1st IAEE Online Conference
7th – 9th June 2021

Timely and cost-effective decarbonisation –
A case study from Cyprus

Chryso Sotiriou
Cyprus University of Technology
Theodoros Zachariadis
Cyprus University of Technology & The Cyprus Institute

Cyprus University of Technology

01 POLICY CONTEXT

02 IDENTIFICATION OF COUNTRY-SPECIFIC MEASURES

03 IDENTIFICATION OF OPTIMAL MIX & TIMING

04 COMBINATION OFABATEMENT MEASURES & CARBON TAX

05 WRAP-UP

INTERNATIONAL

Paris Agreement

Objective to keep the global temperature increase to well below 2°C and pursue efforts to keep it to 1.5°C

* Translated into reduction of GHG emissions

EU

The EU has set itself targets to reduce its GHG emissions up to 2050

Medium-term: 2030
Long-term: 2050

2030 Climate and Energy Framework

EU targets

- At least **40%** cuts in **GHG emissions** (from 1990 levels)
- At least 32% share for renewable energy
- At least 32.5% improvement in energy efficiency

The 40% GHG target is implemented by:

- EU Emissions Trading System (ETS) (43% from 2005)
- **Effort Sharing Regulation (ESR)** (30% from 2005)

EU ETS

- power sector
- energy-intensive industry sectors
- commercial aviation

Non-ETS or ESR

- transport
- buildings
- agriculture
- waste

NATIONAL ACTION NEEDED
Member States are responsible for national policies and measures

Current non-ETS Target:

Cyprus
24%

OBJECTIVE

Explore mitigation pathways for non-ETS sectors for Cyprus, combining **GHG reduction measures** coupled with the implementation of a gradually increasing **carbon tax** in these sectors.

STEPS taken

IDENTIFICATION OF COUNTRY-SPECIFIC MEASURES

Marginal Abatement Cost Curve

IDENTIFICATION OF OPTIMAL MIX & TIMING

Cost-Optimisation Model

COMBINATION OF ABATEMENT MEASURES & CARBON TAX

Cost-Optimisation Model & Long-Term Energy Forecast Model

Identification of country-specific measures

Sotiriou C., Michopoulos A. and Zachariadis T., **On the cost-effectiveness of national economy-wide greenhouse gas emissions abatement measures**.
Energy Policy 128 (2019) 519–529, **doi: 10.1016/j.enpol.2019.01.028**

APPROACH

► Covers all non-ETS sectors; **residential, tertiary, industry, road transport, agriculture**

► Different types of mitigation measures; **improving energy efficiency, switching to low- or zero-carbon fuels, and inducing behavioural change towards public transport modes**

Regarding the Mitigation Measures:

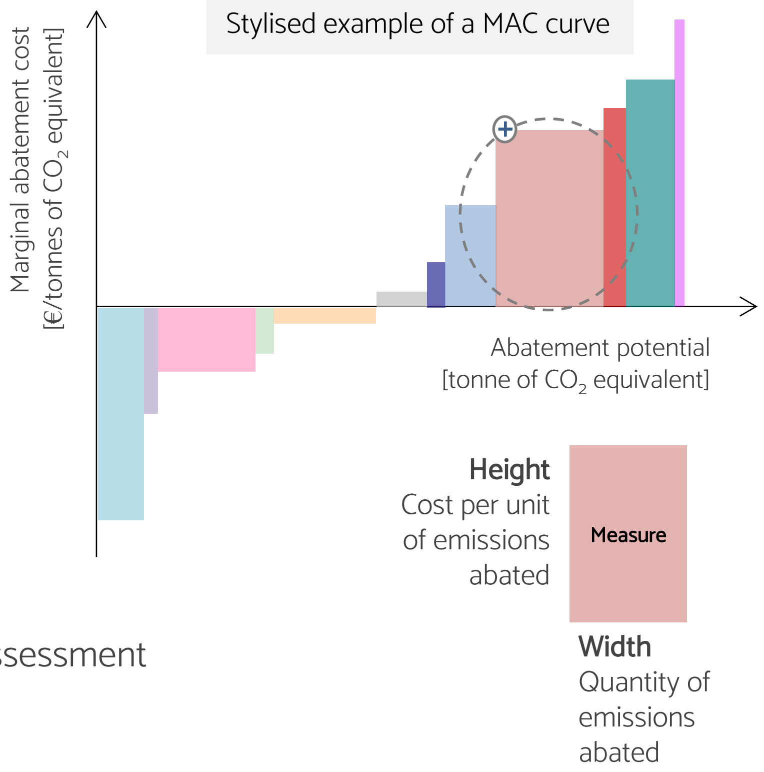
- Identification of **country-specific climate change options**
- **Comprehensive data collection effort** for selecting economic and technical data
- **Nationally appropriate data** were applied that are mainly derived from local market information and judgement of national experts
- Early national studies have been used providing **country-specific projections** of fuel prices in Cyprus and economic and technological data for energy efficiency measures for the building sector, etc.

Bottom-up “measure-explicit” MAC Curve

- A large number of emission abatement measures is identified
- Engineering and economic information are collected
- Assessment **of each measure’s abatement cost** and **potential**

$$AC(j) = \frac{c_j^{mit} - c_j^{ref}}{E_j^{ref} - E_j^{mit}}$$

$$C_j = \sum_{t=0}^{T} \frac{IC_{j,t}}{(1+r)^t} + \frac{MC_{j,t}}{(1+r)^t} + \frac{FC_{j,t}}{(1+r)^t} \quad \text{and} \quad E = A \cdot EF_{GHG}$$



METHODOLOGY

► **Social planner’s approach**, an economic (and not a financial) assessment

► **Inclusion of GHG and air pollution costs**
Additional side-benefits of reduction in air pollutant emissions are considered; external costs of GHG, nitrogen oxide and sulphur dioxide emissions are added => AC with externalities

Measures	Sub-categories
Full Renovation	Single- and Multi-Family Buildings constructed pre- and post-2008
Roof Insulation	Single- and Multi-Family Buildings constructed pre- and post-2008
Wall Insulation	Single- and Multi-Family Buildings constructed pre- and post-2008
Pilotis Insulation	Multi-Family Buildings constructed pre- and post-2008
Heat Pumps	Single- and Multi-Family Buildings constructed pre- and post-2008
Windows Replacement	Single- and Multi-Family Buildings constructed pre- and post-2008
Lightbulbs/electric appliances	Single- and Multi-Family Buildings constructed pre- and post-2008
Solar thermal water heaters	Single- and Multi-Family Buildings constructed pre- and post-2008
Full Renovation	Buildings constructed pre- and post-2008
Roof Insulation	Buildings constructed pre- and post-2008
Wall Insulation	Buildings constructed pre- and post-2008
Pilotis Insulation	Buildings constructed pre- and post-2008
Heat Pumps	Buildings constructed pre- and post-2008
Windows Replacement	Buildings constructed pre- and post-2008
Lightbulbs/electric appliances	Buildings constructed pre- and post-2008
Solar thermal water heaters	Buildings constructed pre- and post-2008
Combined heat and power generation	Buildings constructed pre- and post-2008
Replacement of electricity transformers	
Replacement of electric motors	
Replacement of electric inverters	
Installation of LED light bulbs	
Installation of photovoltaics	
Replacement of fuel oil fired burners	
Combined heat and power generation	
Promotion of Public Transport	
Electric Private & Light Goods Conveyance Vehicles	
Low-Carbon Trucks	
Anaerobic Digestion for Animal Waste	

- Residential
- Services
- Industry
- Road Transport
- Agriculture

DATA

Residential

- Data from a **detailed national study**
- Distinguish **two building types**: single-family houses and multi-family buildings
- Classify buildings according to **two construction periods**: buildings completed before 2008 and from 2008 onwards
- **Cost and (useful) energy saving** data for each individual measure for the four different classes of buildings
- **Main technologies** used for space heating and cooling in residential buildings by construction period, and their corresponding average thermal **efficiency**.
- **Number of interventions** foreseen for residential buildings

Services

- Data from a **detailed national study**
- Classify buildings according to **two construction periods**: buildings completed before 2008 and from 2008 onwards.
- **Cost and (useful) energy saving** data for each individual measure for the two different classes of buildings.
- **Main technologies** used for space heating and cooling in office buildings in Cyprus by construction period, and their corresponding average thermal **efficiency.**
- **Number of intervention**s foreseen for office buildings

Industry

- In-situ visits and interviews with the energy managers of the plants.
- Data provided by local firms that are highly involved with the design, construction and maintenance of industrial equipment.
- Cost and energy saving data for each individual measure.

Road Transport

- Data including a) investment cost, b) maintenance cost and c) lifetime for each measure
- **Fuel consumptions** by different mode and fuel
- **Average kilometres travelled** each year
- **National estimates** on the number of yearly new registrations
- **Occupancy rate** of different modes

Agriculture

- **forecast of the evolution of the animal population** in Cyprus by animal type.
- **specific waste-related information** for the kinds of animals whose waste is most likely to be utilised in anaerobic digestion.
- investment and operation cost of installations that will have to use these additional amounts of animal waste.

Baseline analysis

Only non-ETS emissions are considered. This means that:

a) measures reducing electricity-generated emissions are excluded; and

b) abatement calculations include only the reduction of direct GHG emissions, thereby ignoring the indirect effect on emissions due to changes in electricity consumption, which would be subject to the ETS

Measures	Sub-categories
Full Renovation	Multi-Family Buildings constructed pre-2008
Roof Insulation	Multi-Family Buildings constructed pre-2008
Wall Insulation	Single- and Multi-Family Buildings constructed pre-2008
Pilotis Insulation	Multi-Family Buildings constructed pre-2008
Heat Pumps	Single- and Multi-Family Buildings constructed pre-2008
Combined heat and power generation	
Replacement of fuel oil fired burners	
Combined heat and power generation	
Promotion of Public Transport	
Electric Private and Light Good Conveyance Vehicles	
Low-Carbon Trucks	
Anaerobic Digestion for Animal Waste	

Grey	Residential
Green	Services
Orange	Industry
Light blue	Road Transport
Dark blue	Agriculture

COST-EFFECTIVENES

Measure	Abatement Cost [€'2015/ tonnes of CO_2 equivalent]	Cost Category
Heat Pumps, Single-Family building constructed pre-2008	< 0	Net social benefit
Cogeneration in Services	< 0	
Roof Insulation, Multi-Family building constructed pre-2008	< 0	
Heat Pumps, Multi-Family building constructed pre-2008	< 0	
Cogeneration in Industry	< 0	
Replacement of industrial burners	< 0	
Anaerobic Digestion for Animal and Municipal Waste	4	Modest abatement cost
Pilotis Insulation, Multi-Family building constructed pre-2008	59	
Introduction of Electric Private and Light Good Conveyance Vehicles	59	
Promotion of Public Transport	69	
Introduction of Low-Carbon Trucks	95	
Full Renovation, Multi-Family building constructed pre-2008	> 1,000	High abatement cost
Wall Insulation, Multi-Family building constructed pre-2008	> 1,000	
Wall Insulation, Single-Family building constructed pre-2008	> 1,000	

Residential
Services
Industry
Road Transport
Agriculture

Identification of optimal mix & timing

Sotiriou C. and Zachariadis T., **Optimal Timing of Greenhouse Gas Emissions Abatement in Europe**. Energies 12 (2019), 1872; **doi: 10.3390/en12101872**

Cost-optimisation model

Examine least-cost GHG emission abatement pathways, taking into account:

a) emission reduction objectives for two years: 2030 and 2050; and
b) the speed of implementation of each measure; variable over time to reflect the inertia

Set of options described by:

- their emissions **abatement cost**
- their emissions **abatement potential**, and
- their emissions **speed of implementation**

► selection of the amount of abatement to be implemented by measure each year, in order to achieve future emission reduction targets at the minimum cost

Objective function: the total present cost of abatement, *TC*
Decision variables: the abatement potential of each measure, *a*

Models' Components

Objective Function: Minimisation of the total discounted cost,

$TC = \sum_j \sum_t \frac{TC_{j,t}}{(1+r)^t}$ and $TC_{j,t} = \boldsymbol{AC_{j,t}} \cdot \sum_i \frac{a_{j,t}}{(1+r)^i}$

Decision Variables: Emissions abatement achieved for measure for the time period

Constraints: Maximum emissions abatement,

$\sum_t a_{j,t} \leq fa_j$

Maximum implementation speed,

$a_{j,t} \leq s_{j,t}$

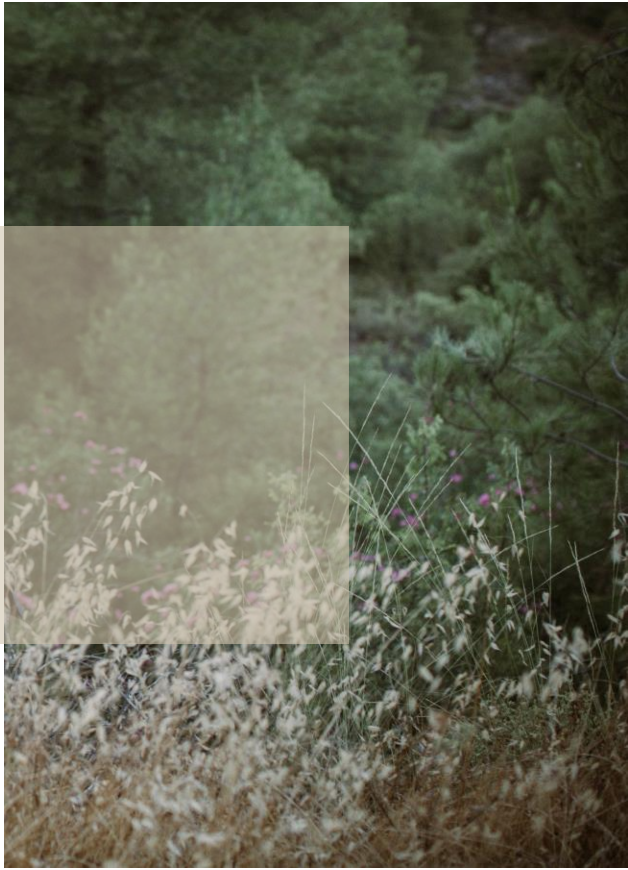
Dependence of implementation speed and cumulative abatement,

$s_{j,t} = f\left(\sum_{i=1}^{t} a_{j,t}\right)$

Emissions reduction target,

$\sum_j \sum_{t=1}^{m} a_{j,t} \geq a_m^{objective}$

Combination of measures & carbon tax



Sotiriou C. and Zachariadis T., **The Importance of a Carbon Tax for Timely and Cost-effective Decarbonisation – A Case Study from Cyprus**. Economic Instruments for a Low-carbon Future. Critical Issues in Environmental Taxation XXII, Edward Elgar Publishing, 2020.
doi: 10.4337/9781839109911

Models :

- Cost-optimisation model
- **Long-term energy forecast model**

  ▼

  To assess the effect of implementing a carbon tax on aggregate energy use and carbon emissions a long-term energy forecast model was employed that is being used by energy authorities of Cyprus for national planning.

  This determines the emissions in future years and hence the required GHG abatement in order to reach emission targets of 2030 and 2050.

  For different carbon tax scenarios, the energy forecast model assesses the changes in fuel consumption and carbon emissions up to 2050.

  The carbon emission reductions are then used as an exogenous input to the optimisation model described in the previous paragraphs in order to determine cost-effective decarbonisation pathways. 1

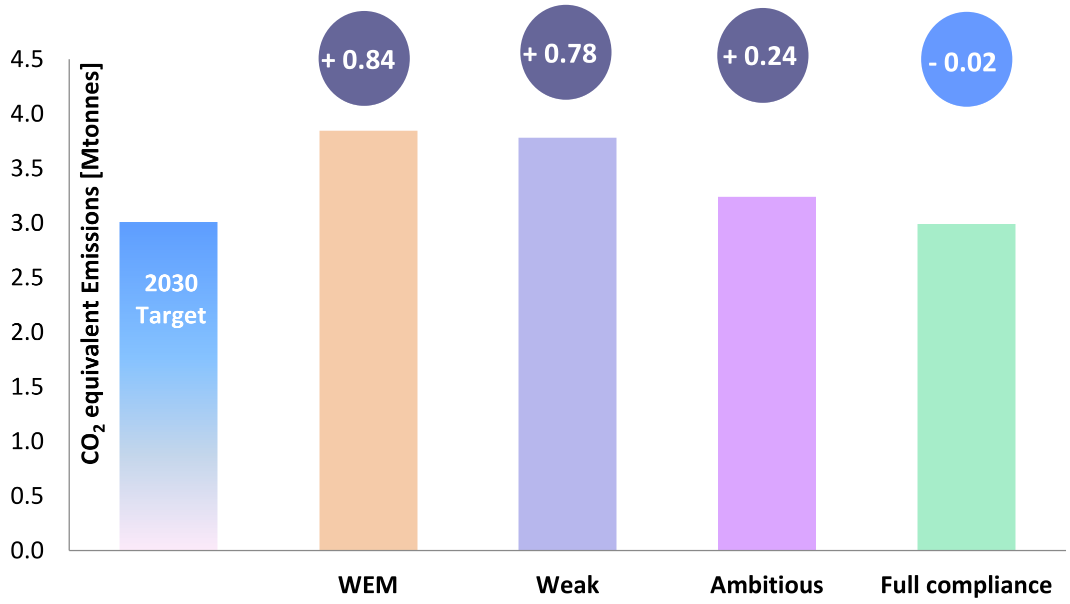
SCENARIOS

Three simulations are being performed having in mind the 2030 target:

'weak' scenario	'ambitious' scenario	'full compliance' scenario
Measures up to 30 Euros per tCO_2 equivalent	Measures up to 120 Euros per tCO_2 equivalent	All measures
	Carbon tax of 120 Euros'2015 per tCO_2 equivalent (period 2020-2025, at an annual increase of 20 Euros'2015 per tCO_2 equivalent)	Carbon tax of 298 Euros'2015 per tCO_2 equivalent by 2030 (period 2020-2030, starting from 27 Euros'2015 per tCO_2 equivalent)

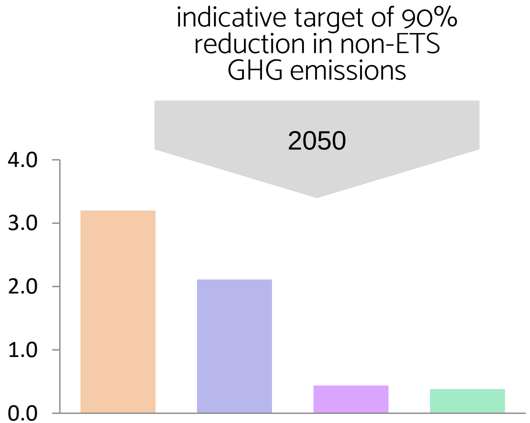
*All scenarios are compared with the "With Existing Measures" (WEM) scenario prepared by the Government of Cyprus in its National Energy and Climate Plan (NECP)

Emissions of non-ETS GHG for 2030

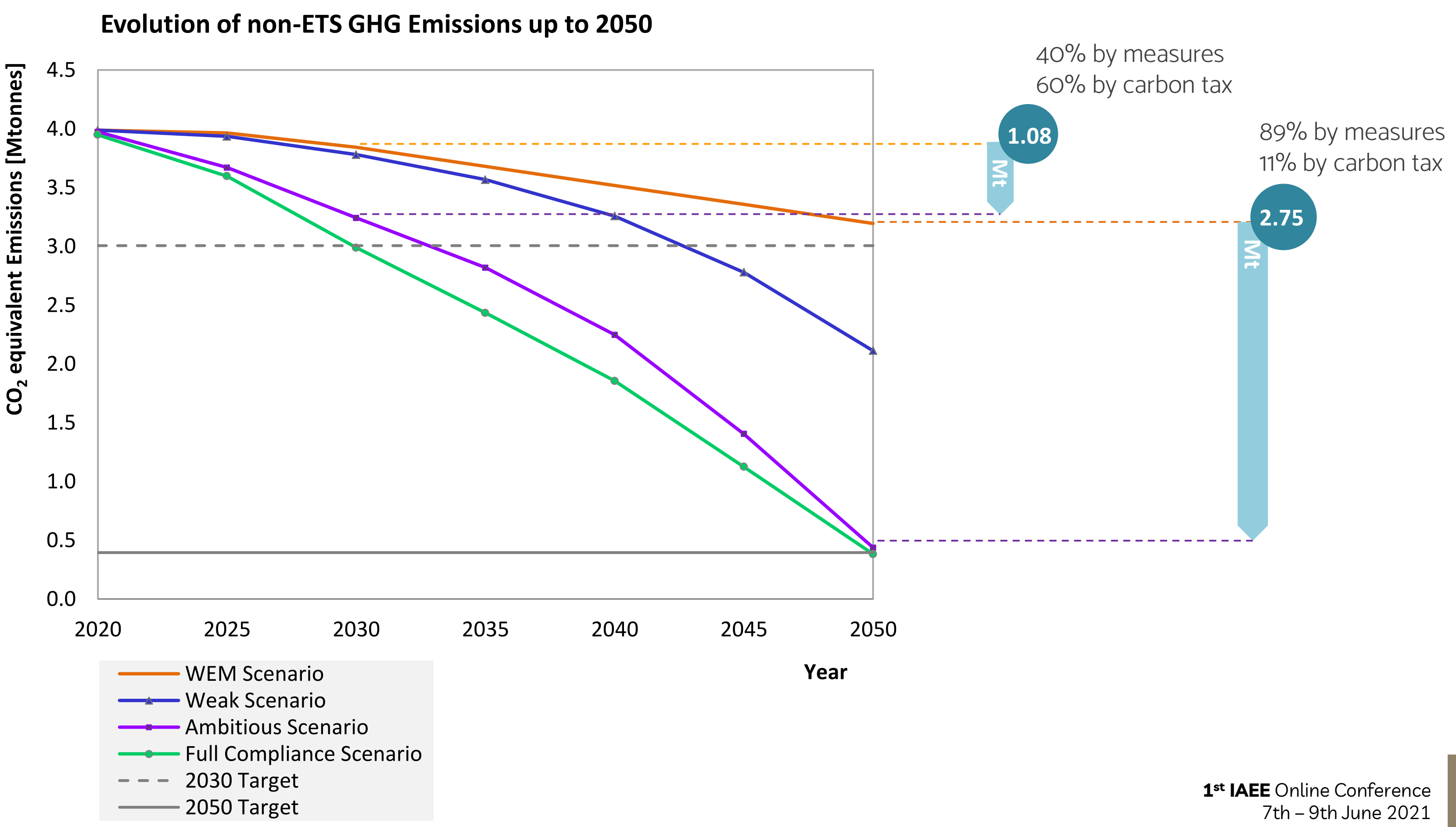


\+ / - Difference compared to 2030 level set by the EU target [Mtonnes]

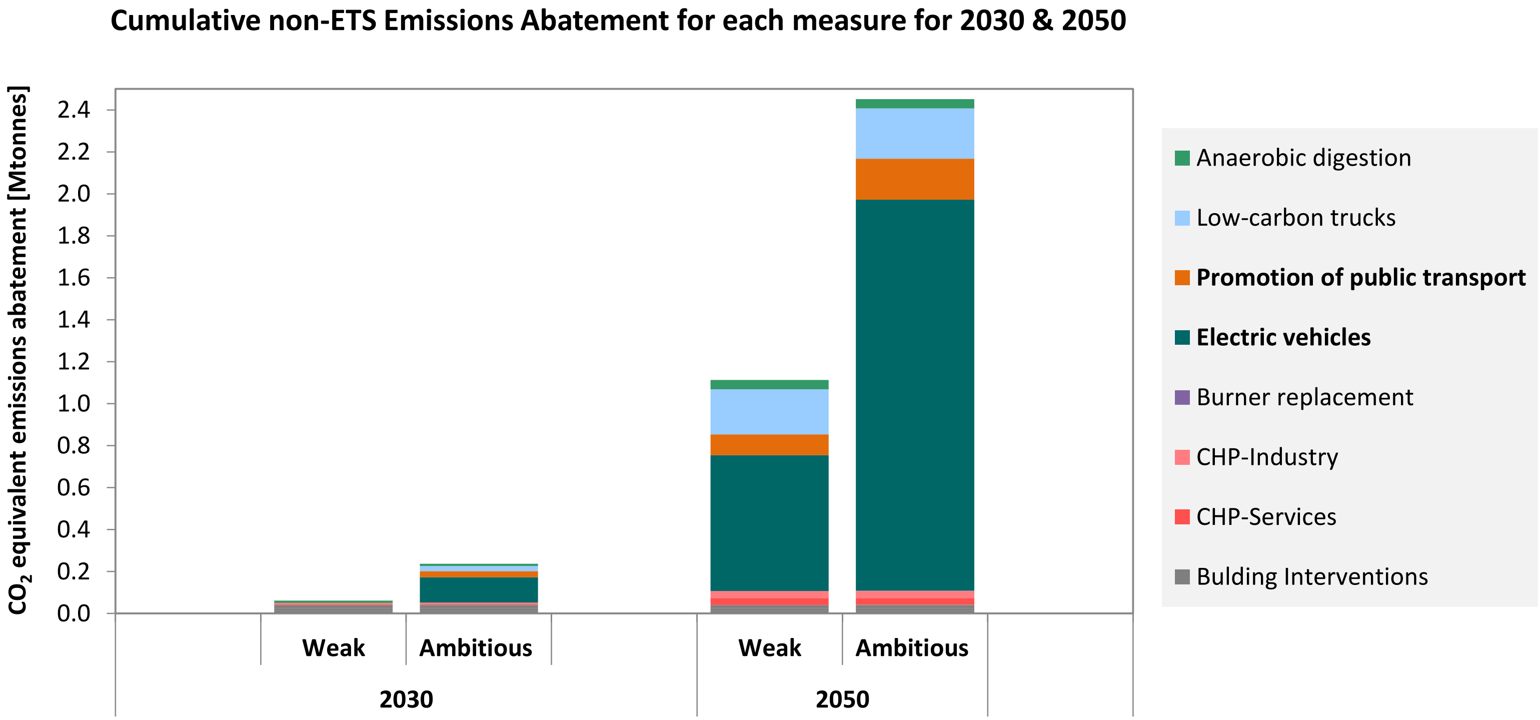
Scenario	Emissions gap [ktonnes of CO_2 equivalent] for:	
	2030 target	2050 target
WEM	837	2,799
Weak	776	1,687
Ambitious	237	41
Full compliance	0	0



MAIN FINDINGS

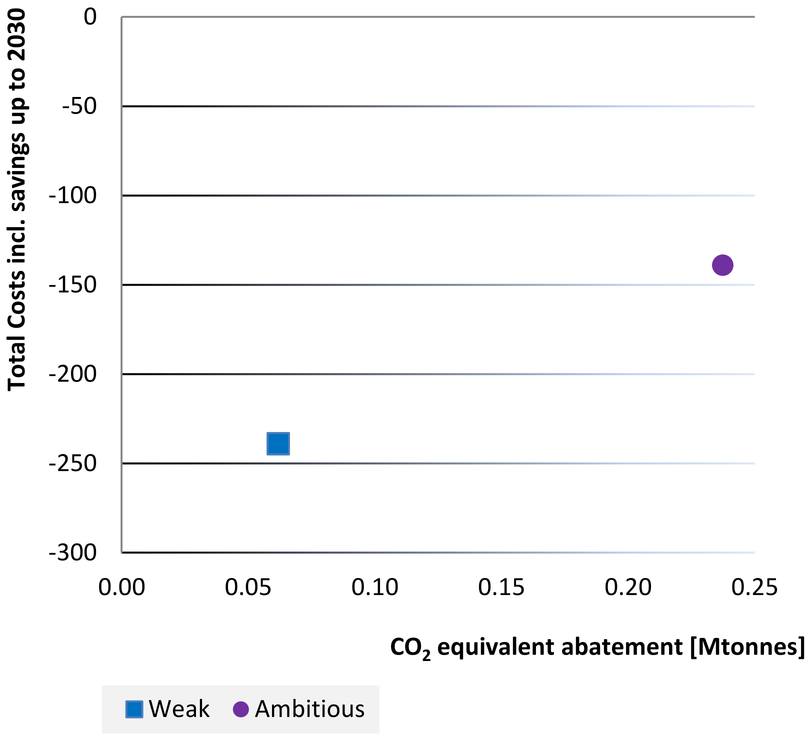


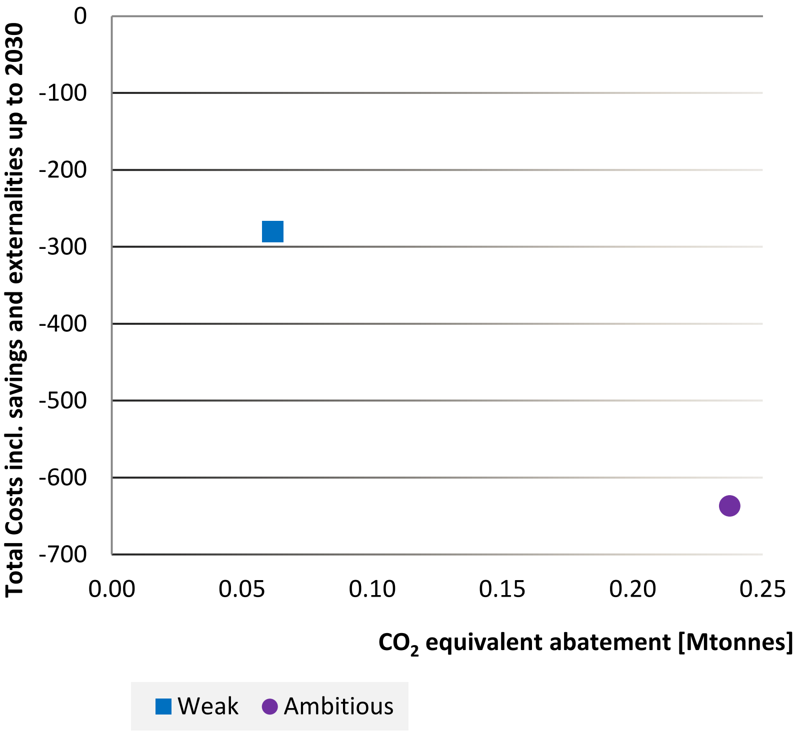
Relationship between 2030 abatement targets of varying ambition (weak and ambitious scenarios) and the possibility for a country to achieve a strong 2050 decarbonisation target



#Lock-in effects are present for 2030 abatement target of lower ambition

#ambitious policies result in the highest investment needs but they turn out to be the socially optimal approach because they can improve air quality and human health to a considerable extent while avoiding adverse impacts from climate change





MAIN FINDINGS

WRAP-UP

- deep decarbonisation in the country's non-ETS sectors is very demanding;

- adoption of greenhouse gas reduction measures coupled with the implementation of a gradually increasing carbon tax in these sectors is necessary;

- 'lock-in' effect - prioritising abatement options which are cheaper and faster to implement but do not have sufficient potential to meet ambitious abatement targets must be avoided;

- early deployment - implementation of seemingly expensive measures is necessary in order to achieve serious decarbonisation in 2050.

1st IAEE Online Conference
7th – 9th June 2021

THANK YOU

Does anyone have any questions?

Chryso Sotiriou
cx.sotiriou@edu.cut.ac.cy