
Policy Adaptation for Scaling up Renewables

1st AIEE Energy Symposium

Jaime Legerén

Anjali Nursimulu



A Power System Decarbonization Monitor (PSDM) for Renewables Policy Adaptation

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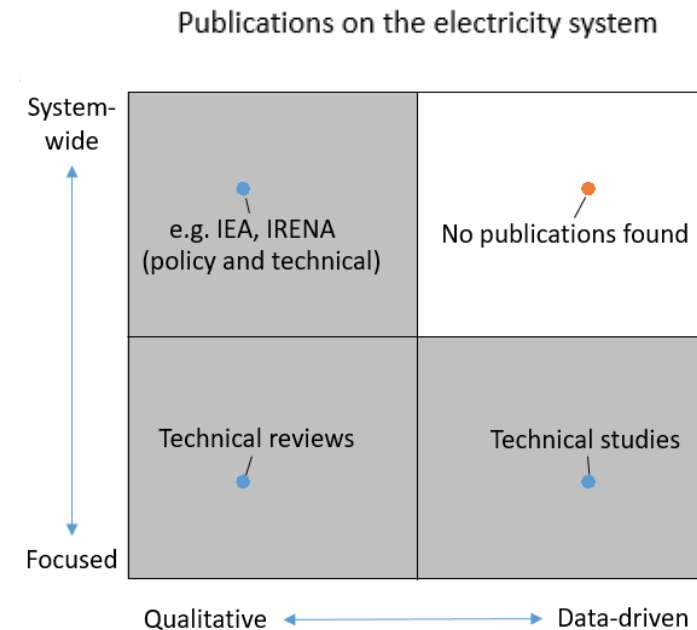
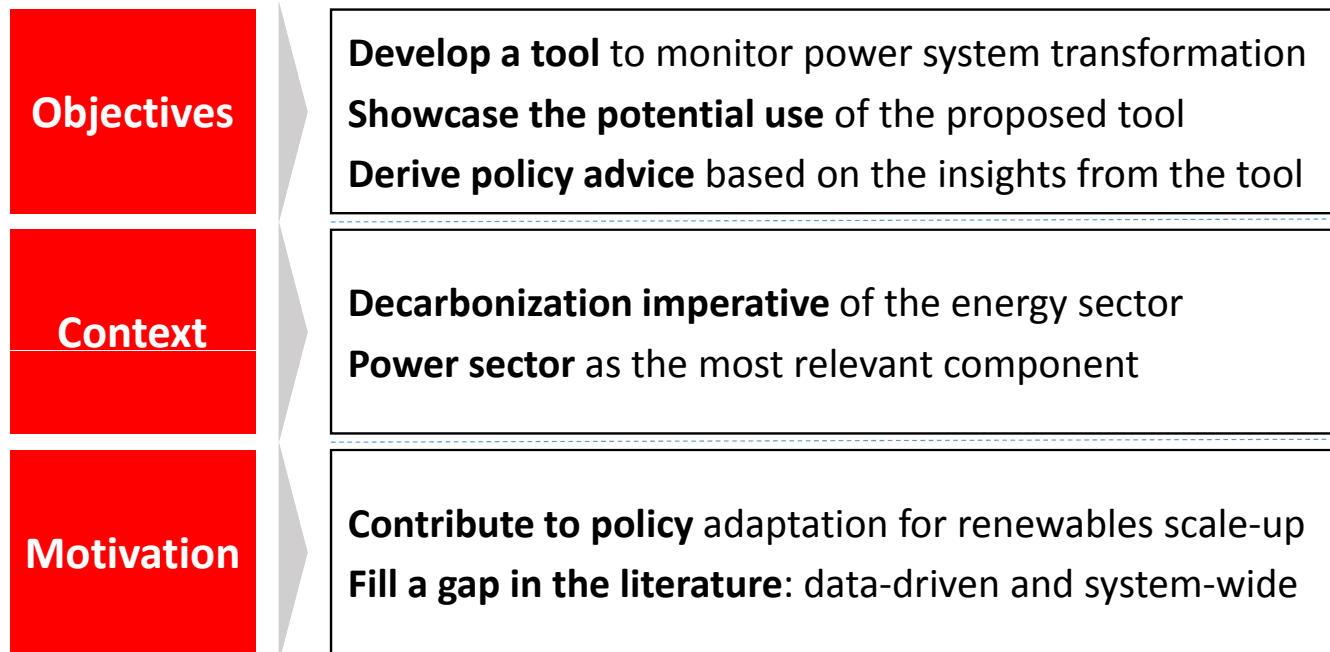
Agenda

1. **Overview** – Policy innovation for power system transformation
2. **Methodology** – Power System Decarbonization Monitor
3. **Analysis** – Strategic insights for decarbonization policy
4. **Conclusions** – Contributions, limitations and future work

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- 1. Overview** – Policy innovation for power system transformation
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Project goal: contribute to the studies on policy innovation for power decarbonization

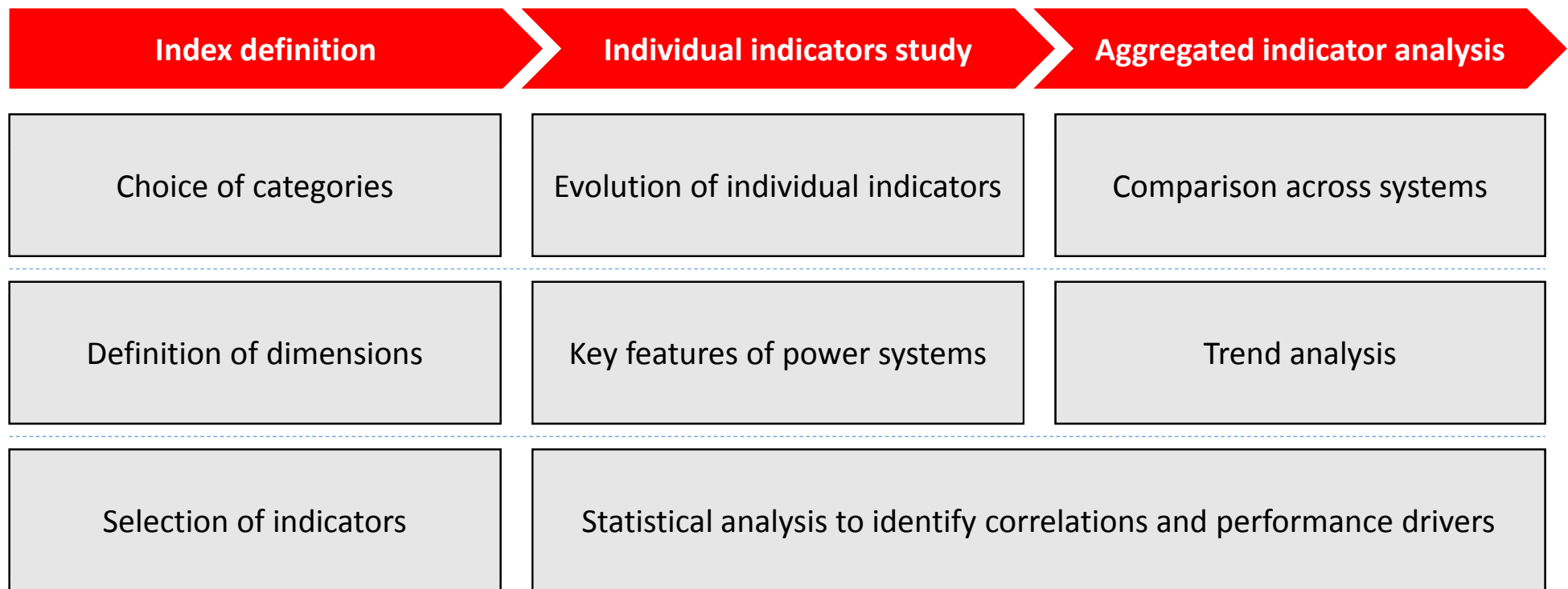


We develop a **system-wide data-driven tool** to monitor **power system decarbonization** and give **policy recommendations**

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Methodology: three steps to derive insights



The PSDM is divided in categories, dimensions and indicators

Index definition

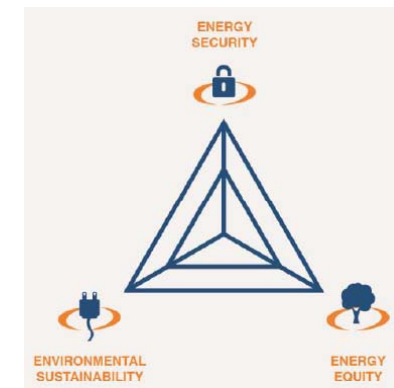
Choice of categories

Definition of dimensions

Selection of indicators

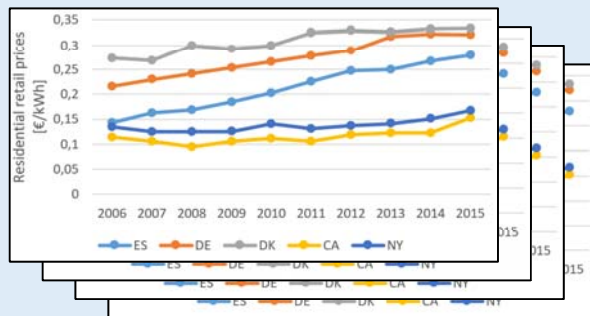
Index	Category	Dimension	Indicator
PSDM	System	Security of supply	<ul style="list-style-type: none"> Installed capacity diversity Generated electricity diversity Capacity adequacy Capacity utilization Import dependence
		Reliability	<ul style="list-style-type: none"> S&T/I T&D losses Flexible generation Interconnections Power storage Demand response VRE curtailment
		Sustainability	<ul style="list-style-type: none"> Power generation costs Generation CO₂ emissions
		Cross-sector integration	<ul style="list-style-type: none"> Heat and power Transportation and power
	Market	Retail market	<ul style="list-style-type: none"> Electricity retail price Installed smartmeters Switching rate Distributed generation Net metering
		Wholesale market	<ul style="list-style-type: none"> Spot market Intraday market Peak – off-peak spread Futures market Balancing costs Profitability of generators Cross-border markets Cross-sector markets
		Market power	<ul style="list-style-type: none"> Concentration of generating companies Concentration of retail companies
	Policy	Effectiveness	<ul style="list-style-type: none"> RE generation target CO₂ emission target Price elasticity of demand
		Efficiency	<ul style="list-style-type: none"> Total cost of transformation Consumption per capita Consumption per GDP
		Equity	<ul style="list-style-type: none"> Burden on consumers
		Stability	<ul style="list-style-type: none"> Number of new policies Change in existing policies System planning

- Composition of the index
 - 3 categories
 - 11 dimensions
 - 41 indicators
- Scoring and weighting to build the Index
- Similarity with World Energy Trilemma



Individual indicators: three levels of analysis

Individual indicator analysis

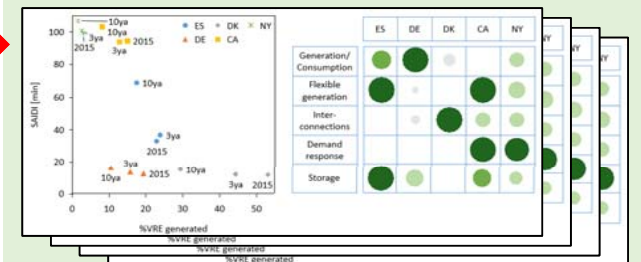


- Time interval from 2006 to 2015
- Analyzed cases: Spain (ES), Germany (DE), Denmark (DK), California (CA) and New York (NY)

Evolution of individual indicators

Key features of power systems

Statistical analysis to identify correlations and performance drivers

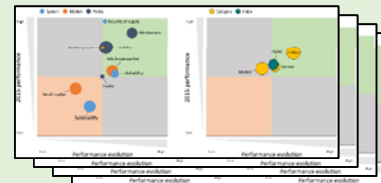
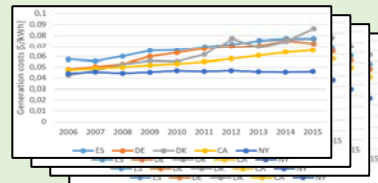


- CO₂ emissions
- Power grid performance
- Generation costs and wholesale prices
- Generators' profits and retail prices
- Gap to policy targets

Aggregated indicators: three levels of analysis

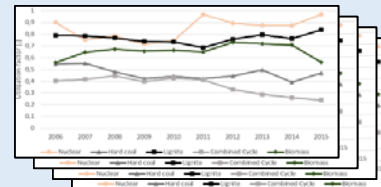
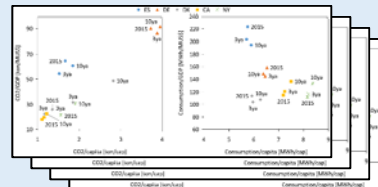
Aggregated indicator analysis

- Contrasting results
- Scoring based on relative performance

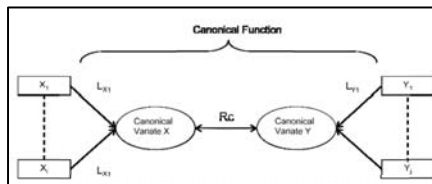


Comparison across systems

- 10ya: average 2006-2015
- 3ya: average 2013-2015
- Recent data: 2015

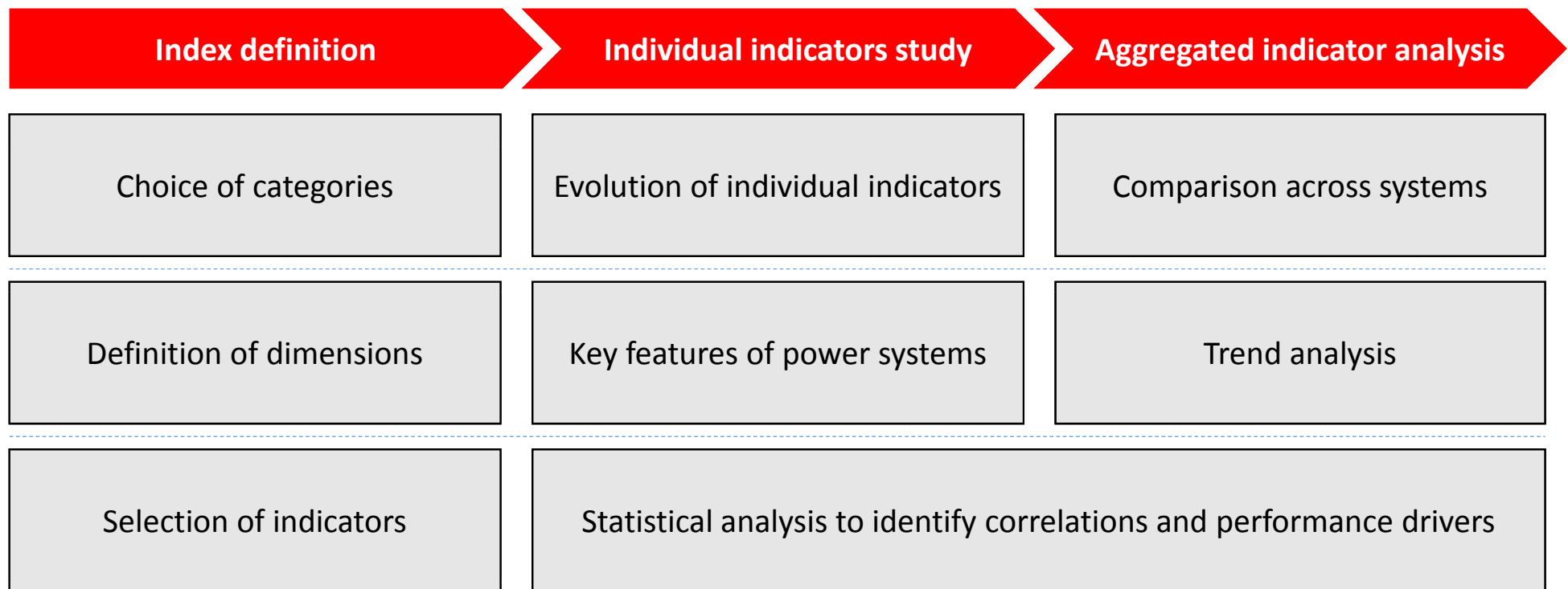


Trend analysis



Statistical analysis to identify correlations and performance drivers

Methodology: three steps to derive insights

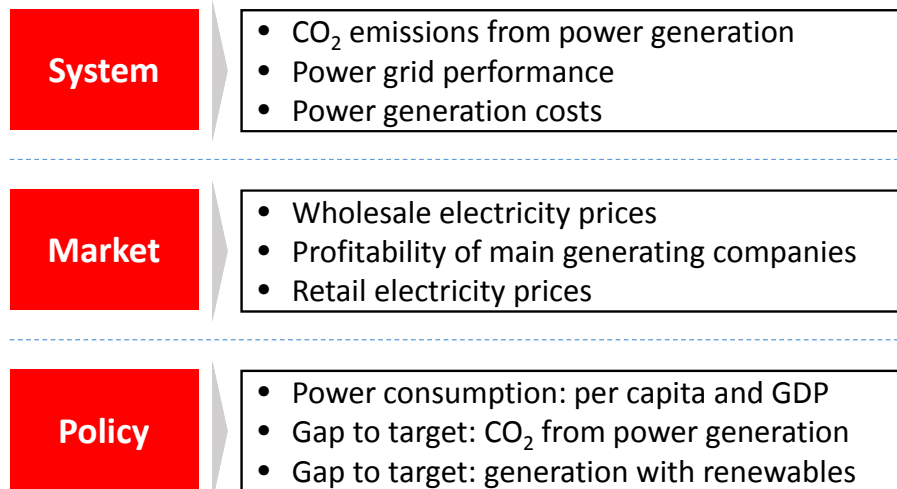


Agenda

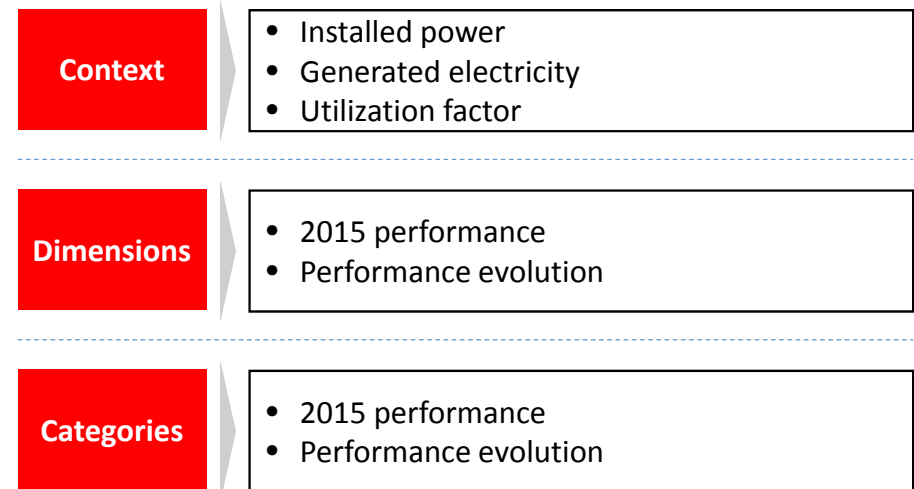
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Two sets of results from the PSDM: Strategic Insights and Country Profile

Strategic insights for decarbonization policy



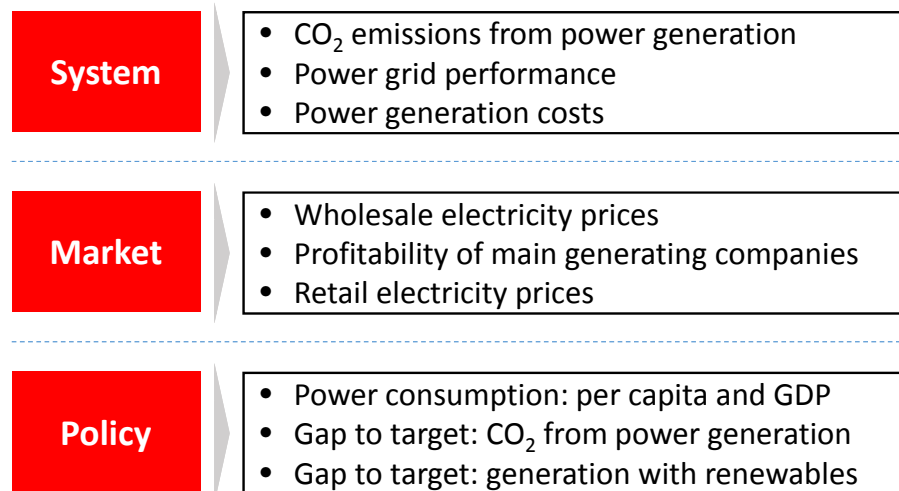
Country evaluation: Germany



We analyze the **evolution of a set of indicators** to derive key insights and evaluate the **performance evolution of Germany**

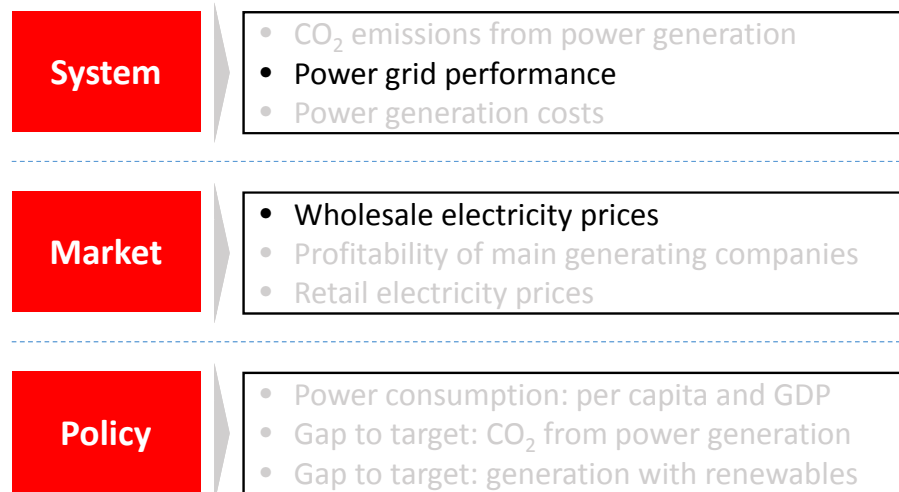
Two sets of results from the PSDM: Strategic Insights and Country Profile

Strategic insights for decarbonization policy



Two sets of results from the PSDM: Strategic Insights and Country Profile

Strategic insights for decarbonization policy



9 recommendations from indicator analysis

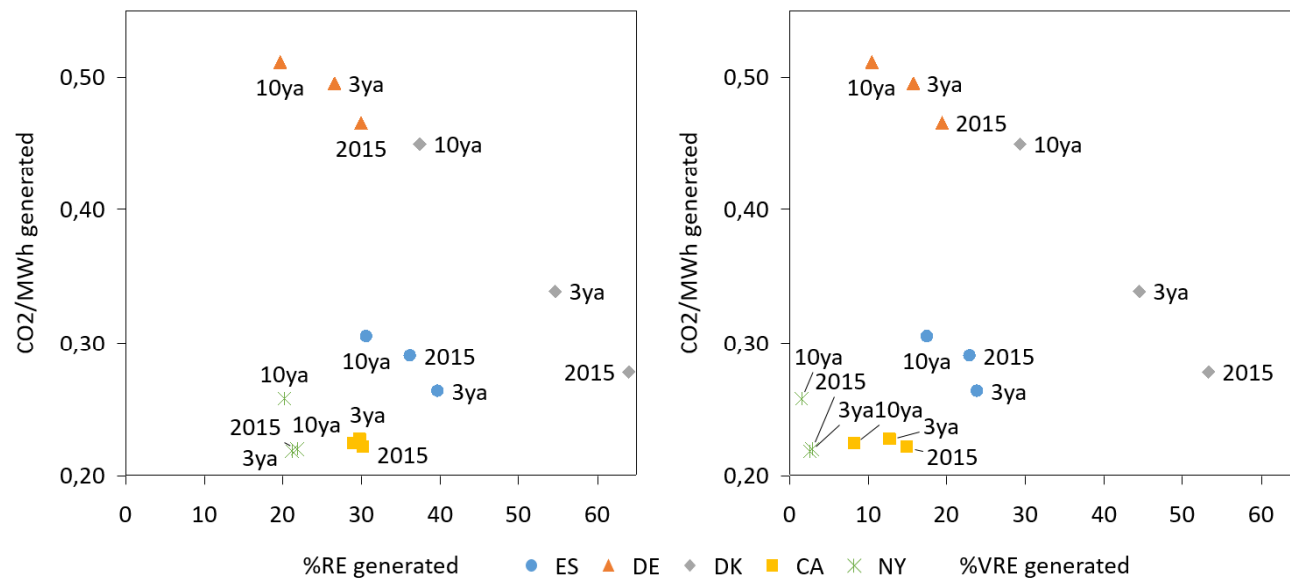
System

- **Sustain power decarbonization with RE**
- Seamlessly integrate VREs
- Carefully address system costs

Market

Policy

Discussion



- **Increasing RE** sustains power generation decarbonization
- Importance of **rest of generation mix** and other factors
- Relevant to take into account **electricity imports**

Note: RE – Renewable Energy; VRE – Variable Renewable Energy

Source: Own elaboration

16

9 recommendations from indicator analysis

System

- Sustain power decarbonization with RE
- **Seamlessly integrate VREs**
- Carefully address system costs

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Policy

The scatter plot shows SAIDI [min] on the y-axis (0 to 100) and %VRE generated on the x-axis (0 to 50). Data points are categorized by country (ES, DE, DK, CA, NY) and time horizon (3ya, 10ya, 2015). Generally, SAIDI decreases as %VRE increases, with some variability between countries and time horizons.

	ES	DE	DK	CA	NY
Generation/Consumption	●	●	●		●
Flexible generation	●	●		●	●
Inter-connections		●	●	●	●
Demand response				●	●
Storage	●	●		●	●

Discussion

- **Increasing VRE** are not harming the SAIDI
- **Different strategies** are adopted depending on **resources**
- **New mechanisms** can be considered (X-system integration)

Note: SAIDI: System Average Interruption Duration Index

Source: Own elaboration

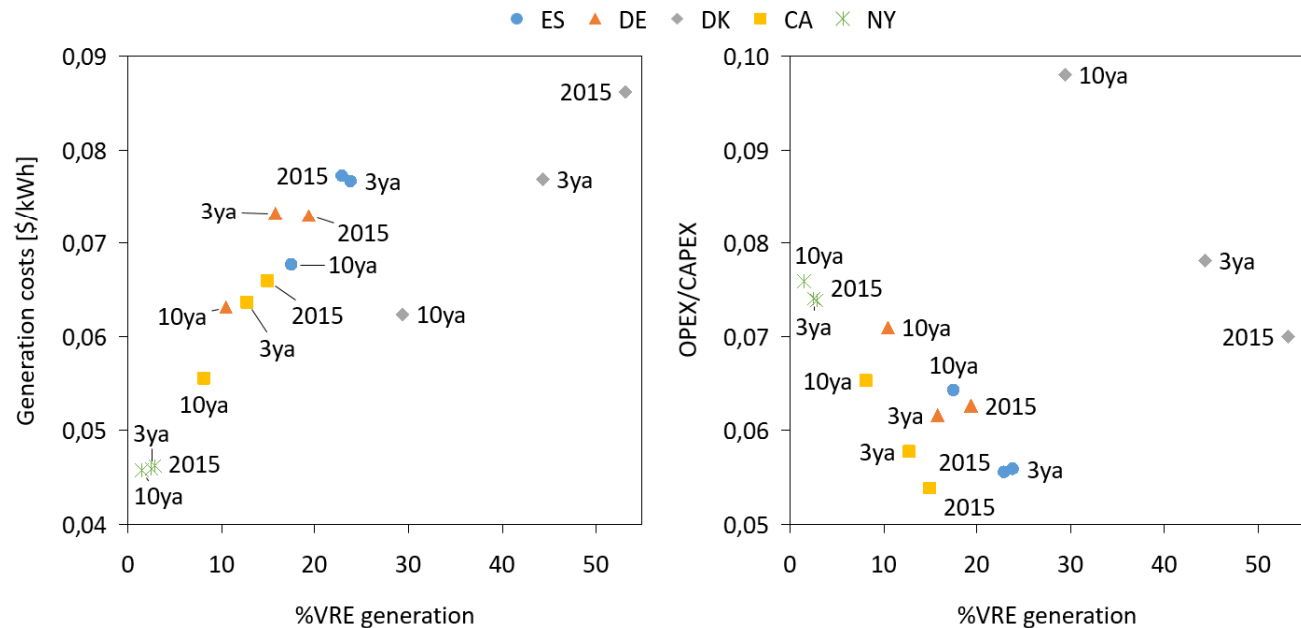
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System

- Sustain power decarbonization with RE
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- **Carefully address system costs**

Market

Policy



Discussion

- VRE scale-up is **increasing power generation costs**
- **Shift of the cost structure** of the industry (OPEX/CAPEX)
- Other aspects to be considered for **full cost calculation**

Note: OPEX – Operational Expenditure; CAPEX – Capital Expenditure

Source: Own elaboration

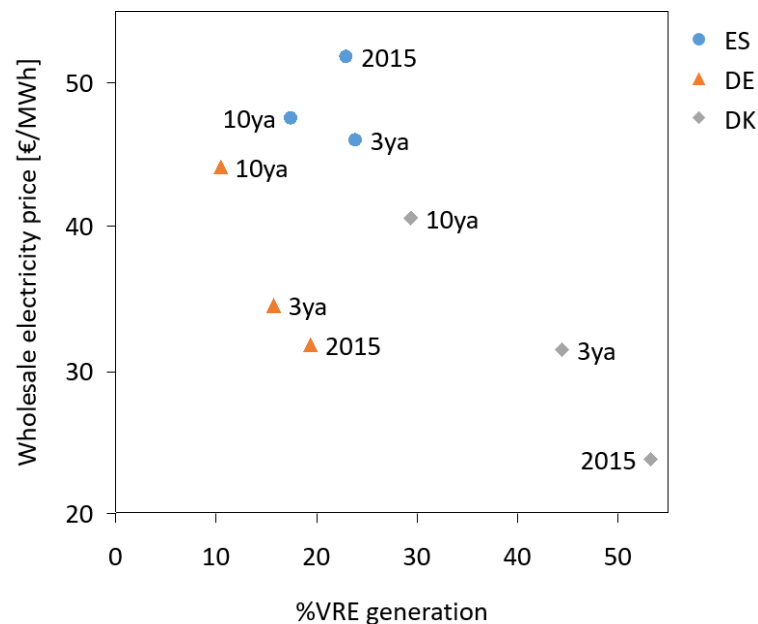
9 recommendations from indicator analysis

System

Market

- **Reconsidering the merit order**
- Fostering competition in power industry
- Reallocating power transformation costs

Policy



Discussion

- **Increasing VRE** are lowering electricity wholesale prices
- This may be reversed: **VRE to provide reliability** services
- **Other factors and markets** are relevant: futures, intraday

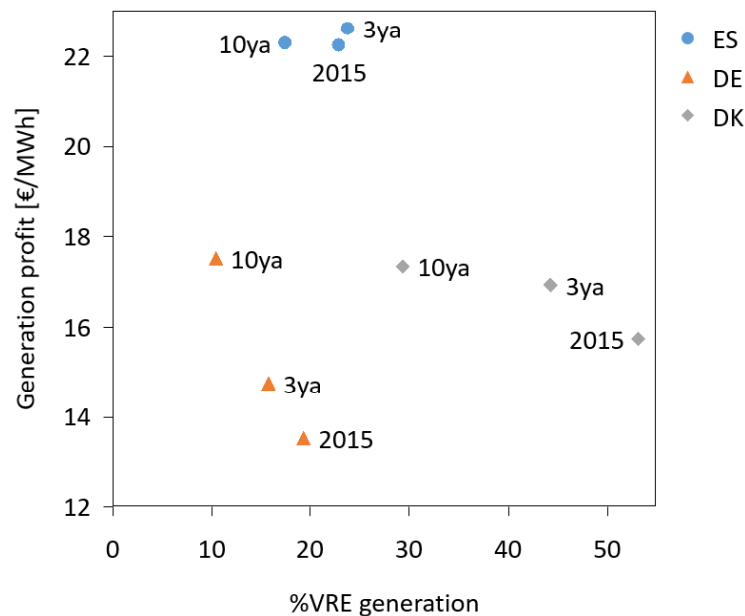
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System

Market

- Reconsidering the merit order
- **Fostering competition in power industry**
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Discussion

- **VRE is tightening profits** from incumbent generators
- **Profits of contributors to grid reliability** are relevant
- **Anticipate** negative consequences of **lower investment**

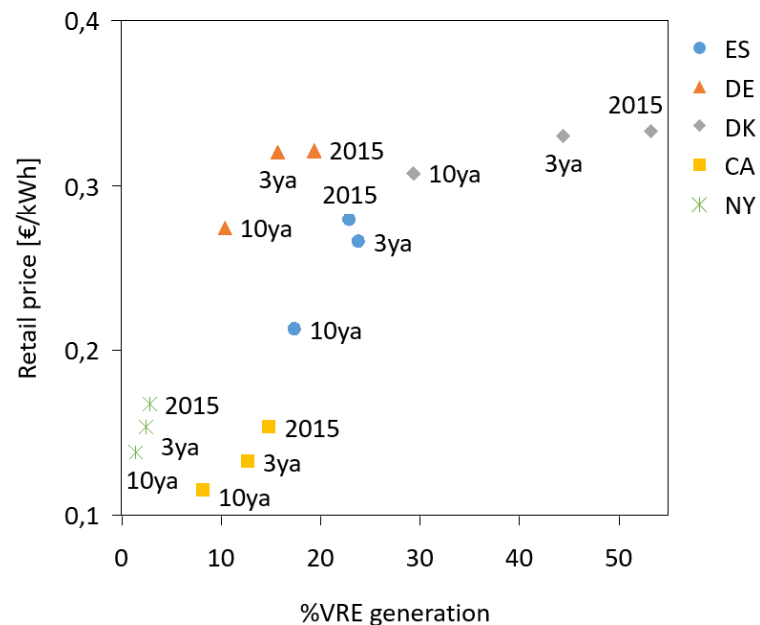
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- Fostering competition in power industry
- **Reallocating power transformation costs**

Policy



Discussion

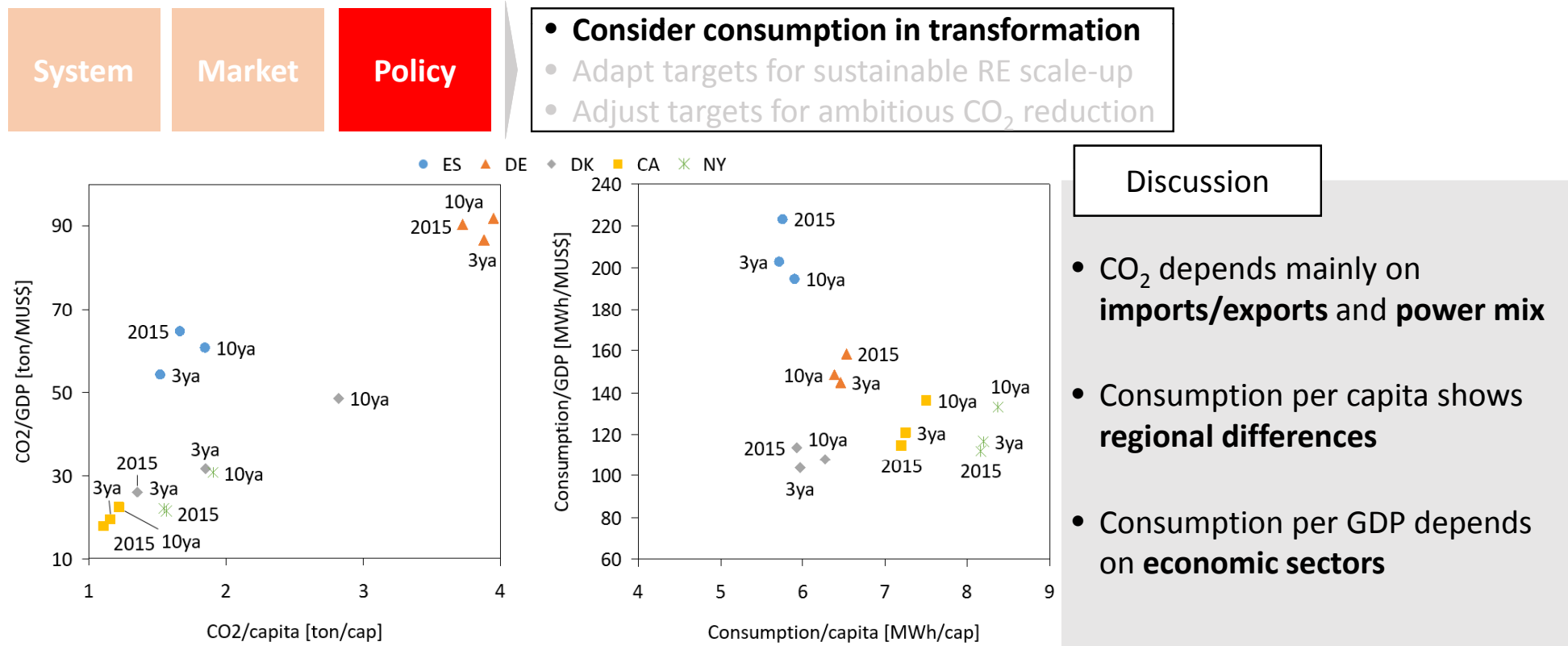
- **Retail prices have increased** with the VRE scale-up
- Some systems are observing an **asymptotic trend**
- Relevant to put them **in perspective** with **income level**

Note: Retail price is only residential retail price

Source: Own elaboration

21

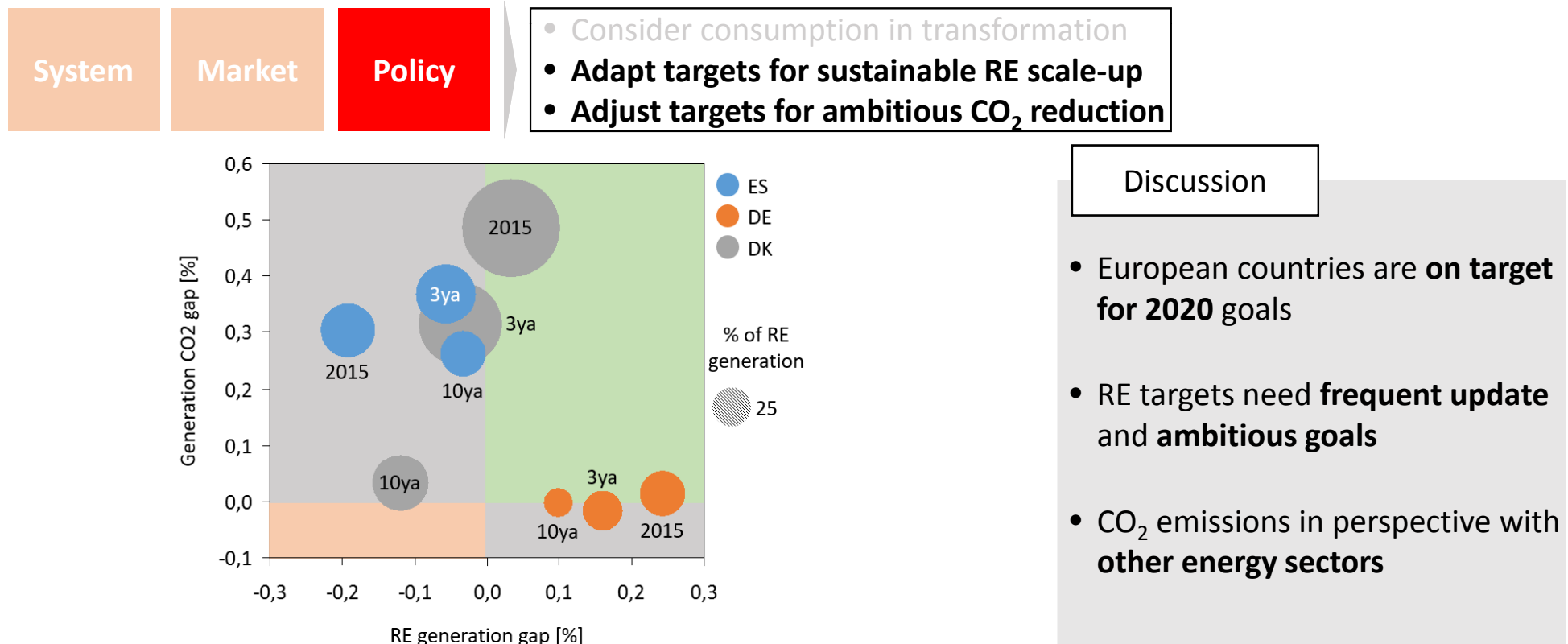
9 recommendations from indicator analysis



Note: CO₂ emissions are only for power generation; Consumption is for electricity

Source: Own elaboration

9 recommendations from indicator analysis



Note: Targets in front of the EU for 2020

Source: Own elaboration

9 recommendations from indicator analysis

Strategic insights for decarbonization policy

System

- Sustain power decarbonization with RE
- Seamlessly integrate VREs
- Carefully address system costs

Market

- Reconsidering the merit order
- Fostering competition in power industry
- Reallocating power transformation costs

Policy

- Consider consumption in transformation
- Adapt targets for sustainable RE scale-up
- Adjust targets for ambitious CO₂ reduction

Two sets of results from the PSDM: Strategic Insights and Country Profile

Country evaluation: Germany

Context

- Installed power
- Generated electricity
- Utilization factor

Dimensions

- 2015 performance
- Performance evolution

Categories

- 2015 performance
- Performance evolution

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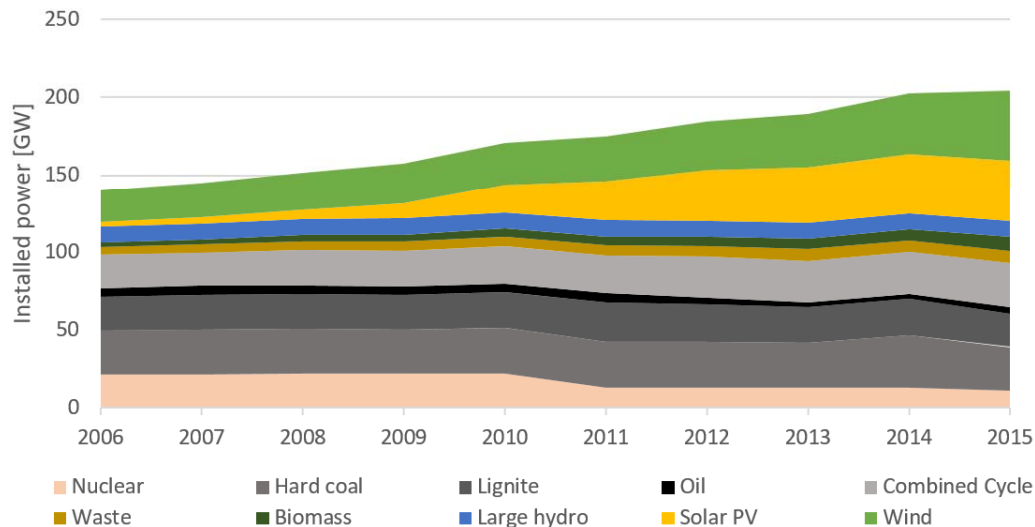
Dimensions

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Categories

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Overview: German power system with PSDM



- **Increase** in installations for **wind** and specially **PV**
- **Nuclear phase out** decreases nuclear installed power
- **Similar capacity** of hard coal, lignite and combined cycle

Country evaluation: Germany

Context

- Installed power
- Generated electricity
- Utilization factor

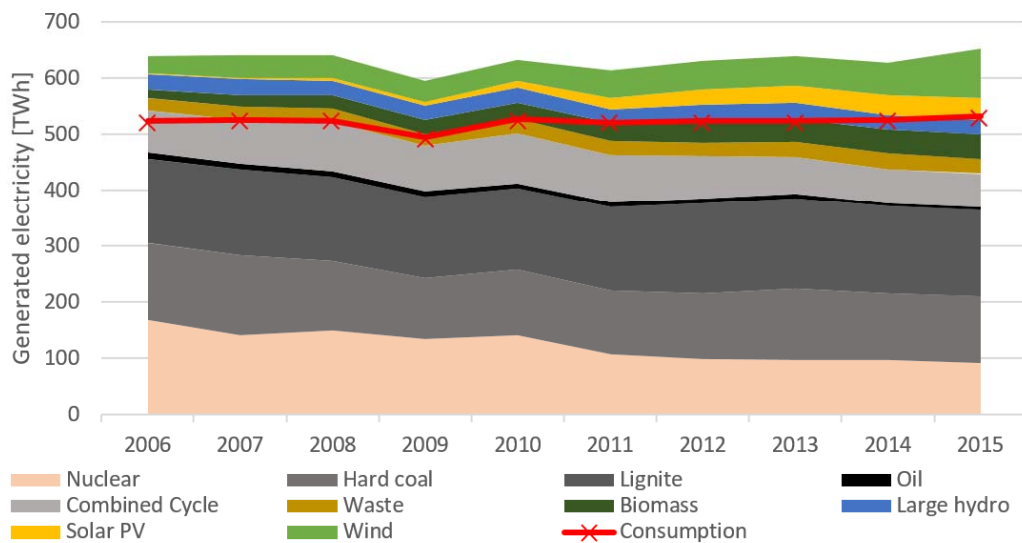
Dimensions

- 2015 performance
- Performance evolution

Categories

- 2015 performance
- Performance evolution

Overview: German power system with PSDM



- **Increase** in generation from **VREs**, but still **low share**
- **Nuclear phase out** decreases nuclear generation
- **Main producers** are hard coal and lignite

Country evaluation: Germany

Context

- Installed power
- **Generated electricity**
- Utilization factor

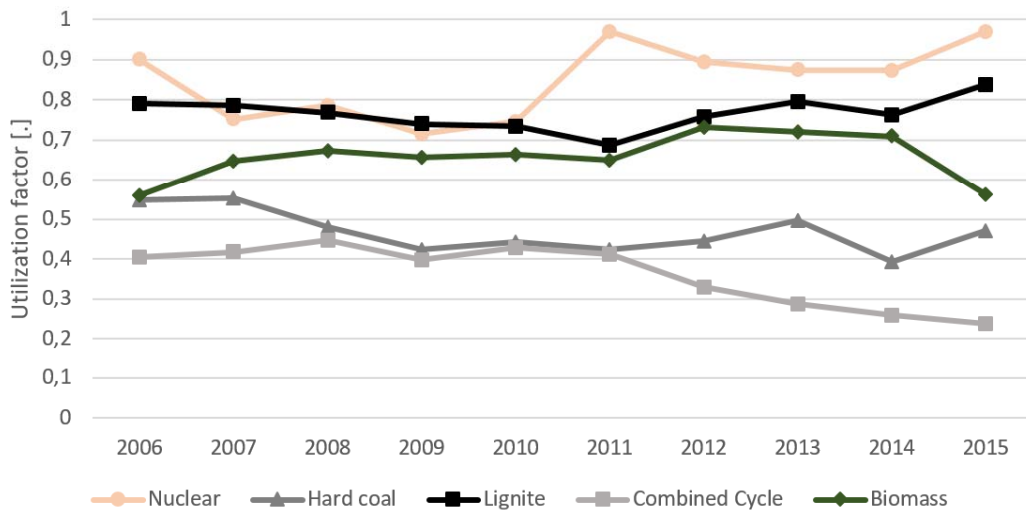
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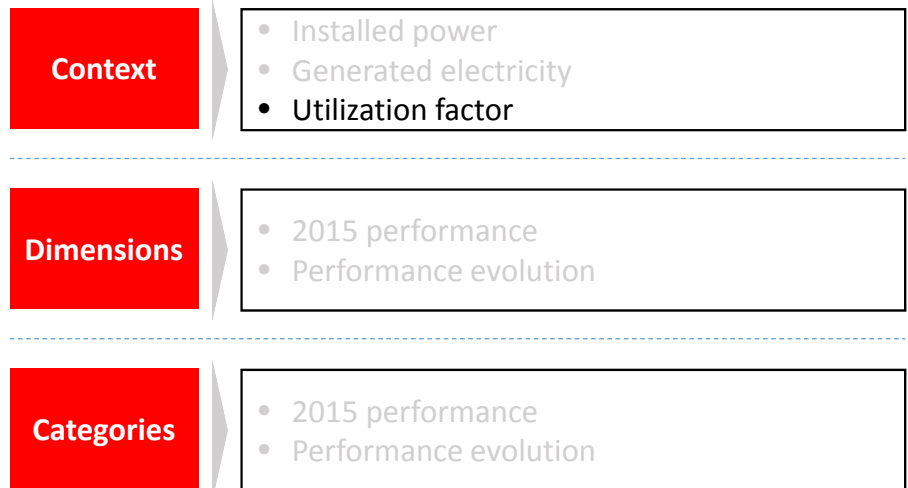
Overview: German power system with PSDM



- **Slight decrease in hard coal and lignite stays constant**
- **Nuclear keeps high UF while it is being phased-out**
- **Natural gas power generation with very low UF**

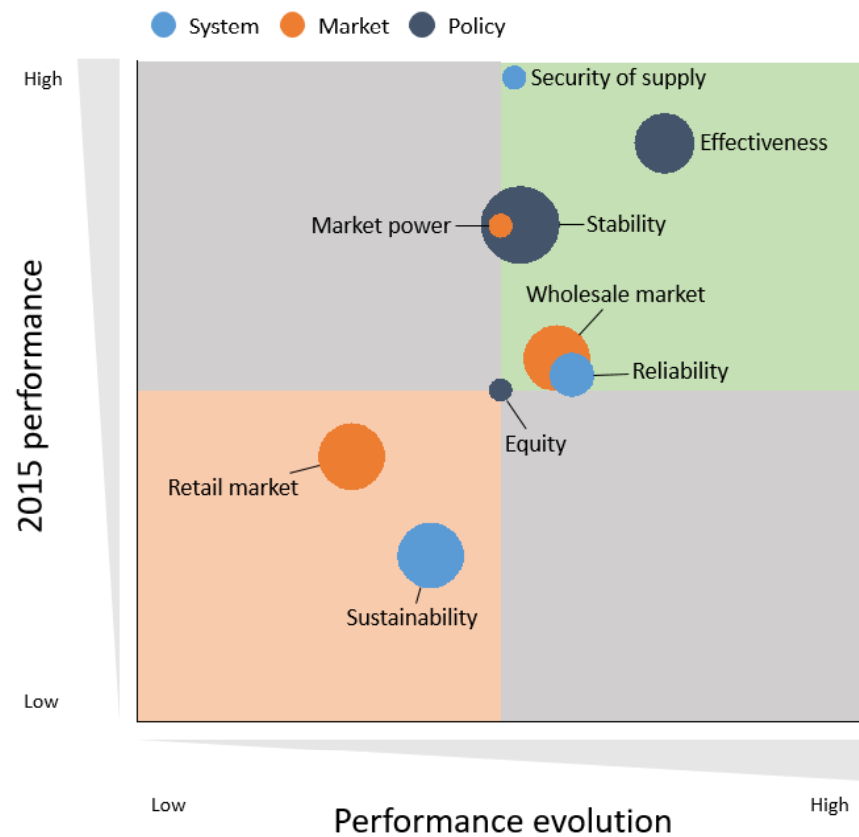
Note: UF – Utilization Factor

Country evaluation: Germany



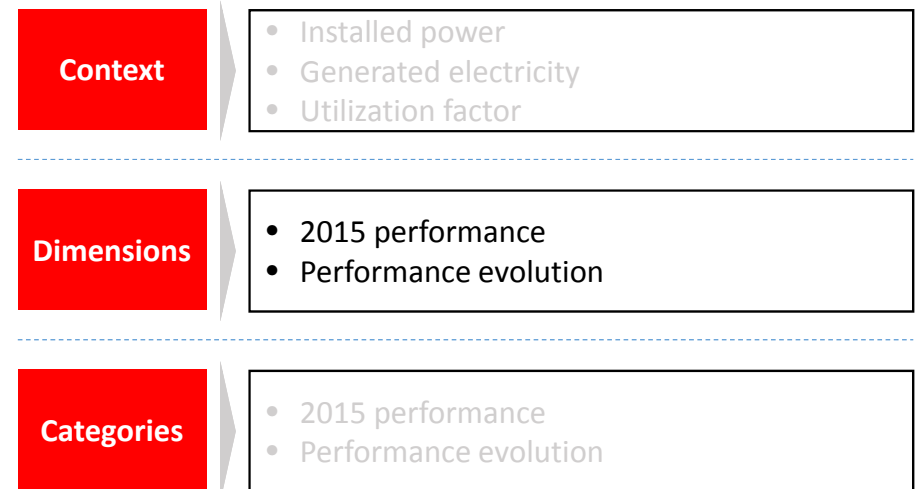
Source: Own elaboration

Overview: German power system with PSDM



Note: Size of the balls represents variability of the dimension between 2006 and 2015

Country evaluation: Germany

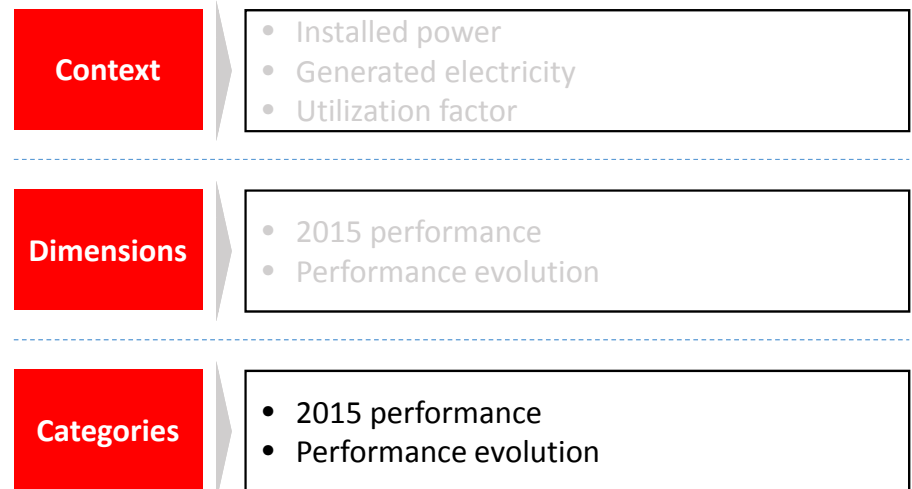


Source: Own elaboration

Overview: German power system with PSDM



Country evaluation: Germany



Note: Size of the balls represents variability of the category between 2006 and 2015

Source: Own elaboration

Overview: German power system with PSDM

Country evaluation: Germany

Country profile summary

- It has a **strong and secure** power system
- Its power generation is **highly CO₂ intensive**
- **Evolving wholesale** power markets
- **Lagging retail** electricity markets
- **Attaining goals**: RE and CO₂ from generation
- **Innovative** and exploratory **policy** approach

Context

- Installed power
- Generated electricity
- Utilization factor

Dimensions

- 2015 performance
- Performance evolution

Categories

- 2015 performance
- Performance evolution

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Key takeaways and next steps for this study

Study contributions

Development of a data-driven, system-wide **methodology** for power system monitoring
Delivery of **strategic insights** for power system **decarbonization** and **RE scale-up**
Benchmarking tool applied to the **German power** sector: comparison and trends

Implications for policy makers

PSMD provides additional **data-driven** insights from power sector performance
Adapting the strategic insights to relevant system features
Make **data and standardized metrics** available for trend analysis and comparison

Limitations and future work

Scarcity of available data for some indicators – Choose indicators as per study goals
Low number of cases analyzed makes challenging the scoring – Analyze more cases
Time and spatial resolution conceals interesting dynamics – Adapt to study goals

Power decarbonization is a must; policy should take fact-based decisions to maximize benefits of sector transformation

Thank you 😊

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