Multi-Criteria-Decision-Making for alternative energy supply scenarios

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Workshop: Deep Transition and Integration of Power and Transport Systems(APEC project EWG 10 2018A)

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Session Introduction

Objectives:

- Achieve a good level of understanding of energy system planning processes
- Achieve a basic level of understanding of how to use MCA tools
- Applying a simplified MCA tool on your own

Key Questions:

- How can we plan sustainable energy systems?
- How can we involve different stakeholder groups?
- How can we evaluate different energy scenarios with the help of a MCA tool?
- What are the preferred sustainable energy scenarios for the different case study islands?

Session Introduction

Agenda:

20 min	Presentation: Introduction to energy supply planning
20 min	Introduction to MCA
60 min	Group work: Evaluation of scenarios
15 min	Group work: Presentation and discussion of results

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- 100% owned by Reiner Lemoine Stiftung (RLS)
- Based in Berlin, established in 2010
- Managing director: Dr. Kathrin Goldammer
- >70 researchers + students
- Main fields
  - Transformation of energy systems
  - Mobility with renewable energy
  - Off-grid systems

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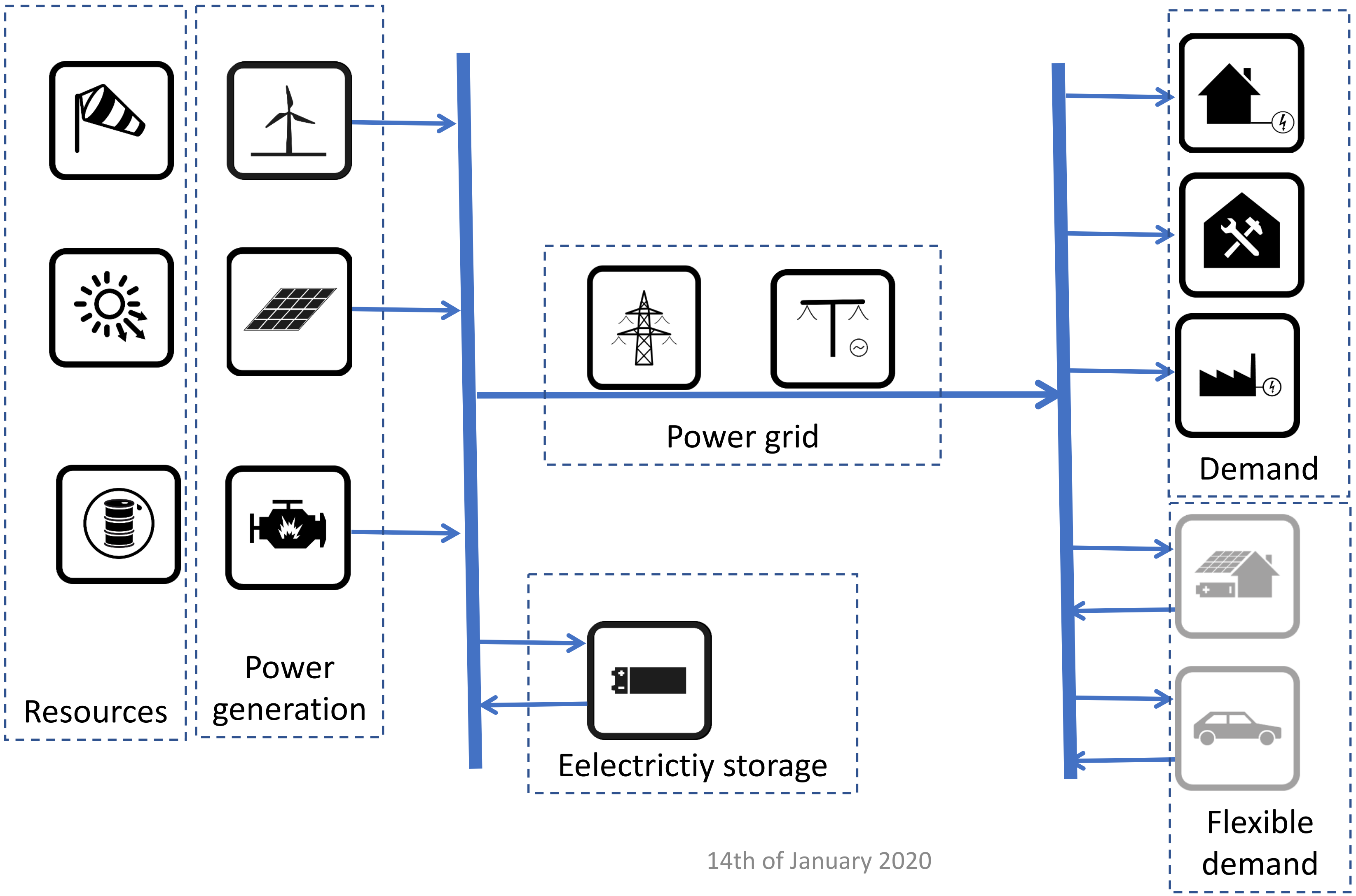
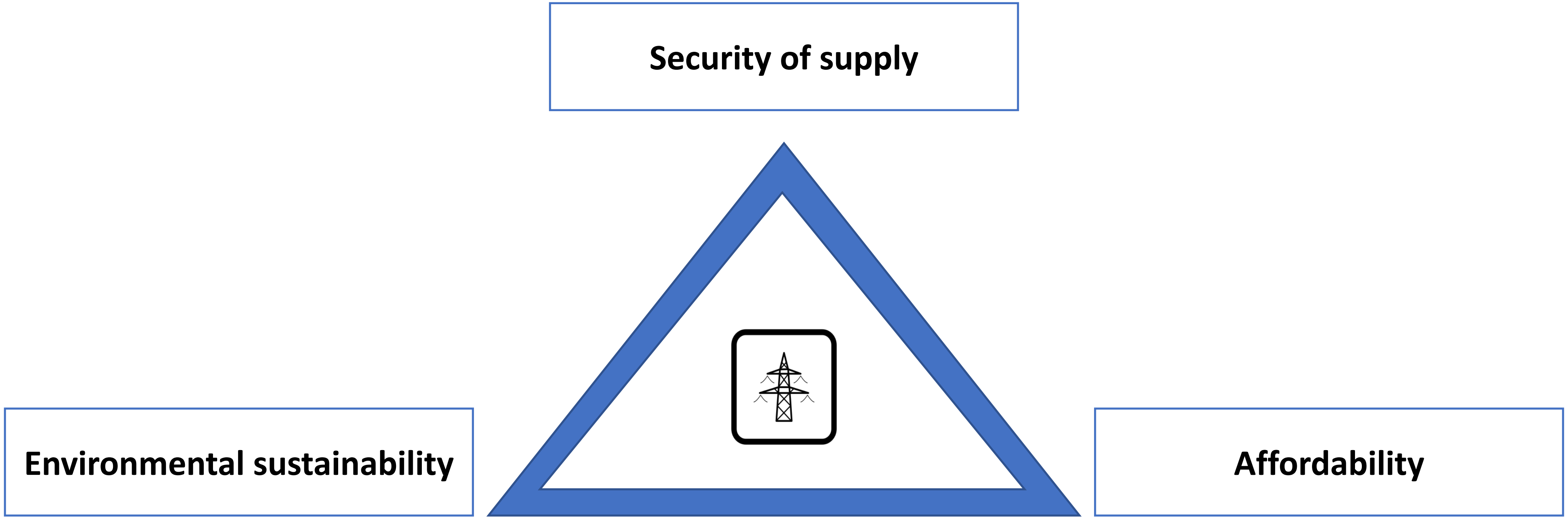
Introduction to energy supply planning

What is an energy supply system?



Traditional targets of energy supply systems



More needed? → MCA!

Energy supply planning

- Energy systems should optimally fulfill all requirements
- Planning is needed!
  - Load forecasting
  - Resource assessments
  - Power generation
  - Distribution
  - Storage

Complexity increases with renewables and decentralication of supply and demand!

Energy system models needed!

Energy system modelling tools

- **Macro-economic** (birds view on energy system; aggregated; long-term; multi-sectoral), e.g. LEAP, GeneSys-Mod
- **Techno-economic** (detailed calculation of supply system and components; energy flows in hourly time steps; optimization of minimal system costs), e.g. oemof, TIMES

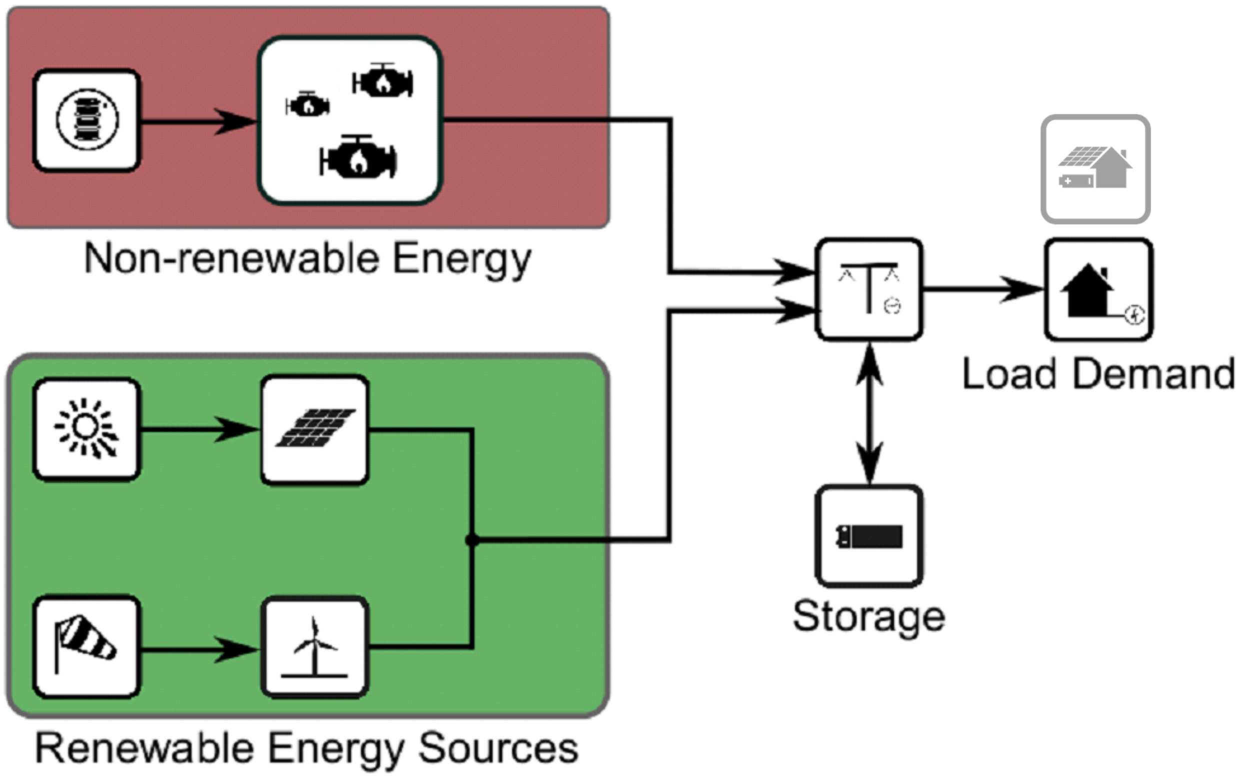
Island systems

- **Project planning** (detailed calcuation of specific energy supply projects; technical and cash-flow analysis; restricted to smaller systems), e.g. HOMER Energy
- **Grid modelling** (stability calculations electrical grids (voltage and frequency); e.g. DIgSILENT, ENAplan

Basic steps of energy system modelling

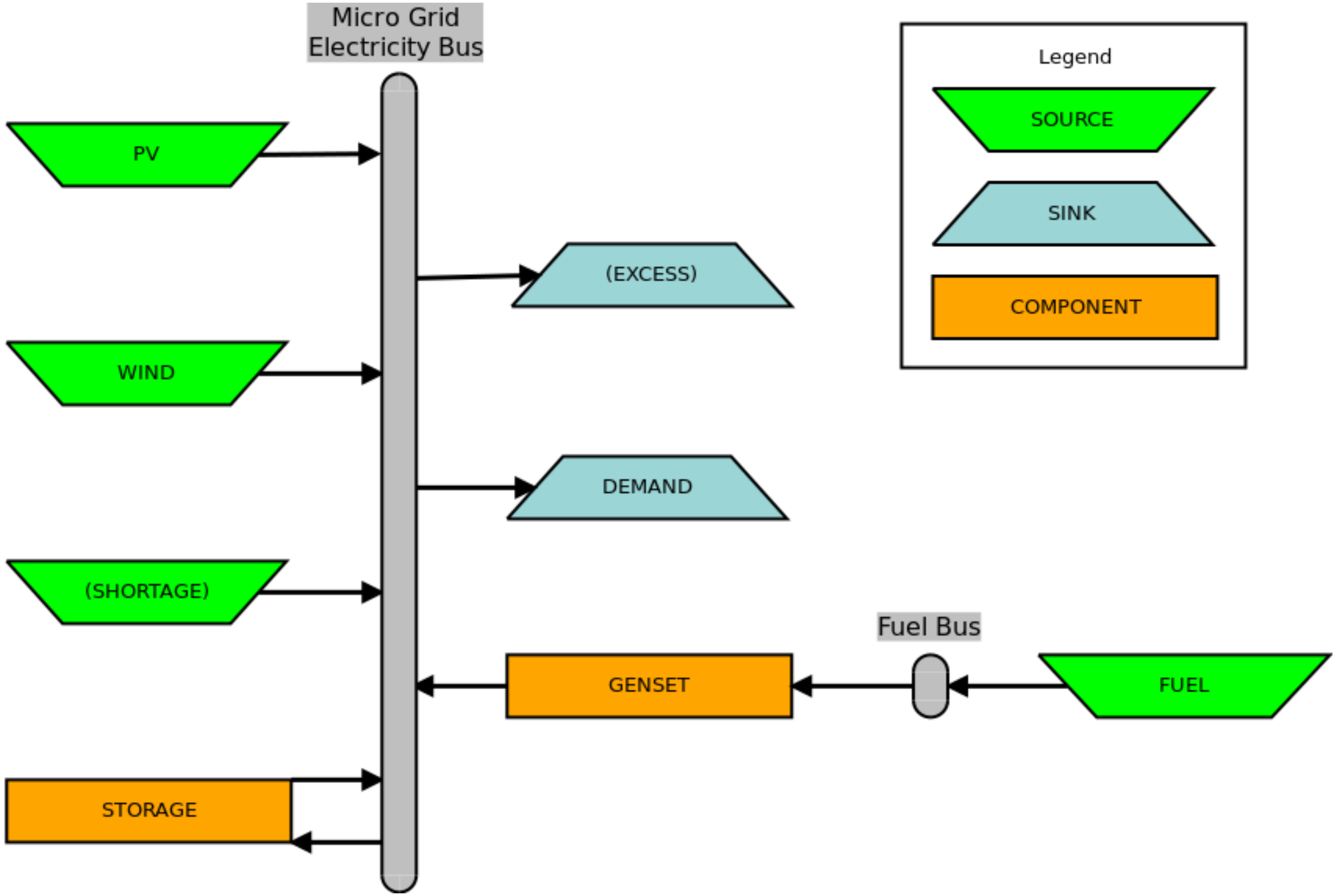
- Define energy supply system
- Implement components into model
- Collect input data
- Calculate scenarios / optimize component sizes or operational strategies
- Derive recommendations

Actual energy system to be simulated



Test island – „Simplified Romblon"
- 1.8 MW load
- 3 diesel plants
- *No RE*

Simplified system



Data requirements of model

- Economic parameters:
  - Fix and variable cost of the system components
  - For internal processing of costs: WACC, project lifetime
- Timeseries with values for each timestep:
  - Sources (non-dispatchable generation)
  - Sinks (non-dispatchable demands)
- Technical parameters:
  - Transformer (eg. generator) efficiencies
  - Technical storage parameters

Scenario calculation / optimization

Scenarios		Results				
Name	**Components**	**Capacities**	**Investment costs total [USD]**	**LCOE [USD/kWh]**	**RE-share [%]**	**GHG emissions [Mtons/year]**
Diesel-only	Diesel plant	2.4 MW	0	0.32	0	11
Wind-diesel	Diesel plant Wind farm	2.4 MW 3.6 MW	5.4 Million	0.27	35%	7.1
PV-battery-diesel	Diesel plant PV Battery storage	2.4 MW 4 MW 1.5 MWh	6.35 Million	0.28	39%	6.3

Scenario calculation / optimization

Scenarios		Results				
Name	**Components**	**Capacities**	**Investment costs total [USD]**	**LCOE [USD/kWh]**	**RE-share [%]**	**GHG emissions [Mtons/year]**
Diesel-only	Diesel plant					
Wind-diesel	Diesel plant Wind farm					
PV-battery-diesel	Diesel plant PV Battery storage					

What scenario should we implement?

Decision-making with stakeholders

Instead of asking every stakeholder (group) to calculate own scenarios and recommend one, we allow to select and evaluate the decision making criteria.

Methods:

- Stakeholder interviews
- Expert consultation
- Group discussion

Characteristics:

- Transparent
- Inclusive
- Accessible

Introduction to Multi-Criteria-Analysis (MCA)

Introduction to Multi-Criteria-Analysis (MCA)

- Decision processes are complex
- Different stakeholder opinions need to be considered
- Different evaluation criteria need to be considered

Scientific view Multi-Criteria-Analysis (MCA)

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Review on multi-criteria decision analysis aid in sustainable energy decision-making

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A R T I C L E   I N F O

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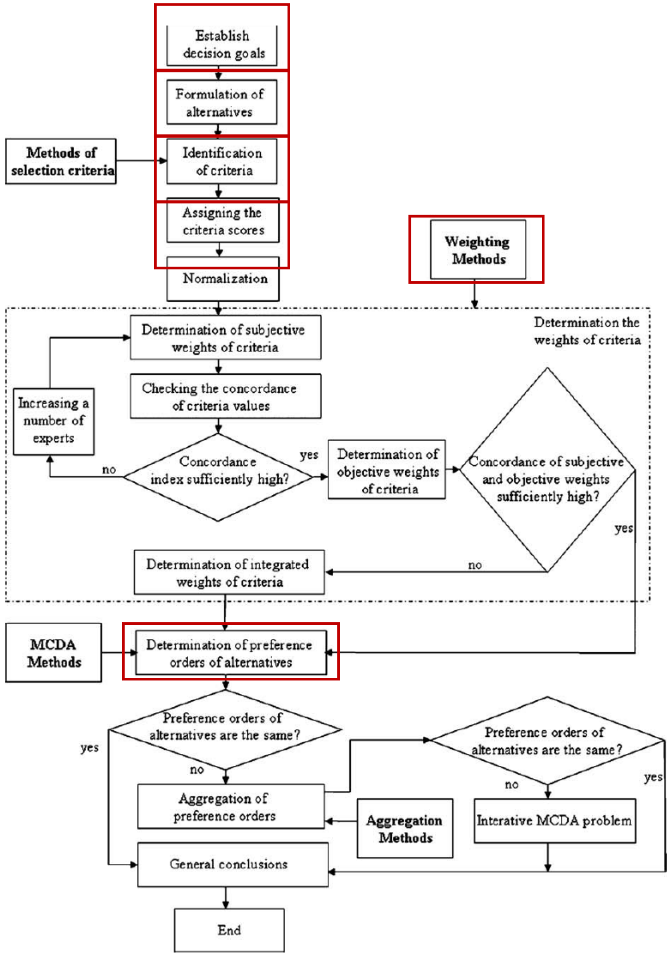
A B S T R A C T

Multi-criteria decision analysis (MCDA) methods have become increasingly popular in decision-making for sustainable energy because of the multi-dimensionality of the sustainability goal and the complexity of socio-economic and biophysical systems. This article reviewed the corresponding methods in different stages of multi-criteria decision-making for sustainable energy, i.e., criteria selection, criteria weighting, evaluation, and final aggregation. The criteria of energy supply systems are summarized from technical, economic, environmental and social aspects. The weighting methods of criteria are classified into three categories: subjective weighting, objective weighting and combination weighting methods. Several methods based on weighted sum, priority setting, outranking, fuzzy set methodology and their combinations are employed for energy decision-making. It is observed that the investment cost locates the first place in all evaluation criteria and CO_2 emission follows closely because of more focuses on environment protection, equal criteria weights are still the most popular weighting method, analytical hierarchy process is the most popular comprehensive MCDA method, and the aggregation methods are helpful to get the rational result in sustainable energy decision-making.



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MCA process

1. Establish decision goals
2. Definition of scenarios / options
3. Identification of evaluation criteria
4. Weighting of evaluation criteria
5. Scoring of scenarios
6. Final ranking

Decision goals

Find optimal future supply system for our test island according to technical, economic, environmental and social criteria.

Definition of scenarios

Scenarios		Comment
Name	**Components**	
Diesel-only	Diesel plant	„nothing changes“, all electricity will be supplied via the diesel plant
Wind-diesel	Diesel plant Wind farm	A wind farm will be installed
PV-battery-diesel	Diesel plant PV Battery storage	A PV battery system will be installed. Decentral PV installations on roof-tops are possible

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Selection of criteria

Methods

- Simple interviews / questionnaires
- Delphi method
- Statistical methods

Criteria types

- Knock-out criteria (e.g. yes / no or upper / lower threshold)
- Quantitative criteria (e.g. costs in USD)
- Qualitative criteria (e.g. low or high environmental impact)

Selection principle of criteria

- **Systemic principle**. The criteria system should roundly reflect the essential characteristic and the whole performance of the energy systems. The comprehensive evaluation function of multi-criteria can obtain better results than the sum of single criteria evaluations.
- **Consistency principle**. The criteria system should be consistent with the DM objective.
- **Independency principle**. The criteria should not have inclusion relationship at the same level criteria. The criteria should reflect the performance of alternatives from different aspects.
- **Measurability principle**. The criteria should be measurable in quantitative value as possible or qualitatively expressed.
- **Comparability principle**. The DM result is more rational when the comparability of criteria is more obvious. Additionally, the criteria should be normalized to compare or operate directly when there are both benefit criteria and cost criteria.

Selection of criteria – exercise

Technical

Economic

Environmental

Social

Importance of criteria

- MANY different options exist…
  - Scoring (e.g. election of criteria)
  - Subjective weighting (e.g. AHP)
  - Objective weighting (e.g. normalization method)

Ranking scale						
5	4	3	2	1	0	Z
Highest importance	High importance	Moderate importance	Low importance	Very low importance	Absolutely no importance	Don't know

Scoring and normalization of scenarios

- Again, MANY different options exist…
  - Elementary (e.g. weighted sum method (WSM))
  - Unique synthesizing criteria (e.g. AHP)

Scenario			Diesel-only		
Category	Criteria	Weighting	Value	**N. Score**	W. score

Ranking of scenarios

- Again, MANY different options exist…
  - Elementary (e.g. weighted sum method (WSM))
  - Unique synthesizing criteria (e.g. AHP)

Scenario			**Diesel-only**		
Category	Criteria	Weighting	Value	**Scoring**	W. score

Final ranking / selection

- Scenario with highest score wins!

Exercise

- Let‘s do our own MCA!

Thank you!

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