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DEPARTMENT OF SUSTAINABLE SYSTEMS ENGINEERING

Integrated Sustainability Assessment and Optimization of Energy Systems

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Sustainable Energy System

1 Zusammenfassung[1, 2, 3, 4]

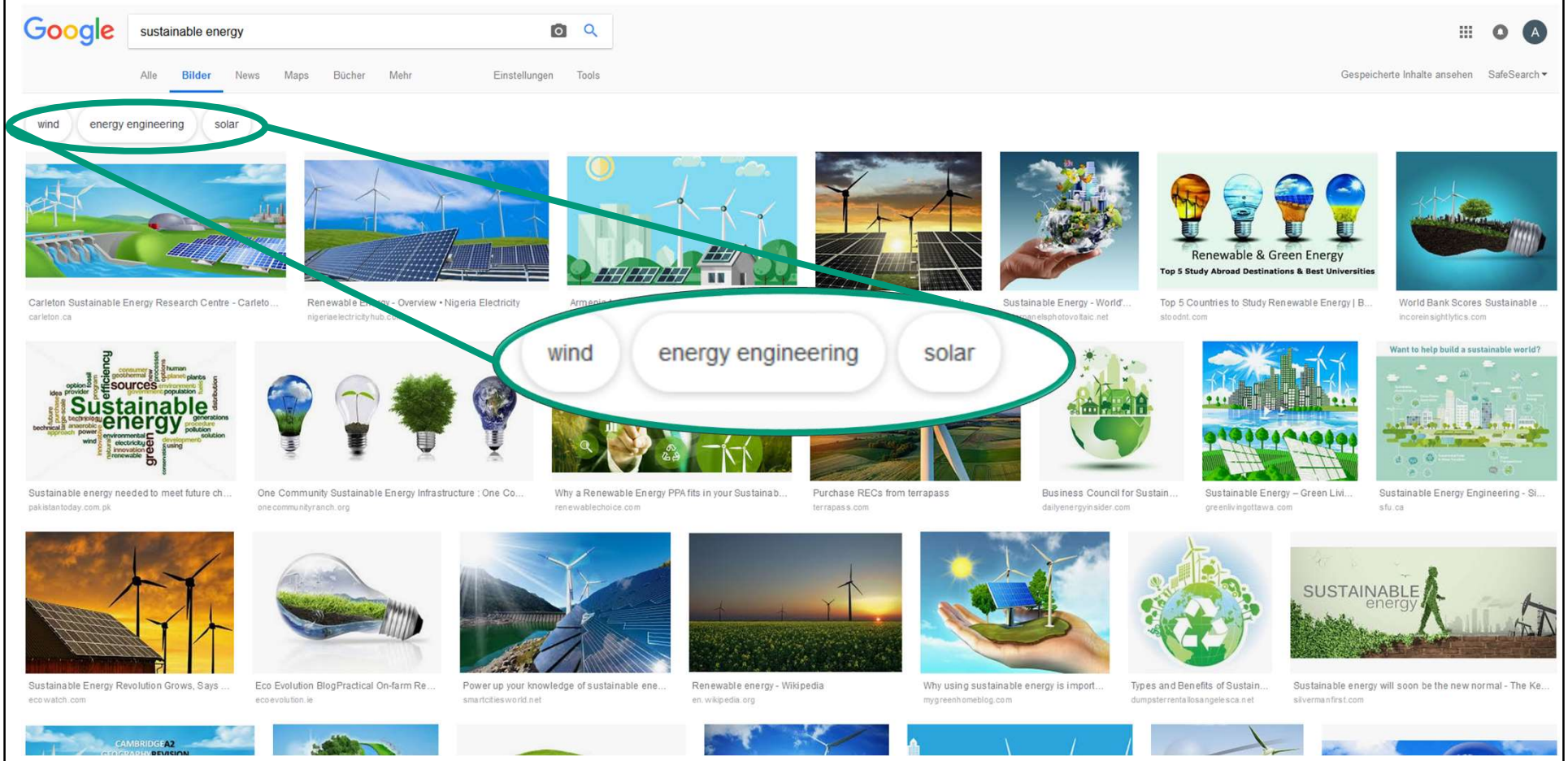
1.1 Die wichtigsten Ergebnisse

Einvernehmliche[5] Feststellung: Das gegenwärtige Energiesystem ist nicht nachhaltig

Joint statement: The current energy system is not sustainable

[German Enquête Commission „Sustainable Energy Supply under the Conditions of Globalization and Liberalization“, 2002]

Sustainable Energy



The InNOSys Project

- Research project on an *integrated sustainability assessment and optimization of energy systems*
- Jan 2018 – Dec 2020

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center
Institute of Engineering Thermodynamics

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ITAS Institute for Technology Assessment and Systems Analysis

zirius
Center for Interdisciplinary Risk and Innovation Studies

GWS SPECIALISTS IN EMPIRICAL ECONOMIC RESEARCH

INEC
INSTITUTE FOR INDUSTRIAL ECOLOGY PFORZHEIM

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

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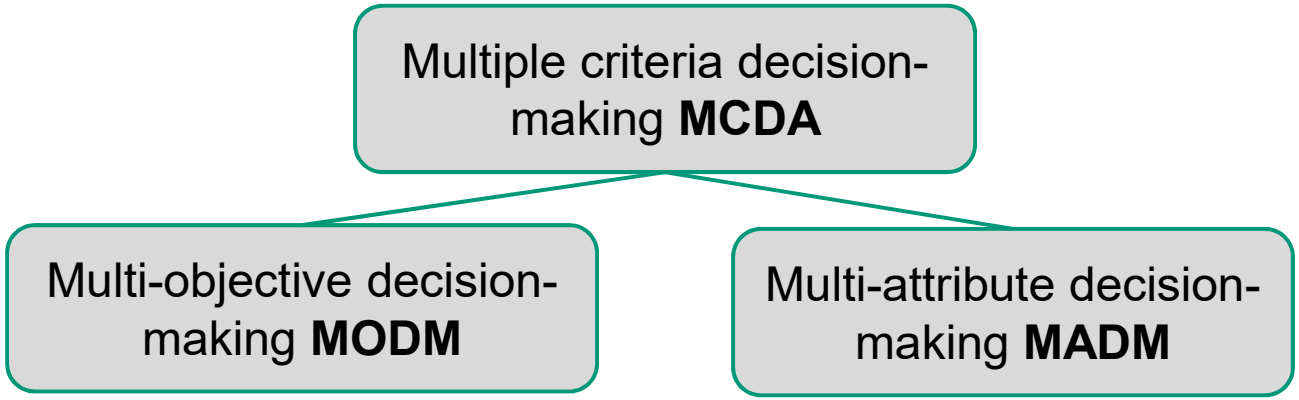
Objectives

- Object of study: Scenarios for energy system transformation until 2050

- Objectives:
  - MADM sustainability assessment approaches for energy scenarios
  - MODM methods for deriving optimized pathways of energy systems (in Germany)

Multi-Criteria Decision Making

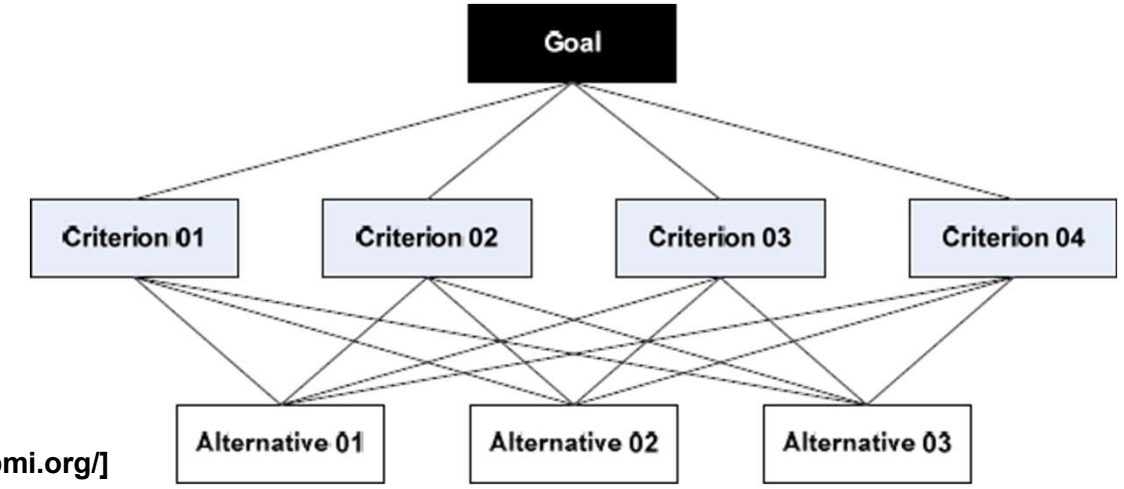
- Two sub-classes form the class of MCDA models



- **MODM**: multiple, usually conflicting objectives
  - → Aim: finding a feasible alternative that yields most preferred / satisfactory set of values for the objective functions
- **MADM**: multi-attribute utility functions
  - → Aim: make a choice among several alternatives

Method Selection

- Chosen MADM methods
  - Analytic Hierarchy Process
    AHP
  - Technique of Order Preference by Similarity of Ideal Solution
    TOPSIS
  - Preference Ranking Organization Methods for Enrichment of Evaluations
    PROMETHEE



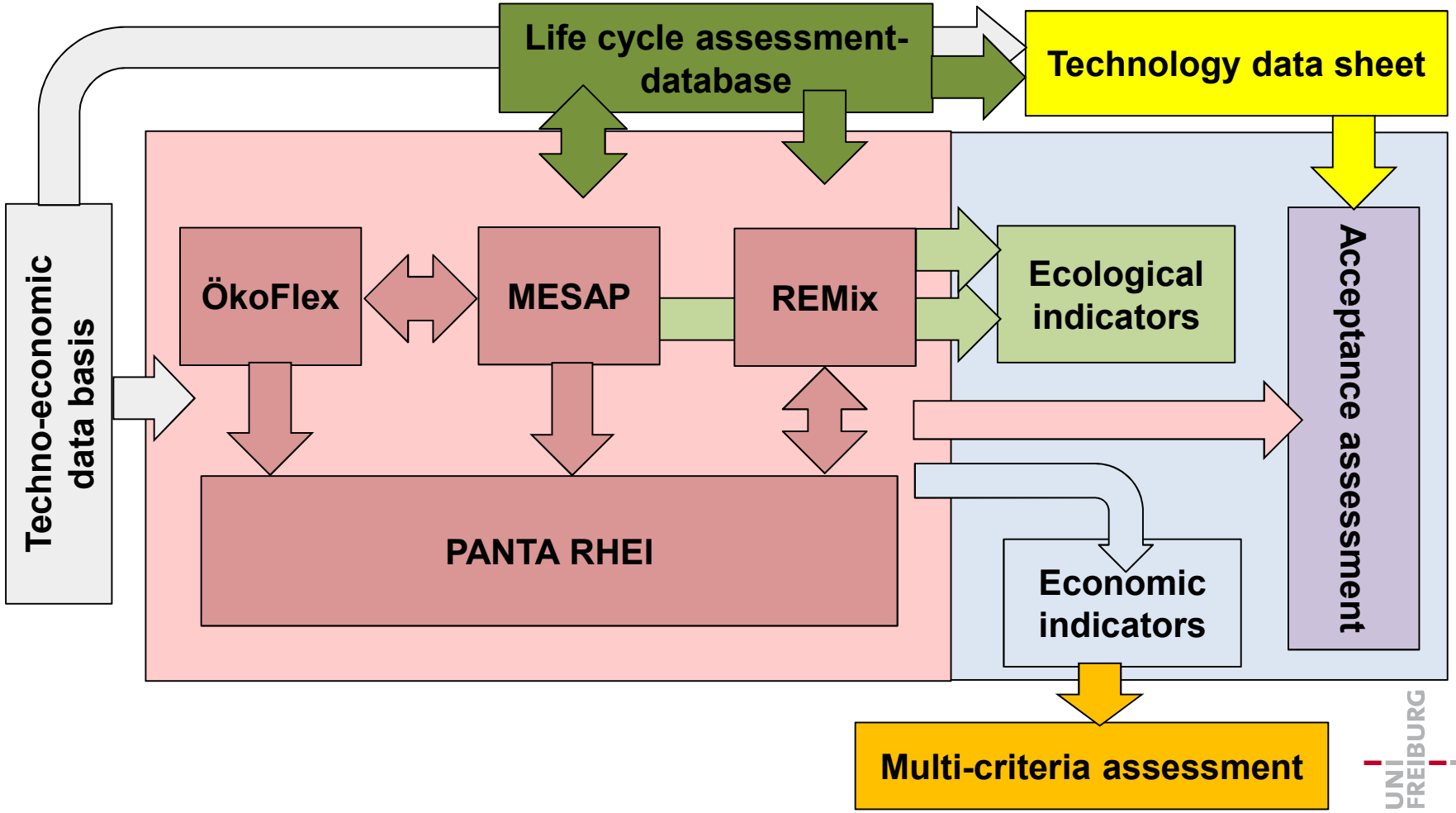
[https://www.pmi.org/]

Indicator (Pre-)Selection

- (Aggregated) indicators selected for focus groups
  - Social
    - Quality of living
    - Distributional justice
    - Intergenerational justice
  - Socio-economic
    - Employment effects installation
    - Employment effects O&M
  - Economic
    - Levelized cost of electricity
    - Security of supply
  - Ecological
    - CO_2 emissions
    - Land consumption
    - Respirable dust
    - Ecological toxicity
    - Resource consumption

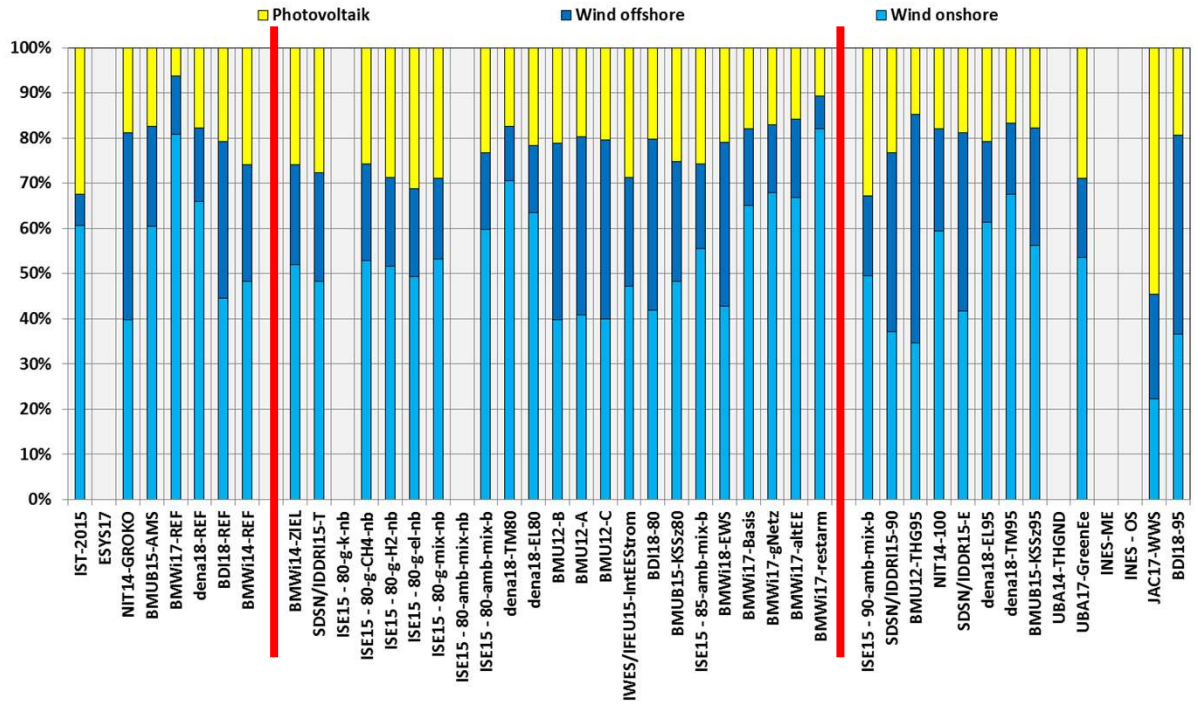
Basic Concept and Model Coupling

- Model used for analysis



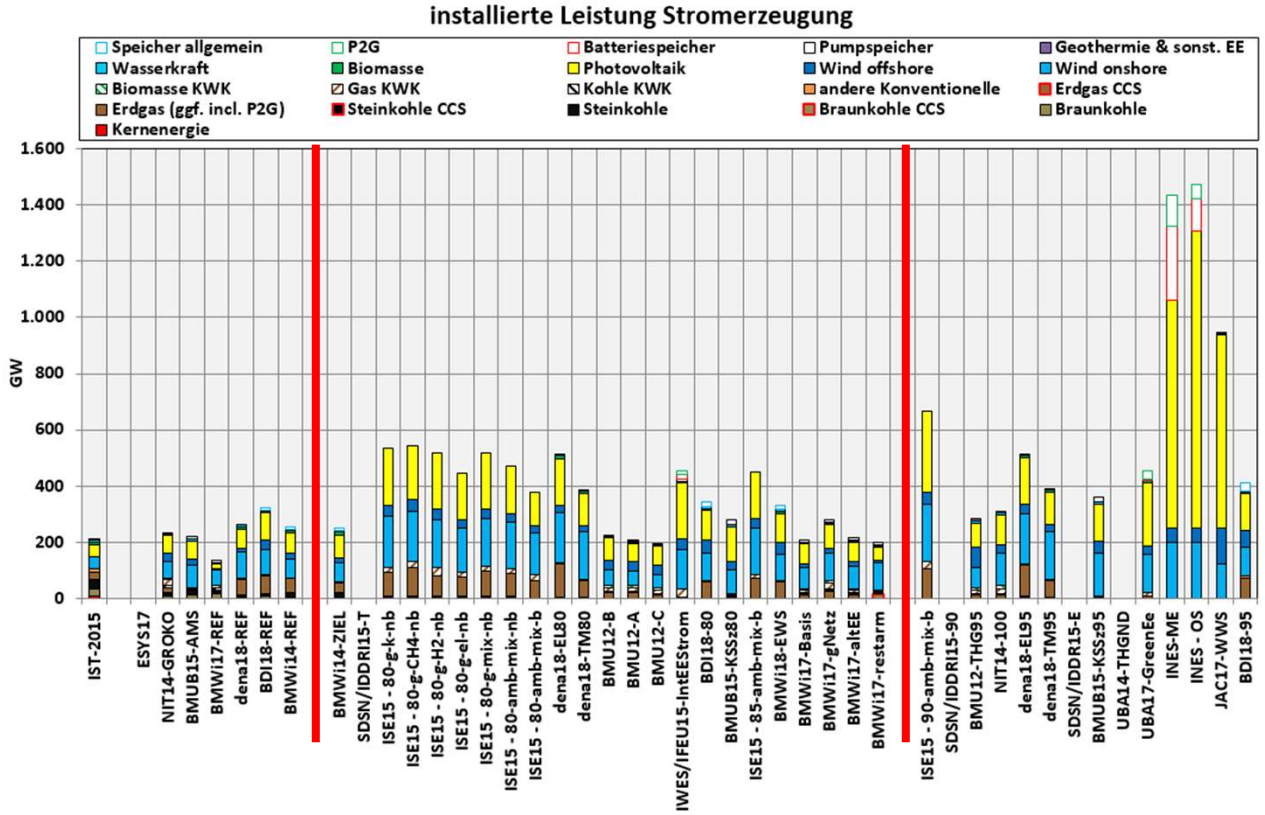
Scenario Classification

- Scenario sets: 80–90 % & 95 % CO_2 emission reduction target
- Average shares of generation capacity in the scenarios
  - 80–90 %: 54 % wind onshore, 23 % wind offshore, 23 % PV
  - 95 %: 48 % wind onshore, 29 % wind offshore, 23 % PV



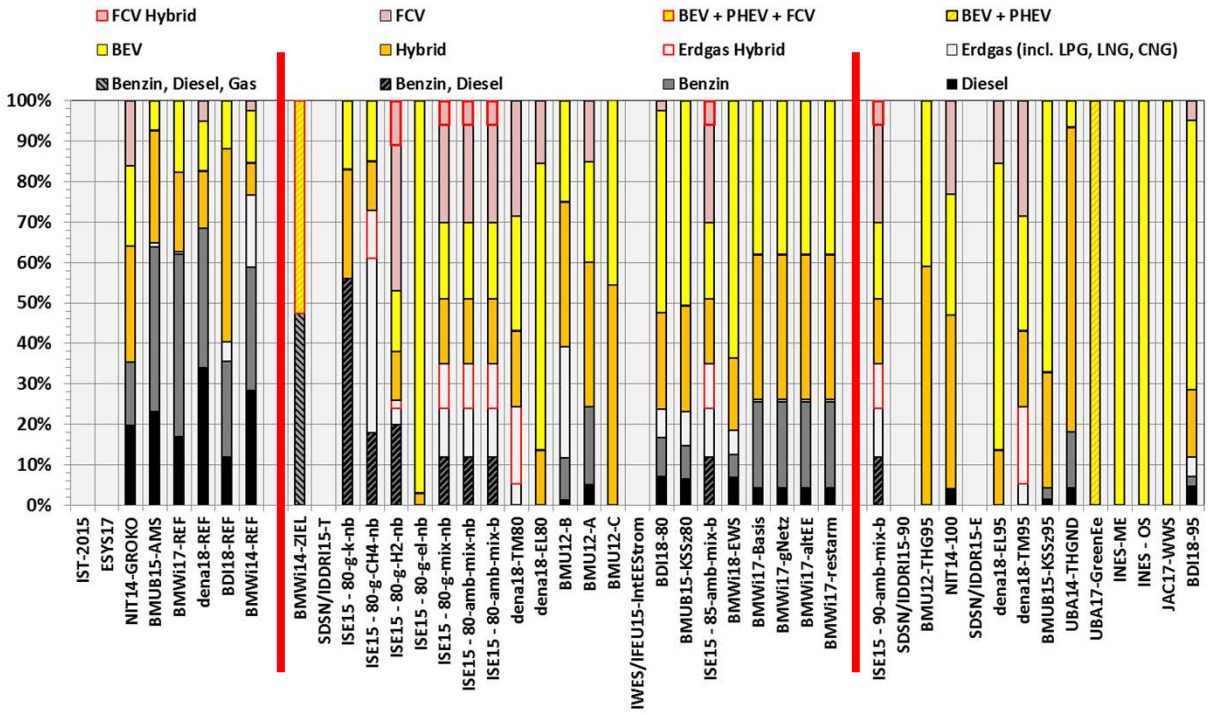
Differences in Scenarios

- Large differences in installed capacity across scenarios
  - 80–90 %: < 400 GW (all technologies)
  - 95 %: 400 – 1400 GW (all technologies)



Differences in Scenarios

- Individual mobility
  - 80–90 %: electric vehicles, hybrid vehicles s with biofuels, fuel cell vehicles, natural gas engines
  - 95 %: electric vehicles, hybrid vehicles with synthetic fuels, fuel cell vehicles



Outlook

- Ten scenarios will be re-calculated for comparable results
  - Harmonized driving factors
  - Harmonized energy intensities
- Criteria weighting facilitated by focus groups
- MADM studies based on weights and selected indicators
- Optimized energy scenarios based on MODM method