
HYDROGEN STRATEGY DRAFT PLAN FOR GREECE

Pantelis Capros

June 2022

Climate-neutrality – 1.5°C strategy

Terms

- “*Climate-neutrality*” => net phase-out of all GHG emissions (Höhne et al., 2015).
- “*Carbon neutrality*” => net zero CO2 emissions.

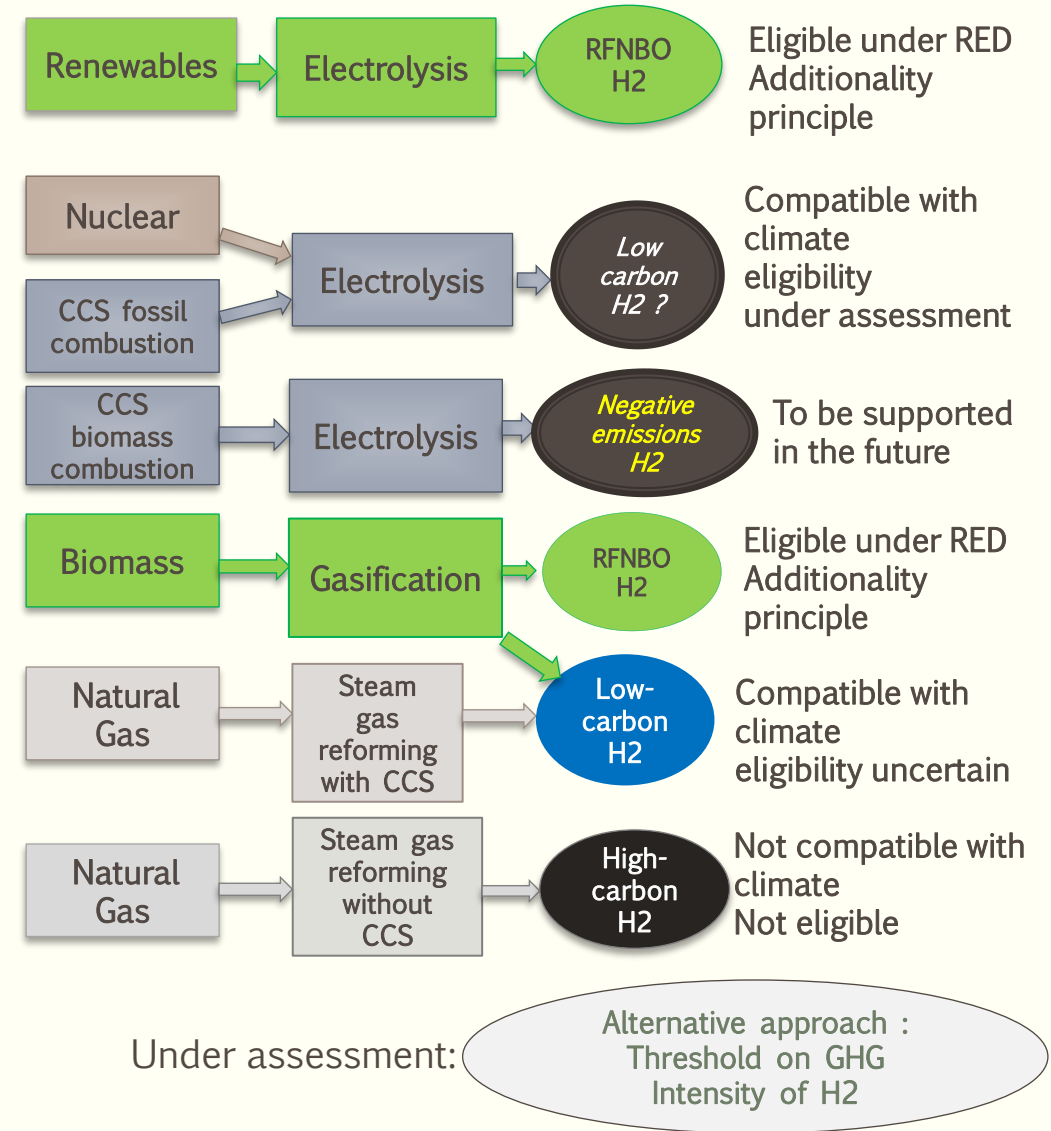
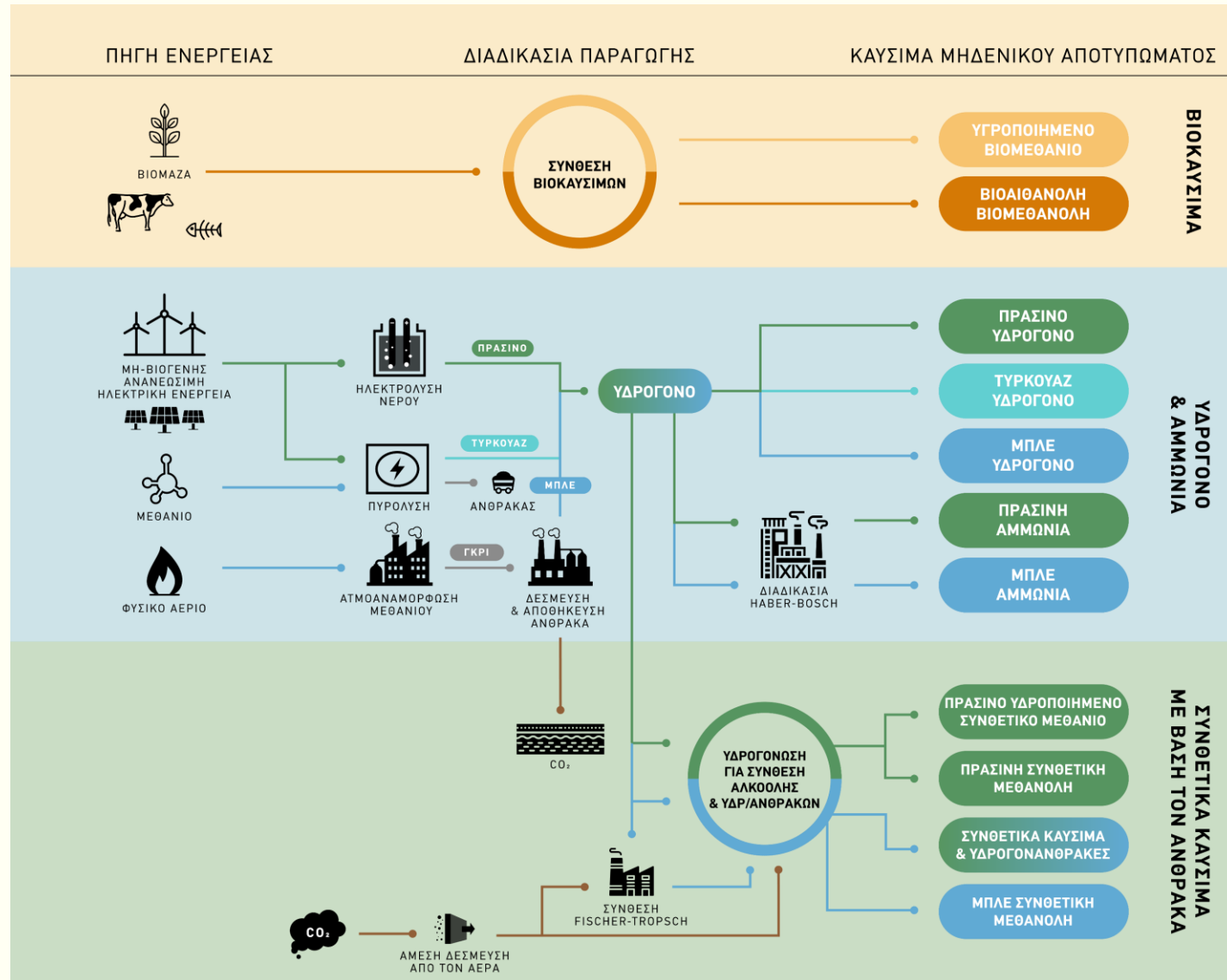
Targets

- **Pillars:** Energy Efficiency, Renewables, Carbon pricing
- **2030:** -55% GHG, 40% RES (RES-E > 60%), -40% Energy use
- **2050:** Net zero GHG emissions

Strategy

- *Decarbonise Power Generation* => Renewables +Storage, mainly
- *Electricity as a zero-carbon carrier in transport and heat* => electrification
- **Produce** green (carbon-neutral) gaseous and liquid fuels => where electrification not possible
 - Biomass origin (limited potential)
 - Electricity origin: Hydrogen from renewables
 - CO2 from biogenic and air capture origins
 - Fossils origin: Requires underground storage of CO2 (unavailable) otherwise not climate neutral
- *Optimize overall efficiency to avoid excessive increase in electricity challenged by RES potential!*

Hydrogen origins and eligibility for support



Typical H2 technology costs

	Total cost (EUR/kg H2 LHV)	
	Currently	Long-term
Hydrogen from		
natural gas steam reforming centralised - Large Scale	1.5	2.9
natural gas steam reforming small Scale	2.0	3.2
natural gas steam reforming centralized - Large Scale with CCS	2.7	4.0
electrolysis PEM- Large Scale	2.8	2.4
electrolysis PEM small-medium scale	3.4	2.9
electrolysis Alkaline - Large Scale	2.7	2.4
electrolysis Alkaline small-medium scale	3.0	2.8
high temperature electrolysis SOEC	3.6	3.0
high temperature water electrolysis SOEC small scale	4.2	3.6
H2 compression station	0.2	0.2
Hydrogen Liquefaction plant	0.4	0.3
H2 liquid to gas refuelling station	0.6	0.6
H2 refuelling station Small	0.7	0.7
H2 refuelling station Medium	0.4	0.4
H2 refuelling station Large	0.3	0.3

	SEC - Natural gas	SEC - Electricity	Overnight investment cost (EUR per kW-output)	
			Currently	Long-term
Hydrogen from				
natural gas steam reforming centralised - Large Scale	1.33	0.094	535	485
natural gas steam reforming small Scale	1.53	0.094	885	1554
natural gas steam reforming centralised - Large Scale with CCS	1.33	1.094	1864	835
electrolysis PEM- Large Scale		1.27	1145	475
electrolysis PEM small-medium scale		1.35	1485	630
electrolysis Alkaline - Large Scale		1.32	920	434
electrolysis Alkaline small-medium scale		1.32	1290	435
high temperature electrolysis SOEC		1.59	1358	743
high temperature water electrolysis SOEC small scale		1.62	2320	1210
H2 compression station		0.07	110	99
Hydrogen Liquefaction plant		0.02	723	582
H2 liquid to gas refuelling station		0.07	826	702
H2 refuelling station Small		0.07	966	854
H2 refuelling station Medium		0.07	503	402
H2 refuelling station Large		0.07	302	218

Priority actions

Demand-push strategy

- Heavy-duty vehicles running on H2
- Refineries and ammonia
- Quotas in gas blending
- Synthetic liquids in aviation and maritime
- Industry

Infrastructure priorities

- Refueling hubs
- Storage, compression, liquefaction
- (later) distribution networks
- (later) industrial applications in selected sectors

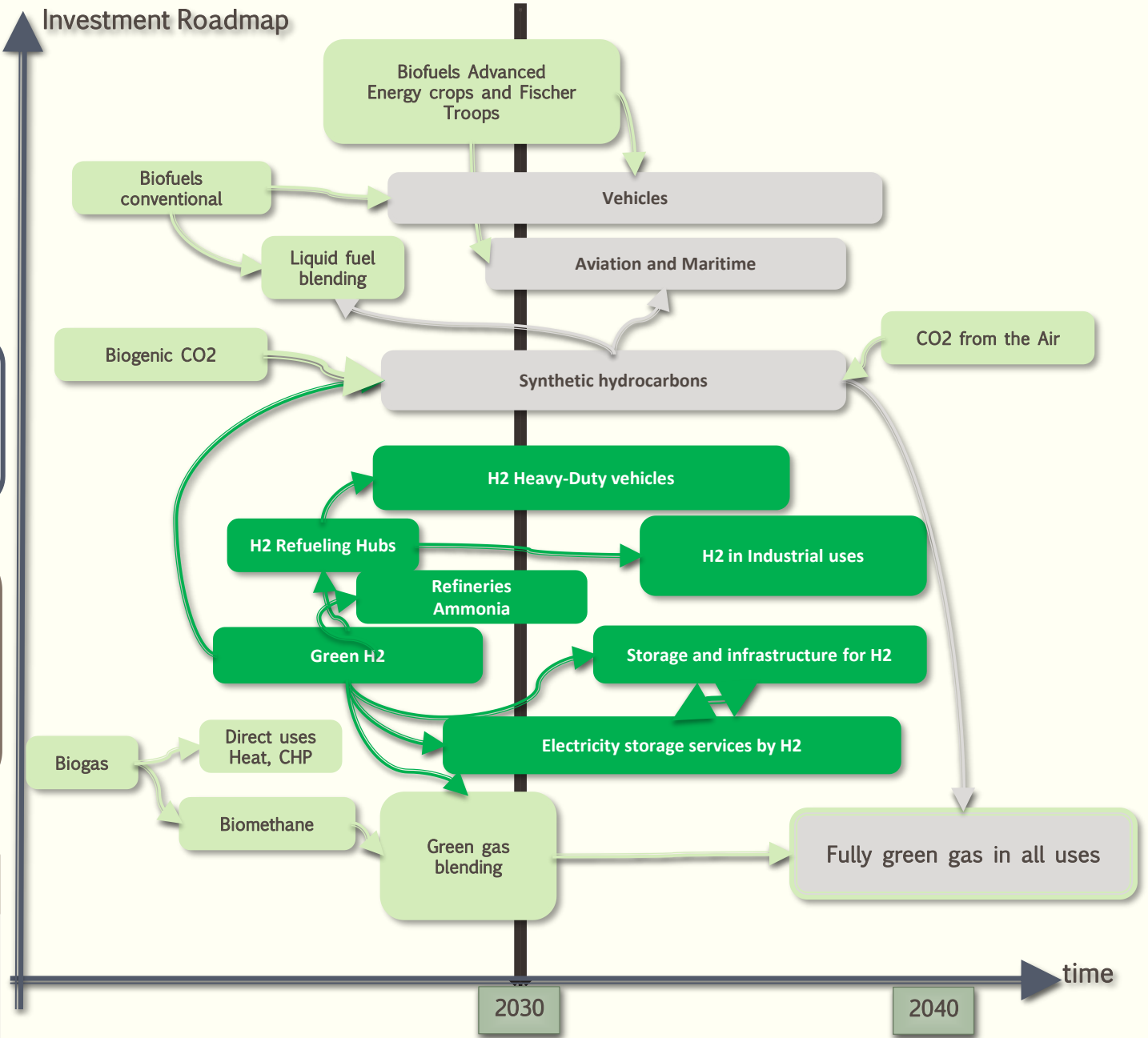
Economic incentives

- Demonstration projects
- Subsidies for transport vehicles
- Refueling, distribution and storage infrastructure
- Premium subsidy to facilitate blending in gas
- Subsidy to eligible bilateral supply contracts

RFNBO: Renewable Fuels of non Biological Origin

- To be promoted and regulated in the forthcoming RED-III
- Eligible for state aid and support schemes
- Certificates or origin is fundamental – additionality principle
- Count in RES-shares used as targets to monitor policy

Investment Roadmap



Greece				
Hydrogen and e-fuels balance (GWh)				
		2030	2040	2050
Net Imports	Hydrogen	-63	-11798	-27042
Maritime	Hydrogen	0	118	1667
	E-fuels	892	2759	8005
Rail transport	Hydrogen	2	10	19
	E-fuels	0	47	75
Road transport	Hydrogen	334	2714	6354
	E-fuels	0	4453	3569
Inland navigation	Hydrogen	0	6	129
	E-fuels	10	734	1986
Aviation	Hydrogen	0	0	0
	E-fuels	271	1808	5610
Refineries	Hydrogen	522	584	689
	E-fuels	0	248	1615
Power sector	Hydrogen	0	571	1587
	E-fuels	0	33	32
Industry	Hydrogen	409	5397	9855
	E-fuels	0	665	3338
Domestic Sector	Hydrogen	0	446	1244
	E-fuels	0	670	3797
Input to E-fuels	Hydrogen	1636	15653	37567
Total system	Hydrogen	2966	37298	86154

Biomethane balance (GWh)				
		2030	2040	2050
Maritime		65	620	2469
Rail transport		0	0	0
Road transport		13	148	321
Inland navigation		1	6	28
Aviation		0	0	0
Refineries		22	171	502
Power sector		153	6124	7185
Industry		67	431	1040
Domestic Sector		96	447	1182
Total		417	7948	12727

Example of a projection for Greece

Hydrogen and e-fuels capacities				
		2030	2040	2050
Electrolyzer	MW	674	8477	19580
E-methanation	MW	6	344	1970
E-liquids	MW	177	1440	2639

Hydrogen price pre-tax (€/kgH2)					
		2020	2030	2040	2050
Power and industry		3.4	2.2	2.1	1.9
Domestic		3.7	2.6	2.5	2.3
Transport		4.6	2.8	2.7	2.5

Price of blended gas (€/MWh-gas)					
		2020	2030	2040	2050
Domestic		44.4	43.6	60.8	84.9
Transport		44.4	43.5	61.2	88.5

Towards development of a competitive Hydrogen industry and value chain

No regret: Sectors that today use grey hydrogen

- Green H₂ in refineries – 2 projects of 10 MW electrolyzers
- Blue hydrogen with CO₂ capture and underground storage (Italy or Prinos)
- Stations for refueling and storage of H₂

Transport sector – Refueling Hubs

- No regret: Heavy Duty Vehicles (buses, coaches, trucks, trains)
- Demonstration: Ship using H₂ or green ammonia for local short-trips
- Ports supplying H₂ and e-fuels for bunkering

Blending of biomethane and H₂ in gas distribution

Long-term: seasonal storage of electricity

Medium term: Use of H₂ in high-temperature uses in industry

Domestic value added opportunities

- Design and construction works
- Production of green hydrogen and e-fuels
- Production of biomethane
- Fuel Cells industry – project qualified for funding
- New technology compressors
- Storage facilities
- Refueling hubs
- Manufacturing of pipes
- Adaptation of heavy-duty vehicles to H₂
- Services – IT systems supporting applications
- Research and Innovation – international subcontracting

R&D strategy

- Hydrogen Valleys
- Technology Hubs
- Start ups - IT

Policy measures – basic principles

Certification and regulation

- Technical standards and safety
- Certification of RFNBOs
- Certification of green hydrogen and biomethane
- Blue hydrogen only if CCS is available
- Certification of blending in gas distribution

Regulatory approach for infrastructure

- Broadening the definition of gas infrastructure
- Dedicated hydrogen infrastructure
- Application of the notion of virtual networks

Governance

- Empowering RAE
- Competences of System Operators
- Management of certification systems
- Harmonization with EU legislation
- Special regulations for enabling first-of-the-kind infrastructure investment

New synergy between TSO and DSO

- New coordination issues
- Design to manage commercial and physical operations
- Reverse flows
- Cross-border trade of hydrogen
- Essential facilities and third-party access
- Tariffs and cost recovery of new infrastructure

Policy measures – basic principles

Priorities

Facilitation and privileged access of electrolysis to RES

Removal of barriers to the use of hydrogen: (a) Safety, (b) Certification, (c) Supply conditions

Enabling first-of-the-kind investment (CAPEX subsidy, security about future market)

Development and access to infrastructure (expansion)

Measures facilitating market development (contracting support, standards for market quotas, roles of system operators in market making)

Approach

Completion of the legislation

Regulatory framework for negotiated third-party access to essential facilities and later regulated third-party access to public infrastructure

Selection of CAPEX-subsidy projects in no-regret areas

Public-private investment undertaking

System operators as investor in essential facilities

Later, application of new regulatory framework for the hydrogen dedicated infrastructure

Policy measures – basic principles

CAPEX subsidy

- Only at the first stages of market development
- Criteria: market development leverage, value chain integration, no regret area, business and technology reliability

Subsidization of new infrastructure

- In the beginning, focus on refueling hubs, local applications of sufficient scale
- Essential facilities: Biomethane upgrading, pipeline compression and injection stations, liquefaction etc.
- Infrastructure to support cross-border trade

Product subsidization to develop markets

- Contracts for economic differences with subsidies indexed on EU ETS prices for selected industrial applications (possible with hydrogen purchasing agreement)
- Contracts for economic differences with subsidies combined with tax exemption of RFNBO and blending obligation quotas
- Contracts for economic differences with subsidies combined with blending obligation quotas in gas distribution

Facilitation of access to low-cost RES power

- Coupling and additionality as a standard
- Priority of new RES investment when coupled with hydrogen applications
- Exemption of green Hydrogen from network costs, losses and levies in the electricity sector