LOUISE-REBECCA Webinar

20 November 2024

# Techno-Economic & Life Cycle Assessment of Waste-To-Energy Plants

REBECCA

This project has received funding from the Research Fund for Coal and Steel under grant agreement No. 101034024

# TECHNO-ECONOMIC ASSESSMENT

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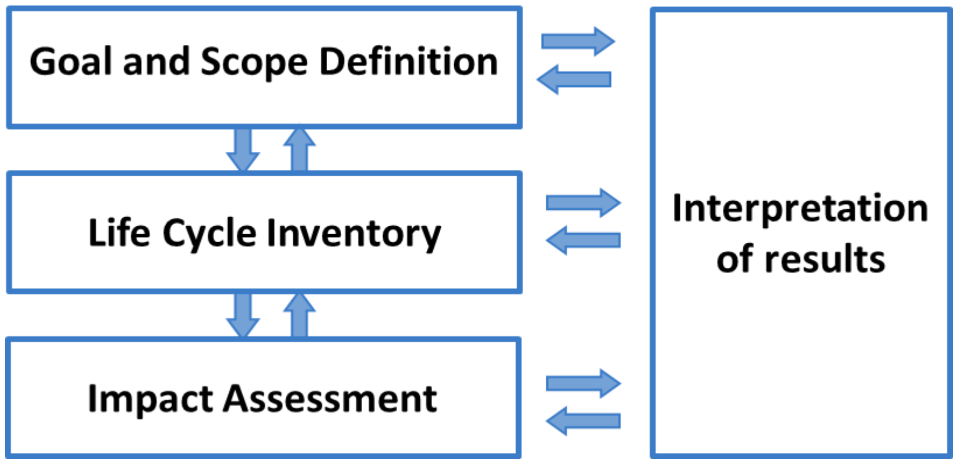
# Introduction

## METHODOLOGY

**Life Cycle Costing (LCC)** is a structured **method** quantifying the **economic impacts** associated to the life cycle of a product, a service or a process.

**LCC** is regulated by a set of **international rules,** and it is structured in **4 steps**:

| Norm | Title |
|---|---|
| **Setac Guidelines** | Environmental Life Cycle Costing: A Code of Practice |
| **ISO 14040:2006** | Environmental management -- Life cycle assessment - Principles and framework |
| **ISO 14044:2018** | Environmental management - Life cycle assessment - Requirements and guidelines |
| **ISO 15686-5:2008** | Buildings and constructed assets -- Service-life planning - Part 5: Life-cycle |

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# Introduction

**METHODOLOGY**

Zabrze CHP Plant is reference Baseline; Retrofit scenarios represent modifications to existing plant aimed at eliminating fossil fuel and reducing the environmental footprint:

- **Retrofit 1:** Fuel switch from coal/RDF mix to 100% RDF
- **Retrofit 2:** Retrofit 1 plus OCAC (Oxygen Carrier Aided Combustion) system

Technical and financial analysis are developed based on simulated performance:

- **DESIGN CASES** refer to nominal performance of equipment and systems; comparison with Baseline provides information about the CAPEX associated to the Retrofit.
- **OPERATING CASES** refer to average operation data; they provide yearly production and consumption parameters which are used to evaluate OPEX of the Retrofit.

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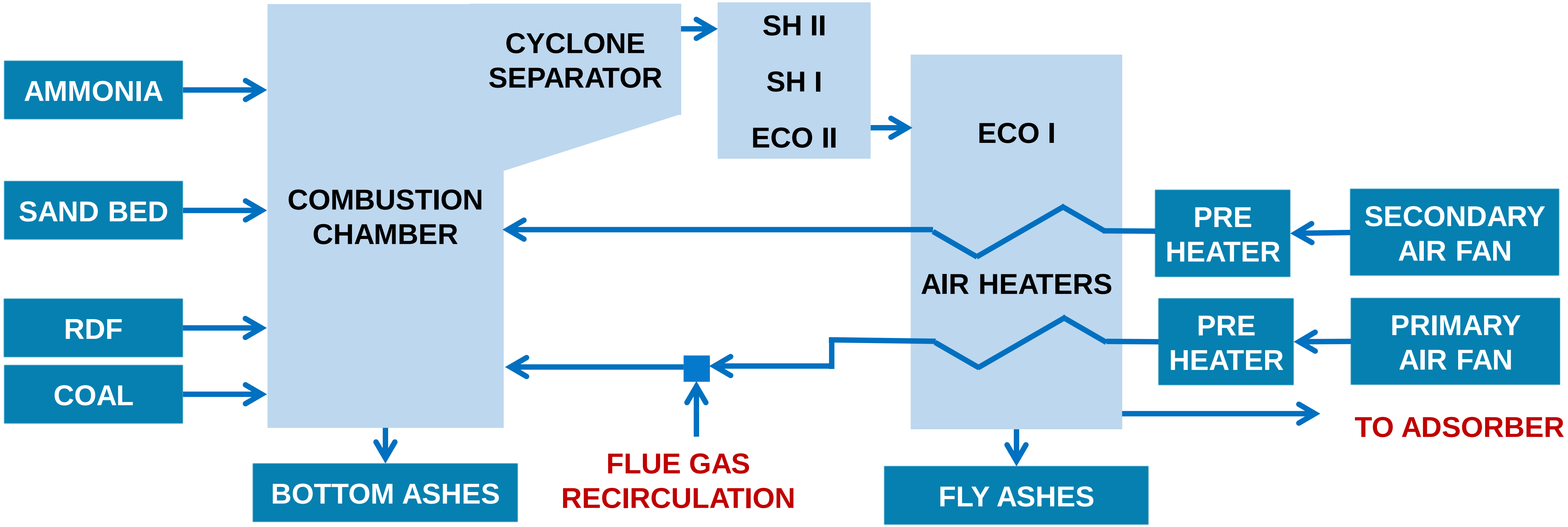
# Baseline: Zabrze CHP Plant

**BLOCK DIAGRAM: CFB STEAM GENERATOR**

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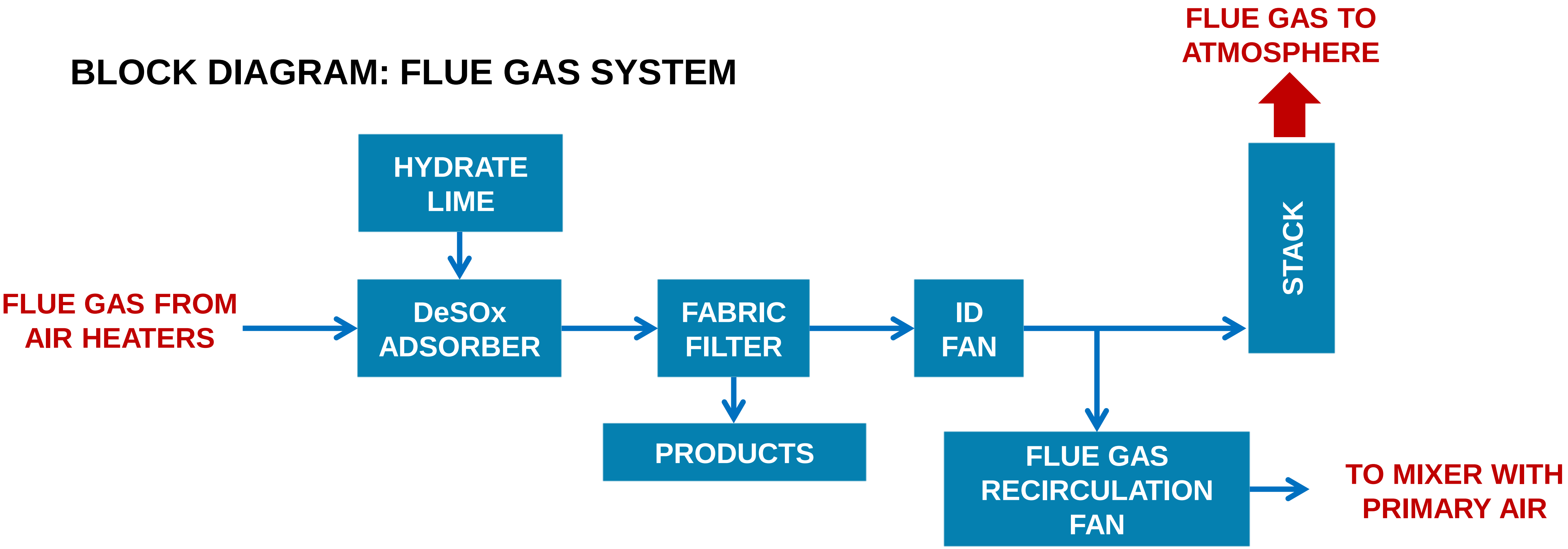
# Baseline: Zabrze CHP Plant

**BLOCK DIAGRAM: FLUE GAS SYSTEM**

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# Technical Analysis

## MAIN MODIFICATIONS REQUIRED TO ZABRZE CHP PLANT

| | RETROFIT 1 | RETROFIT 2 |
|---|---|---|
| NEW RDF RECEIVING, STORAGE AND FEEDING SYSTEM | X | X |
| NEW NATURAL GAS BURNERS | X | X |
| COMBUSTION AIR SUPPLY (PRIMARY AND SECONDARY) | X | X |
| INDUCED DRAFT FAN, RECIRCULATION FAN | X | |
| FABRIC FILTER REVAMPING | X | |
| ASH HANDLING (BOTTOM AND FLY ASHES) | X | X |
| HOT LOOP UPGRADE (REFRACTORY, WATER WALLS) | X | X |
| CONVECTIVE SECTION UPGRADE AND RE-ARRANGEMENT | X | X |

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# Technical Analysis

## YEARLY PRODUCTION AND CONSUMPTION DATA

| | | BASELINE | RETROFIT 1 | RETROFIT 2 |
|---|---|---|---|---|
| RDF CONSUMPTION | t/y | 145,917 | 341,798 | 340,409 |
| COAL CONSUMPTION | t/y | 113,937 | 0 | 0 |
| SAND BED CONSUMPTION | t/y | 3,331 | 3,331 | 0 |
| ILMENITE CONSUMPTION | t/y | 0 | 0 | 3,331 |
| HYDRATE LIME CONSUMPTION | t/y | 2,913 | 2,544 | 2,534 |
| AMMONIA SOLUTION CONSUMPTION | t/y | 244 | 261 | 260 |
| ASH DISPOSAL (BOTTOM + FLY) | t/y | 47,112 | 58,579 | 58,341 |
| ELECTRICITY SALES | MWh/y | 340,129 | 333,639 | 339,226 |

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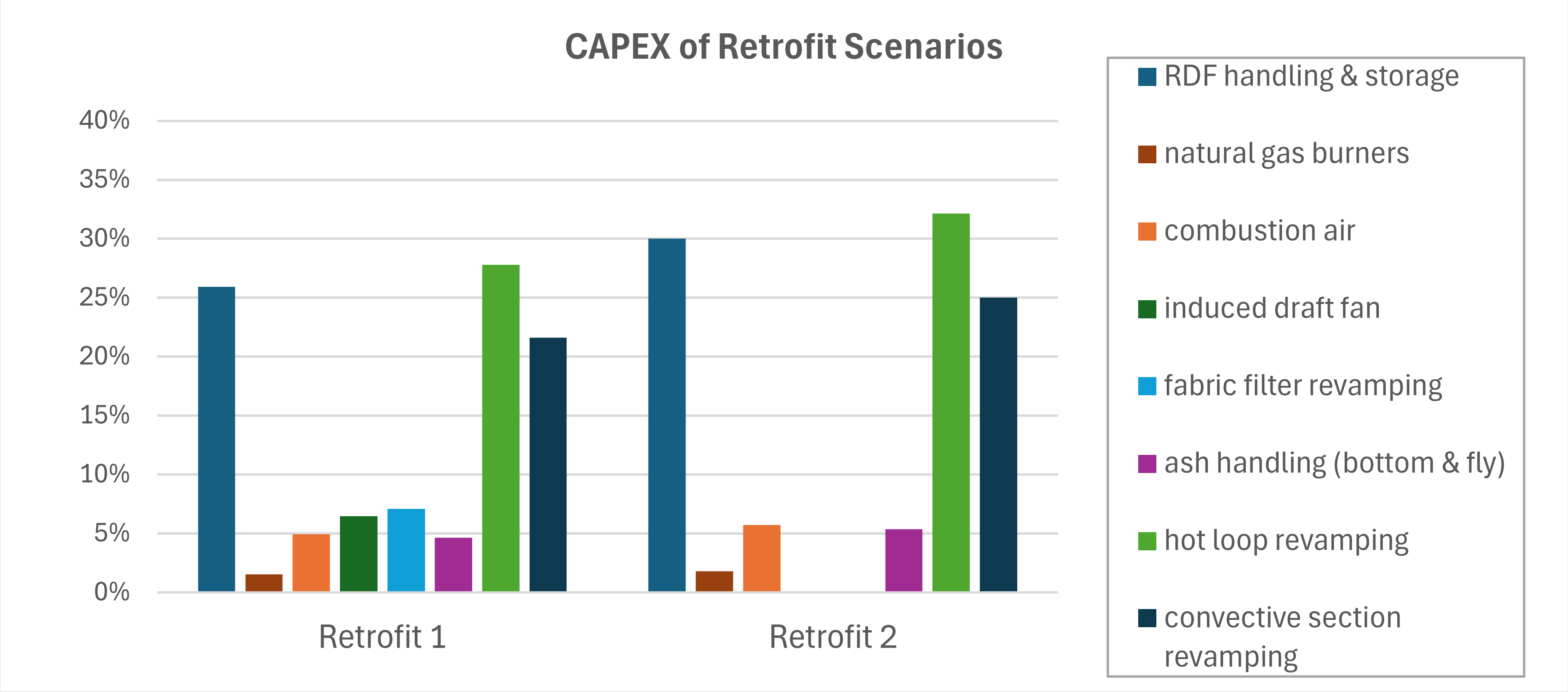
# Economic Analysis

## CAPEX BREAKDOWN

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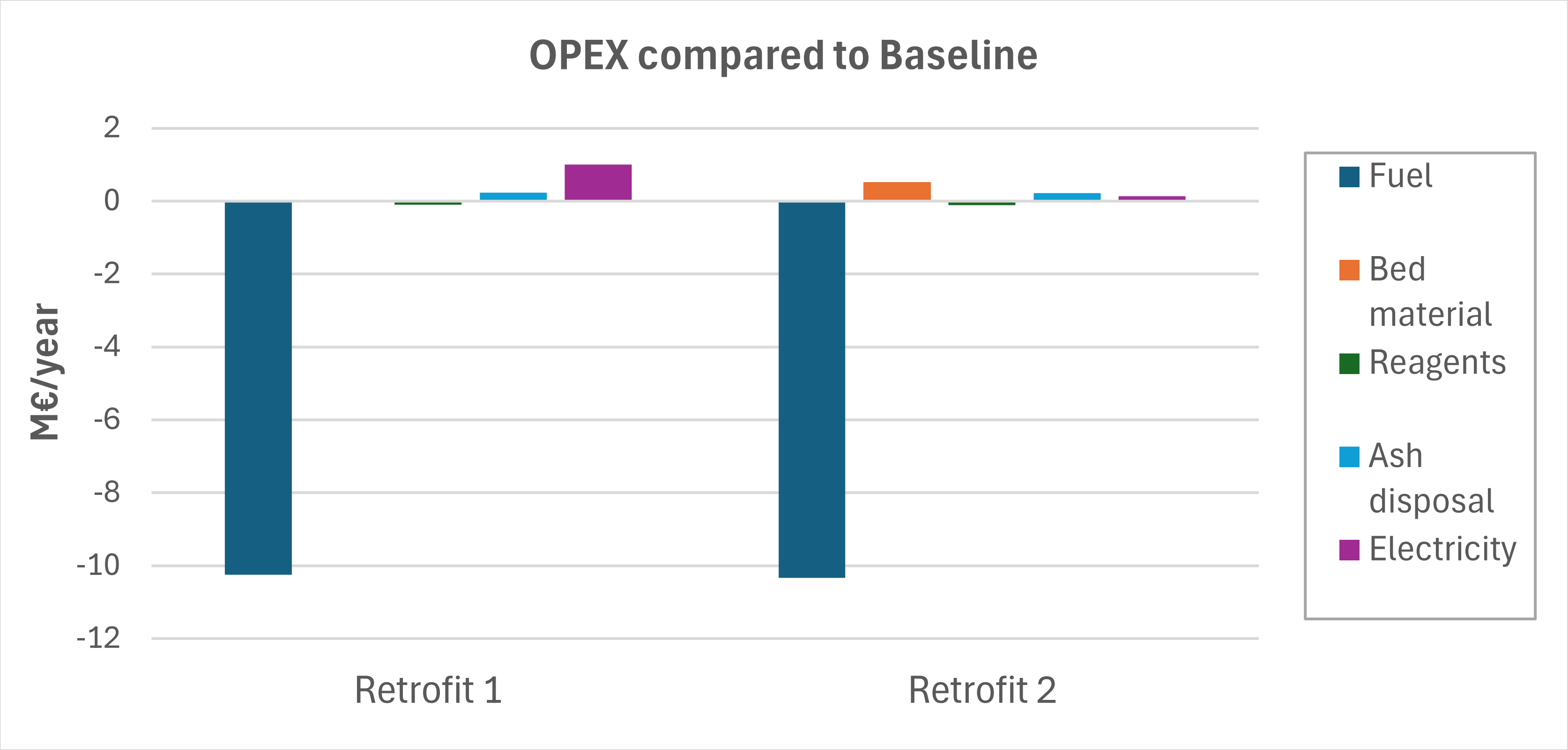
# Economic Analysis

## OPEX BREAKDOWN COMPARED TO BASELINE




FUEL PRICES USED IN THE STUDY

- Coal: 32 EUR/MWh
- RDF: 17 EUR/MWh

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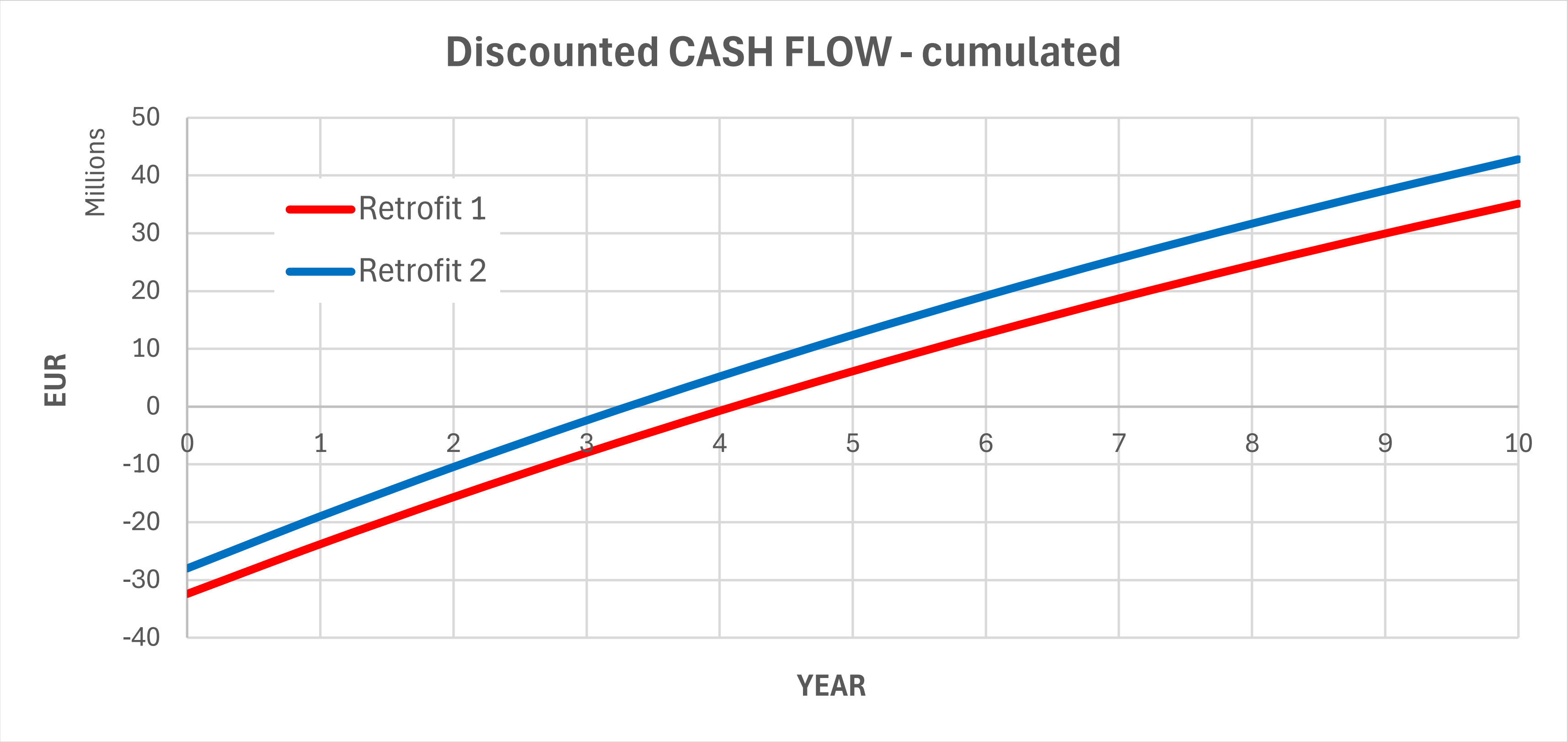
# Economic Analysis

## CASH FLOW



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# Interpretations/Conclusions

Retrofitting an existing CFB from coal to RDF fuel requires detailed analysis of the existing design and combustion mechanism; main modifications are due to increased corrosion and erosion associated to RDF and are common to both Retrofit Options:

- Hot loop protection
- Convective section re-arrangement and protection

Fuel switch to 100% RDF requires a new, large RDF handling system for receiving, storage, treating, transport, and feeding waste to the CFB furnace.

Retrofit 2 with OCAC (Oxygen Carrier Aided Combustion) system provides higher efficiency and leads to more convenient life-cycle investment.

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# ENVIRONMENTAL ASSESSMENT

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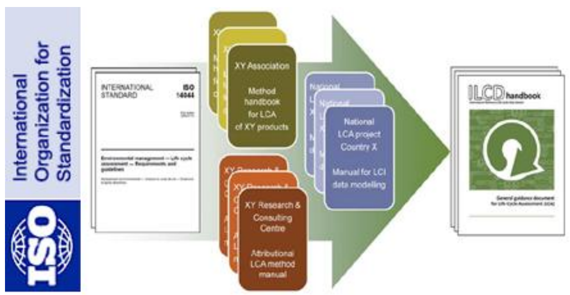
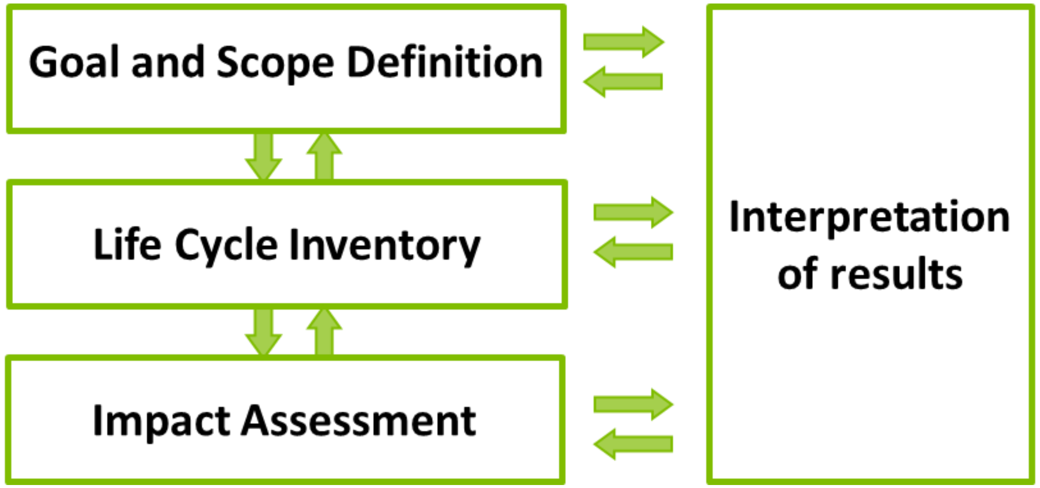
# Methodology

**Life Cycle Assessment (LCA)** is a structured, comprehensive and internationally standardized **methodology**, quantifying the **environmental impacts** associated to the life cycle of a product, a service or a process.

**LCA** is regulated by a set of **international rules,** and it is structured in **4 steps**:

| Norm | Title |
|---|---|
| **ISO 14040:2006** | Environmental management -- Life cycle assessment - Principles and framework |
| **ISO 14044:2006** | Environmental management -- Life cycle assessment - Requirements and guidelines |
| **ILCD Handbook (UE JRC)** | General guide for Life Cycle Assessment - Detailed guidance |

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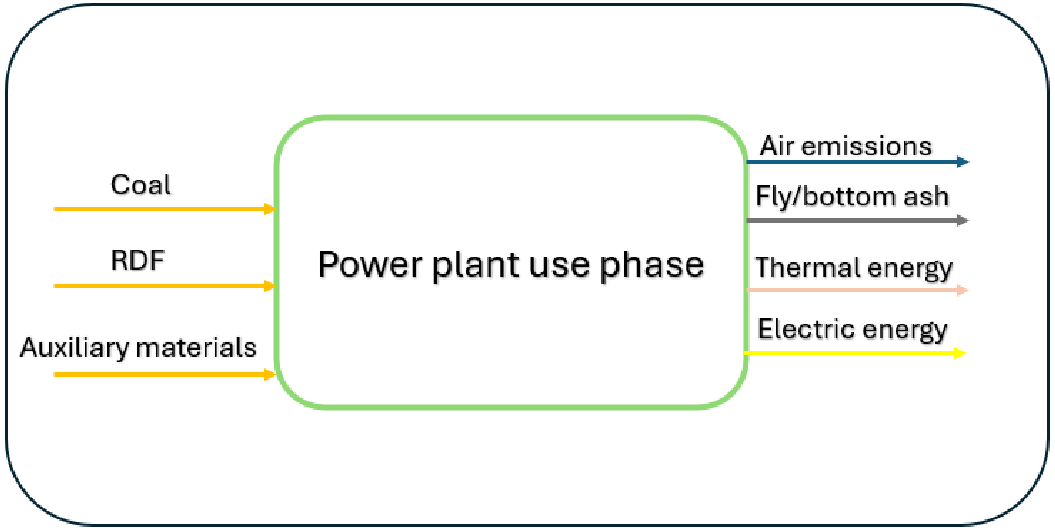
# Goal and Scope definition

Baseline scenario: Fortum plant in **Zabrze** simulated

Innovative retrofitting:

- Scenario 1: reach **100% RDF** (simulated)
- Scenario 2: Scenario 1 + **OCAC**
- Scenario 3: Scenario 2 + **CCS**




**Functional unit:** 1 GWh of total energy produced

**System boundaries:** Plant operation (Energy demand, raw materials, waste)

**Software used:** Sphera

**Main database used:** Ecoinvent 3.8

**Methodology used:** EF v3.1

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# Life Cycle Inventory

| | | | |
|---|---|---|---|
| Fortum - Zabrze | Reference period | Simulated year | hour/months/year |
| | Lifetime (start up 2019) | 4 | years |
| | Type | Combined Heat Power PLANT | |
| | Operating hour | 8000 | h |
| | Lifetime | 50 | years |
| | Thermal output | 129 | MWth |
| | Electrical capacity | 72 | MWe |
| | Combined energy | 200 | MWeq |
| | | | unit of measure |
| Type of fuel | coal | 1,69E+05 | t |
| | RDF | 1,91E+05 | t |
| | LHV coal | 2,19E+04 | kJ/kg |
| | LHV RDF | 1,29E+04 | kJ/kg |
| | Total Input energy | 6,17E+12 | kJ |
| | | 1,71E+09 | kWh |
| | | 2,14E+05 | kW |
| Production | Heat | 1,03E+03 | GWh |
| | Electricity | 5,74E+02 | GWh |
| | Total production | 1,60E+03 | GWh |
| | Scaling factor | 6,23E-04 | 1/GWh |

| | | | |
|---|---|---|---|
| Consumptions | Water (woda surowa) | 4,30E+05 | m3 |
| Auxiliary materials | LFO (Light fuel oil) | 2,39E+02 | t |
| | Hydrated lime | 4,03E+03 | t |
| | Ammonia water | 3,37E+02 | t |
| | Ammonia | 25% | |
| | Water | 75% | |
| | Sand | 4,61E+03 | t |
| Waste | Fly ash ( ceneri leggere prodotte dal coincenerimento) | 3,73E+04 | t |
| | bottom ash (sabbie dei reattori a letto fluidizzato) | 3,17E+04 | t |
| Emissions to air | CO2 | 5,77E+05 | t |
| | NOx | 3,50E+02 | t |
| | SO2 | 2,81E+02 | t |
| | Dust | 2,41E+01 | t |

*Input and Output data for baseline*

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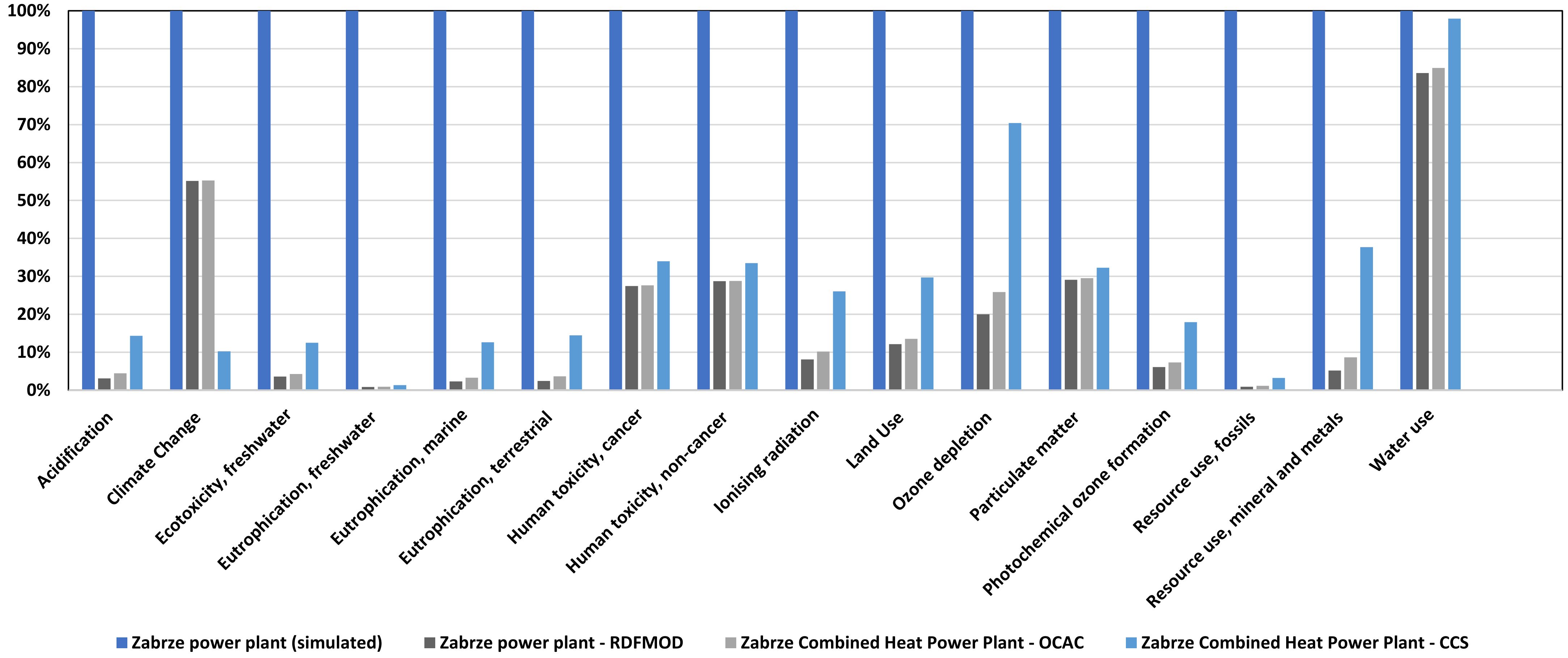
# LCIA Life Cycle Impact Assessment

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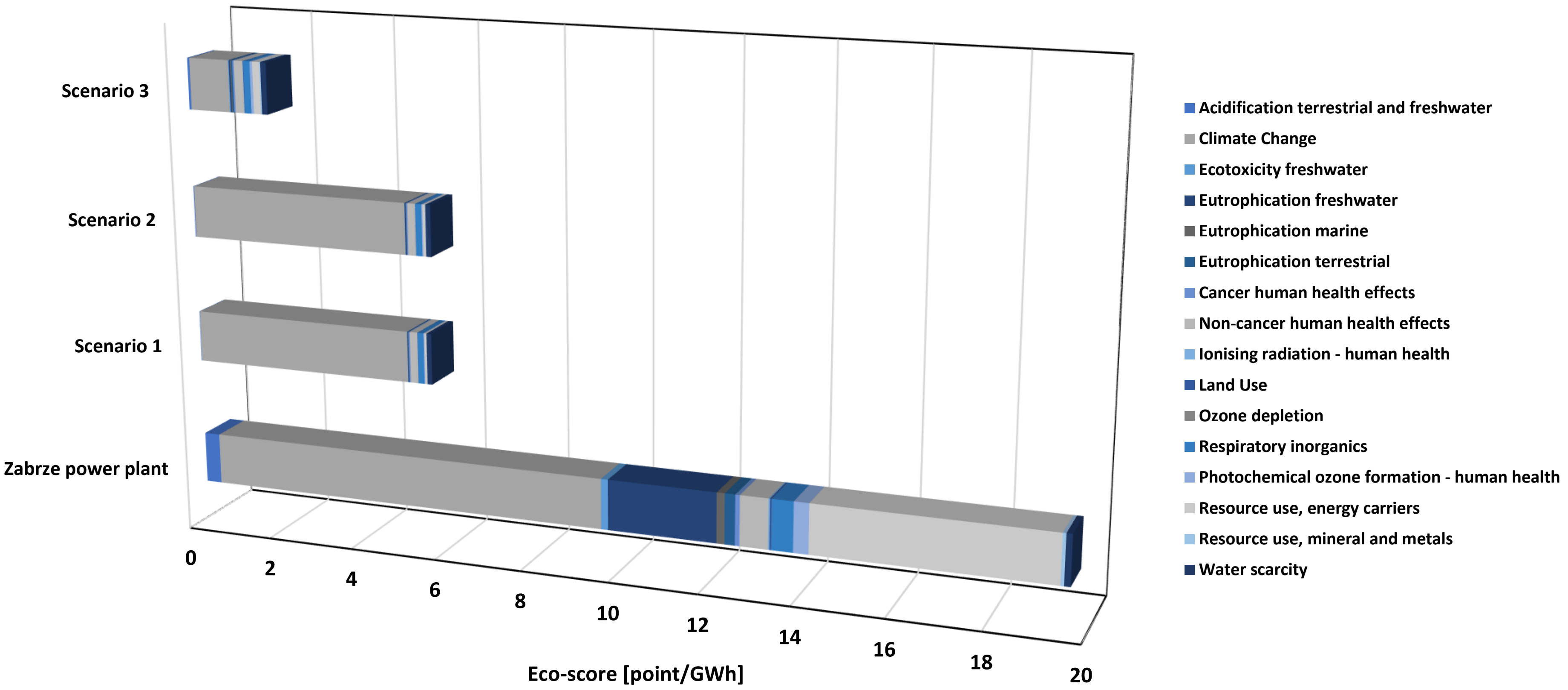
# Interpretation – Normalization & Weigthing




Normalization and weighting can be applied to aggregate the environmental impacts into a single score, reflecting the relative importance of each impact category. The weighting factors were sourced from the report "Development of a Weighting Approach for the Environmental Footprint“ by the Joint Research Centre (JRC).

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# Interpretation/Conclusions

- The LCA analysis has shown that implementing the solution with CCS yields the best environmental results (around -90%) considering the current context and project objectives, specifically focusing on $CO_2$ eq emissions.

- The RDFMOD and OCAC solutions generally exhibit the same trend in terms of environmental impacts, but both provide significant environmental savings when compared to the baseline scenario (around -50%).

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