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

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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

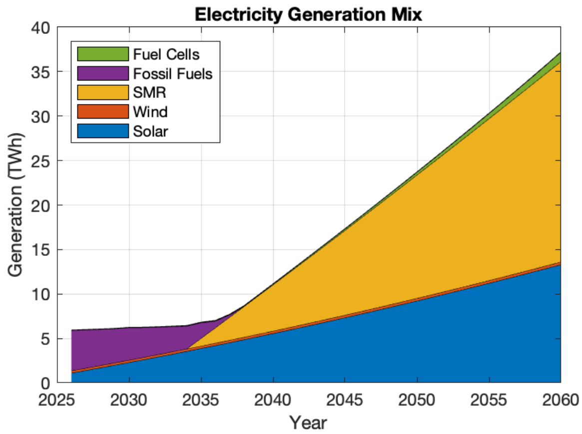
Key hydrogen production trends:

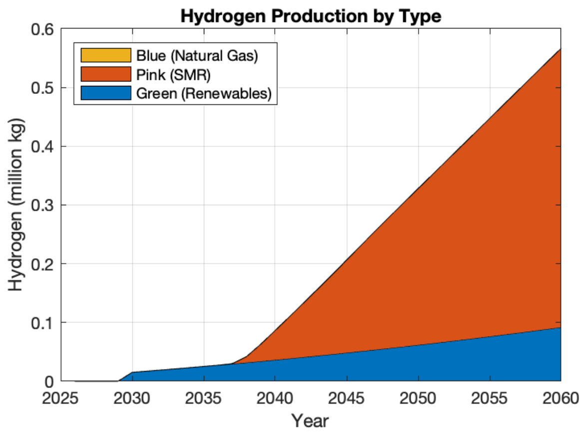
- Hydrogen production reaches over 500,000t/year by 2060
- Hydrogen demand in transport grows 10% annually, reaching over 200,000t/year by 2060
- Green hydrogen production from renewables prioritization over pink hydrogen from SMRs
- Pink hydrogen grows after 2035 with SMRs deployment providing baseload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

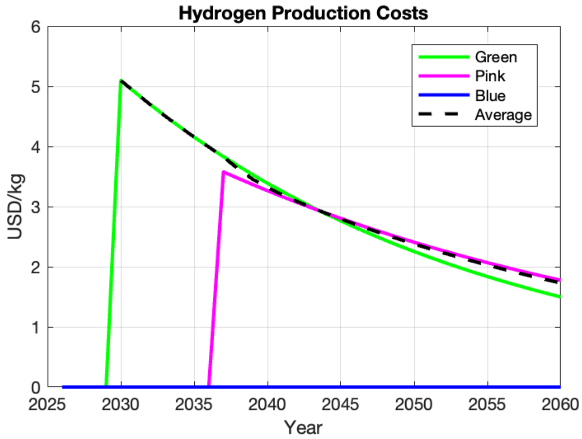
Economic Outlook

- 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

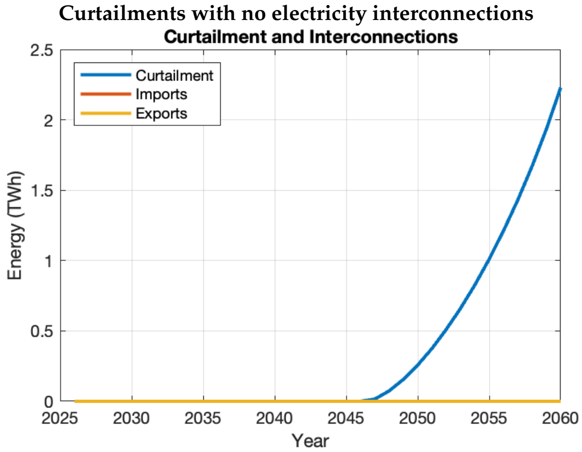
Detailed Results



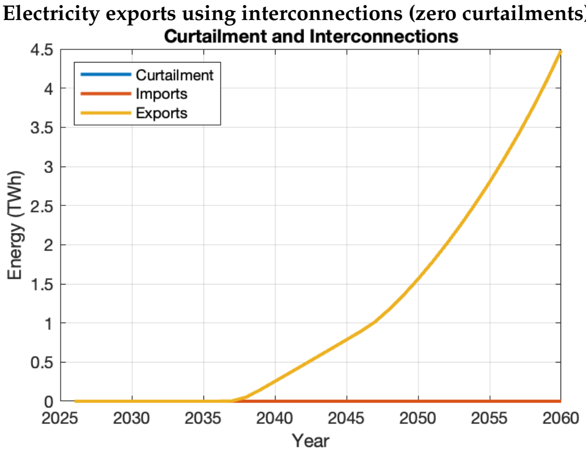




Curtailments with no electricity interconnections



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