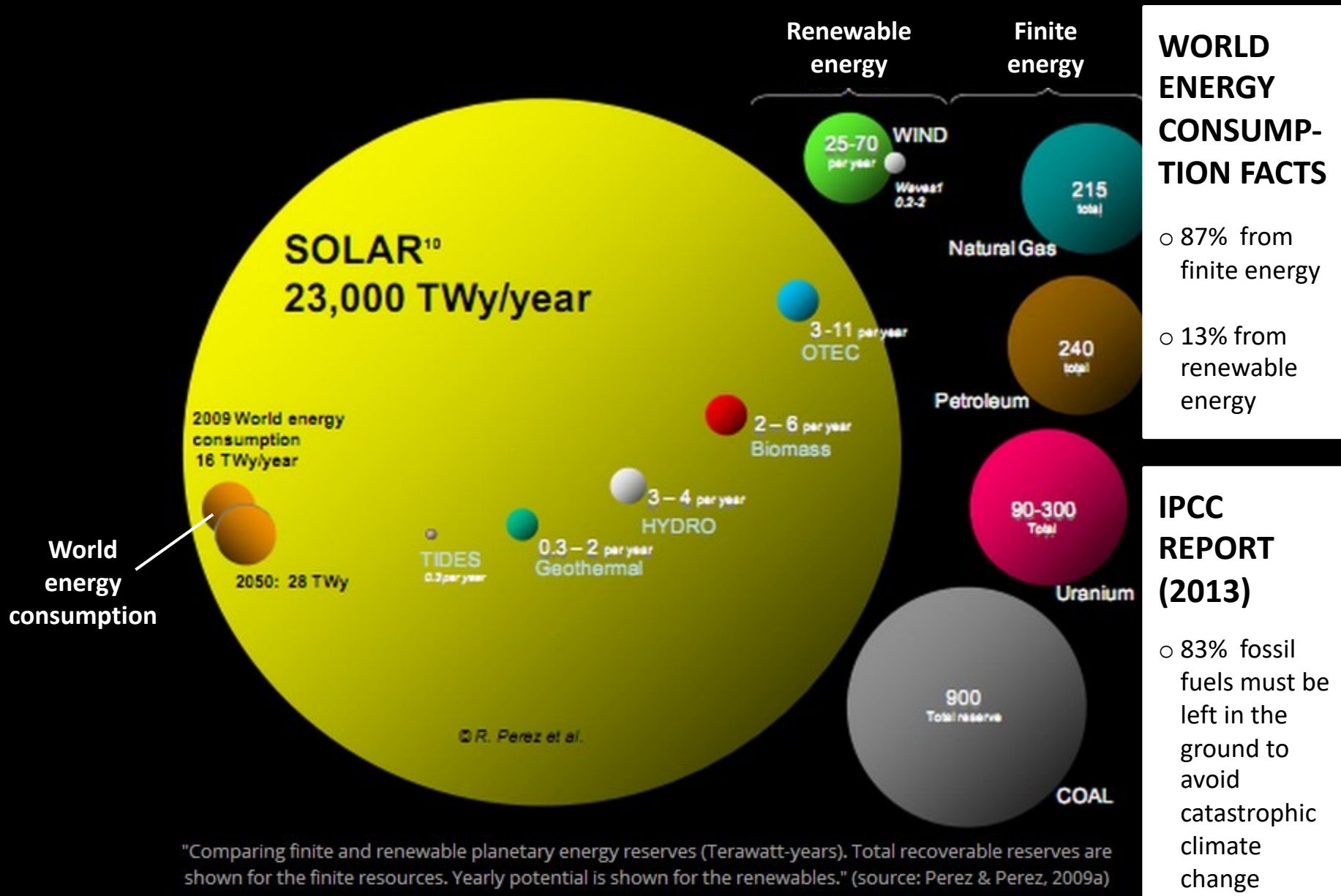
Scenario acronyms:

- STEPS (Stated Policies Scenario): trajectory implied by today's policy settings.
- APS (Announced Pledges Scenario): assumes that all aspirational targets announced by governments are met on time and in full, including their long-term net zero and energy access goals.
- NZE (Net Zero Emissions) hard net-zero by 2050.

Source: IEA World Energy Outlook, 2022



Global availability of energy resources in [TWy]



WORLD ENERGY CONSUMPTION FACTS

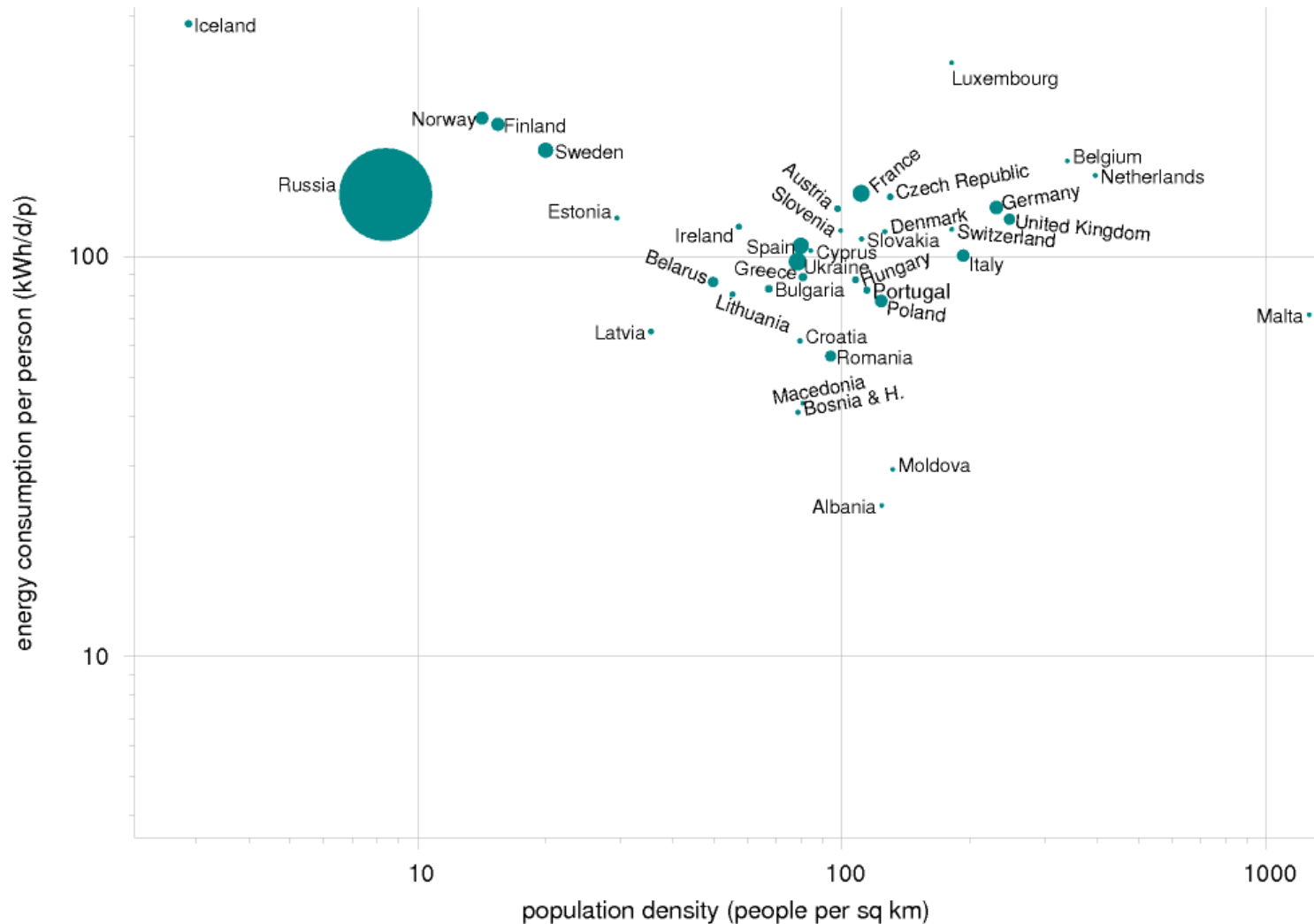
- 87% from finite energy
- 13% from renewable energy

IPCC REPORT (2013)

- 83% fossil fuels must be left in the ground to avoid catastrophic climate change

"Comparing finite and renewable planetary energy reserves (Terawatt-years). Total recoverable reserves are shown for the finite resources. Yearly potential is shown for the renewables." (source: Perez & Perez, 2009a)

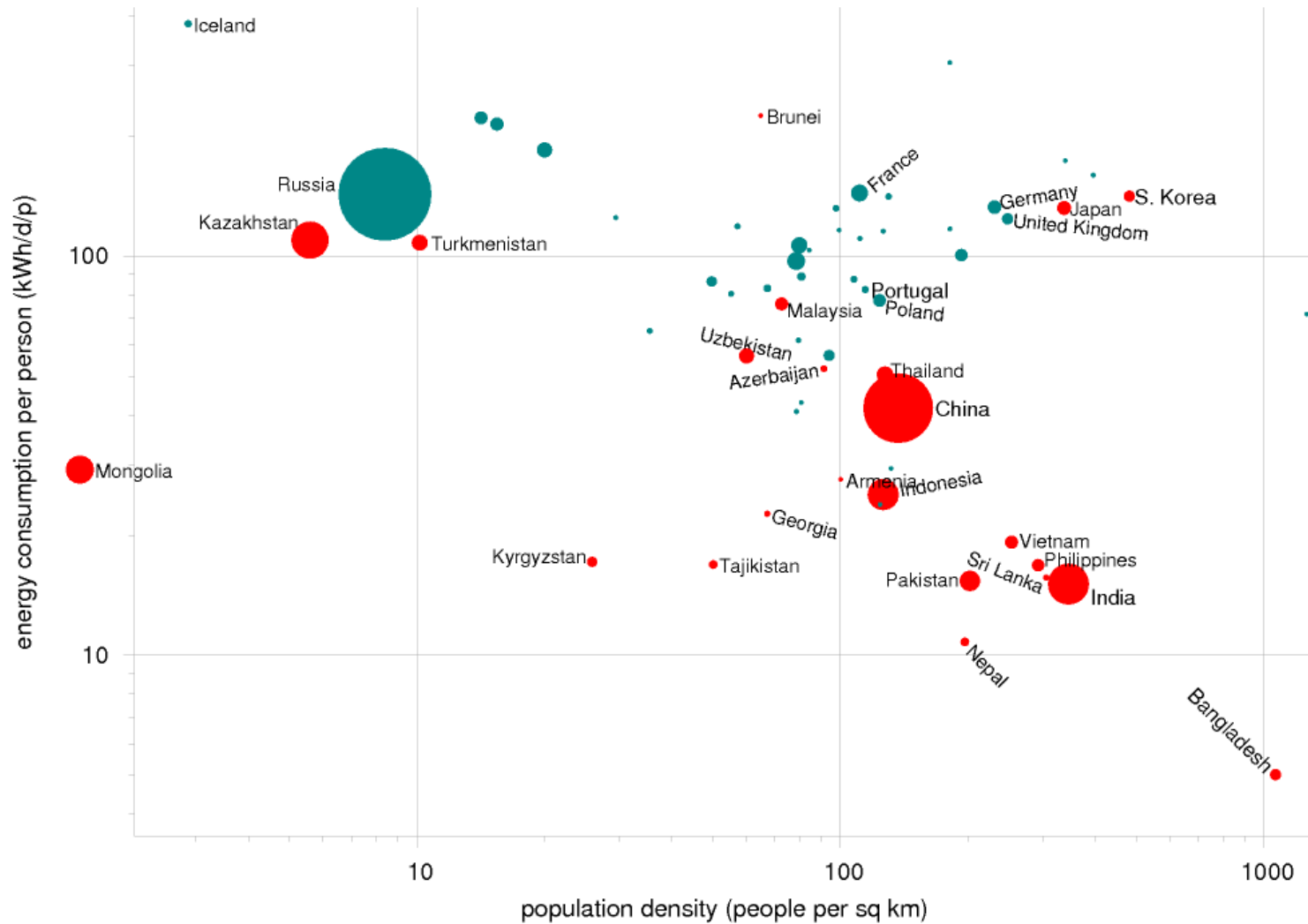
Energy consumption vs population density



Source: D. MacKay TEDx Warwick talk March 2012

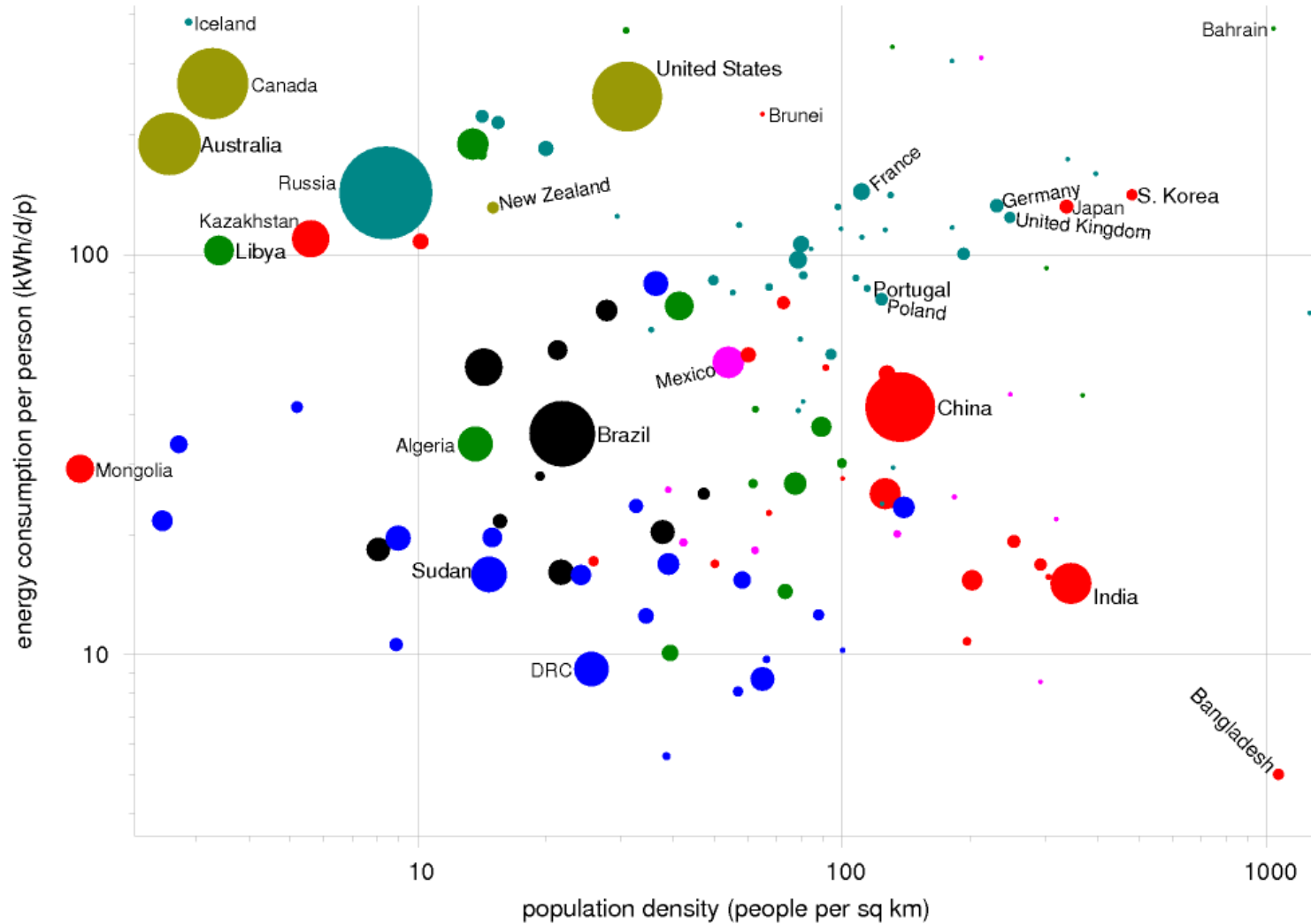
(point size shows land area)

Energy consumption vs population density



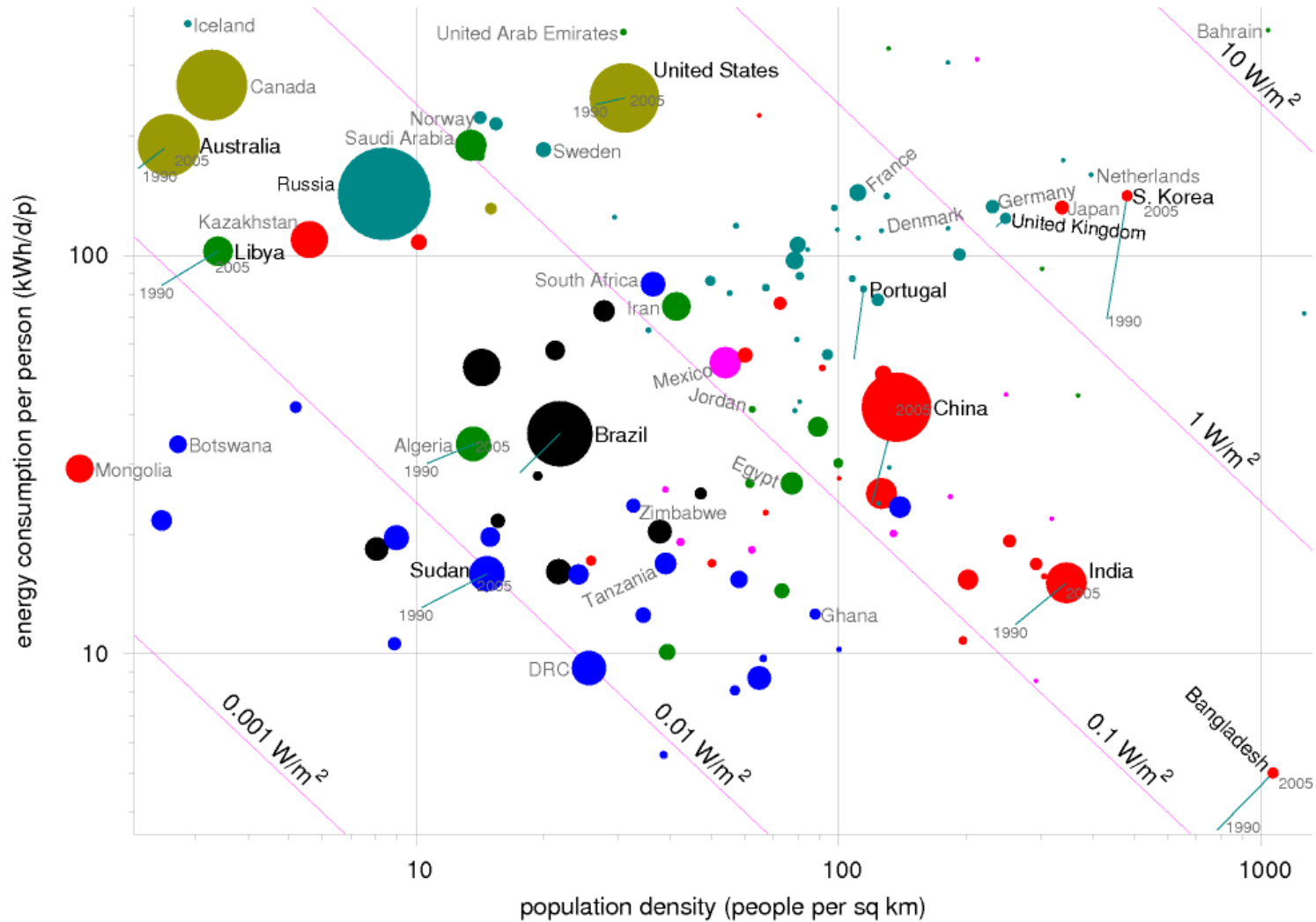
Source: D. MacKay TEDx Warwick talk March 2012

Energy consumption vs population density



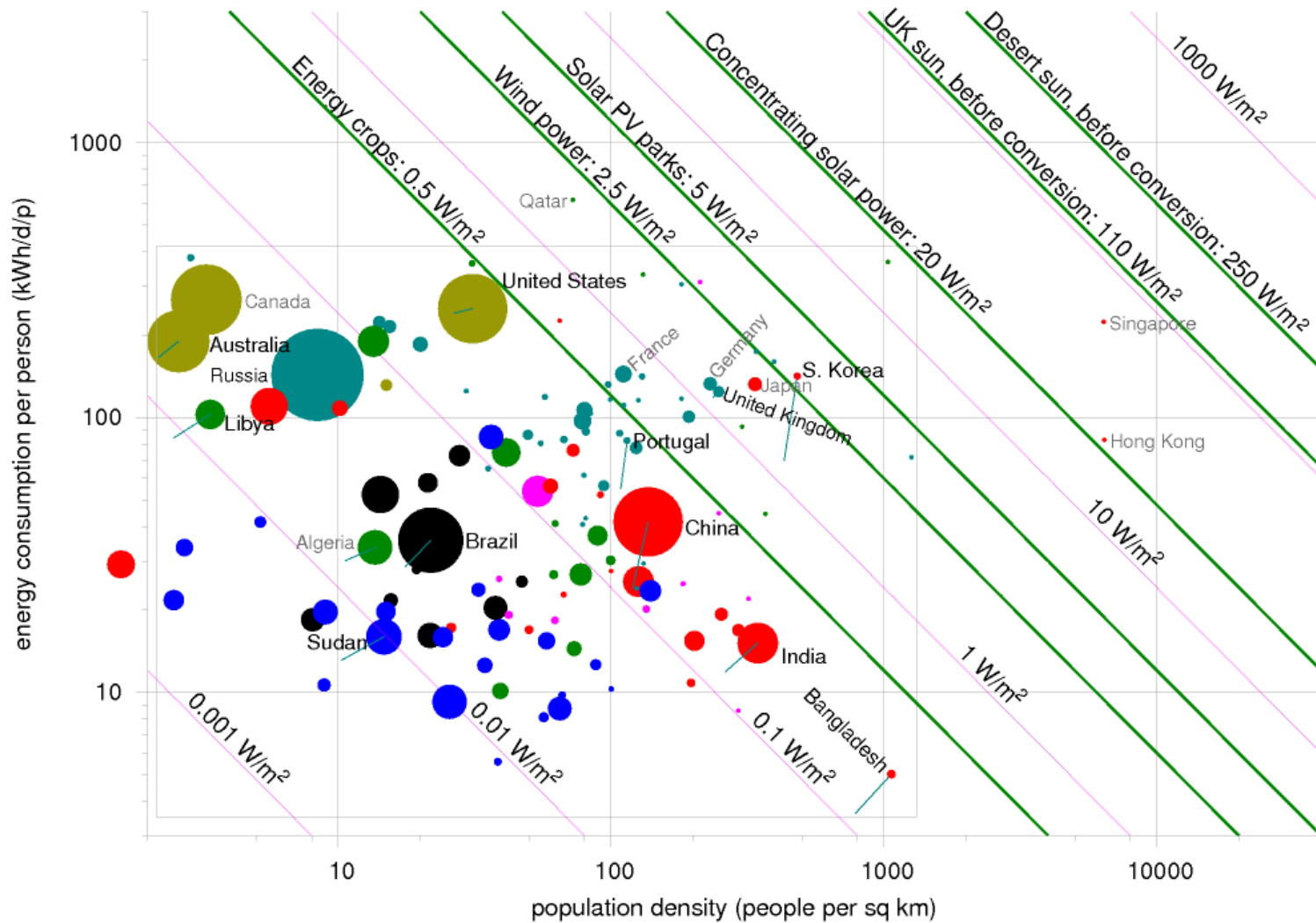
Source: D. MacKay TEDx Warwick talk March 2012

Energy consumption vs population density



Source: D. MacKay TEDx Warwick talk March 2012

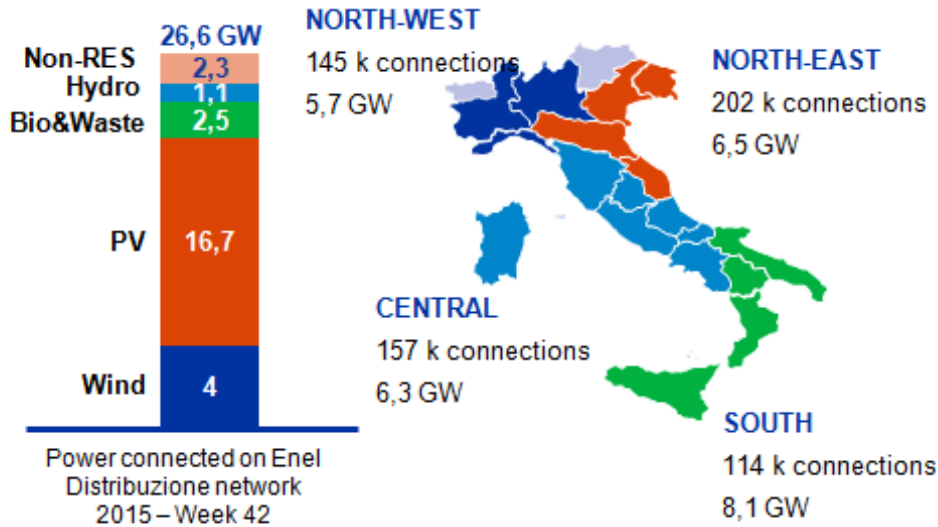
Energy consumption vs population density



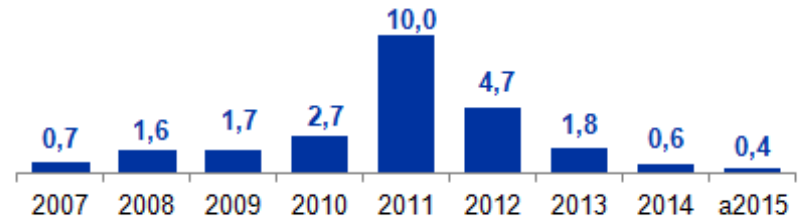
Source: D. MacKay TEDx Warwick talk March 2012

Renewables growth: the case of italy

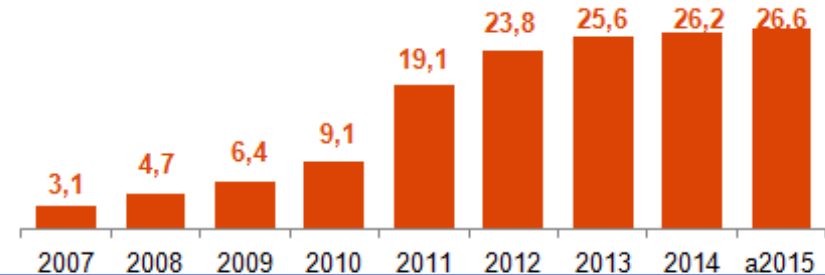
Connections and Power



Connections per year [GW]



Cumulative connections [GW]



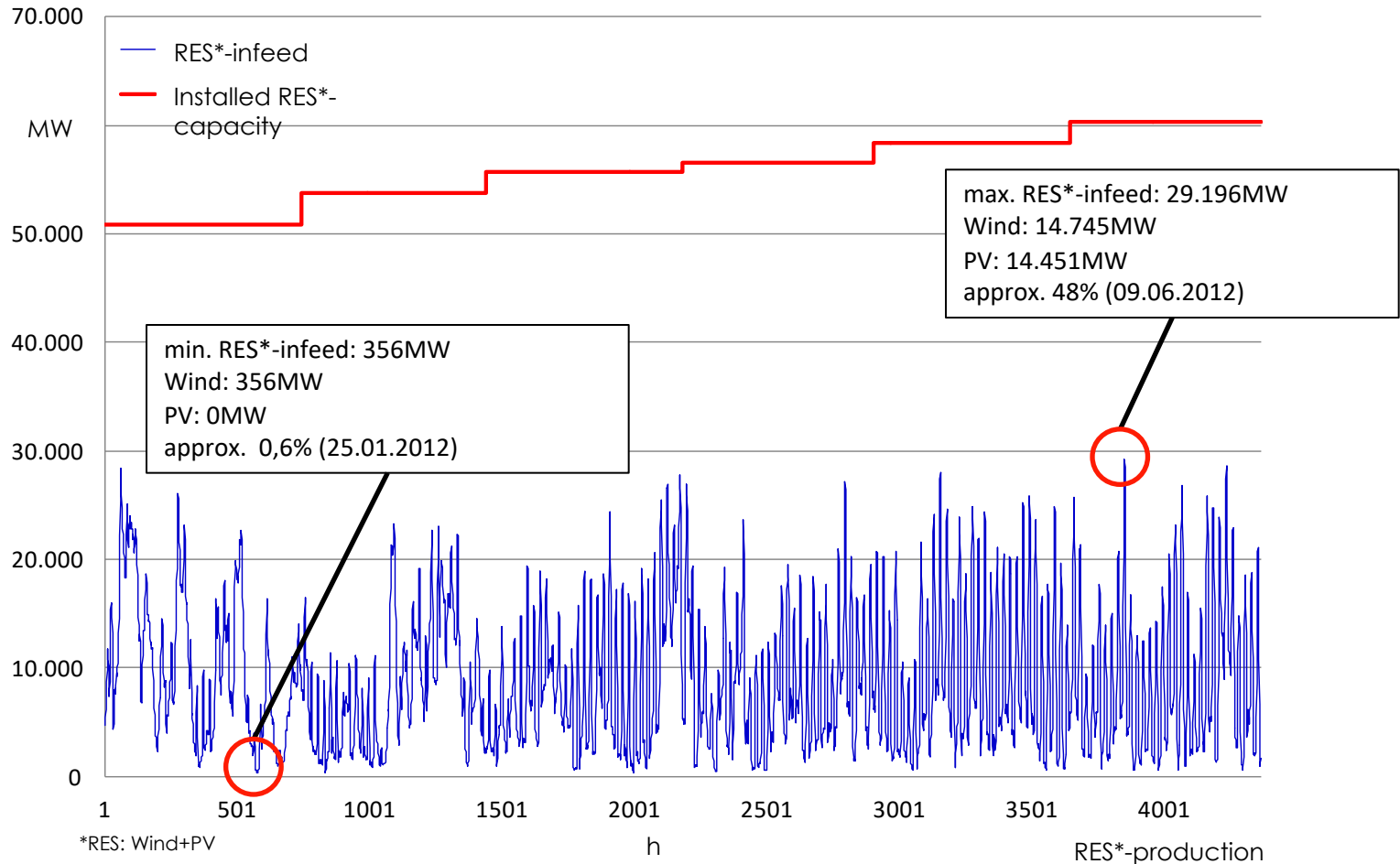
618.000 connections (26,6 GW) on Enel Distribuzione network

Data source C. D'Adamo, PSCC 2016

Time-scales of renewables volatility: intra-seasons

Seasonal volatility Jan 1st – Jun 30th 2012 (Wind+PV) Installed capacity vs real infeed: the case of Germany

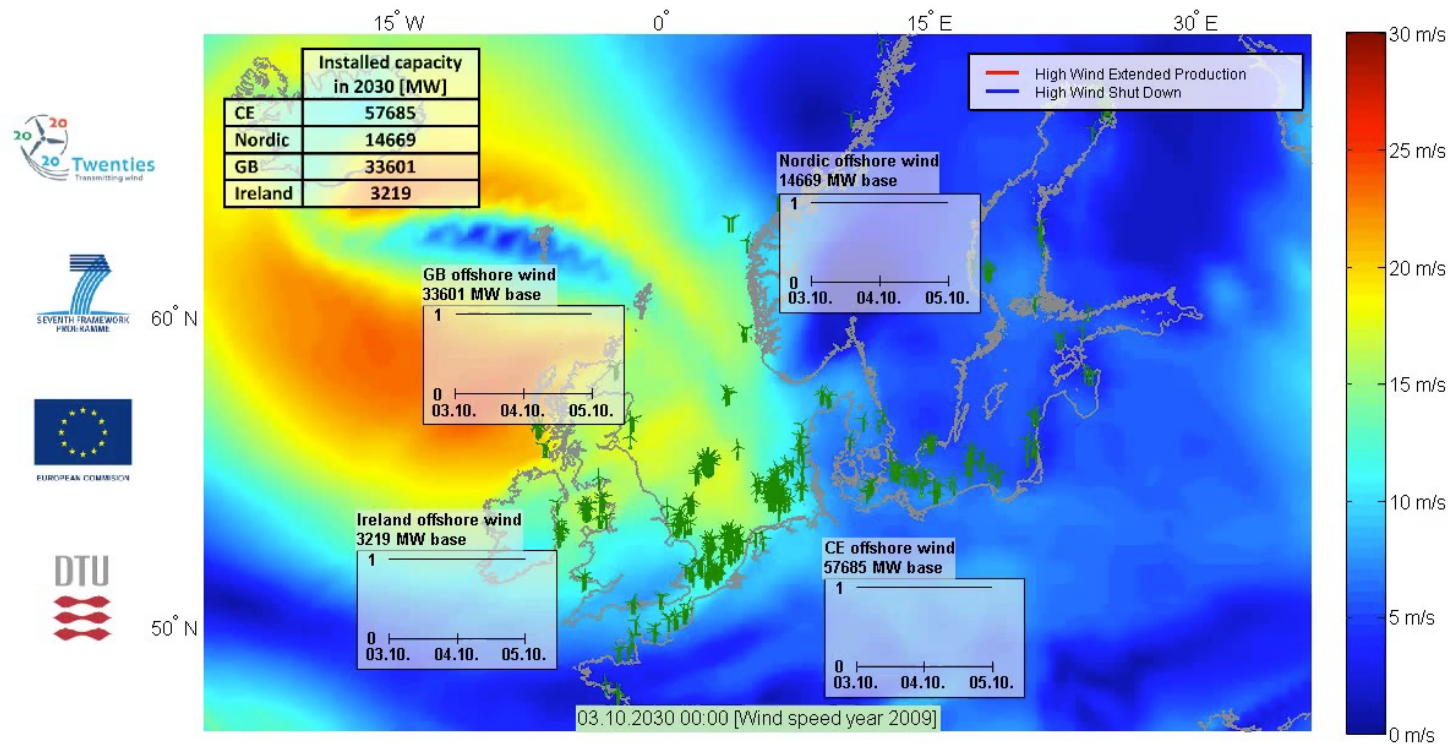
Source: G. Vanzetta



Time-scales of renewables volatility: days/hours

North European Offshore wind power variability in 2030

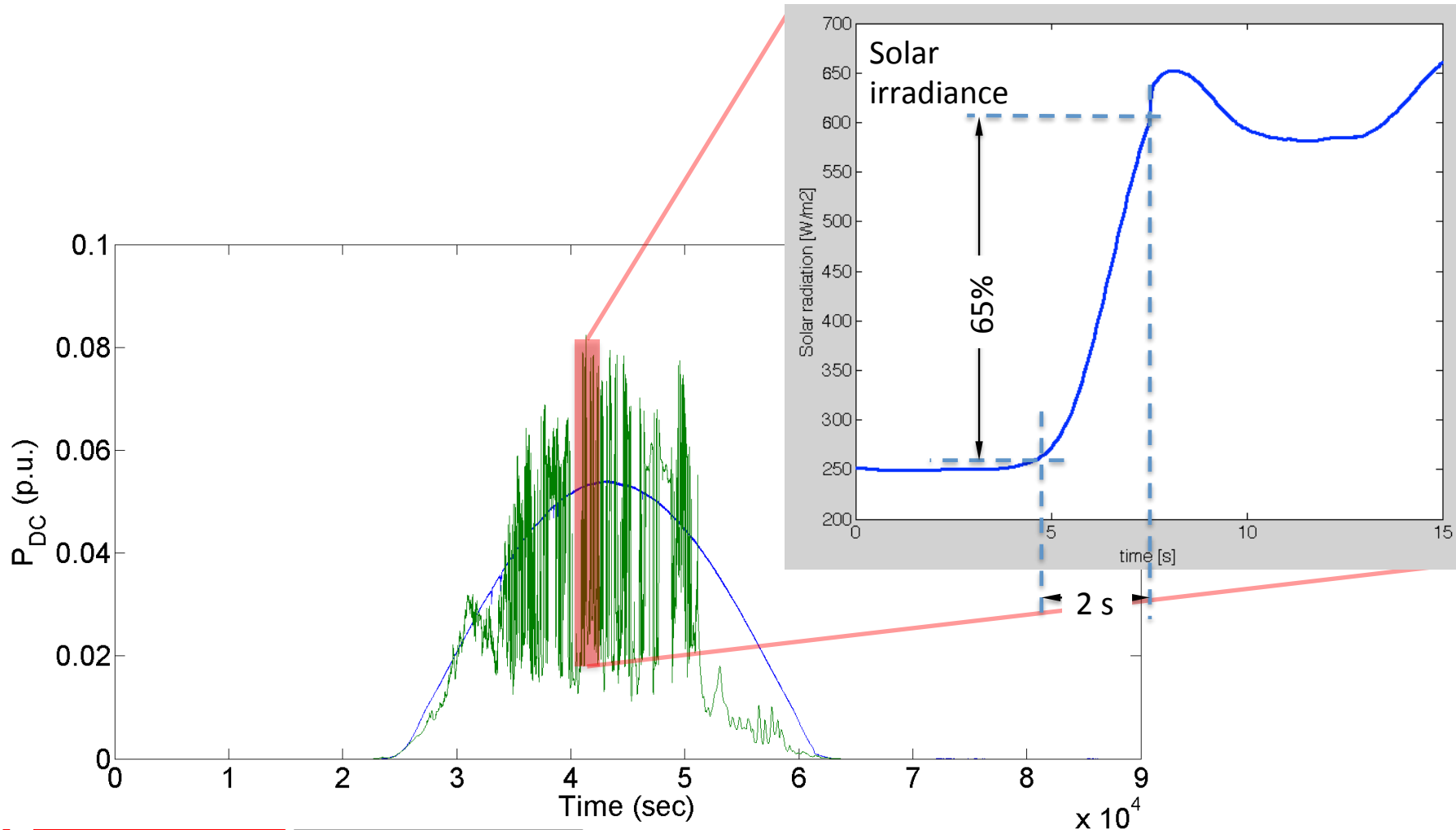
Wind power production aggregated at synchronous area level for offshore wind power in 2030 comparing the production for the **High Wind Shut Down** vs **High Wind Extended Production**.



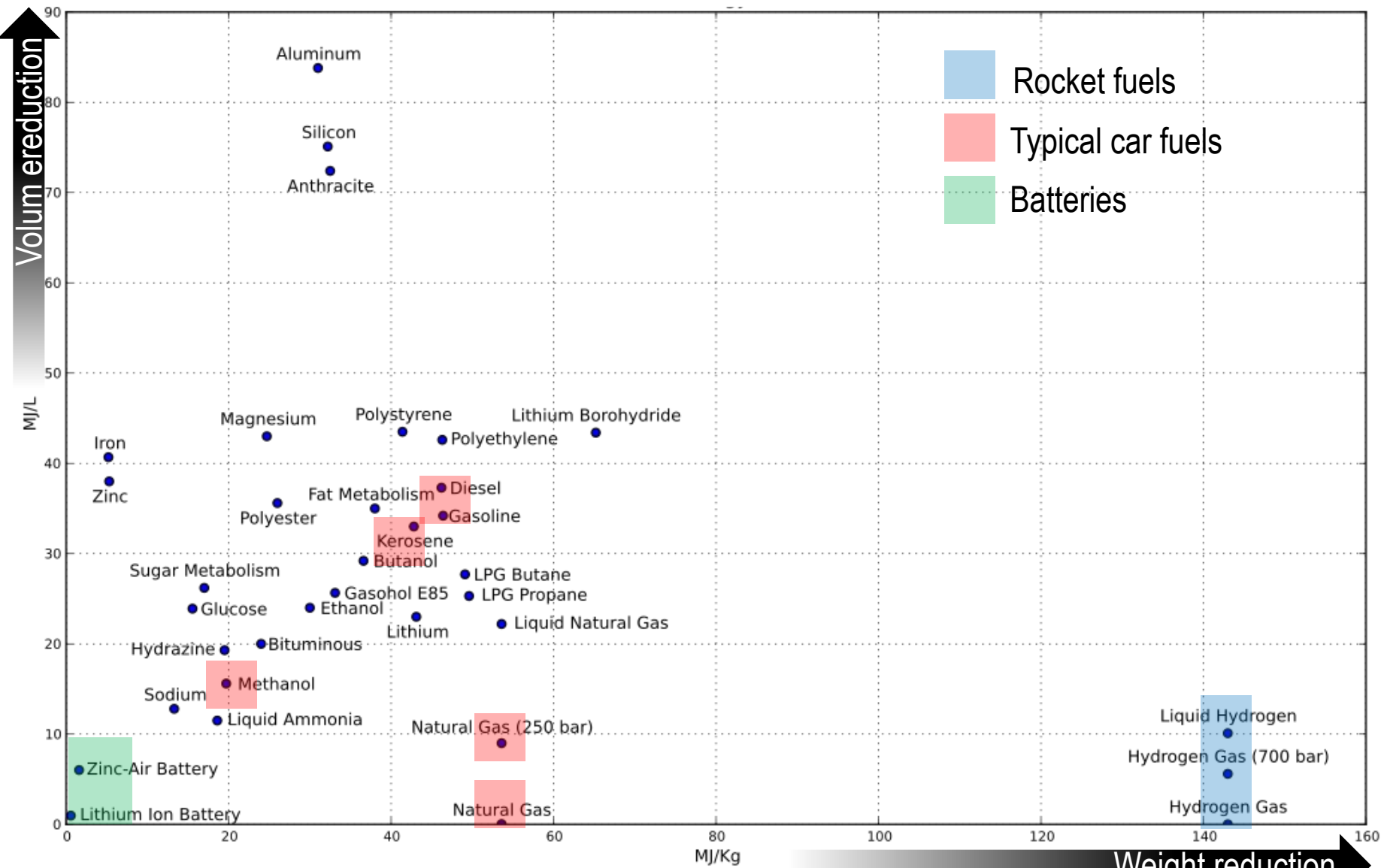
Adapted from: <http://www.youtube.com/watch?v=TCfAclz63sc>

Time-scales of renewables volatility: seconds

Example of daily measured power injected by solar arrays at EPFL



Energy densities for storage systems



Energy systems
