Assessing carbon mitigation options for Ireland in 2050 using marginal abatement cost curves based on an energy system model

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A TRADITION OF INDEPENDENT THINKING

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UCC Energy Policy and Modelling Group (EPMG)

SFI MaREI Centre

MARINE RENEWABLE ENERGY TECHNOLOGIES	DEVICE DESIGN, TESTING AND EVALUATION	TIDAL ENERGY	WAVE ENERGY	OFFSHORE WIND ENERGY
MATERIALS & STRUCTURES	NOVEL MATERIAL DESIGN	STRUCTURAL SYSTEMS	MARITIME STRUCTURES ENGINEERING	-
OBSERVATION & OPERATIONS	MARINE OPERATIONS, MAINTENANCE & MANAGEMENT	OCEAN OBSERVATION	EARTH OBSERVATION	FIELD ROBOTICS
COASTAL & MARINE SYSTEMS	MARINE ECOLOGY	MARINE GOVERNANCE	COASTAL DYNAMICS AND MARINE SYSTEMS MODELLING	RESOURCE ASSESSMENT
BIOENERGY	BIOENERGY SYSTEM DESIGN AND ANALYSIS	SUSTAINABLE BIORESOURCE ASSESSMENT	BIOENERGY LIFE-CYCLE ANALYSIS	-
ENERGY POLICY & MODELLING	ENERGY SYSTEMS MODELLING	LOW CARBON OPPORTUNITIES	ENERGY POLICY	-
ENERGY MANAGEMENT	DEMAND SIDE OPTIMISATION	EN[illegible]NTEGRATION [illegible]ORAGE	INTELLIGENT EFFICIENCY	-

Brian Ó Gallachóir Principal Investigator

Energy Systems Modelling	Economic Opportunities	Energy Policy
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Diarmuid Foley (EU Nuclear)		Kathleen Krah (Spatial Heat Analysis)
		Advertised (Agencies & intermediaries)

3 Research Fellows, 5 Post-Doctorates, 15 PhD Students, 3 MEngSc Students

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Energy Policy Tool: Irish TIMES model

EU Target: 80% - 95% GHG reduction in 2050 relative to 1990 level (based on 2°C consistent scenario)

What is the appropriate mitigation target for Ireland?

Irish TIMES model

Integrated model of Ireland's entire energy system over mid to long term (20-100 years), inputs include:

- Potential of primary energy supply
- Future energy needs (**73 service demands**)
- Environmental constraints (e.g. **max CO_2 emissions**)
- Existing and future technologies (**1300 technologies**)

Supply energy services at **least cost** based on linear optimization

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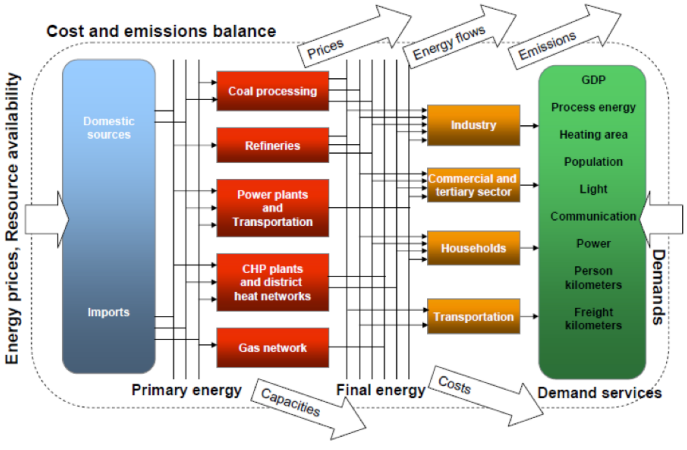
Irish TIMES Model Schematics



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Objective

Research target

Project: Our 2050 – Opportunities for Ireland in a Low Carbon Economy, Resilient Energy Futures

Use Irish TIMES energy systems model to explore low carbon energy futures and identify resilient technologies under uncertainties

Paper Objective

Identify cost-effective mitigation options with marginal abatement cost curves derived from Irish TIMES model

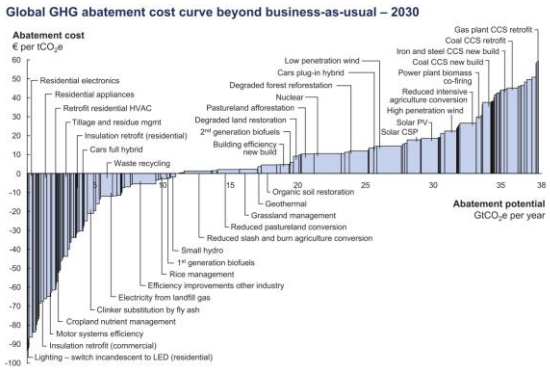
Expert Basis MACC

Marginal abatement cost (MAC) measures the costs accrued for an additional unit of CO2 abatement

Expert Basis MACC

Assesses the cost and emission reduction potential of each measure individually

Rank their MAC from low to high with step-wise graph



Combine MACC and Irish TIMES model

ESOM based MACC

Impose increasingly more stringent CO2 constraints, and graphically relates MAC calculated at different constraint levels

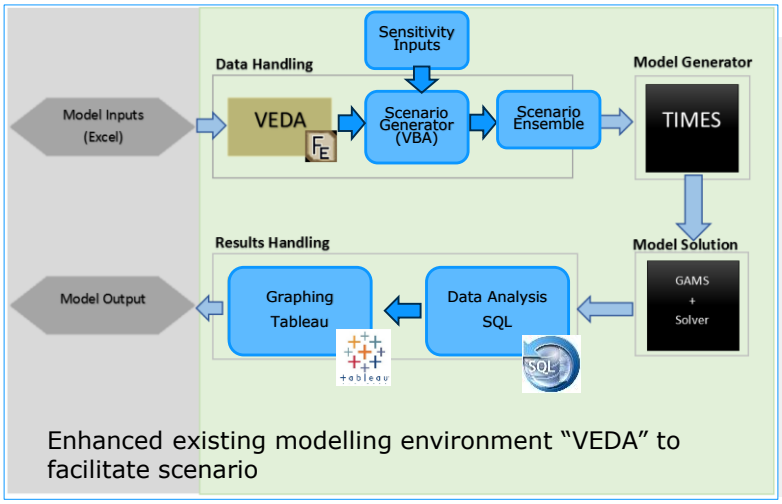
Compared to conventional scenario analysis

- Rank cost effectiveness of mitigation technologies
- Determine mitigation potential
- Characterize impacts on energy systems using trends instead of points

Compared to expert basis MACC

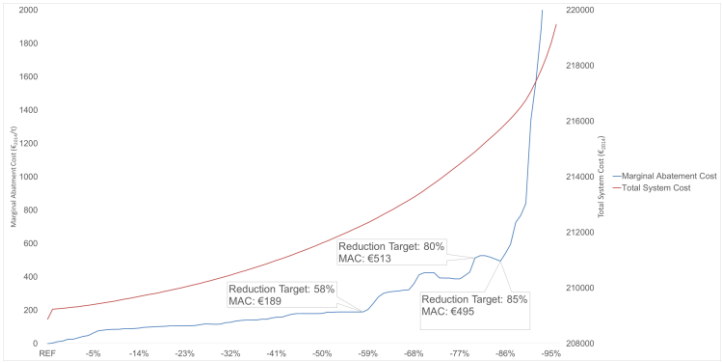
- Interactions among technologies
- Capture inter temporal effects
- Better treatment of uncertainties

Generate large number of scenarios for MACC



Enhanced existing modelling environment "VEDA" to facilitate scenario

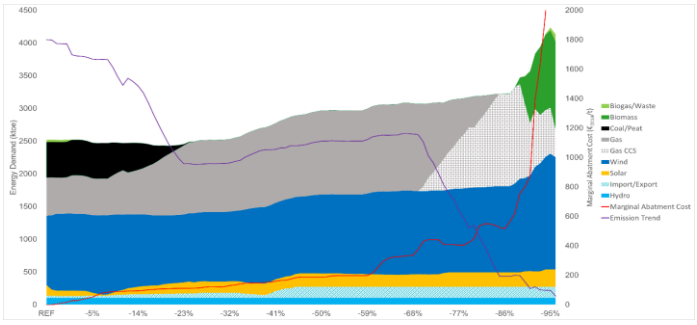
MACC and total system cost in 2050



- Upward sloping: increasing marginal effort
- Fluctuations due to intertemporal dynamics
- Tipping point at 85% CO2 reduction

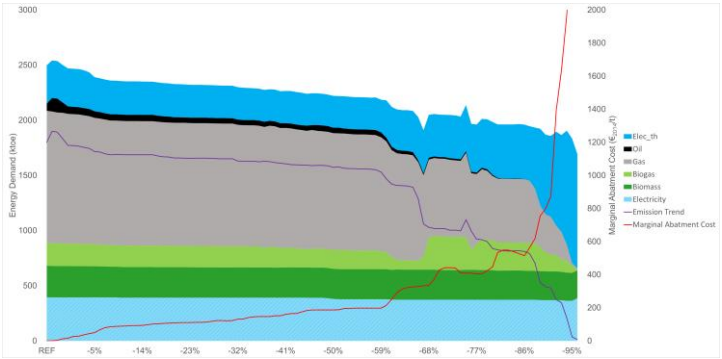
Cause of tipping point

Emission and fuel consumption trend of power generation



Cause of tipping point

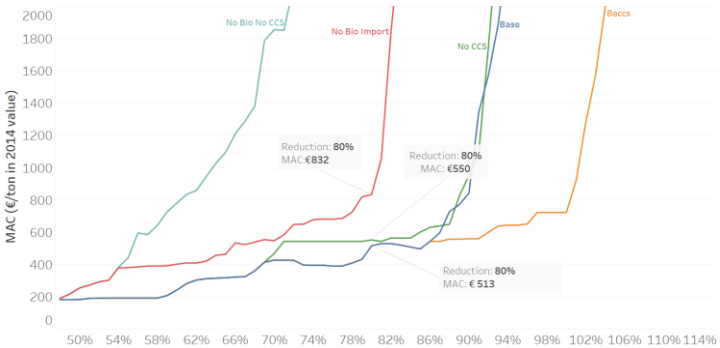
Emission and fuel consumption trend of residential sector



- Electrifying residential and commercial heat increases electricity demand
- High investment cost to expand generation capacity significantly increases MAC

Explore uncertainties

- Availability of **bioenergy import** and **capture and sequestration (CCS)** technologies have great impacts on MACC
- **Bio-energy with carbon capture and storage (BECCS)** plays a critical role in deep decarbonization



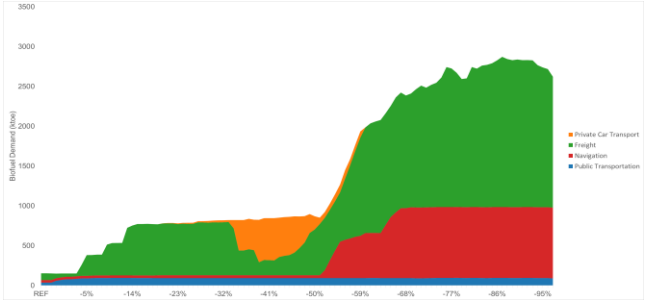
Ranking of Mitigation Technologies

- **Mitigation Potential:** LMDI(Logarithmic Mean Divisia Index) decomposition analysis to determine the amount of CO2 mitigation due to structural changes of using new technologies
- **MAC Range:** the MAC range the mitigation technology penetrates and replaces carbon intensive technology

Mitigation Option	Sector	MAC Range (€$_{2014}$/tCO$_2$)	Mitigation Potential Rel. REF Scenario (kt)
Gas Power Plants	Power Generation	0-108	3500
Biomass Boilers	Industry	0-239	2900
Electric Heat Pumps	Commercial	84-187	400
Coal CCS for Cement Production	Industry	107-141	2400
PIH and EV	Transport	105-240	6000
Navigation Biofuel	Transport	180-320	2800
Freight Biofuel	Transport	42-518	5250
Gas CCS Plants	Power Generation	359-495	7500
Electric Radiators	Commercial	726-2364	800
Electric Boilers and Radiators	Residential	541-2364	1500
Biomass Plants	Power Generation	769-3964	8100
Solar Heater	Residential	2769-3964	1400

Technology interactions

- **Flip-flop behavior:** Competition among technologies for same fuel
- **Razor edge effect:** Possibility of similar alternative scenarios



Biofuel Demand in Transport Sector for different end uses

Future work

Perform systematic uncertainty analysis to evaluate technology robustness

- **Global sensitivity analysis:** Unpack model structure and quantify influences of uncertainties
- **Stochastic Programming:** Hedging strategy under uncertainties
- **Modelling to generate Alternatives (MGA):** Systematically explore near-optimal solutions for alternative scenarios

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Thank You!

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EIRGRID
Energy exemplar
e4sma
Gas Networks Ireland
cagasc
PSI
KTH
UCD DUBLIN
NTR FOUNDATION securing a greener future
epa Environmental Protection Agency
Roinn Cumarsáide, Fuinnimh & Acmhainní Nádúrtha
Department of Communications, Energy & Natural Resources
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