Novel Storage Concepts to increase RES penetration in autonomous systems. The case of Cyprus

Dr. George Tzamalis

Hystore Tech limited

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1. Introduction

The problem:

- The intermittent nature of RES
- Variations between RES generation and load demand profiles
- RES curtailments – limited penetration

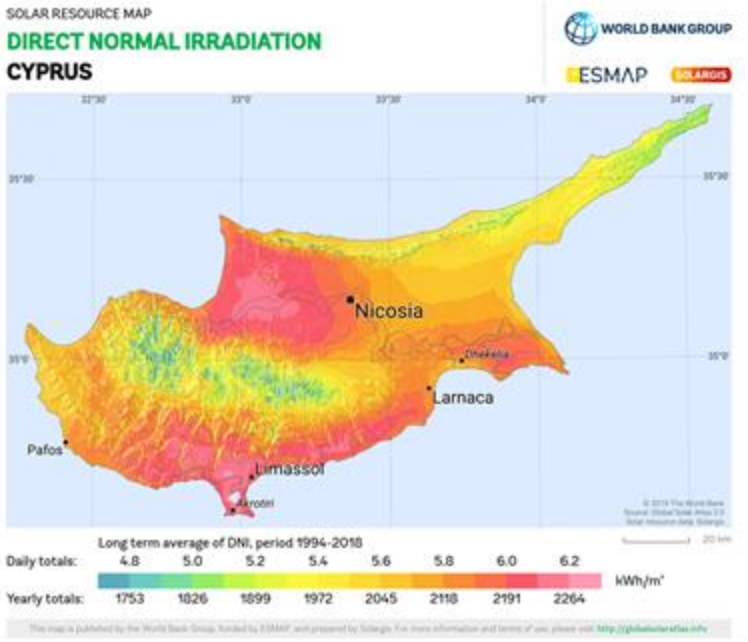
The solution:

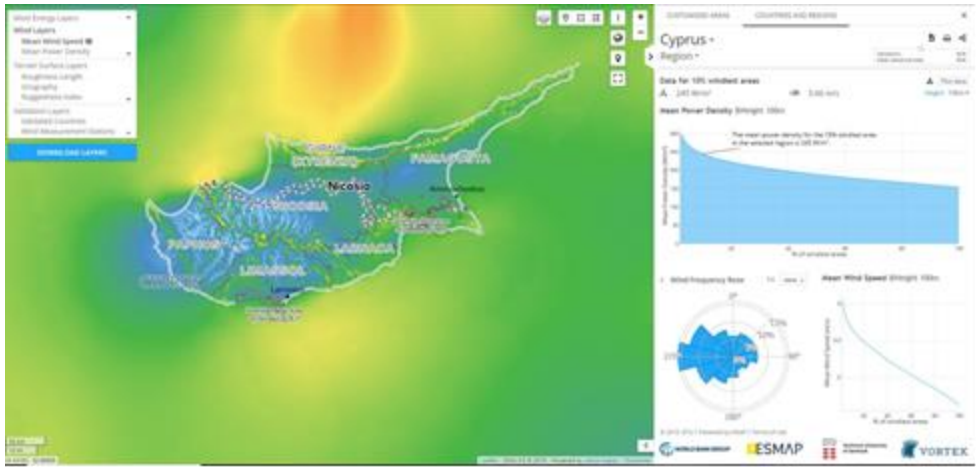
- Energy storage technologies

The main objective:

- Evaluation of RES potential in Cyprus
- Overview of the island's demand profiles
- Suggest best suited RES and energy storage technology
- Most applicable hybridization concepts and/or Smart grids for Cyprus

2. Evaluation of RES potential in Cyprus (1/2)





- The renewable source that is mostly available in Cyprus is the solar irradiation
- Wind potential is generally low and the same is valid for other RES
- Wind speeds rarely exceed the 6m/s and annual capacity factors are smaller than 25% even with the modern long blade wind turbines

2. Evaluation of RES potential in Cyprus (2/2)

Solar irradiation can be turned into electricity by PVs and CSPs

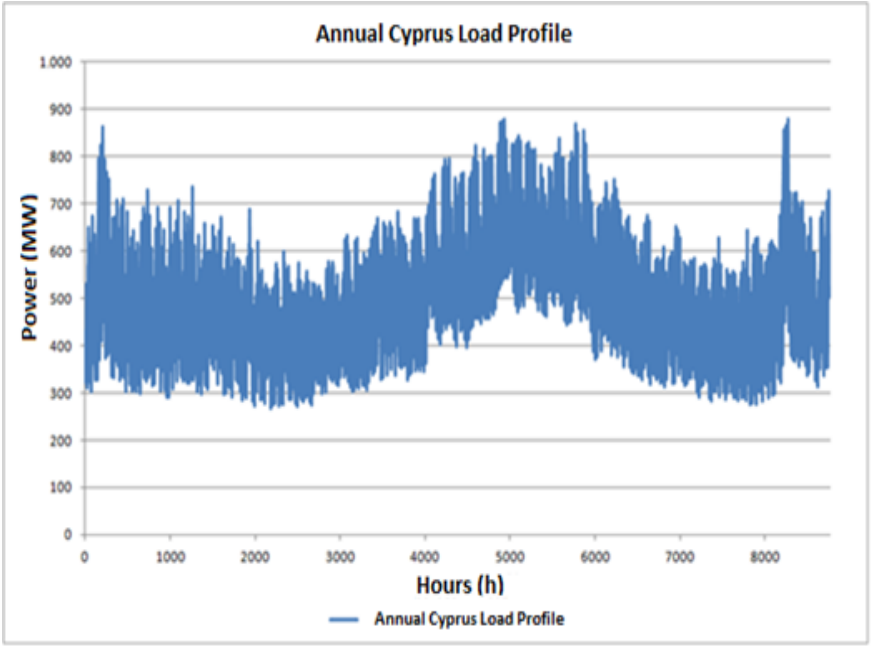
Basic characteristics (storage coupling):

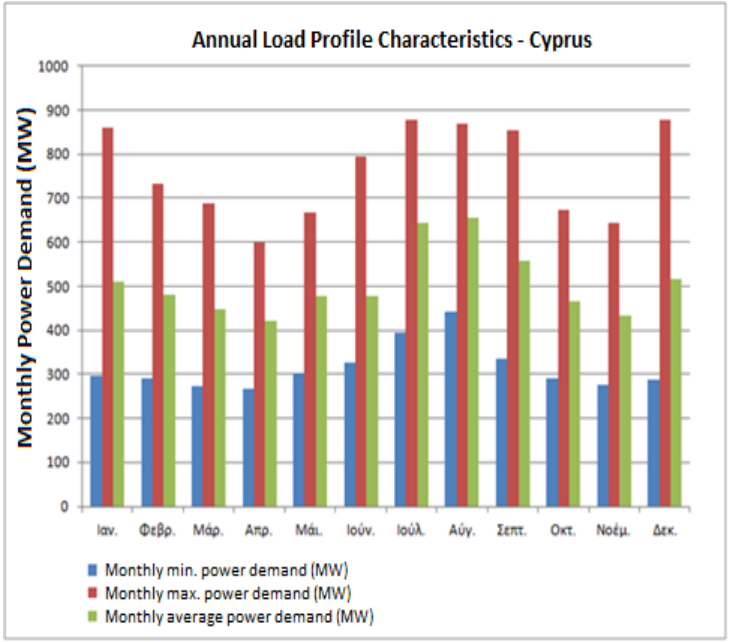
- CSP plants integrate thermal energy storage ability
- PVs should collaborate with external storage facilities to store electricity which then can be used when needed by the grid

Comparison – Decision parameters:

- Maturity, Ease of construction and maintenance, CAPEX and OPEX, Local added value, Grid and demand compatibility, Lifetime and LCOE, Efficiency

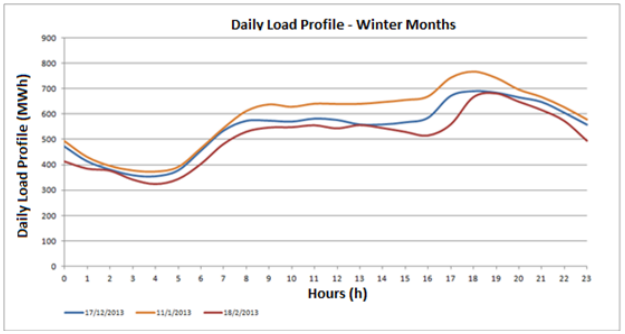
3. Overview of Cyprus demand profiles (1/3)

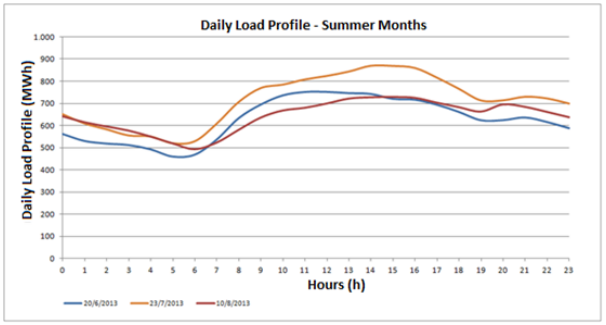


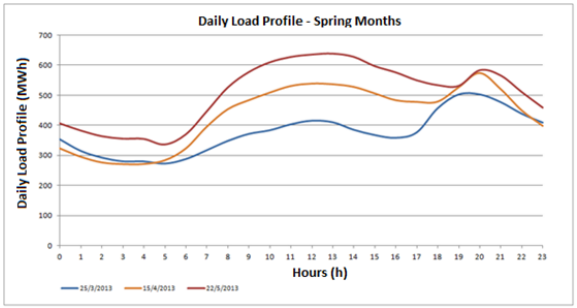


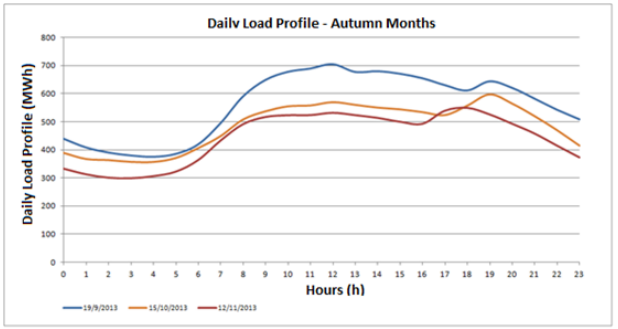
- Significant **seasonal variation** all the year round
- Peak values are reached during summer and the Christmas and New Year Holidays while demand drops during spring and autumn
- Air conditioning and heating demands are the driving factors as far as demand side concerns plus the increased users during summer

3. Overview of Cyprus demand profiles (2/3)









- Significant **daily variation** all the year round
- The daily variation is considerably high and is smaller during spring and autumn
- Low daily demand during the early morning hours → Peak demand occurs in the late afternoon during winter at about 19-20 hours every day
- As environmental temperatures grow up approaching summer a second peak develops around noon
- This peak becomes higher than the one existing in the evening all the year round

3. Overview of Cyprus demand profiles (3/3)

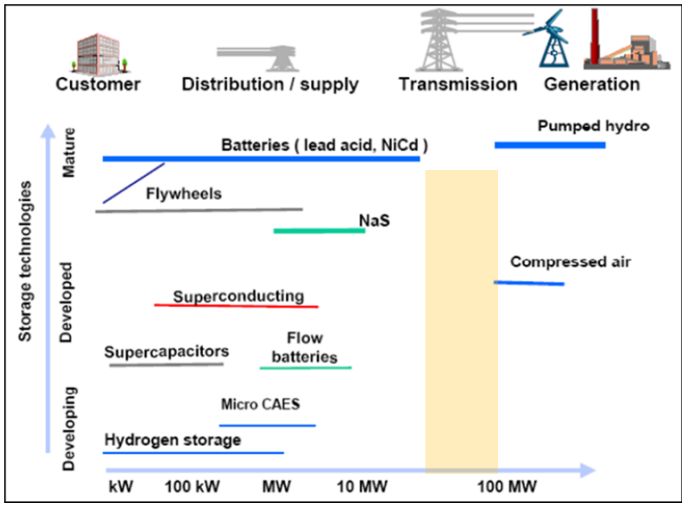
- In the lack of storage, penetration of RES creates difficulties in the operation of the conventional units
- Preliminary study → A need of 400- 800 MWh of daily storage is necessary to smooth the operation of the conventional units of Cyprus grid and to
- Achieve less possible curtailment of RES electricity to be produced by solar power plants (PVs or CSPs)
- The daily and seasonal variation of power demand → a total of at least 200 MW of stored electricity is needed to cover the demand differences between day and night and the seasonal variation

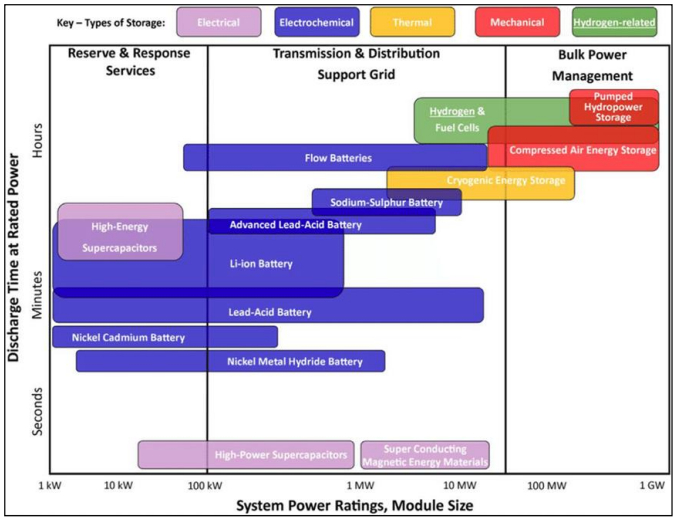
The following parameters should be met by the potential storage systems in Cyprus:

Parameter	Capacity
Total energy content of electricity storage	800 MWh
Daily storage system discharge time	Up to 8 hours
Daily storage system recharge time	Up to 16 hours
Max power available from the electricity storage system	200 MW

4. Novel hybridization and/or storage concepts applicable in Cyprus (1/3)

Based on the data recovered and presented already, the following results are concluded regarding novel hybridization and storage concepts applicable in Cyprus





- When selecting mature technologies for the size of storage needed in Cyprus Pumped hydro is better suited
- If smaller units are planned then the use of batteries is also possible
- Pumped hydro is suitable for operation within the scale of hours whereas batteries are better suited for the management of the characteristics of the distribution grid
- Cyprus should be based on a big part of **Pumped hydro storage** to manage the shift of the demand curve and permit RES penetration together with a smaller part of **Battery storage** to handle the needs of the grid in terms of stabilization and smooth operation

4. Novel hybridization and/or storage concepts applicable in Cyprus (2/3)

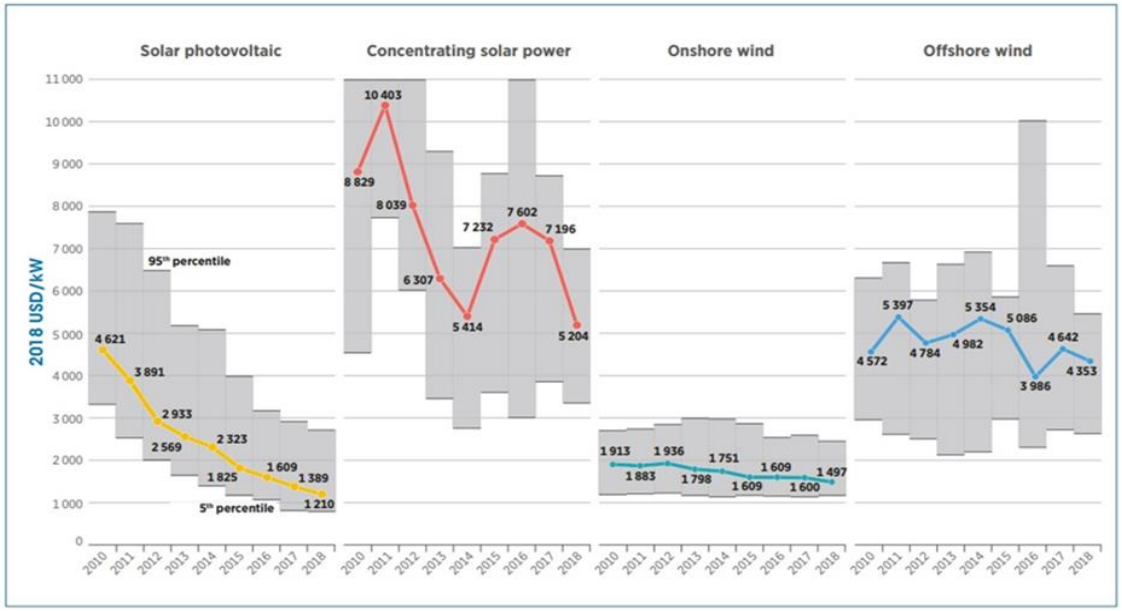
Battery plants can be located anywhere however the pumping storage plants should use the existing reservoirs to save CAPEX costs and improve the water availability

Existing Reservoirs (Dams)	Water availability (M3)			Head	Hybrid Power Station Capacity	Ranking
	Lower Reservoir -1-	Upper Reservoir -2-	Capacity % 2/7/2014	ΔH - 1-2 (m)	(MW)	[0 - 7.5]
Priority projects						
Arminou	4.300.000	800.000	62,0	580	60	7,50
Asprokremmos	52.375.000	1.500.000	72,7	320	60	4,75
Kannaviou	17.168.000	700.000	63,2	400	35	5,25
Evretou	24.000.000	1.200.000	62,6	400	60	6,25
Kalopanagiotis	363.000	180.000	90,4	550	13	5,25
TOTAL					**228**	
Other projects						
Dipotamos	15.500.000	500.000	15,0	220	15	5,75
Lefkara	13.850.000	500.000	16,2	400	20	5,75
Kouris	115.000.000	1.800.000	33,1	250	60	5,75
Germasogeia	13.500.000	450.000	34,3	250	20	4,75
Kalavasos	17.100.000	750.000	10,9	350	35	5,75
Mavrokolympos	2.180.000	700.000	54,3	435	37	6,25
Argaka	990.000	300.000	26,2	400	15	2,00
Pomos	860.000	200.000	17,6	420	13	1,00
Ksiliatos	1.430.000	250.000	33,1	300	10	3,00
Lefkas	368.000	200.000	50	400	8	2,75
Klirou	2.000.000	300.000	50	280	15	5,25
Palaiochori	620.000	200.000	50	300	8	4,25
TOTALS	**183.398.000**	**6.150.000**			**256,0**	

- Storage capacity exceeding 400 MW of power lasting for up to 12 hours is possible using only the existing reservoirs minimizing CAPEX costs
- There are suitable areas to build the upper reservoir at acceptable distances from the lower existing reservoir achieving heads well exceeding the 200 meters
- Existing reservoirs were classified in priority order taking into account several parameters (water availability, capacity, CAPEX, proximity to the grids, environmental issues etc)

4. Novel hybridization and/or storage concepts applicable in Cyprus (3/3)

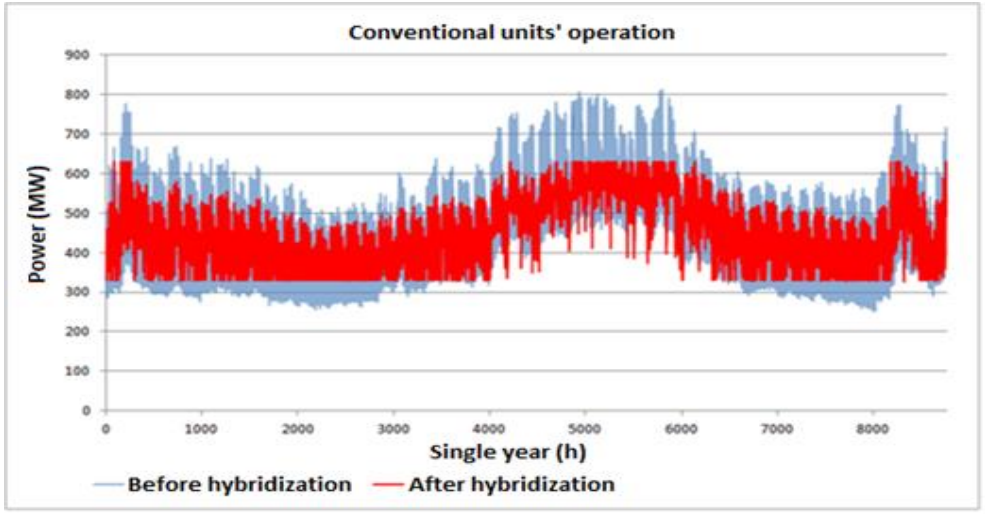
PVs or CSPs?



- Typical CAPEX data for both of them → the margin between PVs and CSPs increased more as PVs cost dropped considerably to less than **700 €/kW**, while CSP's including storage is still at the range of **4.500 €/kW**
- The use of PVs is three times cheaper compared to CSP's
- PVs can also utilize the diffused solar irradiation while CSP's only the direct one. Meteorological data show that in Cyprus **total irradiation is about 10-15% higher than the direct one**
- Energy storage parameter → cost of PVs is going up to around 1.700 €/kW which is still a third of the hybrid CSP/storage cost
- **PV development with pumped-hydro and batteries storage is more financially sound compared to CSPs → increase RES penetration in Cyprus**

5. Expected implications to the Grid and sustainability

Following the previous developed approach the implication of the selected technologies to the grid of Cyprus were examined

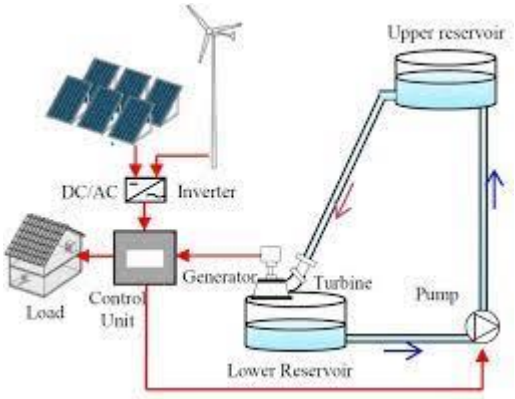


- Change of the operation of the conventional units of Cyprus grid when **165 MW of storage capacity** is applied and **200 MW of additional PVs** are installed
- Important **peak saving** occurs
- Low grid demand is increased minimizing the curtailment of the RES plants as power is needed to recharge the storage units
- Large variation between day and night load demands is significantly reduced up to 50%
- **RES penetration is increased** more than 100%
- **Power safety supply** is also enhanced significantly as there is a back-up of 165 MW of power to meet emergency needs
- **Idle run** of conventional units can be significantly reduced saving costs

6. Conclusions – Suggestions

According to the present preliminary study and in order to reach the goal of increased RES penetration and grid stability in Cyprus the following steps could be followed:

- **Pumped-hydro storage of around 150 MW** using the existing reservoirs and **battery storage of about 60 MW** to stabilize the grid
- Increase the PV installations over Cyprus thus provide **RES power to charge the storage facilities** and minimize the operation of the conventional units
- **CSP installations are more expensive today**. If their costs drop in the future then this technology could be examined again in terms of financial competitiveness compared to PVs
- **Other energy storage technologies** are either more expensive to apply in Cyprus or in a non-matured stage regarding commercial applications



Acknowledgement

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THANK YOU FOR YOUR ATTENTION!

Hystore Tech limited

30, Spyrou Kyprianou
Ergates Industrial Area
2643 Ergates, Nicosia - Cyprus
Tel: +357 96 523803
Fax: +357 22 373595

https://www.hystoretechnologies.com/