Impact of Renewable Energy Policy and Use on Innovation
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“Innovation and employment: Cornerstones of energy transition”
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1. Effect of RE-Policy and Utilization on Technological Change: A Literature Review

2. Technological Change Development: A Quantitative Analysis
   2.1. Research and Development Spending
   2.2. International Trade
   2.3. Innovation

3. Conclusion
1 RE-Policy and Utilization Effect (1)

- Technological Change as process from invention to innovation to diffusion (Jaffe et al. 2001)

- Identifying market failure and market barriers (Mitchel et al. 2011; Beck und Marinot 2004)
  - Positive and negative externalities
  - Market power
  - Obstacles on capital markets
  - Barriers of information

- Market Mechanisms of technological change
  - „induced innovation“ i.e. market participants react to incentives (relative prices) (Hicks, 1932)
  - Regulatory market corrections are justified in case of market failures (Weitzman, 1974)
  - Factors of innovation and diffusion (Fischer et al. 2003; Popp et al. 2010)
    - Typ of policy instrument and stringency
    - Structure of market/ competition
    - Ability to innovate of market participants (firms)
    - Type and costs of technologies
## RE-Policy and Utilization Effect (2)

- Overview of policy instruments on innovation promotion

<table>
<thead>
<tr>
<th>Market pull policies</th>
<th>Technology-specific (Direct)</th>
<th>Non-Technology-specific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market-based</td>
<td>Price-driven</td>
<td>Quantity-driven</td>
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<tr>
<td>Investment incentives</td>
<td>• Investment subsidies</td>
<td>• Tendering systems for grants (quantity)</td>
</tr>
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<td></td>
<td>• Supportive tax policy</td>
<td>• Quota (capacity)</td>
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<td></td>
<td>• Tender (price)</td>
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<tr>
<td>Generation incentives</td>
<td>• Feed-in tariffs</td>
<td>• RE portfolio standards and green certificates</td>
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<td></td>
<td>• Premium feed-in tariffs</td>
<td>• Tendering systems for long term contracts</td>
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<tr>
<td>Command-and-Control</td>
<td>• Technology and performance standards and authorization procedures</td>
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<tr>
<td>Voluntary</td>
<td>• Shareholder and contribution programs</td>
<td></td>
</tr>
<tr>
<td>Investment Promotion</td>
<td>• Green tariffs</td>
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</tbody>
</table>

### Technology push policies

- Public R&D spending (direct funding, grants, prices)
- Tax credits to invest in R&D
- Support for education and training
- Financing demonstration or pilot projects
- Strategic development policies
- Technology exhibitions/fairs
RE-Policy and Utilization Effect (3)

Relevance of policy mix

- Methodological approaches to gasp technological change and policies
  - Dimensions: (OECD 2009)
    - Drivers: Technological Change
      - Invention
      - Innovation
      - Diffusion
    - Impacts: Country level (macro impacts)
      - e.g. reduction of social costs, efficiency, knowledge stock
    - Impacts: Firm level (micro impacts)
      - e.g. innovation rents, productivity, qualification, competitiveness
  - Measure:
    - ...for policies, expenditures, prices
      - Dummy variables for policies
      - Level of policy induces prices (taxes, emissions)
      - R&D expenditures
      - Level of scientists/educational spending
      - Strength of patent protection
      - Pollution abatement costs and expenditures
    - ...for effects
      - Private R&D expenditures
      - Patent applications
      - Trade with research intensive goods
        (level, dynamics, indicators)
      - Development of technology costs
1 RE-Policy and Utilization Effect (4)

- Effects of technological change in renewable energy
  - Competitiveness and International Trade
    - Porter Hypothesis (Porter und Van der Linde 1995) vs. Pollution Haven (Copeland and Taylor 2003)
    - Lead Market Hypothesis (Beise 2004, 2005)

- Reducing technology costs
  - Learning by doing at industry level – learning or up-scaling at the unit level
    - “Learning is a descriptive label for a multi-faceted process,” (Wilson 2012)
    - (knowledge generation, application and exchange)
  - Bosten Consulting Group - experience curves, i.e. relation between cumulative production and costs (unit costs)
  - But: Technology costs not only caused by diffusion. Important factors are:
    - Learning by searching,
    - Costs of components, material, energy, labor.
    - Market characteristics and restrictions
2.1 Research and Development Spending

- **Wind**
  - Highest spending: US, UK, DE (≈ 45 Mio. $)
  - ≈ 6% of total R&D spending for energy
  - + 30% since 1985 (+87% 1990), below IEA average
  - Research intensity (¢/Mio. $ GDP) above IEA average

- **PV**
  - Highest spending: US, JP, DE (≈ 60 Mio. $)
  - ≈ 8% of total R&D spending for energy
  - only + 3% since 1985 (-27% 1990), below IEA average
  - Research intensity above average.

- **Biofuels**
  - DE ranked sixth on spending (≈ 35 Mio. $)
  - ≈ 4% of total R&D spending for energy
  - + 5900% since 1985 (+1200% 1990), above IEA average
  - Research intensity substantially below average.

*But: No Data for BRICS, Korea and private R&D spending*
2.2 International Trade

• “Green” technologies decisive meet climate change challenges.
• Trade as mean for technological transfer.
• Limited literature and market studies.
  • Porter Hypothesis
• Strongly increasing global market dominated by OECD countries.
• Export markets are high income countries, limited exports to others..
• Empirical Analysis:
  • Effect of RE-Policies on trade in export and importing countries.
  • Effect of trade costs.
• Results:
  • trade theory confirmed.
  • Policy in importing countries significant.
  • strong RE policy support increases exports.
  • Innovation is an important element.

Figure: Development of solar PV Technology components
Source: authors’ calculations based on UNCTAD Comtrade 2012

Figure 2: Export flow of solar PV technology components 2008 by region in billion US Dollar. Source: Authors calculation and illustration based on UN Comtrade 2012
2.2 International Trade: Germany

- Largest exporter & importer of respective goods since 1990`s.
  \( PV + 700\%, \) share: \( 12\% \); Wind + 900\%, 13\%; Bio: + 300\%

- Import and export decrease in 2012. (data and EEG-Amendment on PV)

- OECD/EU main export market.

- China and OECD main import markets.

- Limited exports to developing countries.

- Increasing export specialisation/
  Increasing relevance for total exports.  
  \((RET 3,9\% from total exports in 2012)\)

- But, constant relevant trade position \( \rightarrow \) increasing imports.

- Export-Import relation (export specialization) increasing disadvantage.
2.3 Innovation

• Strong increase in global innovation for renewable energy technologies (all patents. ≈ 30%; PV ≈ 300%, Wind. ≈ 600%)
• Strong regional differences.
• Difference in target markets and innovating countries.

Figure: Regional Dispersion of patent applications by regions
2.3 Innovation: Germany

- Development substantial larger than global average
  - **Total:** Large share of global patent applications (EU 2008 PV: 53%; Wind: 47%; Bio: 37%
  (Global 2008:: PV 23%; Wind 20%, Bio: only 12% → US Dominance)
  - **Dynamics 1990-2008:** Substantially stronger than in other EU countries.
    (PV: 510%; Wind: 925%; Bio: 160)

- Main target markets for innovations (Patents) from German inventors.
  - EU and developed countries
  - Developing countries marginal (but China)
  - **But:** Medium research intensity per capita & per GDP
1 Conclusion

- Market failures and obstacles as motivations for introducing RE-Policies
- Regulation as effective mean to change relative prices and thus inducing technological change (innovation)
- Market based instruments more effective (efficient) than command & control instruments
  - Successful technological change need policy mix for technology and market development
  - Market structure and technology costs are essential for policy selection.
  - Policy flexibility and stringency define instrument effectiveness.
- R&D spending
  - DE low increase of spending since 1990 but research intensity above IEA average (except for biofuels)
- Patent Applications
  - DE leading in patent applications in Europe and US with strong growth since 1990
- International Trade
  - DE exports larger than global average but imports increase more than exports
  - Constantly high export market shares for PV, Wind and biofuel technology but no competitive advantage for PV but for Wind and Biofuel technologies.
  - Strongly increasing role of China
Thank you!

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2. Analyse zur Dynamik des technologischen Wandels im Bereich EE

- Deskriptive/quantitative Datenanalyse für die EE-Technologiebereiche
  - Photovoltaikanlagen
  - Windenergieanlagen
  - Biokraftstoffe bzw. Technologiegüter zur Bereitstellung von Biokraftstoffen

- Focus auf Deutschland im internationalen Vergleich

- Innovationsindikatoren
  - Forschungs- und Entwicklungsausgaben (IEA) (bis 2010)
  - Patentanmeldungen (PATSTAT) (bis 2008 Stand Okt. 2010)
  - Handel mit Technologiegütern (UNCTAD) (bis 2011)

- Klassifikation/Differenzierung durch Literatur und Listenabgleich

- Papier soll die Analyse in die bestehende empirische Literatur einordnen
3.3 Country Example: China(1)

- Strong industry and export development
- Political aim: increase RE-utilisation and closing knowledge gap.

- Recent relevance:
  - WTO, US, EU "price dumping in Chinese PV-module industry";
  - increase of importing tariffs.

- Research Questions:
  - Identifying potential causing factors
  - Taking RE and innovation policy into account
3.3 Country Example: China(2)

- Policies to support innovation electricity generation
- Local market is lagging behind trade development
- Rising S&T spending and innovation
  - Relative foreign knowledge share decreases

**Figure:** R&D Spending for RE in central and provincial Chinese governments

- **Figure:** Wind and PV electricity generation in China

- **Figure:** Wind and PV Innovation and Transfer

![Wind and PV Innovation and Transfer](image)
3.3 Country Example: China

Results:
- China developed and increasing competitive advantage
  - Exports account for larger share of total export than global average
  - Chinese industries better in foreign markets than foreign companies in Chinese market.
- Major technology exporters are major component importer.
- Difference in market size for clean energy technology components
- Chinese RET-Trade follows expectations of trade theory.
- Policy and market size in importing countries is significant.
- Trade costs less important than expected.
- R&D significant effect on Chinese exports.
Policy Take-Out:

- Trade, Innovation and utilization markets have to be thought together
- Tackle barriers: Administrative, Regulatory, Finance, Socio-Cultural.
- Increase coordination between different authorities
- Increase trust among banks and investors
- Reduce asymmetric market information
- Push realistic perception of RE-costs and recognition of positive side effects
- Reduce number of authorities and further non-trade, non-economic barriers.


## Abgrenzung Patente

<table>
<thead>
<tr>
<th>IPC Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solar Photovoltaic (PV)</strong></td>
<td></td>
</tr>
<tr>
<td>H01L 27/142, 31/00-31/078</td>
<td>Devices adapted for the conversion of radiation energy into electrical energy</td>
</tr>
<tr>
<td>H01G 9/20 H02N 6/00</td>
<td>Using organic materials as the active part</td>
</tr>
<tr>
<td>H01L 27/30, 51/42-51/48</td>
<td>Assemblies of a plurality of solar cells</td>
</tr>
<tr>
<td>H01L 25/00, 25/03, 25/16, 25/18, 31/042</td>
<td>Devices adapted for the conversion of radiation energy into electrical energy</td>
</tr>
<tr>
<td>C01B 33/02, C23C 14/14, 16/24</td>
<td>Silicon; single-crystal growth</td>
</tr>
<tr>
<td>C30B 29/06</td>
<td>Regulating to the maximum power available from solar cells</td>
</tr>
<tr>
<td>G05F 1/67</td>
<td>Electric lighting devices with, or rechargeable with, solar cells</td>
</tr>
<tr>
<td>F21L 4/00 F21S 9/03</td>
<td>Charging batteries</td>
</tr>
<tr>
<td>H02J 7/35</td>
<td>Dye-sensitised solar cells (DSSC)</td>
</tr>
<tr>
<td><strong>Wind Energy</strong></td>
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<tr>
<td>F03D</td>
<td>Wind energy</td>
</tr>
<tr>
<td>H02K 7/18</td>
<td>Structural association of electric generator with mechanical driving motor</td>
</tr>
<tr>
<td>B63B 35/00 E04H 12/00  F03D 11/04</td>
<td>Structural aspects of wind turbines</td>
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<tr>
<td>B60K 16/00</td>
<td>Propulsion of vehicles using wind power</td>
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<tr>
<td>B60L 8/00</td>
<td>Electric propulsion of vehicles using wind power</td>
</tr>
<tr>
<td>B63H 13/00</td>
<td>Propulsion of marine vessels by wind-powered motors</td>
</tr>
<tr>
<td><strong>Biofuels</strong></td>
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<tr>
<td>C10L 5/00, 5/40-5/48</td>
<td>Biofuels from solid fuels</td>
</tr>
<tr>
<td>C10B 53/02 C10L 5/40, 9/00</td>
<td>Biofuels from torrefaction of biomass</td>
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<tr>
<td>C10L 1/00, 1/02, 1/14</td>
<td>Liquid biofuels</td>
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<tr>
<td>C10L 1/02, 1/19</td>
<td>Biofuels from vegetable oils</td>
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<tr>
<td>C07C 67/00, 69/00 C10L 1/02, 1/19 C11C 3/10 C12P 7/64</td>
<td>Biodiesel</td>
</tr>
<tr>
<td>C10L 1/02, 1/182 C12N 9/24 C12P 7/06-7/14</td>
<td>Bioethanol</td>
</tr>
<tr>
<td>C02F 3/28, 11/04 C10L 3/00 C12M 1/107 C12P 5/02</td>
<td>Biogas</td>
</tr>
<tr>
<td>C12N 1/13-21, 5/10, 15/00</td>
<td>Biofuels from genetically engineered organisms</td>
</tr>
</tbody>
</table>

**Daten:**
- IPC Abgrenzung:
  - Dechezlepretre (2011, 2012)