Introduction to sustainability assessment of energy technologies

RISEnergy
Research Infrastructure Services for Renewable Energy

Part I – Motivation and Challenges

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This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under Grant Agreement N. 101131793

Targets of this module

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Provide an overview of:

- **Motivation and challenges for sustainability assessment (Part I) – *this presentation***
- How sustainability assessment is carried out on a technology level (Part II)
- How HELDA-web tool can be used for comprehensive sustainability assessment of energy technologies (Part III)

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Part I - Motivation and challenges for sustainability assessment

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What will I learn in this presentation?

After working through this material, you should be able to **remember*** and **understand***

- Basic concepts of sustainability
- Main challenges related to sustainability assessment
- Advantages of multi-criteria decision analysis for decision-support in sustainability assessment

*Bloom's Taxonomy on intended learning outcomes

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Motivation

- **Sustainable energy transition is** one of the major and pressing challenges of society, science and industry

- Integrative consideration of **technical, economic, ecological, and social criteria** is required in the context of sustainability

- For the success of the energy transition, the **involvement of relevant stakeholders, e.g. technology developers, policy-makers, decision-makers, technology users,** is necessary

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Sustainability

- In 1987, the United Nations Brundtland Commission defined sustainability as **“meeting the needs of the present without compromising the ability of future generations to meet their own needs.”** [1], [2], [3]
- The 2024 ‘Europe’s Sustainability Transitions Outlook’ report recognizes that Europe’s socio-economic systems and wellbeing of its citizens depend crucially on a **healthy and resilient natural environment**, a **stable climate** and **long-term sustainable use of resources**. [4]

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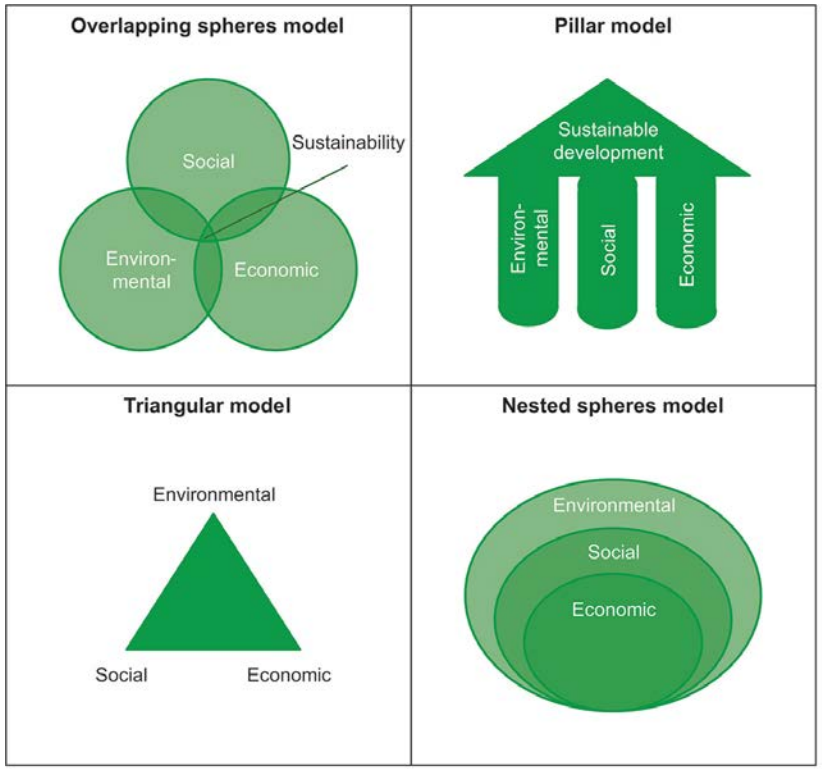
Concepts for sustainable development (1)

Triple-Bottom line model (TBL)

- Sustainability is described by three intersecting dimensions (overlapping spheres, triangular, or pillar model) representing economic, social, and environmental sustainability.
- In the nested spheres model, the environmental dimension forms the outer circle, with society and economy nested within it. This aligns with the idea of planetary boundaries, which all human activities must remain within to avoid disastrous consequences.
- TBL is often used for advancing sustainability in various sectors as well as for technology assessment [5].



Triple-Bottom line model of sustainability (TBL)

Source: [12]

How to operationalize sustainability for technology assessment?

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Concepts for sustainable development (2)

Sustainable Development Goals (SDGs)

- Latest and most relevant political framework for sustainable development. [6]
- Defined by the United Nations in 2015
- 17 Goals with corresponding targets and 230 indicators
- Guiding principles for sustainable energy technologies.

Source: [13]

How to operationalize sustainability for technology assessment?

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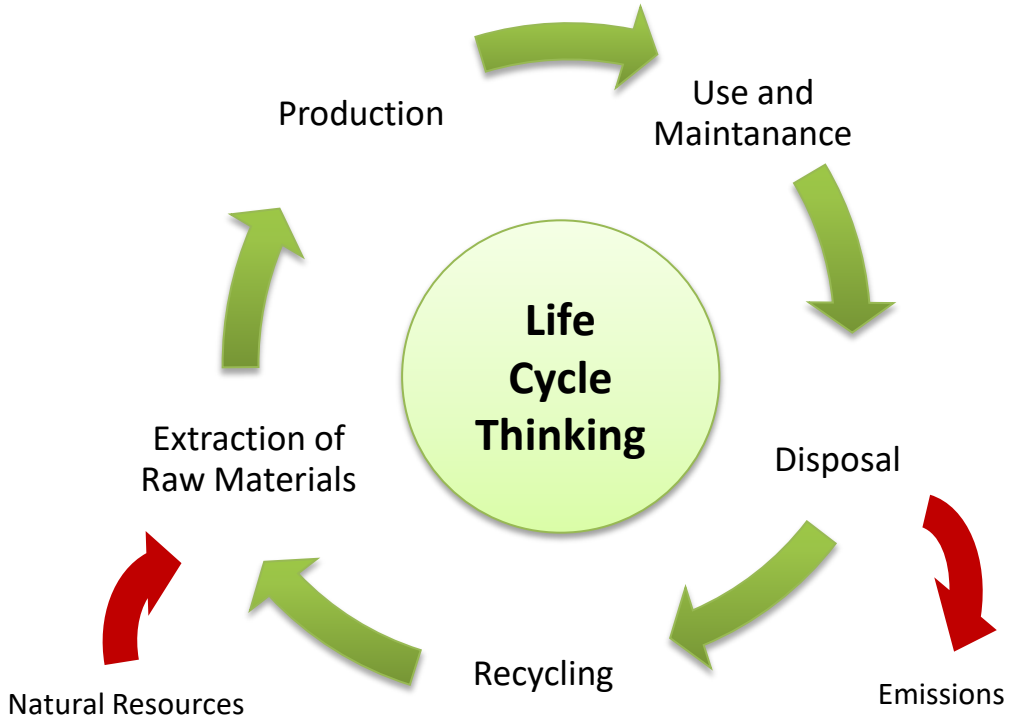
Life-cycle-based sustainability assessment



(Source: KIT-ITAS)

"Any environmental, economic, or social assessment method has to take into account the respective full life cycle (raw material extraction, production, use, recycling or waste disposal) of an activity or product respectively." [7]

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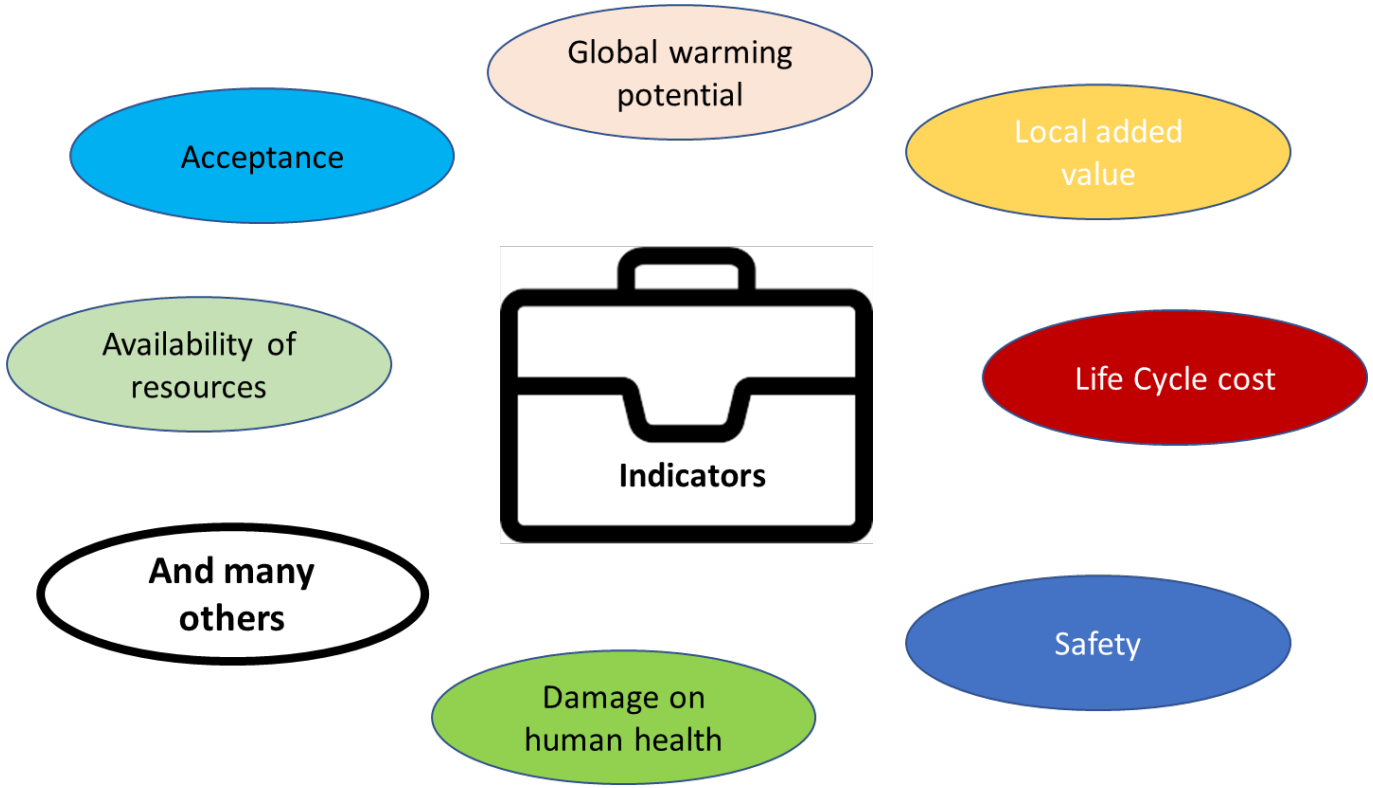
Implementation of sustainability assessment

Selection of criteria and indicators



Which indicators to select?

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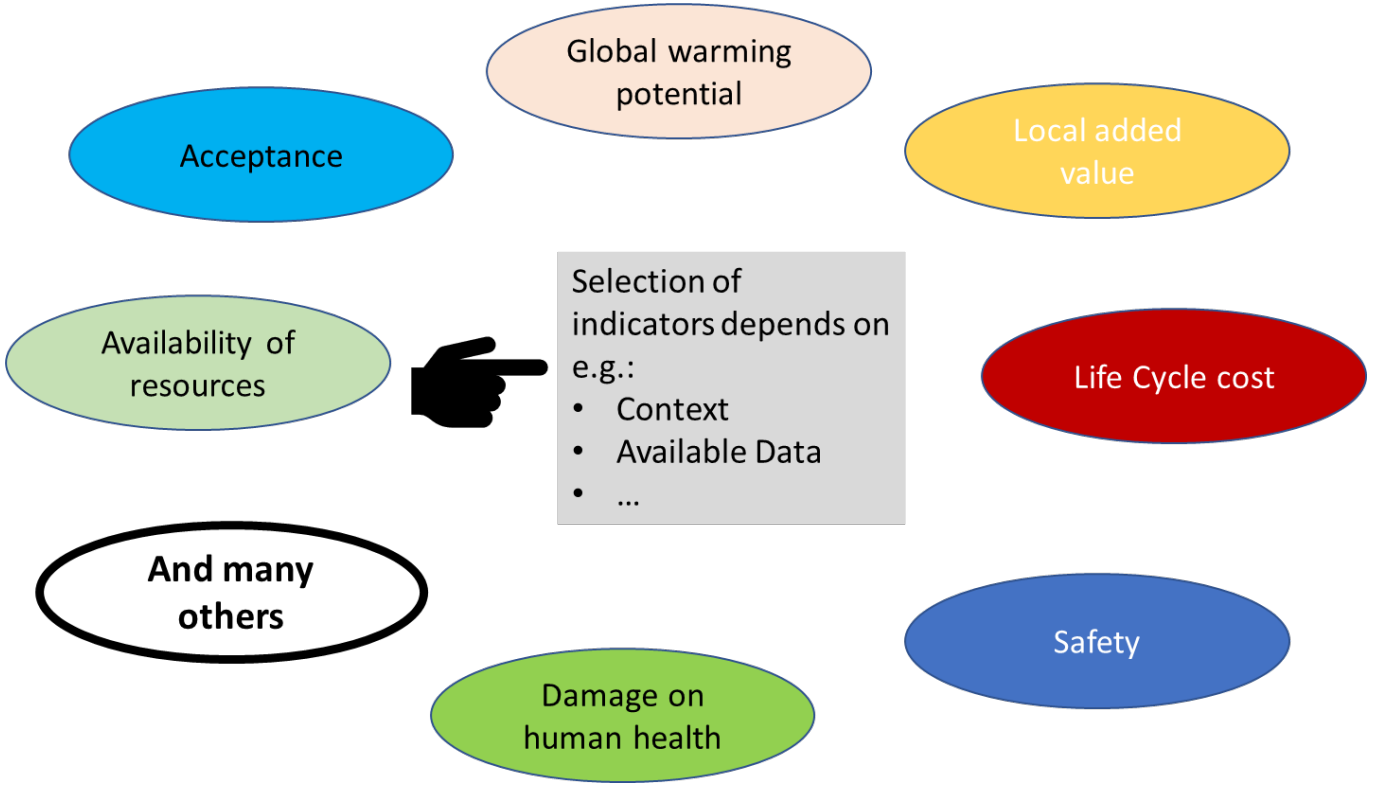
Implementation of sustainability assessment

Selection of criteria and indicators



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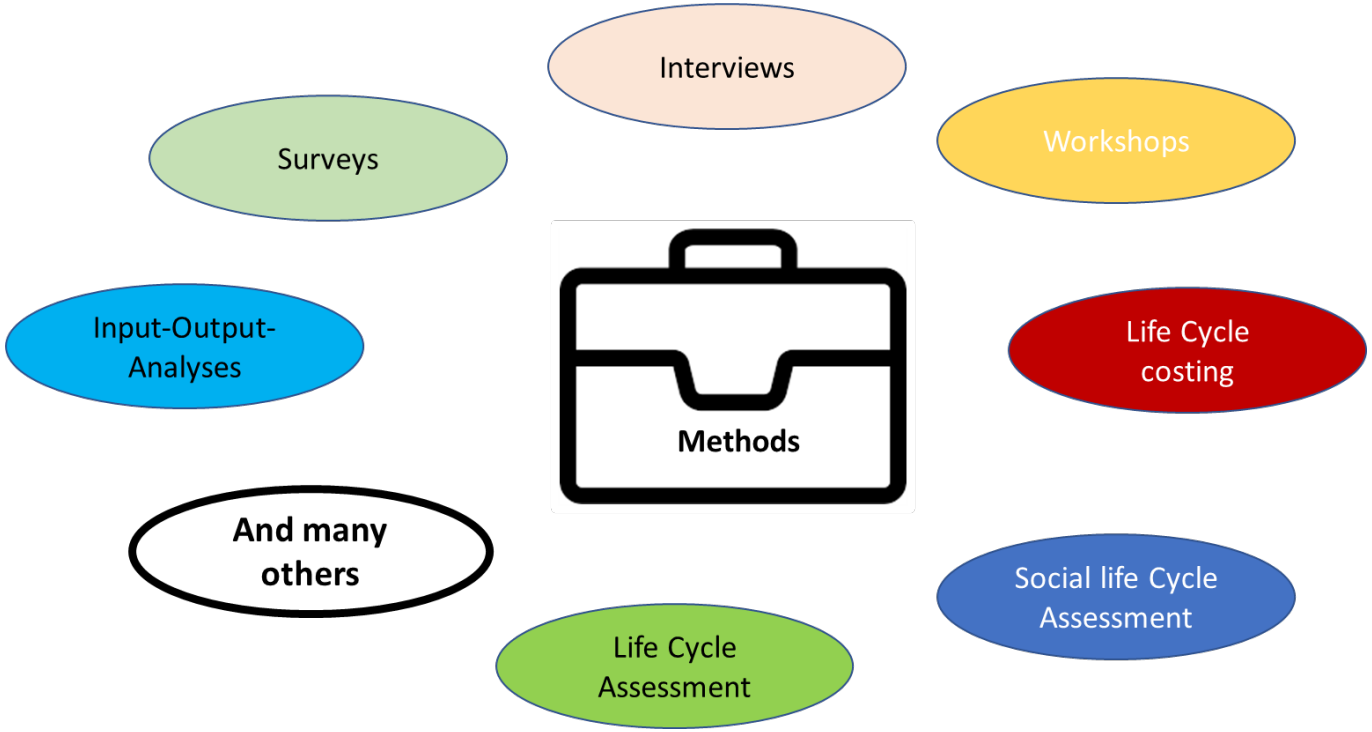
Implementation of sustainability assessment
Selection of methods



Which methods to select?

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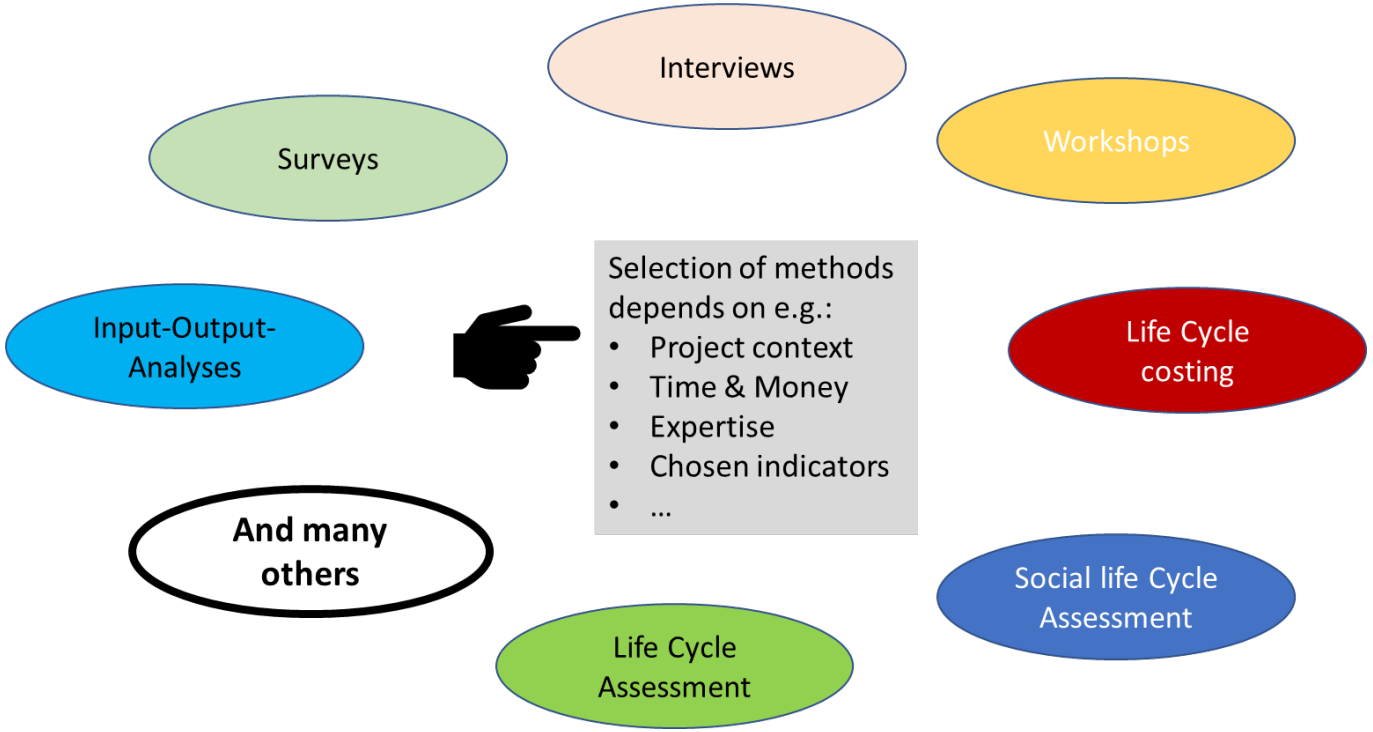
Implementation of sustainability assessment
Selection of methods



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Implementation of sustainability assessment
Data gathering

Different databases need to be identified and aligned depending on the respective use case

- Literature review
- Expert estimates
- Data from technology developers
- Own measurements
- Data from project partners
- (Thermodynamic) modelling
- Commercial or open source databases
- …

Where to gather data for the assessment ?

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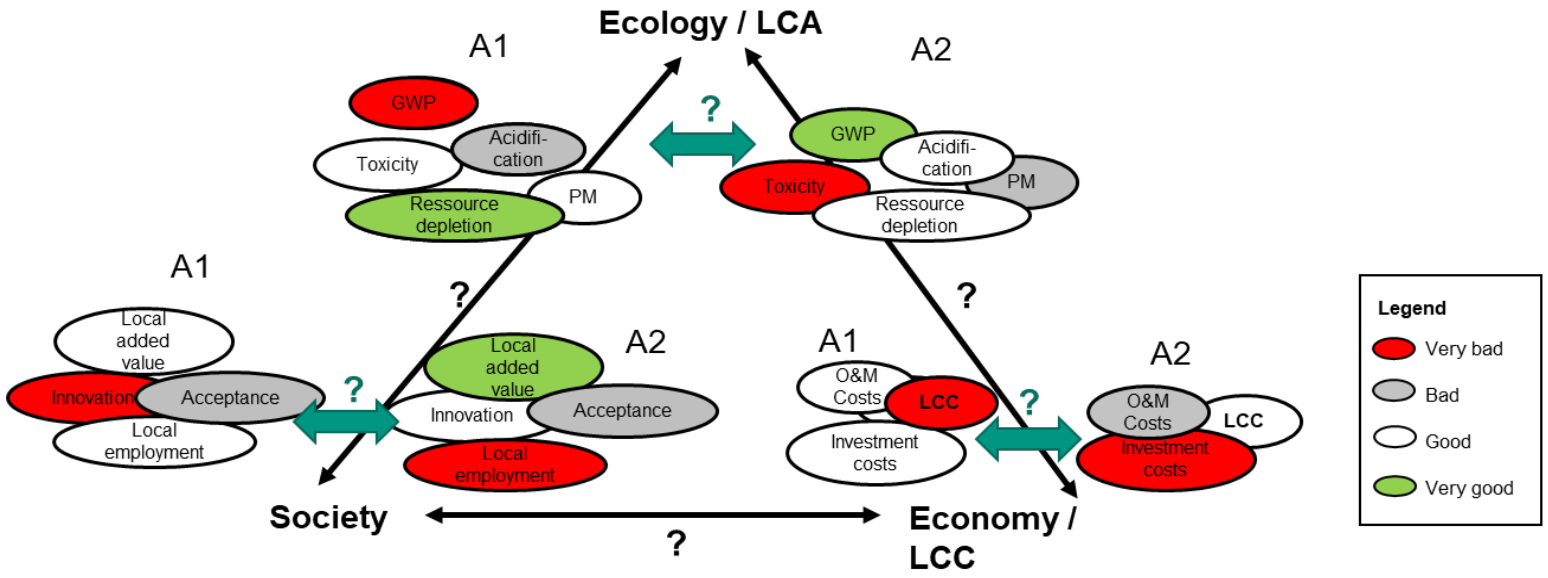
Sustainability as complex decision problem



Schematic comparison of two alternatives A1 and A2 using different environmental, economic, and social indicators

(Source: KIT-ITAS)

High complexity in decision making related to sustainability due to

- Multiple (conflicting) goals and criteria (e.g. min cost, max benefit, min env. impact, ...)
- Complex relations (several alternatives, interlinkages of criteria etc.)
- Many different decision makers (various views, objectives, interests etc.) [8].

How to compare different technologies (alternatives) including multiple criteria and indicators?

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MCDA for sustainability assessment

Overview

Multi Criteria Decision analysis (MCDA)

- Multi Attribute Decision Making (MADM): Mathematical procedures for the assessment of discrete alternatives (products, technologies, strategies etc.)
- Provides guidance to find compromise in case of multiple, conflicting targets
- Choice of methods depending on decision problem and type of information available

Main advantages

- Enables integrated consideration of multiple criteria using weighting and aggregation methods
- Decisions are transparent and justifiable as they are documented and comprehensible
- Enables to quantify different (stakeholder) judgements and make their influence on the result visible [9].

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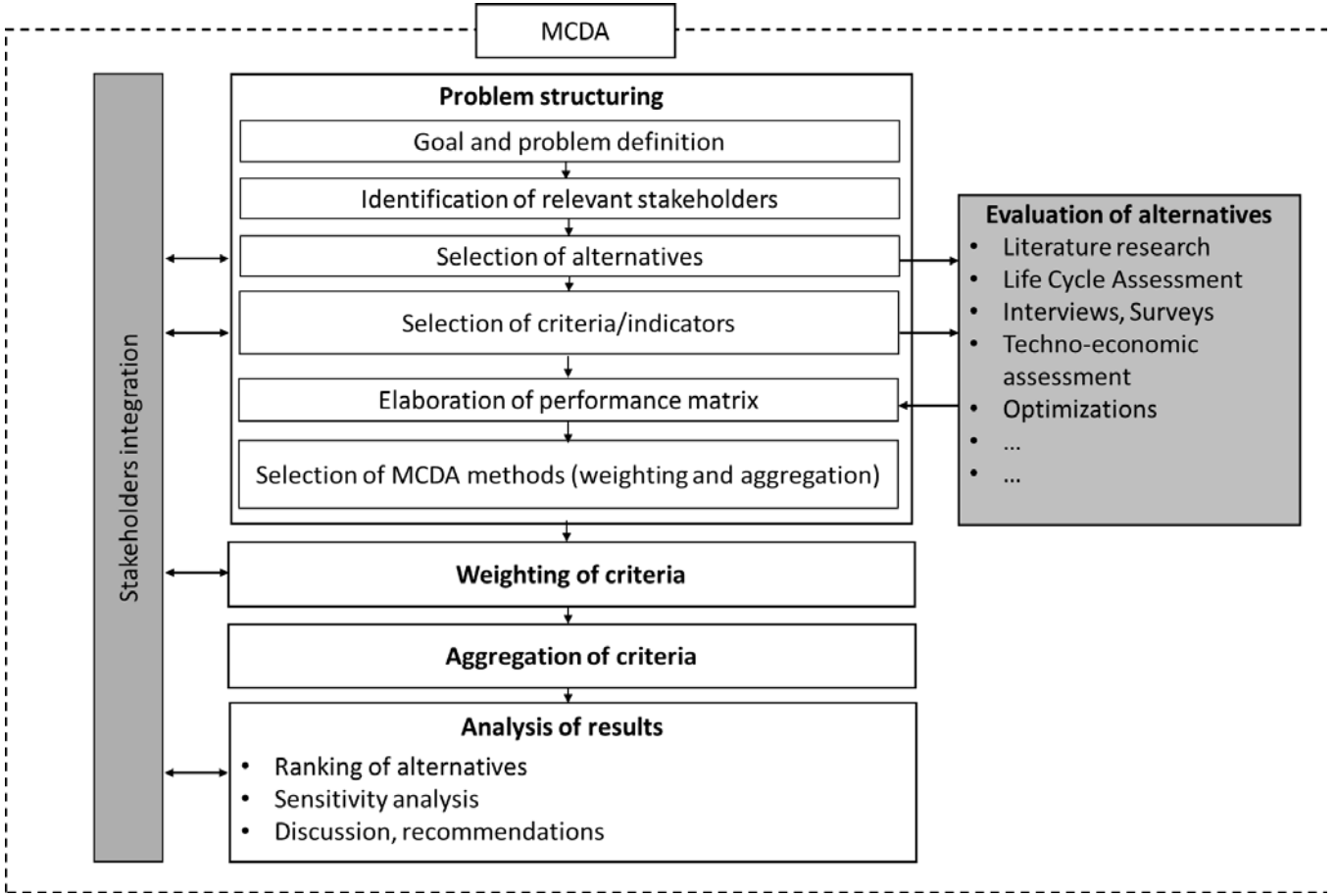
MCDA for sustainability assessment

Procedure

Main steps

1. Problem structuring:
    1. Goal and problem definition
    2. Identification of relevant stakeholder
    3. Selection of alternatives and criteria and/or indicators
    4. Elaboration of performance matrix
    5. Selection of appropriate MCDA methods
2. Weighting of criteria
3. Aggregation of criteria
4. Analysis of results
    1. Ranking of alternatives
    2. Sensitivity analysis



Generic MCDA framework
Source: [18]

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MCDA for sustainability assessment

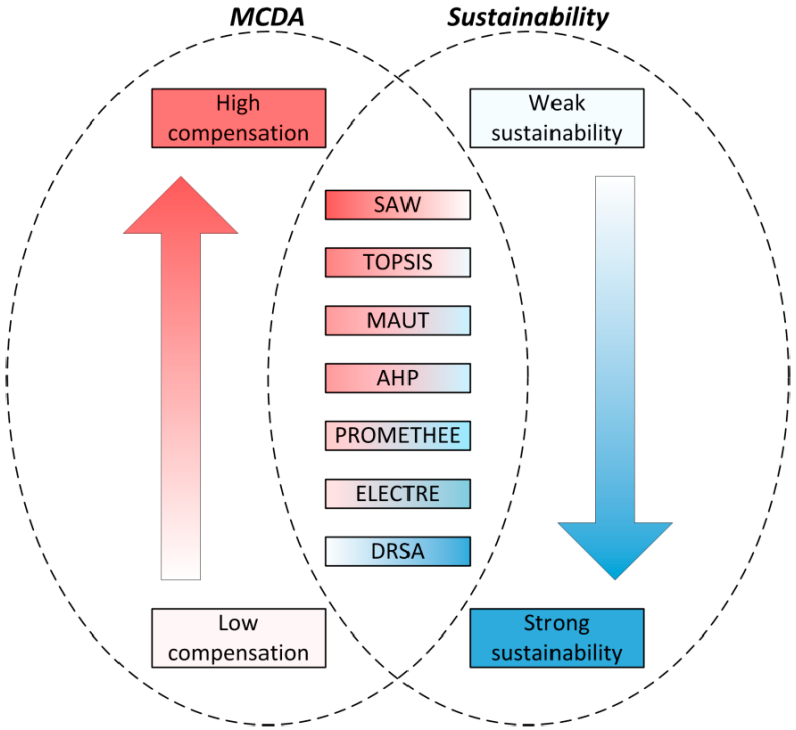
MCDA Methods

Different methods with different implications, e.g.

- full and null/partial compensation of criteria
- handling of qualitative and/or quantitative criteria
- types of weights (tradeoffs vs. relative importance coefficients)
- different levels of mathematical complexity. [10]

Consideration of strong sustainability concept

- Good performance in one criterion cannot compensate for bad performance in another criterion, natural capital is not interchangeable with man-made capital
- Aggregation methods with low compensation are preferred e.g. PROMETHEE, ELECTRE, DRSA. [11]



Compensation degree and sustainability strength for different MCDA methods

Source: [19]

Choice of MCDA methods has implications for sustainability assessment

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MCDA for sustainability assessment

Stakeholder integration

Goals

- Information dissemination
- Inclusion of practical knowledge
- Creating transparency in the evaluation process
- Increasing acceptance
- …

Stakeholders

- Technology Developers
- Technology users
- Policy makers
- …

Formats

- Interviews
- Workshops
- (Online) surveys
- …

Group work during stakeholder workshop, KIT-ITAS, July 2025

(Source: KIT-ITAS)

Goal, stakeholder types and formats depend on respective use case

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Self-testing

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Questions

1. What is the latest and most relevant political framework for sustainable development?
2. What are the main challenges of sustainability assessments on a technology level?
3. What does the abbreviation MCDA mean?
4. Mention three reasons why MCDA is a useful tool for sustainability assessment.

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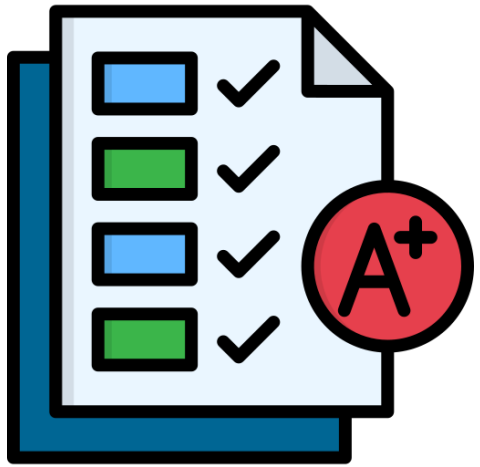
Self-testing



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Questions

1. What is the latest and most relevant political framework for sustainable development?
2. What are the main challenges of sustainability assessments on a technology level?
3. What does the abbreviation MCDA mean
4. Mention three reasons why MCDA is a useful tool for sustainability assessment

Answers

1. Sustainable Development Goals (SDGs), defined by the United Nations
2. Selection of indicators, selection of methods, data gathering
3. Multi-criteria decision analysis
4. Integrated consideration of criteria and indicators, decisions are transparent and justifiable, stakeholder judgements can be included

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Coming soon:
Part II - How sustainability assessment is carried out on a technology level

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Thank you

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RISEnergy
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QR Code to link to training materials section RISEnergy website

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Further reading

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[1] Sustainability https://www.un.org/en/academic-impact/sustainability

[2] What is the sustainable energy transition and why is it key to tackling climate change? https://climatepromise.undp.org/news-and-stories/what-sustainable-energy-transition-and-why-it-key-tackling-climate-change

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