



Advanced Power Technologies: Will They be Ready When We Need Them?

Stephen Gehl
Director, Strategic Technology
Electric Power Research Institute
Palo Alto, CA, USA

Ph: +1 650 855 2770
E-Mail: sgehl@epri.com

Long Range Forecasting

“Fuel cell research is to be strongly recommended as a route to protecting the earth’s resources.”

-- Professor Wilhelm Ostwald, First Meeting of the Bunsen Society, 1897

Will the Technologies Be Ready for Commercial Application When We Need Them?

- Which technologies?
- With what performance characteristics?
- Will they be ready for large-scale application?
- At what cost/price?
- Who will pay?

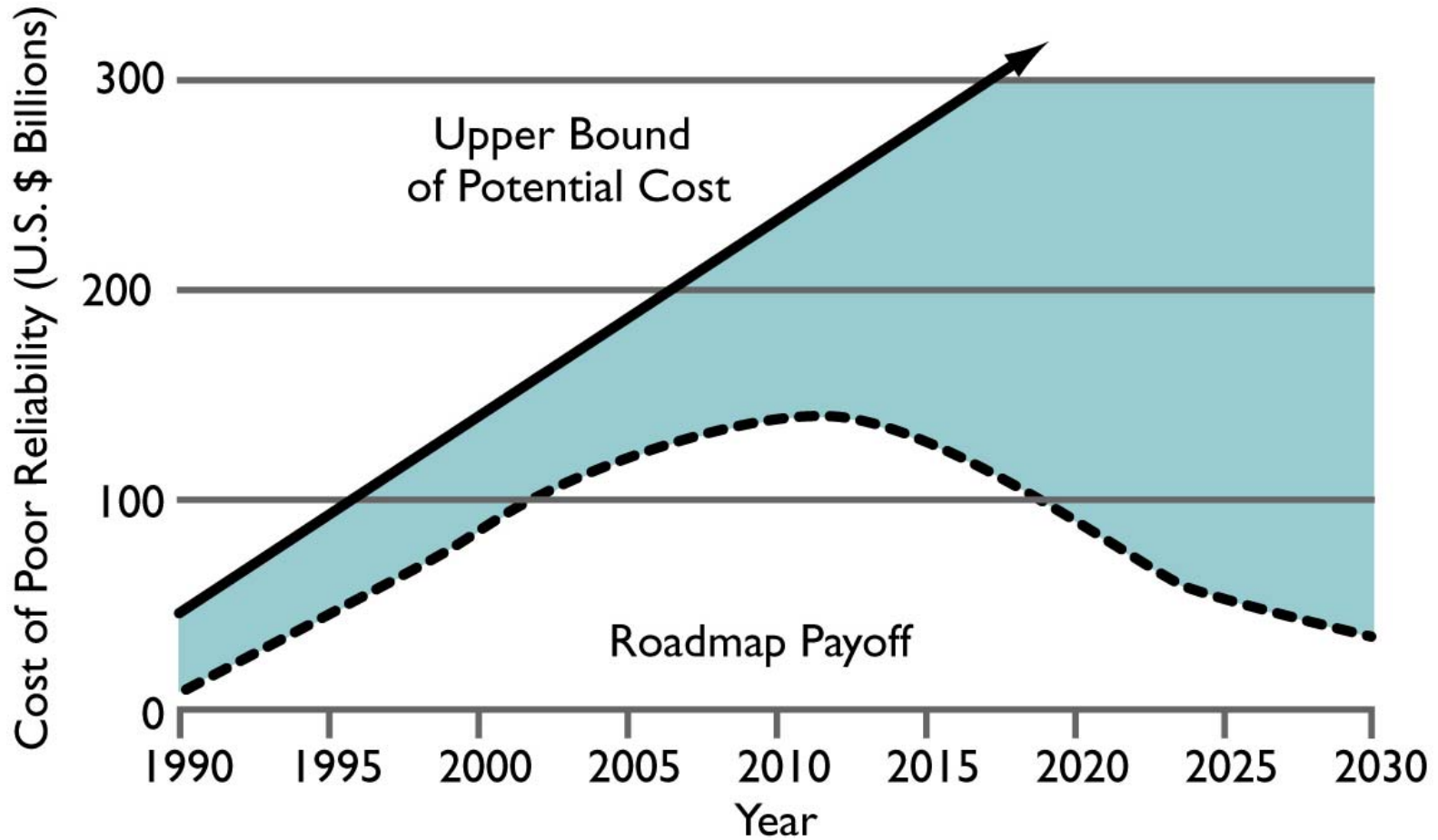
In this presentation, we will provide a few illustrative examples of how to address some of these questions and estimate the dates at which technologies are likely to become commercially available in large quantities.

We will also attempt to assess whether these availability dates match up with when the technologies will be needed.

Which Technologies are of Greatest Interest?

- **Smart Power** – design, development, and deployment of the intelligent power system of the future
- **Clean Power** – accelerated development of a portfolio of clean energy technologies to address climate change
- **Power for All** – development of policies and tools to ensure universal global electrification by 2050

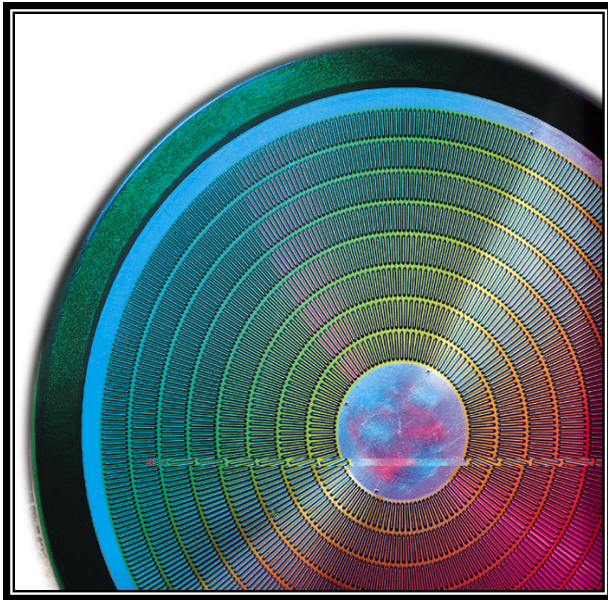
Smart Power



Source: EPRI

Technology Solutions: Flexible Power Delivery System

Flexible AC Transmission Systems (FACTS)



- A collection of electric transmission power flow and control technologies that have extremely fast time response capabilities
- Devices are based on very high-power solid state electronic switches
- Fast and continuous active control of the transmission network
- Allows for continental dispatch of transmission capacity
- Facilitates open access

Targets of Innovation

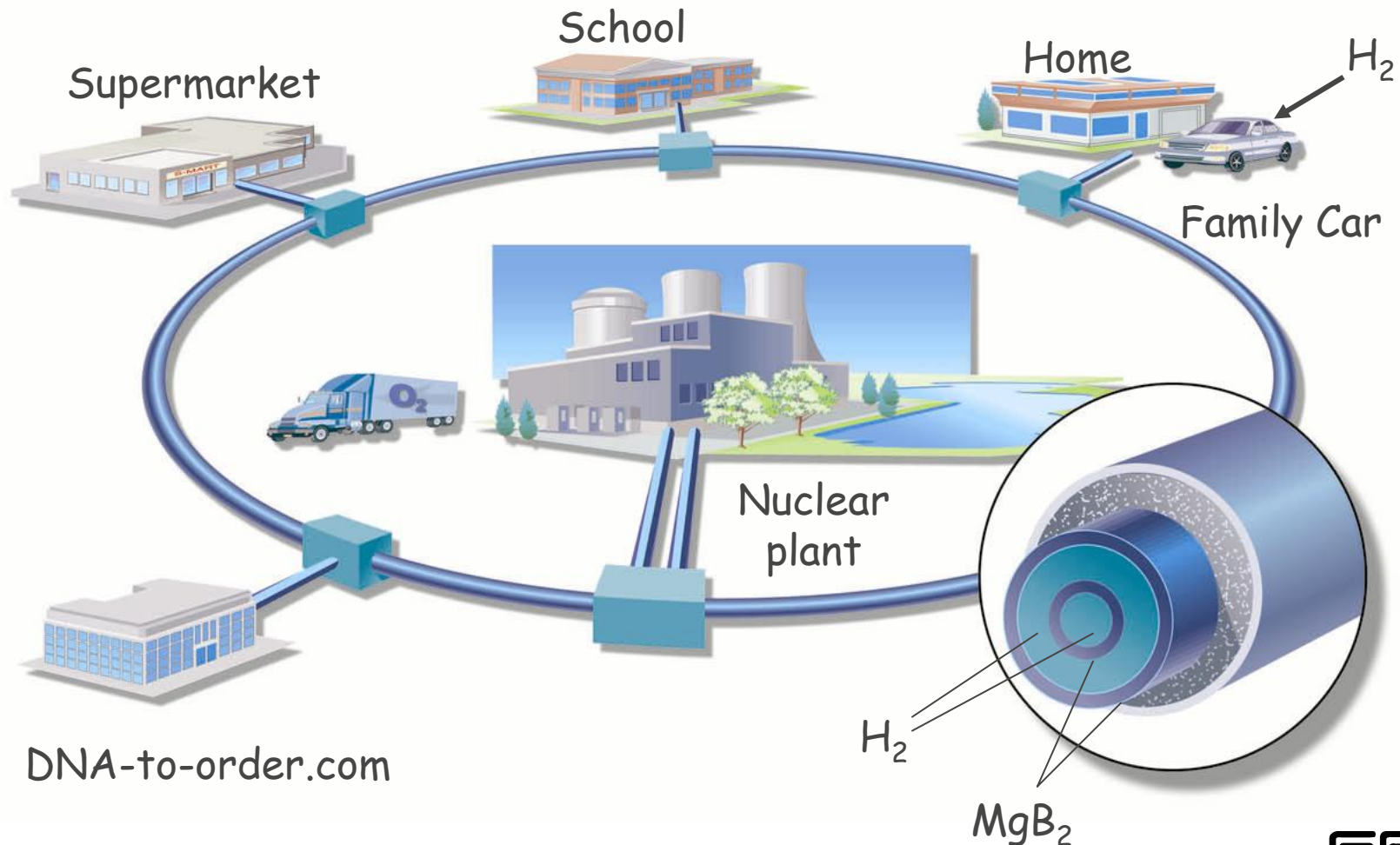


Power Electronics

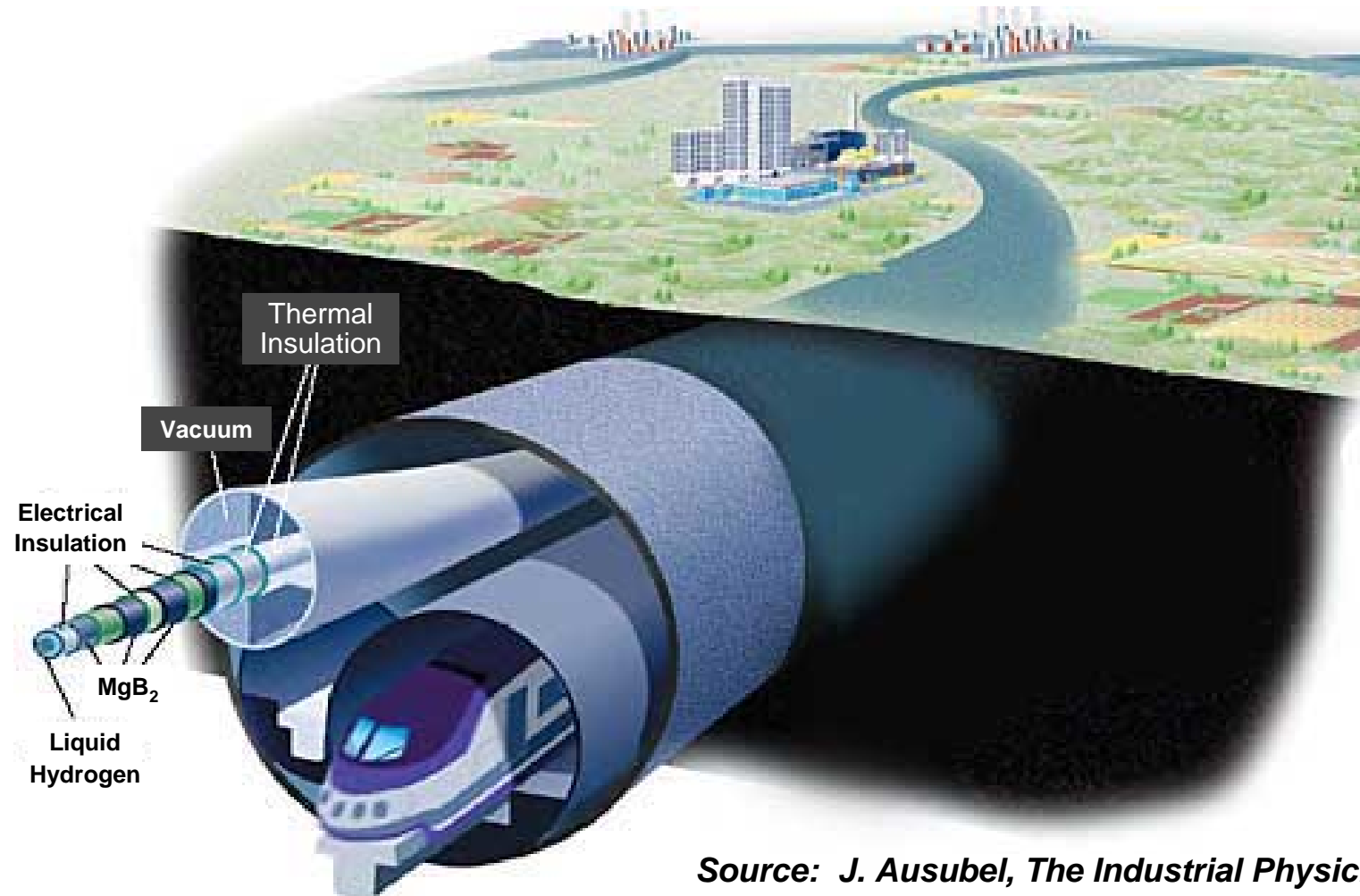


Superconducting Cables

Super Grid of the Future Integrates Superconducting Transmission with H₂ Energy Carrier



The Continental Super Grid, circa 2040



Source: J. Ausubel, *The Industrial Physicist*

Climate Change: Technologies that Fill the Gaps

Technologies that make sense anyway:

- End-use efficiency improvement
- Plant performance improvement
- Nuclear
- Renewables
- Biomass

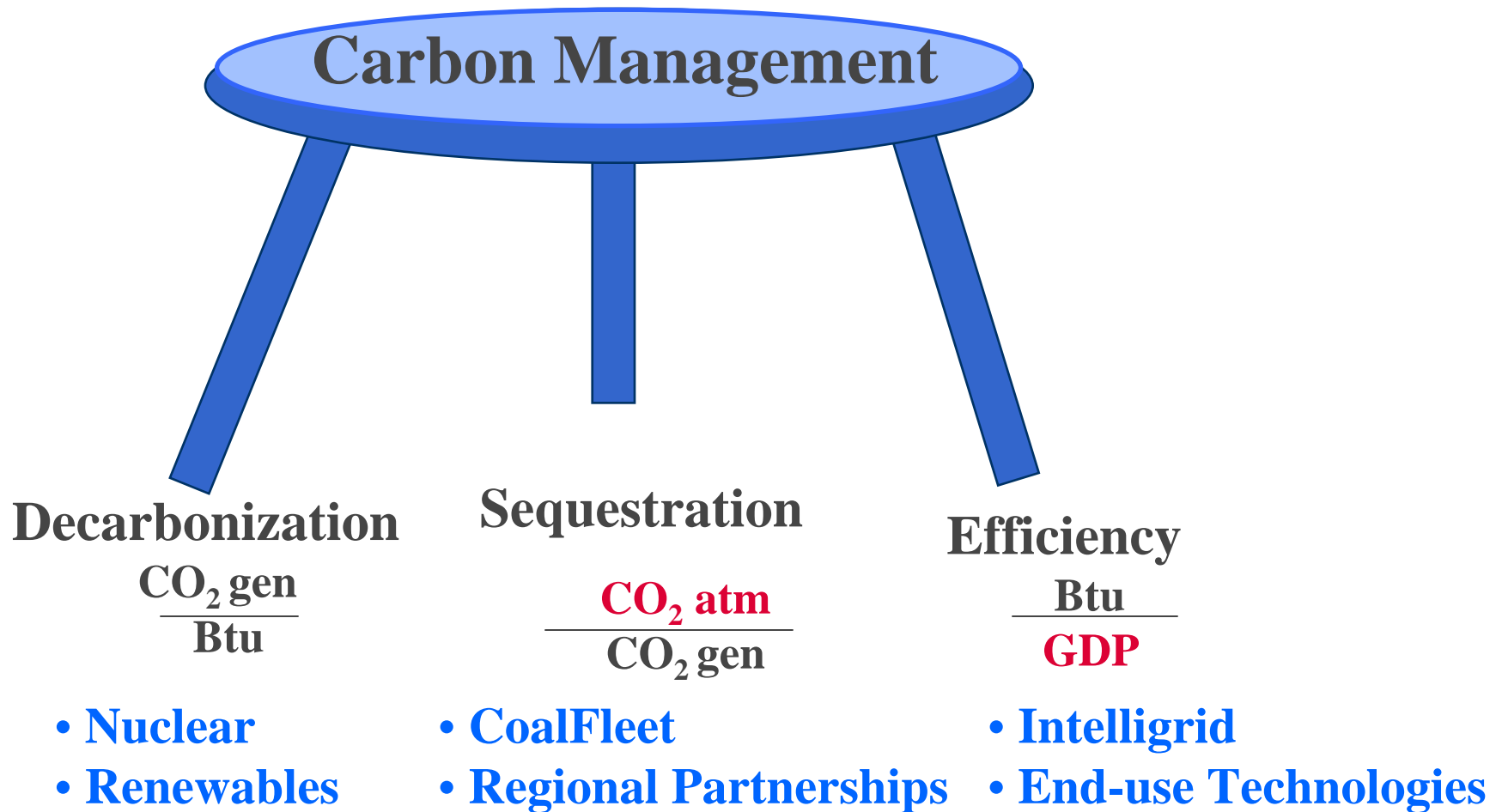
Technologies for a carbon-constrained world:

- Capture and disposal
- Tree planting and soil carbon enhancement

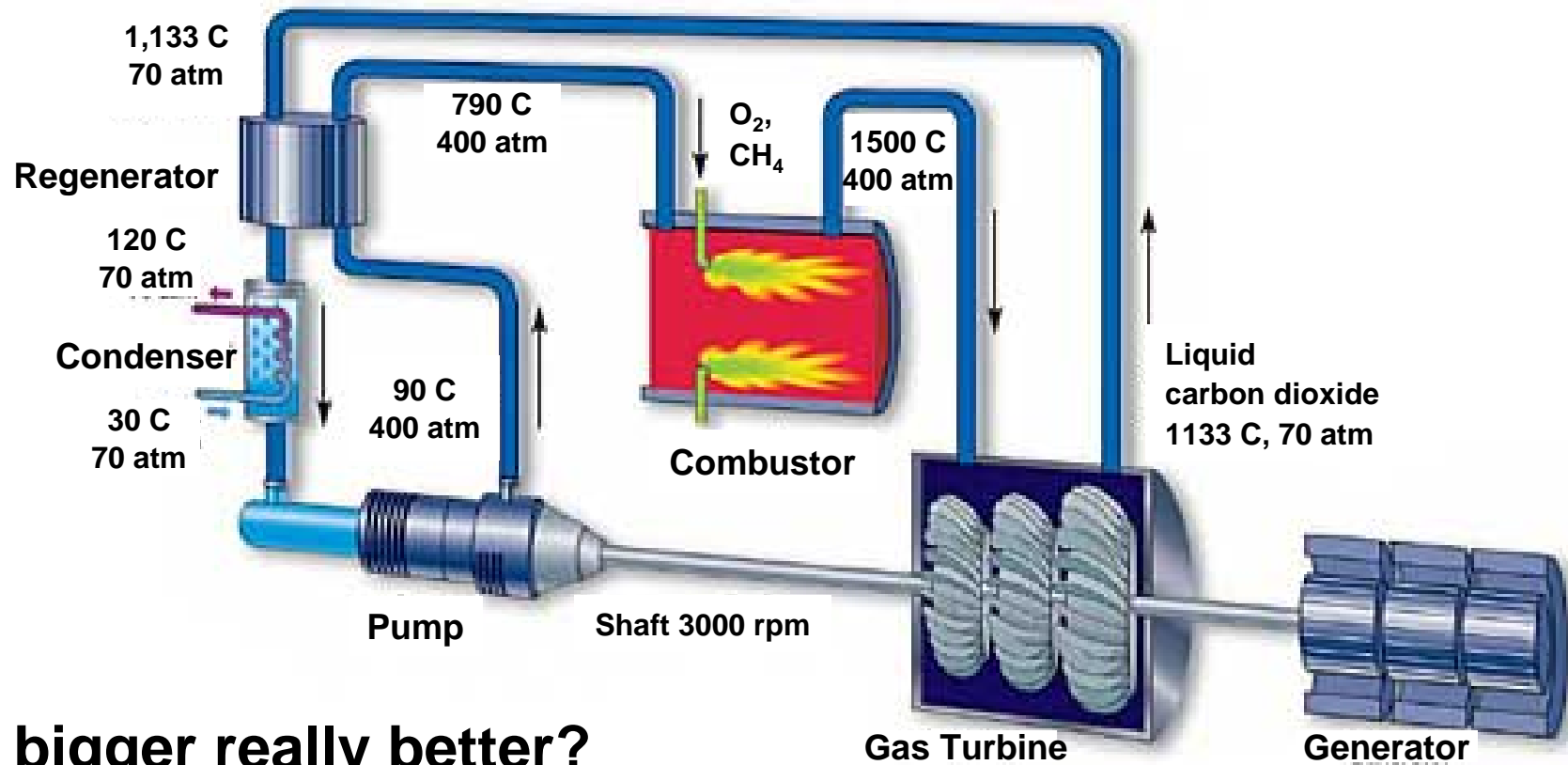
Technology Breakthroughs

- Zero Emission Power Plants (ZEPPs)
- Low-temperature water splitting
- CO₂ capture under ambient conditions

Carbon Management: Integrated Energy Systems R&D



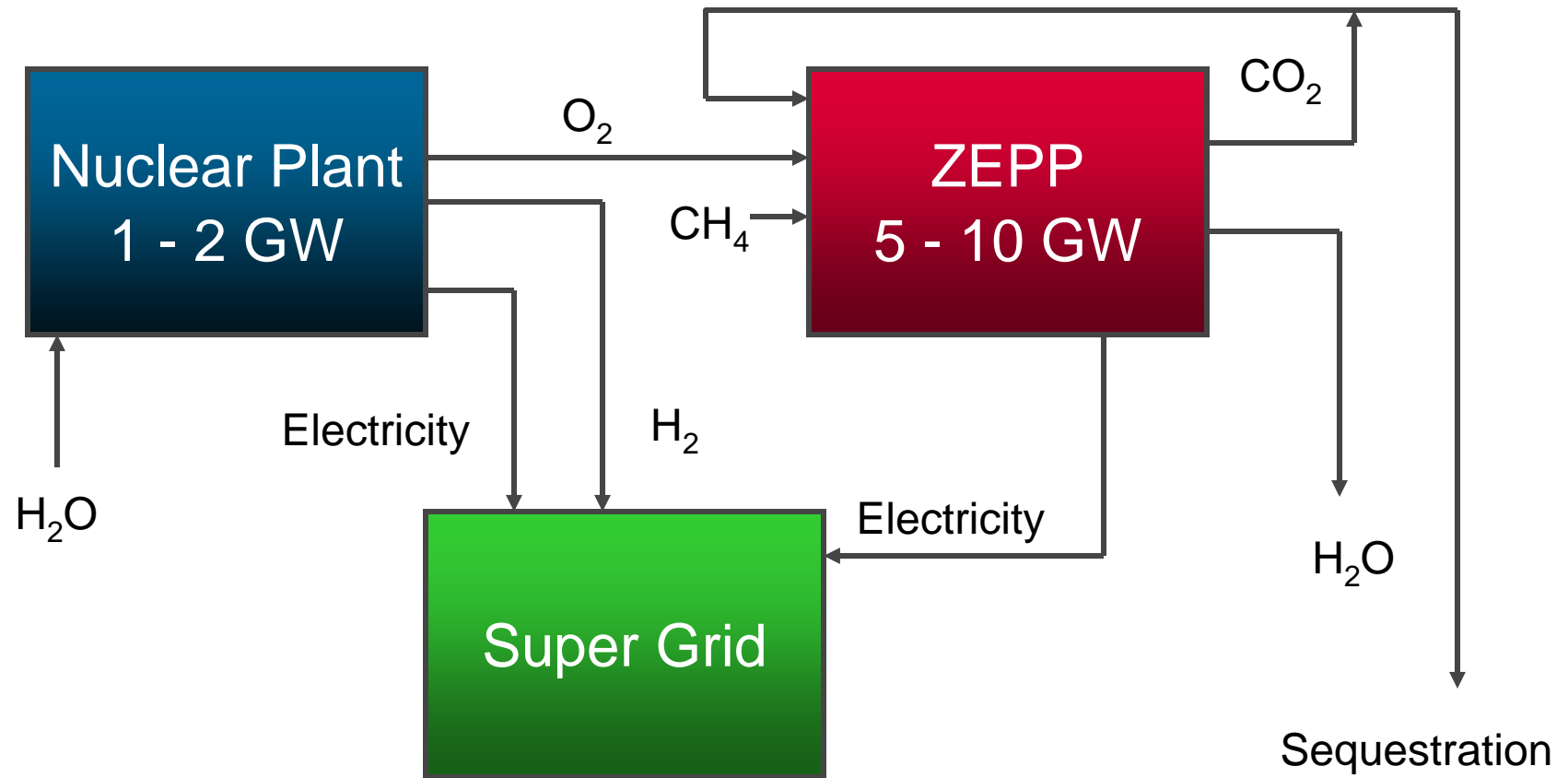
ZEPP Power Plant, circa 2025



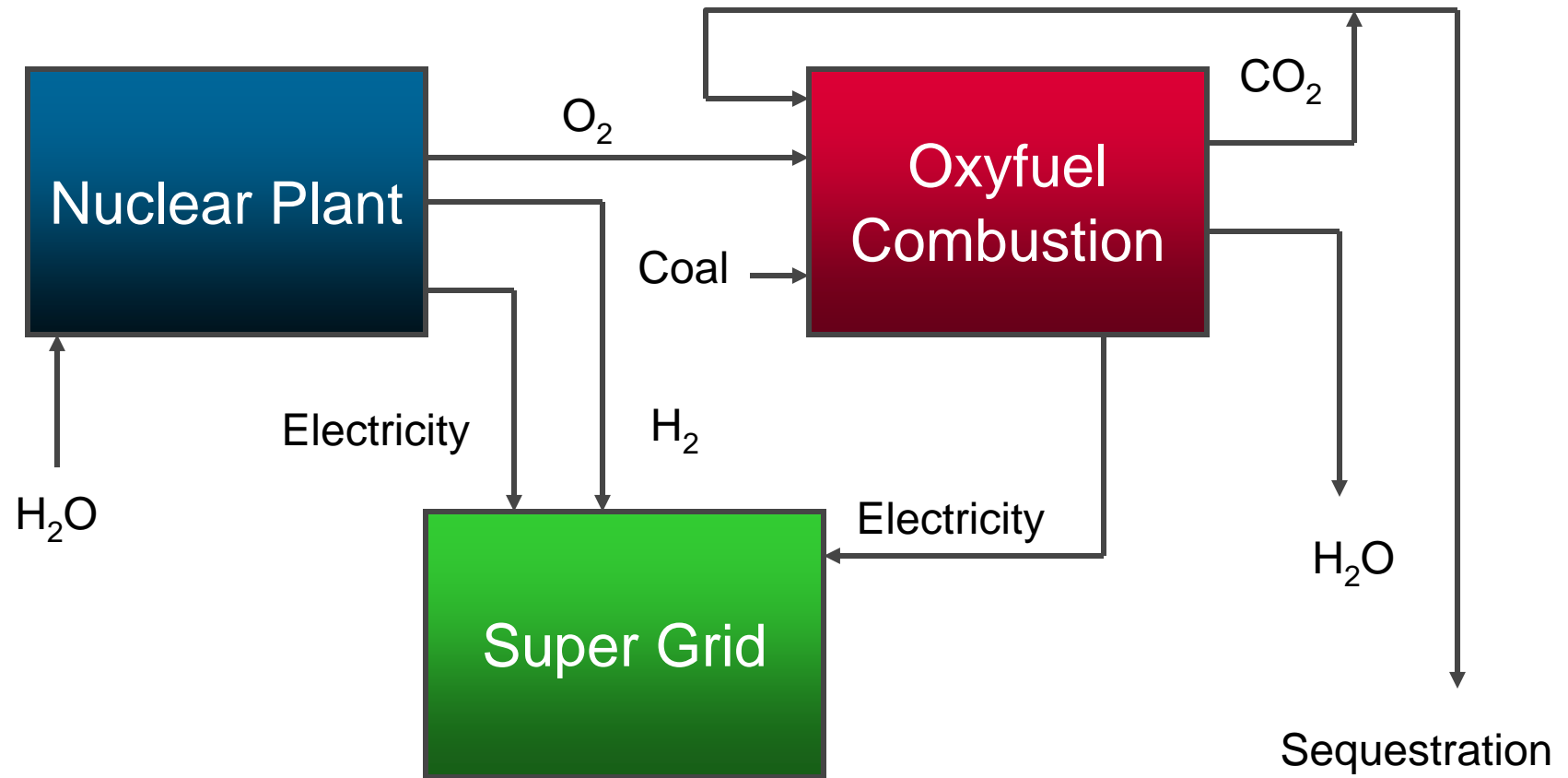
**Is bigger really better?
Is really, really big even better?**

Source: J. Ausubel, The Industrial Physicist

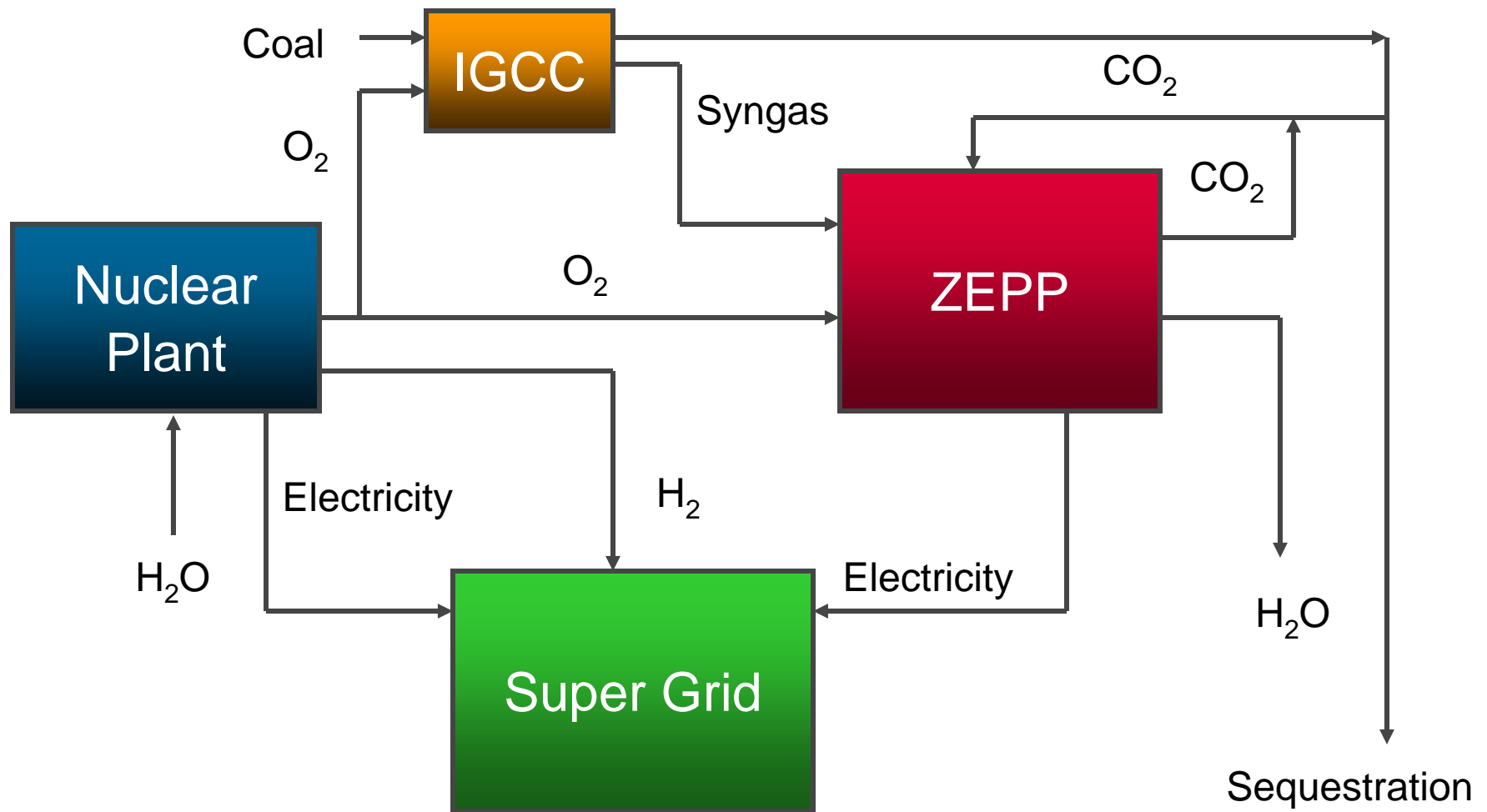
Integrating Advanced Energy Conversion Technologies – Nuclear and ZEPP



Integrating Advanced Energy Conversion Technologies – Nuclear and Oxyfuel



Integrating Advanced Energy Conversion Technologies – Coal-Based ZEPP / IGCC





Innovation: Low-Cost CO₂ Sequestration

Project: CO₂ mitigation with the aid of carbonic anhydrase

Existing Process: CO₂ removal and concentration step for exhaust gases

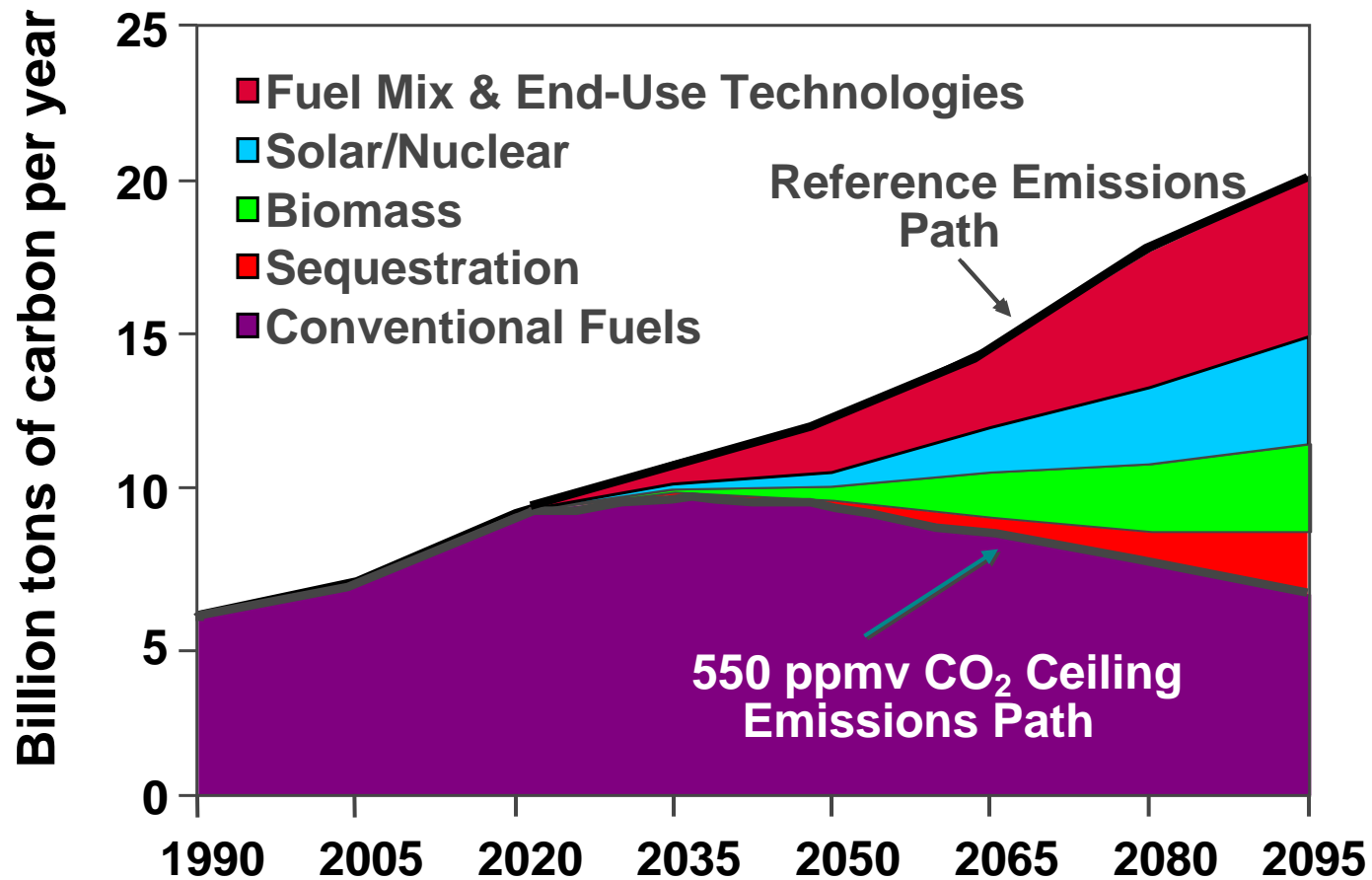
New Process: Enzyme-catalyzed scrubbing of exhaust gases at ambient conditions

Savings: Substantial cost reduction; reduces risk of coal generation

Benefit: Environmental friendly; permanent sequestration

Clean Power

(an illustrative example)

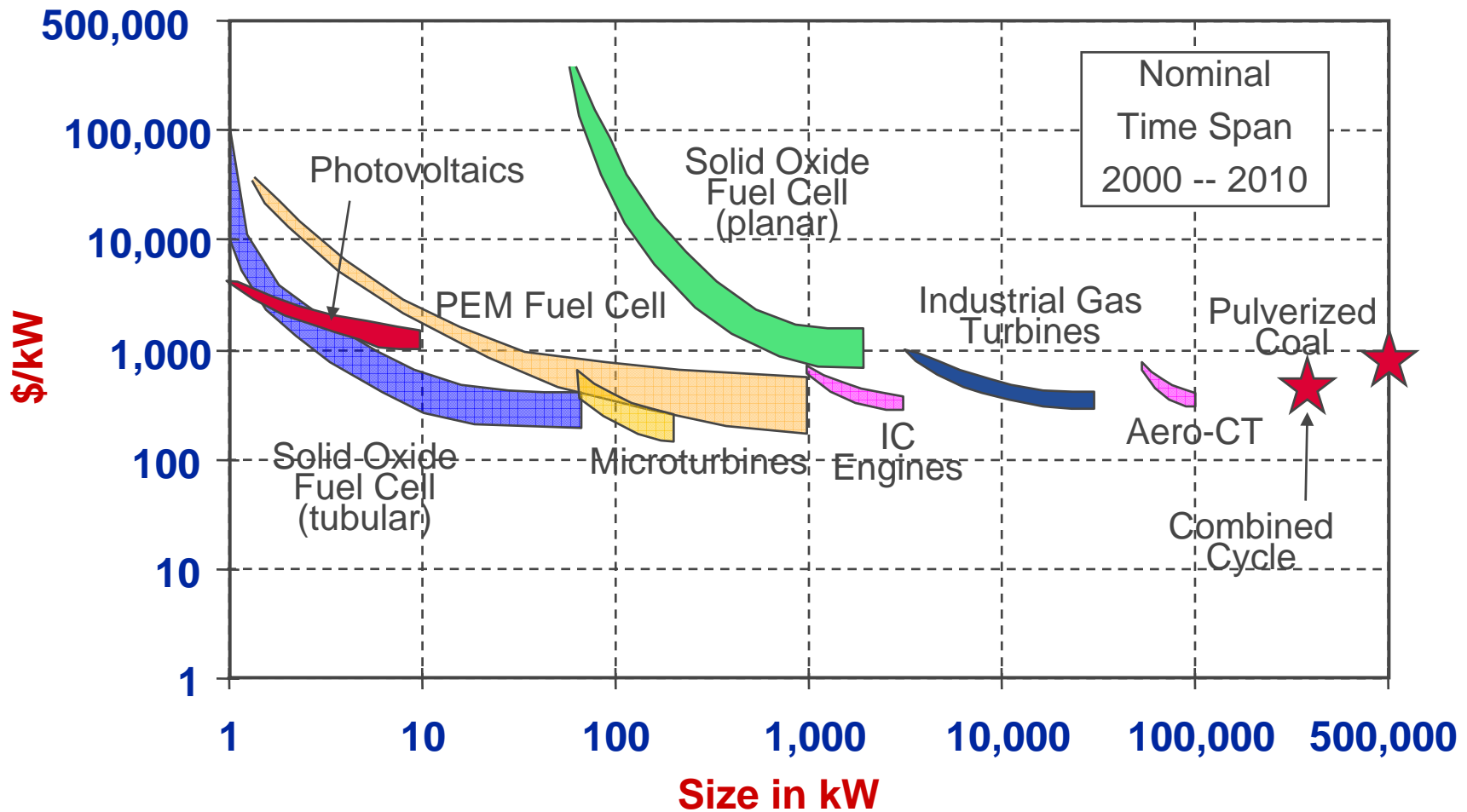


How to Avoid One Gt of Carbon Emissions per Year

Technology	Capacity to Avoid 1 Gt per year
Near Zero-Emitting Coal Plants	1,000 IGCC or other advanced systems -- 500-MW each (1.6x current coal capacity)
Sequestration	3,700 sequestration sites the size of Sleipner
ZEPP Gas Turbine	100 ZEPPs -- 5 GW each
Nuclear Power	500 advanced nuclear power plants -- 1 GW each
Auto Efficiency	Double the efficiency of the U.S. transportation fleet
Wind	300x current U.S. capacity
Solar PV	6,000x current U.S. solar generation
Biomass	Convert a barren area > 15x the size of Iowa's farmland to biomass

DG and Renewables Technology Evolution

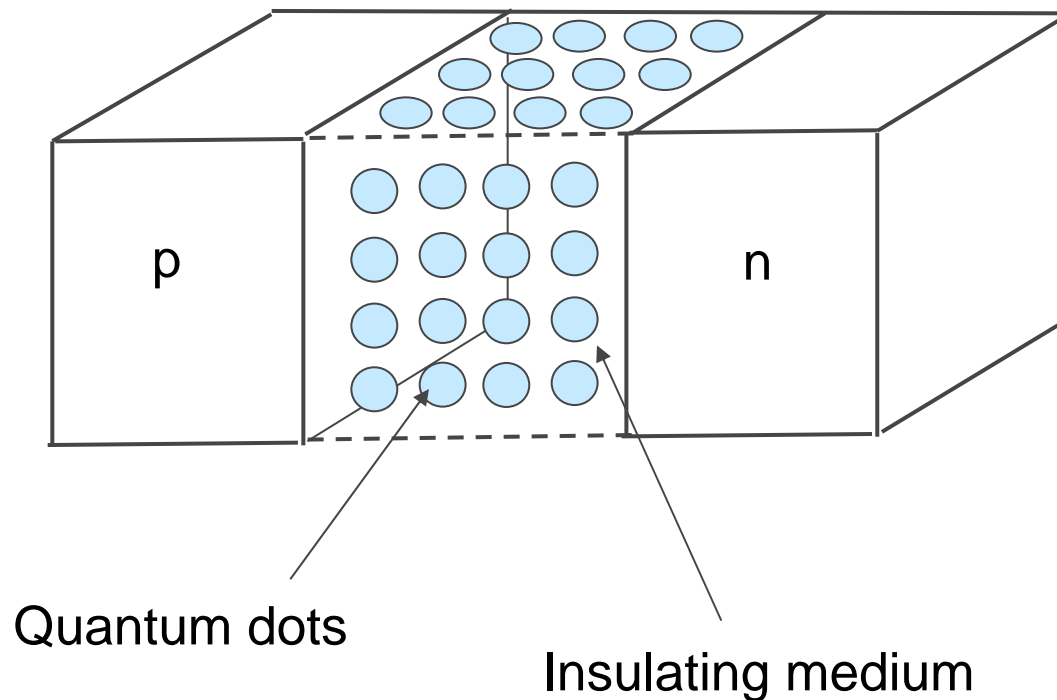
Cost Projections vs. Size over Time



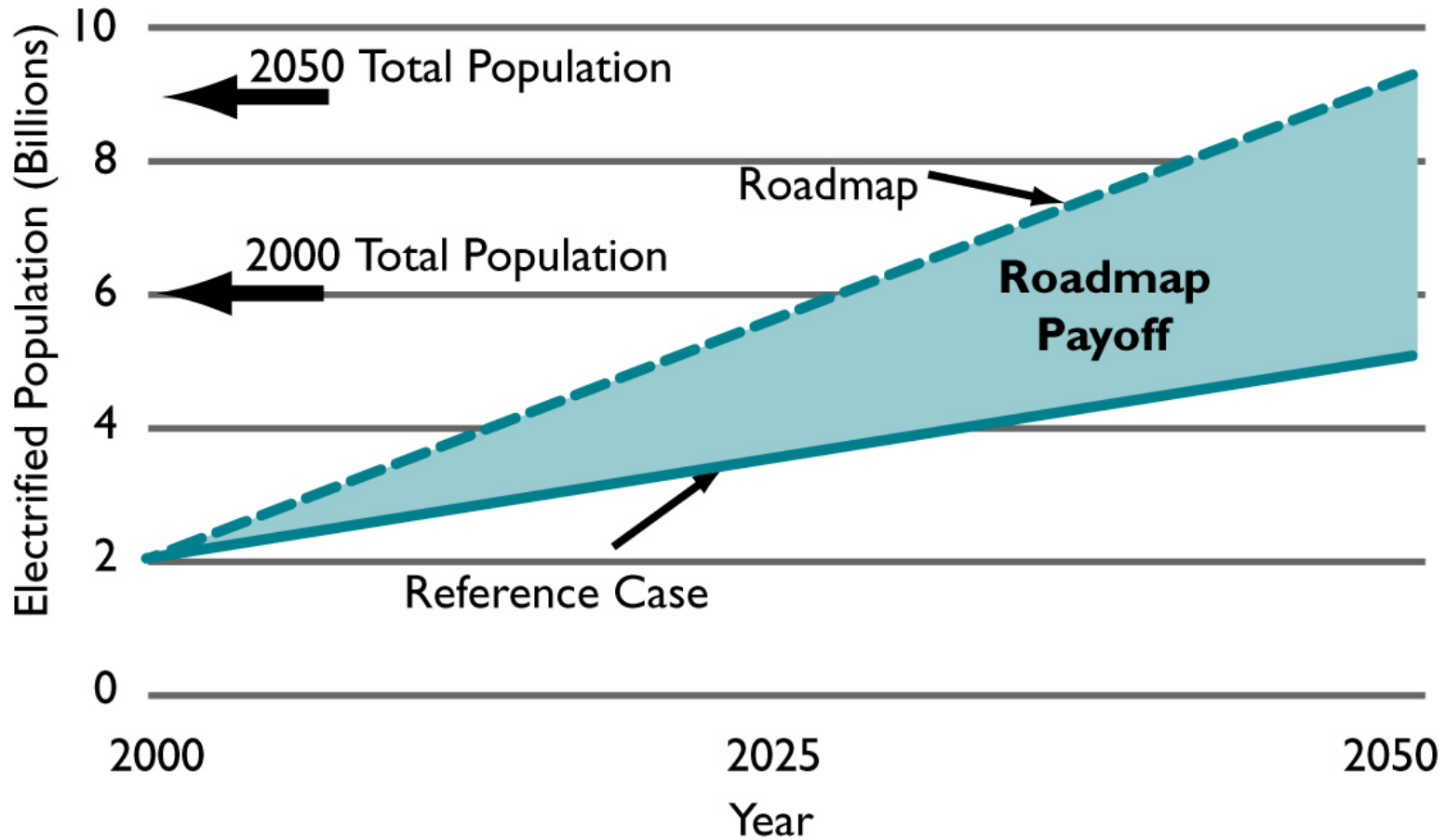
Quantum Dot Solar Cell Array: Conversion Efficiency > 70%

Chalcopyrite ternary semiconductors

$\text{Cu (Ga or In) (S or Se)}_2$

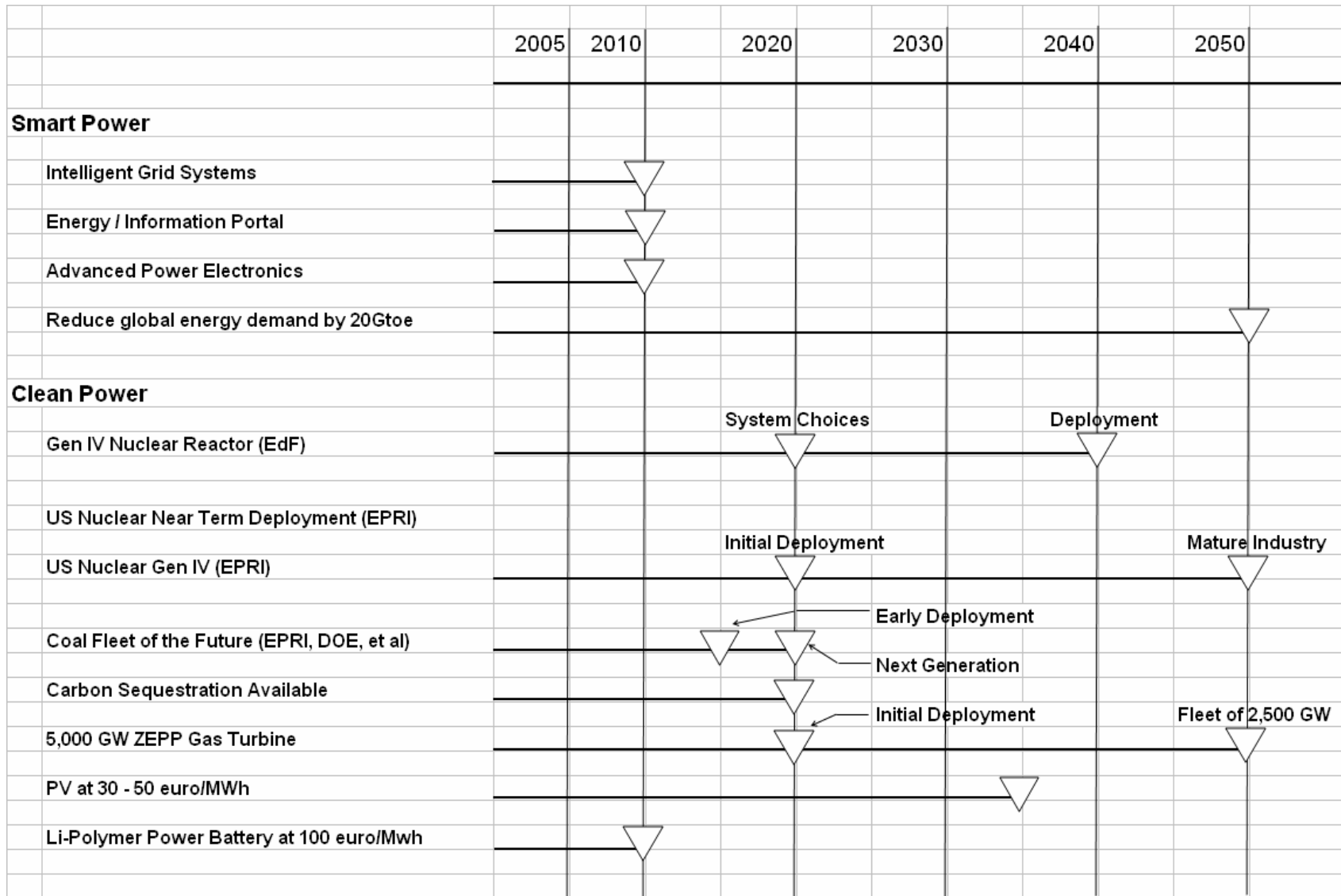


Power For All



Source: EPRI

Will This Schedule Meet Global Needs?



“No Power is as Costly as No Power”

- Homi Bhabha

