Global emissions scenarios and other science in climate-related **finance, investment, and transition risk** assessment applications.

Perspectives from the *Rapid Switch* Project

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

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4 separate but connected ideas

1. Scenarios **modeled with perfect foresight**; versus
   Investing under uncertainty;
2. **Binary risk** associated with large **pre-FID capital** requirements;
3. **Cross-sectorial risk** exposure
4. **Unintended / indirect consequences** / feedbacks.

Case studies (used for illustrative purposes):

CCS / Hydrogen (electrolysis) / Coal plant closures

Idea 1 – **Modelling** with high levels of coordination & foresight vs **Investing under high levels of uncertainty**

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

On the other hand investors participating in decarbonization make decisions under **high levels of uncertainty**, e.g. evolving

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

→ Disconnect between model projections and transition drivers

Decarbonizing the US grid by 2050 (high RE scenario)

Many scenarios involve:

- Increased electrification
- very high penetration of VRE (wind & solar)
- increasing curtailment of VRE
- Reducing VRE capex increases tolerance for low capacity factors

Creates system NEEDS

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

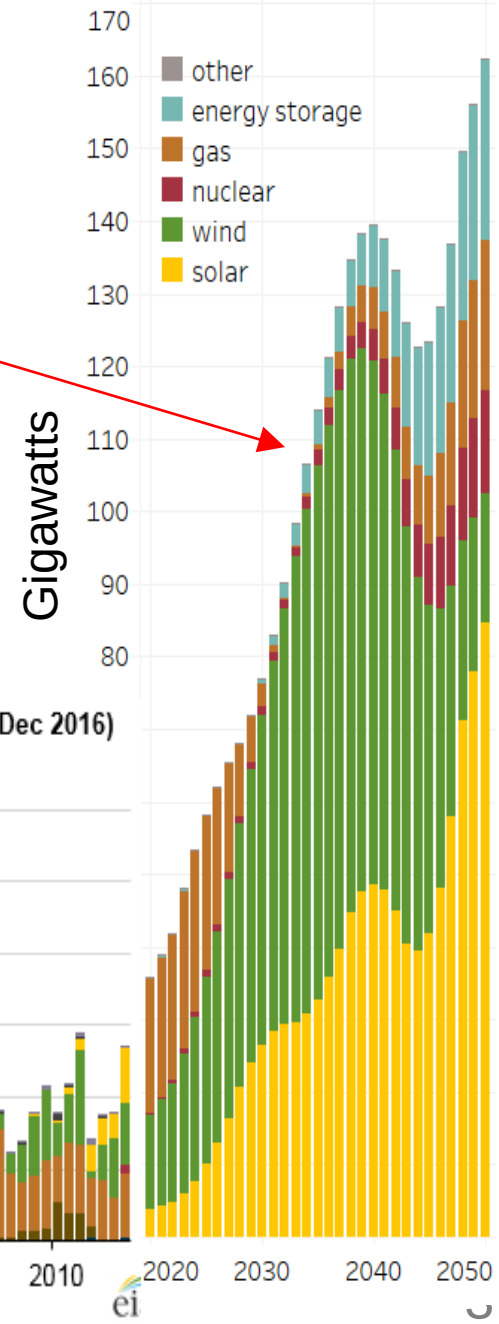
But also system OPPORTUNITIES

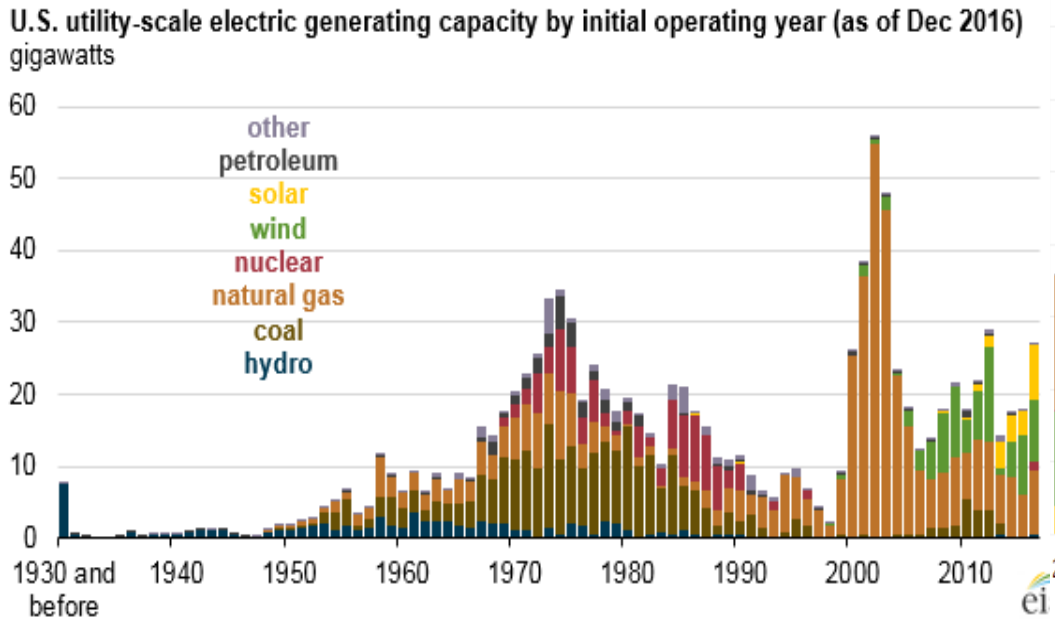
Increasing periods of *zero*-cost electricity

→ Electrolysis for H_2 production; &

→ Dual boiler systems (electricity / gas) industrial heat

1. 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**
2. A new world order of underutilized capital, cross-sectoral coordination **Investors need to evolve**





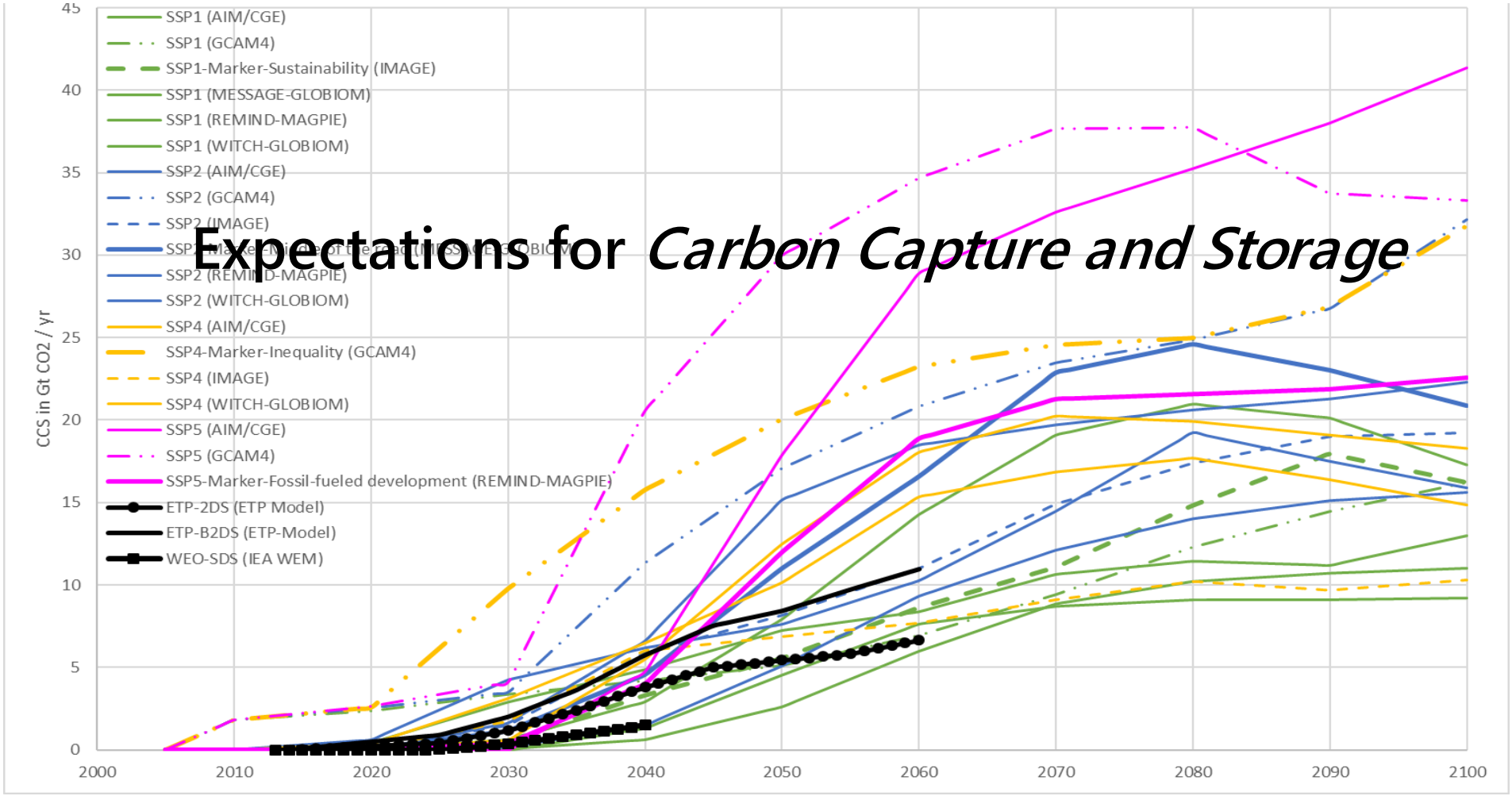
Idea 2 – *binary risk* nature of pre-FID capital investment

- 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 of a **binary-risk** nature.
- 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

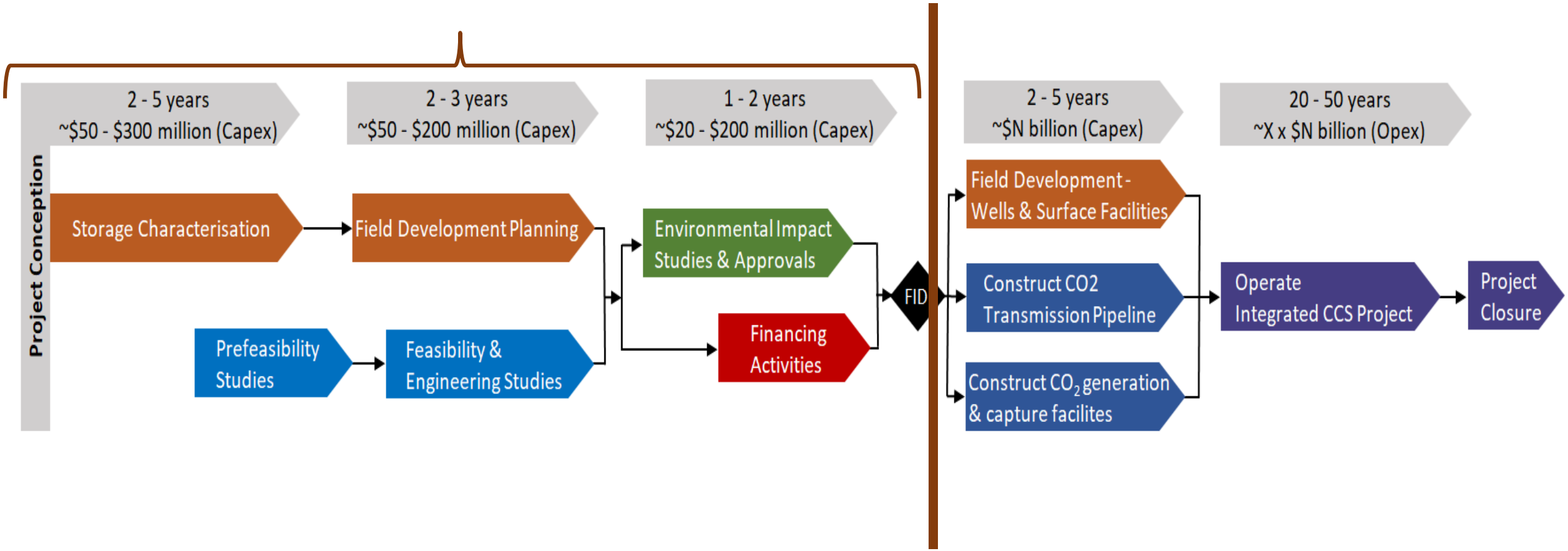
Case study – carbon capture & storage

to mitigate emissions from **fossil fuels power generation** and **industrial processes (FoCCS)** (petrochemicals, cement, steel, ammonia, etc.) and for **BECCS**



CCS project lifecycle – a sequenced (stage-gated) approach

Long-duration, high levels of **binary-risk capital** for exploration in & appraisal before FID → Not bankable
Must be equity



Idea 3 – cross-sectoral risk exposure

Rapid deep decarbonization is enhanced by cross-sectoral integration

But, in the context of:

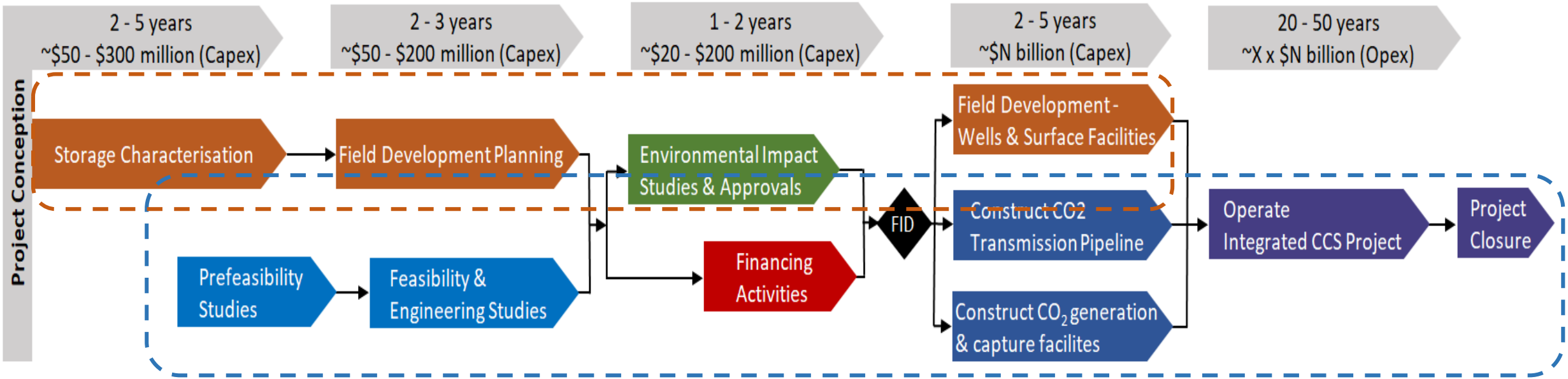
- Rapid technological change
- Changing demographics and demand for products & services
- Shifting policy & incentives for specific technologies
- Changing market designs

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

Case study – Developing CO_2 storage assets for utilities & industry

Very high, long-duration, **binary-risk capital** for 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

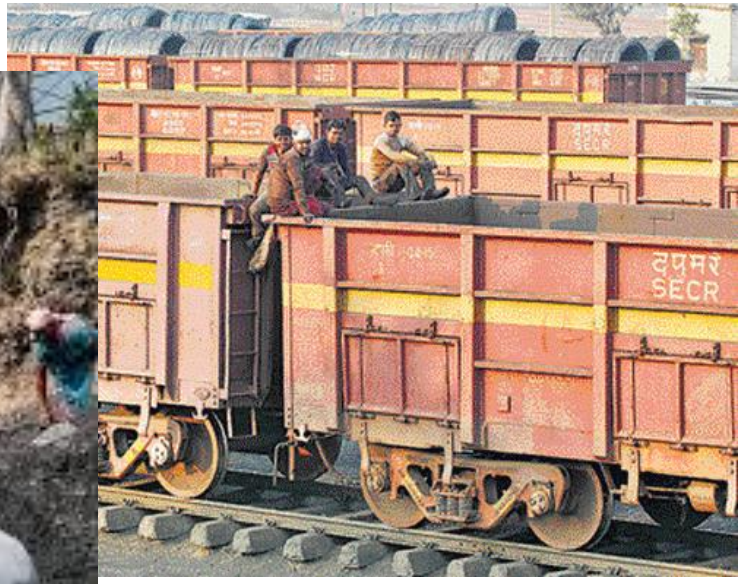
Idea 4 - Unintended consequences & feedbacks (direct & indirect) need to be considered.

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.

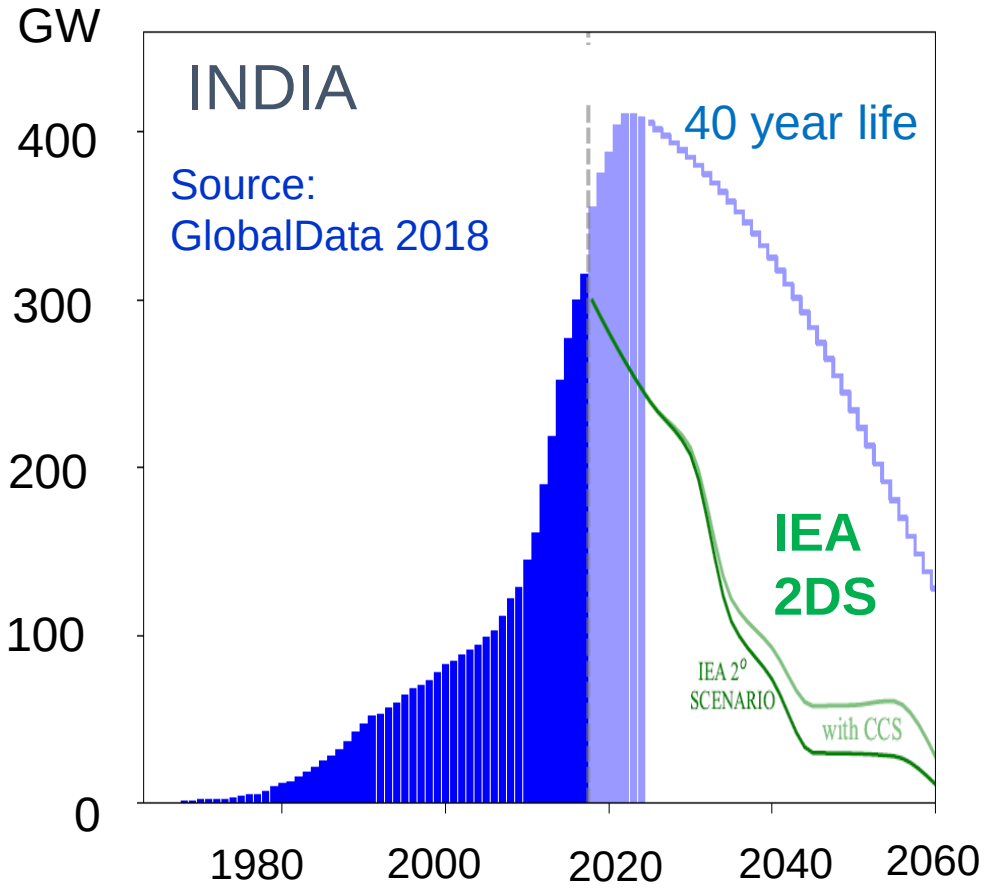
- Value chain participants
- Institutions
- Communities
- etc.



Unintended 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 plants

→ 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

Recap

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

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

Deep-dive analyses of transition scenarios (outside models) to explore bottlenecks (& accelerants):

- **Interdisciplinary** teams - engineering / economics / business / social / behavioural / political sciences
- **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**