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Comparison of Results of OSeMOSYS with TIMES-PLEXOS Model

Modelling ambitious renewable energy targets for Ireland

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Comparison of Results of OSeMOSYS with TIMES-PLEXOS Model

Introduction

Integration of Short-term Dynamics into Long-term Models

- Long-term energy system models cannot incorporate daily operation of power plants
- Related short term constraints may significantly impact longer term investments
- But constraints like ramping rates, start-up costs, minimum stable generation, etc., are usually not considered
- OSeMOSYS was enhanced to capture the impacts of variability on **system adequacy and security** requirements
- System adequacy: Endogenous calculation of capacity credit by OSeMOSYS

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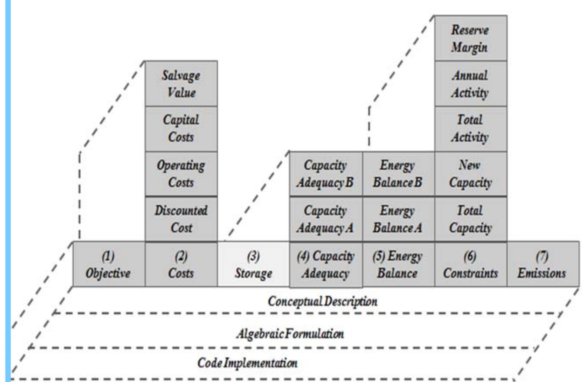
Introduction

OSeMOSYS

Open Source Energy Modelling System

- Limited set of accessible energy systems **models**, often **significant investments** in human resources, training, software.
- **OSeMOSYS** is linear energy systems optimisation model, with **no associated upfront financial requirements.**
- **„Lego block structure“** allows easily adding elements. Every block consists of conceptual describtion, formulas, and code.



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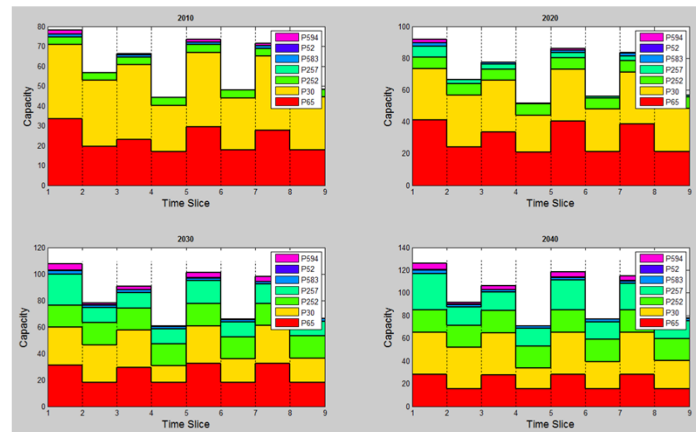
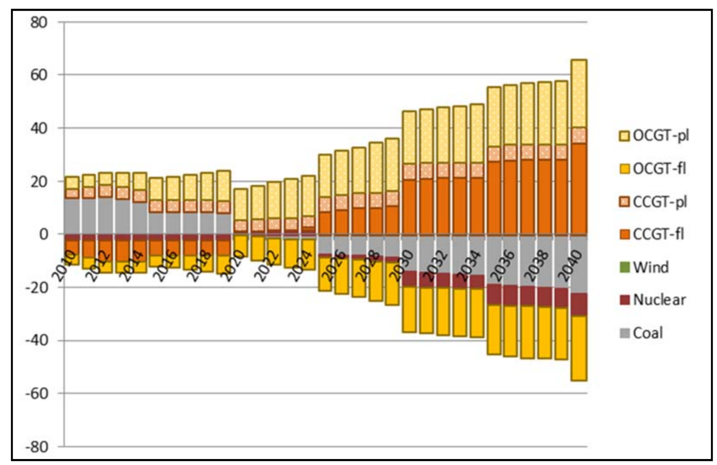
OSeMOSYS Model Enhancements

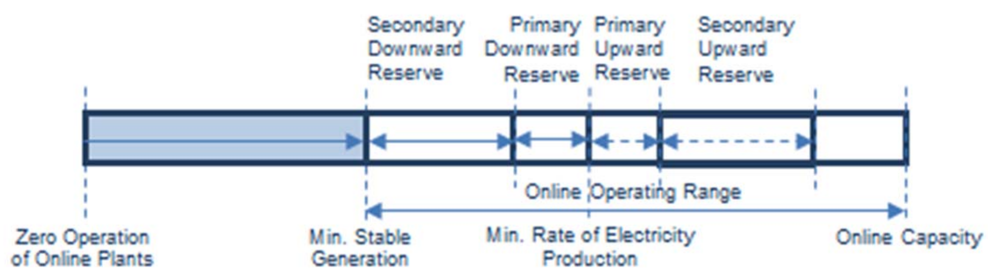
System Security – Operating Reserve

- Primary & secondary, upward & downward reserve
- Specific reserve contributions based on ramping rates can be defined for any technology, also demand-side
- Minimum stable generation levels considered
- Minimum level of spinning reserve can be defined
- Cycling constraints: changes of online capacity and generation from one time slice to another can be limited
- No mixed-integer programming introduced
- Model enhancements documented in detail





System Security – Selected Equations



$$\forall_{y,l,t,f,r}: \boldsymbol{ElectricityForTransmissionTag}_{f,r} = 1 \;\&$$
$$(\boldsymbol{MaxPrimReserveDown}_{y,t,r} \text{ or } \boldsymbol{MaxPrimReserveUp}_{y,t,r}) < \boldsymbol{MinStableOperation}_{y,t,r} \;\&$$
$$(\boldsymbol{MaxSecReserveDown}_{y,t,r} \text{ or } \boldsymbol{MaxSecReserveUp}_{y,t,r}) < \boldsymbol{MinStableOperation}_{y,t,r}:$$

$$OnlineCapacity_{y,l,t,r} * \boldsymbol{MinStableOperation}_{y,t,r} * \boldsymbol{CapacityToActivityUnit}_{t,r} + PrimReserveDownByTechnology_{y,l,t,r} + SecReserveDownByTechnology_{y,l,t,r} \leq RateOfProductionByTechnology_{y,l,t,f,r} \tag{R15}$$

$$\forall_{y,l,t,f,ff=PrimReserveUp,fff=SecReserveUp,r}: \boldsymbol{ElectricityForTransmissionTag}_{f,r} = 1:$$
$$(\boldsymbol{MaxPrimReserveDown}_{y,t,r} \text{ or } \boldsymbol{MaxPrimReserveUp}_{y,t,r}) < \boldsymbol{MinStableOperation}_{y,t,r} \;\&$$
$$(\boldsymbol{MaxSecReserveDown}_{y,t,r} \text{ or } \boldsymbol{MaxSecReserveUp}_{y,t,r}) < \boldsymbol{MinStableOperation}_{y,t,r}:$$

$$RateOfProductionByTechnology_{y,l,t,f,r} + RateOfProductionByTechnology_{y,l,t,ff,r} + RateOfProductionByTechnology_{y,l,t,fff,r} \leq OnlineCapacity_{y,l,t,r} * \boldsymbol{CapacityToActivityUnit}_{t,r} \tag{R16}$$

Comparison of Results of OSeMOSYS with TIMES-PLEXOS Model

Irish Case Study

Background – Irish Case Study

- Comparative UCC study using TIMES & PLEXOS
- Modelled Irelands 40% RE generation target for 2020
- Set up OSeMOSYS in a similar fashion as Irish TIMES model (12 time slices)
- Added detail taken from the Plexos model (8760 time slices), but maintained 12 time slices
- Compared results with TIMES/Plexos
- **Publication:** Deane, J.P., Chiodi, A., Gargiulo, M., Ó Gallachóir, B.P., 2012. Soft-linking of a power systems model to an energy systems model. Energy 42, 303–312.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Modelling elements of Smart Grids – Enhancing the OSeMOSYS (Open Source Energy Modelling System) code

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Irish Case Study

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Parameters

Parameters		Plexos	OSeMOSYS Enhanced	TIMES
Technical	Installed capacity	✓	✓	✓
	Input/output fuels	✓	✓	✓
	Heat rates/efficiencies	✓	✓	✓
	Min. stable generation	✓	✓	
	Up/down ramp rates/reserves	✓	✓	
	Min. up and down times	✓	*	
	Maintenance rates/availabilities	✓	✓	✓
	Repair time	✓		
Economic	Fuel costs	✓	✓	✓
	Emission costs	✓	✓	✓
	Variable O&M costs	✓	✓	✓
	Fixed O&M costs		✓	✓
	Start-up costs	✓	*	
Environmental	Emissions	✓	✓	✓

* Could be considered indirectly through cycling characteristics

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Irish Case Study

Background - Republic of Ireland

- 16% renewable energy target for 2020
- Translates to a 40% renewable generation target
- Technically feasible maximum wind penetration rates are expected to range between 60 – 80% of the load
- Extending the time horizon to 2050, greenhouse gas emission reductions of 80% below 1990 levels


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Scenarios

OSeMOSYS Simple:

Built on core code of OSeMOSYS, similar to the stand-alone TIMES model.

OSeMOSYS 70% Wind:

Draws on external, detailed wind availability assessment. Enabled a more accurate consideration of the 70% wind generation limit.

TIMES-PLEXOS Simple:

Increased temporal resolution (hourly intervals), no additional operational constraints.

OSeMOSYS Enhanced:

Considers increased operational detail (operating reserve requirements, max. contribution of power plants to meeting these reserves, minimum stable generation)

TIMES-PLEXOS Enhanced:

Increased operational detail (start-up costs, minimum stable generation, ramping rates, and operating reserve requirements)

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Comparison of Results of OSeMOSYS with TIMES-PLEXOS Model

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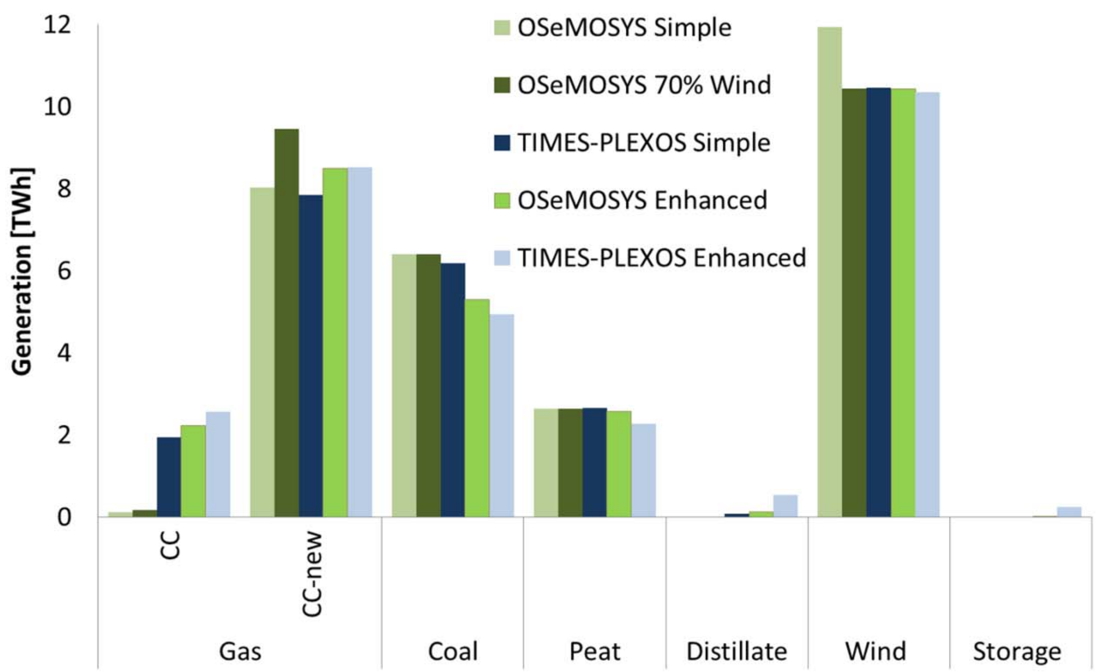
Results for 2020



Annual generation of the modelled power plant types

OSeMOSYS results in shades of green, TIMES-PLEXOS results in shades of blue.

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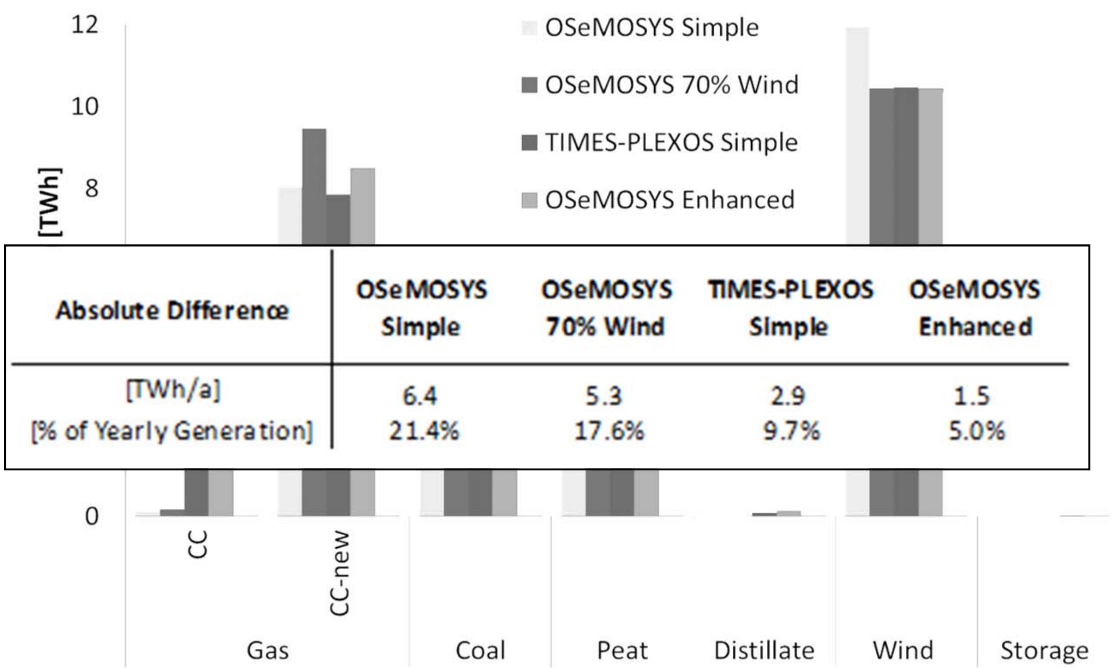
Comparison of Results of OSeMOSYS with TIMES-PLEXOS Model

Case Study

Results for 2020



Absolute Difference	OSeMOSYS Simple	OSeMOSYS 70% Wind	TIMES-PLEXOS Simple	OSeMOSYS Enhanced
[TWh/a] [% of Yearly Generation]	6.4 21.4%	5.3 17.6%	2.9 9.7%	1.5 5.0%

Annual generation of the modelled power plant types
OSeMOSYS results in shades of green, TIMES-PLEXOS results in shades of blue.

Comparison of Results of OSeMOSYS with TIMES-PLEXOS Model

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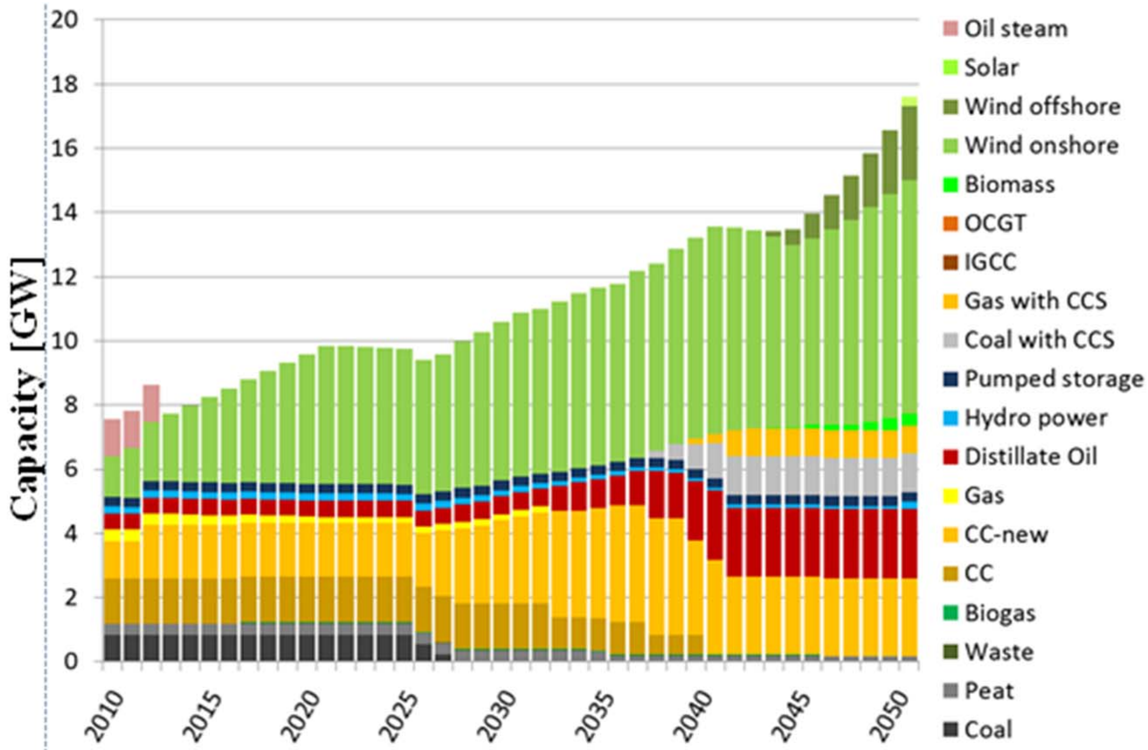
Results for 2050

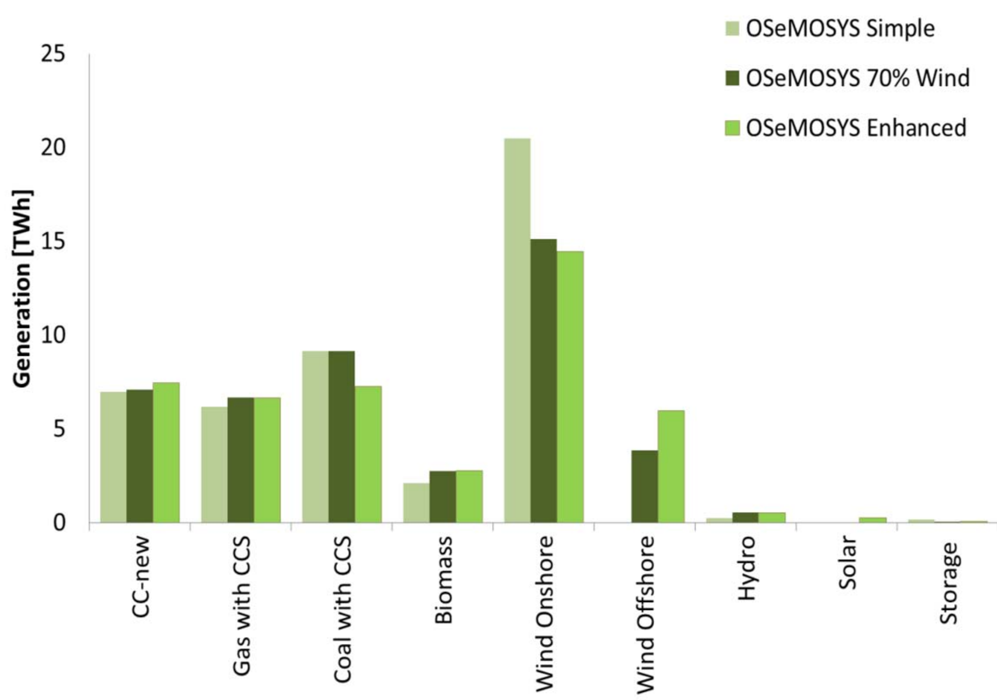


Optimised capacities based on enhanced OSeMOSYS model

Comparison of Results of OSeMOSYS with TIMES-PLEXOS Model

Case Study

Results for 2050



Annual generation of the modelled power plant types

Comparison of Results of OSeMOSYS with TIMES-PLEXOS Model

Case Study

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Results for 2050

Deviation of capacities, discounted costs and emissions from enhanced OSeMOSYS model

OSeMOSYS Simple	Unit	2020	2025	2030	2035	2040	2045	2050
Total capacity	%	0.0	4.0	4.6	3.8	3.3	-2.1	-14.1
Σ |Plant capacity deviations| / Capacity OSeMOSYS Enhanced	%	0.0	4.0	17.4	20.3	15.1	19.8	23.5
Discounted costs	%	-9.0	40.5	-11.3	-4.0	-5.8	-21.5	-14.3
Emissions	%	-1.3	-7.6	-14.4	-5.4	0.0	0.0	0.0

OSeMOSYS 70% Wind	Unit	2020	2025	2030	2035	2040	2045	2050
Total capacity	%	0.0	0.0	-1.4	-1.3	-1.2	-6.4	-7.8
Σ |Plant capacity deviations| / Capacity OSeMOSYS Enhanced	%	0.0	0.0	7.3	12.8	9.4	14.1	13.0
Discounted costs	%	-2.3	-1.9	-0.2	-3.0	-9.1	-15.2	-3.9
Emissions	%	3.5	0.3	-1.3	2.5	0.0	0.0	0.0

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Irish Case Study

Conclusions

- **Long-term energy systems models which omit short-term constraints:** Simple OSeMOSYS model: *21.4% of yearly generation in 2020* assigned to different power plants than in enhanced model.
- **Soft-linking:** two separate models have to be set-up and maintained; no overall optimisation across the two models -> identified capacity investments may not present the economically most efficient pathway
- **Integrating operational aspects into the long-term models**: 95.0% of the dispatch results of the enhanced OSeMOSYS model matched those of an interlinked model with a 700 times higher temporal resolution.

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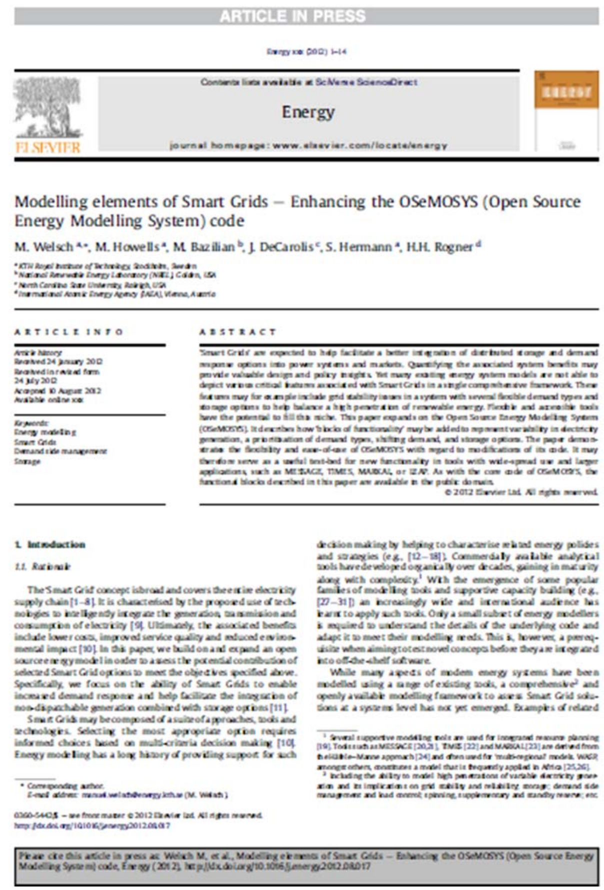
Conclusions

- **Integrating operational aspects into the long-term models**: In conventional model, up to 23.5% of *total capacity in 2050* assigned to different power plants than when considering operating reserves.
- Approach presented for OSeMOSYS, but can as well be implemented in other long-term models.

- M. Welsch, M. Howells, M. Hesamzadeh, B. Ó Gallachóir, P. Deane, N. Strachan, et al. *Ensuring Supporting Security and Adequacy in Future Energy Systems – The need to enhance long-term energy system models to better treat issues related to variability.* minor revisions.
- M. Welsch, P. Deane, F. Rogan., M. Howells, B. Ó Gallachóir, H.H. Rogner, et al. *Incorporating Flexibility Requirements into Long-term Models – A Case Study on High Levels of Renewable Electricity Penetration in Ireland.* under review.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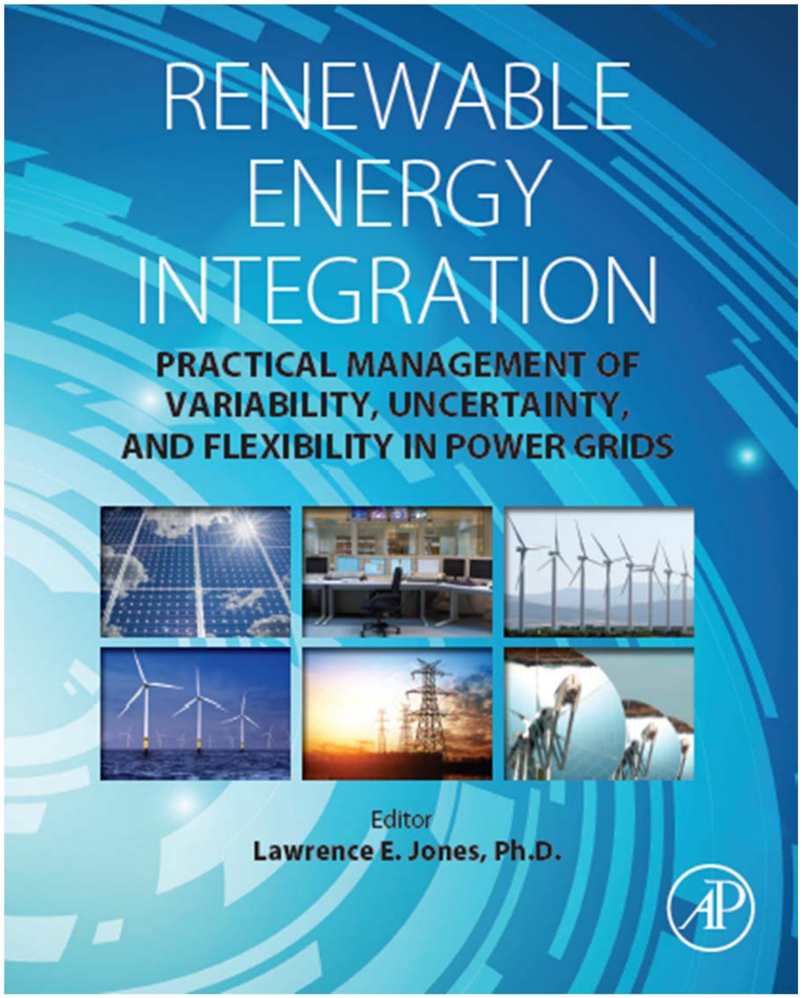
Publication



CHAPTER 17

Long-Term Energy Systems Planning: Accounting for Short-Term Variability and Flexibility

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1. Introduction

According to the International Energy Agency (IEA), the world continues to diverge from a pathway toward meeting internationally agreed climate change targets. Global average temperatures are expected to increase by 2.8–4.5 °C by 2100 if no countermeasures are taken [1]. This calls for a major transformation of our energy systems, in which renewable energy technologies play an important role to mitigate climate change.

The electricity production of renewable energy sources, such as wind and solar power, is variable as a function of the availability of the renewable resource at hand. Variable renewables certainly provide secure quantities of energy when considered over longer time periods, but they do not guarantee the secure delivery of power as and when needed [2]. The variability they introduce adds to the overall fluctuations in power systems. For example, on the supply side, these may be due to outages in conventional power plants, and on the demand side, they may be due to the time dependency of loads. As the shares of renewable electricity generation rise, future power systems need to be increasingly flexibility to cope with such fluctuations to balance supply and demand. Energy policies and strategies are required that facilitate the transformation to such increasingly flexible power systems.

Energy models have successfully proven their use in informing the development of energy policies and strategies from the early 1980s on [3–6]. They commonly serve as test-beds to investigate developments or system configurations that would be impractical, too expensive or impossible to test in real-world

Thank you for your attention