Turning Crete into an energy independent island

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The existing interconnection plans

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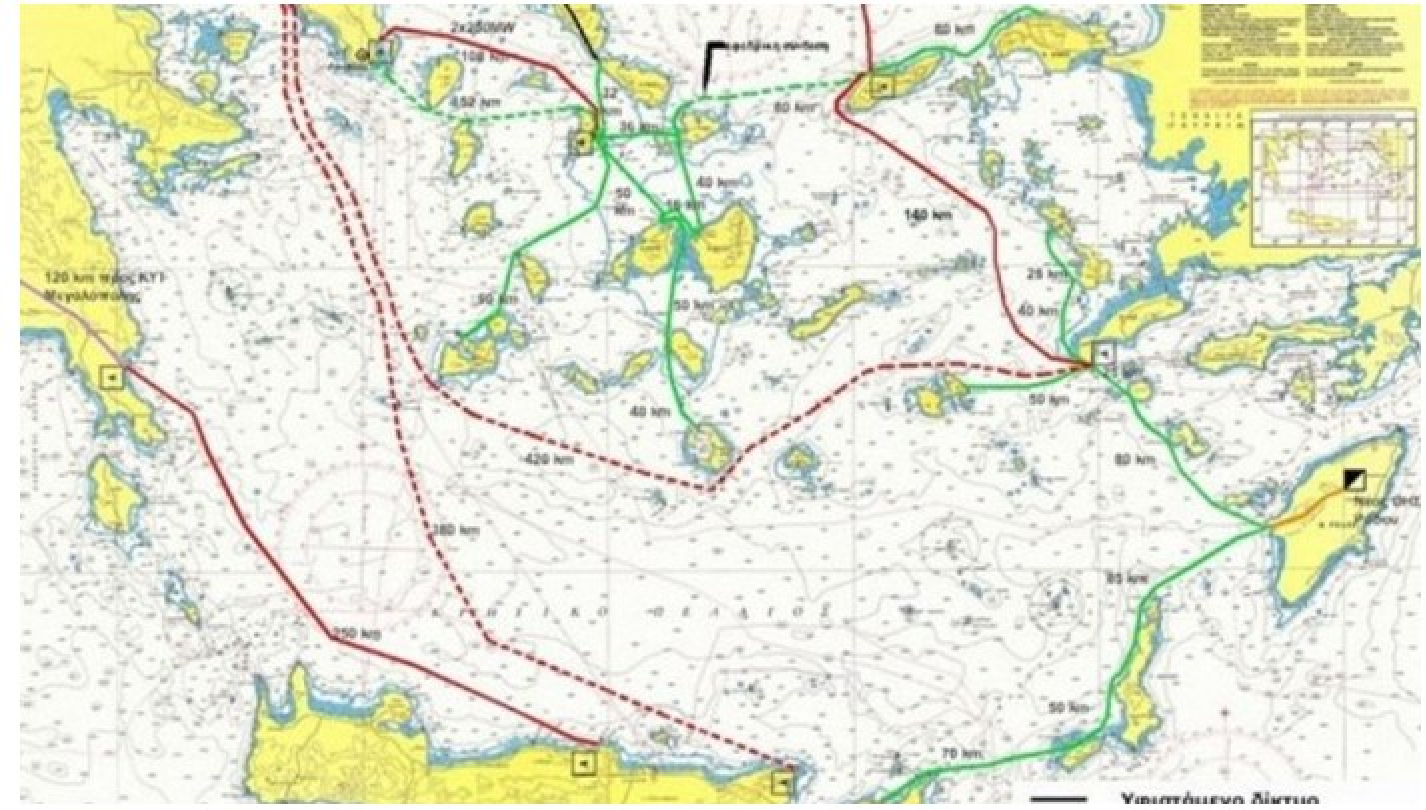


First interconnection:

- 150 kV AC cable,
  2 x 200 MW
- Length 134 km underwater,
  42 km underground
- Maximum depth: 950 m.

Second interconnection

- Cable 400 kV DC, 1,000 MW
- Estimated length: above 330 km underwater.
- Maximum depth: 1,200 m

The existing interconnection plans

The Euroasia Interconnector:

- A Consortium of the involved TSO of Greece, Cyprus and Israel.
- Power: 1,000 MW (phase 1) plus 1,000 MW (phase 2).
- Voltage: 500 kV DC.
- Total underwater cable length: 1,500 m.
- Maximum depth: 3,000 m (between Crete and Cyprus).

Interconnection's objectives

The main objectives of the interconnection are:

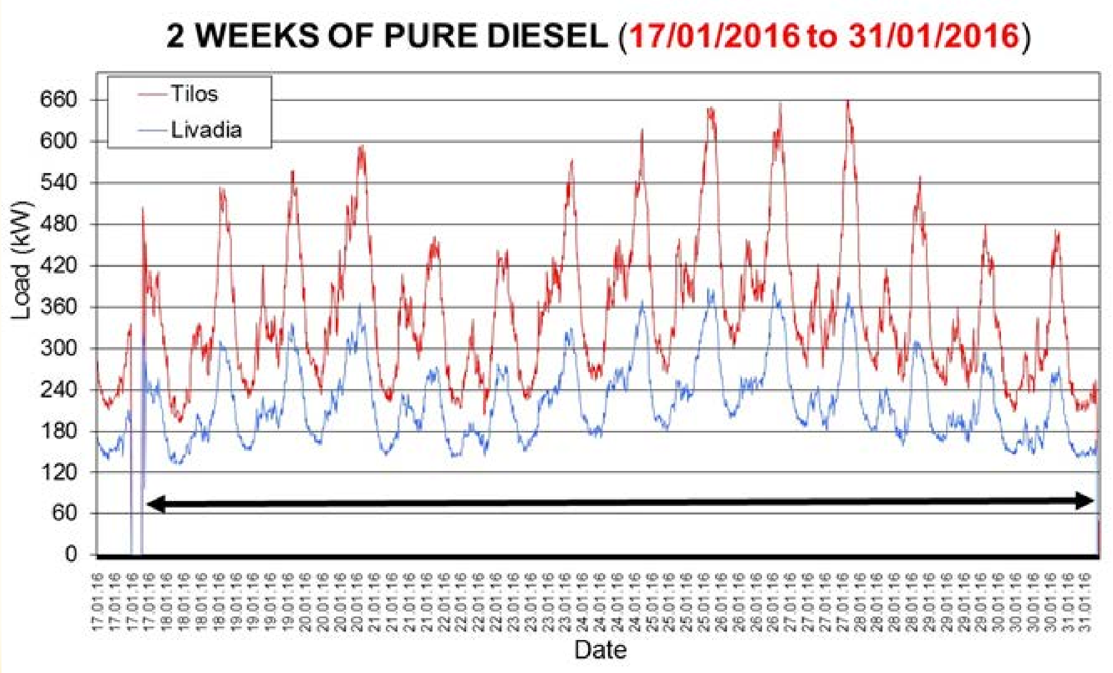
- Support of the insular system's energy supply security, dynamic security and stability.
- Increase of the power production in the island from RES projects.
- Reduction of the existing high overall (fixed and varied) electricity production specific cost (above 0.20 €/kWh).

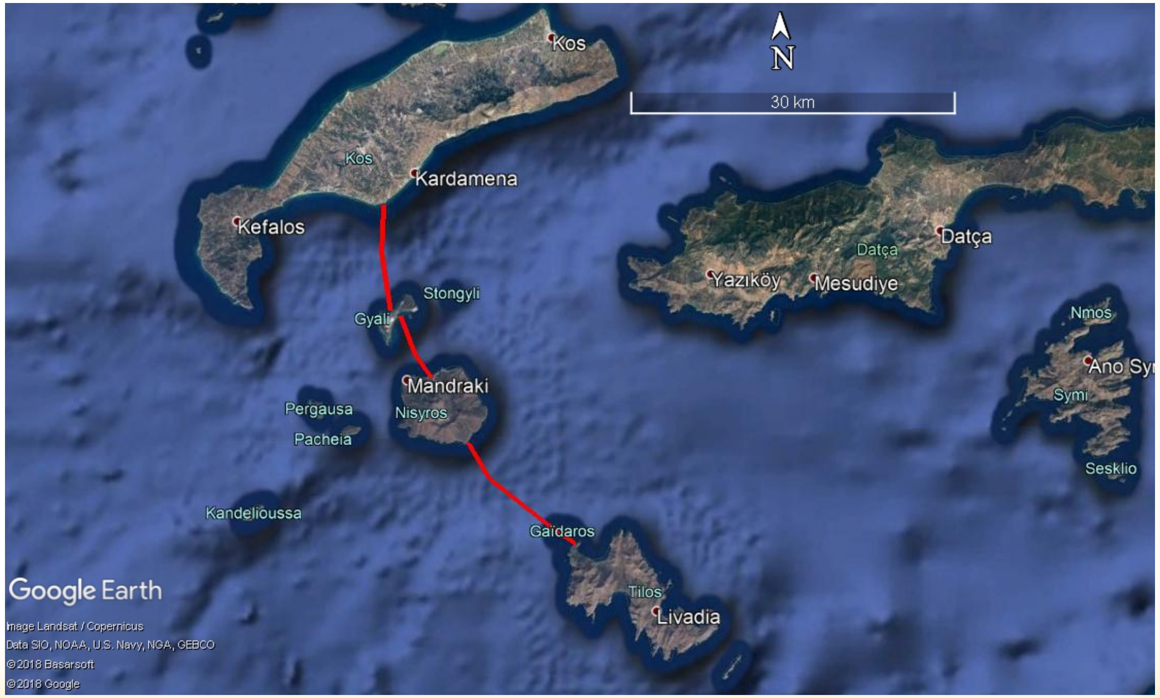
Is interconnection enough…

… to ensure energy supply security?

The experience of Tilos, interconnected with Kos:

- The underwater cable was cut by a passing by fishing trailing net, leaving the island of Tilos for two weeks on a small diesel genset.





… to ensure energy supply security?

The experience of Kasos, interconnected with Karpathos:

- On 2/7/2003, the first of the two cables was cut.
- On 25/7/2003, the second of the two cables was cut too, leaving the island of Kasos without any power at all, for five (5) days.
- On 30/7/2003, a diesel genset was brought in the island to provide power for essential needs.
- The power supply from Karpathos was fully restored after two weeks.

… to ensure energy supply security?

The above examples show

that underwater interconnections cannot fully guarantee energy supply security.

Power production on the island territory should be maintained.

… to reduce the electricity production cost?

- The reduction of the electricity production cost requires the elimination of the existing thermal power plants operation.
- Yet, given the above justification, this is not possible, due to energy supply security requirements.
- This means that some of the existing thermal generators should be maintained at least at stand-by mode.
- This implies that at least the fixed production cost will not be avoided (around 0.11 €/kWh).

Conclusion

It seems that the only way to:

a. maintain high level energy supply security

b. approach lower electricity production cost

c. enable higher and secure RES penetration

is with the installation of guaranteed RES power production plants on the island, the so-called “hybrid power plants”.

The existing situation in Crete and in insular Greece

Characteristic cases of the existing applications - licenses

Astypalaia

Characteristic cases of the existing applications - licenses

Amorgos

Characteristic cases of the existing applications - licenses

Ios

Kythnos

Characteristic cases of the existing applications - licenses

Kasos - Karpathos

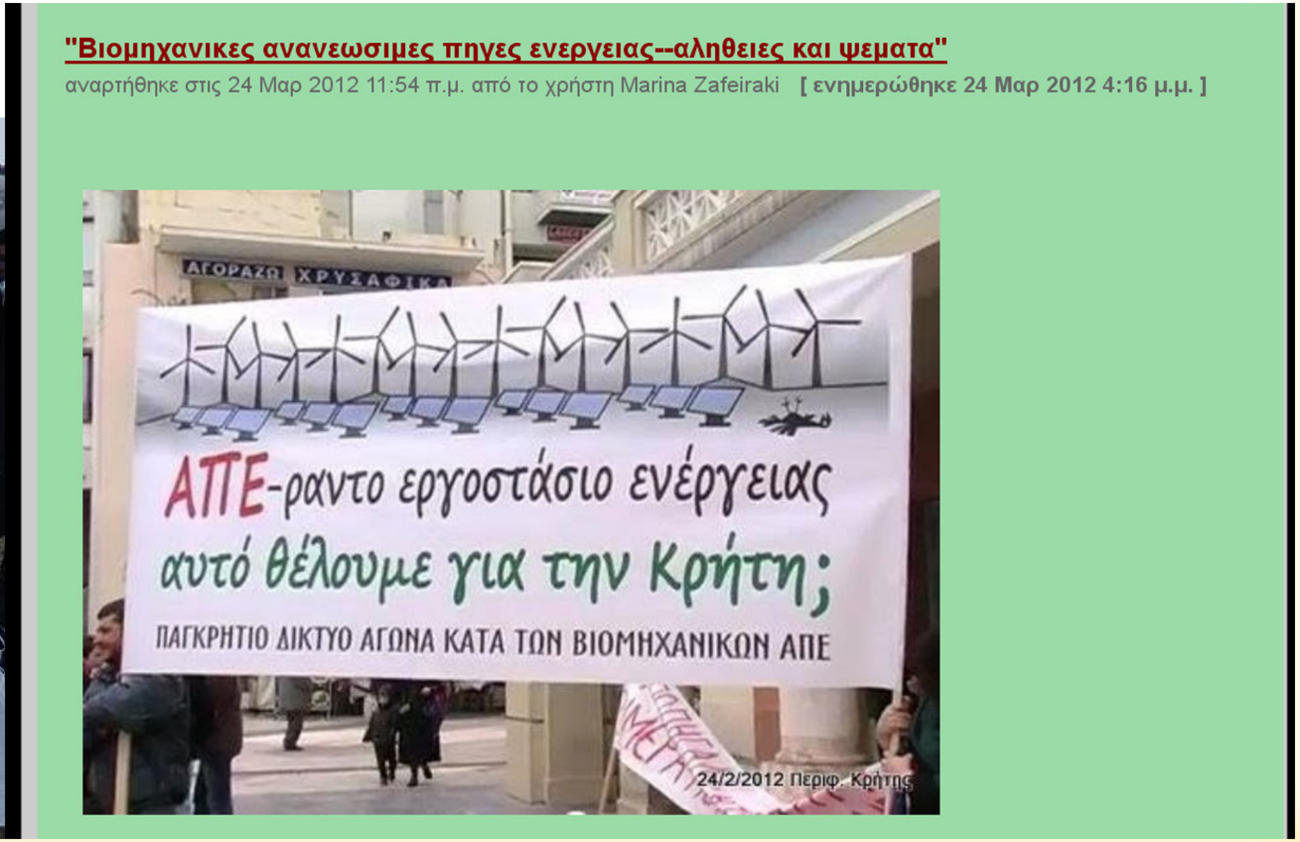
Characteristic cases of the existing applications - licenses

Crete: Total issued and submitted for licensing power: 5,000 MW

Common features of the issued licenses or the submitted applications

- Lack of approach - promote policies for the local communities. In most cases the local communities are informed for the RES projects by the media or the site of the Regulatory Authority of Energy.
- Lack of any communication with the owners of the land. The applications are submitted and the licenses are issued with the land property issue still unclear.
- Plenty of violations with the existing restrictions introduced by the relevant legislation regarding the development of RES projects.

Results: the development of a negative attitude against RES projects



The case of Greece: An example to avoid

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The exploitation of electricity production projects from Renewable Energy Sources for the social and economic development of remote communities. The case of Greece: An example to avoid

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ARTICLE INFO

ABSTRACT

A sensible question

Following the above inconvenient reality, several times,

in open conferences or public dialogues

or with face to face conversations,

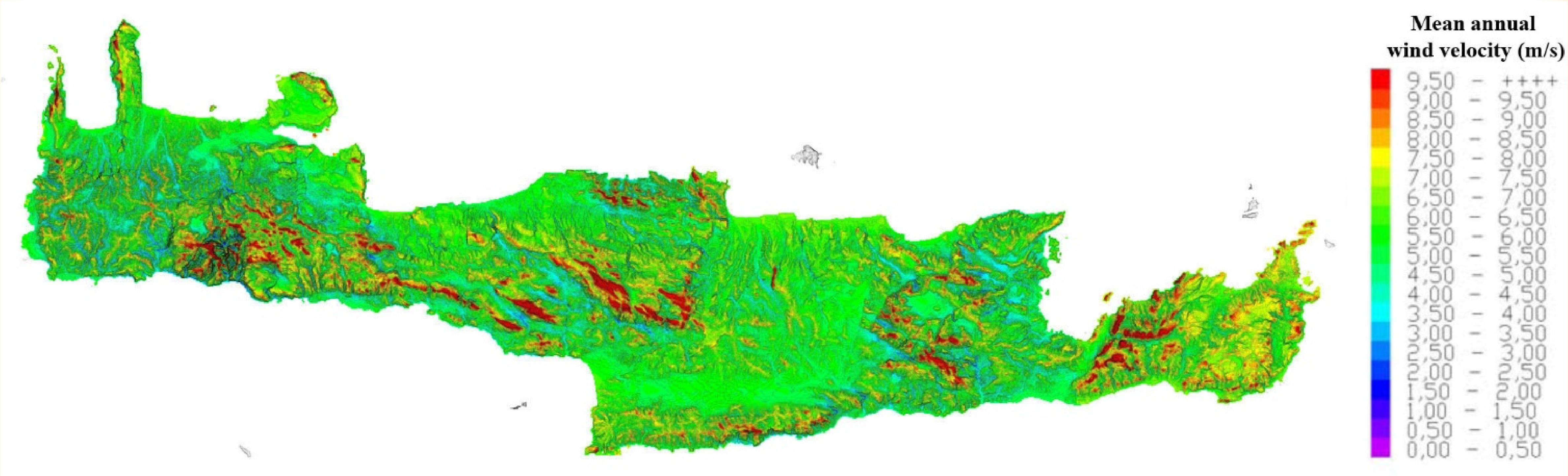
a sensible, common question has been raised:

what type of technologies and how many plants does Crete need

to become energy independent?

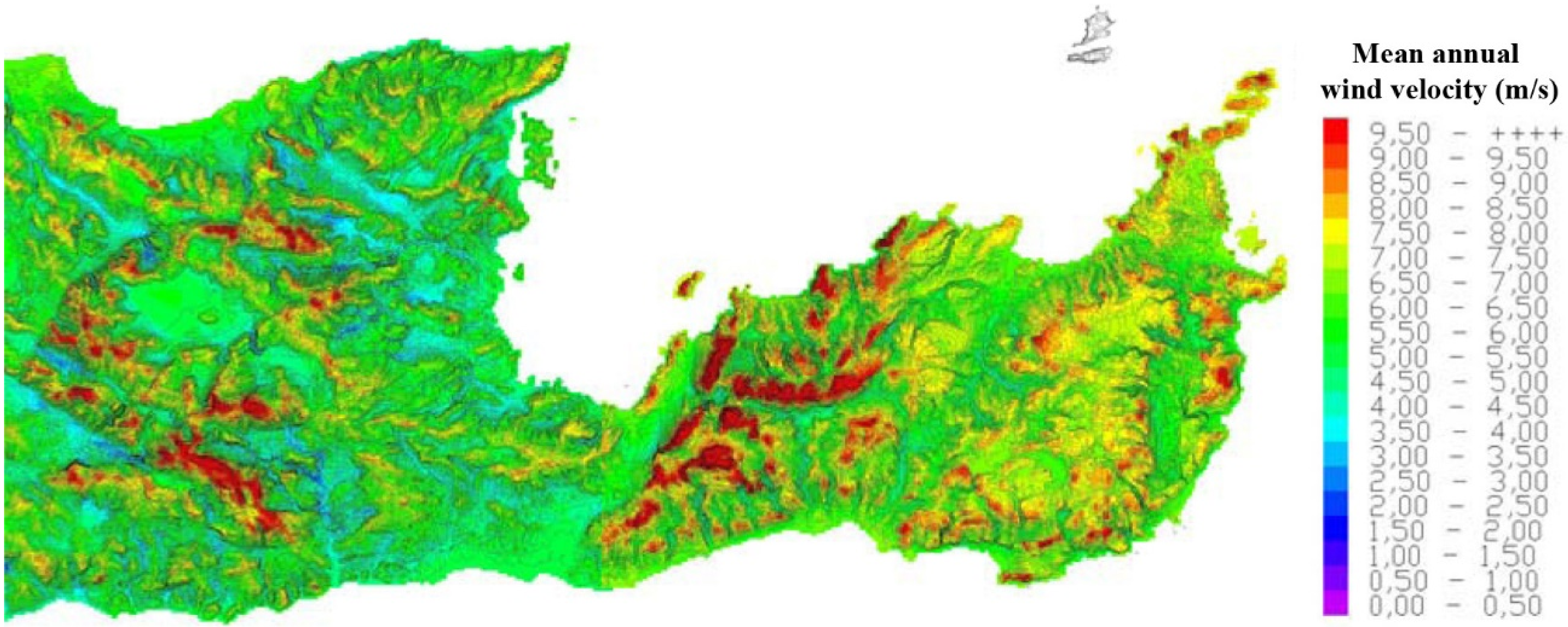
Turning Crete into an Energy Independent Island

The available wind potential



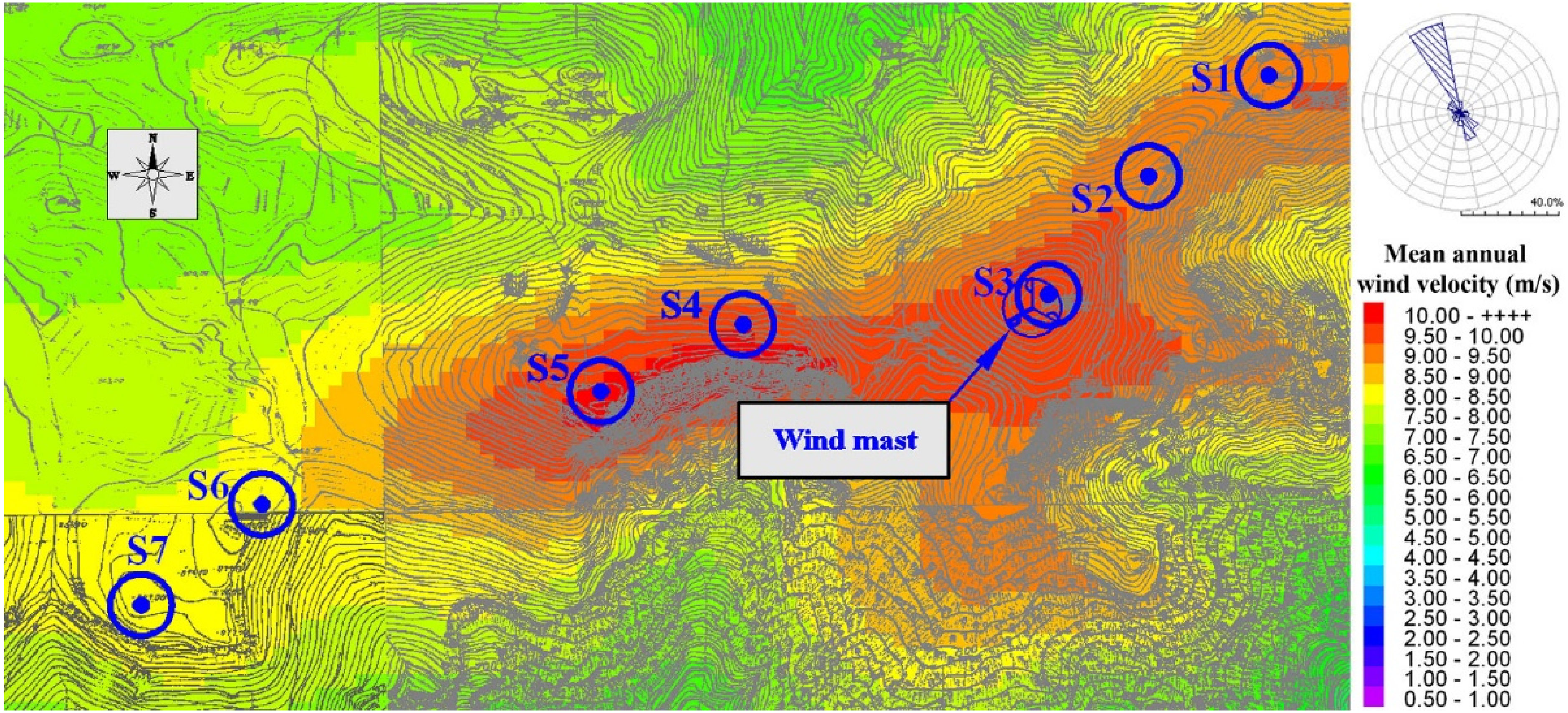
Wind potential map of Crete

The available wind potential



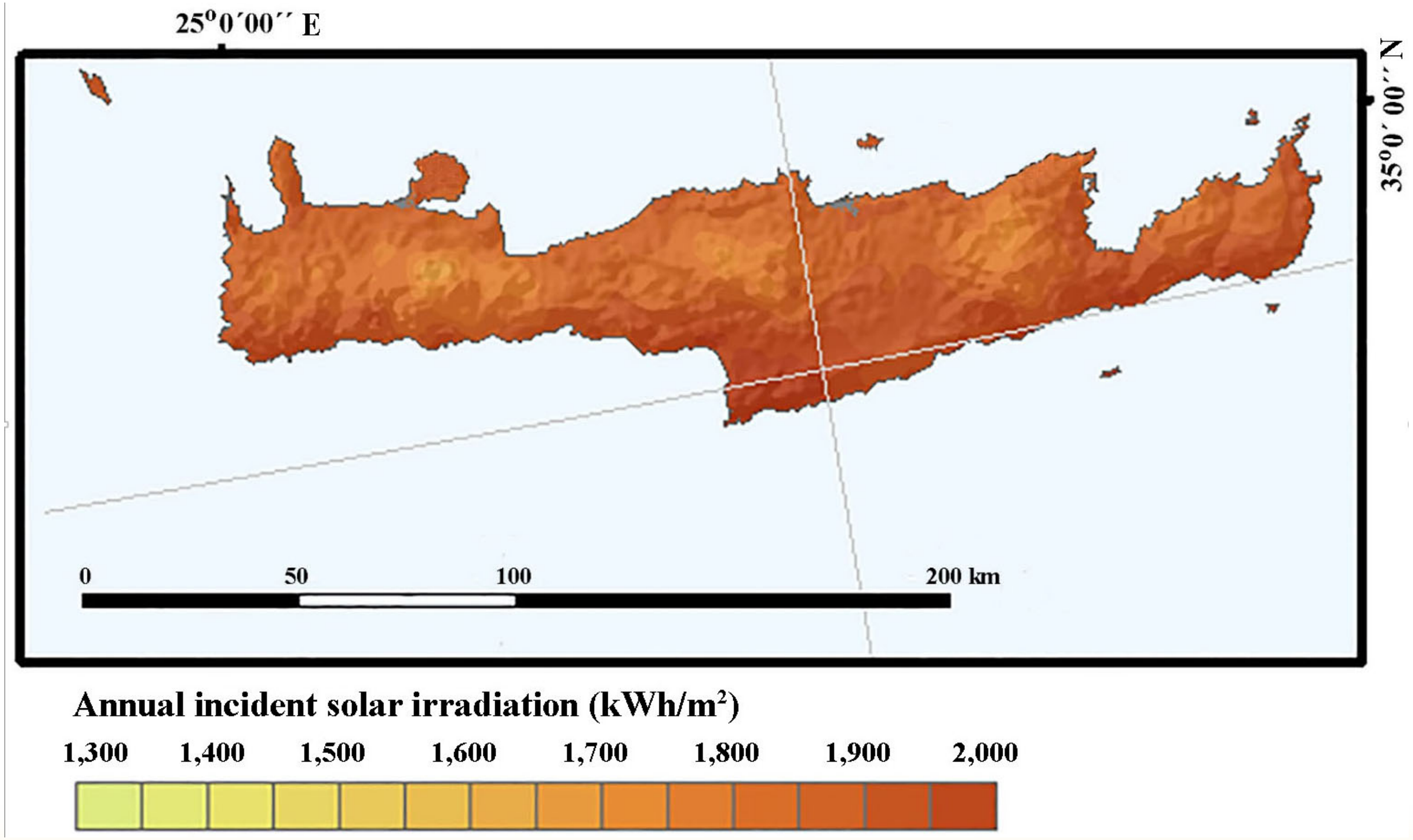
Wind potential map of the eastern Crete

The available wind potential



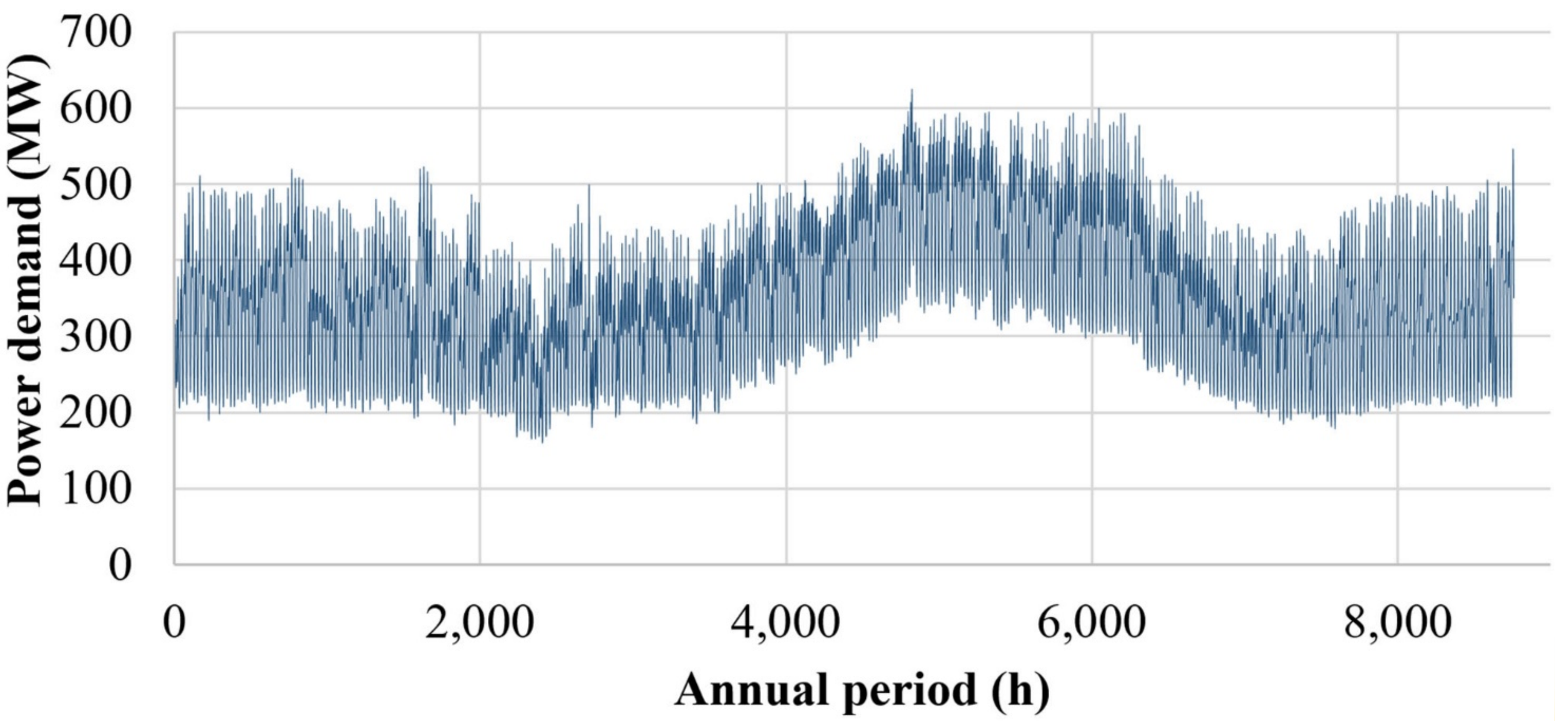
Wind potential map of the southern Crete

The available solar radiation



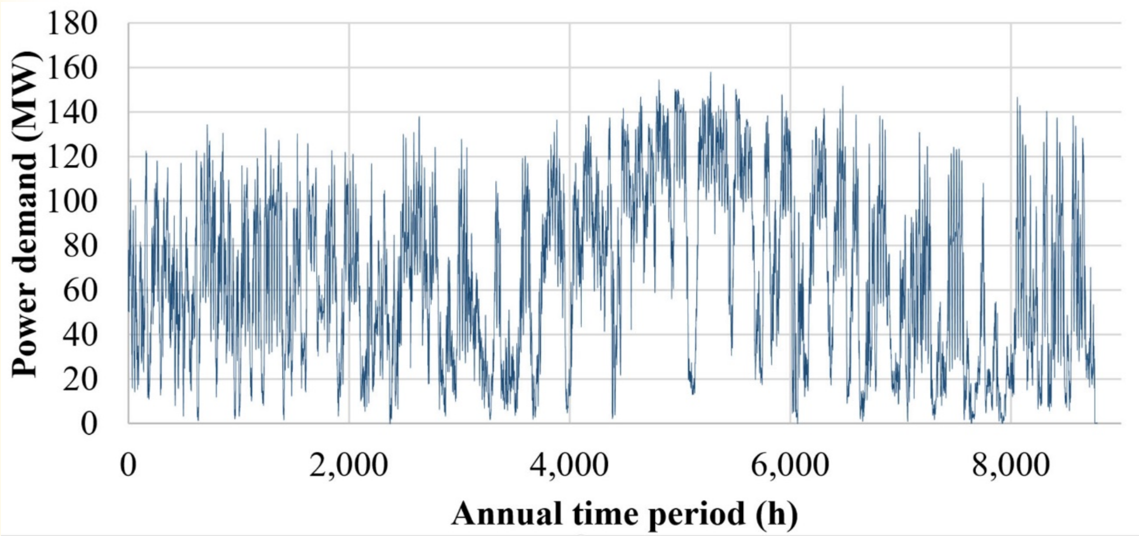
Electricity demand in Crete

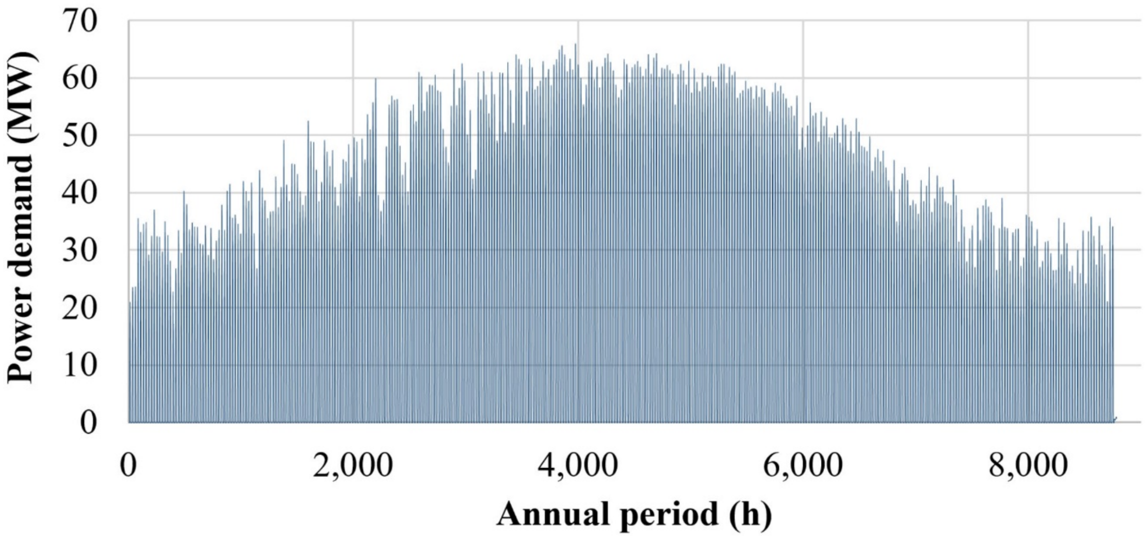
- Annual electricity consumption: 3,074,690 MWh (2016).
- Annual peak demand: 623 MW.
- Annual minimum demand: 160 MW.
- Average daily consumption: 8,423 MWh



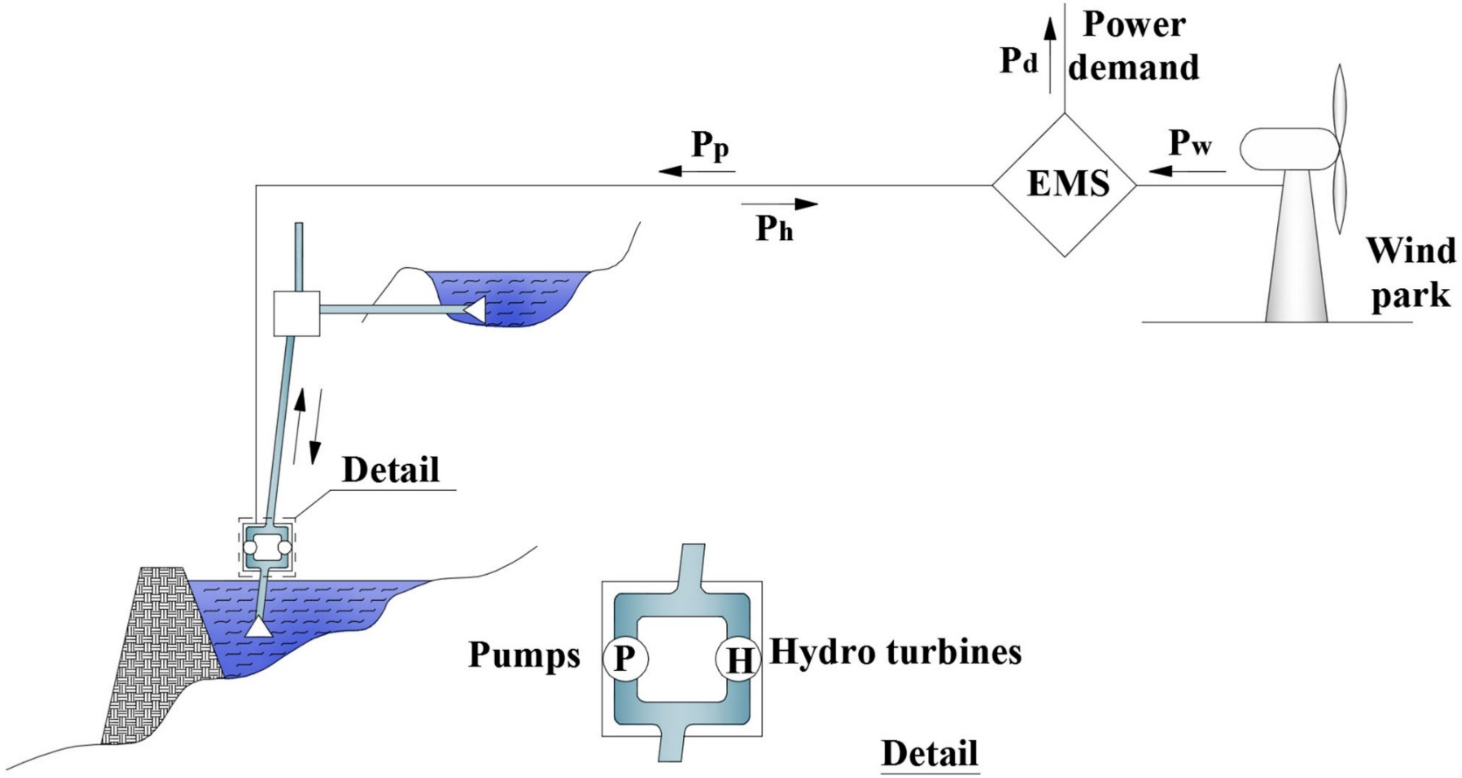
Production from RES technologies

- Wind parks installed power: 220 MW.
- Photovoltaic stations installed power: 90 MW.
- Total annual contribution: around 25% versus the annual consumption.





The introduced hybrid power plant layout



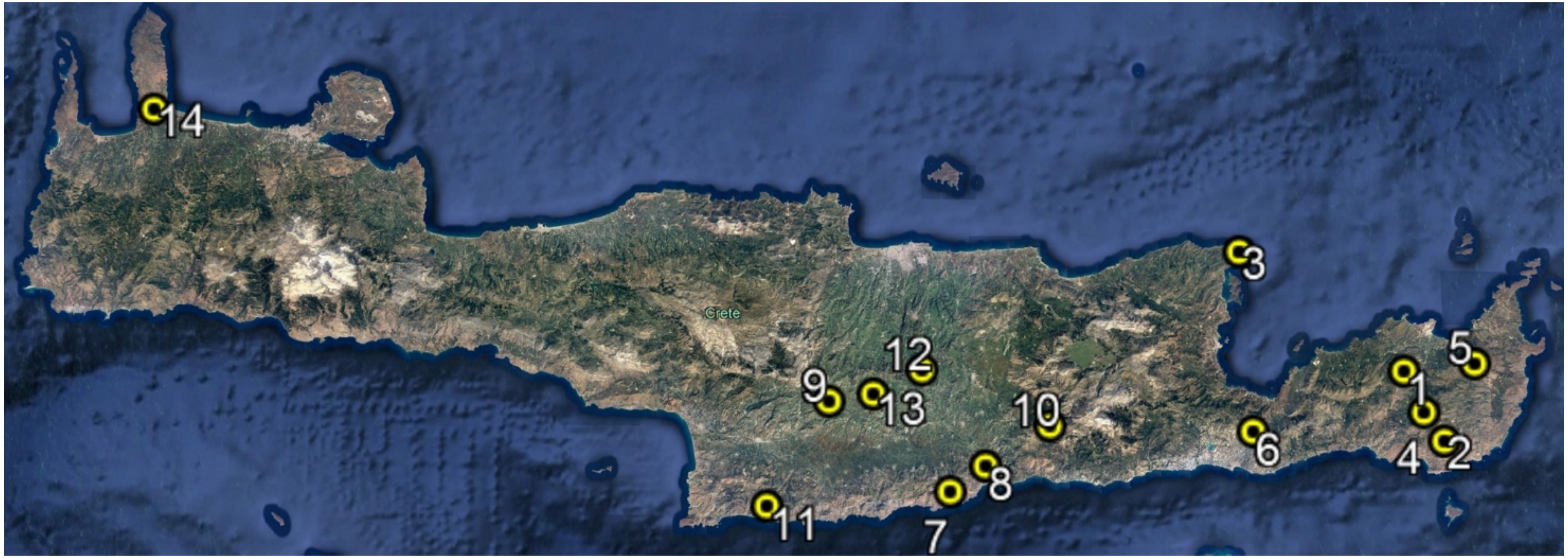
- RES units: wind parks.
- Storage units: Pumped Hydro Storage (PHS) systems.

both of them properly allocated in the insular territory – grid.

Involved wind potential measurements

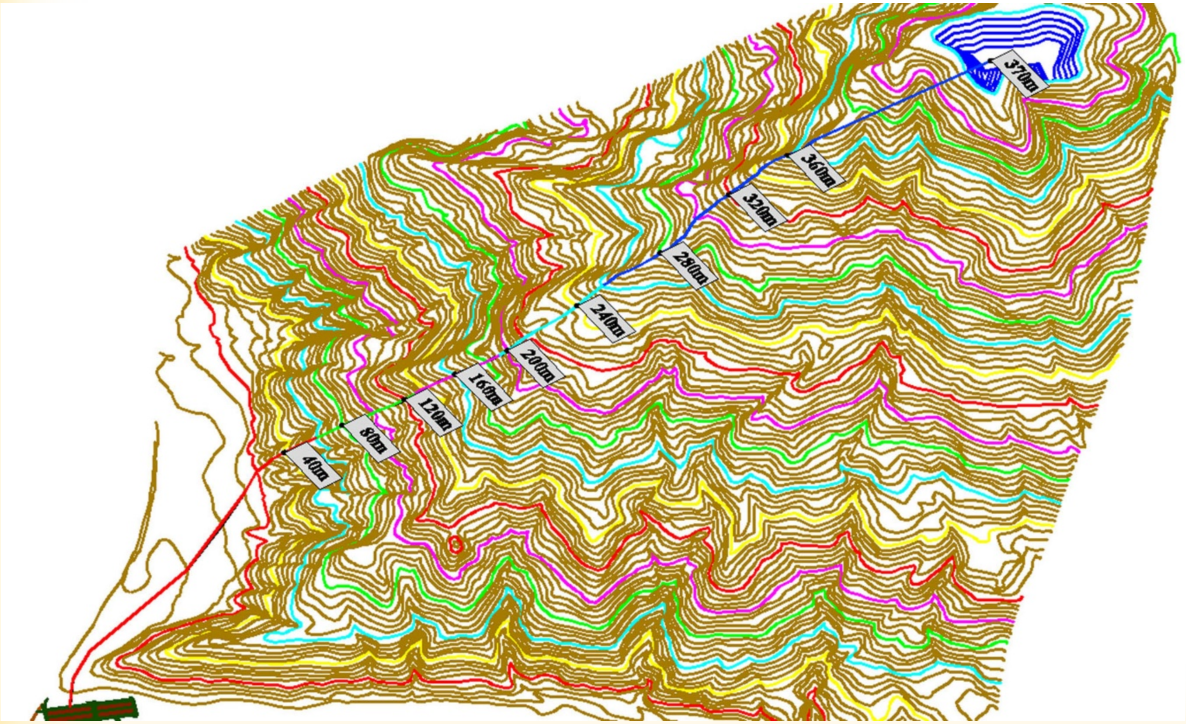
No	Site name	Prefecture	Annual average wind velocity (m/s)
1	Maronia Sitias	Lasithi	9.6
2	Apidi Sitias	Lasithi	9.0
3	Vrouhas	Lasithi	9.5
4	Chandras	Lasithi	9.0
5	Xirolimni	Lasithi	9.5
6	Ierapetra	Lasithi	8.0
7	Tsivi Achentrias	Heraklion	10.5
8	Agios Charalampos	Heraklion	8.7
9	Prinias	Heraklion	8.8
10	Kynigos Viannou	Heraklion	9.6
11	Antiskari Moiron	Heraklion	7.8
12	Partheni	Heraklion	8.9
13	Melidochori	Heraklion	8.8
14	Aspra Nera	Chania	9.2

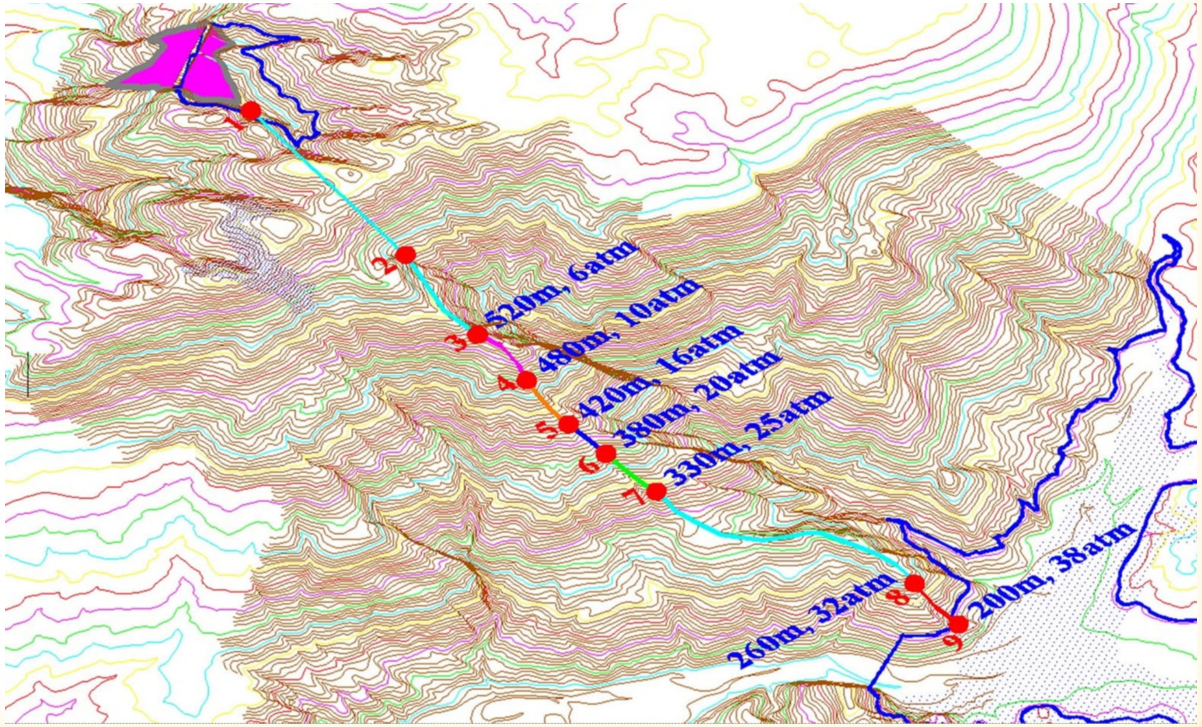
Involved wind potential measurements locations



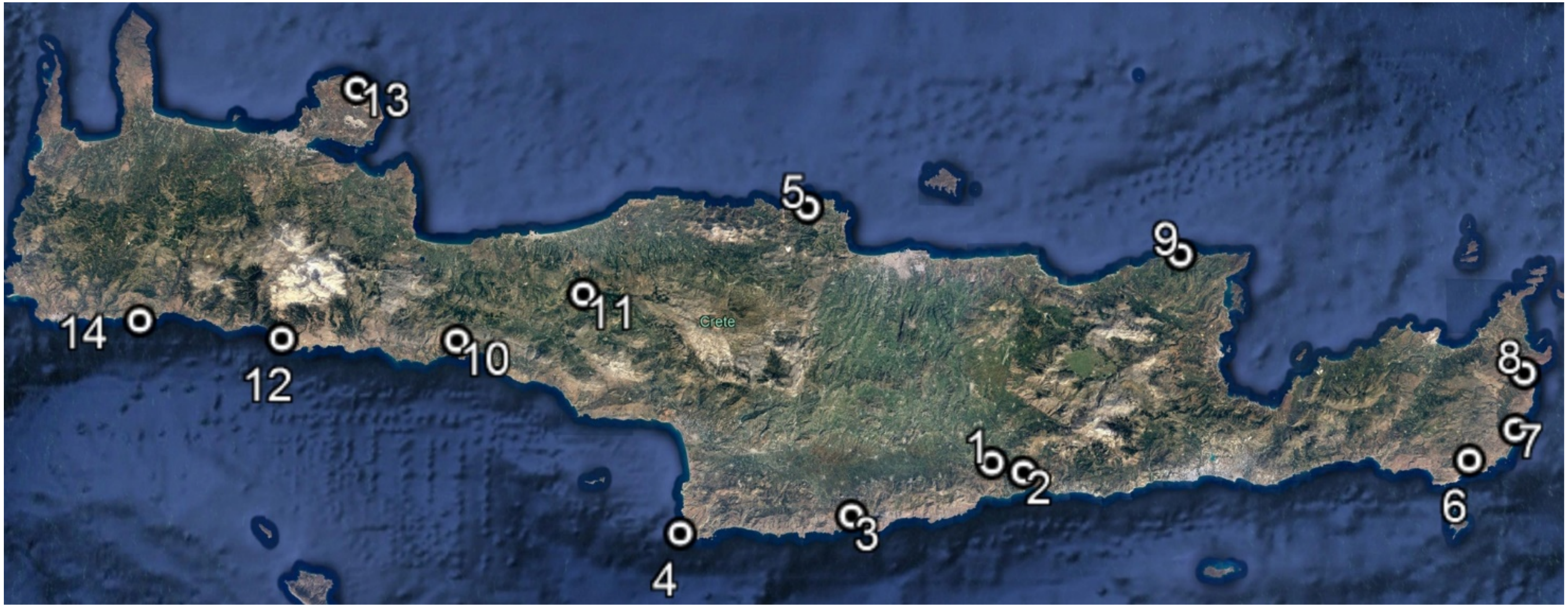
Locations for PHS installations

- In total 14 locations for PHS installations were found, with favourable land morphology.
- All PHS systems were precisely sited, designed and calculated on digitized maps.





The selected locations for PHS systems installation



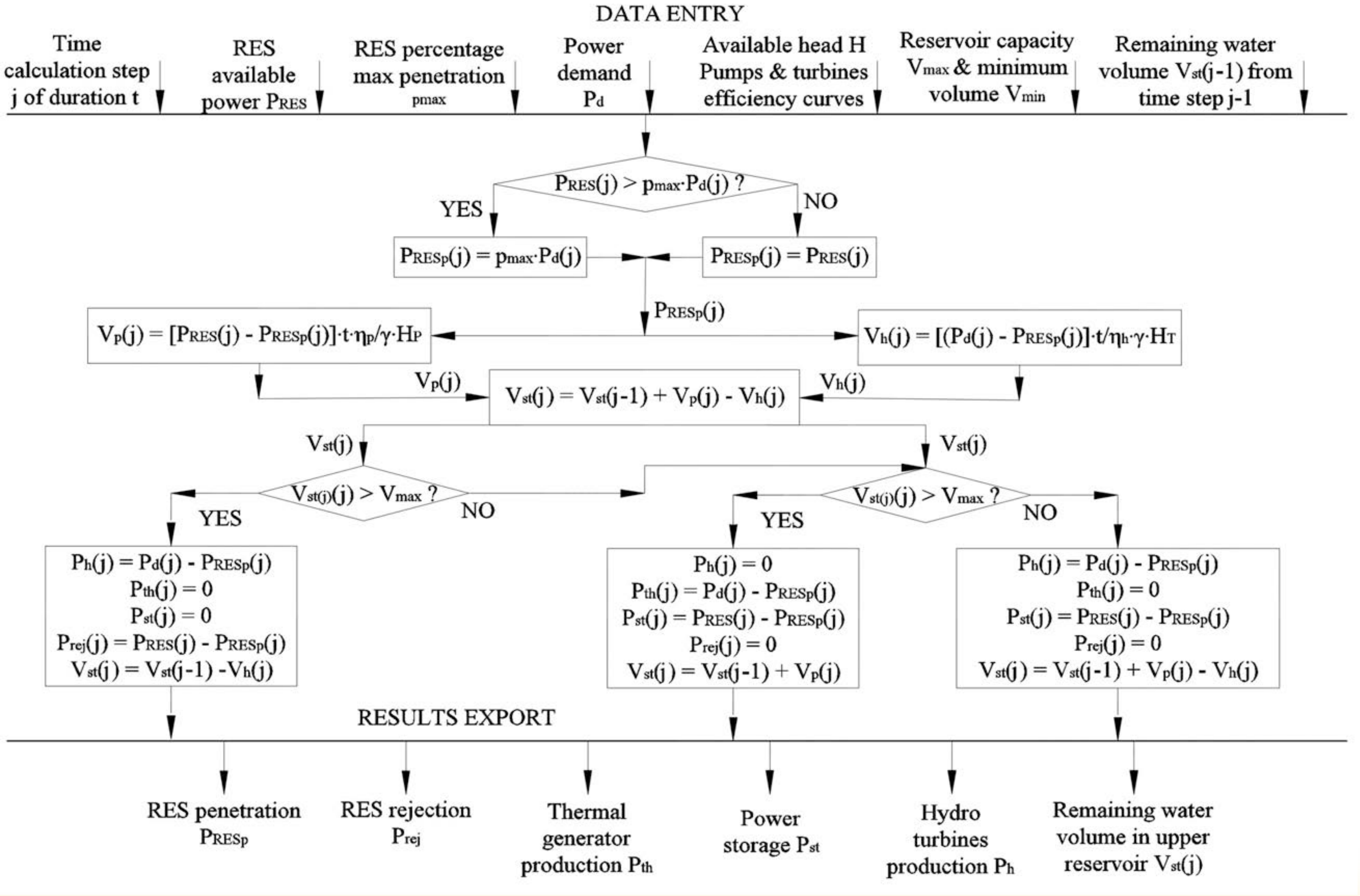
The selected PHS systems features

No	Site name	Reservoirs altitude (m)	Reservoirs volume (m³)	Penstock length (m)	Storage capacity (MWh)
1	Anapodaris[a]	560	2,851,868	1,865	3,139
		156	22,085,319		
2	Chondros Viannou	404	1,538,603	2,632	1,693
3	Gortynas	300	1,100,243	2,440	899
4	Martsalo	220	1,148,871	1,317	689
5	Bobias Heraklion	380	2,045,672	1,383	2,118
6	Atherinolakkos	520	1,926,722	2,444	2,729
7	Kato Zakros	212	2,143,919	1,457	1,238
8	Lagkada	380	1,750,807	2,370	1,812
9	Lithomandra	268	1,514,808	749	1,106
10	Plakias	820	1,941,964	4,728	4,338
11	Potamon Dam[a]	580	1,463,788	2,804	957
		200	22,500,000		
12	Agios Ioannis, Sfakia	640	1,737,917	1,961	3,030
13	Akrotiri Chanion	280	1,703,754	1,846	1,300
14	Sougia	264	1,778,473	1,465	1,279
				Total storage capacity (MWh) :	26,327

Simulation approach

- 14 fourteen hybrid power plants, consisting of one wind park and one PHS system, are formulated, considered, at a first step, independent between them, in the sense that each one of them will operate regardless any other.
- The net power demand time-series, derived by subtracting the existing photovoltaic power production, is divided in fourteen parts, with a division factor for each part equal with the percentage contribution of the storage capacity of each PHS system to the total storage capacity provided by all PHS systems.
- Each one of the as such formulated power demand parts is assigned to the corresponding hybrid power plant, which should cover this power demand part at a first stage on its own.
- Finally, any inadequacies on the assigned power demand coverage by the corresponding hybrid power plant, due to low wind potential availability or low charge level in the storage plant, are investigated whether they can be covered by the other hybrid power plants.

Operation algorithm



Dimensioning results: wind parks power

Wind park's site	Wind turbines' number	Wind park's power (MW)
1	40	120
2	20	60
3	15	45
4	10	30
5	30	90
6	45	135
7	20	60
8	25	75
9	17	51
10	75	225
11	25	75
12	30	90
13	17	51
14	22	66
Total	391	1,173

Dimensioning results: PHS systems

PHS site	Hydro turbines' required power (MW)	Pumps' required power (MW)	Falling pipeline diameter (m)	Pumping pipeline diameter (m)
1	68.1	102.0	4.0	3.0
2	38.3	63.3	2.8	2.2
3	19.2	36.5	2.6	2.0
4	14.9	26.5	2.5	2.0
5	45.7	82.9	3.2	2.5
6	58.5	114.2	3.2	2.5
7	27.0	48.4	3.5	2.5
8	40.6	59.2	3.0	2.5
9	24.4	40.4	3.0	2.2
10	97.1	182.5	3.2	2.5
11	32.0	60.2	3.0	2.2
12	64.0	94.5	3.0	2.2
13	28.3	42.8	3.0	2.4
14	26.3	53.5	2.8	2.2
Total	584.4	1,007.0		

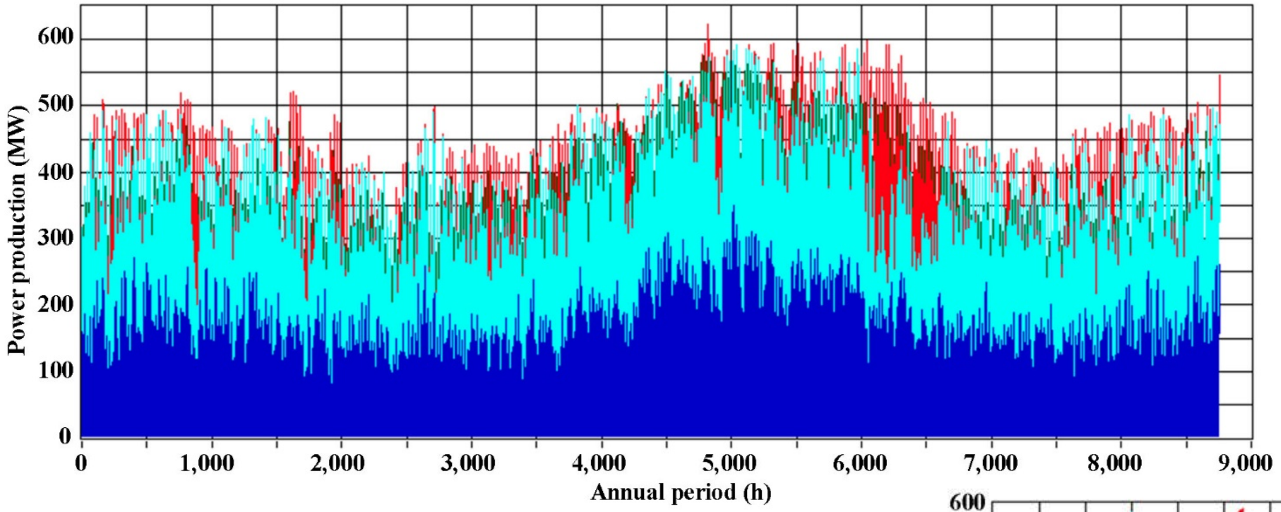
Dimensioning results: energy production and storage

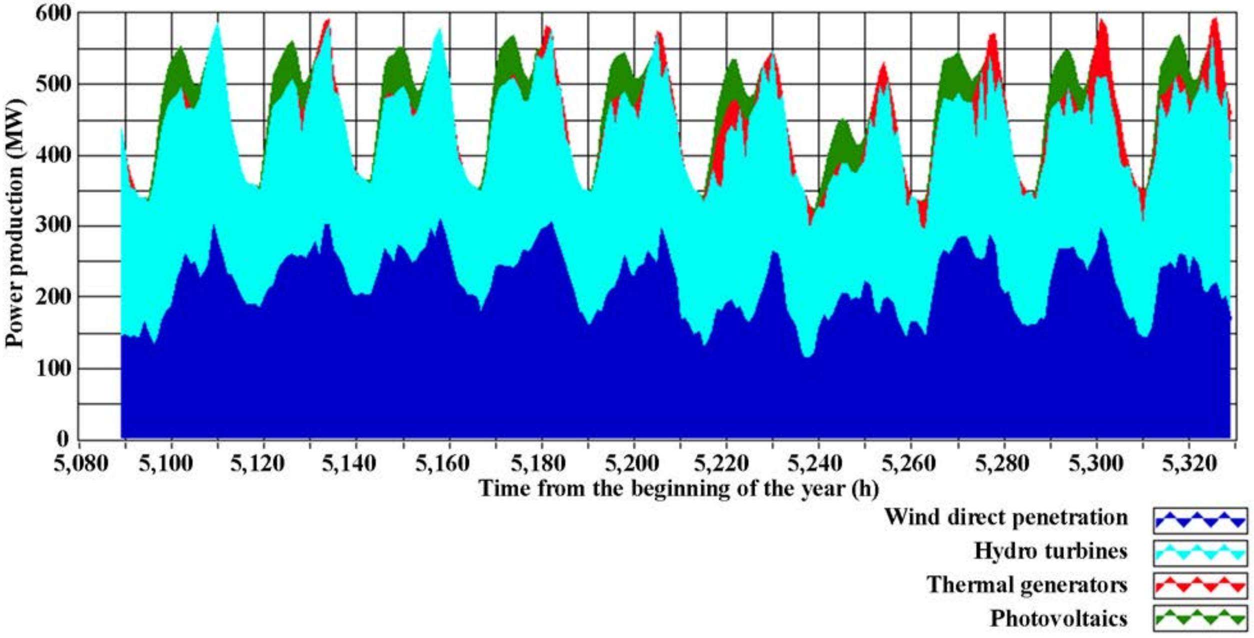
Wind park / PHS site	Wind parks' direct penetration (MWh)	Hydro turbines production (MWh)	Pumps absorbed power (MW)	PHS systems' efficiency (%)
8 / 1	137,273	159,807	257,078	62.16
10 / 2	82,208	91,054	149,487	60.91
11 / 3	36,068	51,048	95,492	53.46
12 / 4	34,164	35,462	61,141	58.00
7 / 5	99,639	120,006	204,792	58.60
2 / 6	133,887	139,641	239,021	58.42
4 / 7	60,286	69,369	123,354	56.24
3 / 8	88,082	95,891	155,656	61.60
5 / 9	54,700	59,980	95,823	62.60
9 / 10	196,981	252,527	441,165	57.24
13 / 11	70,449	79,554	147,986	53.76
14 / 12	131,205	146,653	229,954	63.77
1 / 13	65,702	69,242	113,116	61.21
6 / 14	60,861	63,807	116,840	54.61
Total	1,251,505	1,434,039	2,430,904	58.99

Dimensioning results: energy production and storage

Description	Amount
Thermal generators' production (MWh)	265,719
Existing photovoltaics production (MWh)	123,427
Total annual energy production (MWh)	3,074,690
Annual wind production surplus (MWh)	276,535
Annual RES penetration percentage (%)	91.4
Annual wind surplus percentage (%)	7.0

Power production synthesis graphs





Economic features: set-up cost

Set-up cost component	Cost (€)
Wind parks	1,407,600,000
Anapodaris[a]	170,000,000
Chondros Viannou	95,000,000
Gortynas	105,000,000
Martsalo	99,000,000
Bobias Heraklion	100,000,000
Atherinolakkos	98,000,000
Kato Zakros	95,000,000
Lagkada	102,000,000
Lithomandra	90,000,000
Plakias	112,000,000
Potamon Dam	120,000,000
Agios Ioannis, Sfakia	115,000,000
Akrotiri Chanion	92,000,000
Sougia	90,000,000
Total	2,890,600,000

Economic features: operation cost

- Revenues: the product of the total annual electricity production from the hybrid power plants with the electricity selling price.
- Public rates equal to 3% of the investment's total annual revenues.
- Wind parks' maintenance annual cost equal to 0.010 €/kWh produced by them.
- PHS systems' annual maintenance cost equal to 100,000 € per system, on average.
- Loan annual payment. The set-up cost is assumed to be covered by 50% equities and 50% loan capitals, with a payback period of 15 years and a load rate of 2%.
- Total annual salaries: 7 employees per hybrid power plant (14 plants in total), with 25,000 € annual income per employee on average.
- Equipment insurance 4‰ of the projects' equipment procurement cost, estimated equal to 50% of the total set-up cost.
- Several other annual costs: 50,000 € per hybrid plant.
- Constant amortization over 15 years, calculated over the 70% of the set-up cost.
- Tax coefficient 29%.
- Projects' life period 20 years, Discount rate 3%.

Economic indices

Electricity selling price (€/kWh)	N.P.V. (€·10^9)	I.R.R. (%)	Payback period (years)	Discounted payback period (years)	R.O.I. (%)	R.O.E. (%)
0.12	0.9	8.5	10.1	12.8	81	162
0.14	1.4	11.5	8	9.3	100	200
0.16	2	14.5	6.6	7.4	119	238
0.18	2.5	17.3	5.6	6.2	138	276
0.2	3.1	20	4.9	5.6	157	314

Conclusions

Key features towards the approach of energy independence in Crete.

- the high available wind and solar potential
- the favourable land morphology for PHS installations, leading to set-up cost reduction
- the appropriate distribution of the wind parks in the insular territory, contributing to the maximisation of the wind power supply availability.

- Due to the hybrid power plants geographical distribution 5% additional annual RES penetration is achieved. Respectively, the RES annual surplus is 5.8% reduced.
- The investments can be economically feasible with electricity selling price at 0.12 €/kWh.
- The proposed solution is the only one which can guarantee **high energy supply security**, **low electricity production cost**, **maximisation of RES penetration** and **real energy independence**.
- 100% clear annual RES penetration can be achieved with the integration of smart grid strategies, aiming at energy saving and peak demand shifting
- the expecting benefits from the above projects will be maximized with the extensive involvement of local population, through energy cooperative schemes etc.

Thank you for your attention

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