The Global Energy Revolution and Developing Countries

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2008: Pulling for clean energy

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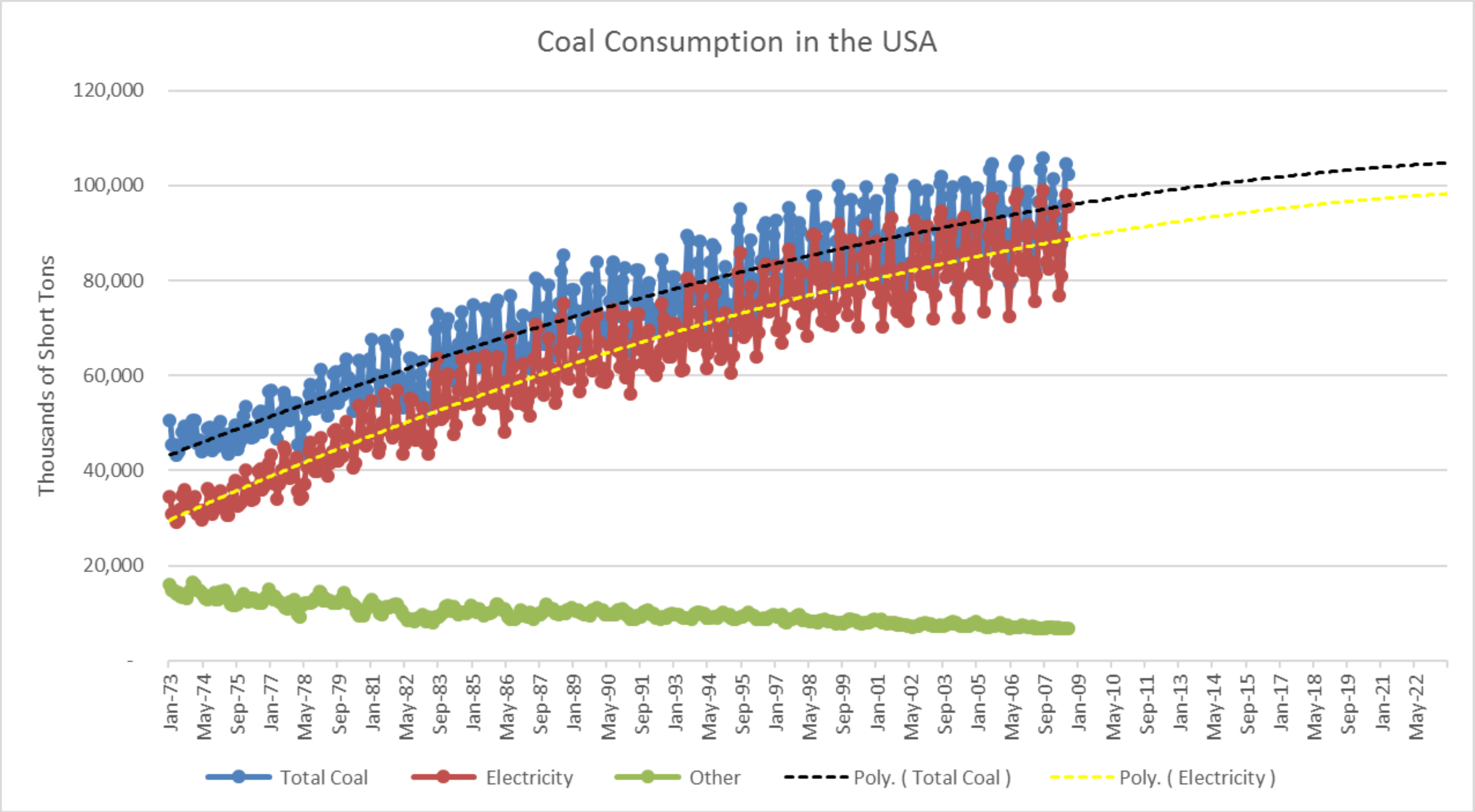
United States Coal Use



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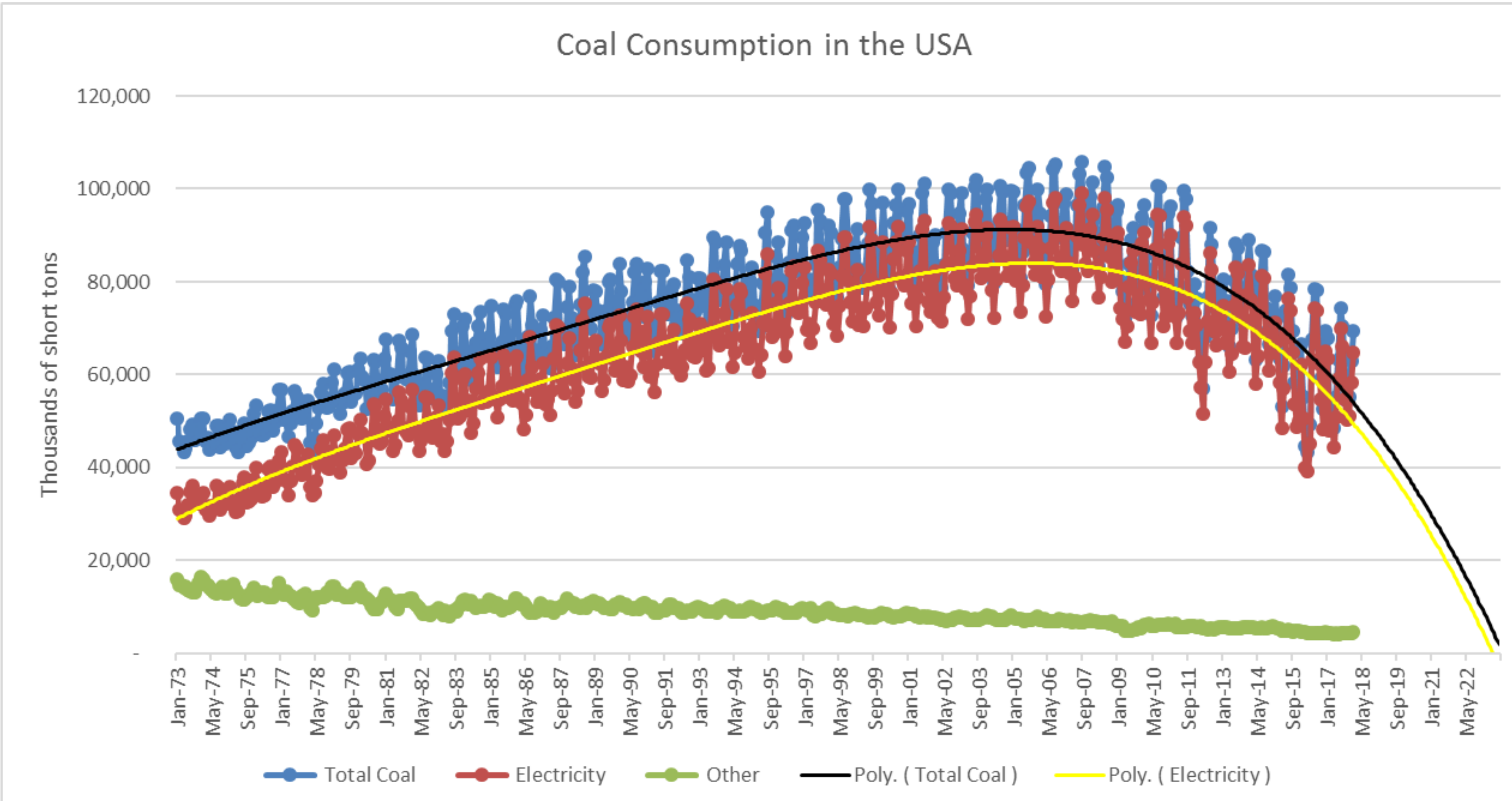
Source: U.S. Energy Information Administration. Electronic data from April 2018 Monthly Energy Review accessed on May 18, 2018.

United States Coal Use



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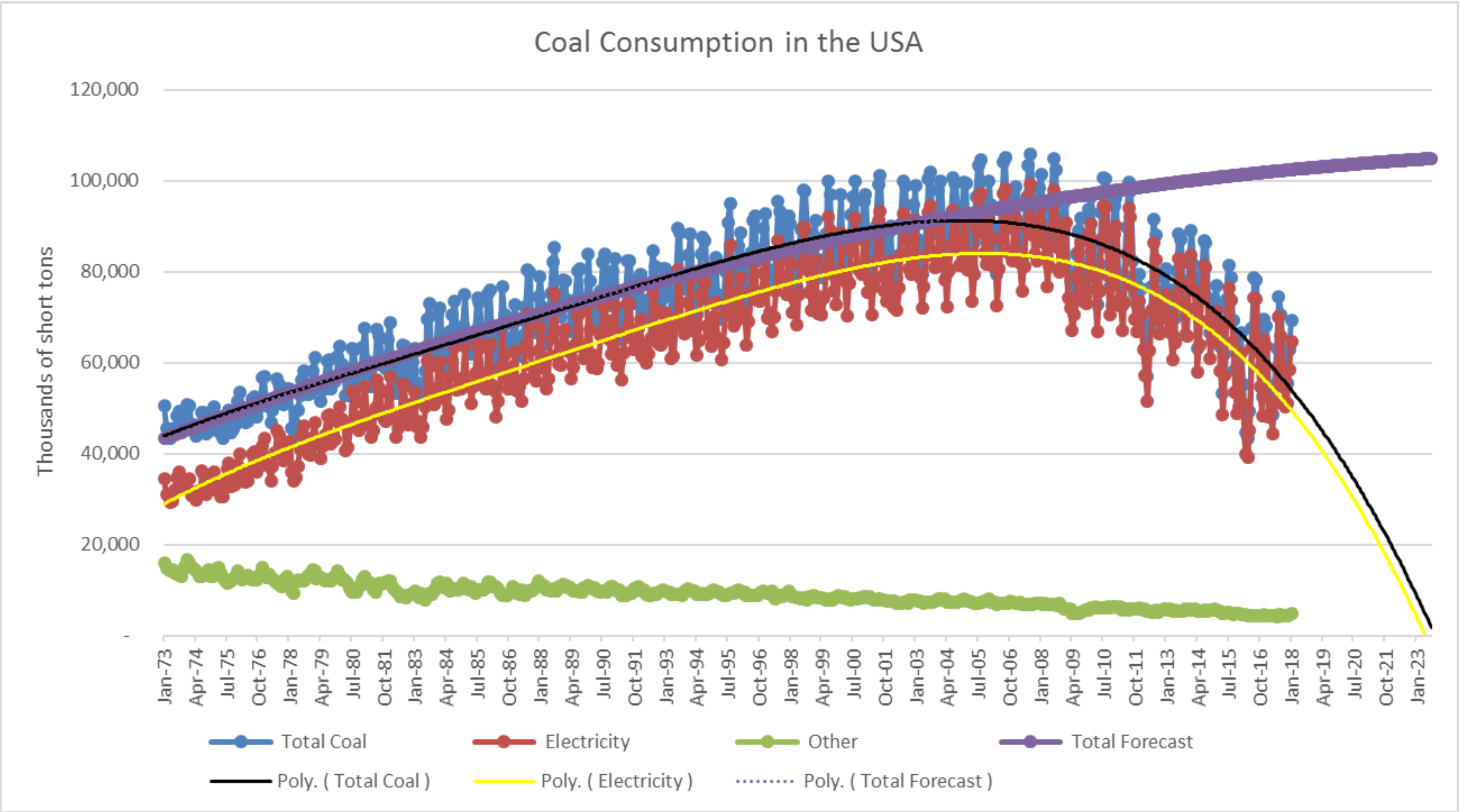

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Source: U.S. Energy Information Administration. Electronic data from April 2018 Monthly Energy Review accessed on May 18, 2018.

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2018+: Riding the tiger?

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Source: Getty Images.

Global Perspectives

NREL: Updated Solar Generation Costs

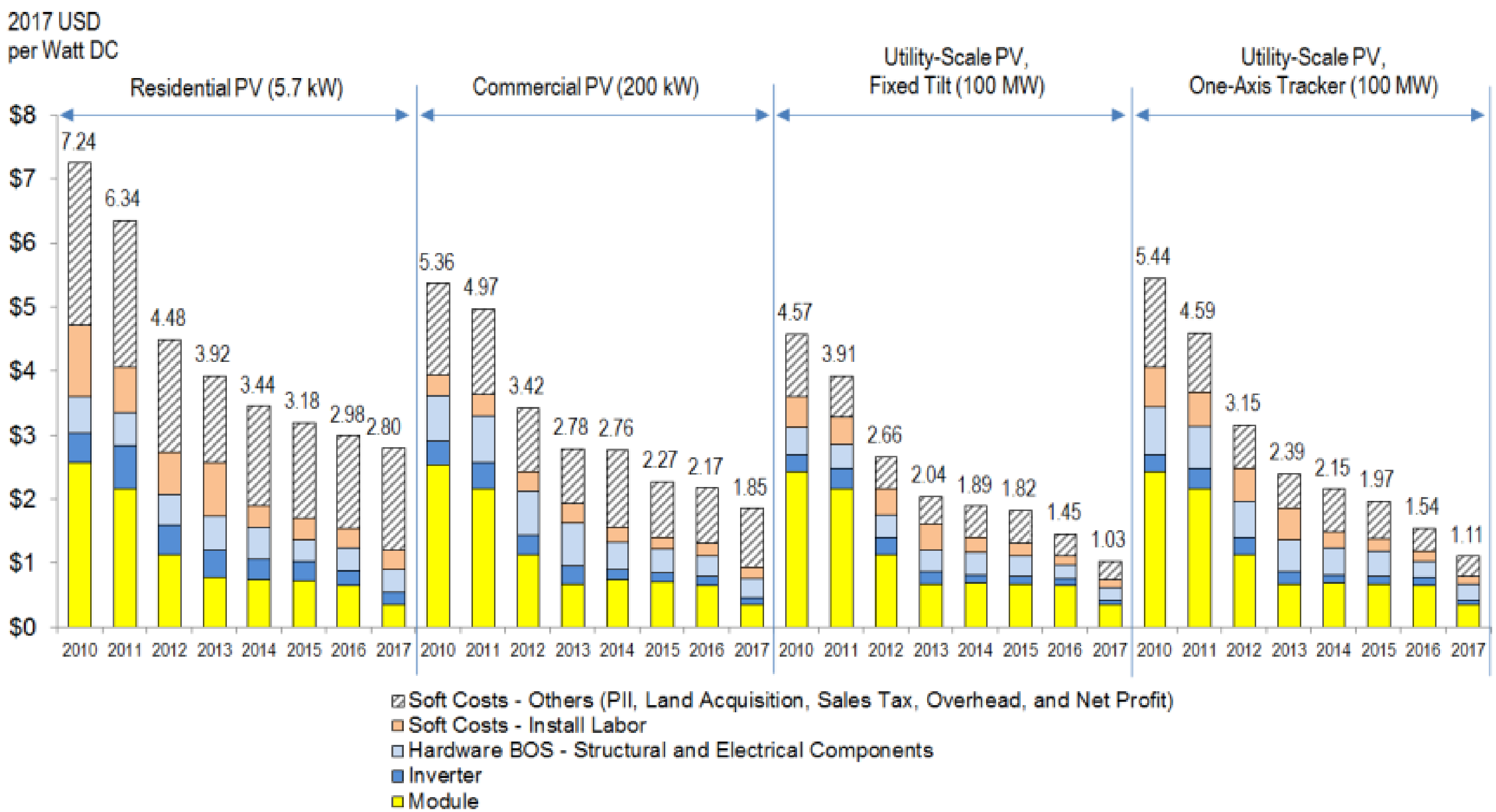

Figure ES-1. NREL PV system cost benchmark summary (inflation adjusted), 2010–2017

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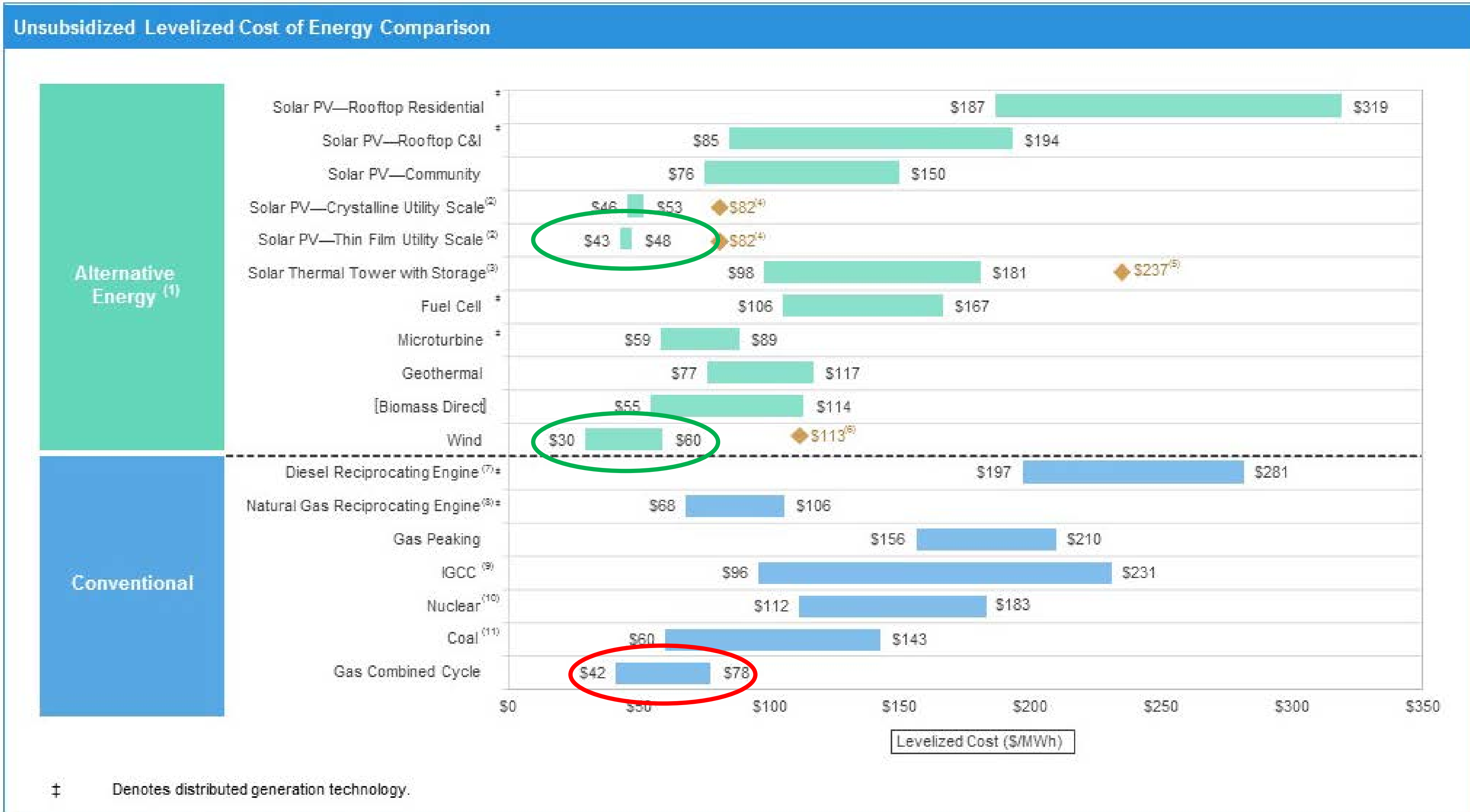
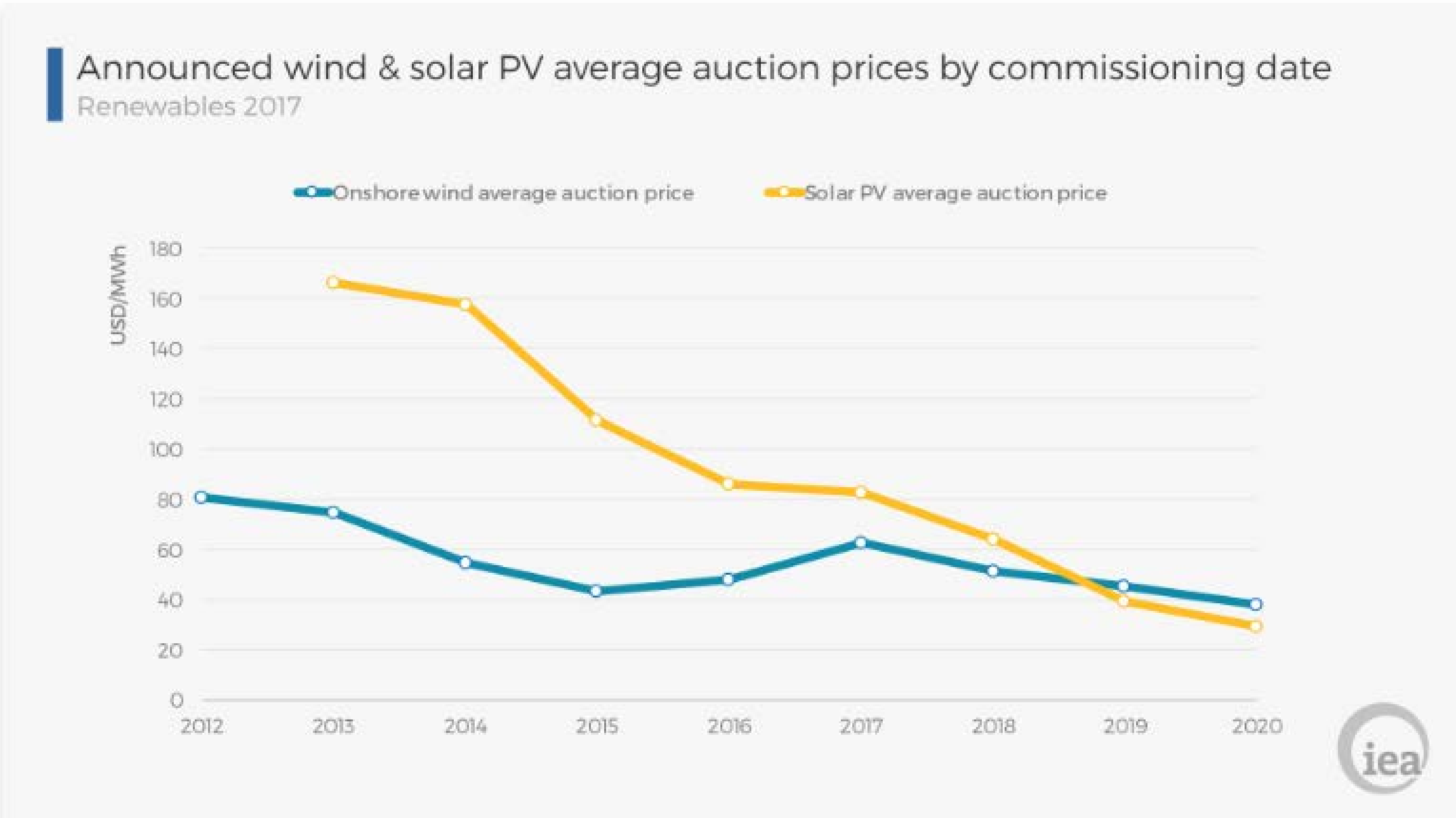
Levelized cost comparisons (2017) Lazard Freres



Cost of Renewable Electricity at Auctions



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https://www.iea.org/newsroom/energysnapshots/announced-wind-and-solar-average-auction-prices.html

Global Response

- **Global investment in renewable energy in 2017 reached $279.8 billion.**
- China accounted $126.6 billion, or 45% of the global total with solar leading the way.
- 157 gigawatts of VRE commissioned in 2017, up from 143GW in 2016, compared with 70GW of net fossil fuel generating capacity.
- Solar alone accounted 98GW, or 38% of the net new power capacity.

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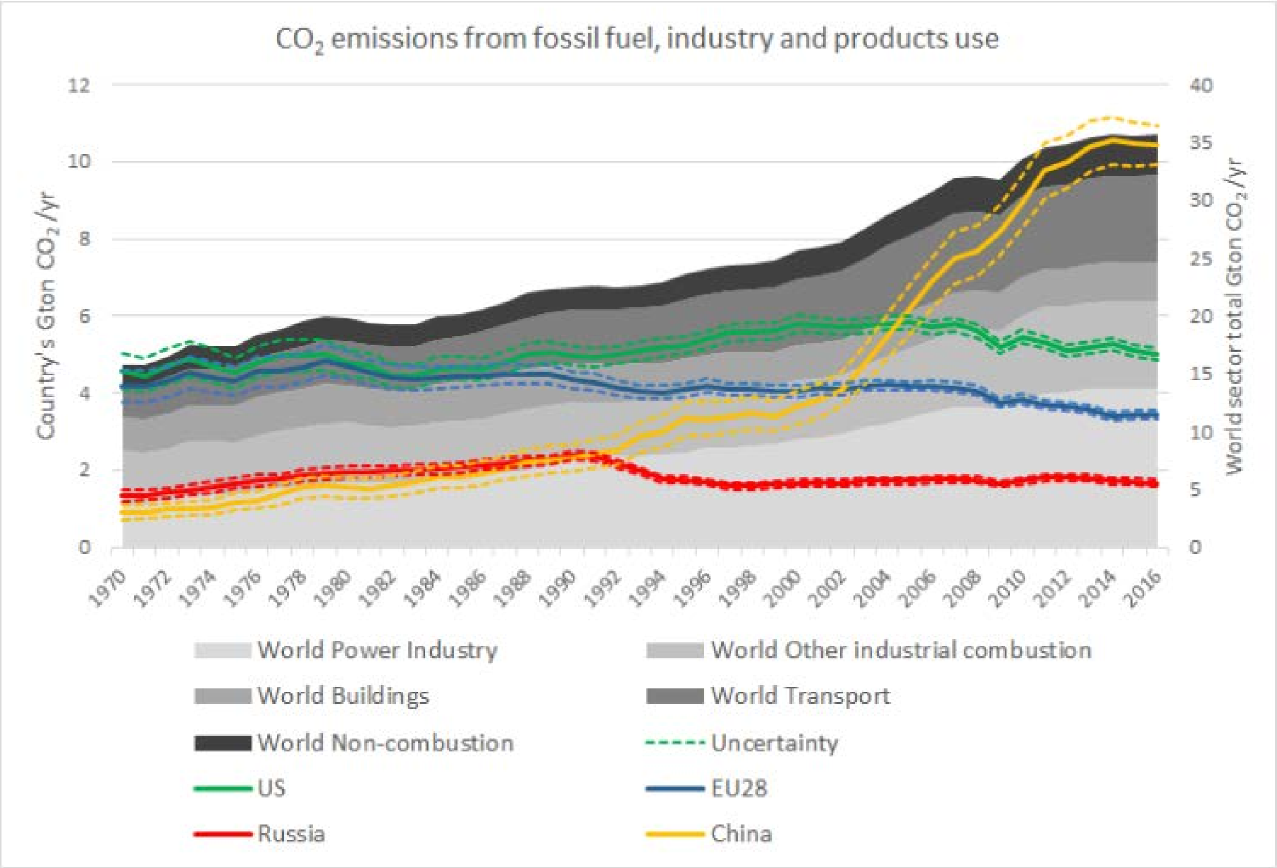
Source: http://fs-unep-centre.org/sites/default/files/publications/globaltrendsinrenewableenergyinvestment2018.pdf

Global CO2 Emissions: Flat for 3 Years



Total annual emissions of fossil CO_2 in Gton CO_2/yr. The fossil CO_2 emissions include sources from fossil fuel and industrial processes and product use (combustion, flaring, cement, iron and steel, chemicals and urea) for the EU28 and large emitting countries with uncertainty (in dashed line) (left axis) and for the world total per sector (right axis).

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Source: http://edgar.jrc.ec.europa.eu/booklet2017/CO2_and_GHG_emissions_of_all_world_countries_booklet_online.pdf

Observations on global emissions

- Global emissions in 2015 declined (slightly) by -0.1% and rose (slightly) by 0.3 in 2016 (due to extra day in 2016 as a leap year).
- This stalling in emissions is historic in that it is not coupled with the GDP trend, as cumulative global GDP grew by about 8 percent.
- The reduction is associated with "a more structural change with a shift away from carbon-intensive activities, particularly in China but also in the United States (p. 12)."

Source: http://edgar.jrc.ec.europa.eu/news_docs/jrc-2016-trends-in-global-co2-emissions-2016-report-103425.pdf

Political Economy of Clean Energy

- **Before: Vicious circle**
  - Relatively high cost and difficult to scale technologies.
  - Private investment very low and a poor political economy for public investment.
  - Relatively low rates of technical advance.
- **Current: Virtuous circle**
  - Competitive cost and scalable technologies;
  - Private investment high and much improved political economy for public investment.
  - High rates of technical advance.

Arent, Douglas, Channing Arndt, Mackay Miller, Finn Tarp, and Owen Zinaman, eds. *The Political Economy of Clean Energy Transitions.* Oxford University Press. 2017.

Summary

- **Rapid <u>rates</u> of technical of advance**
  - Solar
  - Wind
  - Systems integration
- **Cost <u>levels</u> of renewables, especially solar and wind, are clearly in competitive ranges.**
  - Continued technical advance, which is expected, will place more renewables as least cost (subject to systems integration).
- **Renewable generation <u>share</u> is becoming significant**
  - Implications of the next two doublings of renewable power share much more profound than the previous two doublings.

Systems integration at center stage

- **Wind power generation is highly variable on a turbine by turbine basis.**

- **Solar PV is not available at night and is strongly reduced with clouds.**

- **Systems integration matches supply with demand**
  - Dispatchable supply
  - Demand management

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Seasonal variation in wind power output: USA Northern Midwest

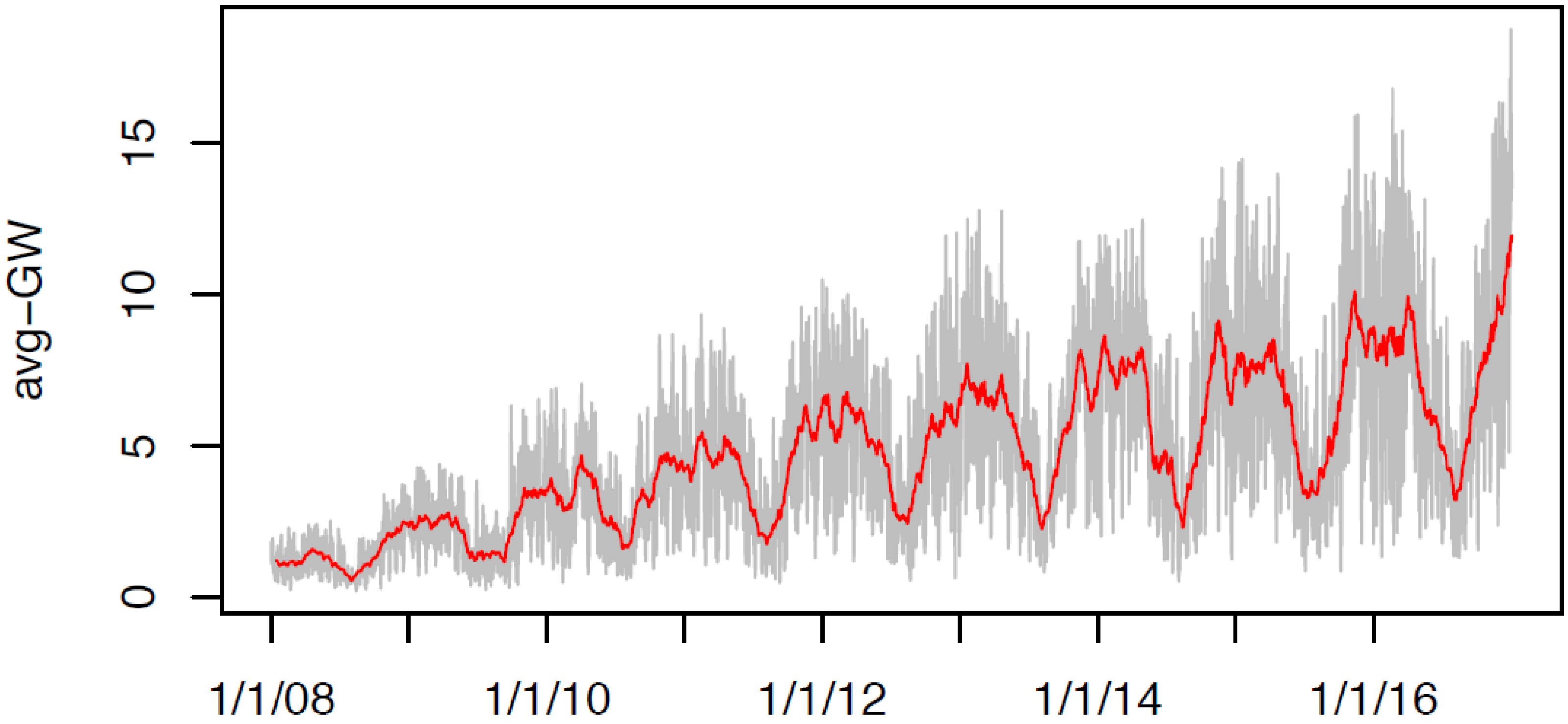
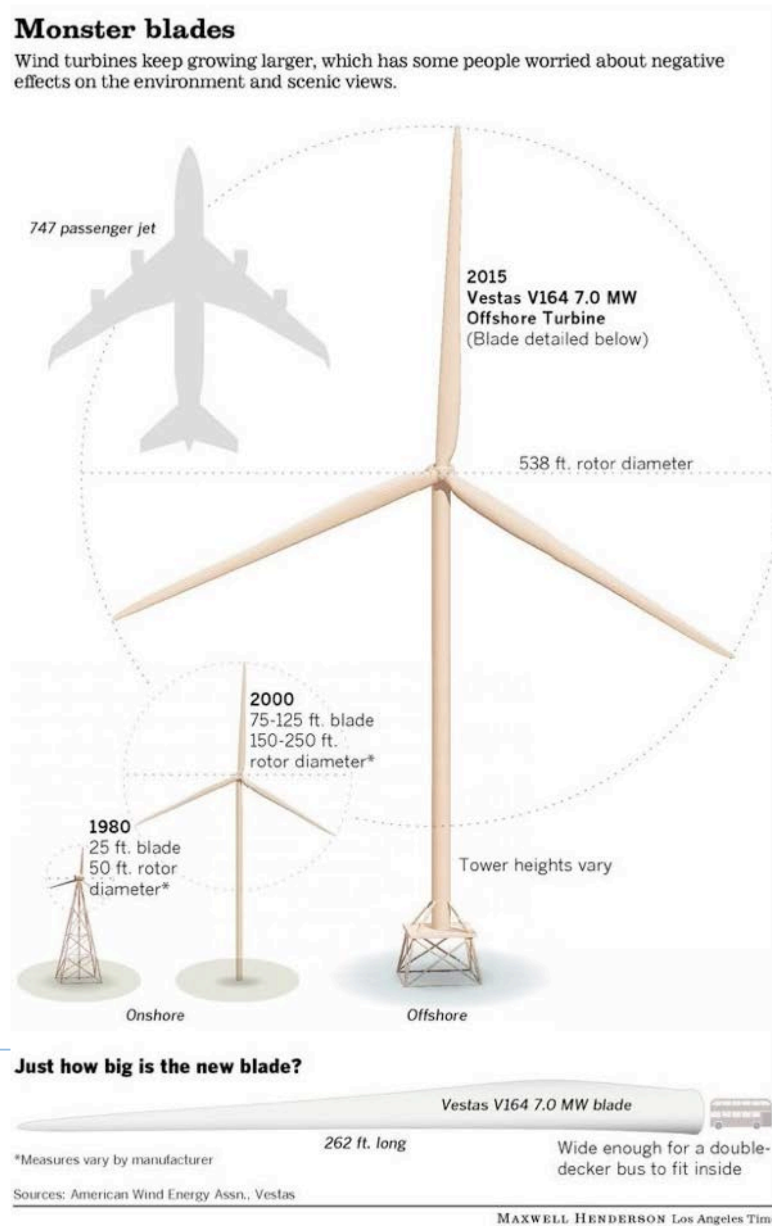


Figure. Daily average (grey) and 31-day rolling average (red) wind generation in MISO and PJM market regions, January 1, 2008 to December 31, 2016

Source: J. Jenkins, unpublished dissertation.

Wind Machines – Scale, Capacity Factor Increasing, Manufacturing Costs Declining



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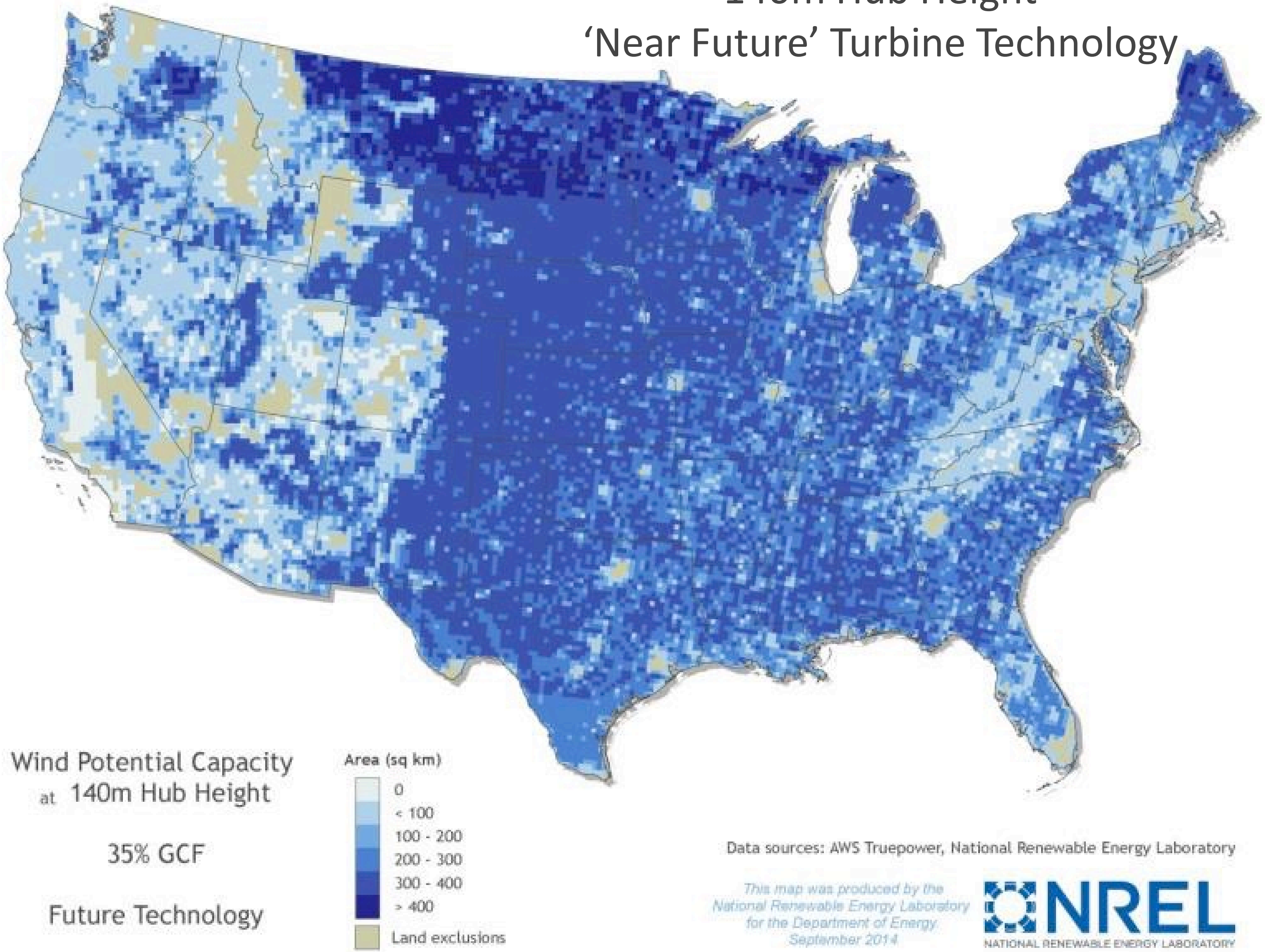
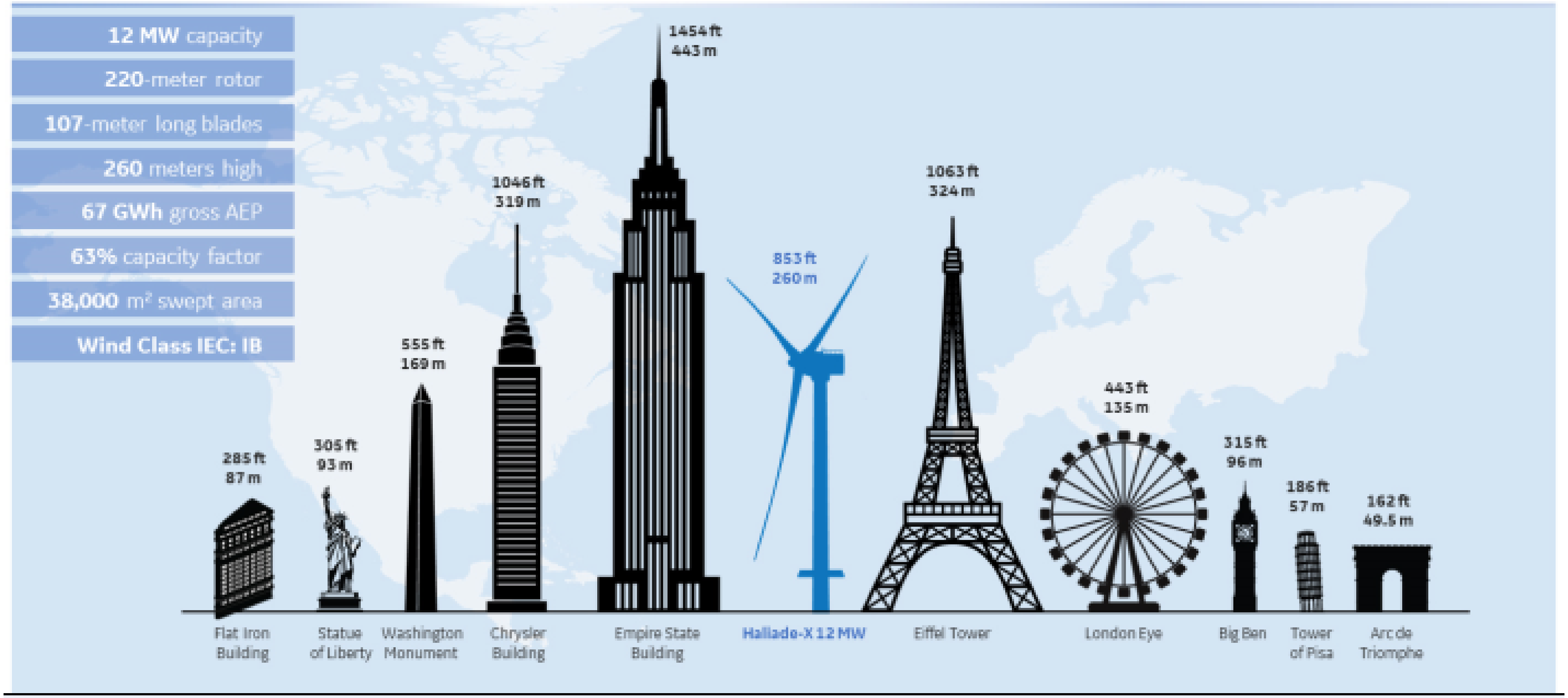
Wind Energy Potential Increasing to More Places

140m Hub Height
'Near Future' Turbine Technology



Offshore: GE Haliade-X 12 MW



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Global looking forward

- **Variable renewable sources are highly likely to represent rapidly increasing shares of electricity generation.**
- **Those best able to profit from this energy revolution will have:**
  - Endowments in renewable resources, notably solar and wind, but also complementary dispatchable resources including hydropower.
  - Needs for distributed power.
  - The ability to systems integrate.

Perspectives on African Energy Futures

The energy revolution and Africa

Those who will profit most are likely to have:

1. **Endowments in renewable sources, notably solar and wind, but also hydropower.**
2. **Needs for distributed power.**
3. **The ability to systems integrate.**

Broadly, good news for Africa

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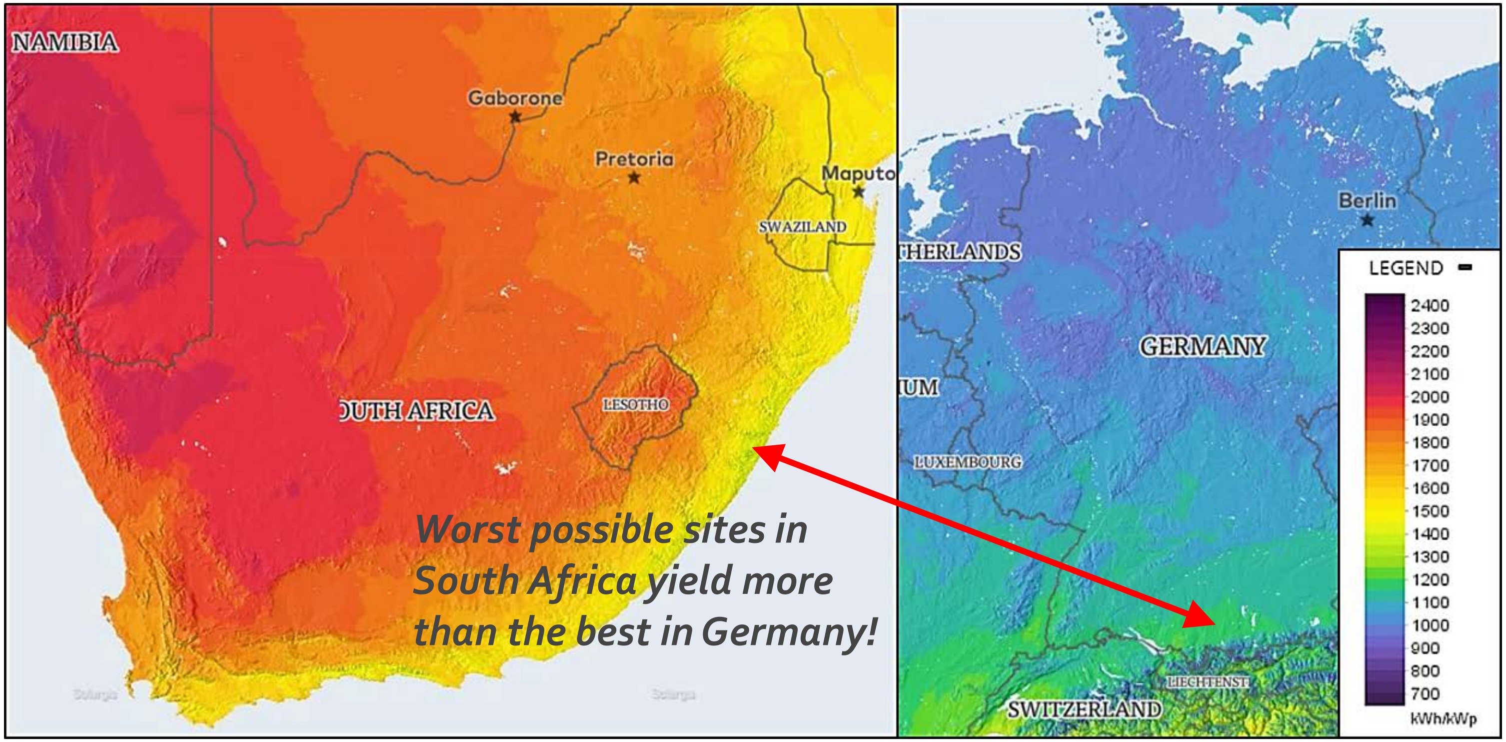
South Africa Case

SOUTH AFRICA HAS EXTENSIVE AND CONSISTENT SOLAR RESOURCES



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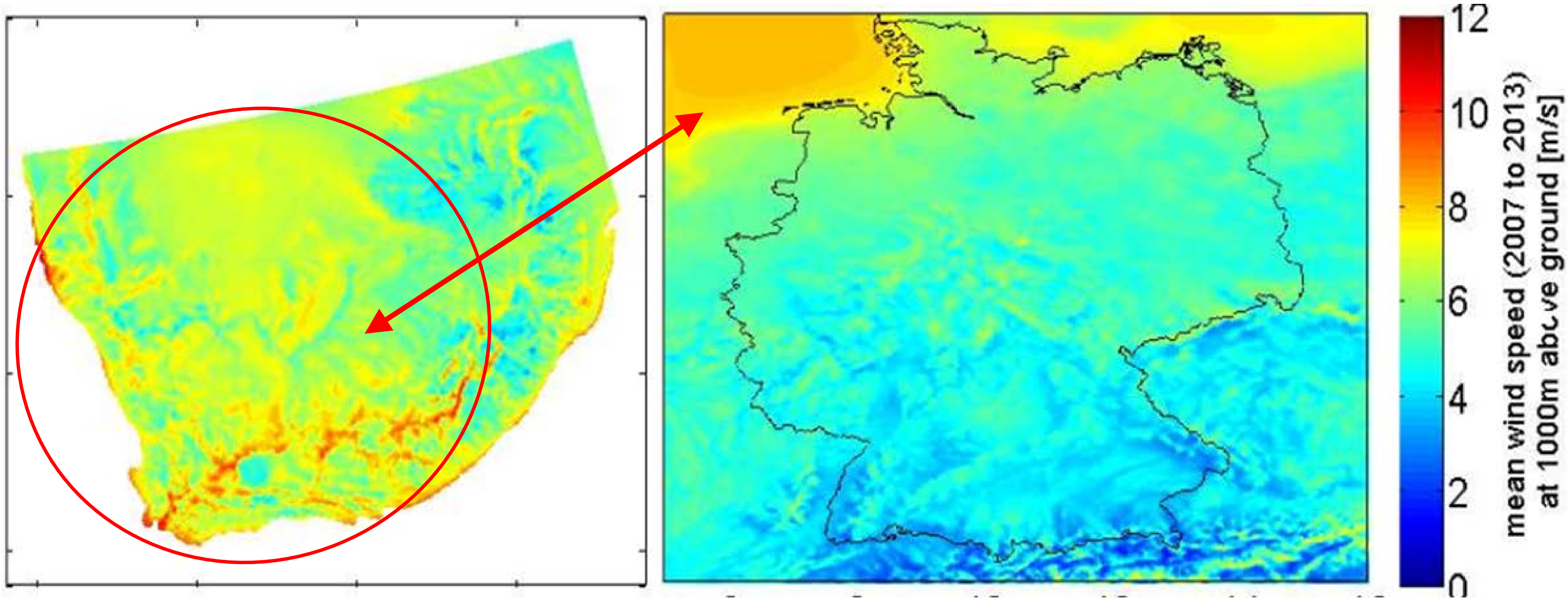
Source: http://www.erc.uct.ac.za/news/quantifying-benefits-energy-transition-south-africa

…AND WIND RESOURCES



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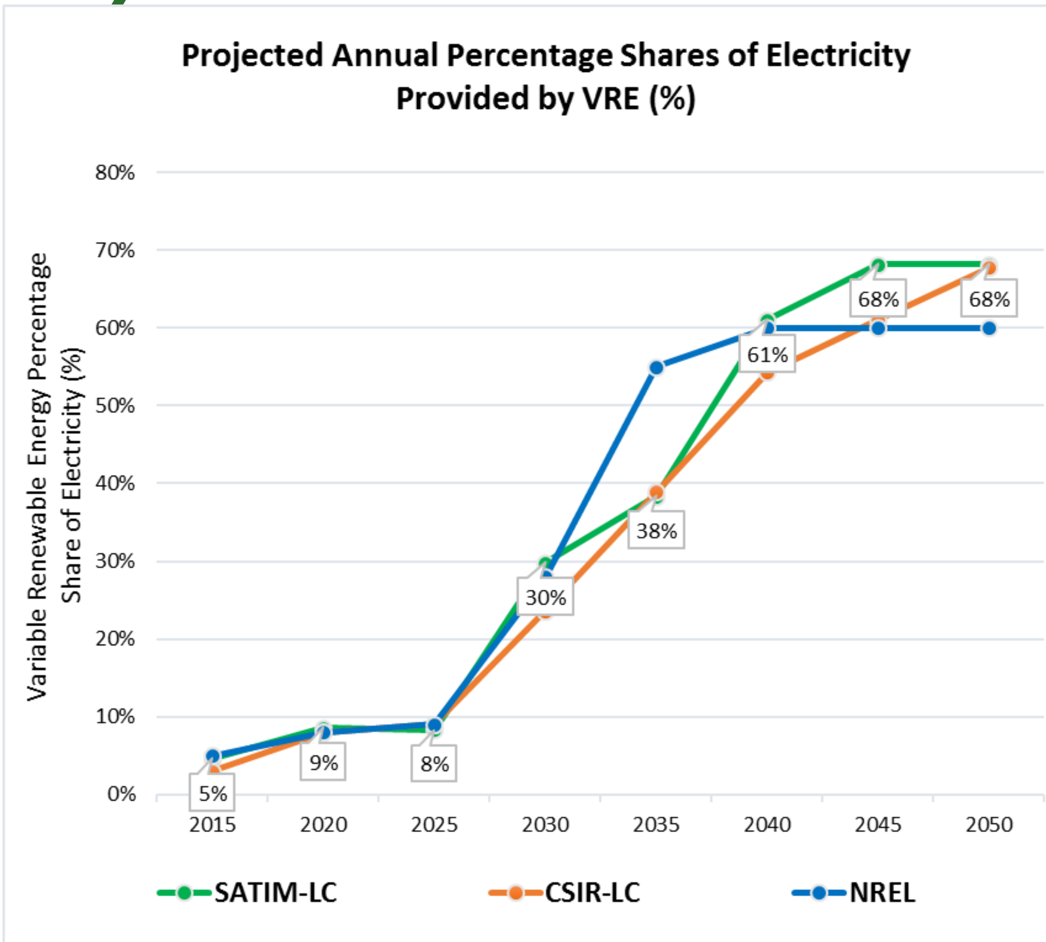
Source: http://www.erc.uct.ac.za/news/quantifying-benefits-energy-transition-south-africa

RSA: Variable Renewable Energy Shares (least cost)



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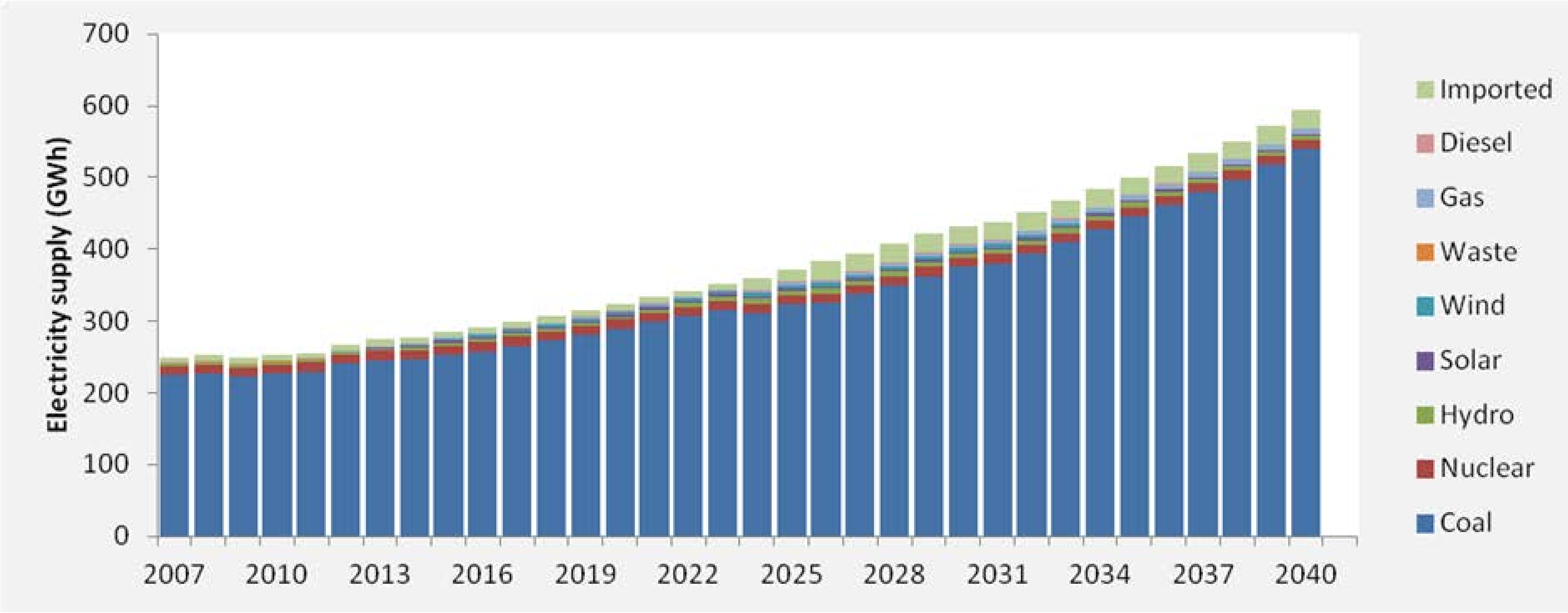
Internal Projections of Electricity Supply for South Africa developed around 2010.



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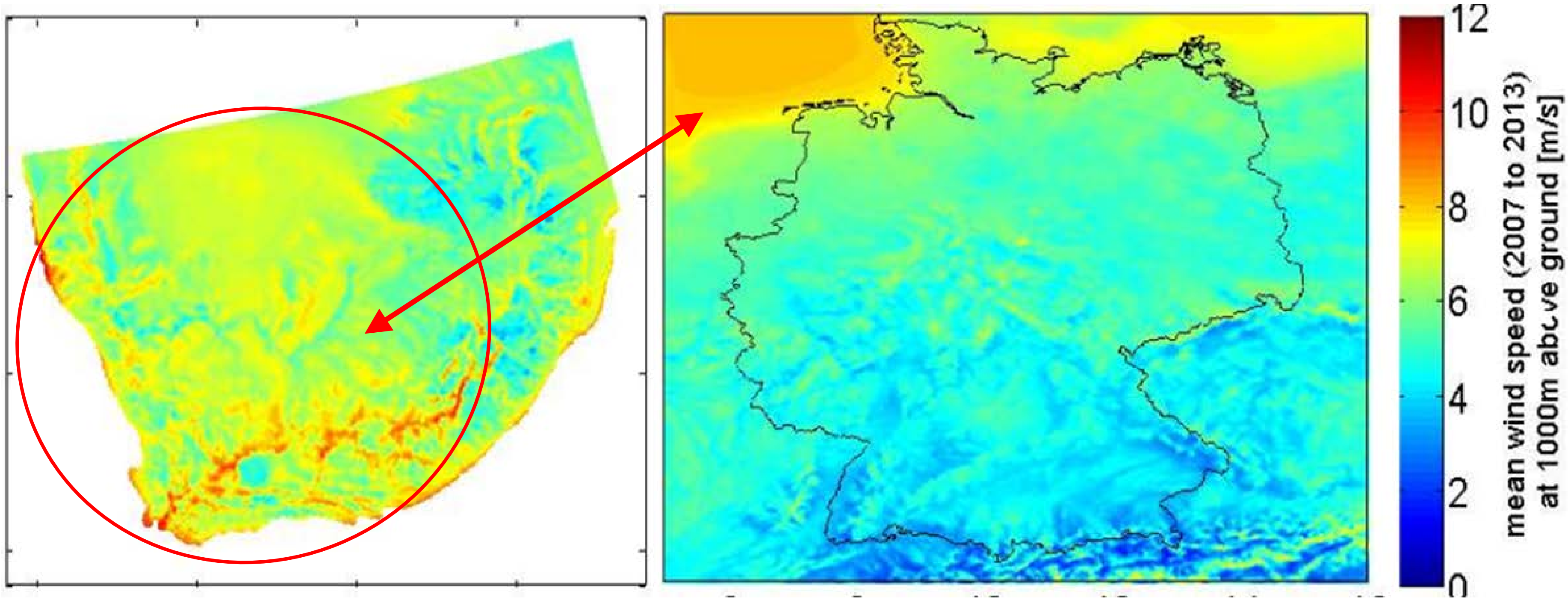
Research questions (1)

- **What energy endowments are available and where are they?**
  - Wind
  - Solar
  - Hydropower
  - Fossil fuels
  - Other (geothermal etc.)

WIND RESOURCES: South Africa and Germany



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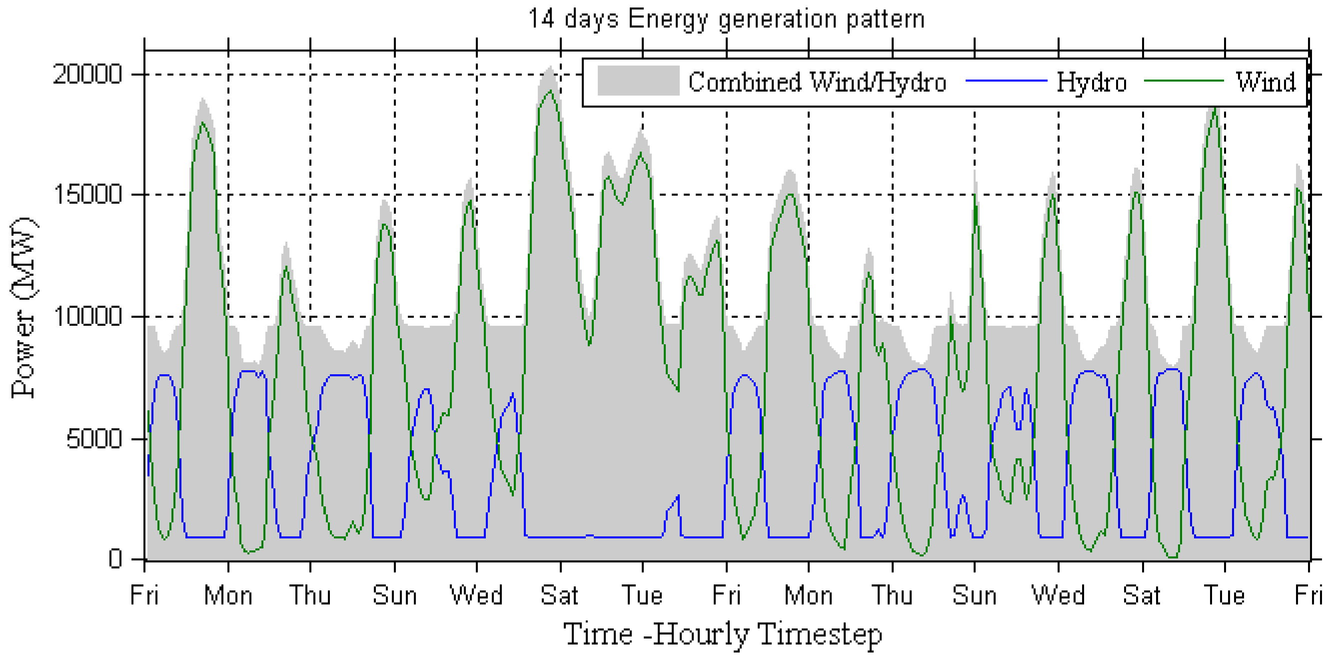
Source: http://www.erc.uct.ac.za/news/quantifying-benefits-energy-transition-south-africa

Research questions (2)

- **How do these endowments integrate?**
  - 2.1 What geographic locations are optimal and **how important are regional power pools?**
  - 2.2 What are the critical transmission investments?
  - 2.3 What is the role of distributed generation with limited distribution via mini- or small-grids versus big grids linking generation at scale?
  - 2.4 Can existing hydropower help with systems integration?

Linked hydropower and wind (Zambezi river linked to RSA)



Source: Gebretsadik, Yohannes, Charles Fant, Kenneth Strzepek and Channing Arndt, "Optimized reservoir operation model of regional wind and hydro power integration." *Applied Energy*. 161(2016): 574-582.

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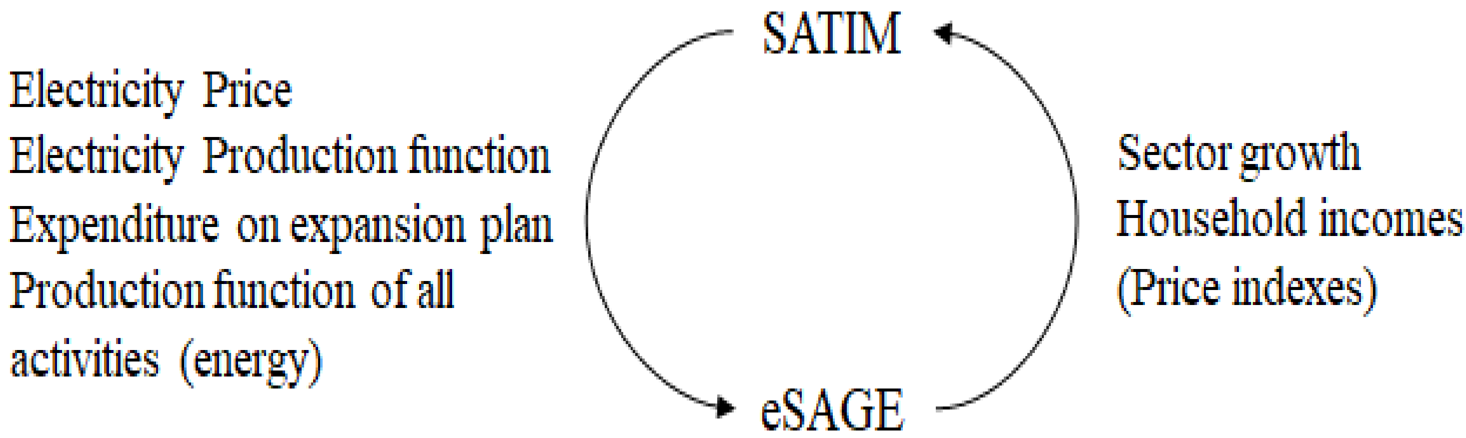
Research questions (3)

- **What are the macroeconomic implications of alternative power investment plans?**
  - GDP
  - Employment
  - Structure of production and investment
  - Exchange rates and trade
  - Etc.

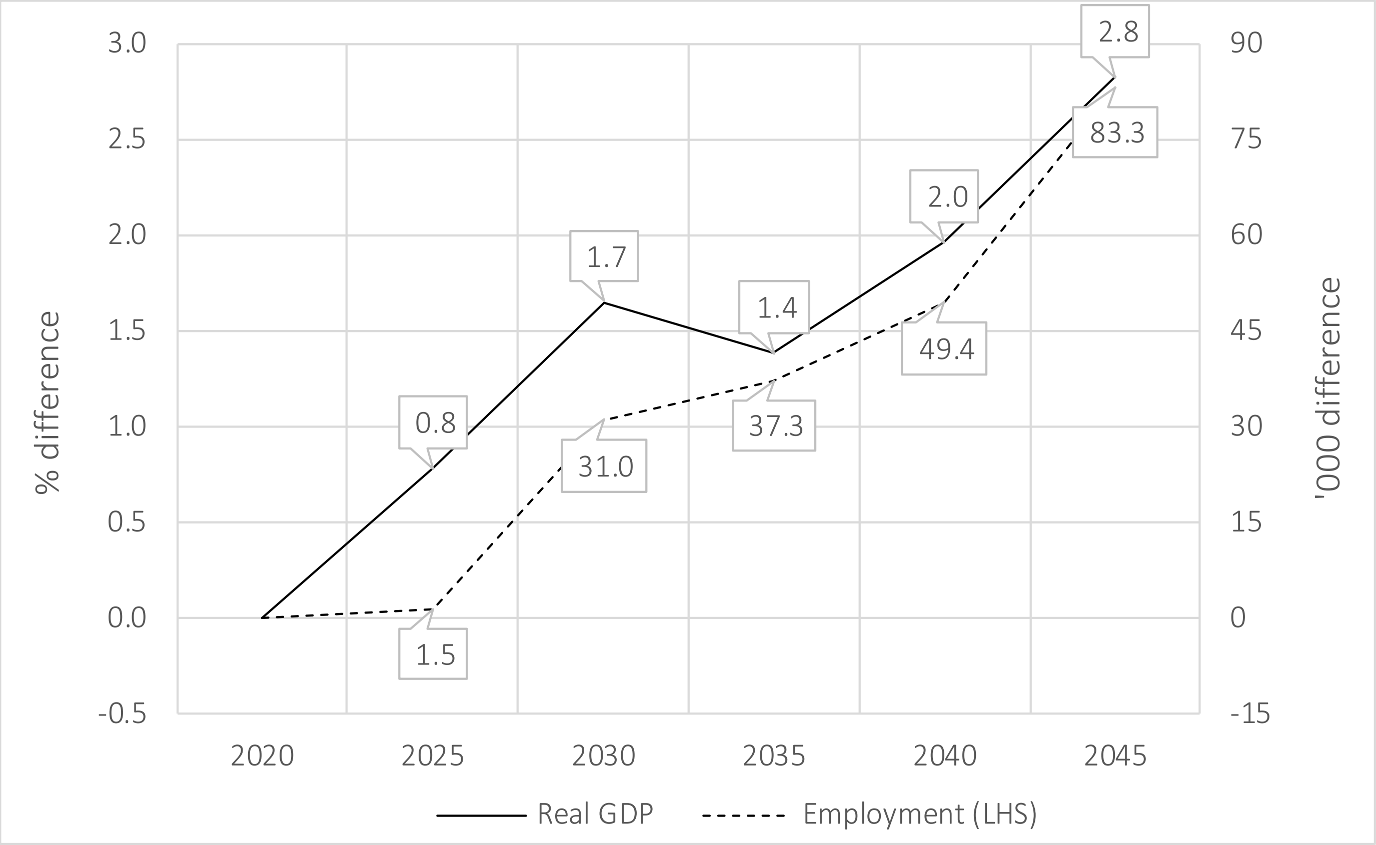
Linked modeling framework

- **SATIM: South Africa TIMES energy model.**
- **eSAGE: Energy oriented version of the South Africa general equilibrium model.**



Arndt, Channing, Rob Davies, Sherwin Gabriel, Konstantin Makrelov, Bruno Merven, Faaiqa Hartley, and James Thurlow. "A sequential approach to integrated energy modeling in South Africa." *Applied Energy.* 161(2016): 591–599.

RSA: Real GDP and Employment Impacts (preliminary results from linked model)



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Research questions (4)

- **How does one leverage the energy revolution for rural growth and development?**
  - *Production*: solar pumping, refrigeration, electric mechanization. What scale?
  - *Natural resources:* Groundwater depletion (aquifer storage recovery).
  - *Nutrition:* Irrigation and refrigeration may permit production of more nutrient dense foods (fruits, vegetables, meat, and milk).
  - *Social:* What are implications for time use and gender roles?
- **How should national build plans and rural electrification programs interact?**

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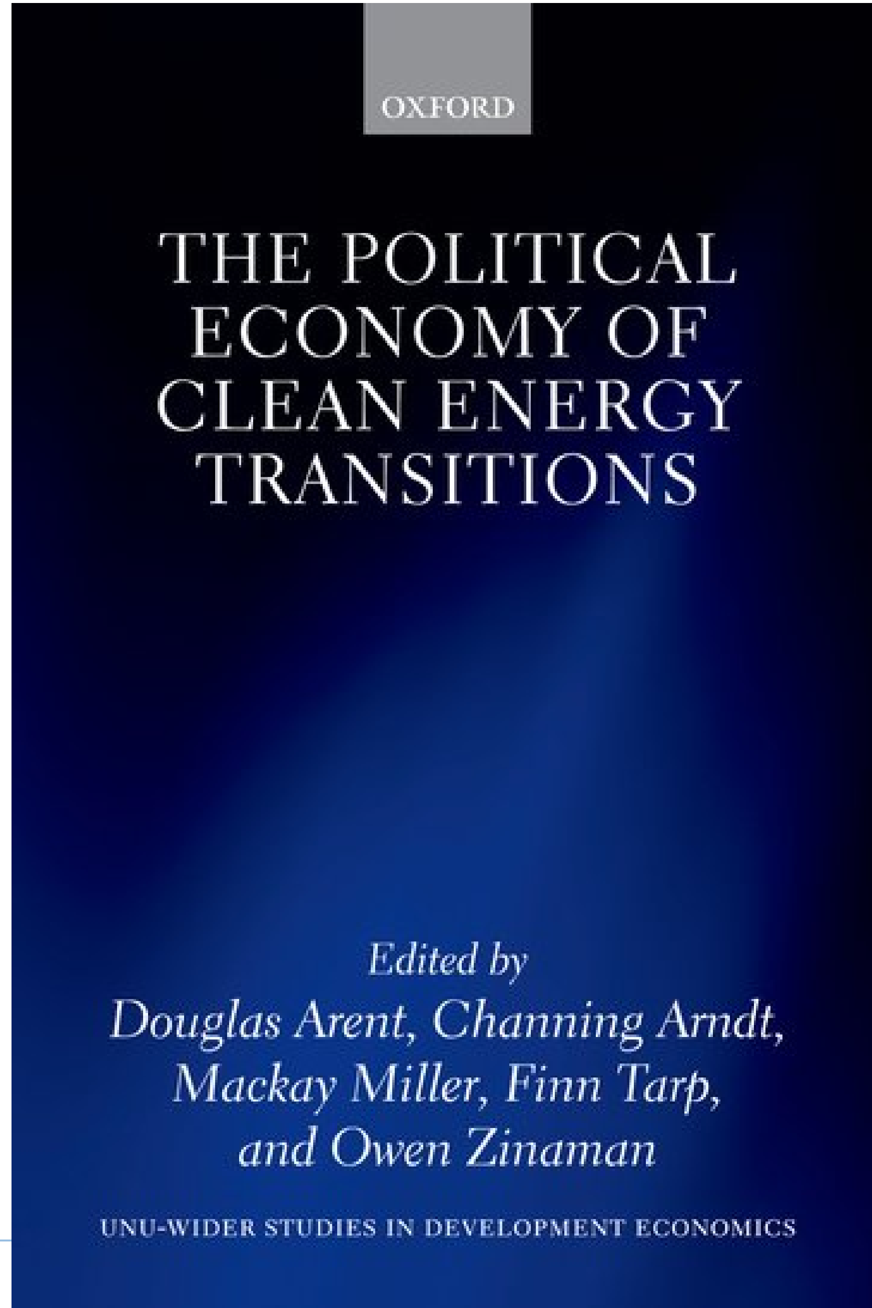
Research questions (5)

- **What institutional models are appropriate?**
  - Traditional utilities, whether state owned or private and regulated, are experiencing difficulties almost everywhere.
  - *Example*: Eskom in South Africa is in danger of a death spiral due to legacy coal generation investments, pressure from independent providers, and defections from the grid by their best customers.

Conclusions

- **The energy revolution provides valuable tools to:**
  - enhance growth and development prospects in Africa and beyond, and
  - meet environmental objectives at global and local scales.
- **The details of how to apply these tools:**
  - will vary across contexts and
  - are not yet fully clear in any context.
- **Accelerated research efforts and fresh thinking are key inputs to realizing these potentials.**



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Other References

- **Arndt C., F. Hartley, G. Ireland, B. Merven, and J. Wright. "Developments in variable renewable energy and implications for developing countries."** ***Regional Renewable Energy Focus.*** **Forthcoming.**
- **Towards Inclusive Economic Development in Southern Africa**
  - Climate and energy theme
  - https://sa-tied.wider.unu.edu
- **Arndt, Channing, Rob Davies, Sherwin Gabriel, Konstantin Makrelov, Bruno Merven, Faaiqa Hartley, and James Thurlow. "A sequential approach to integrated energy modeling in South Africa."** ***Applied Energy*****. 161(2016): 591–599.**

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