OSeMOSYS – An Introduction

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OSeMOSYS – An Introduction

Webinar Overview

- Introduction to energy modelling and the role of OseMOSYS
- Introduction to the OSeMOSYS Model
  - Overview
  - Interfaces
  - Modifications
  - Applications
- Discussant on policy use of OSeMOSYS
Long-term Energy Modelling

- Energy policy across the globe is grappling with a set of unprecedented challenges
- Securing access to energy and mitigating climate change are key policy goals
- Many complex issues require consideration, e.g., economic growth, resource reserves, technological development, (climate) policies

- Energy models provide essential quantitative insights into these 21st Century challenges
- Mitigation efforts & energy system infrastructure require long-term planning
- Models can help to gain strategic insights while managing the various complexities
- Energy models have very different methodologies, and are targeted at different research questions
- Energy models are built, run, critiqued and applied by people
What are Energy Models?

What models are not

- A generator of research papers or consultancy funding
- A name based on a zippy acronym
- e.g., GREEN, BLUE; PRISM, CUBE; ALPHA, GAMMA, DELTA; ALBATROSS
- An anthropogenic entity with a somewhat deranged personality

A structured approach to modelling

- There will never be a universal model which will answer all questions
- Design models to answer specific research questions
- Although some complex models can contribute to a number of different research areas
- A range of models (& model linkages) are required for any given problem
- Developing an expert/educated community of developers and users is critical
- Models of complex systems evolve through structured contact with reality
- Models are only as good as the data you have to populate / challenge them
Model Usefulness

• All models are wrong but some are useful”
  • George Box

• Alternate version

• “Some models are right, (or at least in practice, right enough), and even the wrong ones can still be useful”
  • ‘Limited validity’ of Newtonian Physics vs. general relativity and quantum mechanics
  • ‘Business-as-usual mental model’ of Shell’s executives before presentations by Pierre Wack’s team
"entia non sunt multiplicanda praeter necessitatem"

"entities must not be multiplied beyond necessity"

- William of Ockham: 1288 – 1348

- In modelling terms:
  - Simplicity-elegance-parsimony
  - Complexity as necessary

- BUT energy-economic system is inherently complex

- Problem drives modelling and analysis
Credibility of EU energy review questioned

By Pilita Clark

The credibility of a European energy review has been cast into doubt by experts who point out that long-term plans to cut carbon emissions are based on an economic model owned by a single Greek university that cannot be independently scrutinised.

Experts have “raised a host of questions” about how the European Commission’s use of a non-transparent model could affect the energy review, according to a leaked report by energy specialists chosen by Brussels to advise on the forthcoming “Energy Roadmap to 2050”.

The economic model, known as “Primes”, is owned by the National Technical University of Athens and is designed to show how using different mixes of energy
Model Transparency 1

• “It is the [FUND model] developer's firm belief that most researchers should be locked away in an ivory tower. Models are often quite useless in inexperienced hands, and sometimes misleading.”

• “No one is smart enough to master in a short period what took someone else years to develop.”

• “Not-understood models are irrelevant, half-understood models treacherous, and misunderstood models dangerous.”

• Richard Tol
Model Transparency 2

Open source
- Full documentation (online), including data
- Model source code
- Peer reviewed
- Journal papers
- Dedicated peer review

Expert user group
- Model developers and users in Government, industry, consultancies and academia
- International support network
- Engagement with broader stakeholders

But…
- Intellectual property issues
- Replicability of highly complex models
- Biased (even malicious) attitudes towards energy analysis
“Model for insights, not numbers”
  • Hill Huntington, 1982

But decision makers don’t really want insights!
  • They really want numbers
  • And they don’t deal with uncertainty very well

Examples of numbers
  • Resource availability (barrels, cu.m3, tonnes)
  • Energy demands (GJ, MWhrs, toe)
  • Technology diffusion (number of units, % share)
  • Climate change mitigation GDP costs (billion £, %)
  • Investment required in power sector (million £)
  • Energy price increases (p/kWh, p/litre)
  • ….
Where do the numbers come from?

Model derived

- IPCC AR4
- (median values) 500ppm CO2e, -50% GHG emissions by 2050
- GDP: +1 to -3%, CO2 price 50 - 200 $/tCO2

Scenarios and simple modelling

- Ofgem’s Project discovery, 2009
- £95 - £200 billion investment in UK power sector by 2020

From the ether(!)

- EU’s 20-20-20 target, by 2020
- 20% reduction in GHG emissions (from 1990 levels)
- 20% from renewable resources (final energy basis)
- 20% improvement in energy efficiency (final energy basis)
OSeMOSYS – An Introduction

Introduction

Energy Model Typology

Macro economic feedbacks

Behavioural complexity

Technology richness

"PERFECT" Energy Model

CGE

Econometric, Agent based

Optimisation (OSeMOSYS)


10.12.2013 desa.kth.se 12
OSeMOSYS – An Introduction

OSeMOSYS (Open Source Energy Modelling System)

- At present there exists a useful, but limited set of accessible energy systems models. They often require significant investments in terms of human resources, training and software purchases.
- OSeMOSYS is a fully fledged energy systems linear optimisation model, with no associated upfront financial requirements.
- It extends the availability of energy modelling further to researchers, business analysts and government specialists in developing countries.
- A "lego block structure“ allows easily adding elements. Every block consists of a plain english description, the formulas, and the actual code.
OSeMOSYS (Open Source Energy Modelling System)

- Tool to inform the development of medium- to long-term energy strategies
- Deterministic linear optimisation model
- Demands for energy services are met by technologies which draw on resources
- Minimises the total discounted costs
- Paradigm comparable to MESSAGE or TIMES
- Integrated into LEAP
- Open source -> no associated upfront financial requirements
- Well documented, easy to modify
Technology Definition

• Wide and flexible.

• Any fuel use and conversion, from resource extraction and processing to generation, transmission and distribution and appliances.

• E.g., a coal mine, a wind farm or air-conditioning systems.

• Any combination of input fuels to produce any combination of output fuels.

• Defined by a set of economic, technical and environmental parameters and policy goals.

• Technologies compete against each other in order to minimise the overall discounted costs for society.
OSeMOSYS – An Introduction

Reference Energy System (RES)

- Services
- Energy carriers
- Power plants (Secondary energy)
- Fuel resources (Primary energy)
OSeMOSYS – An Introduction

Reference Energy System (RES)

- All boxes are technologies
- All lines are fuels
- No parameters are assigned to fuels
- Most parameters are assigned to technologies (costs, lifetime, efficiencies, emissions, etc.)
  -> e.g., fuel costs are defined as operational costs of a technology
- Non-technology parameters:
  - Demand
  - Emission constraints
  - Reserve margin, etc.
Design Features

Structured in **blocks of functionality** (fig. on right)

Several **levels of abstraction**:  
- A plain English description
- An algebraic formulation of the plain English description
- The model’s implementation in a programming language
- The application of the model

**Mathematical language:** Gnu MathProg (similar to GAMS)

**Solver:** glpk (open-source)
Objective
To estimate the lowest NPV of an energy system to meet given demand(s) for energy

Costs
Account for the costs incurred by each technology in each year and in each region

Capacity adequacy
There must be enough capacity for each technology in order to meet its energy use or production requirements
  • Capacity adequacy A: Each time slice / Capacity adequacy B: Each year

Energy balance
Operation levels are calculated for each time slice and each year. The production, use and demand must be feasible at each timeslice and annually
  • Energy balance A: Each time slice / Energy balance B: Each year
OSeMOSYS – An Introduction

Constraints
- Maximum/minimum limit on capacity of a technology allowed for a year or total period and a region
- Maximum/minimum limit on new capacities of a technology for a year and a region
- Maximum/minimum limit on activity of a technology for a year or total period and a region
- There must be enough capacity to provide a reserve margin (for specified technologies)

Emissions
- The extent to which pollutants are emitted is determined by multiplying “emissions per unit of activity” and the annual activity of a technology
Example of Mathematical Formulation

**OBJECTIVE**

\[
\text{minimize } \sum \text{TotalDiscountedCost}_{y,t,m,r}
\]

**(OBJ)**

**COSTS**

**TOTAL DISCOUNTED COSTS**

\[
\text{TotalDiscountedCost}_{y,t,m,r} = \text{DiscountedOperatingCost}_{y,t,m,r} + \text{DiscountedCapitalInvestment}_{y,t,m,r} + \text{DiscountedTechnologyEmissionsPenalty}_{y,t,m,r} + \text{DiscountedSalvageValue}_{y,t,m,r}
\]

**(TDC1)**

**OPERATING COSTS**

\[
\text{VariableOperatingCost}_{y,t,m,r} = \sum \text{AverageAnnualTechnologyActivityByMode}[y,t,m,r] \times \text{VariableCost}_{y,t,m,r}
\]

**(OC1)**

\[
\text{AnnualVariableOperatingCost}_{y,t,m,r} = \sum \text{VariableOperatingCost}_{y,t,m,r}
\]

**(OC2)**

\[
\text{AnnualFixedOperatingCost}_{y,t,m,r} = \text{TotalCapacityAnnual}_{y,t,m,r} \times \text{FixedCost}_{y,t,m,r}
\]

**(OC3)**

\[
\text{OperatingCost}_{y,t,m,r} = \text{AnnualFixedOperatingCost}_{y,t,m,r} + \text{AnnualVariableOperatingCost}_{y,t,m,r}
\]

**(OC4)**

\[
\text{DiscountedOperatingCost}_{y,t,m,r} = \text{OperatingCost}_{y,t,m,r} \times (1+\text{DiscountRate}_{y,t,m,r})^{(y-\text{StartYear})+0.5}
\]

**(OC5)**

**CAPITAL COSTS**

\[
\text{CapitalInvestment}_{y,t,m,r} = \text{CapitalCost}_{y,t,m,r} \times \text{NewCapacity}_{y,t,m,r}
\]

**(CC1)**

\[
\text{DiscountedCapitalInvestment}_{y,t,m,r} = \frac{\text{CapitalInvestment}_{y,t,m,r}}{(1+\text{DiscountRate}_{y,t,m,r})^{(y-\text{StartYear})}}
\]

**(CC2)**
Example of Code

# OBJECTIVE #

minimize OBJ_TotalNPVCost: sum{y in YEAR, t in TECHNOLOGY, r in REGION} TotalDiscountedCost[y,t,r];

# CONSTRAINTS AND EQUATIONS #

# TOTAL DISCOUNTED COSTS #

s.t. TDC1_TotalDiscountedCostByTechnology{y in YEAR, t in TECHNOLOGY, r in REGION}:
    DiscountedOperatingCost[y,t,r] + DiscountedCapitalInvestment[y,t,r] + AnnualTechnologyEmissionsPenalty[y,t,r] - DiscountedSalvageValue[y,t,r] = TotalDiscountedCost[y,t,r];

# OPERATING COSTS #

s.t. OCl_OperatingCostsVariable{y in YEAR, t in TECHNOLOGY, r in REGION}: sum{m in MODE_OF_OPERATION} AverageAnnualTechnologyActivityByMode[y,t,m,r] * VariableCost[y,t,m,r] = VariableOperatingCost[y,t,r];

s.t. OC2_OperatingCostsVariableAnnual{y in YEAR, t in TECHNOLOGY, r in REGION}: sum{t in TIMESLICE} VariableOperatingCost[y,t,r] = AnnualVariableOperatingCost[y,t,r];

s.t. OC3_OperatingCostsFixedAnnual{y in YEAR, t in TECHNOLOGY, r in REGION}: TotalCapacityAnnual[y,t,r] * FixedCost[y,t,r] = AnnualFixedOperatingCost[y,t,r];

s.t. OC4_OperatingCostsTotalAnnual{y in YEAR, t in TECHNOLOGY, r in REGION}: AnnualFixedOperatingCost[y,t,r] + AnnualVariableOperatingCost[y,t,r] = OperatingCost[y,t,r];

s.t. OC5_DiscountedOperatingCostsTotalAnnual{y in YEAR, t in TECHNOLOGY, r in REGION}: OperatingCost[y,t,r] / (1 - DiscountRate[t,r])^(y - StartYear + 0.5)) = DiscountedOperatingCost[y,t,r];

# CAPTIAL COSTS #

s.t. CC1_UndiscountedCapitalInvestment{y in YEAR, t in TECHNOLOGY, r in REGION}: CapitalCost[y,t,r] * NewCapacity[y,t,r] = CapitalInvestment[y,t,r];

s.t. CC2_DiscountingCapitalInvestment{y in YEAR, t in TECHNOLOGY, r in REGION}: CapitalInvestment[y,t,r] / (1 + DiscountRate[t,r])^(y - StartYear)) = DiscountedCapitalInvestment[y,t,r];
Interfaces
Current ways to use OSeMOSYS

- LEAP interface
- OSeMOSYS interface (under development)
- Run an input file
  - in the command prompt, e.g., using Notepad++ to write input file
  - GUSEK
  - Matlab
LEAP Interface

LEAP can use OSeMOSYS, the Open Source Energy Modeling System and GLPK, the GNU Linear Programming Kit to calculate capacity expansion in scenarios.

- Include emissions constraints
- Optimization Calculations: In Window
- GNU Linear Programming Kit: C:\Program Files (x86)\LEAP2011\glpsol.exe (Installed OK)
- Model File: C:\Program Files (x86)\LEAP2012\OSeMOSYS_template.TXT

Open
LEAP Interface

LEAP: optimization example complete

- Key Assumptions
- Effects
- Demand
- Transformation
- Transmission and Distribution
- Electricity Generation
- Resources

Manage Scenarios
Branch: All Branches
Variable: Optimize
Scenario: C20: CO2 Tax 20

System Energy Load Shape
Module Costs
Planning Reserve Margin
Optimize: Set to Yes or No to indicate if module capacity expansion will be optimized using OSeMOSYS.

Branch
Expression

Electricity Generator Yes? Uses least cost capacity expansion calculations in this module.
LEAP Interface

Optimizing...

Scenario: Optimization No CO2 Limit
Model file: OSeMOSYS.TXT (version: 2011.11.08)
Data file: OpData3.txt
Results file: OpResults3.txt

LEAP will continue when optimization calculations finish.
OSeMOSYS - An Introduction

Input File - Example of Data File

```plaintext
set EMISSION := CO2 NOX;
set TECHNOLOGY := E01 E21 E31 E51 E70 IMPDSL1 IMPGSL1 IMPHCO1 IMPOIL1 IMPURN1 RHE RHO RL1 SRE
set FUEL := CSV DSL ELC GSL HCO HYD LTH OIL URN RH RL TX;
set TIMESLICE := ID IN SD SN WD WN;
set MODE_OF_OPERATION := 1 2;
set REGION := UTOPIA;

param FixedCost default 0 :=
[*,*,UTOPIA]: E01 E21 E31 E51 E70 RHO RL1 TXD TXE TXG :=
1990  40  500  75  30  30  1  9.46  52  100  48
1991  40  500  75  30  30  1  9.46  52  100  48
1992  40  500  75  30  30  1  9.46  52  100  48
1993  40  500  75  30  30  1  9.46  52  100  48
1994  40  500  75  30  30  1  9.46  52  100  48
1995  40  500  75  30  30  1  9.46  52  100  48
```
Input File - Example of Data File

```plaintext
param OutputActivityRatio default 0 :=
[*,*,RH,1,UTOPIA] : RHE RHO RHu:=
1990 1 1 1
1991 1 1 1
1992 1 1 1
1993 1 1 1
1994 1 1 1
1995 1 1 1

param InputActivityRatio default 0 :=
[*,*,DSL,1,UTOPIA] : E70 RHO TXD :=
1990 3.4 1.428571429 1
1991 3.4 1.428571429 1
1992 3.4 1.428571429 1
1993 3.4 1.428571429 1
1994 3.4 1.428571429 1
1995 3.4 1.428571429 1
```
## Example of Output File

<table>
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<th>Year</th>
<th>Total Annual Capacity (Capacity Units)</th>
<th>Coal</th>
<th>Biogas</th>
<th>Waste</th>
<th>Peat</th>
<th>CC</th>
<th>CC-new</th>
<th>Gas</th>
<th>Hydro</th>
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OSeMOSYS – An Introduction

Input File (1) – Command Prompt

```
C:\Users\welsch\Desktop\bin>glpsol -m OSeMOSYS_2011_11_08.txt -d UTOPIA_2011_11_08.txt -o results.txt
```
Input File (1) – Command Prompt

```
C:\Users\welsch\Desktop\bin>glpsol -m OSeMOSYS_2011_11_08.txt -d UTOPIA_2011_11.txt
GLPSOL: GLPK LP/MIP Solver, v4.46
Parameter(s) specified in the command line:
-m OSeMOSYS_2011_11_08.txt -d UTOPIA_2011_11.txt
Reading model section from OSeMOSYS_2011_11.txt:
OSeMOSYS_2011_11.txt:615: warning: final 815 lines were read
Reading data section from UTOPIA_2011_11.txt:
966 lines were read
Generating cost...
Generating EQ_SpecifiedDemand...
Generating S1_StorageCharge...
Generating S2_StorageDischarge...
Generating S3_NetStorageCharge...
Generating S4_StorageLevelAtInflection...
Generating E9_ModelPeriodEmissionslimit...
Model has been successfully generated
GLPK Simplex Optimizer, v4.46
291855 rows, 293773 columns, 661031 non-zeros
Preprocessing...
22663 rows, 23895 columns, 61908 non-zeros
Scaling...
A: min|aij| = 1.000e-05 max|aij| = 1.000e+05 ratio = 1.000e+10
GM: min|aij| = 1.727e-01 max|aij| = 5.790e+00 ratio = 3.352e+01
EQ: min|aij| = 3.024e-02 max|aij| = 1.000e+00 ratio = 3.007e+01
Constructing initial basis...
Size of triangular part = 20997
  0: obj = 8.38345370e+002 infeas = 6.623e+003 (2266)
  500: obj = 1.369784597e+003 infeas = 4.297e+003 (2268)
 1000: obj = 1.808863782e+003 infeas = 4.125e+003 (2265)
 1500: obj = 4.681993291e+003 infeas = 3.891e+003 (2265)
 2000: obj = 1.218014691e+004 infeas = 3.056e+003 (2263)
   * 2368: obj = 4.049204369e+004 infeas = 7.872e-01 (2263)
   * 2500: obj = 3.005622362e+004 infeas = 6.056e-03 (2257)
   * 3000: obj = 2.718891021e+004 infeas = 3.472e-03 (2255)
   * 3500: obj = 2.662933465e+004 infeas = 3.066e-03 (2255)
   * 3724: obj = 2.662933464e+004 infeas = 3.489e-03 (2255)
OPTIMAL SOLUTION FOUND
Time used: 3.3 secs
Memory used: 491.5 Mb (515402524 bytes)
Model has been successfully processed
Writing basic solution to 'results.txt'...
C:\Users\welsch\Desktop\bin>
```
OSeMOSYS – An Introduction

Input File (2) – GUSEK

Integrated development environment, combines solver (glpk) and editor, freely available.
Input File (3) – Matlab

- Commercial software
- Certain processes can be automised
  - (e.g., drawing graphs,
  - comparing data
  - Scenario management (e.g., saving input and output files in a scenario folder)
function output = compileglpk(glpkFolder, modelFolder, scenarioFolder)

output.paths.curFolder = pwd;
output.paths.glpkFolder = strcat(output.paths.curFolder, filesep, glpkFolder);
output.paths.modFolder = strcat(output.paths.curFolder, filesep, modelFolder);
output.paths.modFolder.scen = strcat(output.paths.modFolder, filesep, scenarioFolder);
output.model.name = 'model';

GLPKmodel = strcat(output.paths.modFolder.scen, filesep, output.model.name, '.mod');
GLPKdata = strcat(output.paths.modFolder.scen, filesep, output.model.name, '.dat');
% GLPKout = strcat(output.paths.modFolder.scen, filesep, output.model.name, '.out');

glpsol = strcat(output.paths.glpkFolder, filesep, 'glpsol.exe');

% cmdLine = ['"' glpsol '" -m ", GLPKmodel, '" -d ", GLPKdata," -o "', GLPKout,"'"

cmdLine = ['"' glpsol '" -m "', GLPKmodel, '" -d "', GLPKdata,"'"

system(cmdLine);
OSeMOSYS – An Introduction

Input File (3) – Matlab
Modifying OSeMOSYS – An Illustration
In **2012**, renewable energy (RE) sources contributed 70% to all electricity capacity additions in the EU.

US blueprint for a secure energy future: By **2035**, 80% from clean energy sources

RE generation may triple until **2035** (IEA’s New Policies Scenario).

By **2050**, the EU intends to reduce GHG emissions by 80% – 95% below 1990 levels.

- Variable RE sources add to overall fluctuations between supply and demand.
- This requires increasingly flexible power systems.
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.
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
Irish Case Study - Background

- Comparative UCC study linking TIMES & PLEXOS
- Modelled Ireland's 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

Irish Test Case - Results for 2020

Annual generation of the modelled power plant types
OSeMOSYS results in shades of green, TIMES-PLEXOS results in shades of blue.
Irish Test Case - Results for 2020

Annual generation of the modelled power plant types
OSeMOSYS results in shades of green, TIMES-PLEXOS results in shades of blue.
Irish Test Case - Results for 2050

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

<table>
<thead>
<tr>
<th></th>
<th>OSeMOSYS Simple</th>
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<tbody>
<tr>
<td></td>
<td>Unit</td>
<td>2020</td>
<td>2025</td>
<td>2030</td>
<td>2035</td>
<td>2040</td>
<td>2045</td>
<td>2050</td>
<td></td>
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<tr>
<td>Total capacity (%)</td>
<td></td>
<td>0.0</td>
<td>4.0</td>
<td>4.6</td>
<td>3.8</td>
<td>3.3</td>
<td>-2.1</td>
<td>-14.1</td>
<td></td>
</tr>
<tr>
<td>[ \sum \text{Plant capacity deviations}] (%)</td>
<td></td>
<td>0.0</td>
<td>4.0</td>
<td>17.4</td>
<td>20.3</td>
<td>15.1</td>
<td>19.8</td>
<td>23.5</td>
<td></td>
</tr>
<tr>
<td>Capacity OSeMOSYS Enhanced</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discounted costs (%)</td>
<td></td>
<td>-9.0</td>
<td>40.5</td>
<td>-11.3</td>
<td>-4.0</td>
<td>-5.8</td>
<td>-21.5</td>
<td>-14.3</td>
<td></td>
</tr>
<tr>
<td>Emissions (%)</td>
<td></td>
<td>-1.3</td>
<td>-7.6</td>
<td>-14.4</td>
<td>-5.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<table>
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<tr>
<th></th>
<th>OSeMOSYS 70% Wind</th>
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<td>2035</td>
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<td>2045</td>
<td>2050</td>
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<tr>
<td>Total capacity (%)</td>
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<td>0.0</td>
<td>-1.4</td>
<td>-1.3</td>
<td>-1.2</td>
<td>-6.4</td>
<td>-7.8</td>
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<tr>
<td>[ \sum \text{Plant capacity deviations}] (%)</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>7.3</td>
<td>12.8</td>
<td>9.4</td>
<td>14.1</td>
<td>13.0</td>
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<tr>
<td>Capacity OSeMOSYS Enhanced</td>
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<tr>
<td>Discounted costs (%)</td>
<td></td>
<td>-2.3</td>
<td>-1.9</td>
<td>-0.2</td>
<td>-3.0</td>
<td>-9.1</td>
<td>-15.2</td>
<td>-3.9</td>
<td></td>
</tr>
<tr>
<td>Emissions (%)</td>
<td></td>
<td>3.5</td>
<td>0.3</td>
<td>-1.3</td>
<td>2.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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</tbody>
</table>
Conclusions

Long-term models which omit short-term constraints:
Need for flexible power systems may be underestimated -> potentially skewed insights for policy development.

Soft-linking: two separate models required; 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 dispatch results of enhanced OSeMOSYS model matched those of an interlinked model with a 700 times higher temporal resolution.

Selected OSeMOSYS Applications
Developed in OSeMOSYS in collaboration with UNDESA

**Aim**
- Provide a transparent tool that facilitates the assessment of various policy pathways associated with integrated resource management and keeps sustainable development as an overarching theme.

**Objectives**
- Served as input to UN Sustainable Development Report
- Simplified testing ground for policies
- Trade-offs and synergies between CLEW and materials sectors
The OSeMOSYS model, along with a generic database will be fully open-source.

**TRANSPARENCY – ACCESSIBILITY – COLLABORATION – SCALABILITY**
OSeMOSYS – An Introduction

Assessing the climate vulnerability of the African continent – Mark Howells (KTH)

Key Actors
Commissioning Institution: The World Bank (WB)
Leading Partner Institutions: Stockholm Environment Institute (SEI)
The RAND Corporation

Objectives
• Study the interactions of a constrained and aging system under future climate uncertainties
• Quantified network infrastructure performance for 4 Power Pools and 7 Water Basins to enable identification of Robust Adaptation strategies
• Integration of water and energy modelling efforts

Work Progress
• OSeMOSYS model of South African Power Pool
• Includes 12 countries; > 620 technologies; > 120 fuels; 48 characteristic time periods for each year; Modelling horizon: up until 2050
• ‘Detailed’ hydro availability representation
• Multiple scenarios showing (a) the impact of reduced hydro availability as compared to a baseline scenario and (b) as compared to a low GI baseline
OSeMOSYS – An Introduction

Sweden Energy Model – Nawfal Saadi (KTH)

- Electricity and heat systems from resource extraction to final use.
- Energy demand of all sectors including residential, industry, agriculture, commercial, services and transport.
- Assessment of energy system’s economical and environmental costs from 2010-2050

- Open source – from data to code
- Bridging the gap between science and policy
- Inspired by the success of the DECC 2050 Pathways Calculator (link)
Sweden Energy Model – Nawfal Saadi (KTH)
In order to consider:

- Additional load on the grid (thus a different capacity need, different emission factor, etc.)
- Benefits of smart charging (mainly avoiding additional peaks, improving emission factor, etc.)
- Benefits of vehicle-to-grid (mainly serving the grid with reserve backup service)
- Investment and operational costs or the long term
Implementation in OSeMOSYS

• The basic modeling structure was used
• Some specific equations and parameters were added and apply only to electric vehicles and related intelligent controls

Some results

Charging facilities capacity

Electricity coming from V2G
Implementing Big Hydro – Taco Niet (British Columbia Institute of Technology)

- Grid Interconnection Group
- Models of Alberta, BC System
- Implemented Big Hydro in OSeMOSYS
- Looking at effects of load/time groupings
- -> Cascading hyrdo power

**Objective:** to understand how net metering of solar rooftop PV may affect the electricity investments in South Africa

Created an energy model of the electricity sector using OSeMOSYS and data from South African TIMES model (SATIM) from the ERC

**Notes on OSeMOSYS usage**
- Required several new parameters involving production limits.
- Very easy to learn and understand how OSeMOSYS works and how to add new parameters, especially for anyone experienced in coding or programming.
- Interface would greatly improve the user-friendliness of OSeMOSYS
OSeMOSYS (Open Source Energy Modelling System)

- **OSeMOSYS** is a fully fledged energy systems linear optimisation model, with **no associated upfront financial requirements**.
- It is (comparatively) easy to adjust the model to anyone’s particular needs!
- It is a collaborative effort -> join in!
- For further information and downloads, visit [www.osemosys.org](http://www.osemosys.org)
Thank you for your attention