



Past, present and future capability of RES penetration into the non-interconnected energy system of Greek islands

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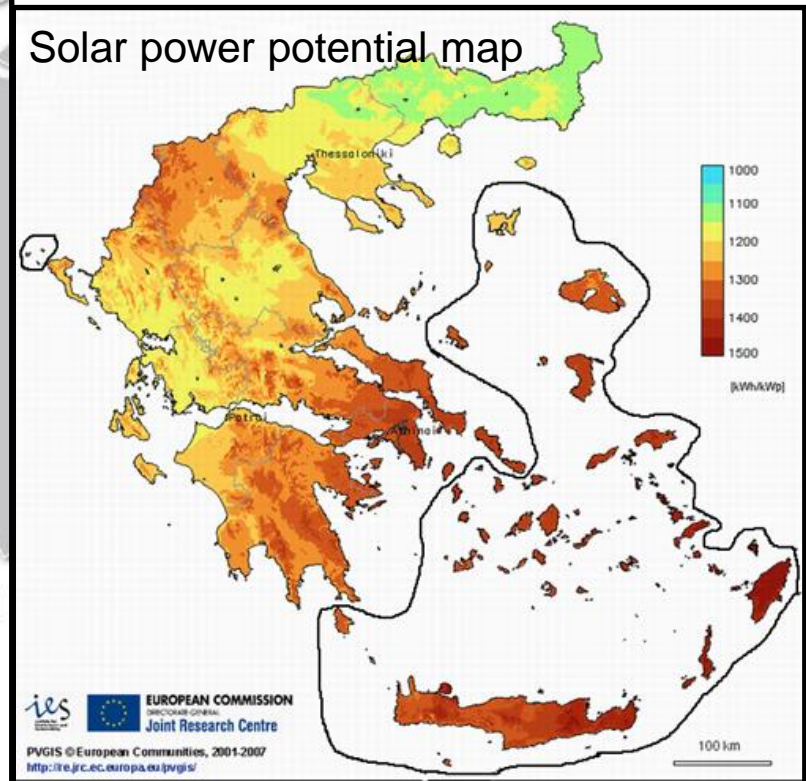
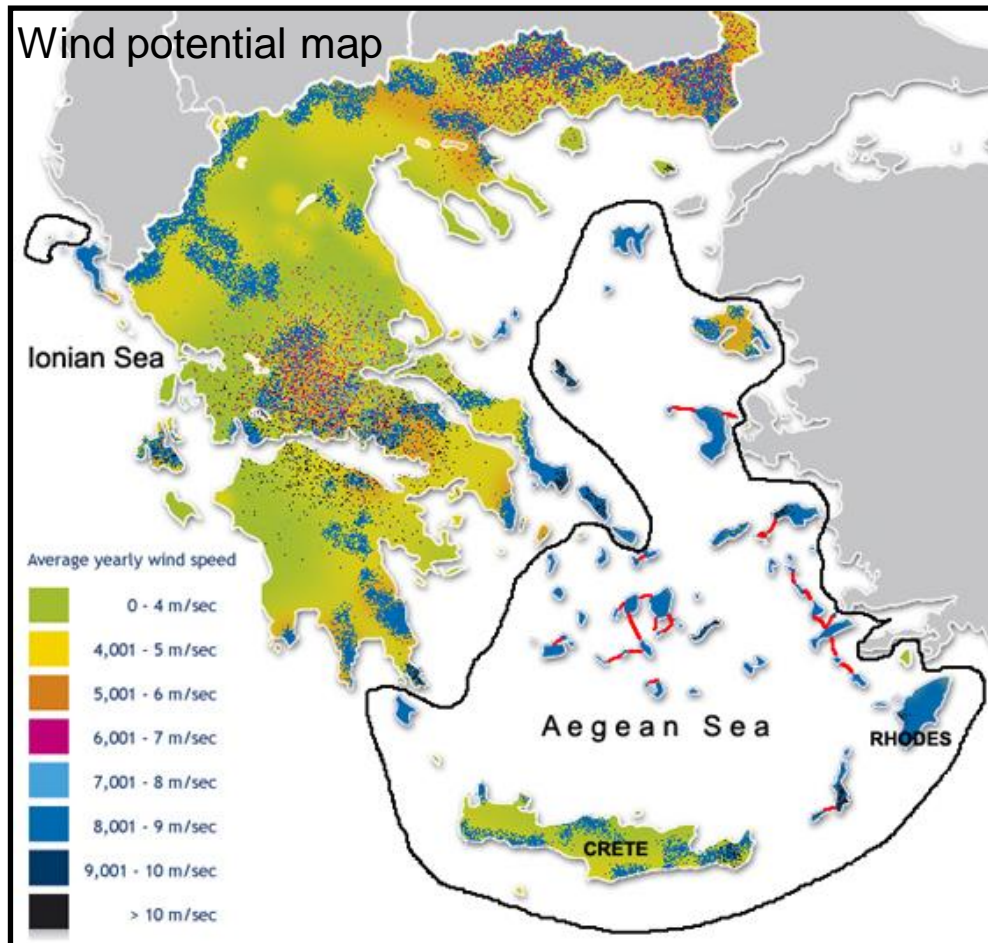
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Geographical distribution

Black lines: non-interconnected islands with mainland

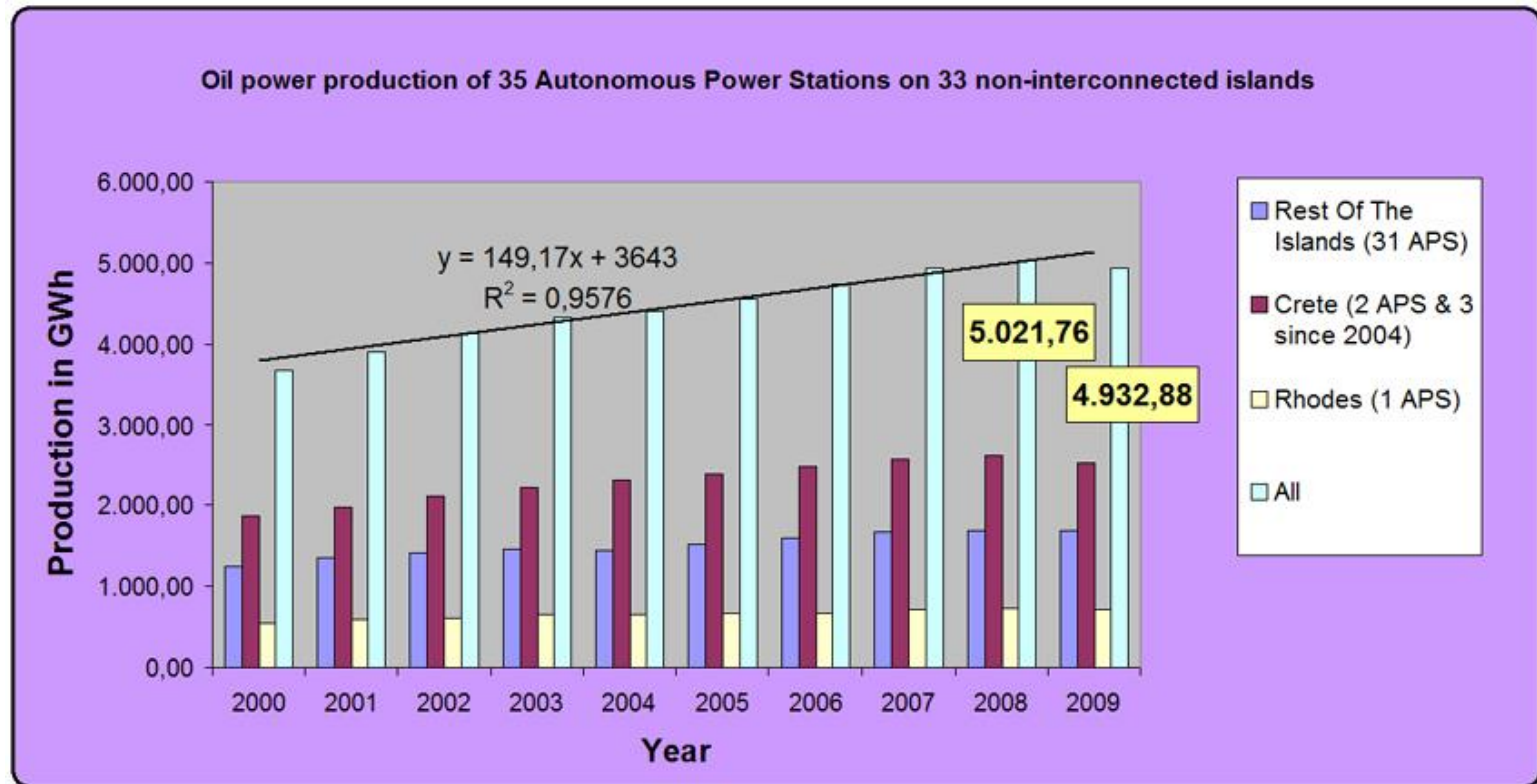


Red lines: underwater connections between islands

RES-E penetration issues on the non-interconnected islands

- **RES-E penetration limit** → 30% of average hourly peak demand of former year,
- **RAE-2003** → methodology for the specification of wind power penetration limit separately for each island,
- **RAE-2007** → specification of maximum allowed PV installations power,
- **RAE-2008** → former 15% & 35% become 28.5 & 45%.

Production from oil Autonomous Power Stations (APS)

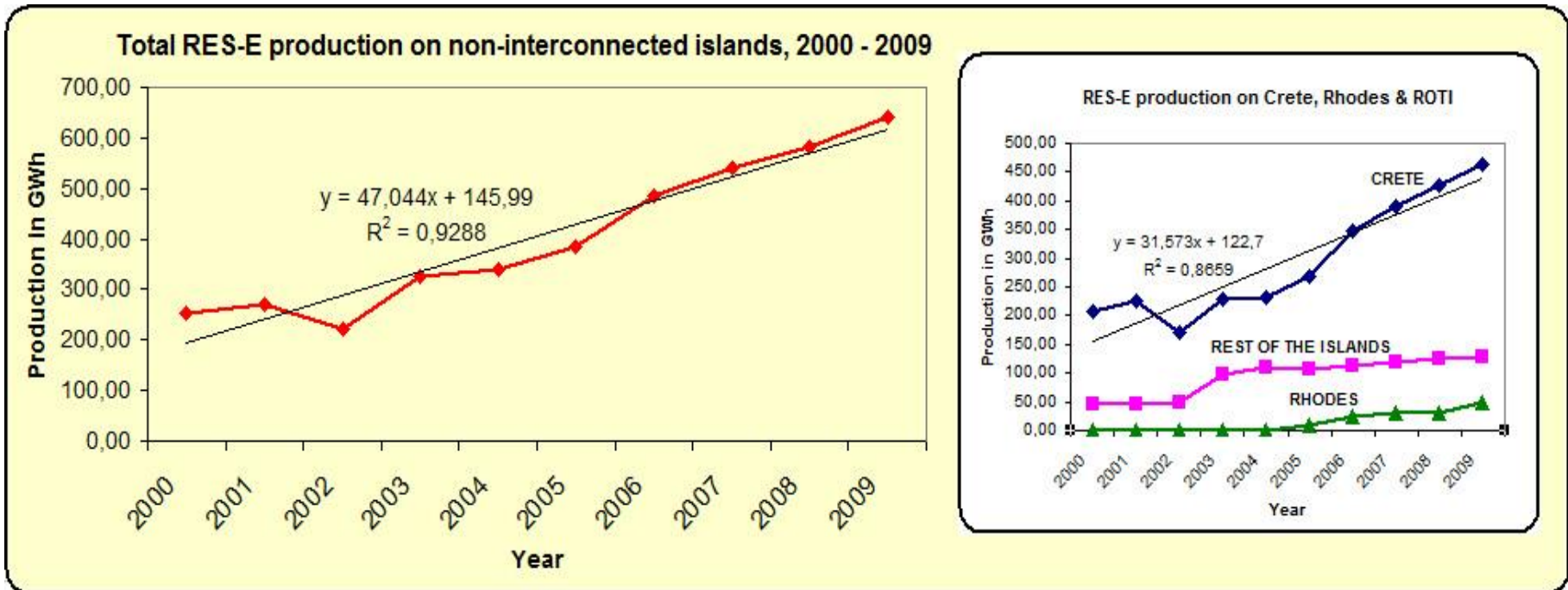


Total installed capacity → 1806 MW

Electrification of 57 islands, 55 → Aegean Sea + 2 → Ionian Sea

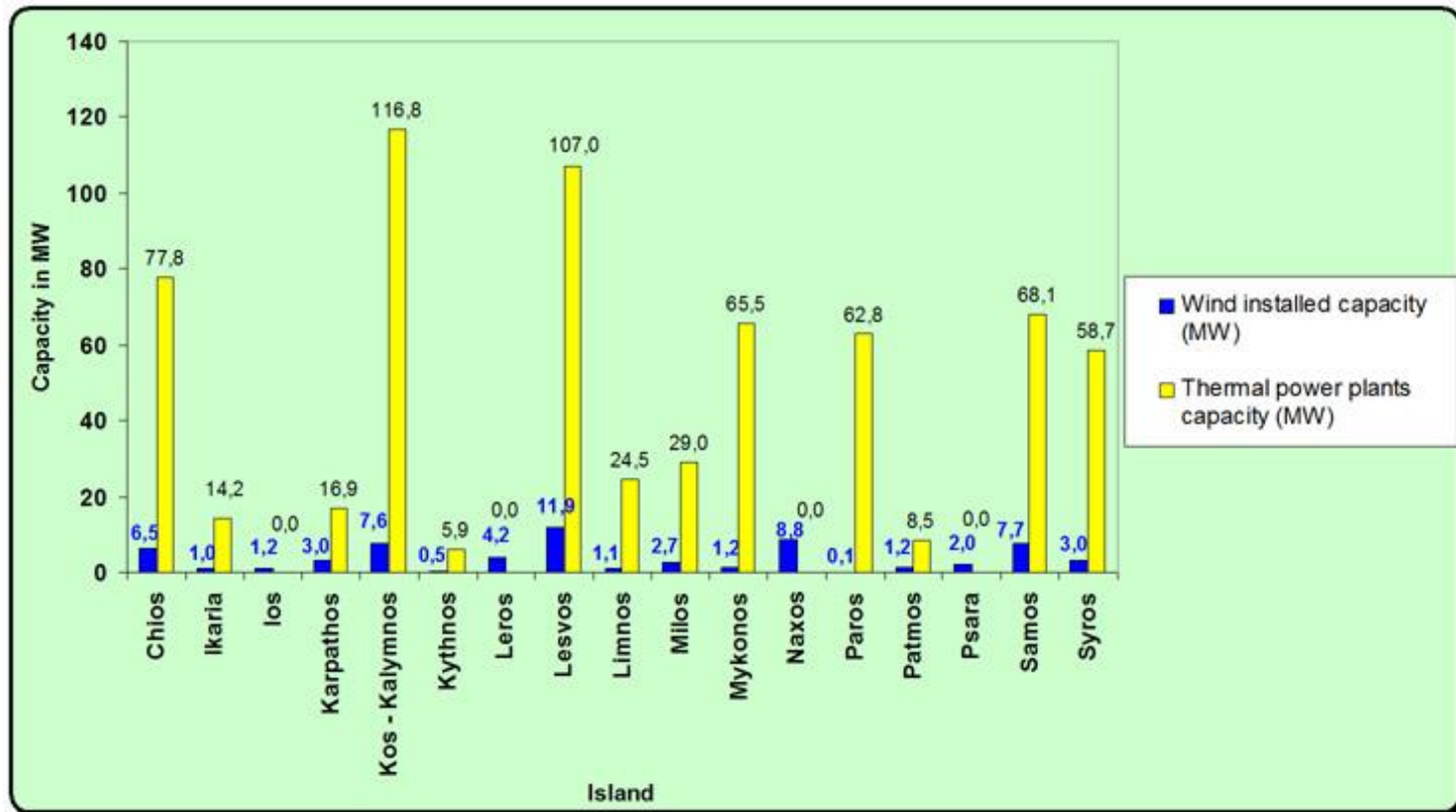
Average annual changes → +4.46% (2000-2007), +1.57% 2008, -1.77% 2009

RES-E production 2000 – 2009



- ❖ 2000 → 6.9% 2009 → 13% (of total production),
- ❖ 99.89% of total RES-E production → Wind power,
- ❖ Rest of it → PVs & small hydroelectric of PPC Renewables in Chania.

Capacity of wind farms installed on islands



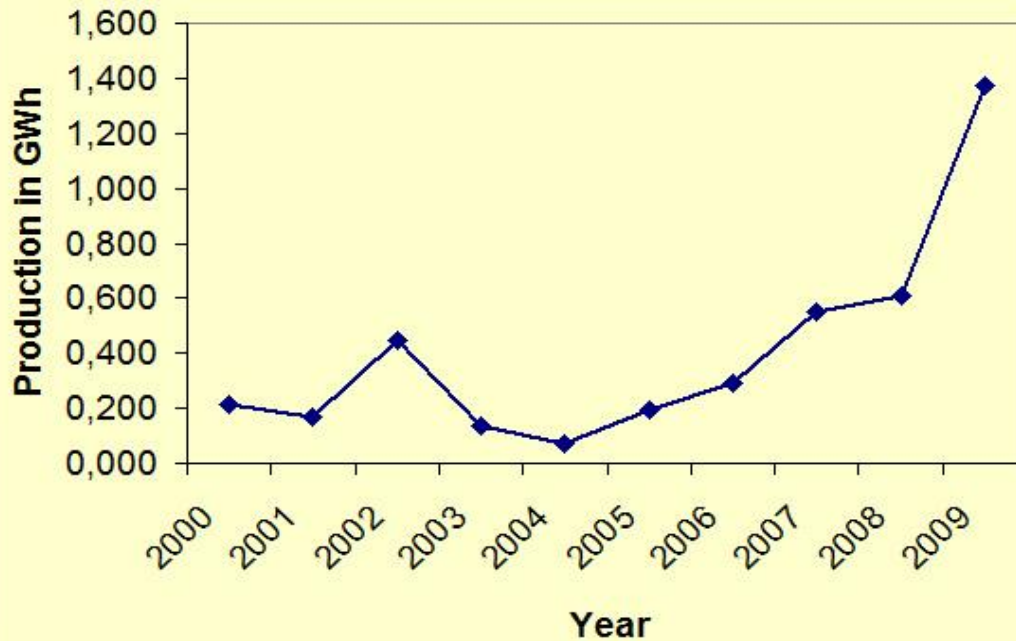
Total wind installed capacity → 254.46 MW

Crete → 166.55 MW (65.54%)

Rhodes → 26.35 MW (10.36%)

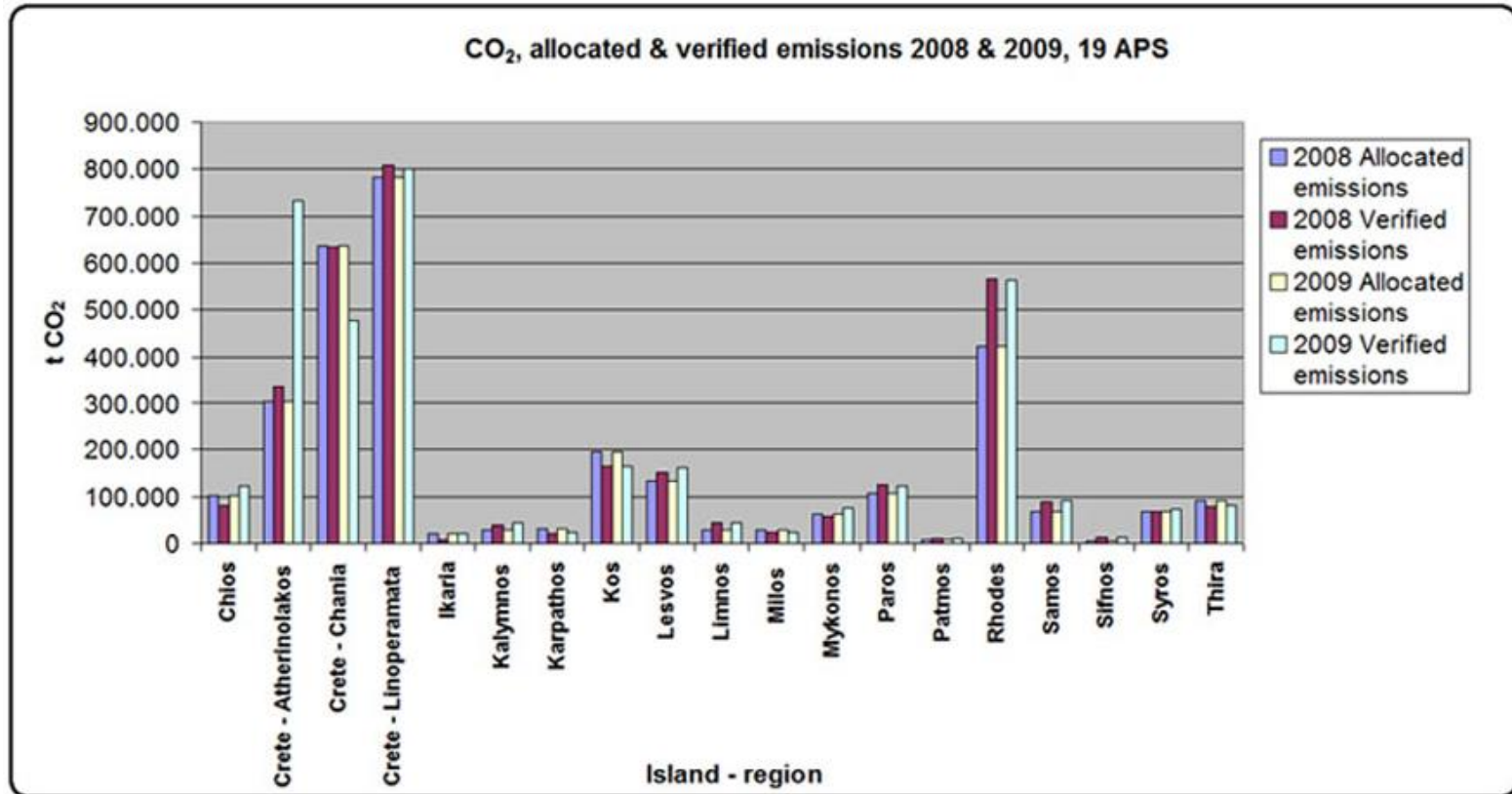
Production from PV installations 2000-2009

PV installations production on the non-interconnected islands, 2000-2009



2000	Antikythira, Arki, Crete, Kythnos, Lesvos, Paros, Sifnos
2001	Antikythira, Arki, Crete, Kythnos, Lesvos, Paros, Sifnos
2002	Antikythira, Arki, Crete, Kythnos, Lesvos, Paros, Sifnos
2003	Crete, Lesvos
2004	Crete, Lesvos
2005	Crete, Lesvos
2006	Crete, Lesvos
2007	Crete, Lesvos, Sifnos
2008	Crete, Lesvos, Naxos, Sifnos, Syros
2009	Chios, Crete, Kythnos, Lesvos, Milos, Mykonos, Naxos, Rhodes, Sifnos, Symi, Sxoinousa, Syros

19 APSs participate in EU-ETS



2008 & 2009 → 9 & 5 of the 19 APS have verified emissions lower than the allocated but in total

2008 → +6.3%, 2009 → +16.9% verified compared to allocated.

Assumptions – estimations

- **Demand estimation:** BAU scenario of NEPC,
- **Average emission:** 0.694 tCO₂/MWh,
- **Allocated emissions for 3rd period 2013-2020:** yearly allowances of 63.99567 Mt CO₂ & 2.994997 for islands APS.

Assumptions – estimations

- **3rd Phase of EU-ETS allocated allowances cost: €20/ton,**
- **Crude oil prices, mean annual variable cost/MWh,**
- **Wind Farms CF=28.7%, PV installations CF=15%,**
- **New jobs in the wind power sector: 15.1/MW,**
- **The already distributed capacity of 3.337 MW for small wind turbines has not been taken into account.**

The No-Change Case basic assumptions

- **In the coming decade the RES-E penetration continues at the rate of the last decade,**
- **not even scheduled changes take place:**
 - ⇒ interconnection of Cyclades,
 - ⇒ natural gas in Crete.

The Scheduled-Changes Case

- Introduction of natural gas power production in Crete in 2013 - 250 MW,
- 53.5% in power generation performance (combined cycle units),
- Emissions: reference price of 0.42 t CO₂/MWh,
- Interconnection of Cyclades with mainland: the 200-MW case has been adopted and gradually applied from 2015 to 2020.

Towards NREAP case

- No natural gas penetration in Crete,
- interconnection of Cyclades and the 200-MW wind capacity remains,
- Wind – Hydro Pumped Storage (WHPS) technology in 21 islands has been applied (Paros, Syros & Mykonos not included):
 - ⇒ targeted (2020) wind capacity → 1,089 MW,
 - ⇒ almost 4-year period for construction → 2014 begin of the system function.

Facts regarding basic economics of 3rd case (the case of Crete)

- **Total investment cost:** 2,105 M€, out of which 1,145 concerns Crete,
- **PPC & PPC Renewables scheduled expenditure for Crete, that could be redirected to the WHPS option,**
- **Engagement of private investors which interest is evidently huge,**
- **Mid-term benefits from:** gained allowances cost, reduction of fuel supply cost, possibility of increasing the CF of the wind farms, which increases the viability of private investments, **and the fact that PPC is enrolled in the NSRF could “solve the equation”.**

Results

YEAR	No Change Case			Scheduled Changes Case			Towards NREAP Case		
	2010	2015	2020	2010	2015	2020	2010	2015	2020
Demand estimation (Gwh)	5,406.00	5,932.00	6,458.00	5,406.00	5,932.00	6,458.00	5,406.00	5,932.00	6,458.00
Oil thermal production (GWh)	4,742.52	5,033.30	5,324.08	4,742.52	2,606.30	2,478.59	4,742.52	4,372.02	2,800.34
Share of thermal production	87.73%	84.85%	82.44%	87.73%	83.44%	74.67%	87.73%	73.70%	43.36%
Emissions (t CO ₂)	3,291,312	3,493,113	3,694,915	3,291,312	2,792,961	2,704,325	3,291,312	3,034,181	1,943,434
Allowances cost in million € (20 €/t)	2.247	59.899	59.899	2.247	55.859	54.087	2.247	59.899	38.869
Excess of the allocated emissions (t CO ₂)	112,374.57	498,116.22	699,917.88	112,374.57	-202,035.55	-290,671.77	112,374.57	39,184.29	-1,051,562.81
Fuels supply cost (million €)	615.058	691.928	773.270	615.058	632.102	649.280	615.058	601.021	406.721
WHPS in: Crete, Rhodes, Kalymnos, Kos, Lesvos, Chios, Samos, Santorini, Limnos, Milos, Karpathos, Ikaria, Sifnos, Patmos, Skyros, Kythnos, Serifos, Amorgos, Simi, Astypalaia, Megisti, (2020 targeted extra wind capacity = 805 MW)							Starting 2014	230.00	805.00
Natural gas thermal production (GWh)				2013 > 250 MW, 2015 > 500 MW	2,343.30	2,343.30			
RES-E production (GWh)	663.48	898.70	1,133.92	663.48	982.40	1,636.11	663.48	1,559.98	3,657.66
Share of RES-E production	12.27%	15.15%	17.56%	12.27%	16.56%	25.33%	12.27%	26.30%	56.64%
PV installed capacity, CF=15% (MW)	11.82	101.39	190.93	11.82	101.39	190.93	11.82	101.39	190.93
PV production (GWh)	15.36	131.81	248.21	15.36	131.81	248.21	15.36	131.81	248.21
PV share in total RES-E (%)	2.32%	14.67%	21.89%	2.32%	13.42%	15.17%	2.32%	8.45%	6.79%
Total wind installed capacity, CF=28.7% (MW)	258.09	305.38	352.69	258.09	338.71	552.67	258.09	568.71	1,357.67
Wind production (GWh)	648.11	766.88	885.70	648.11	850.58	1,387.90	648.11	1,428.17	3,409.45
Wind share in total RES-E (%)	97.68%	85.33%	78.11%	97.68%	86.58%	84.83%	97.68%	91.55%	93.21%
New jobs per wind MW installed	54.7	768.9	1,483.3	54.7	1,775.5	4,503.0	54.7	4,745.2	16,658.5

Comments on results

- In the NREAP the estimated wind potential for the country – needed to meet the 2020 targets – ascends at 7,500 MW, significant percent of it should come from the islands,
- the estimated 1,358 MW of wind power in the 3rd case decreases: 34% the fuel supply cost, 47.4% the CO₂ emissions reduction & creates more than 16 thousand jobs.

Conclusions

- Almost only wind power exploitation capabilities have been examined, solar power potential, biomass potential of islands like Crete and Lesvos with big agricultural production and geothermal power of Milos, Nisyros etc, should be included in further analysis.
- Accumulated knowledge regarding combined exploitation of RES is present, economical crisis also: it consists high priority object to find the best combination, taking into consideration social, political & (but not only) economical factors.



Thank you for your attention

