



**HAL**  
open science

# Introduction to Techno-Economic Assessments of HTS Systems

Loïc Quéval, Andrea Musso

► **To cite this version:**

Loïc Quéval, Andrea Musso. Introduction to Techno-Economic Assessments of HTS Systems. École thématique. 3rd Training School of the Hi-SCALE COST Action 19108, Belgrade, Serbia. 2024. hal-04543729

**HAL Id: hal-04543729**

**<https://hal.science/hal-04543729v1>**

Submitted on 12 Apr 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Introduction to Techno-Economic Assessments of HTS Systems

Loïc Quéval<sup>1,2</sup>, Andrea Musso<sup>3</sup>

<sup>1</sup> University of Paris-Saclay, CentraleSupélec, CNRS, Group of electrical engineering - Paris, 91192, Gif-sur-Yvette, France

<sup>2</sup> Sorbonne University, CNRS, Group of electrical engineering - Paris, 75252, Paris, France

<sup>3</sup> Ricerca Sistema Energetico – RSE S.p.A., 20134 Milan, Italy



**Hi-SCALE**



# Our activities: components for electric grids



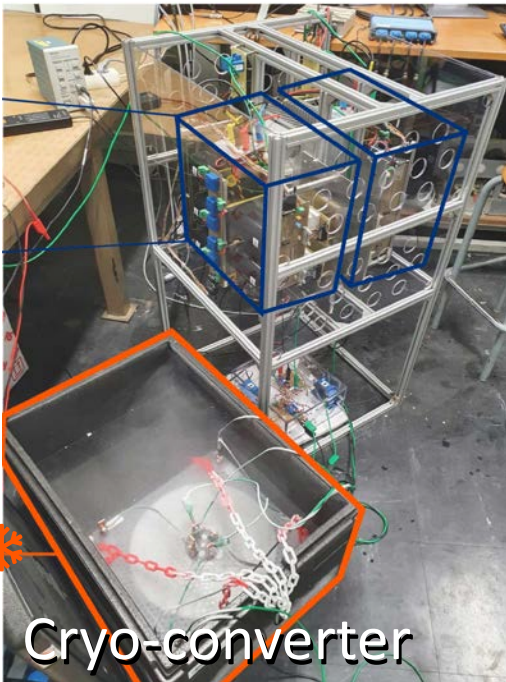
HVDC



Railway



MEA



Cryo-converter



HTS cable



ScFCL

# SuperRail

Paris, France



# 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

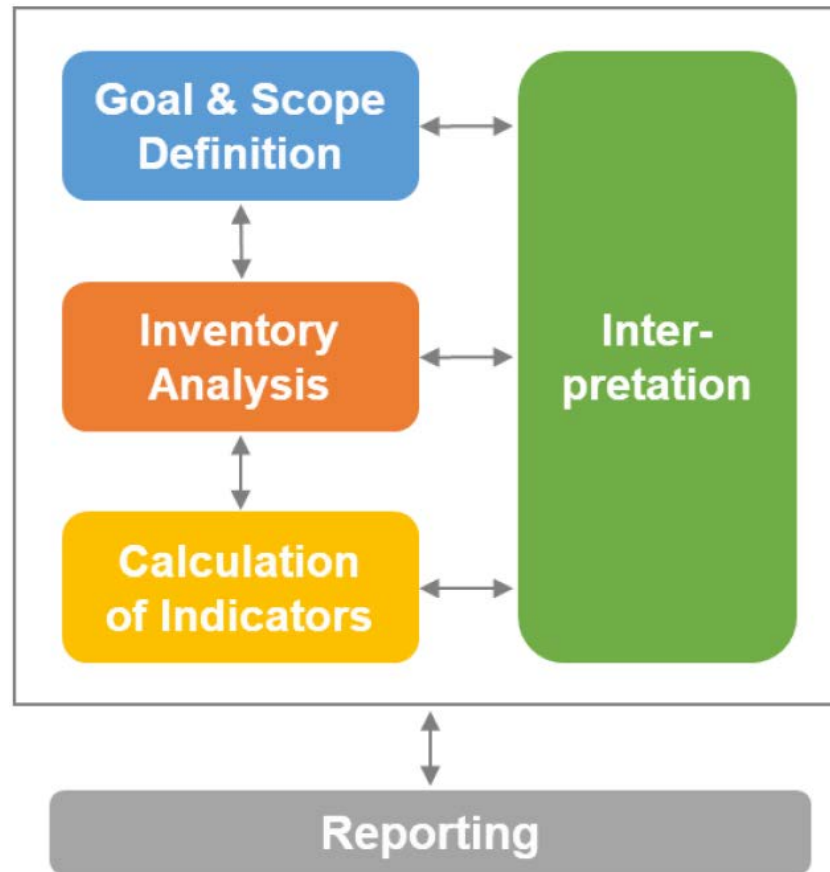
# Content

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

# I. Techno-economic assessment



# Techno-economic assessment framework



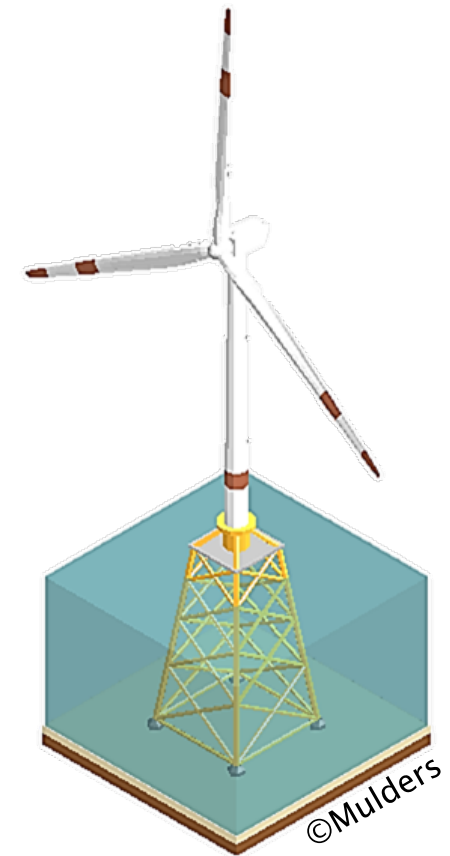
Source: T. Langhorst, *et al.* "Techno-Economic Assessment & Life Cycle Assessment Guidelines for CO2 Utilization (Version 2.0)," Global CO2 Initiative, 2022.

# I. Techno-economic assessment framework

## Definitions

# Product system

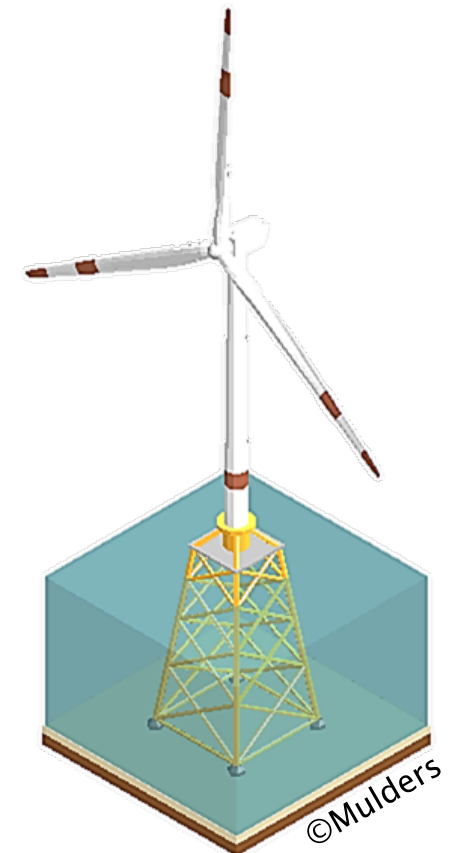
Collection of materially and energetically connected system elements, which perform one or more defined functions.



# 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.

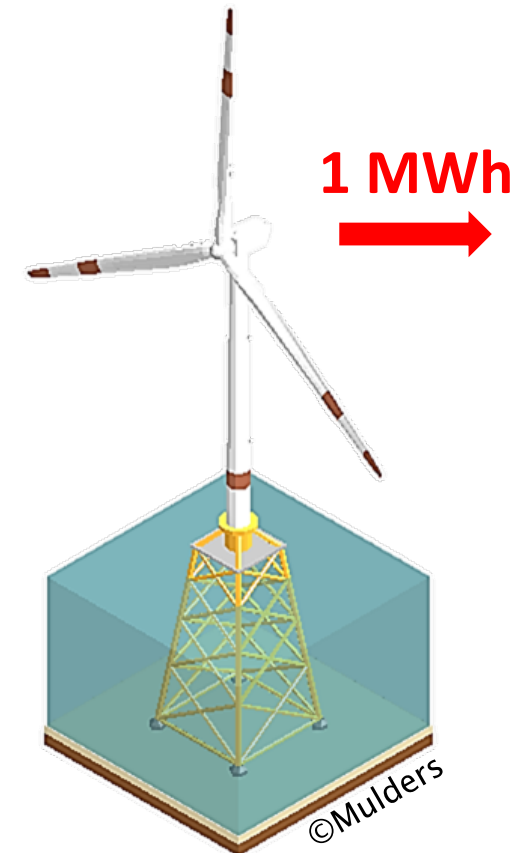
turbine	nacelle	tower	foundation
blade (3)	generator (1)	tower (1)	platform (1)
hub (1)	power converter (1)	3ph AC cable (1)	tendons (3)
shaft (1)	AC filter (1)	transformer (1)	anchors (3)
bearing (1)	protections (1)	grounding (1)	
	bed plate (1)		
	nacelle cover (1)		



# Functional unit

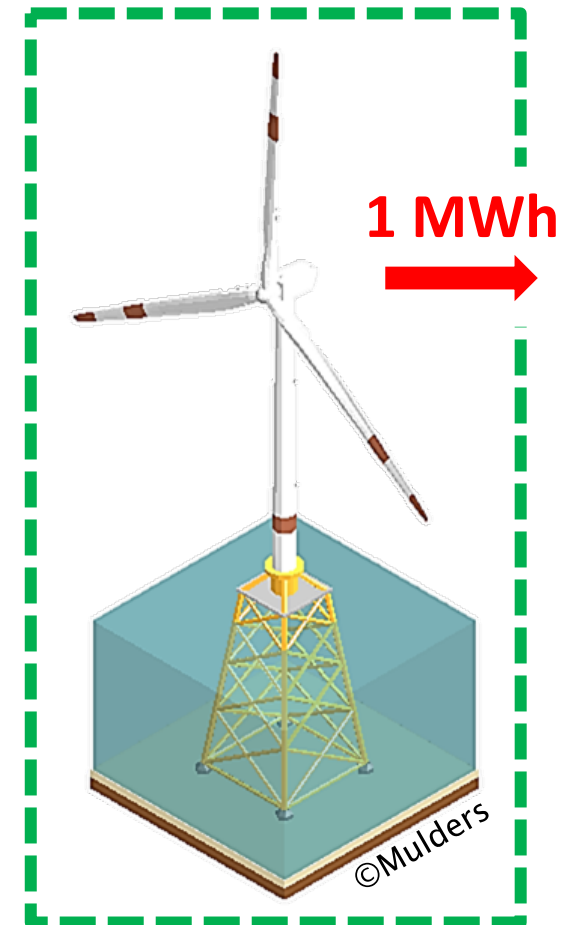
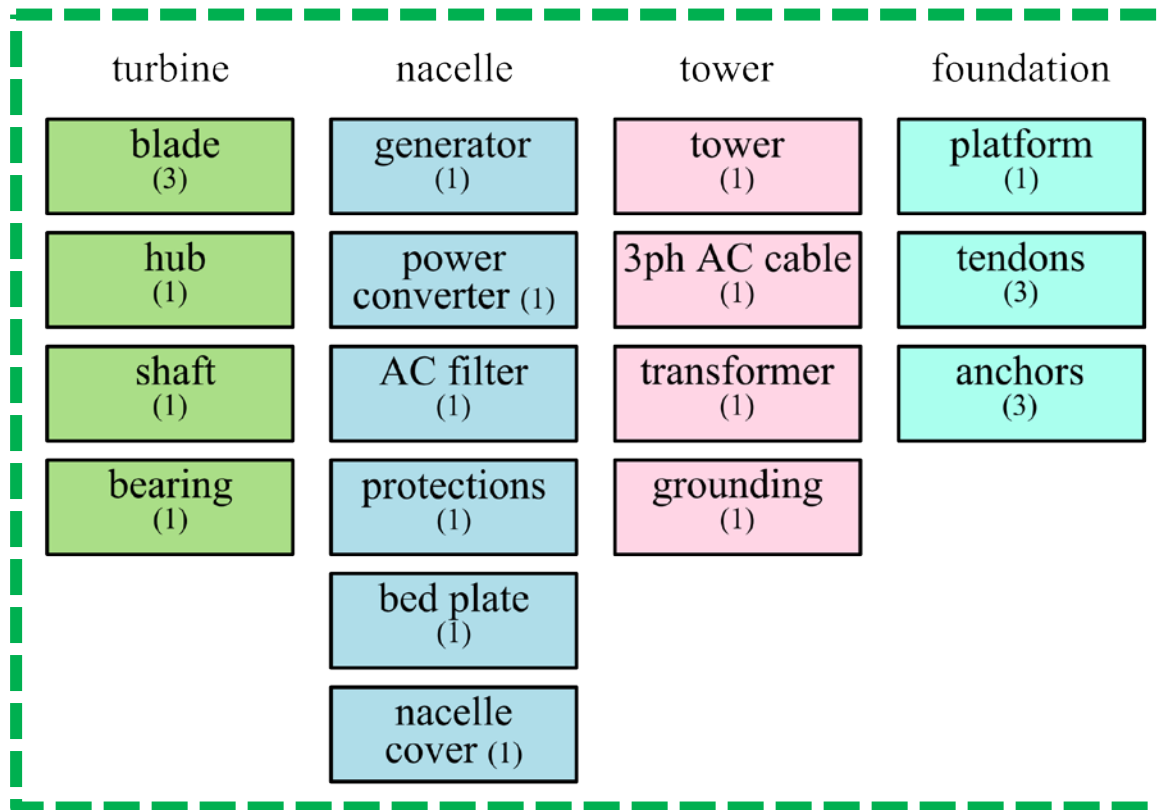
Quantified description of the function of a product system that serves as the reference basis for all calculations.

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)		



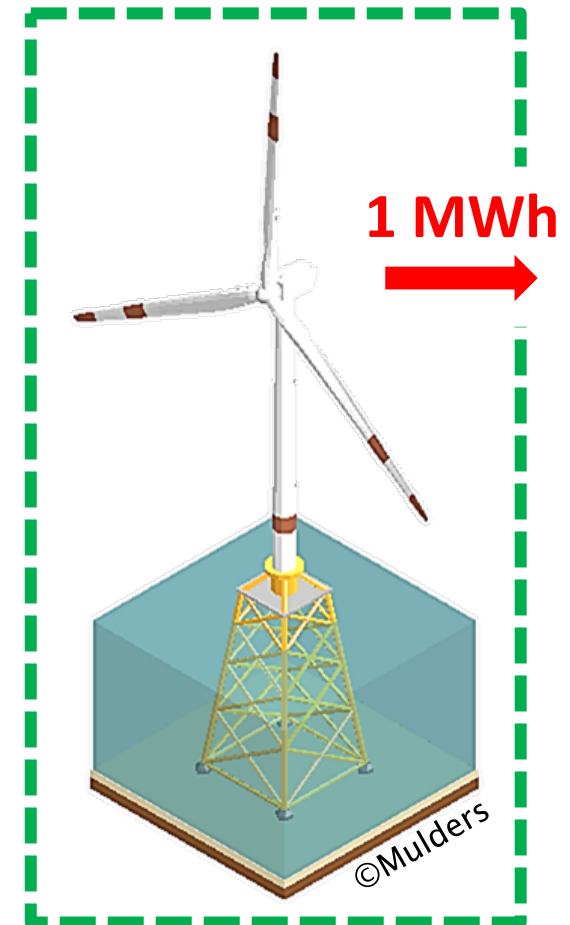
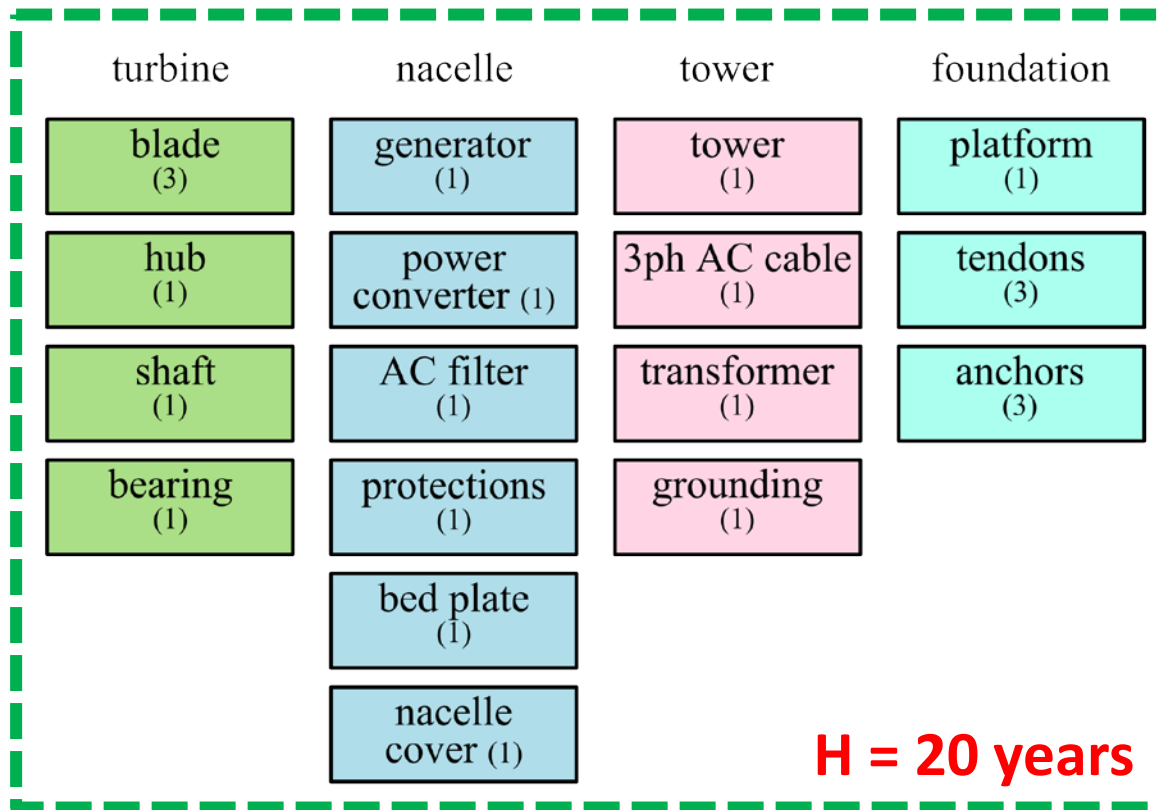
# System boundary

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.

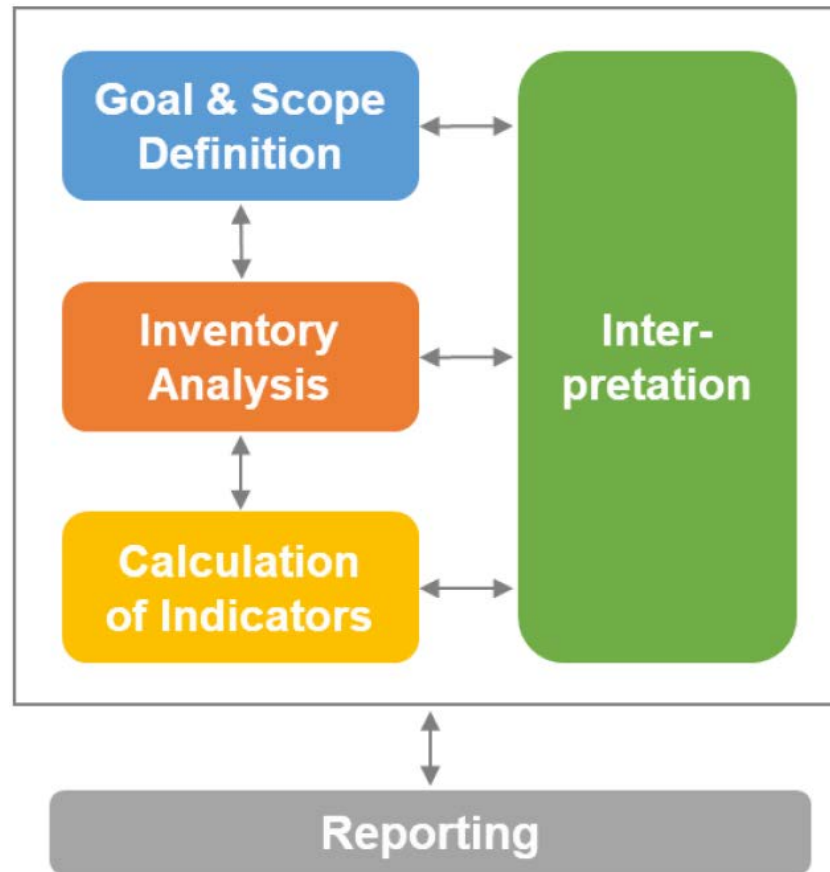


# I. Techno-economic assessment framework

## Framework



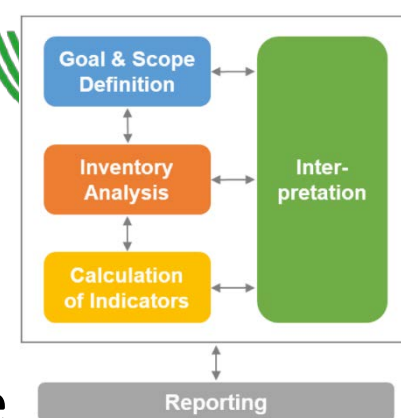
# Techno-economic assessment framework



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

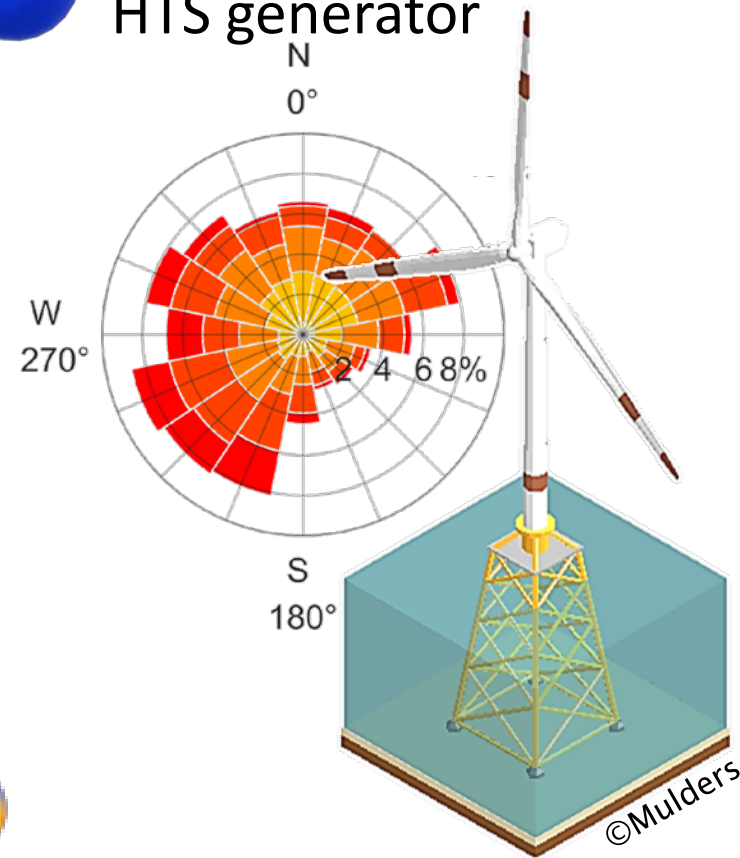
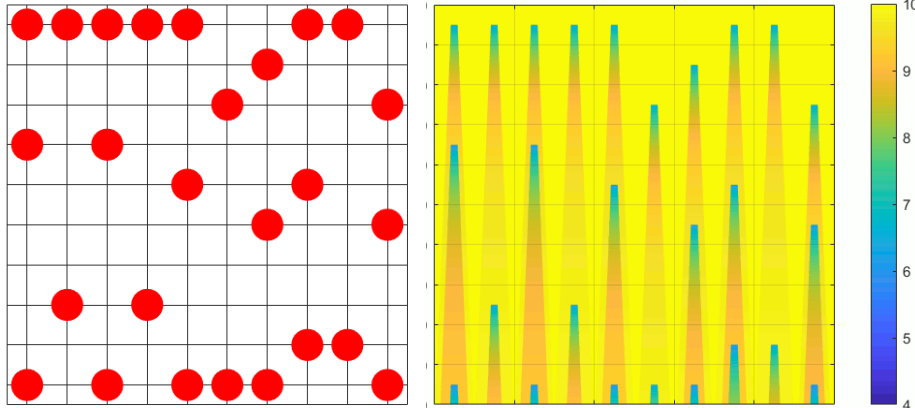
## Phase 1: Goal and scope definition



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

Wind turbine HTS generator

### Scenario:

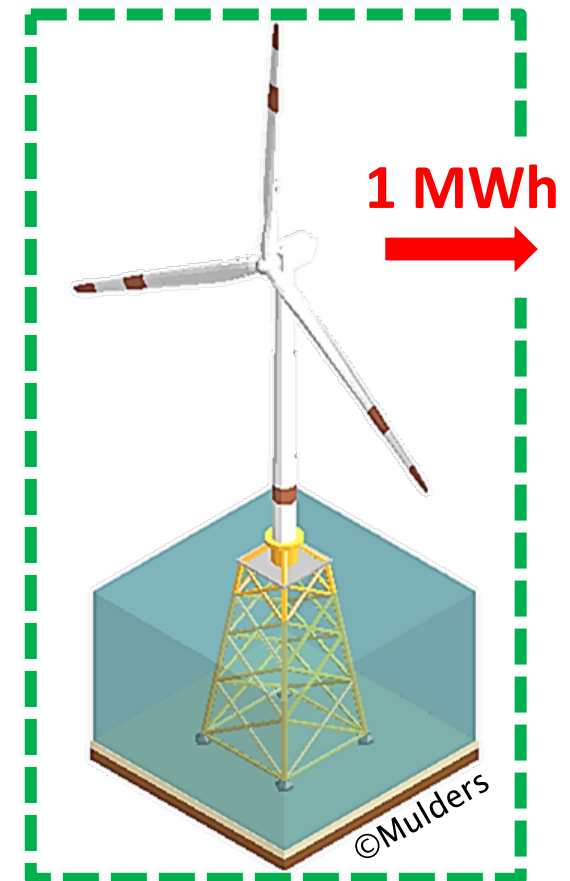
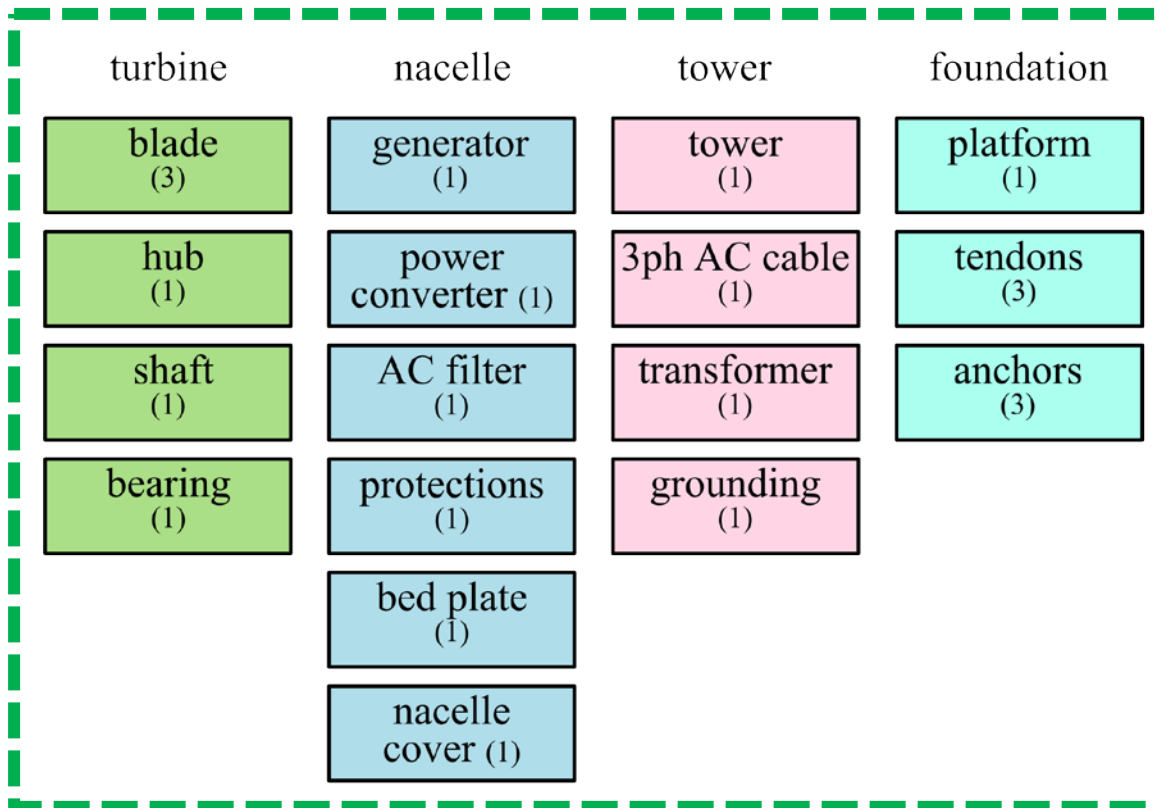


**Performance indicator:**  $PI$  [unit] 

# Techno-economic assessment

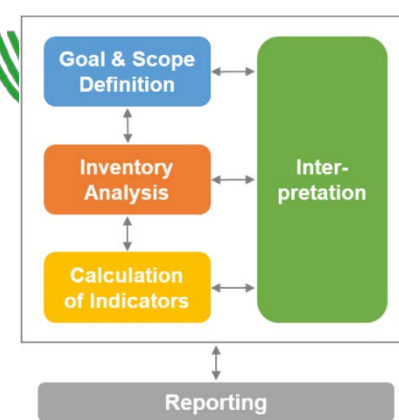
## Phase 2: Inventory analysis

system boundary ?

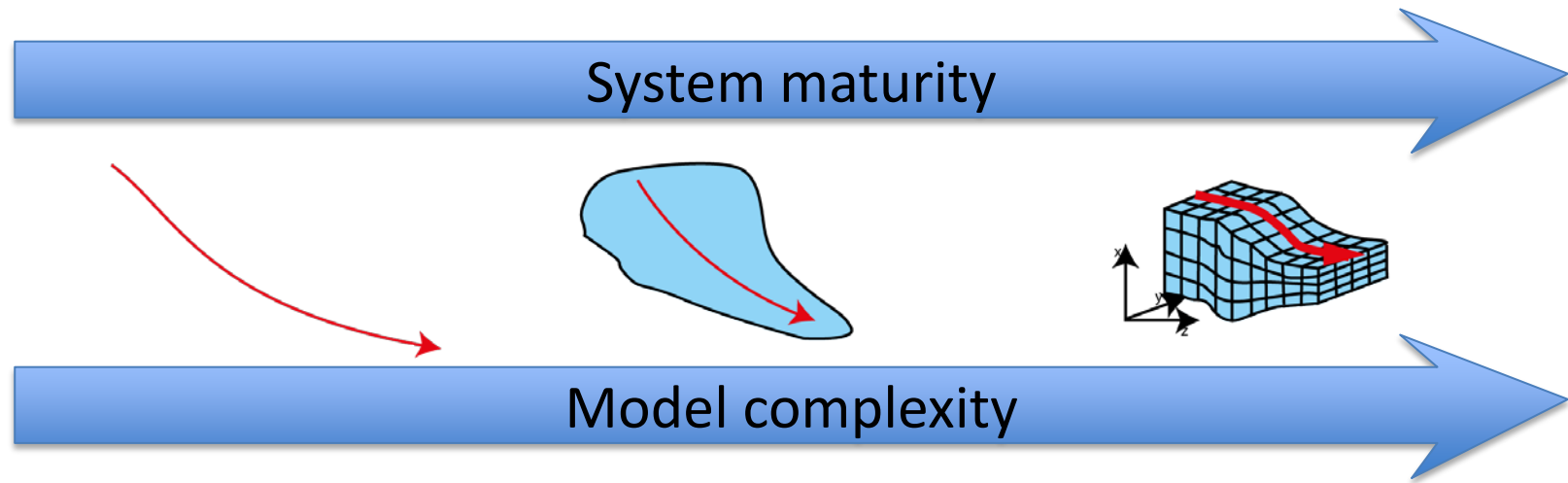


# Techno-economic assessment

## Phase 3: Calculation of indicators



### (i) Modeling

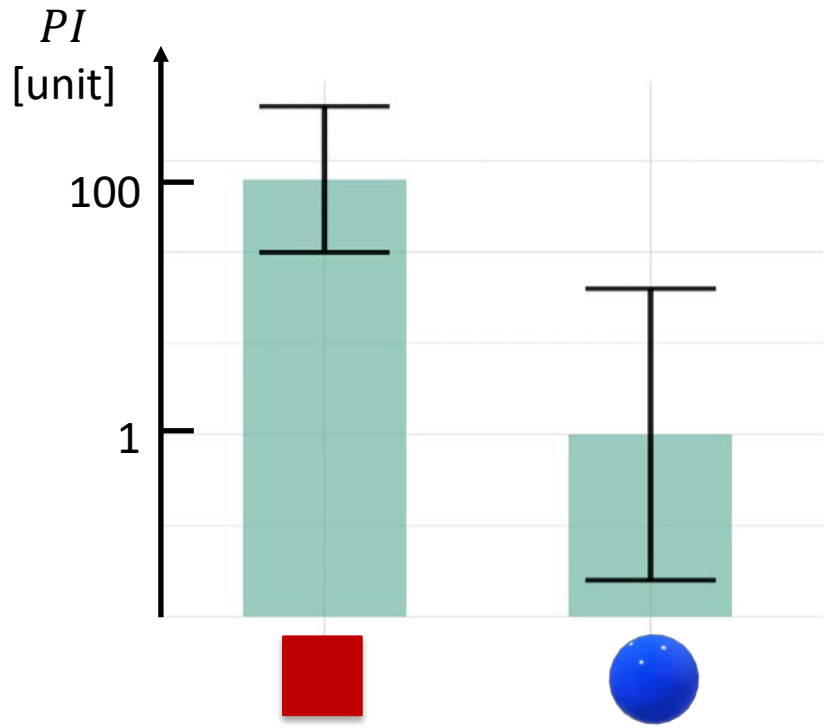
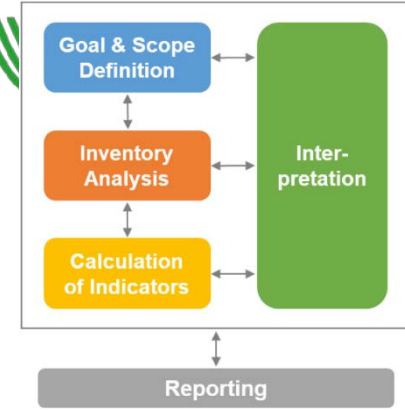


### (ii) Characterization

	Benchmark system	Proposed system
$PI$ [unit]	100	1

# Techno-economic assessment

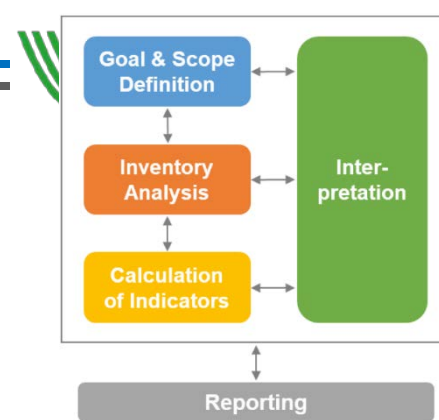
## Phase 4: Interpretation



# 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**

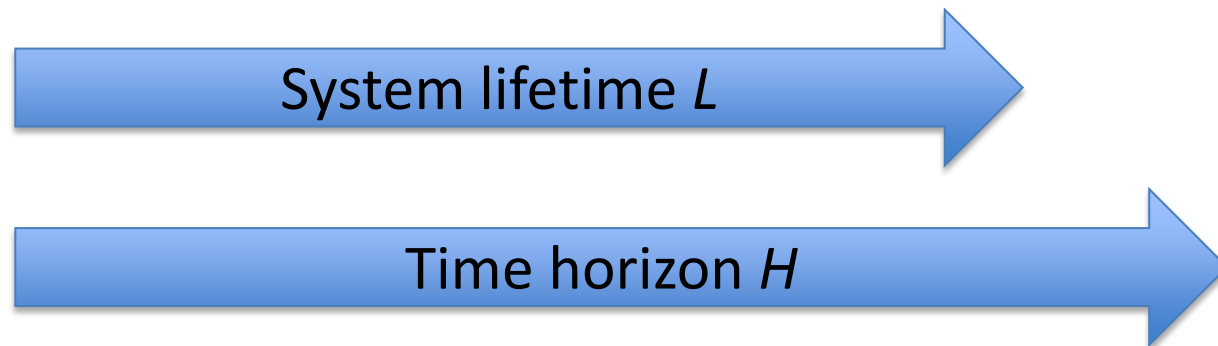
## II. Performance indicator ?

### 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.

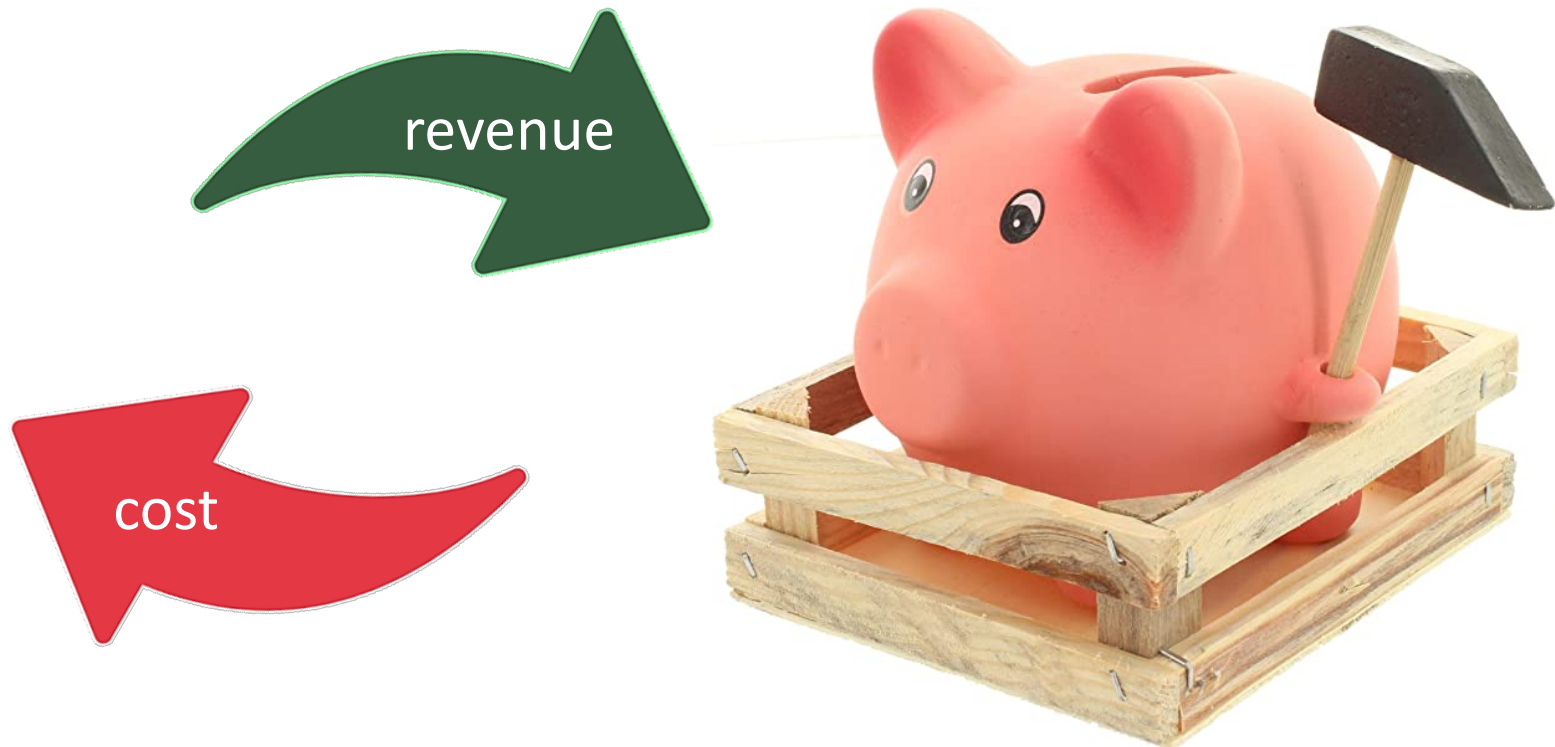
The present value  $PV(F)$  of a cash flow  $F$  is calculated by,

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

- $dr$  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

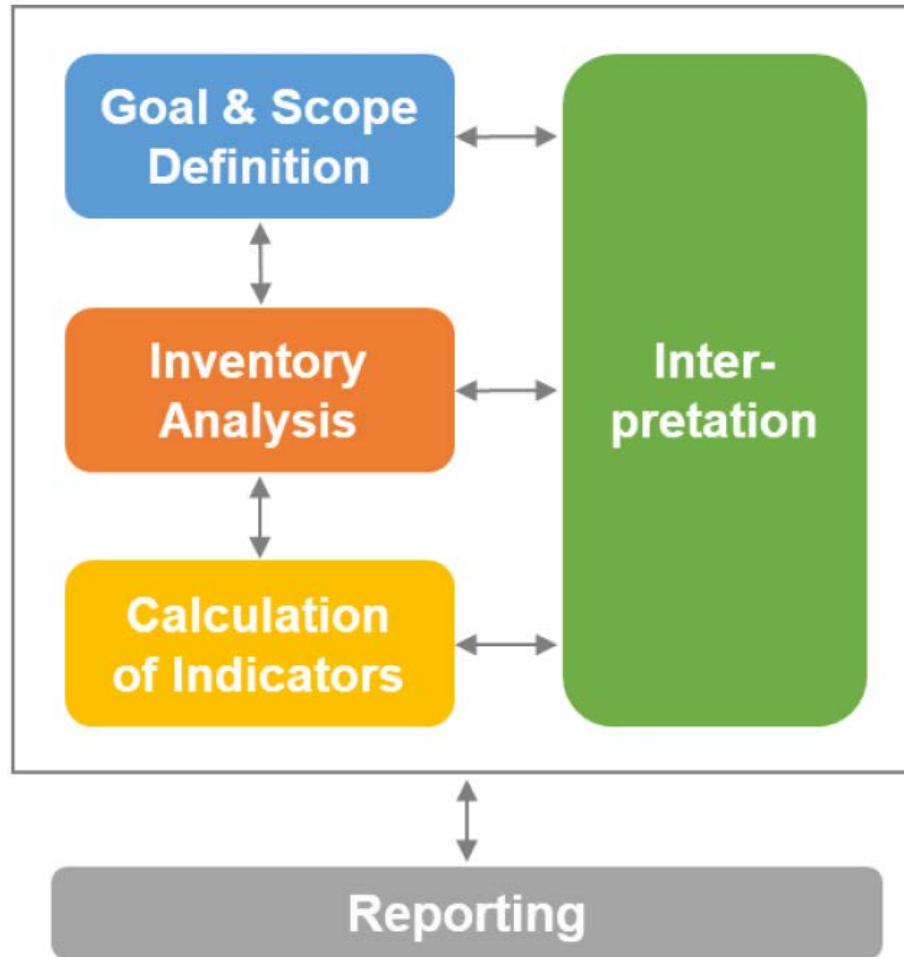
The *LCC* is a techno-economic performance indicator.

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



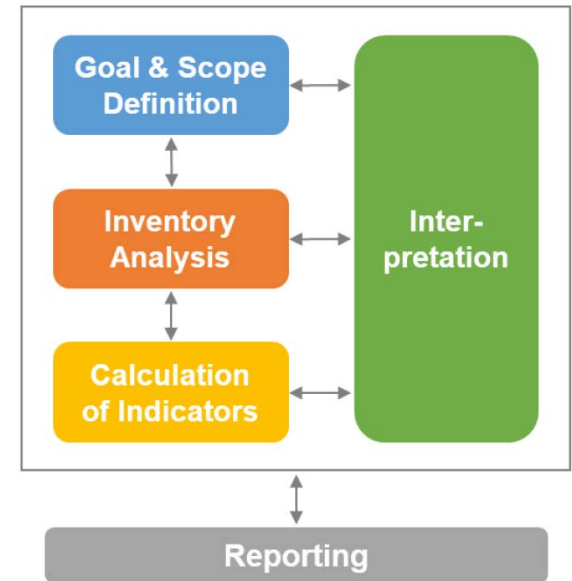
# Phase 1: Goal and scope definition

## Goal definition

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

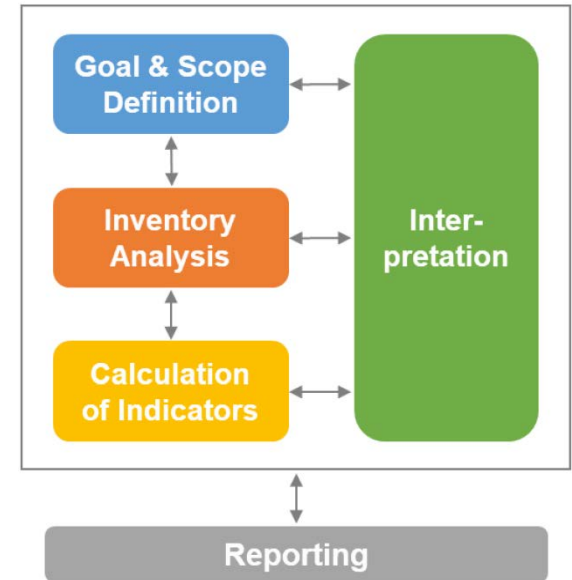
## Scope definition

- 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



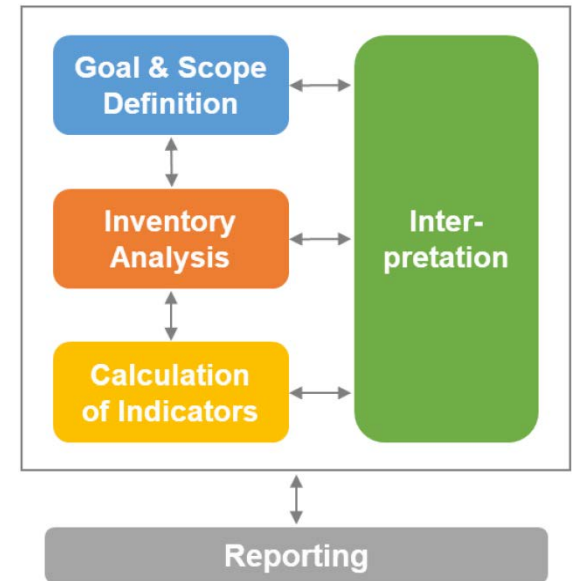
## Phase 3: Calculation of indicators

### Modeling

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

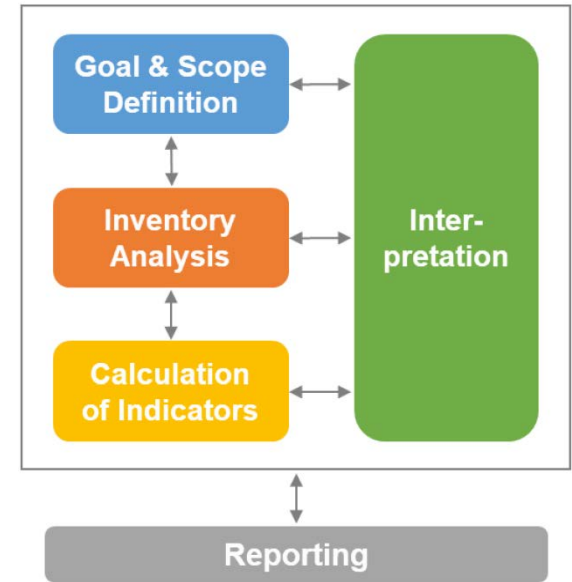
### Characterization

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



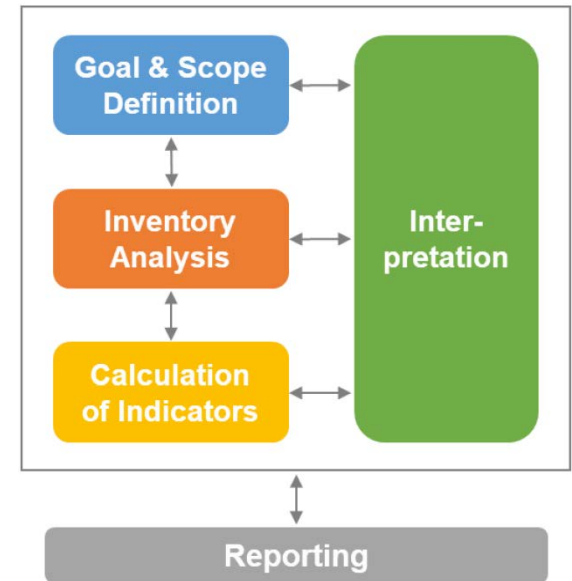
## Phase 4: Interpretation

- 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. Qu val, "Contributions to the techno-economic assessment of technological innovations in electrical engineering," Habilitation thesis, Universit  Paris-Saclay, Paris, France, Dec. 2022. ([link](#))