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Introduction to Techno-Economic Assessments of HTS Systems

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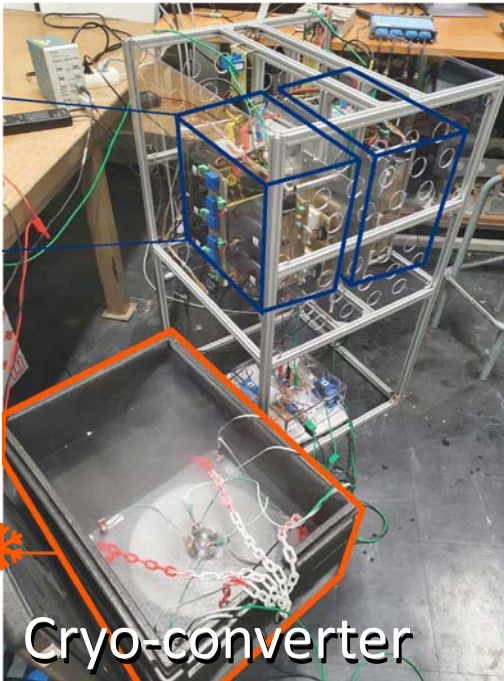
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Hi-SCALE



Our activities: components for electric grids



SuperRail

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INNOVATIVE CRYOGENIC SOLUTIONS

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bpifrance



Motivation

The energy transition to a low-carbon society is both a major challenge for innovation and a great opportunity for the economy.

Technological innovation in the field of electrical engineering can have an important role to play.

But an innovation has little chance of being adopted if it is not competitive over its life cycle.

Research question

How to evaluate the potential of a technological innovation ?

 **Techno-economic assessment (TEA)**

Objectives

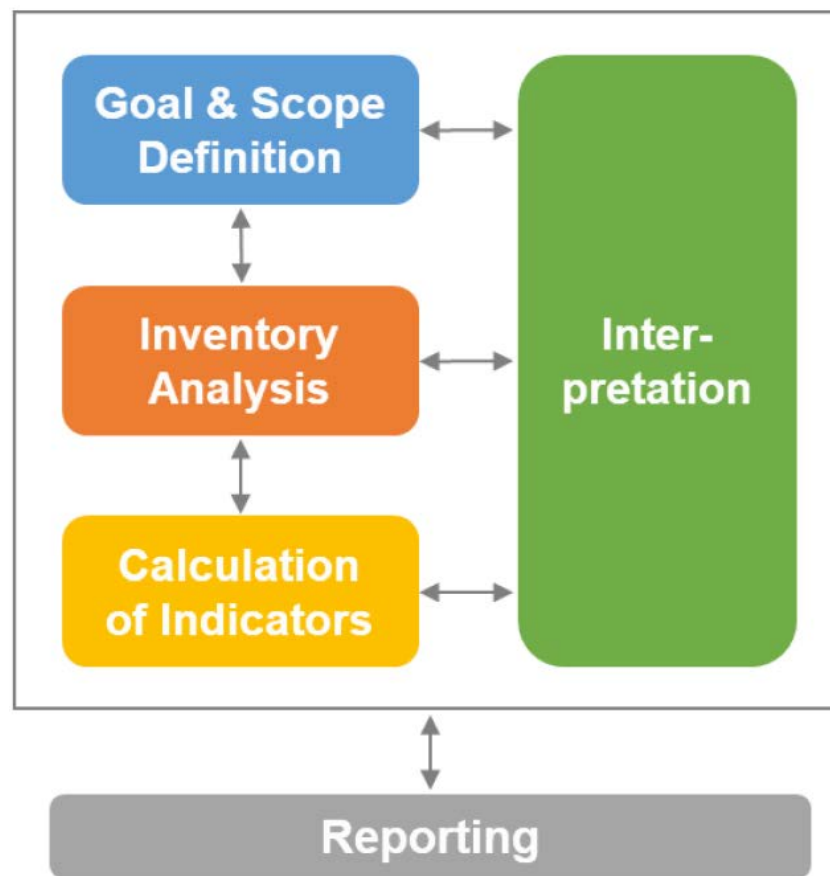
- 1) Understand what is a techno-economic assessment
- 2) Use TEA methodology to assess the potential of an HTS cable system

Content

- I. Techno-economic assessment
- II. Performance indicator ?
- III. TEA checklist

I. Techno-economic assessment

Techno-economic assessment framework



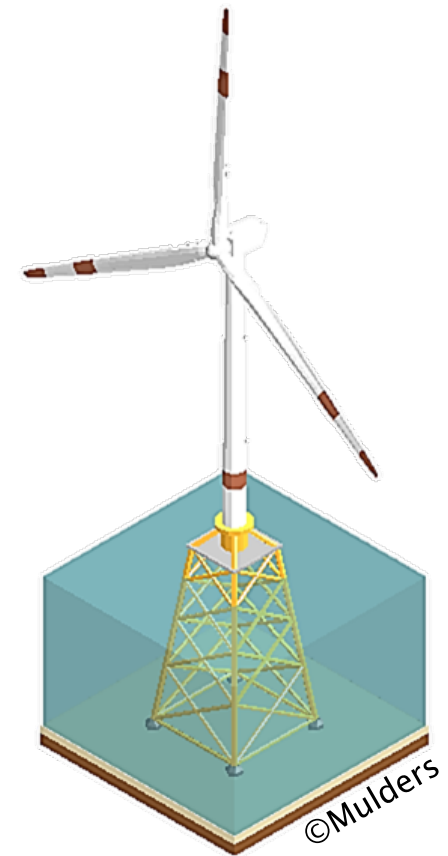
Source: T. Langhorst, *et al.* "Techno-Economic Assessment & Life Cycle Assessment Guidelines for CO2 Utilization (Version 2.0)," Global CO2 Initiative, 2022.

I. Techno-economic assessment framework

Definitions

Product system

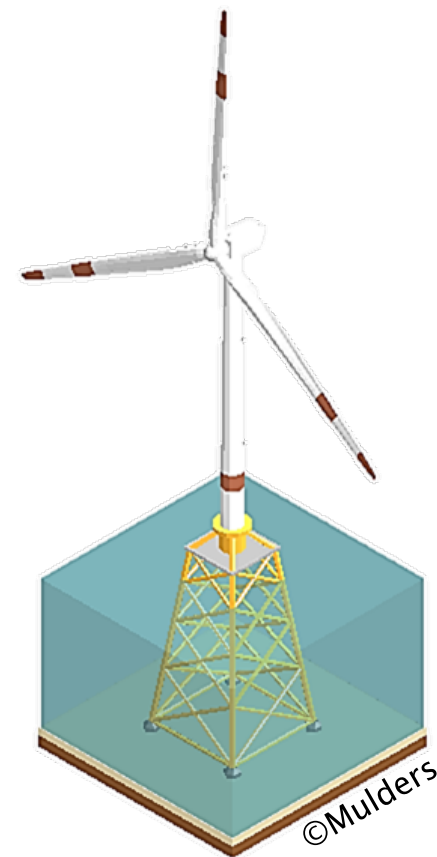
Collection of materially and energetically connected system elements, which perform one or more defined functions.



System element

Smallest unit for which data are inventoried. It can be hardware, software, data, humans, organisms, processes, procedures, facilities, materials, or any combination of these.

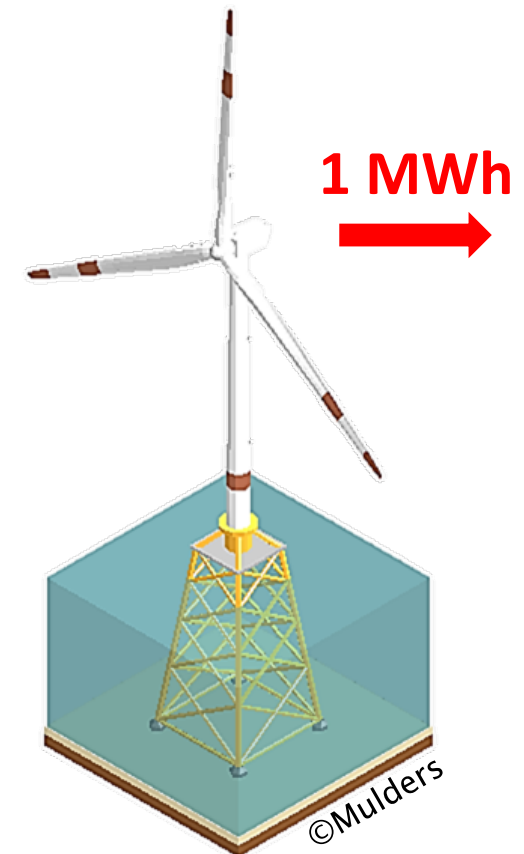
turbine	nacelle	tower	foundation
blade (3)	generator (1)	tower (1)	platform (1)
hub (1)	power converter (1)	3ph AC cable (1)	tendons (3)
shaft (1)	AC filter (1)	transformer (1)	anchors (3)
bearing (1)	protections (1)	grounding (1)	
	bed plate (1)		
	nacelle cover (1)		



Functional unit

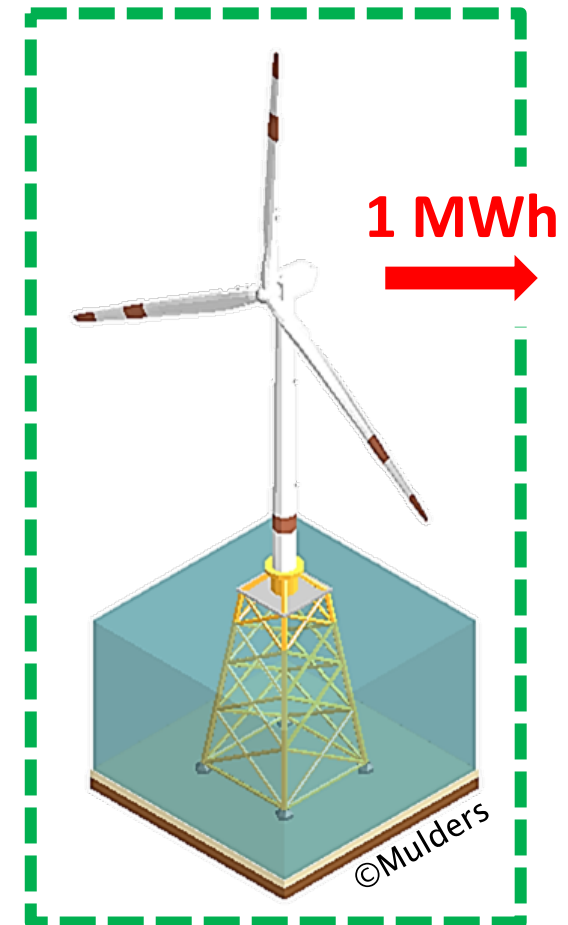
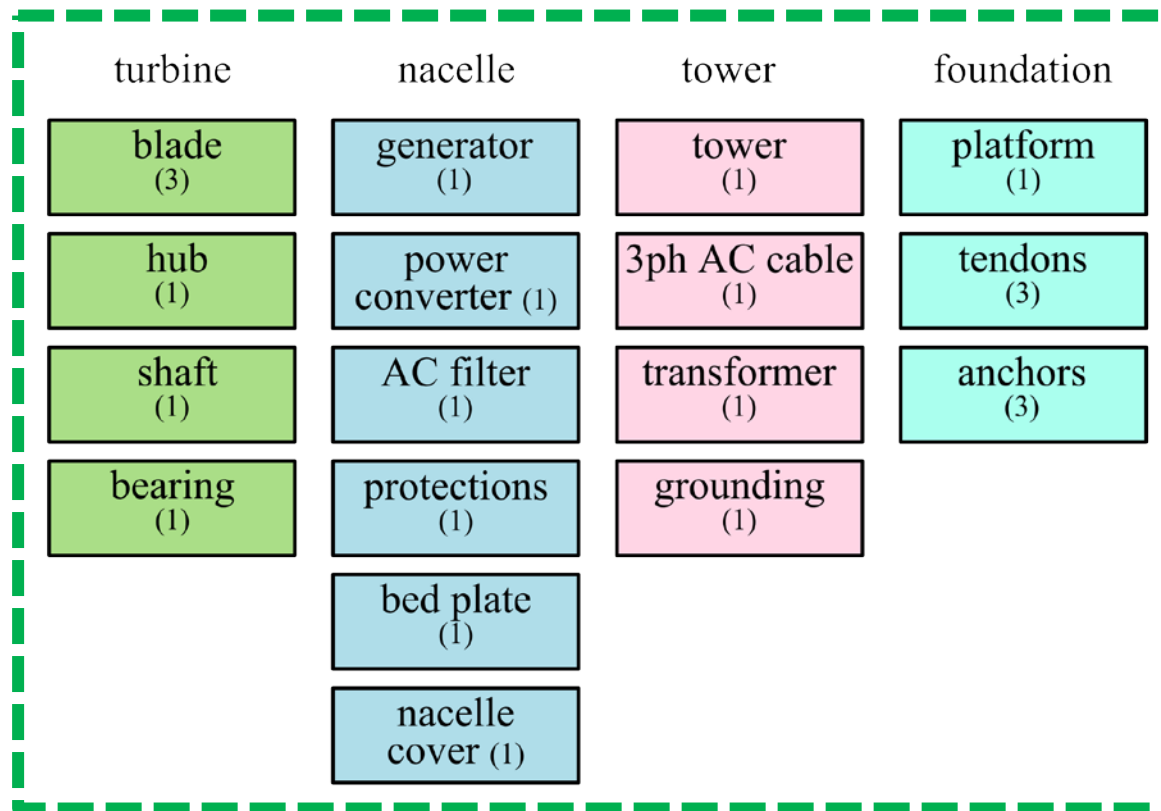
Quantified description of the function of a product system that serves as the reference basis for all calculations.

turbine	nacelle	tower	foundation
blade (3)	generator (1)	tower (1)	platform (1)
hub (1)	power converter (1)	3ph AC cable (1)	tendons (3)
shaft (1)	AC filter (1)	transformer (1)	anchors (3)
bearing (1)	protections (1)	grounding (1)	
	bed plate (1)		
	nacelle cover (1)		



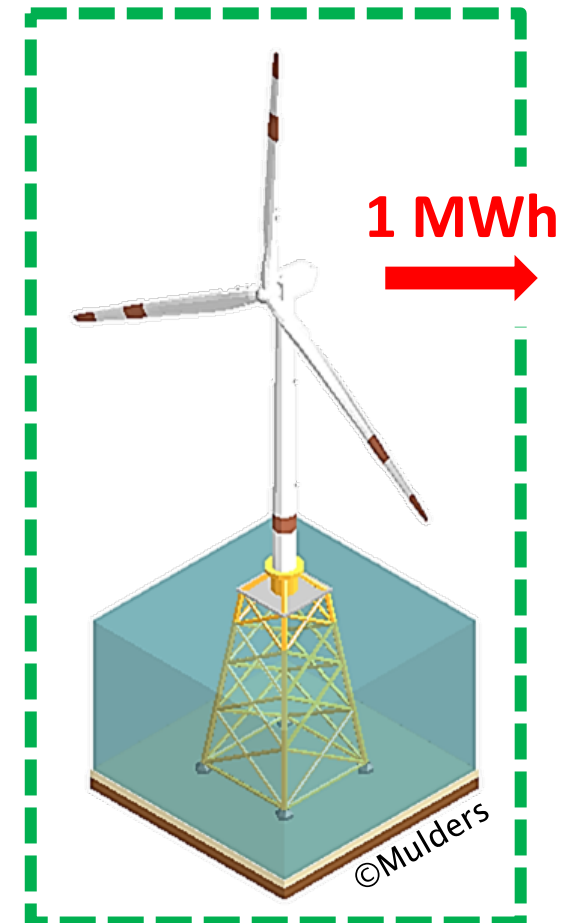
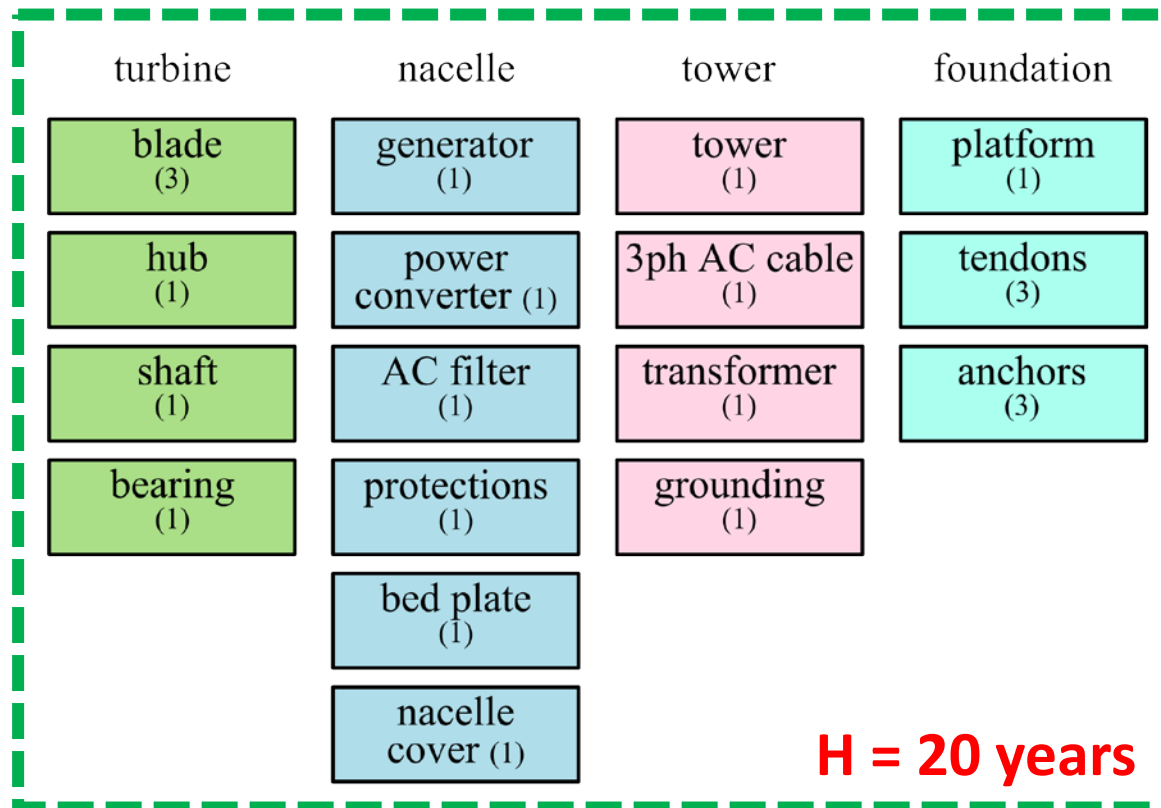
System boundary

Set of criteria specifying which system elements are part of a product system.



Time horizon H

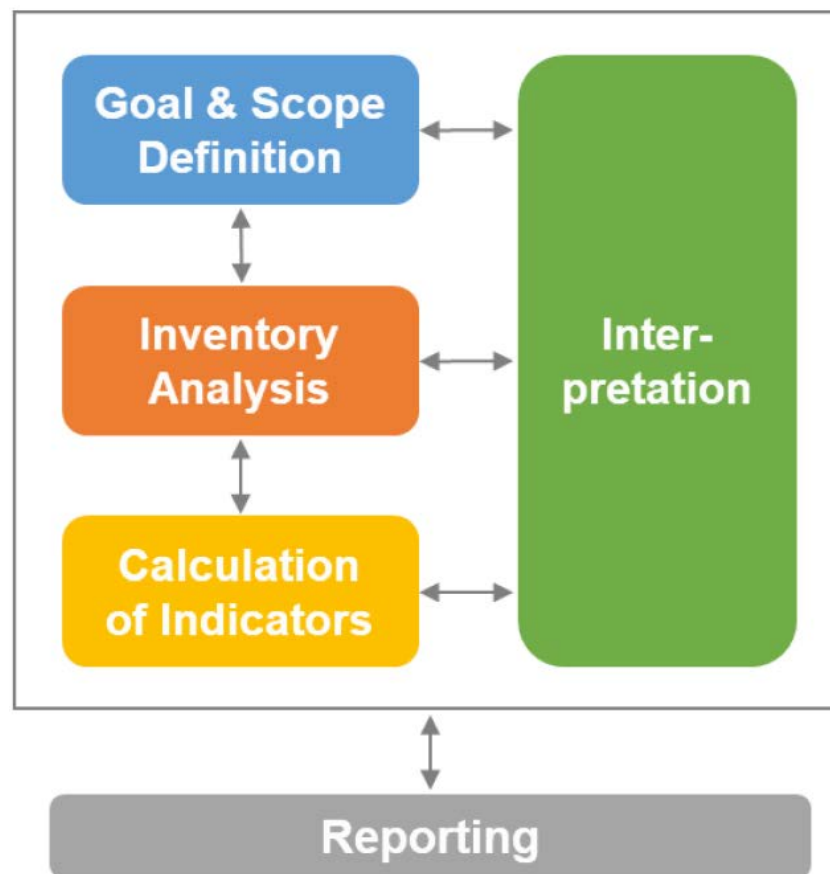
Study period, usually expressed in years, over which the assessment is carried out.



I. Techno-economic assessment framework

Framework

Techno-economic assessment framework



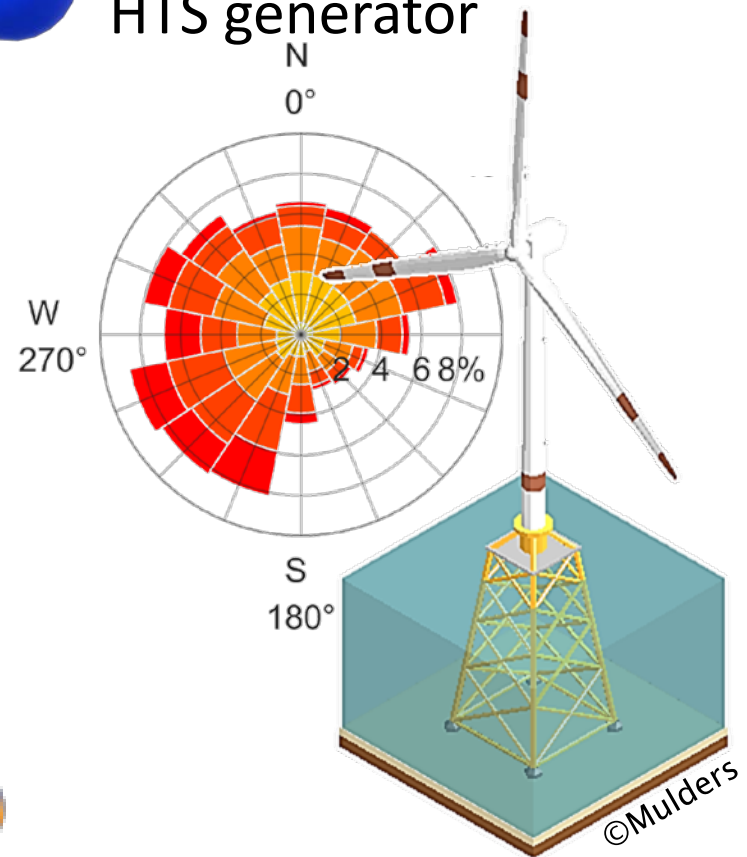
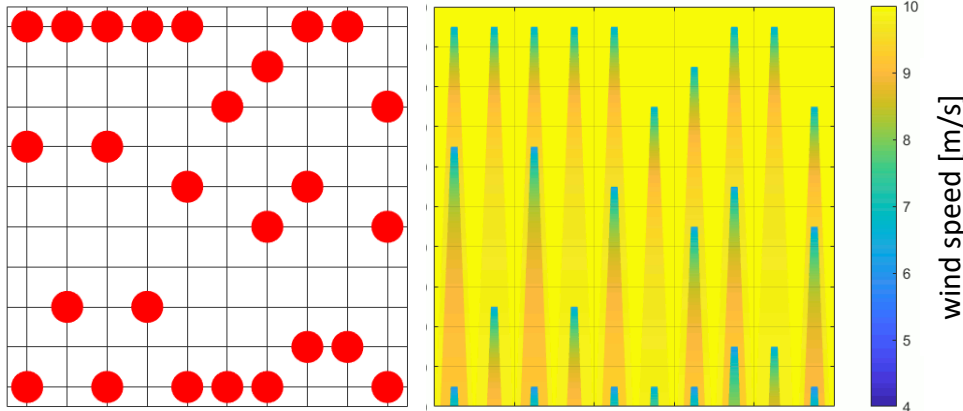
Source: T. Langhorst, *et al.* "Techno-Economic Assessment & Life Cycle Assessment Guidelines for CO2 Utilization (Version 2.0)," Global CO2 Initiative, 2022.

Techno-economic assessment

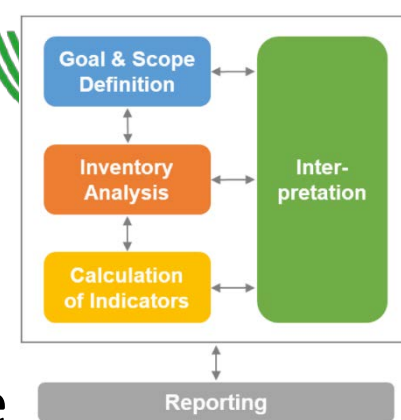
Phase 1: Goal and scope definition

Goal: Wind turbine PM generator  **vs.**  Wind turbine HTS generator

Scenario:



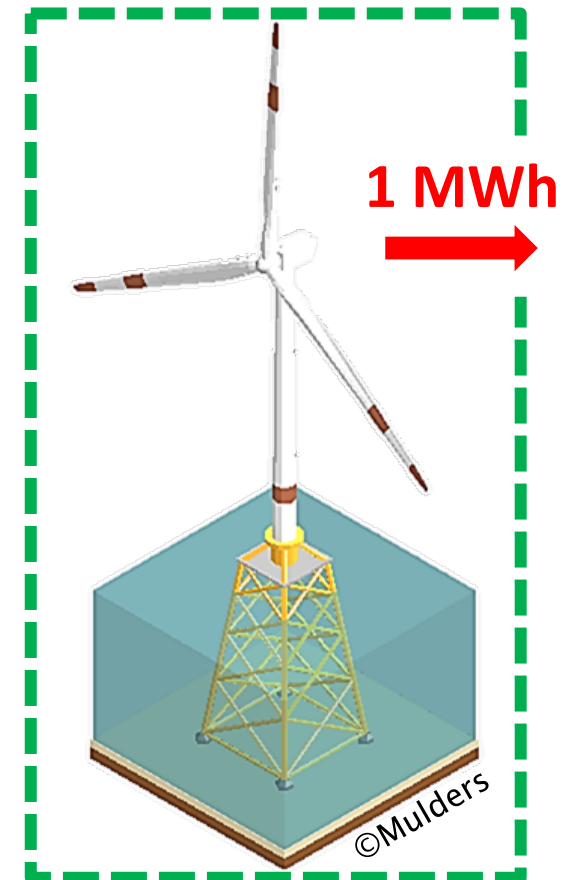
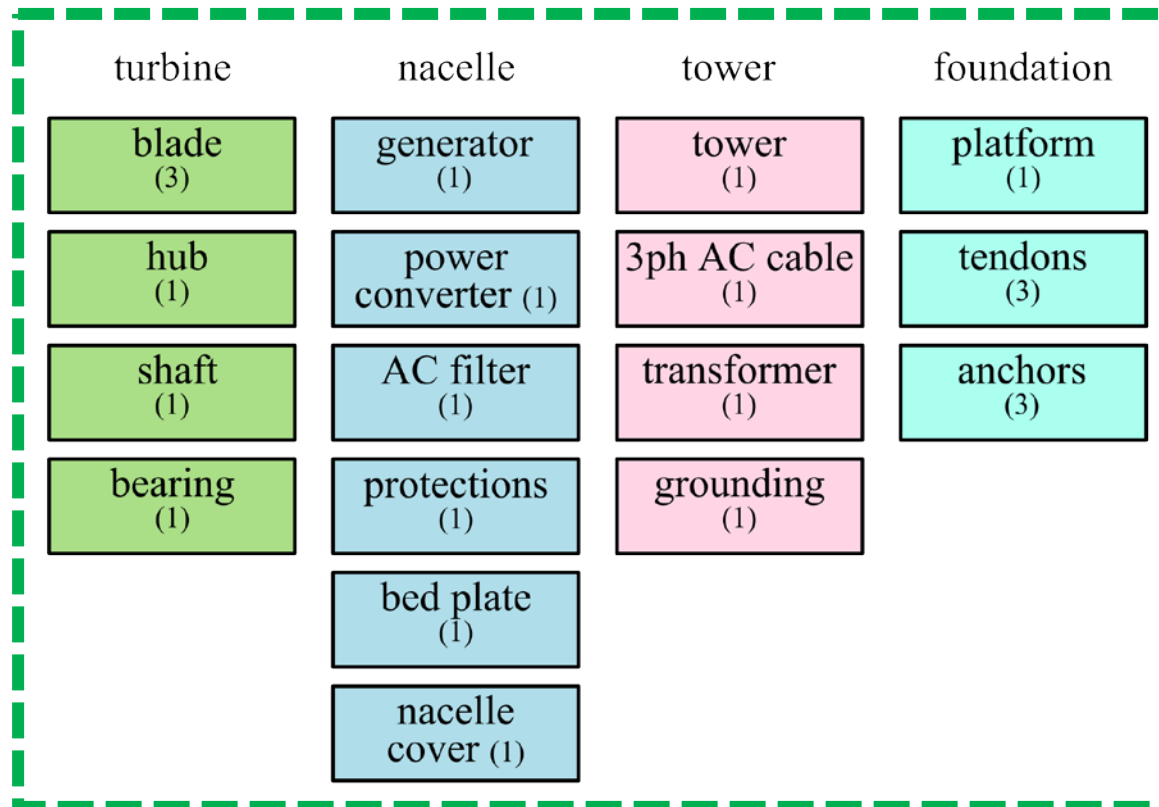
Performance indicator: PI [unit] 



Techno-economic assessment

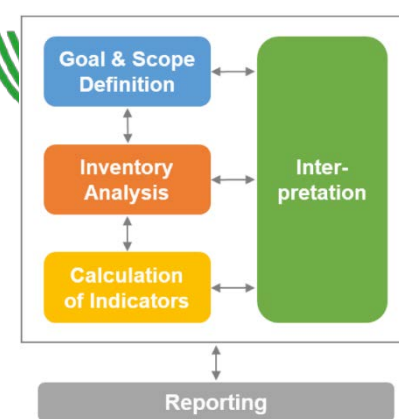
Phase 2: Inventory analysis

system boundary ?

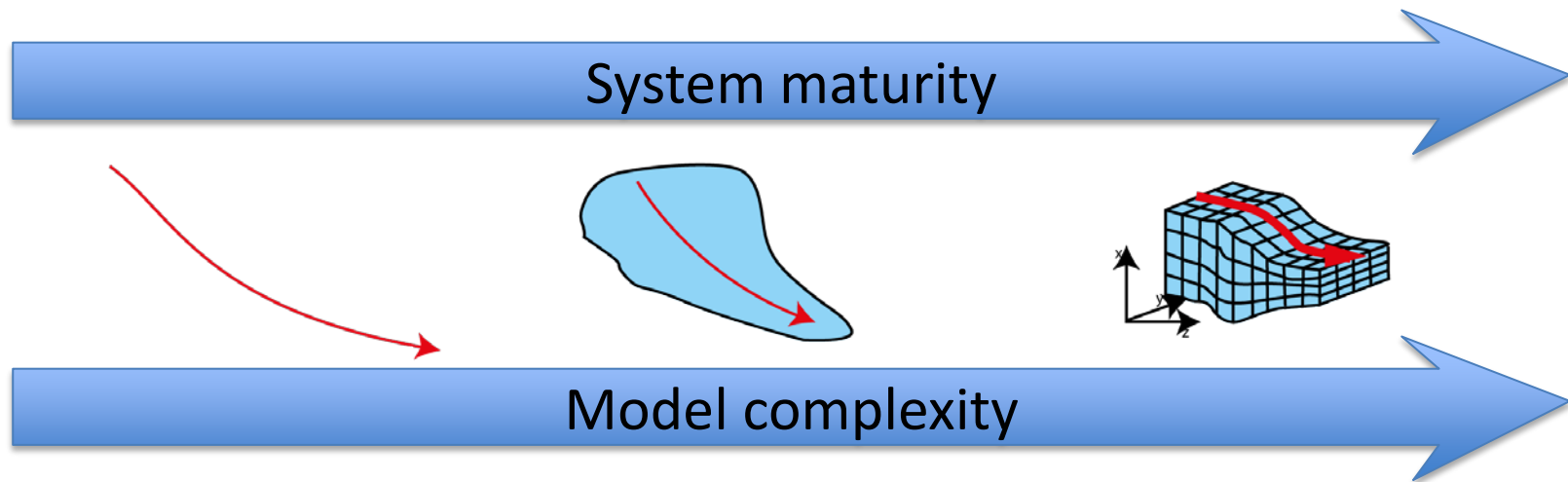


Techno-economic assessment

Phase 3: Calculation of indicators



(i) Modeling

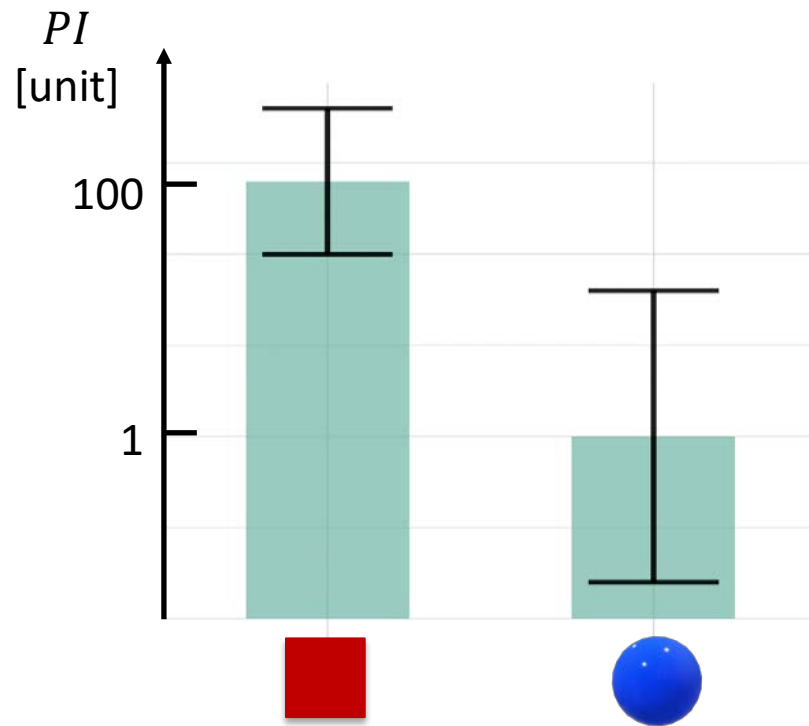
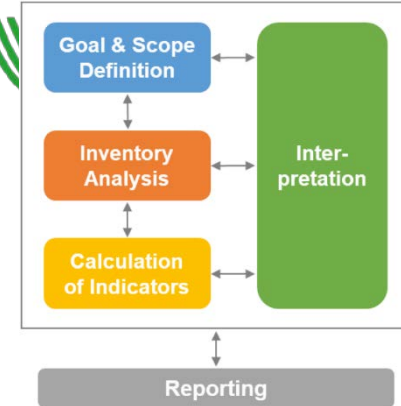


(ii) Characterization

	Benchmark system 	Proposed system 
<i>PI</i> [unit]	100	1

Techno-economic assessment

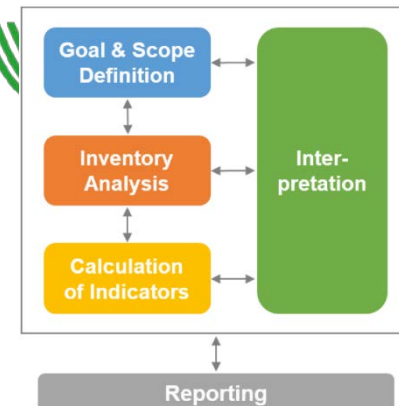
Phase 4: Interpretation



Techno-economic assessment

Phase 5: Reporting

- Transparency
- Accuracy
- Consistency
- Reproducibility



Techno-economic assessment

3 Difficulties

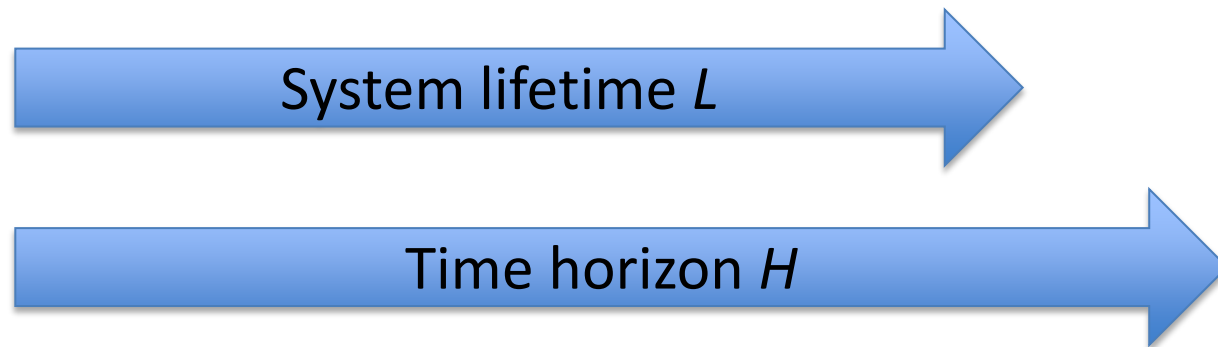
- **Optimization problem:** To be fair, one should only compare 2 systems that have been optimized on the same set of requirements and for the same scenario.
- **Prospective performances:** To be fair, the techno-economic assessment of a technological innovation should rely on projections of the value of its technological and economic parameters when it will reach market maturity.
- **Performance indicator**

II. Performance indicator ?

Life cycle cost (LCC)

System lifetime L

Duration, usually expressed in years, over which the system remains integer and usable for its primary function for which it was conceived and produced.



Cash flow

Real or virtual movement of money.

Present value of a cash flow

Value at the present time of a future cash flow, discounted to account for the time value of money.

The present value $PV(F)$ of a cash flow F is calculated by,

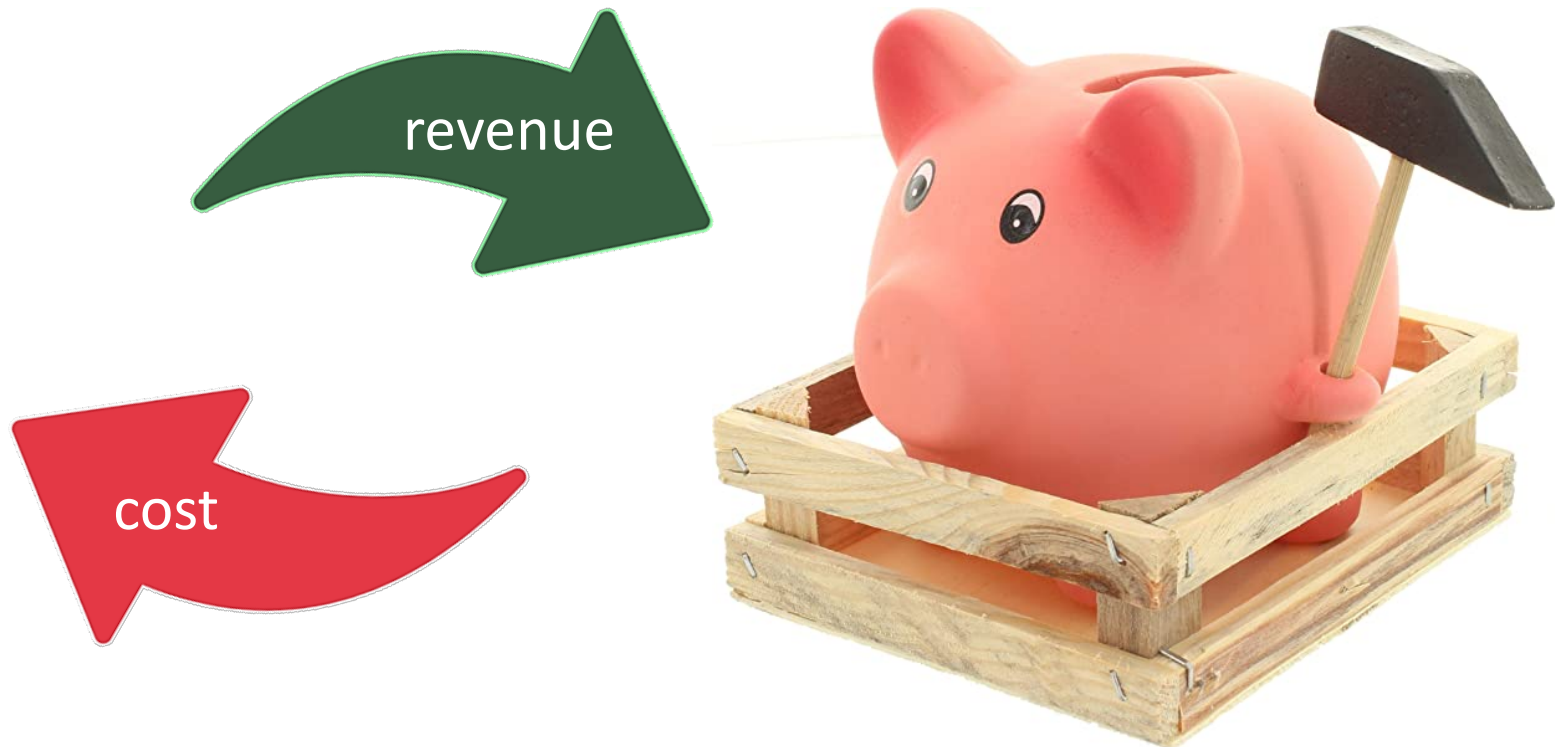
$$PV(F) = \frac{F}{(1 + dr)^t}$$

- dr discount rate
- t duration, usually expressed in years, between the present time and the date of the future cash flow.

Cost & Revenue

A cost (positive value) is a negative cash flow.

A revenue (positive value) is a positive cash flow.



Capital expenses *CAPEX*

Fixed and variable costs due to capital, e.g., equipment, system design, engineering, installation and decommissioning.

Operating expenses *OPEX*

Fixed and variable costs due to operation, e.g., maintenance, reparation, salary of the operator, site access, guarantees and fuel.

Life-cycle cost (LCC)

$$LCC = \sum_{t=0}^H \frac{C_t}{(1 + dr)^t}$$

- C_t costs in year t
- dr discount rate
- H time horizon.

Since all the costs have positive value, the LCC is positive as well.
The present time is $t = 0$ and therefore C_0 is the initial investment.

Life-cycle cost (LCC)

Hypotheses:

- (i) the assessment time horizon H is taken equal to the system lifetime L .
- (ii) the costs include only the capital and operating expenses.

$$LCC = \sum_{t=0}^L \frac{CAPEX_t + OPEX_t}{(1 + dr)^t}$$

- $CAPEX_t$ capital expenses in year t
- $OPEX_t$ operating expenses in year t
- dr discount rate
- L system lifetime.

Discussion

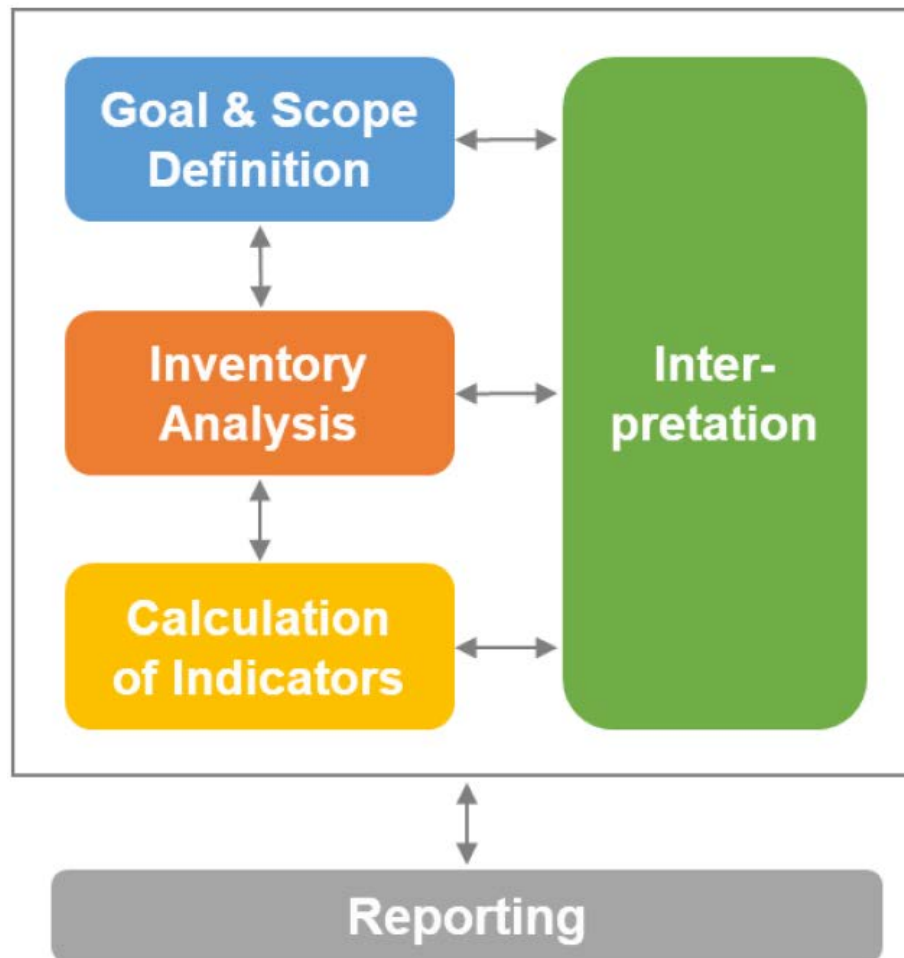
The *LCC* is a techno-economic performance indicator.

It allows one to compare 2 competing technologies that provide the same service on the same time horizon.

One normally wants to choose the technology with the lowest *LCC*.

III. TEA checklist

TEA framework overview



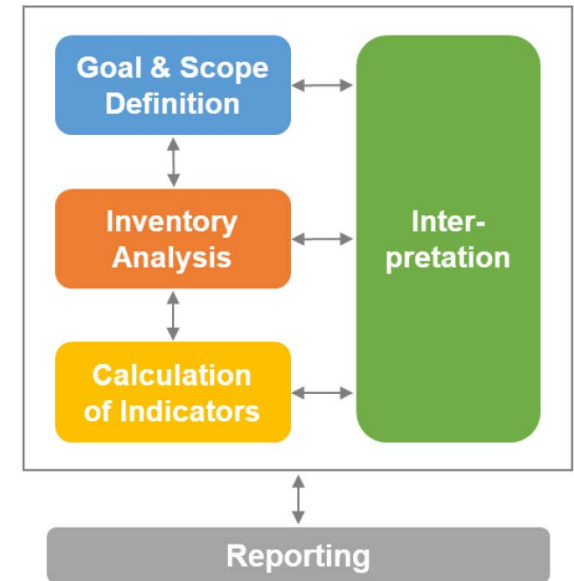
Phase 1: Goal and scope definition

Goal definition

- ☐ Intended application of the study
- ☐ Purpose of the study
- ☐ Target audience
- ☐ Time horizon
- ☐ Location
- ☐ Scenario to be analyze

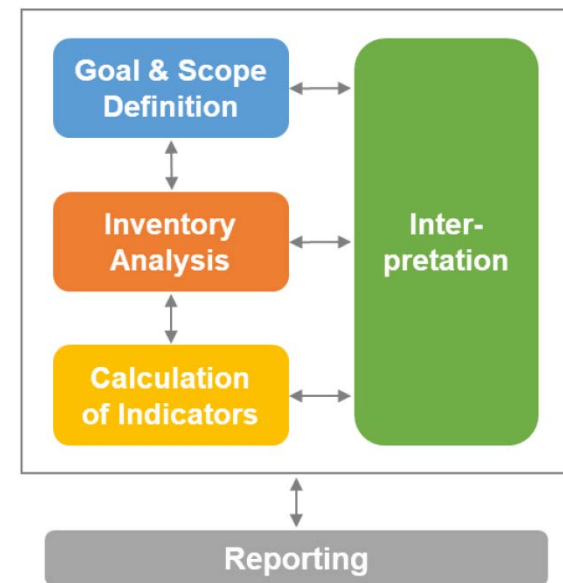
Scope definition

- ☐ Function of the product system
- ☐ Functional unit
- ☐ System boundary
- ☐ Performance indicators



Phase 2: Inventory analysis

- Identify the system elements of the product system
- Collect the technological parameters (e.g. efficiency) of each system element
- Collect the economic parameters (e.g. capital expenses and operating expenses) of each system element



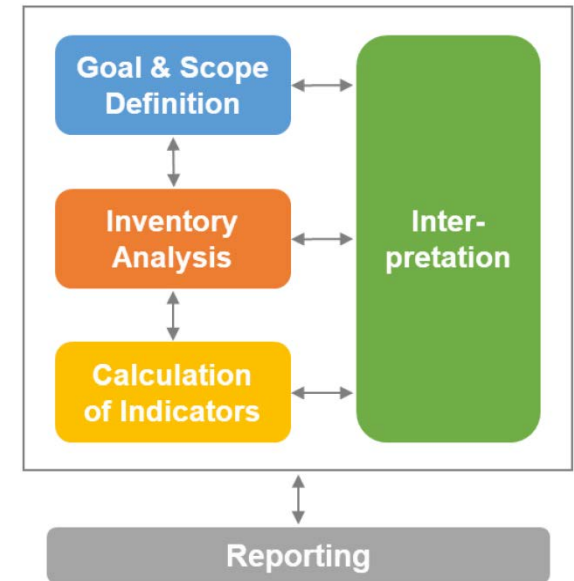
Phase 3: Calculation of indicators

Modeling

- Select the technical models of each system element
- Select the economic model of each system element

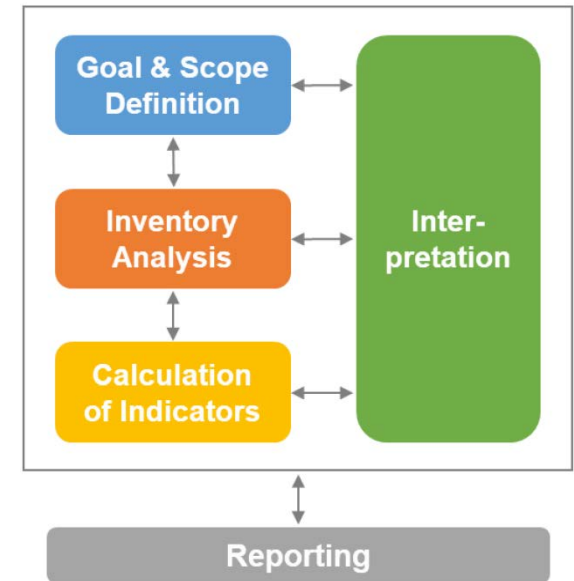
Characterization

- Calculate the performance indicators for each system element
- Calculate the performance indicator for the product system



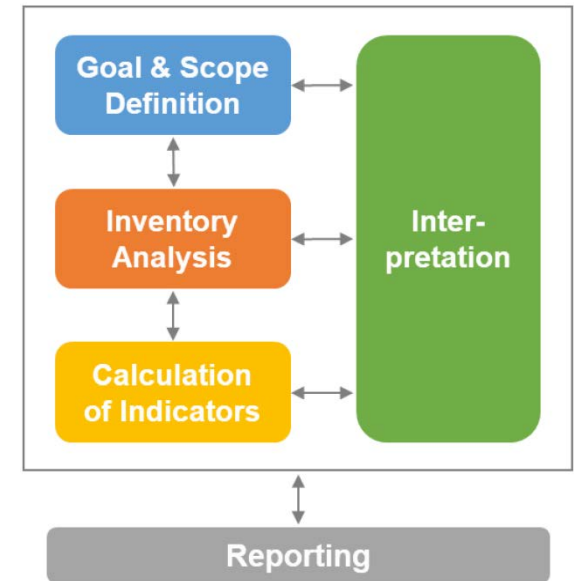
Phase 4: Interpretation

- Perform the scenario analysis
- Describe uncertainty and sensitivity of the results
- Provide conclusions, presenting the whole spectrum of criteria relevant for decision making
- Discuss limitations
- State recommendations, if any



Phase 5: Reporting

- Write the report, depending on the audience and the objectives of the commissioner
- Make sure it offers enough data to enable reproducibility



V. Conclusion

Conclusion

We discussed a framework for the techno-economic assessment (TEA) of a technology.

It needs to be compared to competing technologies providing the same service on the same time horizon, keeping in mind that:

- one should only compare 2 systems that have been optimized on the same set of specifications and for the same scenario,
- the techno-economic assessment of a technological innovation should rely on projections of the value of its technological and economic parameters when it will reach market maturity,
- the life-cycle techno-economic performance of any technology can be quantified using the life cycle cost (*LCC*).

Merci !

More info: L. Quéval, “Contributions to the techno-economic assessment of technological innovations in electrical engineering,” Habilitation thesis, Université Paris-Saclay, Paris, France, Dec. 2022. ([link](#))