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Deep decarbonisation scenarios and their vulnerability to *bottlenecks*

Perspectives from the *Rapid Switch* Project

A research network exploring barriers, bottlenecks and unintended consequences of rapid, deep decarbonization

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Deep decarbonization scenarios = rapid change & enormous disruption across the global energy economy

Bottlenecks are inevitable – anticipating them will be critical

3 separate but connected examples

Scenarios **modeled with high coordination & foresight**; versus **Investing under uncertainty**;

Binary risk associated with large **pre-FID capital** requirements;

Cross-sectorial risk exposure

Unintended / indirect consequences / feedbacks.

Case studies (used for illustrative purposes):

VRE + Hydrogen (electrolysis) / CCS / Coal plant closures

Idea 1 – **Modelling** with high levels of coordination and/or foresight vs **Investing under high levels of uncertainty**

IAM's (and many other decarbonization models) produce scenarios which benefit from high levels of **coordination** (across sectors) and/or **foresight.**

On the other hand investors participating in decarbonization make decisions unde **high levels of uncertainty** with **limited cross sectoral insight**, e.g. evolving:

- Technology cost and performance
- Competition
- Policy
- Market design

→ Disconnect between model projections and transition drivers (e.g. market desig

se-study: decarbonizing the US grid by 2050
gh RE scenario)

ny scenarios involve:

- ncreased electrification
- ery high penetration of VRE (wind & solar)
- ncreasing curtailment of VRE
- Reducing VRE capex increases tolerance for low capacity factors

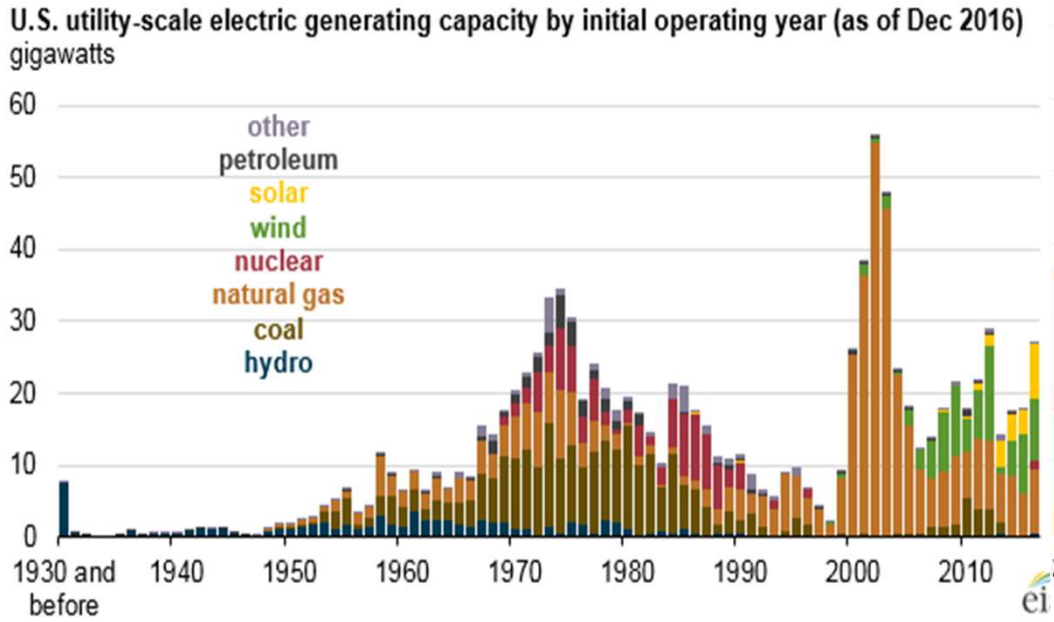
In practice, rising curtailment kills the market driver for new VRE additions **before** the market signal for electrolysis emerges…
a kind of "valley of death"
Markets need to evolve in advance

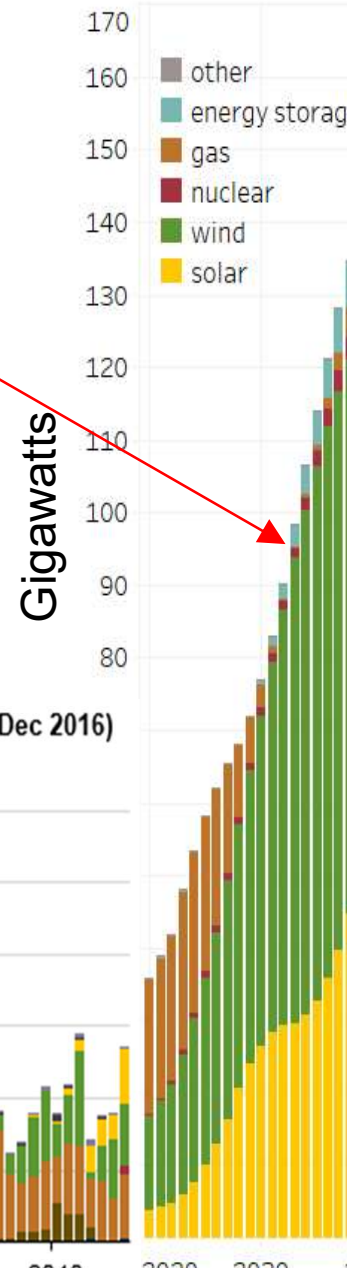
ates system NEEDS

- *Variability* (battery storage) &
- eriodic *scarcity (*flexible demand / back-up)

also system OPPORTUNITIES

- ncreasing periods of *zero*-cost electricity
  - → Electrolysis for H_2 production
  - & Dual boiler systems (electricity / gas) for industrial heat





Idea 2 – *binary risk* nature of pre-FID capital investment

- Deep decarbonization scenarios involve extraordinary levels of capital investment**.**
- Certain modular and distributed low-carbon assets involve minimal pre-investment capital.
- But deep decarbonization can also involve very large, resource-dependent assets with high pre-investment capital.
- Such pre-investment capital is characteristically **binary-risk** – success / failure
- Practitioner perspective - prudent to hasten slowly with such pre-investment studies

  But, IAMs do not recognize (a) the cost; (b) the time; or (c) the binary risk nature

Idea 3 – cross-sectoral risk exposure

Rapid deep decarbonization is enhanced by cross-sectoral integration

But, in the context of:

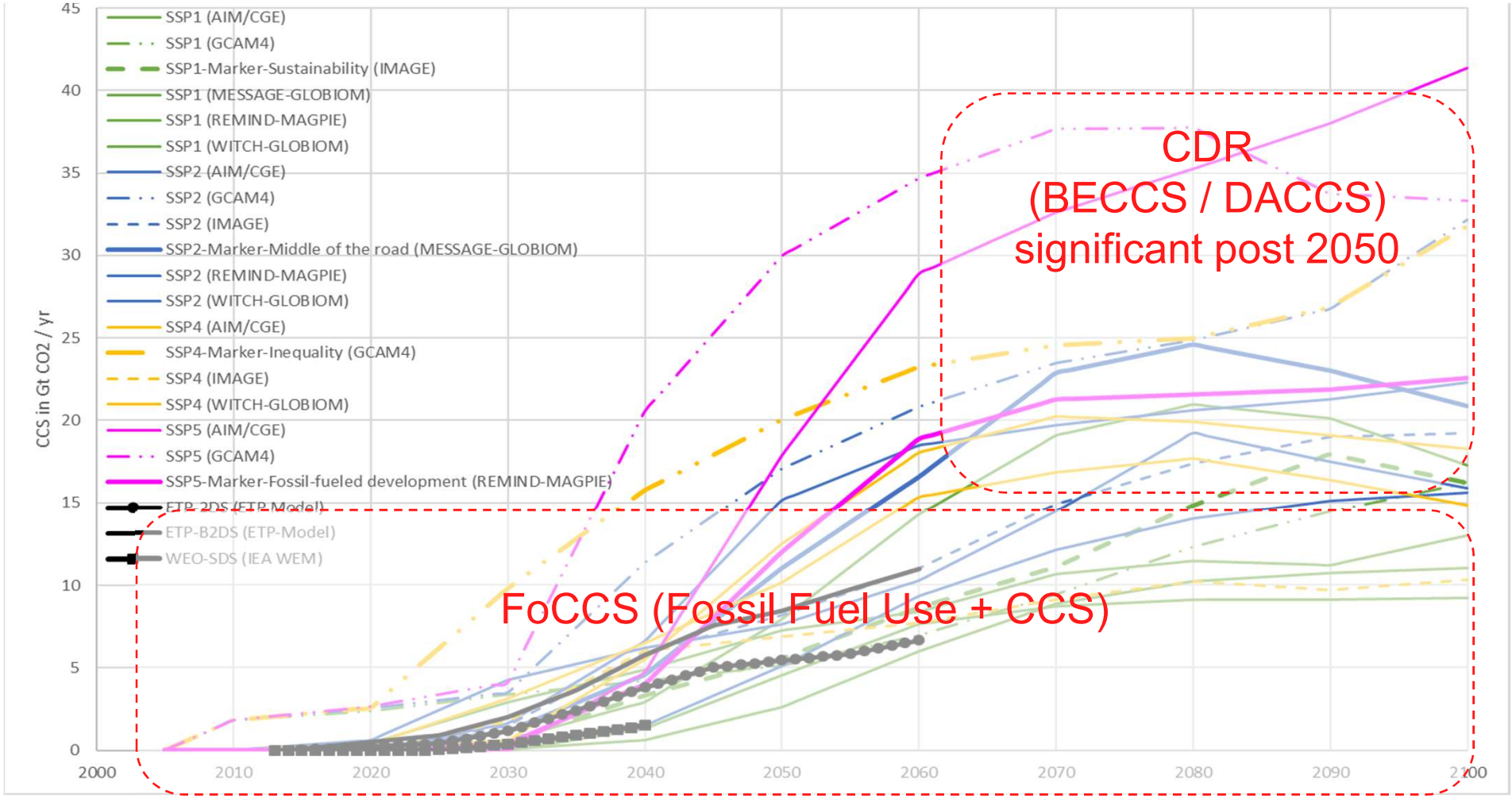
- Rapid technological change
- Changing demographics and demand for products & services
- Shifting policy & incentives for specific technologies
- Changing market designs

Actors in **specific sectors are likely to resist risk exposure to other sectors**?

se Study – CCS

ost IPPC RCP2.6 (2ºC or less) scenarios also rely heavily on CCS

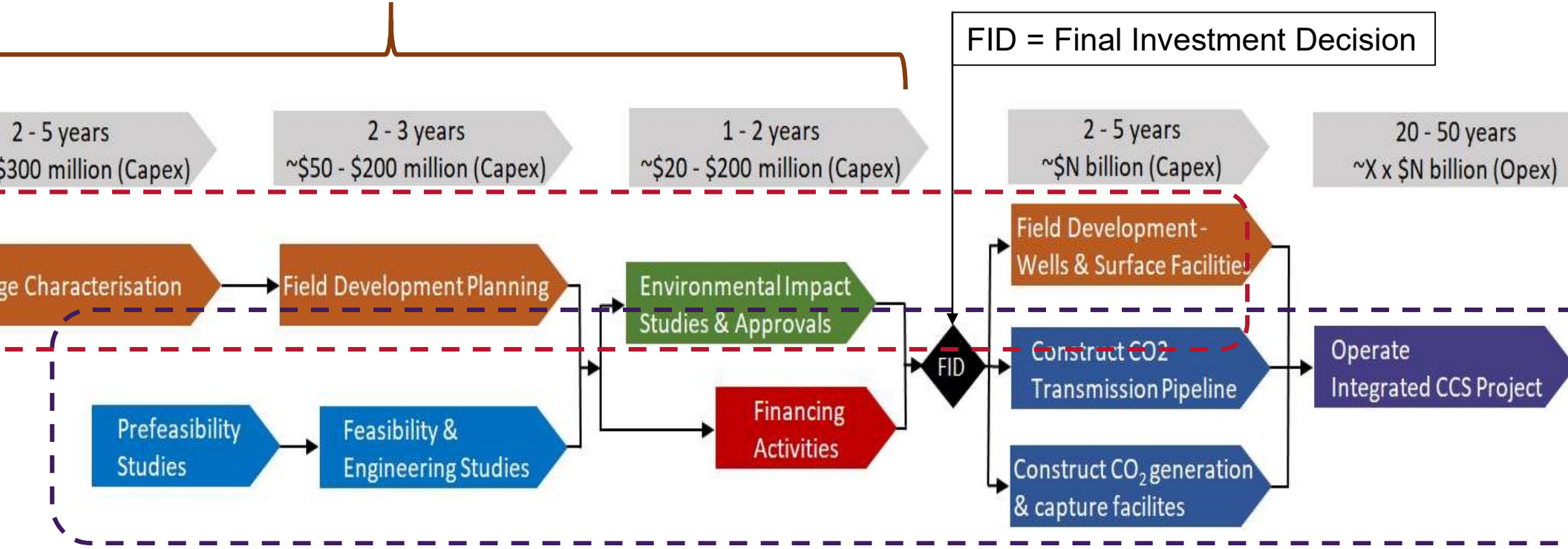
mitigate emissions from **fossil power generation** and **industrial processes** (petrochemic
ment, steel, ammonia, etc.) but also for atmospheric Carbon Dioxide Removal (CDR)



vesting in CO_2 storage assets to serve utilities & industry critical bottleneck – especially in China and India

ery high, long-duration, **binary-risk (equity) capital** r exploration in & appraisal before FID

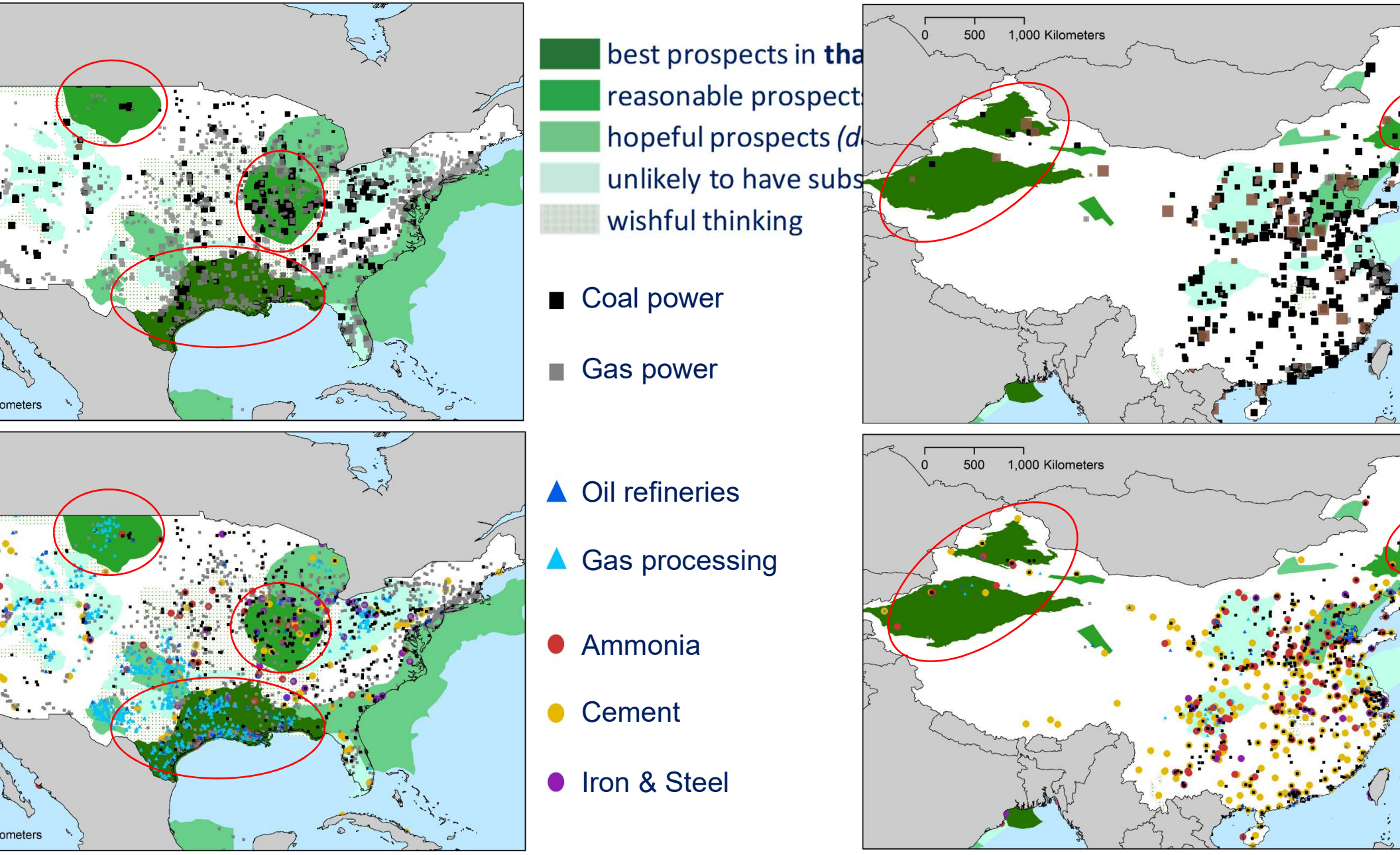
Exclusively the work of oil & gas actors



Cross-sectoral risk barriers

Developers of storage sites (& pipeline owners) exposed to risk that capture projects (power, industry, etc) will either not proceed or remain viable in the longer term

oration prioritises **best (lowest risk) storage close to many CO_2 sourc**



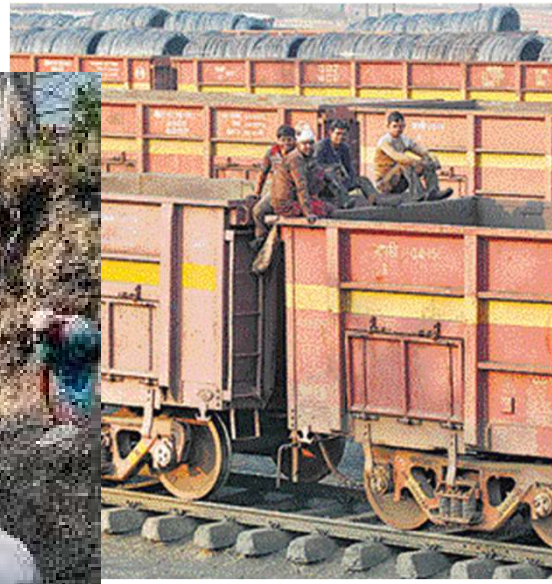
Idea 4 - Unintended consequences & feedbacks (direct & indirect) need to be considered.

Rapid deep decarbonization scenarios can be highly disruptive.

Direct consequences include - incumbent actors' **revenue erosion & stranded assets**.

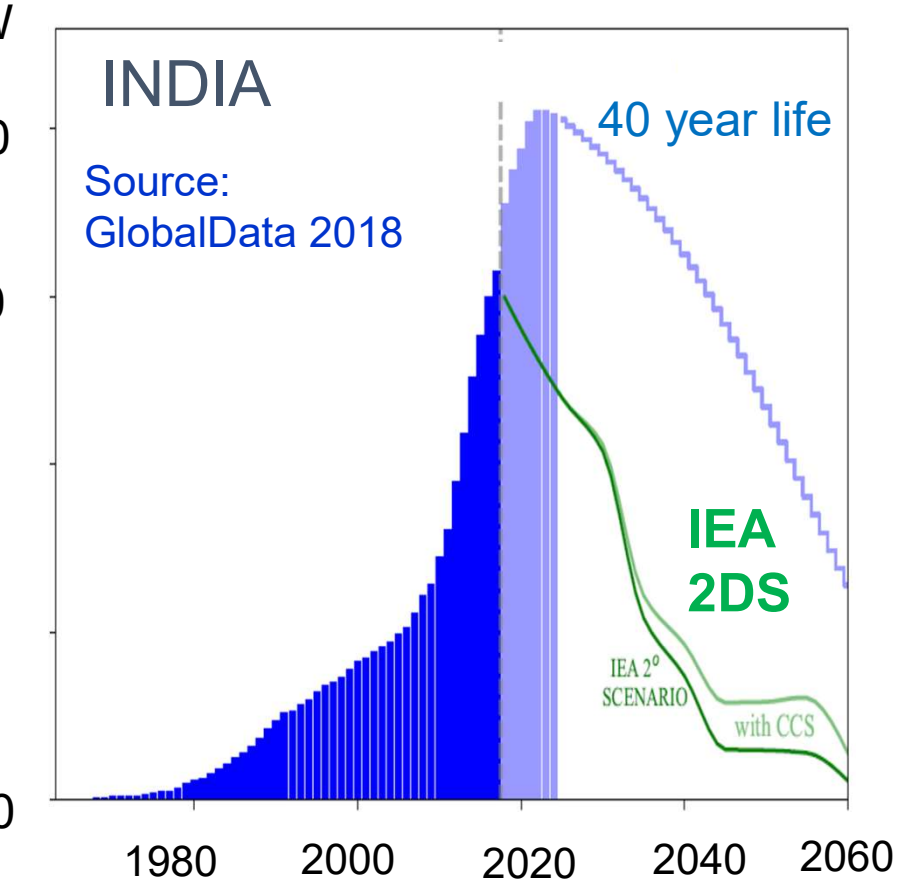
But **indirect, unintended consequences** for other dependent actors might present a greater risk to sustained mitigation.

- Value chain participants
- Institutions
- Communities
- etc.



Idea 4 – unintended (direct & indirect) consequences & feedbacks
Case study: Early withdrawal of coal generation in India

~ $250 Bn of capital destruction



2°C scenario from IEA,
Energy Technology Perspectives 2017

But, implications run much deeper:

What we've seen so far – reduced dispatch of coal plan

- → Declining coal generator revenues
- → Underperforming assets
- → Banks viability beginning to be impacted
- → Finance for new renewables reducing

Still to play out (?)

- → Early decommissioning of coal generators
- → Socio-economic unrest in coal states
- → Indian railways revenue dramatically impacted
- → Broad political opposition to transition

ecap

1. Scenarios **modeled with foresight & coordination**; versus **Investing under uncer**
2. **Binary risk** associated with large **pre-FID capital** requirements;
3. **Cross-sectorial risk** exposure
4. Unintended (direct & indirect) **consequences & feedback**

pid Switch contribution – a polycentric researcher network aiming to contribute:

ep-dive analyses of transition scenarios (outside models) to explore bottlenecks:

- **Interdisciplinary** teams - engineering / economics / business / social / behavioural / political scienc
- **Sector by sector** analyses but exploring cross-sector dependencies
- **Regional focus** (currently focused on US, India and China but aiming beyond)

Grounded with deep **stakeholder engagement** to ensure respect for **local values & conditions**

Identify **signals and signposts** to **anticipate bottlenecks**

Explore options to overcome / avoid bottlenecks – **interventions / alternative pathways**

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