CapellaDays
ONLINE 2020

Integrating MBSE and Life Cycle Assessment to Remove Plastics from the Oceans with The SeaCleaners

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Evaluating the environmental impact of a system

- **Next 10 years will determine our ecological and economical future**[1].
- **EcoDesign** : The integration of environmental aspects into the product development process[2].
- **Life Cycle Assessment** : Methods & Tools to quantify the environmental performance.
- **MBSE** : Methods & Tools to design systems.

The benefits of EcoDesign, Iberdrola, https://bit.ly/2NkfIoY

Why & how to connect MBSE & LCA to form an EcoDesign process ?

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[1] https://www.un.org/press/en/2019/ga12131.doc.htm
[2] extract from https://www.eea.europa.eu/help/glossary/eea-glossary/eco-design

Case-study

The **MANTA**, an innovative vessel that will collect and process plastic waste floating on the oceans.

- Hybrid propulsion system
  - High mobility and unlimited navigation range
  - Optimal Autonomy

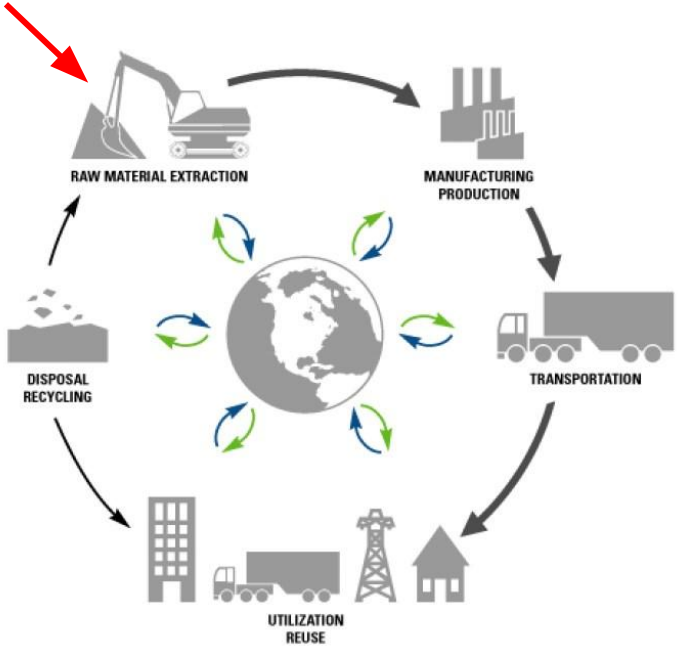
- Waste collection systems at sea
  - On-board factory
  - A waste-to-energy conversion unit

https://www.theseacleaners.org

Methodology: Life Cycle Assessment

Analysis of a system's environmental impacts

- Consider the complete **life cycle**
- Identify & characterize
  - **inputs** (materials, energy…)
  - **outputs** (wastes, air emissions…)
- Compute **indicators** (climate change, ozone depletion)
- Avoid **pollution transfers** between
  - life cycle phases
  - indicators



A generic life cycle of products, NIST, https://bit.ly/3eou838

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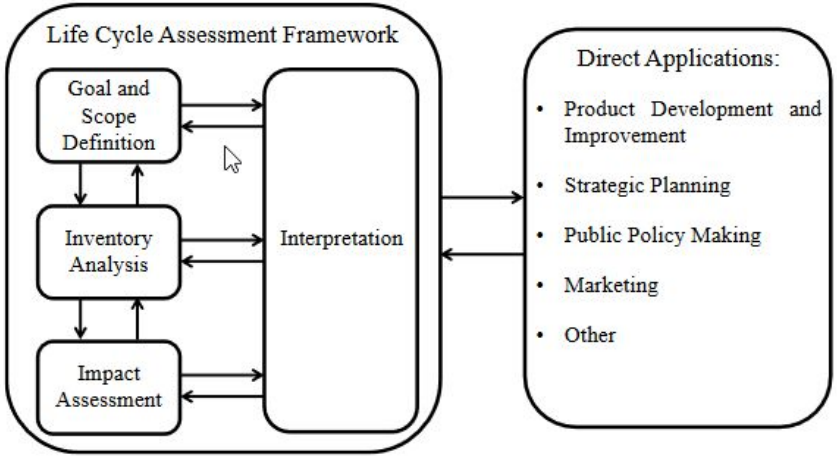
Life Cycle Assessment Framework

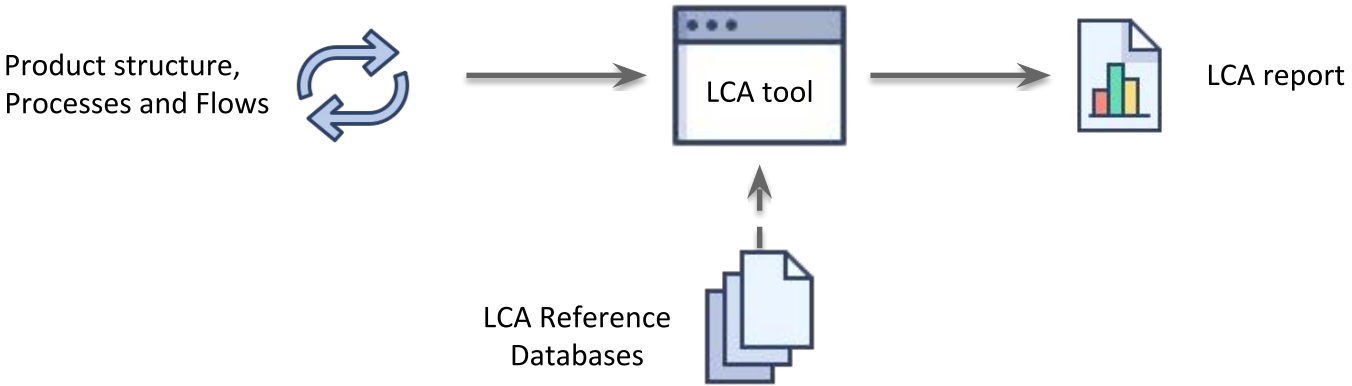
- **Inventory** : flows and processes
- **Input flows** : everything from the environment (materials or services) that is used during the systems life cycle
- **Output flow** : everything (potentially polluting) produced by the system
- **Processes** : set of interrelated or interacting activities within the system that transforms inputs into outputs
- **Methods** to compute **indicators**



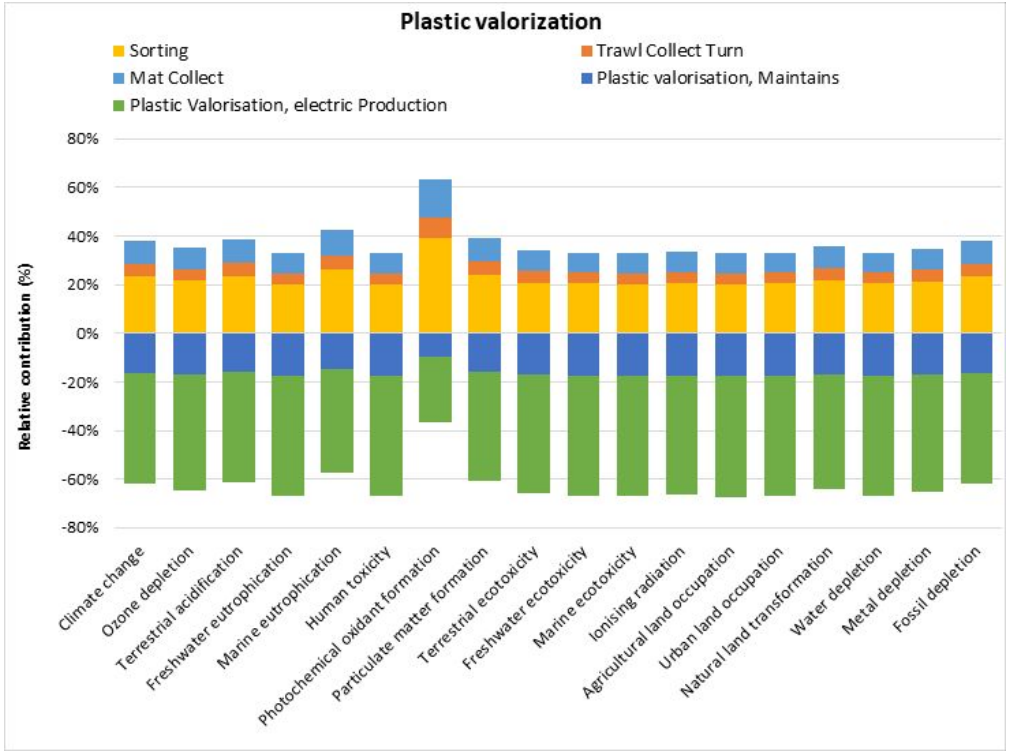
Based on ISO 14040-44, 2006 standards

Life Cycle Assessment Tooling

- Several **tools** implement the LCA approach
  - SimaPro (leader)
  - GaBi
  - OpenLCA
    - open source, based on Eclipse
  - …
- Leverage environmental reference **databases**
  - Generic (common materials and substances)
  - or Domain-specific (energy, maritim, …)

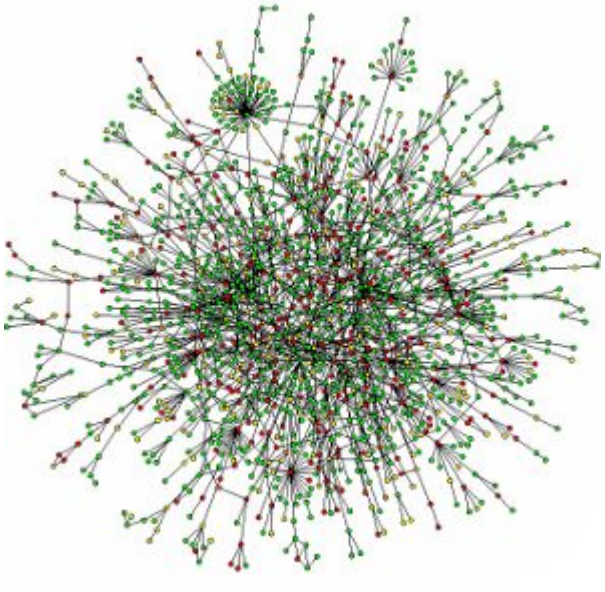


LCA sample Report



Difficulties with Life Cycle Assessment on complex systems

- **Scope the system**
  - Early VS Late analysis
  - System's use-cases
  - Focus on most impacting parts of the system
- **Capture system structure**
  - Many components
  - Many relations
- **Evolutions of the system design**
  - Keep in-sync LCA and System analyses



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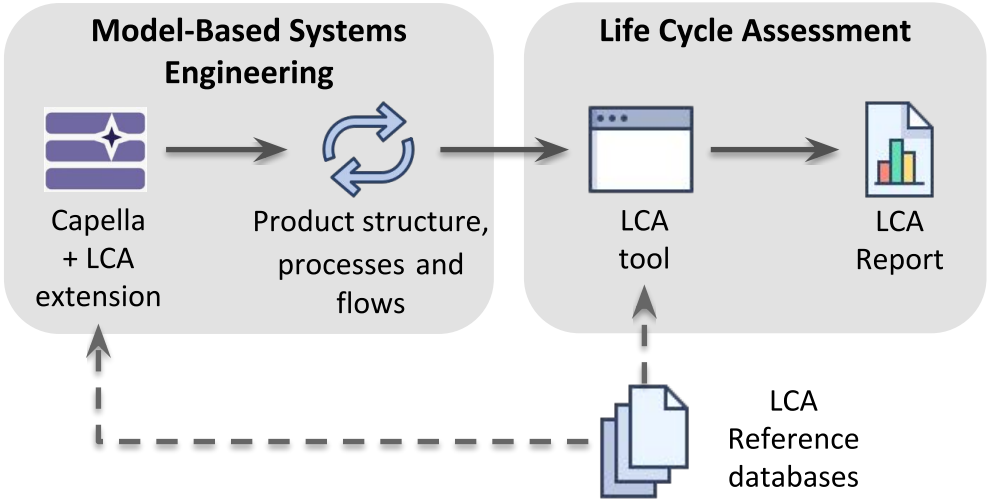
Connecting MBSE and Life Cycle Assessment workflows

- **MBSE Tool**
  - Reference of the product's definition
- **LCA Extension**
  - Import LCA Reference databases
  - Quantity and type of substances, materials or energy, …
  - Attach LCA information to product definition
  - Export data to LCA tools



Partnership on EcoDesign

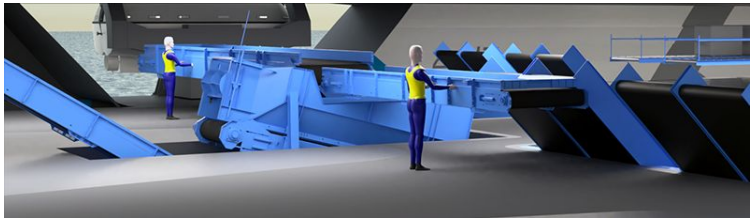
- **Objectives**: Experiment MBSE on MANTA and bridge with Life Cycle Assessment tool

MANTA INNOVATION	OBEO	ALTRAN Part of Capgemini
Lead of the technical hub.	Modeling the MANTA with Capella tool.	Life Cycle Analysis of the MANTA. Support to architecture decisions.
Integrates innovative technological solutions (naval architecture, waste processing and energy production).	Develops a Capella extension to capture technical data to be re-used by LCA tools.	Integrates the system data provided by Obeo into an LCA tool (SimaPro).
OBEO	Define the MBSE/LCA interface.	

Focus on a MANTA's sub-system

- **Waste to Electricity Conversion Unit (WECU)**
  - waste collection → waste to fuel → fuel to energy

- **Why this sub-system?**
  - MANTA was too large for a first experimentation
  - WECU technical solutions was still in research ("pyro-gasification" or "catalytic depolymerization")
  - Environmental impacts were important to assess



👍plastic converted into electricity => less fossil energy used
👍less plastic on-board => longer missions, more plastic removed from the Ocean

👎plastic transformation to fuel => emissions of gas (mitigated) and chars

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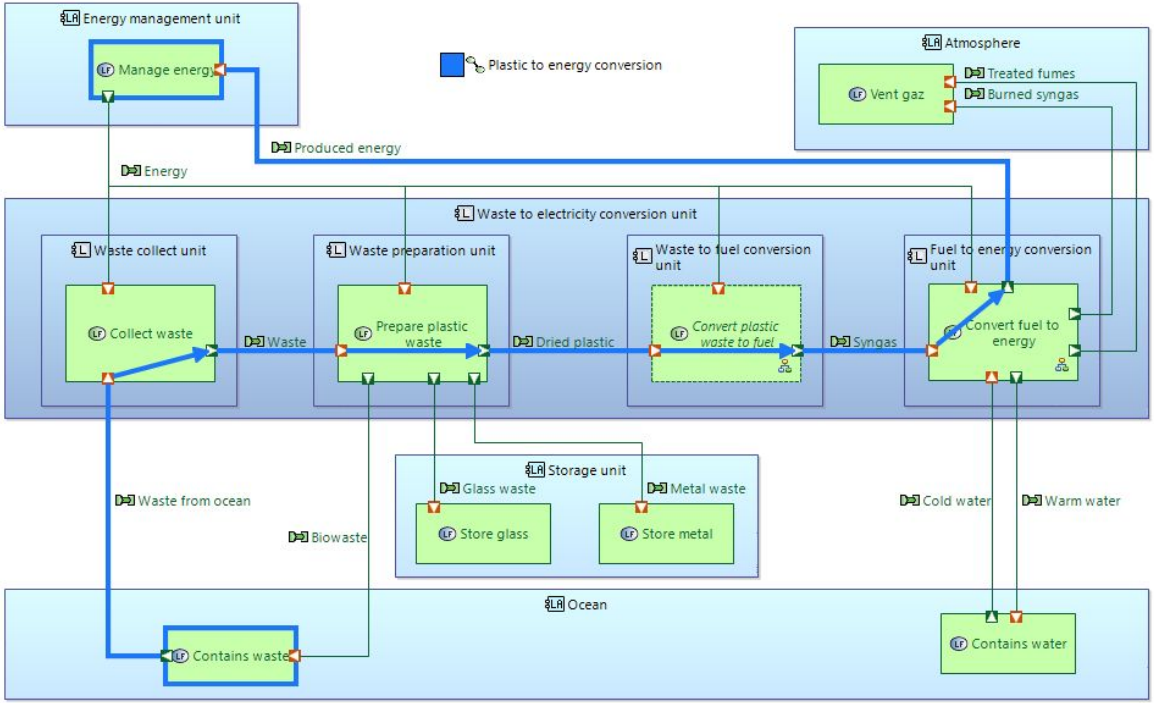
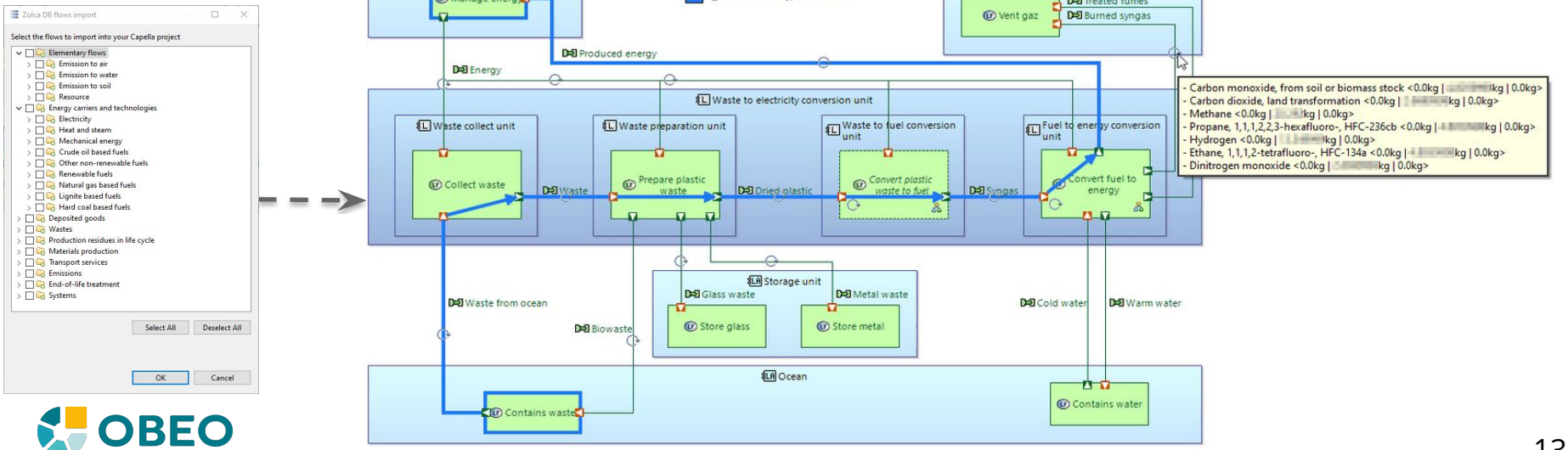
Waste to Electricity Conversion Unit - Logical Architecture



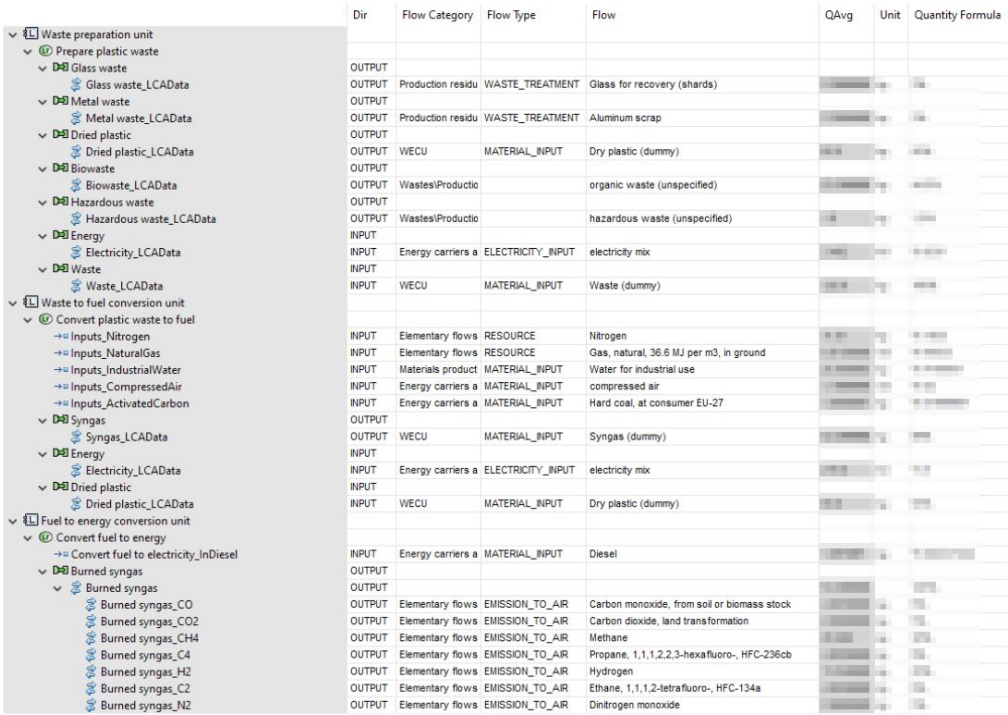
Adding Life Cycle Assessment Data

- **Import** LCA databases content in Capella
- **Attach** LCA data and additional information to **model elements**
  - Components, Functions, Exchanges
- Overview **LCA data** into **diagrams**



Detail Life Cycle Assessment Data

- Manage complex and detailed data
  - LCA data categorization
  - Quantification
  - Dependency to other LCA data
- Contextual data representation
- Tabular view
  - Edition of multiple data
  - Visualization of multiple data



	Dir	Flow Category	Flow Type	Flow	QAvg	Unit	Quantity Formula
Waste preparation unit							
Prepare plastic waste							
Glass waste	OUTPUT						
Glass waste_LCAData	OUTPUT	Production residu	WASTE_TREATMENT	Glass for recovery (shards)			
Metal waste	OUTPUT						
Metal waste_LCAData	OUTPUT	Production residu	WASTE_TREATMENT	Aluminum scrap			
Dried plastic	OUTPUT						
Dried plastic_LCAData	OUTPUT	WECU	MATERIAL_INPUT	Dry plastic (dummy)			
Biowaste	OUTPUT						
Biowaste_LCAData	OUTPUT	Wastes\Productio		organic waste (unspecified)			
Hazardous waste	OUTPUT						
Hazardous waste_LCAData	OUTPUT	Wastes\Productio		hazardous waste (unspecified)			
Energy	INPUT						
Electricity_LCAData	INPUT	Energy carriers a	ELECTRICITY_INPUT	electricity mix			
Waste	INPUT						
Waste_LCAData	INPUT	WECU	MATERIAL_INPUT	Waste (dummy)			
Waste to fuel conversion unit							
Convert plastic waste to fuel							
Inputs_Nitrogen	INPUT	Elementary flows	RESOURCE	Nitrogen			
Inputs_NaturalGas	INPUT	Elementary flows	RESOURCE	Gas, natural, 36.6 MJ per m3, in ground			
Inputs_IndustrialWater	INPUT	Materials product	MATERIAL_INPUT	Water for industrial use			
Inputs_CompressedAir	INPUT	Energy carriers a	MATERIAL_INPUT	compressed air			
Inputs_ActivatedCarbon	INPUT	Energy carriers a	MATERIAL_INPUT	Hard coal, at consumer EU-27			
Syngas	OUTPUT						
Syngas_LCAData	OUTPUT	WECU	MATERIAL_INPUT	Syngas (dummy)			
Energy	INPUT						
Electricity_LCAData	INPUT	Energy carriers a	ELECTRICITY_INPUT	electricity mix			
Dried plastic	INPUT						
Dried plastic_LCAData	INPUT	WECU	MATERIAL_INPUT	Dry plastic (dummy)			
Fuel to energy conversion unit							
Convert fuel to energy							
Convert fuel to electricity_InDiesel	INPUT	Energy carriers a	MATERIAL_INPUT	Diesel			
Burned syngas	OUTPUT						
Burned syngas	OUTPUT						
Burned syngas_CO	OUTPUT	Elementary flows	EMISSION_TO_AIR	Carbon monoxide, from soil or biomass stock			
Burned syngas_CO2	OUTPUT	Elementary flows	EMISSION_TO_AIR	Carbon dioxide, land transformation			
Burned syngas_CH4	OUTPUT	Elementary flows	EMISSION_TO_AIR	Methane			
Burned syngas_C4	OUTPUT	Elementary flows	EMISSION_TO_AIR	Propane, 1,1,1,2,2,3-hexafluoro-, HFC-236cb			
Burned syngas_H2	OUTPUT	Elementary flows	EMISSION_TO_AIR	Hydrogen			
Burned syngas_C2	OUTPUT	Elementary flows	EMISSION_TO_AIR	Ethane, 1,1,1,2-tetrafluoro-, HFC-134a			
Burned syngas_N2	OUTPUT	Elementary flows	EMISSION_TO_AIR	Dinitrogen monoxide			

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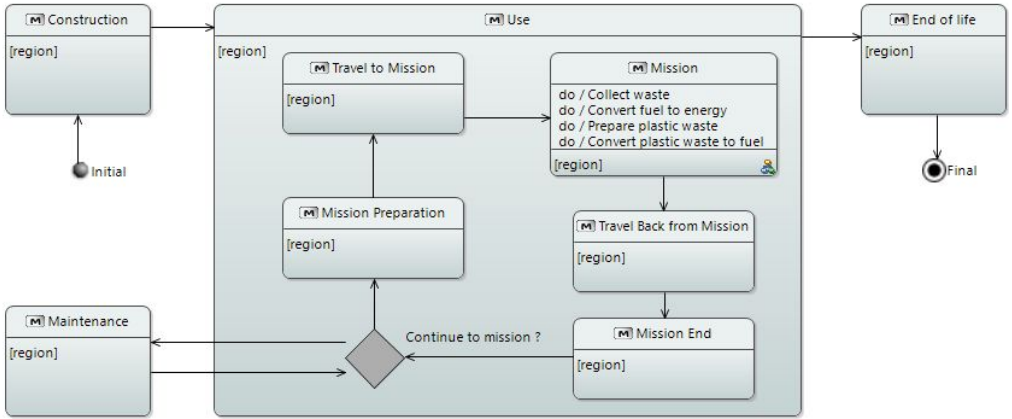
System Life cycle

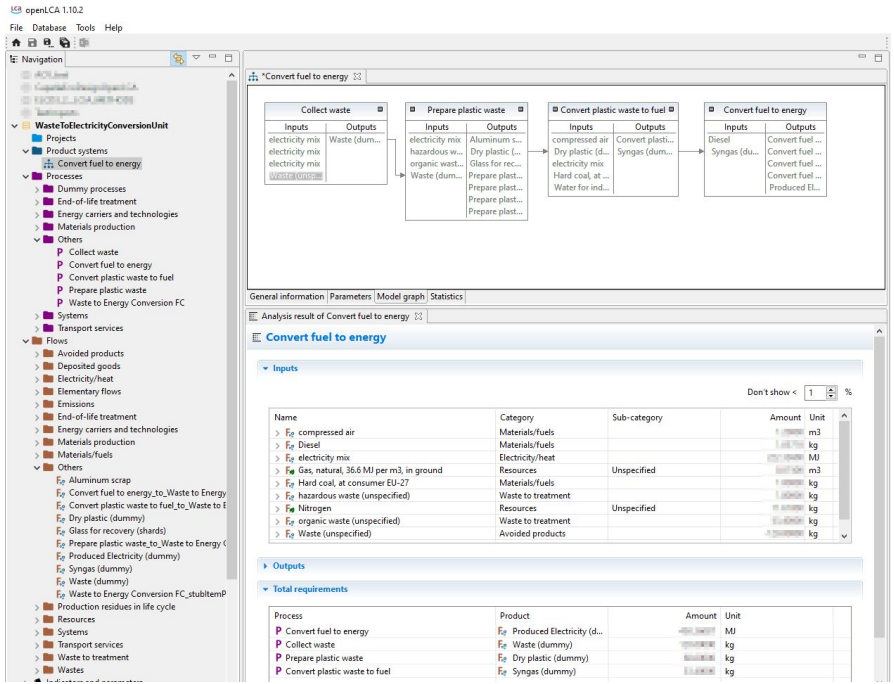
- Modes and states used to represent the **complete system life cycle**

- Function **availability** on modes/states
  - **Qualify** functions context of use in LCA analysis
  - Function life cycle allocation



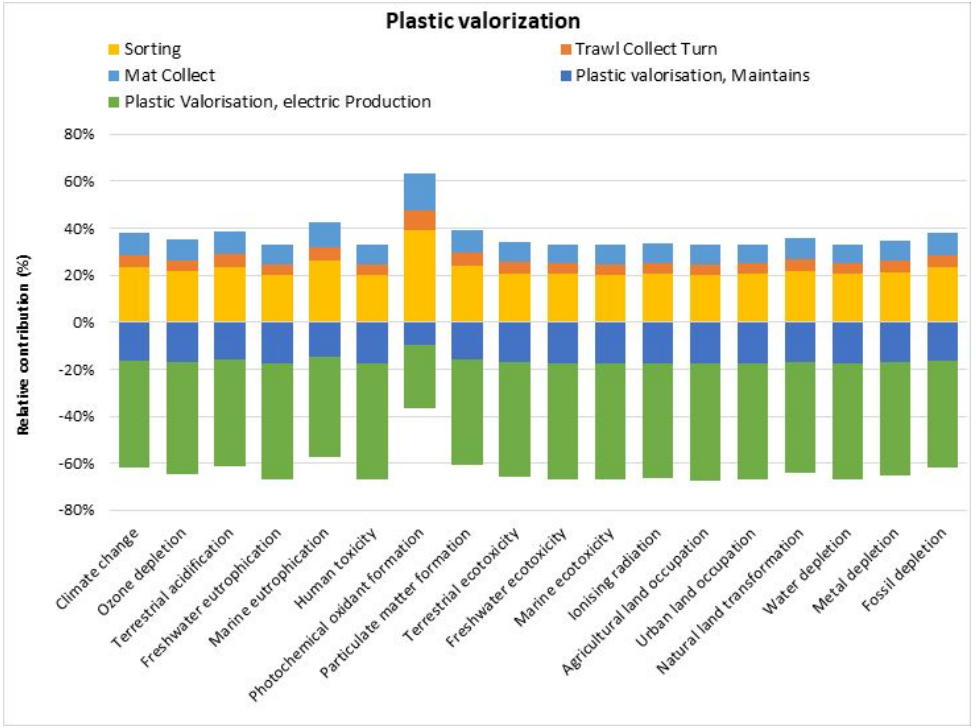
Export to Life Cycle Assessment tools

- **Export** data for LCA tools dedicated work
- **Parameterized** data export based on
  - Functional chains
  - Architecture level
  - Mode and states
  - Free selection of Capella elements



Life Cycle Assessment analysis report

- Compute **indicators** based on **methods**
- **Quantify** distinct system parts impact indicators



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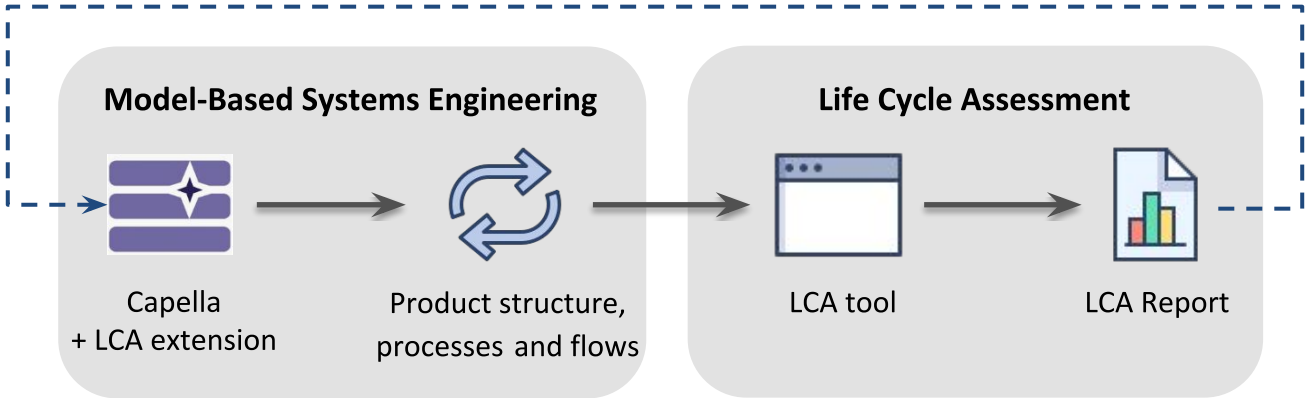
MBSE / Life Cycle Assessment collaborative work

- Feed report information in MBSE analysis
- Use Capella data and enrich them with LCA engineers know-how

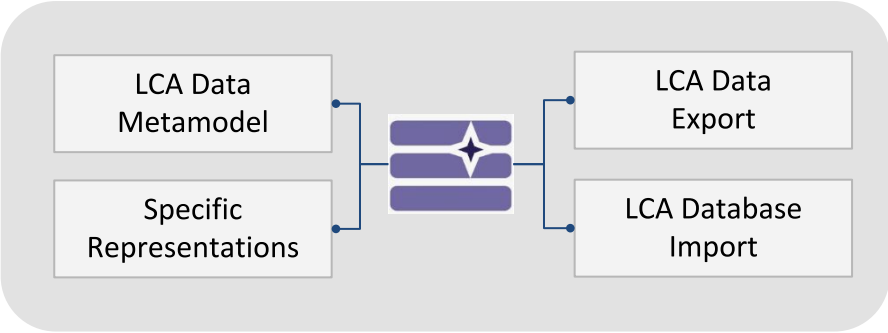
➢ Ease use of LCA data in system design tradeoff
➢ Connect and sync MBSE and LCA



A Life Cycle Assessment extension to Capella

- **Kitalpha Viewpoint**[1] technology to extend Capella
  - LCA data metamodel
  - Extend Capella representations and provide new ones
  - Simplified deployment and integration in the Eclipse environment

- **OpenLCA**[2] **API**
  - Database connection
  - Data import / export format facilities



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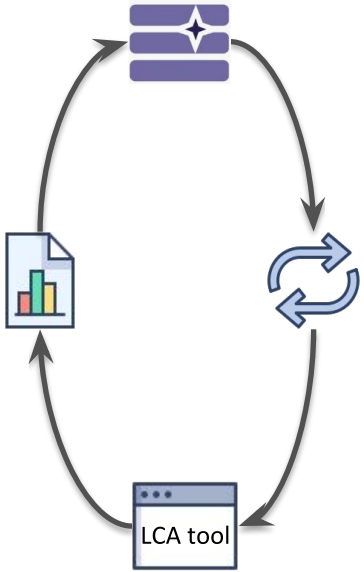
[1] https://www.eclipse.org/kitalpha/
[2] https://github.com/GreenDelta/olca-modules

Conclusion

- **How to connect MBSE & LCA to form an EcoDesign process ?**
  - **Prototype** connection between Life Cycle Assessment and MBSE
    - LCA database import
    - Relation between Capella and LCA concepts
    - Capella integration through diagrams extensions and tables
    - Connection to LCA tools
    - First reflexions on the methodology
- **Why connect MBSE & LCA to form an EcoDesign process ?**
  - **Compute** system environmental performance **indicators**
  - **Integrate** environmental performance in the architecture **tradeoffs**
- **A collaborative work with System engineers and LCA analysts**



A lot remains to be done !

- MBSE / Life Cycle Assessment **connection**
  - **Parameterize** the data export
  - Give LCA **meaning** to MBSE concepts / setup
  - Handle **multiple data formats / tools**
  - **Feedback** LCA analysis results for system design tradeoff

- **Integration** into Capella
  - Editing, scale, **methodology**
  - Take into account the whole system **life cycle**
  - Quantify **life span** of functions / system parts

- **Synchronizing** LCA and MBSE models

- Transform the prototype into a tool

- Open to collaboration !

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Thanks for watching

For any other questions, follow the Capella MBSE Tool page on LinkedIn

Or join us thursday 15th at 5:25 pm CET for our Q&A session
with Capella and Arcadia Experts

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