Harmonized re-modeling of transformation strategies for the German energy system

as a basis for further sustainability assessment

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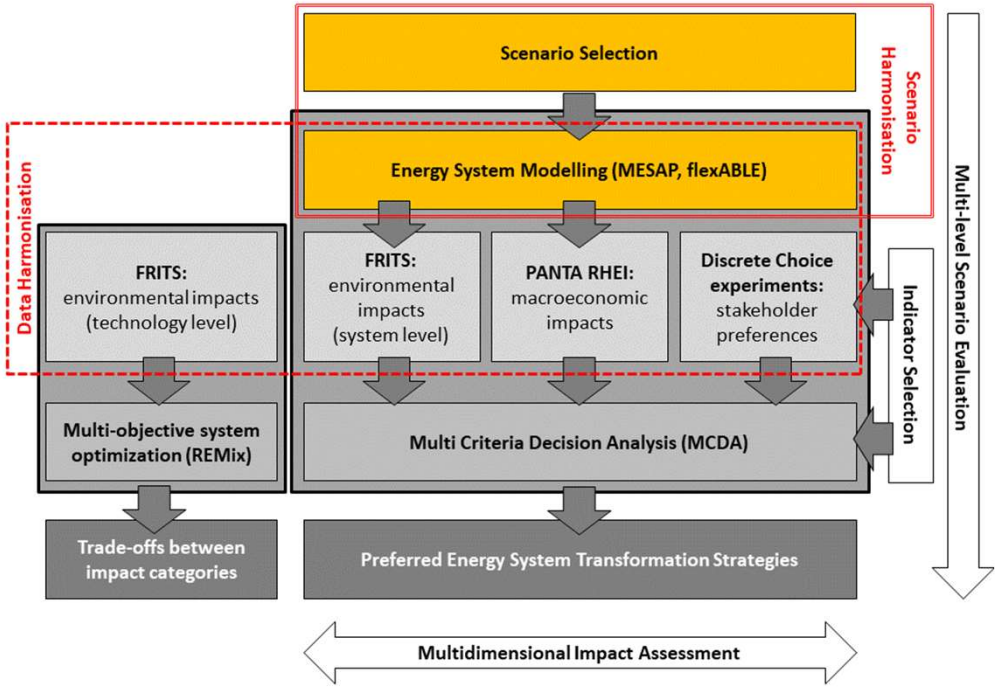
Harmonized scenarios as basis for further impact assessment and MCDA in InNOSys



Scenario Selection

- **Step 1:** Screening of 50+ scenarios for Germany from 19 studies
- **Step 2:** Selection all scenarios meeting the following criteria:
  - Entire energy system is covered (all sectors & relevant energy carriers)
  - Sufficiently new studies (not older than 2012)
  - Sufficiently detailed documentation of scenario results
  - Study commissioned by a relevant stakeholder and/or study carried out by an established research institution
- **Step 3:** Selection of 10 scenarios for detailed impact assessment
  - 5 scenarios with GHG emission reduction of 80%-90%
  - 5 scenarios with GHG emission reduction > 90%
  - Technical transformation strategies as different as possible within each group

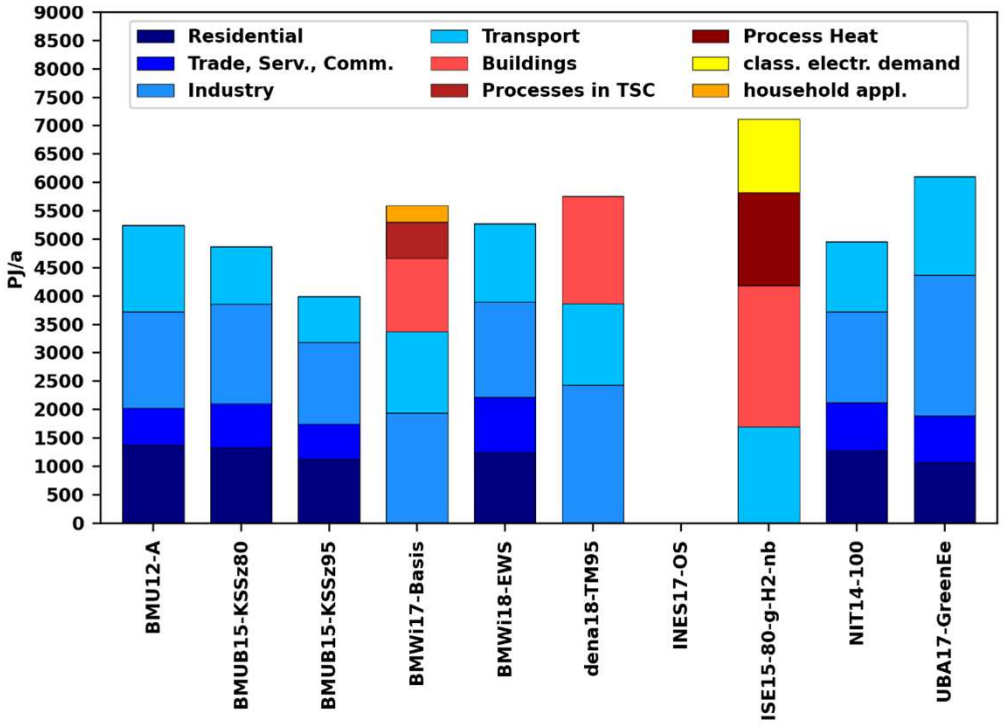
Selected Scenarios

No.	Funding Agency, title and year of original study	Scenario Variant	Research Institutions
I	BMWi: Gesamtwirtschaftliche Effekte der Energiewende (2018)	EWS	GWS, Prognos, DIW, FhG ISI, DLR
II	BMWi: Langfristszenarien für die Transformation des Energiesystems in Deutschland (2017)	Basis	FhG ISI, ifeu, Consentec
III	BMU: Langfristszenarien und Strategien [illegible] Deutschland (2012)	[illegible]	[illegible]LR
IV	BMU: Klimaschutzszenario 2050 (2015)	KSS80	Öko-Institut, FhG ISI, Ziesing
V	FhG ISE: Was kostet die Energiewende? Wege zur Transformation des deutschen Energiesystems (2015)	80-g-H2-nb	FhG ISE
VI	BMU: Klimaschutzszenario 2050 (2015)	KSz95	Öko-Institut, FhG ISI, Ziesing
VII	BEE: GROKO II – Szenarien der deutschen Energie-versorgung auf Basis des EEG-Gesetzentwurfs (2014)	100	J. Nitsch
VIII	UBA: Den Weg zu einem treibhausgasneutralen Deutschland ressourcenschonend gestalten (2017)	GreenEE	ifeu, FhG IWES, CONSIDEO, Dr. [illegible]oer SSG
IX	INES: Erneuerbare Gase – ein Systemupdate der Energiewende (2017)	OptSys	enervis energy advisors GmbH
X	dena: Leitstudie integrierte Energiewende (2018)	TM95	ewi Energy Res. & Scen. gGmbH

„moderate“ climate protection scenarios:
reduction of direct CO_2 emissions ca. 80%

„ambitious“ climate protection scenarios:
reduction of direct CO_2 emissions ca. 95%

Scenario comparison for Germany: assumptions for final energy demand (FED)



Selected scenarios: very different assumptions with respect to FED

→ Unbiased comparison of impacts of different **supply side strategies** requires **harmonisation of demand side** (useful energy & transport services)

Harmonized re-modelling of scenarios: further aspects

- Different studies apply very different models with very different structures, in particular
  - Classification of (end-use) sectors
  - Technologies deployed
- No study reports all the necessary information required for the economic and ecologic impact assessment
- Different assumptions on techno-economic performance of technologies in different studies

→ Harmonized re-modelling of transformation strategies necessary!

Re-modeling approach: Scenario generator MESAP

Socio-economic drivers: GDP, population, living space, ...

Energy intensities per sector and application

Useful energy demand
Industry, Households, Trade & Commerce per application

Transport service
Passenger & freight transport
Road, rail, aviation, navigation

Market Shares:
technologies/
energy carriers

Final energy demand
per application / technology / energy carrier

Market Shares:
technologies/
energy carriers

Conversion sector
generation of power, district heat, synthetic fuels and gases

Primary energy consumption

Techno-economic characterisation:
Efficiency, COP, P2H-ratio, full load hours, costs, emission factors, ...

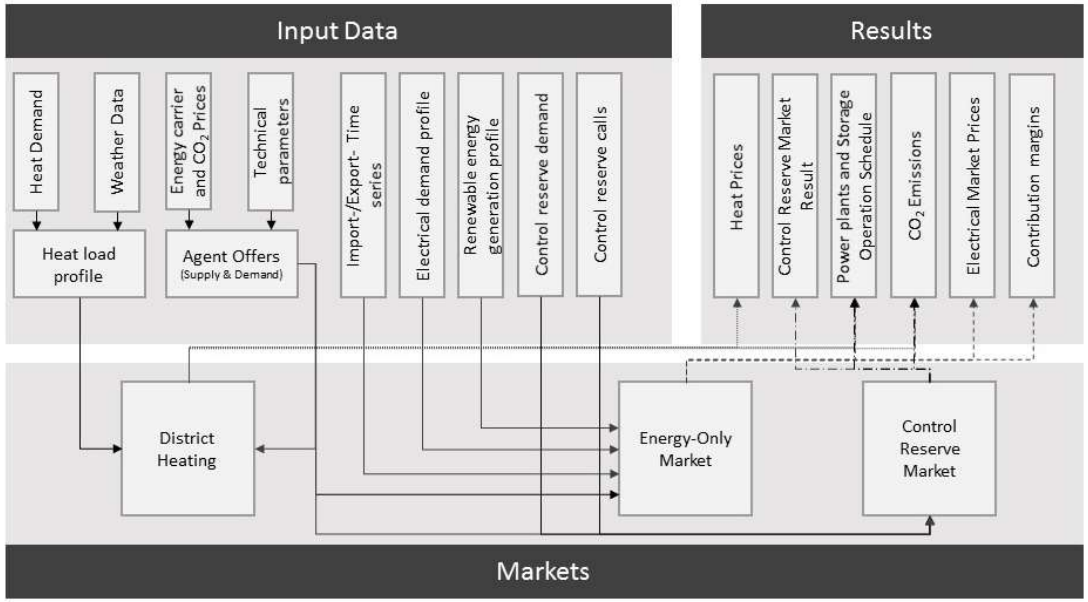
Full load hours
(Power, heat, fuel generation) & storage demand

(Newly) installed capacities
energy & transport technologies

Levelized costs (heat, power), **investment, system costs**

Direct CO_2 emissions

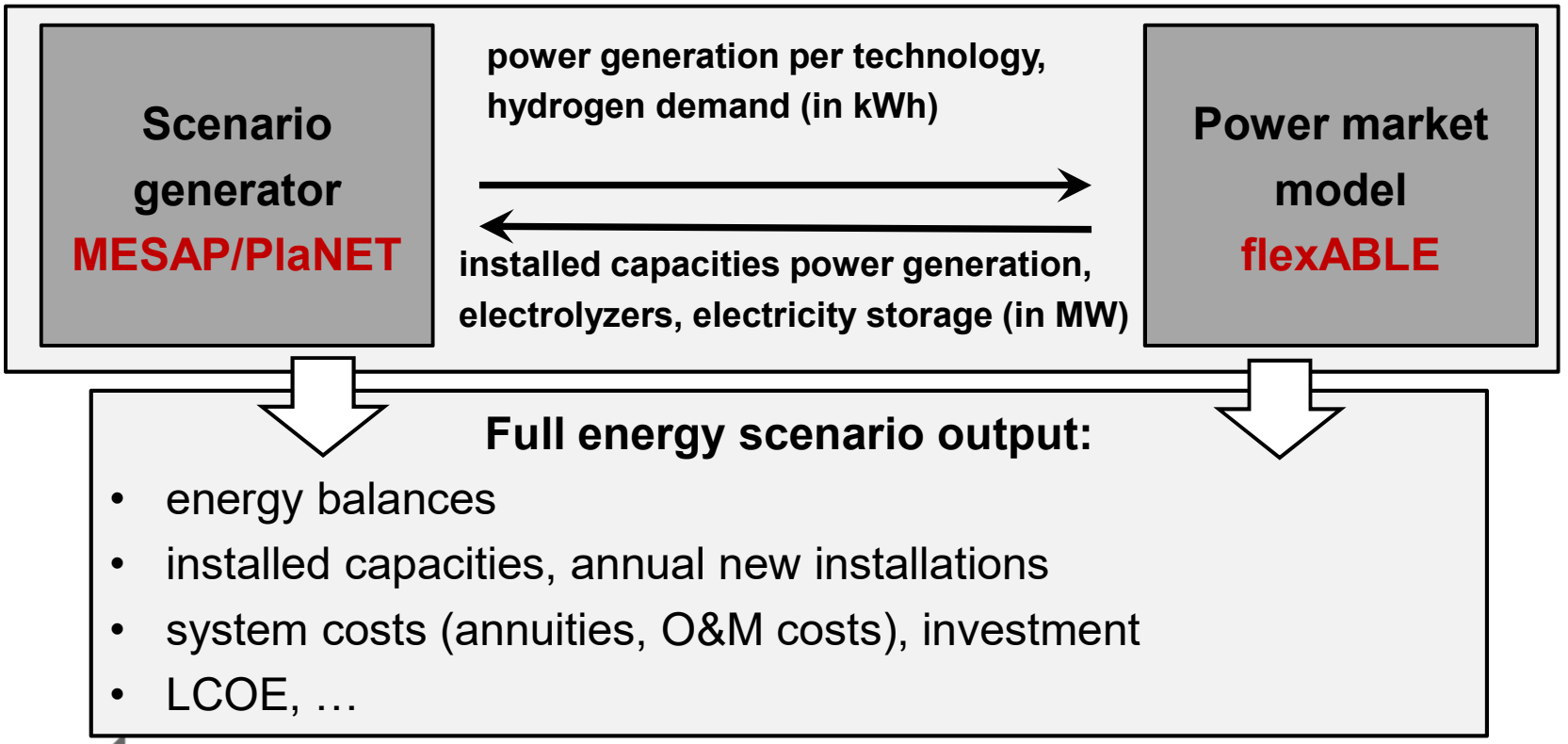
Remodeling approach: Power market model flexABLE



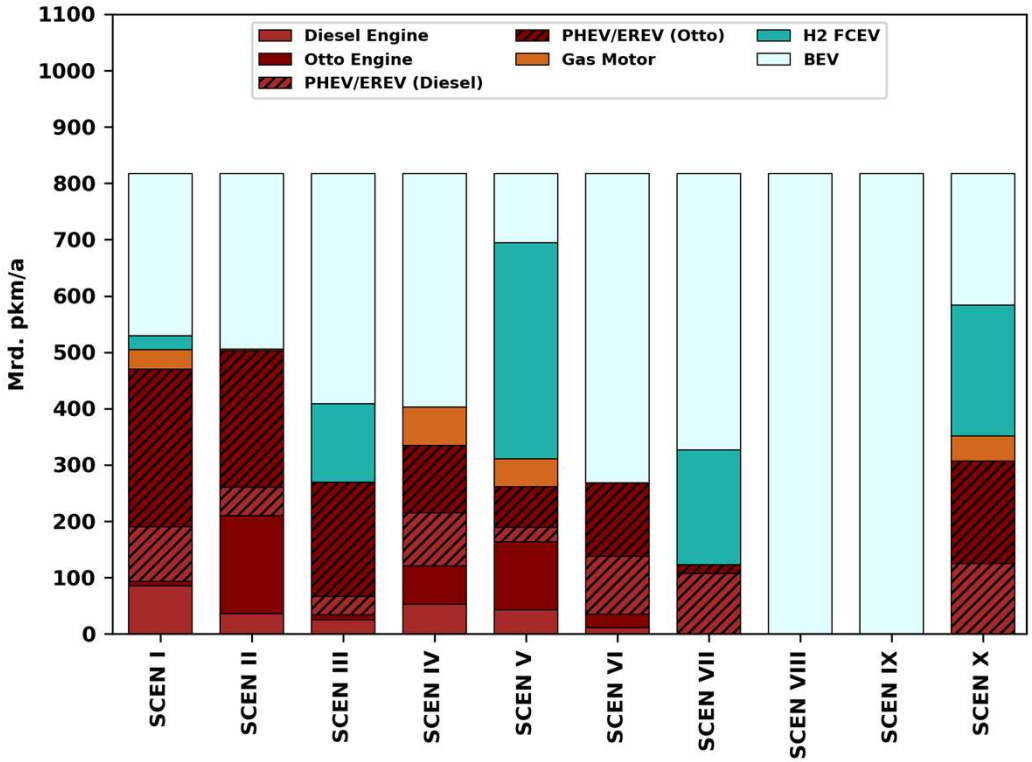
- agent based electricity market simulation model
- time resolution: ¼ hour
- Bottom-up approach, power generation & storage technologies
- Agents formulate bits on both energy-only and control reserve market
- Model calculate market clearance and dispatch of units

(Qussous et al., 2019)

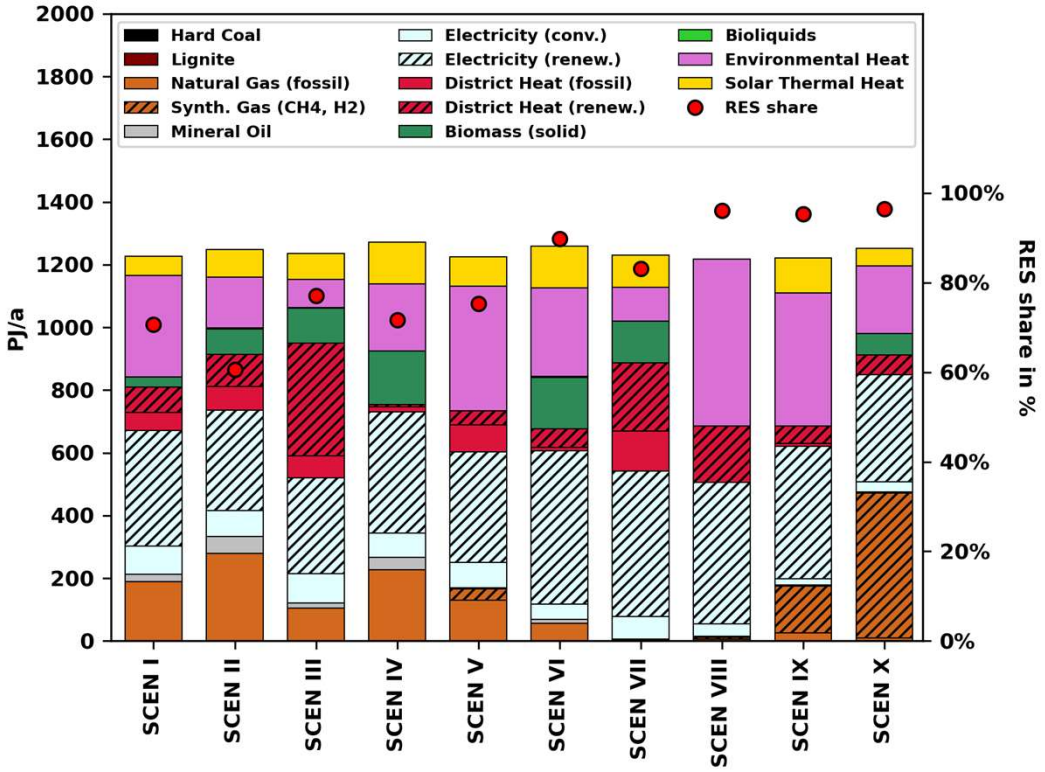
Coupling of MESAP and flexABLE



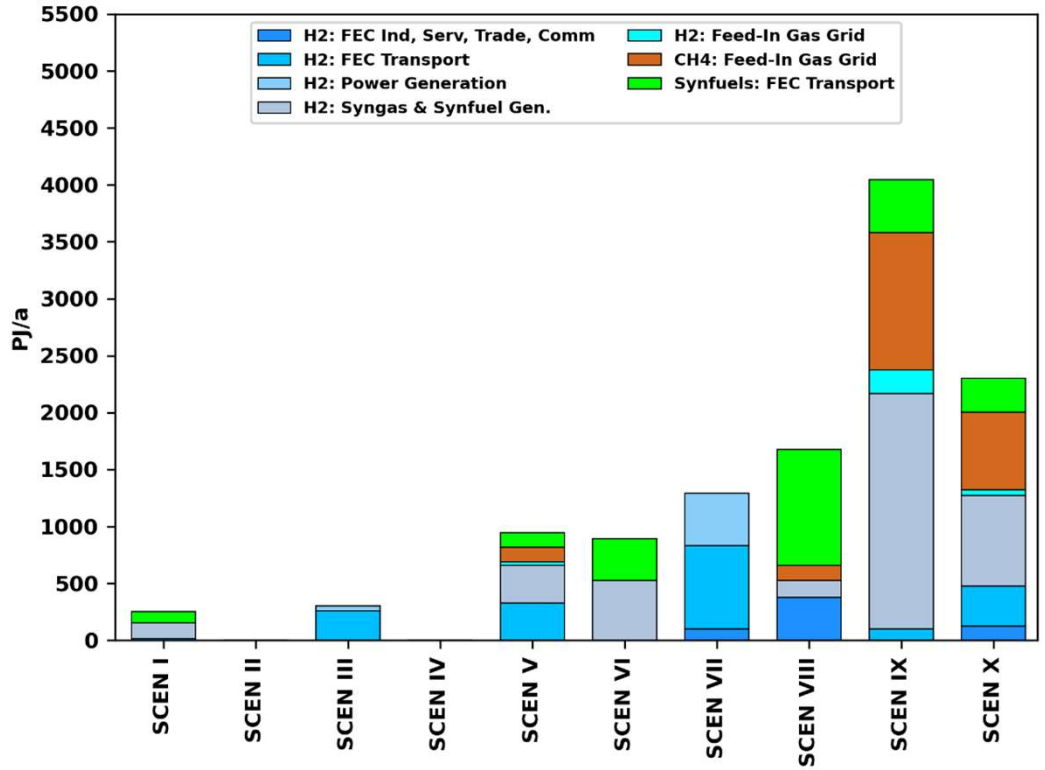
Transport service passenger cars



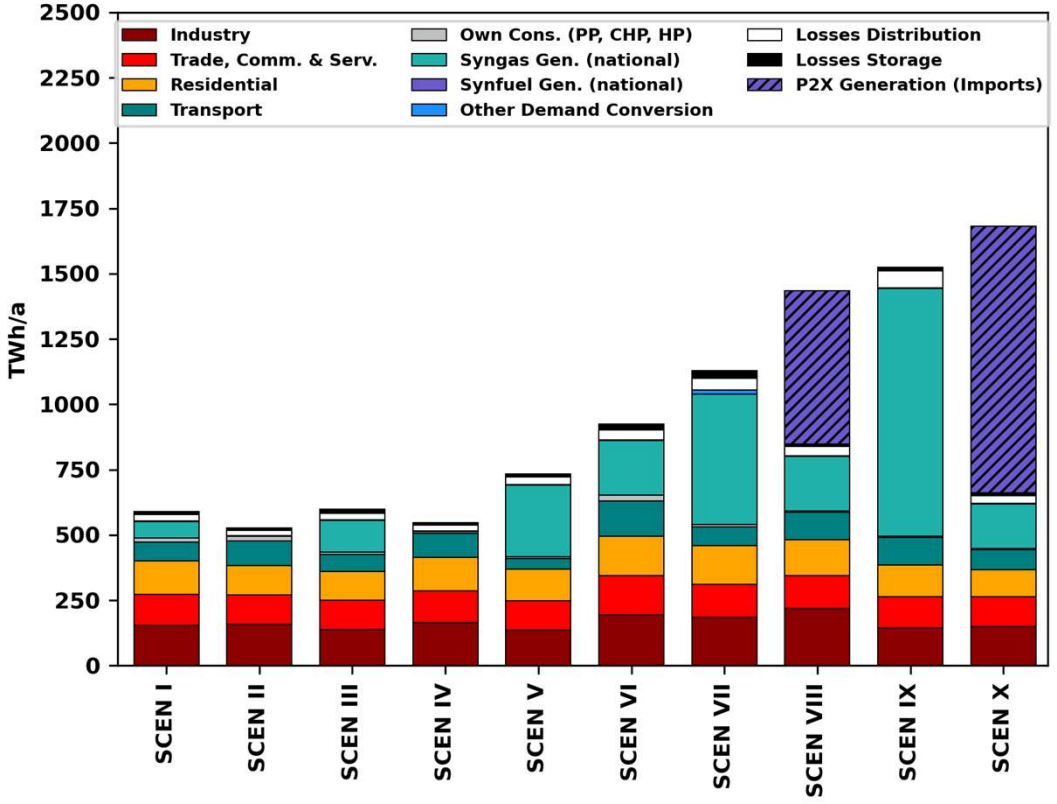
Final energy for space heat (residential sector)



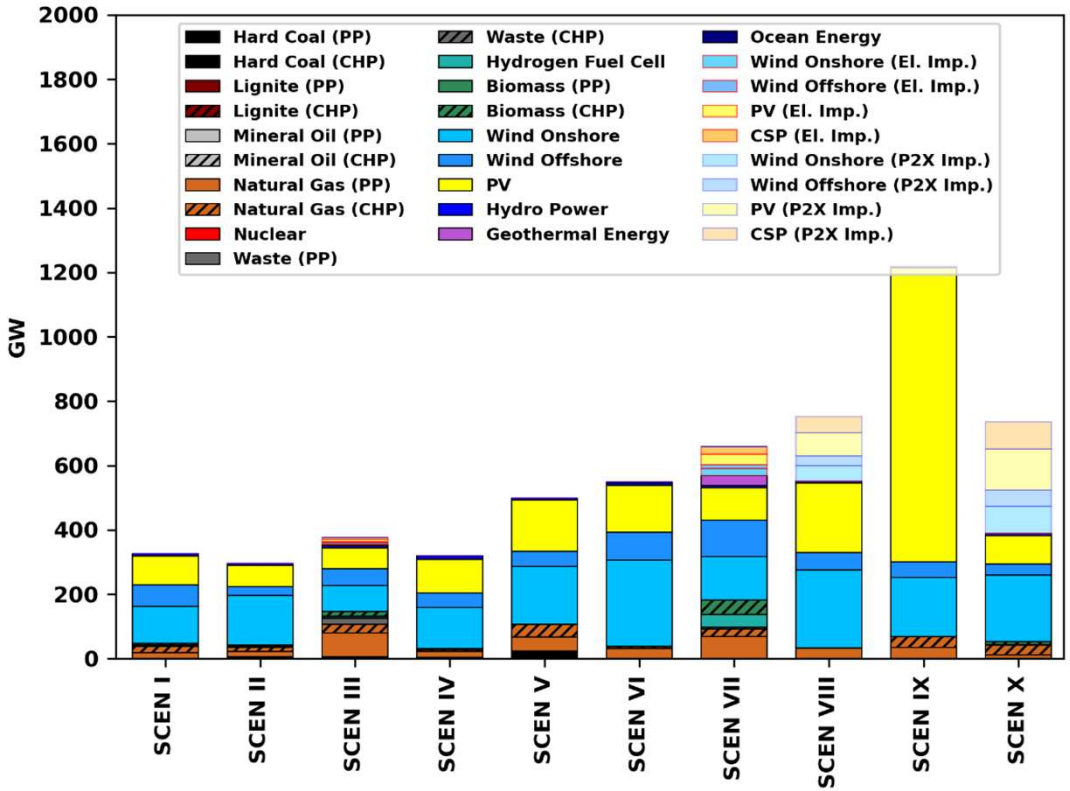
Demand for synthetic fuels and gases



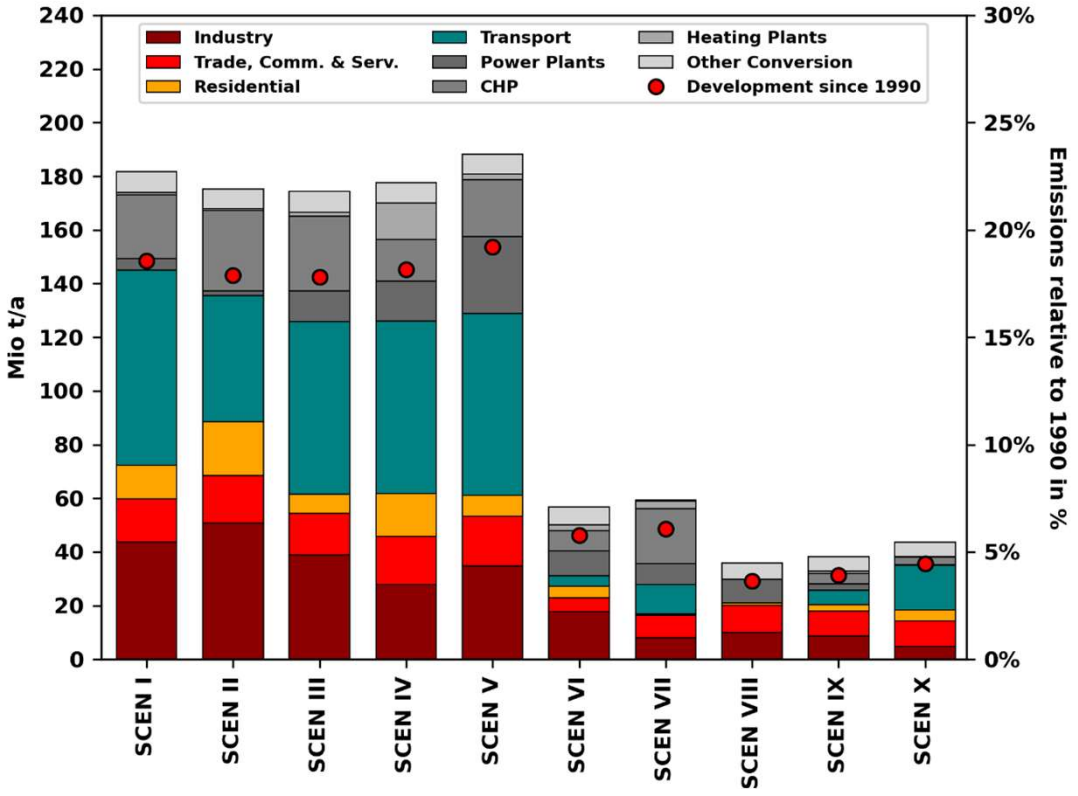
Gross electricity demand per sector



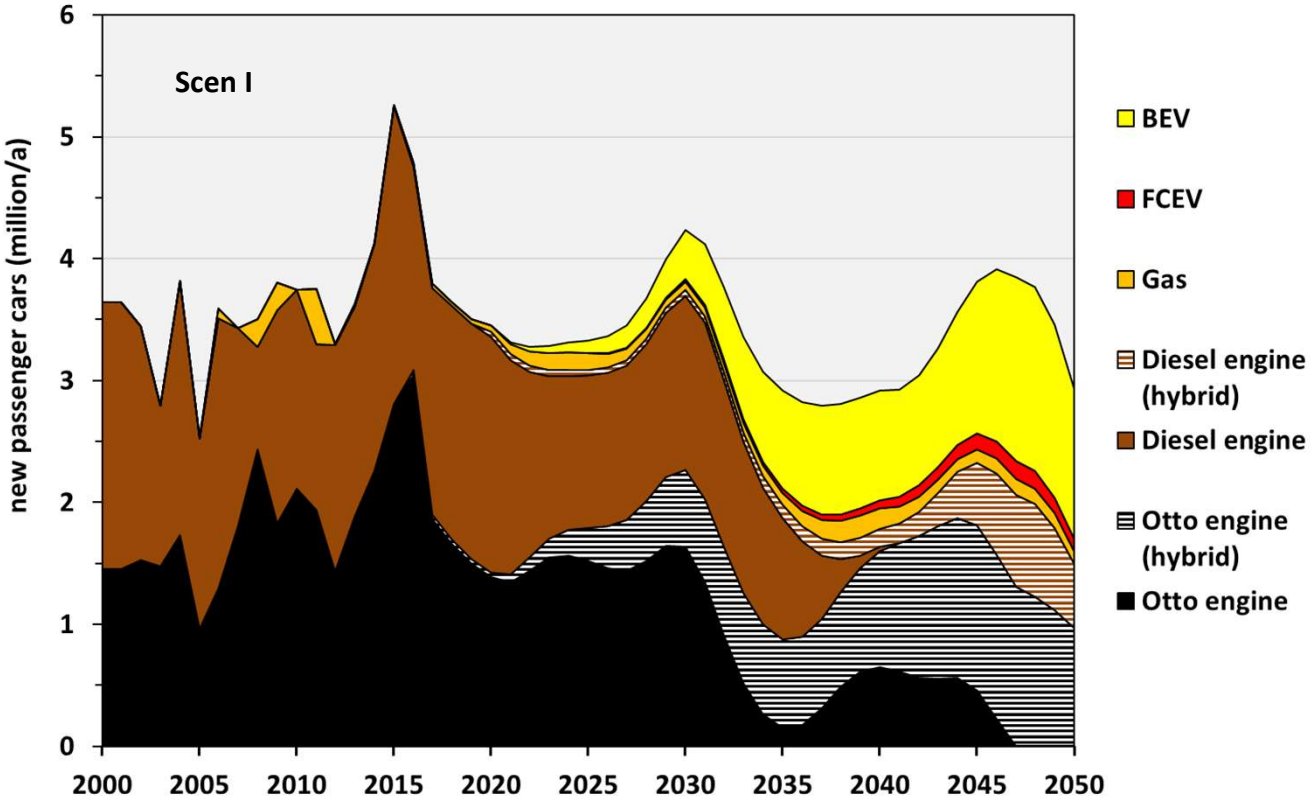
Installed capacities for power generation



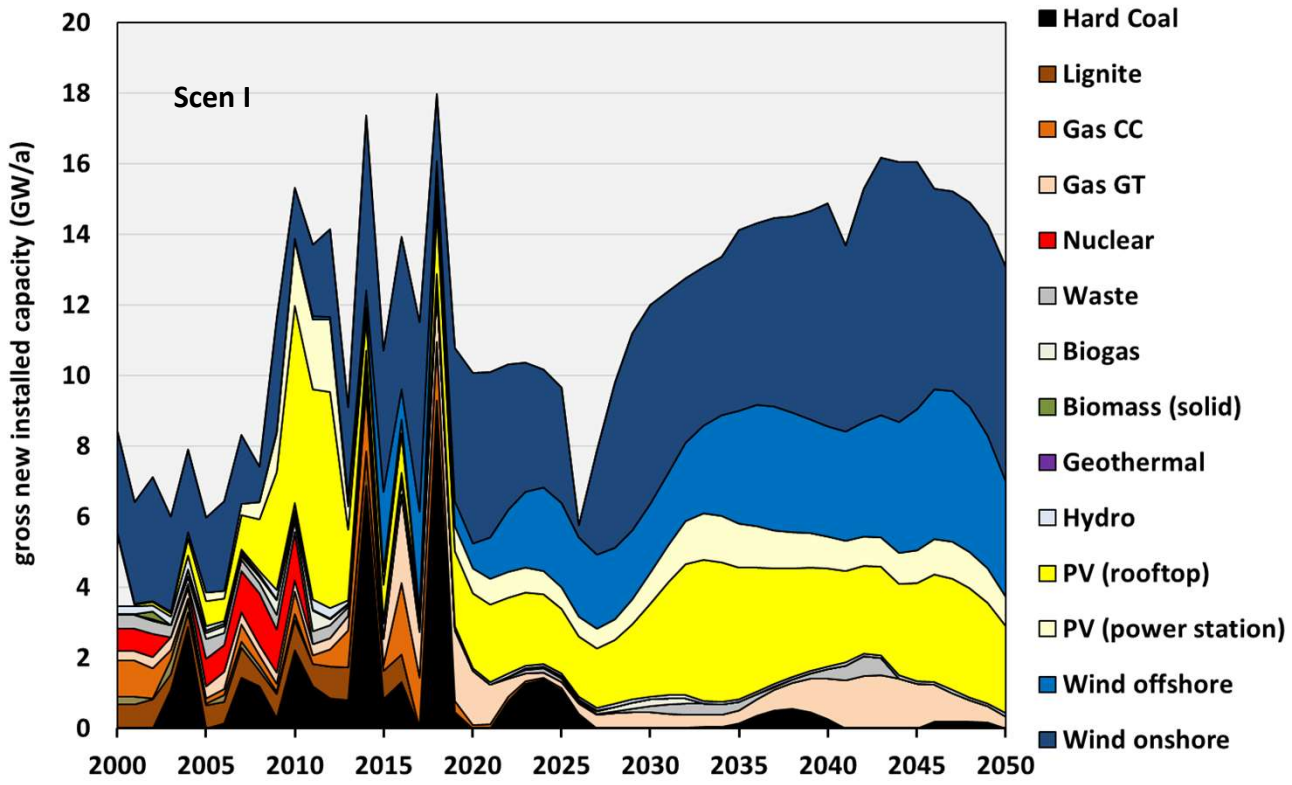
Direct CO_2 emissions per sector



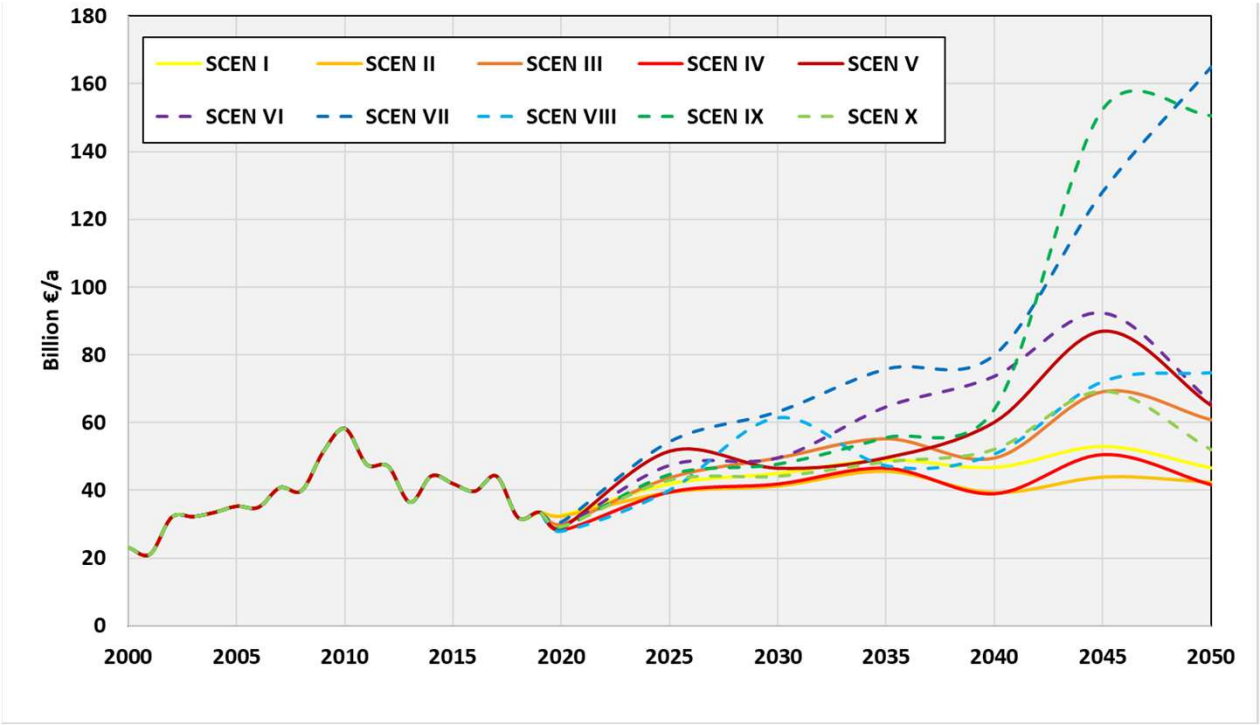
Passenger car market per propulsion technology



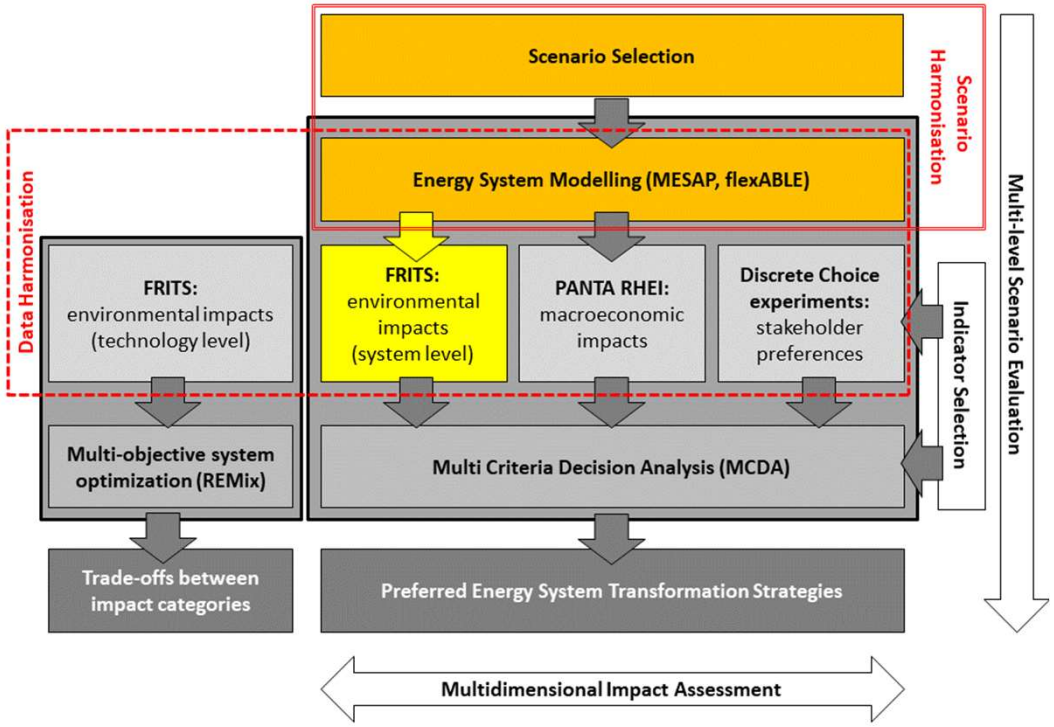
New installed capacities power generation



Invest and O&M costs for power, heat and P2X generation

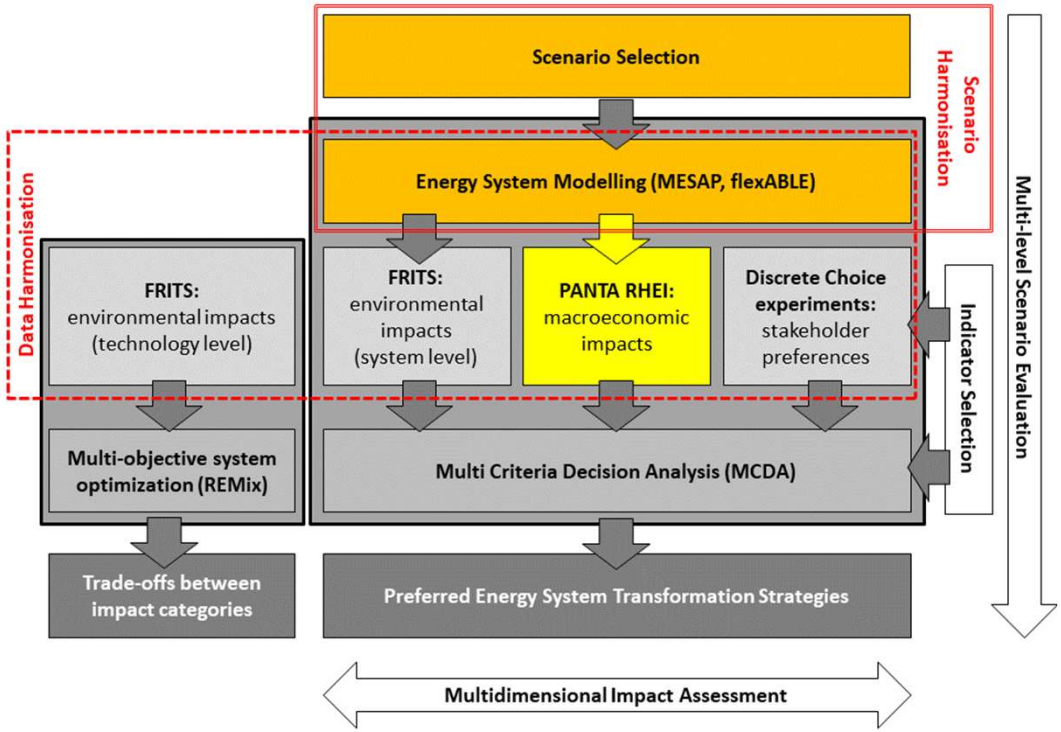


Relevant output for ecologic impact assessment:



- Annual gross new installed capacities (incl. cars and trucks)
- Annual heat, electricity and fuel generation
- Annual mileage transport
- Efficiencies
- …

Relevant output for economic impact assessment:



- Energy carrier & technology mix in each sector
- Annual costs (annuities, O&M costs)
- Annual investment
- Energy imports
- LCOE
- …

Summary: Harmonised re-modeling of selected transformation strategies with MESAP/flexABLE

- Harmonizes assumptions on
  - Socio-economic drivers
  - Useful energy demand and transport services
  - Techno-economic characterizations of energy technologies
  - Fuel and CO_2 prices
- Keeps information on technical strategies (= technology market shares) from original studies and their consequences on system level (e.g. power demand)
- Provides relevant input for further sustainability assessment, in particular economic and ecologic impact assessment

Allows un-biased comparison of ecologic and economic impacts of different supply side transformation strategies!

Thank you very much for your attention!

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