Hydrogen economy

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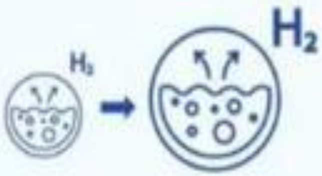
EU hydrogen strategy

towards 2030

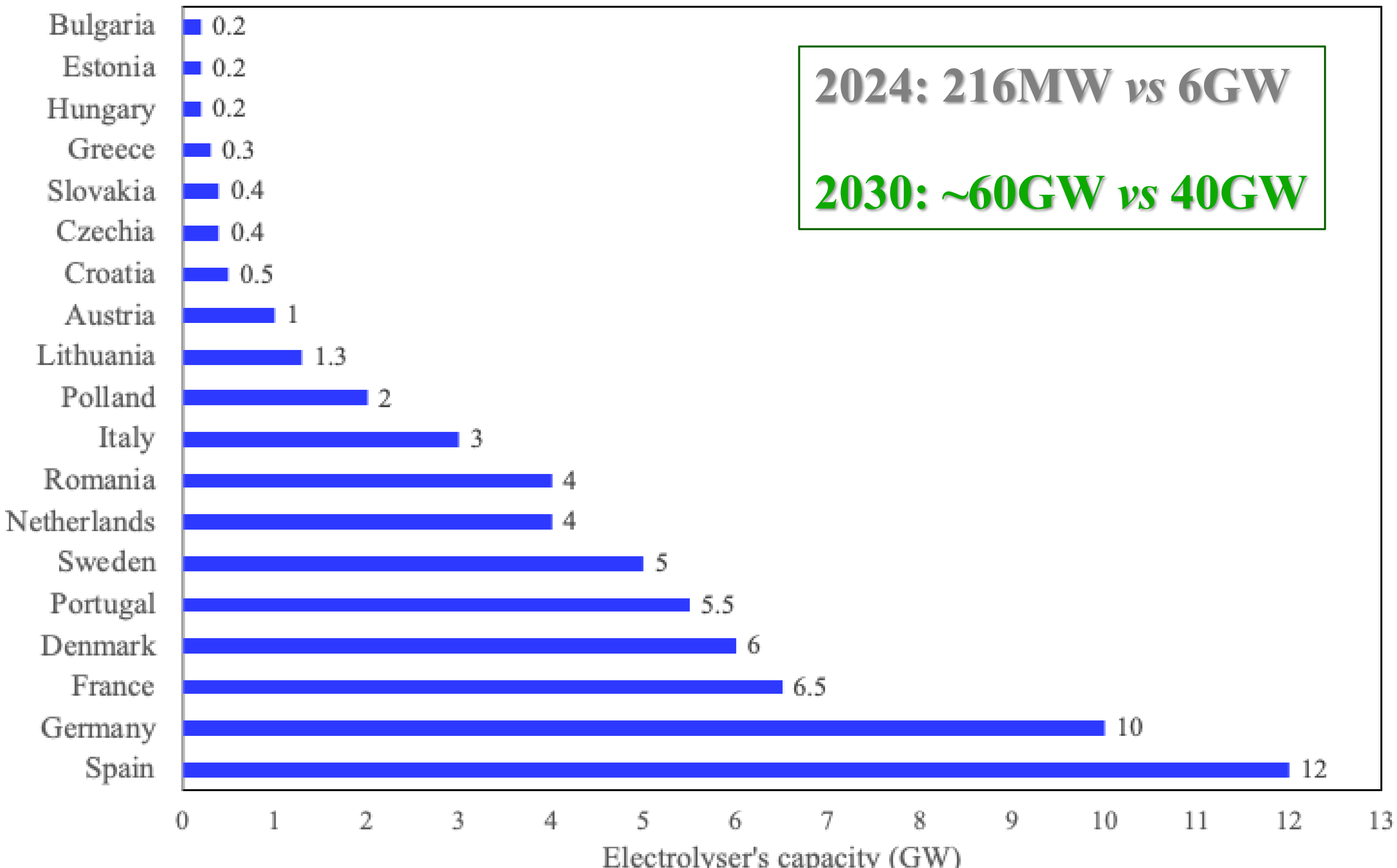
EU H_2 strategy*



2024	2025-2030	2030
• Installation of Electrolysers: at least 6GW for green H_2 production • Production of green H_2: up to 1mt	• H_2 to become part of the integrated energy system • Production of green H_2: more than 10mt	• Large scale integration of green H_2

* Venizelos V., Poullikkas A., 2024, "Comprehensive Overview of Recent Research and Industrial Advancements in Nuclear Hydrogen Production", *Energies*

2030 electrolyser's capacity in EU*



* ACER, 2024

Cyprus H_2 strategy?

- **Recognition of hydrogen as a key component of the energy mix for 2030 and up to 2050**
- **Creation of a long-term national energy strategy considering hydrogen**
- **Creation of a legislative framework - allow the introduction of participants in H_2 market**
- **Harmonization of national regulatory framework with the relevant European Directives**
- **Targeted measures to kick-start the hydrogen value chain: production; transport and storage; use in final consumption**

Feb 2025: Cyprus's H_2 strategy under public consultation

Cyprus’ Energy Transition to Hydrogen Economy

2030 – 2060; Energy-Water-Transport Nexus

Energy-Water-Transport Nexus*

- **Integrated mathematical optimization model examining power-water-transport nexus**
- **Comprehensive simulation of Cyprus' transition toward a hydrogen economy**
- **Long-term decarbonization focus on coordinated investments in:**
  - ~ **renewable energy**
  - ~ **hydrogen infrastructure for power and transport**
  - ~ **desalination units**
  - ~ **small modular reactors (SMRs)** **– if necessary**

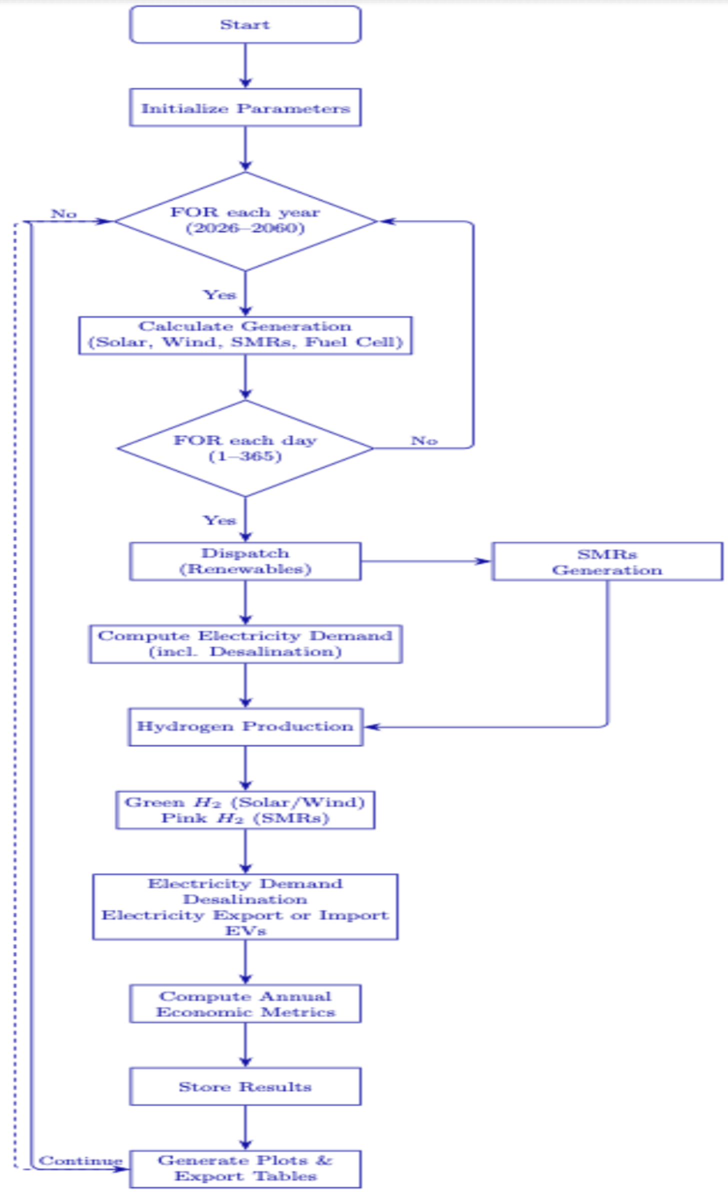
* **Poullikkas A., 2025, *Cyprus' Energy Transition to Hydrogen Economy: 2030–2060, Energy–Water–Transport Nexus Outlook*, see link: Nexus Outlook**

Objective function

- **Minimizing total cost**

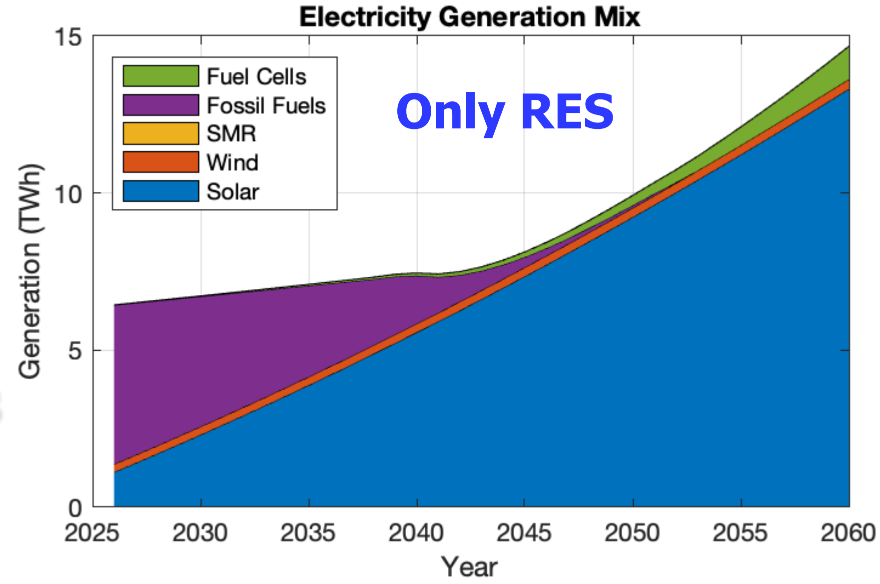
$$\min\left[C\right] = \min \sum_{t=1}^{T} \left[\frac{\left(C_t^{c} + C_t^{f} + C_t^{eCO2} + C_t^{o} + B_t^{in} - B_t^{ex}\right)}{(1+d)^t} \right]$$

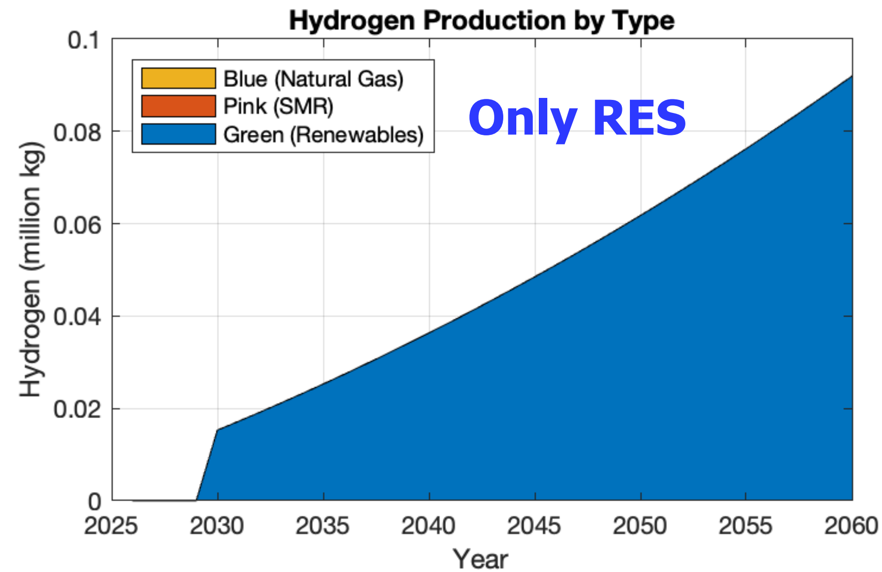
- **satisfy constraints**
  - Nexus energy balance
  - Hydrogen production and storage dynamics
  - Power security
  - Water security
  - Technology learning curves
  - Decarbonization path
  - etc …



Hydrogen economy development*

- **Solar capacity grows from 800MW to over 7000MW by 2060**
- **Generation in 2060 to support Energy-Water-Transport Nexus 14.67TWh**
- **Decarbonization of electricity sector by 2053**
- **H_2 production reaches 90,000t/year by 2060**
- **Transport H_2 demand grows annually, reaching 40,000t/year by 2060**

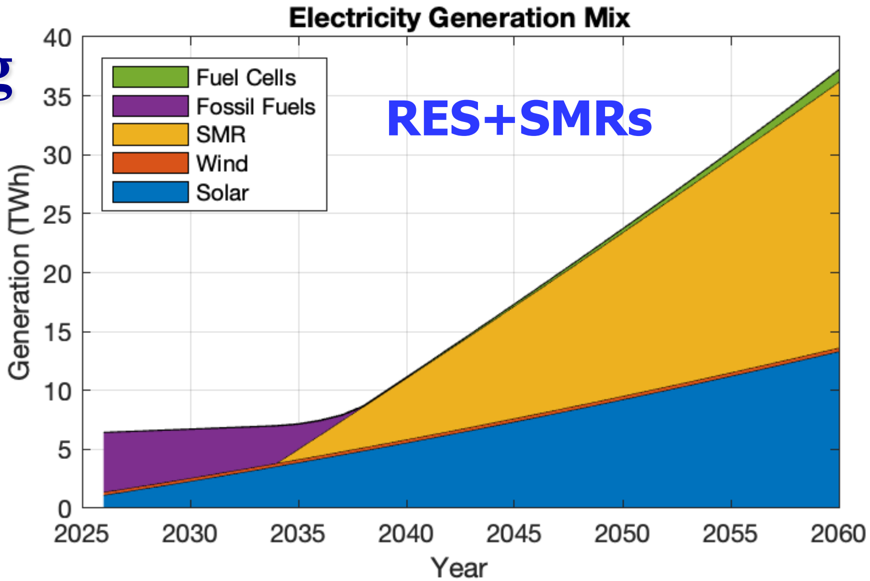


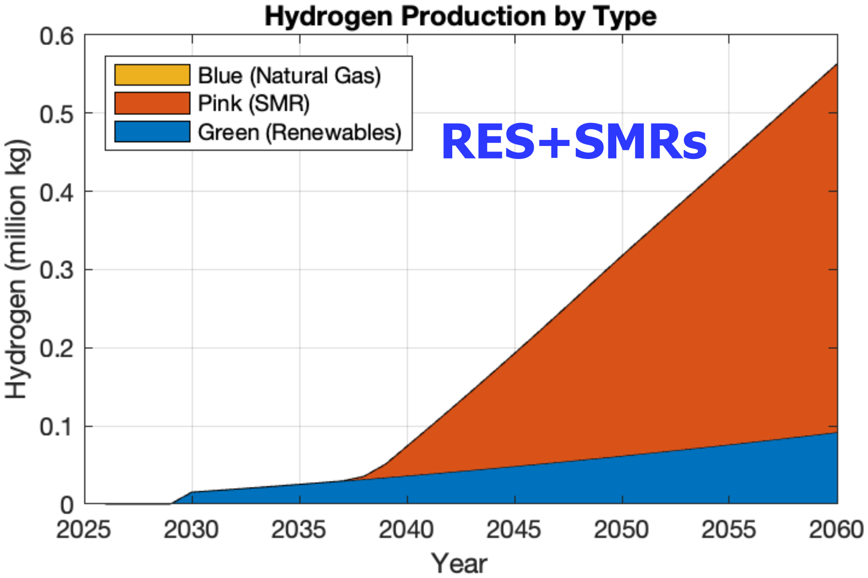


* Preliminary results

Hydrogen economy development*

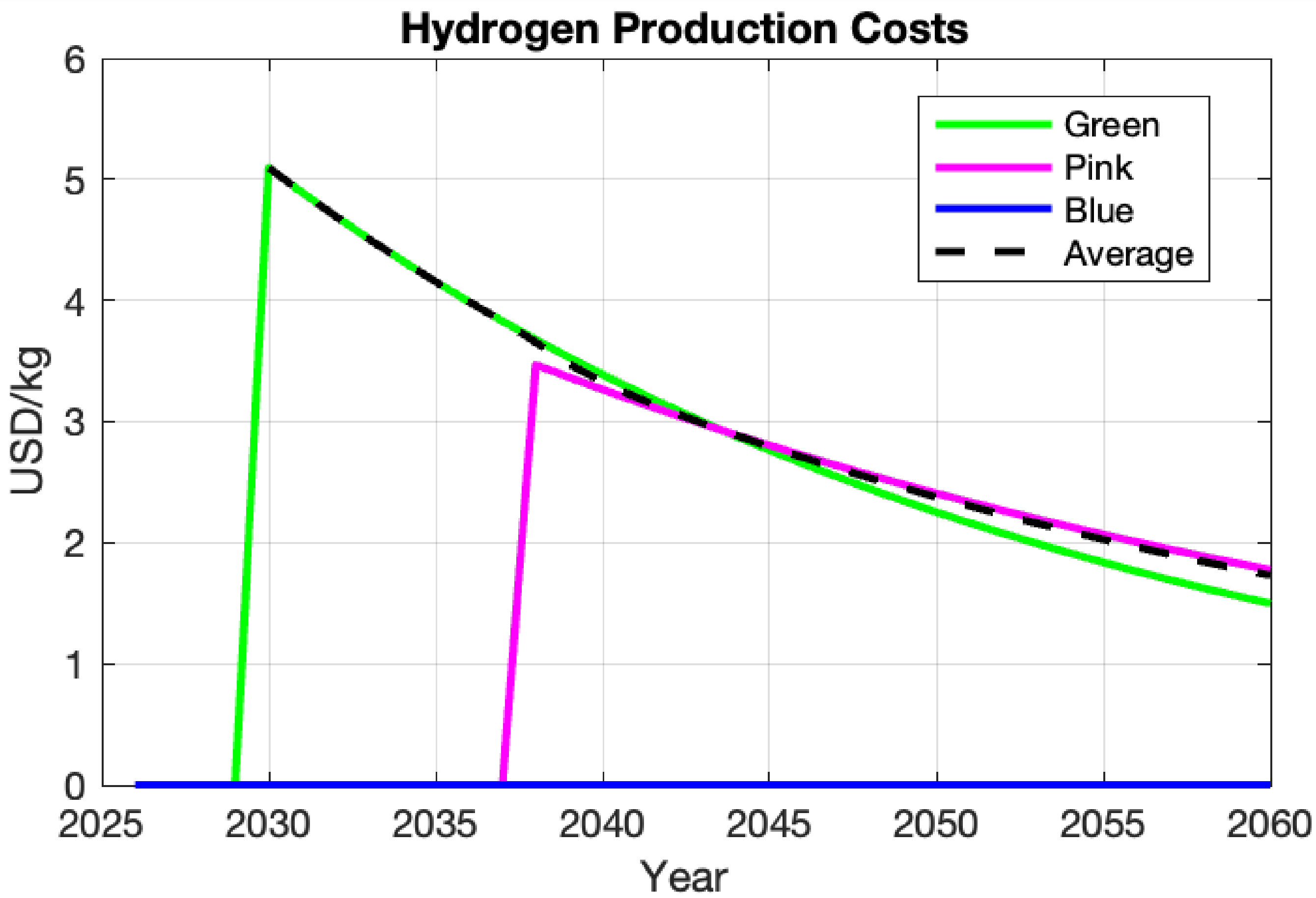
- **SMRs introduced in 2035, reaching 2860MW by 2060** **(PVs 7000MW)**
- **Generation in 2060 to support Energy-Water-Transport Nexus 37.22TWh**
- **Decarbonization of electricity sector by 2037**
- **H_2 production reaches 560,000t/year by 2060**
- **Transport H_2 demand grows 10% annually, reaching 230,000t/year** **(40% penetration)**





* Preliminary results

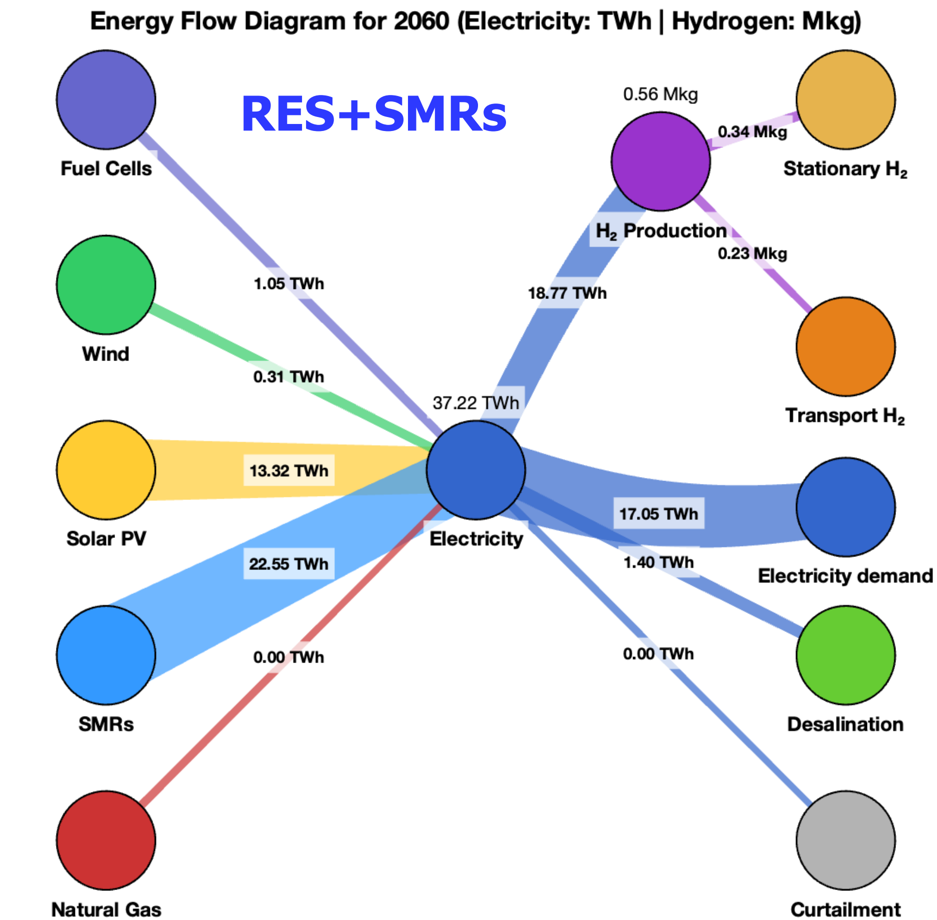
Hydrogen production cost*



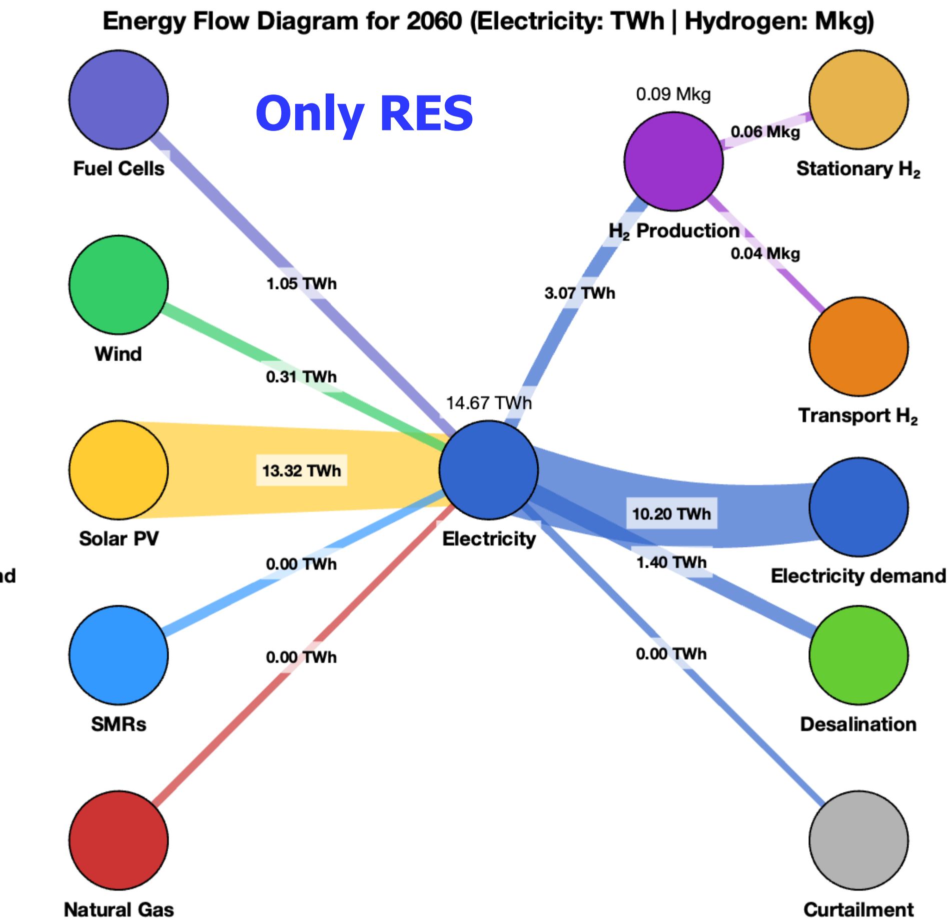
- Green H_2 prioritized, with pink hydrogen growing after 2035
- System-wide average H_2 cost reaches 1.78US$/kg by 2060

* Preliminary results

Energy flow diagrams*



Energy Flow Diagram for 2060
Electricity flows: TWh | Hydrogen flows: Mkg
Total H_2 production: 0.56 Mkg
Electricity for desalination: 1.40 TWh (3.9% of total generation)
Electricity exported: 3.81 TWh (10.5% of total generation)
Note: 1 Mkg H_2 ≈ 33.33 TWh (energy content of H_2 when converted back into electricity or the electricity required to produce H_2 via electrolysis)



Energy Flow Diagram for 2060
Electricity flows: TWh | Hydrogen flows: Mkg
Total H_2 production: 0.09 Mkg
Electricity for desalination: 1.40 TWh (10.3% of total generation)
Electricity exported: 1.58 TWh (11.6% of total generation)
Note: 1 Mkg H_2 ≈ 33.33 TWh (energy content of H_2 when converted back into electricity or the electricity required to produce H_2 via electrolysis)

* **Preliminary results**

Energy–Water–Transport Nexus Outlook

More information can be found on: Nexus Outlook

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Cyprus' Energy Transition to Hydrogen Economy: 2030–2060
Energy–Water–Transport Nexus Outlook

April 2025

Abstract

This outlook presents the outcome of a comprehensive simulation assessing Cyprus' transition towards a hydrogen–based economy from 2030 to 2060. To explore the power–water–transport nexus, an integrated mathematical optimization model is developed to investigate how the power, water and transportation sectors evolve through coordinated investments in renewable energy, hydrogen infrastructure and small modular reactors–based energy systems. The study reflects aggressive growth in green hydrogen retirement of fossil assets and the gradual integration of small modular reactors. Our latest modeling reveals:

- **100% reduction** in CO_2 emissions by 2060 through strategic hydrogen deployment
- **40% penetration** of hydrogen in transport sector by 2060
- **66% reduction** on green hydrogen production cost by 2060
- **100% reduction** on electricity curtailments by a combination of hydrogen electrolyzers and electricity interconnections
- Fuel cells provide growing share of electricity and mobility energy, reducing fossil emissions
- Small Modular Reactors with pink hydrogen production play a crucial role post–2035
- Water production keeps pace with demand through Small Modular Reactors–powered desalination, ensuring water security

Optimization Model Overview

The simulation integrates:

- Renewable expansion: Solar and wind capacity ramp–up annually
- Hydrogen prioritization: Green hydrogen is preferred, followed by pink hydrogen and blue (natural gas–derived)
- Interconnections: Electricity import/export capabilities up to 1,000MW
- Water management: Desalination is incorporated to support water demand growth

Key Results

Electricity Generation Mix

The generation mix shows a dramatic shift from fossil fuels to renewables and Small Modular Reactors (SMRs):

- Solar grows from 800MW to over 7,000MW by 2060
- Fossil fuels (heavy fuel oil, diesel and natural gas) capacity is phased out from 2030 onward, significantly reducing CO_2 emissions
- SMRs are introduced in 2035 supporting pink hydrogen and water desalination, reaching 2,860MW by 2060
- Fuel cells contribute 5–8% of electricity generation by 2060

Hydrogen Economy Growth

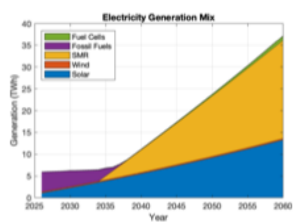
Key hydrogen production trends:

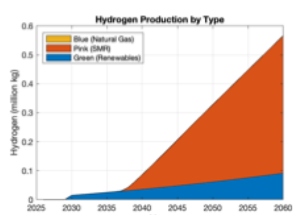
- Hydrogen production reaches over 500,000t/year by 2060
- Hydrogen demand in transport grows 10% annually, reaching over 200,000t/year by 2060
- Green hydrogen production from renewables prioritization over pink hydrogen from SMRs
- Pink hydrogen grows after 2035 with SMRs deployment providing baseload production
- Green hydrogen production cost fall below 2US$/kg after 2050
- System–wide average hydrogen cost reaches 1.78US$/kg by 2060

Economic Outlook

- Capital investments front–loaded with a strong increase in hydrogen infrastructure
- Interconnection exports grow, providing new revenue streams
- Capital expenditures peak in 2035 during SMRs build-out

Detailed Results





For PhD opportunities or more information contact Prof. Andreas Poullikkas, Professor of Energy Systems (email: a.poullikkas@frederick.ac.cy). Special tuition waivers of up to 90% are available for qualified PhD candidates

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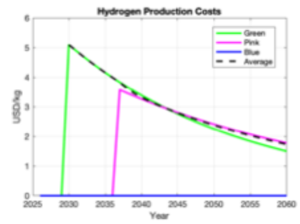
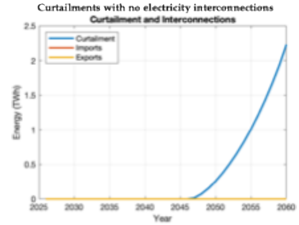
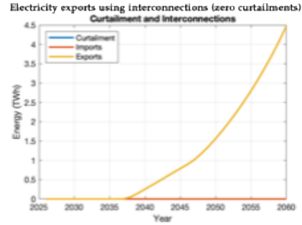


Curtailments with no electricity interconnections



Electricity exports using interconnections (zero curtailments)



Water–Energy Nexus

- Desalination grows from 219Mm^3/year to 416Mm^3/year
- 100% of desalination powered by renewables and SMRs by 2060
- Desalination plants co–located with hydrogen facilities reduce costs
- Hydrogen storage enables time–shifting of desalination energy demand
- Co–location reduces infrastructure costs by 20–30%

Water Production *vs* Demand

Year	Water Production (Mm^3)	Water Demand (Mm^3)
2030	231	276
2035	265	290
2040	292	305
2045	321	321
2050	351	337
2055	383	354
2060	416	373

Transport–Energy Nexus

- Electrolyzers dedicated to transport fuel: 1300MW by 2060
- Transport–specific storage: 5,000t capacity
- Hydrogen refueling stations co–located with existing gas stations
- Early focus on fleet vehicles and buses (2026-2035)
- Heavy trucks transition begins (2035-2045)
- Maritime applications emerge post–2040

Hydrogen Transport Sector

Year	Fuel Cell Capacity (MW)	H_2 Vehicles	H_2 Consumed (t/year)	Refueling Stations
2030	250	12,000	17,520	12
2035	450	35,000	51,100	20
2040	800	80,000	116,800	30
2045	1,100	130,000	189,800	40
2060	1,500	200,000	292,000	50

Economic Implications

- Average annual investment: 1.0US$B/year
- Cumulative fuel import reductions 38.2US$B
- Cumulative avoided carbon penalties 14.6US$B
- Electricity price impact: +12% during transition (2026–2035), -8% by 2060
- Desalination energy savings: 18% by 2040, 28% by 2060
- Total cost of ownership savings: 3,200US$/vehicle/year by 2040

Total System Costs (2026-2060, billion US$)

Component	CapEx	OpEx
Power Generation	18.2	12.5
Hydrogen Production	8.4	6.2
Water Desalination	3.1	2.8
Transport Infrastructure	4.5	3.1
Total	34.2	24.6

Policy Recommendations

Based on our modeling, we recommend:

1. **Early investment in electrolyzer infrastructure** to enable rapid green hydrogen scale–up
2. **Phased fossil fuels retirement** beginning in 2030 with full phase-out by 2045
3. **SMRs deployment** starting in 2035 to provide clean baseload power
4. **Transport sector incentives** to achieve 40% hydrogen penetration by 2060
5. **Water–energy nexus planning** to coordinate desalination with renewable energy availability
6. **Development of hydrogen refueling infrastructure** starting with major transport corridors
7. **Implementation of regulatory framework** for SMRs integration
8. **Establishment of hydrogen export partnerships** with European neighbors

Conclusion

Cyprus' transition to a hydrogen economy is technically feasible and economically viable according to our modeling. The power–water–transport nexus approach demonstrates how strategic investments can simultaneously achieve:

- **Deep decarbonization** in power sector (100% CO_2 emissions reduction)
- **Energy security** through diversified sources
- **Water security** *via* coordinated desalination
- **Clean transportation** fuel alternatives

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