Co-funded by the Horizon 2020 programme
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Cyprus University of Technology

ODYSSEE-MURE

National seminar in the frame of the project

"ODYSSEE-MURE, Monitoring EU Energy Efficiency First Principle and Policy Implementation"

Challenges of the 'Fit-for-55' policy proposals for Energy Efficiency and Decarbonisation in Cyprus, with Emphasis on the Transport Sector

12 November 2021

Location:

The Cyprus Institute, Andreas Mouskos Auditorium

Konstantinou Kavafi 20, 2121 Aglantzia, Nicosia

AGENDA

13.00 - 13.15	Welcome – Presentation of the Odyssee-Mure project *(Theodoros Zachariadis, Cyprus University of Technology & The Cyprus Institute)*
13.15 - 13.45	Modelling in road passenger and freight transport to explore decarbonisation challenges *(Despina Yiakoumi, The Cyprus Institute)*
13.45 - 14.30	Preliminary results of Green Deal scenarios and comparison with NECP *(Constantinos Taliotis, The Cyprus Institute)*
14.30 - 15.30	Discussion *(Georgia Christofidou, Directorate General for European Programmes, Coordination and Development)*
15.30-15.45	Wrap-up and next steps *Theodoros Zachariadis, Cyprus University of Technology & The Cyprus Institute)*

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"ODYSSEE-MURE, Monitoring EU Energy Efficiency First Principle and Policy Implementation"

12 November 2021

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PARTICIPANTS

1. Ms. Georgia Christofidou, Director, Ministry of Finance (Directorate General for European Programmes, Coordination and Development)
2. Mr. Yiannis Nicolaides, Director, Department of Road Transport
3. Ms. Evi Anayiotou, Senior Officer of Sustainable Mobility, Ministry of Transport, Communications and Works
4. Ms. Katerina Piripitsi, Senior Officer of Energy Planning, Ministry of Energy, Commerce and Industry
5. Mr. Demetris Psyllides, Officer of Sustainable Mobility, Ministry of Transport, Communications and Works
6. Ms. Evita Michaelides, Senior Officer, Ministry of Finance (Directorate General for European Programmes, Coordination and Development)
7. Mr. Christodoulos Ellinopoulos, Officer of Energy Efficiency, Ministry of Energy, Commerce and Industry
8. Mr. Marios Theophilou, Officer, Ministry of Finance (Directorate General for European Programmes, Coordination and Development)
9. Mr. Lefteris Eleftheriou, Officer, Ministry of Finance (Directorate General for European Programmes, Coordination and Development)
10. Dr. Nestor Fylaktos, Associate Research Scientist, The Cyprus Institute
11. Dr. Constantinos Taliotis, Postdoctoral Research Fellow, The Cyprus Institute
12. Dr. Marios Karmellos, Postdoctoral Research Fellow, The Cyprus Institute
13. Dr. Despina Yiakoumi, Postdoctoral Research Fellow, The Cyprus Institute
14. Dr. Theodoros Zachariadis, Associate Professor, Cyprus University of Technology and The Cyprus Institute

SUMMARY

of the seminar organised in the frame of the Odyssee-Mure project on 12/11/2021 in Nicosia

The seminar was organised with in-person attendance. Because of restrictions related to the pandemic, the number of participants had to remain limited to about 15 persons. Because of this, and in view of the policy environment during autumn 2021, it was decided to specialise the seminar's topic on two timely and very relevant aspects:

- The implications of the 'Fit-for-55' policy proposals of the European Commission on the energy system of Cyprus
- The particular challenges associated with road transport, which is the main sector that is responsible for emissions out of the EU Emissions Trading system.

Governmental officers from three Ministries dealing with major aspects of the European Green Deal were invited to the seminar: from the Ministry of Energy, Commerce and Industry, the Ministry of Transport, Communications and Works, and the Ministry of Finance. Moreover, researchers who conduct the main energy and transport modelling work for national authorities also participated and made presentations.

Prof. Zachariadis opened the seminar and presented the scope of the Odyssee-Mure project as well as currently available information about energy efficiency trends in Europe, based on the latest presentation from the 2020 project workshop (available on the project website: https://www.odyssee-mure.eu/private/workshop-papers/sofia/22-eu-energy-efficiency-trends-nov-2020.pdf). He then made the connection between the project and the EU 'Fit for 55' policy proposals, especially those related to energy efficiency and mobility.

Then, Dr. Yiakoumi presented the new modelling framework that will help national energy and transport authorities to explore policy options for improving energy efficiency and reducing emissions in the Cypriot transport sector.

In the next presentation, Dr. Taliotis presented preliminary results from a modelling study that was conducted with the same models that were used in the NECP of Cyprus, in which he explored the implications of the proposed 'Fit for 55' energy and climate targets on final energy demand, renewable energy penetration, transport decarbonisation, and overall greenhouse gas emissions of the energy system of Cyprus.

Based on these presentations, a detailed discussion took place between all participants, coordinated by Ms. Georgia Christofidou of the Ministry of finance, about the policy implications of the European Green Deal and the 'Fit for 55" package:

- Ms. Piripitsi and Mr. Ellinopoulos stressed the need to explore in detail the implications on energy efficiency from the new binding targets for energy savings in buildings, enterprises and the public sector up to 2030 foreseen in the recast Energy Efficiency Directive, taking into account the new provisions of the proposed revised Energy Taxation Directive.
- Mr. Yiannis Nicolaides emphasised the challenges for accelerating the penetration of electric vehicles and increasing the use of public transport modes, and underlined the importance of a combination of regulatory policies and economic incentives for this purpose.
- Ms. Evi Anayiotou explained the progress in sustainable mobility investments and in the implementation of Sustainable Urban Mobility Plans for the cities of Cyprus.

Participants expressed the appreciation of the contribution of Odyssee-Mure to understanding drivers and trends in energy efficiency of individual sectors and economy-wide, and expressed the wish for this project to continue.

The Odyssee-Mure project, 2019-2021: Monitoring EU Energy Efficiency First Principle and Policy Implementation

Theodoros Zachariadis

Cyprus University of Technology, t.zachariadis@cut.ac.cy
& The Cyprus Institute, t.zachariadis@cyi.ac.cy

National Odyssee-Mure seminar, Nicosia, 12 November 2021

Co-funded by the Horizon 2020 programme of the European Union

ODYSSEE-MURE

Cyprus University of Technology

Odyssee-Mure for Cyprus

- Project partner: Cyprus University of Technology
- Data collection for updating Odyssee database: Preparation of national energy balance with the aid of data from Cystat + available studies
- Data collection for updating Mure database: With the aid of national authorities and NGOs (MECI, CEA etc.)
- Policy brief prepared in January 2021:
  “The role of Energy Efficiency Measures for a Green Economic Recovery after the COVID-19 Pandemic”
- Case study prepared in Dec. 2020:
  Addressing the Energy Efficiency First principle in the national energy and climate strategy of Cyprus
- National energy efficiency profile and report – available at www.odyssee-mure.eu

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Today's Agenda

First, an overall presentation of energy efficiency trends in the EU: https://www.odyssee-mure.eu/private/workshop-papers/sofia/22-eu-energy-efficiency-trends-nov-2020.pdf

Then we will focus on:

- Recent (July 2021) "Fit-for-55" policy proposals by the European Commission
- Implications for the entire energy system of Cyprus (energy efficiency, renewables, mobility, decarbonisation)
- Implications for road transport decarbonisation

Feedback from national authorities is more than welcome!

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European Green Deal Scenarios

Preliminary model results & comparison with the NECP

Dr. Constantinos Taliotis

Odyssee-Mure national seminar, Nicosia, Cyprus, 12/11/2021

Previous NECP Scenarios

It is important to view the preliminary scenarios of the Green Deal having in mind the official NECP projections of 2019. Two main scenarios were submitted in the **NECP** of Cyprus:

- **With Existing Measures (WEM):** considers legislation and actions that were already in place – insufficient to meet the 2030 commitments
- **Planned Policies and Measures (PPM):** considers implementation of additional legislation and actions, including strong shift to sustainable mobility – reaches 21% lower ESR emissions in 2030 compared to 2005 (current commitment for Cyprus is 24%, to be revised to 32% under "Fit for 55")

NECP Vehicle Fleet Projections

		NECP WEM							NECP PPM						
		2020	2025	2030	2035	2040	2045	2050	2020	2025	2030	2035	2040	2045	2050
Light duty vehicles (passenger cars)	Diesel	69,175	40,372	37,055	25,485	25,485	-	-	69,175	40,372	28,964	17,395	17,395	-	-
	Diesel hybrid	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Diesel PHEV	-	-	-	-	-	-	-	-	252	799	1,474	1,923	2,110	2,273
	Gasoline	471,639	538,687	485,950	409,366	312,578	336,869	387,716	471,639	472,909	344,664	257,720	149,979	171,575	208,762
	Gasoline Hybrid	5,170	5,170	59,927	125,850	200,639	222,298	227,621	5,170	5,170	59,927	125,850	200,639	222,298	227,621
	Gasoline PHEV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BEV	191	467	41,770	112,672	187,184	222,298	227,621	191	467	58,196	129,098	203,611	222,298	227,621
	LPG	214	739	1,174	963	437	562	562	214	739	1,174	963	437	53	159
	Natural gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hydrogen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Buses	Diesel	3,014	3,230	3,450	3,715	4,006	4,315	4,646	3,014	4,372	5,574	5,669	5,923	6,359	6,733
	Hydrogen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BEV	-	-	-	-	-	-	-	-	138	436	804	1,049	1,151	1,239
	CNG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MCs	Gasoline	50,925	54,667	58,383	62,806	68,087	74,642	77,267	50,928	48,476	46,000	49,557	53,408	57,687	61,176
	BEV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trucks	Diesel	12,978	13,923	13,907	13,380	12,877	13,406	14,752	12,976	13,848	13,441	12,948	12,780	13,957	15,044
	BEV	-	-	961	2,636	4,377	5,182	5,272	-	297	1,870	3,545	4,989	5,182	5,272
	Natural gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Light Trucks	Diesel	119,614	128,323	137,032	147,643	159,035	165,056	162,628	119,614	126,670	133,726	144,063	155,192	164,054	158,644
	BEV	-	-	-	-	-	6,269	21,941	-	-	-	-	-	3,134	18,806
	PHEV Diesel	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gasoline	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Grand Total	**732,920**	**785,578**	**839,609**	**904,516**	**974,707**	**1,050,896**	**1,130,026**	**732,921**	**713,710**	**694,771**	**749,084**	**807,324**	**869,857**	**933,352**

In connection to the Fit for 55 package and the Green Deal, four new preliminary scenarios were assessed:

- **Scenario A:** Net zero GHG emissions by 2050 and achievement of 2030 **Fit For 55** CO_2 emission reduction targets in ETS and non-ETS sectors. This means that the 2030 target for the ETS sectors changed from 43% reduction to 61% reduction, as compared to 2005 levels. The equivalent 2030 target for sectors under the ESR changes from a 24% reduction to a 32% reduction, as compared to 2005 levels. This scenario only looks into the electricity supply and road transport sectors.
- **Scenario B:** Achievement of 2030 **Fit For 55** CO_2 emission reduction targets in ETS and non-ETS sectors, as in scenario A, taking into account all three main sectors of the energy system (i.e. electricity supply, road transport, Heating & Cooling). In this case, the 2030 emission targets are kept constant throughout the horizon until 2050; any further post-2030 emission reduction is entirely due to perceived cost-effectiveness of relevant technology investments.
- **Scenario C:** Building on scenario B, this scenario also considers potential development of the EuroAsia Interconnector, with the same assumptions as employed for the NECP of the Republic of Cyprus. It should be noted that the Carbon Border Adjustment Mechanism is not accounted for in this scenario, in case of potential electricity imports from Israel.
- **Scenario D:** Building on scenario A, this scenario also considers the potential inclusion of building and road transport sectors into a new ETS scheme. As such, it also takes into account the heating and cooling sector.

Electricity Supply – Capacity

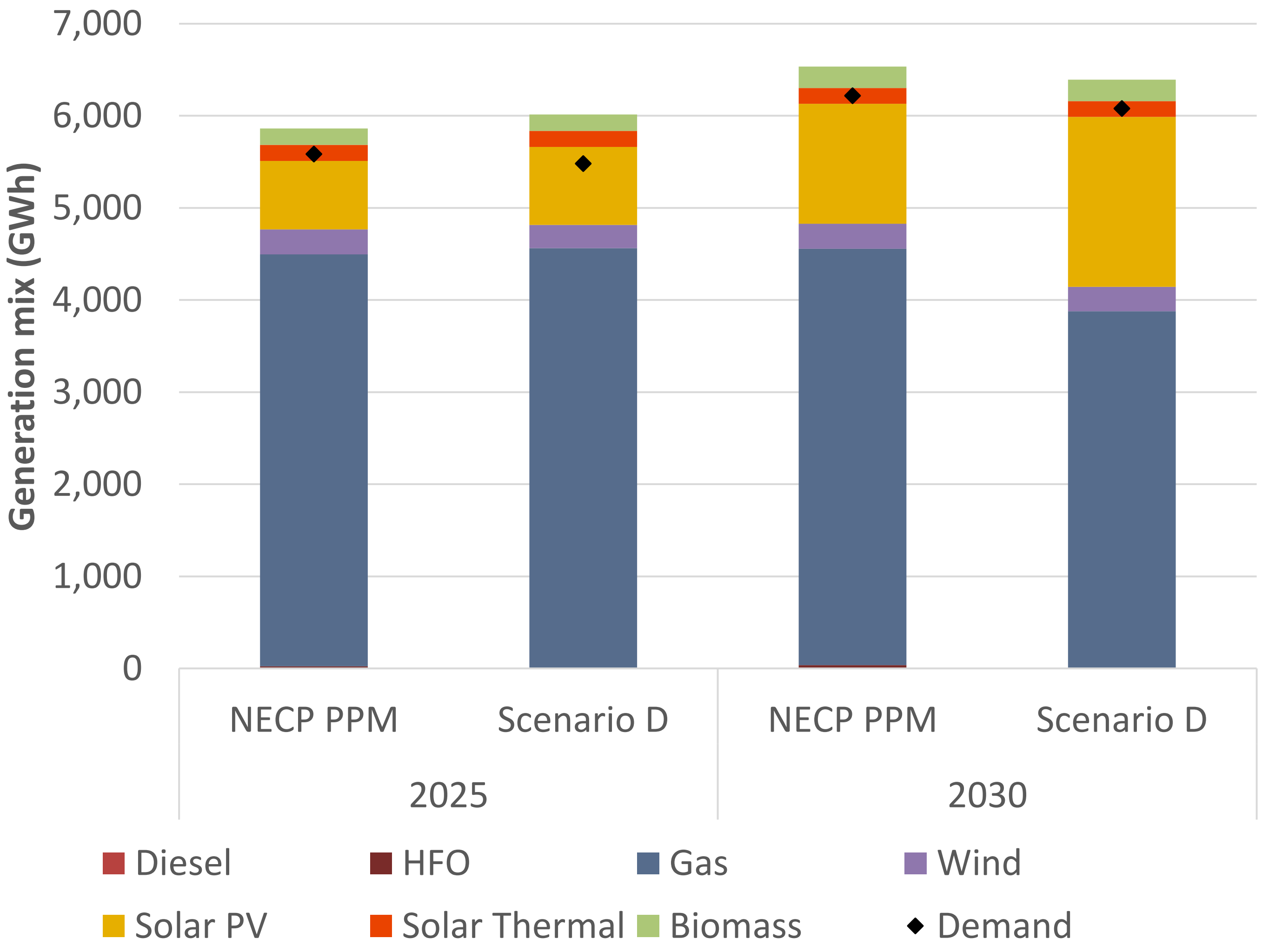
Important differences compared to PPM scenario of NECP:

- One less CCGT unit
- Additional renewable energy investments (350 MW of solar PV in this scenario by 2030)
- Storage investments

	2025		2030	
	PPM	Scenario D	PPM	Scenario D
Vasilikos	868	868	868	868
Dhekelia	102	102	102	102
Moni	150	150	150	150
New CCGT	432	216	432	216
Solar PV	460	523	804	1154
Solar Thermal	50	50	50	50
Wind Onshore	198	198	198	198
Wind Offshore	0	0	0	0
Biomass & waste	42	42	58	58
Pumped Hydro	0	0	0	130
Li-Ion Batteries	0	0	0	0

Electricity Supply – Generation

- Renewable energy share in electricity (RES-E) rises to **39.3% in scenario D** versus **30.3% in NECP PPM**.
- Minor decrease in final electricity demand (140 GWh in 2030) despite elevated electricity demand in transport sector.



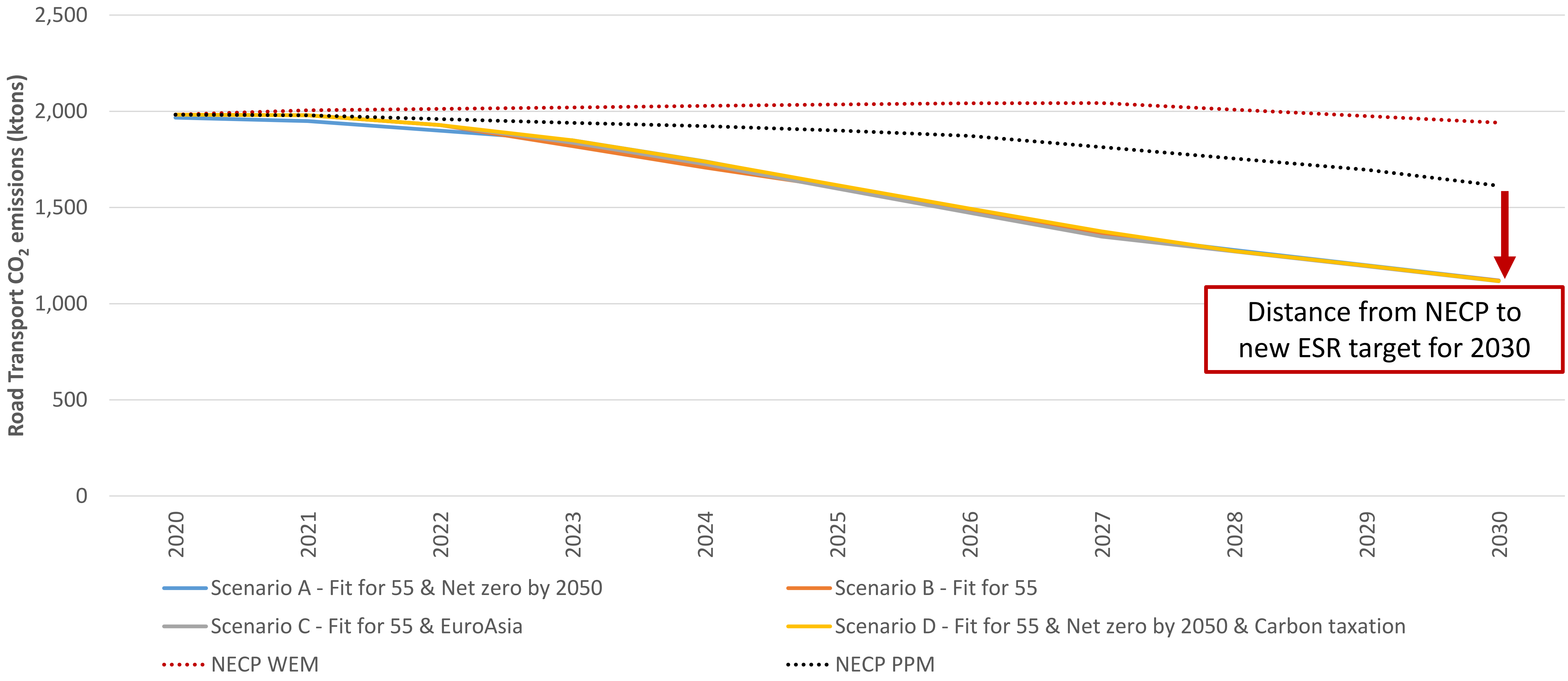
Vehicle Fleet Projections

		Scenario A - Fit for 55 & Net zero by 2050							Scenario B - Fit for 55						
		2020	2025	2030	2035	2040	2045	2050	2020	2025	2030	2035	2040	2045	2050
Light duty vehicles (passenger cars)	Diesel	69,175	40,372	28,964	17,395	17,395	-	-	69,175	40,372	28,964	17,395	17,395	-	-
	Diesel hybrid	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Diesel PHEV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gasoline	471,425	414,087	269,607	87,119	-	-	-	471,425	398,896	254,415	71,927	-	-	-
	Gasoline Hybrid	5,170	5,170	51,076	51,769	125,425	114,658	109,213	5,170	5,170	54,175	55,219	95,411	100,699	126,291
	Gasoline PHEV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BEV	191	58,551	140,704	373,100	427,518	499,838	482,001	191	73,742	152,796	384,841	457,532	513,797	536,294
	LPG	214	739	1,287	1,642	1,723	1,780	1,456	214	739	1,287	1,642	1,723	1,780	1,820
	Natural gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hydrogen	-	-	-	-	-	-	72,684	-	-	-	-	-	-	-
Buses	Diesel	3,014	4,372	5,574	5,669	4,916	2,744	1,532	3,014	4,372	5,574	5,669	5,923	6,359	6,733
	Hydrogen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BEV	-	138	436	804	2,055	4,766	6,441	-	138	436	804	1,049	1,151	1,239
	CNG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MCs	Gasoline	42,344	41,024	42,562	44,331	32,430	17,671	-	42,875	42,134	41,433	45,029	38,833	26,313	6,284
	BEV	-	-	-	939	16,243	37,893	58,713	-	-	-	241	9,840	26,970	48,489
Trucks	Diesel	12,976	13,095	8,925	4,248	1,312	1,312	1,618	12,976	13,102	8,932	4,254	413	413	413
	BEV	-	1,051	6,386	12,245	16,456	17,826	18,698	-	1,044	6,379	12,238	17,356	18,726	19,904
	Natural gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Light Trucks	Diesel	119,614	82,072	43,956	4,800	-	-	-	119,614	90,519	52,403	9,021	-	-	-
	BEV	-	44,598	89,769	139,262	155,192	167,188	177,450	-	36,151	81,323	135,042	155,192	167,188	177,450
	PHEV Diesel	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gasoline	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Grand Total	**724,122**	**705,268**	**689,247**	**743,323**	**800,666**	**865,676**	**929,808**	**724,653**	**706,378**	**688,118**	**743,323**	**800,666**	**863,396**	**924,918**

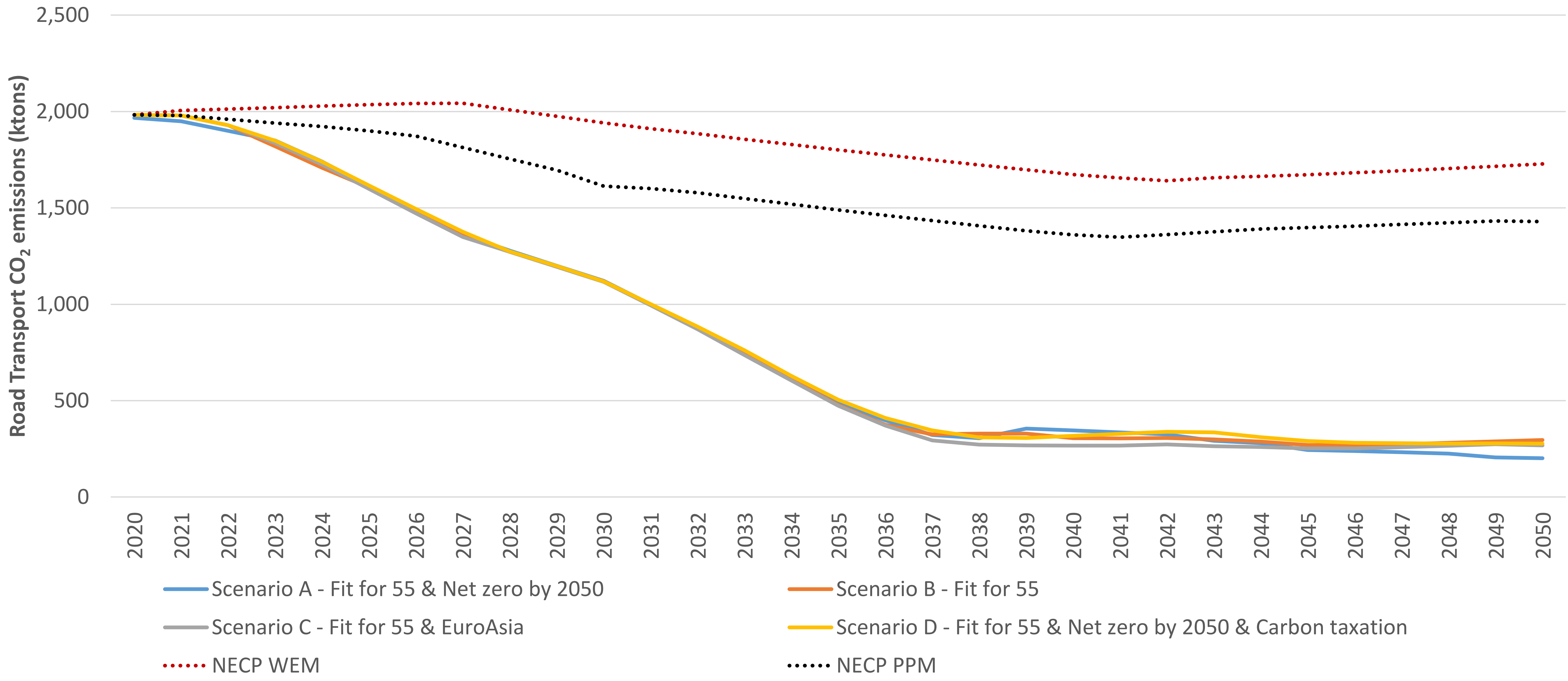
Vehicle Fleet Projections

		Scenario C - Fit for 55 & EuroAsia							Scenario D - Fit for 55 & Net zero by 2050 & Carbon taxation						
		2020	2025	2030	2035	2040	2045	2050	2020	2025	2030	2035	2040	2045	2050
Light duty vehicles (passenger cars)	Diesel	69,175	40,372	28,964	17,395	17,395	-	-	69,175	40,372	28,964	17,395	17,395	-	-
	Diesel hybrid	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Diesel PHEV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gasoline	471,425	395,531	251,050	68,562	-	-	-	471,425	400,312	255,831	73,343	-	-	-
	Gasoline Hybrid	5,170	5,170	55,897	56,590	71,810	88,298	102,772	5,170	5,170	25,895	20,725	20,725	-	-
	Gasoline PHEV	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BEV	191	77,107	154,440	386,835	481,132	527,979	550,125	191	68,127	157,201	358,534	416,804	448,639	501,848
	LPG	214	739	1,287	1,642	1,723	1,780	1,820	214	739	1,287	1,642	1,668	1,117	551
	Natural gas	-	-	-	-	-	-	-	-	4,199	22,460	59,385	115,469	167,638	162,050
	Hydrogen	-	-	-	-	-	-	9,181	-	-	-	-	-	-	-
Buses	Diesel	3,014	4,372	5,574	5,669	5,923	6,359	6,733	3,014	4,372	5,574	4,457	2,173	-	-
	Hydrogen	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BEV	-	138	436	804	1,049	1,151	1,239	-	138	436	2,016	4,799	7,510	7,973
	CNG	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MCs	Gasoline	42,875	42,134	44,316	44,331	34,984	28,284	11,837	42,875	42,134	45,762	30,269	17,788	939	-
	BEV	-	-	-	939	13,689	33,291	44,192	-	-	2,782	15,002	30,747	46,894	51,522
Trucks	Diesel	12,976	13,095	8,949	4,272	420	707	707	12,976	13,049	8,880	4,202	-	-	-
	BEV	-	1,051	6,362	12,221	17,349	18,431	19,609	-	1,059	6,251	11,833	16,894	17,876	19,013
	Natural gas	-	-	-	-	-	-	-	-	37	180	458	875	1,263	1,304
Light Trucks	Diesel	119,614	90,519	52,403	9,021	-	-	-	119,614	90,519	52,403	9,021	-	-	-
	BEV	-	36,151	81,323	135,042	155,192	167,188	177,450	-	36,151	81,323	135,042	155,192	167,188	177,450
	PHEV Diesel	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gasoline	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Grand Total	**724,653**	**706,378**	**691,001**	**743,323**	**800,666**	**873,469**	**925,667**	**724,653**	**706,378**	**695,228**	**743,323**	**800,528**	**859,064**	**921,711**

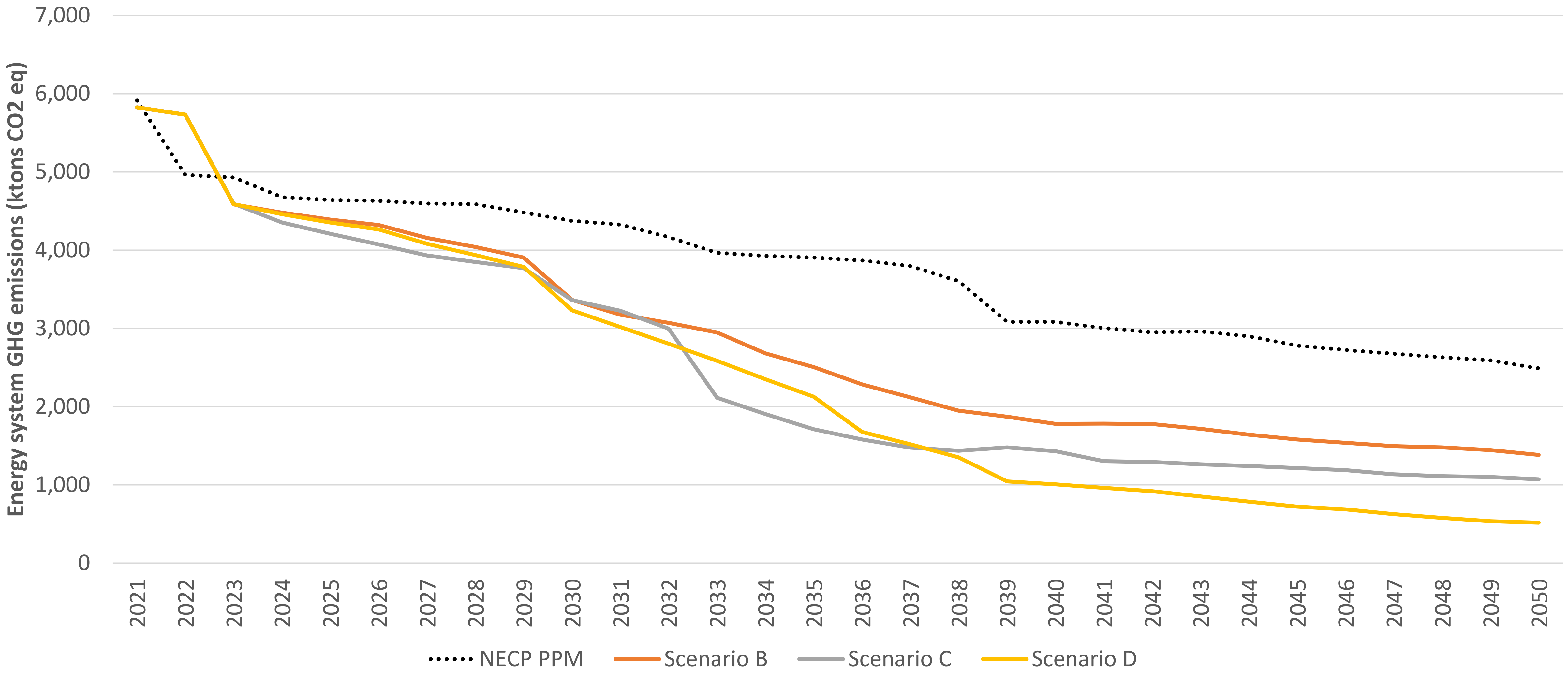
Road transport CO_2 emission projections up to 2030



Road transport CO_2 emission projections up to 2050



Energy system GHG emissions



Annualised Investment requirements – 2021-2030

- The PPM scenario already assumes major investments in sustainable mobility
- Significant additional total investment requirements are needed to align with the more ambitious ETS and ESR targets:
  - Renewable energy technologies
  - Storage technologies
  - Electric vehicles

			Difference with PPM			
Sector		**NECP PPM**	**Scenario A**	**Scenario B**	**Scenario C**	**Scenario D**
Power generation (new CCGT plants, PVs etc.)	Capital Investments	1,310	-82	-83	26	-137
	O&M Costs	731	-25	-25	-17	-33
Electricity storage technologies (pumped hydro & batteries)	Capital Investments	0	56	56	56	56
	O&M Costs	0	7	7	8	7
Electricity Interconnector	Capital Investments	0	0	0	118	0
	O&M Costs	0	0	0	0	0
Sustainable Mobility (buses & tram, bus lanes, cycle lanes etc)	Capital Investments	2,016	-19	0	0	-19
	O&M Costs	133	0	0	0	0
Private transport (shift to sustainable transport modes, more efficient cars, electric cars, biofuels etc.)	Capital Investments	10,837	4,096	4,240	4,238	4,167
	O&M Costs	4,204	-311	-233	-233	-242
	Total (M€)	**19,231**	**3,722**	**3,961**	**4,195**	**3,799**

Conclusions

- The new Scenarios A/B/C/D do not differ significantly for the period up to 2030. The inclusion of a 2030 emissions target both for the current ETS and for ESR sectors forces the system to move in the same direction in all cases (i.e. increased electrification).
- In the electricity supply sector, **renewable energy capacity in 2030 should be increased by an additional 350-420 MW** as compared to what was envisioned in the PPM scenario of the NECP. This should be accompanied by **storage investments** (up to **1,040 MWh** in 2027-2030).
- The number of **electric vehicles should increase to 190-220,000** by 2030 to achieve the new proposed ESR emissions target.
- **Electricity consumption in road transport** increases to approximately **1,050 GWh by 2030** in all scenarios.

Comments on the preliminary results

- All the new scenarios are demanding: **60-65% of new vehicle registrations after 2025 should be electric**.
- The results of the new scenarios highlight **what must be done** in order to meet some of the major decarbonisation targets of the 'Fit for 55' proposals.
- This does not suggest that projected investments are feasible with the existing policies and market dynamics.
- Without the push from the suggested new ETS structure (scenario D), realisation of these scenarios becomes **even less probable**.
- **Not all aspects of 'Fit for 55'** have been modelled. In particular, not all additional energy efficiency policies have been considered – it is a matter of current model updates.

Thank You

Decarbonizing Road Transport in Cyprus

Modelling to explore policies and measures in road transport that can address the new challenges of the European Green Deal

Dr. Despina Yiakoumi

Odyssee-Mure national seminar, Nicosia, Cyprus, 12/11/2021

Modelling road transport in Cyprus

Modelling road transport in Cyprus

- Aim: Determine cost-effective pathways to decarbonize road transport.
- Project the likely rate of uptake of different powertrains in road transport.
- Provide insights on the most economically optimal pathways to decarbonise road transport and any innovations needed
- On road transport segments to be considered: Heavy Good Vehicles, Light Good Vehicles, buses, coaches, passenger cars, motorcycles
- Powertrains considered: Diesel fuelled ICE, Petrol fuelled ICE, Natural Gas fuelled ICE, Fuel Cell Hydrogen, Battery Electric, and hybrids powertrains.

Analytical Tools to be used (1)

Vehicle cost model

- Bottom-up vehicle cost calculation
- Vehicle categories based on duty cycles and daily mileages of each segment
- Battery packs and hydrogen fuel cell capacity sizing to be calculated for each vehicle category
- Fuel consumption: Estimate energy consumption of each vehicle category
- Output: Vehicle CAPEX, vehicle OPEX and vehicle fuel consumption

Analytical Tools to be used (2)

Road Transport Model

- The vehicle parc will be calculated based on how attractive vehicles are to the operator/user.
  - The attractiveness is represented by the Total Cost of Ownership (TCO) over a time period. The TCO analysis covers purchase costs, residual value, maintenance cost and fuel cost.
  - The market shares will vary proportionally to the TCO based on a logit based choice model.
- This methodology is derived from Energy Technology Institute (ETI)'s Gas Well to Motion (WtM) model[1] and from the Road Freight Model[2] currently maintained by Energy Systems Catapult (ESC).

[1]Joss, M. (2017) *Natural Gas Pathway Analysis for Heavy Duty Vehicles*. Energy Technologies Institute, Available at: https://www.eti.co.uk/library/an-eti-perspective-natural-gas-pathway-analysis-for-heavy-duty-vehicles
[2]Yiakoumi, D. *et al.* (2019) *Decarbonising Road Freight*. Energy Systems Catapult, Available at: https://research.brighton.ac.uk/en/publications/decarbonising-road-freight

Use of analytical tools

Vehicle Cost Model

- Vehicle CAPEX
- Vehicle OPEX
- Vehicle fuel consumption

→

Road Transport Model

- Vehicle parc

Road Transport Model Overview

Road Transport Model

General inputs:

Commodity prices, tax on fuels, cost of refuelling stations, charger vehicle ratio, power of chargers, capacity of refuelling stations etc.

Vehicle inputs:

Vehicle categories, mileages, fuel consumption, powertrains, OPEX, CAPEX, vehicle demand, vehicle stock, penalty on sales, supply cap etc.

Uptake module:

- Calculate the TCO
- Calculate the market shares of the powertrains based on a two step sequential Logit-based choice model

Fleet module:

Add new vehicles on the stock and apply scrappage rate

Outputs:

Total number of powertrains in the market, sales of powertrains, TCO, energy use, number of refuelling stations, fuel price yearly

Key design principles of the model:

- Time horizon: 2015-2050
- Yearly calculations
- Platform: Matlab
- Outputs: Excel

Calculation of total cost of ownership (TCO)

Calculation of the market shares of the different powertrains based on their TCO

TCO = **Vehicle price** − **Residual value** + **Fuel expenditure** + **Maintenance**

$$Vehicle\ price = \{vehicle's\ CAPEX\} \times (1 + \{margin\ to\ get\ component\ costs\})$$

$$Residual\ value = \{Vehicle\ price\} \times \{Percentage\ of\ vehicle\ price\ for\ which\ it\ can\ be\ sold\ after\ TCO\ years\}$$

$$Fuel\ expenditure = \{annual\ mileages\} \times \{fuel\ consumption\} \times \{fuel\ price\} \times TCOyears$$

$$Maintenance = OPEX \times TCOyears$$

Commodity price + Transport to station costs + Station CAPEX and OPEX + Station profit margin = Fuel price

Uptake module – Market shares

Logit choice model description:

- Generates probabilities/ market shares of powertrains of discrete choices to capture variations in fleet decision making
- Market shares vary smoothly in proportion to their total costs of ownership. More realistic approach compared to the “winners takes all” approach, where the technology with the lowest overall costs takes 100% of the market.

Methodology:

- The calculation of market shares is carried out in a two-step, sequential logit model
- The first choice is between diesel, petrol, gas, battery electric, hydrogen, powertrains and the second choice is for the specific diesel, petrol, gas, hydrogen, electric option.
- Two step sequential logit model instead the standard logit model to avoid over-prediction of market shares of a specific powertrain technology

Input Data

Powertrains

powertrain types	Fuel Input 1	Fuel Input 2	HGVs	LGVs	buses	coaches	passenger vehicles	Motorcycles
ICE Diesel	Diesel		✓	✓	✓	✓	✓	✗
ICE Diesel Hybrid	Diesel		✓	✓	✓	✓	✓	✗
ICE Diesel PHEV	Diesel	Electricity	✗	✓	✓	✓	✓	✗
ICE Petrol	Petrol		✗	✓	✗	✗	✓	✓
ICE Petrol Hybrid	Petrol		✗	✓	✗	✗	✓	✗
ICE Petrol PHEV	Petrol	Electricity	✗	✓	✗	✗	✓	✗
ICE Gas HPDI (LNG)	LNG	Diesel	✓	✗	✗	✓	✗	✗
ICE Gas Stoichiometric (CNG Steel)	CNG		✓	✓	✓	✓	✗	✗
ICE Gas Stoichiometric (CNG Comp)	CNG		✓	✓	✓	✓	✗	✗
ICE Gas Stoichiometric (LNG)	LNG		✓	✗	✗	✓	✗	✗
ICE Gas CNG	CNG		✗	✗	✗	✗	✓	✗
Battery Electric	Electricity		✓	✓	✓	✓	✓	✓
Fuel cell hydrogen	Hydrogen		✓	✓	✓	✓	✓	✗
Hybrid Fuel cell / Battery Electric	Hydrogen	Electricity	✓	✓	✓	✓	✗	✗

Input Data

Vehicle categories	:	To be determined • Mileages • Duty cycles • Gross vehicle weight • Chassis description (e.g. axle number for HGVs) • Fuel consumption for diesel
Powertrain categories	:	13 categories, compatible with Euro VI standards
Types of refuelling infrastructure for HGVs	:	Major distribution hub and Depot
Location for electric chargers for passenger vehicles	:	Home, on-street, public, rapid, work
Electric chargers for HGVs	:	Ratio chargers/vehicles derived based on battery sizes of the vehicles
Electric chargers for passenger vehicles	:	Power determined based on existing chargers and expected improvements
Infrastructure cost	:	literature

Thank You

Appendix

Current Status of Land Transport

- Heavy reliance on internal combustion engines in all modes of road transport.
- Heavy reliance on passenger cars (>90% of passenger trips).
- No rail transport – Nicosia tram line potential development by 2028.

2019 Fleet	Petrol	Diesel	Hybrid	EVs (*2018)	Total
Passenger Cars	541,792	135,463	9,290	114	**686,659**
Motorcycles	57,973			218	**58,191**
Buses		6,358			**6,358**
Heavy Duty Trucks	11	18,818			**11,829**
Light Duty Trucks	6,622	120,375	6	6	**127,009**
Total	**606,387**	**281,104**	**9,296**	**338**	**897,035**

powertrain types	Description
ICE Diesel	Standard Euro VI diesel Engine
ICE Diesel Hybrid	Standard Euro VI diesel Engine with the addition of energy recovery and storage
ICE Diesel PHEV	Hybrid powertrain which has both a combustion engine and an electric motor. Each one is capable of powering the vehicle on its own. Plug-in hybrids use regenerative braking as their energy source, but they can also be plugged in to recharge the battery.
ICE Petrol	Standard Euro VI Petrol Engine
ICE Petrol Hybrid	Standard Euro VI Petrol Engine with the addition of energy recovery and storage
ICE Petrol PHEV	Hybrid powertrain which has both a combustion engine and an electric motor. Each one is capable of powering the vehicle on its own. Plug-in hybrids use regenerative braking as their energy source, but they can also be plugged in to recharge the battery.
ICE Gas HPDI (LNG)	Gas is injected directly into the cylinder with a small amount of pilot diesel. Typical gas/diesel ratios are around 95%/5%
ICE Gas Stoichiometric (CNG Steel)	Gas is injected directly into the cylinder of a petrol type spark ignited engine. Configured with a Steel CNG tank.
ICE Gas Stoichiometric (CNG Comp)	Gas is injected directly into the cylinder of a petrol type spark ignited engine. Configured with a Carbon composite CNG tank.
ICE Gas Stoichiometric (LNG)	Gas is injected directly into the cylinder of a petrol type spark ignited engine. Configured with an LNG tank.
Battery Electric	Electric powertrain which draws electricity from a battery only
Hydrogen fuel cell	Electric powertrain which produce electricity using a fuel cell powered by hydrogen and a buffer battery. Battery is also used for energy recovery storage
Hybrid Hydrogen Fuel cell / Battery Electric	Electric powertrain which produce electricity using a fuel cell powertred by hydrogen and an electric battery

Calculation of market shares

1. *Calculate the utility of each vehicle, fuel and engine type*

For each powertrain option i in the model, the utility (attractiveness) is calculated in each year:

$$U_i = price\ coefficient \times (TCO_i + technology\ penalty_i)$$

2. 1st step sequential logit model: Calculate the market share split between the generic diesel, gas, battery electric, hydrogen, catenary hybrid and catenary battery

$$P_i = \frac{e^{U_i}}{\sum_{t=1}^{T} e^{U_t}}$$

3. 2nd step sequential logit model: Determine the market shares of the individual powertrain options ($P_{\{j|i\}}$)

4. Calculate the market shares for individual vehicles

The probability of choosing variant j within a group of powertrains i is given by:

$$P_j = P_i \times P_{\{j|i\}}$$

Two step sequential Choice Model

- New HGV buyer
  - Diesel
    - Diesel EURO VI
    - Diesel Hybrid
  - Gas
    - Gas Stoich (LNG FT)
    - Gas Stoich (Steel CNG FT)
    - Gas Stoich (Comp CNG FT)
    - Gas HDPI (LNG FT)
  - Battery
  - Hydrogen
    - Hydrogen + Battery Regen
    - Battery / Hydrogen Hybrid

Decarbonising Road Freight project

Project aim: cost-effective pathway to decarbonise road freight across the UK's transport and energy systems and influence future research

Workshops with industry and academia

Literature review

Define scope of the project

Close connection between modelling and the real world

Analytical capabilities:

- *ESME tool*: techno-economic system approach
- *Developed vehicle cost model*: calculate vehicle costs and fuel consumption
- *Developed prototype Road Freight Model (RFM):* consider operator's behaviour

Project commissioned and funded by:

UKERC UK Energy Research Centre

Collaboration:

CATAPULT Energy Systems

ADVANCED PROPULSION CENTRE UK

Decarbonising Road Freight - Scenarios

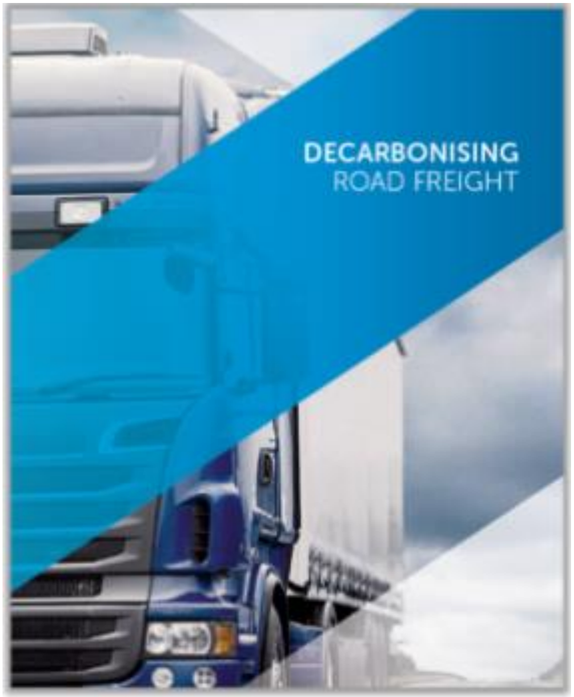
Base case

Stricter Legislation
a) EU regulation scenario
b) Zero emission HGVs from 2040

Shift Demand

CCS deployment:
a) CCS doesn't materialise
b) CCS is delayed by 10 years

Catenary motorway



Source: https://research.brighton.ac.uk/en/publications/decarbonising-road-freight