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# Energy transition on track or in troubled waters: Insights from recent trends and experiences in Germany and elsewhere

**Kyoto University**

**Dr. Felix Chr. Matthes**

**Kyoto, 30th September 2016**

# Transforming the energy system
# Economic background

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- **German population 81 million**
- **German GDP in 3,026 bn € (3,359 bn US$) in 2015**
  - Highly industrialized (26% of GDP from industry)
    - Strong manufacturing industry
    - Strong primary industries (2015: Crude steel production 43 mln t, Primary aluminum production 531,000 t)
  - Strong net exporter (net trade surplus in 2015: ~ 248 bn €)
- **Primary energy (2015): Oil 34%, natural gas (21%), hard coal (13%), lignite (12%), renewables (12,5%) , nuclear (7,5%)**
- **Power generation (2015): lignite (24%), renewables (31%), hard coal (18%), nuclear (14%), natural gas (9%), others (4%)**
- **Strong federal structures (significant impact of states on energy legislation), strong municipalities (~900 municipal utilities)**
- **Member of the European Union (internal market, increasing integration of energy and climate policies)**

# Transforming the energy system
# There are many drivers

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- **Primary drivers**
  - contribution to avoid dangerous climate change
  - minimize overall vulnerability of the country (e.g. nuclear risks, energy security)
  - modernize the country with cutting-edge technology to strengthen the economic basis of the country
- **There are however other dimensions**
  - major investment needs exist anyway
  - increasingly volatile global fuel markets
  - major technological innovation and cost decrease is underway (solar PV, offshore wind, storage, ICT)
  - major cost increases for conventional technologies
  - deep crisis of coal industry (high fixed costs and uncertain future)
  - major uncertainties on the macroeconomic and international policy environment

# Transforming the energy system
# Not to forget the broader framework

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- **Liberalised energy markets (since 1996)**
  - utilities are increasingly vulnerable to switching customers
  - unbundled electricity and gas network operations (legal/ownership)
  - central trading platforms (electricity exchange) provide price transparency
  - broad market transparency on generation, networks
- **A strong tradition of decentral/cooperative economic activities (since the early 20$^{th}$ century)**
  - strong decentral/cooperative sector (businesses, financial sector etc.)
  - robust legal and institutional framework for the decentral/cooperative sector

# The 'Double U-turn' of German Policy
# It was not only about nuclear!

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- **Highly controversial Energy Concept 2010 (September 2010)**
  - Lifetime extension of nuclear plants (by 8 to 12 years)
  - Ambitious climate and energy policy targets
  - Some additional policies (Energy & Climate Fund!), significant gaps in respective policies
- **Revision of the 2010 decisions (Spring/Summer 2011)**
  - Reversion of NPP lifetime extension, acceleration of phase-out
  - Confirmation of targets
  - Additional policies (efficiency, CHP, renewables, infrastructure, regulation)
  - Result: continuation of (well-discussed and well-prepared) strategies, now with a clear long-term focus
- **Comparable debates within the EU (apart from nuclear): Low-carbon Economy Roadmap 2050, Energy Roadmap 2050)**

# The German case study
# 'Energiewende' as a comprehensive strategy

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| | GHG emissions | Renewable Energies | | Energy efficiency | | | | Nuclear power |
|---|---|---|---|---|---|---|---|---|
| | | Gross final consump-tion | Power generation | Primary energy | Space heating | Final Energy | Power consump-tion | |
| **2011**<br>**2015**<br>**2917**<br>**2019** | | | | | | | | **-41%**<br>**-47%**<br>**-54%**<br>**-60%** |
| **2020** | **-40%** | **18%** | **35%** | **-20%** | **-20%** | **-10%** | **-10%** | |
| **2021**<br>**2022** | | | | | | | | **-80%**<br>**-100%** |
| **2030**<br>**2040** | **-55%**<br>**-70%** | **30%**<br>**45%** | **50%**<br>**65%** | | | | | |
| **2050** | **-80 to -95%** | **60%** | **80%** | **-50%** | **-80%** | **-40%** | **-25%** | |
| Base year | 1990 | | | 2008 | 2008 | 2005 | 2008 | 2010 |

BReg 2010+2011

# The historical context
# Electricity generation & electricity policy

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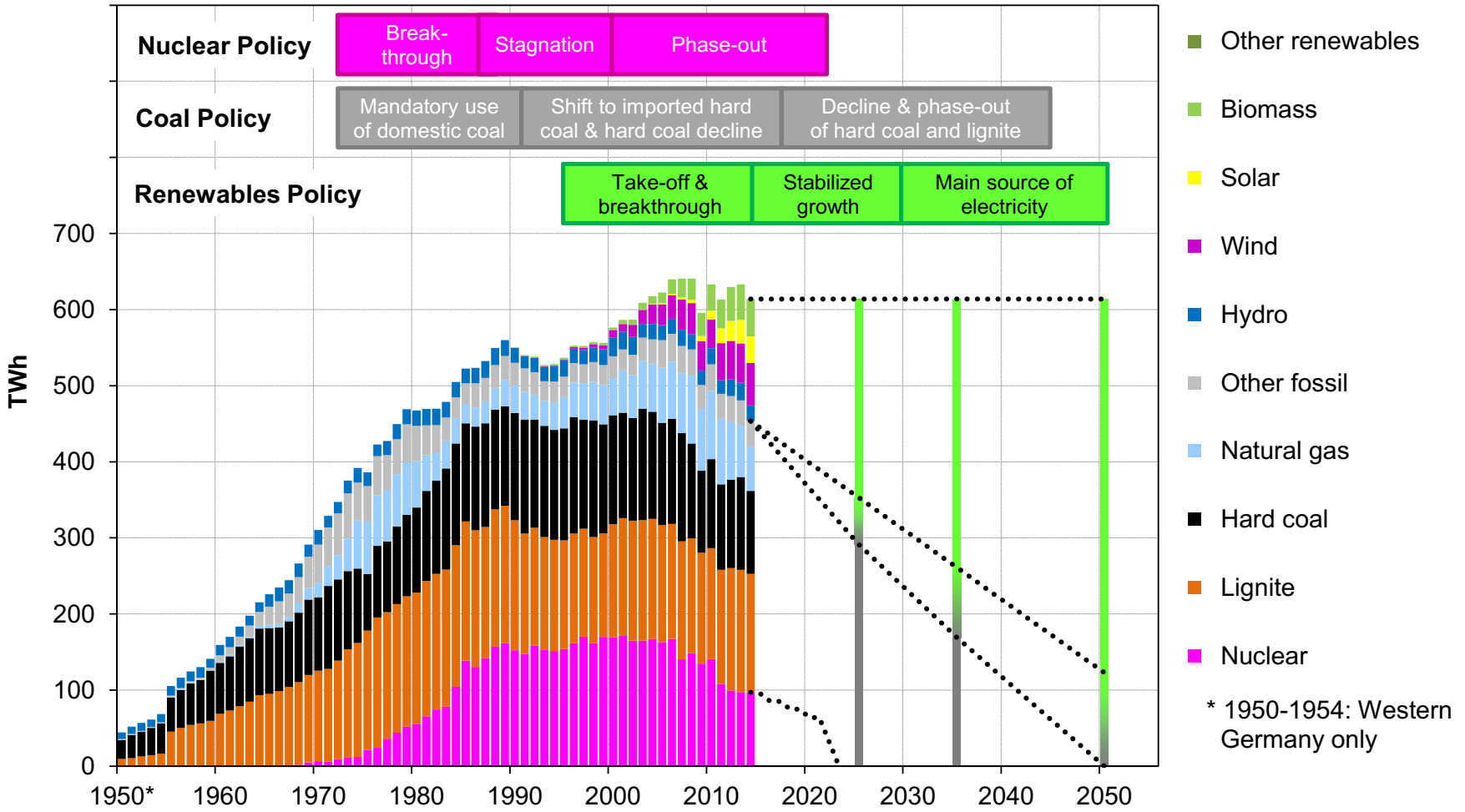


Kohlenstatistik, Matthes (1999, 2015)

# The historical context
# Long history of CO2 emissions & ambitious goals

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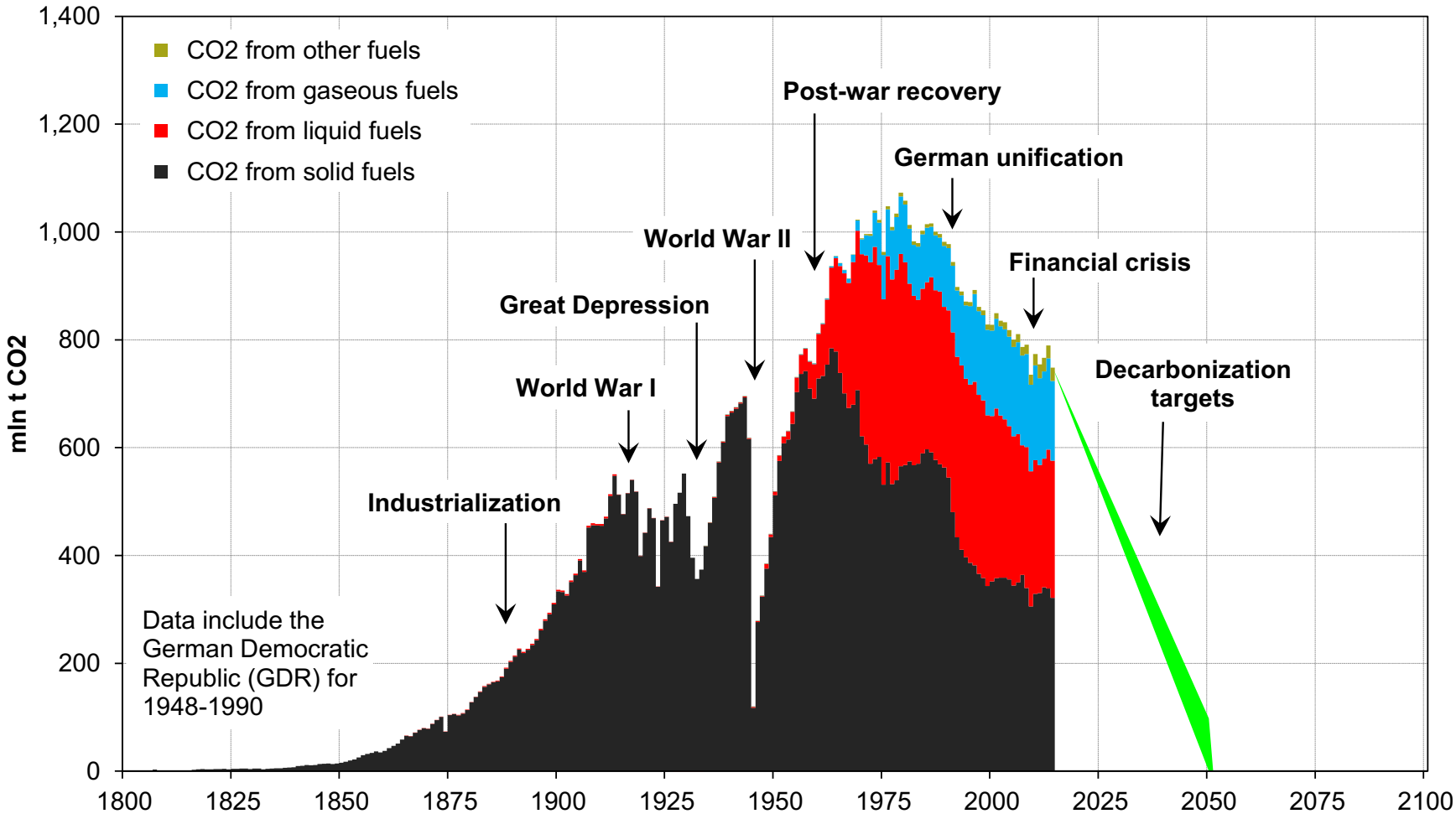


CDIAC, UBA, Öko-Institut

# The EU ETS: Robust long-term commitment
## Long-term caps and/or other long-term mechanisms

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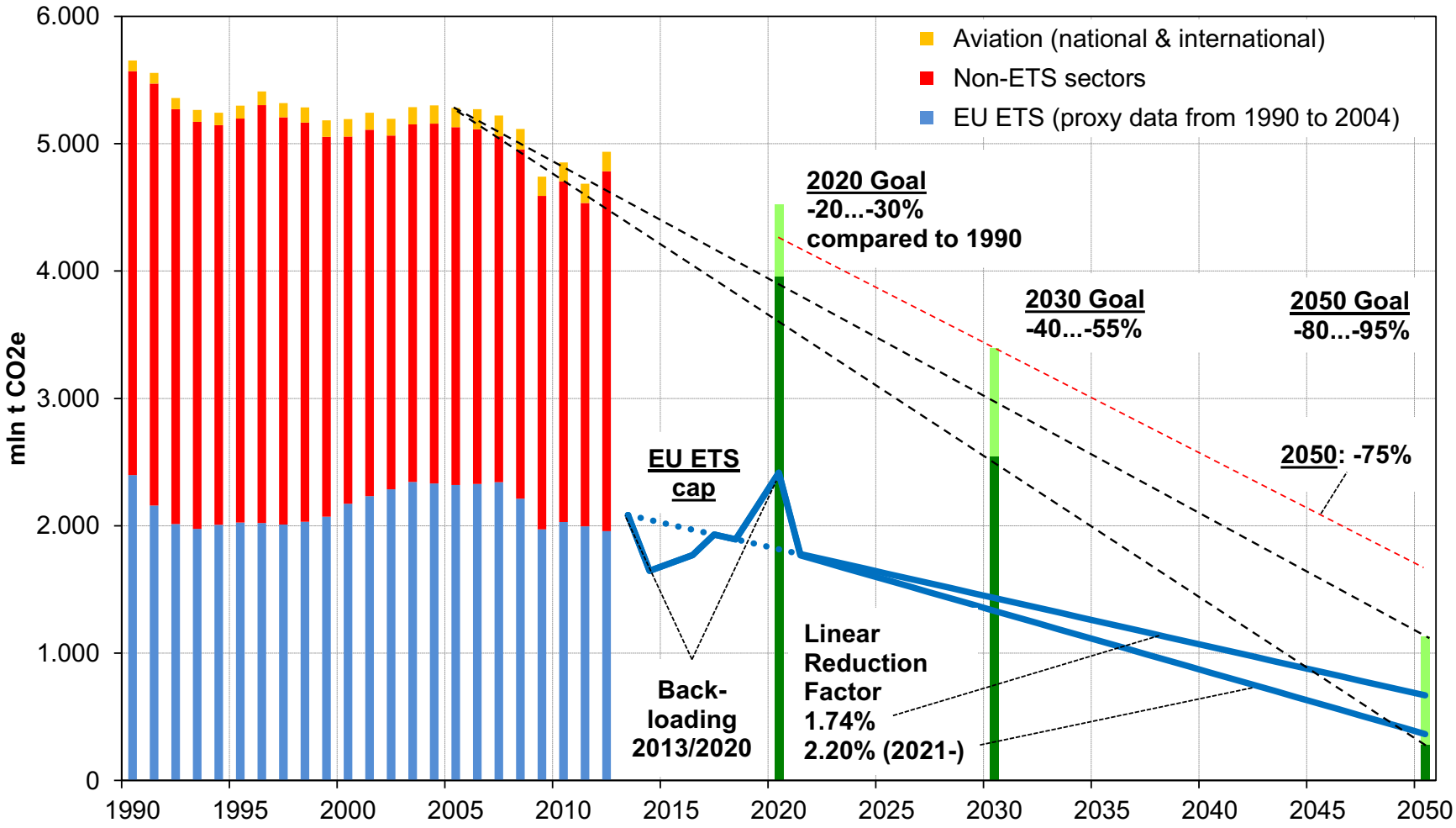


Öko-Institut 2014

# The bigger picture on the future electricity system
## The market and regulatory environment

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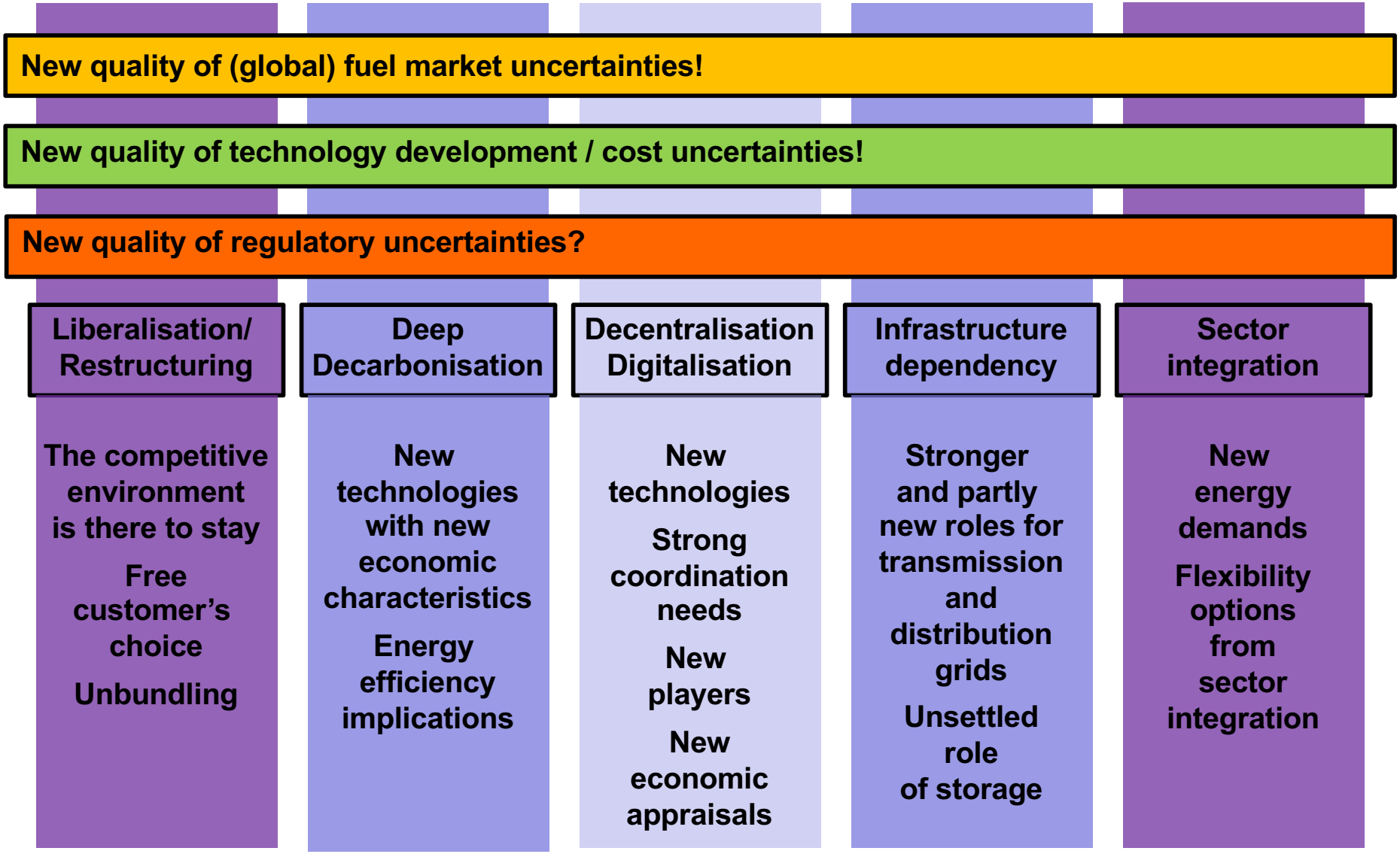


Matthes 2016

# The changing costs of new supply systems
# Storage costs as (additional) game changer?!

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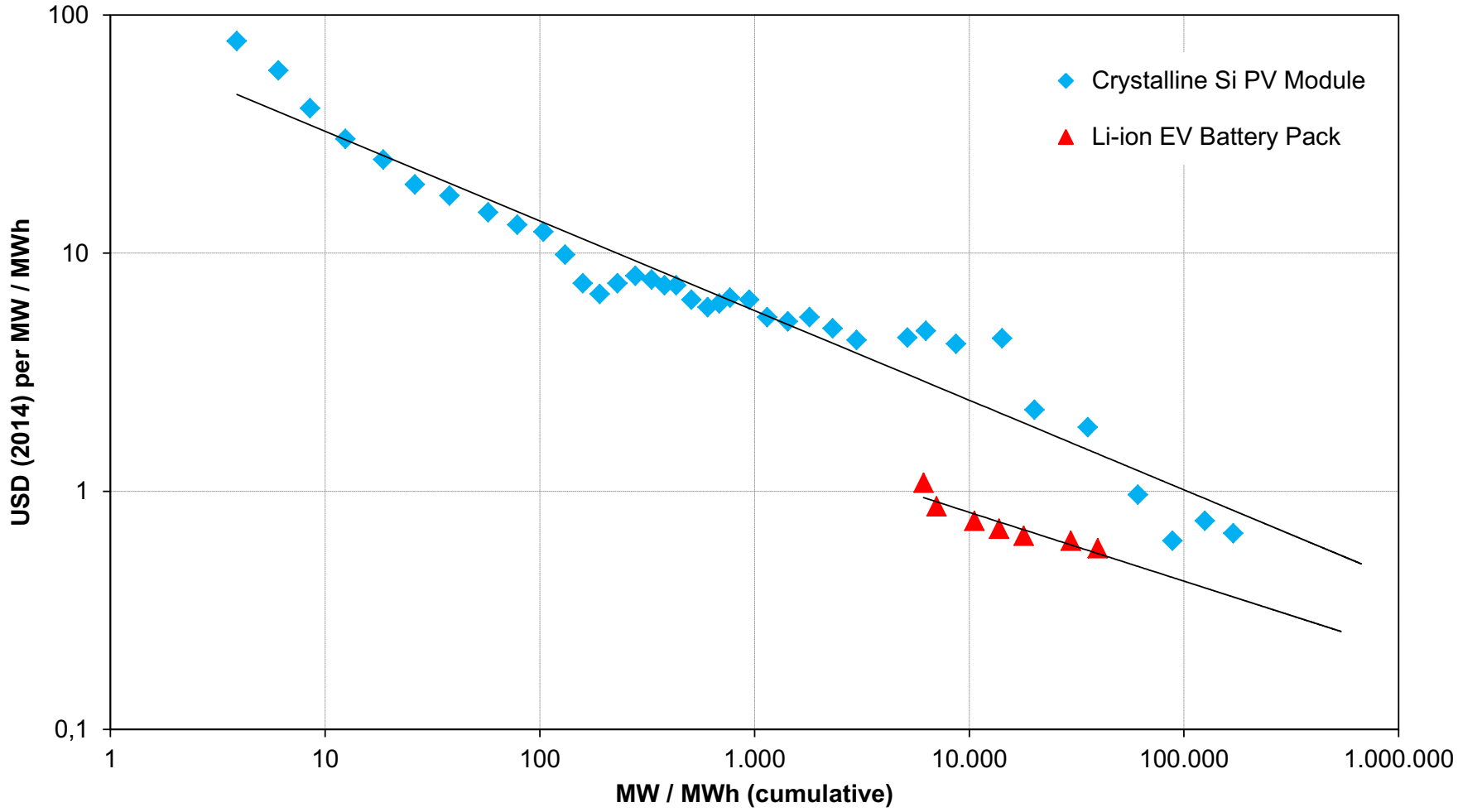


BNEF, Öko-Institut

# Energy transition in Germany
# Expansion of power generation from renewables

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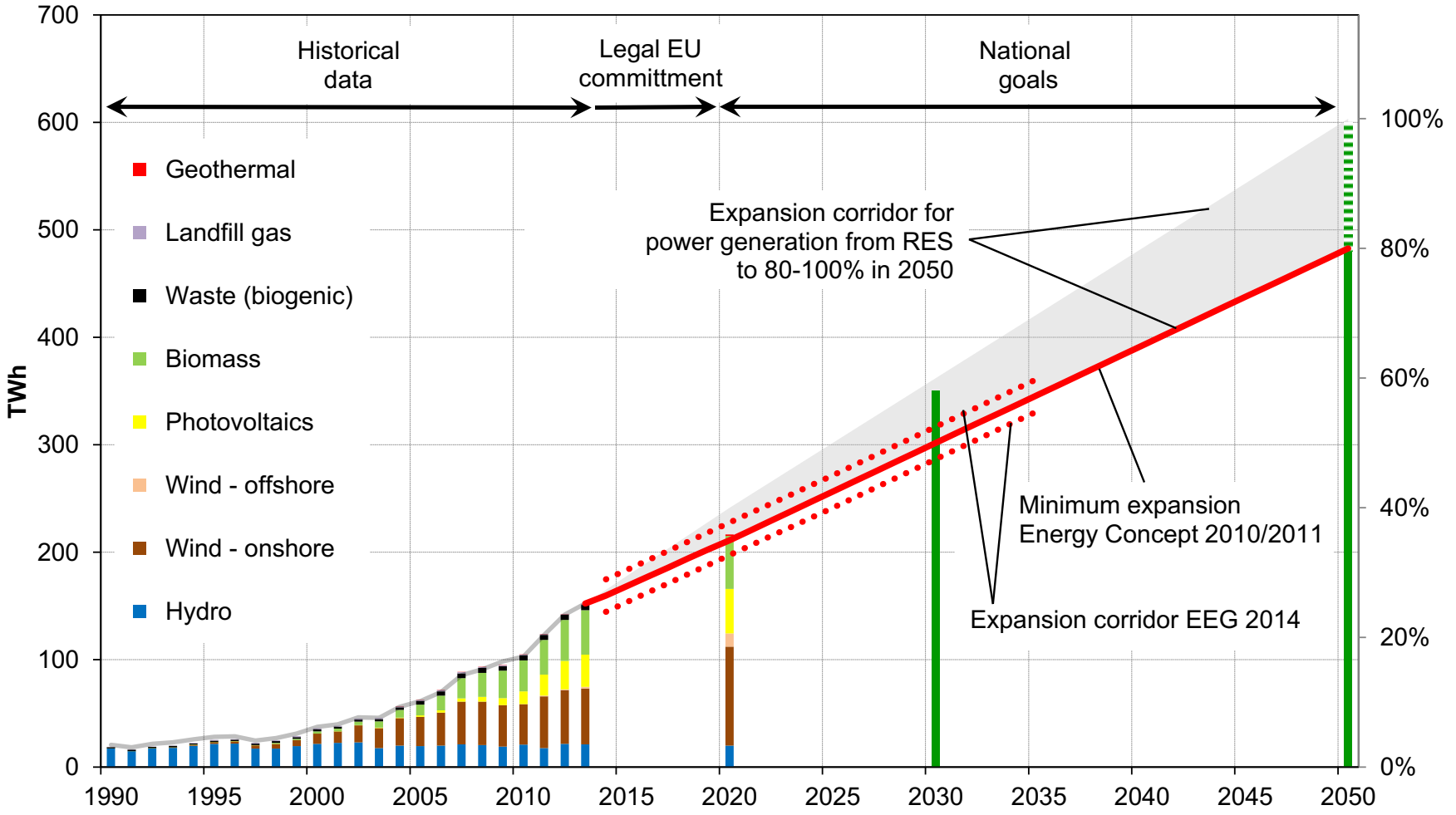


**Germany: Historical & projected roll-out of power generation from RES**

BMU. BMWi, Öko-Institut 2014

# Structural change in power generation structures
# Historical patterns (average week, stylized)

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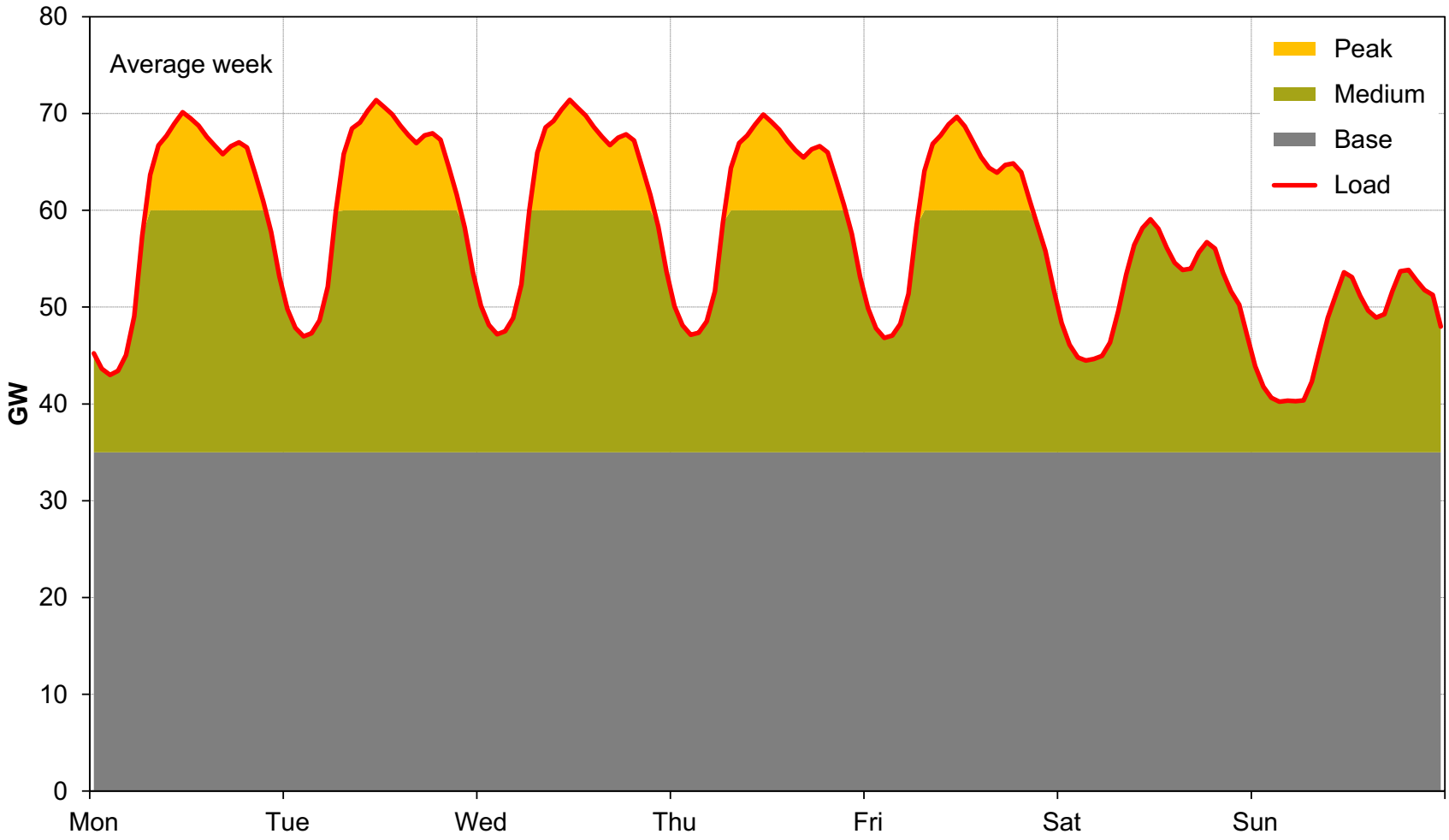


Matthes 2016

# Structural change in power generation structures
# Historical data 2015 (average week)

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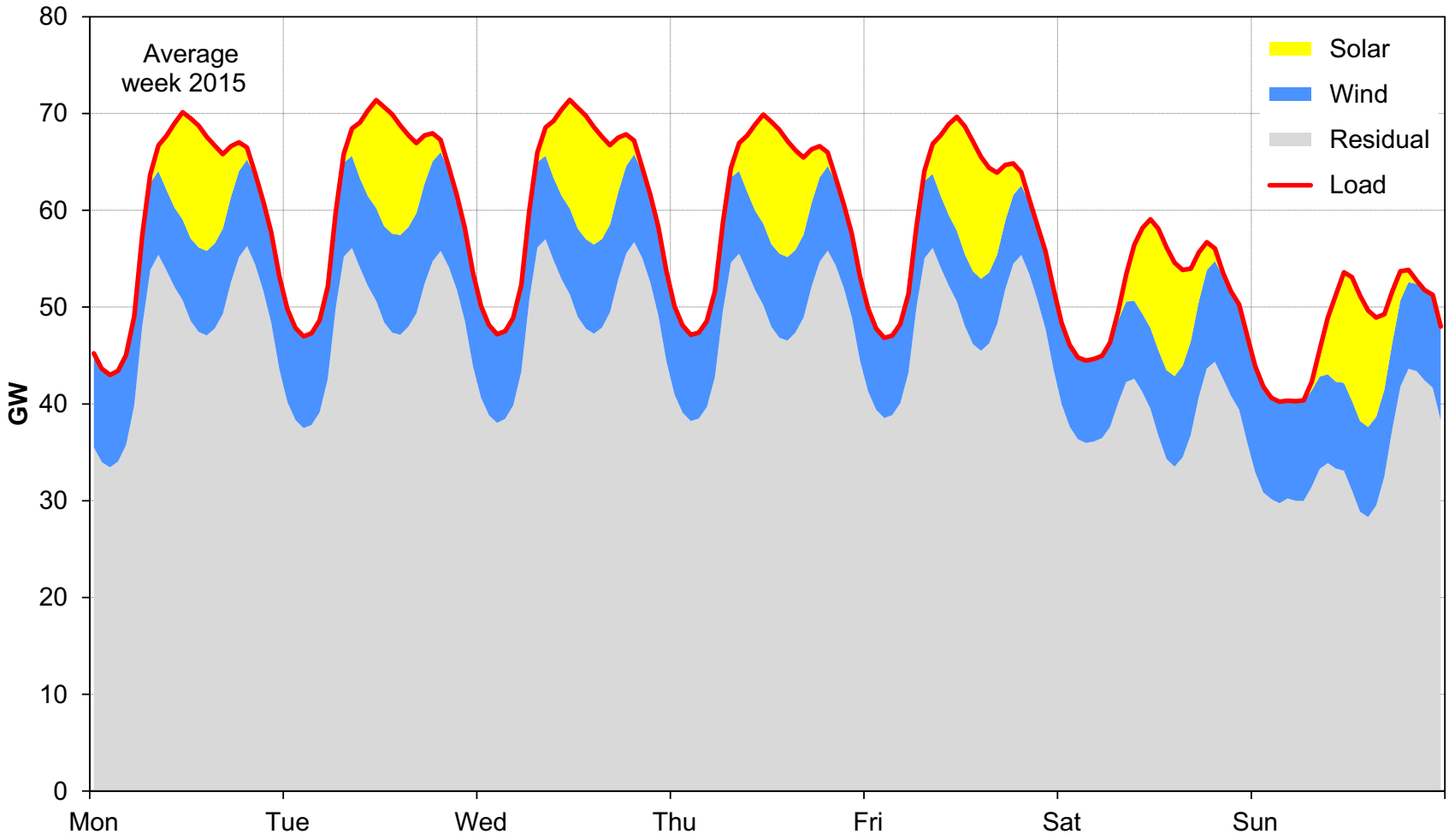


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# Structural change in power generation structures
# Illustrative projection 2025 (average week)

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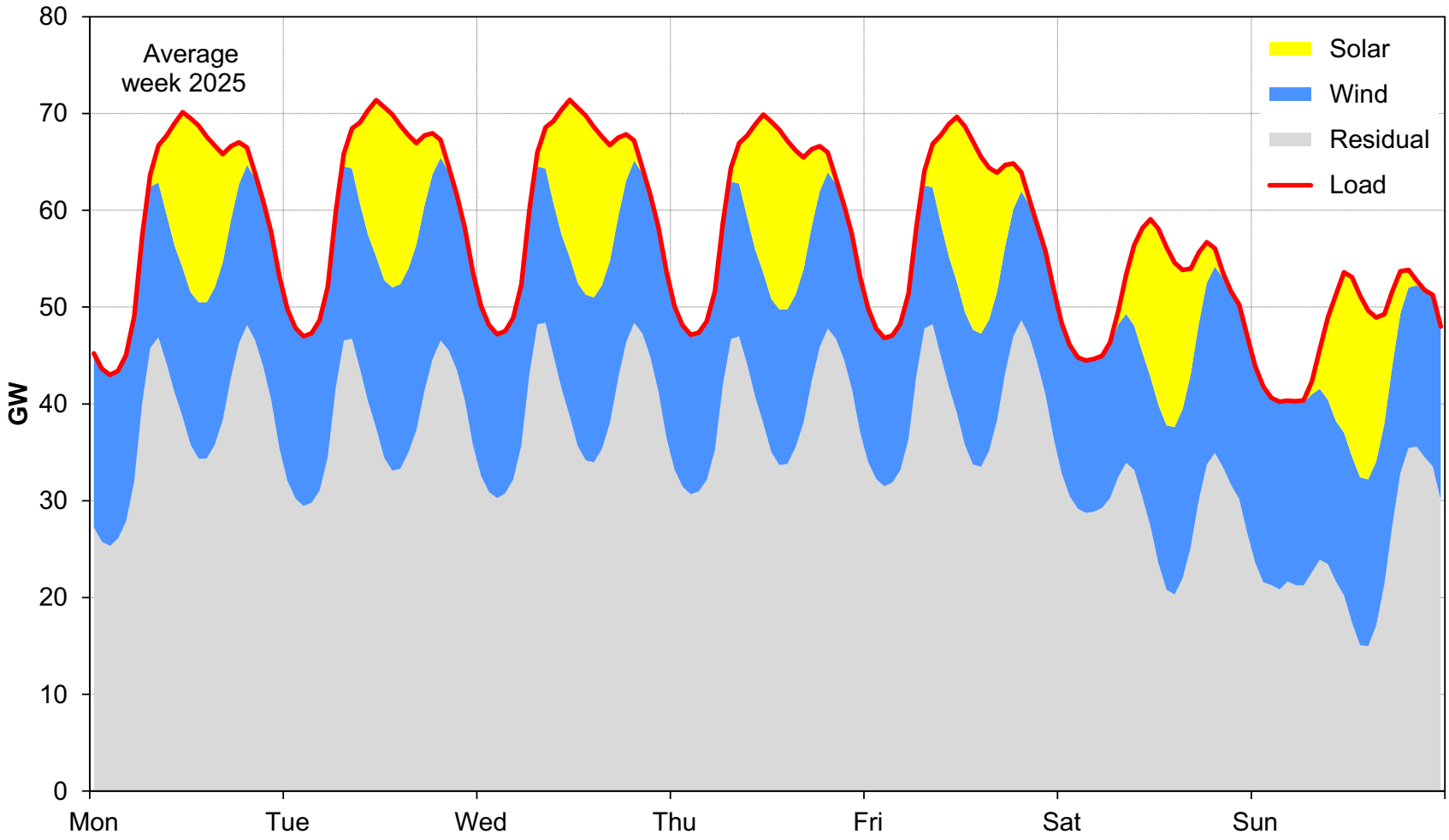


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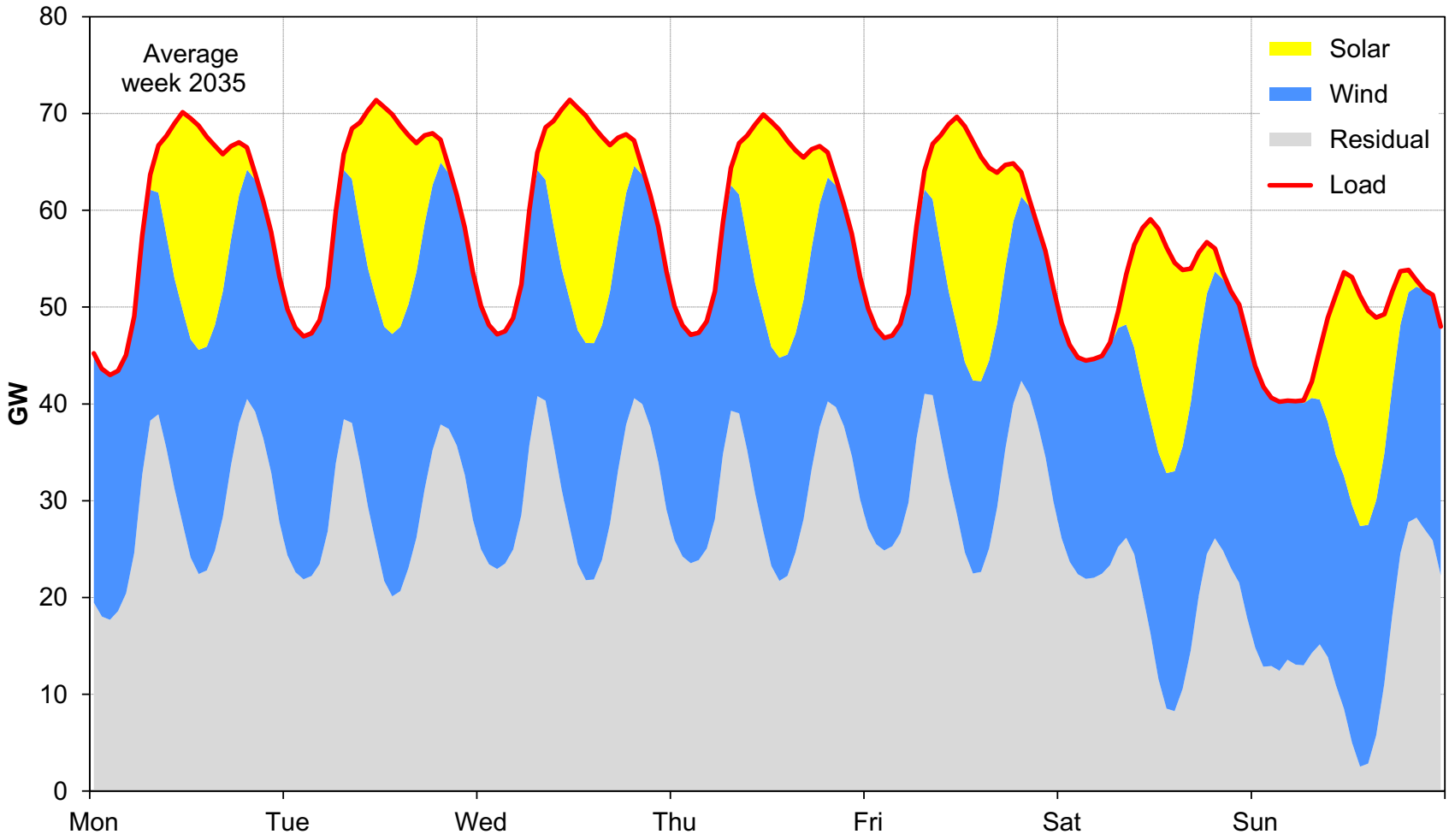


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# Structural change in power generation structures
# Illustrative projection 2045 (average week)

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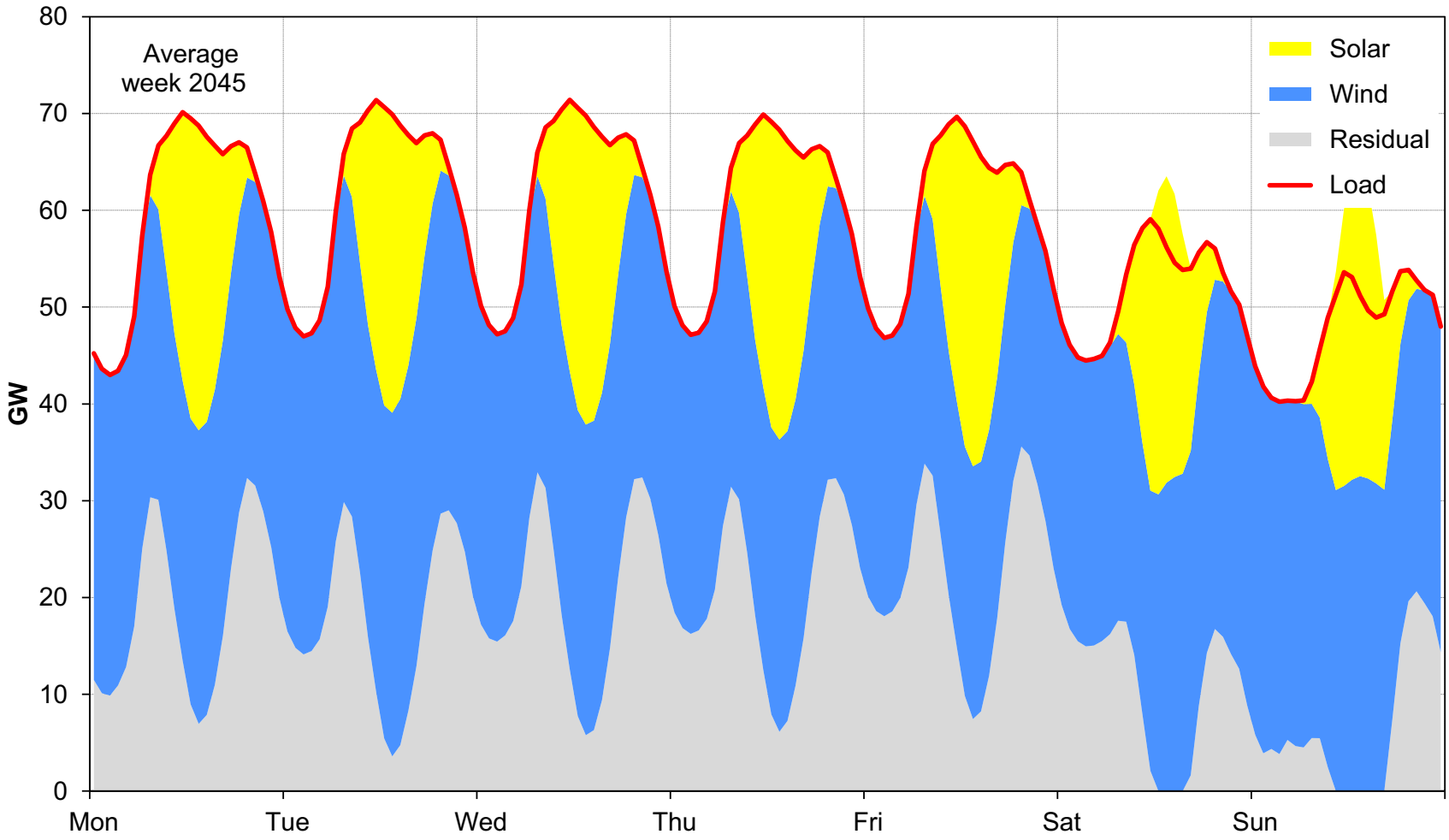


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# Structural change in power generation structures
# Historical patterns (windy & sunny week, stylized)

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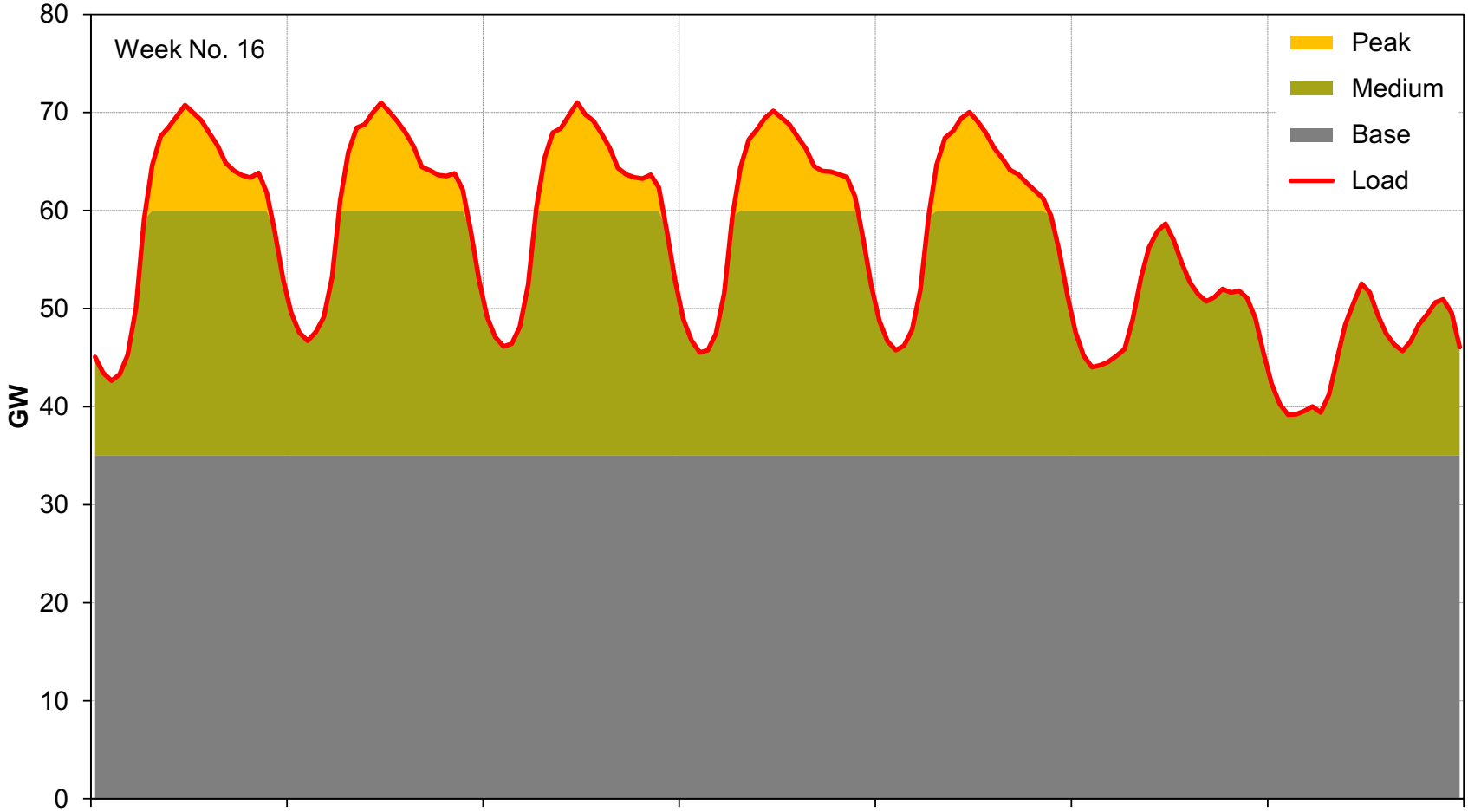


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# Structural change in power generation structures
# Historical data 2015 (windy & sunny week)

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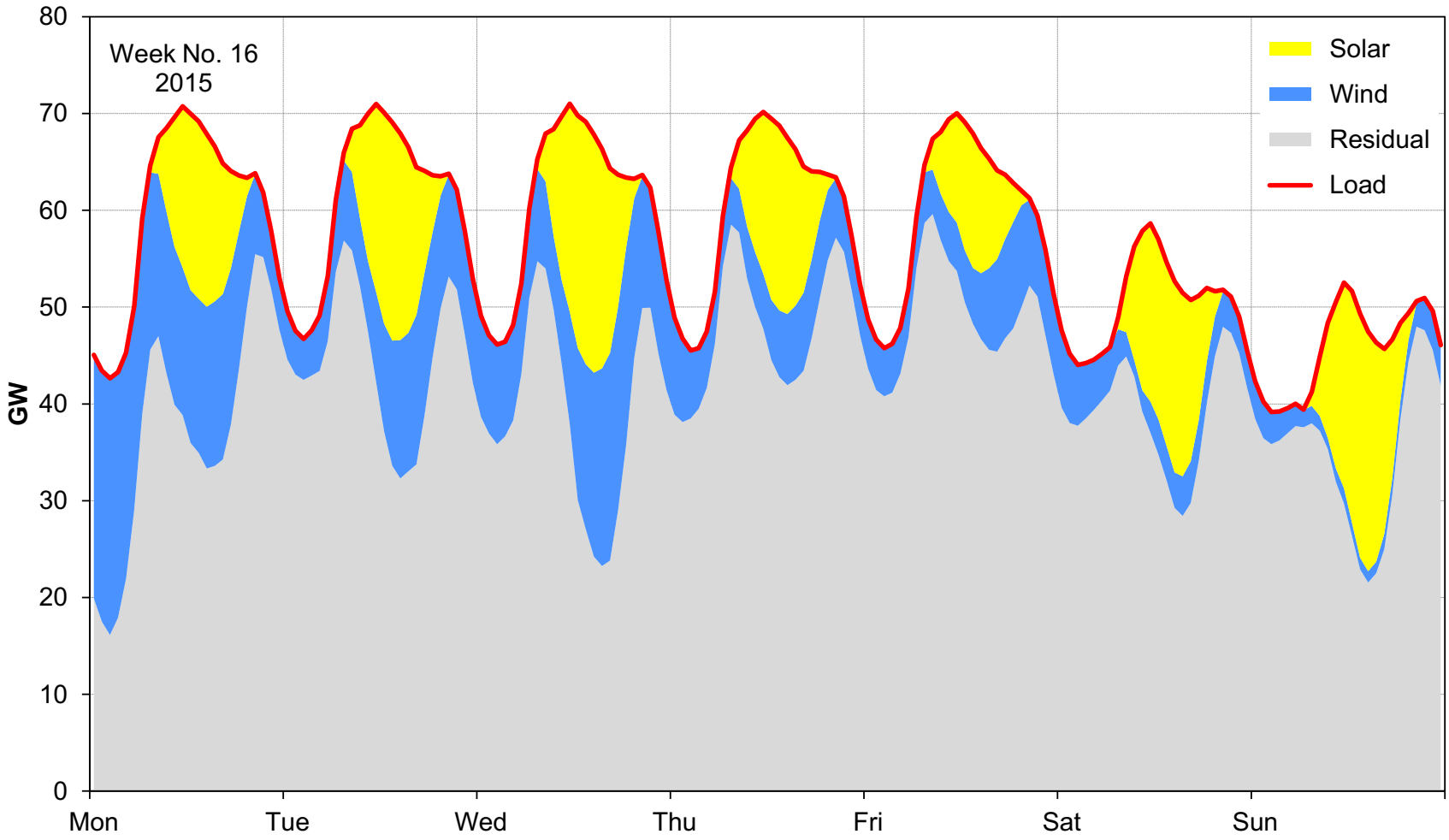


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# Structural change in power generation structures
# Illustrative projection 2025 (windy & sunny week)

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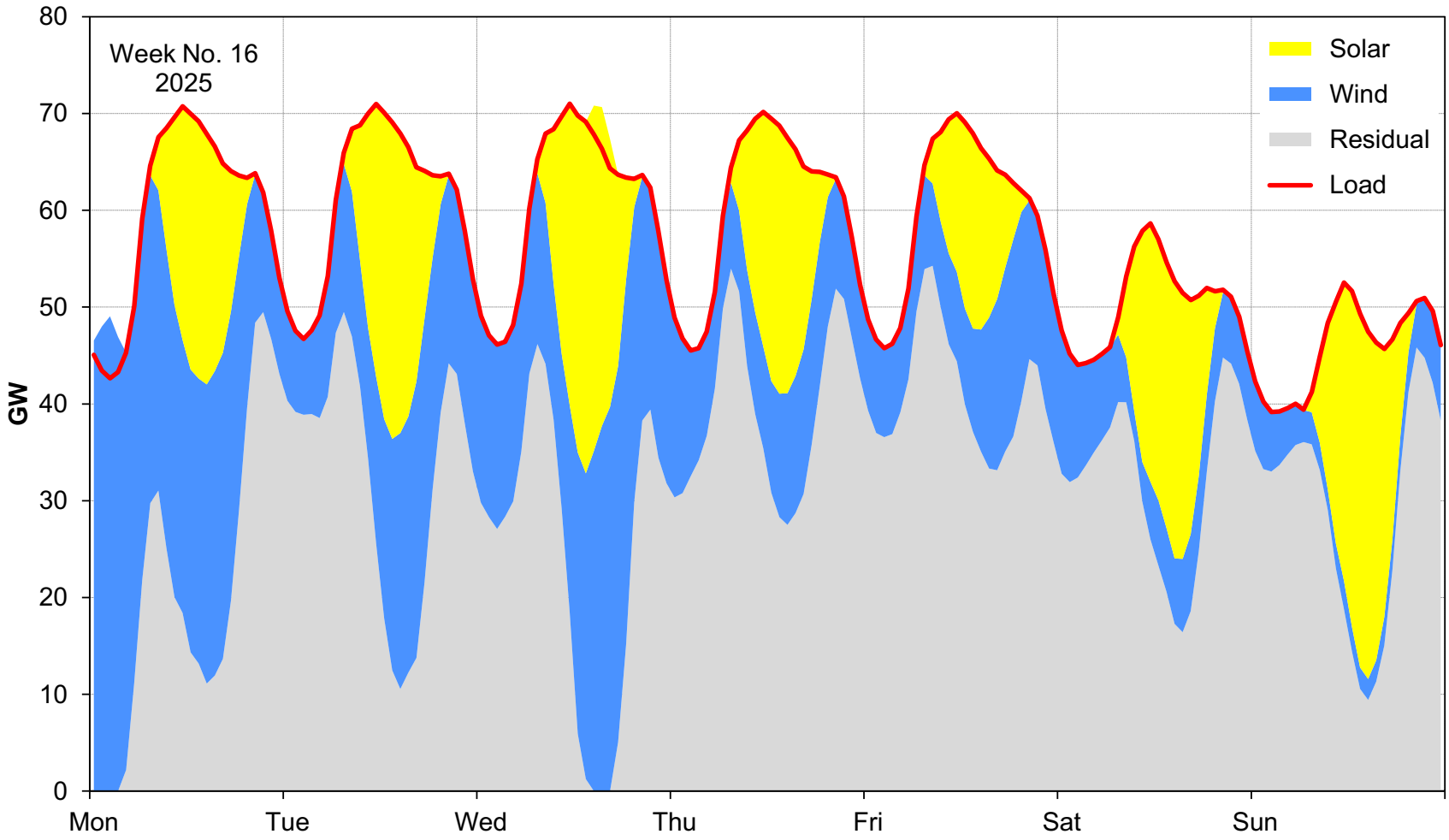


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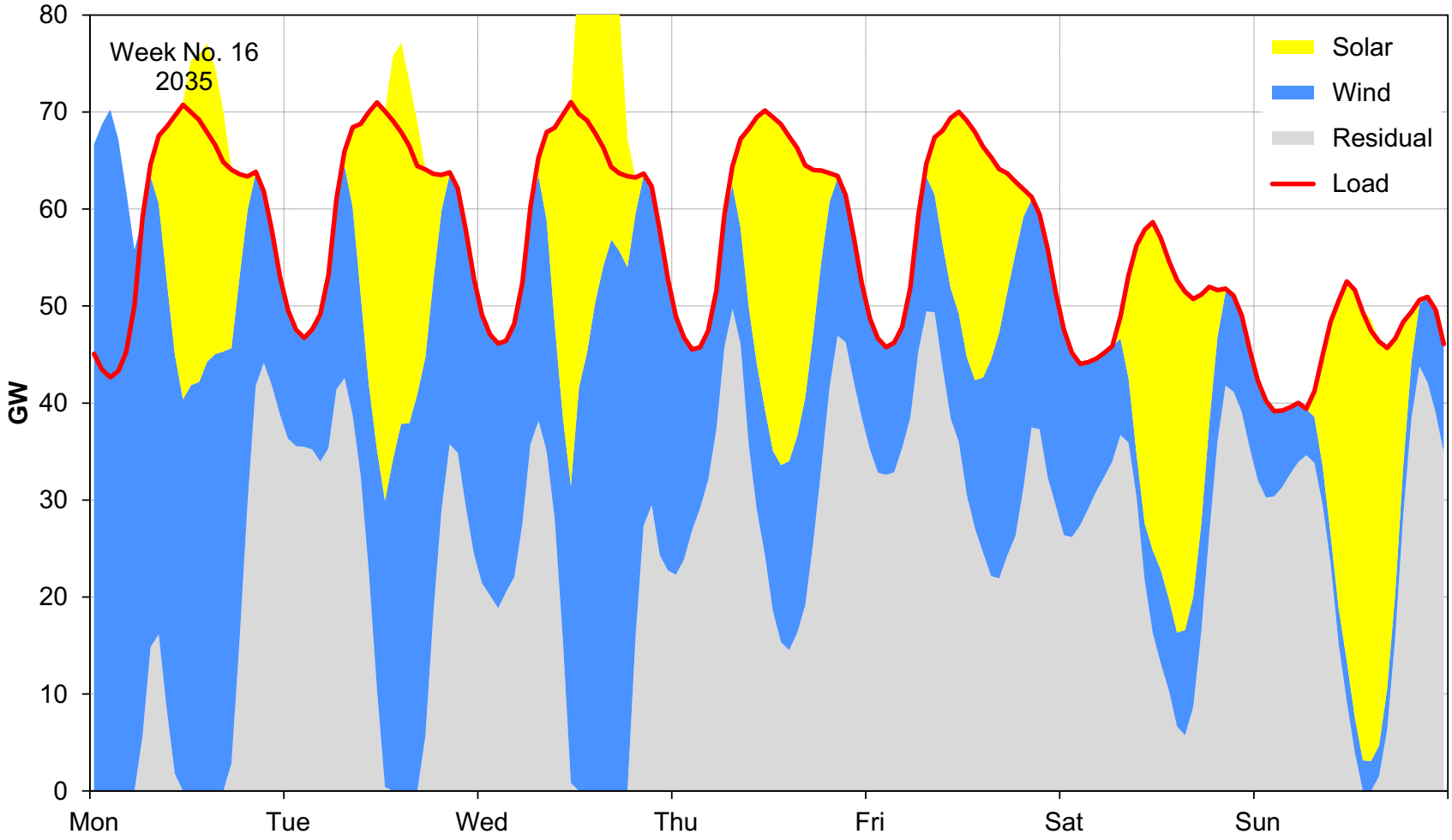


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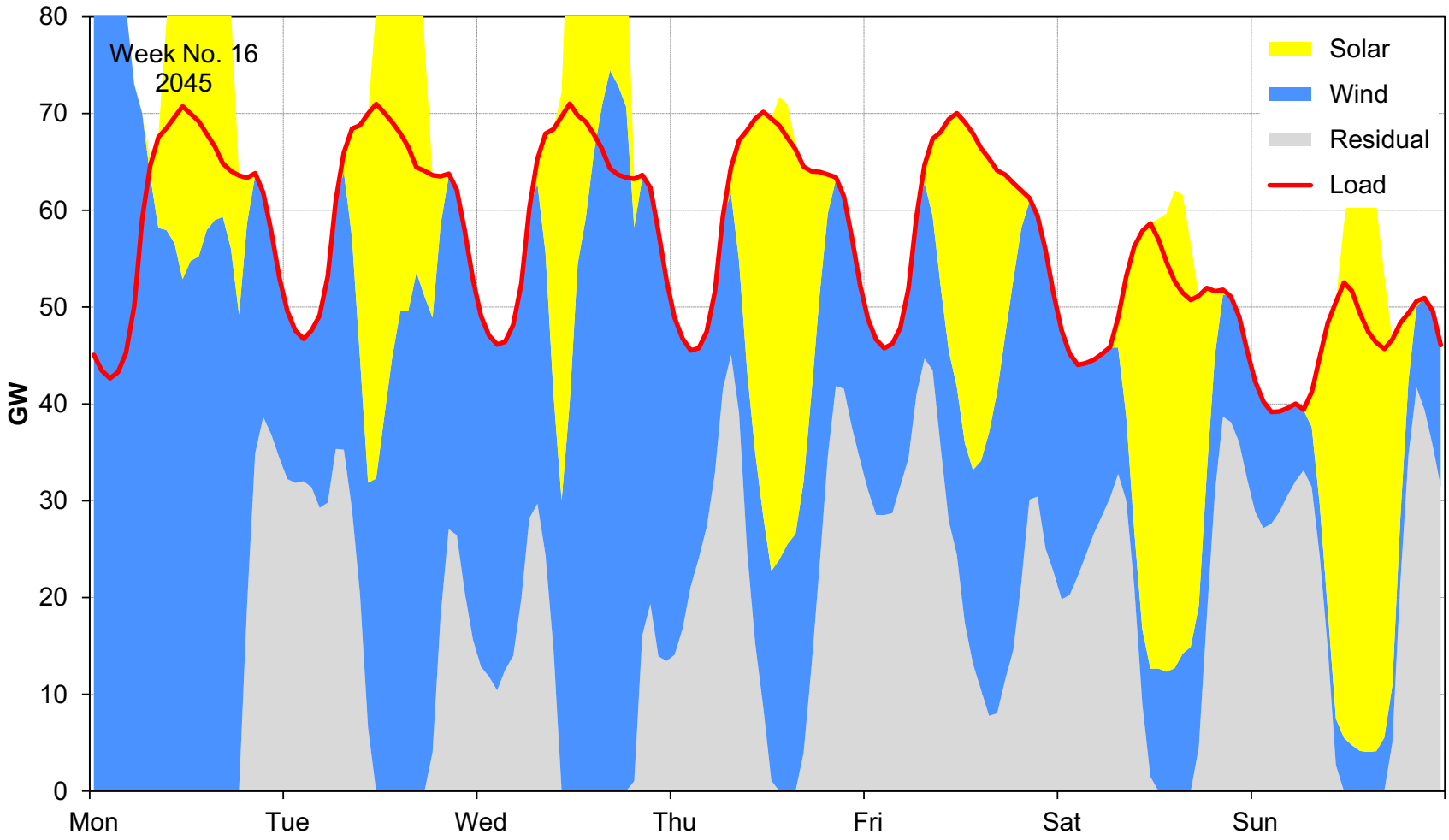


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# Expansion of German RES generation capacities
# Phases of the transition towards a new market design

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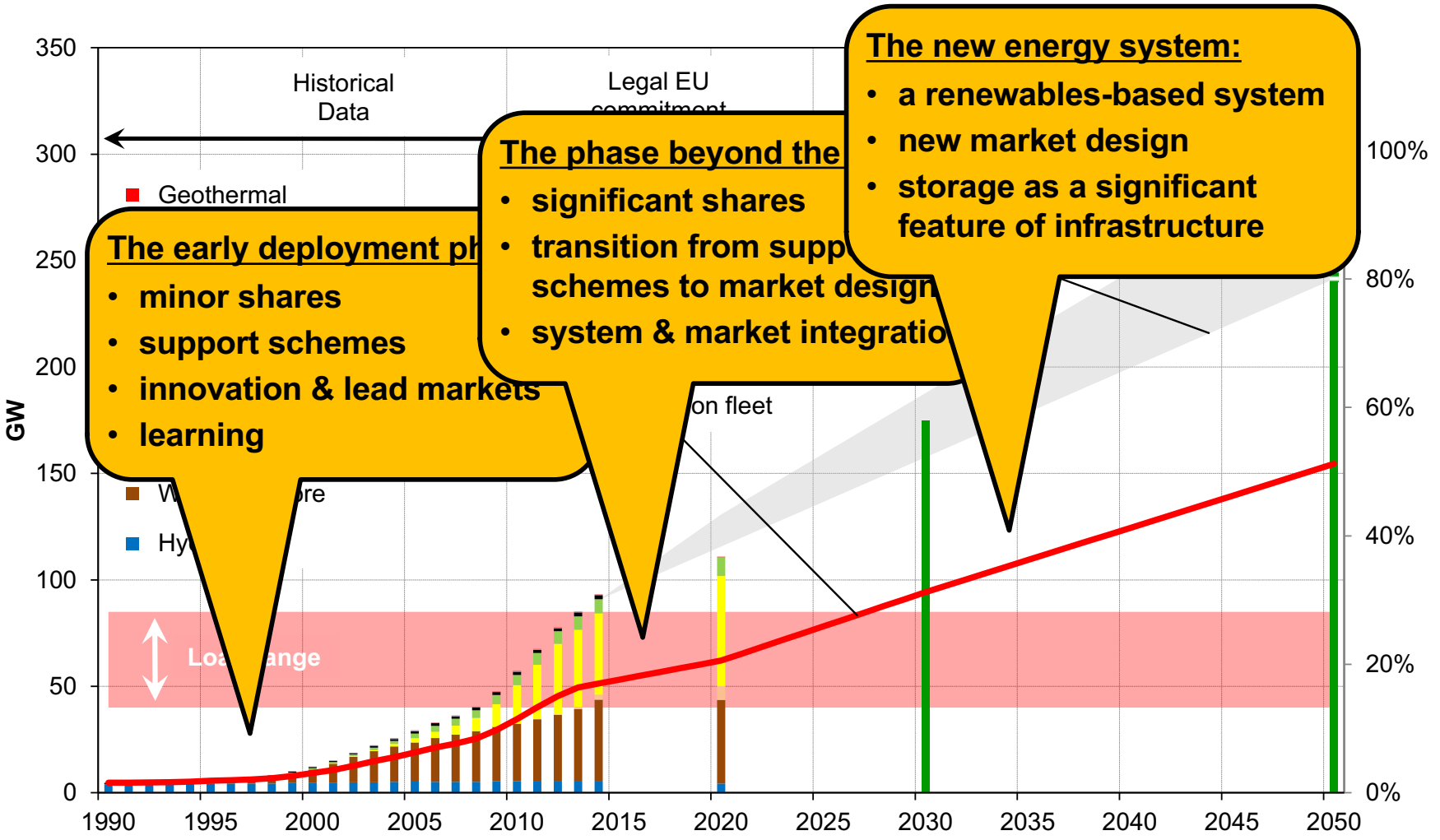


**Germany: Historical & projected roll-out of RES generation capacities**

BMU. BMWi, Öko-Institut 2014

# What about the costs?
# Perspective 1: Historical wholesale prices

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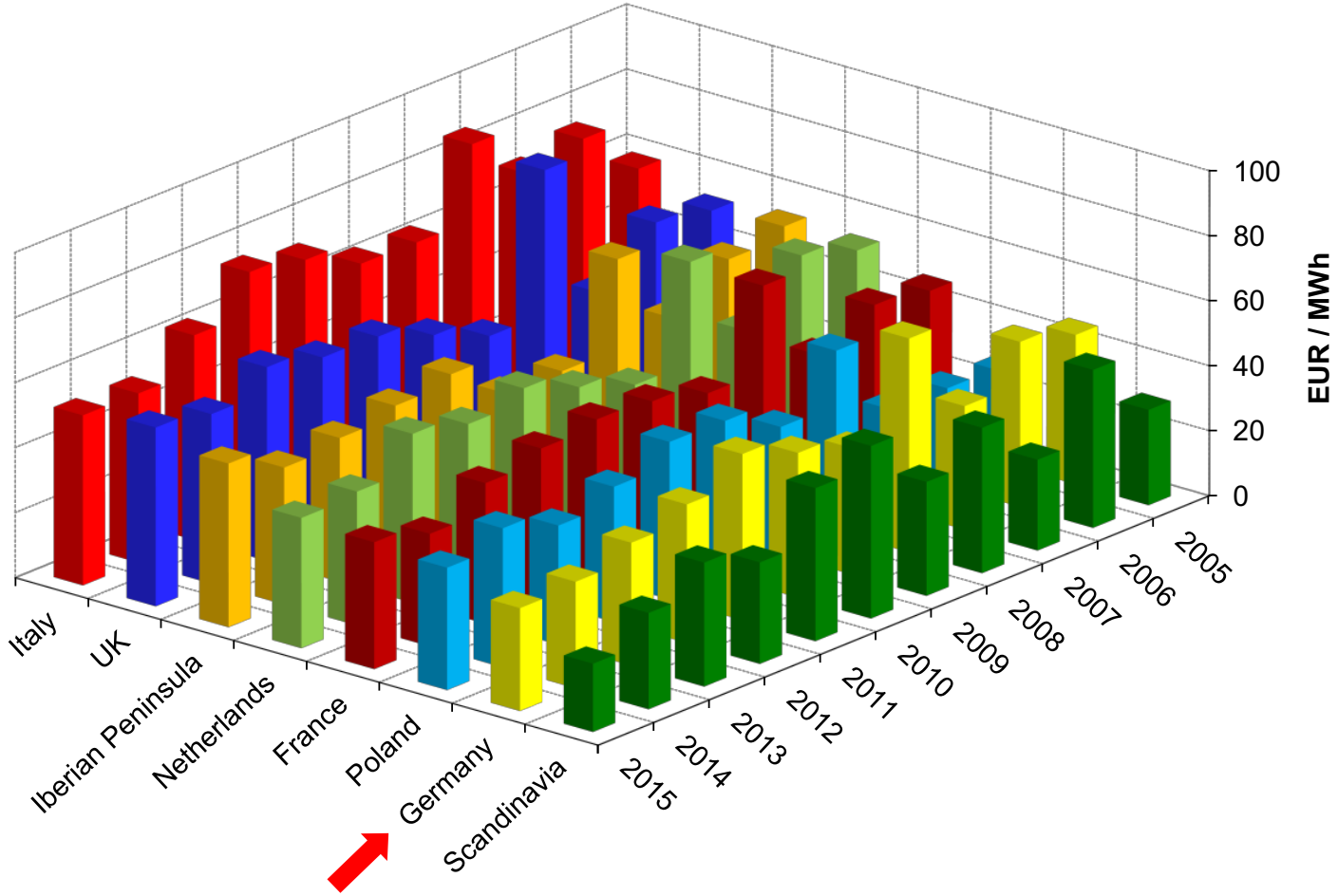


**Different wholesale (base) electricity price trends and levels in Europe**

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# What about the costs?
# Perspective 3: Retail electricity prices (households)

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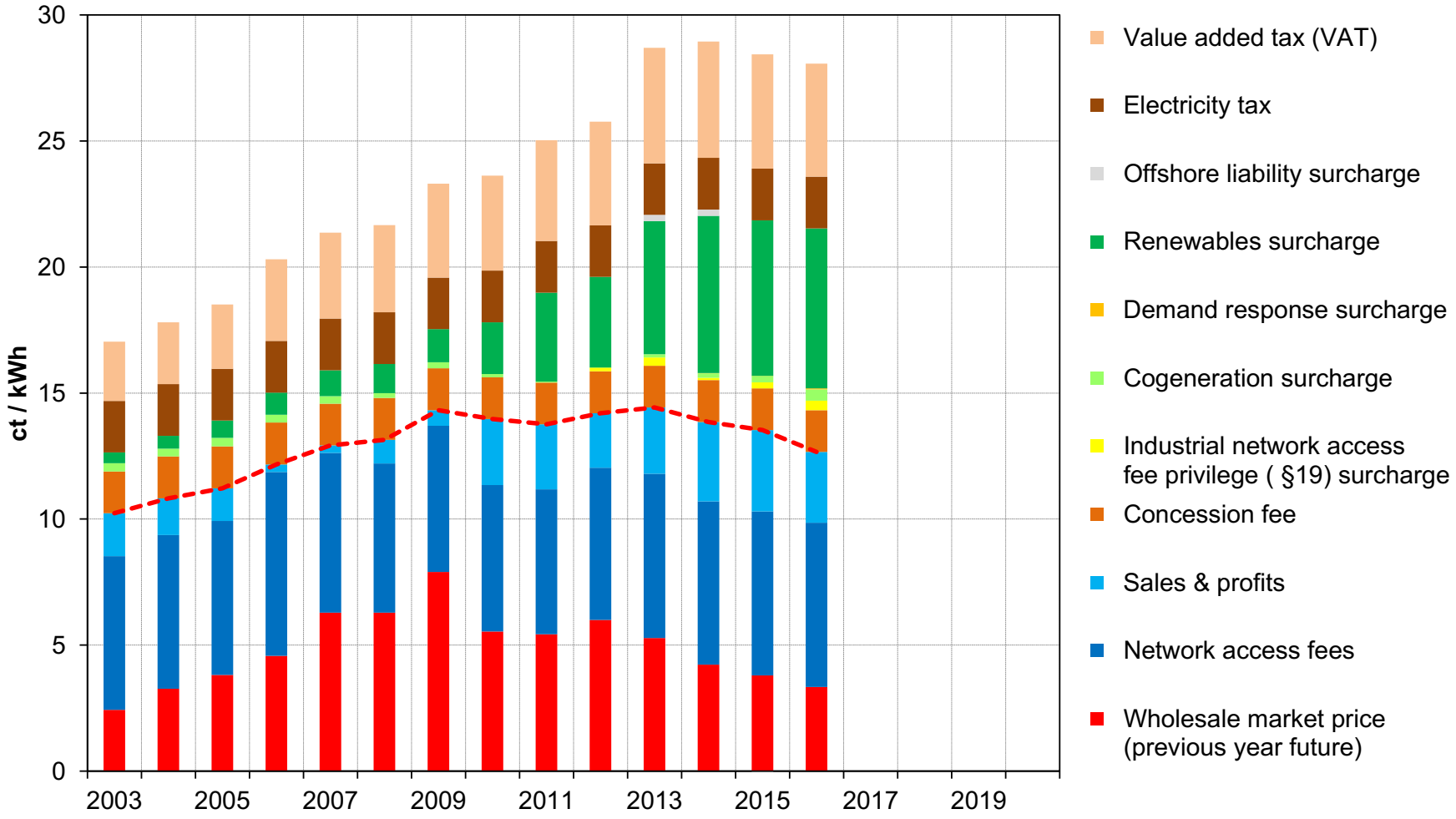


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# What about the costs?
# Perspective 2: Financing actual RES investments

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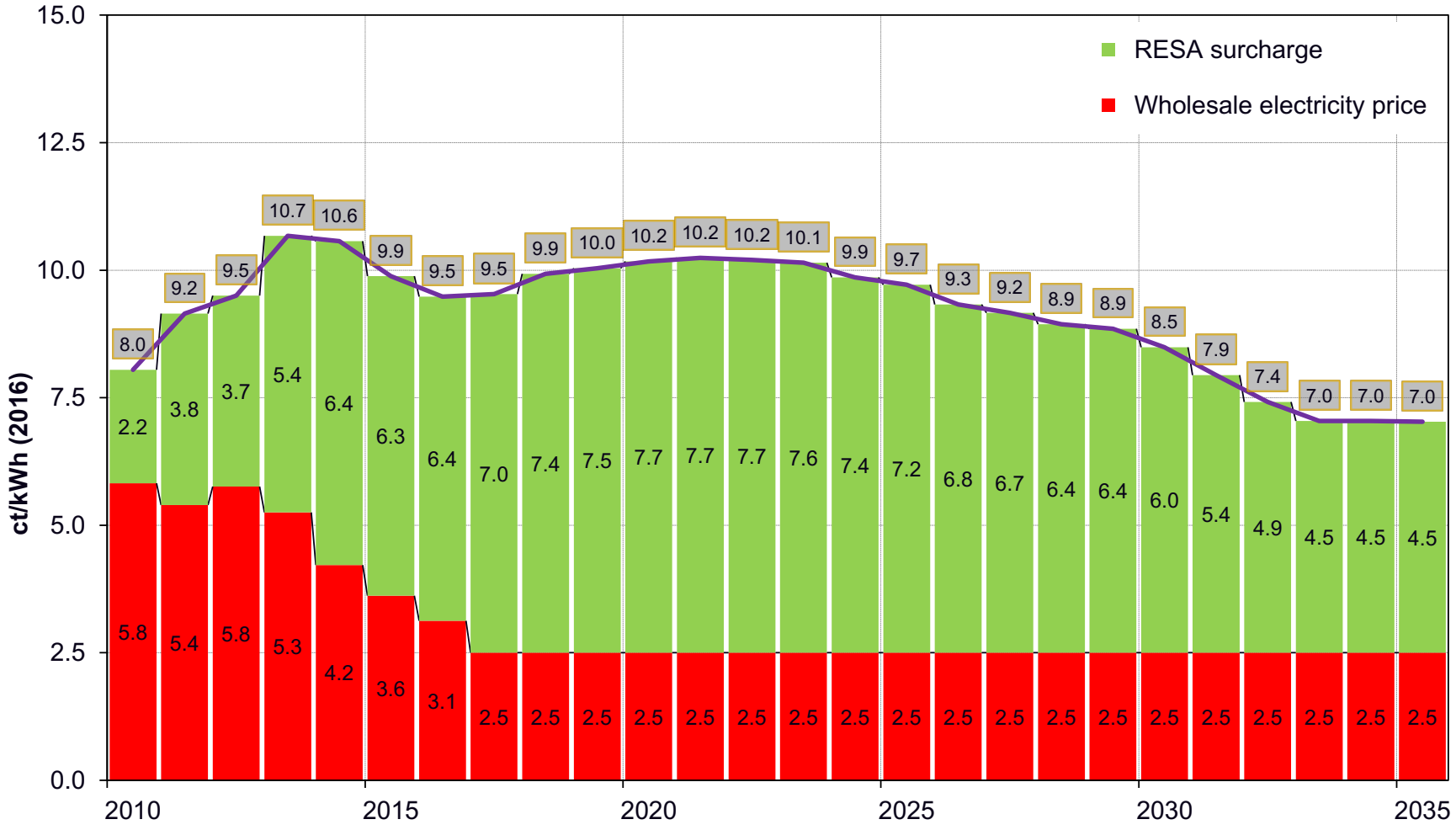


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# Insights from the EU Energy Roadmap 2050
# Primary energy supply for different trajectories

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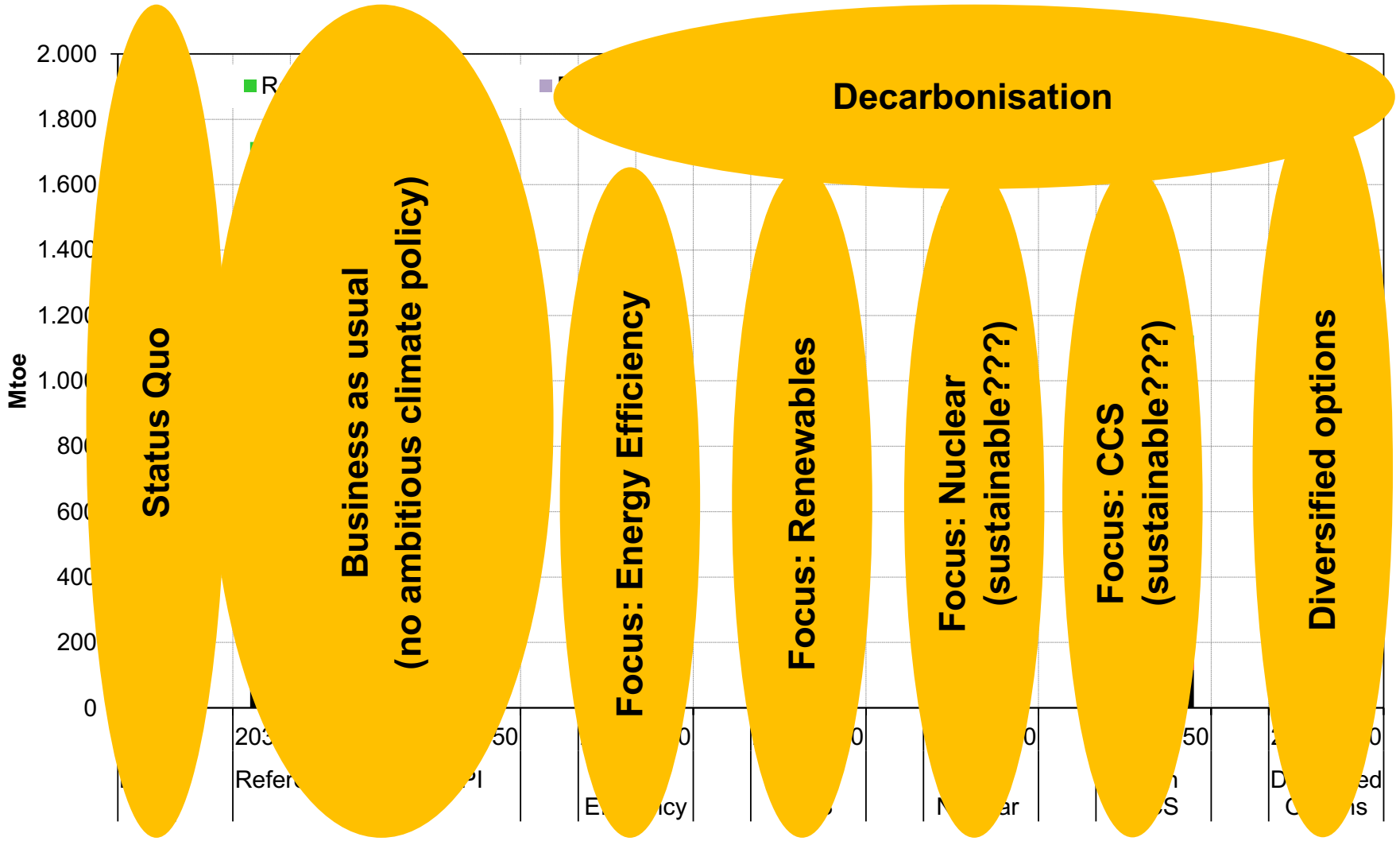


**Status Quo**

European Commission, E3MLab 2011

# Power generation for different trajectories
# Renewables dominate for each trajectory

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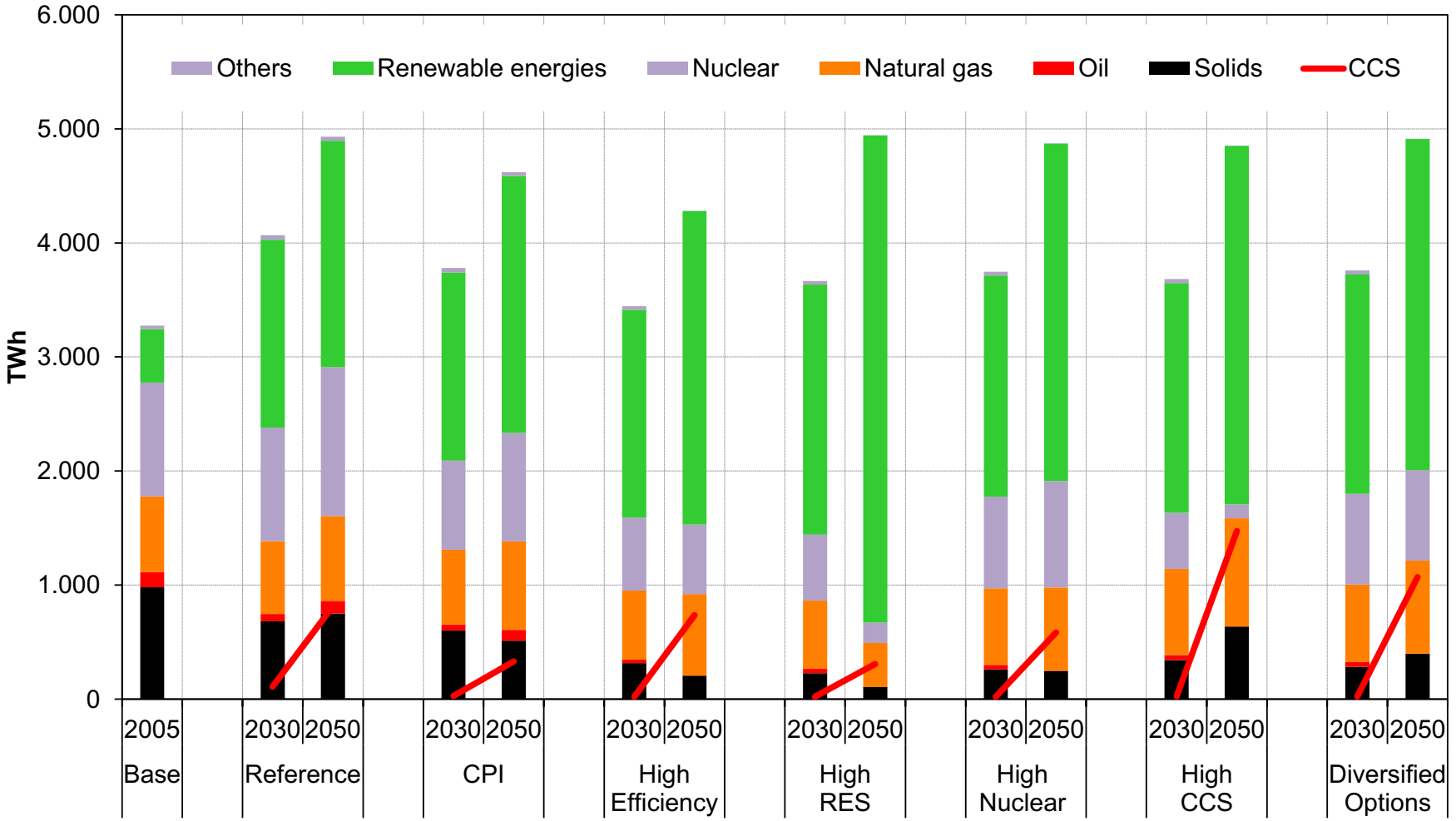


European Commission, E3MLab 2011

# Insights from the EU Energy Roadmap 2050
# The longer-term system cost trends

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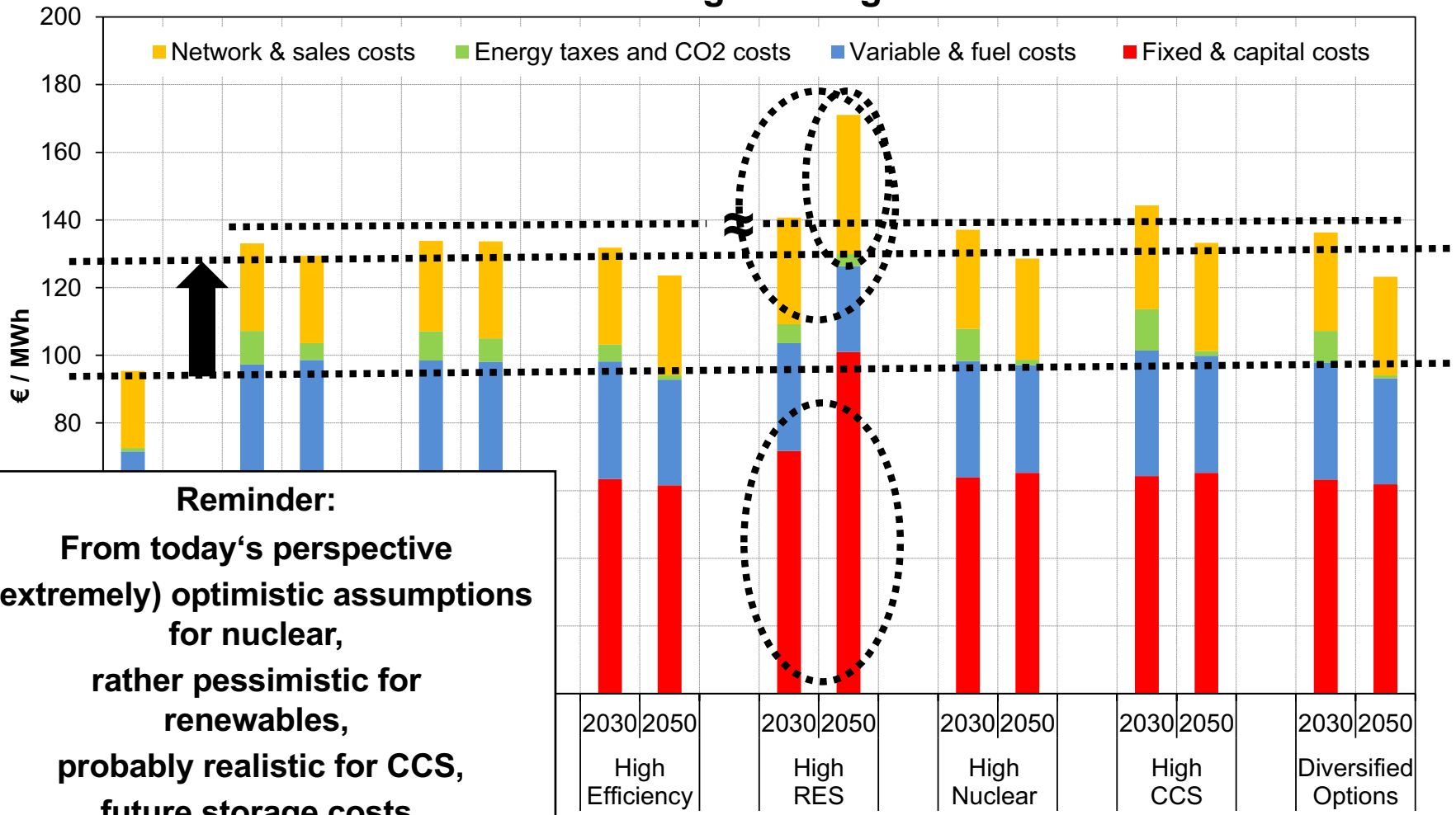
**1. higher system costs** **2. (very) comparable system costs** **3. capital-intensive**

**4. medium-term challenge: storage costs**




**Reminder:**

**From today's perspective**

**(extremely) optimistic assumptions for nuclear,**

**rather pessimistic for renewables,**

**probably realistic for CCS,**

**future storage costs**

**widely unknown**

European Commission, E3MLab 2011, Matthes 2012

# A long-term thought experiment on Germany
# Embarking on different tracks

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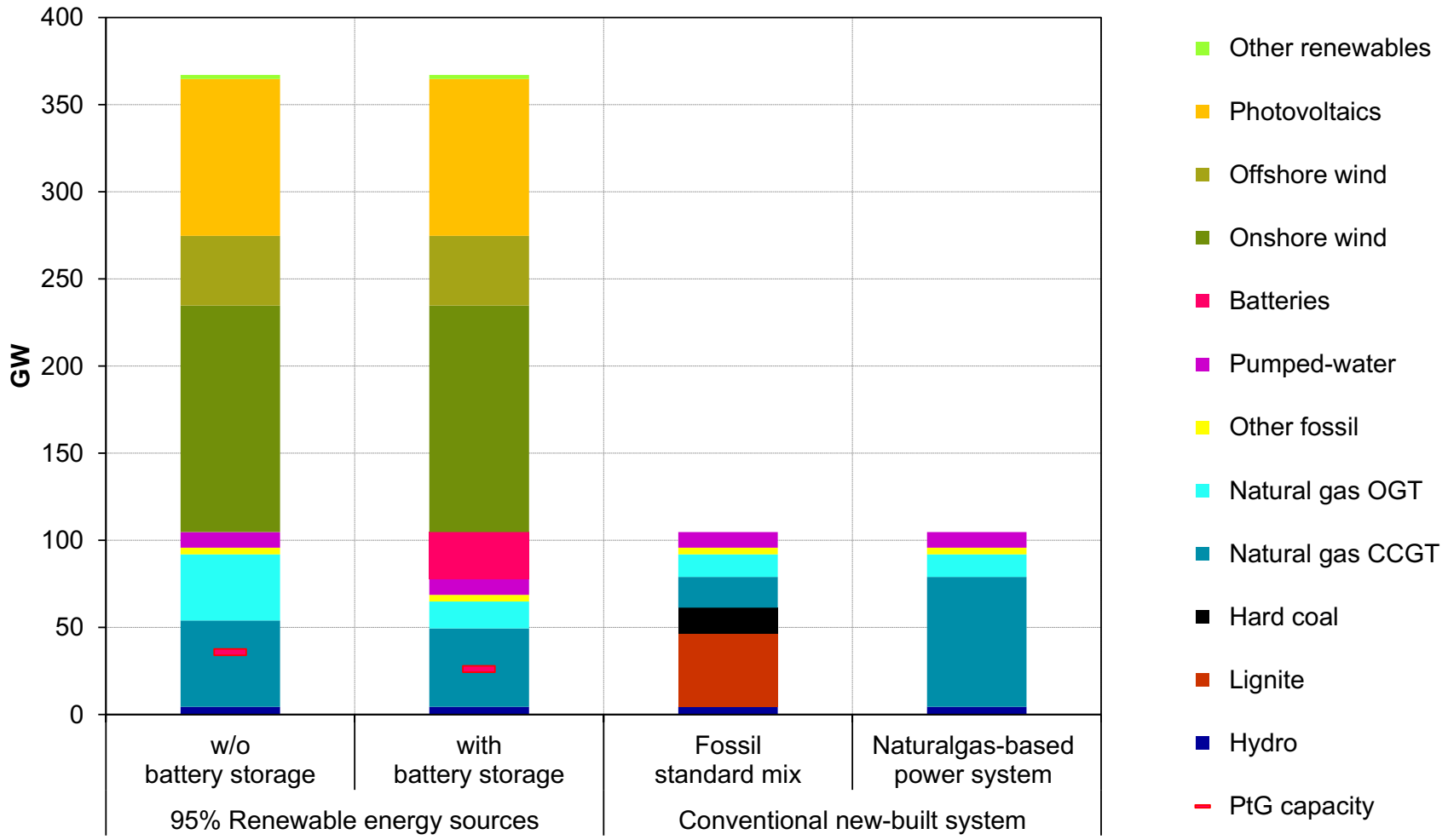


Öko-Institut (2016)

# A thought experiment on Germany
# Going renewables is the more robust way

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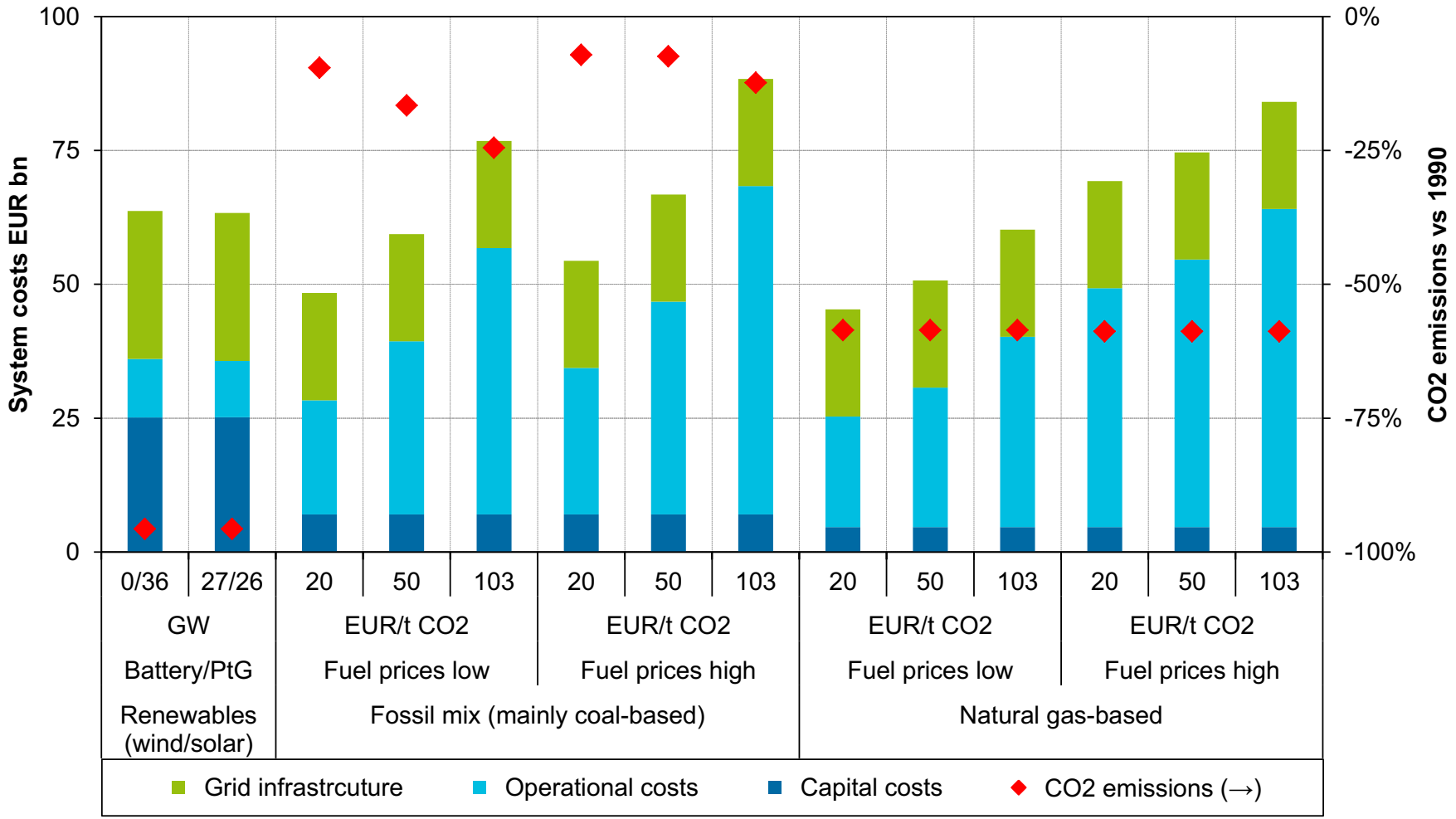


Öko-Institut (2016)

## Beyond the economics of the system
## New structure of players … and assets

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- **The traditional German power system**
  - Running a (centralized) system based on 500 large generation units
- **The emerging new power System in Germany (as of summer 2015)**
  - approx. 1.5 million PV installations
  - approx. 30,000 wind power installations
  - approx. 10,000 biomass power plants
  - approx. 30,000 small- and medium-scale cogeneration plants
  - approx. 700 conventional power generation units
- **The need for a new market design**
  - for phase 1 of roll-out of renewables (0…25% market share) investment certainty and broad economic participation are priority #1
  - for phase 2 a new balance needs to be found between priorities from phase 1 and the increasing need for coordination and an appropriate sharing of risks

# Expansion of power generation from renewables
# New structure of players & the need for coordination

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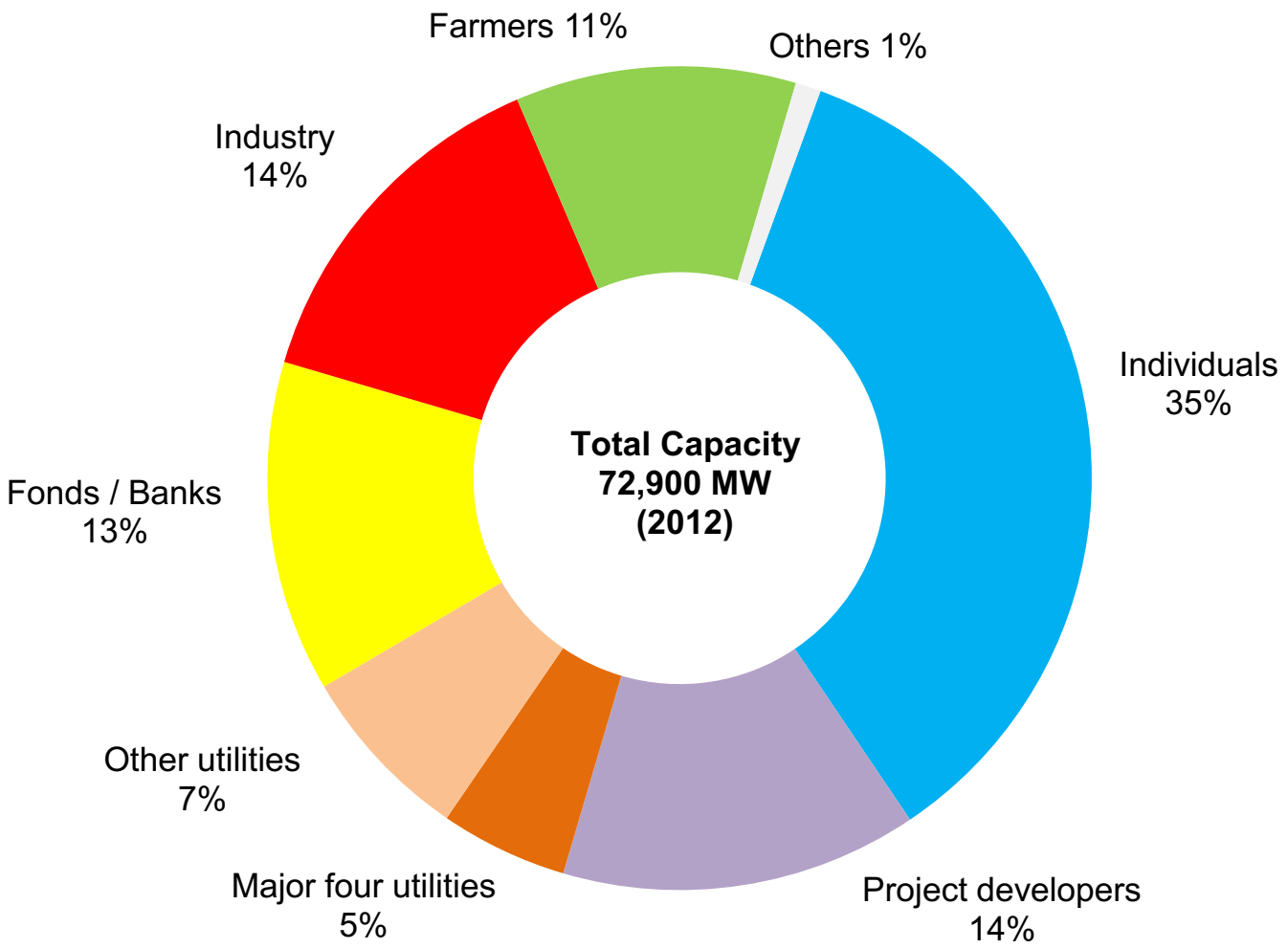

# The geographic dimension of Energiewende
## The old geography

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**Low load / medium conventional region North**

Low load

Medium nuclear capacities

Low conventional capacities

**High load / high coal region West**

High load

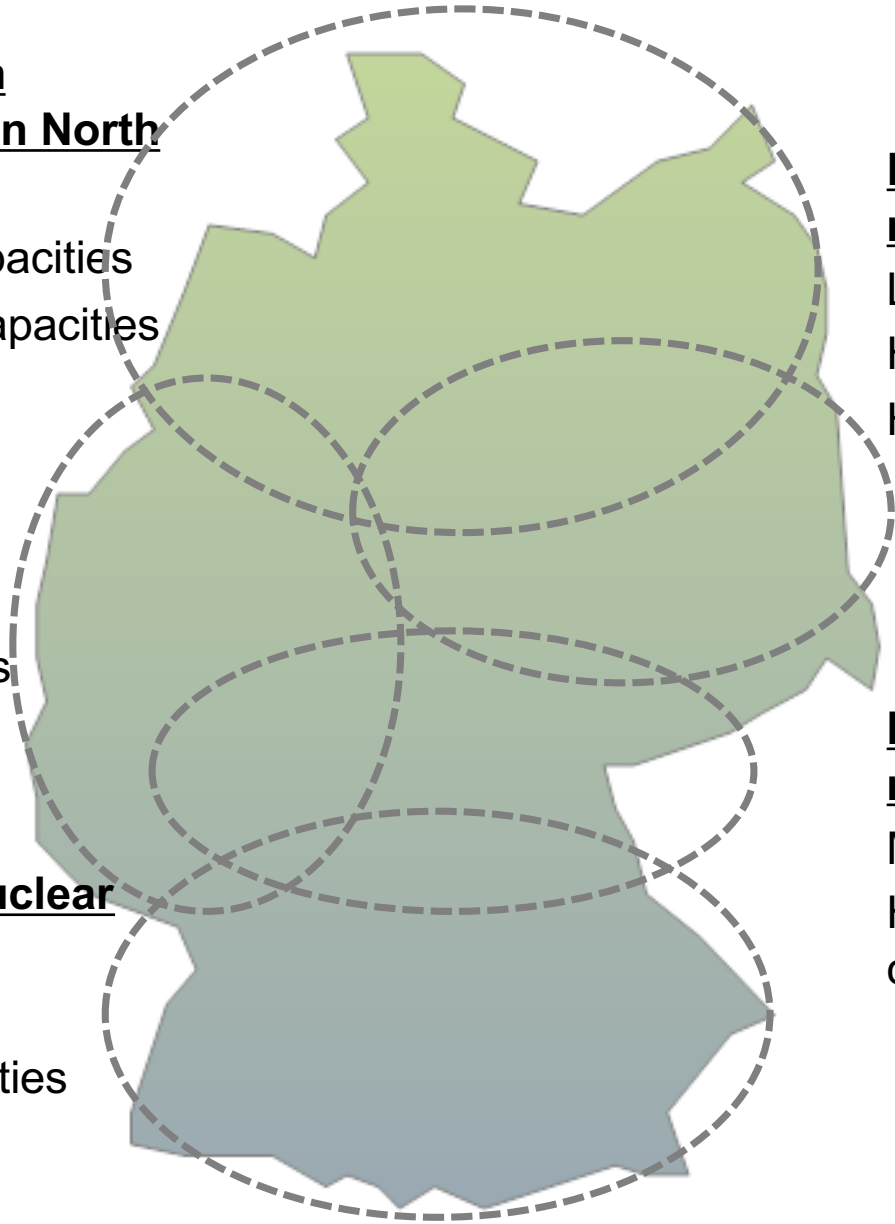
High coal capacities

High CHP capacities

**High load / high nuclear region South**

High load

High nuclear capacities



**Low load / high coal region East**

Low load

High coal capacities

High CHP capacities

**Medium load / storage region Center**

Medium-/ high-load

High pump-storage capacities

# The geographic dimension of Energiewende
## The new geography

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**High wind region North**

Low load

High onshore/offshore wind

**High load /medium RES region West**

High load

Medium RES

High CHP

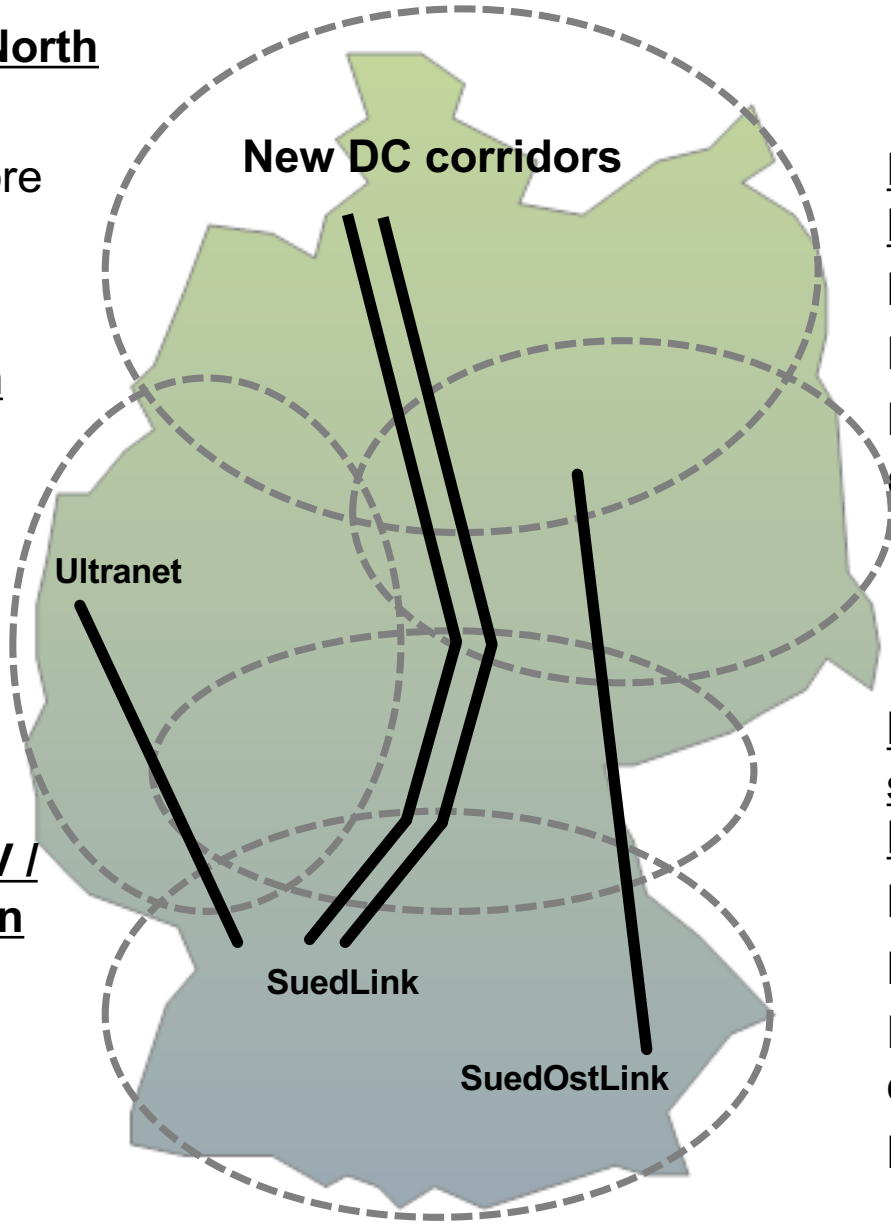
Coal phase-out

**High load / high PV / high storage region South**

High Load

High PV

Access to storage capacities abroad




**Low load / high wind Region East**

Low load

High wind

High CHP

Coal phase-out

**Medium load / infra-structure & storage Region Center**

Medium/high load

Medium RES

High pump storage capacities

Large electricity transits

# The future is unknown and uncertain …
# … but we may be able to describe it structurally

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- **From an overall perspective on all challenges and (foreseeable) trends some structural features of the future energy system will probably be robust ones**
  - Significantly more energy efficient but not necessarily less consuming
  - Mid-term low CO2 and longer-term zero CO2
  - Much more diverse (technology options, centralized / distributed / decentralized, economic perspectives and appraisals etc.)
  - Much more (but not exclusively) distributed and decentralized
  - Much more coordination-intensive
  - Much more capital-intensive
  - Much more infrastructure-intensive (and subject to much more regulatory efforts?!)
  - Much more sensitive to public acceptance
  - Not significantly more expansive (than the counterfactual)
- **Transition will be step-wise and priorities will differ in different steps / phases. Without reflection on these long-lasting and robust structural features one might end on a dead track**

# Energy transition
# What do we know and what are the challenges?

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- **Energy transition: a policy-driven structural change of the energy system**
- **The target system is technically feasible and affordable**
  - manifold options at the supply & flexibility side exist already or are in the pipeline
  - costs of the target system do not differ significantly from the counter-factual, transition costs and distributional effects are however significant)
- **The real challenges arise from structural changes that needs to be reflected carefully for the design of the transition process a**
  - structurally changing technology patterns
  - structurally changing economics (a zero marginal costs system)
  - structurally changing players / market participants
  - structurally changing spatial patterns

# Effective, innovative & efficient strategies
# The Four-Pillars Approach

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- **Paving the Way – for clean generation and flexibility options (renewables & complementary flexibility)** ☺
  - innovation, level-playing-field & roll-out
  - sustainable economic basis (coordination & enabling investments)
- **Designing the Exit-Game – for the non-sustainable capital stocks**
  - security of supply, flexibility, emission levels and fixed costs
  - output management (ETS etc.) vs. capacity management
  - nuclear power (☺) and high-carbon assets (☹ )
- **The infrastructural dimension: Triggering adjustments in time** ☹
  - integration of centralized and distributed and storage and demand flexibility options
  - reflection of the new geography of the energy system
- **The innovation side: Making innovation work in time** ☺
  - for energy efficiency, generation, flexibility, storage and integration

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# Thank you very much

**Dr. Felix Chr. Matthes**
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