University of Pittsburgh

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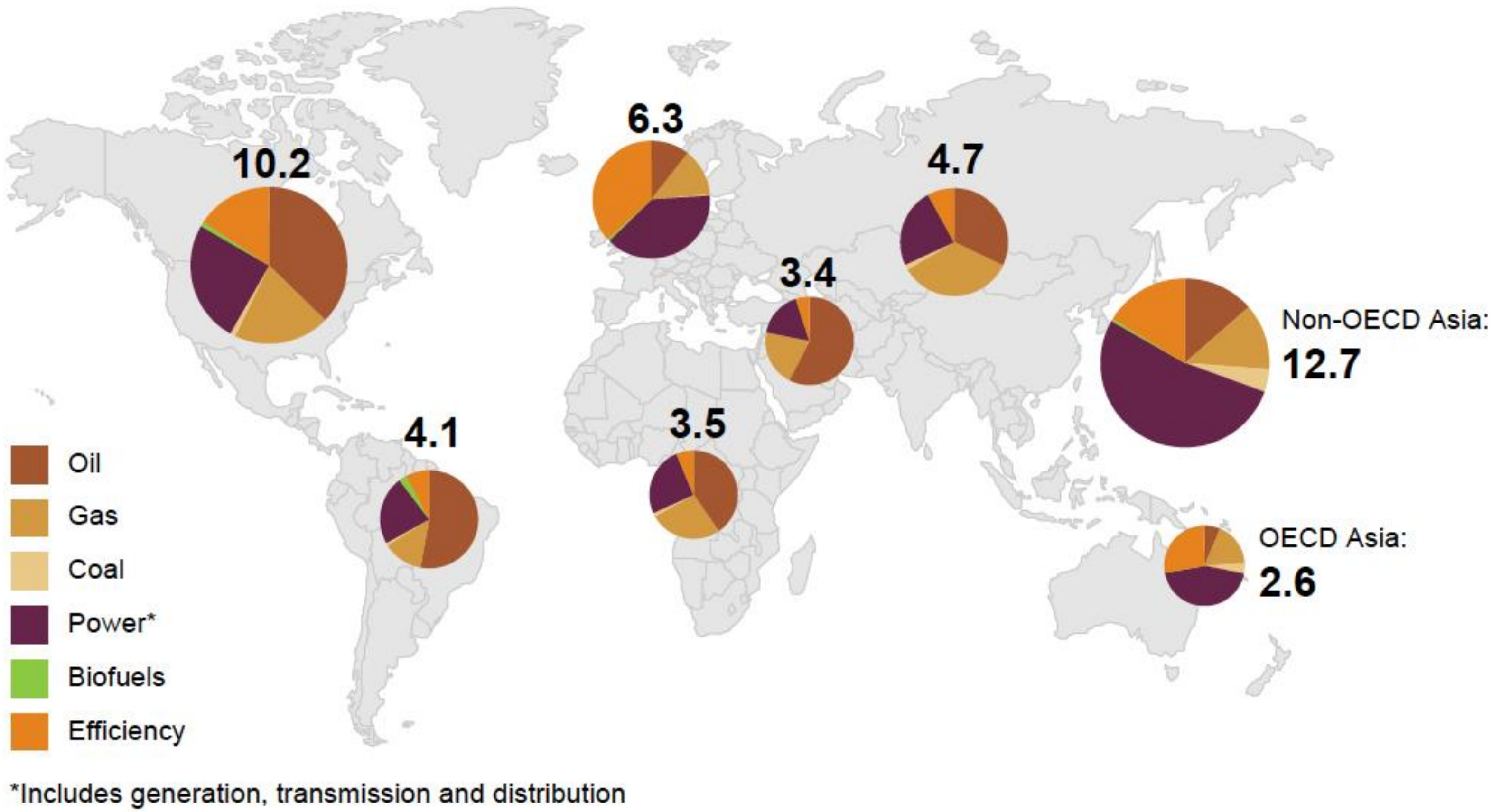
Understanding the risks in future energy development

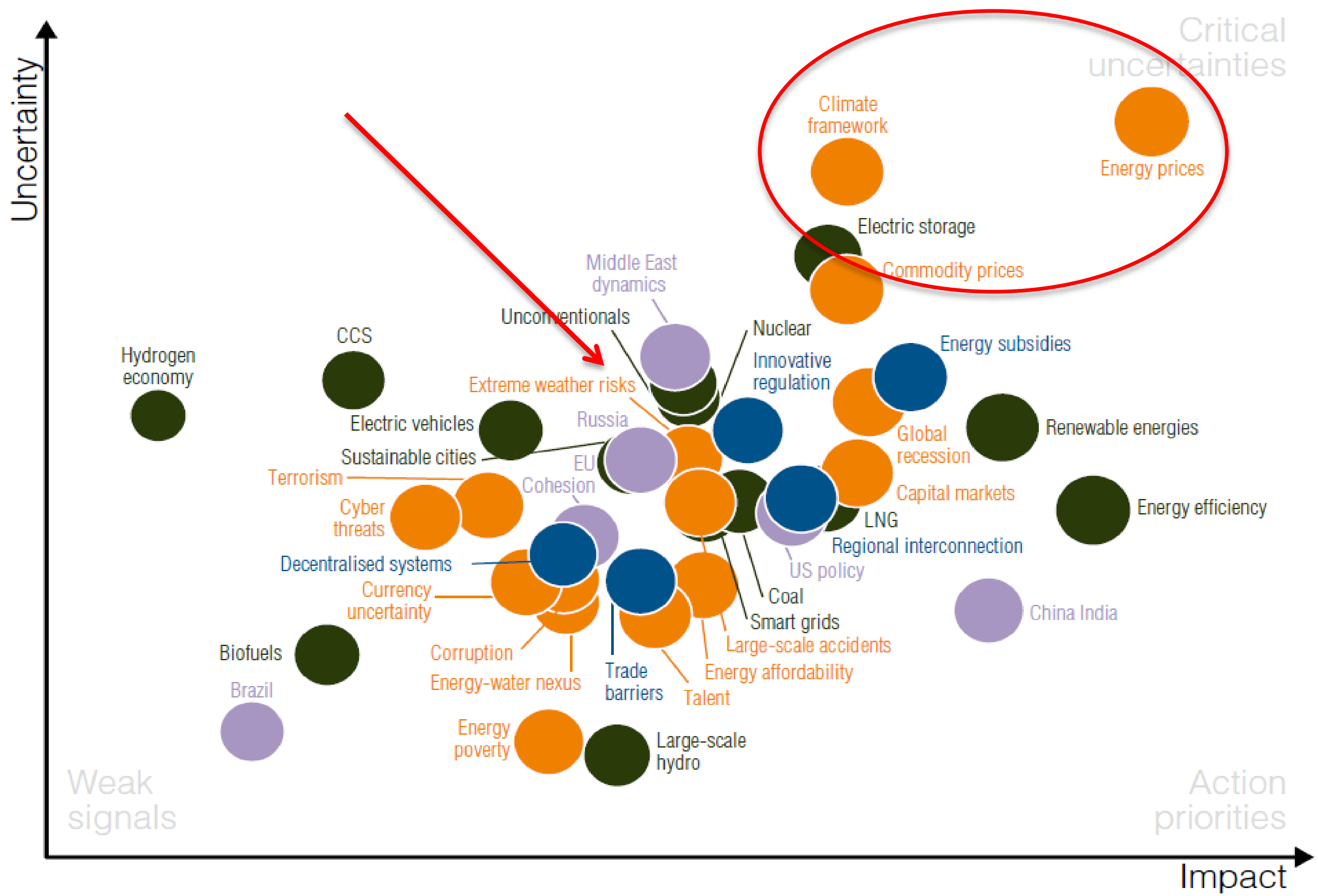
- Economist- worked in traditional forecasting, investment advisory services
- Doctoral work focused on long-term mitigation; how to transition towards more sustainable energy
- More and more difficult to only quantitatively understand energy consumption and production
- Moved to World Energy Council to work on scenarios- important to understand the human factor and non-market factors
- What the future of energy looks like depends on our decisions today
- Key to this is risk mitigation and opportunity identification

Investment needs to 2035 (US $TRILLIONS)

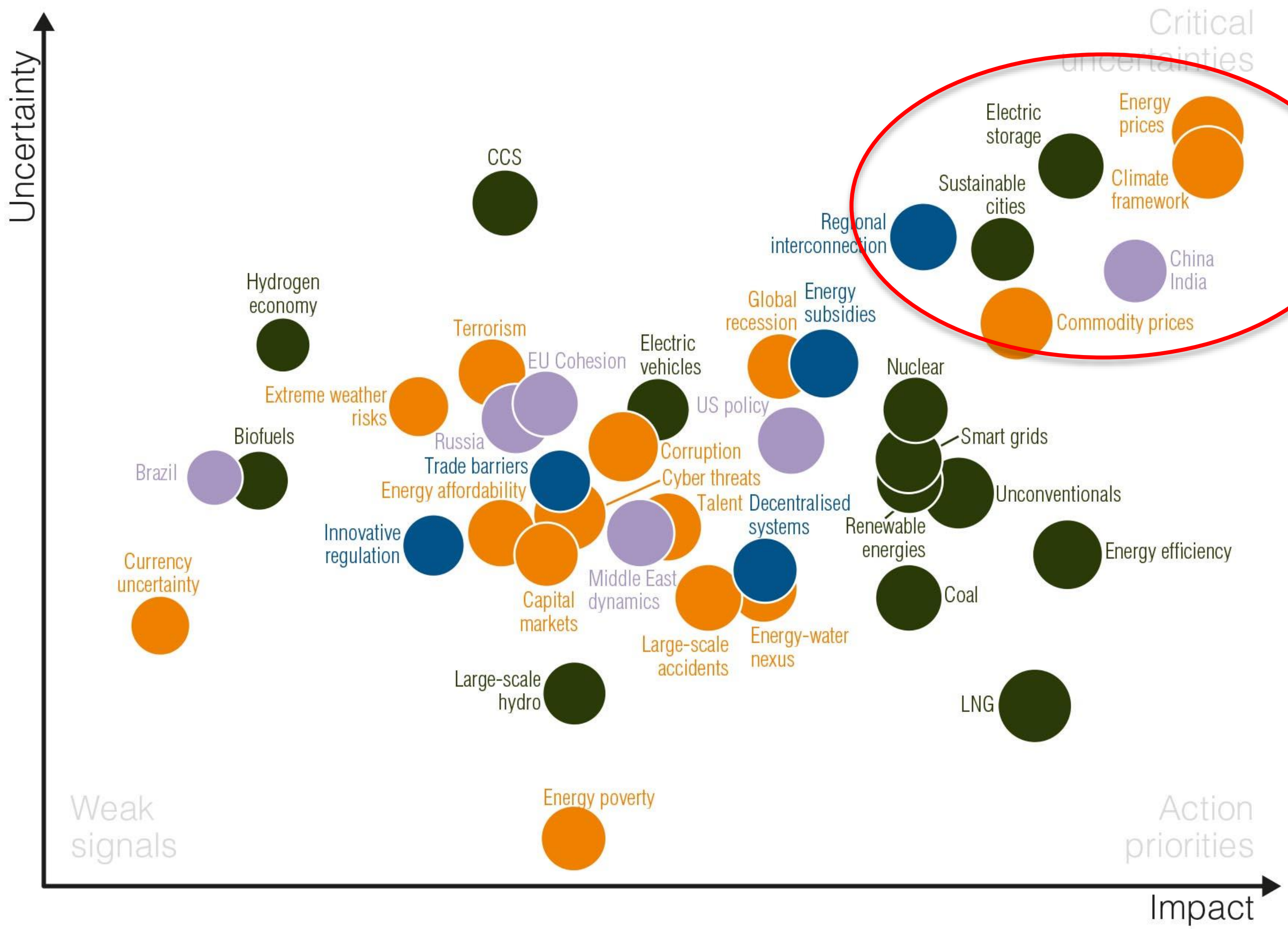


TOTAL NEARLY $50T DOLLARS

Issues Monitor: Global



Issues Monitor: North America



Risk mitigation in the energy sector

- Risk mitigation is about understanding the inputs and having the ability to accept the uncertainties at a project level and adapt to them
- Energy infrastructure needs to be continuously adaptable to the current environment
- Emerging risks need to be better understood:
  - to enable the development of appropriate technical and design responses and
  - To understand the financial implications.

What is at risk?

Meeting energy demands

Secure energy is critical to maintaining and driving economic growth.

Delivering social benefits

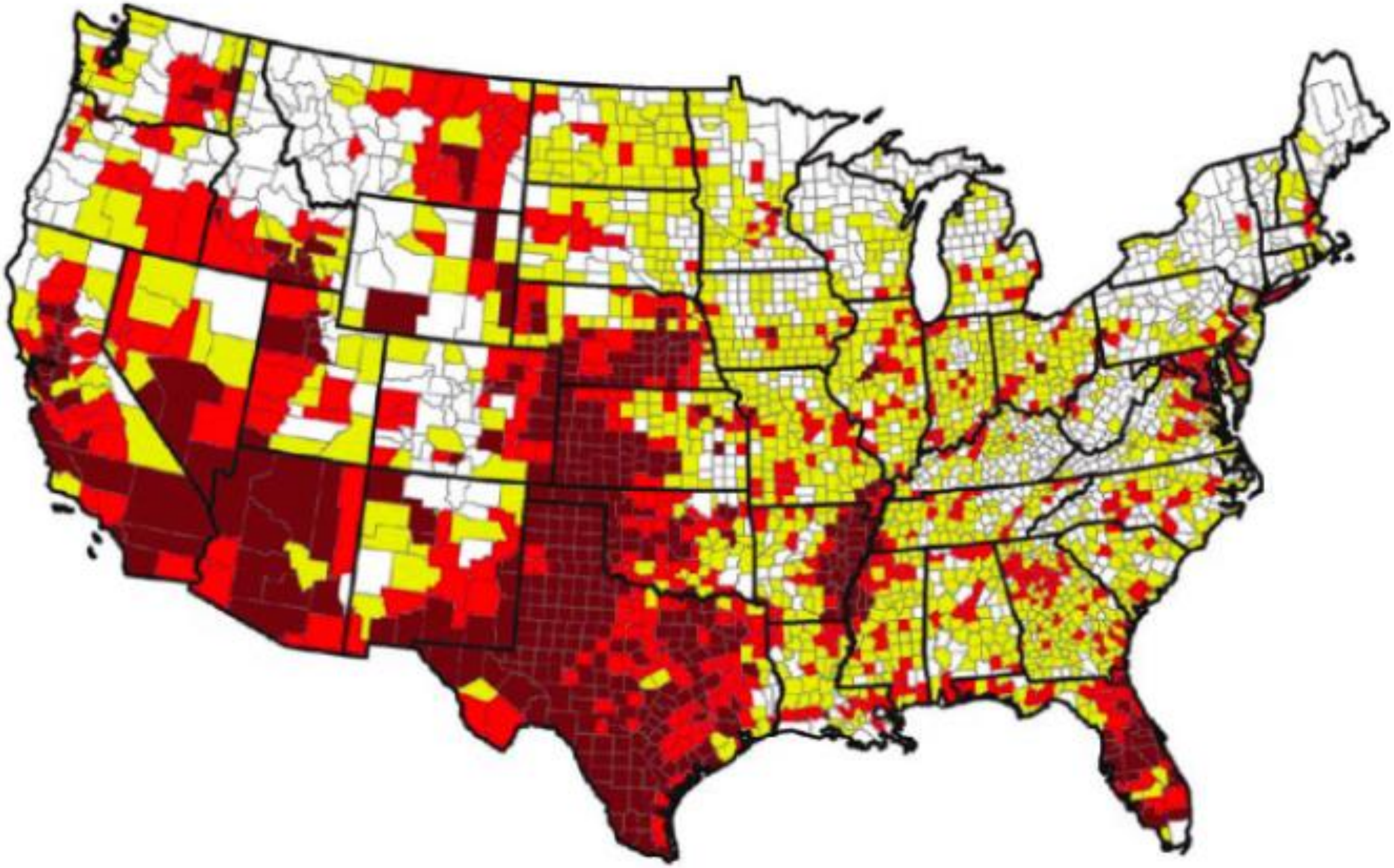
Energy must be accessible and affordable at all levels of society.

Minimising environmental impacts

The impact of energy production and energy use on the environment must be reduced.

Different drivers of change

Pre-determined	Factors that shaped world energy 1970 – 2015	Pre-determined elements 2015 – 2060
Population/ workforce	Global population grew 2x (1.7% p.a.)	Global population will grow 1.4x (0.7% p.a.)
New technologies	ICT revolution Productivity growth rate of 1.7% p.a.	Pervasive digitalisation; combinatorial impacts and productivity paradox
Planetary boundaries	1,900+ Gt CO_2 consumed	1,000 Gt CO2 consumed to 2100 for the 2°C target
Shifts in power	Rapid economic rise of developing nations Growing role for global institutions e.g. UNFCCC, IMF, WTO, etc. including G20	2030: India is most populous country 2035 – 45: China is the world's largest economy

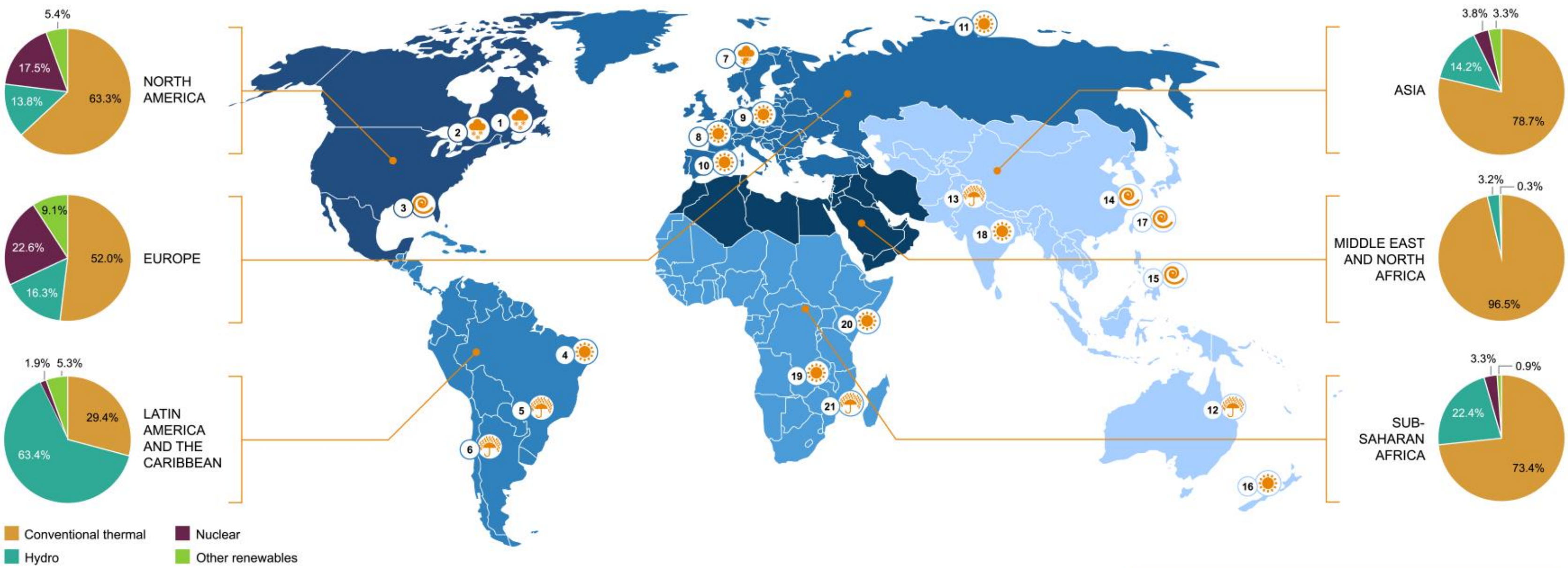


Water Supply Sustainability Risk Index (2050)

Low (929) Moderate (1192) High (608) Extreme (412)

TOTAL PRIMARY ENERGY SUPPLY BY REGION

(Source: World Energy Council)



EXAMPLES OF EXTREME WEATHER EVENTS AND THEIR CONSEQUENCES (1994–2015)

1 **EASTERN CANADA. January 1998**, ice storm toppled hundreds of transmission towers and downed 120,000 km of power lines.

2 **ONTARIO, QUEBEC. December 2013**, ice storm left 600,000 customers without power. Estimated total cost of the storm for the municipal electricity distribution company was CA$13 million including CA$1 million in lost revenue.

3 **US, GULF OF MEXICO. 2004–2005**, due to hurricanes, 126 oil and gas platforms were completely destroyed and 183 were damaged.

4 **BRAZIL. December 2014**, due to drought, biggest dams in Brazil were at 16% of capacity. Brazil relies on hydropower for over 80% of its electricity generating capacity.

5 **BRAZIL/PARAGUAY. November 2009**, heavy rains and winds caused transformers on a key high-voltage transmission line to short-circuit, causing 20 turbines of the world's second largest hydroelectric dam to shut down. An estimated 87 million people were affected by power loss.

6 **CHILE. March 2015**, torrential storms with the equivalent of 7 years' worth of rain in 12 hours left thousands without electricity due to impact on transmission lines and dam flooding.

7 **NORWAY. 2006**, a severe storm set adrift a drilling rig in the North Sea off the coast of Norway.

8 **FRANCE. July 2009**, due to a long-lasting heat wave, about 20 GW of France's overall 63 GW of nuclear power capacity had to be shut down forcing the government to import electricity from neighbouring countries.

9 **GERMANY. 2006**, the Isar nuclear power plant cut production by 60% for 14 days due to excess river temperatures and low stream flow in the Isar river.

10 **SPAIN. 2004–2005**, a drought reduced hydroelectric production resulting in losses of US$123 million.

11 **SIBERIA AND ARCTIC. 1994**, warming permafrost contributed to an oil pipeline spill of more than 160,000 tons. Correcting pipeline damage and deformations costs the Russian oil and gas industry US$1.8 billion annually.

12 **AUSTRALIA, QUEENSLAND. 2010–2011** deluges swamped coal mines, driving the cost of thermal coal burned in power plants to a 30-month high.

13 **PAKISTAN. September 2010**, flooding led to a month-long shutdown of the country's largest oil refinery, contributing to the country's electricity deficit.

14 **CHINA. August 2015**, a typhoon impacted hydropower production, and caused dam failure which led to further environmental and economic devastation.

15 **PHILIPPINES. November 2013**, Typhoon Haiyan crippled critical infrastructure including transmission and distribution lines. The cost of rebuilding is estimated at more than double the Philippines' GDP.

16 **NEW ZEALAND. March 1998**, a failure of four high-voltage transmission cables, partly due to high demand caused by hot weather and less-than- optimal operating conditions due to high soil temperature and dryness. The event cost the utility NZ$128 million plus costs arising from associated lawsuits.

17 **TAIWAN. August 2015**, Typhoon Soudelor caused power outages for more than 3.22 million households in Taiwan, the biggest power loss ever to result from a typhoon in Taiwan's history.

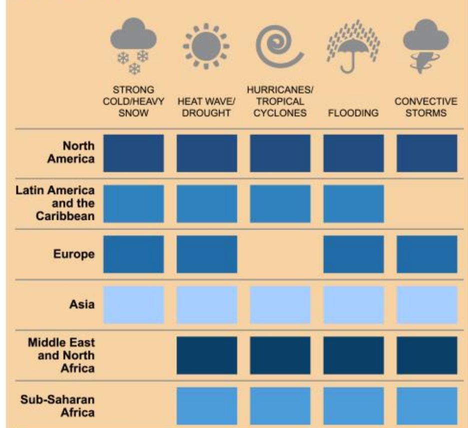
18 **INDIA. July 2012**, a heat wave led to high energy demand and triggered the largest electricity blackout in history affecting 670 million people, about 10% of the world population.

19 **ZAMBIA. June 2015**, a drought led to decreased water levels at hydroelectric plants and cuts of nearly 25% of the country's electricity generation.

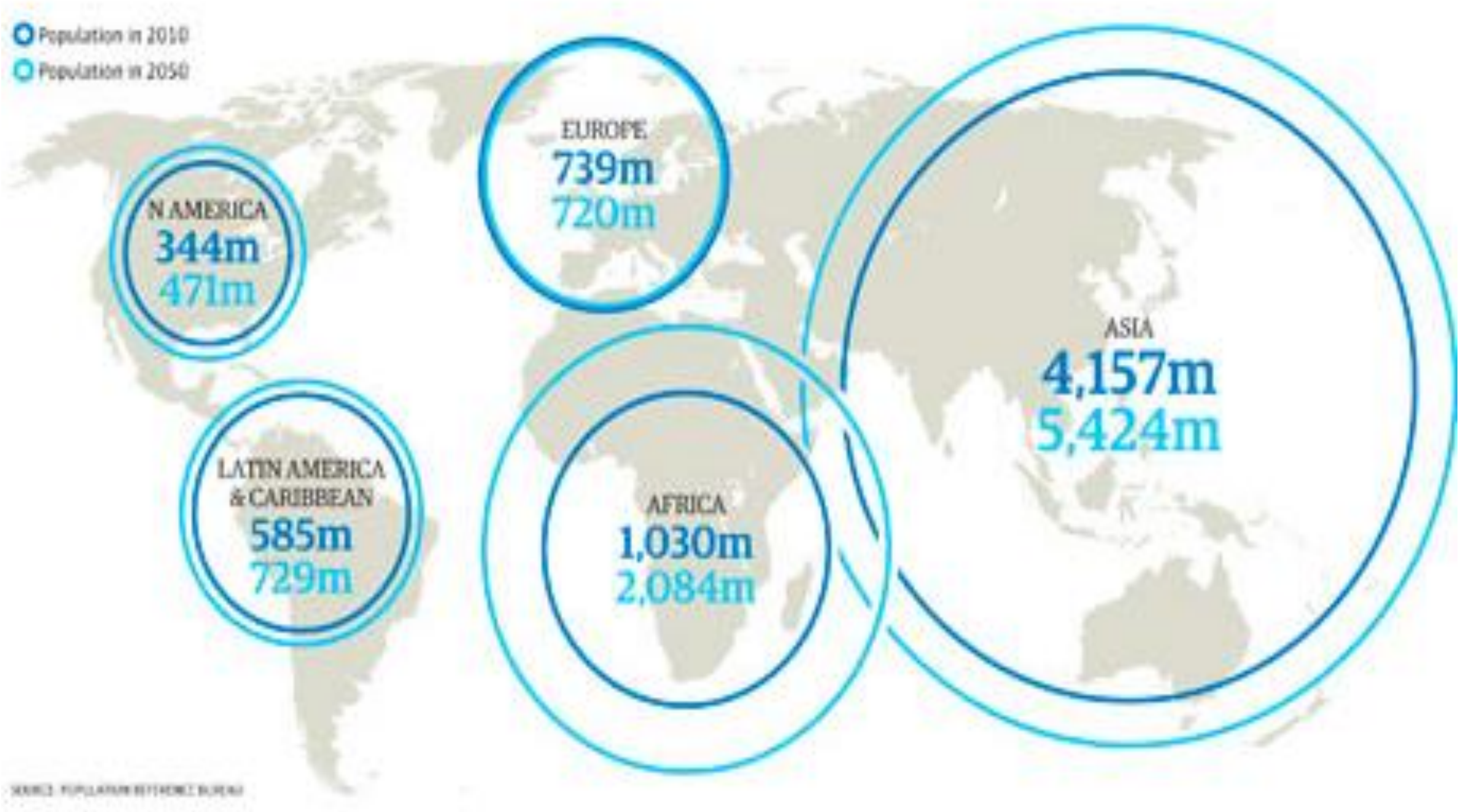
20 **KENYA. 2009**, a drought led to two months of power rationing as more than 30% of electricity generation came from hydropower at the time.

21 **MOZAMBIQUE/SOUTH AFRICA. January 2013**, flooding in Mozambique cut power exports to South Africa by half as key power lines to South Africa were damaged.

TYPES OF EXTREME WEATHER EVENTS BY REGION



Changing demographics



Trade-offs become more complicated

Risk landscape is changing

3 USA, 2012

POWER GENERATION

Human error // virus

A US power utility's ICS was infected with the Mariposa virus when a 3rd-party technician used an infected USB drive to upload software to the systems. The virus resulted in downtime for the systems and delayed plant restart by approximately 3 weeks.

4 USA, 2013

NON-ENERGY INFRASTRUCTURE

Malware

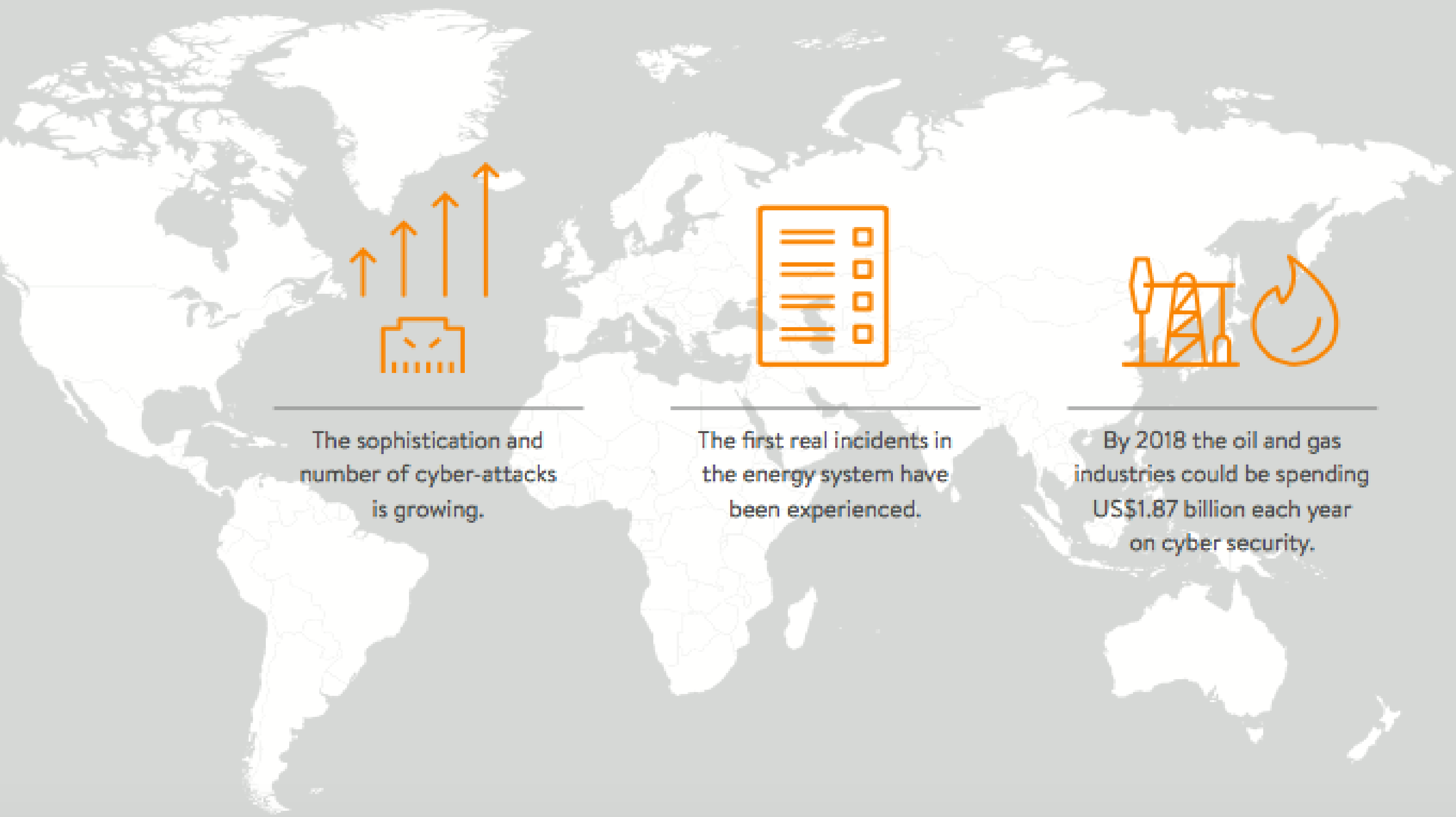
The small Bowman Avenue Dam, near New York City, is used for flood control rather than power generation. Hackers gained partial access to the dam's systems using standard malware, highlighting the vulnerability of all infrastructures.

5 UKRAINE, 2015

POWER GRID

Hacking // human error

This well-planned hack on 3 power-distribution companies caused outages to 80,000 energy customers. It is the first known hack to cause a power outage. The hack began with a spear-phishing campaign targeted at the companies' IT staff.



Developing resilient energy infrastructures

- Avoiding traditional design and moving towards smarter systems
  - Decentralized energy systems
  - Developing micro grids
  - Integrating more renewables into existing energy systems
  - Improving efficiency of existing infrastructures through upgraded cooling systems
  - Developing better uses of waste water
  - Big data or installing technology can help to improve these systems through monitoring measures

Financing new infrastructures

- This all comes with a huge price tag for the now and requires new thinking for the future
- Financial community needs further incentive, and guarantees, that investment will come to fruition
- Modelling needs to be updated and coordinated with better information
- Insurance needs regulation to be able to fill in
- Government cannot often afford, or agree, as to what to do
- Consumers do not think they should pay more

Building systemmic resilience

- Stakeholders need to work together in new ways
- As we have flexible technologies, we need to develop flexible frameworks for resilience
- What is the role of the regulator? The consumer? The grid operator? The generator?
- Key to resilience is embracing technical creativity and approaching this with regulatory and financial stability