Optimisation of the manufacturing value chain

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Outline

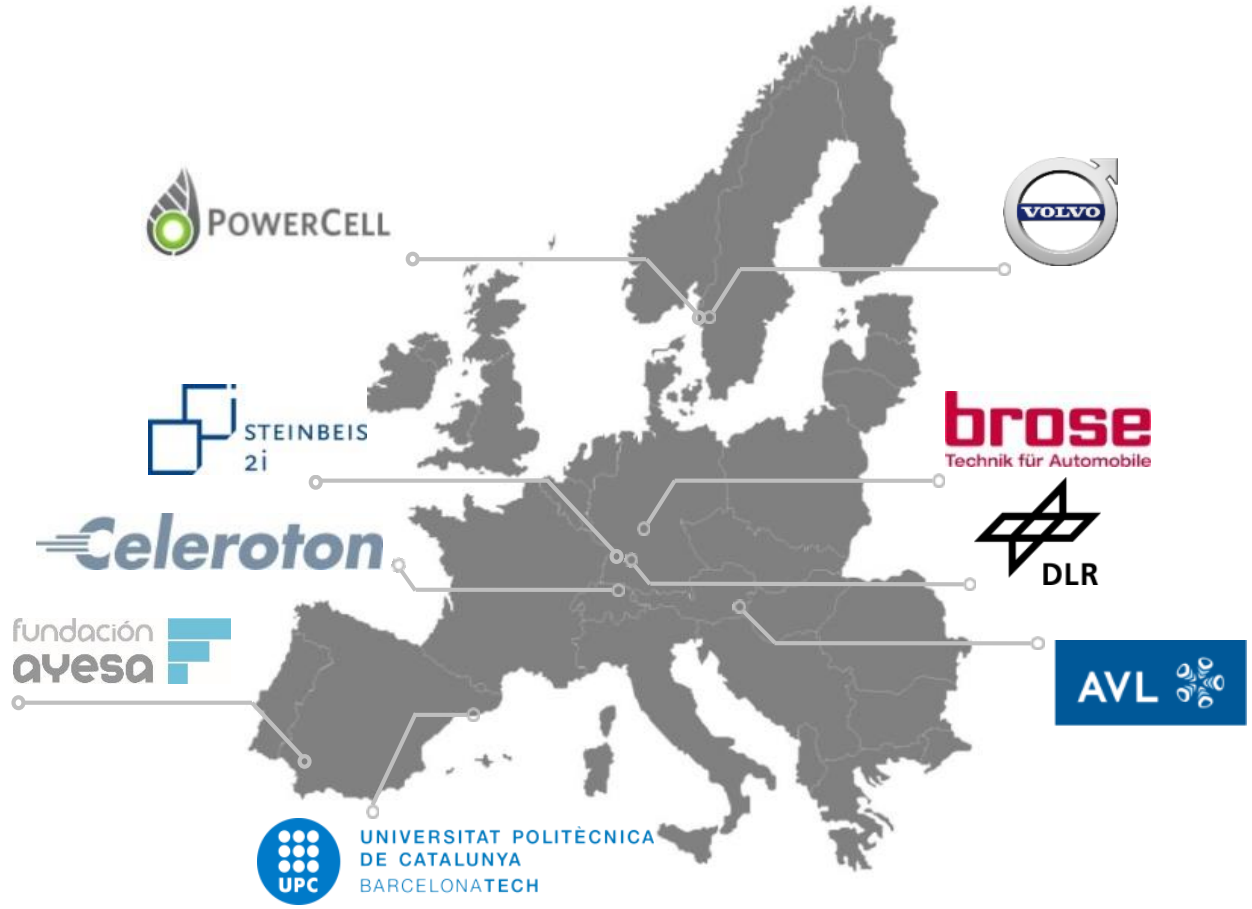
1. INN-BALANCE overview
2. Manufacturing roadmap
3. Manufacturing optimization framework
4. Use cases
5. Manufacturing studies
6. Conclusions

INN-BALANCE overview

Consortium and key data

Industrialization-ready Balance of Plant (BoP) components for fuel cells in hydrogen vehicle

- Jan. 2017-Dec. 2019
- Total Budget: 6.15M Euros
- FCH JU 2 project pillar: transport
- Coordination: Fundacion Ayesa, Spain
- Fundación Ayesa is in charge of the manufacturing-oriented design optimization, the low-cost sensorization based on state observers and fault-tolerant strategies.



www.innbalance-fch-project.eu

INN-BALANCE overview

Context

Challenges for automotive fuel cells systems mass production and commercialization:

- Technical reliability (e.g. freeze start) and performance.
- High cost due to low production volume.
- BoP design not suitable for automated manufacturing.
- Supply chain still not in place for some components.

Objectives

- New generation of low-cost fuel cell.
- Balance of Plant components for automotive applications.

➢ Develop highly efficient and reliable fuel cell BoP components.

➢ Improve and tailor development tools for design, modelling and testing BoP.

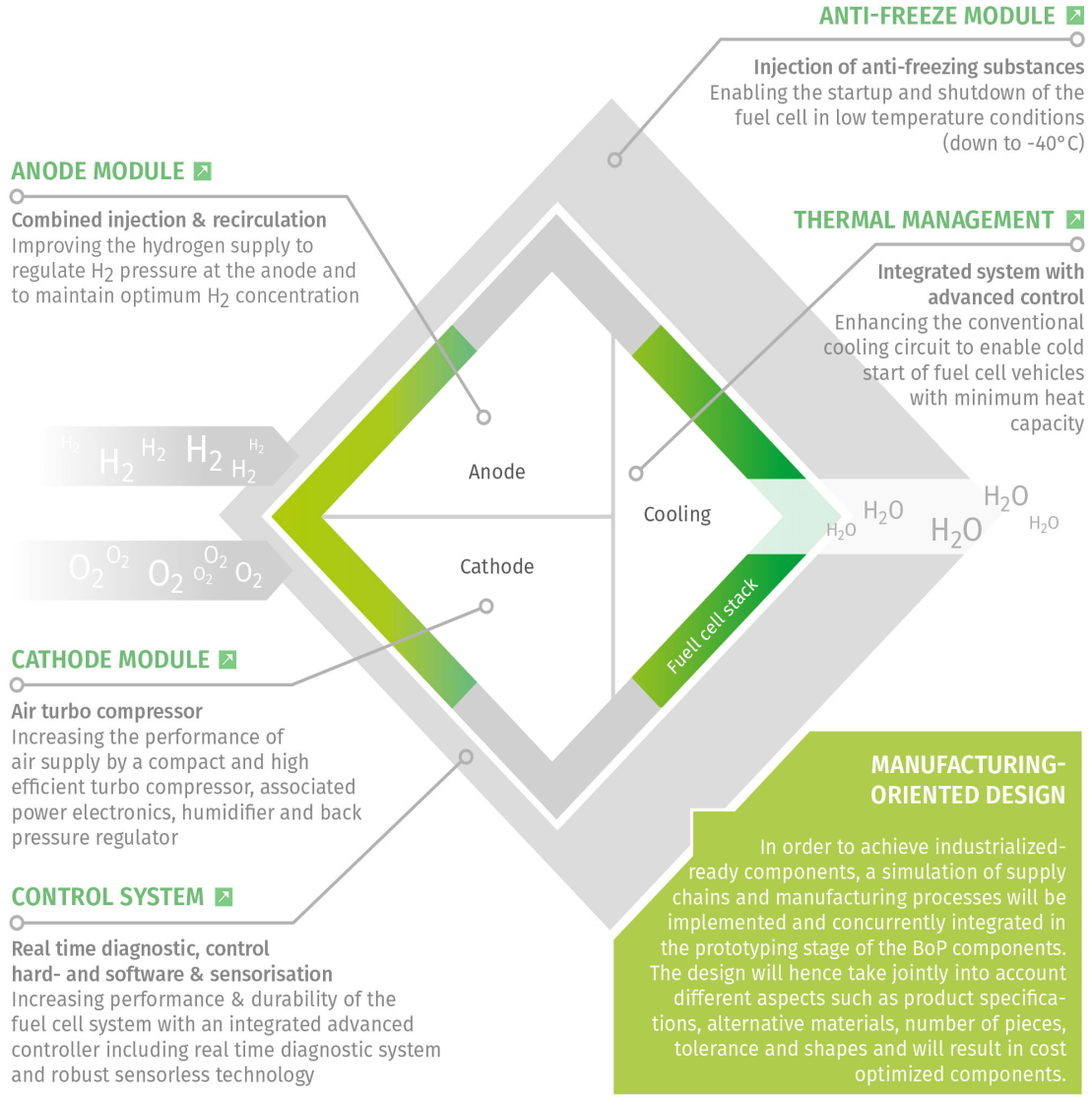
➢ Achieve high technology readiness levels (TRL7).

➢ Reduce costs of current market products in fuel cell systems.

INN-BALANCE overview

Activities

- ➢ BoP developments
  - New air compressor
  - Combined hydrogen injection and recirculation
  - Advanced control and diagnosis devices
  - New concept for thermal management
- ➢ Cost optimization and manufacturing process
- ➢ Integration into a vehicle powertrain to test drivability, durability and performance



INN-BALANCE overview

Organization

- WP1 Architecture and system level optimisation (Powercell)
- WP2 Diagnosis, control and sensorization (AVL)
- WP3 Turbo compressor and cathode module (Celeroton)
- WP4 Anode module (AVL)
- WP5 Thermal management module (DLR)
- WP6 Manufacturing and cost optimization for market implementation (Fundación Ayesa)
- WP7 System integration, testing and evaluation (Volvo Cars)
- WP8 Exploitation, Dissemination and IPR Management of Results (Steinbeis 2i)
- WP9 Communication (Steinbeis 2i)
- WP10 Management and quality (Fundación Ayesa)

INN-BALANCE overview

Expected impacts

- High-performance fuel cell BoP components with lower production cost and long life-cycles
- Increased reliability, durability and competitiveness of fuel cell systems

➢ Standardized platform of BoP component and requirements for European equipment manufacturers

➢ Secure and competitive supply chain

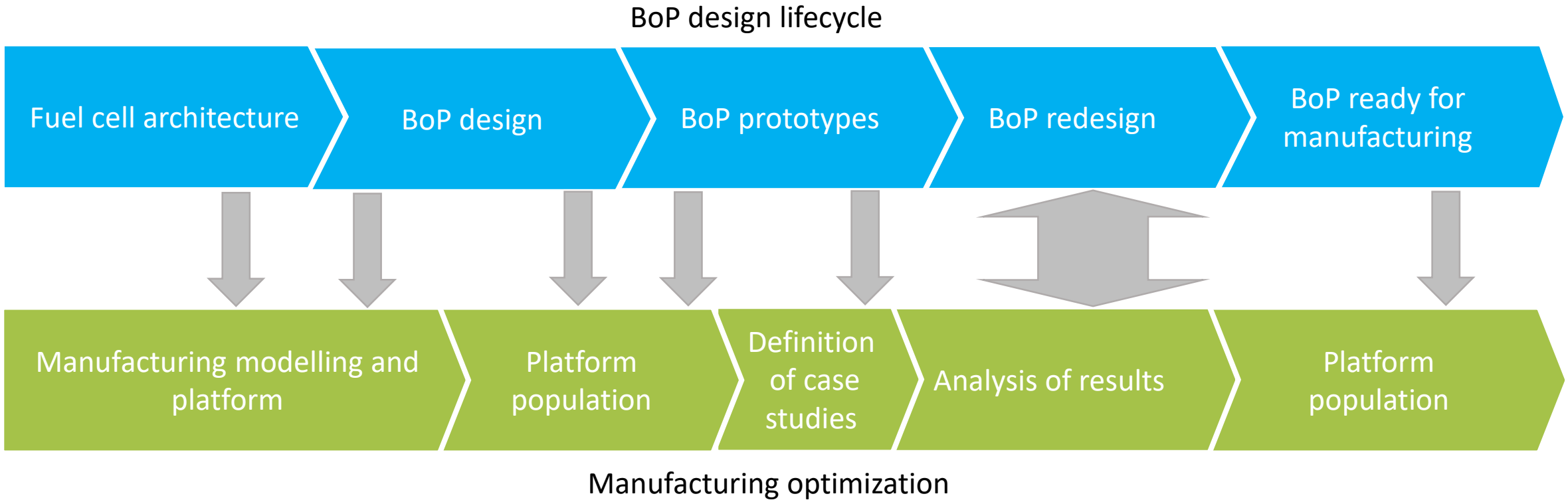
BOOSTING AUTOMOTIVE FUEL CELLS COMMERCIALIZATION IN EUROPE

Manufacturing and cost optimization for market implementation

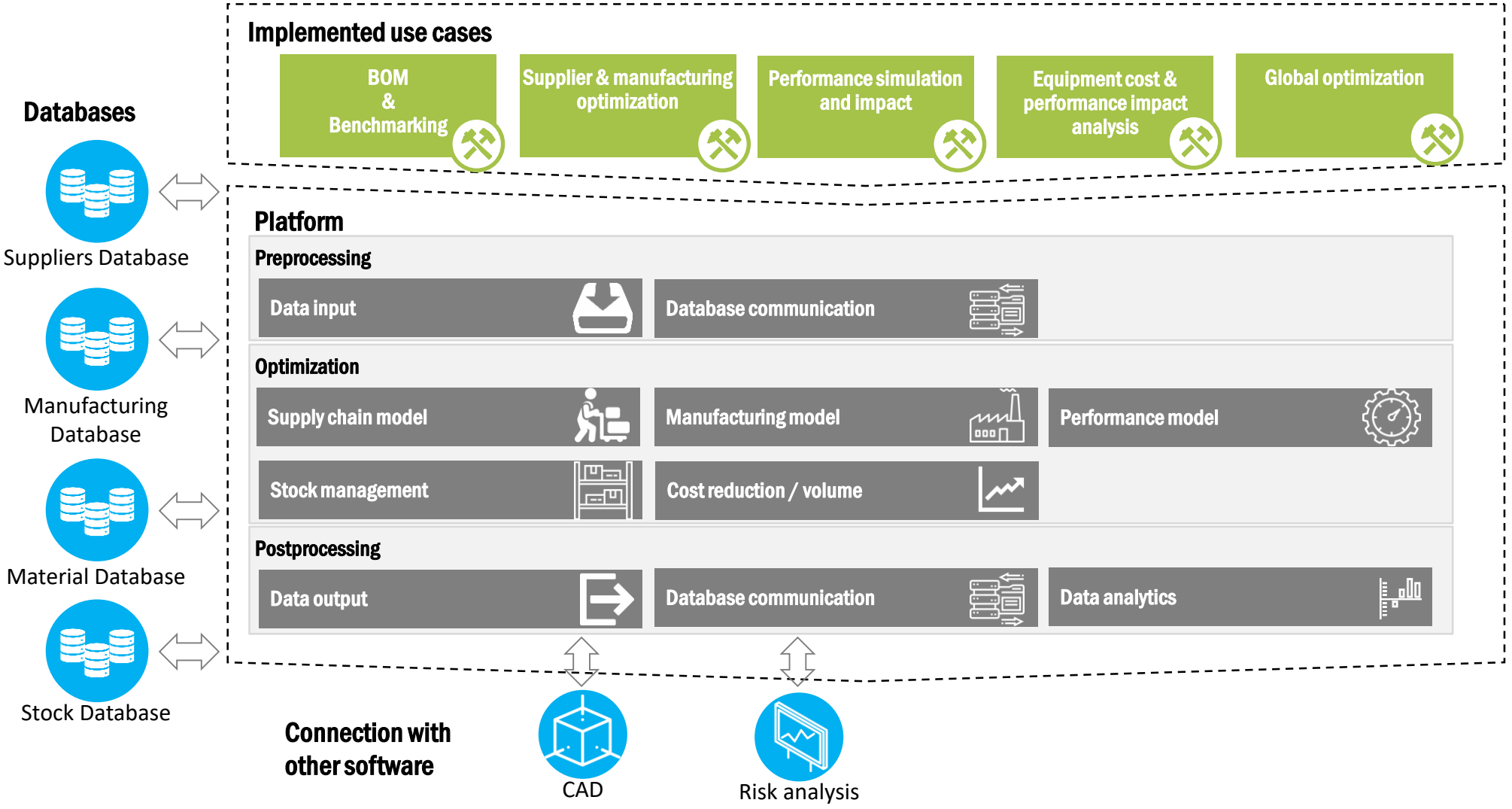
- Supply chain analysis and modelling
- Manufacturing process analysis and modelling
- Product specifications and quality analysis
- Manufacturing-oriented design optimisation framework
- Cost-effectiveness study of improved manufacturing and benchmarking

Manufacturing roadmap

Manufacturing approach



Manufacturing optimization framework



Manufacturing optimization framework

Components main features

Component	Description	Main features
	**Suppliers, manufacturing, material and stock databases:** Stores important data needed to feed the optimisation framework	• Structured data • Extensible and modifiable • Easy to access
	**CAD connection:** Linkage to CAD software to obtain data from different parts, equipment, 3D models…	• Extraction of direct design data • Whole view of the process • Assemblies and parts information • Improvement of design process
	**Risk Analysis connection:** Linkage to Risk analysis software to introduce risk management related to supply chains.	• Risk data about suppliers to include in the optimization • Evaluation of risks
	**Data input:** Manages the inputs introduced by the user, asking variables and avoiding entering incorrect data	• User-friendly • Automatic error avoidance • Storage of needed data
	**Database communication:** Manages the protocols to communicate the databases with the optimization framework	• Easy and modifiable • Fast communication

Manufacturing optimization framework

Components main features

Component	Description	Main features
	**Supply chain model:** Models the restrictions associated with the supply chains	• Cost of transport • Capacity of transport • Production volume • Discount according to volume • Multiple suppliers
	**Manufacturing model:** Implements the restrictions associated with the manufacturing processes and materials	• Material costs. • Use of machines. • Number of machines. • Estimation of manufacturing time. • Incompatibilities between materials and manufacturing processes.
	**Performance model:** Model of the performance of the system, with different equipment and options modelled	• Dynamic simulation of the system • Equilibrium speed / complexity • Possibility to choose different KPIs
	**Stock management:** Models the ordered materials and equipment stocks and the final goods stock	• Estimation of stock cost and quantities • Easy to add new storage facilities • Easy to change stock unit costs
	**Cost reduction/ volume:** Estimates the costs depending on the ordered volume	• Estimation of cost reduction • Comparison between different hypothesis

Manufacturing optimization framework

Components main features

Component	Description	Main features
	**Data output:** Presents the results to the user	• Visual • Schematic • Exportable to other software
	**Data analytics:** Analyses the output data to obtain conclusions and extra results for the user	• User-friendly • Modifiable options • Visual

Use cases

BOM and benchmarking

Concept:
The main objective of the *BOM & benchmarking* use case is to calculate the cost of a system composed of different parts (equipment), allowing the user to do it with several systems, comparing costs and features between them. The user introduce the different components from a portfolio of suppliers and the platform calculates the costs and compare with other introduced options.

System 1
****
Fixed cost for part 1: 100000
Fixed cost for part 2: 45000
Fixed cost for part 3: 20000
Fixed cost for part 4: 78000
Fixed cost for part 5: 123000
Cost of assembling all the parts: 10.4167
Total cost of the system: 366010.4167

System 2
****
Fixed cost for part 1: 140000
Fixed cost for part 2: 30000
Fixed cost for part 3: 25000
Fixed cost for part 4: 57000
Cost of assembling all the parts: 10.4167

Total cost of the system: 252010.4167

Main features:
- Provide a user friendly interface to select components from data bases.
- Gather information from the data bases regarding the selected components.
- Calculate the whole costs according to the different parameters and with the models of the supply chain and manufacturing costs.
- Present an itemized BOM and total costs.
- Compare the costs with other selected options.

Examples:
- Quantify the impact on the fuel cell system costs of different humidifiers of different providers.
- Quantify the impact on the fuel cell system costs of different sensors from different providers.

Use cases

Supplier and manufacturing optimization

Concept:
The main objective of the *Supplier and manufacturing optimization* use case is to calculate the best option, which minimizes the system cost, starting from user introduced requirements for the system and from databases with different suppliers, manufacturing processes and materials. The user includes equipment and specs and the platform calculates the best option amongst all the providers.

```
************************************************
******SUPPLY CHAIN & MANUFACTURING RESULTS*****
************************************************
Order 1000 VA1 valve units from Argentina for part 1
Cost of bought part 1 (valve) : 40060

Order 270000 kg of aluminium from Argentina for part 2
Discount of 50% in the aluminium from Argentina for part 2
Cost of manufactured part 2: 687860.0437 with option machining - aluminium

Cost of buying the 42 needed mach.machining: 2100000

Cost of assembling all the parts: 1041.6667
```

```
************************************************
**************SAFETY STOCK RESULTS**************
************************************************
Cost of stock for valve from VA1: 18.2

Cost of stock for aluminium from Argentina: 2356.1048

************************************************
*******************TOTAL COST*******************
************************************************
Total cost: 2831705.0151
```

Main features:
- Provide a user friendly interface to introduce components and specs with quality tolerance.
- Search in data bases components and providers to cover specs.
- Calculate the supply chain and manufacturing costs of all the options.
- Provide the best option that minimize costs.
- Provide an itemized BOM with cost per part.

Examples:
- Selection of humidifiers with certain specs considering the optimal cost.
- Selection of valves with certain specs considering the optimal cost.
- Selection of sensors with certain specs considering the optimal cost.

Use cases

Performance analysis and impact

Concept:
The main objective of the *Performance analysis and impact* use case is to calculate the impact on the performance of the system of different components from a provider portfolio. The user selects the components of the fuel cell system from provider portfolio and the platform run performance simulations to calculate the impact on performance.

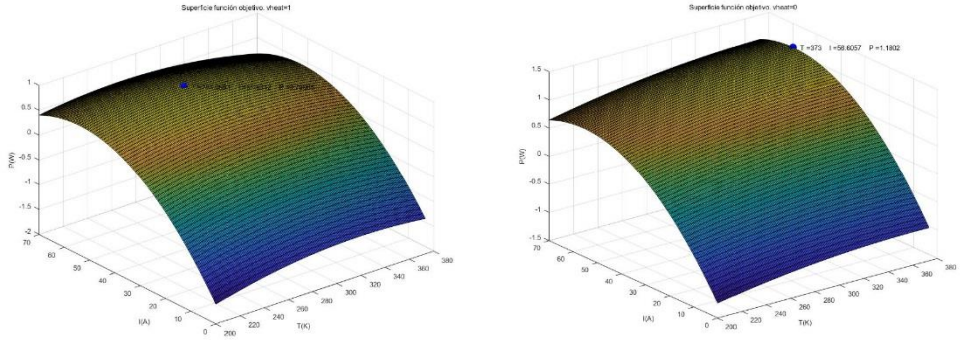
Main features:
- Provide a user-friendly interface to select components from provider porfolio.
- Customize the fuel cell system model with the data of each component.
- Run performance simulations.
- Calculate and analyze the KPIs.
- Calculate the whole costs according to the different parameters and with the models of the supply chain and manufacturing costs.
- Compare performance and costs of different options.

Examples:
- Quantify the impact on the fuel cell system performance of a humidifer with certain specs.
- Quantify the impact on the fuel cell system performance of a sensor with certain specs.
- Quantify the impact on the fuel cell system performance of a valve with certain specs.

Use cases

Equipment cost & performance impact analysis

Concept:
The main objective of the *Equipment cost & performance impact analysis* use case is to calculate the impact of an equipment or part in the total cost and in the performance of the system. The user introduces the components of the fuel cell system from the portfolio and the platform run simulations to calculate the impact on the cost and performance.



Main features:
- Provide a user-friendly interface to select components from provider porfolio.
- Customize the fuel cell system model with the data of each component.
- Run performance simulations.
- Calculate and analyze the KPIs.
- Compare performance of different options.

Examples:
- Quantify the impact on the cost and performance of a humidifier from the provider portfolio.
- Quantify the impact on the fuel cell cost and performance of a provider sensor.
- Quantify the impact on the fuel cell cost and performance of a certain provider valve.

Use cases

Global optimization

Concept:
The main objective of the *Global optimization* use case is to calculate the best option considering the supply chains, the manufacturing and the performance for the system, i.e. to find a trade-off solution, starting from user introduced requirements for the system, from databases with different suppliers, manufacturing processes and materials and from a model of the system performance.

Main features:
- Provide a user friendly interface to introduce components and specs with quality tolerance.
- Search in data bases components and providers to cover specs.
- Calculate the supply chain and manufacturing costs of all the options.
- Customize the fuel cell system model with the data of each component.
- Provide the best option that minimize costs and maximize performance.
- Provide an itemized BOM with cost per part.

Example:
- Selection of humidifiers with certain specs considering the optimal cost and performance
- Selection of valves with certain specs considering the optimal cost and performance.
- Selection of sensors with certain specs considering the optimal cost and performance.

Manufacturing studies

Cathode module

Scenario - humidification:

4 providers
Different specifications
Different packaging and costs
4 different assemblies
Active/passive control
Different valves with time responses, energy consumption and costs.
Sensors vs observers

Manufacturing platform:

Cost benchmarking
Performance impact on durability, hybridization and efficiency
Optimum options
Analysis of extended number of automotive providers.

Conclusions

Systematic approach for optimizing the manufacturing value chain:

emulates the experience of human design process with the capacity to compute more complex and multiple options.

Reduction the design time:

this implies the reduction of number of iteration and man power.

Reduction of number of prototypes:

this implies the reduction of costs to built different prototypes to achieve the manufacturable product.

Integration of information of different design units on an holistic approach:

multidisciplinary design optimization