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Competing technological innovation systems as a challenge for mission-oriented innovation policy - insights from the German "Energiewende"

„They always say time changes things, but you actually have to change them yourself"

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Content

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1 Problem

- **Societal challenges** like environmental problems are the center of contemporary Science Technology & Innovation (STI) policy.
- **A new mission-oriented approach’** leads to a technology non-specific policy design assigned to a variety of technological solutions
- **Policy challenges**: choices, dynamics of technologies, steering, timing and monitoring of processes and instruments, unequal framework-conditions and prerequisites

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2 New missions and grand challenges for STI policy

- **Traditional mission-oriented policy:** Aims to build up big science and technological areas like aerospace or nuclear energy, where a huge research infrastructure and massive financial support are necessary (Freeman and Soete, 2004; Gassler, Polt and Rammer, 2008).

- **New mission-oriented policy:** Priority setting is thematically oriented to serve specific societal needs (“grand challenges”). Tries to find solutions without pre-selecting or treating technological options preferentially.

2 New missions and grand challenges for STI policy

Grand challenges…

- …are based upon societal needs and political will.
- ...require system transformations that encompass economic, technological and social dimensions.
- ... have many different technological solutions with the ablity to solve the same problem.

Grand challenges call for a new STI policy.

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3 Analytical Framework: Competing Technological Innovation Systems

Two different Approaches:

- **TIS:** Systemic framework concerned with the emergence of new technologies, their respective system as well as the system's internal dynamics.

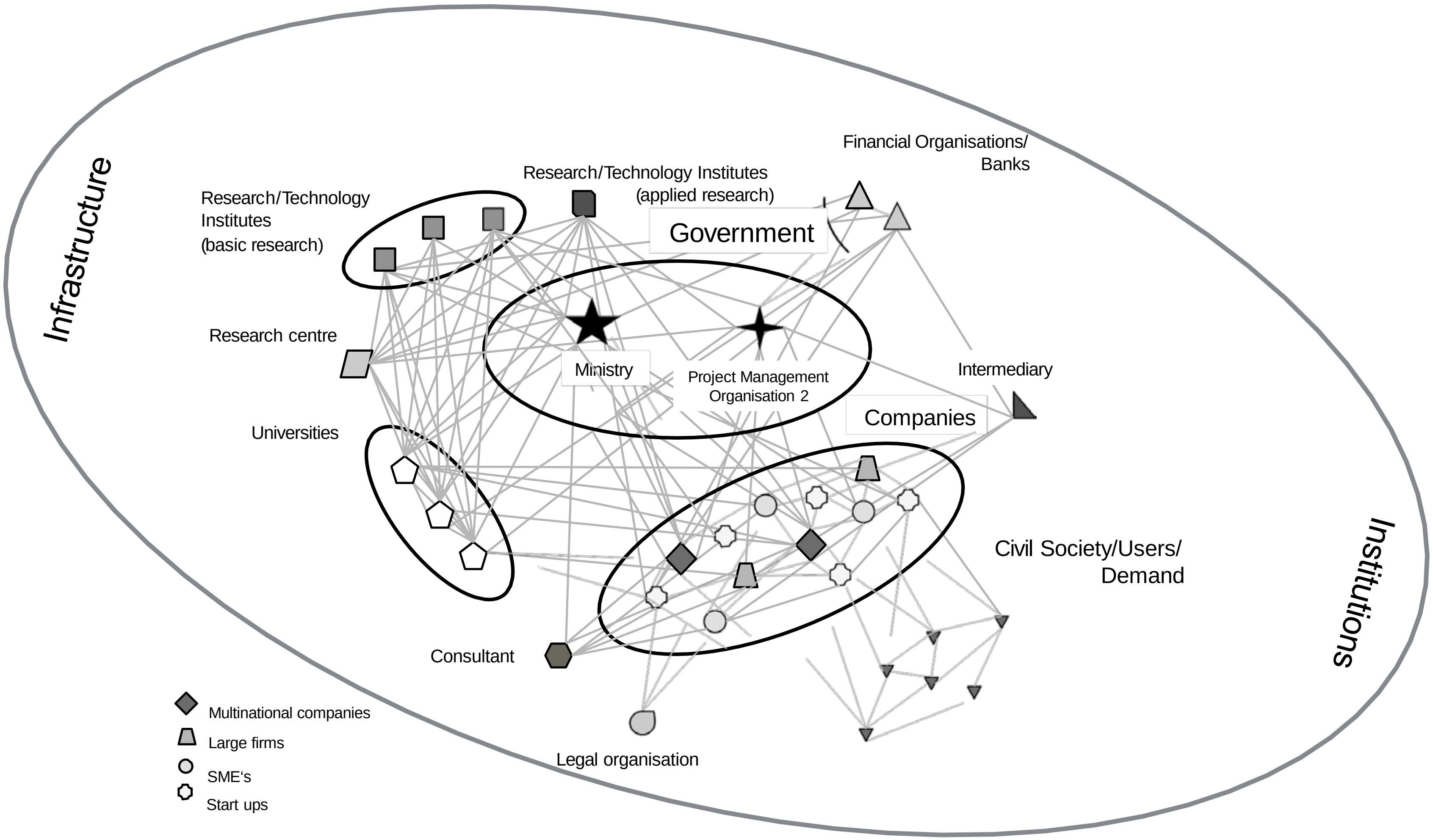
- **Dynamic Approach:** Framework to explain radical and large-scale changes in socio-technical systems, identifies intervention points in terms of systemic failures but also focus on the timing and utilization of "windows of opportunity" (Rip & Kemp 1998; Sartorius & Zundel 2005).

3.1 Technological Innovation Systems (TIS)

" [...] *A dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology*" (Carlsson and Stankiewics, 1991:93).

- **Focuses on internal activities and processes that contribute to the overall development of TIS.**
- System elements can be seen as <u>sub-functions</u> of the system. Operationalization becomes possible.
- All TIS functions need to be given to develop properly.

Schematic Representation



Source: own elaboration based on Wieczorek & Hekkert, 2012

Functional & Structural Analysis

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Source: own elaboration based on Wieczorek & Hekkert, 2012 / Hekkert et al. 2007

Technological Innovation Systems (TIS)

- Creates manageable sub-problems within the respective innovation system (Borrás and Equist, 2013).

But…

- …little attention on the interaction between TIS has been given so far.
- …no dynamic perspective.

Studying TIS brings:

1. Insights about interfaces and inaction processes
2. The ability to operationalize new missions into sub-goals
3. The ability to concrete and specify policies

3.2 Dynamic Approach

Multi-level Perspective

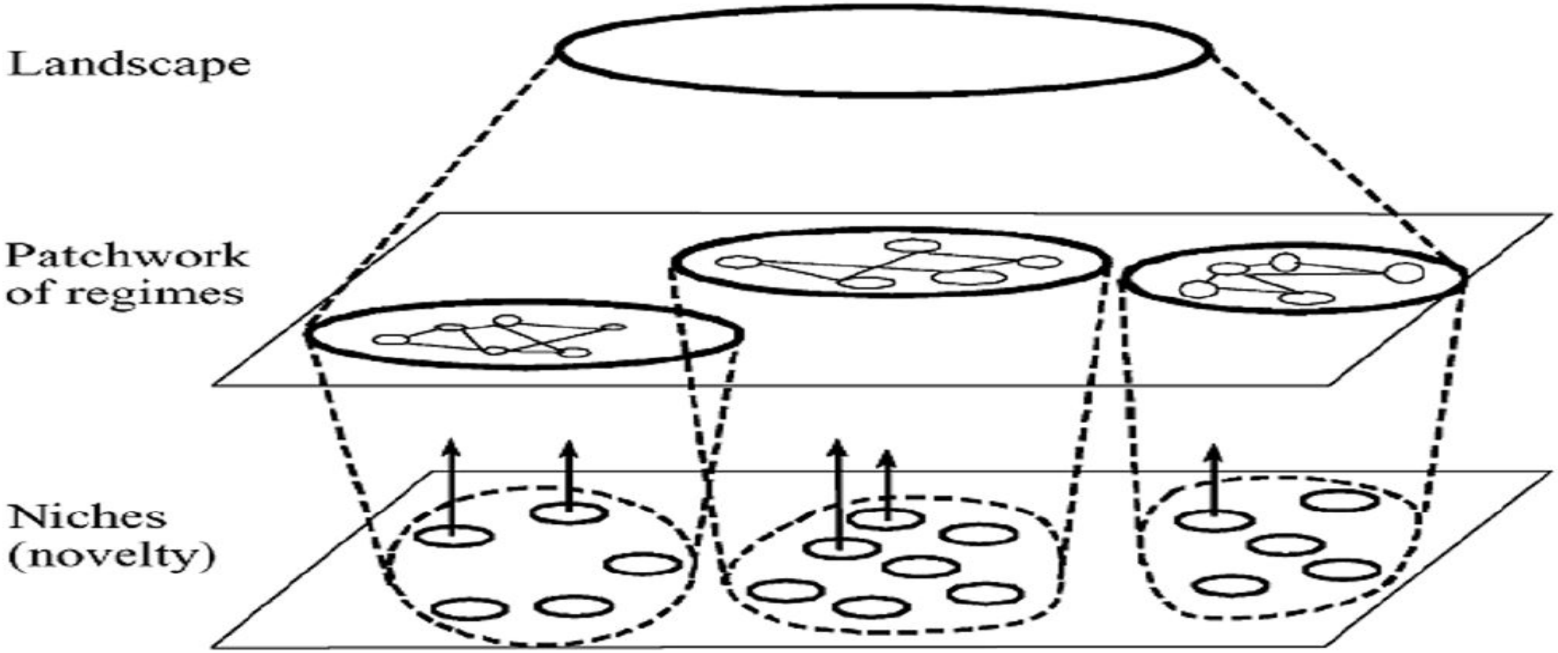
Transition as the result from the interplay of developments in three different but interdependent analytical levels (Rip and Kemp, 1998; Geels, 2002):

- niches
- socio-technical regimes
- exogenous landscape-level

- ➢ Change from one socio-technical regime to another.
- ➢ **Focuses on dynamics in the development of technologies.**

Stable phase: Favors incremental innovations.
Destabilized phase: Opens a “window of opportunity” for radical innovations.

Multi-Level Perspective



Source: Geels, 2002

Multi-Level Perspective

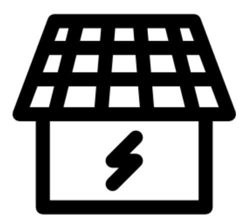
- *Niches* provide answers to socio-technical problems (Geels and Schot 2007) and create the "seeds for change" (Geels 2002).
- *Regimes* give the blueprint for social issues and provide the ordinary problem-solving activity. Existing regimes are characterized by path dependency and lock-in effects and are in an ongoing process of self-stabilization process (Geels 2011, Dosi 1982, Zundel et al., 2005).
- The *landscape* represents (far) distant variables that (almost) cannot be influenced by technology itself.

Two kinds of competition

- old-versus-new

vs.

- new-versus-new



vs.

3 Analytical Framework: Competing Technological Innovation Systems

- **TIS approach:** The TIS framework enables the assessment of internal functions and to set concrete policy goals.
- **Dynamic approach:** Policy strategies can be implemented according to the state of the respective techno-economic system.

  - ➢ The functional TIS approach and the dynamic approach complement each other.
  - ➢ It is useful to combine both to study the change of technological paradigms.

We uses the functional approach to compare different TIS within one single country using the notion of technological competition as introduced by Sartorius and Zundel (2005)

4 Testing the concept with insights from the German Energiewende

1. Assessment of how old-versus-new competition is institutionalized and how policy favors new technologies in comparison to the old ones
2. Assessment of the emerging TIS' functionalities to illustrate their status and stage of development.
3. Assessment of the installment speed of a emerging TIS as it is dependent on the similarities and overlaps with already established TIS.

Example: Energiewende - Energy transition

Data: literature review and secondary data from monitoring reports published by the German Federal Ministry for Economic Affairs

4 Testing the concept with insights from the German Energiewende

The German Energiewende (Energy Transition)

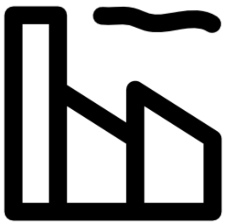
Energy Transitions: Structural change in energy systems

German Energiewende:

- Politically-induced shift to a decentralized renewable energy system in Germany.
- Aims to replace nuclear fuel, coal and other non-renewable energy sources with renewable energy production technologies like wind, solar, hydro or biomass.
- First policy document was published in September 2010.

(BMWI 2014a)

4.1 Fostering the new mission: Organizing competition in the German energy market

old-versus-new  **vs.** 

- **First step:** The amount of renewable energy has to be determined.
- The aim is to avert a carbon lock-in.
- Policy makers facilitate the development of new TIS by favoring sustainable technologies e.g. introducing of the EEG

Four main points of the EEG

1. Feed-in obligation
2. Feed-in priority
3. Feed-in tariffs
4. Market premium

4.1 Fostering the new mission: Organizing competition in the German energy market

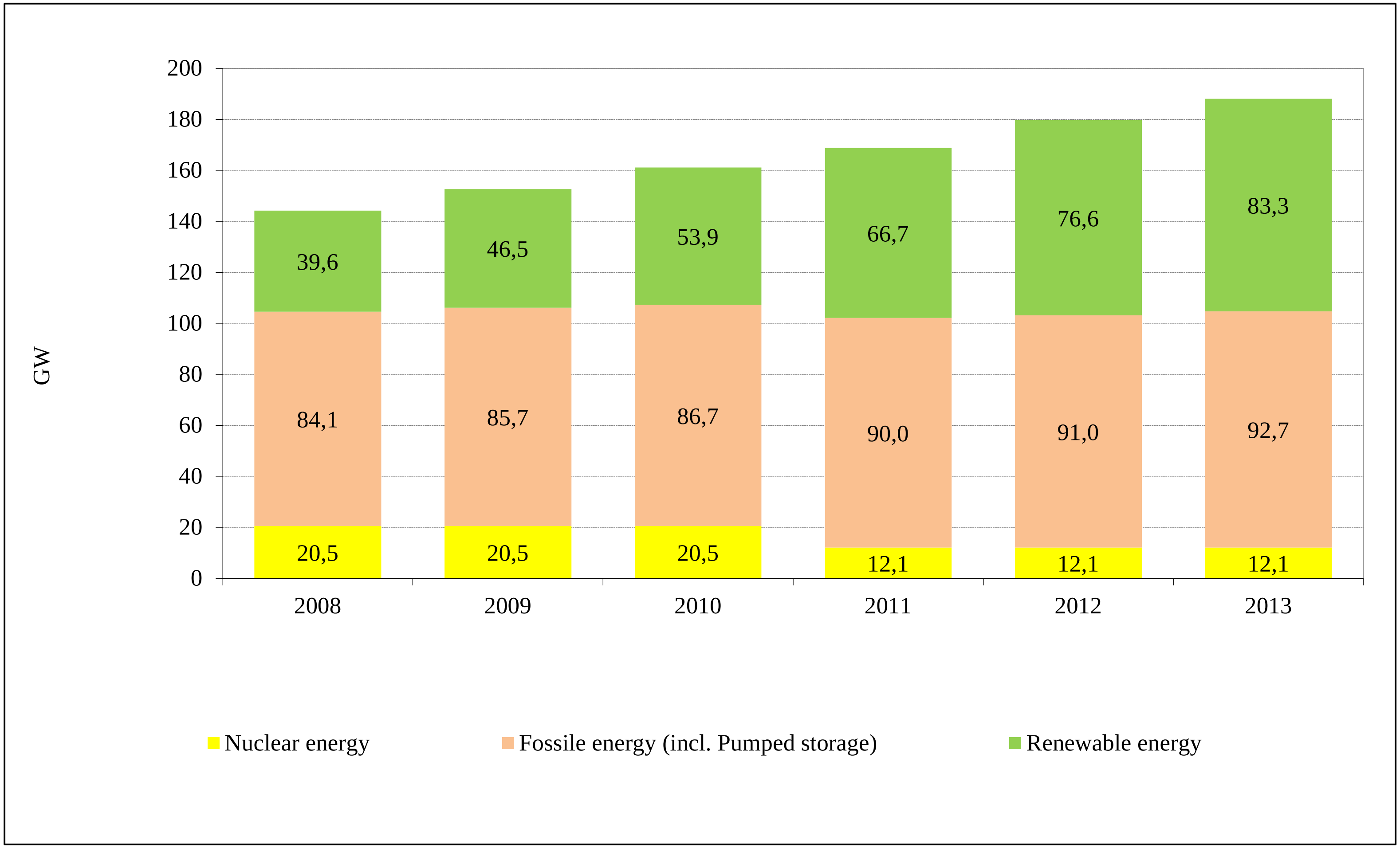
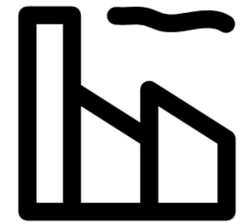


Figure 1: Installed capacity of power plants connected to the German grid (Source: BMWi, 2014b: 50; with reference to Bundesnetzagentur and Bundeskartellamt, 2014)

4.1 Fostering the new mission: Organizing competition in the German energy market

old-versus-new  **vs.** 

- **Increased share of renewable energy generation**
- Need for a ’smart grid’: Transition from a centralized conventional technology-based energy production (large power plants) to a decentralized power system (small scale generation) is necessary.
- Electric grid as another TIS: How political authorities organize the grid development will determine the market structure. If the grid is not adapted to renewable technologies, it will complicate their development.

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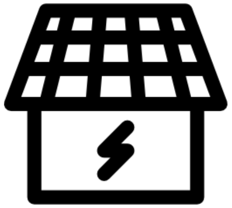
4.2 Fostering the new mission: Organizing competition in the German energy market

new-versus-new

vs.



- **Second step:** The energy mix within the amount of renewable energy has to be determined.
- Determination through a market-based process considering the different production costs of a specific renewable energy technology.

Two decision-making dimensions:

1. Binary ‘yes or no’ or a discrete decision between a finite number of specific alternatives.
2. Need for continuous decision-making when deciding the specific shares of the renewable energy sources.

Functional & Structural Analysis

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Source: own elaboration based on Wieczorek & Hekkert, 2012 / Hekkert et al. 2007

4.2 Fostering the new mission
Function 1: Entrepreneurial Activities

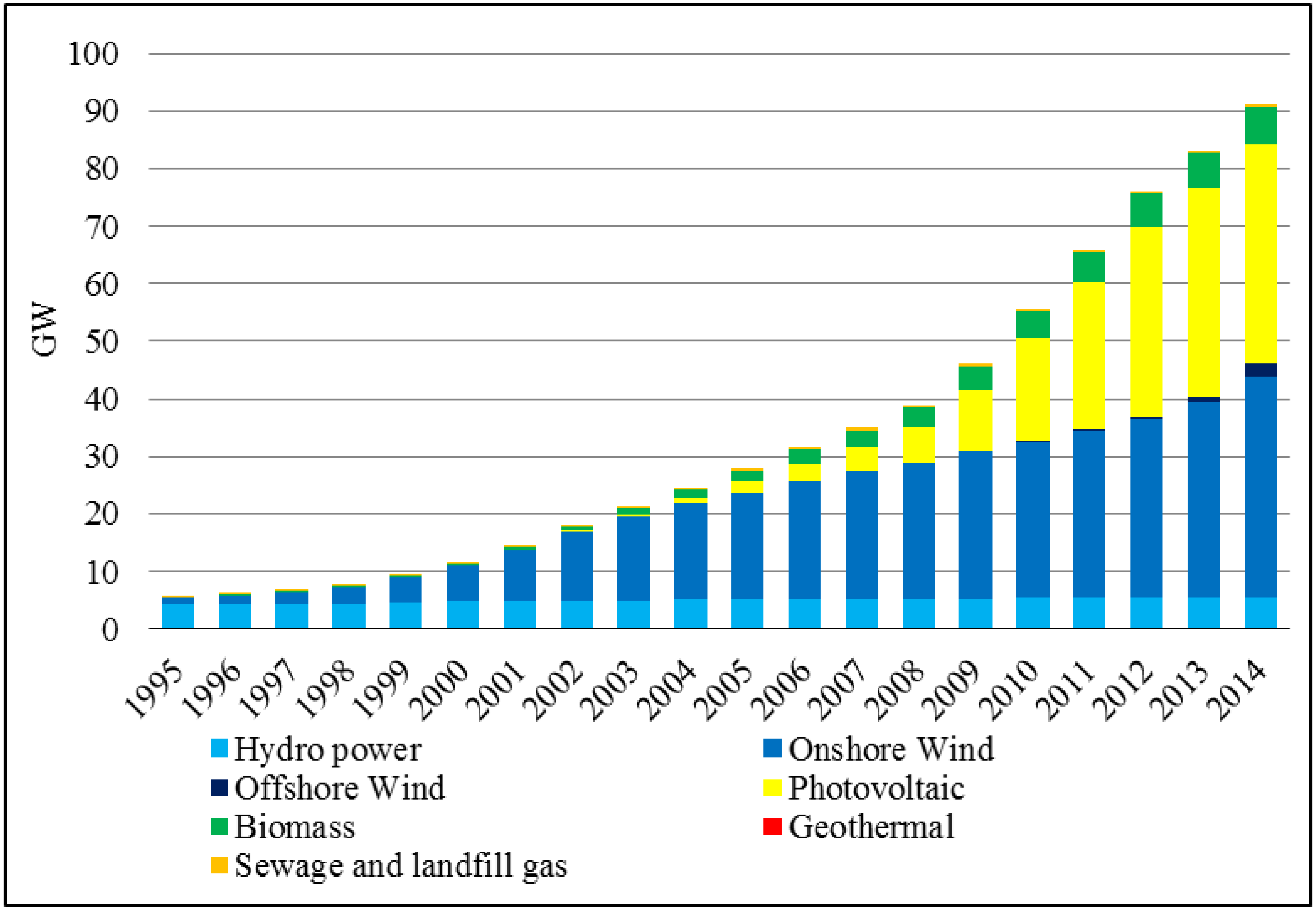

Figure 2: Installed capacities in gigawatt connected to the German power grid for the generation of electricity by renewable energy sources (Source*:* AGEE-Stat, 2015)

4.2 Fostering the new mission
Function 1: Entrepreneurial Activities

- The higher extension of solar and wind capacities might be due to the high volatility of wind and solar energy sources

- **Increase in entrepreneurial activities in terms of installed capacities as well as in the number of new market entries.** (Reduction of the activities from the Big Four).

4.2 Fostering the new mission
Function 2: Knowledge Development

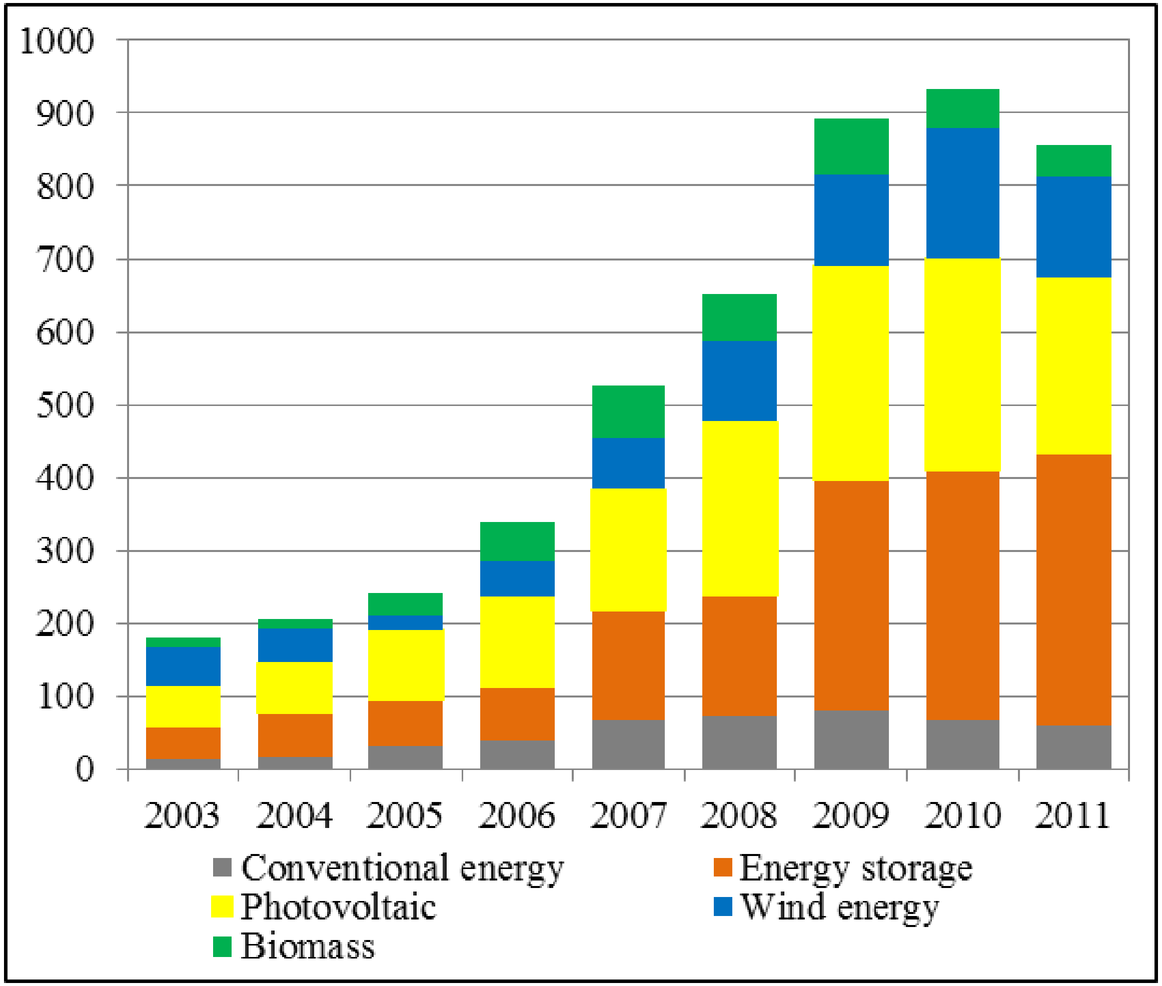

Figure 3: German patent applications (*Source:* GWS et al., 2014: 116, 122, 128, based on the OECD Patent Database).

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4.2 Fostering the new mission
Function 2: Knowledge Development

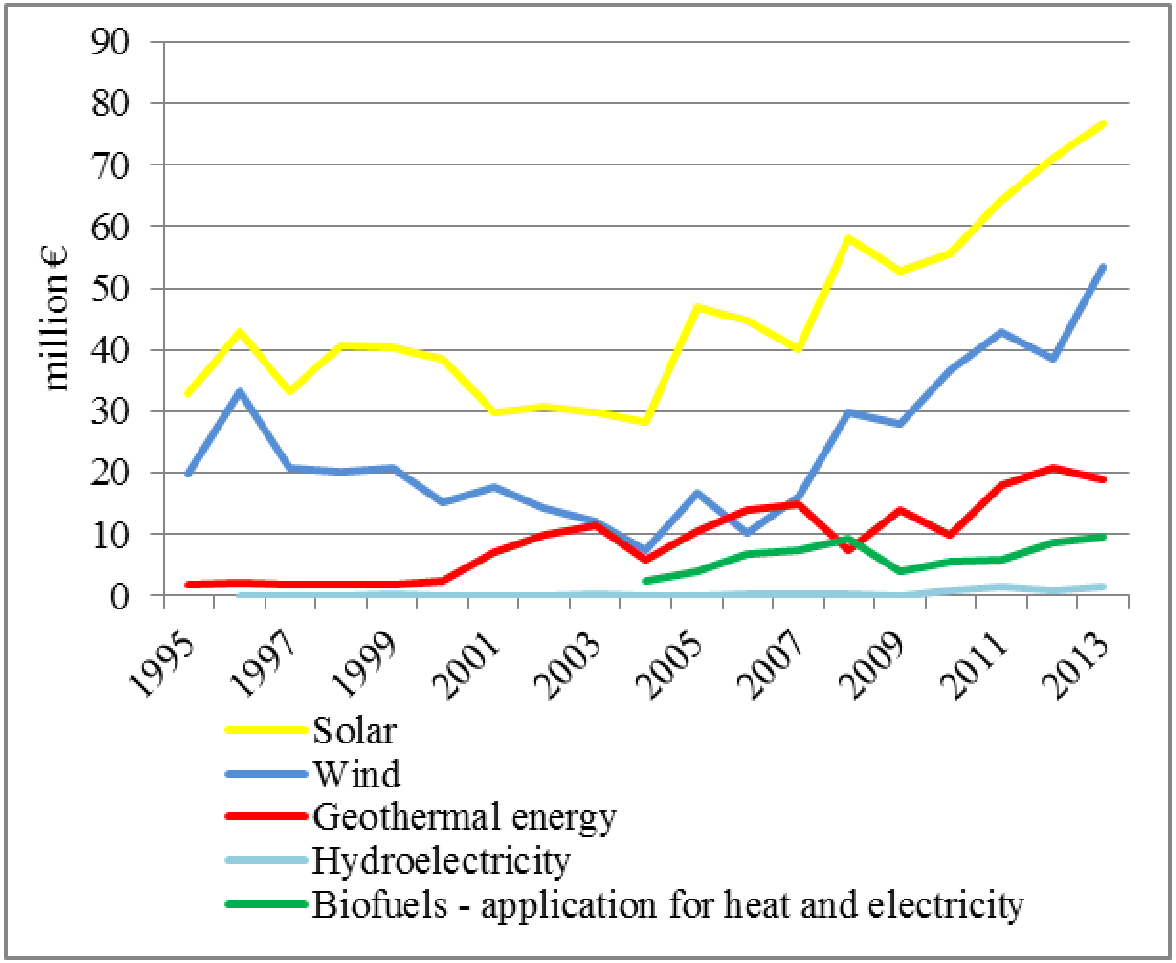

Figure 4: Total R&D expenditures for renewable energies in Germany in millions of € (*Source:* OECD Dataset RD&D Budget, 2015).

4.2 Fostering the new mission
Function 2: Knowledge Development

- Energy storage technologies are considered as a key technology for the development of wind and solar energy.
  - ➢ Storage technologies make them more compatible to the electrical grid and improve energy supply.
- The German total R&D expenditures for renewable energy sources exceeds all other related technologies (OECD 2015).
- Another indicator is the government support for renewable energy technologies. Solar energy has been a clear focus since 2006 and it has received a high share of the financial support (BMWi, 2013; BMWi, 2014a).

4.2 Fostering the new mission
Function 3: Knowledge Diffusion

- The state and diffusion of R&D knowledge can be measured by network sizes.
- Between 2012 and 2014, four networks of solar energy were established and funded, including a solar thermic installation network and five networks of water installations.
- Smart grids were strongly supported by seven networks. In the energy storage sector five networks were installed.

4.2 Fostering the new mission
Function 3: Knowledge Diffusion

Google search as a soft indicator

A search on February, 17th 2015 shows:

Energiewende	6.6 million hits
renewable energies	7.5 million hits
photovoltaic	9 million hits
solar energy	4-5 million hits
wind energy	4-5 million hits
hydroelectricity	2.5-3 million hits
biomass	8.5 million hits.

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4.2 Fostering the new mission
Function 4: Guidance of Search

- An example for guidance is the announcement of government goals.

Yearly expansion for renewable energy technologies until 2030:

solar energy	2.5 GW
onshore wind energy	2.5 GW
biomass	0.1 GW
offshore wind energy until 2020	6.5 GW
offshore wind energy until 2030	15 GW

4.2 Fostering the new mission
Function 5: Market Formation

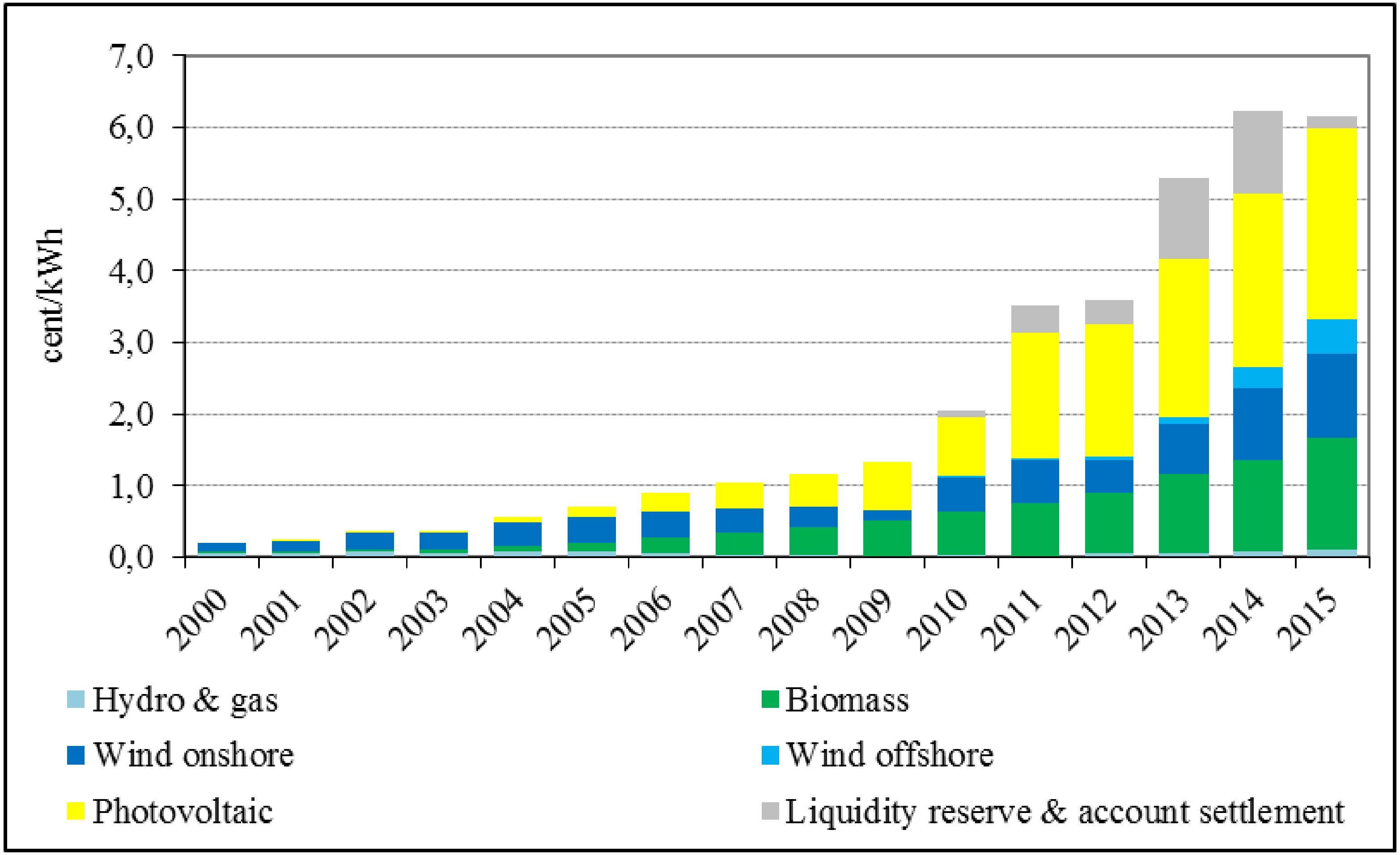

Figure 5: Development of the apportionment in the framework of the EEG (*Source:* BMWi, 2014b: 22).

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4.2 Fostering the new mission
Function 5: Market Formation

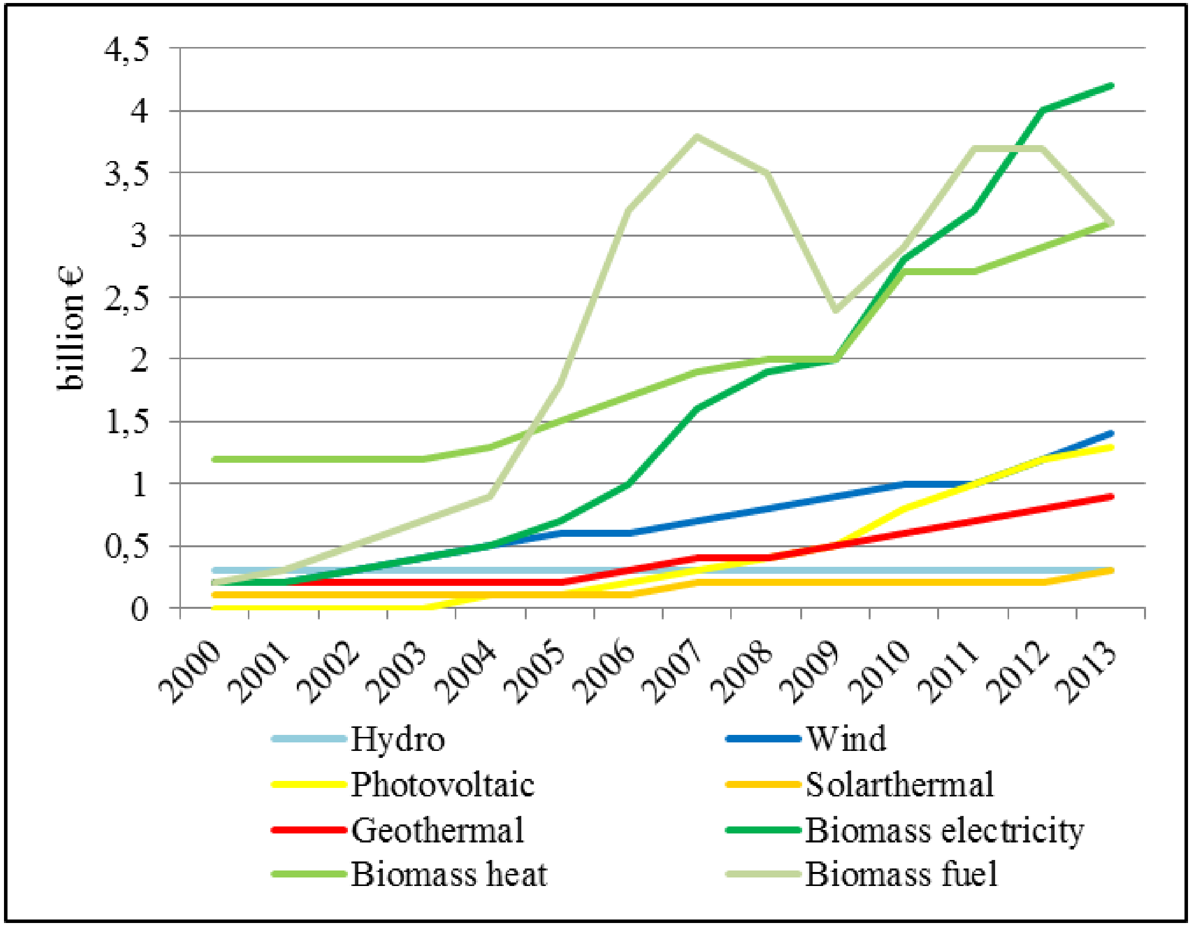


Figure 6: Earnings of the operation of renewable energy plants in Germany (*Source:* BMWi, 2014c: 23, with reference to calculations of the Centre for Solarenergy and Hydrogen Research Baden-Württemberg)

4.2 Fostering the new mission
Function 5: Market Formation

- The electricity production costs of onshore wind power are now the lowest compared with other renewable energies.

- Solar power generation has experienced a dramatic cost decrease in the last three years.

- Biomass generated the highest earnings.

- Hydro&gas technologies remained constant.

4.2 Fostering the new mission
Function 6: Resource Mobilization

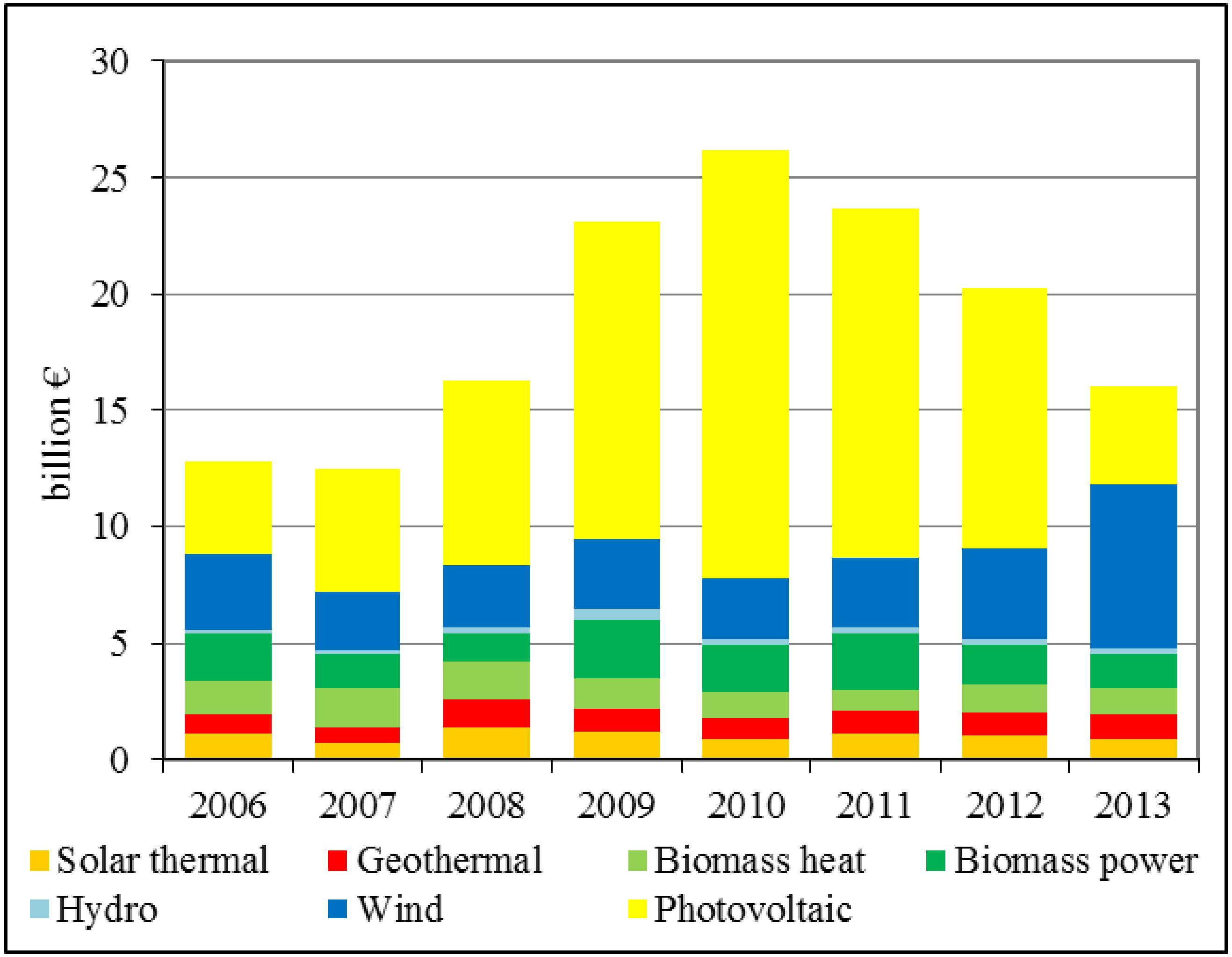


Figure 7: Investments in renewable energies in Germany (Source: BMWi, 2014b: 88).

4.2 Fostering the new mission

Function 6: Resource Mobilization

- The employment in the renewable energy sector has almost doubled since 2000 (BMWi, 2014b).

Employment in Germany 2013 (ibid.):

138,000 people	wind energy sector
176,000 people	biomass sector
69,000 people	solar energy sector

4.2 Fostering the new mission
Function 7: Creation of Legitimacy

Opinion poll carried out by the German TNS Emnid Institute (2013; 2014) shows:

- The renewable energy sector is widely accepted.
- The highest local acceptance rate is for solar energy with slightly over 70 % with a little less for wind energy.
- The acceptance of biomass energy production is much lower.
- Compared to classical power plants renewable energies are much more locally accepted.

4.3 Checking the overlaps of new TIS to the existing sectorial innovation system

- Renewable TIS are at different levels of readiness.

Two possible explanations:

- Different speed of technological development
- Different complementarity to existing infrastructure and networks.

➢ Similarities to the established sectoral innovation system (SIS) may may facilitate the diffusion of new technologies (Malerba, 2002).

➢ This overlay can be assessed by an in-depth examination of a TIS.

4.3 Checking the overlaps of new TIS to the existing sectorial innovation system

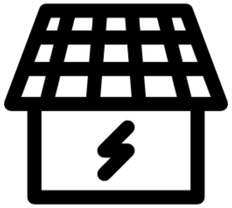
We can see varying conditions, which explain the different function fulfilment of each TIS.

- Wind offshore parks have a similar power volume to conventional power plants .The Big Four German power plant operators are the promoter of this technology.
- In general, the wind TIS has slowly emerged with new actors and has recently established targeted and applied research institutes. This has caused a differentiation into two TIS (on- and offshore).

4.3 Checking the overlaps of new TIS to the existing sectorial innovation system

We can see varying conditions, which explain the different function fulfilment of each TIS.

- Germany has a long and established research photovoltaic infrastructure due to the proximity of this technology to the semiconductor industry since the 1980s.
- Many new firms have been founded.
- But established technological players such as Bosch or Siemens still play an important role in the photovoltaic market.



4.3 Checking the overlaps of new TIS to the existing sectoral innovation system

We can see varying conditions, which explain the different function fulfilment of each TIS.

- Biomass is the only renewable energy that is easily storable and can be produced by demand.
- The related TIS is closely linked to the strong mechanical engineering industrial base in Germany as well as the existing farmers' associations.
- The Second has a strong lobby group in Germany.

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4.3 Checking the overlaps of new TIS to the existing sectoral innovation system

We can see varying conditions, which explain the different function fulfilment of each TIS.

- A major problem within the hydropower generation sector in Germany is the regional environment.
- Almost no investment in hydropower generation.
- The diffusion channels of this energy source are similar to the old TIS.

4.3 Checking the overlaps of new TIS to the existing sectoral innovation system

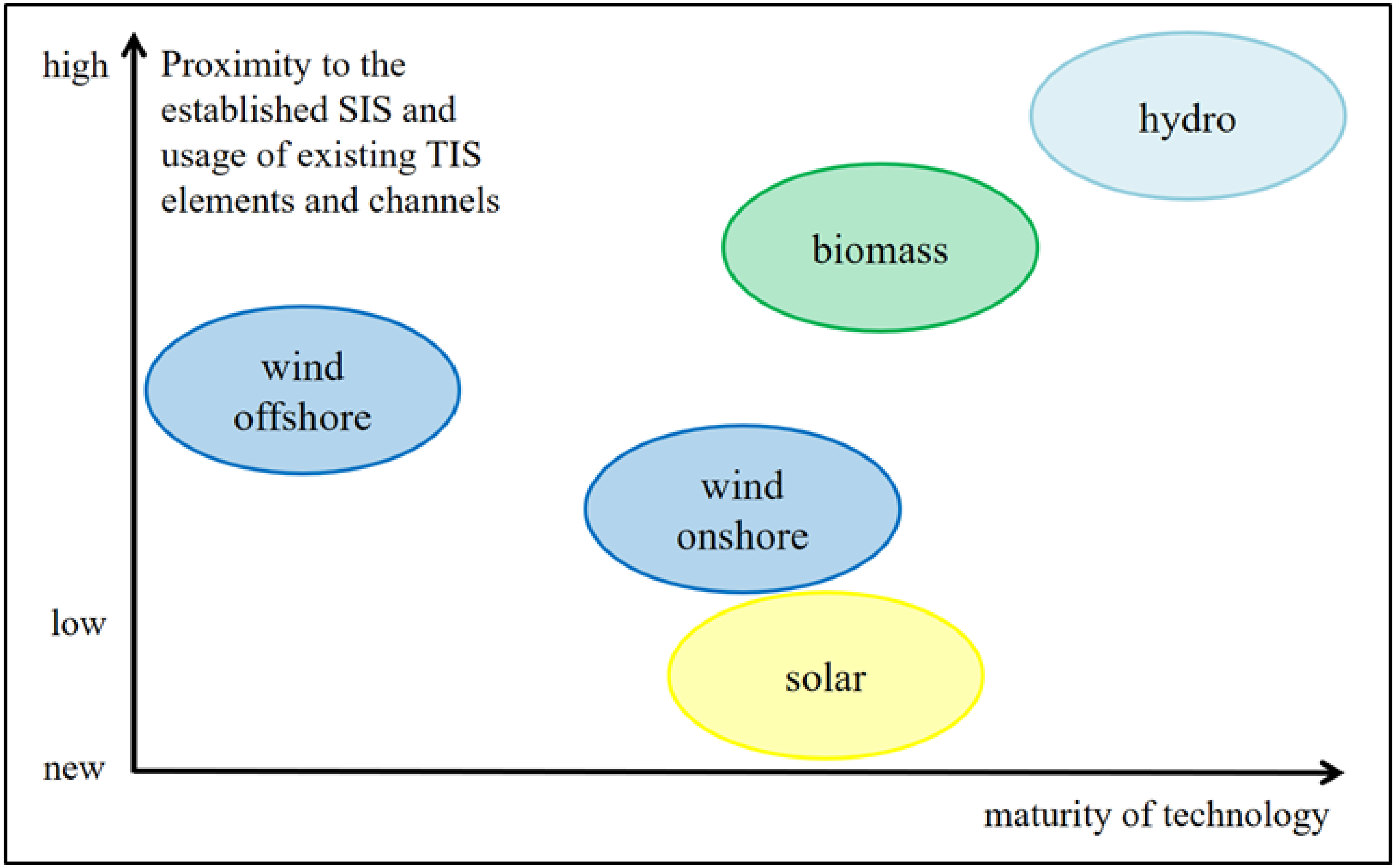

Figure 6: The different stages of maturity of the renewable energy generation TIS (*Source:* own depiction).

5 Conclusion

- We interpret the new mission orientation of STI policy as a competition between different but interdependent TIS, which have to be governed and steered according to the overall goals of the mission.
- Connection between two policy approaches:
  - TIS and dynamic approaches on transformation
  - It is important to know the different stages of technology maturity in order to best fit policy measures.
- In regards to the old vs. new TIS competition, the Energiewende example has shown that a clear-cut and a sustainable political strategy against the old TIS is needed.
- Policymakers have to consider the different starting conditions for each TIS as well as their degree of technological maturity.
- Additional research is needed for modeling the possible development paths a TIS can take and for defining a more precise and reliable indicator set.

THANK YOU FOR YOUR ATTENTION!

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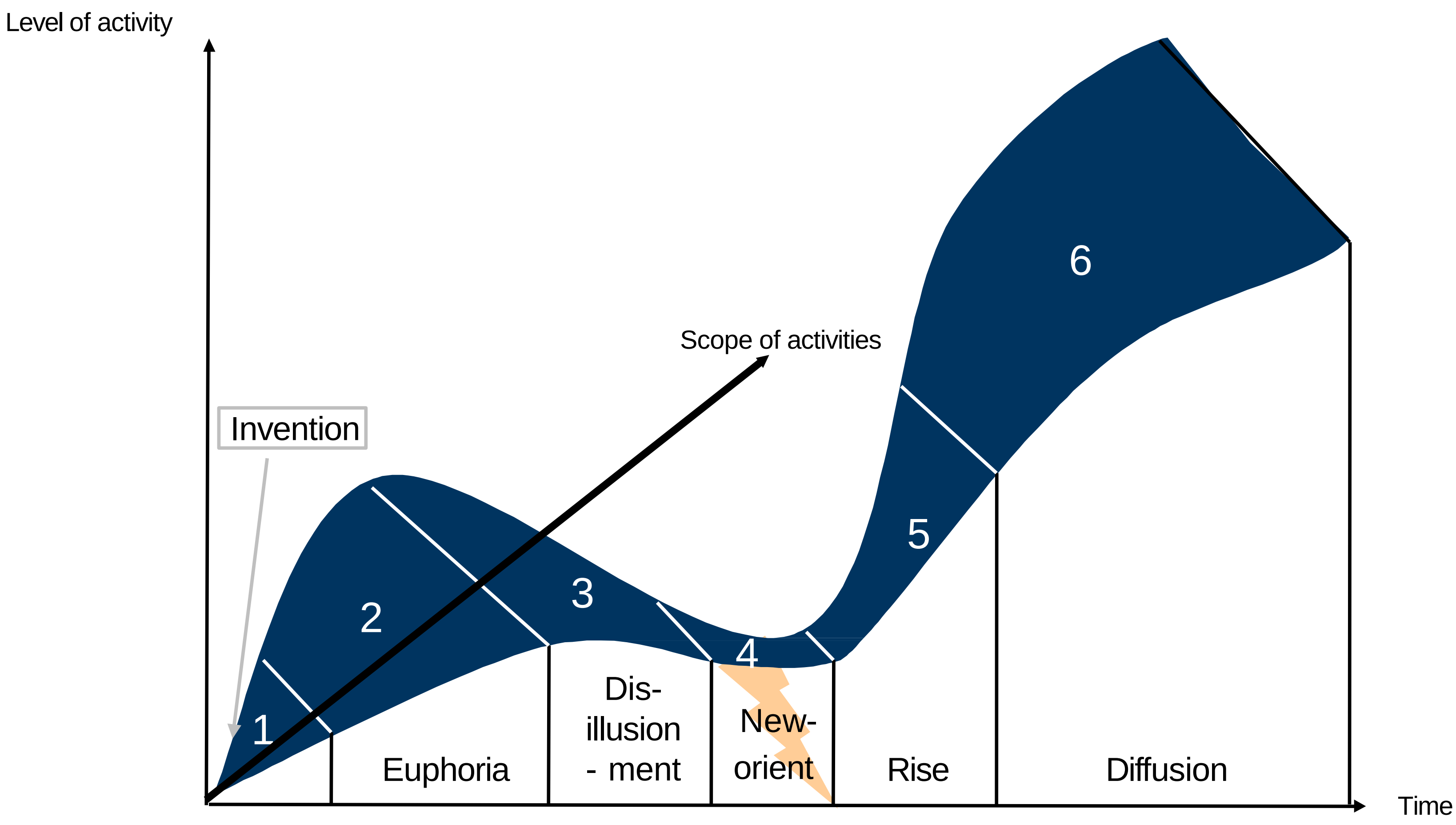
6 Outlook

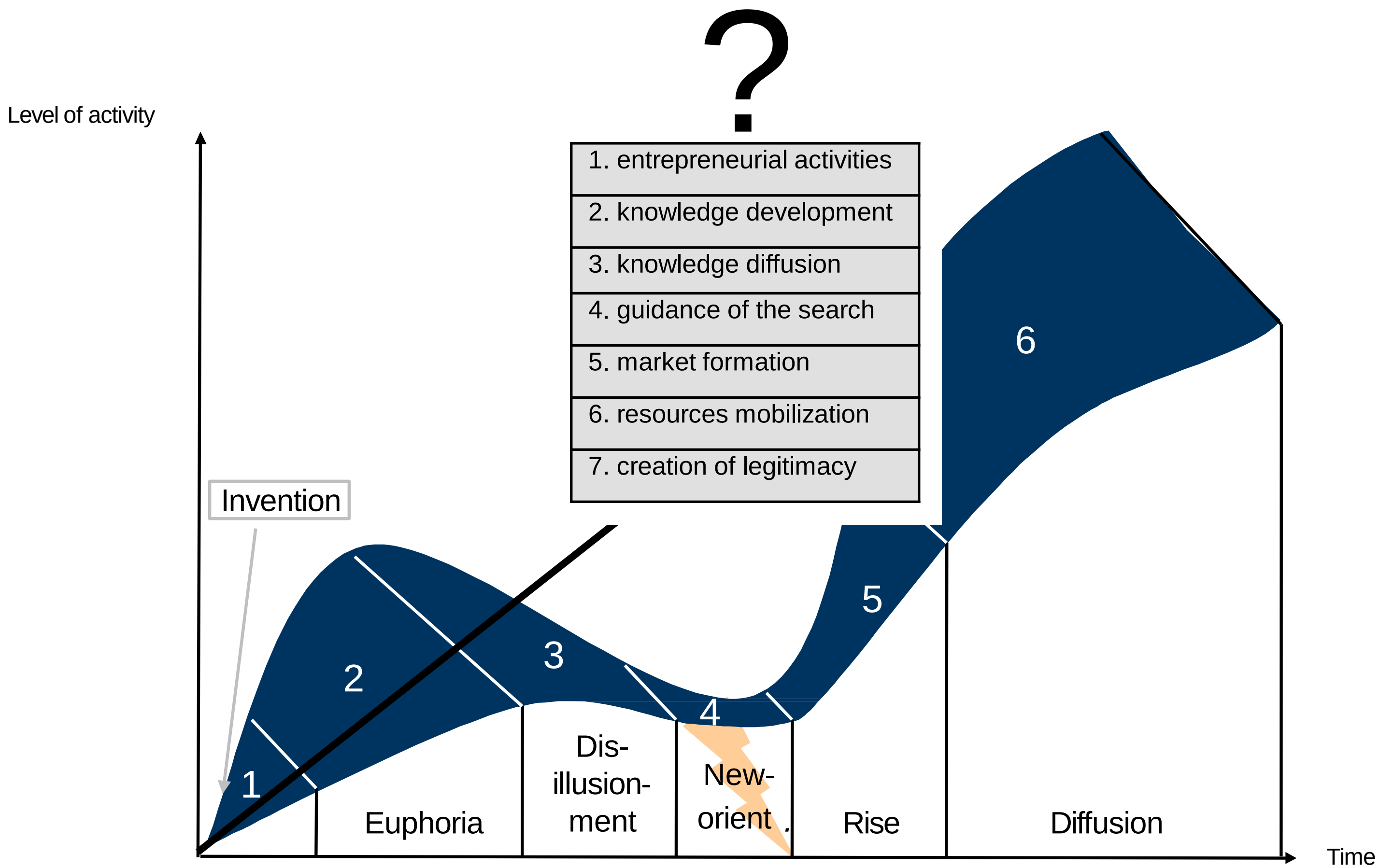
Science and Technology Cycle



Source: Meyer-Krahmer and Dreher, 2004

6 Outlook

Interaction patterns along the Science and Technology Cycle



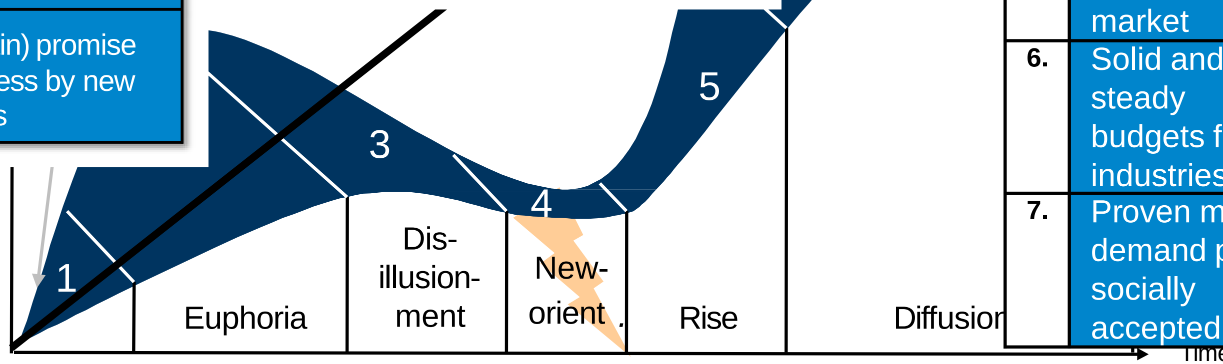
6 Outlook

Interaction patterns along the Science and Technology Cycle (work in progress!)

1.	R&D
2.	Basic and applied reearch
3.	Univ.- industry interaction
4.	Techology-push
5.	Infant market with innovators
6.	Poor and unsteady public intervention
7.	(uncertain) promise of progress by new solutions

?

1. entrepreneurial activities
2. knowledge development
3. knowledge diffusion
4. guidance of the search
5. market formation
6. resources mobilization
7. creation of legitimacy



1.	Manufacturing and services
2.	Use based experience and applied research
3.	Established cross- industry arenas
4.	Demand-pull
5.	Growing and established market
6.	Solid and steady budgets for industries
7.	Proven market demand plus socially accepted