

Grid Integration of Variable Renewable Energy Sources

Research Challenges and Opportunities

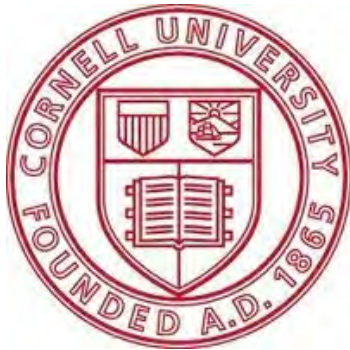
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PSERC Public Webinar

August 10th, 2011



Electricity Research Centre (ERC), Industry Members

2



Other stakeholders on ERC board:



Major Funding sources:



Electricity Research Centre (ERC), 2011

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Prof. Mark O'Malley



Dr. Ciara O'Connor



Ms. Magdalena
Szczepanska



Ms. Rachael O'Hegarty

ERC has four research strands across two institutions, UCD and TCD:

Operations

Dr. Damian Flynn



Networks

Dr. Andrew Keane



Economics

Dr. Eleanor Denny
(TCD)



Systems

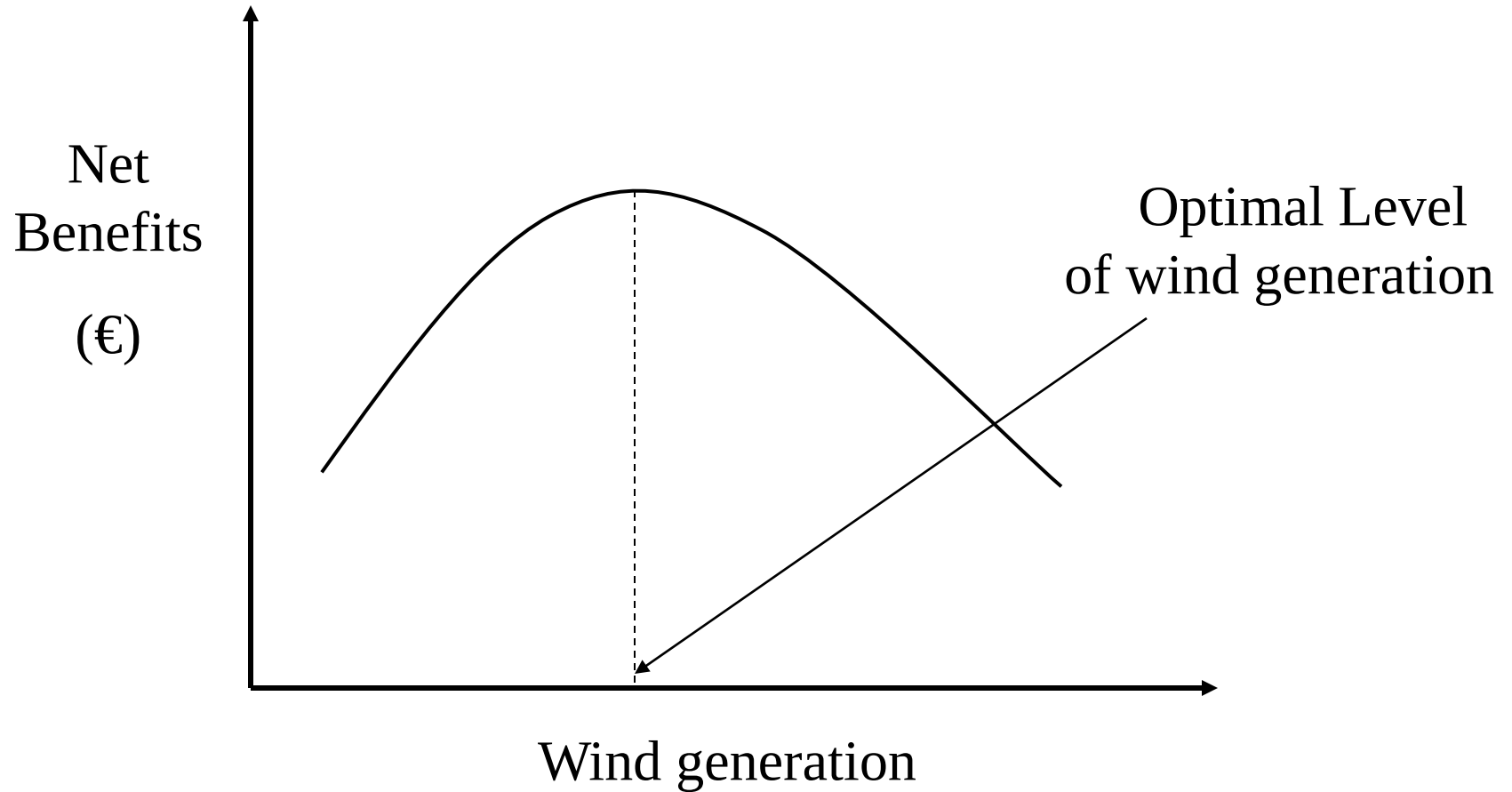
Prof. Mark O'Malley





Variable renewable energy sources

Moon Shot For Wind



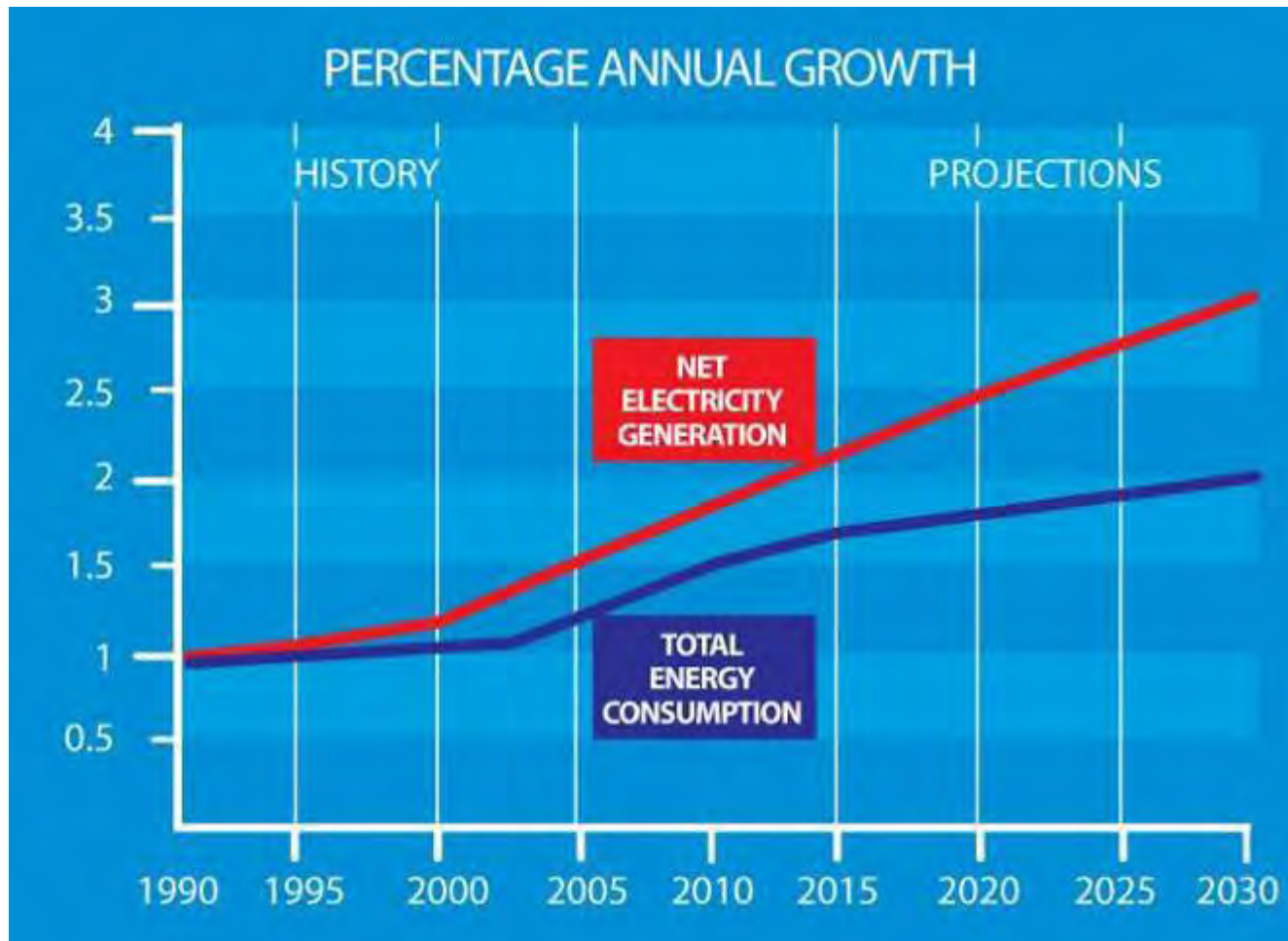
Portfolio

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Electrifying the Future

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Source: Energy Information Administration (EIA), 2008.



Analysis and Technology

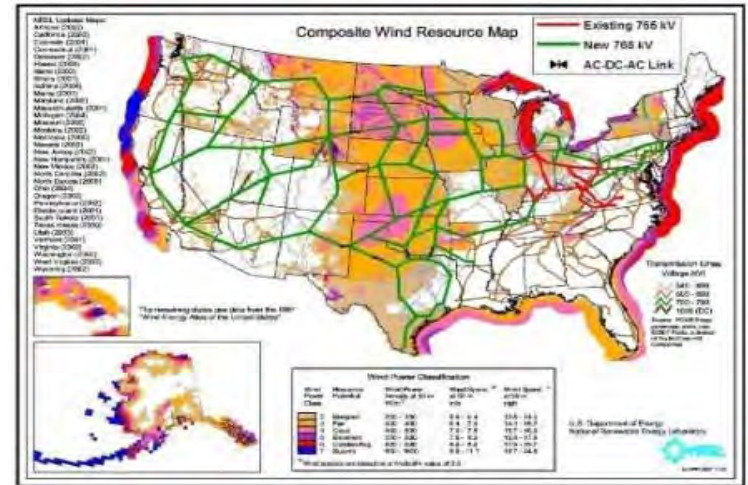


Some Research Areas

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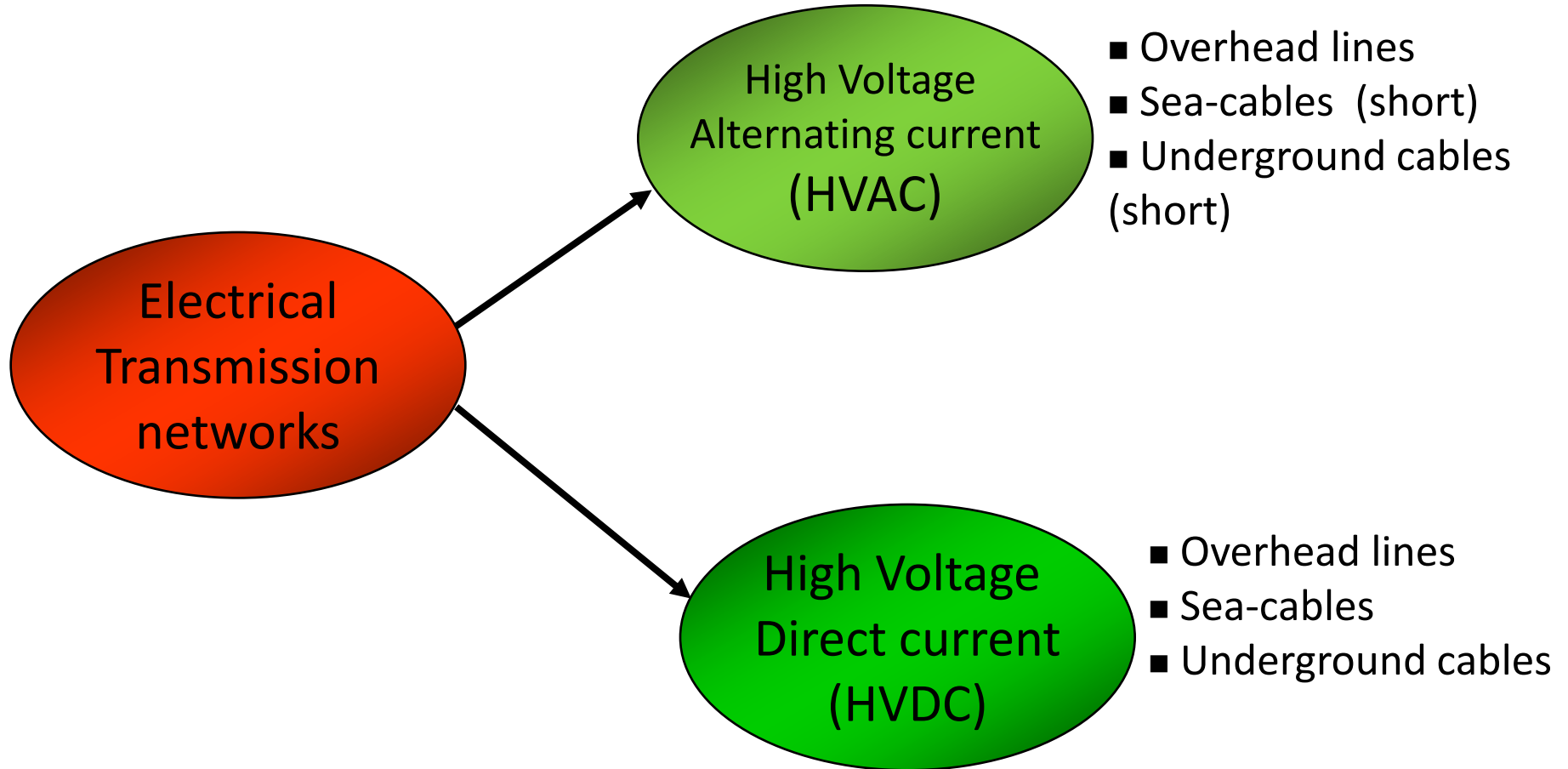
- Transmission
- Generator technologies
- Resource characteristics
- Societal issues
- etc.





AC/DC ?

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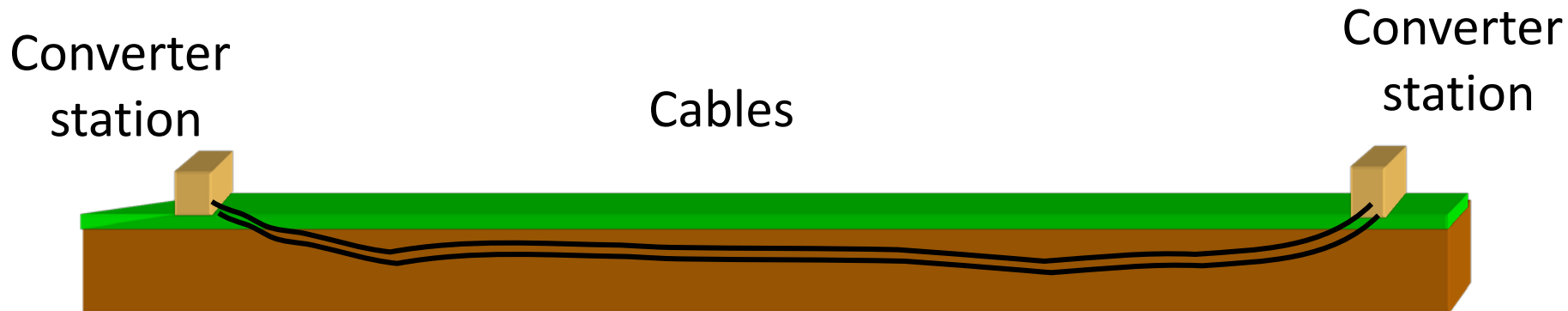
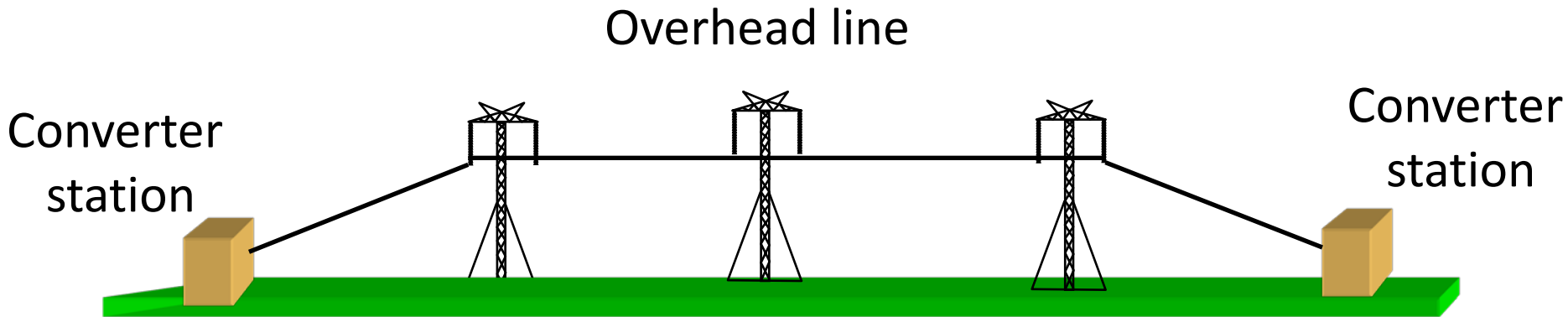


Underground ?



High Voltage Direct Current (HVDC)

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Some Research Topics

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- New transmission devices
- New network topologies
- New tools and methods
- etc.

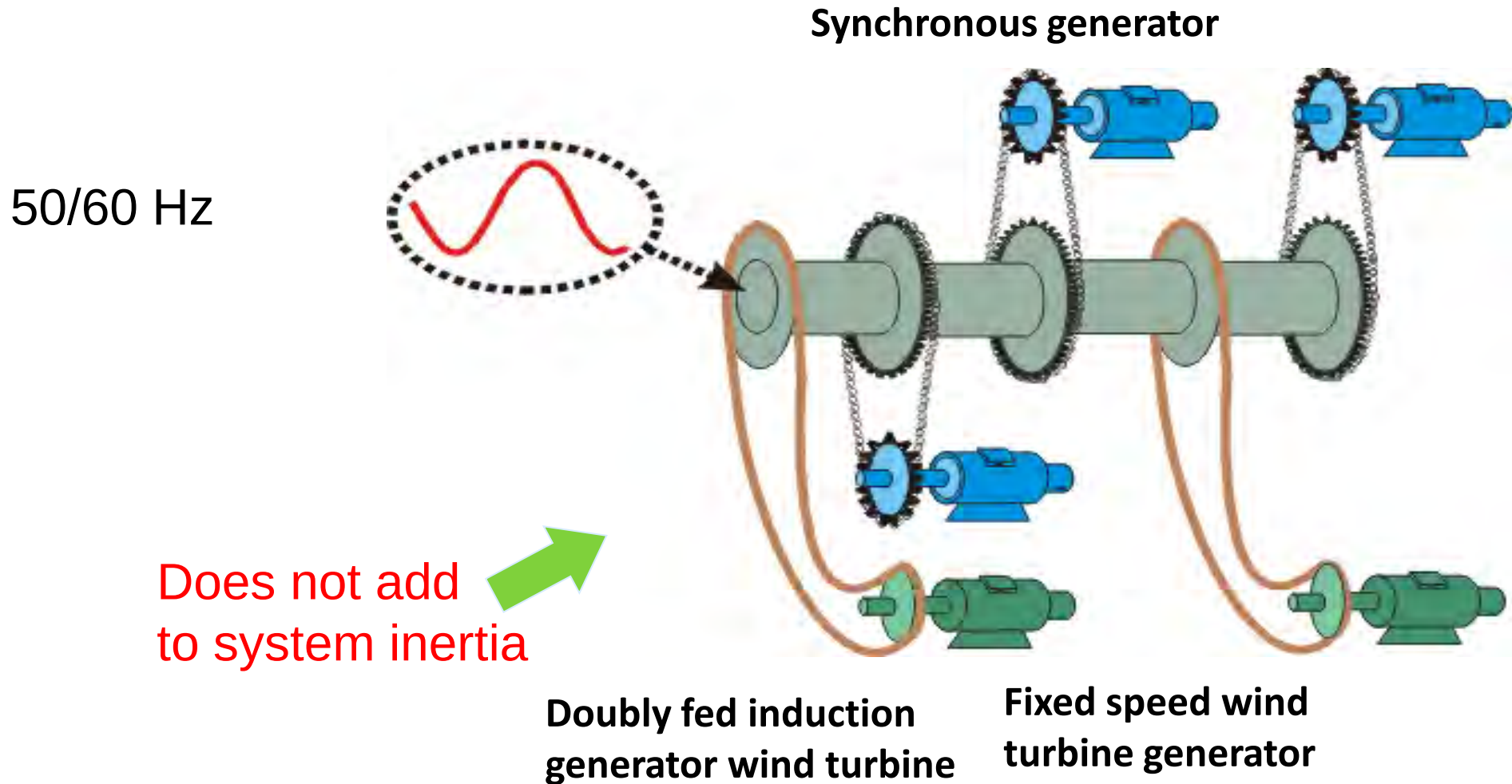




Asynchronous generation
technologies are changing the grid
fundamentally

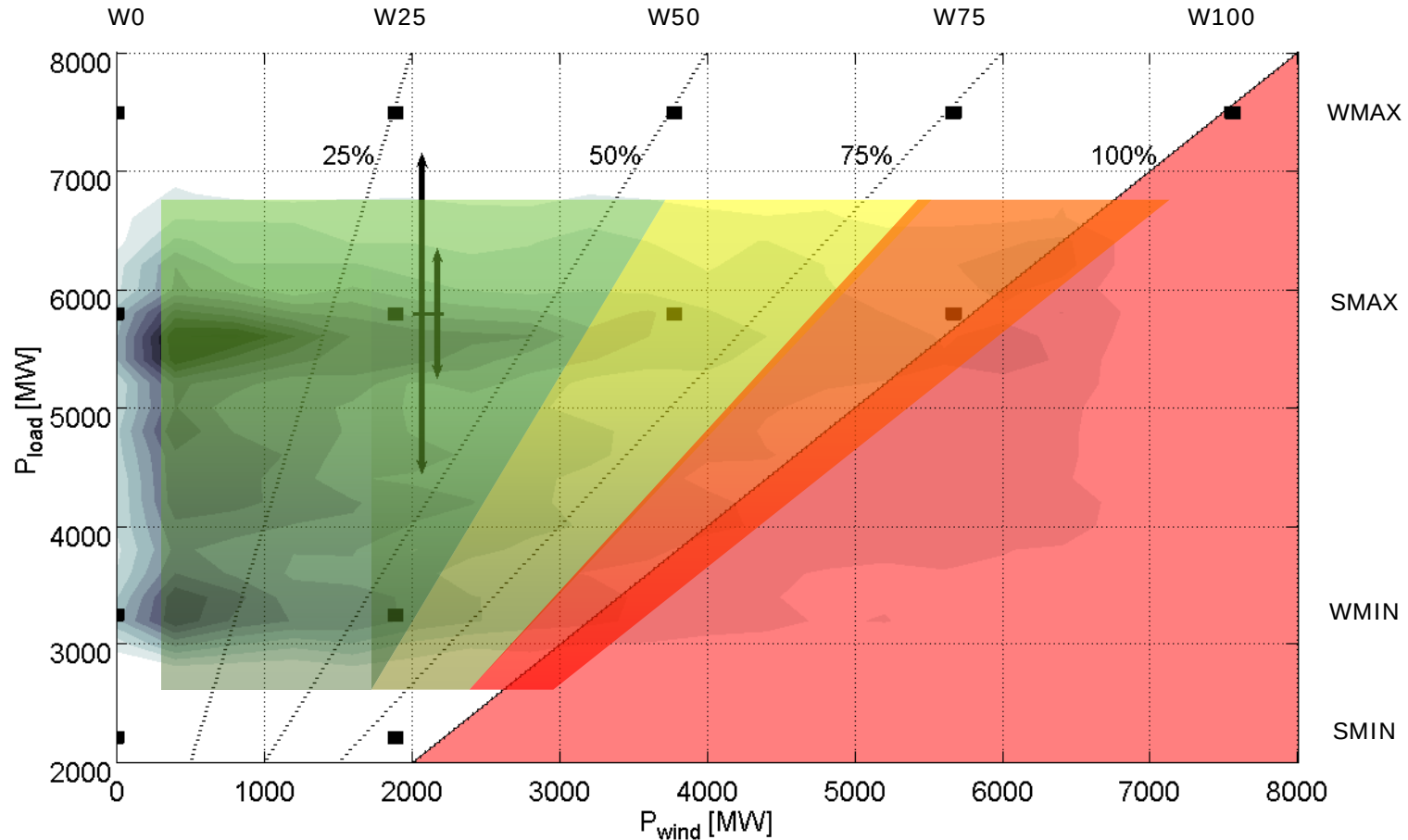
Simple Model of the Grid

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Operational Boundaries

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EirGrid, "All Island TSO Facilitation of Renewable Studies", Final Report, 2010 .

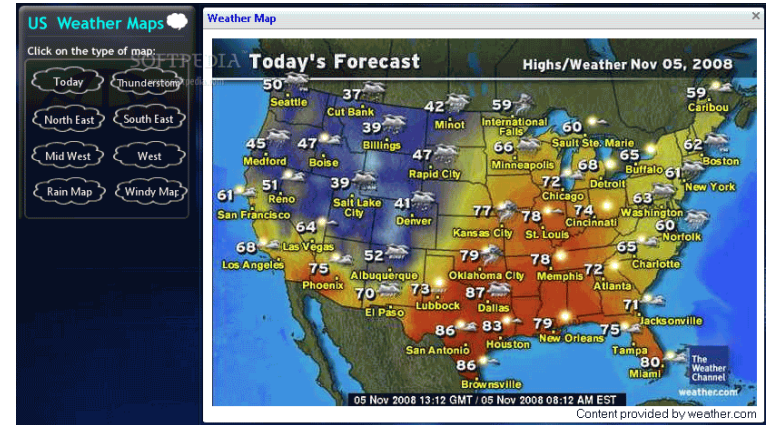
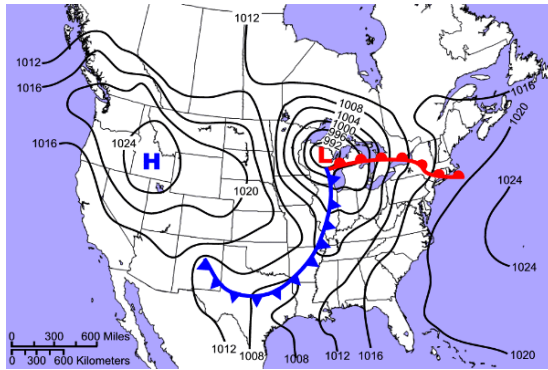
<http://www.eirgrid.com/media/Renewable%20Studies%20V3.pdf>

Some Research Topics

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- Asynchronous system at scale
- New methods and tools
- Correct portfolio
- New generator designs
- etc.

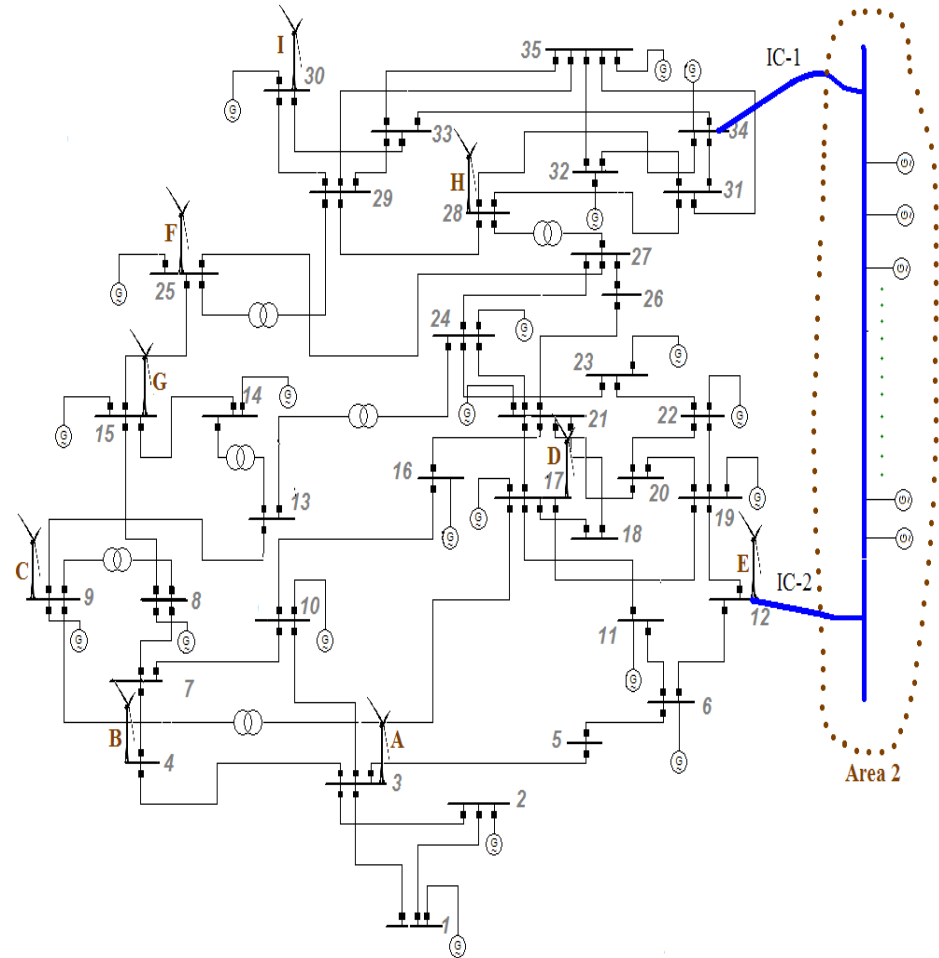
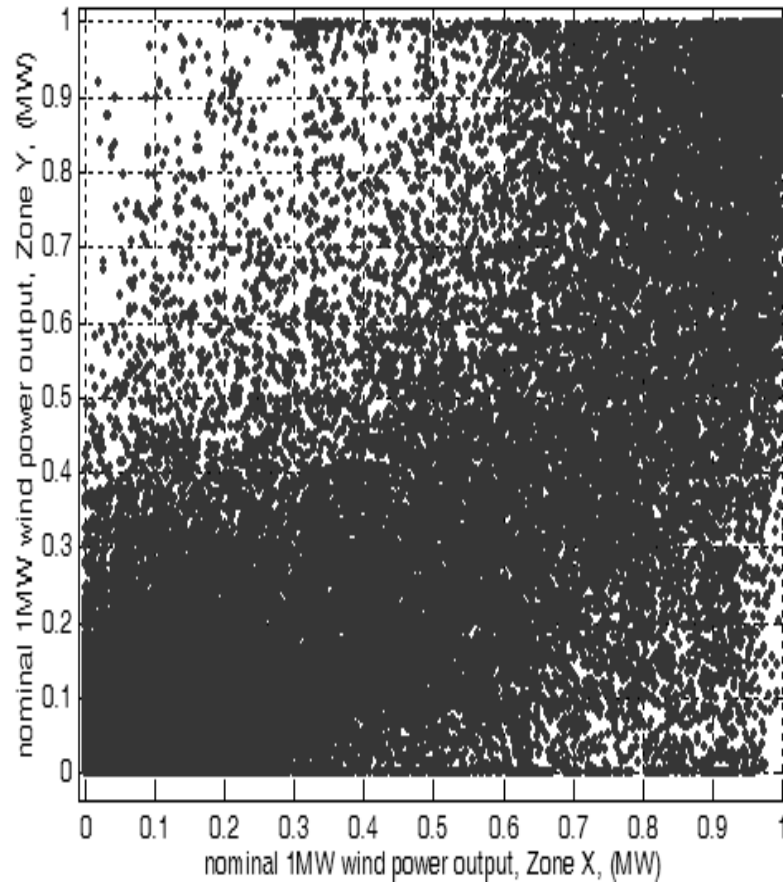




Resource characteristics are spatially distributed, variable and difficult to predict

Spatially Distributed

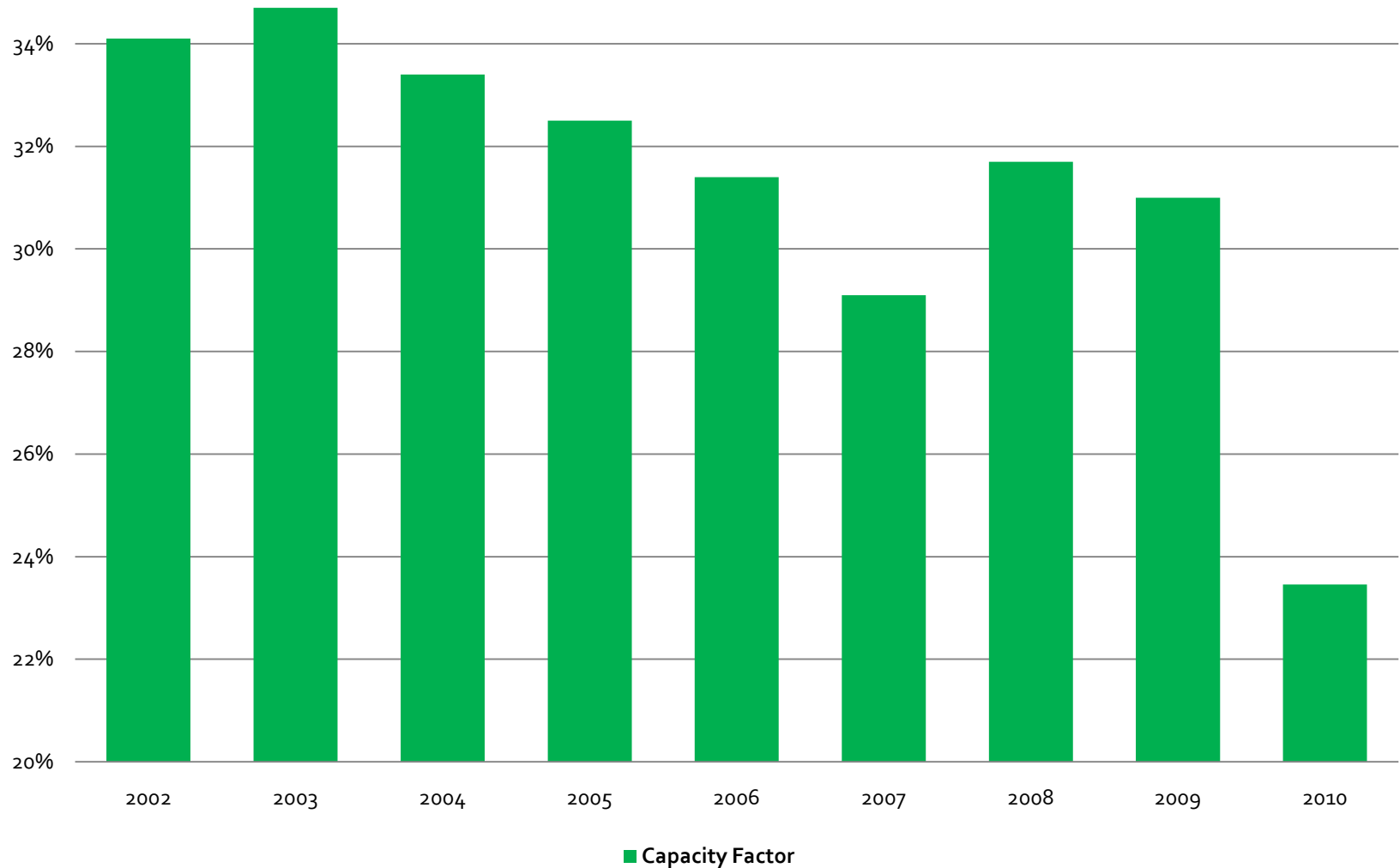
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Capacity Factor Variability

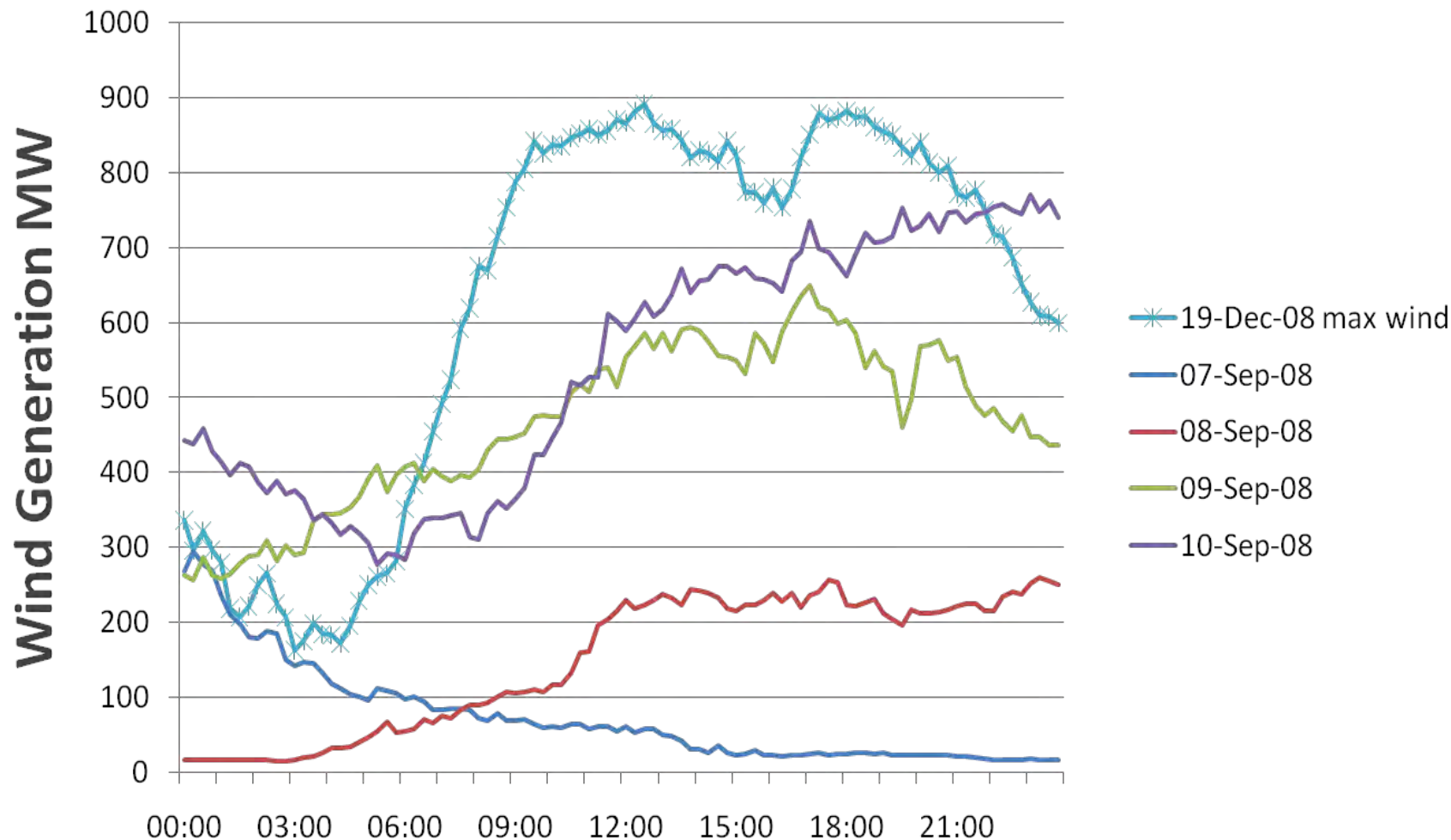
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Wind Capacity Factor



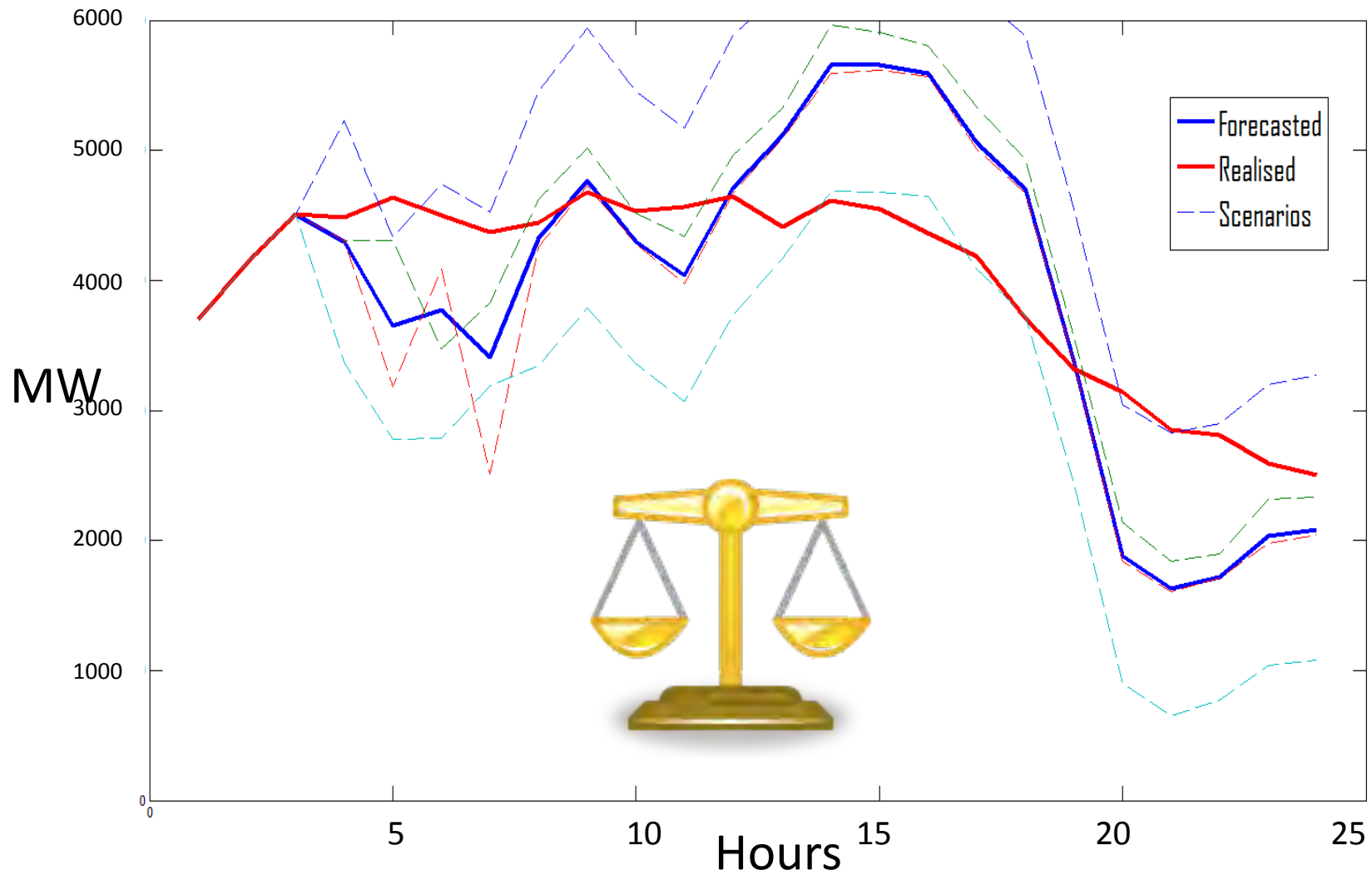
Wind Generation Variability

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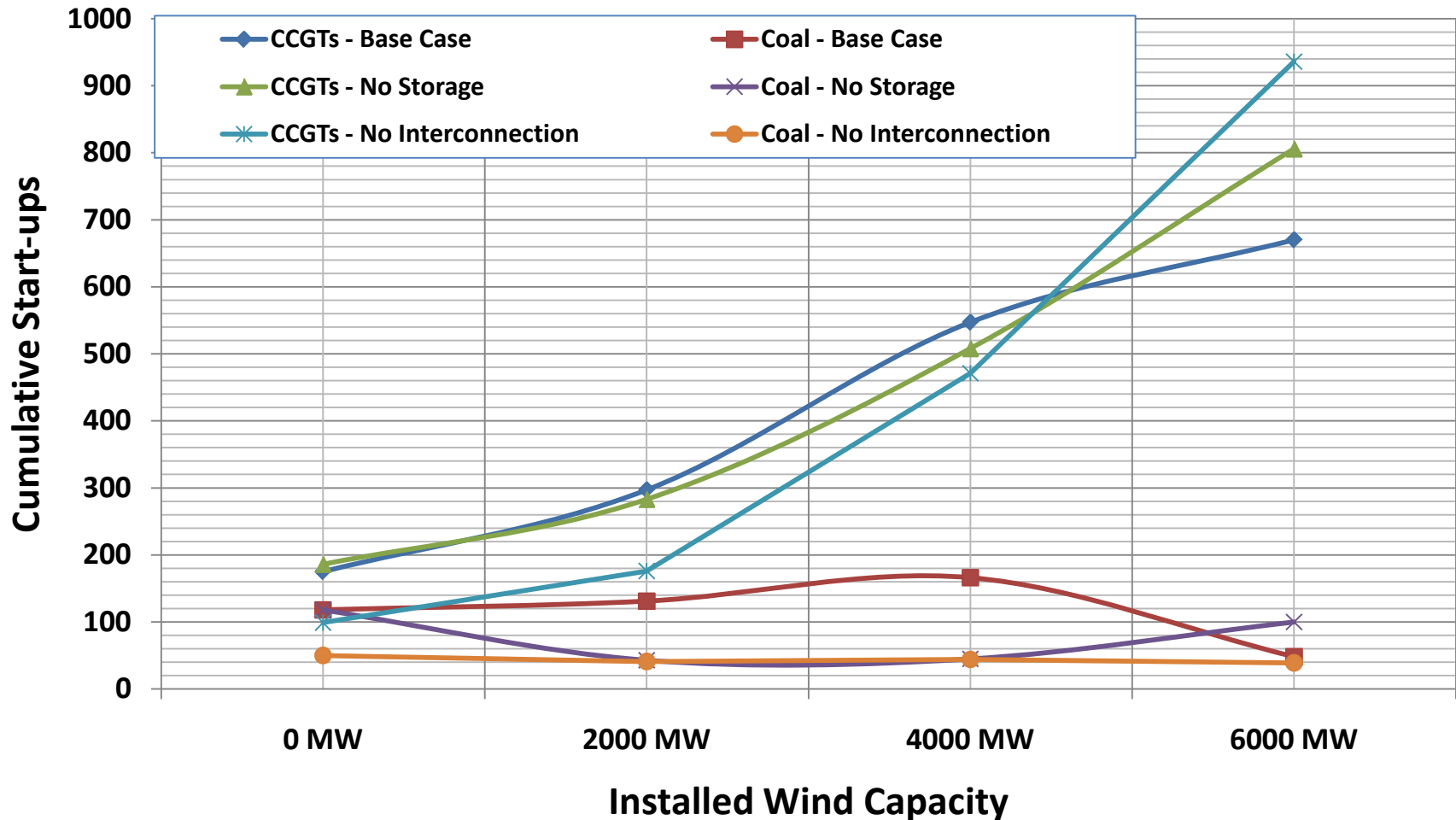
Wind Forecasting

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Impact of Wind on Base-load Start-ups

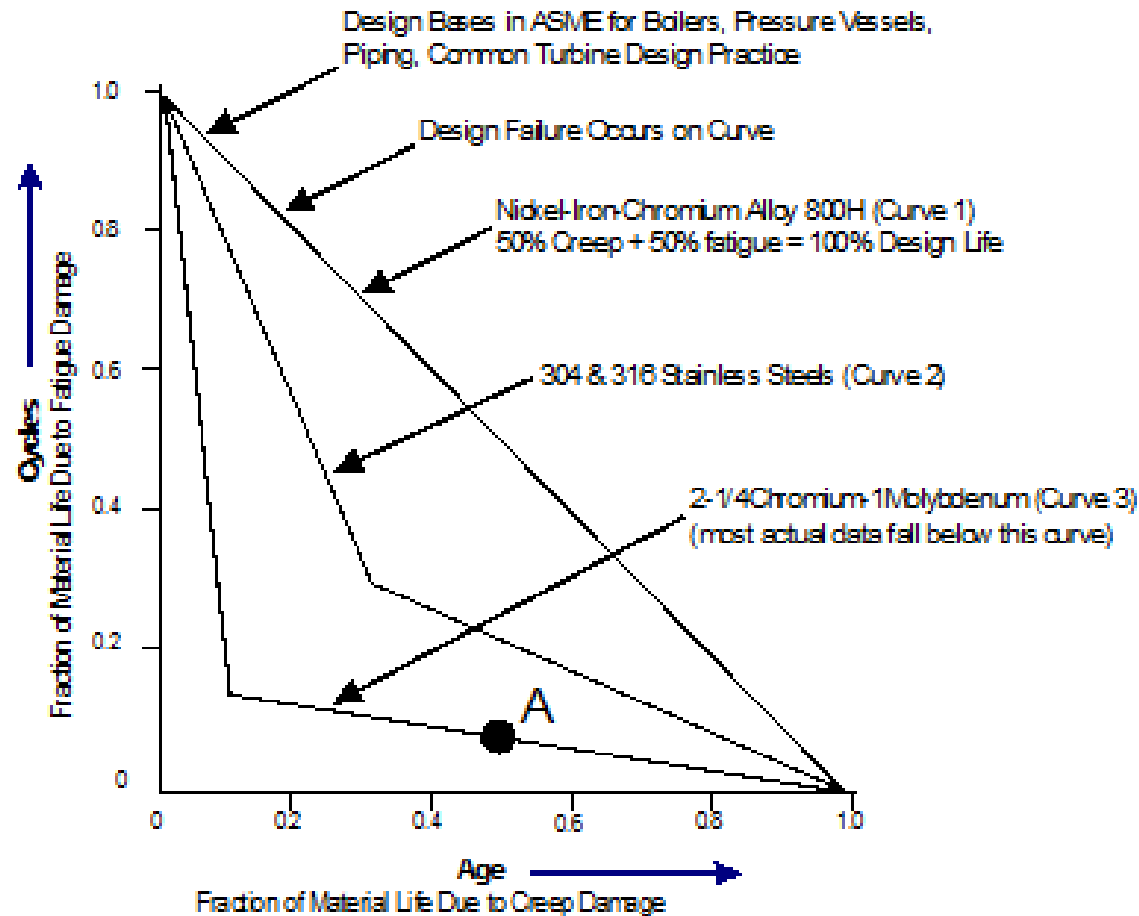
24



Troy, N., Denny, E. and O'Malley, M.J. "Base load cycling on a system with significant wind penetration", *IEEE Trans. Power Syst.*, Vol. 25, pp. 1088 - 1097, 2010.

Generator Cycling

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Some Research Topics

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- Optimisation under uncertainty
- Tools and techniques
- Forecasting
- Materials
- etc.

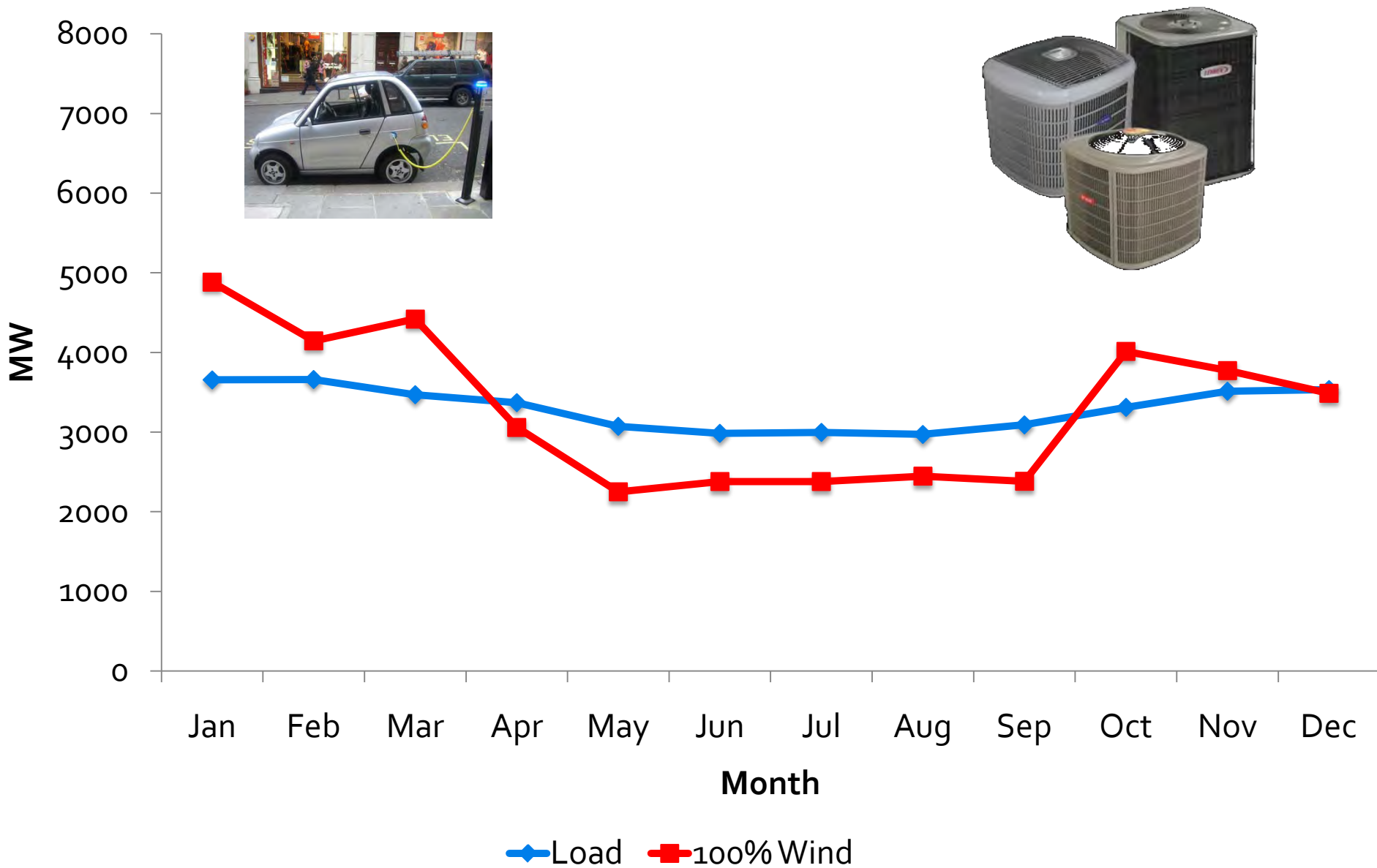




Societal issues are fundamental

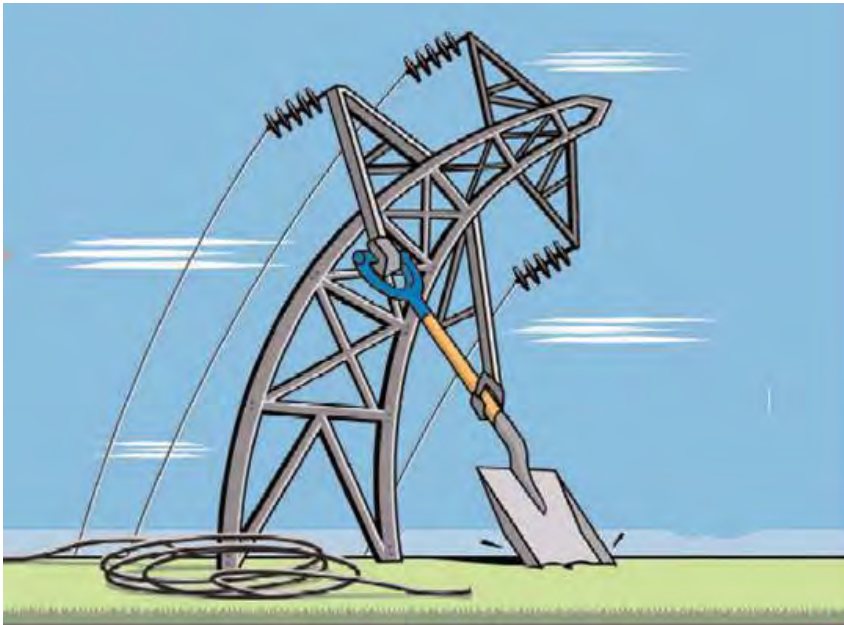
Yearly Load & 100 % Wind

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Public Acceptance Of Transmission

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Electricity Markets

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Generation

**Transmission &
Distribution**

Demand

**System and Network Operators
& Market Operator**

Market



Some Research Topics

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- What will demand side really look like
- Acceptance of required technologies
- Electricity market design
- etc.





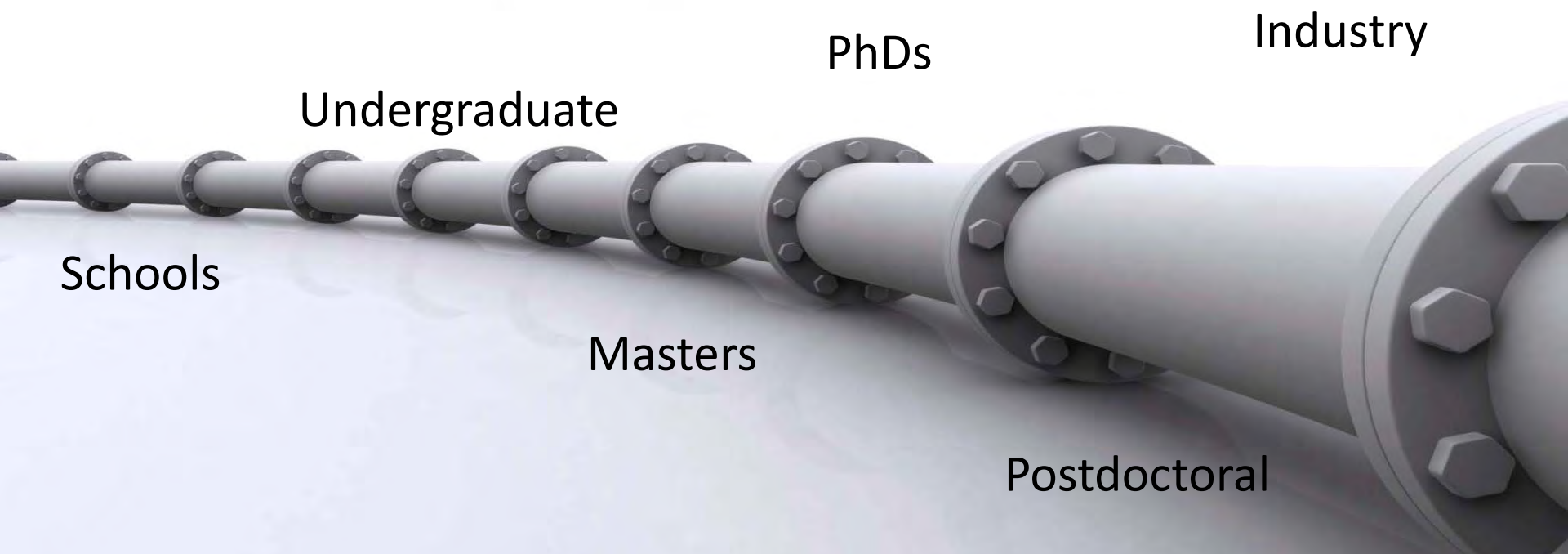
Direction ?

Learning from others

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	Capacity pen. (%)	Energy pen. (%)	Max. inst. pen. (no exports) (%)	Max. possible inst. pen. (%)	<i>Söder Metric</i> (%)
Ireland	16.36	10.00	> 50	81.82	67.92
Iberian Peninsula	20.88	15.00	> 55	99.30	93.76
West Denmark	34.95	30.00	>100	195.71	59.05
ERCOT	11.40	8.00	> 25	27.43	26.61
South Australia	22.06	20.00	86	118.63	67.08
Tasmania	5.06	5.00	17 %	18.04	9.96
Crete	16	15.1	> 40	57.14	57.14

The Pipeline



- Portfolio - analysis and technology
- Research areas is very broad
- Learning from others - Industry is critical
- More graduates needed

Acknowledgements

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- Dennis Ray, Ms. Sinead Duignan
- Cornell University and National Renewable Energy Laboratory
- Industry: ABB, Bord Gais, Bord Na Mona, Commission for Energy Regulation, Cylon Controls, EirGrid, EPRI, ESB Energy International, ESB Networks, ESB Energy Solutions, Gaelectric, Intel, Siemens, SSE Renewables, United Technologies Research Centre (UTRC), Viridian
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- Current research Team: Dr. Damian Flynn, Dr. Eleanor Denny, Dr. Andrew Keane, Dr. Ciara O'Connor, Dr. Andrej Gubina, Mr. Paul Smith, Mr. Michael Power, Dr. Daniel Burke, Mr. Batsaikhan Nyamdash, Mr. Eknath Vittal, Mr. Peter Richardson, Ms. Niamh Troy, Mr. Aonghus Short, Ms. Amy O'Mahoney, Ms. Paul Cuffe, Mr. Eamonn Lannoye, Mr. David Kavanagh, Mr. Colm Lowery, Mr. Stefano Verde, Ms. Lisa Rutledge, Ms. Muireann Lynch, Mr. Eamon Keane, Mr. David Fletcher, Mr. Lasantha Meegahapola, Mr. Erik Ela, Mr. Mario Džamarija, Mr. Gaspar Artac, Ms. Sinead Duignan O'Hegarty, Ms. Magda Szczepanska
- Graduated PhDs: , Dr. Ronan Fitzmaurice, Dr. Daniel Burke, Dr. Aidan Tuohy, Dr. Garth Bryans, Dr. Eleanor Denny, Dr. Ronan Doherty, Dr. Meadhbh Flynn, Dr. Andrew Keane, Dr. Gill Lalor, Dr. Jonathan O'Sullivan, Dr. Michael Walsh
- Graduated Masters: Ms. Sonya Twohig, Mr. Jody Dillon, Mr. Shane Rourke, Mr. Paul Sheridan, Mr. Fintan Slye
- Collaborators: Peter Meibom, Brian Parsons, Michael Milligan, Erik Ela, Prof. Janusz Bialek, Dr. Brendan Fox, Prof. John FitzGerald Dr. Chris Dent

Recent publications

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- Troy, N., Flynn, D. and O'Malley, M.J., "Multi-mode Operation of Combined-Cycle Gas Turbines with Increasing Wind Penetration", *IEEE Transactions on Power Systems*, in press, 2011.
- Vittal, E., O'Malley, M.J. and Keane, A., "Rotor Angle Stability with High Penetrations of Wind Generation", *IEEE Transactions on Power Systems*, in press, 2011.
- Burke, D.J., and O'Malley M.J. "A Study of Principal Component Analysis Applied to Statistical Distributed Wind Power", *IEEE Transactions on Power Systems*, in press, 2011.
- Meibom, P., Barth, R., Hasche, B., Brand, H., Weber, C. and O'Malley, M.J., "Stochastic optimisation model to study the operational impacts of high wind penetrations in Ireland", *IEEE Transactions on Power Systems*, Vol. 26, pp. 1367 - 1379, 2011.
- Doherty, R. and O'Malley, M.J. "The Efficiency of Ireland's Renewable Energy Feed-In Tariff (REFIT) for Wind Generation", *Energy Policy*, Vol. 39, pp. 4911 - 4919, 2011.
- Keane, A, Tuohy, A., Meibom, P., Denny, E., Flynn, D., Mullane, A. and O'Malley, M.J., "Demand side resource operation on the Irish power system with high wind power penetration", *Energy Policy*, Vol. 39, 2925 - 2934, 2011.
- Keane, A., Milligan, M., D'Annunzio, C., Dent, C., Dragoon, K., Hasche, B., Holttinen, Samaan, N., Soder, L. and O'Malley, M.J., "Capacity Value of Wind Power, *IEEE Transactions on Power Systems*, Vol. 26, pp. 564 - 572, 2011.
- Tuohy, A. and O'Malley, M.J., "Pumped Storage in Systems with Very High Wind Penetration", *Energy Policy*, Vol. 39, pp. 1965-1974, 2011.
- Burke, D.J., and O'Malley M.J. "Factors influencing wind energy curtailment", *IEEE Transactions on Sustainable Energy*, Vol. 2, pp. 185-193, 2011.
- Burke, D.J., and O'Malley M.J. "A Study of Optimal Non-Firm Wind Capacity Connection to Congested Transmission Systems", *IEEE Transactions on Sustainable Energy*, Vol. 2, pp. 167 - 176, 2011.
- Holttinen, H, Meibom, P., Orths, A., Lange, B., O'Malley, M.J., Tande, J, Estanqueiro, A., Gomez, E., Söder, L., Strbac, G., Smith, J.C. and van Hulle, F., "Impacts of large amounts of wind power on design and operation of power systems, results of IEA collaboration", *Wind Energy*, Vol. 14, pp. 179-192, 2011.
- Hasche, B., Keane, A. and O'Malley, M.J. "Capacity value of wind power: calculation and data requirements: The Irish power system case", *IEEE Transactions on Power Systems*, Vol. 26, pp. 420 - 430, 2011.

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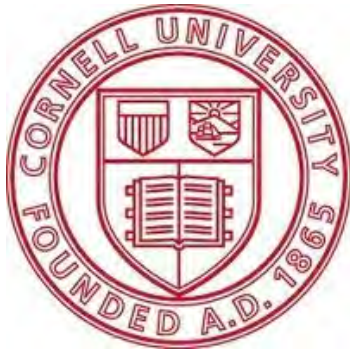
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