MODELLING THE TRANSITION TOWARDS HIGH SHARES OF RENEWABLE ENERGY SOURCES WITH THE ENERTILE MODEL

使用ENERTILE模型模拟向高份额的可再生能源转变

Workshop: ANALYZING AND DESIGNING POLICIES AND MARKETS FOR LARGE-SCALE UTILIZATION OF RENEWABLE ENERGY SOURCES

研讨会：可再生能源的大规模利用——政策和市场的分析与设计

Beihang University, Beijing

北京航空航天大学

Dr. Frank Sensfuß, Fraunhofer ISI, 26.06.2019
Steps towards decarbonisation
Impact on modelling

- Decrease the use of coal without CCS in all sectors
- Decrease the use of gas without CCS in all sectors

Strong increase of generation by renewable energy sources

- Regional distribution of renewables is important
- Electricity grids are important
- Time dependency of renewables is important for
  - Electricity sector
  - Heat grids & Heat pumps
  - Transport
  - Industry
The Enertile model

High resolution weather & renewable potential data

Invest & 8760 hours of dispatch
For every country

8760 hours of Dispatch for every country

Integrated linear least cost optimisation for 2030-2050

>140 million hourly generation variables

>15 thousand investment variables

Enertile 模型

高分辨率天气和可再生潜力数据

每个国家投资与8760小时调度

每个国家8760小时的调度

电网
可再生能源发电厂和存储
热网中热发电机

电动车
热泵
THE CHALLENGE: DECARBONIZE ELECTRICITY, HEAT & HYDROGEN SUPPLY
挑战：脱碳
电力、热力和氢气供应

Pathways differ in terms of electrification strategy, grid, nuclear and CCS
在电气化战略、电网、核能和CCS方面不同路径

<table>
<thead>
<tr>
<th>Diversification</th>
<th>Directed Vision</th>
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<td>3.0893.049</td>
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- Hydrogen: 557 486
- Heat in grids: 430 502 403
- Heat in Houses with HP: 802 848 493
- Electricity Transport: 370 653 420 282
- Electricity Other: 

CO₂-Limit 2050
63 Mt (-96%)

~ 315 TWh of natural gas
ELECTRICITY SUPPLY (EUROPE)
RENEWABLES TAKE THE LEAD

电力供应（欧洲）
可再生能源领先

Pathway: Diversification

<table>
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<tr>
<th>Year</th>
<th>Wind Onshore</th>
<th>Wind Offshore</th>
<th>Solar CSP</th>
<th>Solar PV</th>
<th>H2 Electrification</th>
<th>Geothermal</th>
<th>Hydro</th>
<th>Nuclear</th>
<th>Waste + Oil</th>
<th>Lignite</th>
<th>Hardcoal + CCS</th>
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<th>Gas + CCS</th>
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<td>487</td>
<td>557</td>
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HEAT SUPPLY IN HEAT GRIDS (EUROPE)
ELECTRIFICATION OF HEAT SUPPLY
热网供热（欧洲）
供热电气化

Pathway: Diversification

<table>
<thead>
<tr>
<th>Year</th>
<th>Heat Pump (Heat Grid)</th>
<th>Electric Heater</th>
<th>Gas CHP GUD</th>
<th>Gas CHP GT</th>
<th>Gas Boiler</th>
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<td>2050</td>
<td>302</td>
<td>71</td>
<td>71</td>
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</table>
Regional Differentiation of weather balances wind profile

气候平衡 风廓线的区域分异
Electricity Generation Europe January 11 to 17 year 2050
欧洲发电 2050年1月11日至17日
HEAT GENERATION IN HEAT GRIDS (EUROPE)
JANUARY 11 TO 17 YEAR 2050
欧洲热网供热
2050年1月11日至17日

Pathway: Diversification

- Storage Discharge
- Electric Heater
- Heat Pump (Heat Grid)
- Gas CHP GUD
- Gas CHP GT
- Gas Boiler
- Heat Demand
**Pathway: Diversification**

- **Storage Discharge**
- **Electric Heater**
- **Heat Pump (Heat Grid)**
- **Gas CHP GUD**
- **Gas CHP GT**
- **Gas Boiler**
- **Heat Demand**
HEAT GENERATION (HEAT GRIDS), UK
JANUARY 11 TO 17 YEAR 2050
英国热发电 (热网)
2050年1月11日至17日
Dispatch June 2050, week 24-Electricity
2050年6月第24周 电力调度
Dispatch June 2050, week 24 - heat grid
2050年6月第24周热网调度

Diversification

Heat Generation (GWh/h)

Days

Storage Discharge
Electric Heater
Heat Pump (Heat Grid)
Gas CHP GUD
Gas CHP GT
Gas Boiler
Storage Charge
Heat Demand
MAIN FINDINGS - Energy System

- A stable electricity & heat grid system with 96% decarbonisation is possible
  - Foreseeable CO₂ prices well above 100 €/t are needed in the end
- There are different technology pathways to reach the target
  - Renewables and especially wind energy will be an important factor
  - Heat grids are an important option to adopt to different developments in technology
- If you want to keep cost as low as possible
  - Strengthen the electricity grid
  - Create a competitive market environment for the direct use of electricity in other sectors such as heat grids
- If you want to keep requirements for generation infrastructure low
  - Prefer direct use of electricity over hydrogen/“synthetic hydrocarbons” wherever possible and economically feasible
MAIN FINDINGS - Modelling

主要发现 - 能源系统

• Deep Decarbonisation leads to challenges in modelling the electricity sector
  • 深度脱碳导致电力行业建模面临挑战
    • Temporal resolution of dispatch needs to be high
    • 调度的时间分辨率需要很高
    • High resolution weather data is crucial
    • 高分辨率天气数据至关重要
    • Electricity grid is key
    • 电网是关键
• Modelling needs to go beyond the electricity sector
  • 建模需要超越电力部门
    • Heat
    • 热
    • Electric cars
    • 电动车
    • Fuels (Hydrogen etc.)
    • 燃料（氢等）
• The amount of data and computational power is enormous, but recent studies show that modelling is on the way to meet the challenge
  • 数据量和计算能力是巨大的，但最近的研究表明，建模正在迎接挑战
THANK YOU FOR YOUR VALUABLE TIME!

Contact
Dr. Frank Sensfuß
Phone: +49 (0) 721 / 68 09 – 133
Mail: frank.sensfuss@isi.fraunhofer.de
Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Straße 48, 76139 Karlsruhe
www.isi.fraunhofer.de

www.enertile.eu
Pathway: Diversification

Solar PV
Solar CSP
H2 Electrification
Waste
Lignite
Hardcoal
Gas
Wind Onshore
Hydro
Biomass
Geothermal
Wind Offshore
Nuclear
**Trading capacity (NTC) between countries 2050 in GW**

2050年国家之间的交易能力（NTC）

- **Diversification** (多样化)
- **Optimised** (优化)
- **Localisation** (位置)
- **Restricted** (受限)
UTILISATION OF POTENTIAL FOR WINDONSHORE

National Champions

Strong use of hydrogen

Localisation

More generation infrastructure required