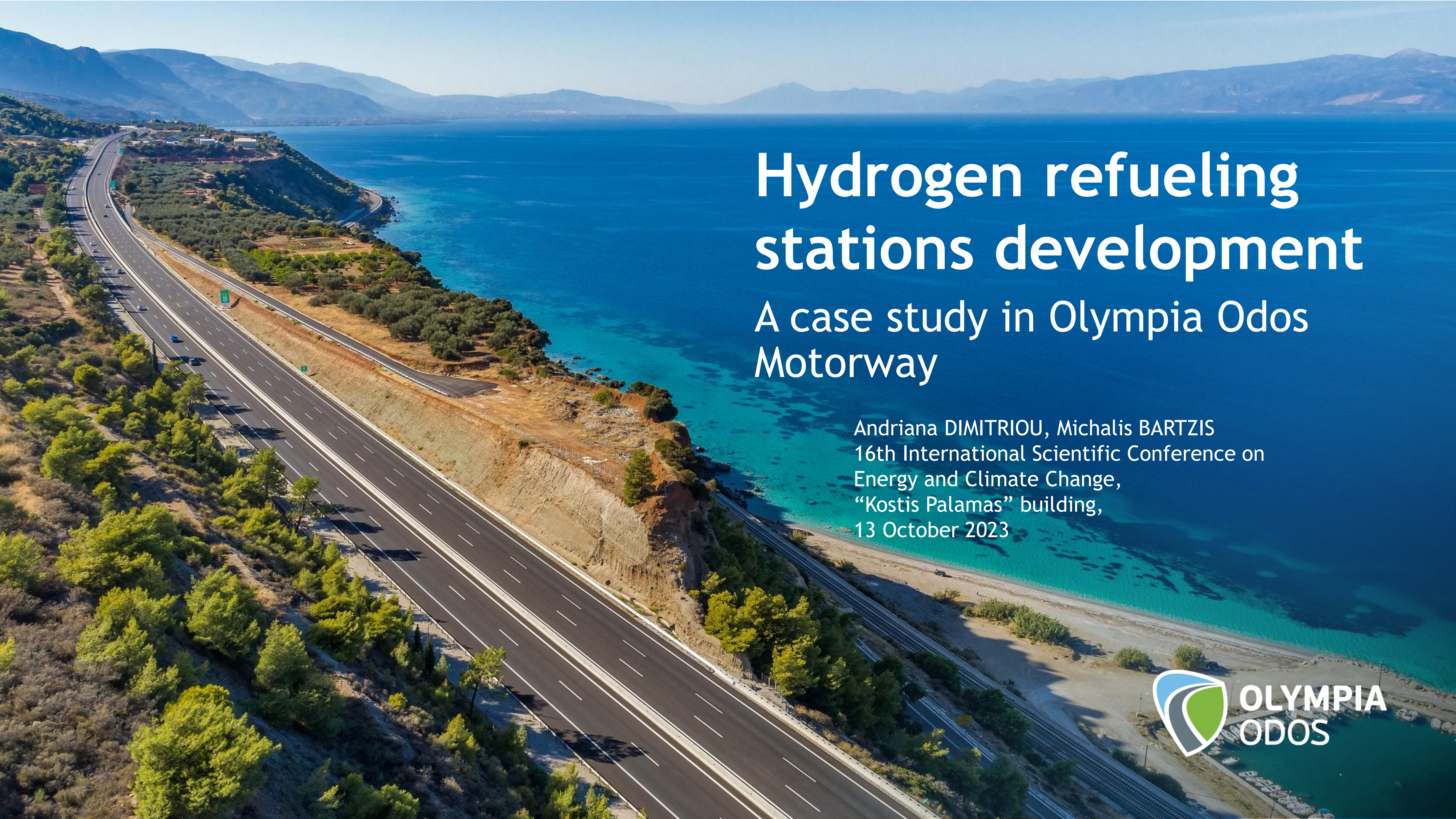

Hydrogen refueling stations development

A case study in Olympia Odos Motorway

Andriana DIMITRIOU, Michalis BARTZIS
16th International Scientific Conference on Energy and Climate Change,
“Kostis Palamas” building,
13 October 2023

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Olympia Odos at a glance

Services

- **37** Interchanges/Exits
- **5** Technical bases
- **7** Frontal Toll Stations
- **15** Motorists Service Stations
- **2+1** Traffic Management Centers
- **35** W.C.- parkings
- **5** Customer Service Centers
- **42** Hybrid gates

Our route towards Net zero

60%

Reduction of yearly energy consumption

50%

Reduction of yearly energy consumption

GOAL:
Zero CO_2 emissions by 2030

0%

LED

in 17 tunnels

LED

in tunnels & open road

PV Parks

Next project

CO_2

«Green» energy

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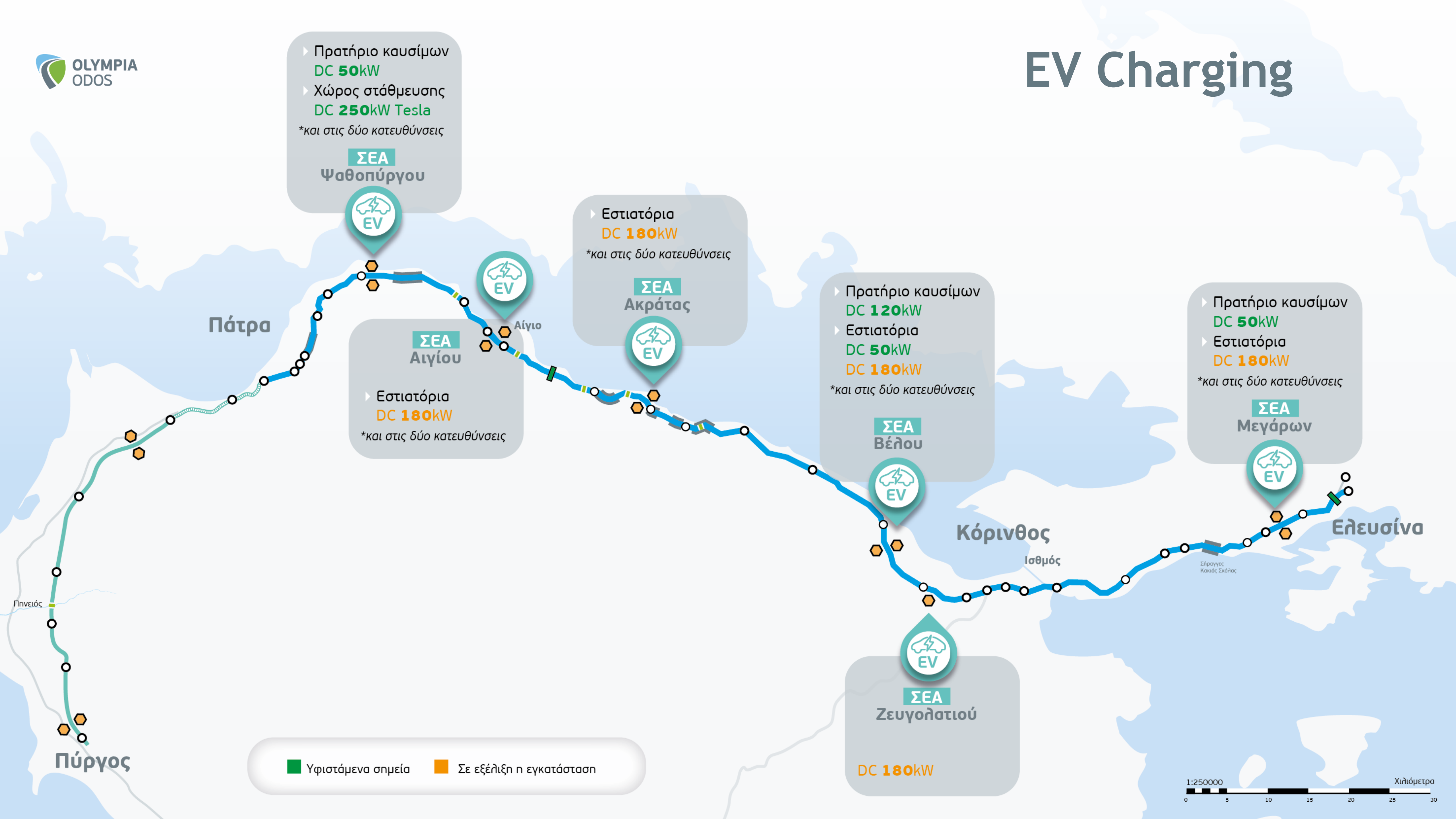
EV Charging


OLYMPIA ODOS
Πρατήριο καυσίμων
DC 50kW
Χώρος στάθμευσης
DC 250kW Tesla
*και στις δύο κατευθύνσεις
ΣΕΑ Ψαθοπύργου
EV
Πάτρα
ΣΕΑ Αιγίου
Εστιατόρια
DC 180kW
*και στις δύο κατευθύνσεις
EV
Αίγιο
Εστιατόρια
DC 180kW
*και στις δύο κατευθύνσεις
ΣΕΑ Ακράτας
EV
Πρατήριο καυσίμων
DC 120kW
Εστιατόρια
DC 50kW
DC 180kW
*και στις δύο κατευθύνσεις
ΣΕΑ Βέλου
EV
Κόρινθος
Ισθμός
Πρατήριο καυσίμων
DC 50kW
Εστιατόρια
DC 180kW
*και στις δύο κατευθύνσεις
ΣΕΑ Μεγάρων
EV
Ελευσίνα
Σήραγγες Κακιάς Σκάλας
Πηνειός
Πύργος
EV
ΣΕΑ Ζευγολατιού
DC 180kW
Υφιστάμενα σημεία
Σε εξέλιξη η εγκατάσταση
1:250000
Χιλιόμετρα
0 5 10 15 20 25 30

Energy pioneering at Motorists Service Stations

Joining Forces for Hydrogen initiatives

- REAH2 project/Construction of HRS for passenger cars, light-duty and heavy-duty vehicles in Akrata MSS
- TRIERES project/Greek Small Scale Hydrogen Valley

Co-funded by the European Union

H2 TRIÉRĒS

Clean Hydrogen Partnership

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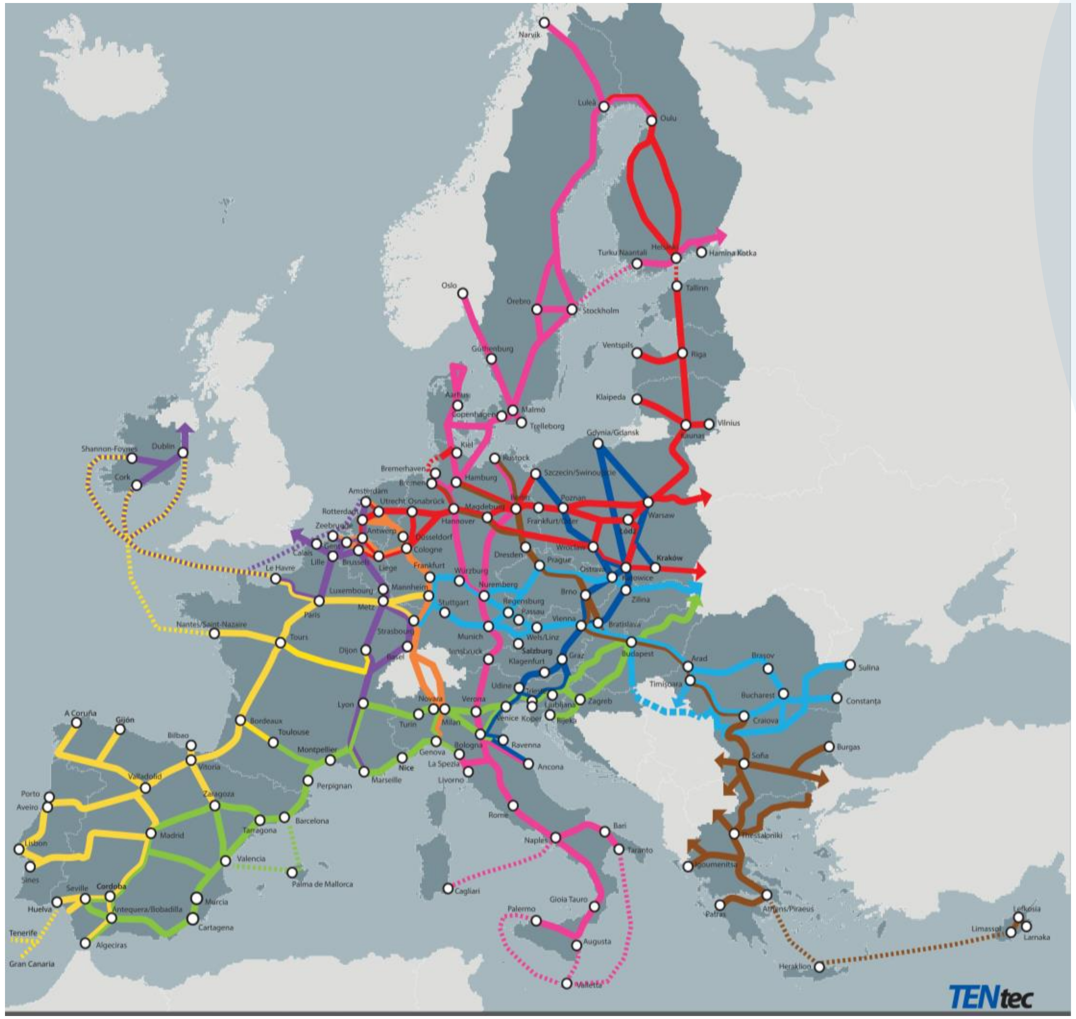
Legislation



Alternative Fuels Infrastructure Regulation

- ✓ 1 HRS every 200 km along the Ten-T core network by 2030
- ✓ 1 HRS in every major urban node
- ✓ 1 tone/day, for all modes of road transport

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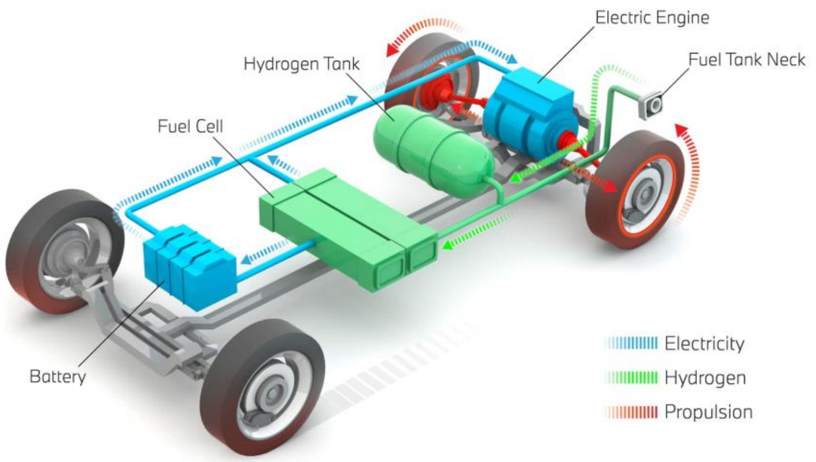
Hydrogen Refueling Stations Legislation in Greece

Greece has recently issued the legislation concerning the HRS stations

- Greek Law N. 4439/2016
- Ministerial Degree 118664/2023
- ISO 19880-1:2020 “Gaseous hydrogen - Fueling stations”

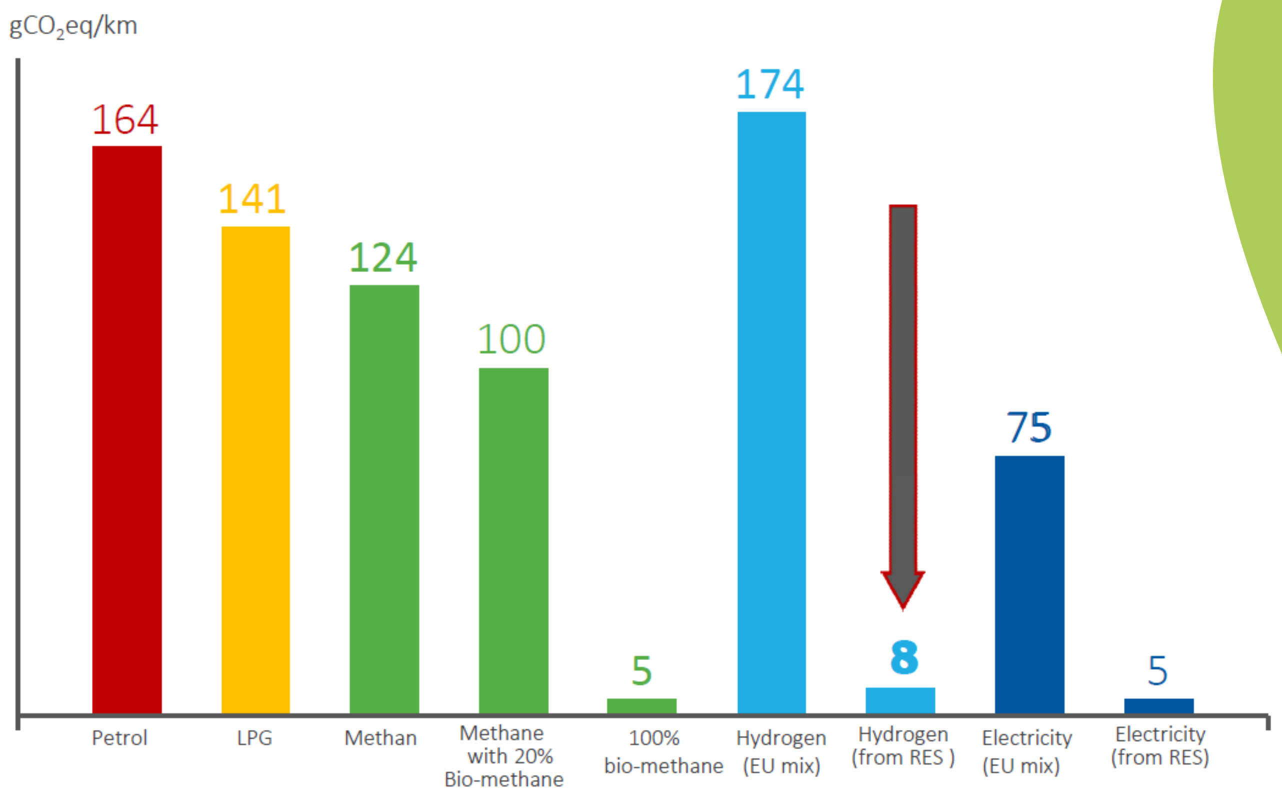
Why hydrogen for mobility?

- Water vapor is the only emission of hydrogen fuel cell vehicles
- Long distance driving range (~500 km for cars/ ~1000 km for trucks)
- Quick refueling (3’-5’ for cars, 10’-20’ for trucks)



Source: BMW

Comparison of commercially available fuels and electricity



Green hydrogen:
Hydrogen produced from electrolysis of water using renewable energy sources

Idea Statement

Is it possible to meet the hydrogen demands of Olympia Odos users by 2030, by producing our own “green” hydrogen?

Questions to be answered

- **How much hydrogen do we need by 2030 to fuel the hydrogen vehicles on Olympia Odos motorway?**

- **What's needed to produce “green” hydrogen in terms of:**
  - Infrastructure
  - Power from PV panels
  - Space
  - Resources

Methodology

1. Estimate 2030 hydrogen demand on Olympia Odos
2. Size refueling station components
3. Calculate electricity use
4. Determine solar plant size

Estimation of 2030 H2 demand

- **1.800 kg** of H2 per day
- **450** hydrogen vehicles per day
- **2** HRS across the motorway
- ~ **1 tone** of H2 per station daily

- 1000 tones of CO_2 per year

	Parameters	Values
1	Total motorway length, L (km)	200
2	The market share of hydrogen vehicles (passenger cars, vans, trucks & buses), M.S. (%)	1,5
3	% of passenger cars on the fleet (PVs)	0,87
4	% of vans on the fleet (LCVs)	0,12
5	% of trucks & buses on the fleet (HDVs)	0,01
6	PV tank capacity (kg)	5
7	LCV tank capacity (kg)	6
8	HDV tank capacity (kg)	30
9	Mean tank capacity of the "Average Vehicle" according to the synthesis of fleet	8,01
10	% tank filling per single fueling	0,50
11	Single fueling, F (kg)	4,005
12	Range for single fueling, (km)	240
13	Average Daily Traffic, Av.Tr. (vehicles/day)	25.000
14	Required amound of H2 per day (kg)	1.802
15	Number of hydrogen "Average Vehicles" to be served per day	450
16	Number of Stations across the motorway	2
17	Required amount of H2 per Station daily (kg)	~ 1 tone H2 per day

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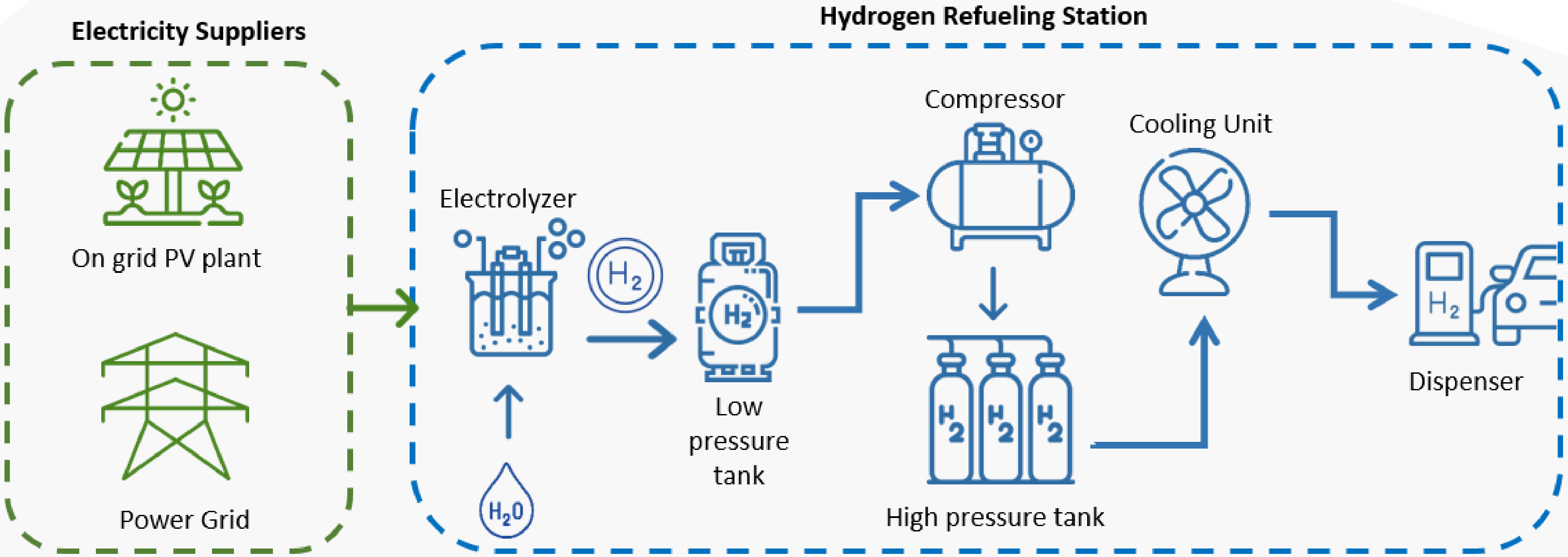
Hydrogen Refueling Station components



- Electric energy supply (solar panels on-grid or off-grid)

- Electrolyzer
- Hydrogen storage tanks
- Compressor
- Precooling Unit
- Dispenser

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Sizing of the HRS components

- Commercially available electrolyzer with high production rate (kg/h)
- Commercially available compressor of 5 stages
- Enough storage tanks to cover the production

Electrolyzer technical specifications	
Manufacturer	Nel
Model	M Series Containerized
Electrolytic cell type	PEM
Hydrogen production rate (kg/h)	44,25
System Consumption (kWh/kg)	50,4

Compressor	
Manufacturer	Linde
Model	IC90/60
Number of stages	5
Maximum discharge pressure (MPa)	90
Compression rate (kg/h)	56
Engine electrical power (kW)	186

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Scenarios for “Green” Solar HRS

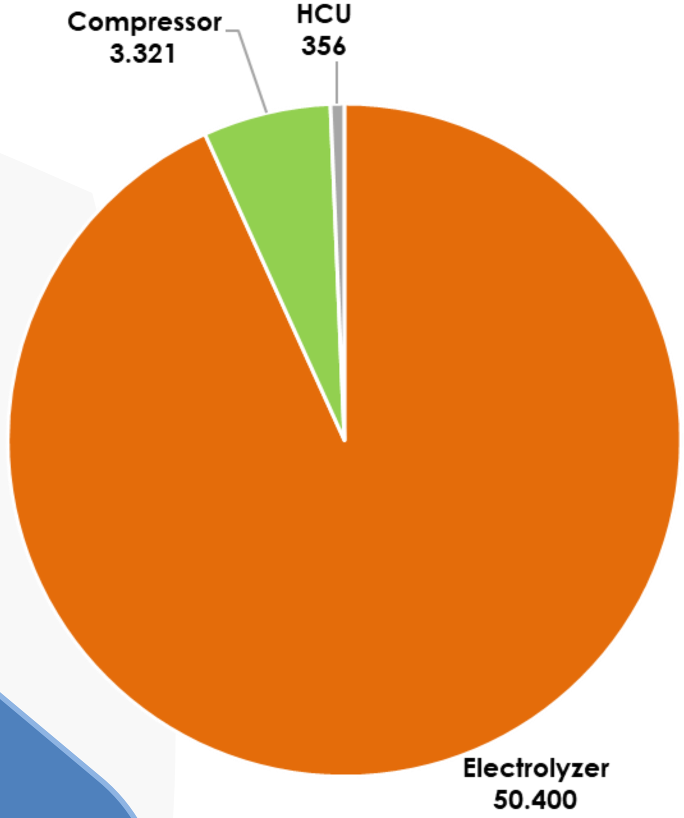
- Off-grid solar HRS
  - It can not use the grid
  - No batteries
  - We assume average sun 7.5h per day
  - Pros: 100% “green” power
  - Cons: no continuous supply of H2
- On-grid solar HRS
  - It can use grid power
  - We assume seasonal variations
  - Pros: continuous supply of H2
  - Cons: not 100% “green” power

Results for "Green" HRS of 1 tone

	Photovoltaic plant	Zero grid	High grid (75%)	Mid grid (50%)	Low grid (25%)	Minimum grid (5%)
1	Daily average energy demand Etot (kWh/day)	54.078	54.078	54.078	54.078	54.078
2	Daily Generation by the grid (kWh/day)	-	40.558,34	27.038,89	13.519,45	2.703,89
3	Daily generation by the photovoltaic plant Eel,ph (kWh/day)	54.078	13.519,45	27.038,89	40.558,34	51.373,90
4	Peak Sun Hours in north Peloponeese SPH (h)	7,5	3,5	6,0	9,0	11,5
5	Number of pannels Npv	18.631	9.981	11.645	11.645	11.543
6	Surface of each panel ap (m2)	1,90	1,90	1,90	1,90	1,90
7	Total area occupied Aph (m2)	35.400	18.964	22.125	22.125	21.932

9.000 lt of water daily

Electrical cinsumption of HRS components (kWh/day)



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A more realistic scenario - “Hybrid” HRS

- Part of the demand of hydrogen is delivered from a central facility (or full delivery)
- Pros : less workload for the electrolyzer
- Cons: not sure if hydrogen delivered is “green” + CO2 from delivery

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Results for "Hybrid" HRS of 1 tone

	Photovoltaic plant	Low delivery (25%)	Mid delivery (50%)	High delivery (75%)	Full delivery (100%)
1	Daily average energy demand Etot (kWh/day)	41.478	28.878	16.278	3.678
2	Daily generation by the photovoltaic plant Eel,ph (kWh/day)	20.738,89	14.438,89	8.138,89	1.838,89
3	Peak Sun Hours in north Peloponeese SPH (h)	6,0	6,0	6,0	6,0
4	Number of pannels Npv	8.931	6.218	3.505	792
5	Surface of each panel ap (m2)	1,90	1,90	1,90	1,90
6	Total area occupied Aph (m2)	16.970	11.815	6.660	1.505

Realistically we would need ~1.500 m^2 of solar panels for the installation of 1 off-site HRSs on the motorway

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Conclusions

- “Green” hygrogen requires extensive recourses (infrastructure, power, space, water)
- More suitable as a fuel for heavy vehicles
- Seems to be one of the few available "ways to go”

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Thank you!
Any Questions?

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Check out our services at:
www.olympiaodos.gr

Traffic Prediction | Interactive Map | OLYMPIA PASS | Olympia Odos App

Ευρωπαϊκή Ένωση
Ταμείο Συνοχής 2014-2020
Ευρωπαϊκό Ταμείο
Περιφερειακής Ανάπτυξης 2007-2013
ΕΣΠΑ 2014-2020
ανάπτυξη - εργασία - αλληλεγγύη
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης