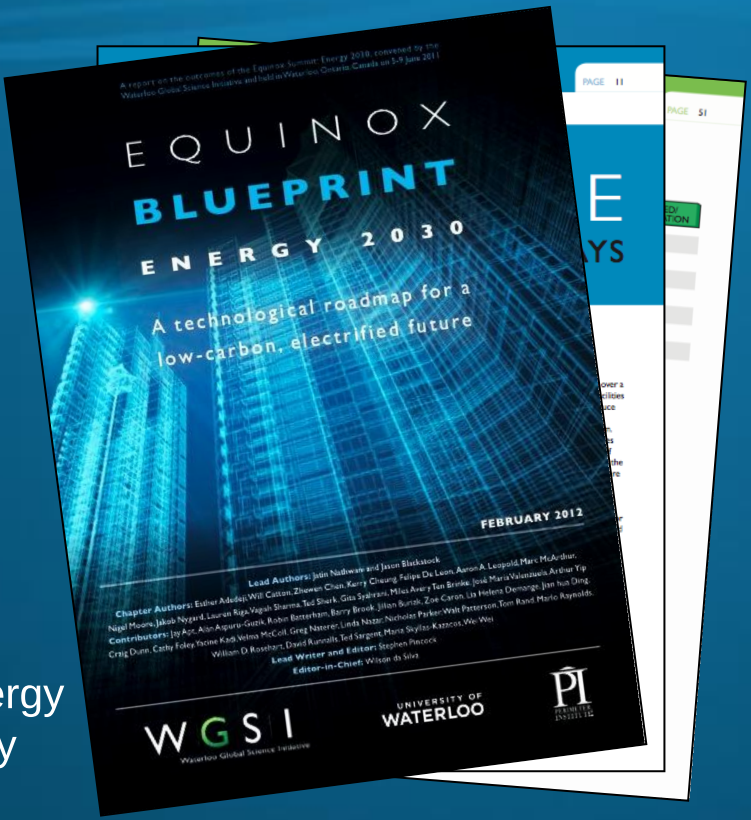
EQUINOX SUMMIT ENERGY 2030

Equinox Energy 2030: A technological roadmap for a low carbon electrified future



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Today's Goals

- Challenges
  - A View of Global Energy Transitions
- Innovation
  - Promise of scientific and technology innovation
- Bring coherence to a complex problem
  - Offer fresh thinking

Energy Transitions and the Global Challenge

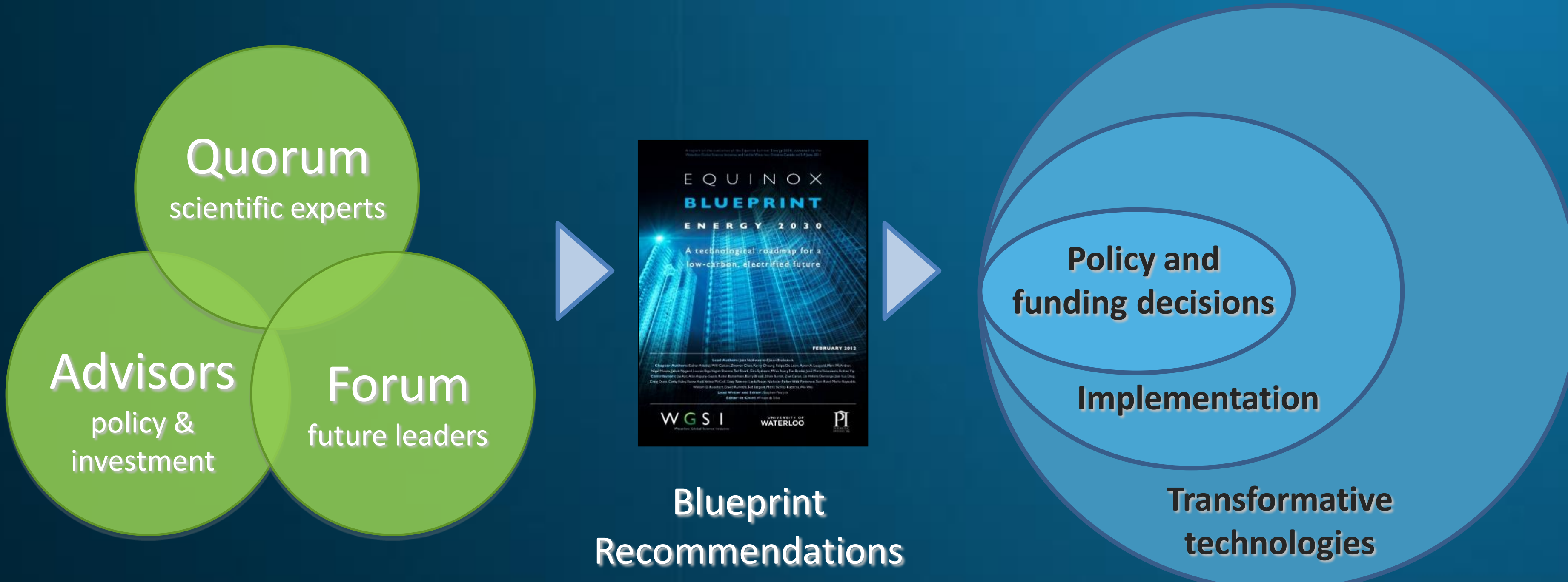
ENERGY 2030

- Today's **Global Energy Consumption: 16.5 TW**
  - of which **2.5 TW** is non-carbon (mainly hydro, nuclear..)
- By 2050: **30 TW**
  - Likely higher (31- 40 TW)
- By 2050: **15 TW** of new non carbon
  - Equal to 6 x today's renewable global capacity

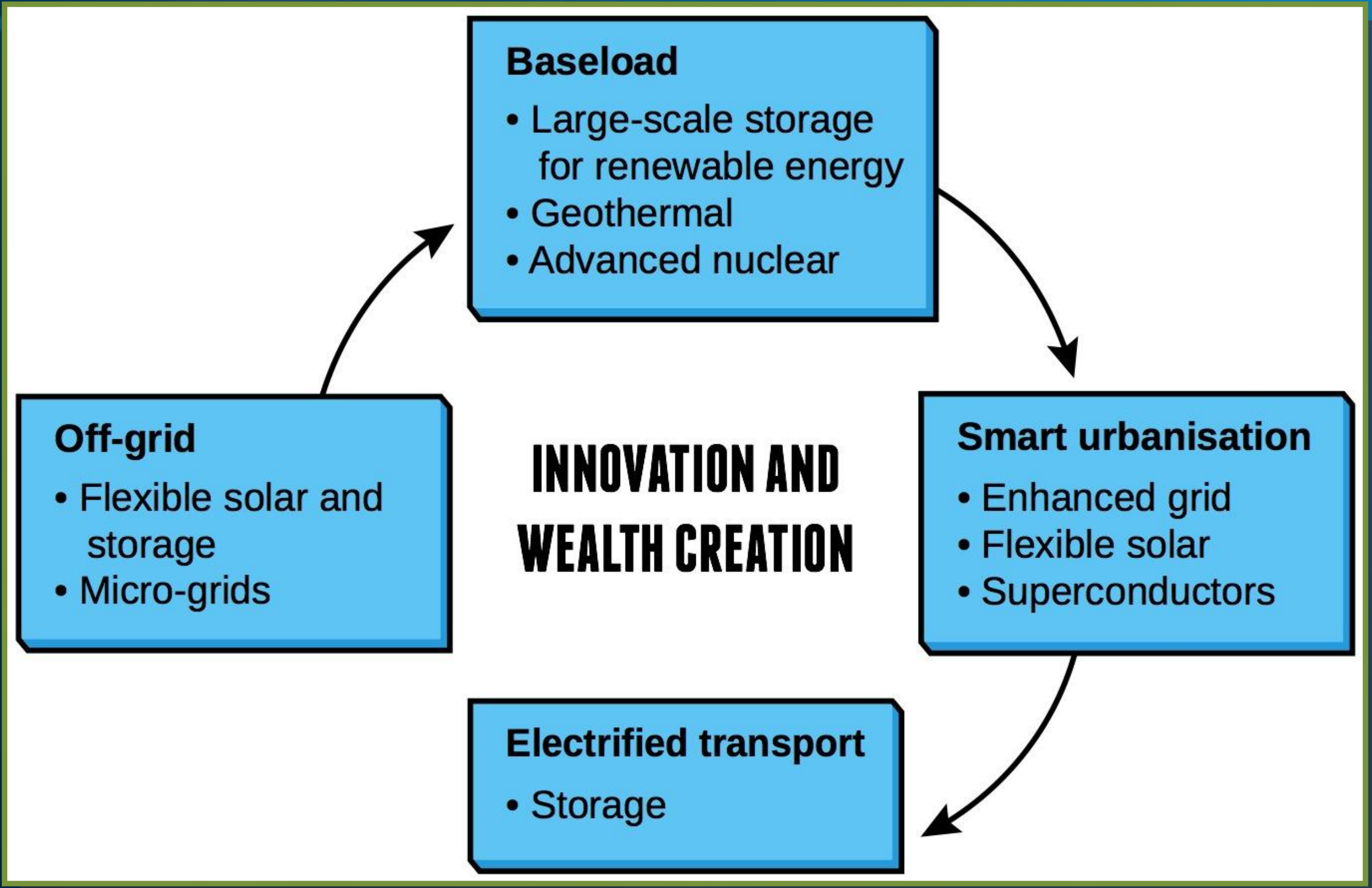
If goal is to stabilize global emissions profile to 550 ppm GHG emissions, approx 50% of Global Energy Demand must be non- carbon forms of energy

All new growth to be met by non-carbon sources

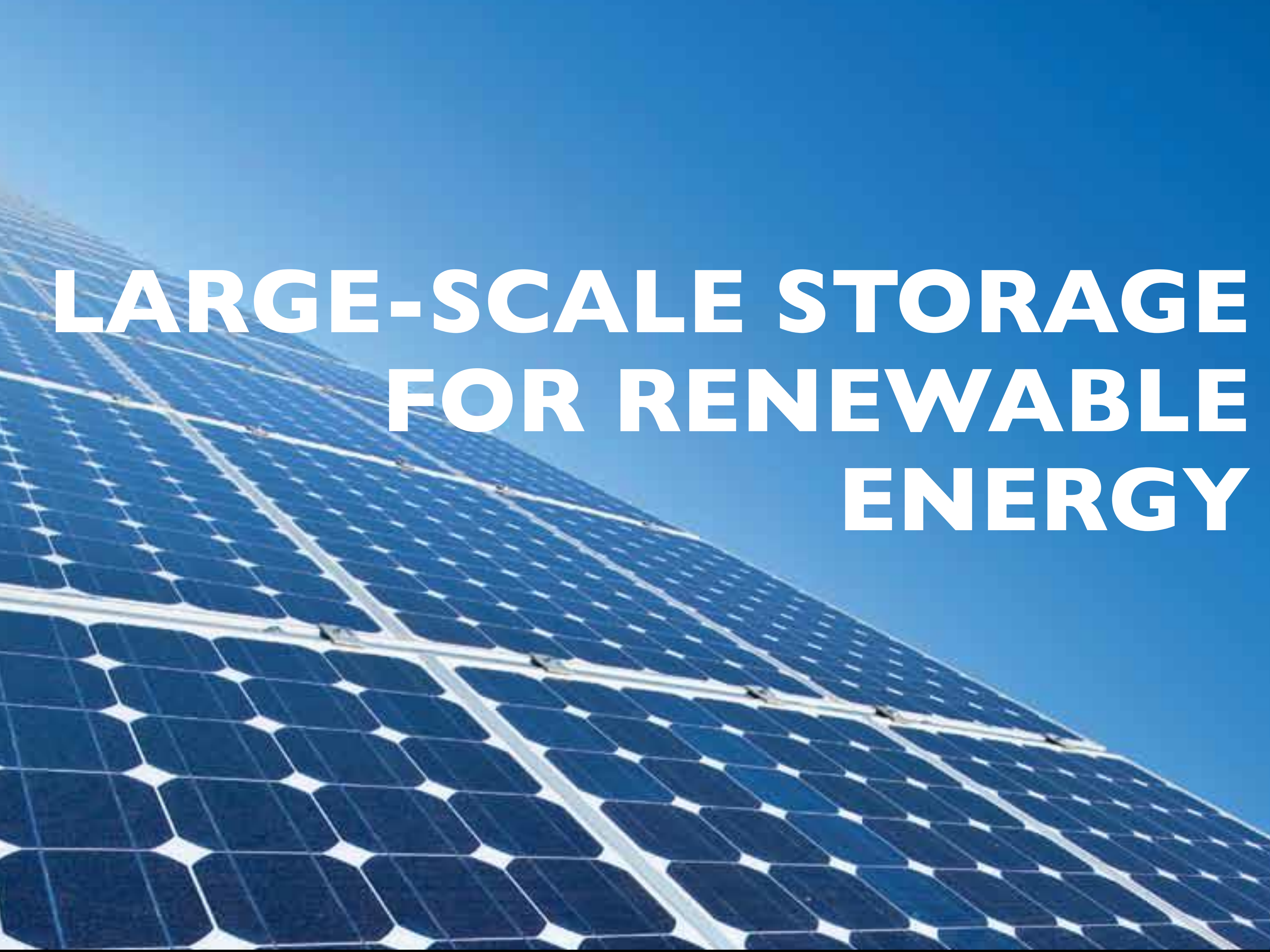
The Equinox Process



Low-Carbon Electricity Ecosystem

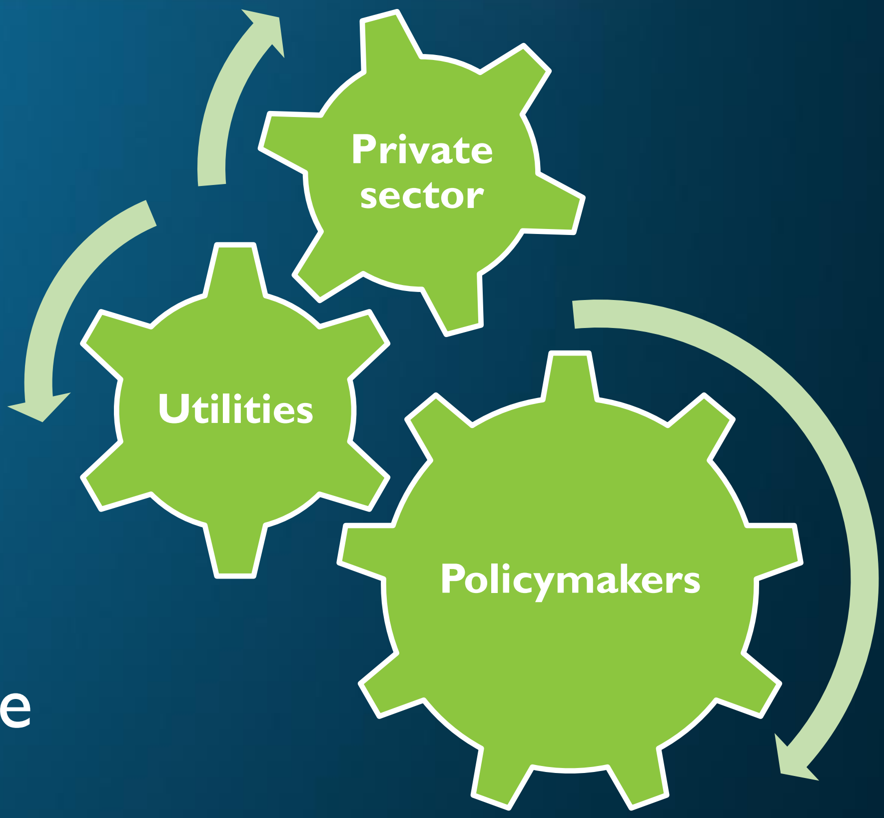


LARGE-SCALE STORAGE FOR RENEWABLE ENERGY



Implementation:
Large scale storage

- Regions with high intermittent renewable energy production
- Policymakers and electrical utilities to coordinate regulatory framework
- Private sector to build energy storage infrastructure



2020-2030

Establish a thriving market in energy storage through deployment on a global scale

Flow batteries are among many storage solutions that can enhance and amplify the value of intermittent and variable renewable resources for baseload integration. They are illustrative examples of what niche they can fulfill in terms of power and energy requirements for grid applications.

Electricity energy storage alone does not solve all the problems associated with the grid integration characteristics of renewables. Transmission and distribution systems, and ancillary services, are responsible for managing the flow of electricity. However, storage provides a well-established time dimension solution, critically strengthening power quality and reliability from renewable generation.

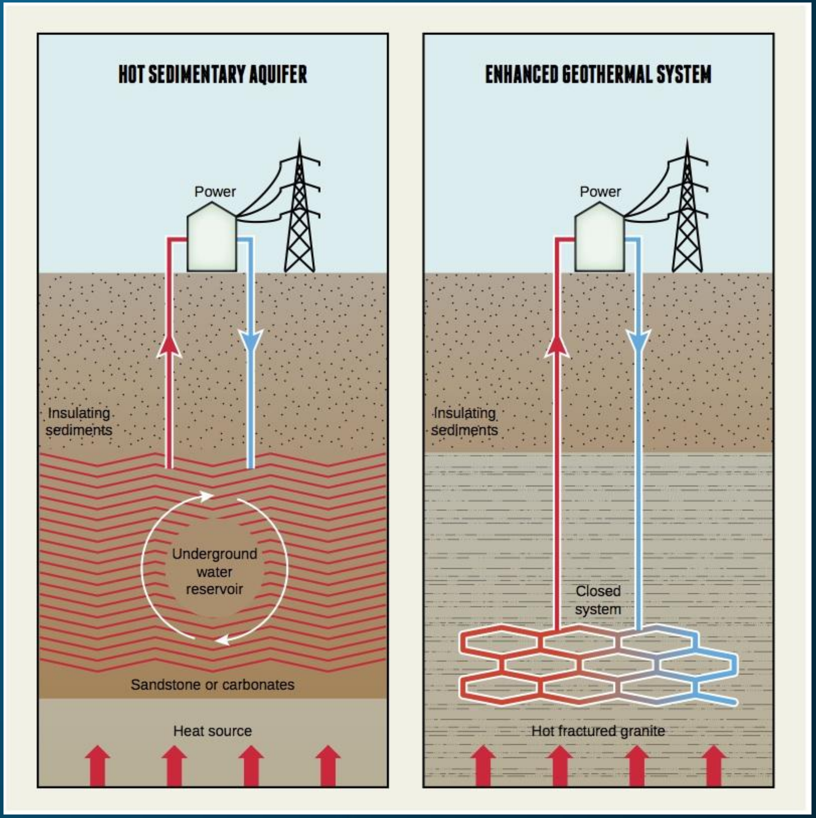
The Krafla geothermal power plant in Iceland produces 60 MW of energy. Iceland's five major geothermal power plants produced approximately 26.2% of the nation's energy in 2010.

ENHANCED GEOTHERMAL POWER

Enhanced Geothermal Power

Geothermal technologies

- Enhanced Geothermal Systems (EGS)
- Co-produced systems
- Advanced binary-cycle plants



The Enhanced Geothermal Systems technologies stand out within the spectrum of geothermal energy resources because they can provide near-inexhaustible decarbonised baseload power.

For the large-scale commercial deployment of EGS, some economic certainty needs to be established. The barriers to geothermal development are not insurmountable, but there needs to be a basket of risk-diversifying approaches in place, as well as adequate development framework and strategy.

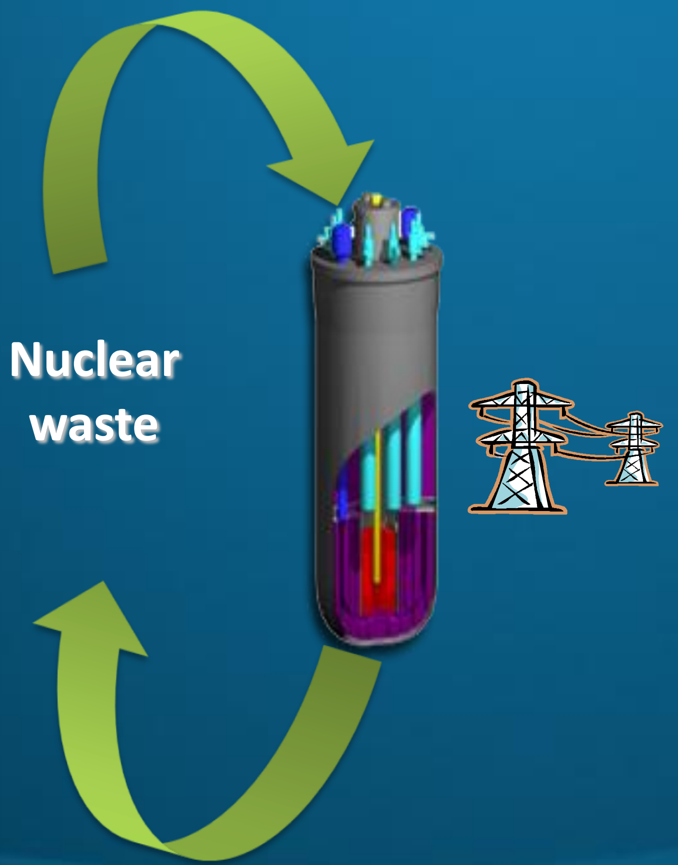
Implementation: Enhanced Geothermal Technologies

- Convene International stakeholders
  - Information sharing;
  - assess opportunities;
  - de-risk industry
- “Ten Enhanced Geothermal Projects’ is timely and relevant.
  - Initial funding and global working structure
  - Develop program strategy moving forward

ADVANCED NUCLEAR POWER

Challenging your assumptions about nuclear

- Nuclear waste is fuel
  - Avoids long-term storage
- Closing the fuel cycle
  - Inexhaustible supply
- Inherent safety
  - Public acceptance
- Decarbonizes base load
  - Eliminates coal



Advanced Nuclear Power

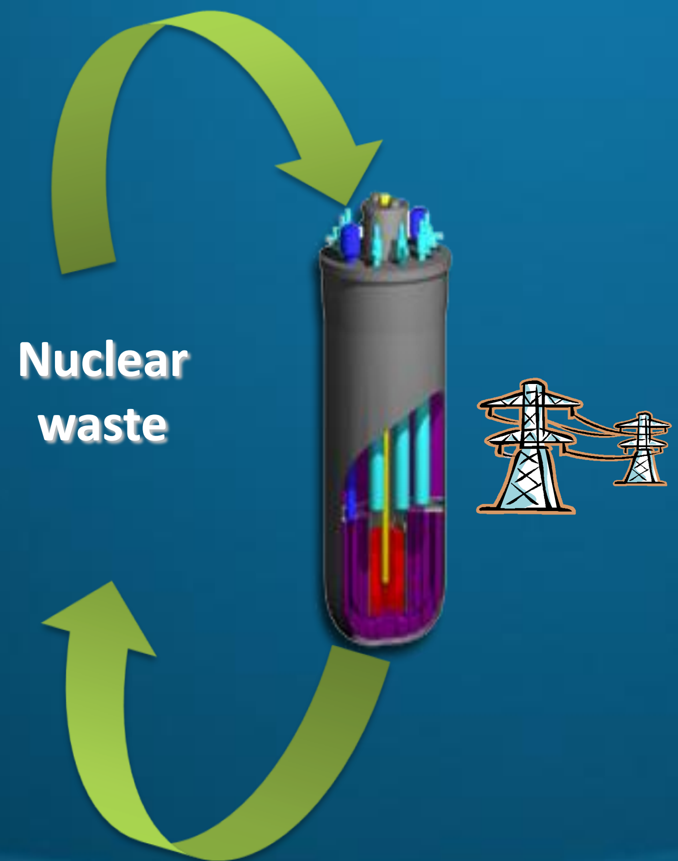
Next generation designs

- Integral Fast Reactors:
  - allow the nuclear fuel cycle to be closed
  - ‘burn’ most the nuclear fuel waste
  - turn waste liability into an asset
- Thorium Accelerator-Driven System:
  - sub-critical fission through the constant introduction of fast neutrons into the reactor core

The path towards sustainability

2020 | 2030 | 2040 | 2050

- 400 – 800 GWe
  - Business as usual, open fuel cycle
- 1200 GWe by 2030 / 7000 GWe by 2050
  - Accelerated alternative scenario
  - Only made possible by closing fuel cycle
- Commercial demos
  - IFR by 2020 & Th-ADS by 2030
  - Multilateral initiative scale of ITER



OFF-GRID ELECTRICITY ACCESS

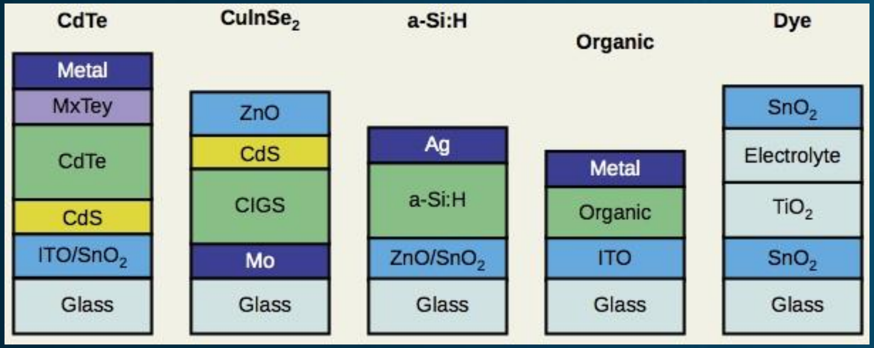
Access to affordable energy is a critical requirement for improving the quality and longevity of life for a significant portion of humanity.

Emerging solar technologies and renewables-based, self-sustaining energy options for communities have the potential to break the cycle of energy poverty, by evolving the energy economy away from fossil fuels.

Off-Grid Electricity Access

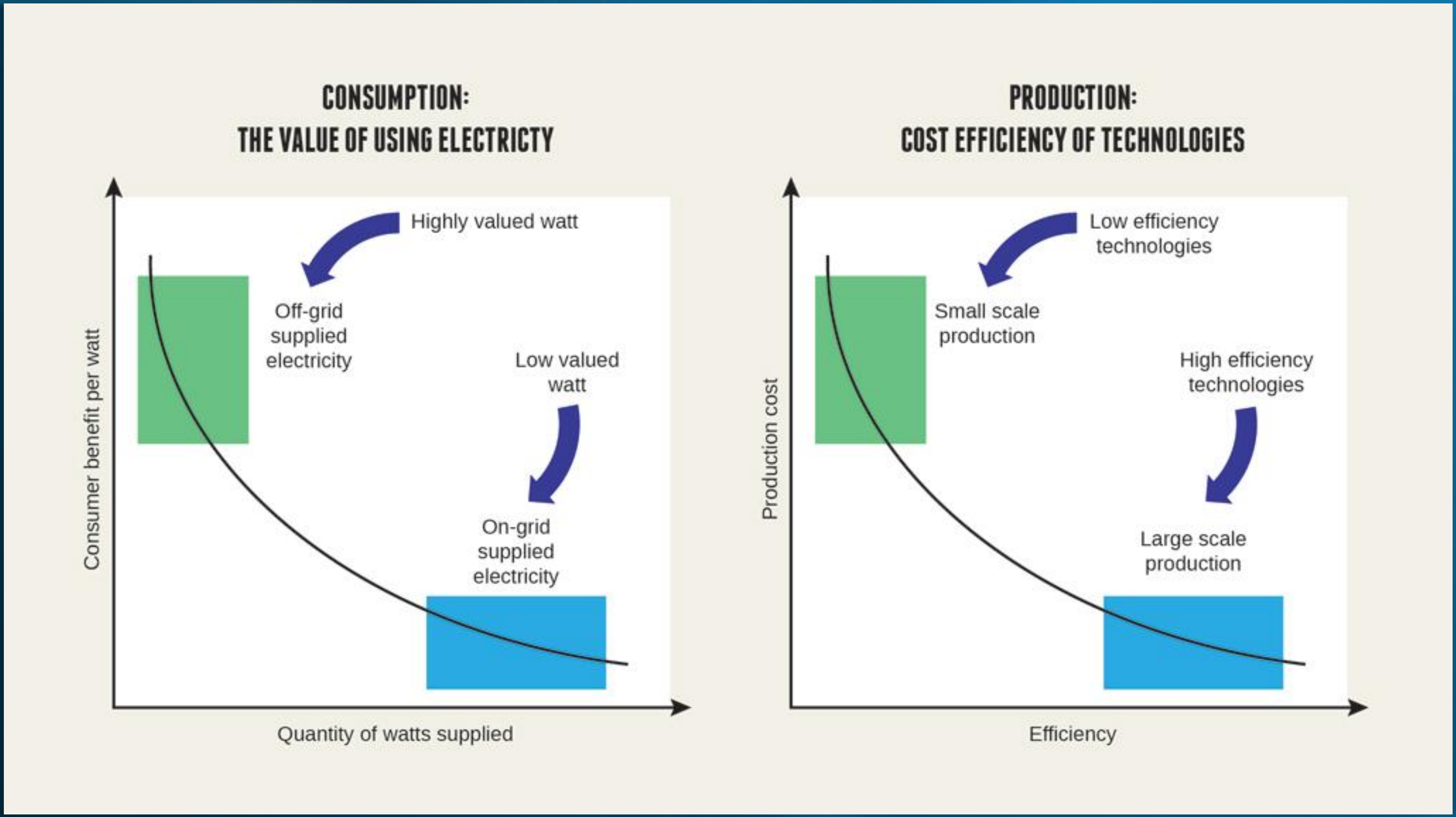
Organic Photovoltaics (OPV) as an illustrative example

- PV technologies in development form an ecosystem from silicon-based photovoltaics to thin films and emerging next-generation nanotechnology concepts
- They in turn are a part of a larger system with the potential to be integrated within smart micro-grids, along other local renewable resources



The thin film family: amorphous silicon, copper indium gallium diselenide (CIGS), cadmium telluride (CdTe), organic thin films and dye-sensitised integrated photovoltaic

Low WTP : High kWh use
High WTP : Low kWh use

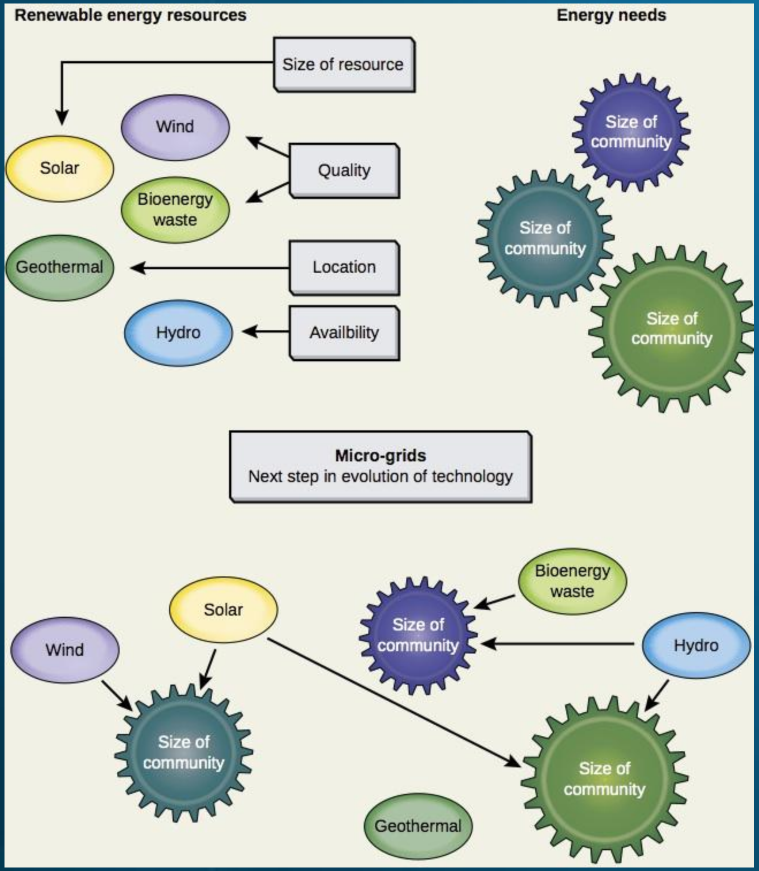


High WTP, Low kWh

- 2.5 billion people without electricity (500 million households)
- @$200/system, $100B
  - – Cost of systems being purchased now in Haiti

Off-Grid Electricity Access

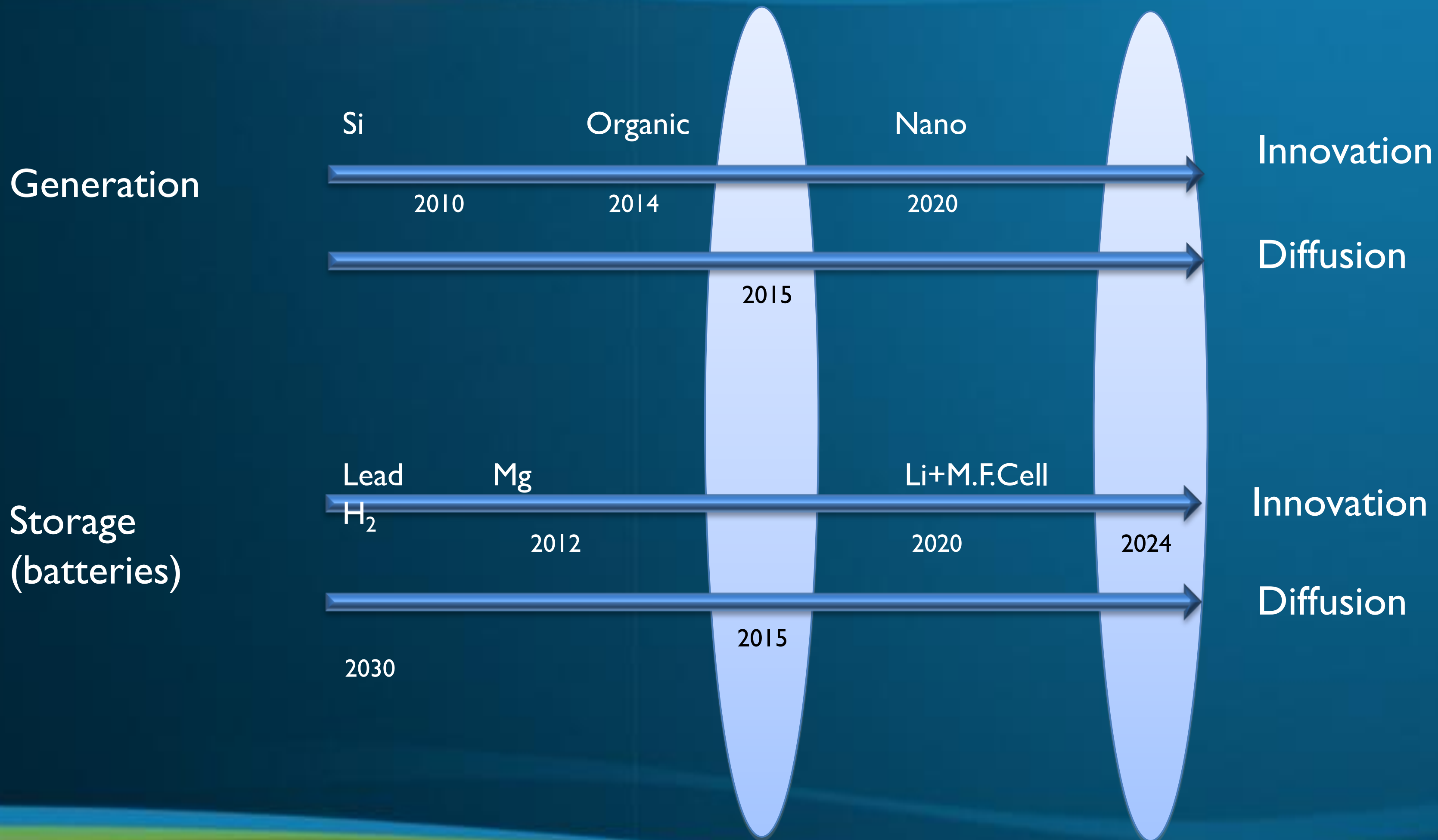
Beyond OPV: Micro-grids



Realistic Partnership Potential

Business/ Industry	Civil Society	Government	International Organizations
Digicel			UNFCCC (NAMAs) UNHCR Red Cross/Crescent Development Banks

Timelines



Generation
Si
Organic
Nano
2010
2014
2020
Innovation
Diffusion
2015
Storage
(batteries)
Lead
H_2
Mg
Li+M.F.Cell
2012
2020
2024
Innovation
Diffusion
2015
2030

Implementation: Off-Grid Electricity Access

Near-term
•Identify partners, align finances
•R&D, efficiency increases in Organic Photovoltaics

Within 5 Years
•Finances in place/business models developed
•Policy framework and incentives in place
•Societal acceptance and scale-up of production

Within 20 years
•Expansion of market
•next-generation Organic Photovoltaics

Chicago City Hall Green Roof.

Buildings

- 6 Billion people in urban centres by 2025
- Buildings emit 7.5 Gt CO_2 or equivalent 1.5 billion cars

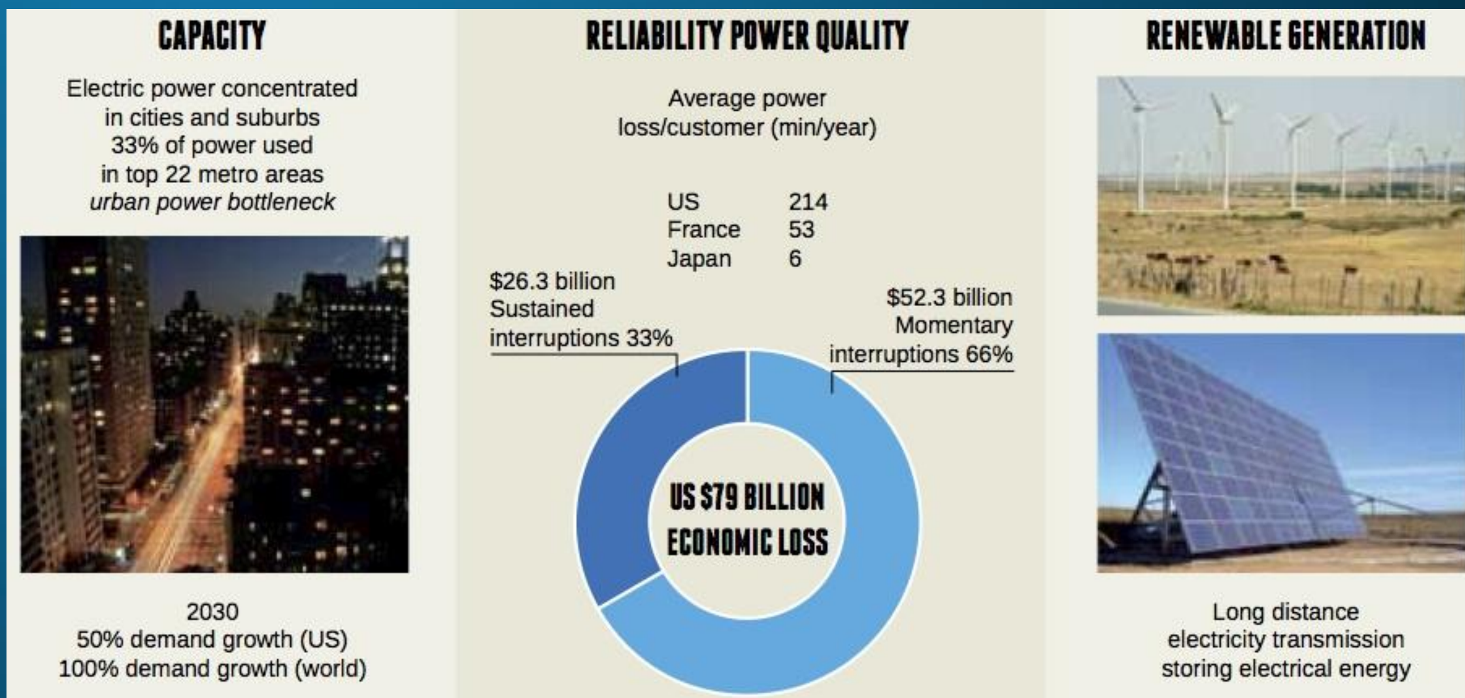
Smart Urbanization

- Need an intelligent infrastructure that can accommodate renewable energy solutions:
  - Matching load with renewable energy availability
  - Electrification of transportation

- Knowledge is literally power
  - Ability to influence future construction & design
  - Ability to influence behaviour now

Smart Urbanization

The growth of the electrification of transportation and the expansion of ICT will add stresses on the existing electricity distribution and supply infrastructure



Set of challenges in electricity transmission and distribution

Smart Urbanization: Conclusions

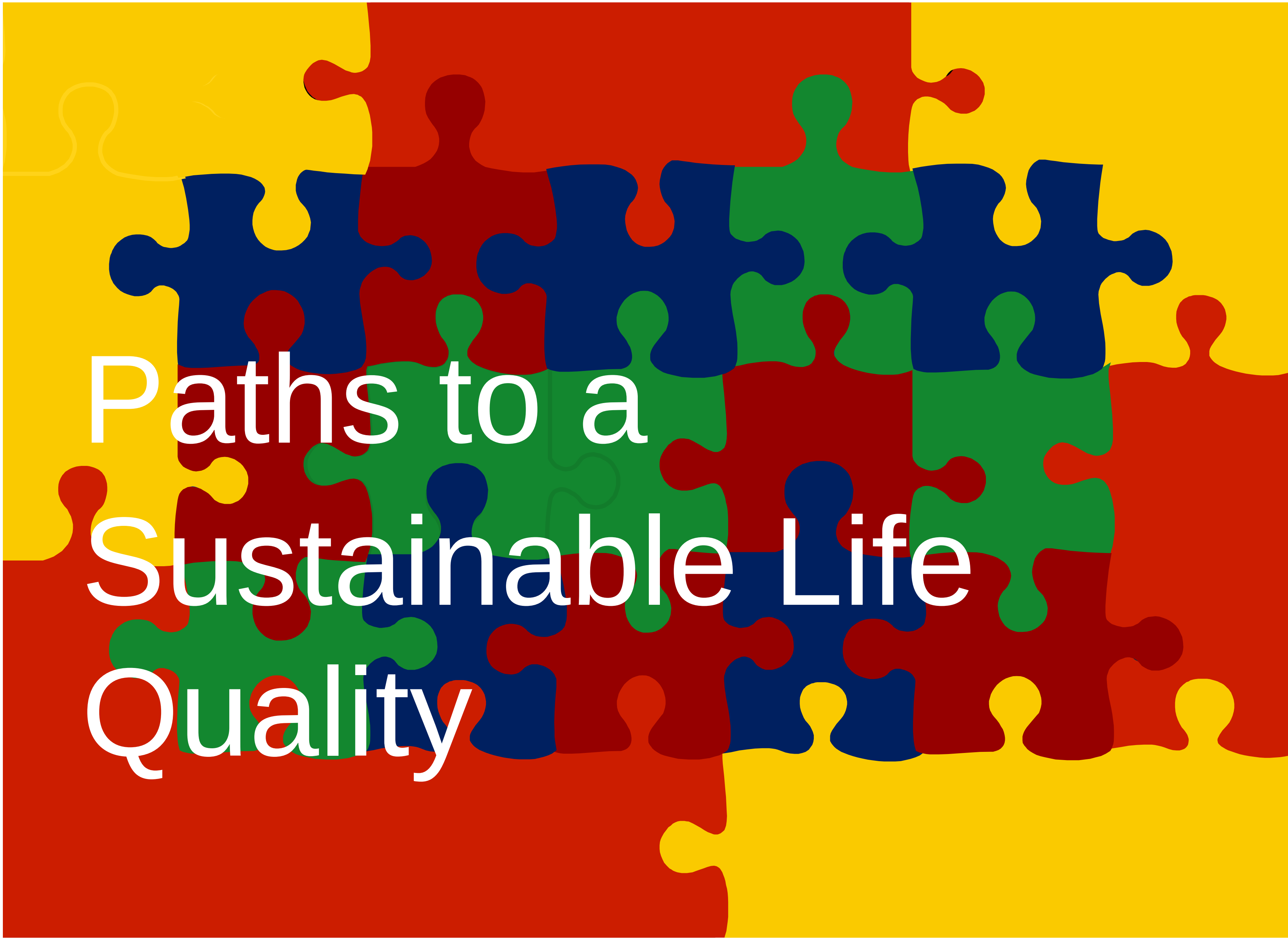
Smart Urbanization will require planning supported by:

- Smart Grid technologies integrated through ICT
- Electrification of Transport
- ICT to enable mobility in dense urban environments
- Superconducting technologies for reliable transmission in dense urban cores

Equinox Energy 2030: Summary

- An energy ‘ecosystem’ view to approaching possible, low carbon technologies
- Potential pathways identified to help research, development and implementation of long-term solutions
- Technical details help convey the complexities, challenges and opportunities posed by a few transitional technological systems.

Paths to a Sustainable Life Quality



WGSI

Waterloo Global Science Initiative

The Waterloo Institute for Sustainable Energy (WISE)

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