IEA-ETSAP Technology Collaboration Programme - Ireland’s experience

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Professor of Energy Policy and Modelling, UCC

IEA ETSAP Workshop on Energy Modelling & Applications
Todai, Tokyo, Dec 14 2016
What is IEA ETSAP?

- One of 39 IEA Technology Collaboration Programmes [www.iea.org/tcp/](http://www.iea.org/tcp/)
- 40 years international **cooperation** on energy **systems** modelling (since first oil crisis)
- **Developing and maintaining** (MARKAL and TIMES) tools
- **Assisting policy decisions** by modelling possible future energy pathways
- Focus on key role of **technology** to meet goals
- Biannual **workshops** and **training**
>200 Users in 73 countries

www.iea-etsap.org
TIMES Model

• linear programming bottom-up energy model
• integrated model of the entire energy system
• medium to long term prospective analysis (20 - 50 years)
  – Demand driven (exogenous) in physical units
• partial and dynamic equilibrium (perfect market)
• optimal technology selection
• minimize the total system cost
• environmental constraints
• energy and emission permits trading
• price-elastic demands
Net Social Surplus

Graph showing the relationship between purchase price (c$/kWh) and global electricity (‘000 TWh, year 2000). The graph illustrates the demand and supply curves, consumer surplus, and producer surplus. The categories include investment, O&M, waste, and fuel.
Minimise System Costs

\[ NPV = \sum_{y \in \text{YEARS}} (1 + d_{r,y})^{\text{REFYR}-y} \cdot \text{ANNCOST}(y) \]

where:

- NPV is the net present value of the total cost (the OBJ);
- ANNCOST(y) is the total annual cost in year y;
- \(d_{r,y}\) is the general discount rate;
- REFYR is the reference year for discounting (2005);
- YEARS is the set of years for which there are costs in the horizon.
Total System Cost

- Capital Costs incurred for investing and dismantling plant;
- Fixed and variable Operation and Maintenance (O&M) Costs;
- Costs for exogenous imports and for domestic resource production;
- Revenues from exogenous exports;
- Delivery costs for required fuels consumed by plant;
- Taxes and subsidies associated with fuel flows and plant activities;
- Salvage value of plant at the end of the planning horizon;
- Welfare loss resulting from reduced end-use demands.
In Summary …

**Given...**

- technology data (e.g. 1300)
- service demands (e.g. 73)
- import fuel prices
- Supply curves
- emission constraints
- other parameters
  - discount rate
  - time horizon definition
  - time slice definition

**Models provide...**

- technology investments
- technology activities
- emission trajectories
- adjusted demands
- marginal energy prices
- imports/exports
- total system cost
TIMES Model

Cost and emissions balance

Domestic sources

Energy prices, Resource availability

Imports

Primary energy

Coal processing

Refineries

Power plants and Transportation

CHP plants and district heat networks

Gas network

Final energy

Industry

Commercial and Public Services

Households

Transportation

Service Demands

GDP

Process energy

Heating area

Population

Light

Communication

Power

Person kilometers

Freight kilometers

Prices

Energy flows

Emissions

Demands

Costs

Capacities

TIMES

Model
Global model (ETSAP-TIAM) now available in addition to modelling tools (TIMES)
15 Region global TIMES model available to ETSAP Contracting Parties
Developed by GERAD and currently updated by ETSAP Collaborative Project
Includes several thousand technologies and models climate forcing
ETSAP-TIAM

- distributed to 10 ETSAP Contracting Parties
- available on request by participants
- several projects have used TIAM:
  - EMF-22, EMF-24 (Stanford, US)
  - Low Carbon Society (NIES, Japan, UK-ERC, ...)
  - IPCC-IAMC, special report on Renewable Scenarios
  - IEA-RETD, Achieving Climate and Energy Security (ACES)
  - EC-FP7, REACCESS on Energy Corridors for EU
  - Asian Modelling Exercise
- currently being updated and re-calibrated in ETSAP project led by DTU
Workshops & Training

- ≥ two workshops per annum on energy systems modelling
  - Cork, Ireland May 30-31 2016
  - Madrid, Spain Nov 17-18 2016
  - Tokyo, Japan Dec 14 2016
  - Sao Paulo, Brazil Jan 30 2017
  - Maryland, USA July 10-11 2017

- joint organiser of IEW (International Energy Workshop), Maryland, USA, July 12-14 2017

- Deliver ≥ 2 training courses for the ETSAP tools biannually
  - Tokyo, Japan Dec 15-16 2016
ETSAP Outputs

Annex XII Report > 300 publications 2011-2013 (including 110 peer-review papers) from:

i) **Global Models:** incl. IEA ETP model, original TIMES Integrated Assessment Model (TIAM), derived TIAM models, ETSAP-TIAM model

ii) **Regional Models:** Pan-European TIMES model, MARKAL-TIMES Models for Europe, Asia and North America.

iii) **National Models** of 32 countries (including China).

iv) **Sub-National Models:** Western China, Reunion Island (France), Lombardy (Italy), Pavia (Italy), and Kathmandu Valley (Nepal).

v) **Local Models** for rural areas and cities in Austria, Germany and Italy, other bigger cities such as Madrid (Spain), Beijing, Guangdong and Shanghai (China), Johannesburg (South Africa) and New York City (United States).

ETSAP Recent Outputs

- Methodologies and case studies
- Demonstrating use of energy systems models
- Support energy and climate policy
- Critical analysis of rich and varied applications
- Includes diverse global case studies
- Role of technology in energy systems

[www.springer.com/gp/book/9783319165394]
UCC Green Campus

- world’s first green flag campus
- world’s 1st university to achieve the ISO 50001 standard
- 4th in world in the UI World Green Metric University Rankings 2015
- Environmental Research Institute 2000
- SFI MaREI Centre 2015
<table>
<thead>
<tr>
<th>Ireland</th>
<th></th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population</strong></td>
<td>4.5m</td>
<td>127m</td>
</tr>
<tr>
<td><strong>GDP PPP</strong></td>
<td>€165bn €36k</td>
<td>€3993bn €31k</td>
</tr>
<tr>
<td><strong>Electricity Consumption</strong></td>
<td>26 TWh 5.6 MWh</td>
<td>988 TWh 7.8 MWh</td>
</tr>
<tr>
<td><strong>Peak Demand</strong></td>
<td>5.1 GW</td>
<td>200 GW</td>
</tr>
<tr>
<td><strong>CO₂ Emissions</strong></td>
<td>35 Mt 7.6t</td>
<td>1265 Mt 10t</td>
</tr>
<tr>
<td>*<em>Installed Capacity</em> **</td>
<td>9 GW</td>
<td>293 GW</td>
</tr>
<tr>
<td><strong>Total Fossil Fuels</strong></td>
<td>7 GW</td>
<td>185 GW</td>
</tr>
<tr>
<td><strong>Hydro</strong></td>
<td>0.2 GW</td>
<td>27 GW</td>
</tr>
<tr>
<td><strong>Wind</strong></td>
<td>2 GW</td>
<td>3 GW</td>
</tr>
<tr>
<td><strong>Solar</strong></td>
<td></td>
<td>34 GW</td>
</tr>
</tbody>
</table>

*Value in italics are per person
Technical support on developing low carbon sector roadmaps for Ireland

Low Carbon Energy Roadmap for Ireland

Paul Jenney, John Corrigan, Alessandro (Alber), Maurizio Gargiulo, Nora Hogan, Denis O’Shea, James O’Flynn, John Hickey and Brian O’Gallagher

20 December 2013

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Informing Energy Policy

A TRADITION OF INDEPENDENT THINKING

UCC
University College Cork, Ireland
Colaiste na hOllscaile Corcaigh

Energy Modelling to Inform the White Paper
December 2015
Brian Ó Gallachóir, Paul Deane, Alessandro Chiodi,
James Glynn and Fionn Rogan.
Climate and Air Ireland - Synergies and Tensions

A GAINS Ireland and Irish TIMES analysis

Andrew Kelly\textsuperscript{a}, Alessandro Chiodi\textsuperscript{b}, Miao Fu\textsuperscript{a}, J.P. Deane\textsuperscript{b}, Brian P. Ó Gallachóir\textsuperscript{b}

\textsuperscript{a} EnvEcon, Dublin, Ireland

\textsuperscript{b} Energy Policy and Modelling Group, Environmental Research Institute, University College Cork, Ireland
Ireland 2050 - BaU

TFC 200 TWh
Elec = 17% =34 TWh
=33% growth on 2015
Ireland 2050 CO2-80

TFC 136 TWh
Elec 25% =34 TWh
CO2 MAC and Sectoral Emissions Trajectories in 2050 under 0-96% Carbon Constraints

The trends of CO2 marginal abatement costs and emissions in each sector under 1-100% mitigation targets in 2050 compared to 1990. The interim targets in 2030 and 2040 are linearly interpolated. The model found no feasible solutions above 96% reduction target. The MAC curve is not linear and a tipping point can be identified at 80% reduction constraint.
Multi-Model Approach 1 – Power Systems

**Step 1**
- TIMES Model Parameters
  - Target year: 2020
  - RES40 scenarios

**Step 2**
- Input/Output:
  - Generation Portfolio
  - Plants AF
  - Efficiencies

**Step 3**
- Process:
  - Half hourly chronological demand profile based on historical profile shape

**Step 4**
- Model Setup
  - LP/MIP
  - Xpress MP Solver
  - 1 Year Simulation Horizon
  - 365 Simulation Steps
  - 30 Minute Resolution

**Step 5**
- PLEXOS Model Parameters
  - Min stable levels
  - Ramp rates/limits
  - Start costs
  - Min up and down times

**Step 6**
- Outputs:
  - CO₂ Emissions by Region, Fuel and Plant
  - Capacity factors by Plant Type
  - Wind Curtailment

**Step 7**
- Wind Production Profiles
  - Vary wind production profile
  - Determine effect on reliability of system

**PLEXOS Modeling Tool**

**Input/Output:**
- 2020 Els Demand (Annual)
- 2020 Peak Demand

**Models Input:**
- Electricity demand shape
- Half hourly chronological wind profiles

**TIMES Modeling Tool**

**Process:**
- Seasonal Fuel Prices
- Timeslice Definition
- Emission Factors
Japan

OPGM Model:
- Cost Minimization Model
- 10-min consideration of Wind & PV

Global Energy Model (DNE21):
- Cost Minimization Model
- Temporal Resolution: 4 hours

More plausible evaluation of wind & PV integration in rough time-resolution model

Ireland

Irish TIMES:
- Energy Systems Model
- Low Carbon Roadmap
- 12 time slices

PLEXOS_Ireland:
- Dispatch Model
- 15 min – 1 hr temporal
- power plant detail

Irish TIMES:
- SNSP = 75%
- Equiv 50% VRE

More plausible power system results in Irish TIMES

Extract 2020 or 2030 power system results

Similar approach in Japan
Quantifies Wind Curtailment

Wind integration reduced.
What about Agri-GHG?
Multi-model 2: AGRI-TIMES

Technology Component

Livestock sector
Tillage sector
Energy Crops

Supply Component
Land
Water

Service Demands
Livestock (6)
Tillage (6)

Fossil Fuels Imports
Domestic Fossil Fuels
Renewable Potentials
Renewable Imports

Irish TIMES (Energy System)

CO₂, NH₃, N₂O

Agriculture (Energy)(1)
Services (12)
Residential (20)
Transport (13)
Industry (13)
Non-Energy (1)
## GHG sectoral reductions (rel. 1990)

<table>
<thead>
<tr>
<th>Sectors</th>
<th>2005</th>
<th>2030</th>
<th>2050</th>
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<tbody>
<tr>
<td></td>
<td>GHG-50</td>
<td>GHG-60</td>
<td>GHG-50</td>
</tr>
<tr>
<td>Power Generation</td>
<td>37%</td>
<td>-56%</td>
<td>-55%</td>
</tr>
<tr>
<td>Industry (incl. process)</td>
<td>26%</td>
<td>-35%</td>
<td>-39%</td>
</tr>
<tr>
<td>Transport (incl. int. aviation)</td>
<td>149%</td>
<td>95%</td>
<td>68%</td>
</tr>
<tr>
<td>Residential and services</td>
<td>1%</td>
<td>-58%</td>
<td>-60%</td>
</tr>
<tr>
<td>Agriculture (CO₂, non-CO₂)</td>
<td>-3%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>Transformation</td>
<td>62%</td>
<td>-100%</td>
<td>-100%</td>
</tr>
<tr>
<td>Energy</td>
<td>44%</td>
<td>-30%</td>
<td>-36%</td>
</tr>
<tr>
<td>Non-Energy</td>
<td>-3%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>24%</strong></td>
<td><strong>-17%</strong></td>
<td><strong>-20%</strong></td>
</tr>
</tbody>
</table>
Multi-model 3: TIMES-MSA

Primary energy prices, Resource availability

\[ \text{Min } NPV = \sum_{r=1}^{R} \sum_{y \in \text{YEARS}} (1 + d_{r,y})^{\text{REFYR}-y} \cdot \text{ANNCOST}(r, y) \]

Partial Equilibrium

Primary energy

- Domestic sources
- Imports

Transformation
- Refinery
- Power Plants
- Gas Network
- Briquetting...

Final energy

- Gas
- Natural Gas
- Electricity

Consumption
- Industry
- Services
- Transport
- Residential...

Service Demands

- Heat
- Light
- Motion
- Res Heat
- Ind Heat
- Person Km
- Freight Km...

MACRO Stand Alone (MSA) General Equilibrium

Macroeconomic Model

- Energy Costs
- Demand Response
- MACRO Stand Alone (MSA) General Equilibrium
- Macroeconomic Model

Max \[ U = \sum_{t=1}^{T} \sum_{r} nwt_{r} \cdot pwt_{t} \cdot dfact_{r,t} \cdot \ln(C_{r,t}) \]

Labour
- Capital
- Investment
- Consumption

Capacities
- Prices
- Energy Flows
- Emissions
- Costs
- GDP

What about impacts on GDP? Multi-model 3: TIMES-MSA
Quantify GDP ‘loss’ of mitigation

- Estimates potential reduction in macro consumption
- Energy Service Demand reductions drive additional TFC reductions
- Scenario-relative reductions in emissions and emission costs
Multi-model 4: TIMES and Policy Simulation
Simulating Policy Measures – Policy Roadmap

Multi-model 4: Energy Efficiency Policy Roadmap

Total Final Consumption (GWh) for all scenarios

Reference Scenario: 157.4 GWh
Efficient Driving: -1.6 GWh
High Efficiency Vehicles (best): -1.6 GWh
Mileage Reduction: -2.7 GWh
Private Car Occupancy: -6.9 GWh
Modal Shift: -5.7 GWh
Building Regulations 2011: -0.8 GWh
Building Regulations 2013: -1.2 GWh
CFL Lighting: -1.8 GWh
Retrofit (best): 0.3 GWh
GVA Change: 8.2 GWh
Efficiency Change: -0.7 GWh
Double-counting potential: -1.9 GWh
Energy Efficiency+ Scenario: 135.8 GWh
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