

# The Cost of Wind Power:

## Learning Rates and Decomposition of Cost Reduction Drivers



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# Research Questions

- 1) What is the percentage reduction in the cost of onshore wind every time installed capacity doubles?
- 2) What is the individual contribution of the main drivers of cost reduction?

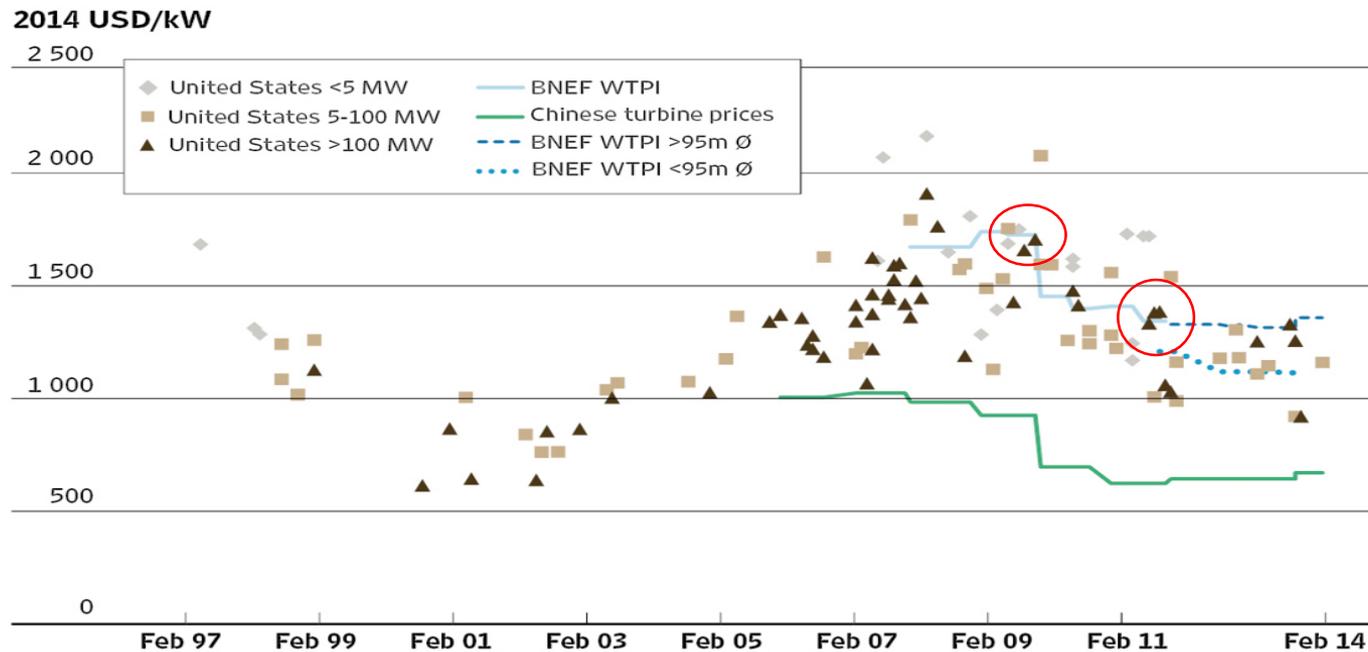
# Literature review

Study	Year released	Dataset	Methodology	Results	Coverage quality
Marsh, G. (1998)	1998	1980 - 1985	Cost of electricity ECU(1990)/kWh plotted against cumulative electricity production	Learning curve - 18%	Regional. Germany, Denmark, United Kingdom and Netherlands
Durstewitz, M. and Hoppe-Kilpper, M. (1999)	1999	1990 - 1998	Wind turbine price (DM 1995/kW) plotted against cumulative installed capacity	Learning curve - 8%	Germany only.
Kouvaritakis, N., Soria, A. and Isoard, S. (2000)	2000	1995 -	Two factors learning curve. Investment cost 1995 (US\$1990) & R&D Investment plotted against cumulative installed capacity	Learning curve - 16%	POLES model. Costs source and coverage not mentioned.
K. Ibenholt, Explaining learning curves for wind power, Energy Policy 30 (2002) 1181-1189	2002	1991 - 1999	Investment costs plotted against cumulative installed capacity.	Learning curve - 11%	Germany only. 41 data points
Miketa, A., Schrattenholzer, L., (2004)	2004	1971 - 1997	Two factors learning curve. Electricity cost (USD90 per watt) R&D plotted against cumulative installed capacity	Learning curve for investment costs plotted against cumulative installed capacity - 9.73%	Denmark, Germany, United Kingdom
Klaassen, G., Miketa, A., Larsenb, K. and Sundqvist, T., (2005)	2005	1986 - 2000	Two factors learning curve. Investment cost (US\$98/kW) & Research and Development plotted against cumulative installed capacity	Learning curve for investment costs plotted against cumulative installed capacity - 4.8 to 5.8%	Denmark, Germany, United Kingdom
Kobos, P., Erickson, J. and Drennen, T. (2006)	2006	1981 - 1997	Two factors learning curve. Electricity (USD90 per watt) & Research and Development plotted against cumulative installed capacity	Learning curve for investment costs plotted against cumulative installed capacity - 14.2%	Worldwide
G.F. Nemet, Energy Policy 37 (2009) 825–835.	2009	1981 - 2006	Investment costs (wind turbine capital cost 2006) USD/W plotted against cumulative installed capacity	Learning curve - 11%	Worldwide
European Wind Energy Association (EWEA), (2009)	2009	1986 - 2006	Cost of electricity by turbine size plotted against cumulative installed capacity	Learning curve - 9 - 17%	European countries, mostly Germany, Denmark and United Kingdom
Patrick Criqui, Silvana Mima, Philippe Menanteau, Alban Kitous. Elsevier, 2014, pp.1-18	2014	1980 - 2010	Investment cost plotted against cumulative capacity	Learning curve - 6%	The dataset appears to be global. There is no mention of the coverage.

# Wind turbine prices

## RENEWABLE POWER GENERATION COSTS IN 2014

FIGURE 4.3: WIND TURBINE PRICES IN THE UNITED STATES AND CHINA, COMPARED TO THE BNEF TURBINE PRICE INDEX, 1997-2014



Sources: Wiser and Bollinger, 2014; CWEA, 2013; BNEF, 2014c; and Global Data, 2014.

Note: BNEF WTPI represents the half-year average for non-Asian markets, while the United States data are for the specific month of a particular turbine contract and the Chinese data are annual averages.

# Literature review

Early analysis covered few countries, but was comprehensive (data until mid- to late 90's)

Later analysis often covered few countries with similar shared goals, but was not comprehensive

Global analysis, has used only data to 2006, and has often not been transparent or used limited sample

No analysis of LCOE learning rates despite technology progress

# Literature review

Current learning curve analysis is easily open to criticism

Lack of accurate learning curve analysis may:

- Compromise scenario analysis

- Provide misleading cost reduction expectations

- Allow misplaced criticism of renewables competitiveness

We are missing an opportunity to highlight wind's increasing competitiveness with robust data

# Methodology

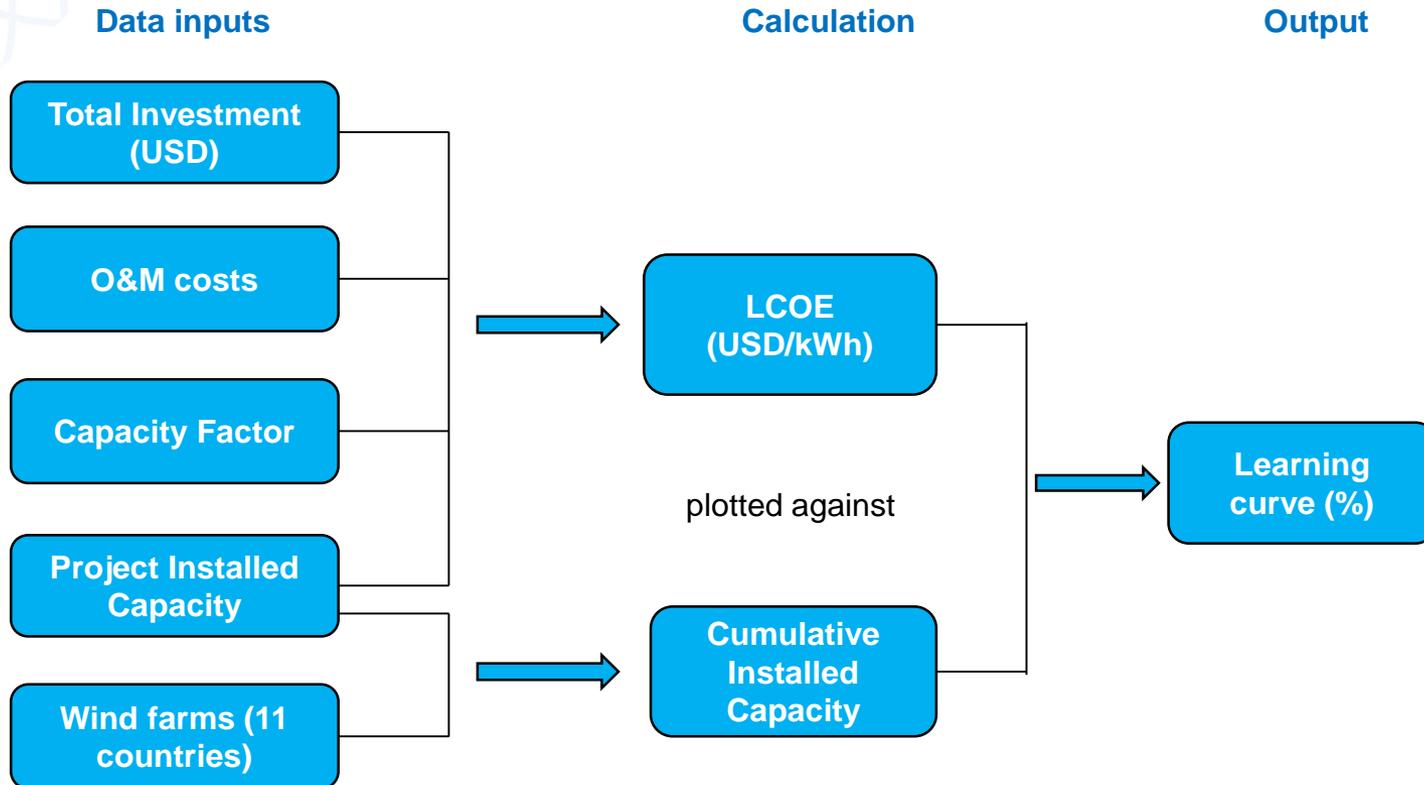
Comprehensive new analysis of global learning curves for wind 1990 - 2014

Total installed cost and LCOE

Decomposition of LCOE learning curve



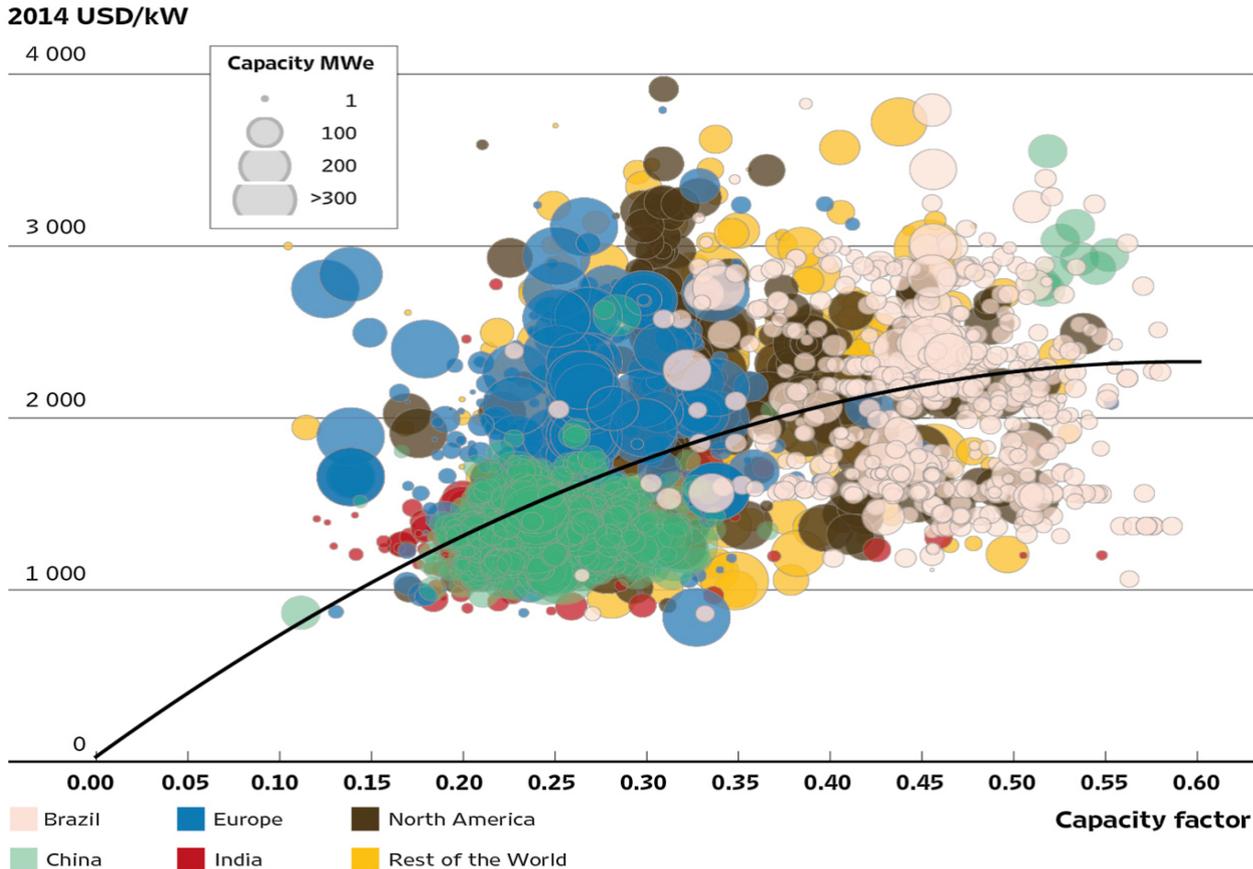
# Learning Curve Methodology



# Capacity factors & Investment Costs

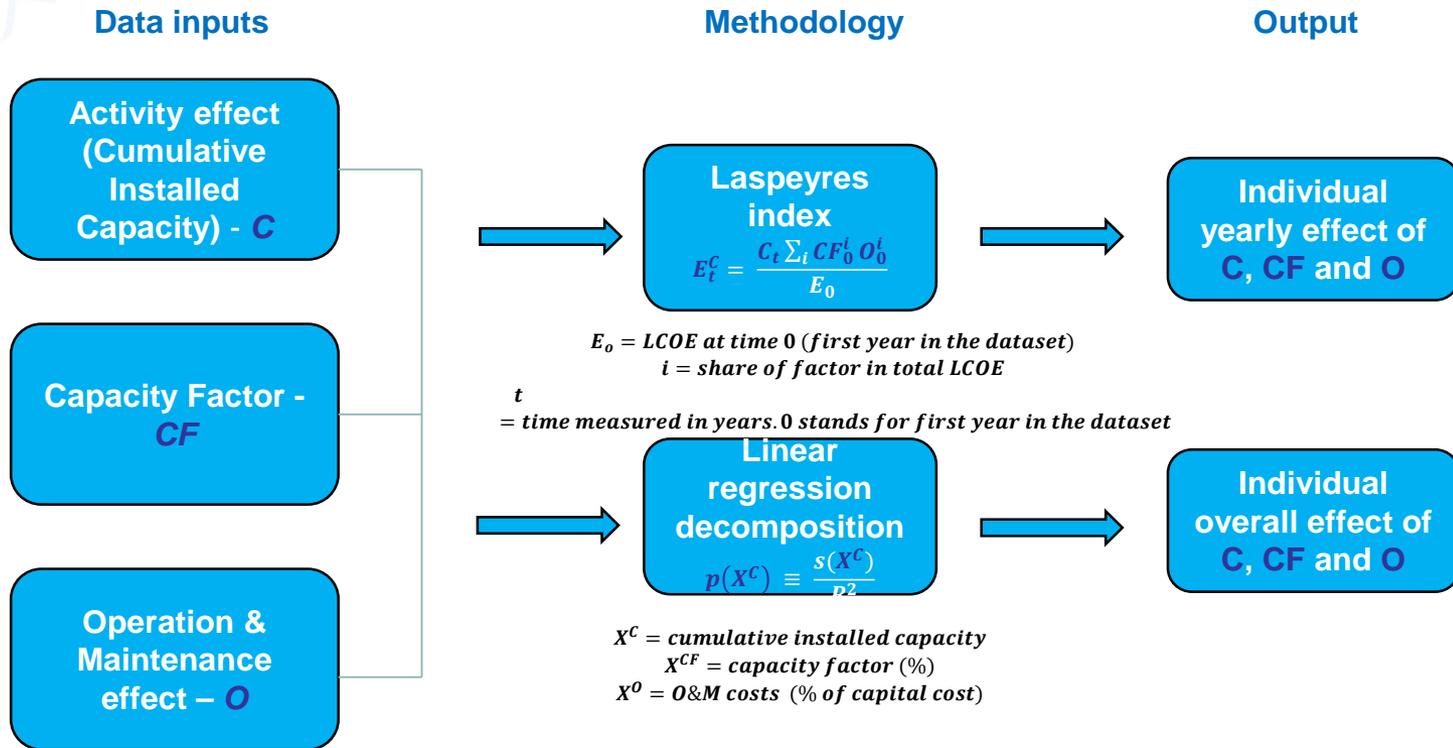
RENEWABLE POWER GENERATION COSTS IN 2014

FIGURE 4.13: TOTAL INSTALLED ONSHORE WIND FARM COSTS RELATIVE TO PROJECT CAPACITY FACTORS BY REGION

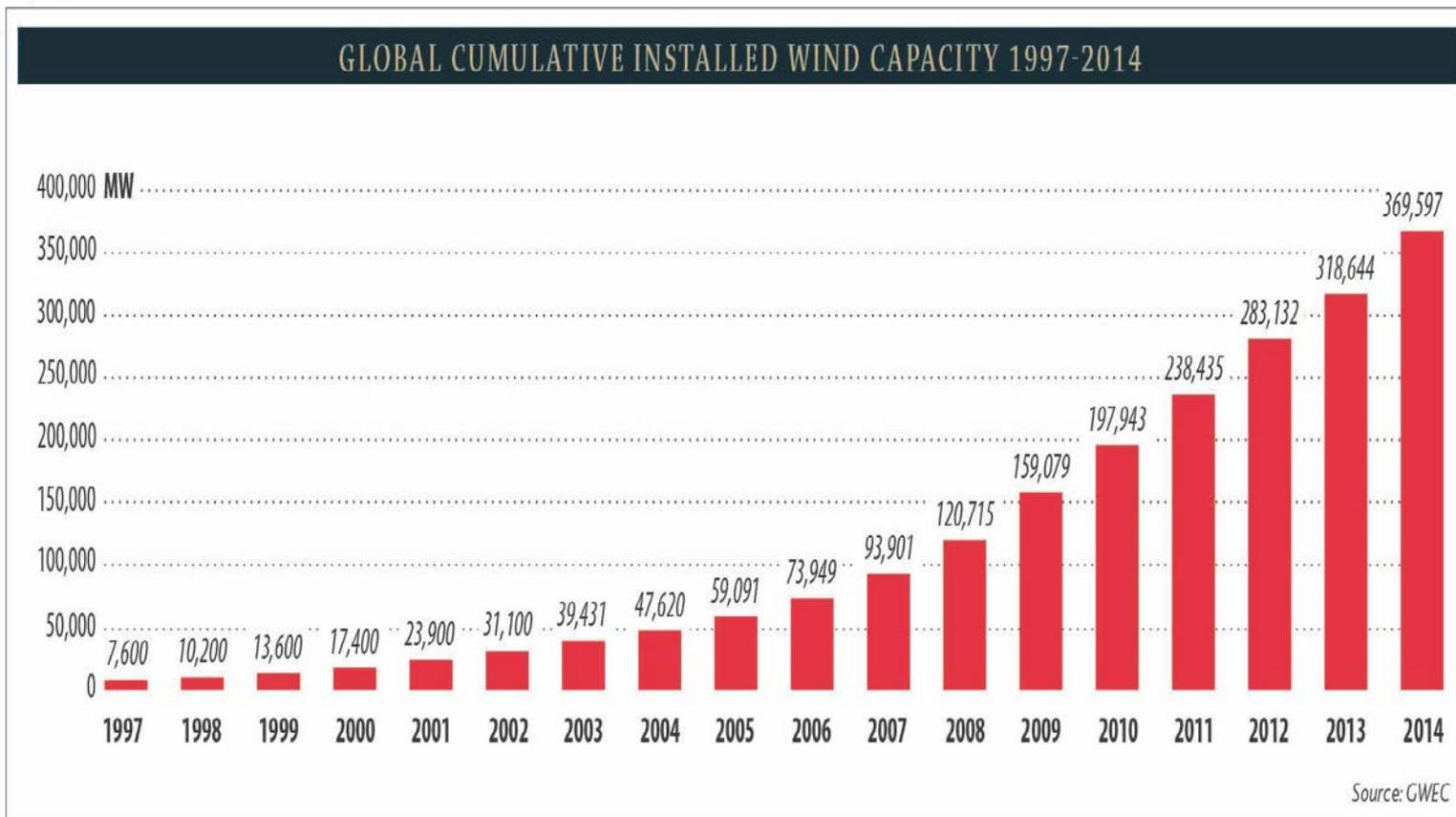


Source: IRENA Renewable Cost Database.

# LCOE Decomposition Methodology



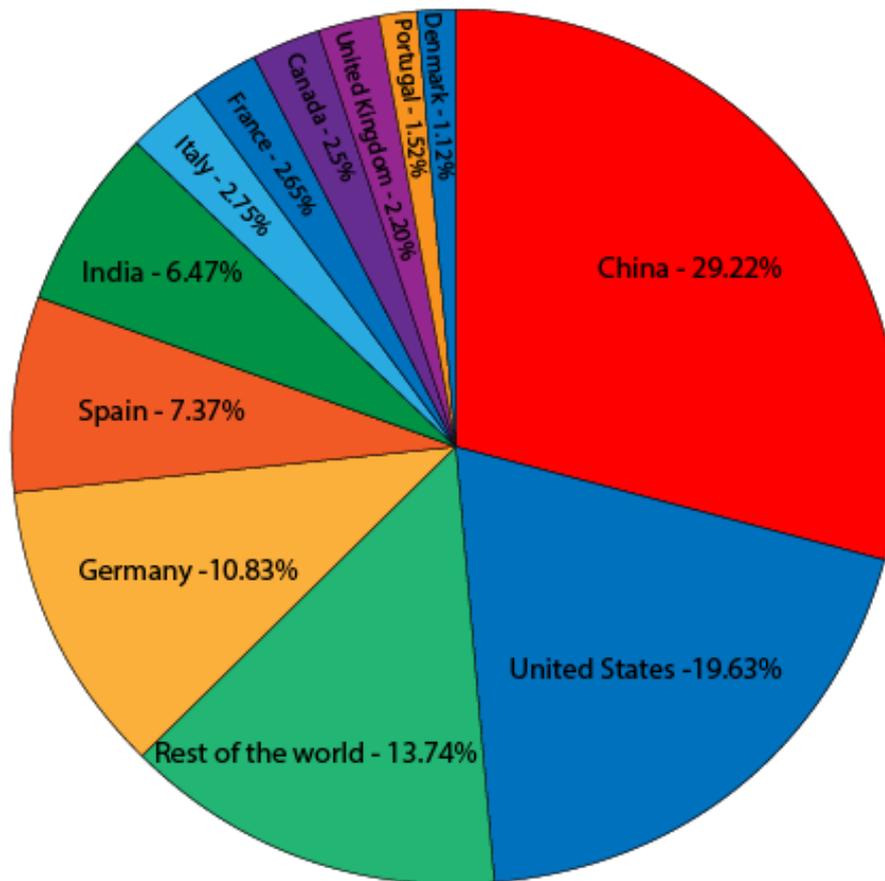
# Database





# Database

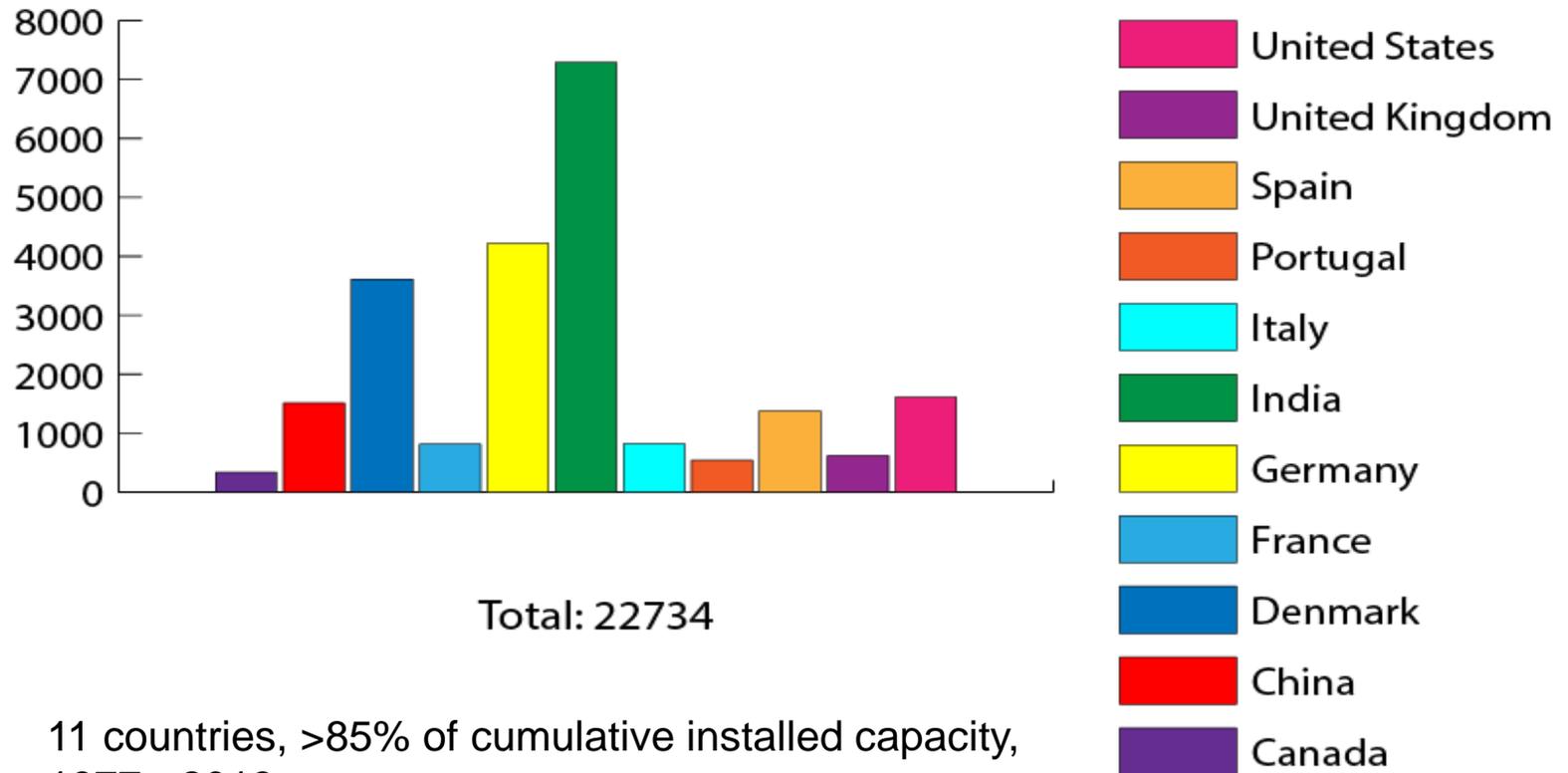
Share of cumulative installed capacity in 2013



Total: 311 GW

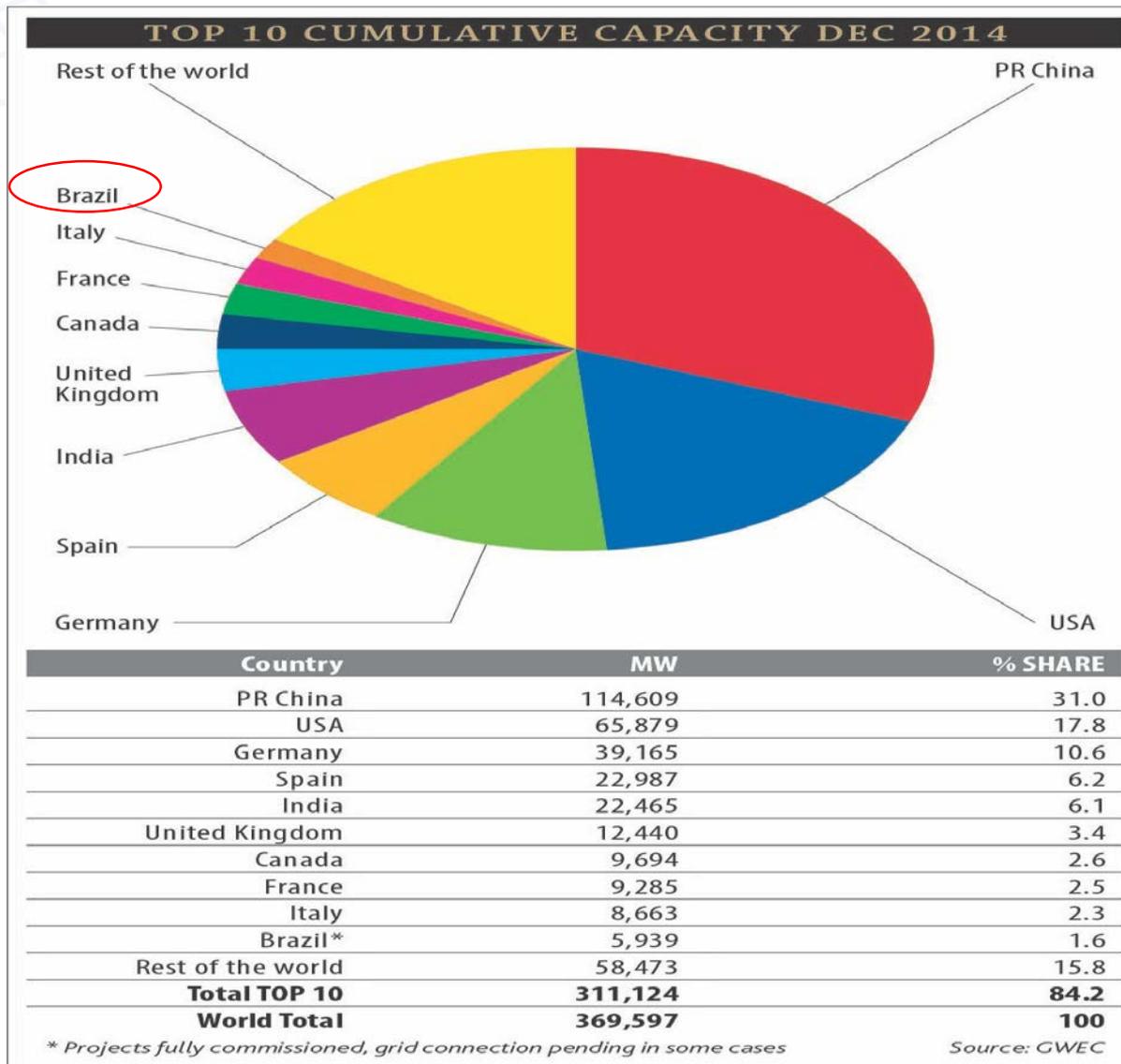
# Database

## Number of wind farms



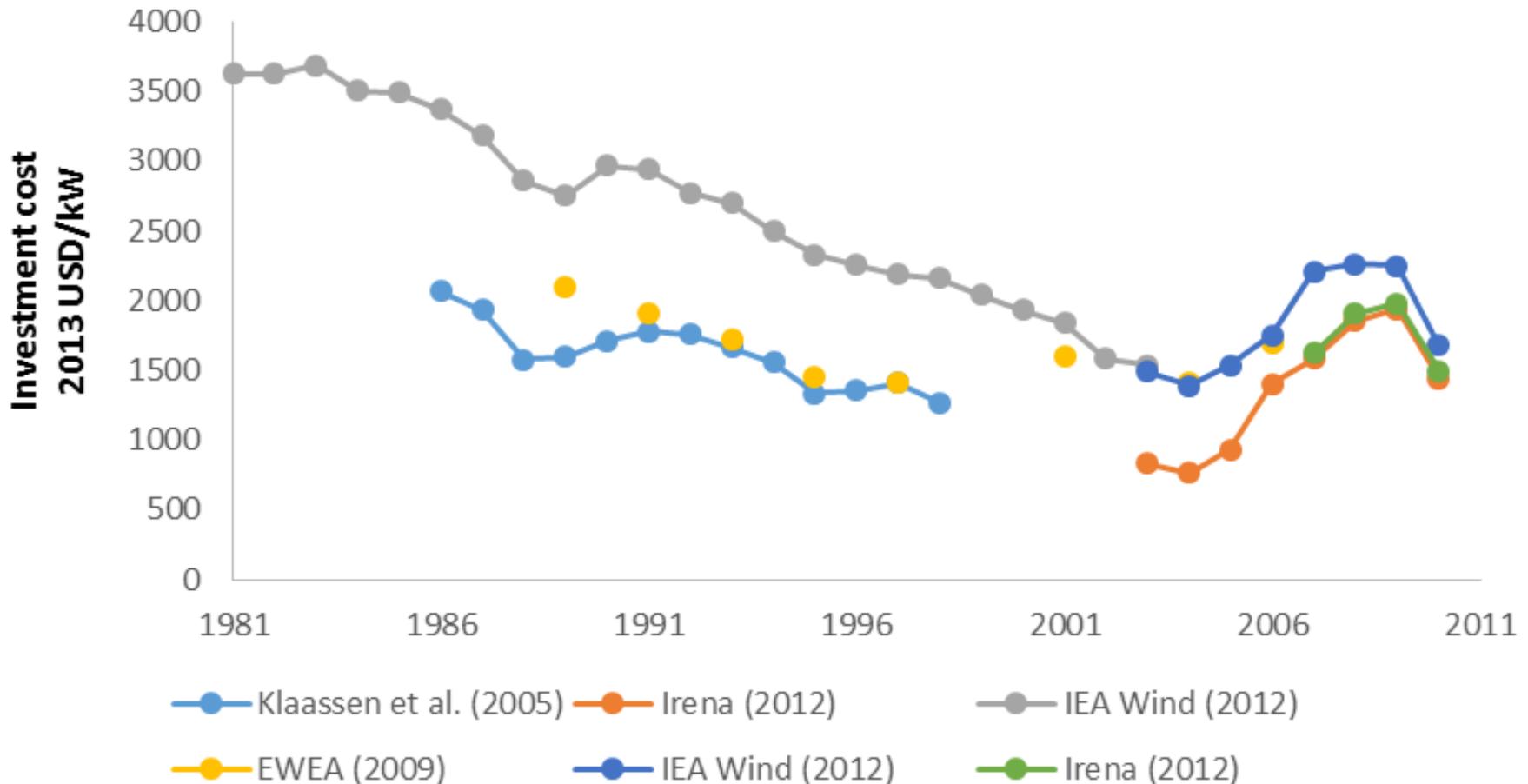
11 countries, >85% of cumulative installed capacity, 1977 - 2013

# Database



# Data collection example: Denmark

## Investment cost comparison



# Statistical robustness

Only representative sample is needed for each country and year

Of 12 countries, not all are statistically necessary in a given year, allows for some data gaps

Comprehensive data for pre-2000 mostly available

Some data can be calculated, just time consuming and expensive

Data imputation used to infer the value of important data points in the time series

# Potential Findings

## Learning curve analysis:

Higher installed costs have been combined with lower LCOE

An accurate/statistically robust learning curve for onshore wind

## Decomposition analysis:

True drivers of cost reduction

Contribution of technology improvements to cost reductions

# Implications

## **Policy making:**

Policy makers will have a better monitoring tool  
Quantifying learning investments (past and future)  
Forecasting breakeven points  
Evidence for renewed and more targeted policy support

## **Energy modelling:**

Energy models will benefit from more accurate inputs in order to forecast the development of wind and other technologies

# Progress & Timeline

## Current status:

Data collection, methodological tinkering

## Timeline:

End of September 2015 – Data collection process completed

End of December 2015 – Report writing

End of March 2015 – Peer review ready versions

## Data:

Data needs are vast. Thus, we would appreciate any datasets on investment costs, wind resource and capacity factors of onshore wind farms

# IRENA's Cost Analysis



**Bringing Our Future Forward**

**Thank you!**

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