POSSIBLE FUTURES FOR GERMANY'S ELECTRICITY INFRASTRUCTURE FROM A SOCIO-TECHNICAL PERSPECTIVE

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Motivation

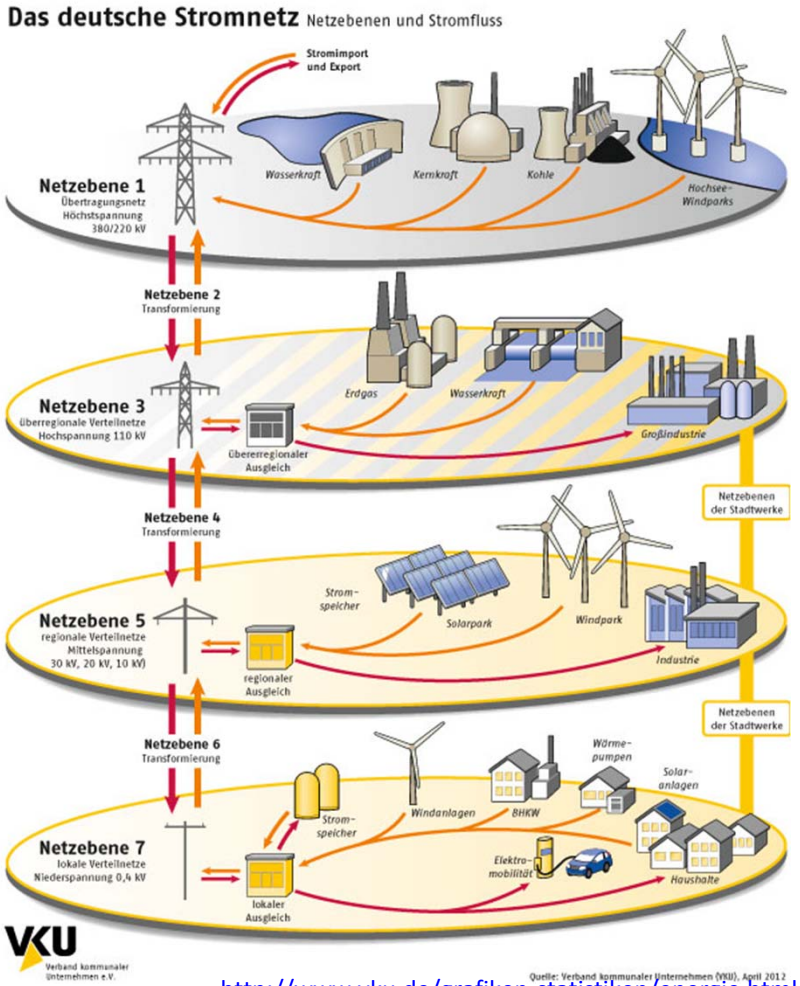
- Germany‘s energy system is in a state of transition *Energiewende* (& ist targets…)

- Electricity sector: not only RES↑, also requires **other infrastructures** to change/expand in a coherent manner:
  - Transmission, distribution grids
  - IT infrastructure
  - Demand-side infrastructure

Postulations

- **Postulation 1:** Infrastructure design determines „what is possible“ / sets technical boundaries, e.g.
  - DSM requires smart grids
  - Pan-European balancing require transmission grid capacities

- **Postulation 2:** Different infrastructure configurations are consistent with different visions of the future system logic
  - „Decentralized paradigm“
  - „Centralized paradigm“



http://www.vku.de/grafiken-statistiken/energie.html

Motivation

- Electricity-related infrastructure is highly path-dependent and resistant to transformational changes (Markard, 2011)

→ Need for anticipated planning!

- Electricity-related infrastructure has an embedded societal dimension, e.g.
  - Generation and grids are highly visible
  - Demand side ↔ user behavior
  - IT ↔ big data

→ Socio-technical system (Hughes, 1987)

Problem Statement

- Such issues neglected in existing mitigation scenario work (with quantitative models)

The aim of this paper is to
develop and analyze a set of long-term scenarios for possible future developments of the German electricity infrastructure
that acknowledge its socio-technical character to a greater extent than is done to date.

- Potentially these scenarios can be used as a basis in a societal communication process

Research Questions

1. Which **infrastructure-related challenges** arise in possible low-carbon futures from a socio-technical perspective?

2. What are **consistent** infrastructure-futures?

3. Which infrastructure-related path dependencies are particularly resistant to change, constituting **bottlenecks** in the transition?

Applied Methods

- Qualitative approach to scenario development and analysis to explore the option space for Germany's electricity infrastructure

- Scenario development: Combination of
  - [Logic] Field anomaly relexation (FAR) (Rhyne, 1995)
  - [Software] Cross-impact-balance (CIB) matrix (Weimer-Jehle, 2006)
- Scenario analysis:
  - Branching point analysis (Foxon et al, 2013)

Branching Points

"Branching points are defined as **key decision points** in a pathway at which **actors' choices**, made in response to internal or external pressures, determine whether and in what ways the pathway is followed" (Foxon, 2013, p.147)

- Historical branching points (BP) that determined pathway followed by German electricity sector:
  - ***BP 1: Want to mitigate greenhouse gas emissions in the energy sector***
  - ***BP 2: Want to liberalize the European electricity sector***
  - ***BP 3: Want to support renewable energy deployment***
  - ***BP 4: Societal want to phase-out nuclear power***

Research Questions

1. Which **infrastructure-related challenges** arise in possible low-carbon futures from a socio-technical perspective?

1. Selection of scenario determinants for German electricity system

I. RES generation large-scale („centralized“)
II. Local RES generation („decentralized“)

III. Residual load provision
IV. European Transmission Grid Integration
V. Distribution Grid & Intelligent /Smart Solutions
VI. Storage

VII. Demand-Side Paradigm: Towards Energy Services?

Today: $S_1P_1R_1I_1D_1L_1E_1$

(i) Selection of scenario determinants

Storage Deployment	Residual Load **P**rovision	Large-scale **R**enewables	Pan-European Grid **I**ntegration	Smartening the **D**istribution Grid	**L**ocal Renewable Energy	Future **E**nergy Services
S	**P**	**R**	**I**	**D**	**L**	**E**
S1: Some - especially short-term	**P1:** "Baseload-band"	**R1:** Selected technologies (e.g. offshore)	**I1:** Very little progress	**D1:** Pilots – mainly grid expansion	**L1:** Stagnation	**E1:** Little public consciousness on services
S2: Break-through in medium-term storage	**P2:** "Flexible, but high FLH!"	**R2:** Dedicated deployment in periphery	**I2:** PCI's and beyond	**D2:** Intelligent distribution grid (passive)	**L2:** Dedicated & diversified increase	**E2:** Shift in some sectors where convenient
S3: Break-through in long-term storage	**P3:** "Residual system"	**R3:** Europe-wide coordinated exploitation	**I3:** Security of Supply on European level	**D3:** Smart distribution grid (active)	**L3:** Dispersed solutions mainstream	**E3:** New demand-side paradigm

Research Questions

2. What are **consistent** infrastructure-futures?

Using the Scenario Wizard

1)

Deskriptoren:	Variante [1]	Variante [2]	Variante [3]
S. Storage Deployment	S1 Some - especially short-term	S2 Breakthrough in medium-term storage	S3 Breakthrough in long-term storage
P. Residual Load Provision	P1 Baseload-Band	P2 Flexible but high full load hours	P3 Residual system
R. Large-scale Renewables	R1 Selected technologies	R2 Dedicated deployment in periphery	R3 Europe-wide coordinated exploitation
I. Pan-European grid Integration	I1 Very little progress	I2 PCI's and beyond	I3 Security of Supply on European level
D. Smartening the distribution grid	D1 Pilots- mainly grid expansion	D2 Intelligent distribution grid	D3 Smart grid and market
L. Local Renewable Energy	L1 Stagnateion at 2017 level	L2 Dedicatd & diversified increase	L3 Dispersed solutions mainstream
E. Future Energy Services	E1 Little public consciousness	E2 Shift in sectors where convenient	E3 New demand-side paradigm

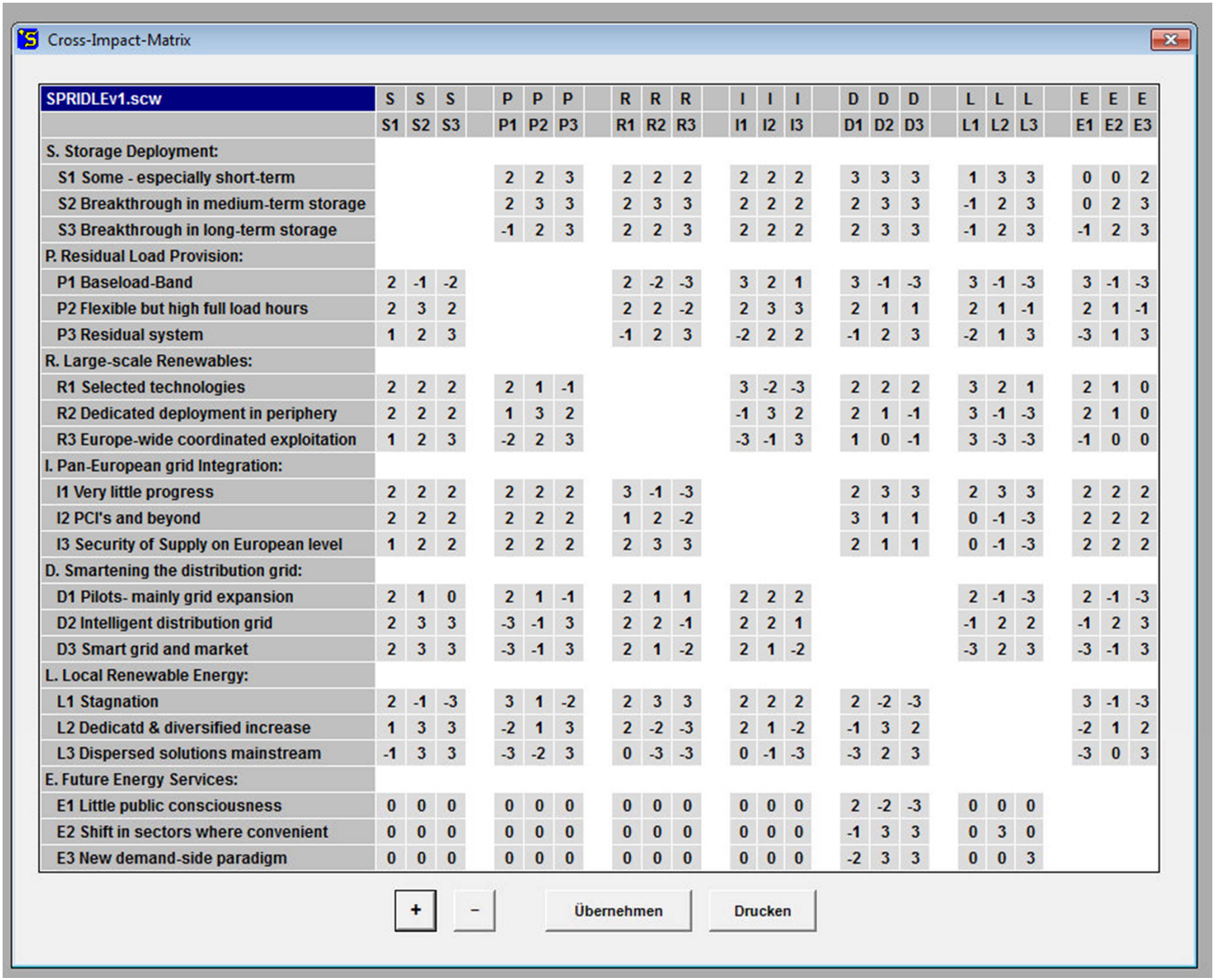
2)

In a world with a lot of A – can I imagine B ? **[gestalt criterion]**

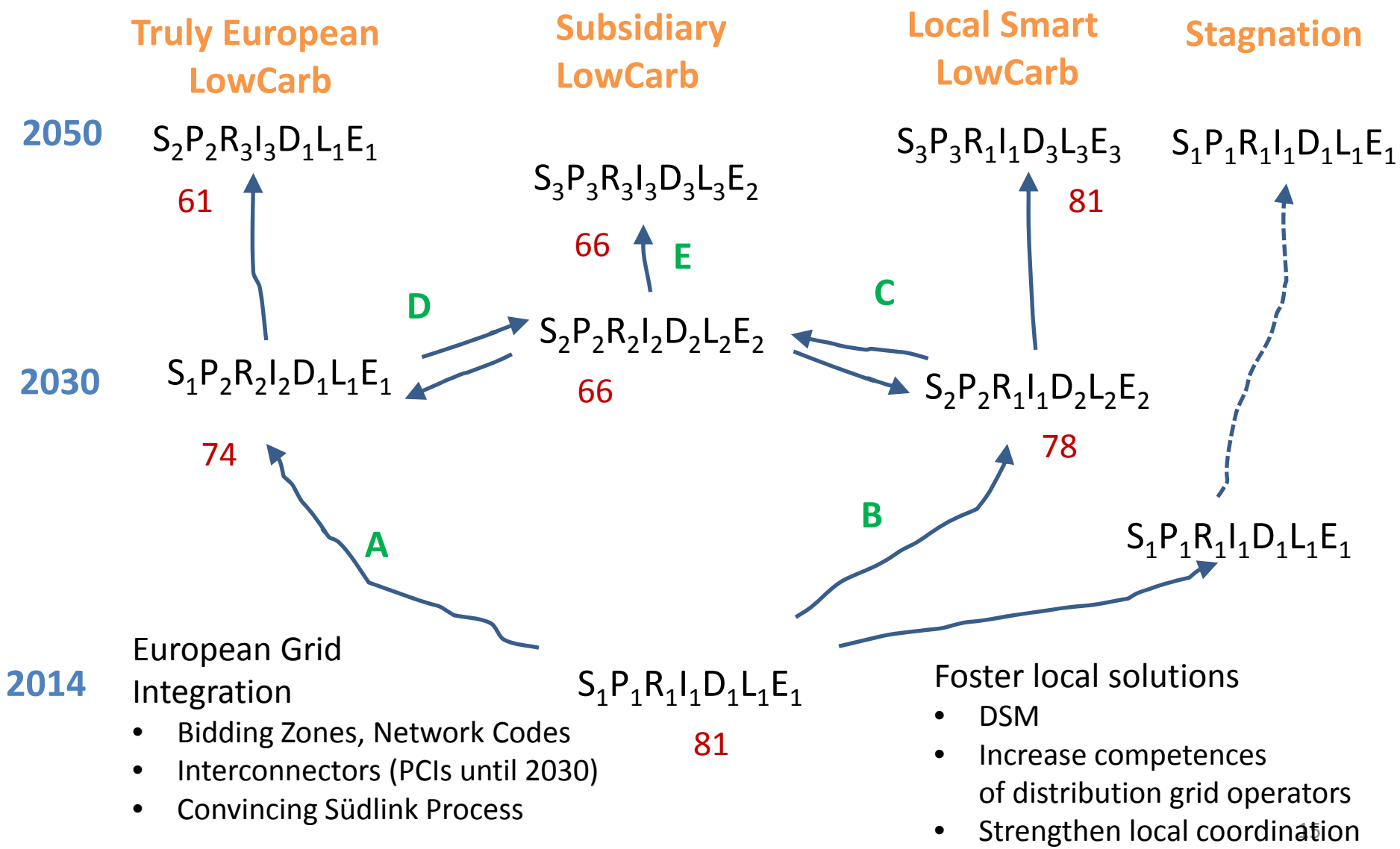
+3: Hell, yes!
+2: Yes
+1: Maybe
0: Have nothing to do with each other
-1: Maybe not
-2: No
-3: Really not!

<u>gestalt-formation process:</u>
the active rendering of
the chaotic world
of stimuli into
useable, organized wholes
or meaningful units

http://www.gestaltpress.com/culture-self-and-field-a-gestalt-guide-to-the-age-of-complexity/


Cross-Impact-Matrix
SPRIDLEv1.scw
S S S P P P R R R I I I D D D L L L E E E
S1 S2 S3 P1 P2 P3 R1 R2 R3 I1 I2 I3 D1 D2 D3 L1 L2 L3 E1 E2 E3
S. Storage Deployment:
S1 Some - especially short-term 2 2 3 2 2 2 2 2 2 3 3 3 1 3 3 0 0 2
S2 Breakthrough in medium-term storage 2 3 3 2 3 3 2 2 2 2 3 3 -1 2 3 0 2 3
S3 Breakthrough in long-term storage -1 2 3 2 2 3 2 2 2 2 3 3 -1 2 3 -1 2 3
P. Residual Load Provision:
P1 Baseload-Band 2 -1 -2 2 -2 -3 3 2 1 3 -1 -3 3 -1 -3 3 -1 -3
P2 Flexible but high full load hours 2 3 2 2 2 -2 2 3 3 2 1 1 2 1 -1 2 1 -1
P3 Residual system 1 2 3 -1 2 3 -2 2 2 -1 2 3 -2 1 3 -3 1 3
R. Large-scale Renewables:
R1 Selected technologies 2 2 2 2 1 -1 3 -2 -3 2 2 2 3 2 1 2 1 0
R2 Dedicated deployment in periphery 2 2 2 1 3 2 -1 3 2 2 1 -1 3 -1 -3 2 1 0
R3 Europe-wide coordinated exploitation 1 2 3 -2 2 3 -3 -1 3 1 0 -1 3 -3 -3 -1 0 0
I. Pan-European grid Integration:
I1 Very little progress 2 2 2 2 2 2 3 -1 -3 2 3 3 2 3 3 2 2 2
I2 PCI's and beyond 2 2 2 2 2 2 1 2 -2 3 1 1 0 -1 -3 2 2 2
I3 Security of Supply on European level 1 2 2 2 2 2 2 3 3 2 1 1 0 -1 -3 2 2 2
D. Smartening the distribution grid:
D1 Pilots- mainly grid expansion 2 1 0 2 1 -1 2 1 1 2 2 2 2 -1 -3 2 -1 -3
D2 Intelligent distribution grid 2 3 3 -3 -1 3 2 2 -1 2 2 1 -1 2 2 -1 2 3
D3 Smart grid and market 2 3 3 -3 -1 3 2 1 -2 2 1 -2 -3 2 3 -3 -1 3
L. Local Renewable Energy:
L1 Stagnation 2 -1 -3 3 1 -2 2 3 3 2 2 2 2 -2 -3 3 -1 -3
L2 Dedicatd & diversified increase 1 3 3 -2 1 3 2 -2 -3 2 1 -2 -1 3 2 -2 1 2
L3 Dispersed solutions mainstream -1 3 3 -3 -2 3 0 -3 -3 0 -1 -3 -3 2 3 -3 0 3
E. Future Energy Services:
E1 Little public consciousness 0 0 0 0 0 0 0 0 0 0 0 0 2 -2 -3 0 0 0
E2 Shift in sectors where convenient 0 0 0 0 0 0 0 0 0 0 0 0 -1 3 3 0 3 0
E3 New demand-side paradigm 0 0 0 0 0 0 0 0 0 0 0 0 -2 3 3 0 0 3
+
-
Übernehmen
Drucken

(ii/iii) possible timeline & branching points



(iii) Tentative characterization of branching points

Branching Point	Theme	Key actors
A	**Want to realize a European energy transition**	Incumbent Utilities, Large Corporations
B	**Want to realize a local / regional energy transition**	Citizens, local actors, start-ups
C: „Local smart can‘t make it all the way“	Full potential of local/smart not accessible (legal/institutional barriers): **Need to move towards European solutions**	
D: „European Gridlock“	No majority in Europe for ultimate European solutions: **Need to move towards local solutions**	
E: Diversify!	All solutions are needed	

Possibilities

- Analyze scenarios from the perspective of institutional change
  - Which development are necessary conditions?
  - Which developments are sufficient conditions?
- Possibility to switch between trajectories
- Different CIMs lead to different scenarios!!
- Accessible for non-modelers as structured basis for discussion

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FONA
Forschung für nachhaltige Entwicklungen
BMBF

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

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