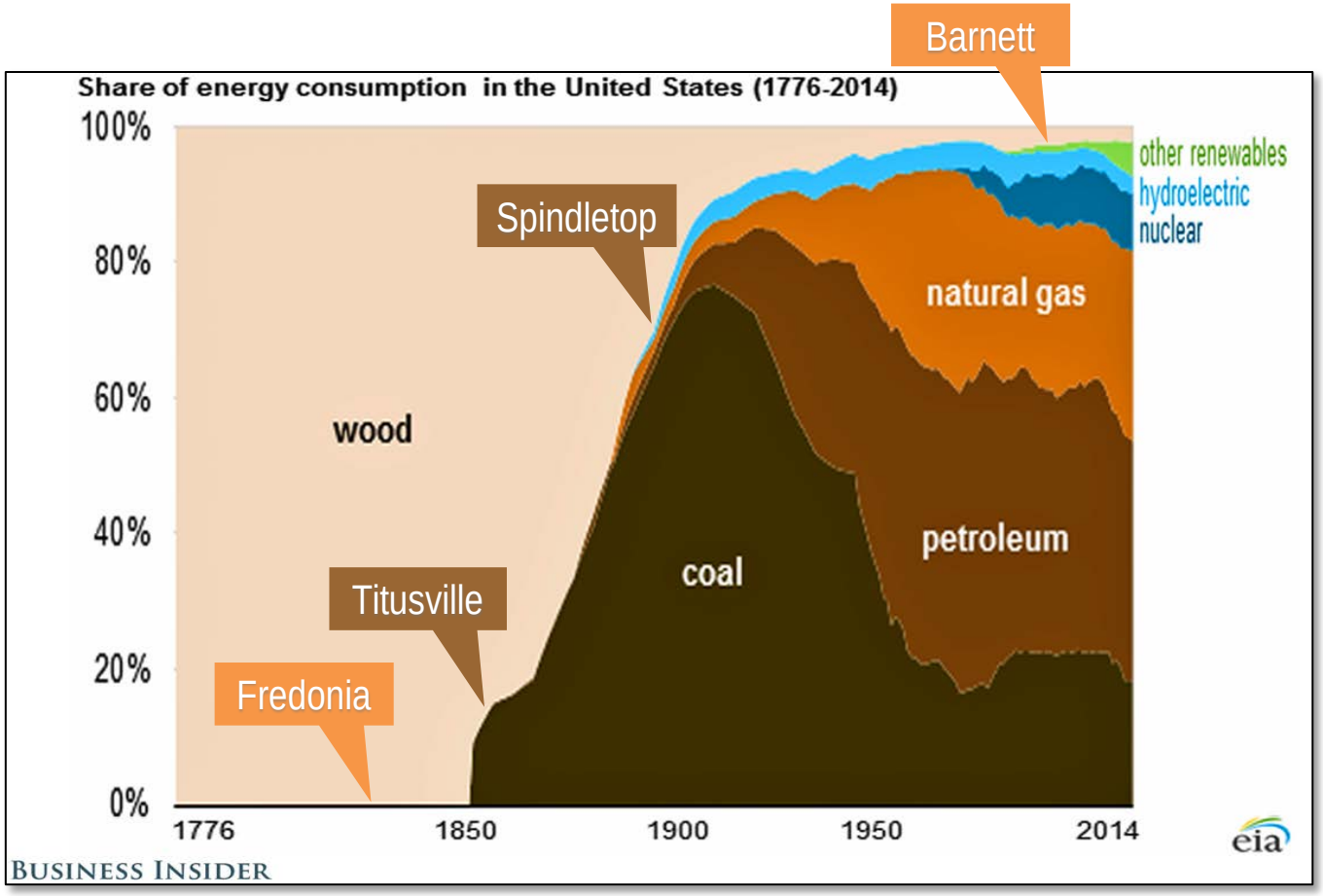
# Finding Coal's Future

In an Age of Energy Abundance

# We Have Developed Resource Options to Meet Our Energy Appetite

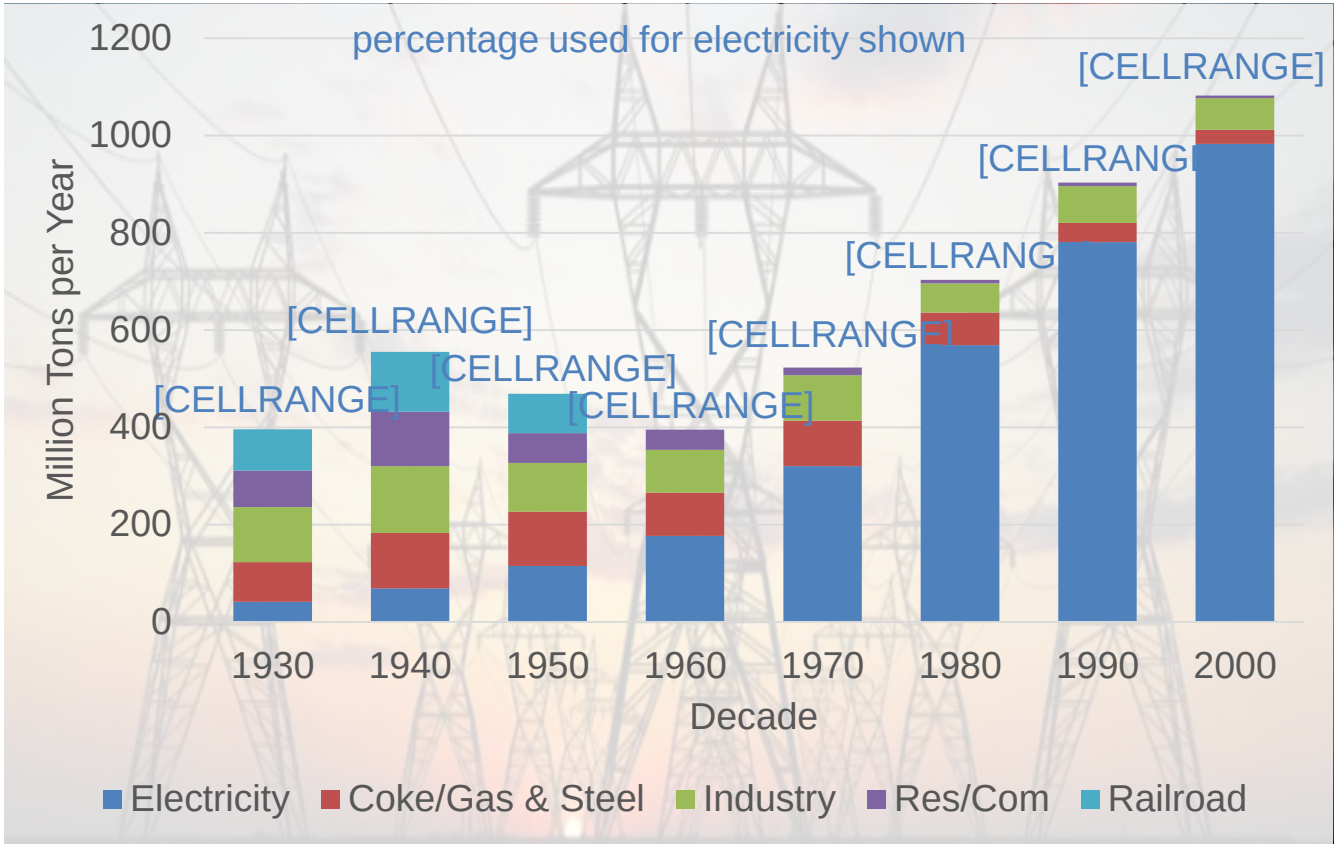



There is plenty of raw energy resource. Coal is the most abundant, but there are surging supplies of natural gas and oil.

There is also a growing renewable energy share.

What role is best for coal in this era of abundance?

# We Have Decreasingly Diverse Use of Coal in the U.S.




**WHY?**

Cheap energy options

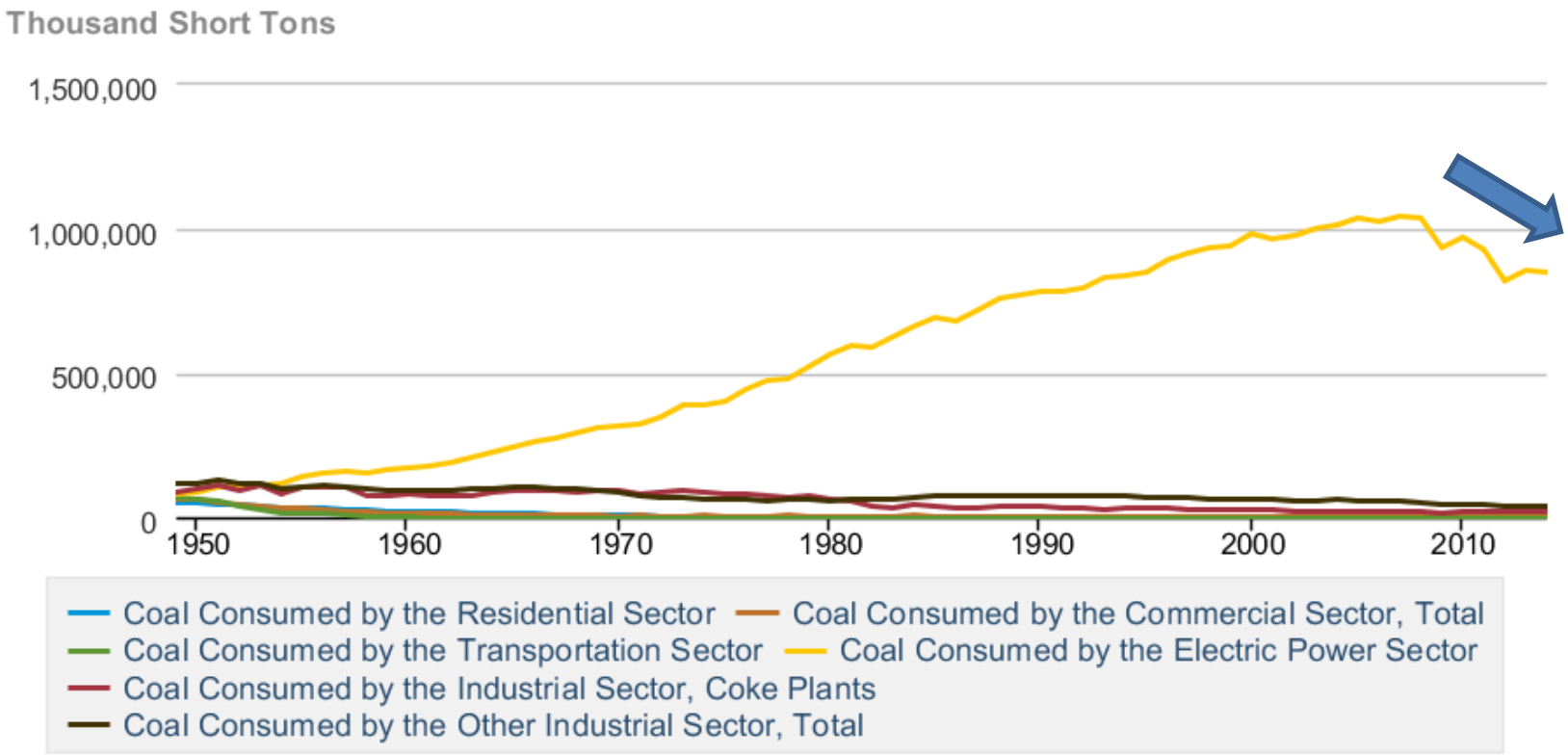
Ratepayer-subsidized capital
- technology
- production
- delivery

Maturing economy

Environmental issues

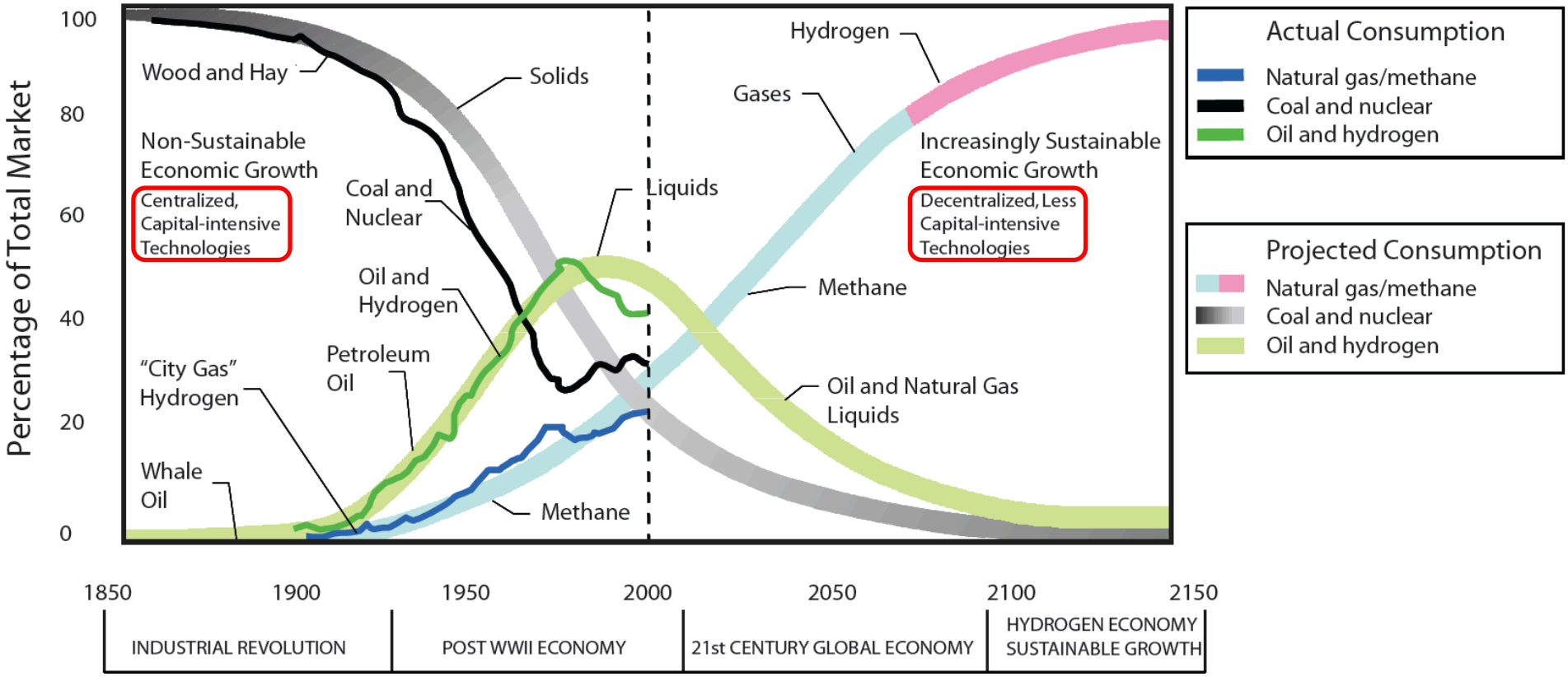
*Source information from Neville Holt, EPRI - 2002*

# Coal Consumption is Declining in All Sectors in the U.S.



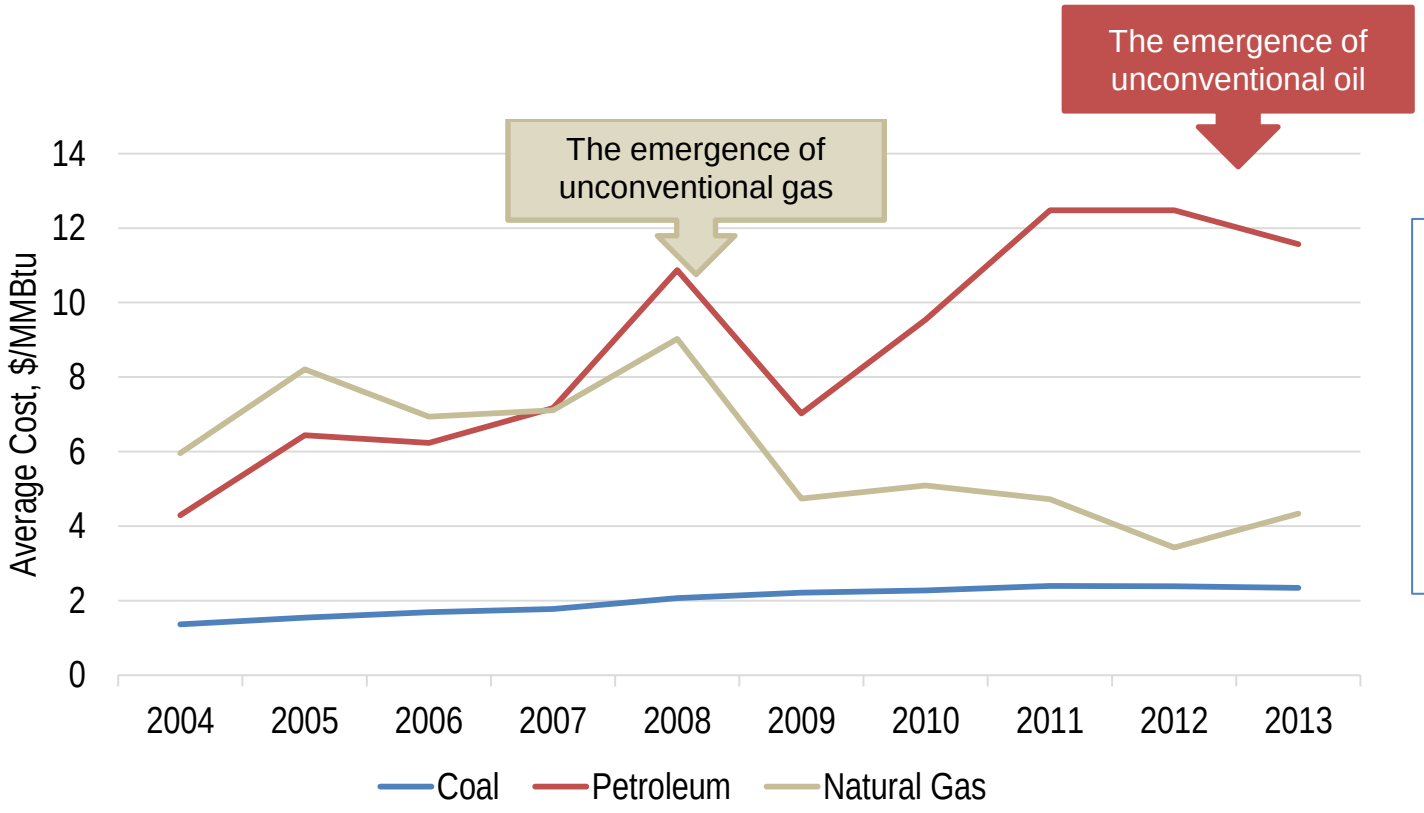

Data source: U.S. Energy Information Administration

# Is This The Future?




*Source: Robert Hefner,* ***The Age of Energy Gases***

# Coal's Opportunity?



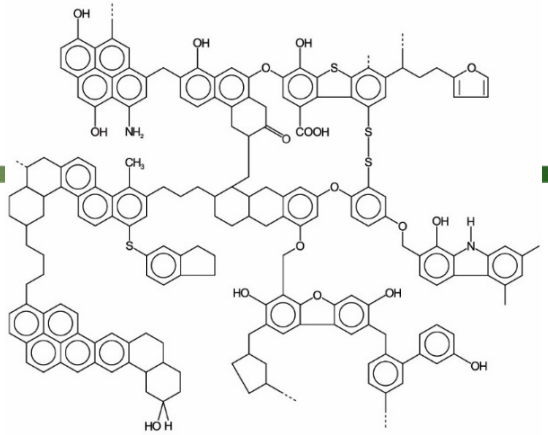

☑ Abundant

☑ Accessible

☑ Affordable

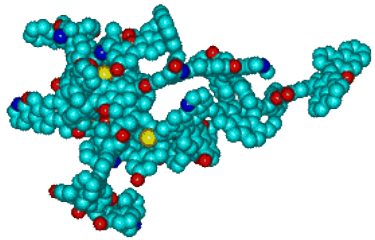
Will a cost incentive persist and be enough to encourage *acceptable* uses for coal in the U.S.?

# Coal's Dilemma



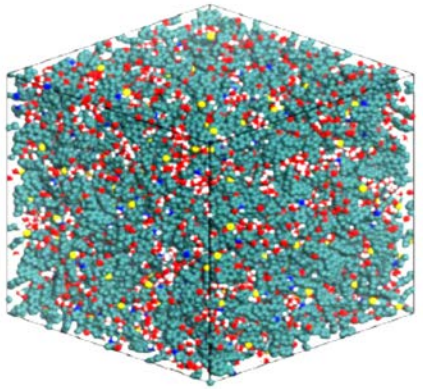

**Chemical complexity**

- Results in emissions and waste streams.

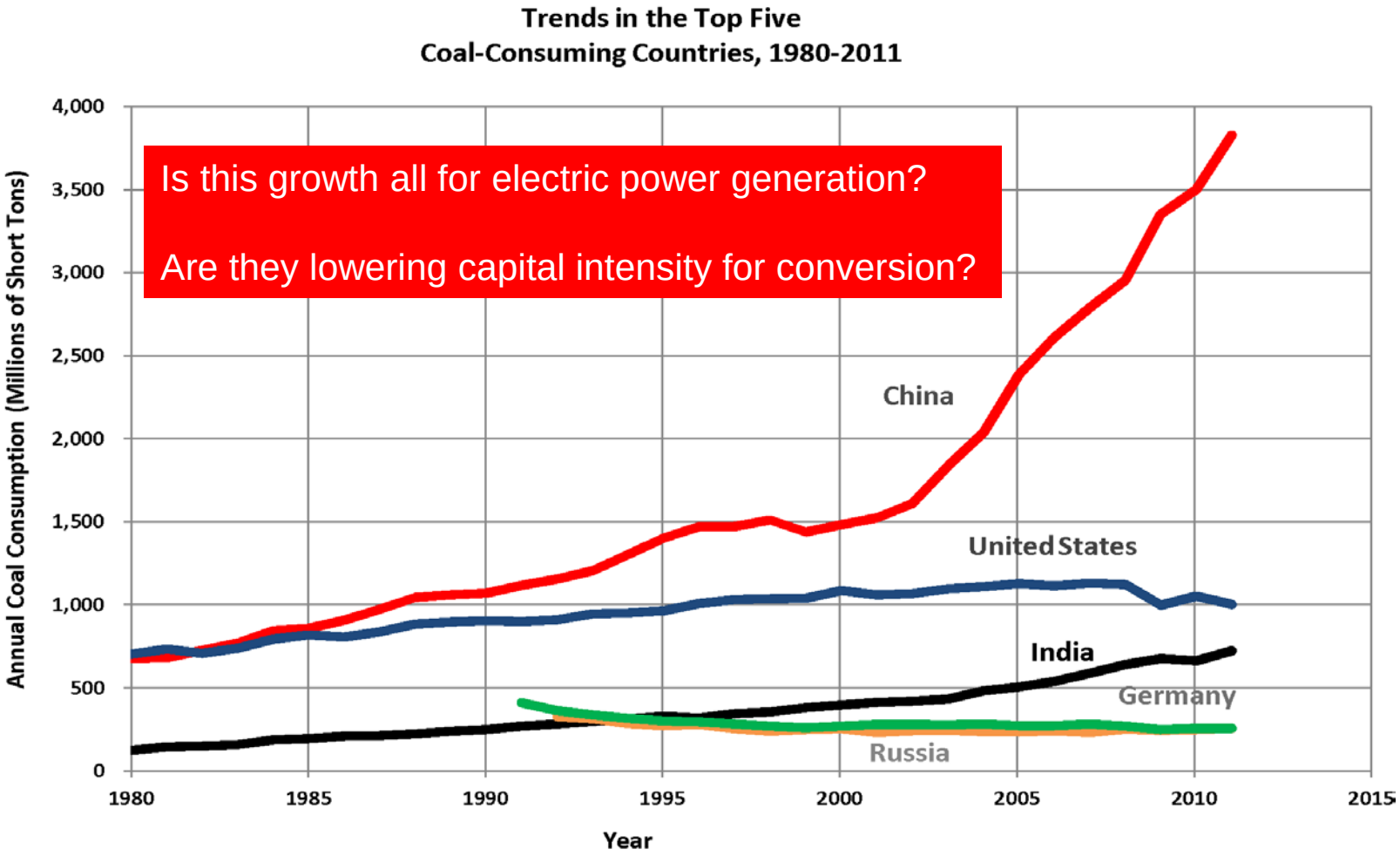


**Conversion complexity**

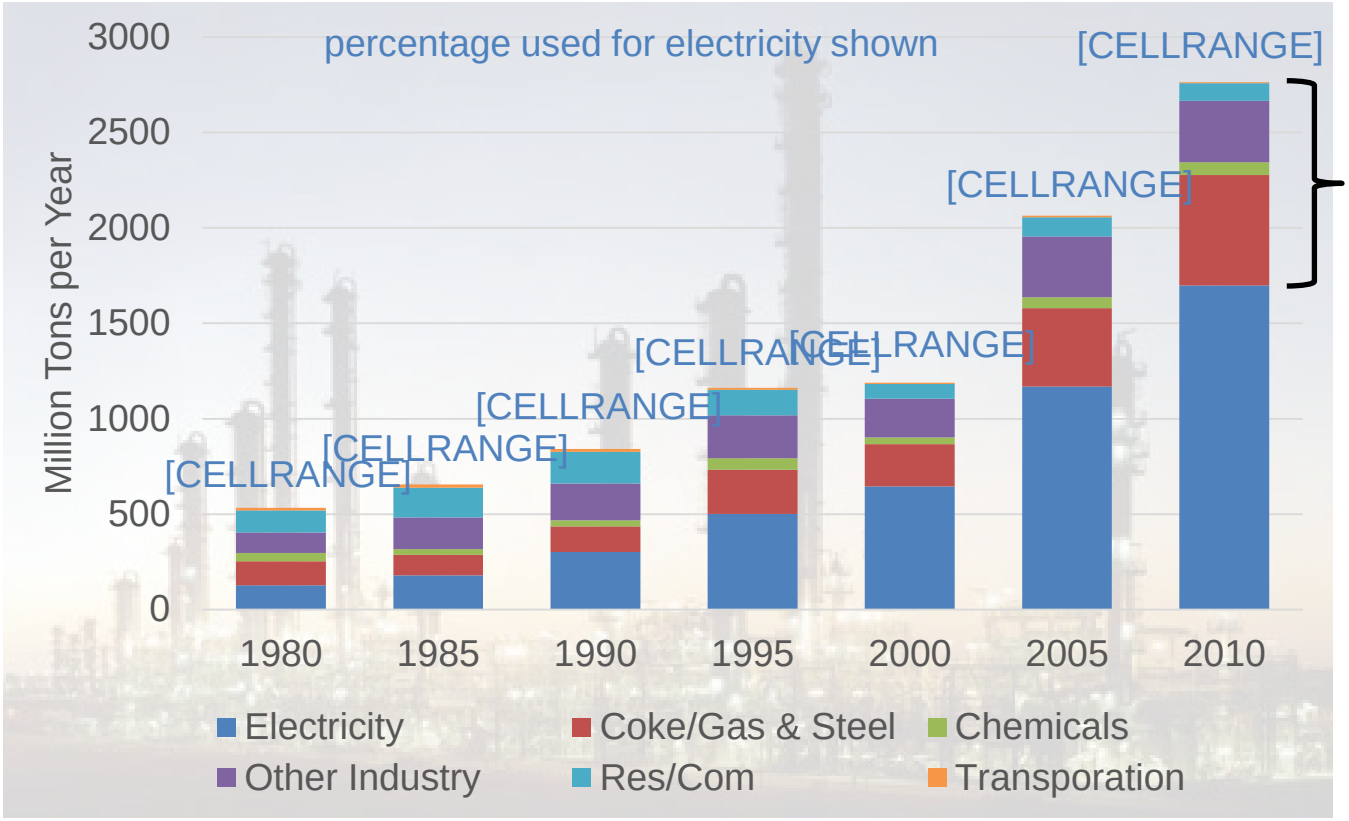
- Leads to capital intensity for processing to make products.



# What Can We Learn From the Uses of Coal in China and India?



# There Are More Substantial and More Diverse Coal Uses in China



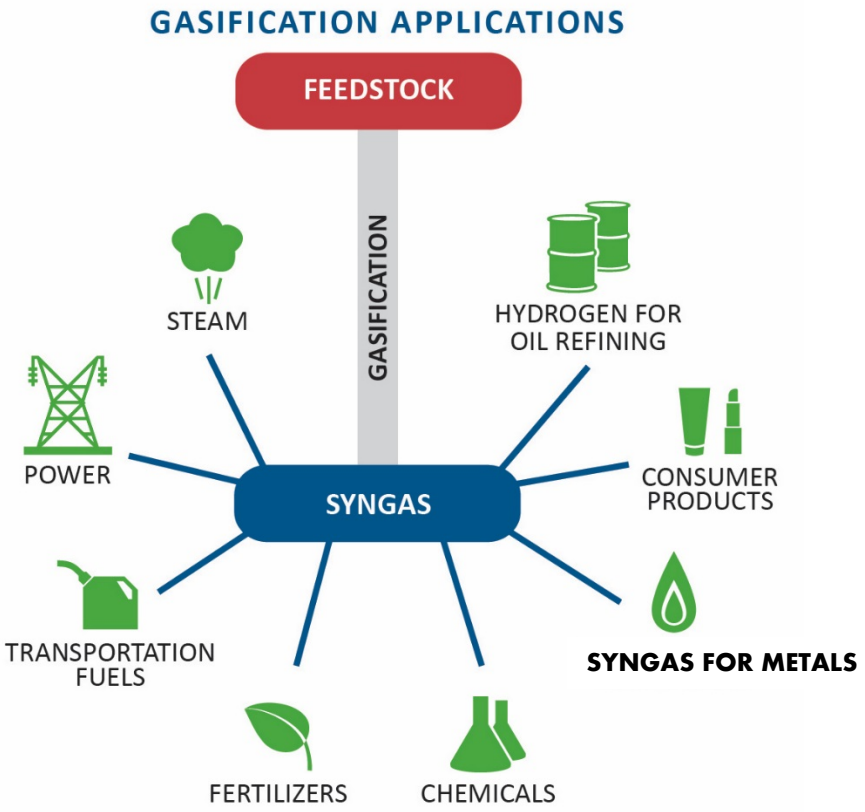

Non-power uses are roughly equivalent to the total U.S. consumption.

**Why?**

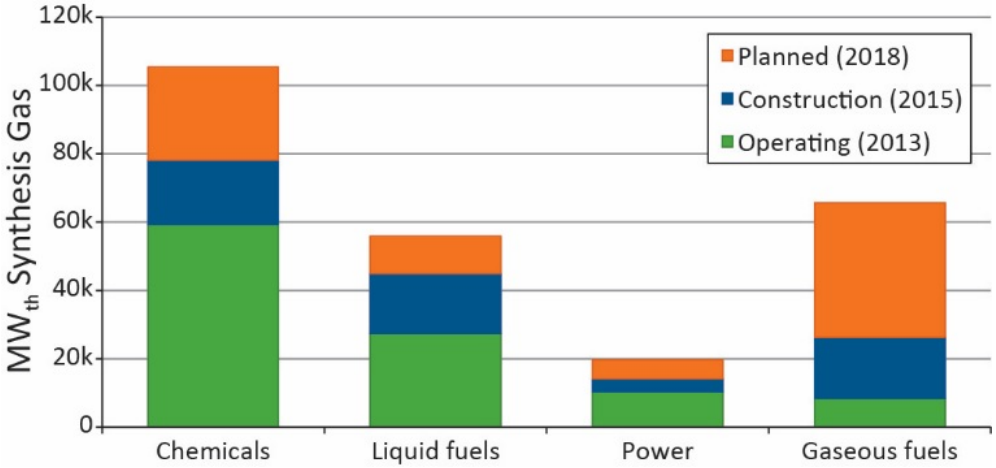
- ☑ Developing economy
- ☑ Necessity
- ☑ **Technology**

*Source: IEA Statistics, 2012*

# Diversifying Uses – Make Carbon-Containing Products




*Source: Gasification Technology Council*




China's growing uses of gasified coal.

*Source: Gasification Technologies Council. (2014).*

Combine pre-combustion and *non-combustion* carbon capture.

# Technical Innovation is Needed for Coal Use to Grow

## Address Coal's Conversion Complexity

**Translate innovations from other fuels to coal applications.**

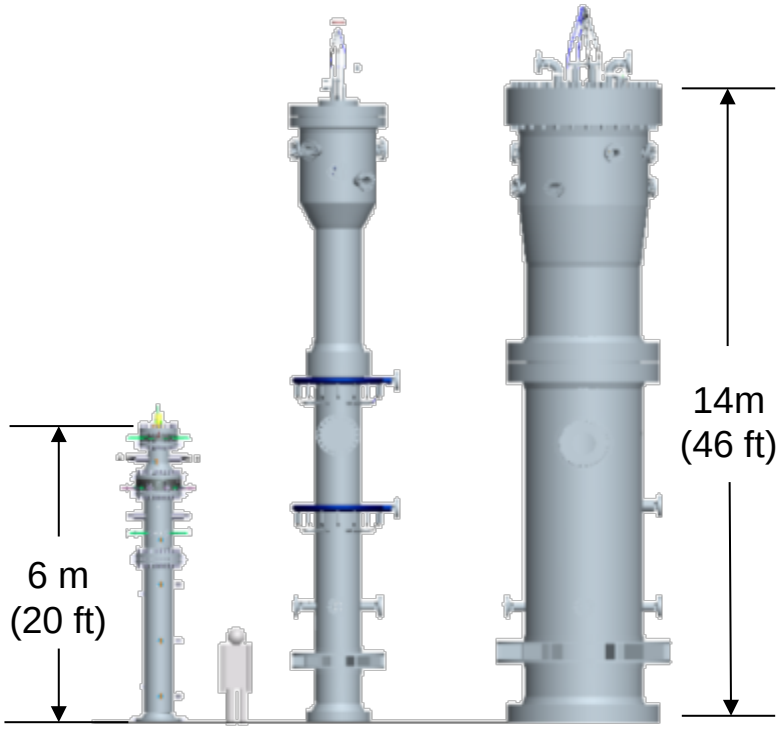
Technical innovations for cross-cutting solutions (turbines, catalytic synthesis, advanced power cycles, …) share the risk among multiple stakeholders.

**Demonstrate and deploy innovative processes in the developing world.**

Technical innovations are occurring (MTO, XTL, CTO, CTA…) that need a place to grow.

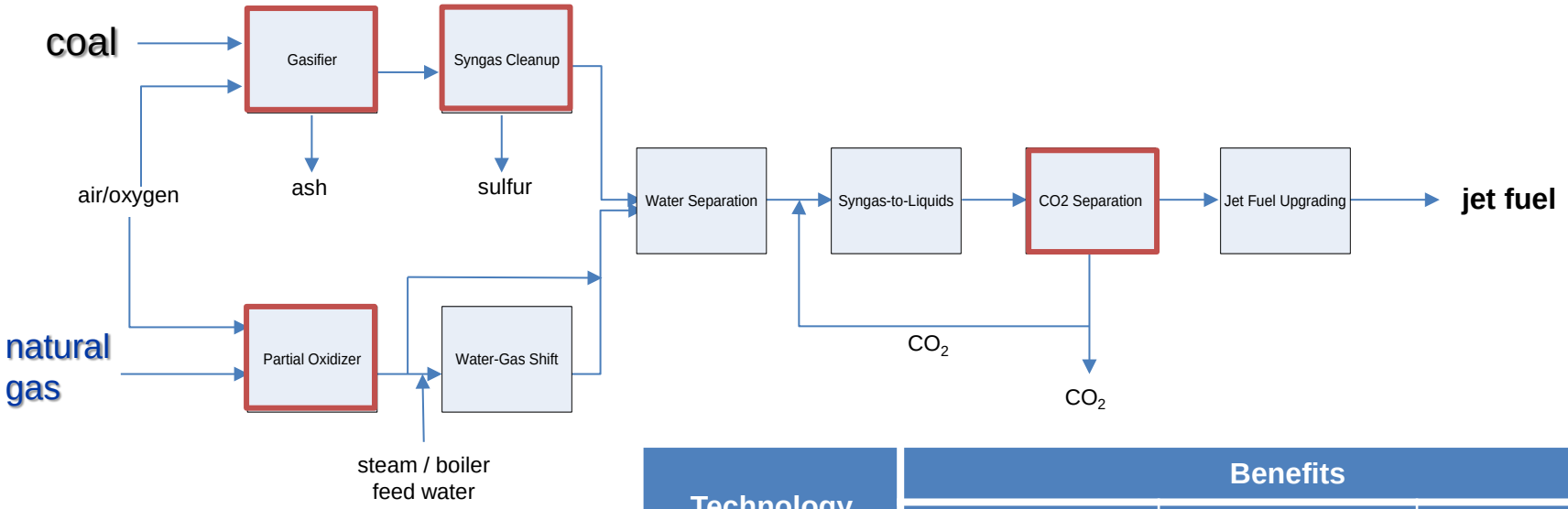
# Attack CAPEX and OPEX

## Advanced Gasifier Technology




- Reduce reactor volume by 90%
- >95% availability (MTBF/MTTR)
- Lower water use by up to 30%
- High efficiency (99+% carbon conversion)
- Lower oxygen use
- Gasify all ranks of coal, petcoke
- Lower disposal costs
- **Lower product cost by 15-25%**

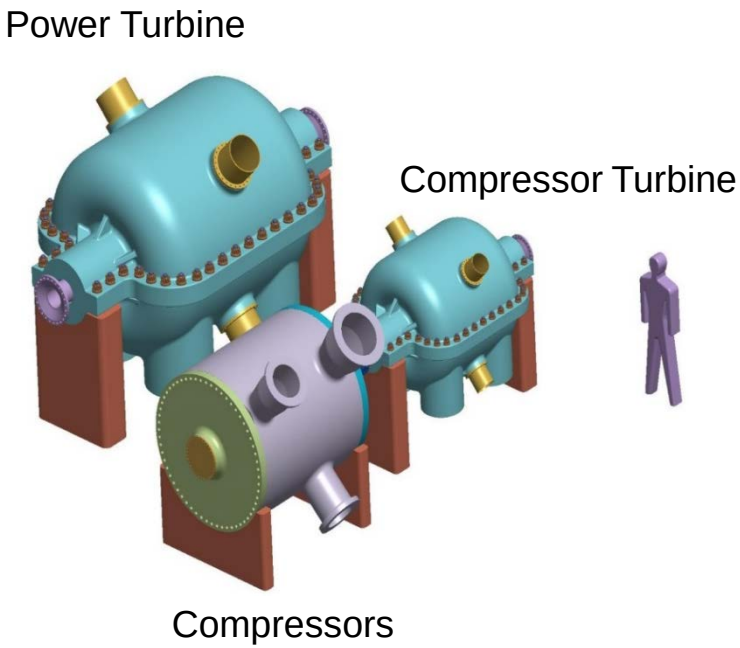
# Create Hybrid Processes



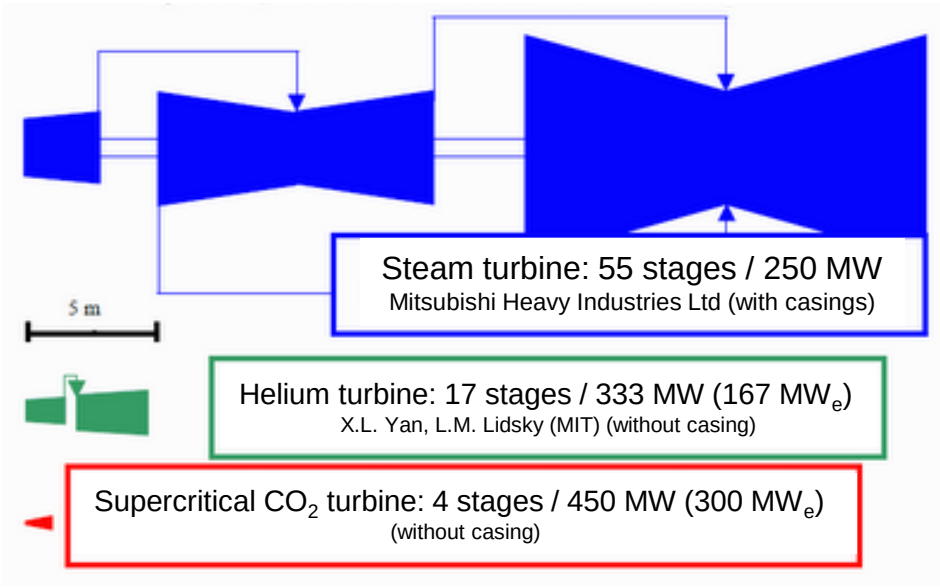

| Technology | Benefits | | |
|---|---|---|---|
| | Cost of Electricity Reduction | Thermal Efficiency Improvement | CAPEX Reduction |
| Advanced Gasifier | >15% | 7-10% (cold gas) | 23% |
| Warm Gas Cleanup | 5-10% | >3% (HHV) | 10-15% |
| **Cumulative Impact** | **20-25%** | **7-8% (HHV)** | **33-38%** |

**DOE/NETL Cooperative Agreement DE-FE0023592**

# Develop Cross-Cutting Technology




$sCO_2$ Turbine for a 550 MWe Plant

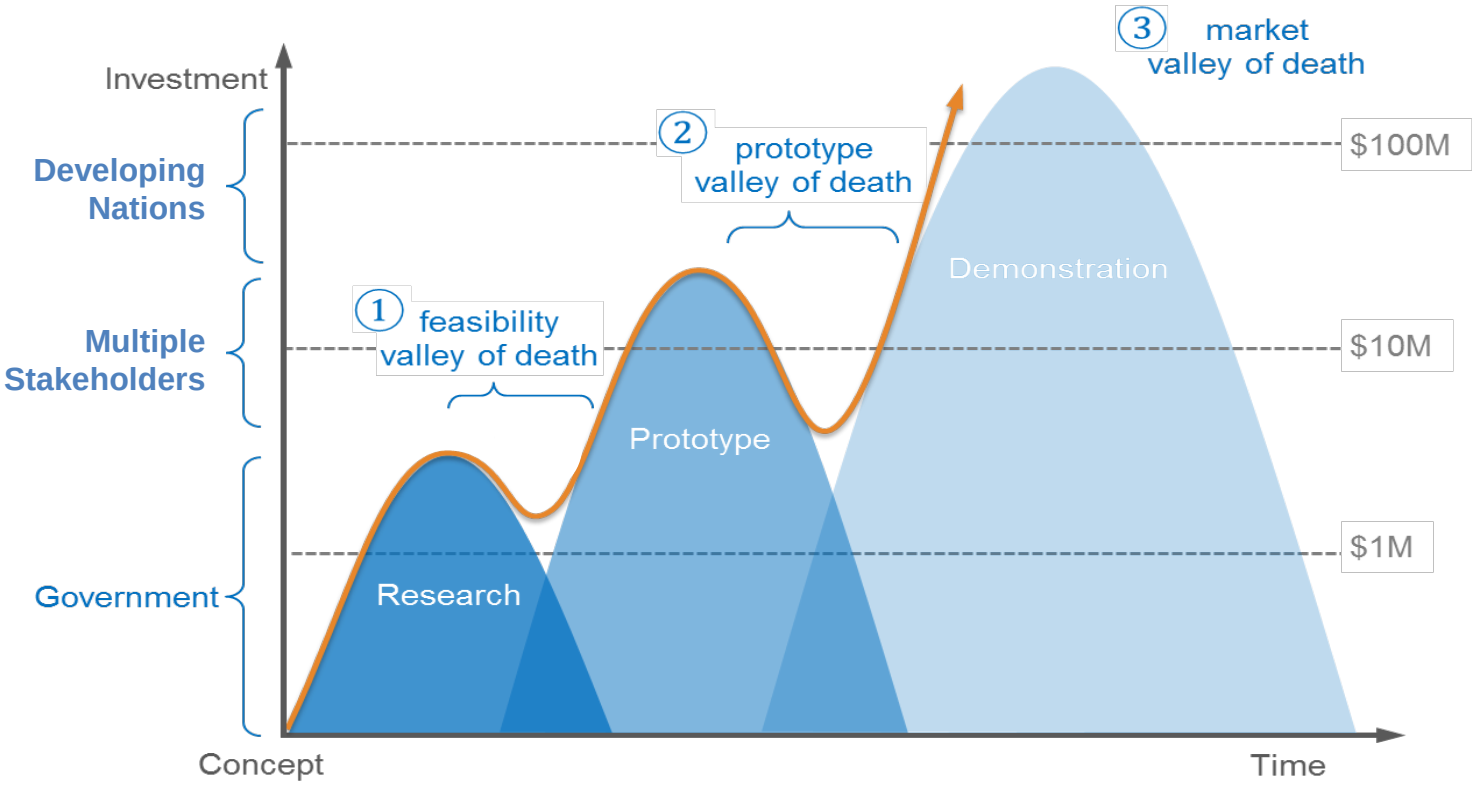



Comparisons with Other Turbines

- Very small systems – high efficiency heat transfer at moderate temperatures
- Allows 2-5x increase in power output for same footprint
- Lowest increase in electricity cost for carbon capture

# Innovation Has Its Own Challenges

## Mountains to Climb to Reach the Market




Now is a critical time for building partnerships.


The future ain't what it used to be.
Yogi Berra