



2EN

renewable energy
services and applications

A comparison between the WindSim results and the real parks production



George Droukas

2EN [Enallaktiki Energiaki SA], founded in 2001, is a dynamically developing company with extensive experience in the field of Renewable Energy.

Featuring a high level of expertise, vast experience on RES studies and highly trained staff, 2EN undertakes all the tasks, from planning, designing and legal procedures to materials procurement, construction, operation and maintenance of projects.

goals

- Developing and constructing high-quality projects.
- Developing meteorological measurement systems.
- Developing innovative autonomous hybrid power plants.
- Strengthening its international sales network.
- Improving service quality by complying to international standards.

quality

2EN has established, documents, develops and maintains a quality system that meets the requirements of international standards:

- ISO/IEC 17025:2005

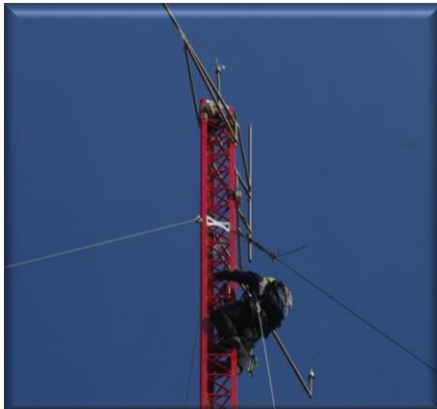


- Installation, maintenance and operation of hundreds of measuring stations on behalf of numerous Greek or international companies.
- Installation of meteorological stations network in the Gobi Desert in Mongolia, in Turkey, in Libya and in Albania.
- Participation in the construction of the wind atlas of Greece.
- Measurements with captive balloons and radiosondes, on behalf of the National Observatory of Athens.
- Wind potential site assessment for large scale wind farm installations.
- Remote sensing measurements with LiDAR (WINDCUBE), ensuring the integrity, the safety and the continuous operation of the system.
- Wind farm micrositing & Energy yield assessment for more than 500MW of wind farms of several companies.
- Design and construction of PV power plants and rooftop systems.
- Technical due diligence of power plants.
- Providing technical consultancy services to numerous investors or banks.
- Participation in numerous exhibitions in Europe.

□ Wind Energy Assessment &/or Technical due diligence &/or Construction Monitoring of Wind Farms

- Skopia 20MW Wind Farm (**Operating**)
- Krekeza 30MW Wind Farm (**Operating**)
- Gouri Meles 32,2MW Wind Farm (**Operating**)
- Lykosterna 9,2MW Wind Farm (Under Development)
- Kedrolaka 1,7MW Wind Farm (Under Development)
- Fikthi 1,8MW Wind Farm (Under Development)
- Gerampi 24MW Wind Farm (Under Development)
- Gavrovo 24MW Wind Farm (Under Development)
- Chionaki 14MW Wind Farm (Under Development)
- Sterniza 21MW Wind Farm (Under Development)
- Profitis Ilias 22MW Wind Farm (Under Development)
- Rouskio 28MW Wind Farm (Under Development)
- Atherinolakos 21MW Wind Farm (**Operating**)
- Akoumia 21MW Wind Farm (**Operating**)
- Koprinos 15,3MW Wind Farm (**In start-up period**)
- Karines 29,7MW Wind Farm (Under Development)
- Vigla 60MW Wind Farm (Under Development)
- Melissi 24MW Wind Farm (**Operating**)
- Trikorfo 24MW Wind Farm (**Operating**)

sum total
423 MW



2EN has managed in the time that is active in the market, to ensure partnerships with major companies operating in the field of renewable energy.

Some of the major clients are:



SUMMARY

1. Park 1 - Site description
2. Park 1 – Measured AEP
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4. Park 1 - AEP Results
5. Park 2 - Site description
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7. Park 2 – Windsim parameters
8. Park 2 - AEP Results

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The whole work that 2EN had to do was a due diligence analysis of two existing Wind Farms in Central Greece.

We gave to the customer a technical description of the plant, analyzed the production of the wind farm and examined the documentation concerning the construction contracts, the licensing procedure as well as the service and the insurance.

Calculation of AEP using Windsim and comparison with the real Production of the two parks is the subject of this presentation.

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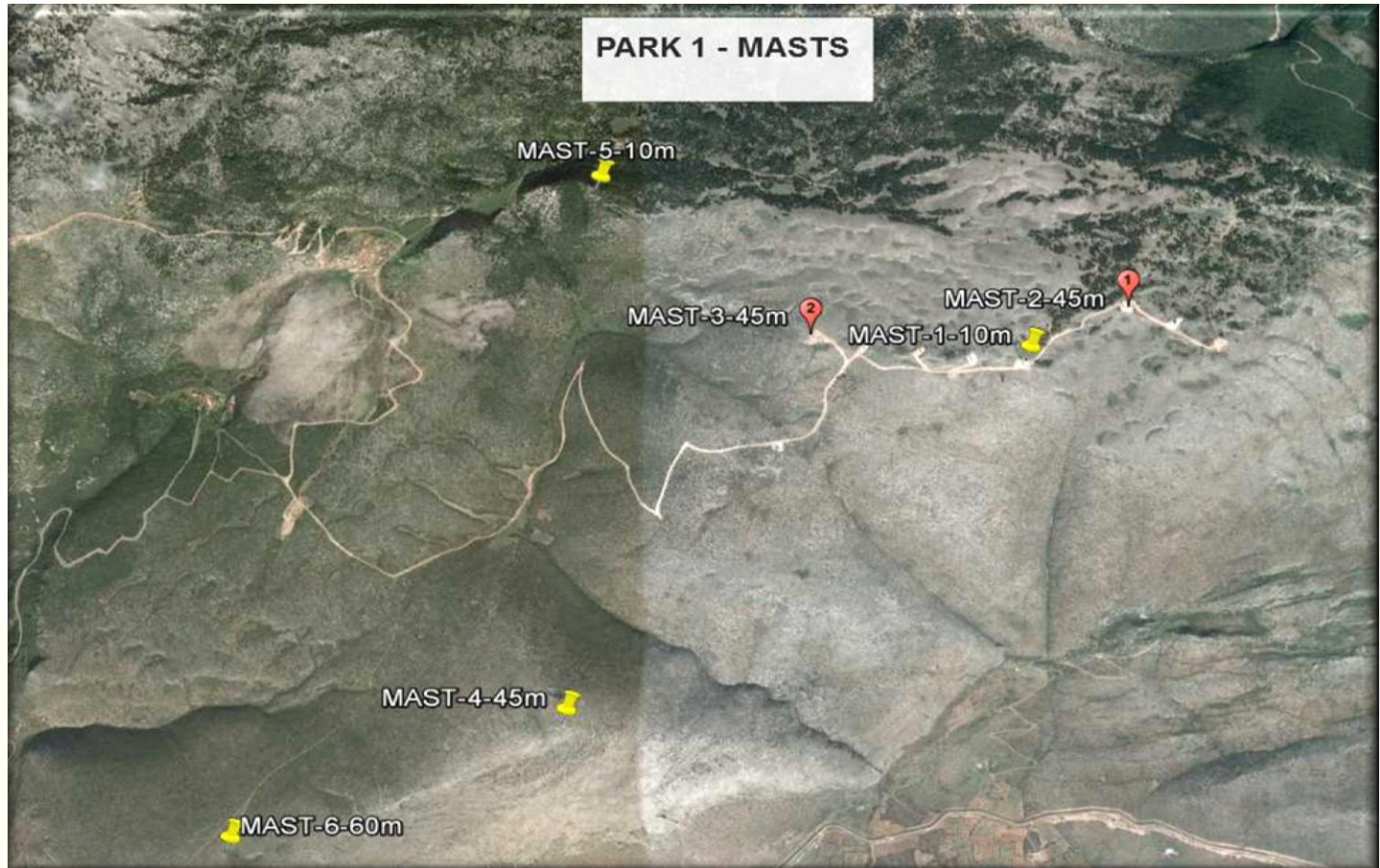
Park's 1 site is a 2 Km long, ridge line, situated in Central Greece. Topography is complex. Site altitude varies from 950 up to 1015 meters above sea level



SUMMARY

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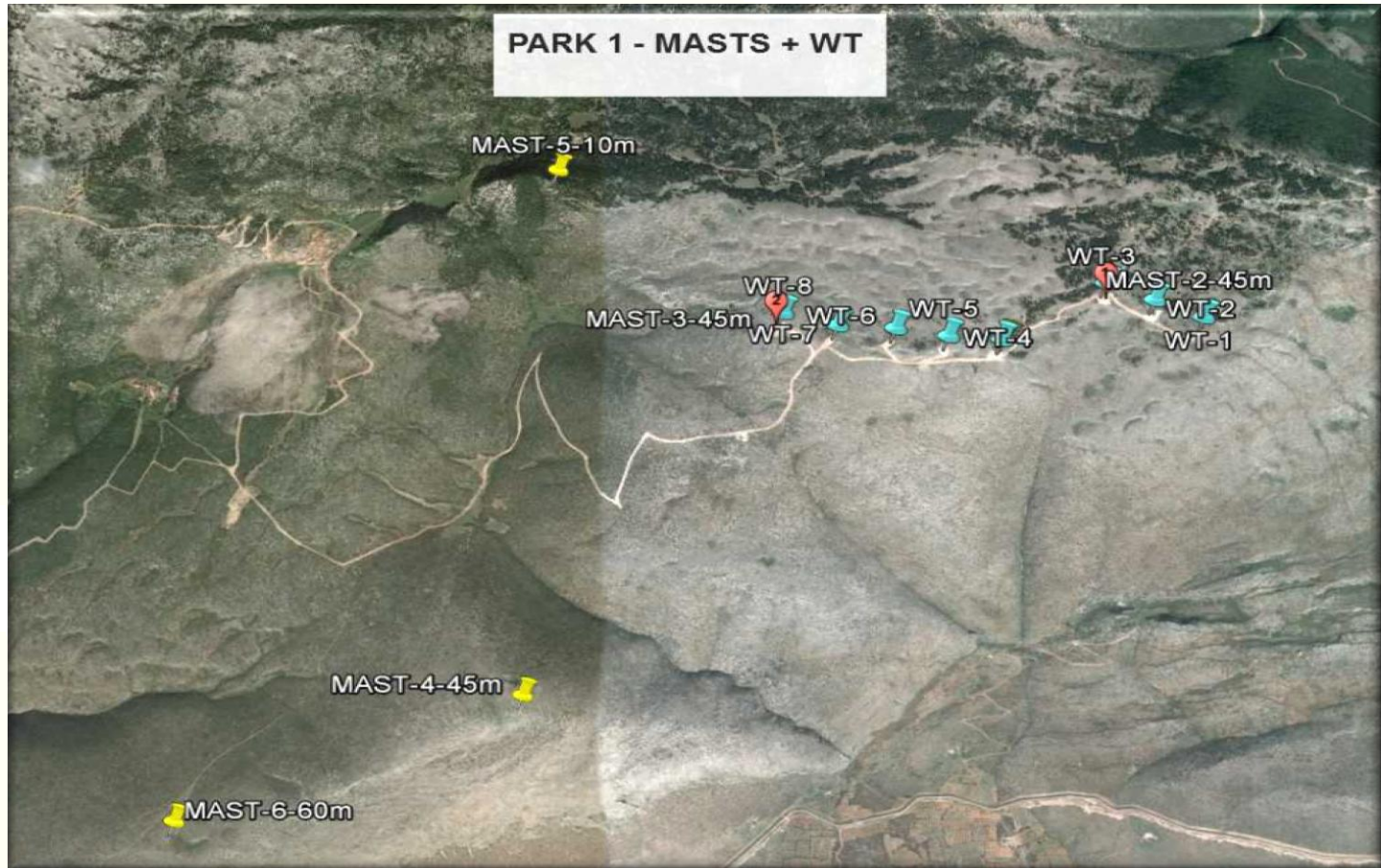
Almost 5 years of data, measured and predicted (MCP) from the two 45m mast's inside the wind farm used for the Energy Yield assessement.



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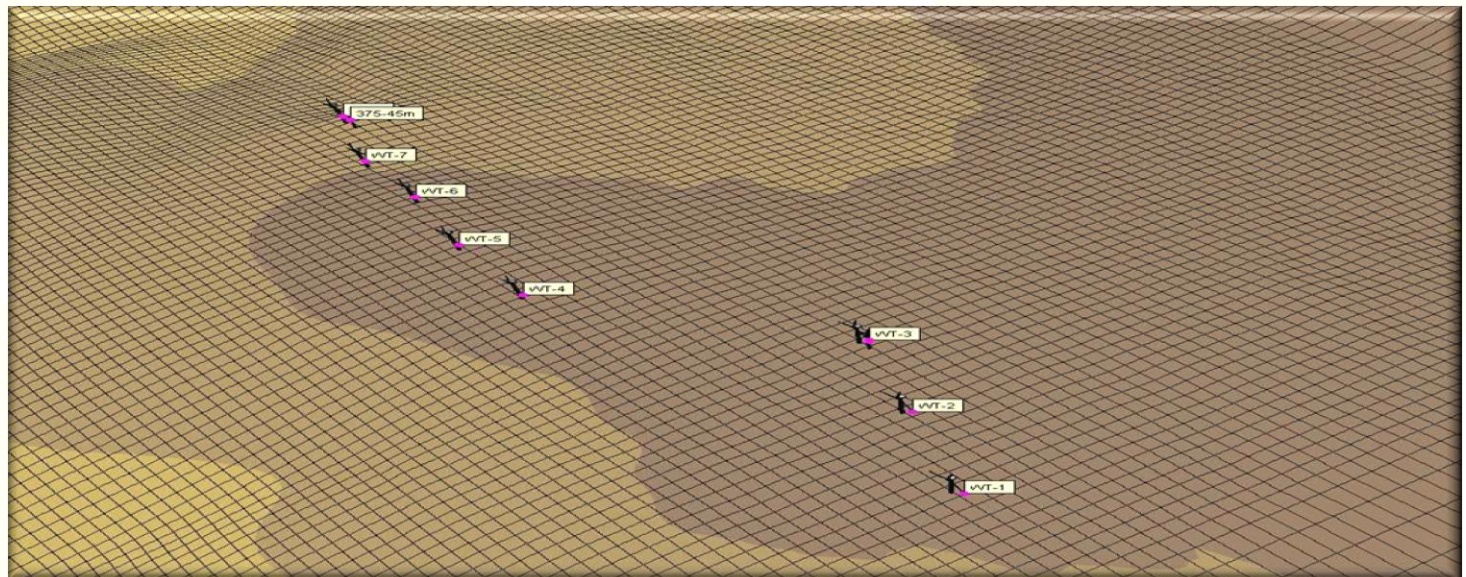
8 wind turbines VESTAS V90 3000Kw with 80 meters hub height were installed at the site of PARK-1.



SUMMARY

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7. Park 2 – Windsim parameters
8. Park 2 - AEP Results

The nesting technique was used for the calculations. A computational domain with dimensions 30kmX30km used as the former 3D model and a 10kmX10km refine model used for the simulations. ASTER Global Digital Elevation Model (GDEM) v.2. dtm with 23m resolution used for the calculations on former model and Digital terrain model from Hellenic Cadastre with 5m resolution used for the calculations on the refine model. Corine Land Cover 2000 of European Environment Agency (EEA) data is been used for roughness.

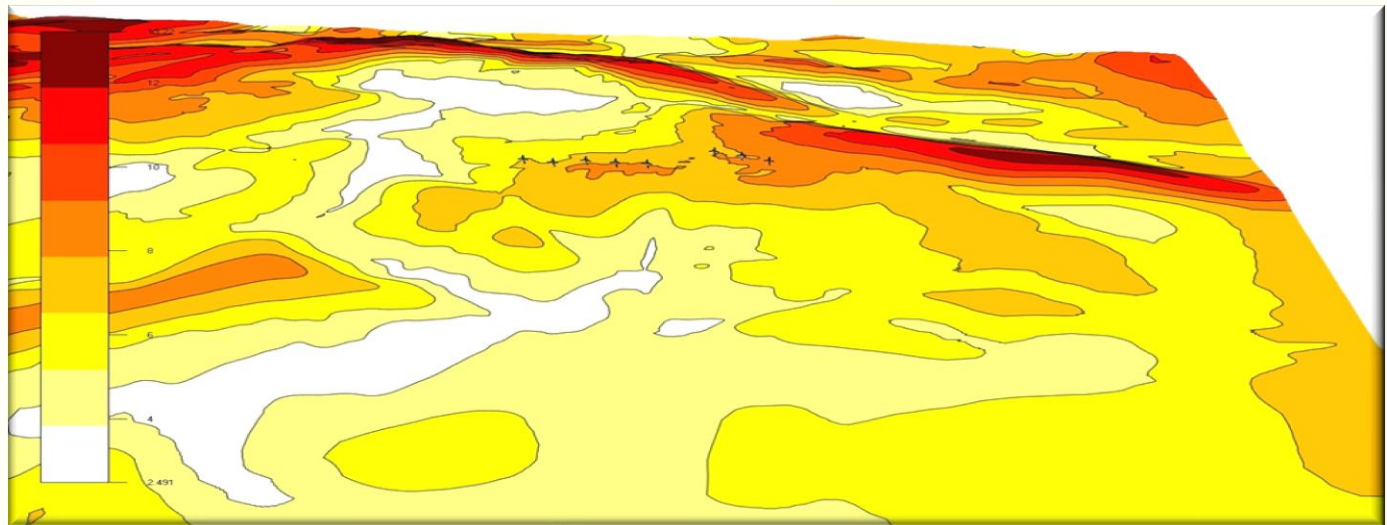


SUMMARY

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7. Park 2 – Windsim parameters
8. Park 2 - AEP Results

WIND FIELDS MODULE PROPERTIES	
SECTORS :	16
DO NESTING:	TRUE (From Windsim model)
SOLVER	GCV
NUMBER OF ITERATIONS	500-2800
CONVERGENCE WIZARD	False
CORIOLIS	False
TURBULENCE MODEL	Standard k-ε

ENERGY MODULE PROPERTIES	
AIR DENSITY	No correction (1.09 kg/m ³)
ENERGY INTERPOLATION	True
ENERGY WAKE MODEL	Wake model 1
MULTIPLE WAKES MODEL	Based on sum of squares
WAKE ROTOR DIAMETER	1-50



SUMMARY

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8. Park 2 - AEP Results

# W/T	Hub height (m)	AEP without wakes (MWh/y)	AEP including wakes (MWh/y)
1	80	9155	9055
2	80	9002	8923
3	80	8826	8350
4	80	8949	8865
5	80	8644	8300
6	80	8776	8620
7	80	7892	7816
8	80	7523	7519
TOTAL :		68767	67448

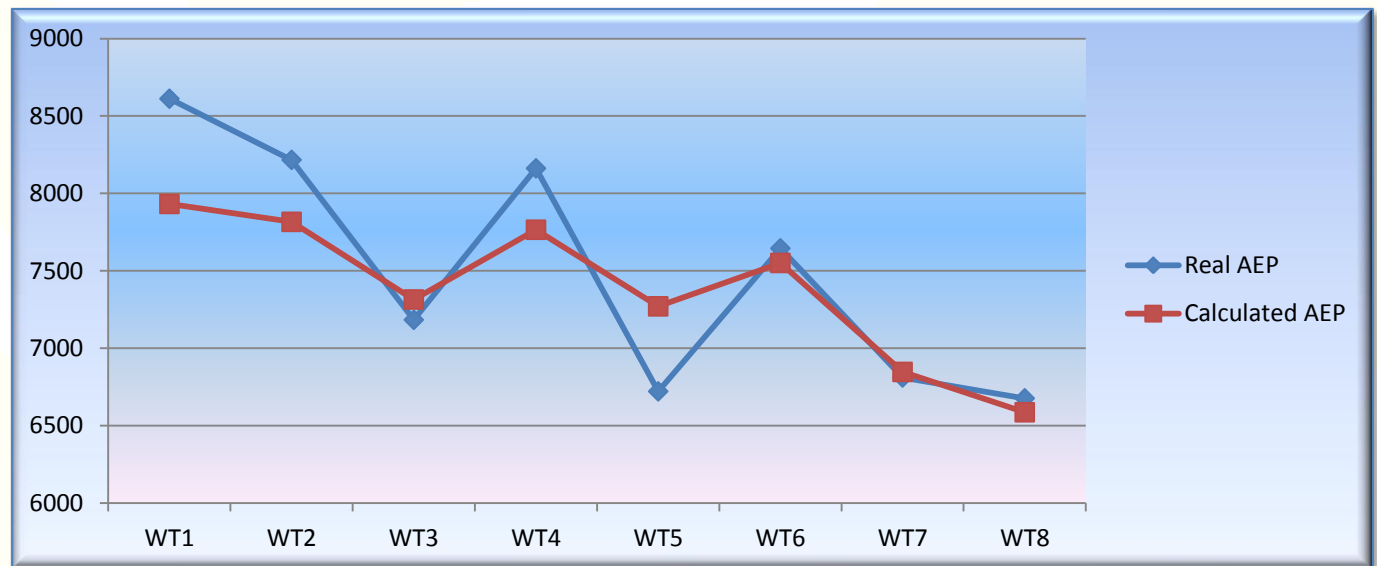
AEP 24 MW wind farm 1	
Annual Energy Production without losses	68.77 GWh/y
Annual Energy Production including wake losses	67.45 GWh/y
Annual Energy Production including wake losses and 12.4% availability losses	59.09 GWh/y
Annual Energy Production including wake losses, 12.4% availability losses, long term corrected	59.09 GWh/y
Capacity factor	28,1%
Equivalent operating hours	2452

Sector management for WT 2,5 and 7 was taken in account with no remarkable decrease in AEP. Tables with availability, production and malfunctions per WT per month were provided by the customer and processed by 2EN.

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8. Park 2 - AEP Results

# W/T	Windsim calculated AEP including wakes (MWh/y)	Calculated AEP including wake losses, 12.4% availability losses, long term corrected	Measured AEP (MWh/y)	% Difference
1	9055	7932	8612	
2	8923	7816	8217	
3	8350	7315	7183	
4	8865	7765	8162	
5	8300	7271	6722	
6	8620	7551	7645	
7	7816	6847	6811	
8	7519	6587	6677	
	67448	59090	60029	-1.56



SUMMARY

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5. **Park 2 - Site description**
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7. Park 2 – Windsim parameters
8. Park 2 - AEP Results

Park's 2 site is a 2.2 Km long, ridge line, situated in Central Greece. Topography is complex. Site altitude varies from 920 up to 1140 meters above sea level



South part of the Wind farm
(WT's 3-10).View from WT-2

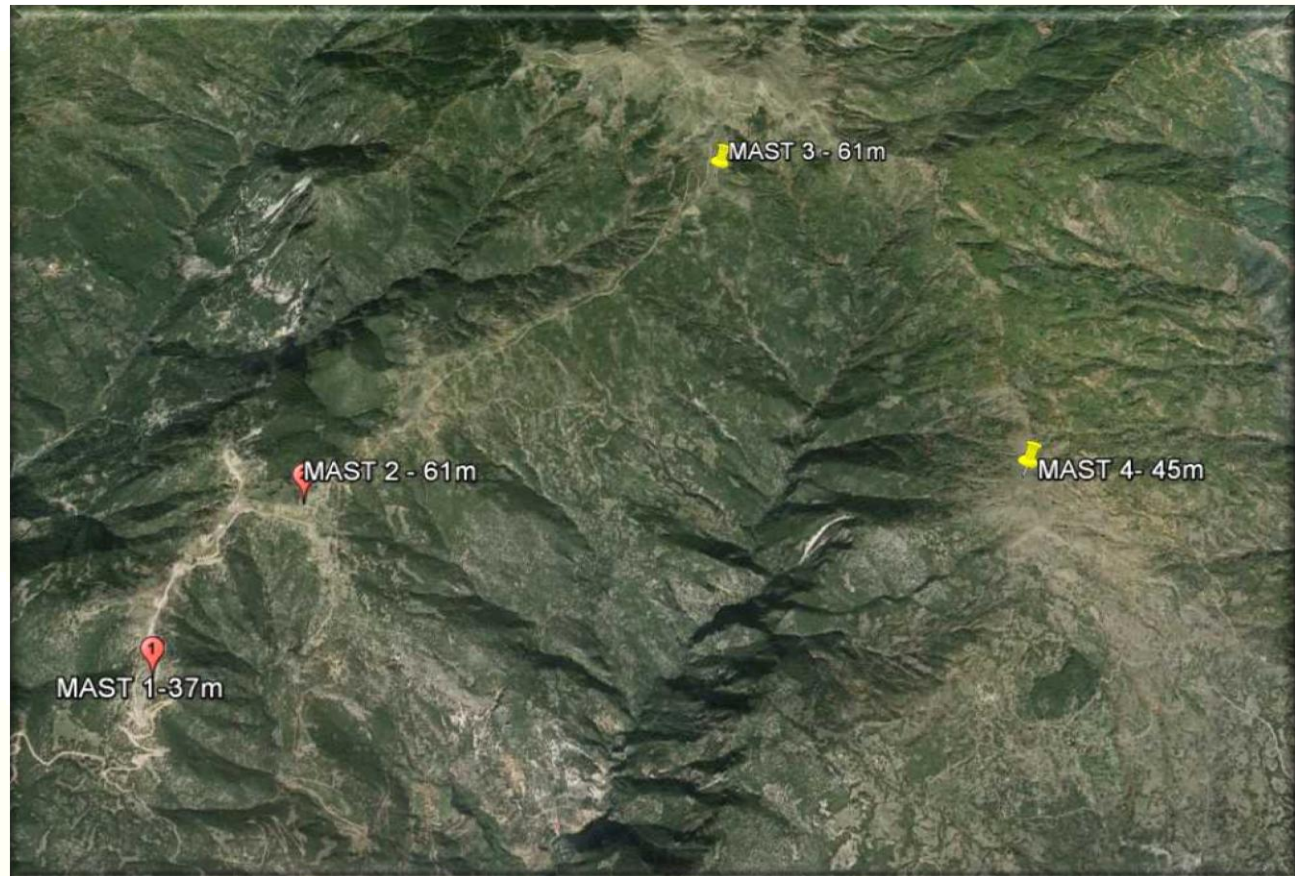


View of WT's 4-10

SUMMARY

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5. **Park 2 - Site description**
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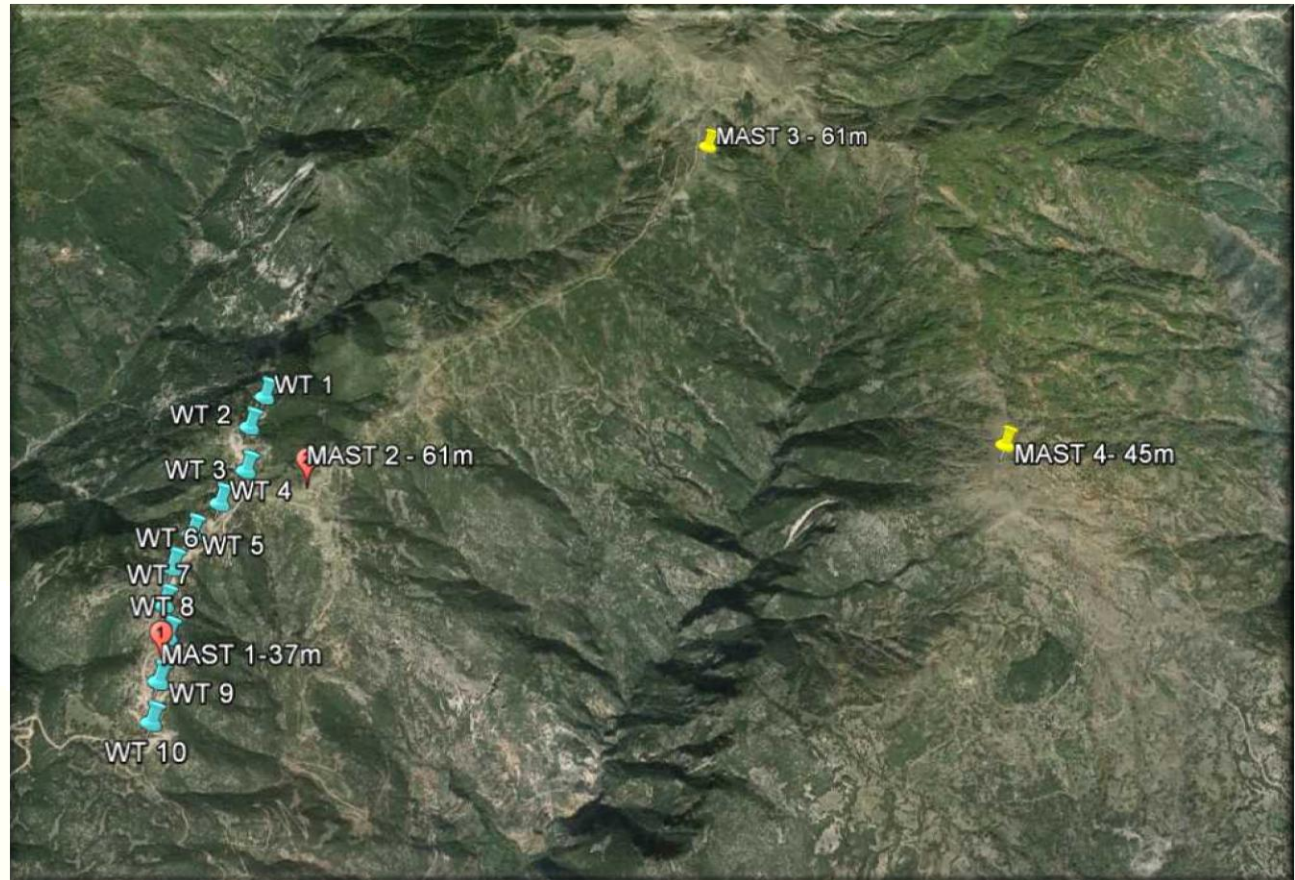
Almost 5 years of data from the two mast's inside the wind farm (37m & 61m) used for the Energy Yield assesement.



SUMMARY

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10 wind turbines VESTAS V90 3000KW (down rated at 2400KW) with 80 meters hub height were installed at the site of PARK-2.



SUMMARY

1. Park 1 - Site description
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5. **Park 2 - Site description**
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SUMMARY

1. Park 1 - Site description
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5. Park 2 - Site description
6. **Park 2 – Measured AEP**
7. Park 2 – Windsim parameters
8. Park 2 - AEP Results

Park 2 was in operation since August 2011.

Data from February 2013-January 2014 were detailed enough to be used for comparison.

Tables with availability, production and malfunctions per WT per month were provided by the customer and processed by 2EN.

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8. Park 2 - AEP Results

The nesting technique was used for the calculations. A computational domain with dimensions 30kmX30km used as the former 3D model and a 10kmX10km refine model used for the simulations. ASTER Global Digital Elevation Model (GDEM) v.2. dtm with 23m resolution used for the calculations on former model and Digital terrain model from Hellenic Cadastre with 5m resolution used for the calculations on the refine model. Corine Land Cover 2000 of European Environment Agency (EEA) data is been used for roughness.

WIND FIELDS MODULE PROPERTIES	
SECTORS :	16
DO NESTING:	TRUE (From Windsim model)
SOLVER	GCV
NUMBER OF ITERATIONS	250-600
CONVERGENCE WIZARD	False
CORIOLIS	False
TURBULENCE MODEL	Standard k-ε

ENERGY MODULE PROPERTIES	
AIR DENSITY	No correction (1.09 kg/m ³)
ENERGY INTERPOLATION	True
ENERGY WAKE MODEL	Wake model 1
MULTIPLE WAKES MODEL	Based on sum of squares
WAKE ROTOR DIAMETER	1-50

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8. **Park 2 - AEP Results**

# W/T	Hub height (m)	AEP without wakes (MWh/y)	AEP including wakes (MWh/y)
1	80	4126	4118
2	80	4457	4414
3	80	4308	4156
4	80	4813	4734
5	80	4767	4724
6	80	4796	4750
7	80	4767	4705
8	80	5468	5316
9	80	5307	5245
10	80	4737	4691
TOTAL :		47.544	46.852

AEP 24 MW wind farm 2	
Annual Energy Production without losses	47,5 GWh/y
Annual Energy Production including wake losses	46,9 GWh/y
Annual Energy Production including wake losses and 11.0% availability losses	41,7 GWh/y
Annual Energy Production including wake losses, 11.0% availability losses, long term corrected	41,7 GWh/y
Capacity factor	19,8%
Equivalent operating hours	1737

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8. **Park 2 - AEP Results**

# W/T	Windsim calculated AEP including wakes (MWh/y)	Calculated AEP including wake losses, 12.4% availability losses, long term corrected	Measured AEP (MWh/y)	% Difference
1	4118			
2	4414			
3	4156			
4	4734			
5	4724			
6	4750			
7	4705			
8	5316			
9	5245			
10	4691			
	46.852	41.698	41.151	-1.3

SO FAR, SO GOOD BUT.....

If we compare AEP per wt.....

# W/T	Windsim calculated AEP including wakes (MWh/y)	Calculated AEP including wake losses, 11% availability losses, long term corrected	Measured AEP (MWh/y)	% Difference
1	4118	3665	3556	
2	4414	3928	4215	
3	4156	3699	3889	
4	4734	4213	4572	
5	4724	4204	3981	
6	4750	4228	4196	
7	4705	4187	4735	
8	5316	4731	2882	
9	5245	4668	4594	
10	4691	4175	4531	
	46.852	41.698	41.151	-1.3

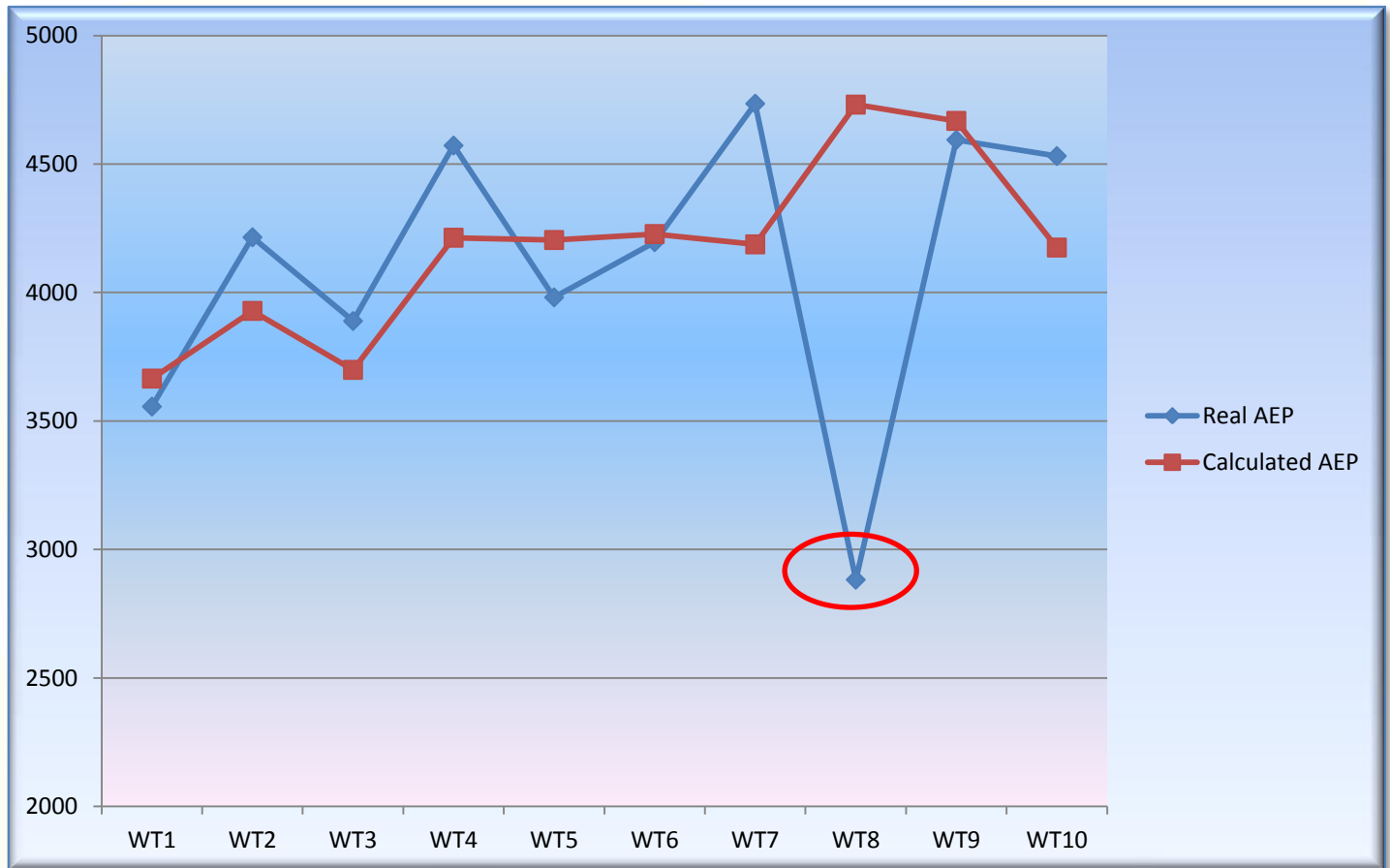
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Wt 8 produces almost half of the predicted energy.

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8. **Park 2 - AEP Results**



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8. **Park 2 - AEP Results**

1. Position of WT 8 was good. Met mast 2 was at the place of wt 8 with average wind speed at 37m for 3 years 6.2m/s .
2. We expected from our experience after visiting the site that Wt 8 should be one of the best Wt's.
3. Availability of Wt 8 was almost 92%.

So what was the problem?

We asked from the customer a possible sector management policy for the site and...

Wind	W1	W2	W3	W4	W5
E1	330702	4256107	0	55	10
E2	330222	4255926	350	50	10
E3	330154	4255618	185	240	12
E4	330042	4255474	5	80	12
E5	329872	4255393	185	240	12
E6	329760	4255236	4	75	12
E7	329589	4255138	189	230	12
E8	329461	4254978	12	62	12
E9	329160	4255025	260	300	10

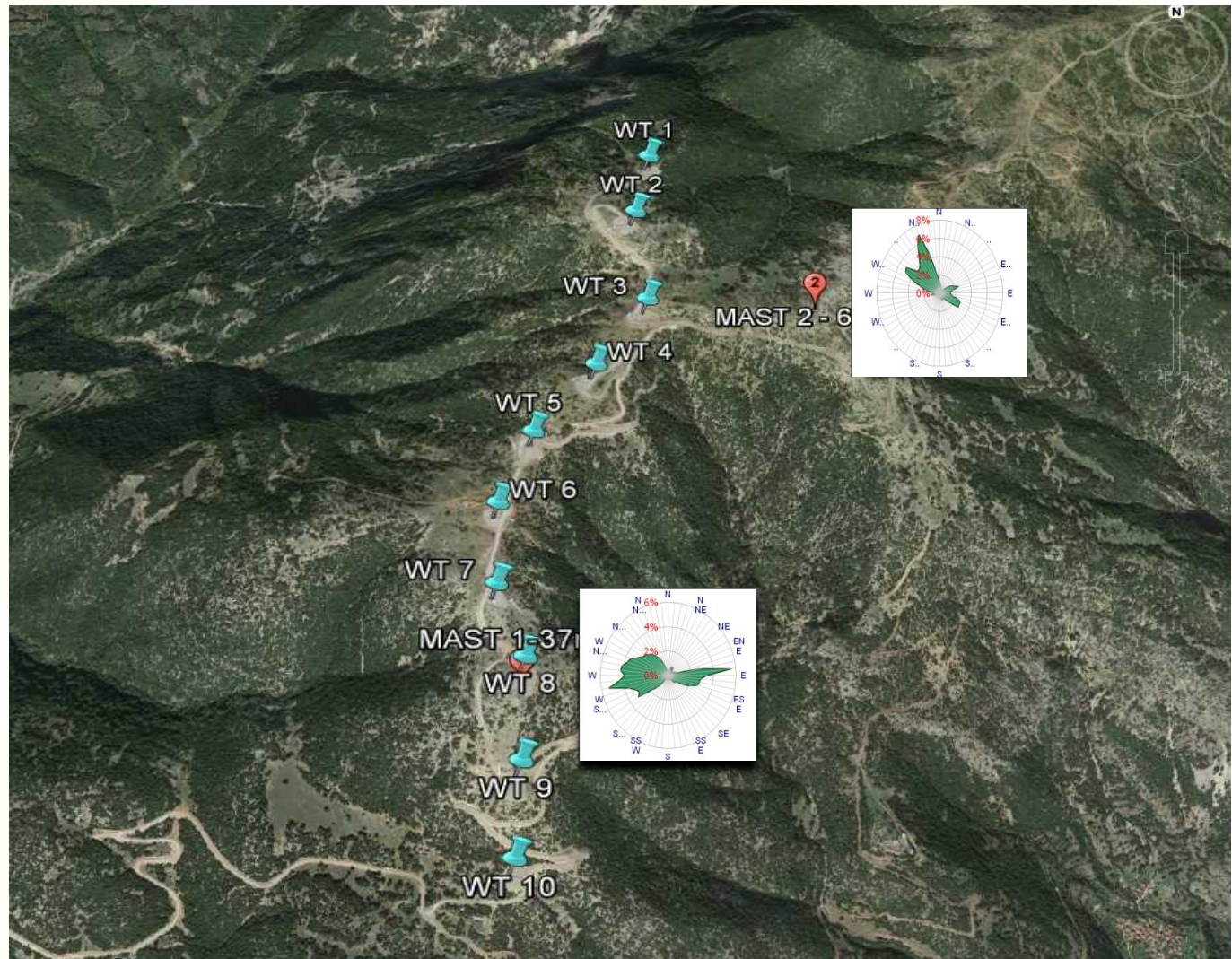
So let's take a look at the site again...

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SUMMARY

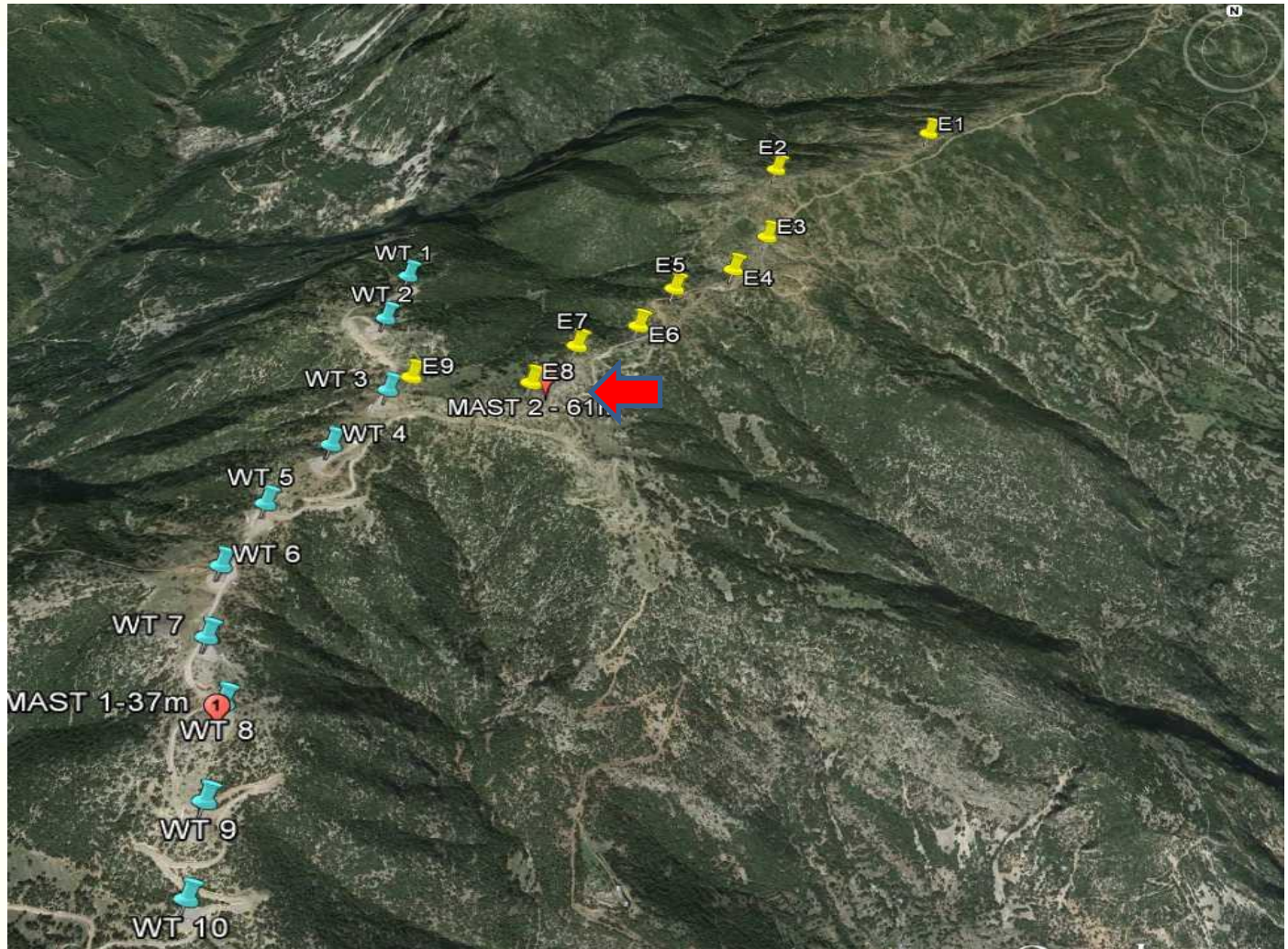
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So the production of WT 8 is so low because there is a sector management policy at the main Energy direction.....

But why????

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THANK YOU