National Technical
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European Geosciences Union

Spatial Analysis of Desalination Energy Demand in Greece: Feasibility Zones from the coastline for Water-Energy Planning

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Presentation Outline

- Introduction
- Study area
- Key Assumptions
- Input parameters
- Methodology
- Spatial Results
- Zonal Statistics
- Results
- Key Insights & Conclusion

Introduction

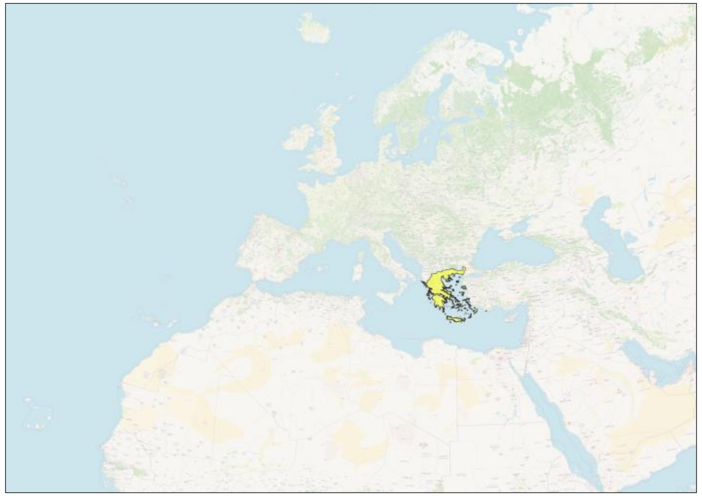
- Greece faces increasing on freshwater resources
- Main drivers: climate variability, uneven population distribution, tourism & agriculture
- **Desalination** is a reliable, climate independent water supply solution

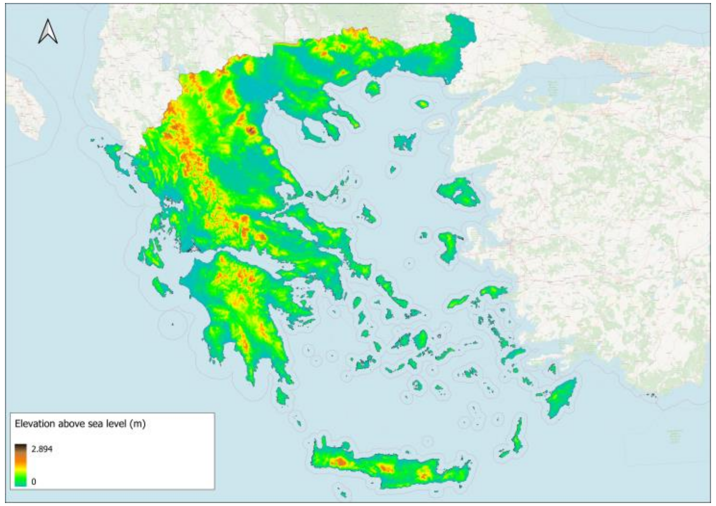
However, **energy demand** is not only from desalination. Water transport to inland areas increases energy requirements.

This study investigates how distance from the coastline affects total energy demand using a GIS-based spatial analysis across Greece.

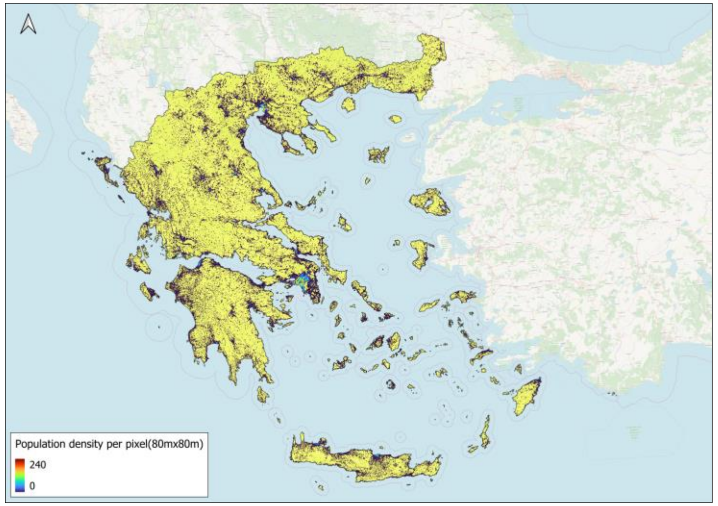
Study Area

- Greece: predominantly coastal country with complex topography ~75% mountainous and semi-mountainous terrain
- Population (~10.4 million) unevenly distributed
- High population density in coastal and urban areas
- Inland and island regions require energy-intensive water supply
- Distance from coastline is a key factor for desalination feasibility





Elevation data: FABDEM
Population data: WorldPop



Key Assumptions

- | Average daily water consumption: **173 L/capita/day**
- | Desalination plants are located along the coastline
- | Pipelines follow the upstream flow path (upstream flow length)
- | Pipe diameter (*D*): **0.5 m**
- | Flow velocity (*V*): **2 m/s**
- | Pipe material: HDPE
- | Pump efficiency (n_{pump}): **80%**
- | Specific Energy Consumption (SEC): **5 kWh/m^3**
- | Minimum residual pressure: **15 m**

Input parameters

1

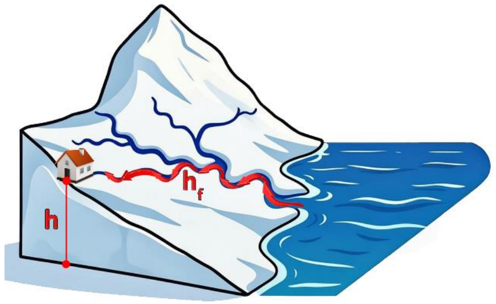
Head

$$U = \rho \cdot g \cdot h \quad [\text{kWh/m}^3]$$

ρ = water density (1000 kg/m³)

g = gravitational acceleration (9.81 m/s²)

h = elevation difference from DEM (m)



2

Friction losses

Calculated using the Colebrook-White equation:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{k_s}{3.7D} + \frac{2.51}{Re\sqrt{f}}\right)$$

f = Darcy friction factor

k_s = roughness (HDPE ≈ 0.007 mm)

D = pipe diameter (m)

Re = Reynolds number = $\frac{VD}{\nu}$

$$h_f = \frac{f \times V^2}{D \times 2 \times g} \times \mathbf{L(upstream\ flow\ length)}$$

$$\frac{h_f}{L} = \frac{f * V^2}{D * 2 * g} = 4{,}9\ m/km$$

$$E_f = \frac{\rho \times g \times h_f}{n_{pump} \times 3.6 \times 10^6} \quad [\text{kWh/m}^3]$$

3

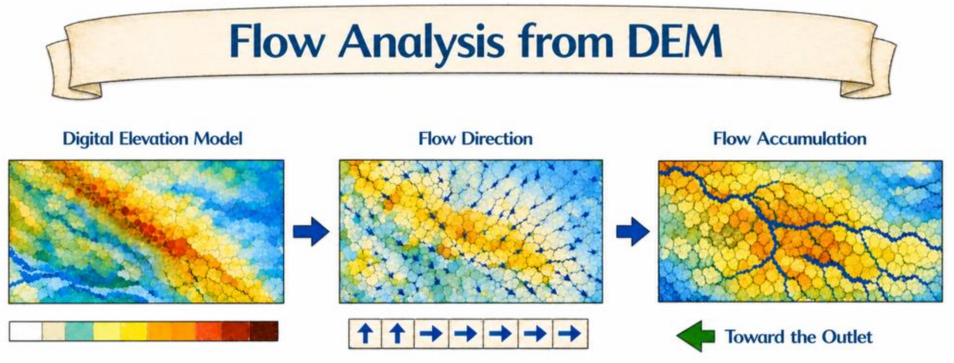
Total dynamic head

$$E_{tot} = \frac{\rho \times g \times (H + h_f + 15)}{n_{pump} \times 3{,}6 \times 10^6} + SEC \quad [\text{kWh/m}^3]$$

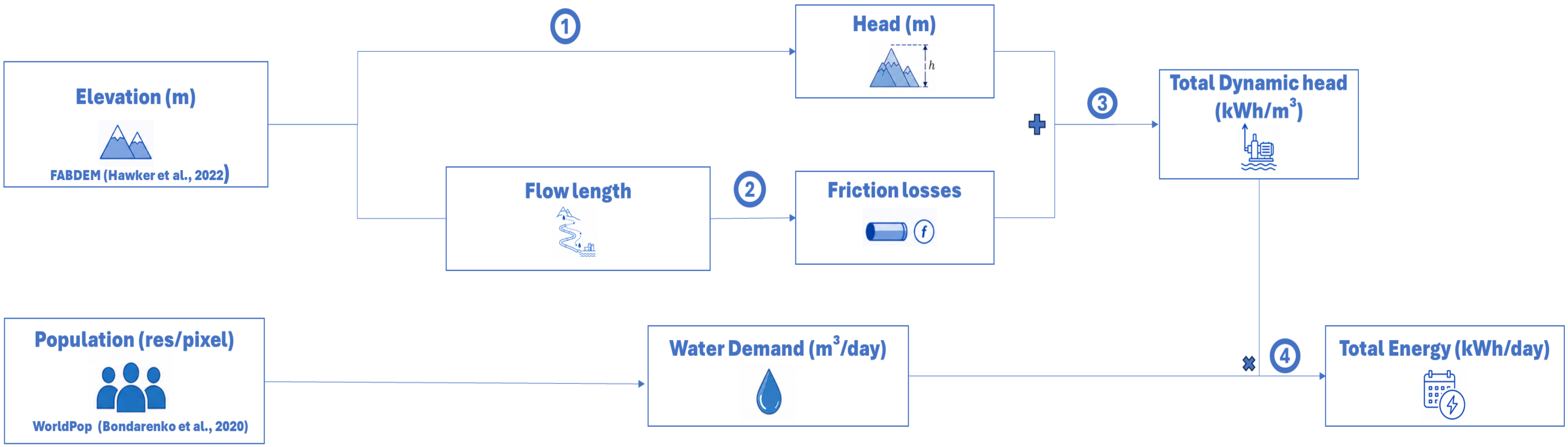
4

Total daily energy demand

$$E_{day}\left[\frac{kWh}{day}\right] = E_{tot}\left[\frac{kWh}{m^3}\right] \times Q_{day}\left[\frac{m^3}{day}\right]$$



Methodology



Spatial Results

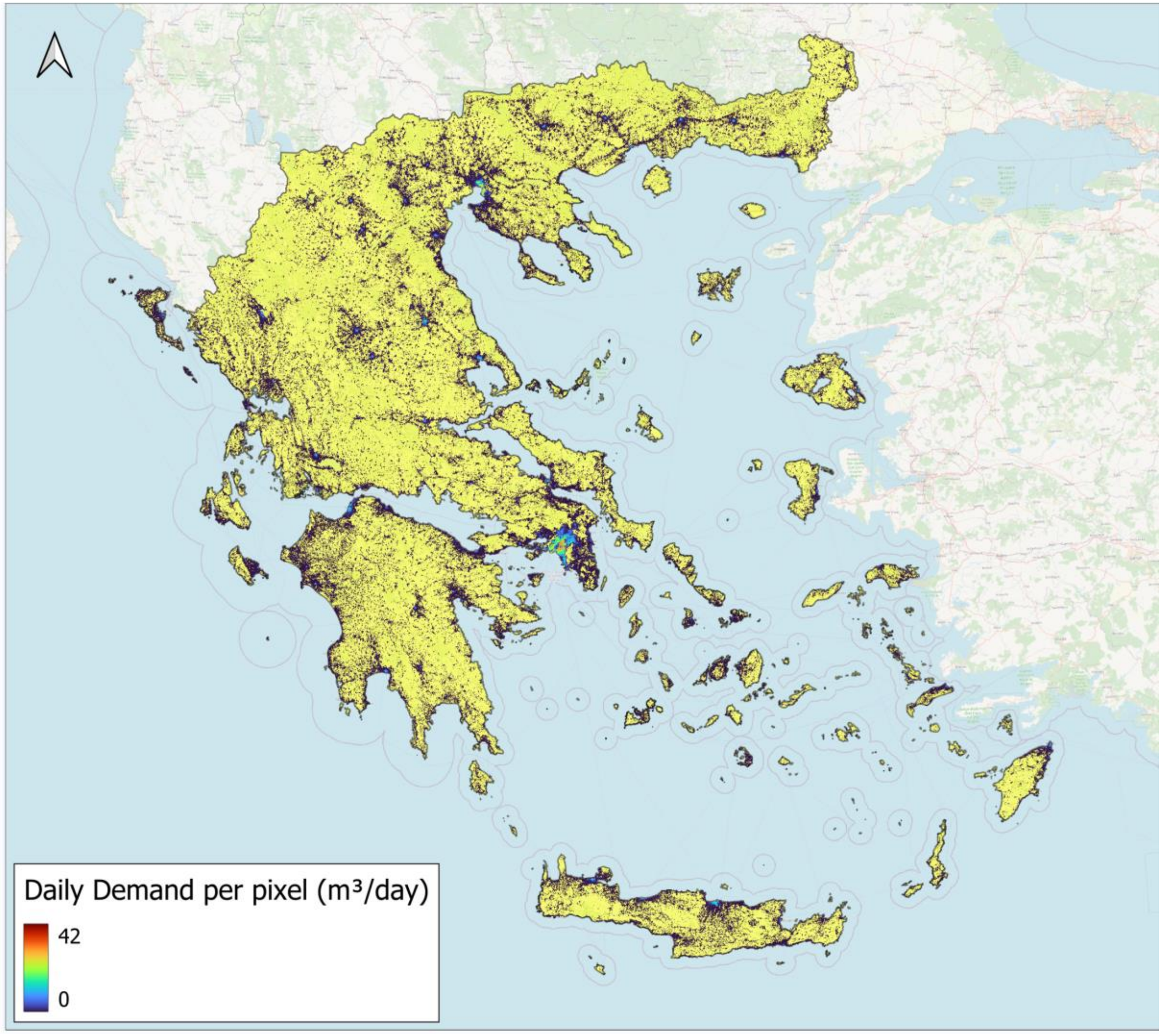


Figure 1: Spatial Distribution of daily water demand (m³/day)

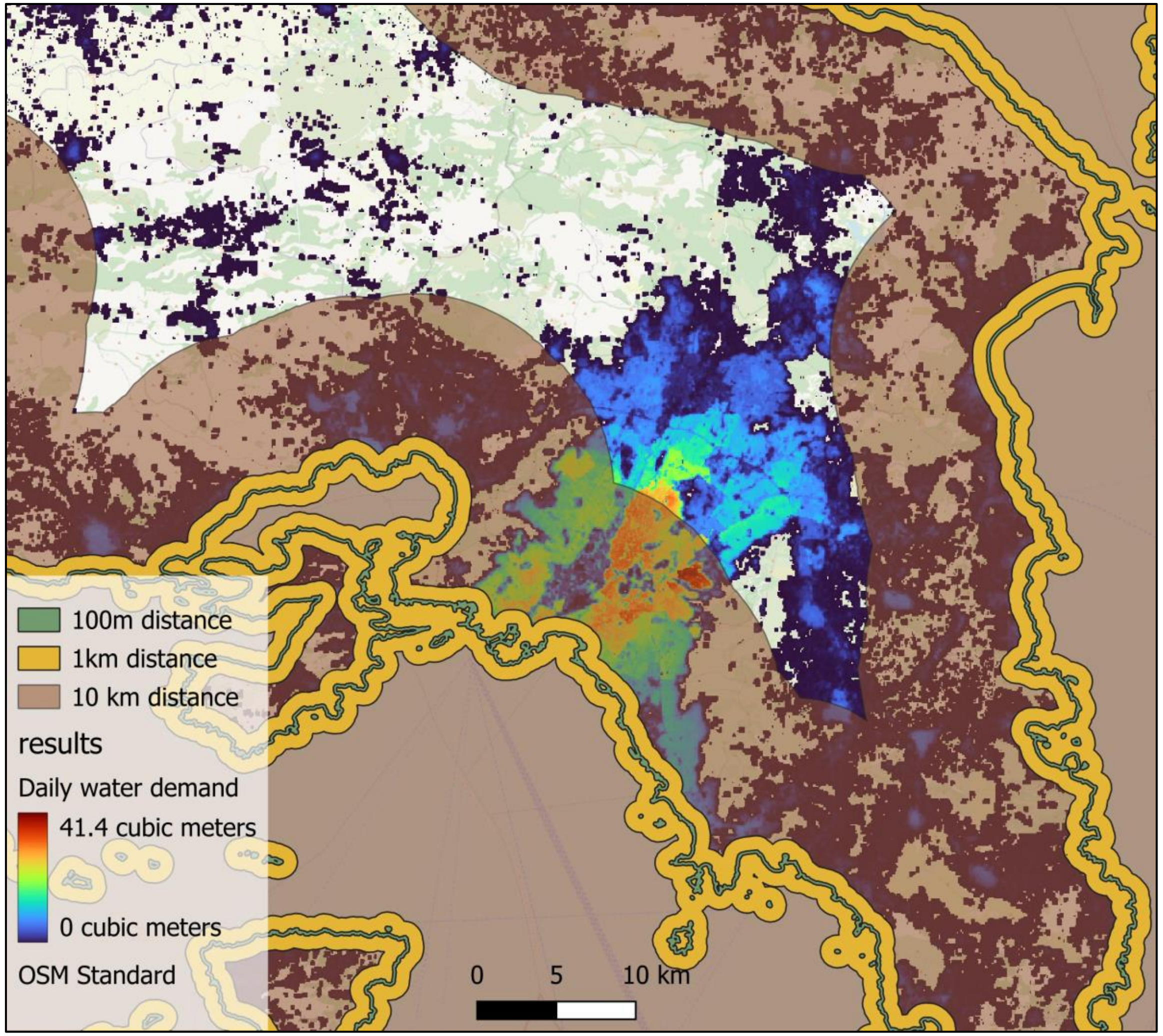


Figure 2: Zonal Distribution of daily water demand (m³/day)

Spatial Results

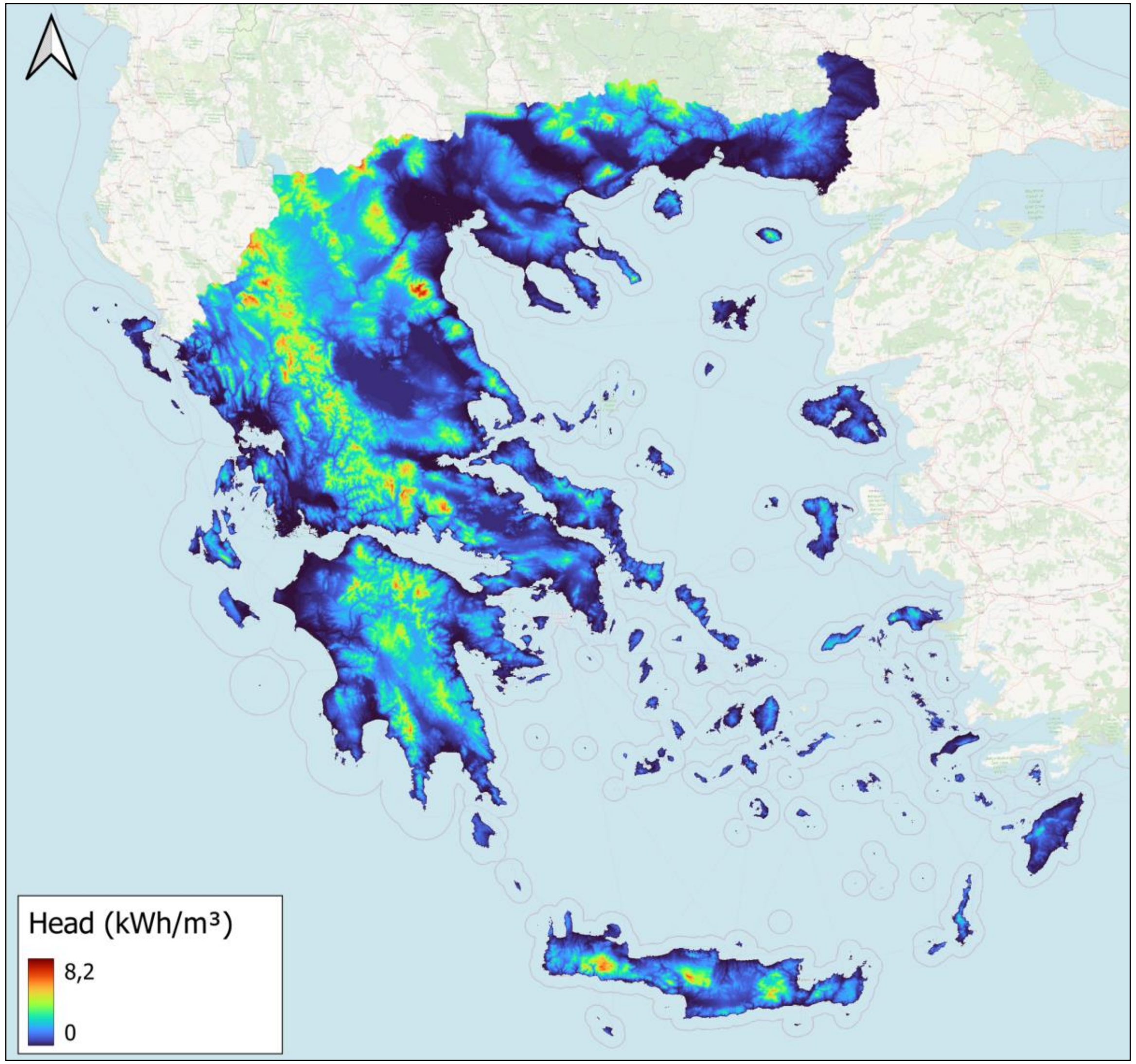


Figure 3: Spatial distribution of head (kWh/m³)

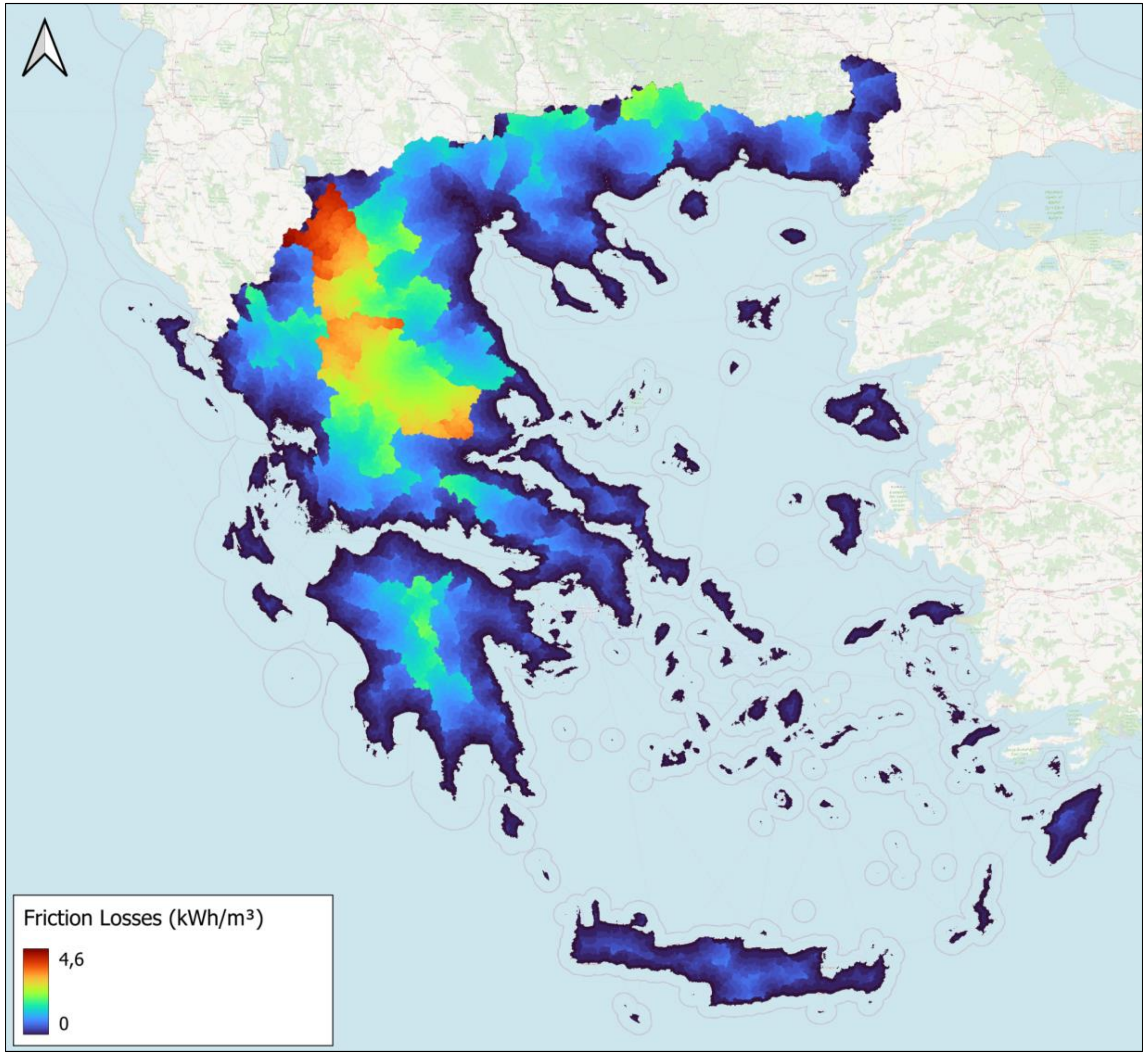


Figure 4: Spatial distribution of friction losses (kWh/m³)

Spatial Results

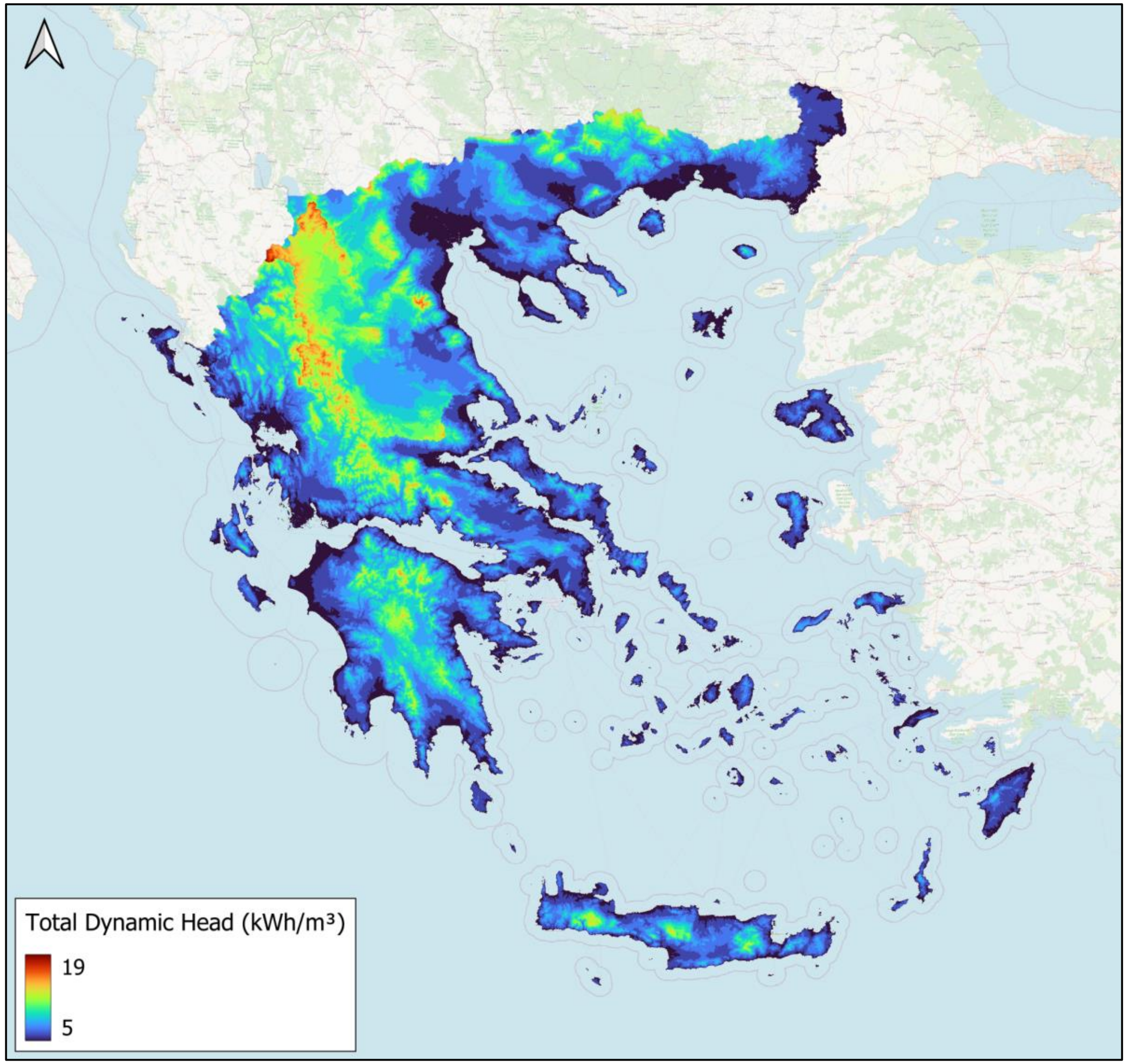


Figure 5: Spatial distribution of Total dynamic head (kWh/m³)

Spatial Results

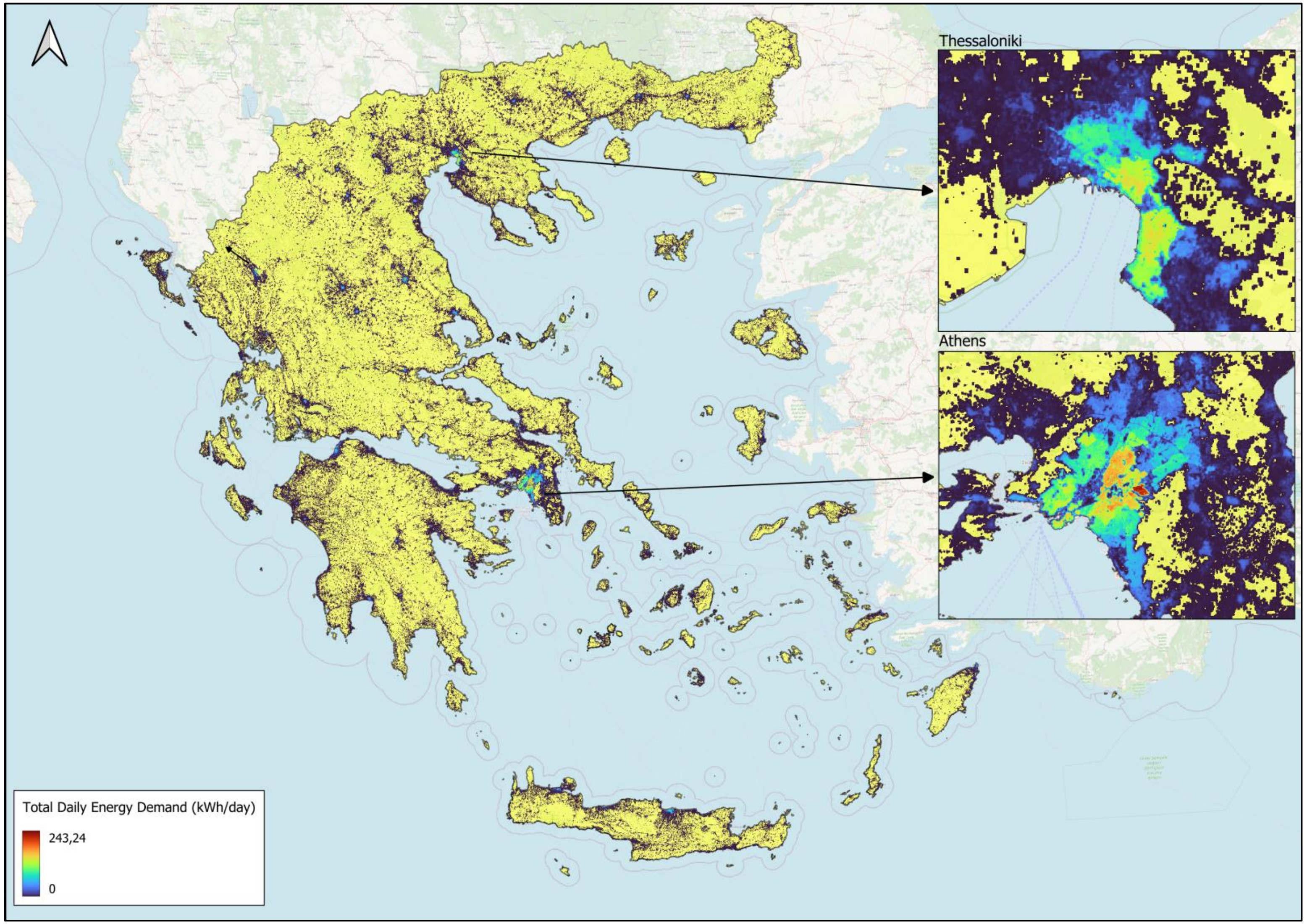


Figure 6: Spatial distribution of total daily energy demand (kWh/day)

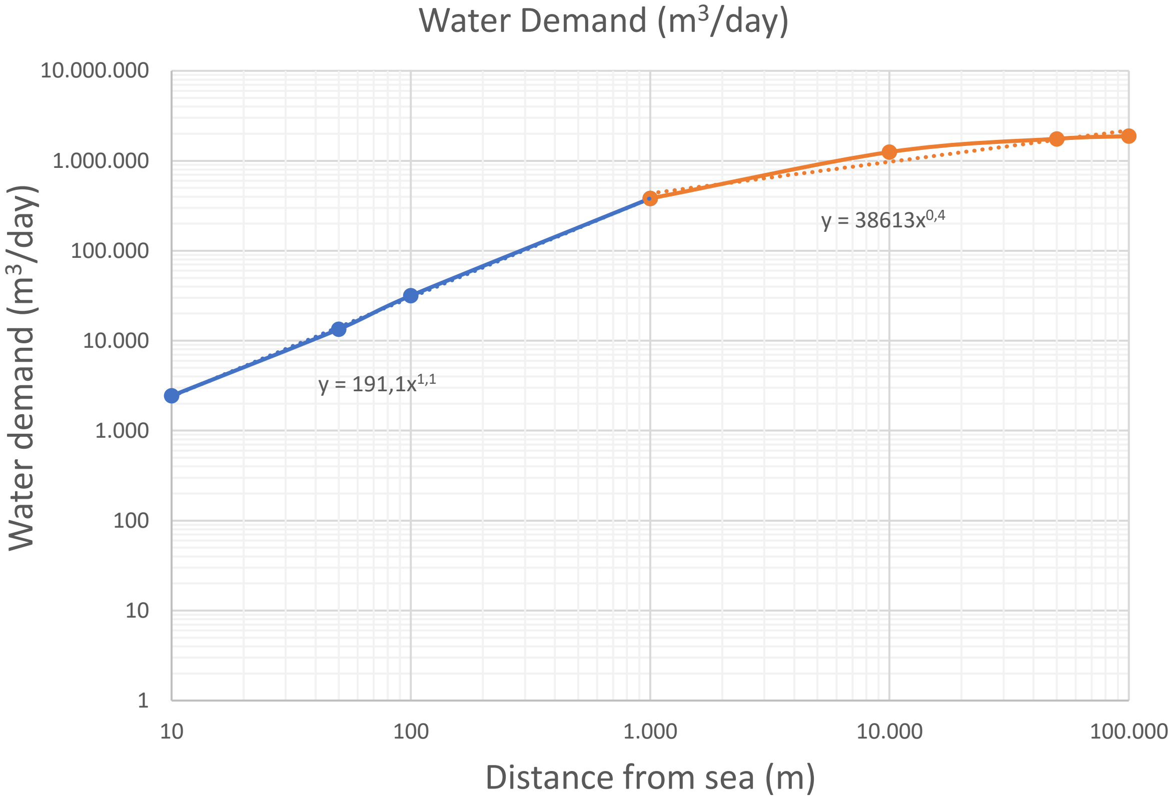
Zonal Statistics

Feasibility zones (m)	Population	Water Sum (m³/day)	Head mean (kWh/m³)	Friction losses mean (kWh/m³)	Total Energy Sum (kWh/day)
10	14105	2440	0,050	0,0009	7374
50	77707	13443	0,055	0,0010	47523
100	183088	31674	0,067	0,0013	133658
1000	2206090	381654	0,241	0,0105	1930724
10000	7236643	1251939	0,748	0,1141	6732018
50000	10161296	1757904	1,158	0,5020	10006415
100000	10872522	1880946	1,317	0,7002	11038554
Greece	10923722	1889804	1,356	0,7518	11180669

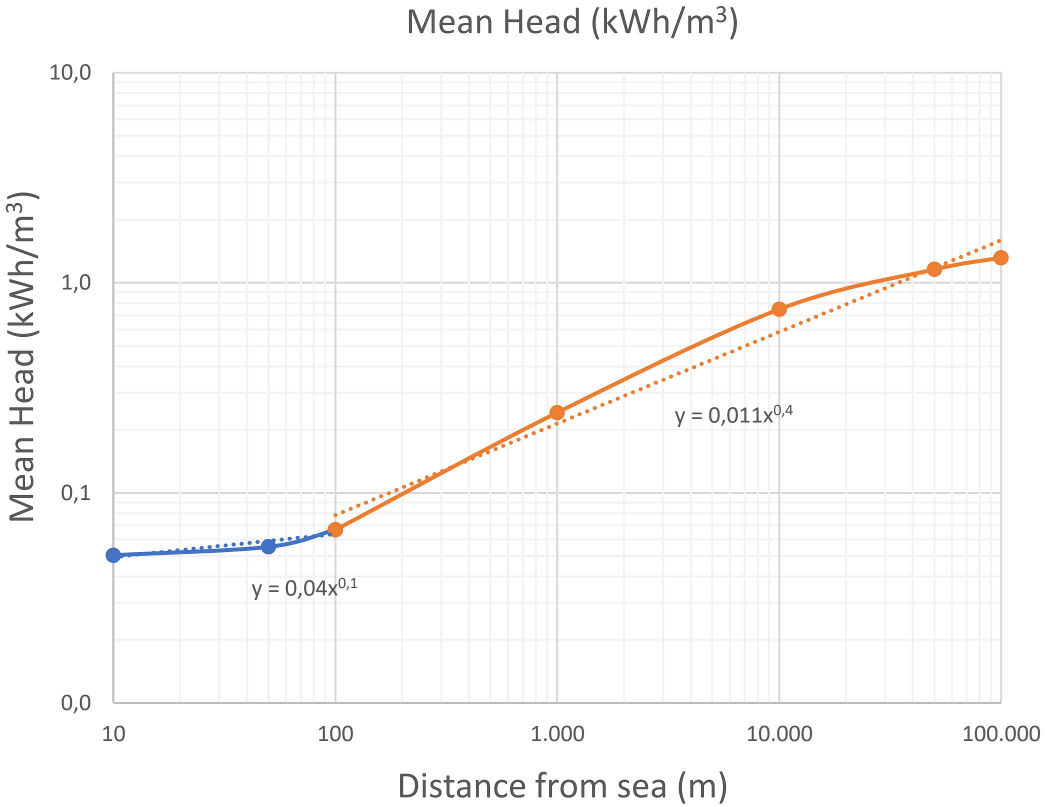
Feasibility zones (m)	Population (%)	Water Sum (%)	Head mean (%)	Friction losses mean (%)	Total Energy Sum (%)
10	0,13	0,13	3,72	0,11	0,07
50	0,71	0,71	4,08	0,13	0,43
100	1,68	1,68	4,91	0,17	1,20
1000	20,20	20,20	17,78	1,40	17,27
10000	66,25	**66,25**	55,17	15,18	**60,21**
50000	93,02	93,02	85,41	66,78	**89,50**
100000	99,53	99,53	97,11	93,14	98,73
Greece	100,00	100,00	100,00	100,00	100,00

Table: Aggregated and relative energy demand across distance-based feasibility zones

Results

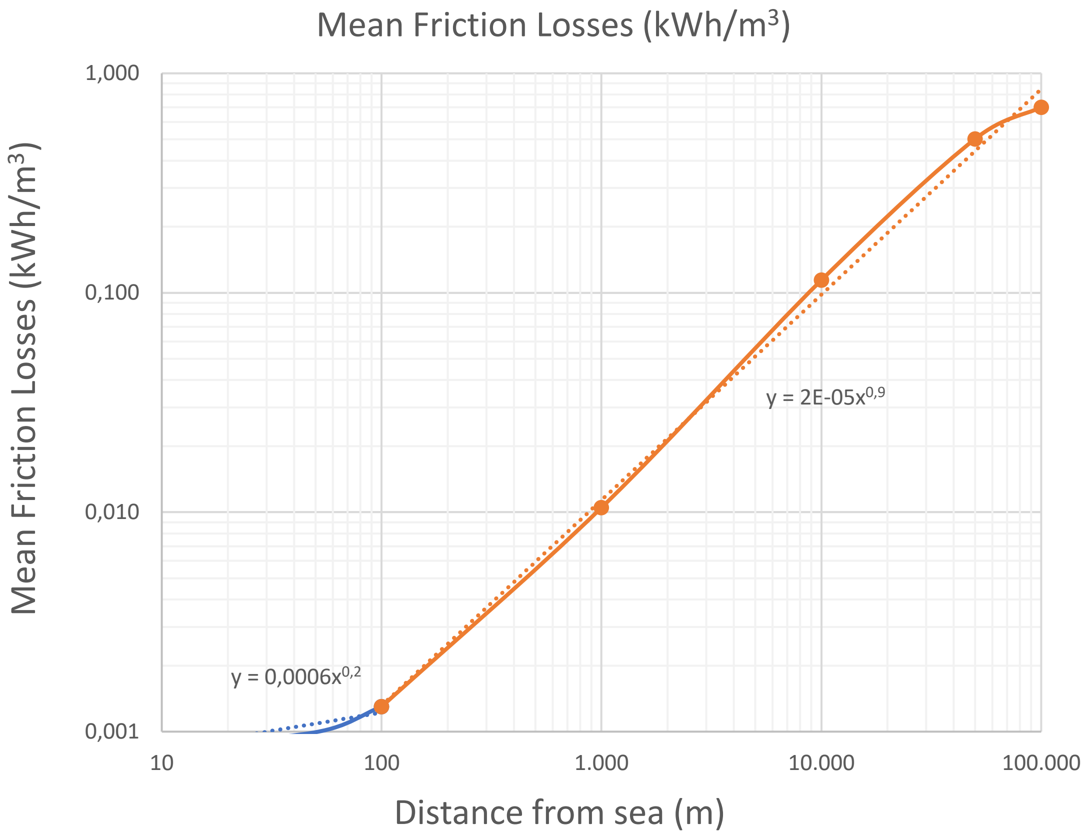


Water Demand (m3/day)
10.000.000
1.000.000
100.000
10.000
1.000
100
10
1
Water demand (m3/day)
y = 191,1x1,1
y = 38613x0,4
10
100
1.000
10.000
100.000
Distance from sea (m)

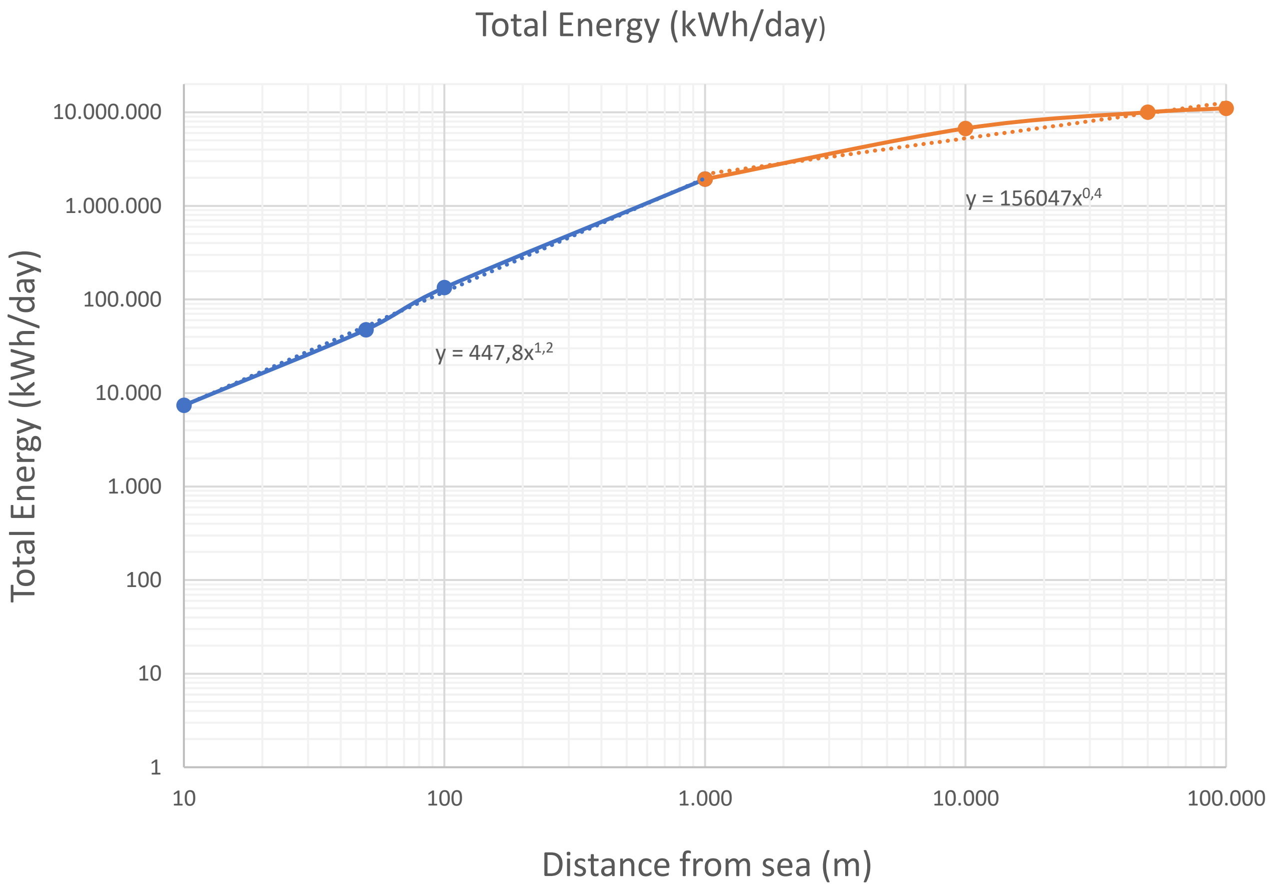


Mean Head (kWh/m3)
10,0
1,0
0,1
0,0
Mean Head (kWh/m3)
y = 0,04x0,1
y = 0,011x0,4
10
100
1.000
10.000
100.000
Distance from sea (m)

Results



Mean Friction Losses (kWh/m³)
1,000
0,100
0,010
0,001
10
100
1.000
10.000
100.000
y = 2E-05x^0,9
y = 0,0006x^0,2
Mean Friction Losses (kWh/m³)
Distance from sea (m)



Total Energy (kWh/day)
10.000.000
1.000.000
100.000
10.000
1.000
100
10
1
10
100
1.000
10.000
100.000
y = 156047x^0,4
y = 447,8x^1,2
Total Energy (kWh/day)
Distance from sea (m)

Key Insights-Conclusion

- Instead of the shortest path, pipelines follow the "thalweg" (the lowest point of a valley) in reverse. This minimizes excavation costs by following natural gradients upstream
- Water demand is the most influencing parameter to total energy demanded per zone and not the geomorphological conditions as each curves' shape is identical
- There is a critical spatial threshold in 1 km, where changes in distance lead to smaller proportionate changes in water demand and total energy.
- Geomorphology appears via head and friction losses curve, a spatial critical threshold at 100m, where the changes grow bigger according to distance from sea
- ~90% of total energy demand occurs beyond 10-50 km from the coastline
- For every 10% increase in distance from the coastline, the total energy demand increases by 8%
- Meeting 100% of domestic water demand through desalination would require ~**11 GWh/day**, corresponding to an **~8% increase** relative to Greece's daily electricity consumption (~137 GWh/day, considering residential and public sector use).

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