

Development of dynamic scenarios: Depicting path dependencies and nonlinearities within storylines

Philip Mayer¹, Kristina Govorukha¹, Stefan Vögele², Dirk Rübbelke

¹ TU Bergakademie Freiberg, Schloßplatz 1, 09599 Freiberg, Tel.: +49 (0)3731 39 4082

² Forschungszentrum Jülich, Institut für Energie- und Klimaforschung (IEK-STE), Wilhelm-Johnenstraße, 52425 Jülich, Tel.: +49 (0)2461 61 9835

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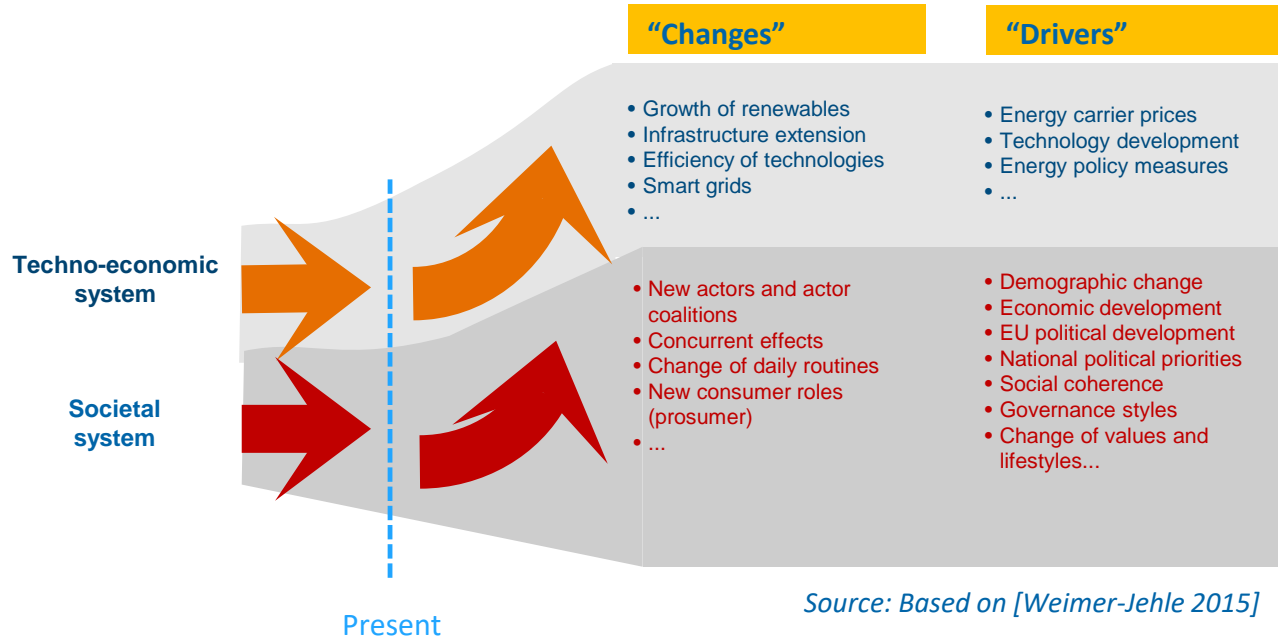
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Structure

1. Motivation and research question
2. Dynamic approach for the construction of storylines
3. Results and quantification
4. Conclusions
5. Reference List

1. Motivation and research question



- Development of system is not driven by economic and technological factors exclusively.
- Changes in the public's perception or acceptance towards technologies play an important role [see e.g. Wüstenhagen et al. 2017, Wittneben 2012].

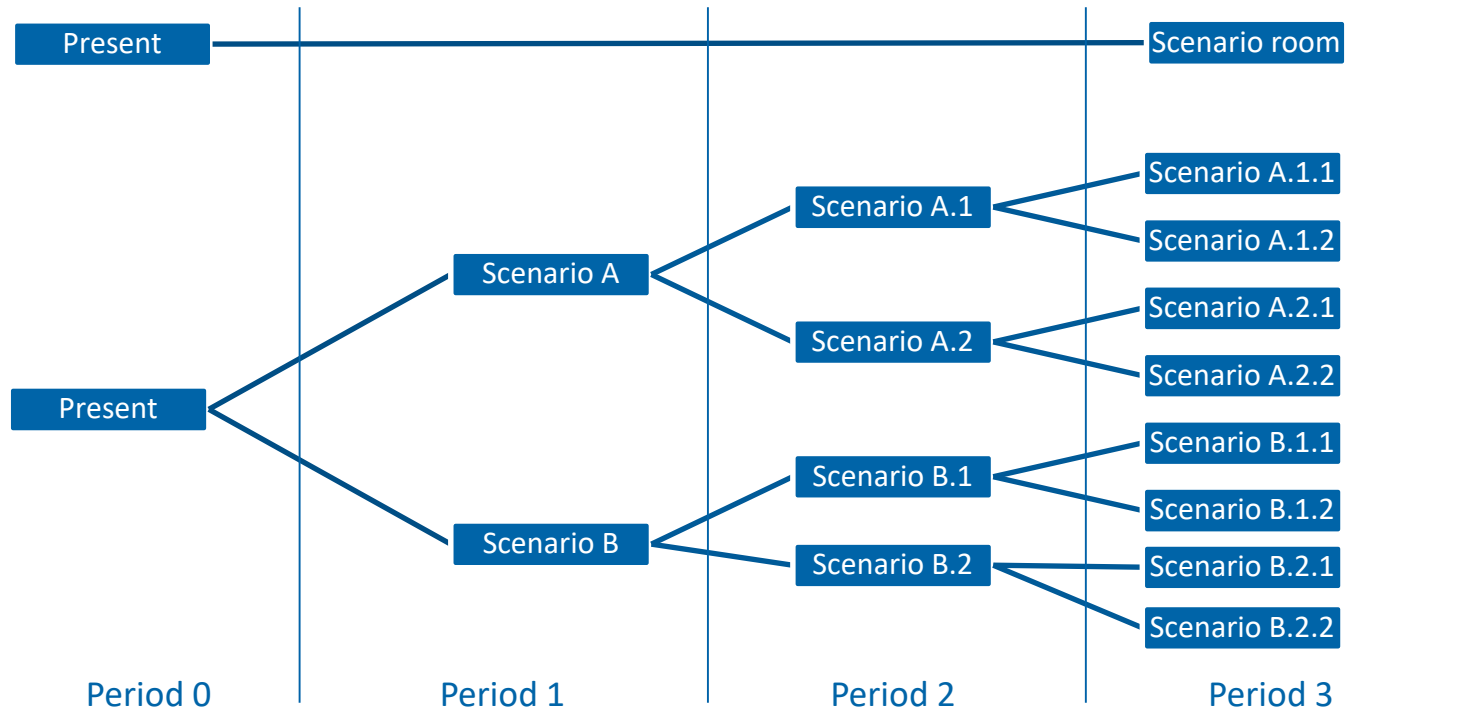
Integrated Context Scenarios

- The combination of consistent narratives with quantitative models offers the opportunity of higher consistency of scenario analysis [see Alcamo 2008]
- Gains from context scenarios:
 - Securing consistency in framework assumptions [see Schweizer&Kriegler 2012] and input parameters [see Weimer-Jehle et al. 2016]
 - Facilitation the process of model coupling
 - Expansion of quantitative modelling frameworks by qualitative aspects
- Cross-Impact Balance (CIB) Analysis:
 - Proved to perform especially robust in the area of energy and climate research [see Weimer-Jehle et al. 2016]

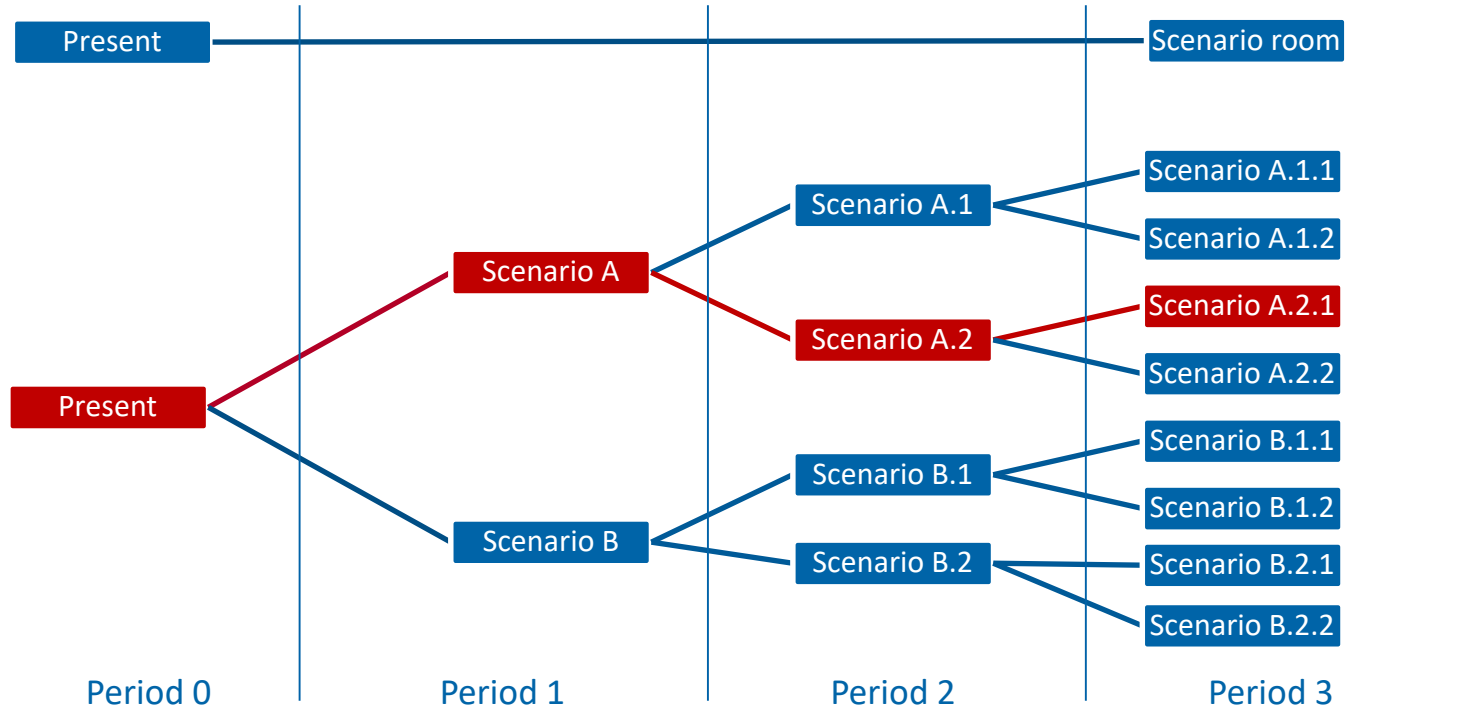
Research Question

- Challenge: CIB produces a snapshot at a given point in time, without explicitly depicting the developments that lead to the described future.
- Question arises how the consideration of dynamic developments can be implemented in the construction of storylines within the CIB methodology.

Identification of possible pathways:



Identification of possible pathways:



Introducing „stock“ and „flow“ descriptors

- **Flow:** Variation of descriptor in period t_n depends on the variation of previous period t_{n-1}
- **Stock:** Interdependencies with other descriptors change, if threshold is reached

Descriptors	Category	Possible variations for the future				
		1	2	3	4	5
Global economic cohesion	static	Protectionism	Open economies	Bilateral trade agreements	-	-
Trade of energy sources	static	Trade restrictions	No trade restriction	-	-	-
Prices for energy commodities	static	Increase	Constant	Decrease	-	-
GDP Growth	flow	Very small increase	Small increase	Moderate increase	High increase	Very high increase
International climate change policy	static	Unambitious	Moderate	Ambitious	-	-
Energy consumption	stock	Slight increase	Moderate increase	Strong increase	-	-

Introducing „stock“ and „flow“ descriptors

➤ Flow Descriptor: GDP Development

		Possible variations in t_{n+1}				
		Very small	Small	Moderate	High	Very High
Variation in t_n	Very small	0	X	0	0	0
	Small	X	0	X	0	0
	Moderate	0	X	0	X	0
	High	0	0	X	0	X
	Very high	0	0	0	X	0

➤ Stock Descriptor: Energy Consumption

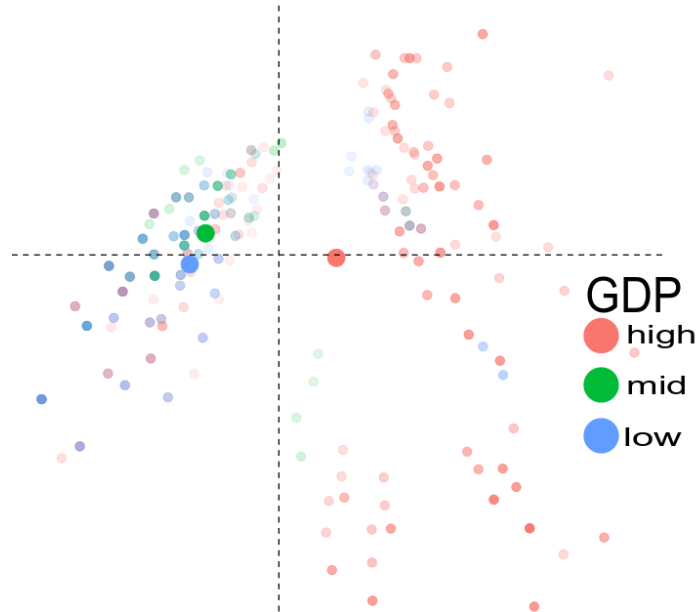
- Threshold: „Very high“ GDP development
- Decoupling of GDP growth and energy consumption
- Translated into CIB methodology by altering cross-impacts between descriptors “Growth of GDP” and “Energy consumption”

Static Scenario Spaces

Original Scenario Space							
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Global Cohesion	protectionism			collaboration		protectionism	collaboration
Trade of Energy Commodities	restricted			not restricted		restricted	
Energy Commodity Prices	constant						high
GDP Growth	very small	small	moderate	high	very high	moderate	high
Climate Policy	moderate					ambitious	
Energy Cons.	moderate increase						strong increase

Modified Scenario Space								
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Global Cohesion	collaboration		protectionism			collaboration		protectionism
Trade of Energy Commodities	not restricted		restricted			not restricted		restricted
Energy Commodity Prices	low		constant					
GDP Growth	very high		very small	small	mod	high	very high	mod
Climate Policy	unambitious	moderate						
Energy Cons.	slight increase		moderate increase					

Expansion of the scenario space



- Dynamic approach reveals 556 possible developments.
- Scenarios with higher GDP growth (25th percentile) appear to be clustered.

Quantification of the development paths

EMME – Electricity market optimization model for dispatch and investment

➤ Objective function:

$$Z = \sum_{h,i,d} Pr(h, i, d) \cdot Cst(i, d) + \sum_{h,d,k} Im(h, d, k) \cdot T + \sum_{i,d} Inv(i, d) \cdot Cap(i, d) \quad (1)$$

➤ Subject to:

$$\sum_i [Pr(h, i, d)] - \sum_k Im(h, d, k) + \sum_j Im(h, j, d) = Dm(h, d) \quad (2)$$

$$Pr(h, i, d) \leq Cp(h, i, d) \quad (3)$$

$$Im(h, i, d) \geq NTC(j, k) \quad (4)$$

Quantification of the development paths

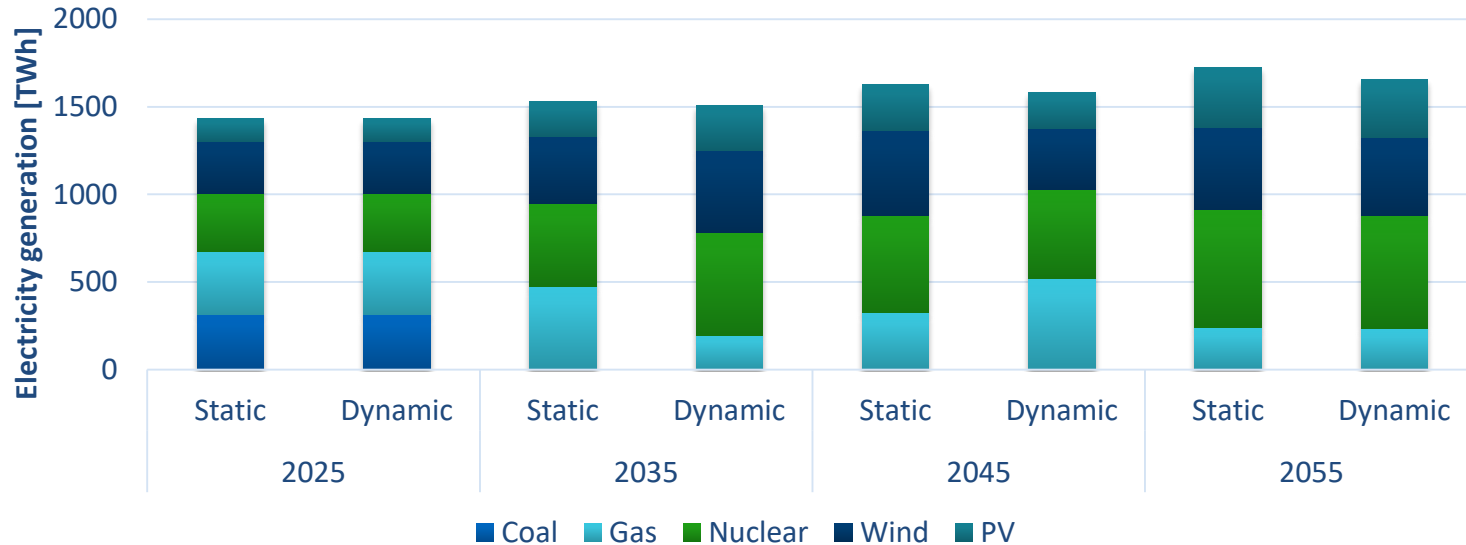
➤ Static Scenario:

Descriptor/Period	2025	2035	2045	2055
Global Cohesion	collaboration			
Trade of Energy Commodities	not restricted			
Energy Commodity Prices	constant			
GDP Growth	high growth			
Climate Policy	moderate			
Energy Consumption	moderate increase			

➤ Dynamic Scenario:

Descriptor/Period	2025	2035	2045	2055
Global Cohesion	protectionism		collaboration	
Trade of Energy Commodities	restricted		not restricted	
Energy Commodity Prices	constant		low	constant
GDP Growth	high	moderate	very high	high
Climate Policy	moderate	ambitious	low	moderate
Energy Consumption	moderate increase		slight increase	moderate increase

Quantification of the development paths



Exploring new development paths

- Introducing dynamic developments into the CIB methodology provides new insights on a multitude of consistent trajectories

- Constructing pathways within the storyline enables the scenario analysis to depict more differentiated developments, with respect to:
 - Political changes: e.g. policy or regime shifts (as defined by [Strunz 2014])
 - Technological aspects: e.g. windows of opportunity for emerging or controversial technologies (with respect to acceptance or public perception)
 - System tipping points: e.g. irreversible transitions

Thank you for your attention!
Looking forward to your comments and questions.

5. References List

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