Integration of variable renewables: what the market can do to help or hinder

Mark O'Malley

mark.omalley@ucd.ie

Outline

- Integration of variable renewables
  - Technological issues:
    - Inertia product ?
    - future proofing the market design
  - Resource issues: shorter term issues - **raised already**
- Some lessons from Ireland **and other sources**
- Missing money etc. pass …….

wholeSEM Annual Conference 2015: Hybrid Energy Modelling – Linkages and Interdisciplinarity

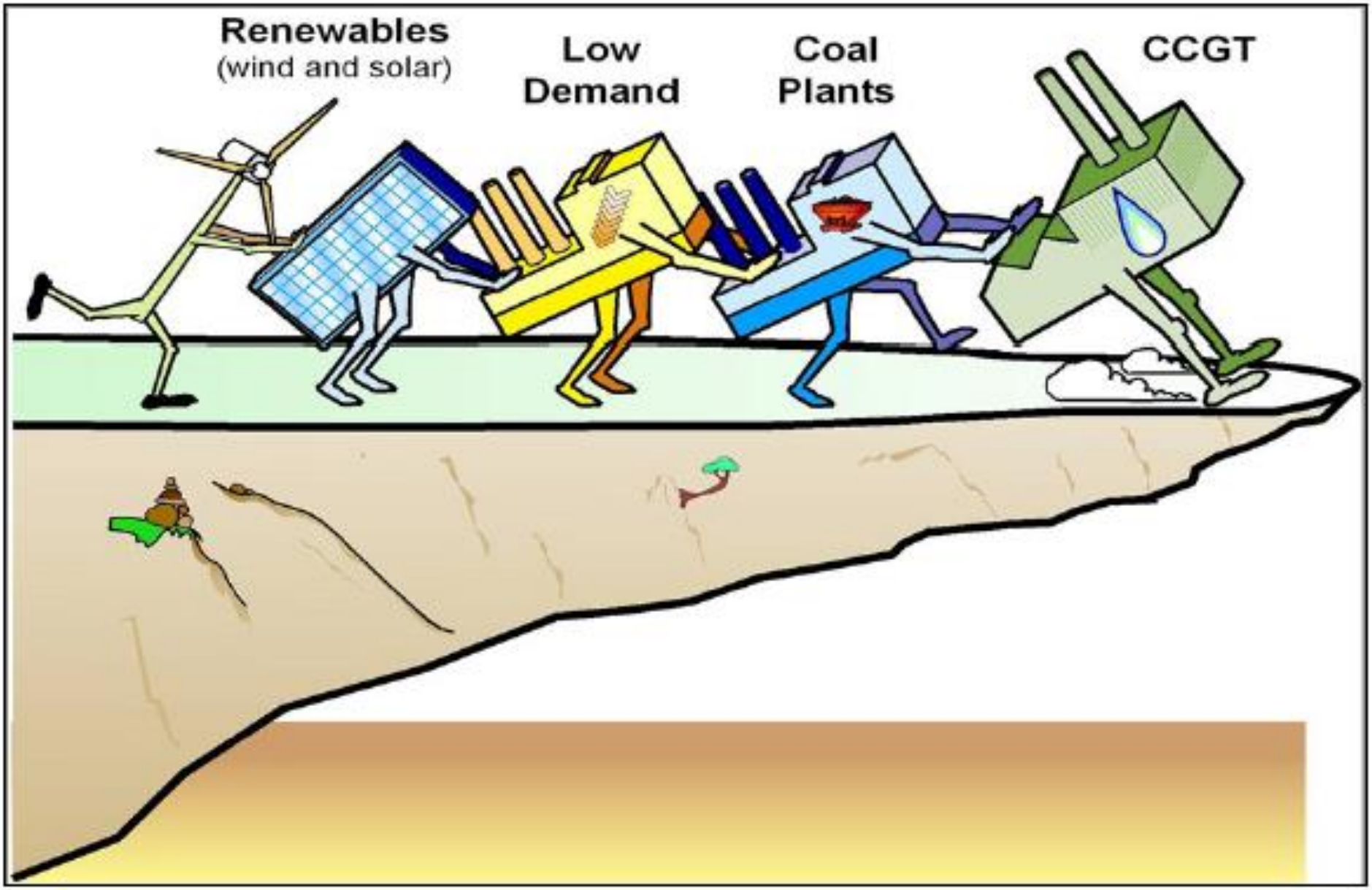
Publication date: Jan 29, 2015 11:24 AM

Start: Jul 06, 2015 12:00 AM
End: Jul 07, 2015 12:00 AM

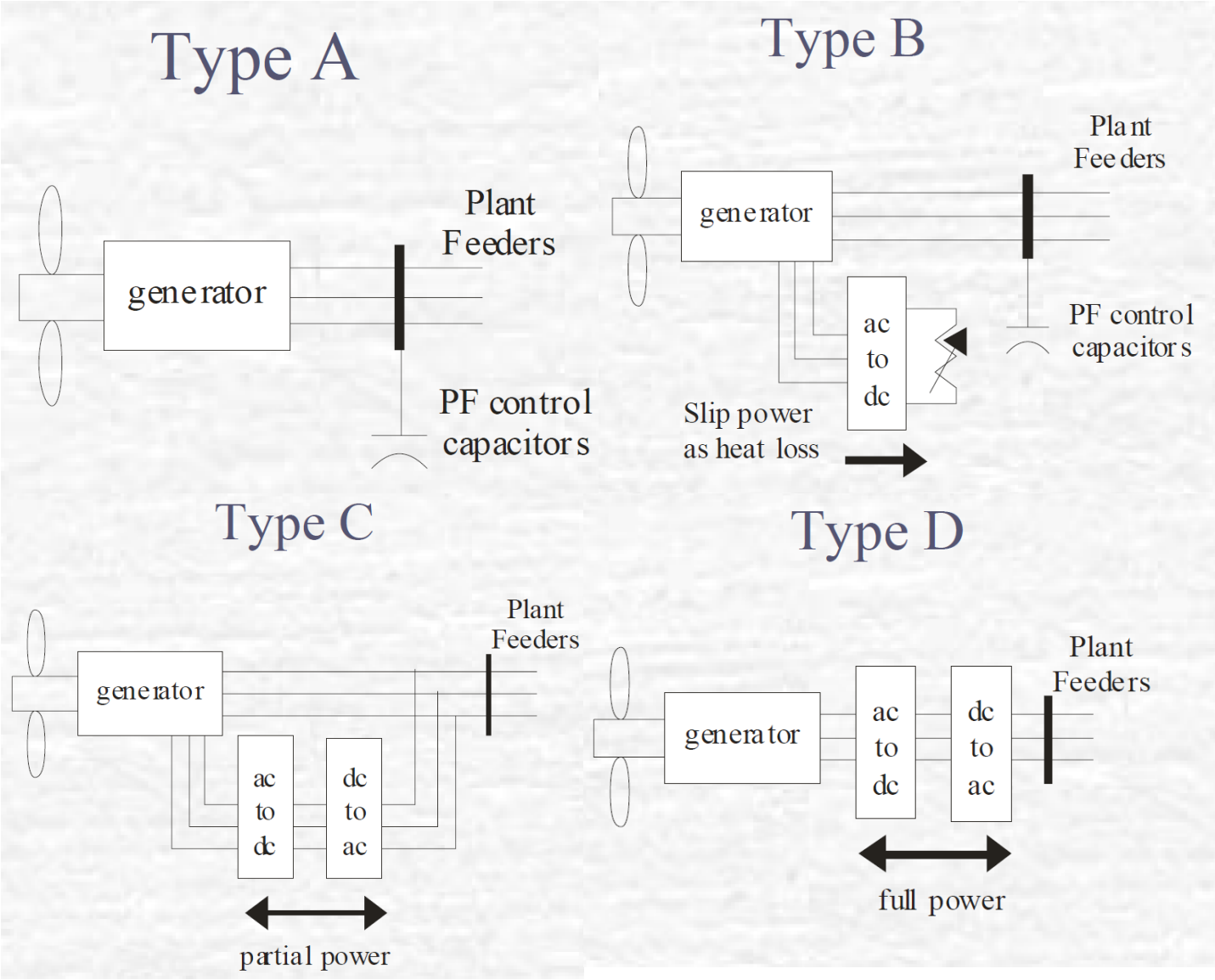
Location: Murray Edwards College, University of Cambridge, Cambridge, CB3 0DF

wholeSEM

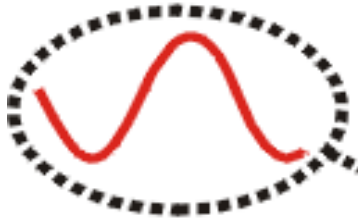
Variable Renewable Energy Technical Characteristics


Renewables
(wind and solar)
Low
Demand
Coal
Plants
CCGT

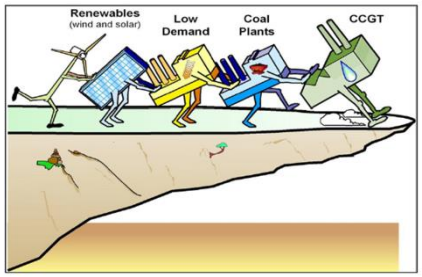
Wind turbine (solar PV) generation technology – non synchronous



Adding non-synchronous generation

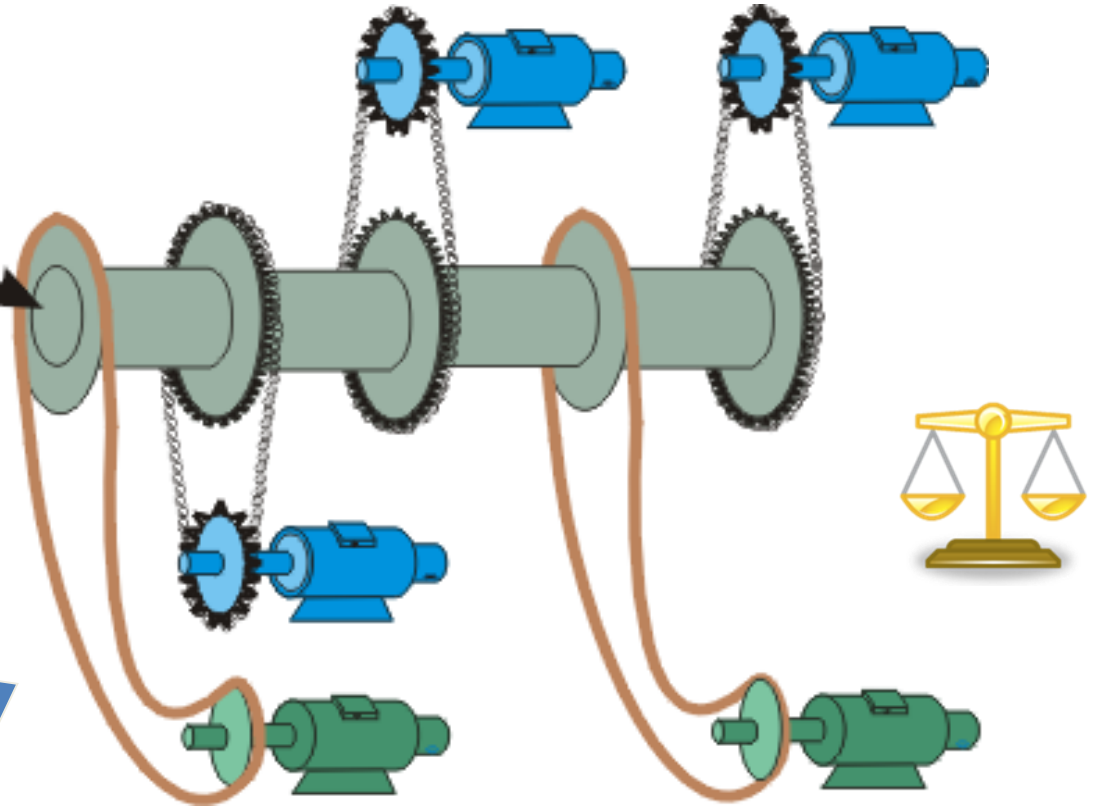


50/60 Hz



Does not add
to system inertia

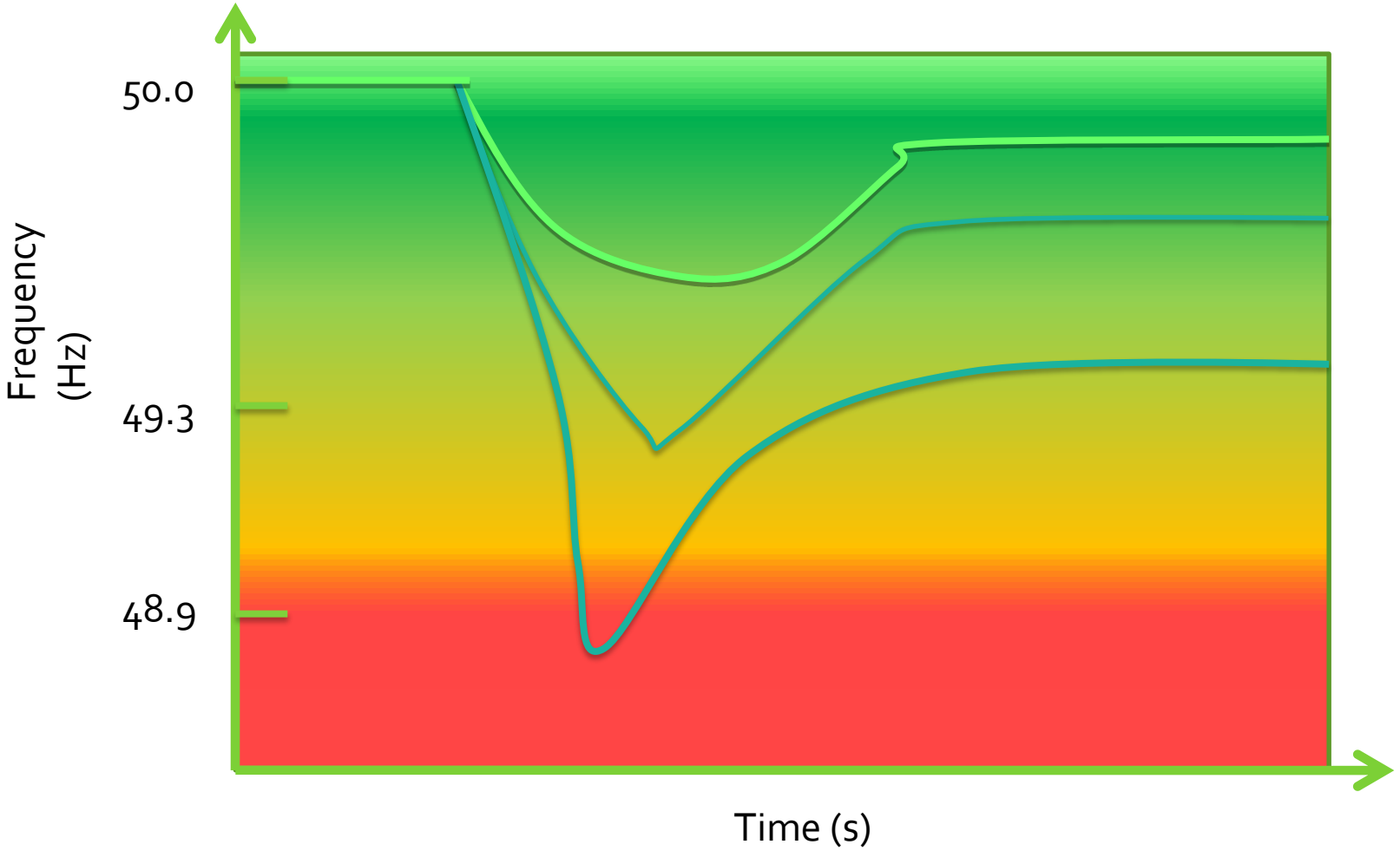
Synchronous generator



Doubly fed induction generator wind turbine

Fixed speed wind turbine generator

Frequency stability & the nadir



Source: Jonathan O'Sullivan, EirGrid

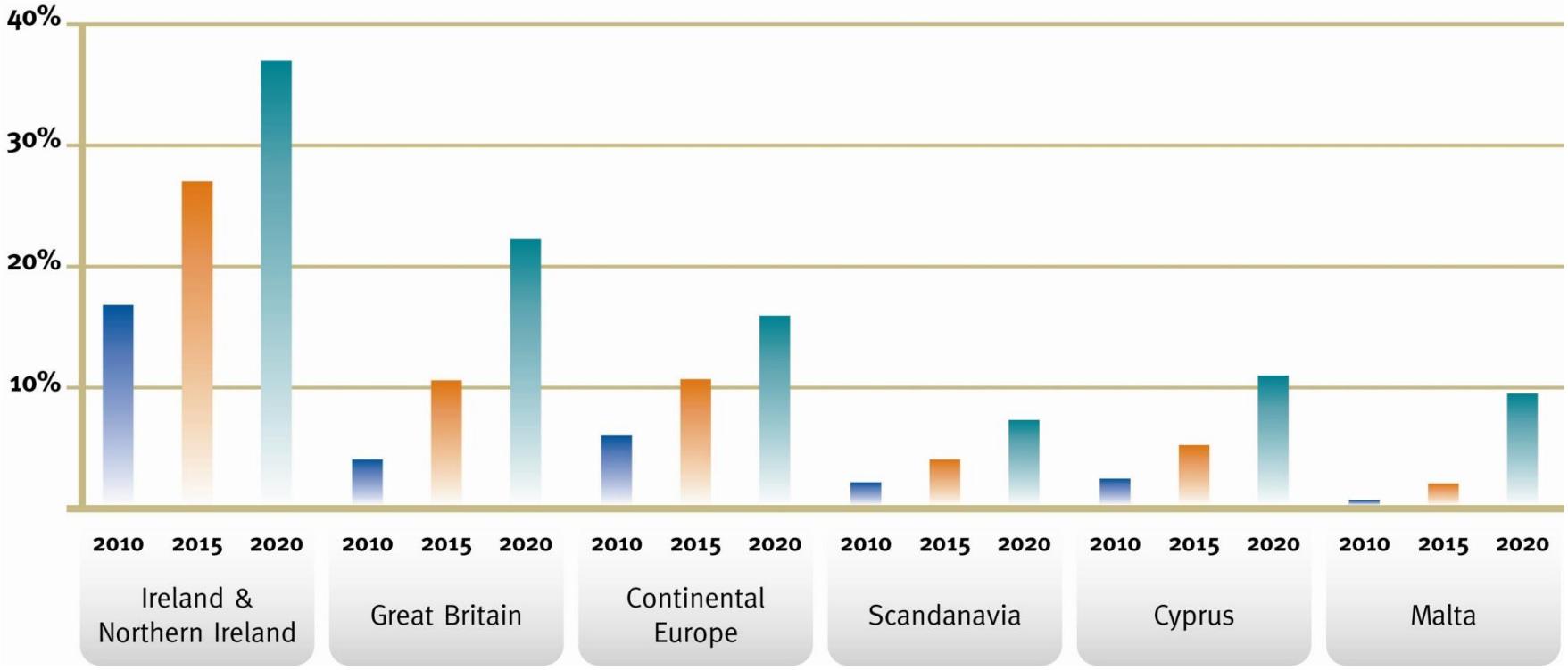
The Vatican Sept 28th 2003

Wind Installed in Republic of Ireland

Source: EirGrid http://www.eirgrid.com/operations/systemperformancedata/all-islandwindandfuelmixreport/

Synchronous systems in Europe

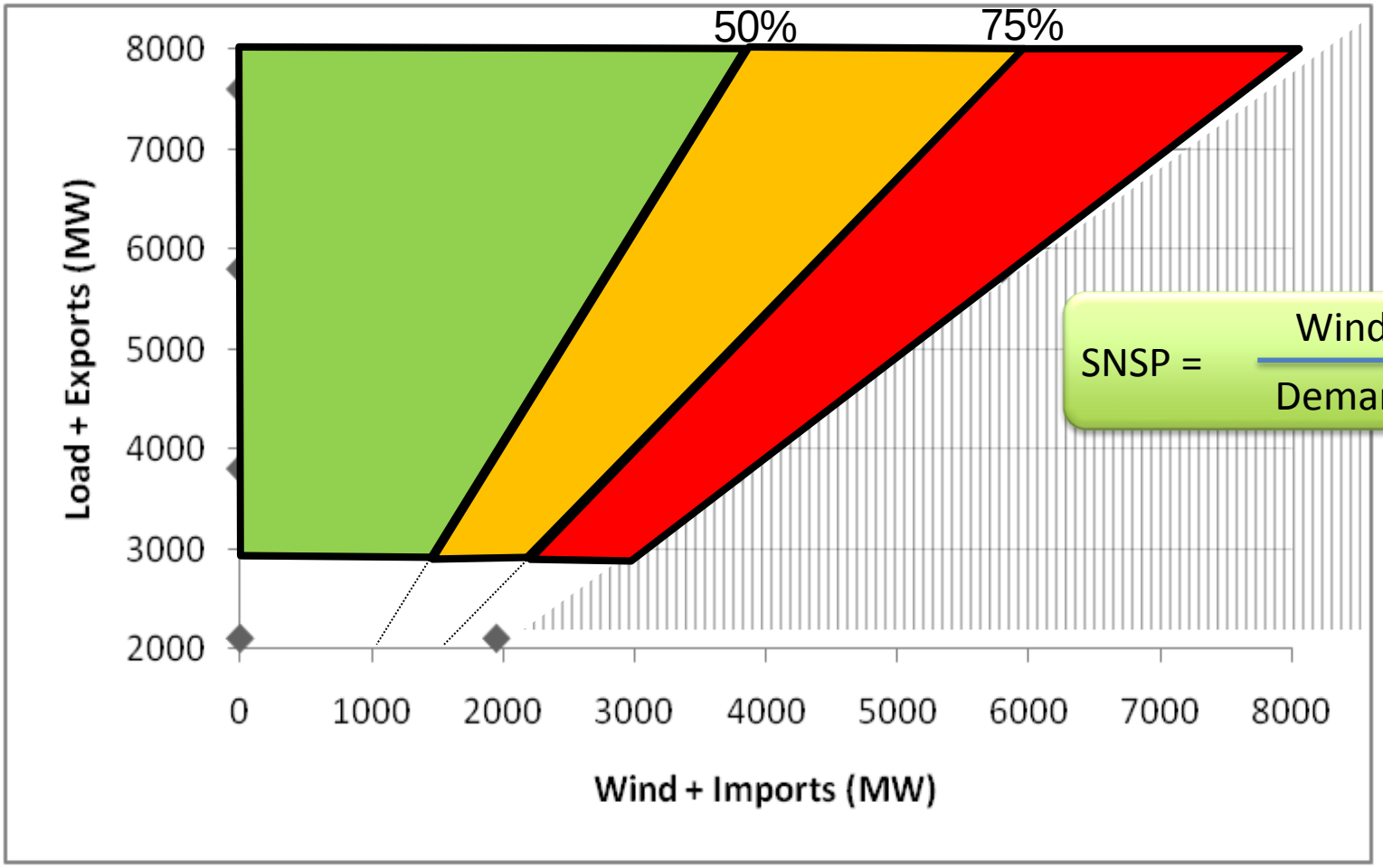
Targets for non-synchronous sources in European Systems



http://www.eirgrid.com/operations/ds3/

* Based on analysis of National Renewable Action Plans (NREAPs) as submitted by Member States

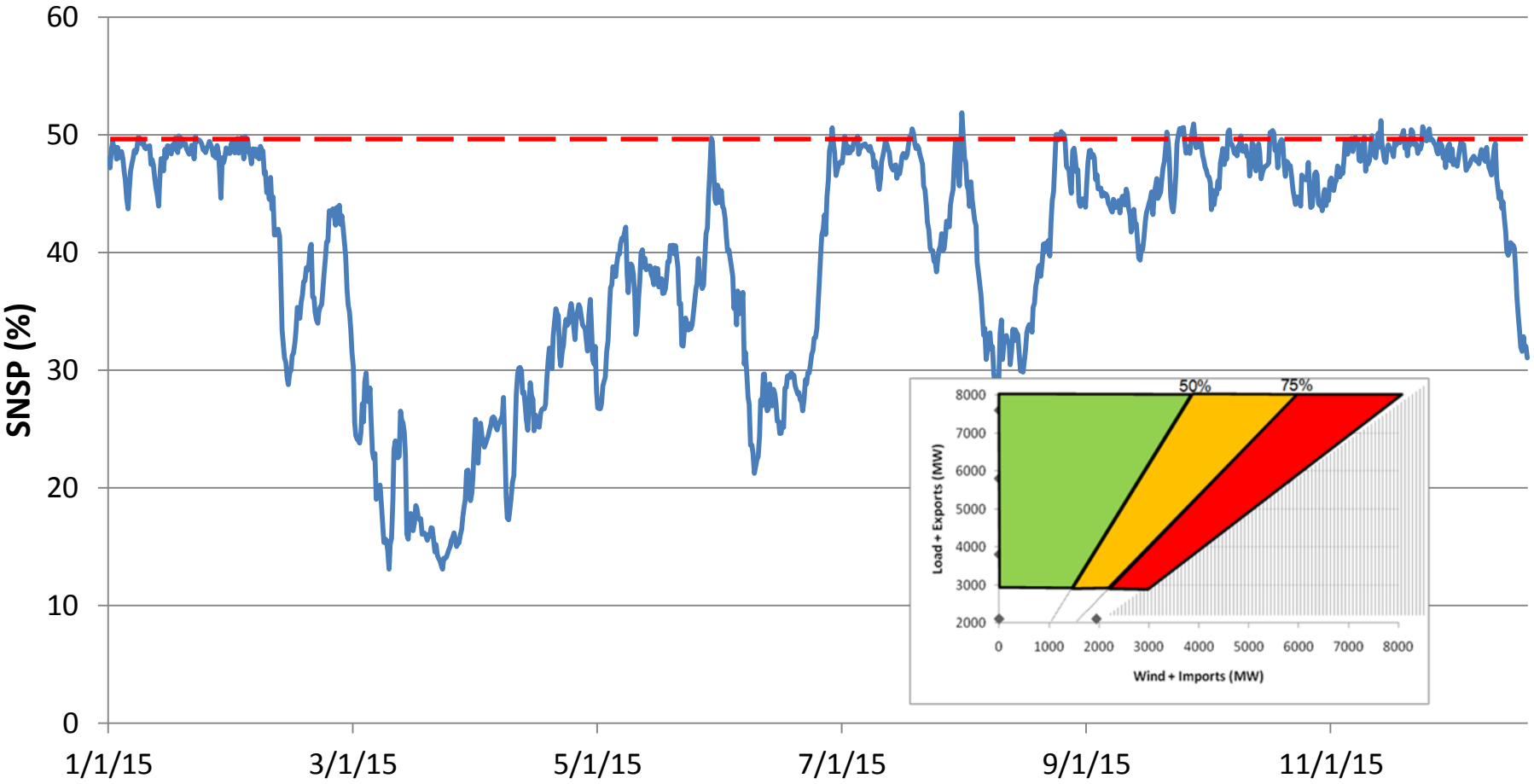
System Non-Synchronous Penetration (SNSP)



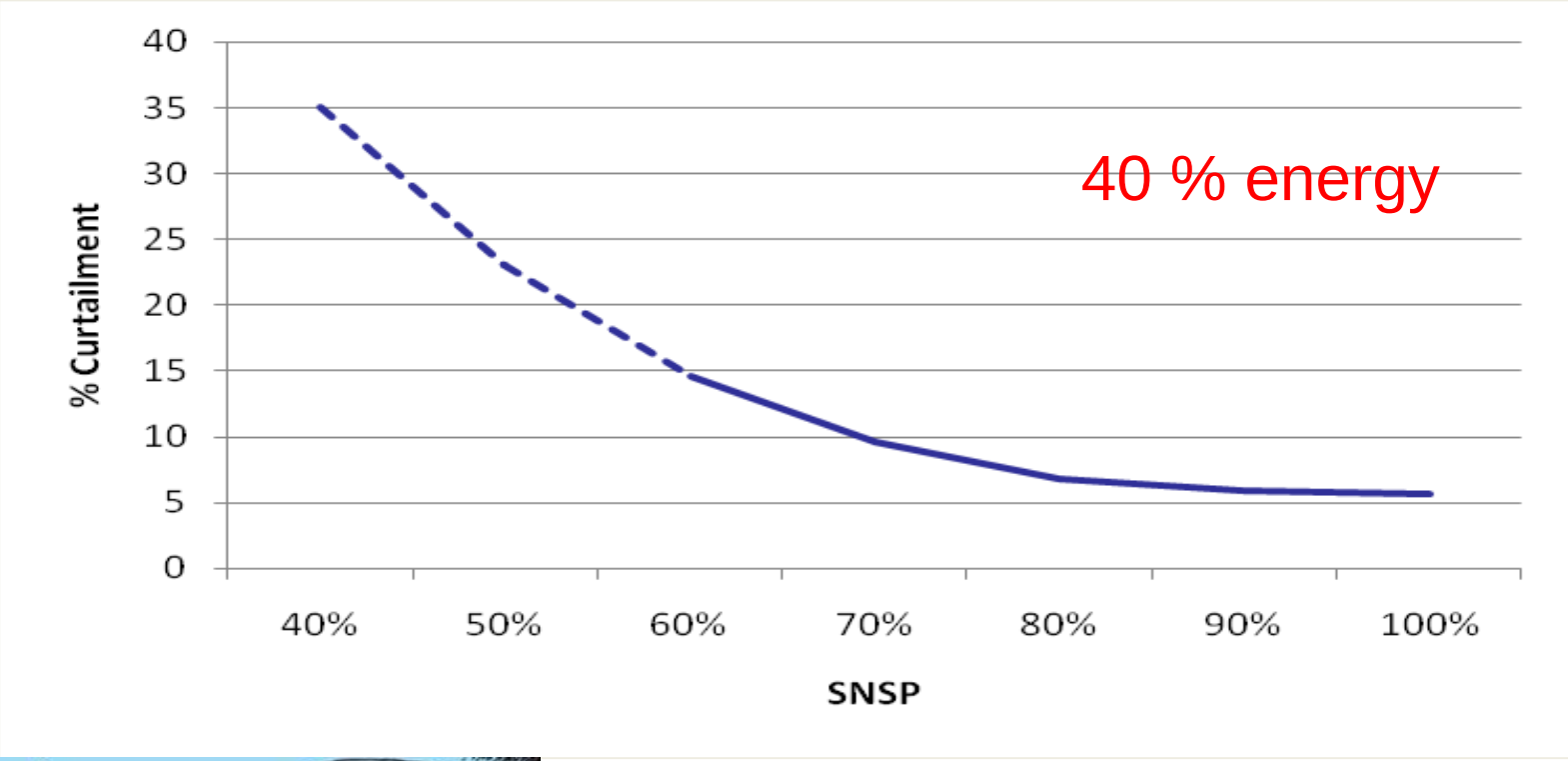
$$\text{SNSP} = \frac{\text{Wind + Imports}}{\text{Demand + Exports}}$$

O'Sullivan, J., Rogers, A., Flynn, D., Smith, P., Mullane, A., and O'Malley, M.J., "Studying the Maximum Instantaneous Non-Synchronous Generation in an Island System – Frequency Stability Challenges in Ireland", *IEEE Transactions on Power Systems*, Vol. 29, pp. 2943 – 2951, 2014.

SNSP – Ireland – Early 2015



Impact of SNSP on Wind Curtailment



Curtailment is form of flexibility – can the markets get the balance right ?

In ERCOT they used 2 %

Mainland Europe & US

Western Wind and Solar Integration Study Phase 3 – Frequency Response and Transient Stability

N.W. Miller, M. Shao, S. Pajic, and R. D'Aquila
GE Energy Management
Schenectady, New York

NREL Technical Monitor: Kara Clark

Link to Executive Summary

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Subcontract Report
NREL/SR-5D00-62906
December 2014

Contract No. DE-AC36-08GO28308

Pushing the Limits

Europe's New Grid: Innovative Tools to Combat Transmission Bottlenecks and Reduced Inertia

By Wilhelm Winter, Katherine Elkington, Gabriel Bareux, and Jan Kostevc

IN THE FUTURE A GROWING AMOUNT OF POWER electronics will lead to a transition of the power system to a structure with very low synchronous generation. Due to large transit power flows and uncertainties, transmission systems are being operated under increasingly stressed conditions and are close to their stability limits. Together with the integration of large amounts of renewable generation with power electronic interfaces and the addition of high-voltage direct current (HVdc) links into the power system, these challenges will necessitate a review of the operation and control of transmission networks. This article will demonstrate the need for R&D performed by network operators and explain a set of challenges, focusing on three main areas: transmission grid operation in a new power system environment, the need to increase overhead line (OHL) utilization, and the impact of reduced inertia on power system frequency.

Transmission Grid Operation in a New Power System Environment

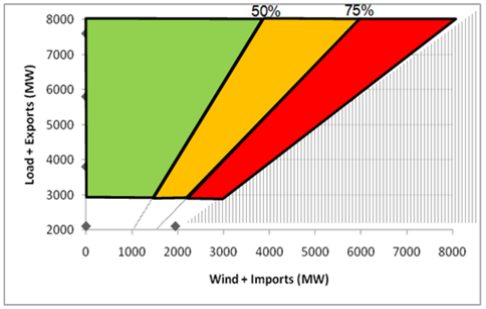
The tools currently in use by transmission system operators (TSOs) for operational planning and system operation must evolve significantly to work in an environment characterized by large-scale integration of renewable energy sources with low predictability and limited controllability as well as one that is close to its stability limits. The insertion of new equipment such as phase shifters and HVdc lines and the development of an integrated European electricity market with huge power flows over large distances will bring further challenges. These challenges are unprecedented, but fortunately the European Wind Integration Study (EWIS) project, finalized in 2010

Digital Object Identifier 10.1109/MPE.2014.2363534
Date of publication: 7 January 2015

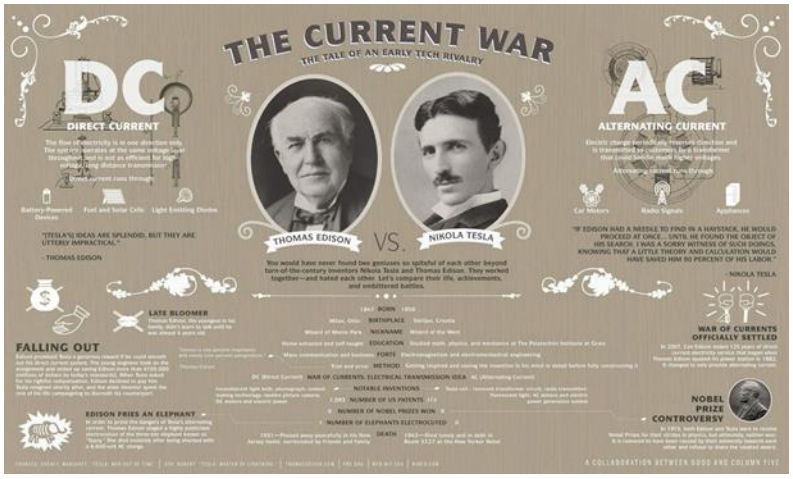
1540-7977/15©2015IEEE

http://www.nrel.gov/docs/fy15osti/62906.pdf

Future > 75 % SNSP



50/60 Hz ?



Synchronization of Parallel Single-Phase Inverters With Virtual Oscillator Control

Brian B. Johnson, *Member, IEEE*, Sairaj V. Dhople, *Member, IEEE*, Abdullah O. Hamadeh, and Philip T. Krein, *Fellow, IEEE*

Markets for Inertial Response ?

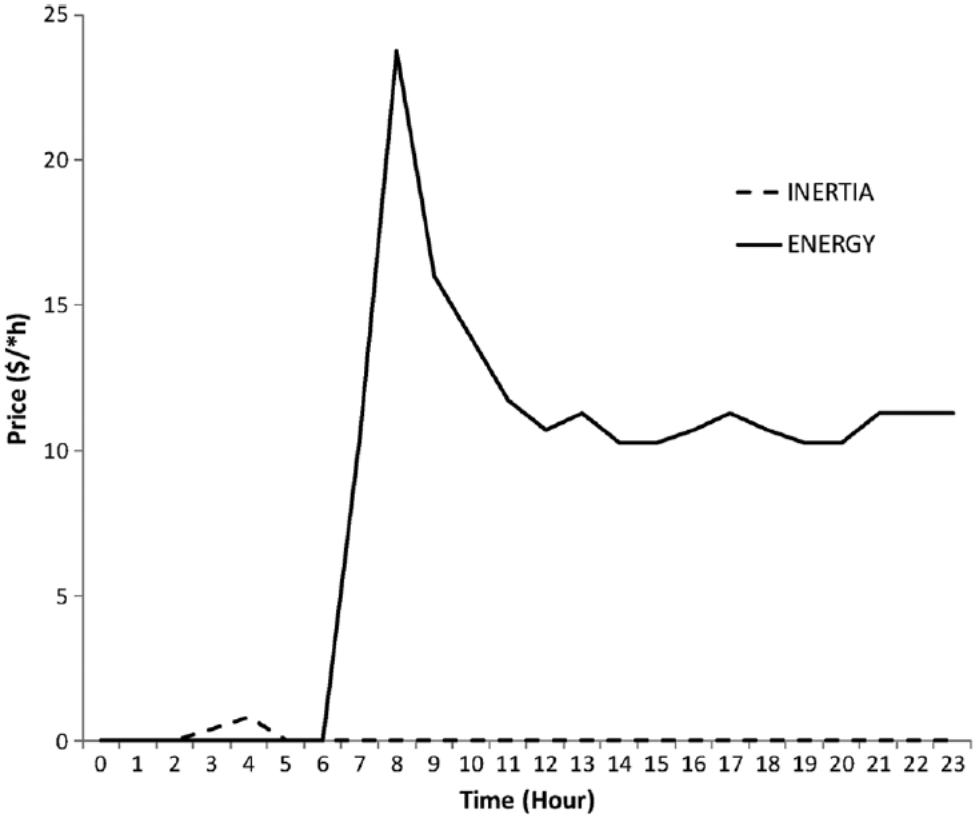


Fig. 10. Prices for energy and synchronous inertia for 50% wind penetration system with all other PFR constraints eliminated. Prices are in ($/MVAs-h) for inertia and ($/MW-h) for energy.

Ela, E., Gevorgian, V, Tuohy, A., Kirby, Milligan, M. and O'Malley, M.J. "Market Designs for the Primary Frequency Response Ancillary Service— Part I: Motivation and Design", IEEE Transactions on Power Systems, Vol. 29, pp.421- 431, 2014.
Ela, E., Gevorgian, V, Tuohy, A., Kirby, Milligan, M. and O'Malley, M.J. "Market Designs for the Primary Frequency Response Ancillary Service— Part II: Case Studies", IEEE Transactions on Power Systems, Vol. 29, pp. 432- 440, 2014.

Not a new idea

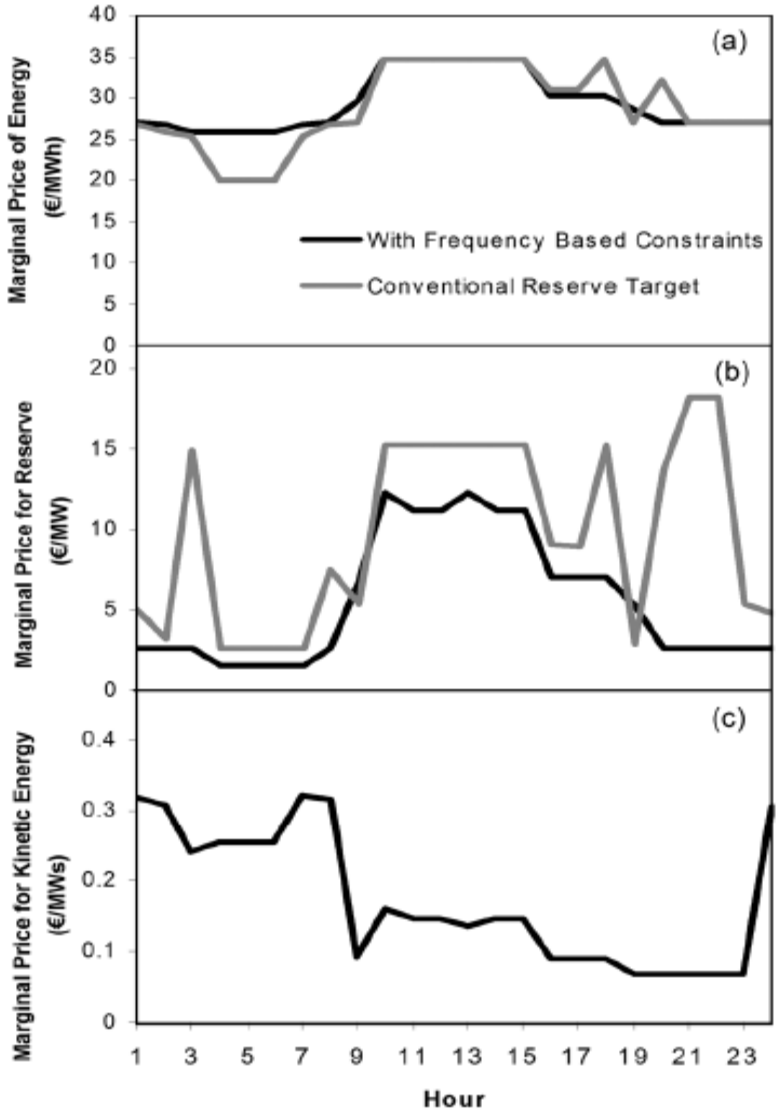
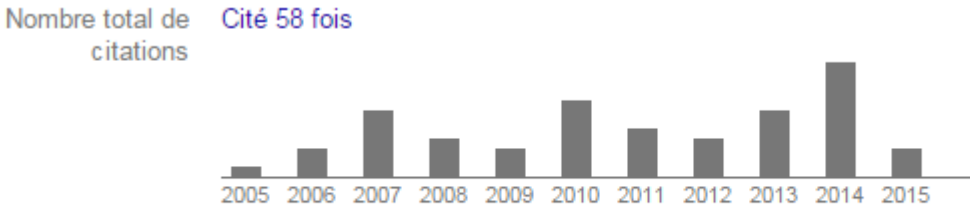


Fig. 11. Market prices for July 2004 test day for (a) energy, (b) reserve, and (c) kinetic energy.

Doherty, R., Lalor, G. and O'Malley, M.J., "Frequency Control in Competitive Electricity Market Dispatch", IEEE Transactions on Power Systems", Vol. 20, pp. 1588 - 1596, 2005.

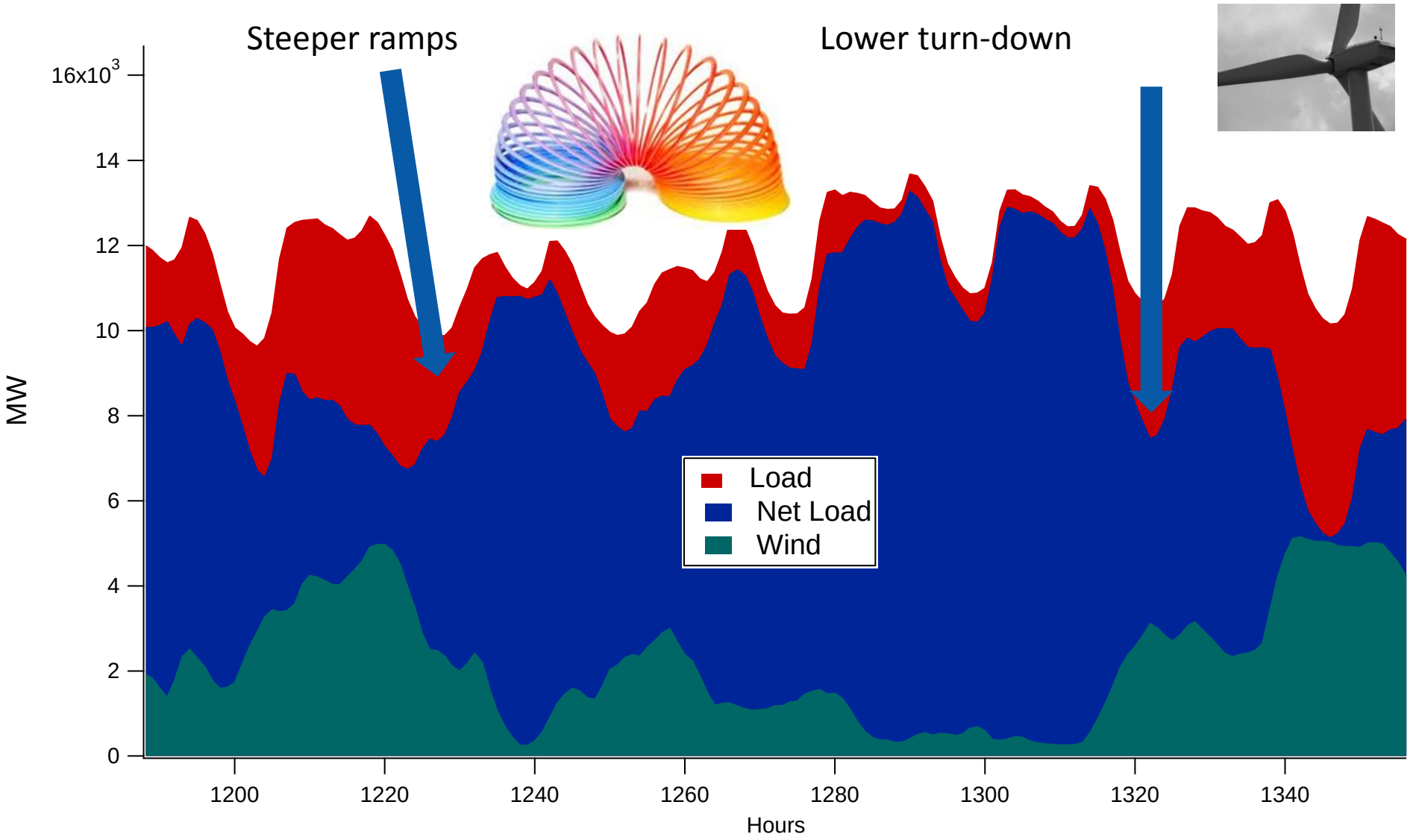


Key Take Aways

- Variable renewable energy (VRE) technologies are non synchronous
- At high penetrations of VRE may lead to a fundamental change in electricity system
- Should we
  - Introduce an “inertia” market now
  - Should we future proof the market designs ?

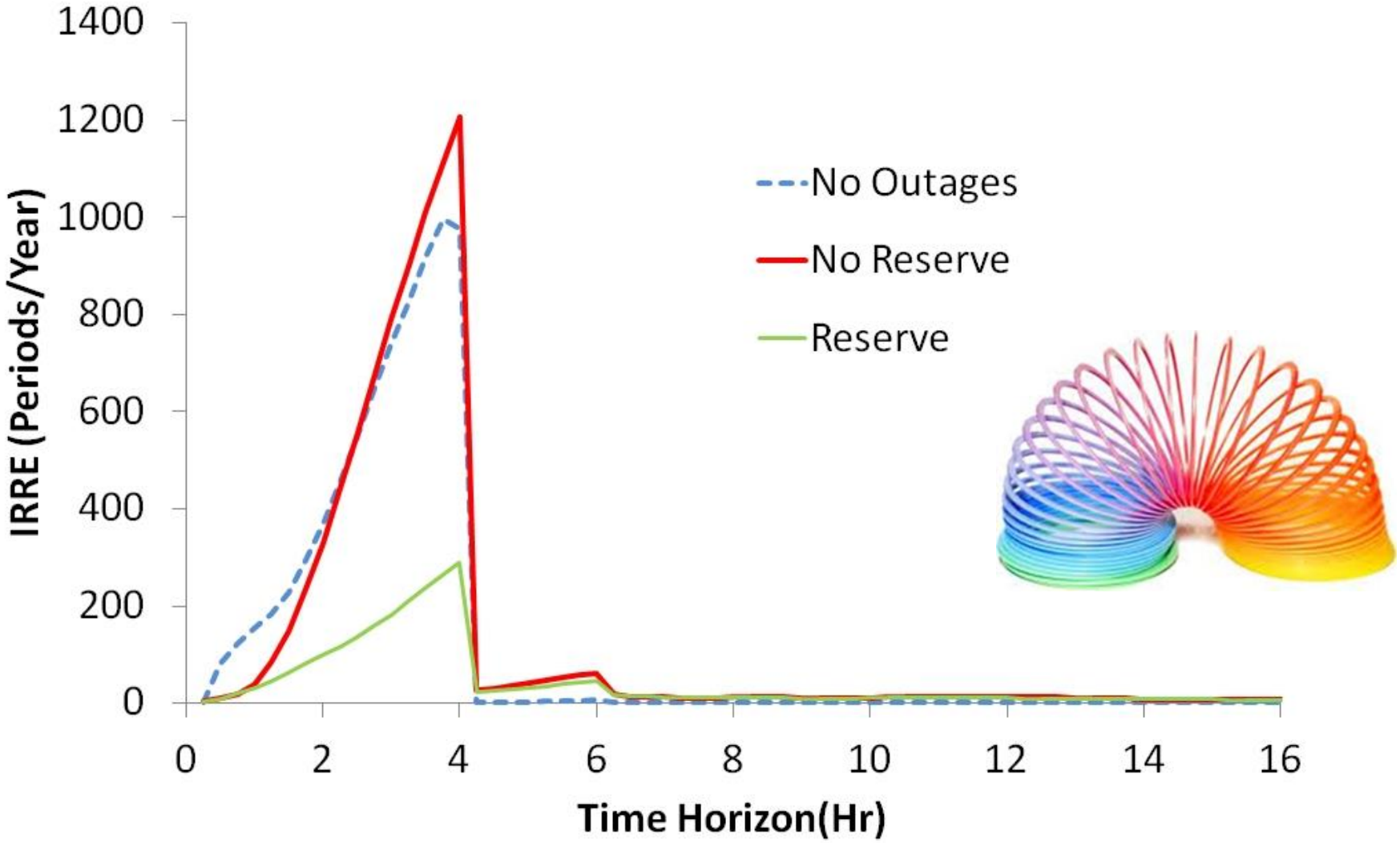
Variable Renewable Energy Resource Characteristics

With Variable Renewables More Flexibility is Needed



Source: Michael Milligan , NREL

Paying for something you cannot quantify: Flexibility Metrics



Lannoye, E., Flynn, D. and O'Malley, M.J. "Transmission, variable generation and power system flexibility", *IEEE Transactions on Power Systems*, Vol. 30, pp. 57 – 64, 2014.

Lannoye, E., Flynn, D., O'Malley, M., "Evaluation of Power System Flexibility" *IEEE Transactions on Power Systems*, Vol. 27, pp. 922 – 931, 2012.

Can Thermal Power Plant Skip ?

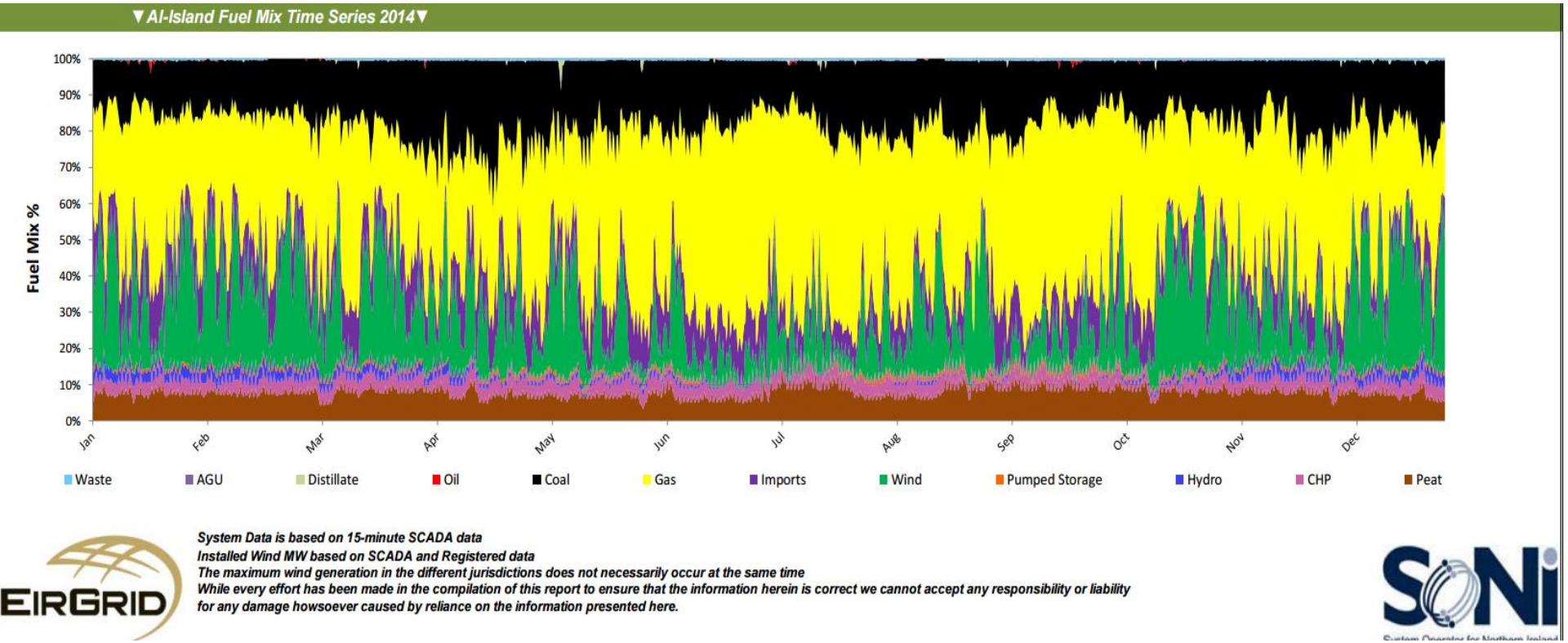
Table 3.2: **The load following ability of dispatchable power plants in comparison**

	Start-up time	Maximal change in 30 sec	Maximum ramp rate (%/min)
Open cycle gas turbine (OCGT)	10-20 min	20-30%	20%/min
Combined cycle gas turbine (CCGT)	30-60 min	10-20%	5-10%/min
Coal plant	1-10 hours	5-10%	1-5%/min
Nuclear power plant	2 hours - 2 days	up to 5%	1-5%/min

Source: EC JRC, 2010 and NEA, 2011a.

NEA 2012 “Nuclear Energy and Renewables: System Effects in Low-carbon Electricity Systems” Nuclear Energy Agency ISBN 978-92-64-18851-8

The Role of Gas in Ireland



http://www.eirgrid.com/media/All_Island_Wind_and_Fuel_Mix_Summary_2014.pdf

DS3 Programme (Delivering a Secure Sustainable Electricity System (**DS3**))

Grid Code

Performance Monitoring

DSM

System Services

ROCOF

Frequency

Voltage

Renewable Data

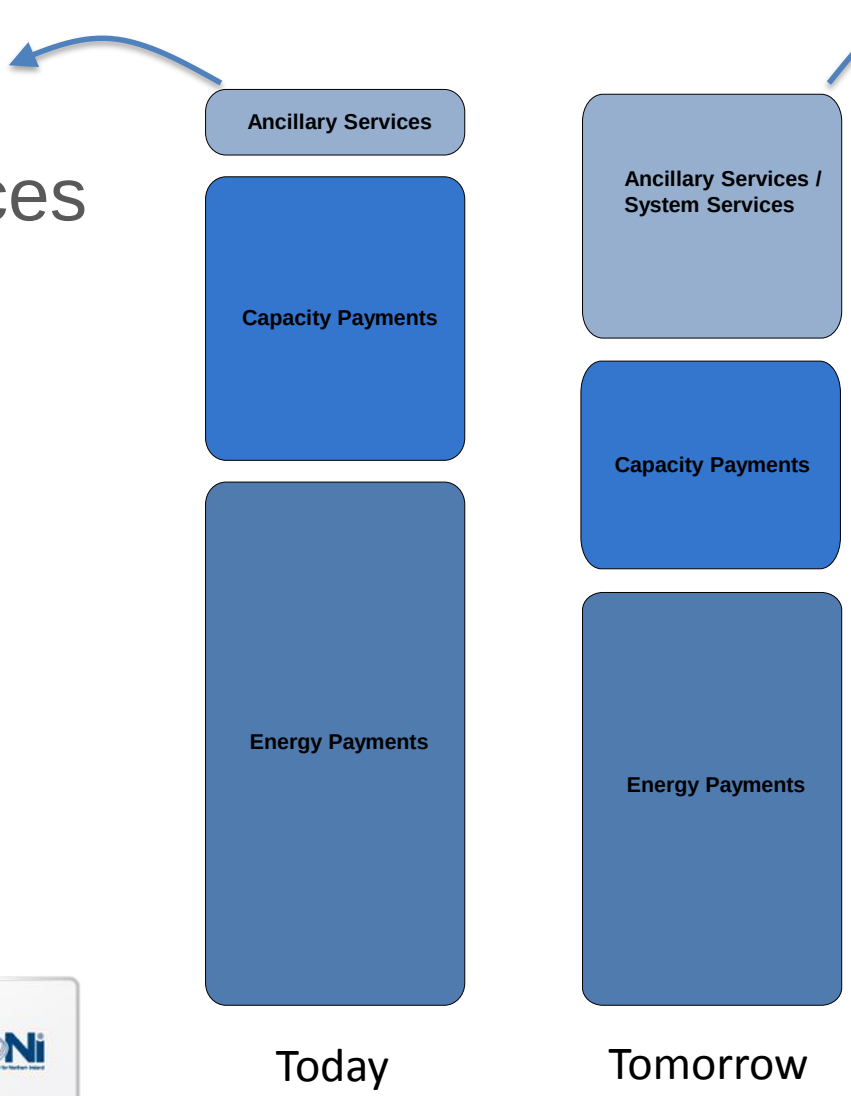
WSAT

Control Centre Tools

Model Dev. & Studies

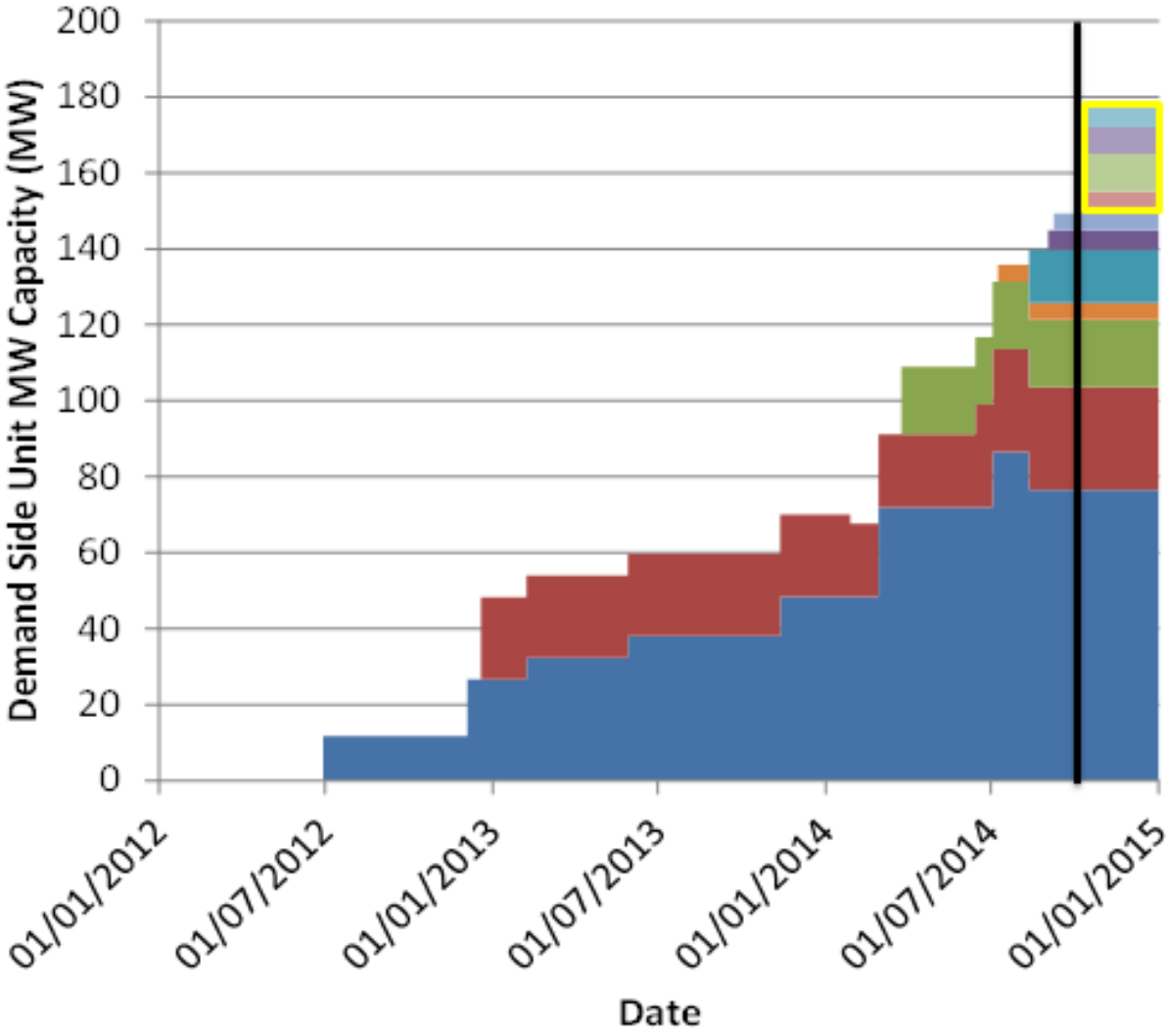
System services: Incentivising the Portfolio

- 60 €m
- 7 Services

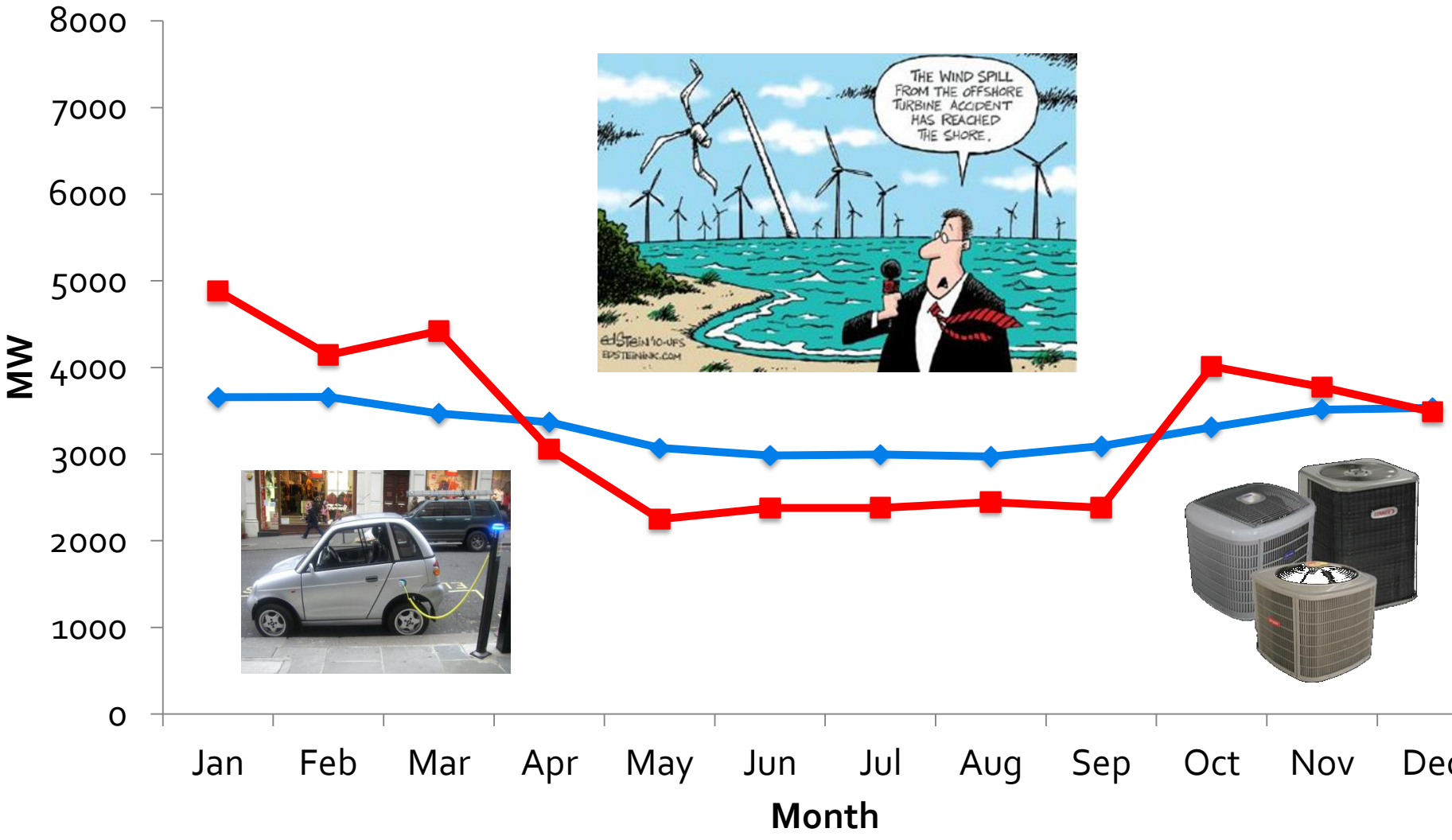


- 235 €m
- 14 Services

DSM – A New Service Provider…



100 % Wind we will have to change how we live



Key Take Aways

- Flexibility is a competitive field
- How do you measure flexibility
- Flexibility is both physical and institutional
- Good market design that considers the physics enables flexibility
- Transmission is the great enabler of flexibility
- Curtailment is form of flexibility – how to get the balance right
- Thermal power plant are flexible and can be made even more flexible
- Large penetrations of variable renewables may alter how we use energy

Conclusions

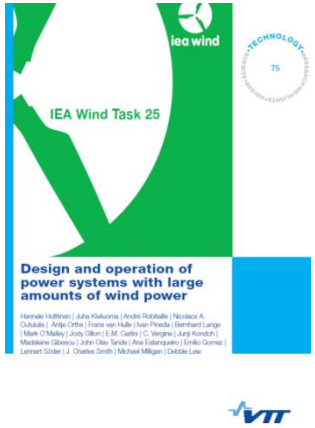
- The nonsynchronous nature of future system could be a game changer technologically – what about the market ?

- Flexibility comes in many shapes and forms – all need to compete

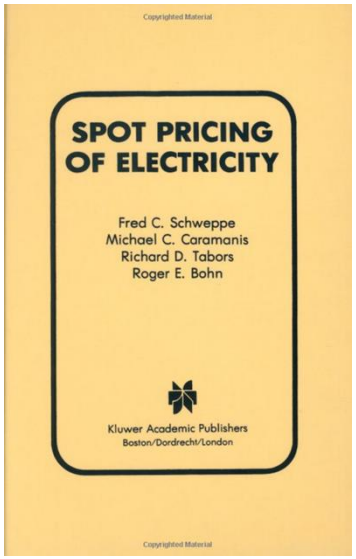
Acknowledgements

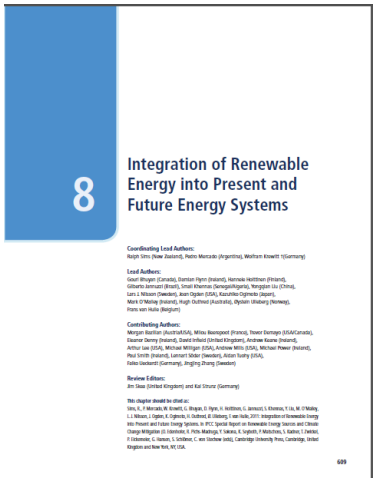
- My colleagues for many of the slides – NREL, EirGrid, UVIG, DTU etc.

Recommended reading



Holttinen, H, et al., "Design and operation of power systems with large amounts of wind power. Final summary report, IEA WIND Task 25, Phase two 2009–2011, 2013. http://www.vtt.fi/inf/pdf/technology/2012/T75.pdf





Krewitt, W. et al. Integration of Renewable Energy into Present and Future Energy Systems. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2011.