Carbon risk and green steel investments: Real Options Analysis and MonteCarlo simulations to assess decarbonization policies.

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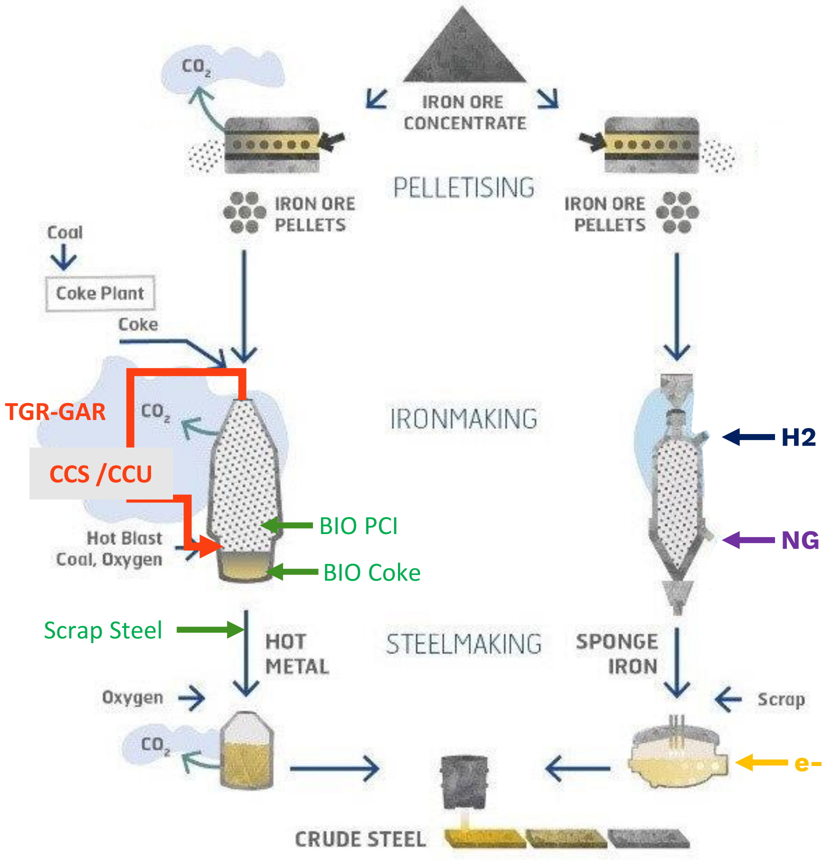
French Steel Sector

- ~17MtCO2, 20% of French industrial GHG
- Uses coal for both **energy** and **process** needs
- Only 5 blast furnaces (BF) in France, 1 firm
- Aging assets (40-50 yo) that will need to be replaced/refurbished 2020-2030 with several billions euros investments
- Two main families of solutions :
  - **Keep existing assets :** Invest in the existing BF and use an existing array of solutions : energy efficiency, biomass, carbon capture & storage (CCS), pay residual CO2
  - **Invest** in new assets with breaktrhough technologies, including a bridge : coal-> natural gas - > hydrogen

→Those two pathways expose the actors to different risks and markets. Actors still include those two options in their decarbonization pathways

Blast Furnace(BF) Direct Reduction Shaft



Classical & Innovative Steel Route

Decarbonization policies : ambitious but uncertain ETS

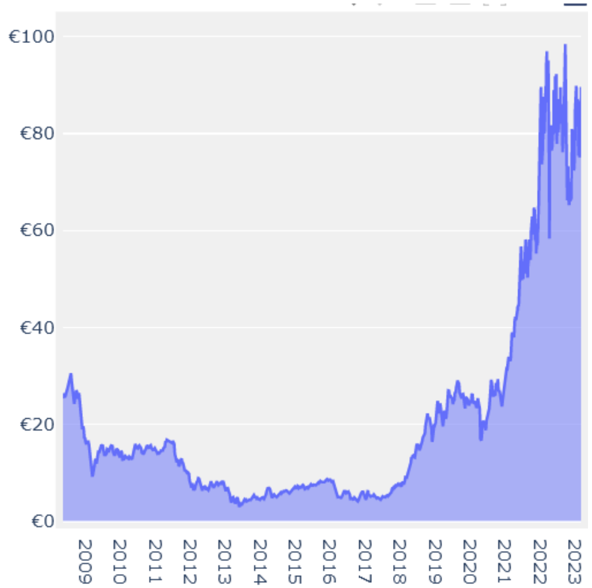
European Emission Trading System : EU - ETS

- High volatility with a complex system of allowances, benchmark, auctionning

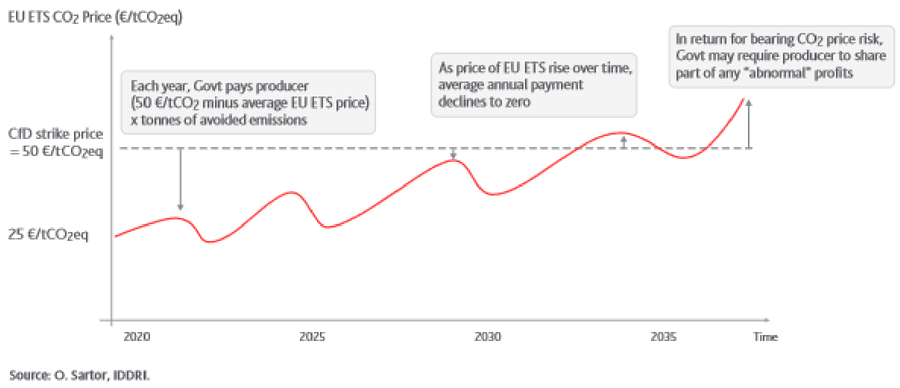
- High regulation risk :
  - End of game uncertainty
  - Market Stability Reserve (MSR)
  - Fit for 55 (FF55) : Benchmarks & Linear Reduction Factor modification
  - Carbon Border Ajustement Mechanism (CBAM) implementation

- Debates around Carbon Contract for Difference / Carbon floor
  - First of a kind (FOAK) or industrial policy ?
  - Include technological risk or carbon market risk ?
  - Design of the carbon markets ?
  - Asymetry if ETS > Carbon floor ?
  - Guarantee a steel price or a carbon price ?

  => Are they more efficient than CAPEX subsidies ?



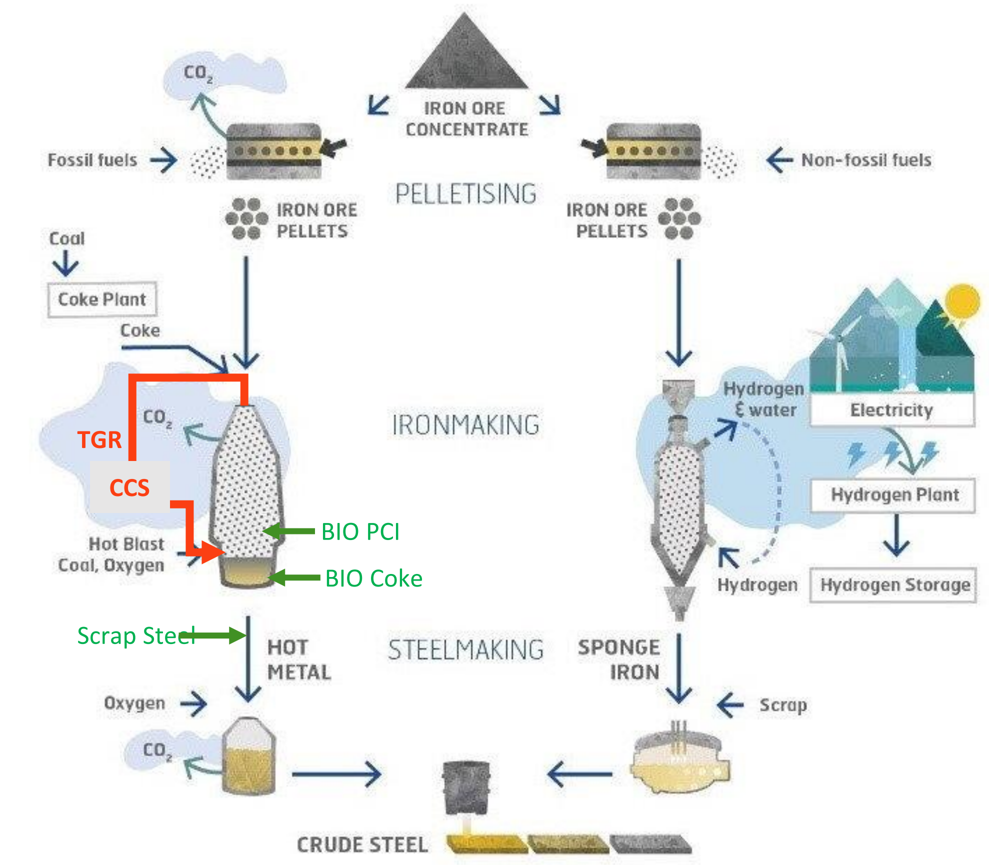
ETS Allowance price - *Sandbag*



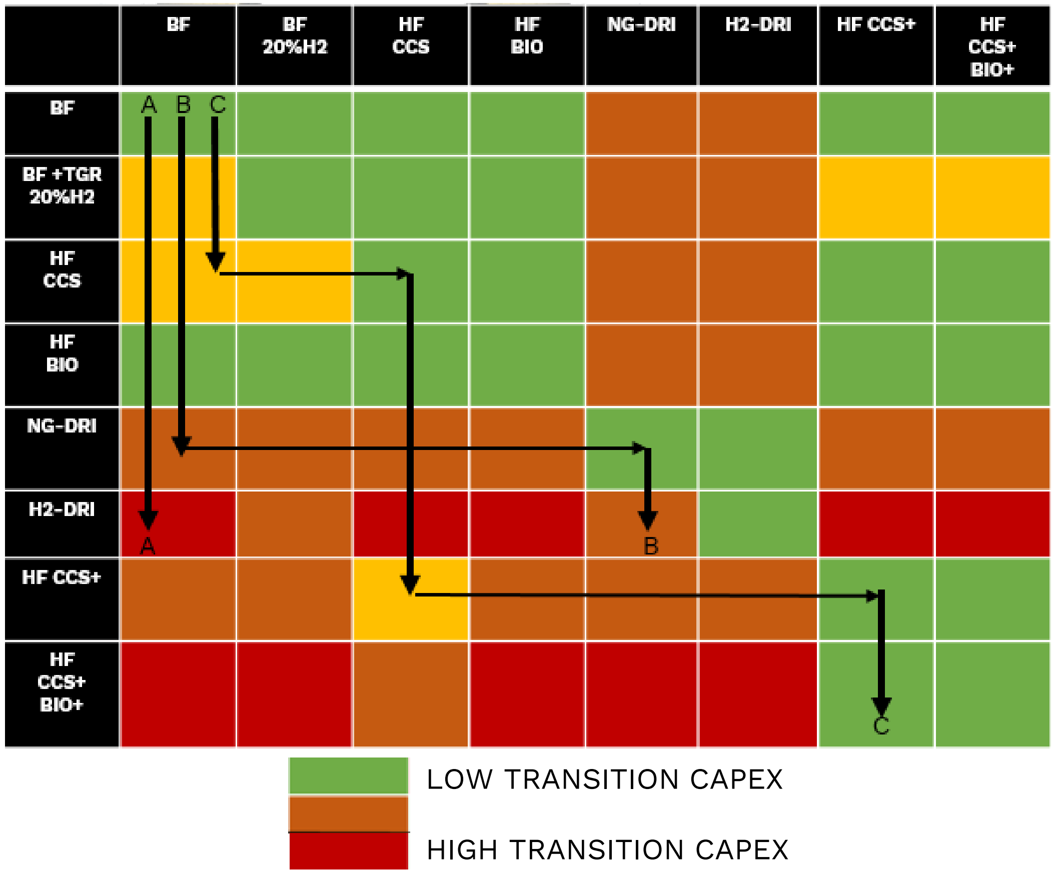
A CfD Implementation – *IDDRI*

Decarbonization technologies & transition risks

BLAST FURNACE **H_2-DRI**



Hybrit Steel Route



Investments towards decarbonization can be done in **one giant step**, or several **short hops**

Problematics

2020-2030 is a decade with multiple problems for steel actors :

1. Need to replace aging assets
2. Technology developement : uncertainty & risks
3. Increasing decarbonization pressure (regulation, markets, image, strategy)
4. High regulation uncertainty
5. Difficulty to access to capital

How can you model those industrial constraints and their interactions to make decision under uncertainty ?

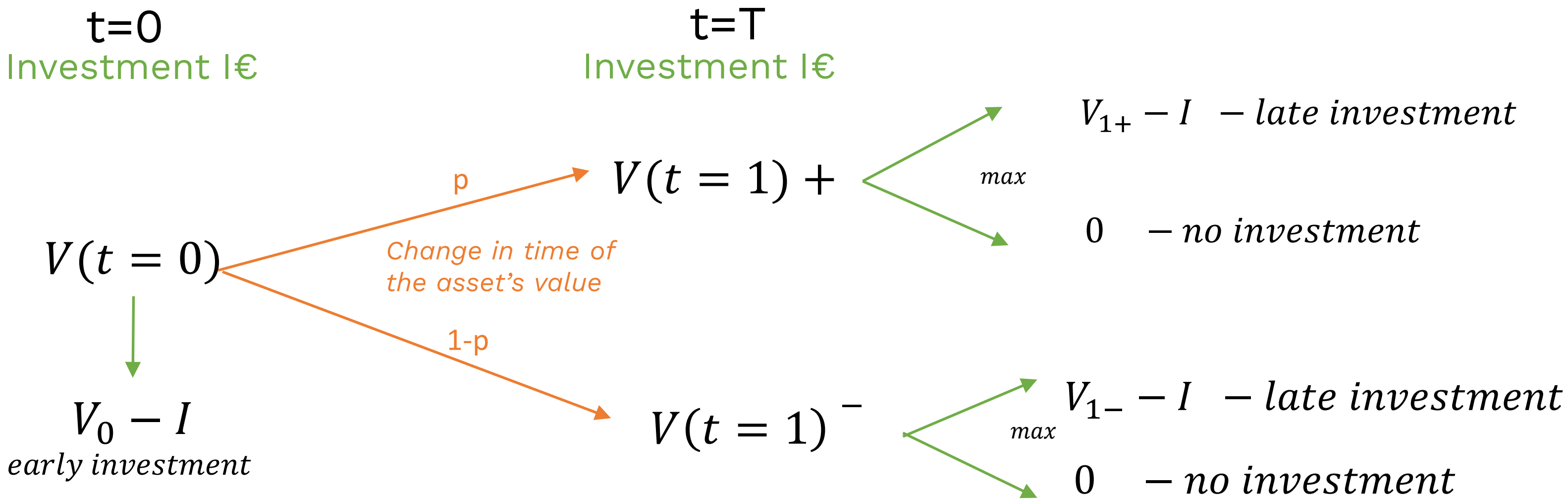
How to design better policies ?

Modelisation framework : Real options

- Real Options are a common tool to model risk in the energy sector [Longstaff 2001, Bastian-Pinto 2009, Agaton 2020, Laude 2021].
- It is similar to running many investment scenarios, mimizing the risk of loosing money, and weighting with their perceived probabilities

<u>Should I invest **today, tomorrow or never ?**</u>

$V(t)$: *Value of the asset*
V_t: *Value of the futur cash flows*
I: *Capital expenditure*



$$V(t=0) = max \begin{cases} V_0 - I & \rightarrow early\ investment \\ \frac{p * V(t=1)^+ + (1-p) * V(t=1)^-}{(1+DR)} & \rightarrow wait \end{cases}$$

Modelisation framework : Real options tool

2 main interests compared to a classical Net Present Value Optimisation/Simulation framework

- **Many options** can be valued :
  - Delay an investment — *Pay a prime to keep an aging asset and wait for the uncertainty to reveal*
  - Operative changes : — *Biomass <-> Coal or H2<->Gaz with some facility depending of spot price*
  - Retrofit : — *The existing asset has a strating value, replacing it early results in stranded asset*
  - Gradual investments — *A bridge technology or a dead-end one with the same cash flows don't have the same value*

$$V(A,t=0) = max \begin{cases} CF(A,t) + CV(A,t+1)/(1+DR) \rightarrow No\ Investment, keep\ A \\ CF(A',t) + CV(A',r+1)/(1+DR) \rightarrow Operative\ change\ from\ A \rightarrow A' \\ I(A \rightarrow B) + CF(B,t) + CV(B,t+1)/(1+DR) \rightarrow Investment\ in\ techno\ B \\ I(A \rightarrow C) + CF(C,t) + CV(C,t+1)/(1+DR) \rightarrow Investment\ in\ techno\ C \\ I(A \rightarrow D) + CF(D,t) + CV(D,t+1)/(1+DR) \rightarrow Investment\ in\ techno\ D \end{cases}$$

$I(A \rightarrow B)$: *CAPEX from A to*
$CF(B,t)$, *Cash – Flow of tech B*
CV(C,t+1) – Continuation Value of tech C

- Enhanced with a **stochastic description of the environnement**

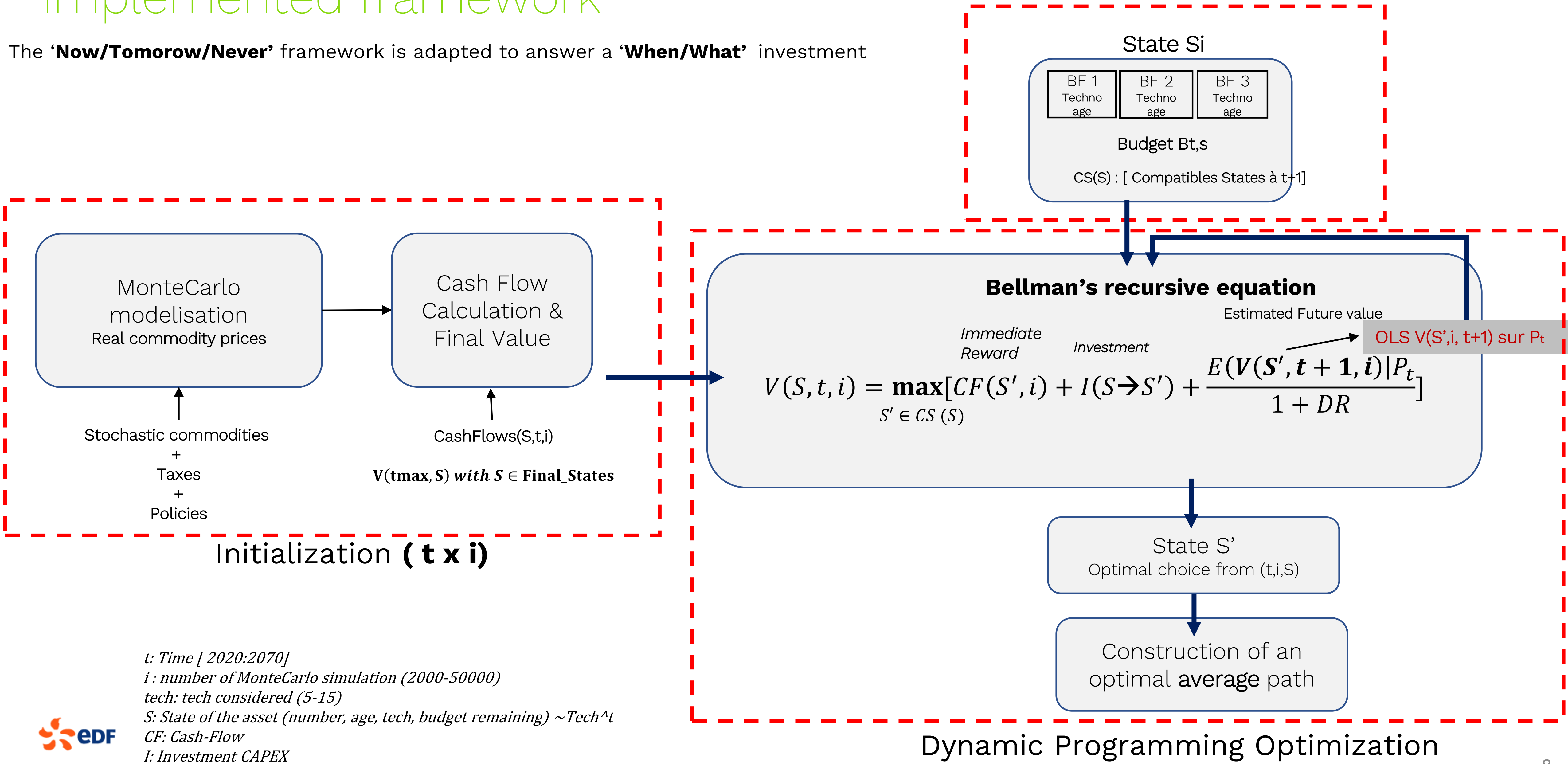
  New description of the associated risks : technology, commodity & regulation

  - Commodity Risk : Correlated Geometric Brownian Movment (Electricity, Gaz, Coal, CO2) with decorrelation to 2050
  - Regulatory Risk : Energy Taxation (FR), CO2 price (ETS free allocation, Benchmarks & rules)
  - Technological risk : Risk of failure of a new technology, increase of costs (H2, CCS)

Implemented framework

The ‘**Now/Tomorow/Never’** framework is adapted to answer a ‘**When/What’** investment

Initial & Compatible States (S ~ $Tech^t$)



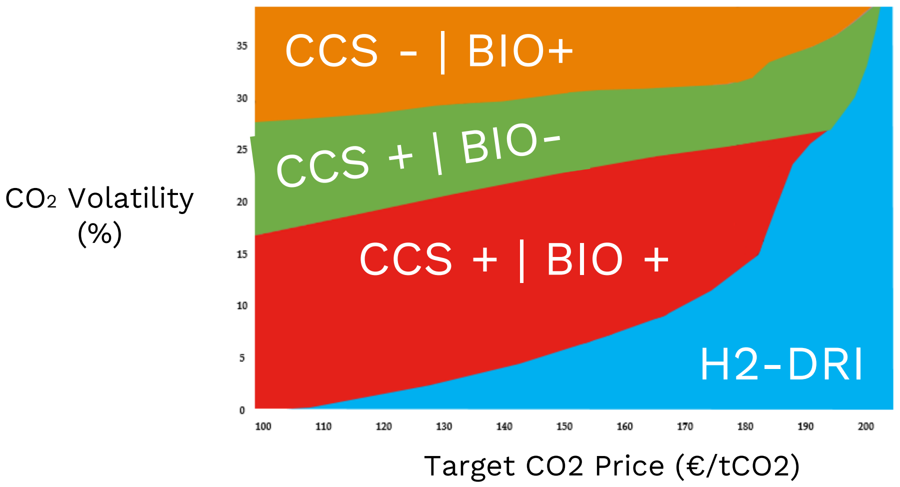
t: Time [2020:2070]
i : number of MonteCarlo simulation (2000-50000)
tech: tech considered (5-15)
S: State of the asset (number, age, tech, budget remaining) ~Tech^t
CF: Cash-Flow
I: Investment CAPEX
E(V) : Estimated Continuation Value

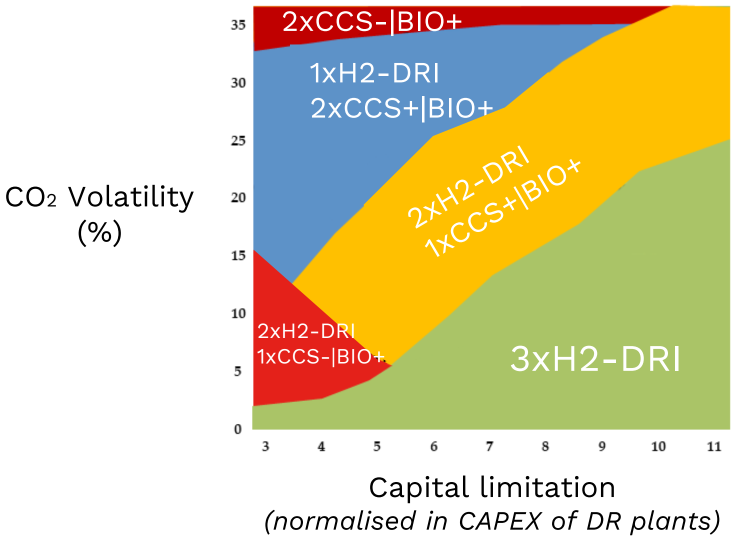
Results – Commodity modeling (1/2)

No budgeting limit

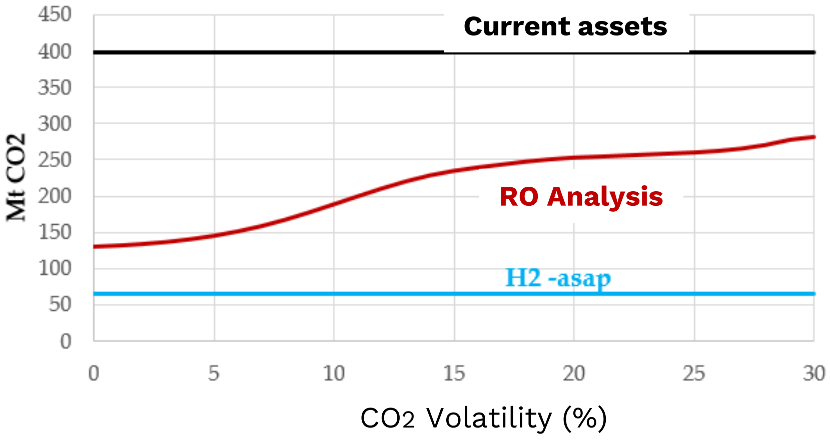
Budgeting limit – 3 assets

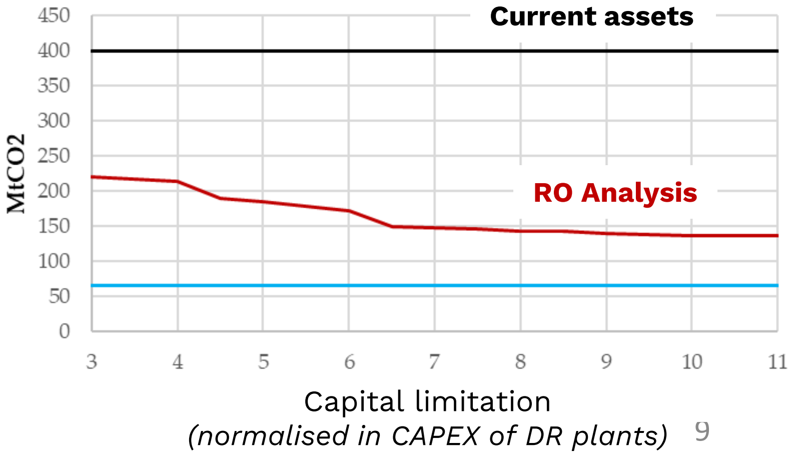
2050 Assets





Cumulated emissions 2018-2050





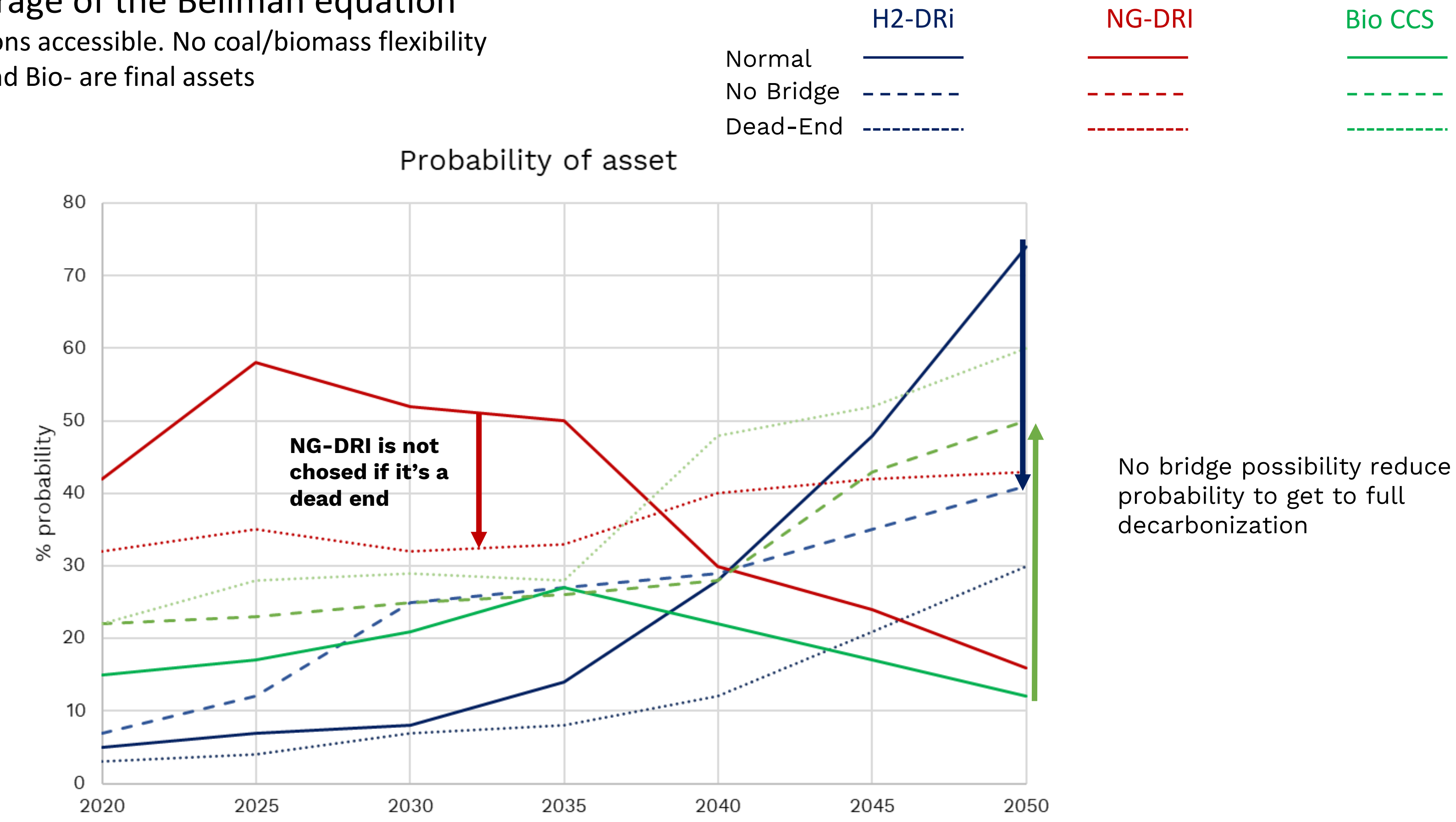
EDF

Results – Commodity modeling (2/2)

The value of a technology is the average of the Bellman equation

No bridge : Only Bio+CCS and H2-DRI are solutions accessible. No coal/biomass flexibility

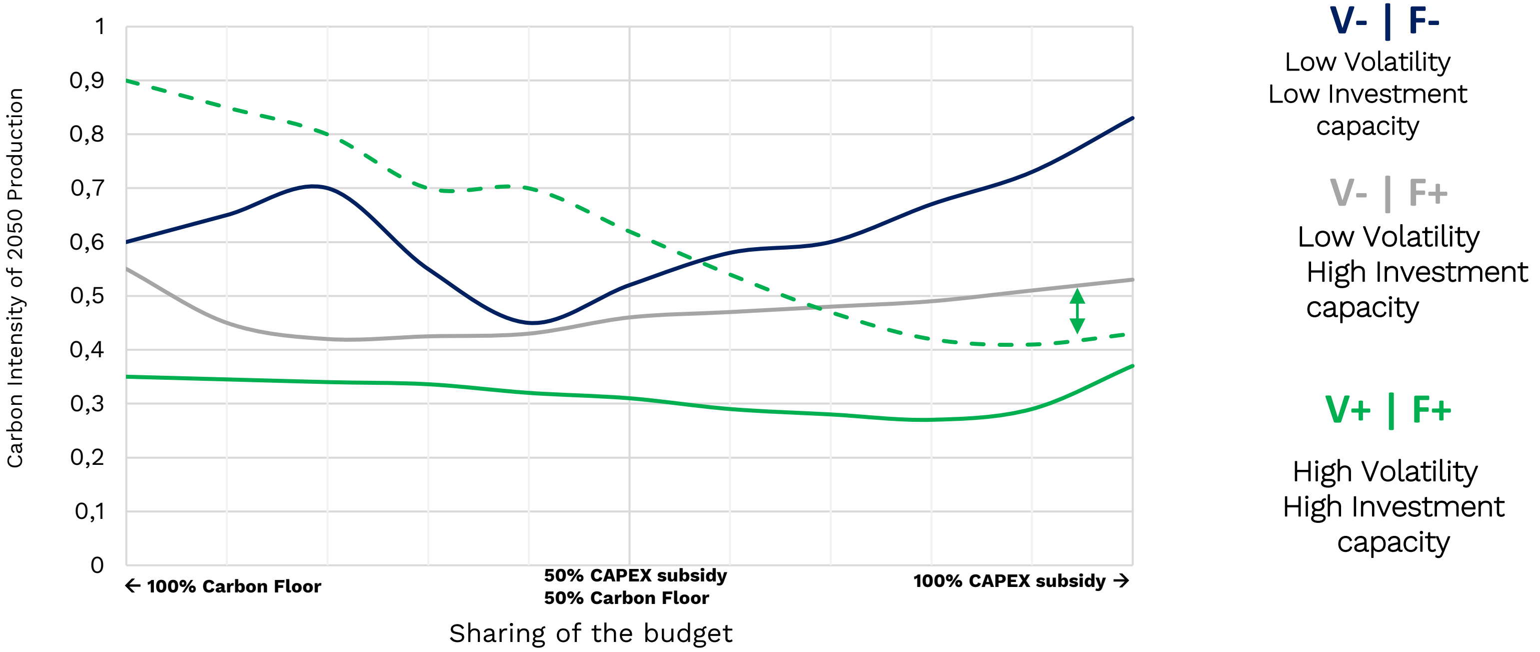
Bridge is Dead-End :All solutions but NG-DRI and Bio- are final assets



- NG-DRI has an high value even if it's no commonly used as bridge (54%)
- 20 to 37% NG-DRI 's value consists of the possibility to evolve to H2-DRI
- Biomass solutions gain less from bridge possibilities and replace H2-DRI as only moderate risk technology
- Dead-end solution value is not affected by the bridge

Results – CfD

A 1 billion budget that can be shared among two policies : a carbon floor price or a capex subsidy for low carbon solutions



- Some sweet spots exists combining both kind of policies : appearance of threshold effects
- Deadweight appears ↖↘ : a reduction by half of the policy budget has almost no impact on CO_2 intensity
- The stochastic and deterministic environnement has a great impact on the best policy

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Discussion & Outlooks

Discussion

- It is possible to include **gradual investments** values in a classical OR formalism but it cannot be compared to traditional scenario based approaches
- European steel decarbonization need **long-term signals** to plan effectively the transition : CO2 markets, Commodity prices & Technology
- **Bridge technologies** (NG-DRI) values highly depends on the carbon market modelisation : they should not be rulled out for they can make deep decarbonization cheaper (-10-50%) while having low lock-in results
- Other technologies (Biomass) are valued very positvely in uncertain environnement for they are versatile : they also may result in **mid-decarbonization lock-in**
- **Decarbonization policies can interact,** and can affect very differently the industry with likely deadweight effets

Discussion

Foresight …

- This approach could be coupled with a representation of diffusion dynamics and learnind effects that could complement the transition risk modeling

- Interaction between risks need further research

- Policies & Market failures are highly relevant issues to study but require a sturdy study framework

- Carbon market was taken as exogenous : feedback from exhibited behaviors could strongly impact the CO2 price seeing :
  - The importance of the steel emissions in the ETS market
  - The close choices than may lead to an investment rush when a CO_2 uncertainty will be removed

- Sailing the deep decarbonization of industry is a major challenge and will last decades. Using project finance, real options and behavioral economics in prospective tools can help to design efficient policies in the long run, while avoiding deadweights or stranded assets.

Results – Commodity modeling (2/2)

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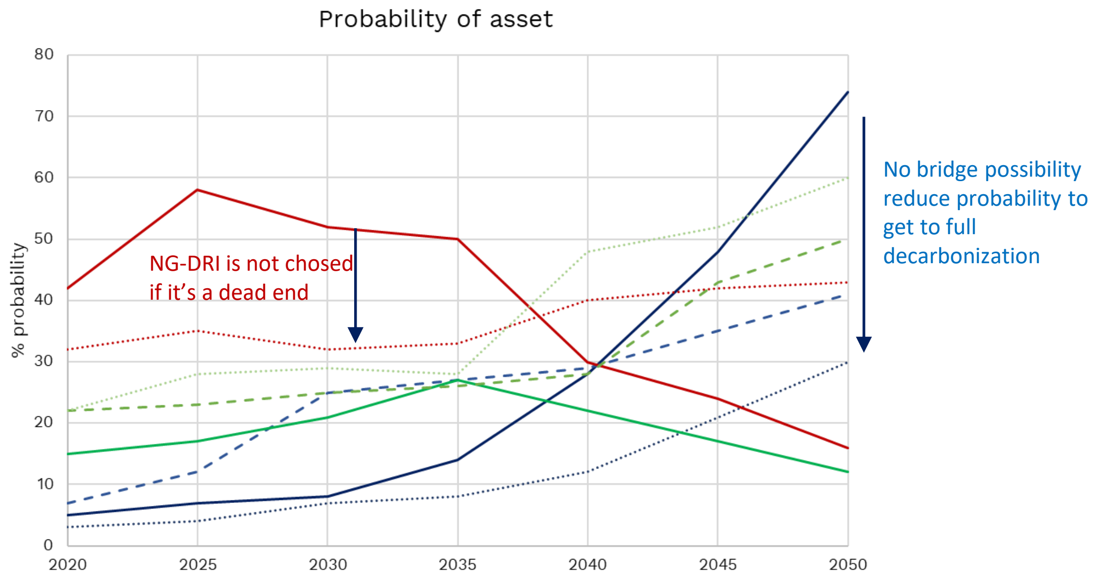

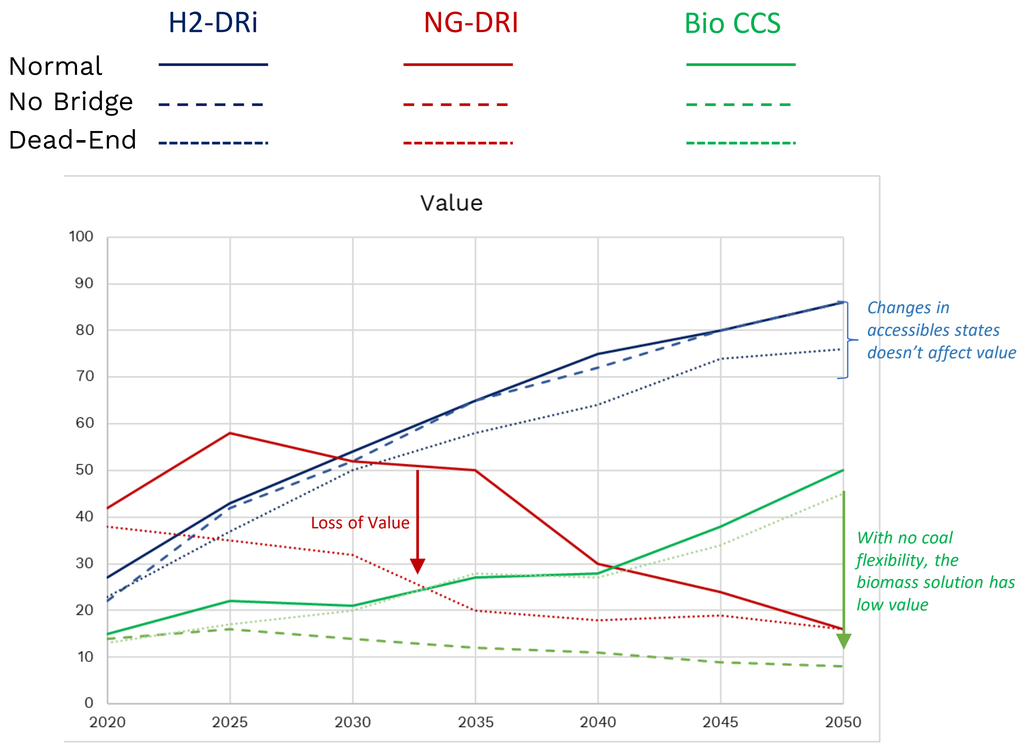

!! Value is average among points of space excepted acheived states!!

H2-DRI has an high value, but this value is acheived from points that are not necessarly reachable

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