Workshop: « What instrumentation for the ecological planning of complex innovations? »

7th October 2022

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ENGIE Research & Innovation
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Extending Cost-Benefit Analysis of an Industrial Pilot Project for the Energy Transition

A Case Study in the French Container Glass Sector

Key Messages

- Major innovations for the industrial energy transition are at the pilot stage.
- Standard Cost-Benefit Analysis (CBA) might suggest that investing in a pilot project is not socially justified.
- Standard CBA should be extended to incorporate long-term benefits of the pilot project.
- Public support mechanisms should be designed in this perspective.

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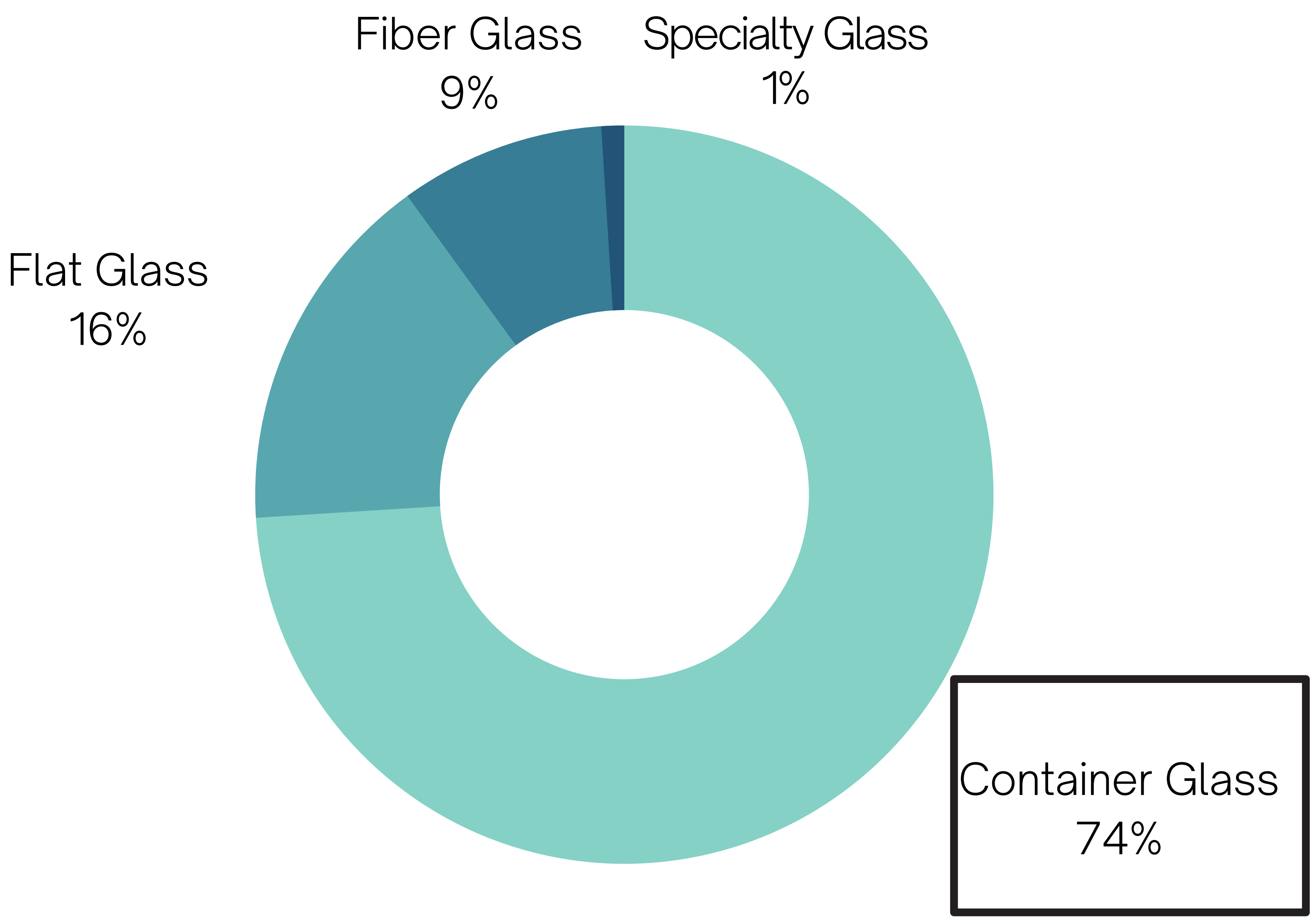
Container Glass Sector: a Flagship in France Industry

47% of European glass production is carried out in France (Fives, 2020).

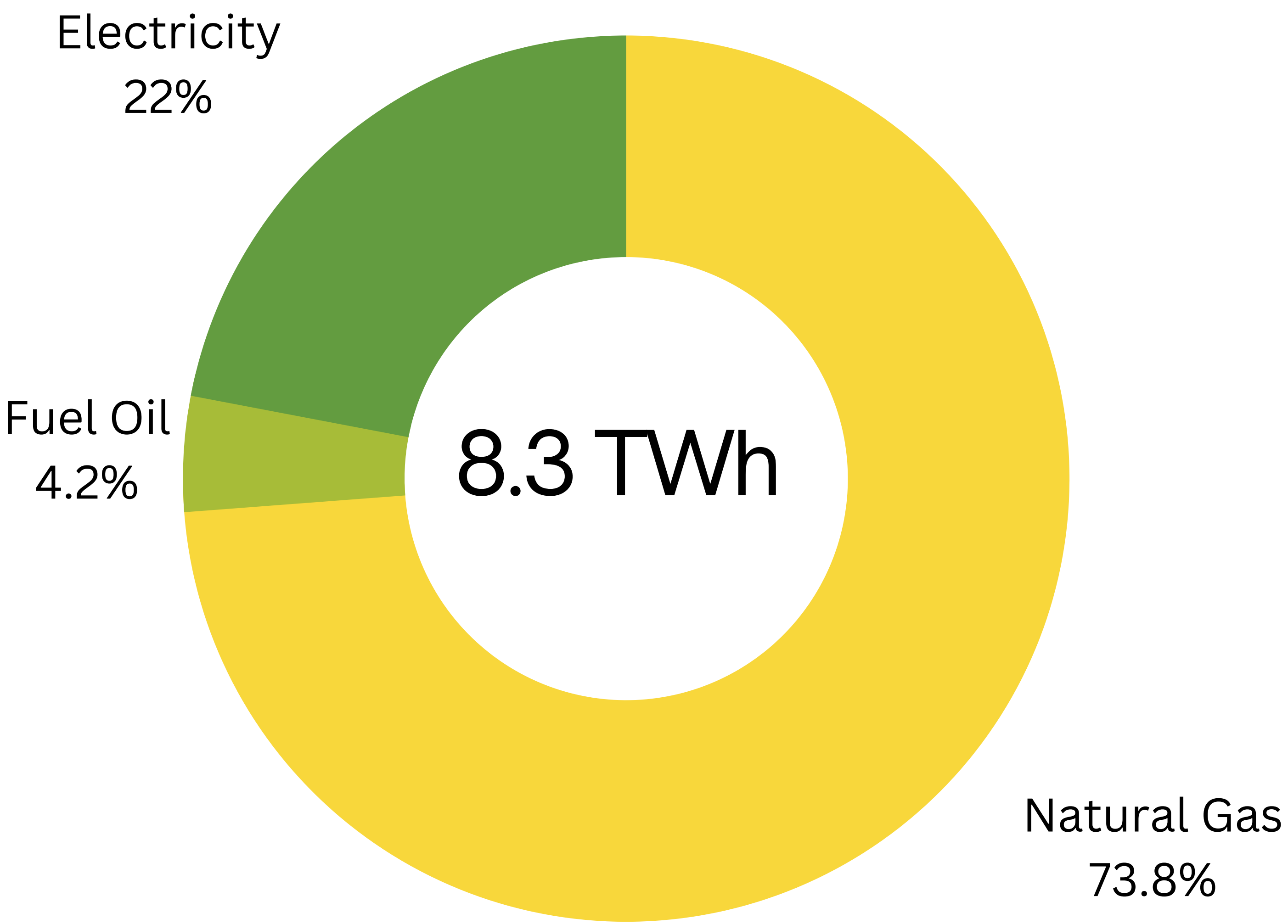
5.6 Mtons of Glass has been produced in France in 2020 (Glass Global).



4.1 Mtons of Container Glass has been produced in **56 Melting Furnaces by 25 companies.**

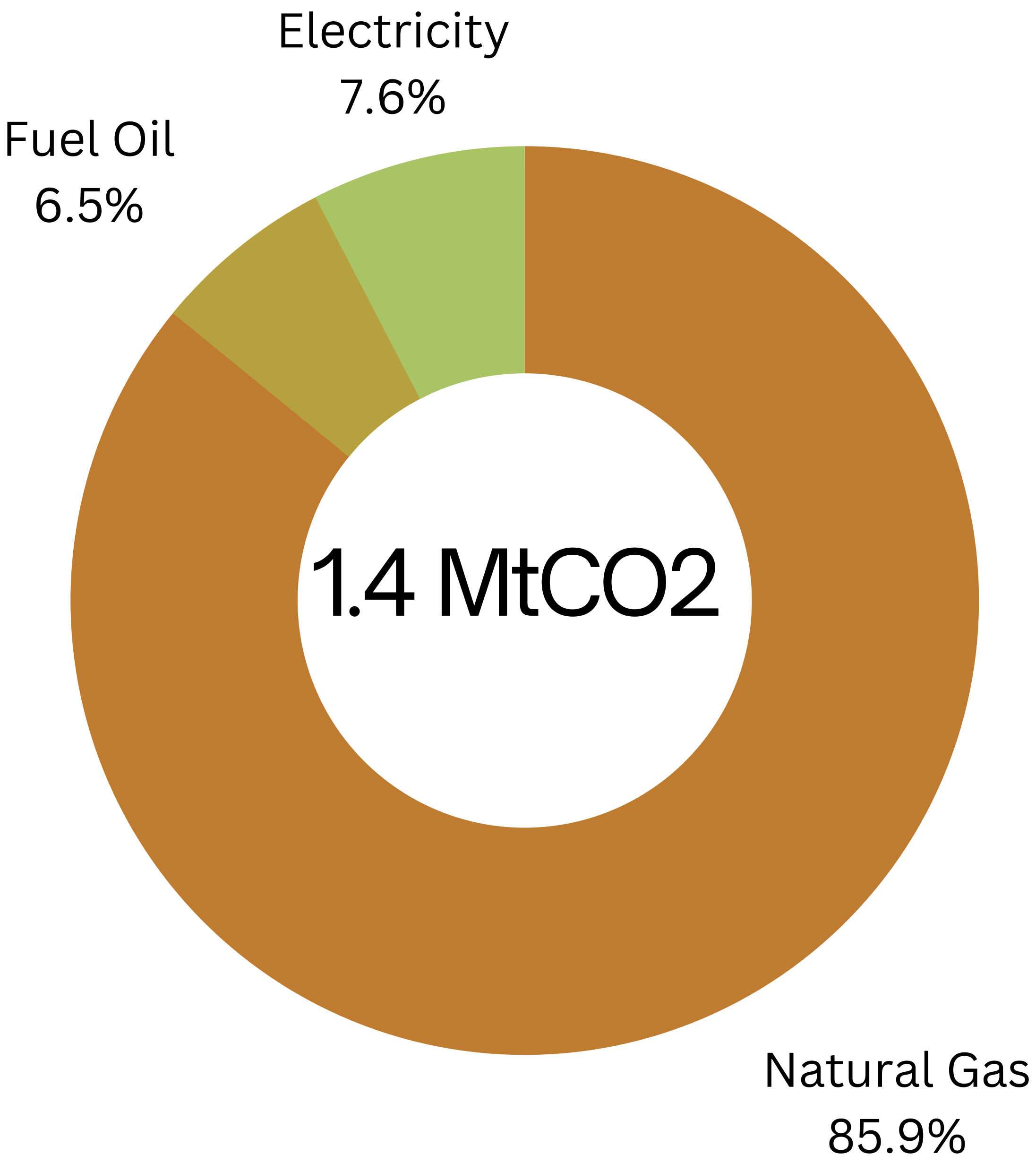
Container Glass Sector Mostly Consumes Fossil Fuels

Energy Sources in Container Glass Sector of France (ADEME, 2021)



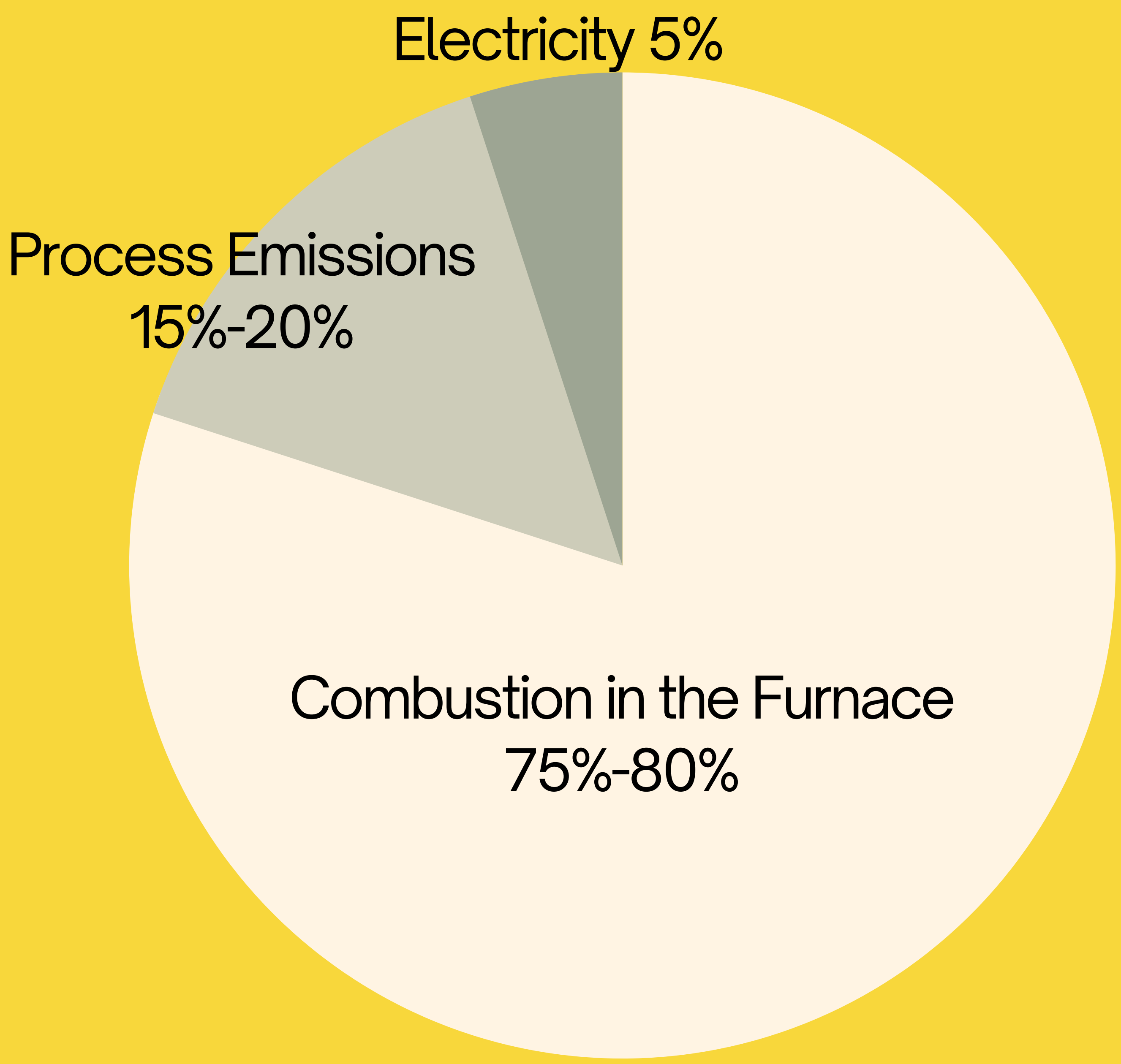
In total, 3% of thermal energy and 2% of electrical energy of French industries

Emission Sources in Container Glass Sector of France (ADEME, 2021)



In total, 3% of the French national total GHG emissions

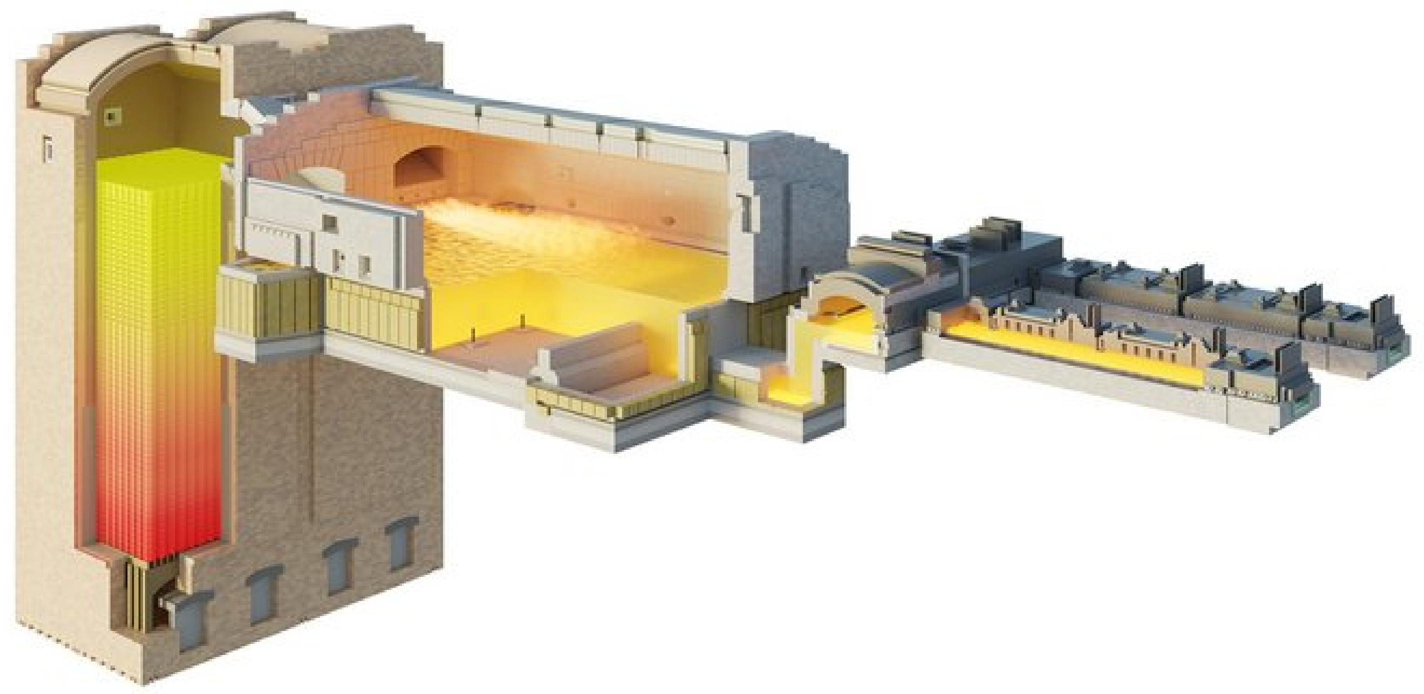
Decarbonizing the **Glass Melting Furnace**: the Most Important Lever for Carbon Neutrality of the Sector

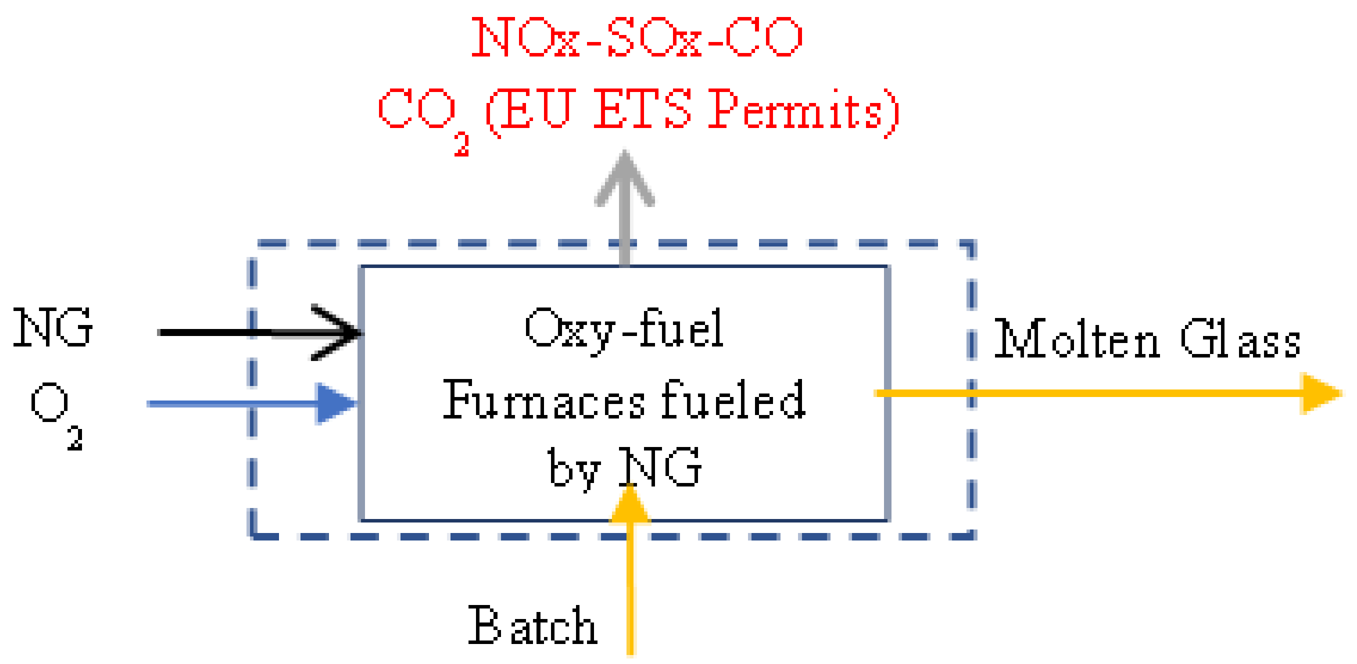


Sources of Emission in a Container Glass Site (ADEME, 2021)

Pilot Project: Decarbonizing the Glass Melting Furnace

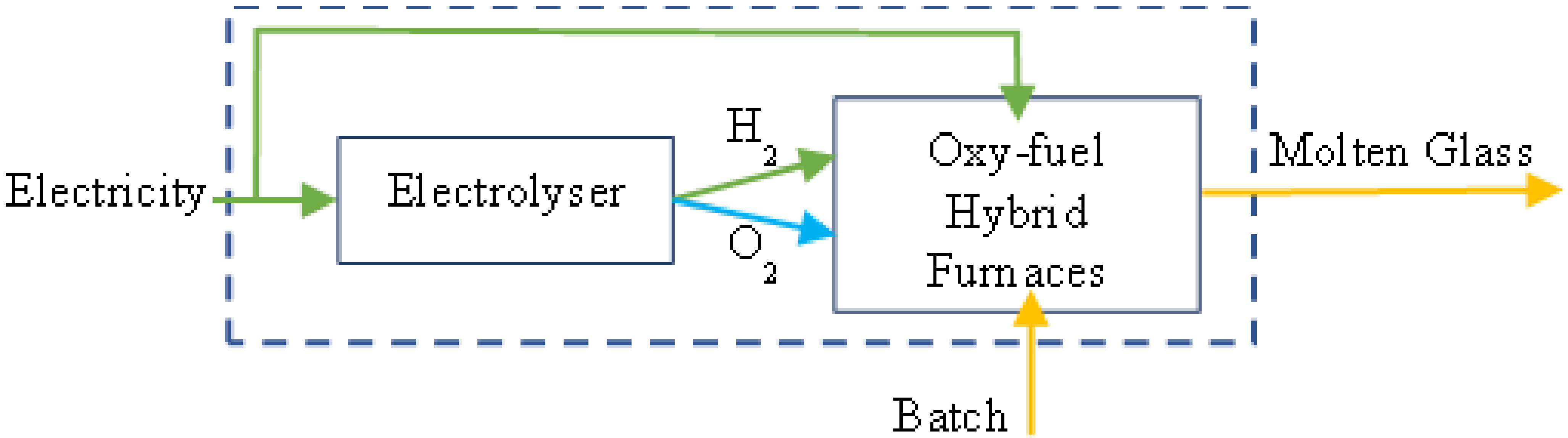
Reference Case: NG-fired Furnace





Pilot Project: Decarbonizing the Glass Melting Furnace

Decarbonization Project: Hybrid Furnace (80% Electricity - 20% Hydrogen)



Numerical Illustration

Reference Case Furnace Information

Annual Glass Production	112 000 tGlass/year
Year of Last Reconstruction	2021
Annual NG consumption of the Furnace	128 GWh/year
Annual CO_2 Emission	44013 tCO_2/year
Annual NO_x Emission	214 tNO_x/year
Annual SO_x Emission	131 tSO_x/year
Annual CO Emission	7 tCO/year
O_2 Consumption of the Oxy-Fuel Furnace	4340 tO_2/year

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Abatement Cost: a common metric in cost-benefit analysis of green projects

The Cost of Carbon Abatement for a Decarbonization Project is defined as:

$$\text{Levelized Cost of Carbon Abatement (LCCA)} = \frac{\text{Total Discounted Cost of the Project Compared to the Reference}}{\text{Total Discounted Abatement of Carbon Compared to the Reference}}$$

Familiar Formula for LCOE!

References:

- Friedman et al. (2020): “Levelized Cost of Carbon Abatement”
- Criqui (2021): “Les coûts d’abattement’’, Referred to as: “Méthode 3”
- H-Vision in the Netherlands, Zero Emission Valley in France (Teyssier d’Orfeuil, 2020)

LCCA is a key indicator to be compared with the Social Cost of Carbon for Evaluation of the Project

Levelized Cost of Carbon Abatement (LCCA) ≤ Social Cost of Carbon (SCC)

Abatement cost of project is accepted by the society!

The official French SCC of the government since 2019 does not reflect exactly the social cost of carbon but rather a political carbon price trajectory

Cost-Benefit Analysis at Project Level

$$\text{Levelized Cost of Carbon Abatement (LCCA)} = \frac{\textit{Equivalent Annualized Cost} - \textit{Equivalent Annualized Benefits}}{\textit{Annual Abatement of Carbon}}$$

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#	Source of the Cost	Equivalent Annualized Cost
1	CAPEX	1.5 M€

#	Source of CAPEX
1	Hybrid Furnace CAPEX
2	Alkaline Electrolyser CAPEX (5MW)
3	Connection to the Electricity Grid
4	Installation Costs
5	Electrolyser Stack Replacement Cost
Total Investment = 19 M€	

Cost-Benefit Analysis at Project Level

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2	O&M (1.5% of CAPEX)	0.25 M€

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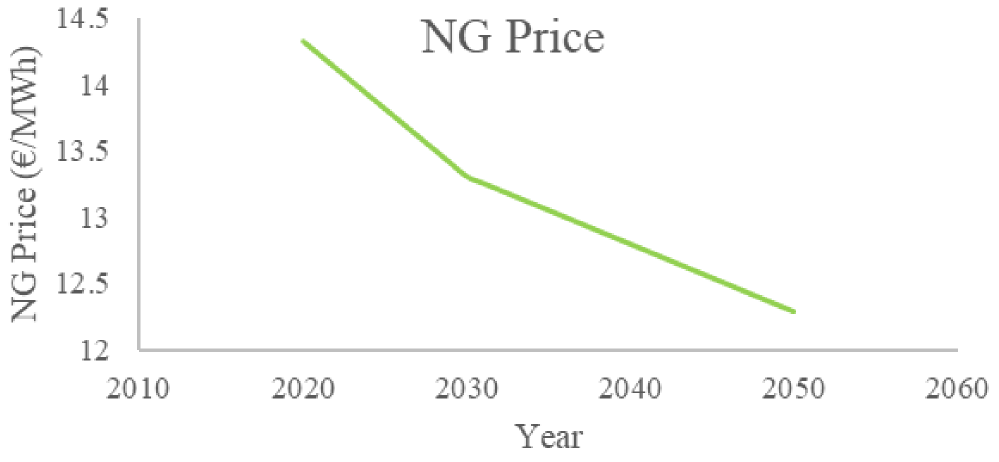
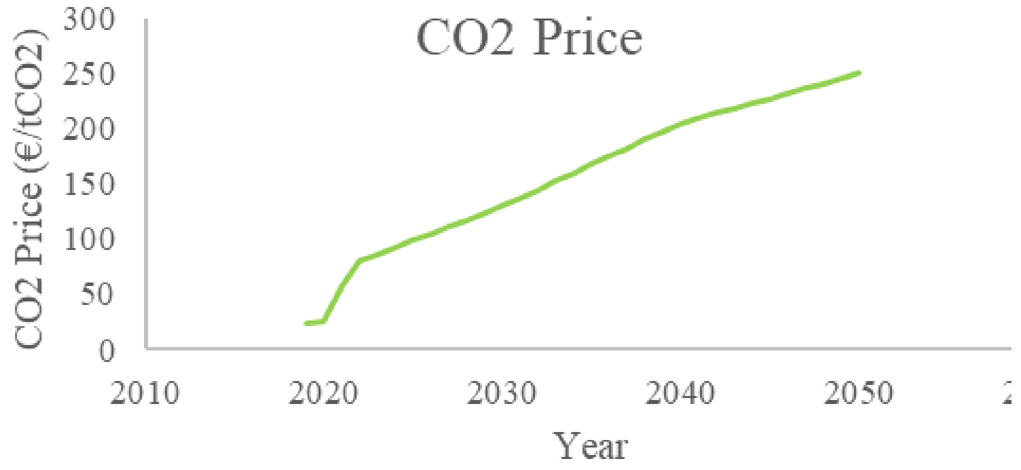
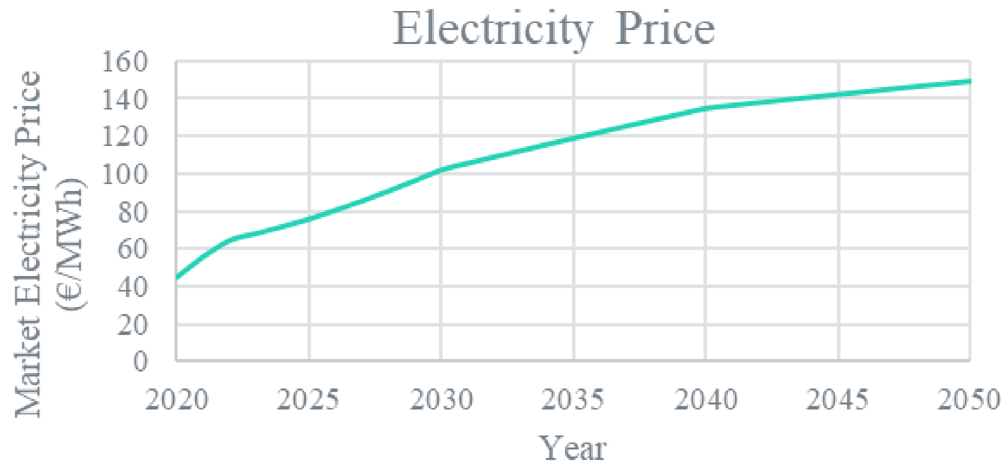
#	Source of the Cost	Equivalent Annualized Cost
1	CAPEX	1.5 M€
2	O&M (1.5% of CAPEX)	0.25 M€
3	Electricity Consumption Cost	21 M€

Electricity Price Evolves with NG and CO2 Prices from IEA NZE Scenario







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Total Equivalent Annualized Costs With Discount Rate of 3%		**23 M€**

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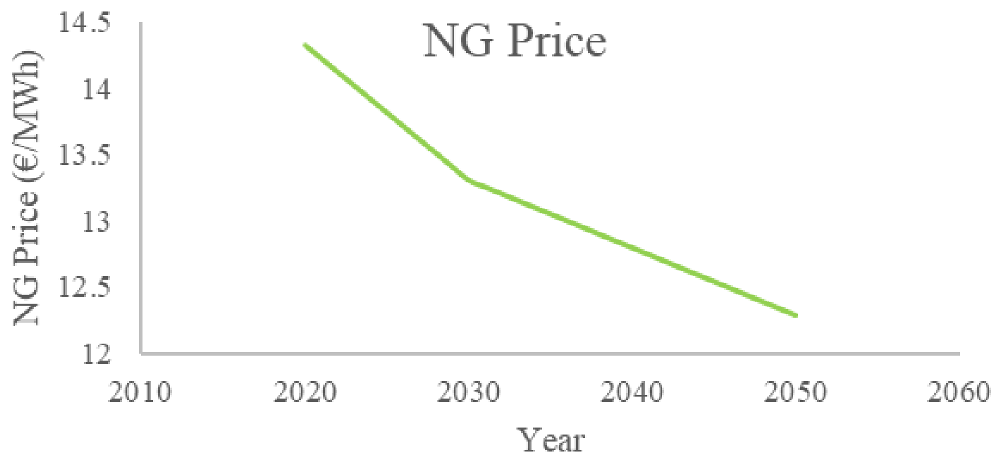
#	Source of the Benefits	Equivalent Annualized Benefit
1	Savings on NG Consumption	1.5 M€

NG Price Evolves According to IEA NZE Scenario



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#	Source of the Benefits	Equivalent Annualized Benefit
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2	Savings on Oxygen (50 €/tO2)	0.5 M€

Cost-Benefit Analysis at Project Level

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#	Source of the Benefits	Equivalent Annualized Benefit
1	Savings on NG Consumption	1.5 M€
2	Savings on Oxygen (50 €/tO2)	0.5 M€
3	Savings on NOx-SOx-CO	4.5 M€

Environmental Prices Handbook: EU28 Version by CE Delft 2018

Pollutant	Central Value (€2015/t)
Carbon Monoxide (CO)	52.6
Nitrogen Oxides (NOx)	14800
Sulfur Oxides (SOx)	11500

Cost-Benefit Analysis at Project Level

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#	Source of the Cost	Equivalent Annualized Cost
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3	Electricity Consumption Cost	21 M€
Total Equivalent Annualized Costs With Discount Rate of 3%		**23 M€**

#	Source of the Benefits	Equivalent Annualized Benefit
1	Savings on NG Consumption	1.5 M€
2	Savings on Oxygen (50 €/tO2)	0.5 M€
3	Savings on NOx-SOx-CO	4.5 M€
Total Equivalent Annualized Benefits With Discount Rate of 3%		**6.5 M€**

Cost-Benefit Analysis at Project Level

$$\text{Levelized Cost of Carbon Abatement (LCCA)} = \frac{\textit{Equivalent Annualized Cost} - \textit{Equivalent Annualized Benefits}}{\textit{Annual Abatement of Carbon}}$$

One Furnace Lifetime = 15 years (2032-2047)

$$\text{LCCA} = \frac{23\ \text{M€} - 6.5\ \text{M€}}{44013\ \text{tCO}_2} = 370\ \text{€/tCO}_2$$

Cost-Benefit Analysis at Project Level

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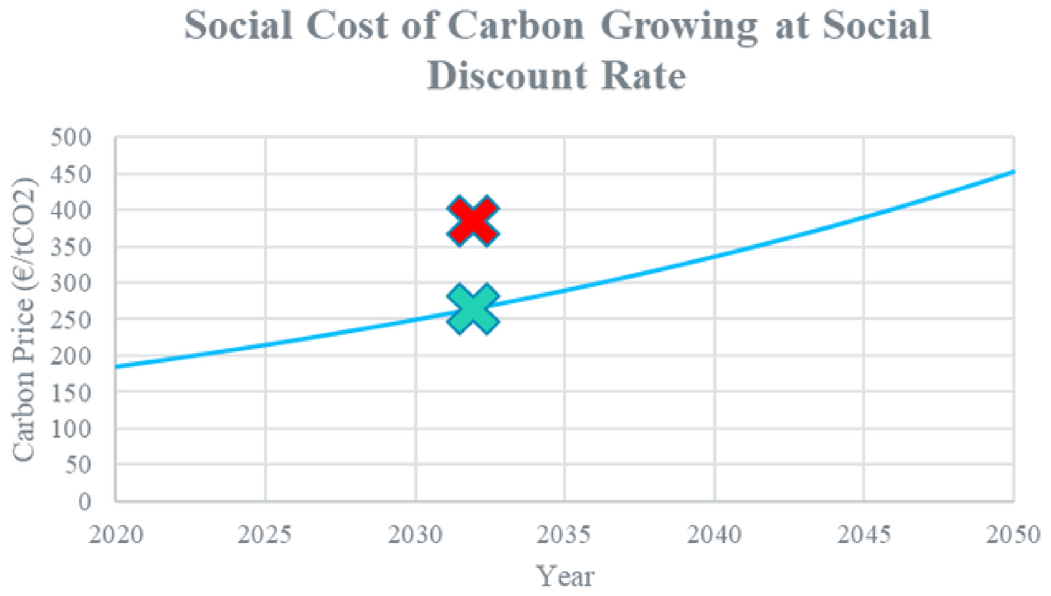
$$\text{Social Cost of Carbon (SCC) at 2032} = 265 \text{ €/t}CO_2$$

LCCA > SCC

In this framework, the Pilot Project is not socially worthwhile.



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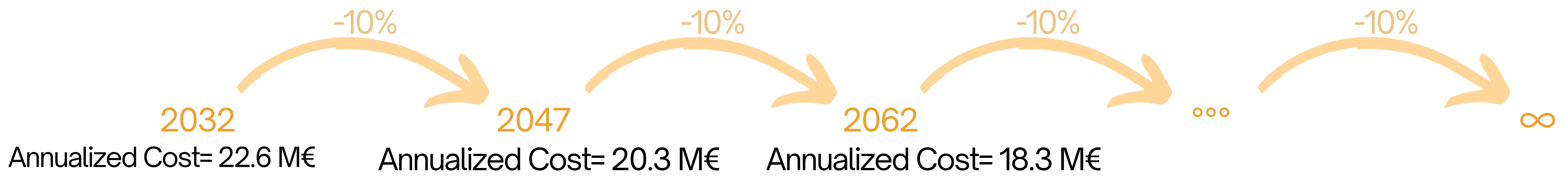
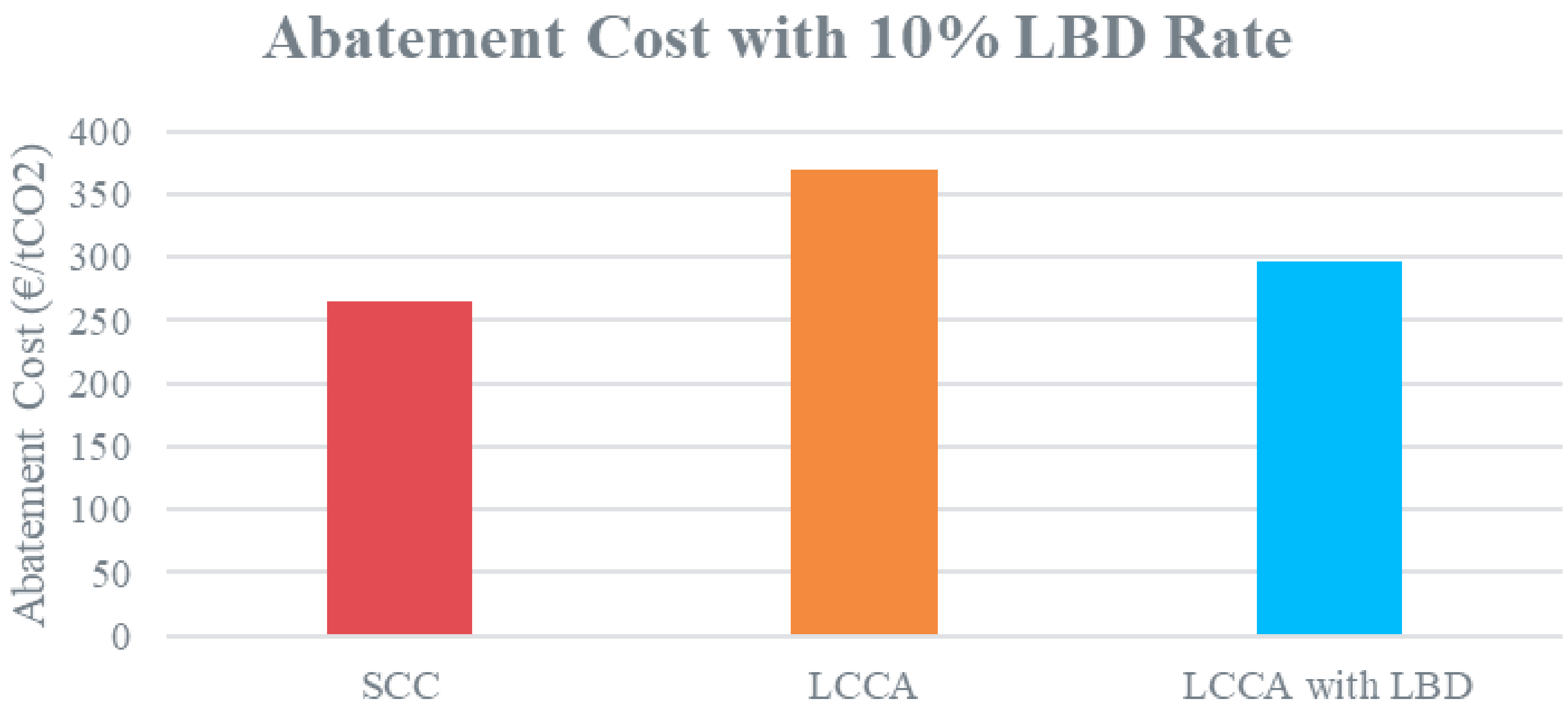
Cost-Benefit Analysis (CBA) with Learning-by-Doing (LBD) Effects

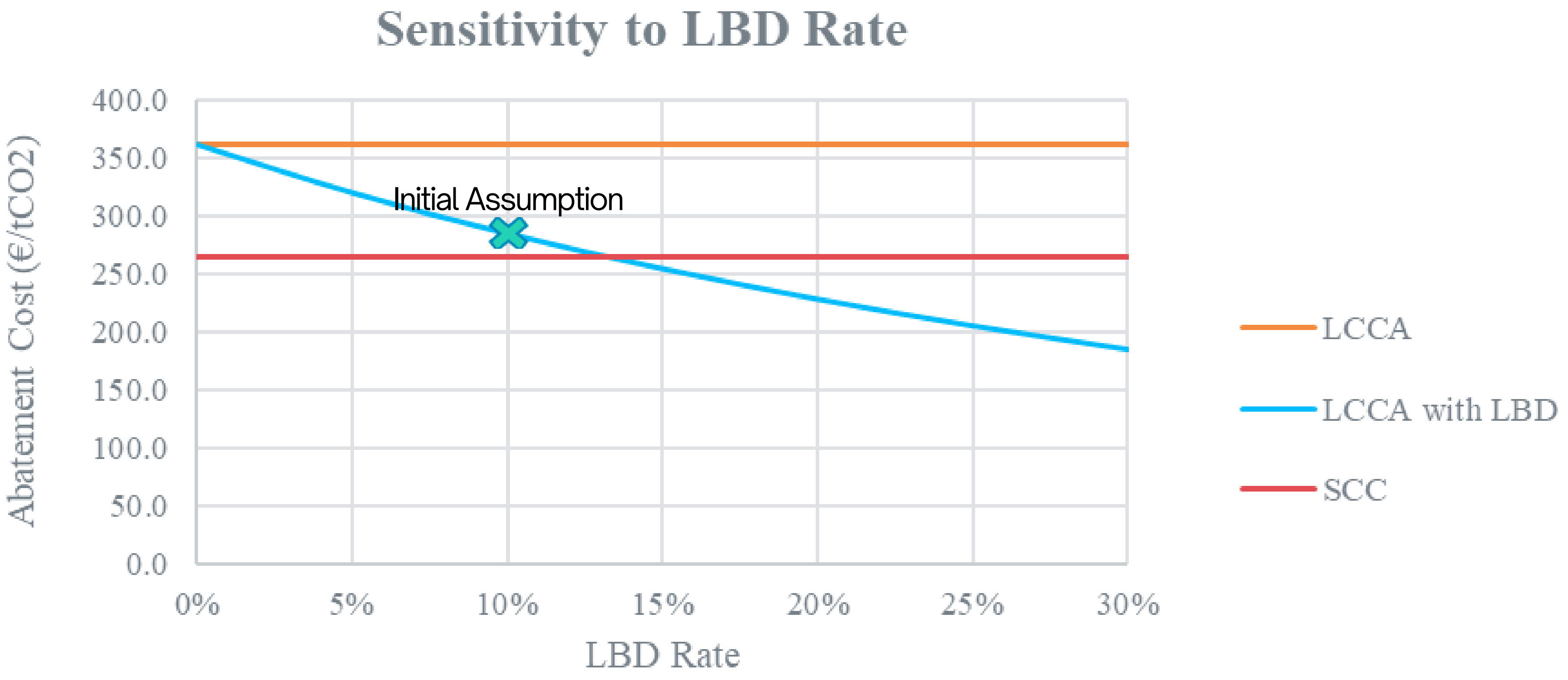
Cost of the investment decreases through deployment and innovation

Applying a LBD rate of 10% could decrease the abatement cost by 25%

We assume the project is **renewed** with **10% lower cost** at the end of the each 15 years lifetime





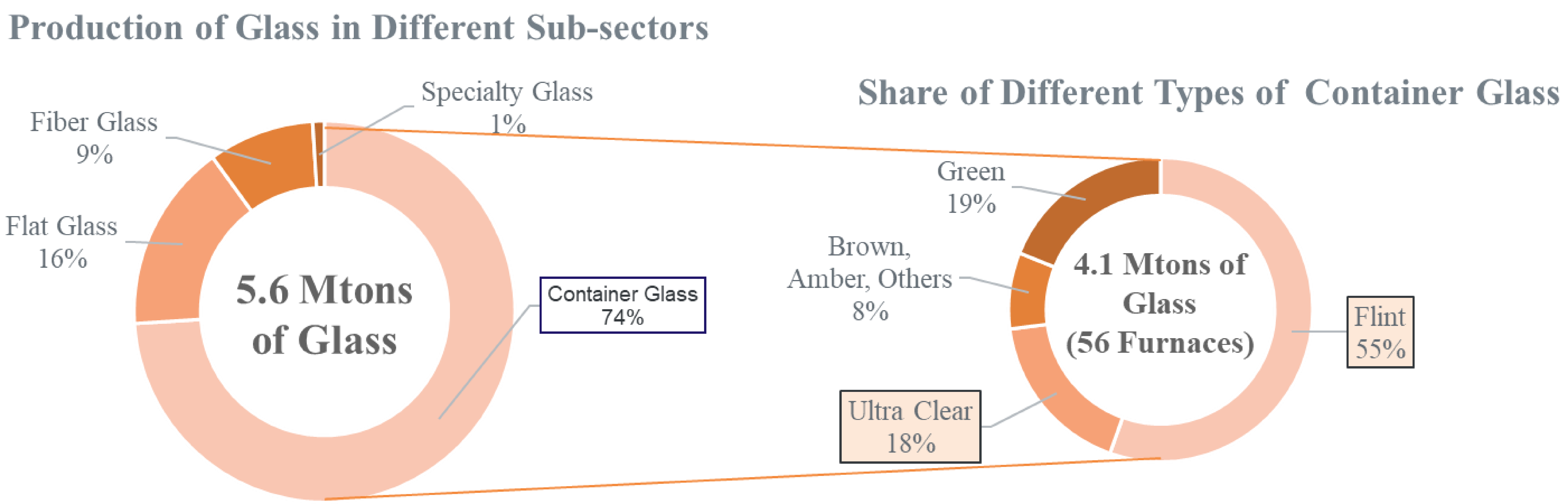


A learning rate of **14%** makes the project socially worthwhile.

Cost-Benefit Analysis (CBA) with LBD and Spillover Effects

Investing in decarbonization pilot project has positive impacts on the other similar polluting units of the whole sector

How many similar furnaces could be affected by the pilot project?

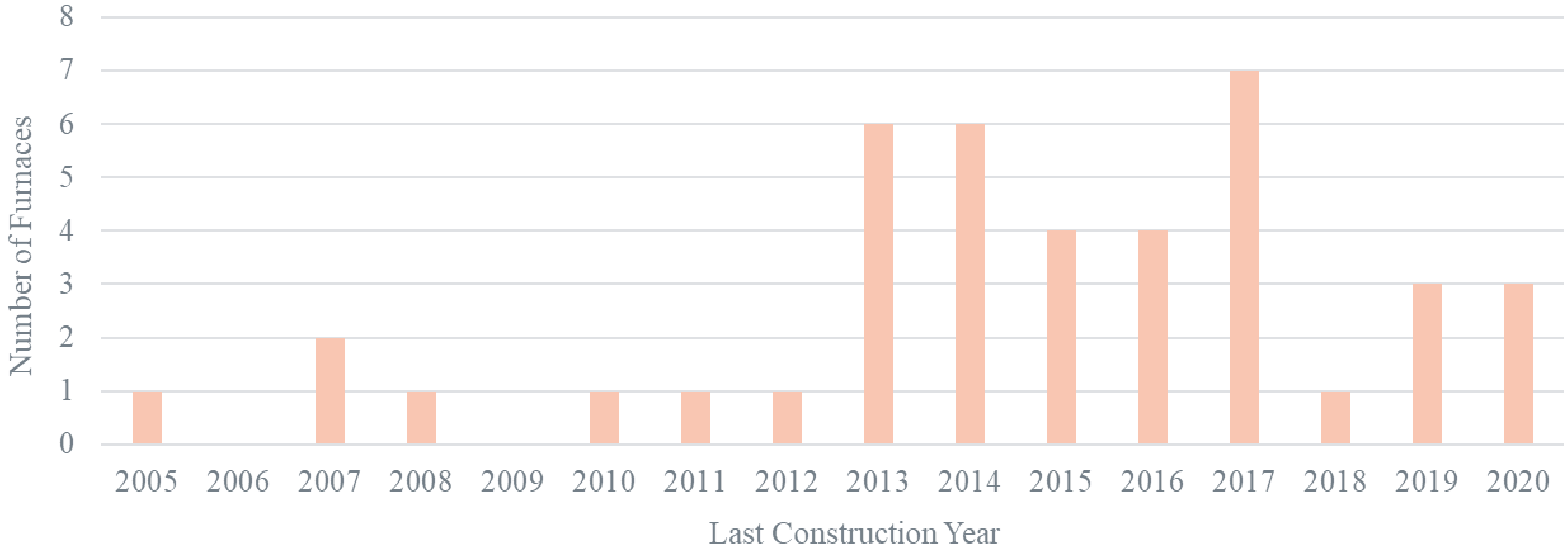


Source: Glass Global 2020

Flint and **Ultra-Clear** types of glass have similar characteristics.

How many similar furnaces could be affected by the pilot project?

Constructed Flint and Ultra Clear Container Glass Furnaces: **46 Furnaces** (Glass Global, 2020).



At latest, **only 2 Lifetimes of Furnaces** are left to fully decarbonize the sector before 2050!

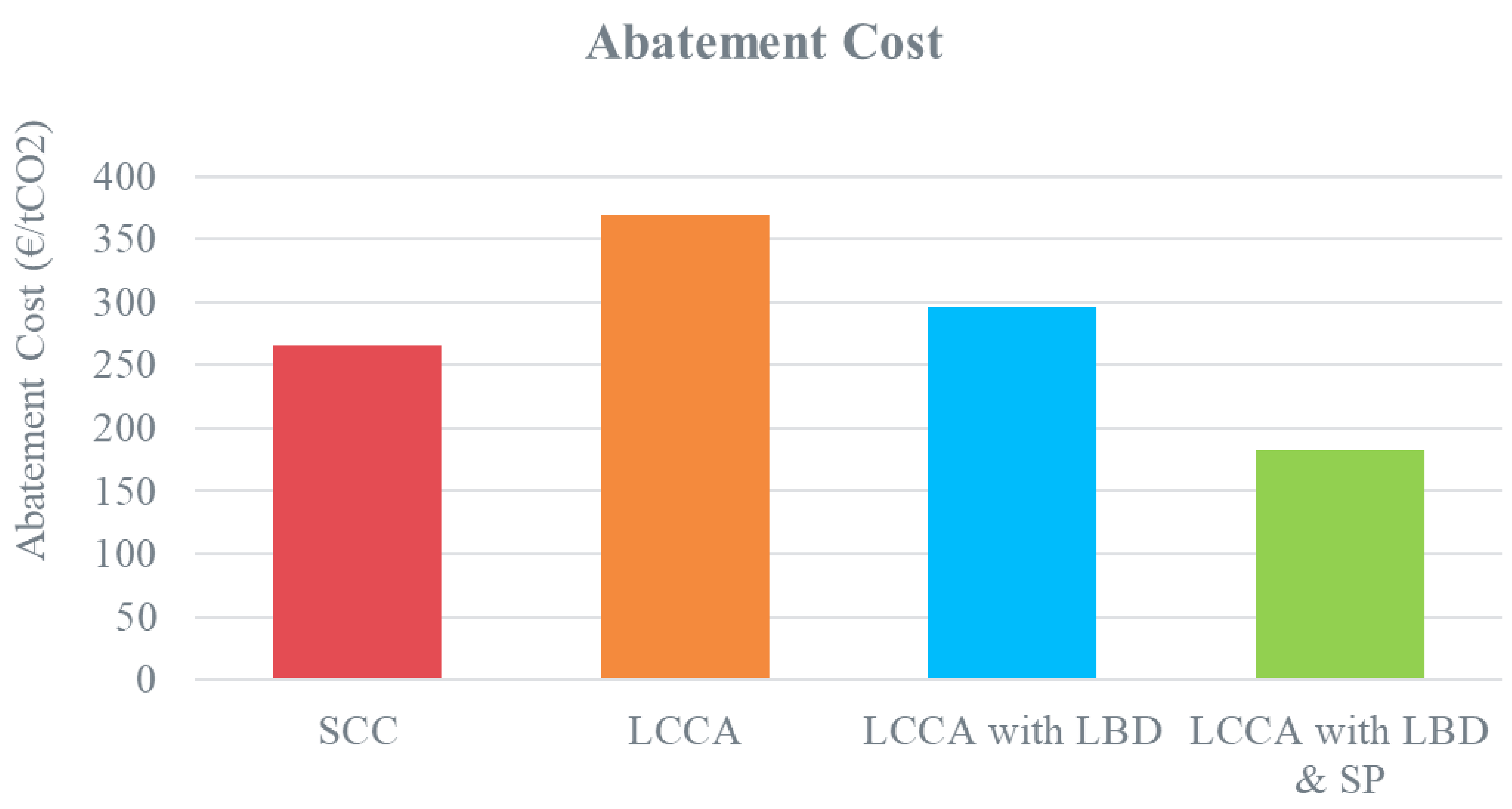
The schedule for the decarbonization of the sector

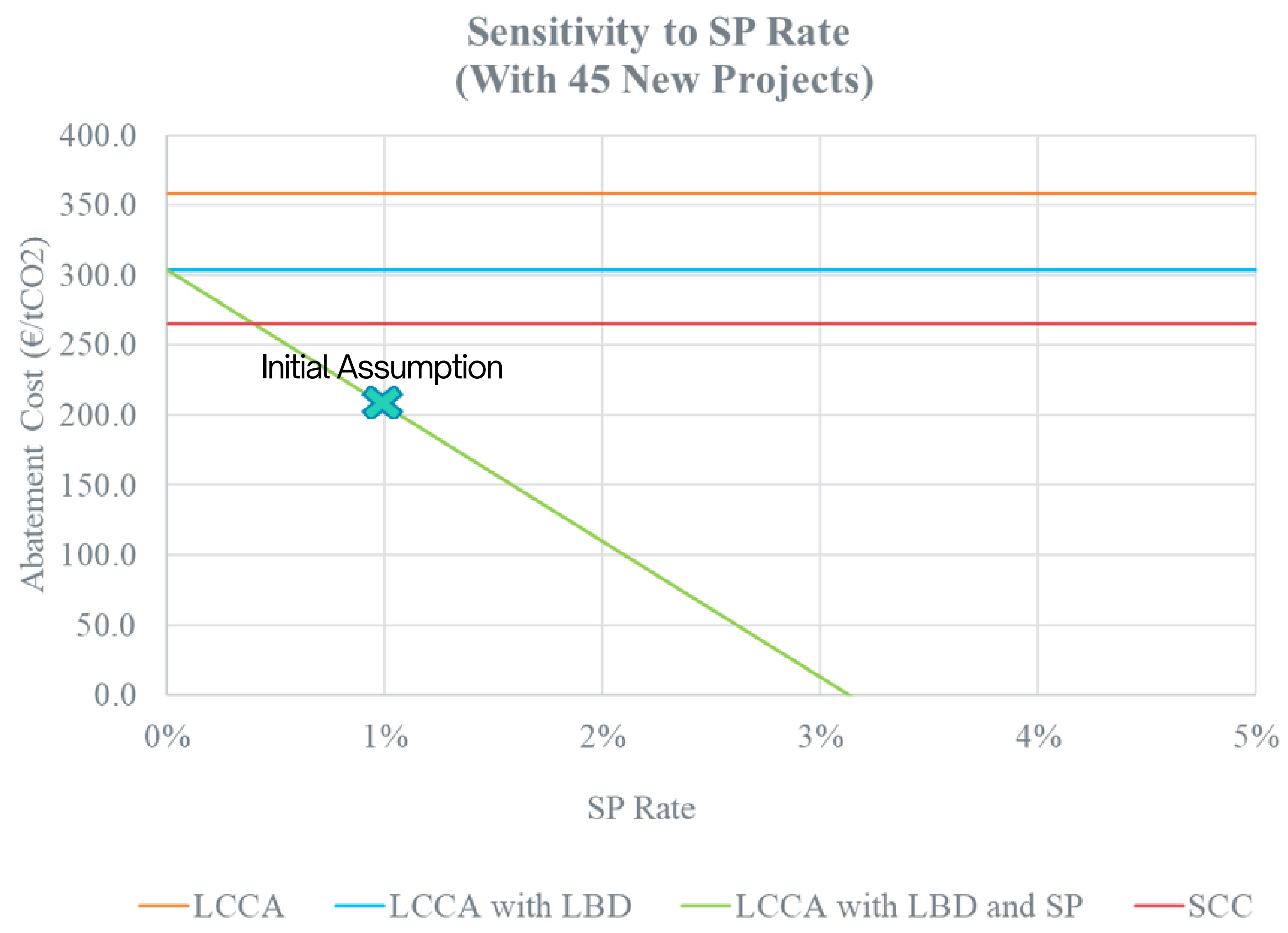
We Assume Other Furnaces in the Sector will be Decarbonized in their Second Reconstruction

We assume the benefits of decarbonization of each similar furnace is affected the LCCA of the pilot project discounted according to the time of occurrence

Applying a Spillover Rate of 1% from all other similar furnaces could decrease the abatement cost by about 50%

- Initially, a Spillover (SP) Rate of 1% due to each new project is considered
- LBD rate is kept fixed at 10%





A spillover rate of less than **0.5%** makes the project socially worthwhile.

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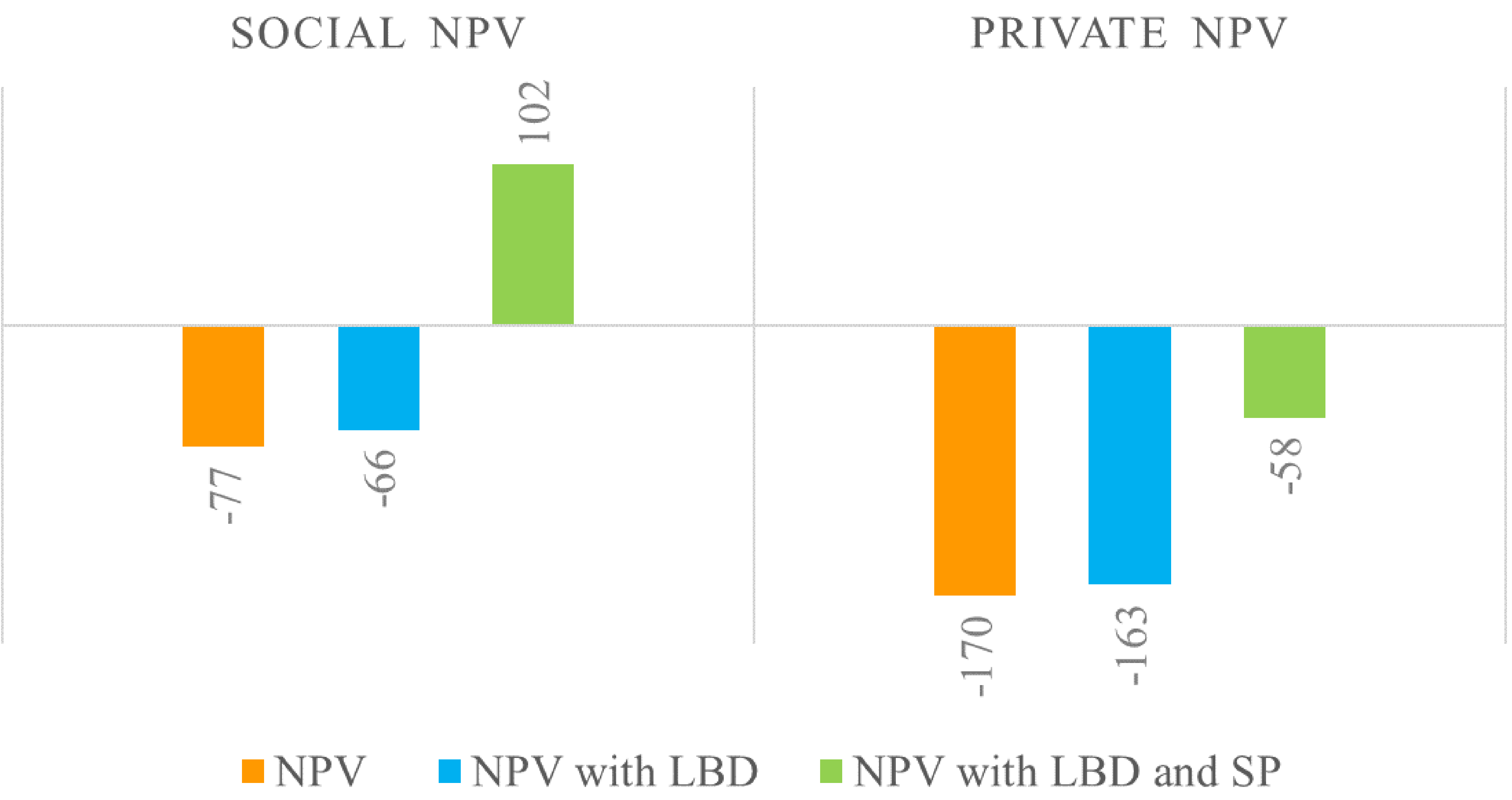
The pilot project is less worthwhile from the private investor point of view

Abatement Cost < Carbon Price ⟷ NPV > 0

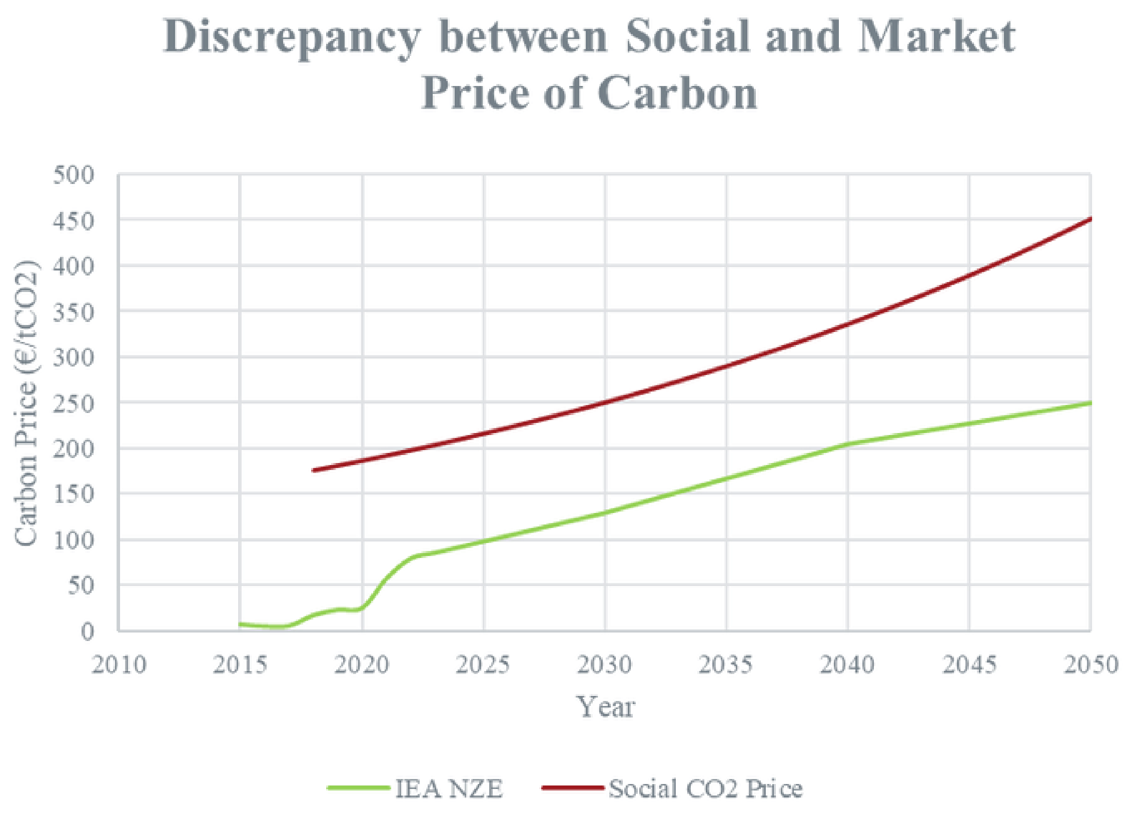


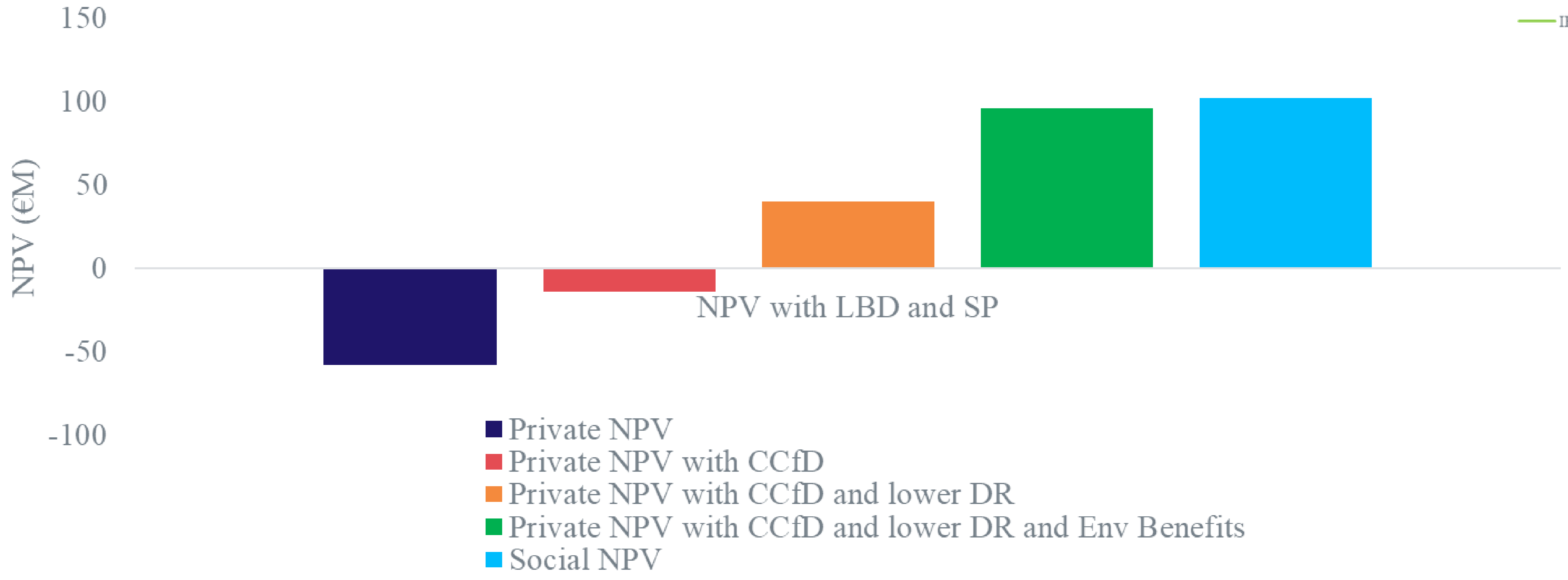
Social Perspective:
- 3% Social discount rate
- Environmental Benefits from Air Pollution Abatement
- CO2 Abatement Benefits at SCC

Private Perspective:
- 8% Private discount rate
- No Environmental Benefits from Air Pollution Abatement
- CO2 Abatement Benefits at EU ETS Market Price

Implementing public support mechanism reflects the social value of the pilot project for the private investors

- **Carbon Contract for Differences (CCfD):** The social planner pays the industry the difference between SCC and Market Price of CO2 until 2040 (if the different is negative, the social planner is paid back)
- **Private discount rate:** reduced from 8% to 5% due to lower level of risks
- Full **internalization of environmental benefits** (through regulation) i.e. abatement of NOx, SOx, and CO





Some Open Questions

- How to identify LBD and Spillover rates in concrete terms?
- How to internalize the Spillover rate?
- What is the implication of CCfD mechanism at the sector level?
- Where the public fund should come from?

Thank you so much for your attention!

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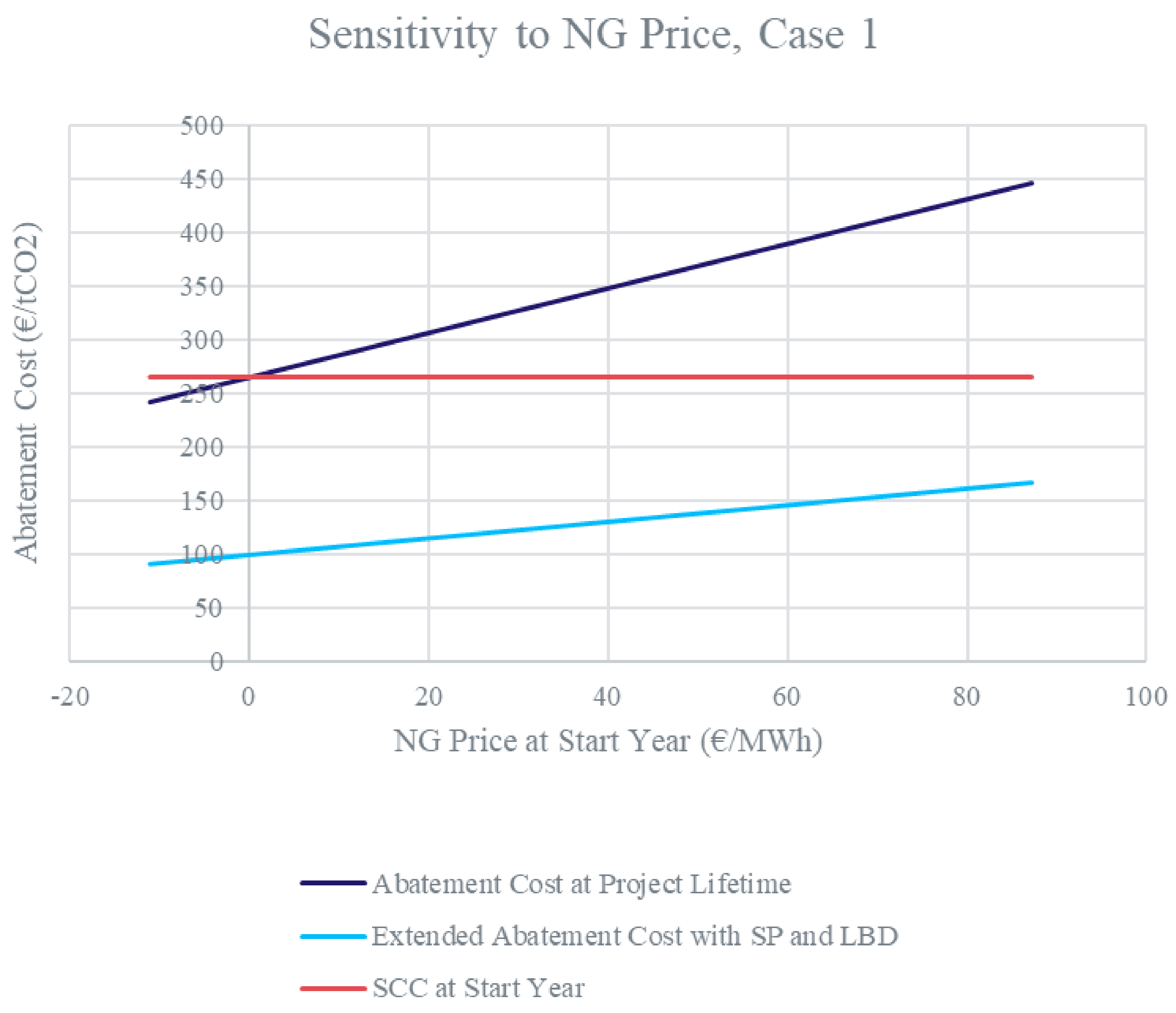
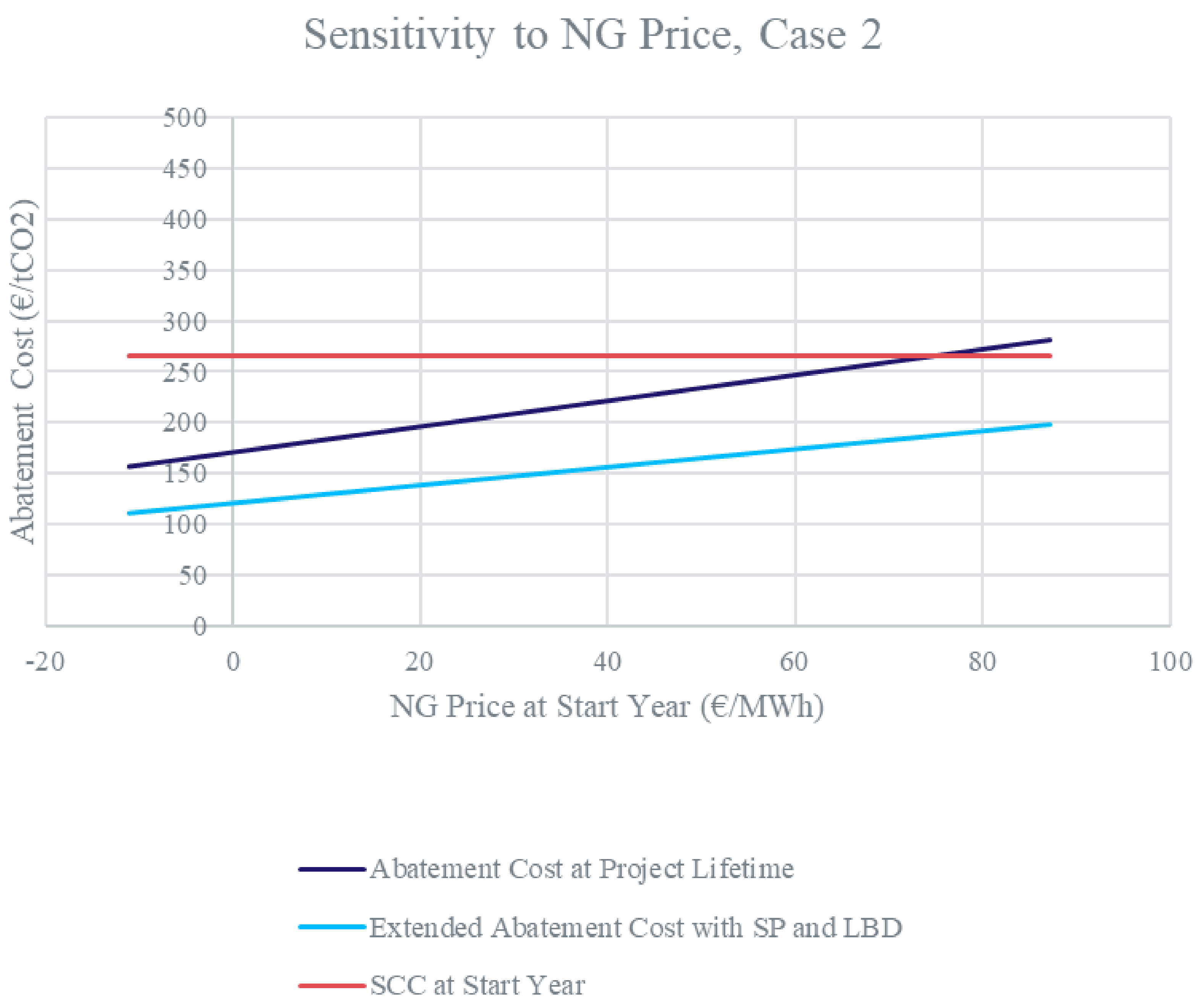
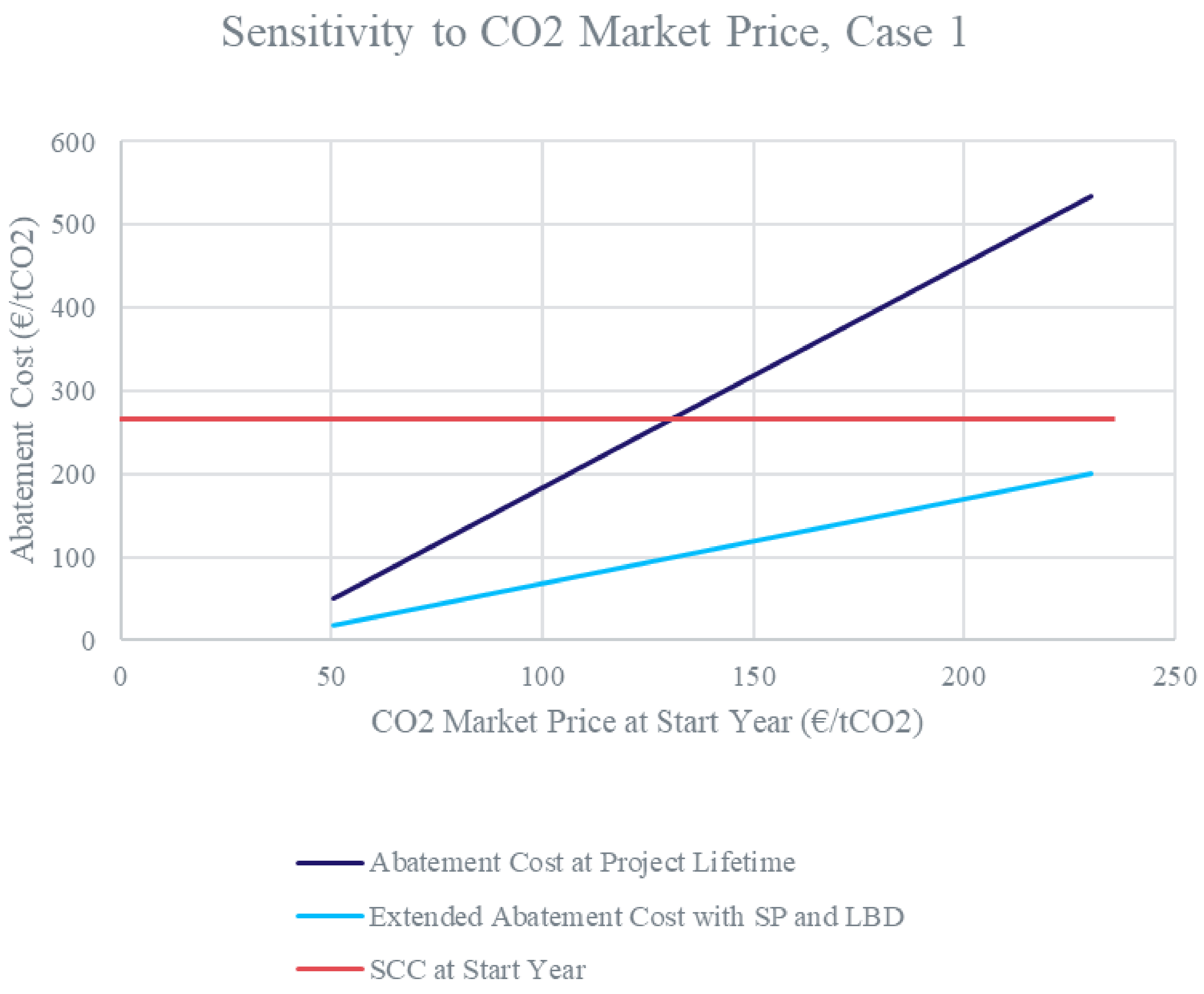
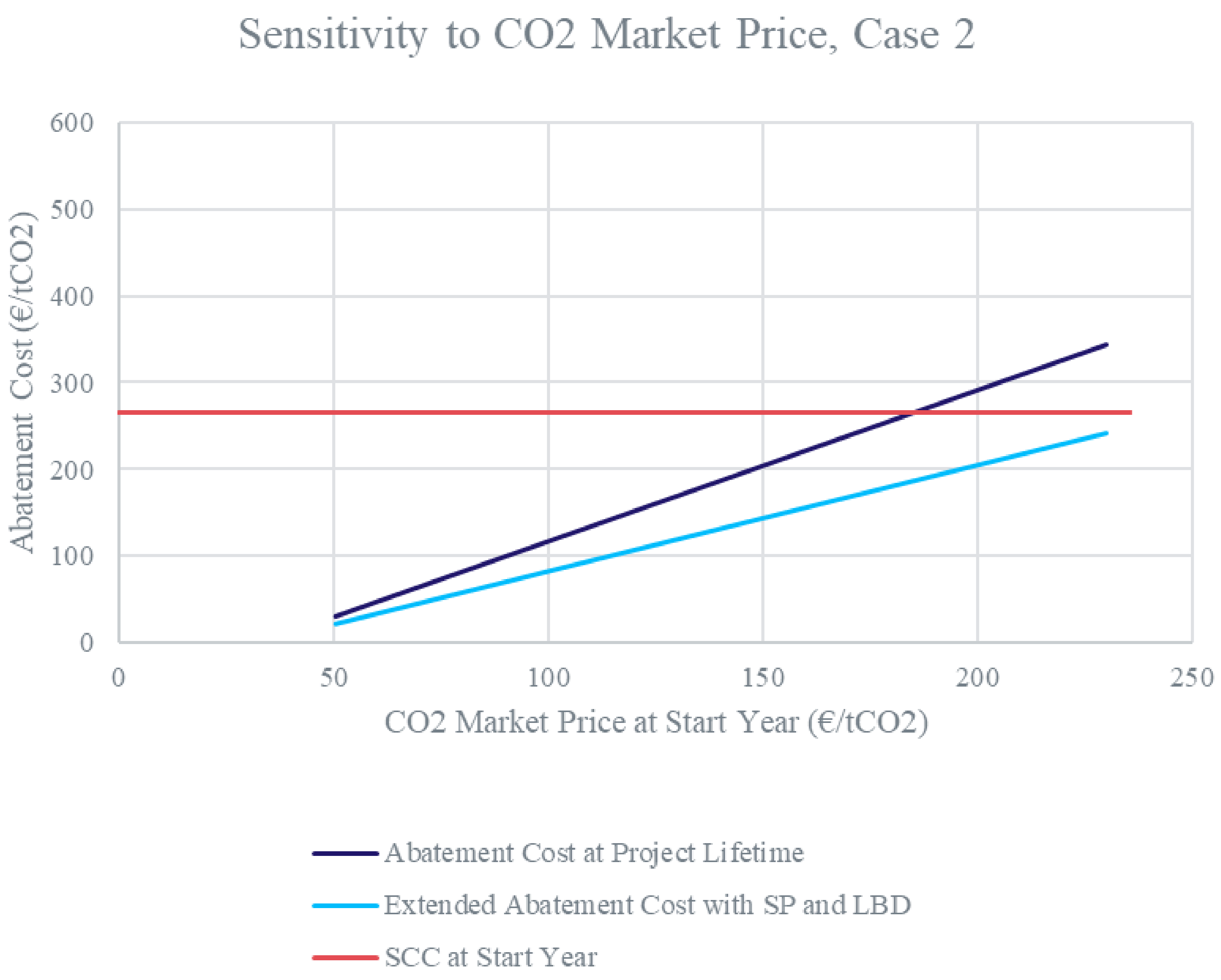
Sensitivity Analysis to the NG Price





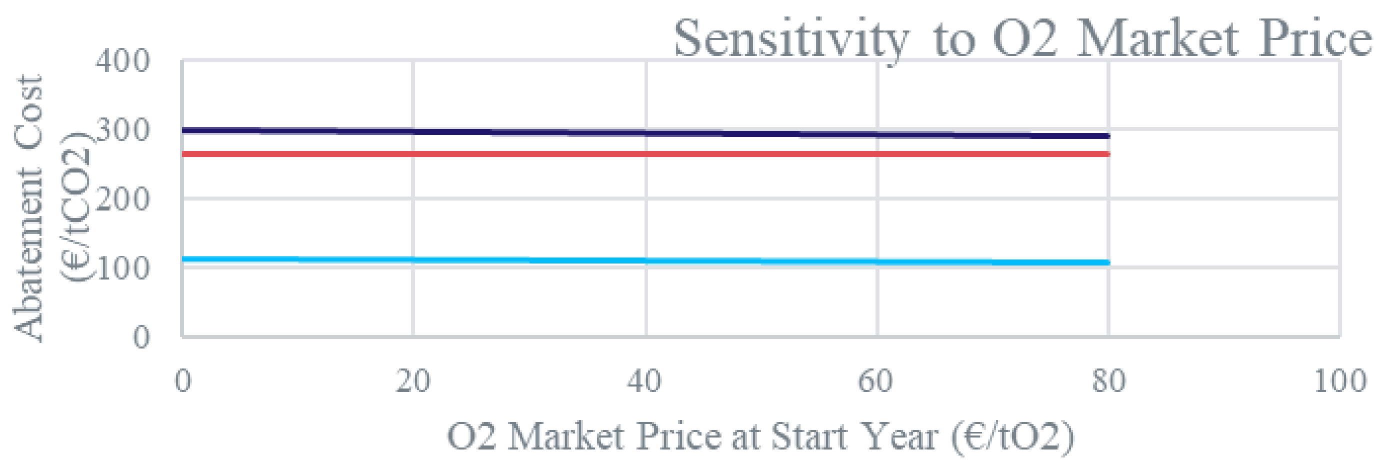
Sensitivity Analysis to the CO2 Price

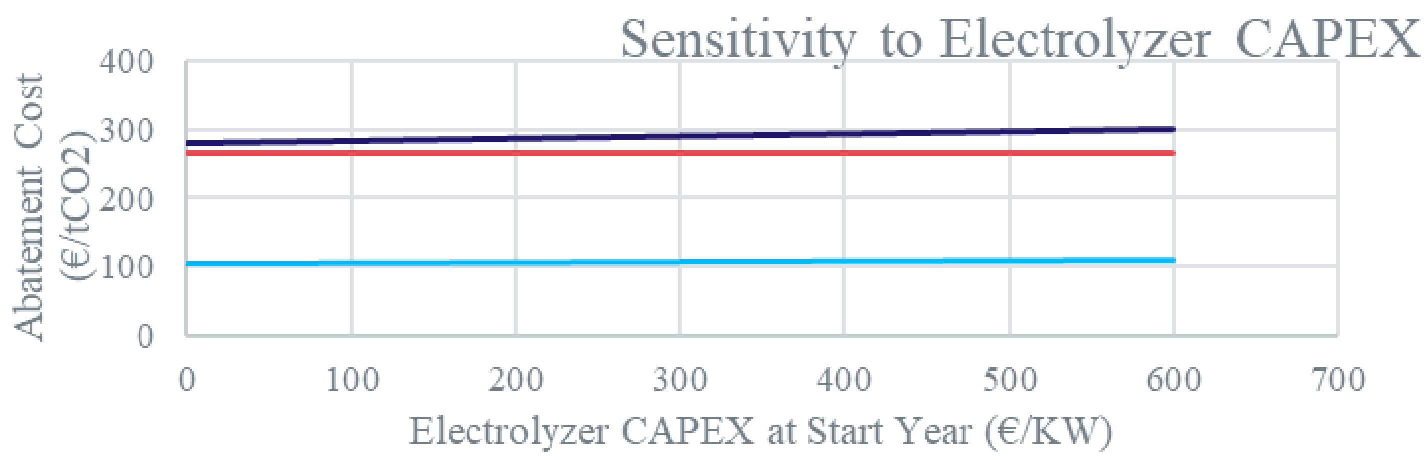


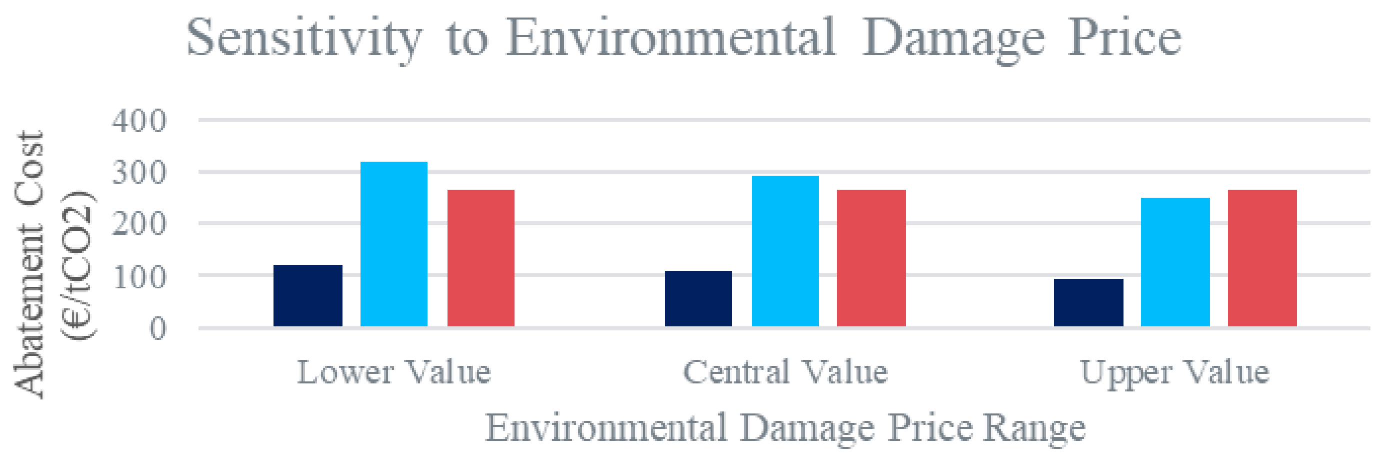


Sensitivity Analysis to Other Input Prices

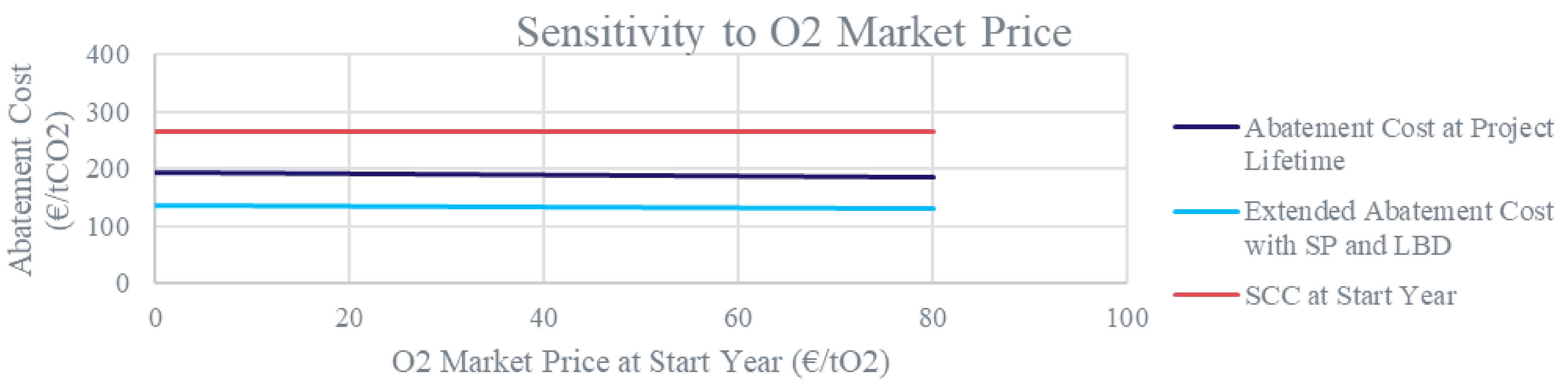
IEA NZE Scenario, Electricity Case 1

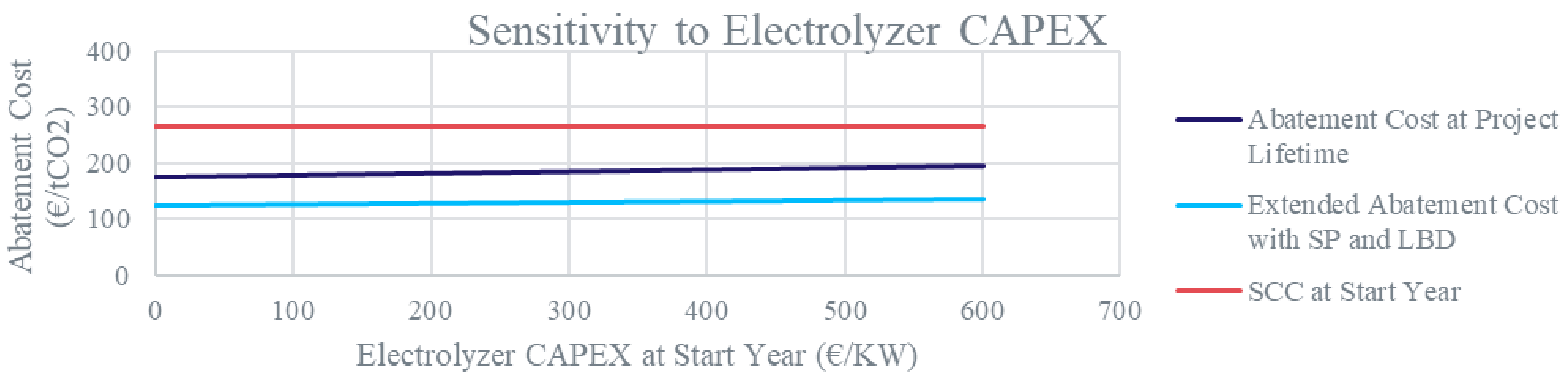


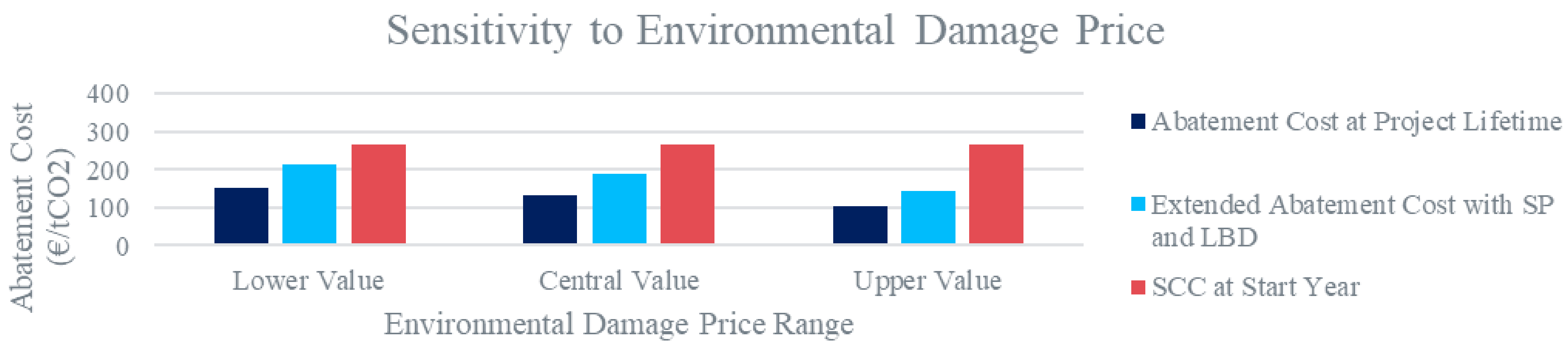




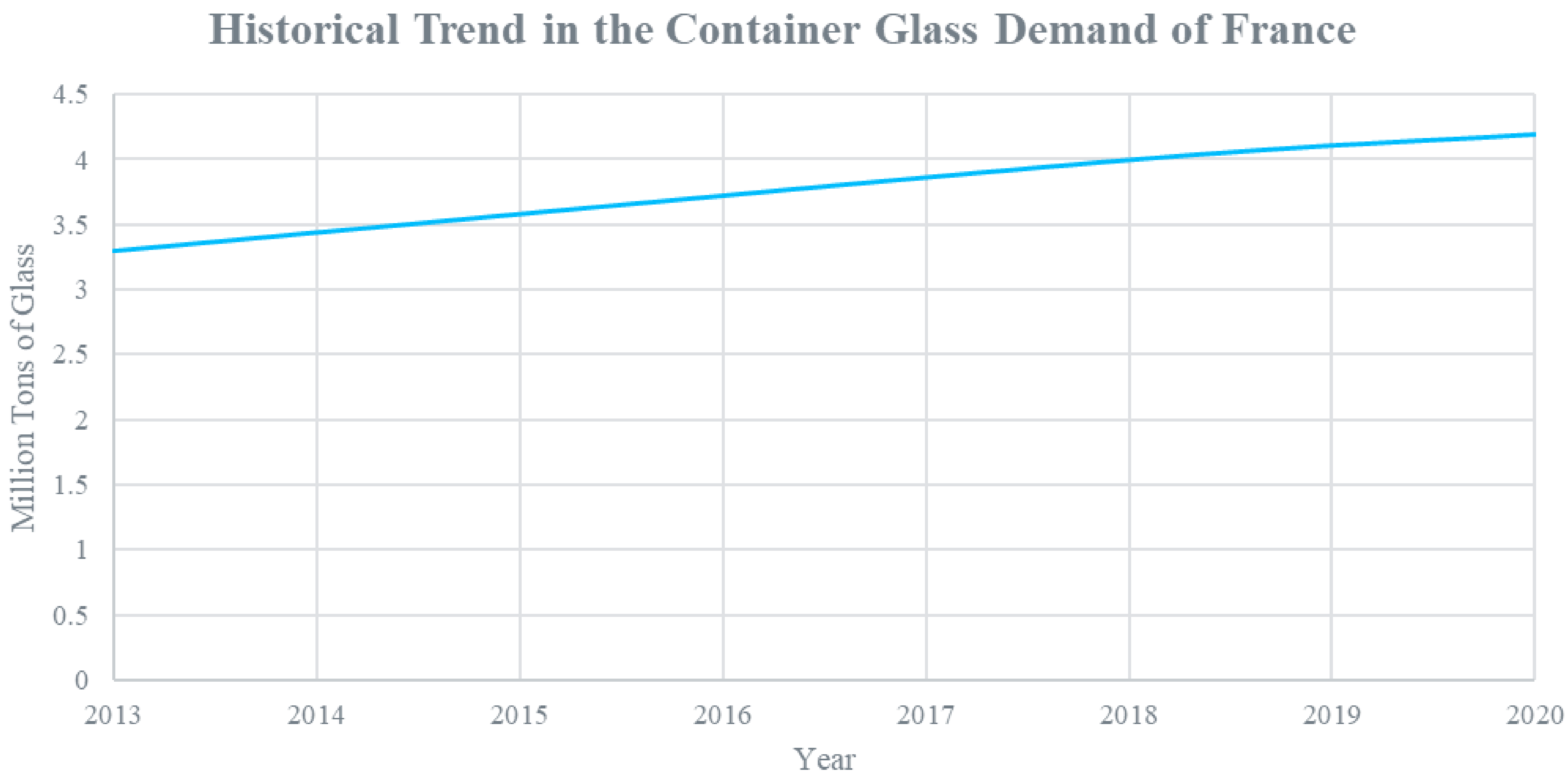
IEA NZE Scenario, Electricity Case 2







Container Glass Demand in France



Calculation of LCCA with Learning

$$LCCA = \frac{EAC - EAB}{A}$$

$$EAC = \frac{NPC}{d_{\lambda}}$$

$$EAB = \frac{NPB}{d}$$

$$NPC = \sum_{n=0}^{n=T} \frac{C_n}{(1+i)^T}$$

$$NPB = \sum_{n=0}^{n=T} \frac{B_n}{(1+i)^T}$$

$$d_{\lambda} = \frac{1 - \frac{1-\lambda}{(1+i)^T}}{i}$$

$$d = \frac{1 - \frac{1}{(1+i)^T}}{i}$$

$$LCCA_{\lambda} = \frac{\left(\frac{i}{1 - \frac{1-\lambda}{(1+i)^T}} \sum_{n=0}^{n=T} \frac{C_n}{(1+i)^T}\right) - \left(\frac{i}{1 - \frac{1}{(1+i)^T}} \sum_{n=0}^{n=T} \frac{B_n}{(1+i)^T}\right)}{A}$$

Calculation of LCCA with Learning and Spillover

$$SP = \sum_{n}^{N} \lambda'(NPC) \frac{1}{(1+i)^{T'_n}}$$

$$LCCA_{\lambda\lambda'} = \frac{\left[\frac{i}{1 - \frac{1-\lambda}{(1+i)^T}} \sum_{n=0}^{n=T} \frac{C_n}{(1+i)^T} (1 - \lambda' \sum_{n}^{N} \frac{1}{(1+i)^{T'_n}}) \right] - \left[\frac{i}{1 - \frac{1}{(1+i)^T}} \sum_{n=0}^{n=T} \frac{B_n}{(1+i)^T} \right]}{A}$$