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BLUE AND GREEN ENVIRONMENT

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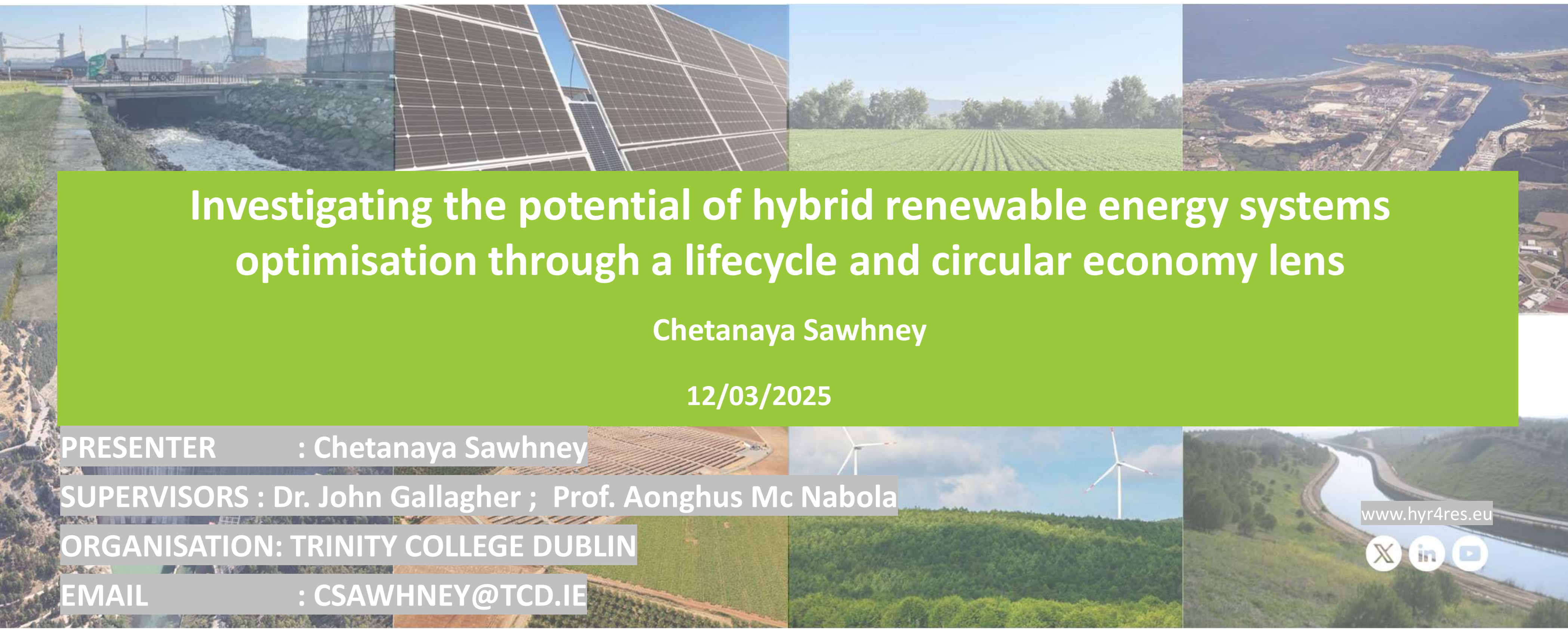

Investigating the potential of hybrid renewable energy systems optimisation through a lifecycle and circular economy lens

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12/03/2025

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Presentation Agenda

1. Background
   - Renewable Energy - Hybrid Systems
   - Is Renewable Energy Green and Sustainable?
   - Sustainable Development - Life Cycle Assessment (LCA)
   - Life Cycle Assessment (LCA) vs Life Cycle Sustainability Assessment (LCSA)
2. Life Cycle Sustainability Assessment
3. Methodology
   - Phases of LCSA
   - Stages of Project Life Cycle
   - Goal and Scope
   - Inventory Analysis
   - Impact Assessment – LCA + LCC + SLCA
4. Data Analysis and Results
   - Data Collection
   - Data Crunching
   - Multi-Criteria Decision Analysis
   - Interpretation

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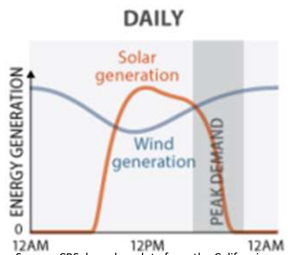
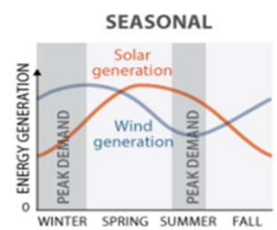
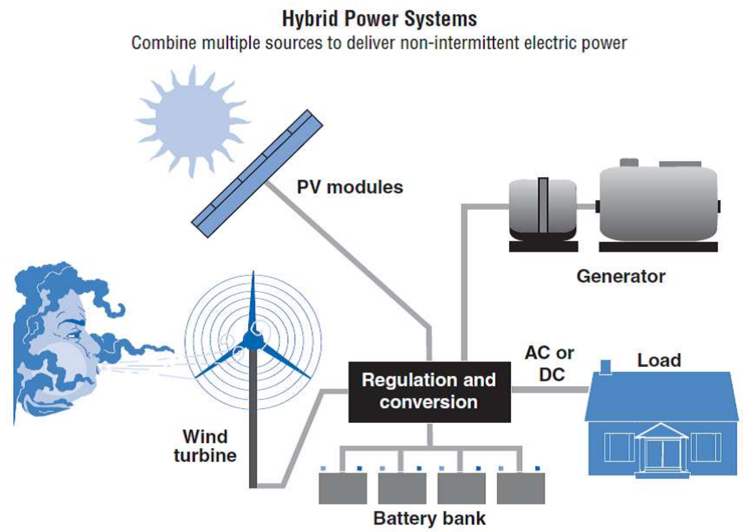
Renewable Energy – Hybrid Systems



Source: CRS, based on data from the California Independent System Operator and the U.S. Energy Information Administration

Variability





Intermittent Renewable Energy Sources (IRES): These sources, such as wind and solar power, produce energy intermittently due to their fluctuating nature.

Depend on External Factors – Wind Speed, Available Sunlight

Hybrid Renewable Energy Systems – More Reliable and Sustainable as compared to stand-alone systems

Combine multiple sources to deliver Non-Intermittent electric power

Is Renewable Energy - Green and Sustainable?

Green Washing – presents a significant obstacle to tackling climate change. By misleading the public to believe that a company or other entity is doing more to protect the environment than it is, greenwashing promotes false solutions to the climate crisis that distract from and delay concrete and credible action (UN, 2024).

False Solution ? – Huge Debate on CCS, CCUS, Large-scale Hydro, Nuclear etc.

Greenwashing – the deceptive tactics behind environmental claims | United Nations

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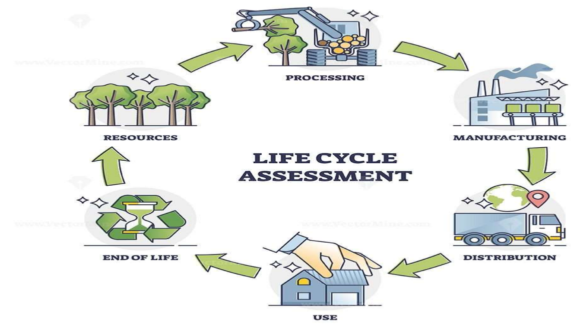
Sustainable Development

Brundtland (1987) – Our Common Future defines Sustainable Development as *"to meet the current generation's needs without compromising the future generation's ability to meet their own."*

Sustainability emphasises the balance between Environmental, economic and Social aspects.

Sustainability Assessment Tool

Life Cycle Assessment (LCA)



Life cycle assessment represents a comprehensive form of analysis of the cumulative potential environmental burdens for a product or system over a defined lifespan.

Environmental impact indicator – Global Warming Potential (GWP) quantifying greenhouse gas (GHG) emissions measured as a Carbon Footprint (kg CO_2 eq.)

ISO Standards

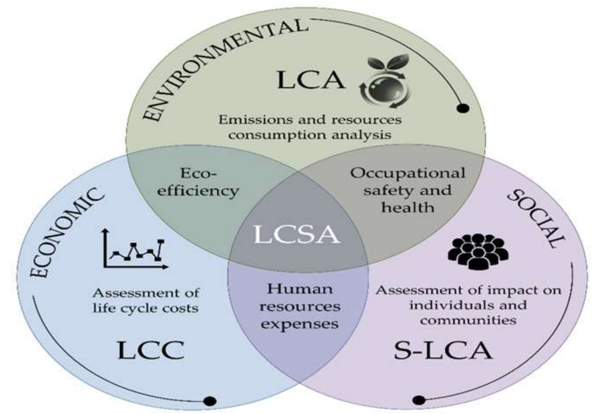
- ISO 14040 LCA Principles and Framework – Goal, Scope, Inventory Analysis
- ISO 14044 encompass LCA Requirements and Guidelines – Interpretation

Limitations

Life-Cycle Assessment

Need for a Holistic Approach

Life Cycle Sustainability Assessment - LCSA



LCA covers Sustainability only from the environmental dimension and not as a whole.

Economic viability of the system/ process and its social impact on the stakeholders are two important pillars of Sustainability that LCA lacks.

LCSA covers a broad and complete approach to Sustainability.

It is a methodology that considers all three pillars of Sustainability – Environmental, Economic and Social from a Life Cycle Perspective.

2. Life Cycle Sustainability Assessment - LCSA

Environmental Life Cycle Assessment	Life Cycle Cost	Social Life Cycle Assessment	Life Cycle Sustainability Assessment

The integration of the three pillars of sustainability from a life cycle perspective is referred to as life cycle sustainability assessment (LCSA).

LCSA gives the highest level of assessment among the existing environmental and sustainability.

It encompasses environmental, economic, and social aspects, i.e., the pillars of sustainability, allowing a more holistic understanding of the sustainability of products and processes, which translates into better support for decision-makers.

LCSA could be a decisive framework for much-needed Climate Finance and an effective tool against greenwashing and False solutions.

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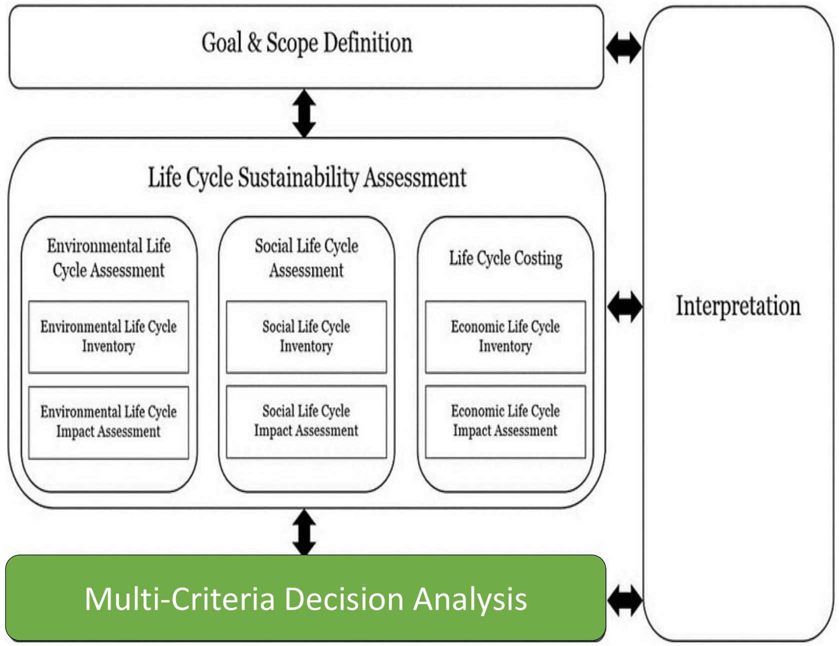
3. Methodology

In literature – UNEP mentions 4 approaches to LCSA

According to (COST Action - CA23157, 2024), LCSA is defined as the combination of environmental LCA (base LCA), life cycle costing (LCC) and social LCA (S-LCA), and should follow the systematic methodology of LCA [1].

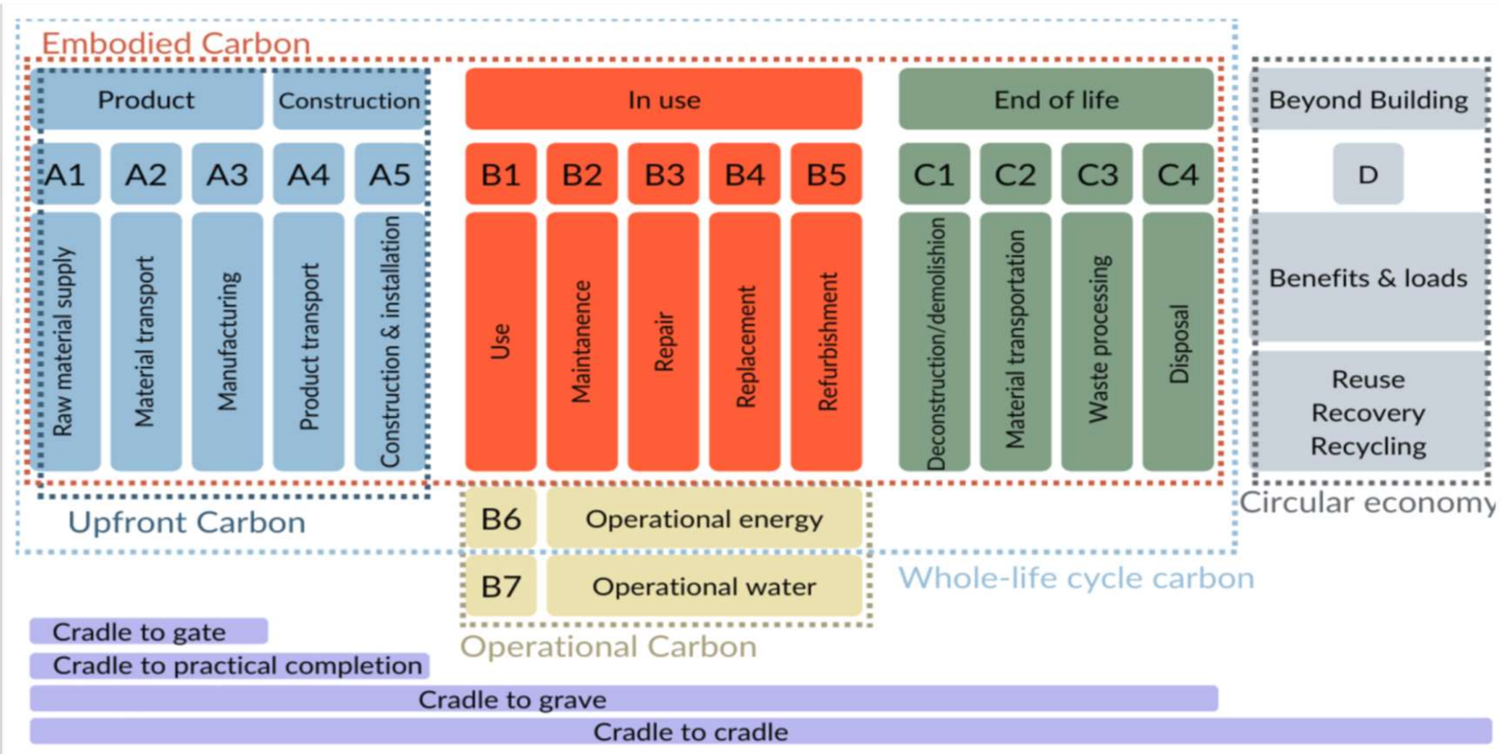
As per, ISO 14040 and ISO 14044 standards LCA is carried out in four phases
Phase 1 - Goal and Scope Definition,
Phase 2 - Life Cycle Inventory (LCI) Analysis,
Phase 3 - Life Cycle Impact Assessment (LCIA)
Phase 4 - Results Interpretation [2, 3].

Integrating the three approaches into a comprehensive LCSA is natural since LCC and S LCA measure the economic and social sustainability dimensions using comparable procedures outlined in ISO 14040 [1].



1. *COST Action CA23157 EUROPEAN NETWORK FOR MULTIPLE VIEW LIFE CYCLE SUSTAINABILITY ASSESSMENT (MultiViewLCSA)*. (n.d.). COST | European Cooperation in Science and Technology. https://www.cost.eu/actions/CA23157/
2. Onat, N., Kucukvar, M., Halog, A., & Cloutier, S. (2017). Systems thinking for life cycle sustainability assessment: A review of recent developments, applications, and future perspectives. *Sustainability*, *9*(5), 706. https://doi.org/10.3390/su9050706
3. UNEP/SETAC LCI, Guidelines for Social Life Cycle Assessment of Products. 2009.

Stages of Project Life Cycle



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LCSA – Phase 1 - Goal and Scope Definition

Goal and Scope

To study the Direct & Indirect Life Cycle Impacts, to evaluate the Sustainability of Hybrid RE Systems in Irrigation Communities (Valle Inferior Pilot Plant)

This study will analyse the Environmental, Economic and Social Impact of hybrid renewable – Solar and Pump As Turbine (PAT), at the pilot site

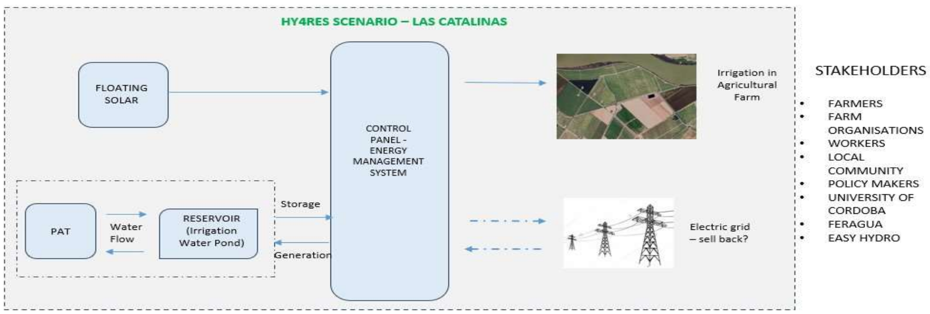
LCSA approach will be examined, for the following:

- Comparative data analysis of standalone Renewable Energy Technology (Solar and PAT individually) and Hybrid RE technology for the pilot site.
- Comparative data analysis of On-grid and Off-grid criteria for the pilot plant (to evaluate the scope of selling back to the grid in case of surplus).
- Comparative data analysis of conventional energy technology (Non-RE grid electricity) and Hybrid RE technology for the pilot plant.
- Analysis of life cycle cost and energy payback period.

This study will emphasise the cradle-to-grave life cycle approach, and explore the scope for circularity and eco-design

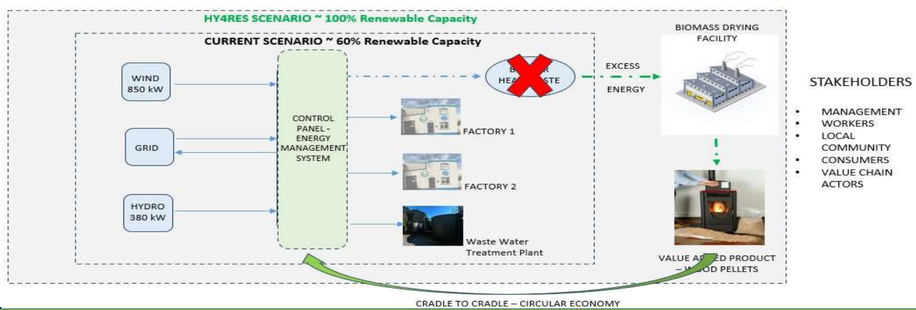
System Boundary – Valle Inferior - Las Catalinas

System boundaries refer to determining which unit processes should be included in the assessed system



System Boundary – Aquaculture – Island Sea Food

System boundaries refer to determining which unit processes should be included in the assessed system



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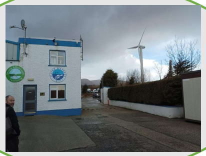
Inventory Analysis

A database will be generated, that will include raw materials, manufacturing, installation and transport processes for each technology.

Hydro

1	DI Pipework
2	PE Pipework
3	Turbine & Generator
4	Concrete
5	Transformer and Cabinet
6	Concrete Block
7	Steel - Rebar
8	Roof (steel)
9	Wiring
10	Gantry (steel)
11	Corrugated roof
12	Air vent
13	Acoustic Doors
14	Geotextiles
15	Formwork (wood)
16	Frame & roof timbers
17	Plasterboard
18	Gutters
19	Hardcore/Blinding
20	Cable Stays
21	Wood cladding
22	Contraction/Expansion joint
23	Painting
24	Waterbar
25	Fencing Panels
26	Sleepers
27	Temp steel fencing
28	Dry stone reinforcing wall
29	Acoustic wool
30	Ducting
31	Steel fixings
32	Lead
33	Glass
34	Welding
35	Timber
36	Slate roof
37	Exc & Fill
38	Transport
39	Rock breaking
40	Bitumen
41	Craneage
42	Formwork (steel)
43	Finishing
44	Rubber Seals



Wind

1	rotor blades
2	hub
3	stator/rotor
4	nacelle
5	steel tower
6	foundation - steel
7	foundation - concrete
8	Excavation
9	Hardcore/blinding
10	Electricity Cables
11	Transportation

PV

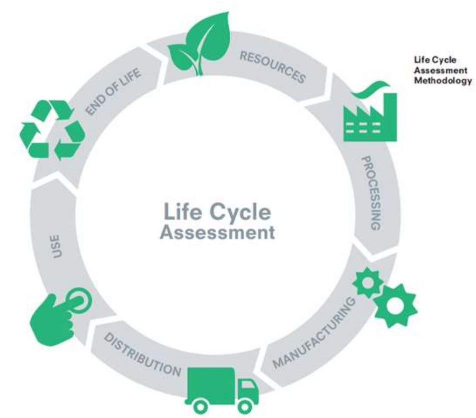
1	Silver anodised aluminium frame
2	High transmission 3.2mm ARC glass
3	Anti-reflective coating (Silicon nitride)
4	PV cell (silicon wafers)
5	EVA (Ethylene Vinyl Acetate)
6	Rear contact (aluminium)
7	White polyester
8	Frame
9	Electricity Cable
10	Inverter
11	Transportation

Impact Assessment – LCSA = LCA + LCC + SLCA

Life Cycle Assessment (LCA) - Environmental Impact Indicators

Impact category	Units	Information
Global warming potential (GWP)	kg CO_2 eq.	GHG emissions contributing to climate change and their effects on ecosystem health, human health and material welfare (measured in equivalents kg CO_2 eq./kWh).
Abiotic resource depletion potential (ARDP)	kg Sb eq.	Protection of human welfare, human health and ecosystem health (measurement based on quantity of minerals extracted as a fraction of concentration of global reserves).
Acidification potential (AP)	kg SO_2 eq.	Impacts of acidifying substances on soil, surface water, groundwater, organisms, ecosystems and building materials (expressed as equivalent sulphur dioxide concentrations).
Human toxicity potential (HTP)	kg 1,4-DCBe eq.	Substances that are toxic to human health, calculated with USES-LCA, describing fate, exposure and effects of these substances (equivalent 1,4-dichlorobenzene).
Fossil resource depletion potential (FRDP)	kg kJ eq.	Depletion of energy as fossil fuel deposits used to generate electricity (measured in equivalent kg kilojoules)

Goedkoop et al., 2008



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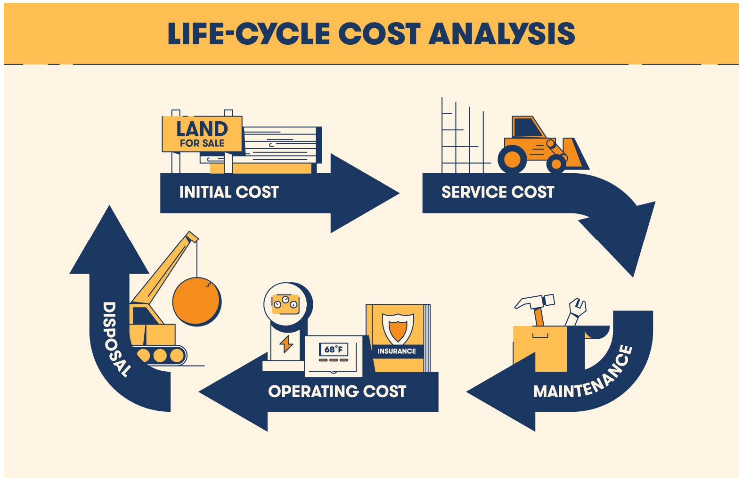
Impact Assessment – LCSA = LCA + LCC + SLCA

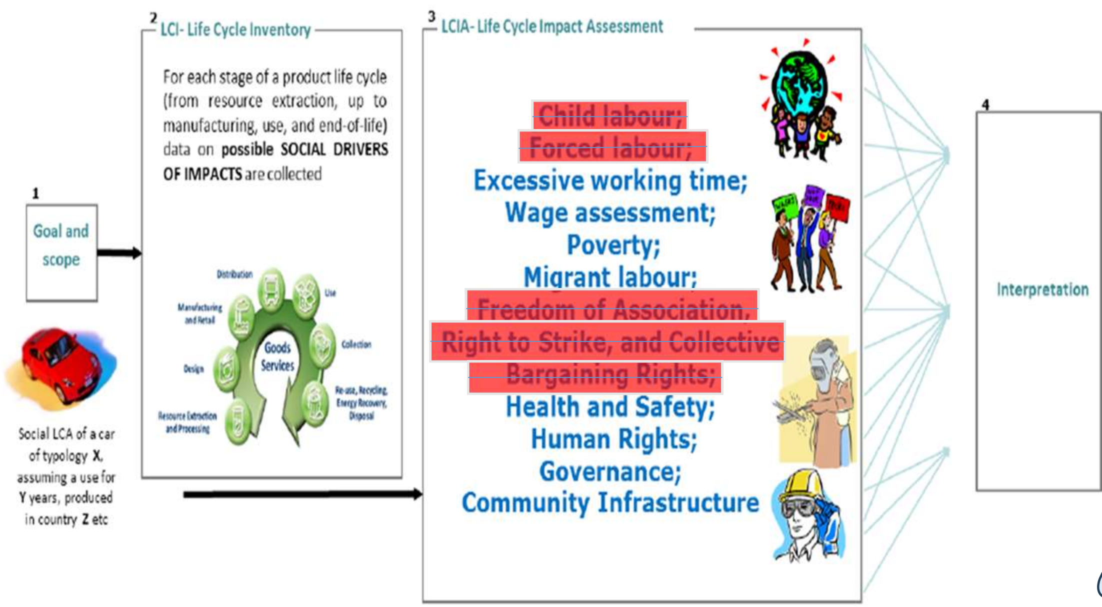
Life Cycle Cost (LCC) - Economic Impact Indicators

CAPEX	Base plant costs	*Engineering costs*
		Procurement and construction costs
	Owner's costs	*Land costs*
		Additional site costs
		Project management
		Licenses application and regulatory fees
	Integration Costs	
OPEX	Operating costs	*Labour costs*
		Waste treatment
	Maintenance costs	*Fixed maintenance*
		Variable maintenance
		Replacements
	Other operating costs (if applicable)	Fuel costs
		Insurance
		Fuel reprocessing
		Emissions costs
End of Life	Decommissioning costs	*Disassembling*
		Fuel final storage (if applicable)



Impact Assessment – LCSA = LCA + LCC + SLCA

Social Life Cycle Assessment (SLCA) - Social Impact Indicators



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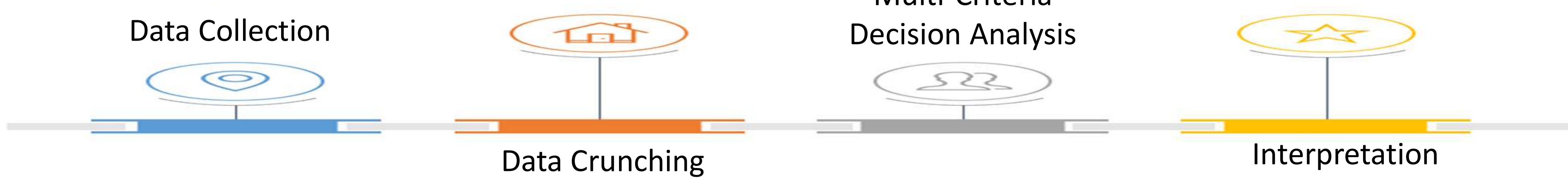
4. Data Analysis and Results



Hydro Turbine and Construction Material (Tentative List)

List Of Material	Quantity	Unit	Material Information	Manufacturer Information	Packaging	Cost	Remarks (If any)
Air Valves							
Actuator							
Control Panel							
Modem							
Telemetry							
Coupling							
Door and Vents							
Ductile Iron							
Gearbox and Coupling							
Generator							
Lifting Frame							
Pipes							
Bends							
Pressure Switches							
Screens							
Sensors							
Sensor Stands							
Telephone Line							
Transformer and Switch Gear							
Turbine							
Turbine Bearing							
Valves							
Weir Plates							

Contractor / Engineering / Labour Work - Details / Cost (Tentative)

S. No.	List Of Material / Detail/ Nature of Work	Number of Labour involved	Man Hour	Specific Equipment/ Construction Material Used or purchased	Fixed Cost	Recurring Cost (If any)	Remarks (If any)
1	Contractor - Labour Work for Laying the Pipes and other Civil Work						
2	Electrical Work						
3	Generator Commissioning						
4	Mechanical Commessioning						
5	Grid Connections						
6	Electrical Commissioning						
7	Design Development and Site Management						
8	Third-Party Costs						
9	Land Owner Costs						
10	Contingency and Prelims (Anything Extra)						
11	Study/ Report/ Pre Assessment						

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