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GIS-based approach for optimal siting and sizing of renewables considering techno-environmental constraints and the stochastic nature of meteorological inputs

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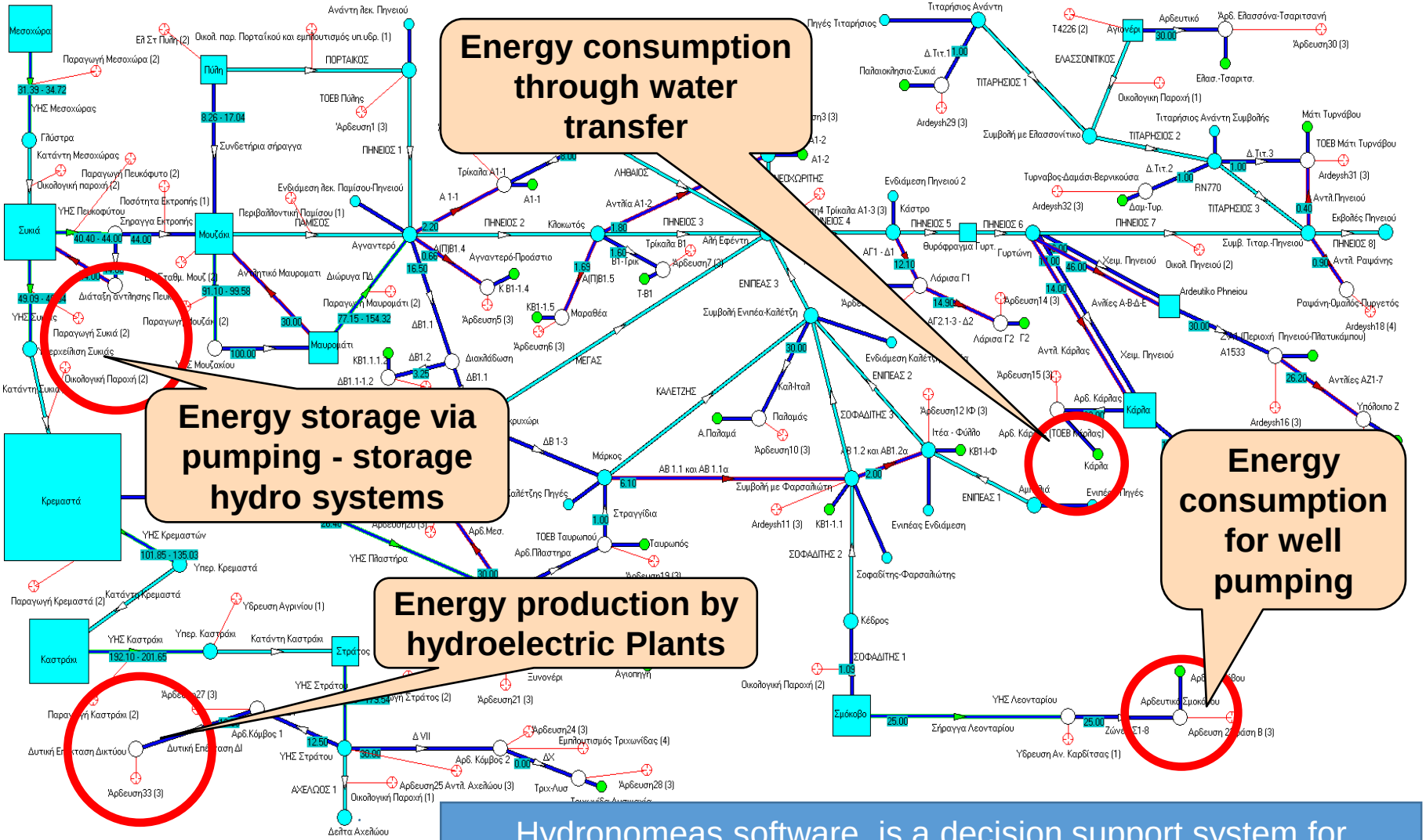
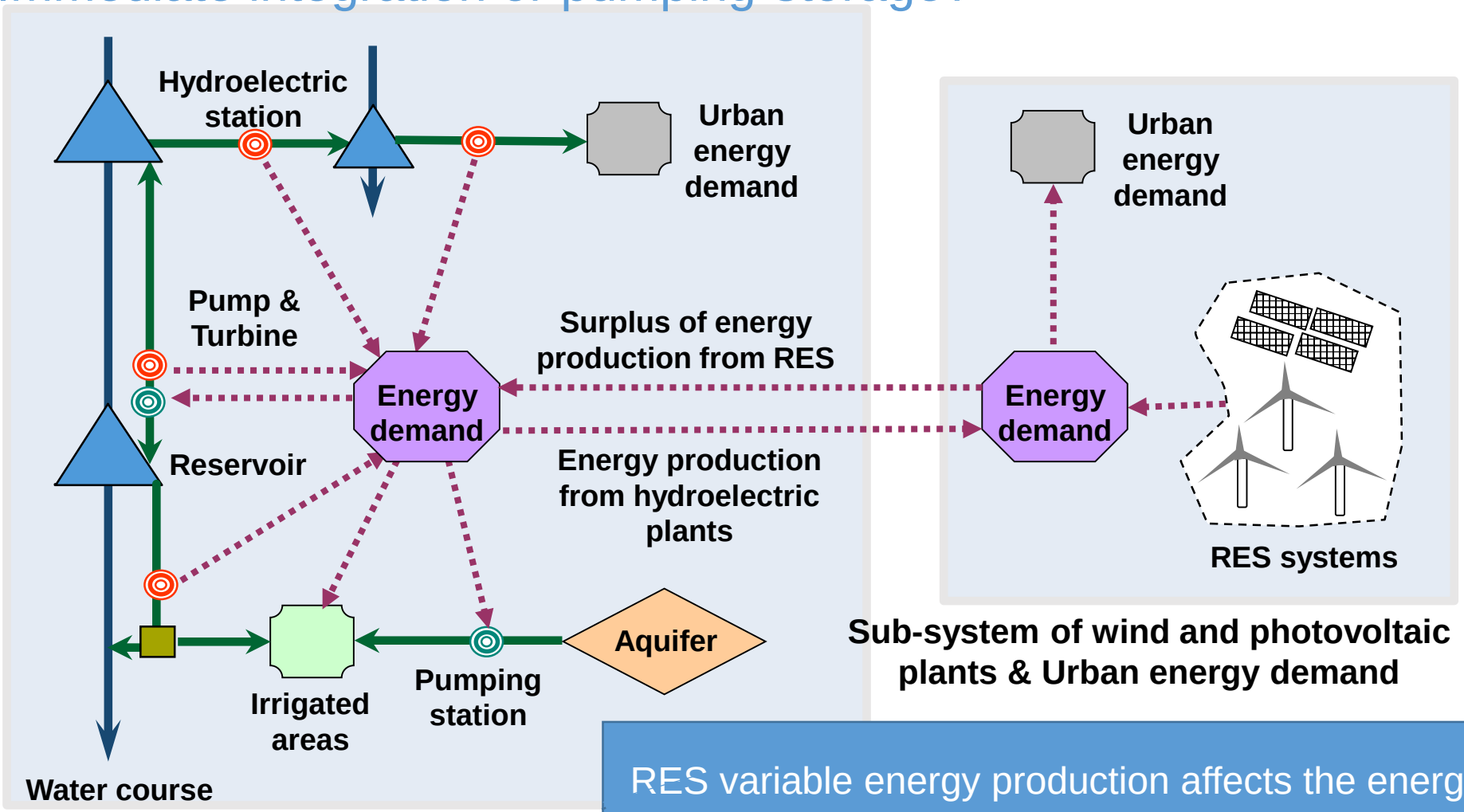
Drivers of this project

- Provide **support to Hydronomeas** decision software, regarding the **possible installed wind and solar power and thus energy production** in the region of Thessaly
- Develop a d**ecision tool** for **RES (Renewable Energy Sources) spatial planning** at the regional scale based on legislation and research, by applying **various constrains** (e.g. technical, environmental etc.)
- Support the **siting assessment** of the **already installed or under license** RES, a tool that could be of use also to the non-scientific decision makers (e.g. Ministry of environment, RAE (Regulatory Authority of Energy)
- Accelerate **feasible RES penetration** in the energy system, in order to **achieve national and EU goals** for sustainable energy development

Hydronomeas software



RES penetration in the energy system
Immediate integration or pumping-storage?



RES variable energy production affects the energy and water management system of Hydronomeas

Why Thessaly? Pros and Cons

- Located in the **center of Greek mainland**, Thessaly has the advantage of **proximity to the high voltage (400kV) electricity grid lines**, as well as **pumping-storage reservoirs** operating in west Greece, able to store the energy surplus of the variable RES energy production
- Regarding elevation and land use, Thessaly is the **biggest valley** and thus **agriculture center of Greece**, that leads to
  - An urgent need of water and energy supply to the cultivated areas
  - A significant percent of low sloped areas suitable for RES siting
- Considering the **solar and wind potential and the topographic and geographic features of Thessaly,** it's expected in advance that **exploitable solar potential in the area is much higher than wind potential.**

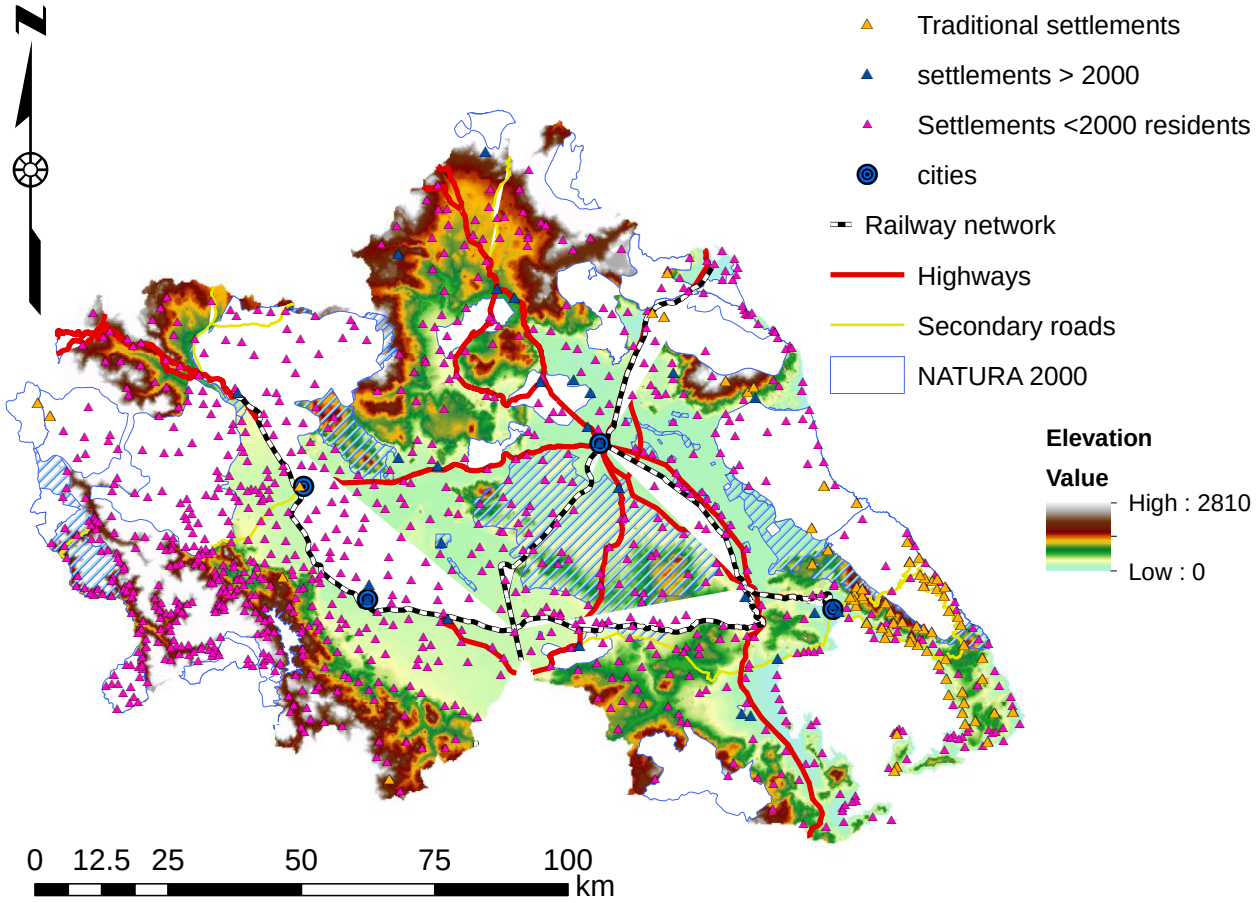
Significant facts about Thessaly

General Information

- Area of 14,050 km^2
- Elevation ranging from 2,810 to 0m
- Average slope 13%
- 718,964 residents (6.65%)
- Dense Road network (4000 km in total)
- NATURA 2000 areas cover 49%
- UNESCO Meteora site covers almost 3km^2

Energy Information

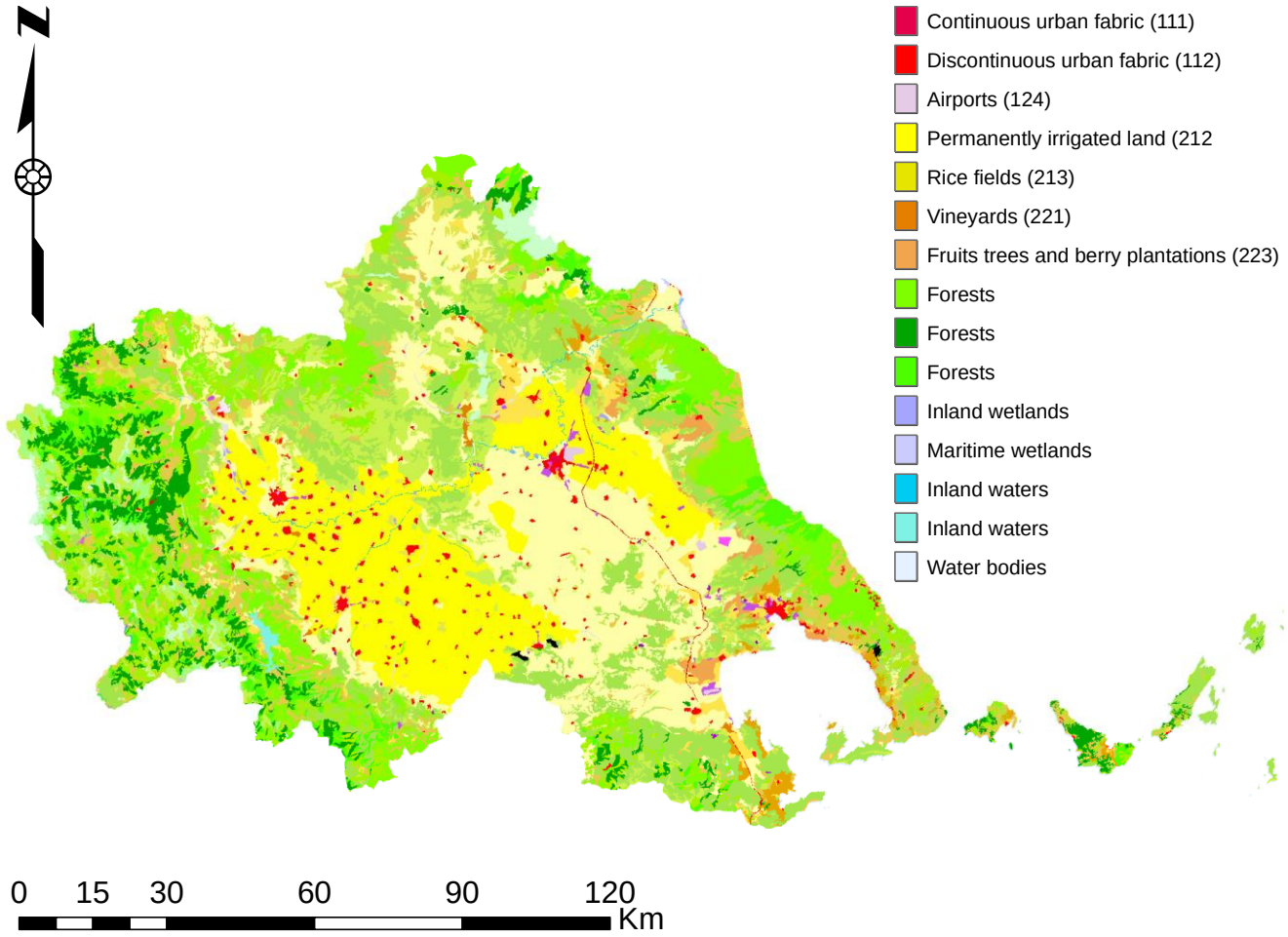
- 1 Windfarm with 17 MW installed power (20 W/T)
- 10 photovoltaic parks with totally 28 MW installed power



	Operation License	Connection offer	Production License	Max allowed installed capacity (MW)
Photovoltaics	28.24	7.5	-	-
Wind turbines	17.00	714.45	1288.96	7056.62
Hybrid systems	27.12	-	-	-

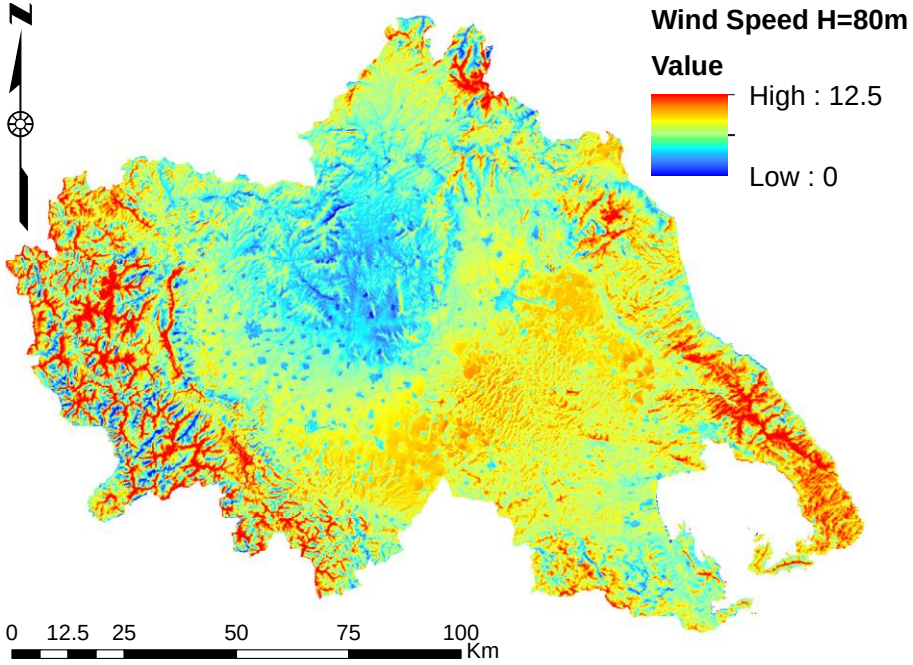
Land uses restrictions in Thessaly

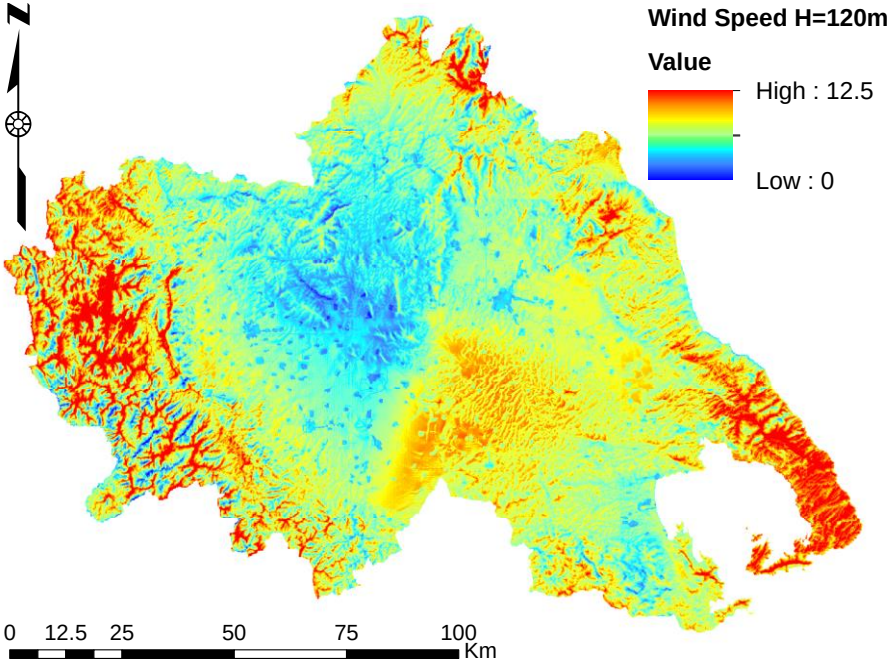
- **Residential areas are** scattered in the area [500, 1000, 1500 m buffer zone]
- **Irrigated land** and permanent crops are marked as high productivity areas from legislation, and thus as infeasible RES installation sites
- **Forests** cover also significant percent of the region. Although legislation allows RES installation special licenses are required.



Corine 2000 land use map (legend with land uses of interest)

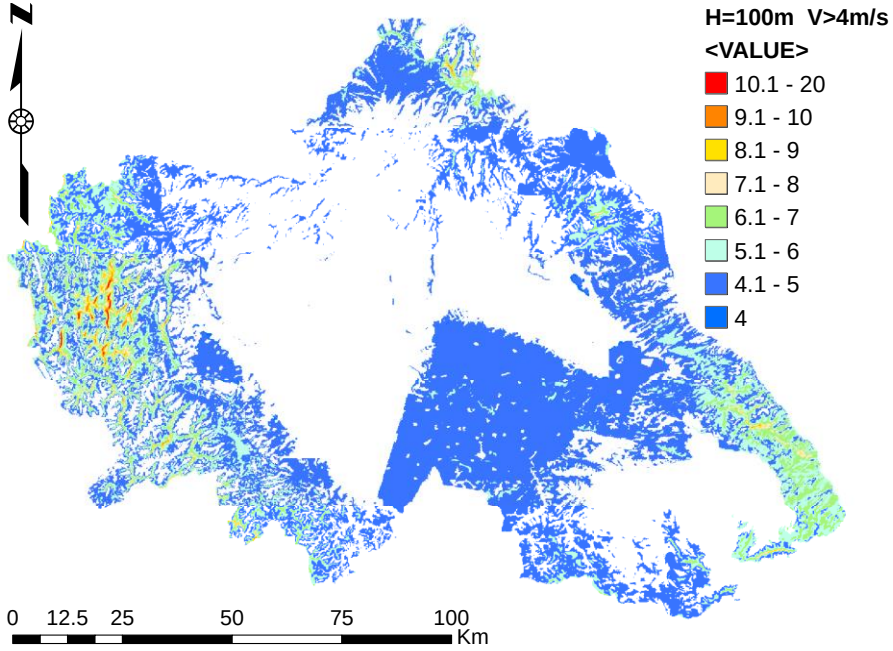
Wind potential of Thessaly (1)

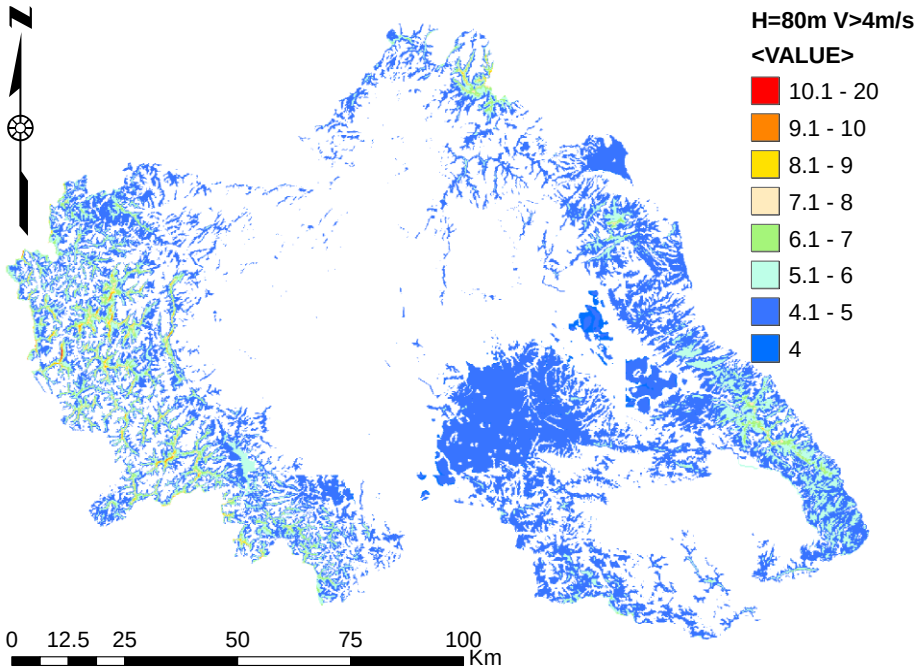




- RAE provides Wind Potential maps at 80m,100m and 120m height with pixel size 150x150m, that is sufficient for the current analysis and is developed from CRES (Center for Renewable Energy Sources and Savings), using data from 100 station well scattered at the Greek territory
- It is easily observed that yearly average wind speed (m/s) is developed in the high elevation areas that are unfortunately marked as NATURA 2000 sites

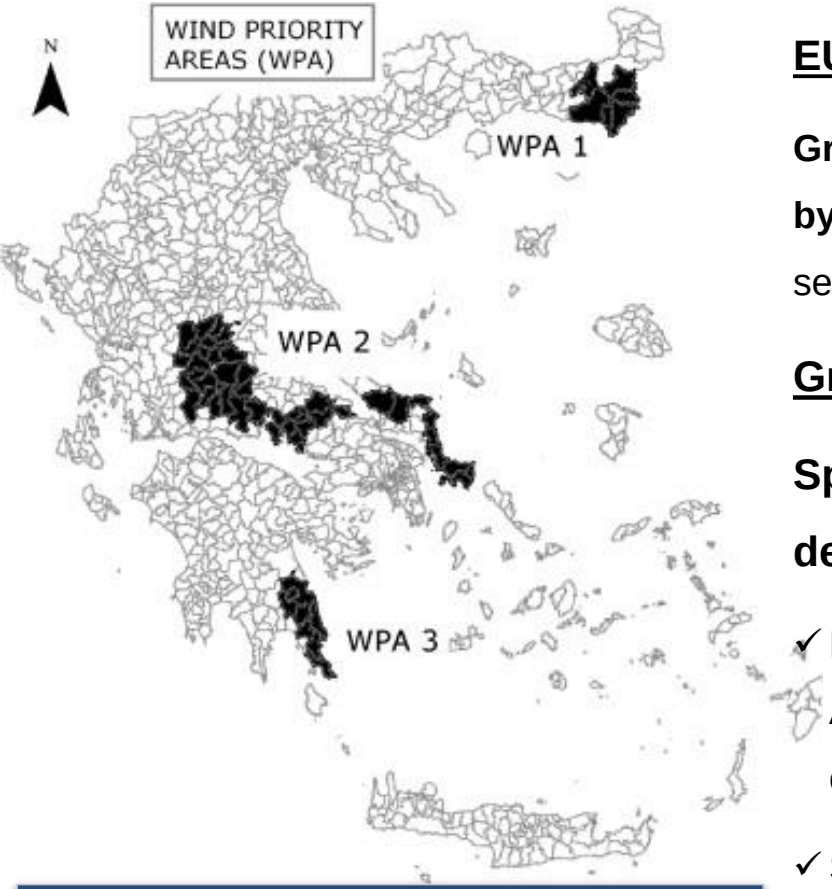
Wind potential of Thessaly (2)





- The areas with exploitable wind potential increase significantly, improving as concluded the total wind turbines installed capacity in Thessaly
- Choosing height of wind tower significantly alters both the stretch of areas with feasible wind potential and max installed Wind power
- Moreover the complementary areas (solar & wind) are increasing.

Legislation for RES installations spatial planning and licensing



Standard Wind Turbine Characteristics	
Rotor Diameter (m)	85
Tower Height (m)	80
Rated Power (MW)	2
Rated Speed (m/s)	12
Operating Range (m/s)	[3-22]

EU Directive 2009/28/EC

Greece should provide 18% of **its energy production from RES by 2020** (Adapted at national legislation with law 3468/2006 and set to **20%)**

Greek legislation

Special framework for spatial planning & sustainable development of renewable energy sources (2008)

- ✓ Divides Greek territory to Wind Suitability Areas & Wind Priority Areas altering the allowed density of Wind energy installations (# of Standard wind Turbines/km^2) from 0.66 to 1.05 respectively
- ✓ Sets exclusion & buffer zones based on various criteria

Law 3851/2010

- ✓ Allows RES installation in NATURA 2000 areas and high productivity area

GIS Methology

Exclusion of infeasible sites applying spatial constrains

- Exclusion contacted in groups i.e. (environmental, residential, technical, land use restrictions)
- For certain exclusion zones extra buffer zone is applied to the infeasible sites

Evaluation of feasible sites using appropriate criteria

- Classification of the selected criteria values, according to legislation and existing research studies in order to apply MCA (multi criteria analysis) i.e. weighted overlay tool

MCA applying the classified criteria

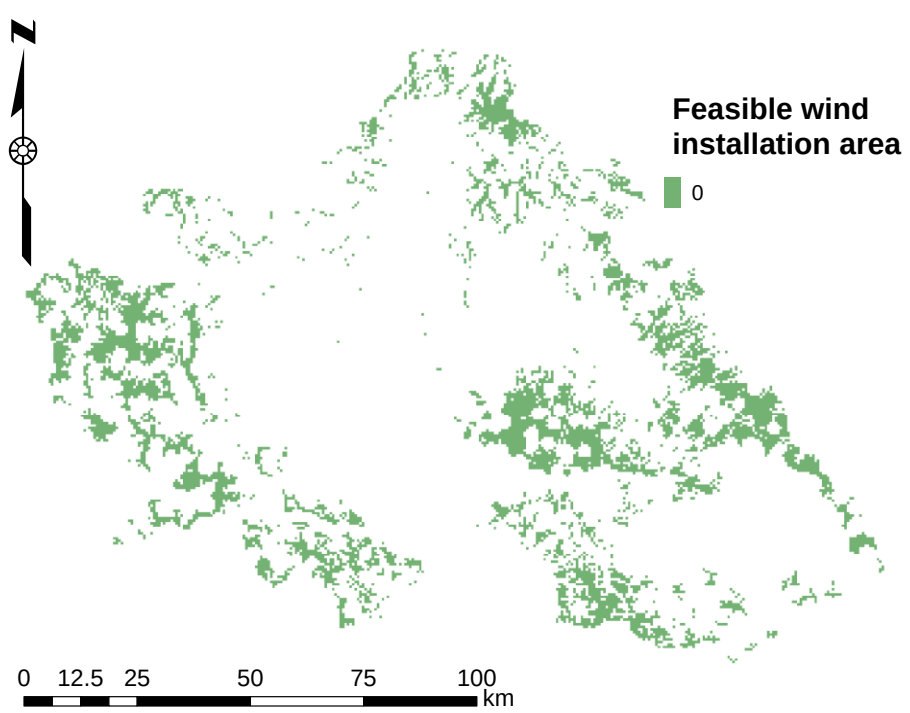
- Choose weights for each criterion according to its significance for the study area
- Statistical presentation of the MCA results i.e. histogram

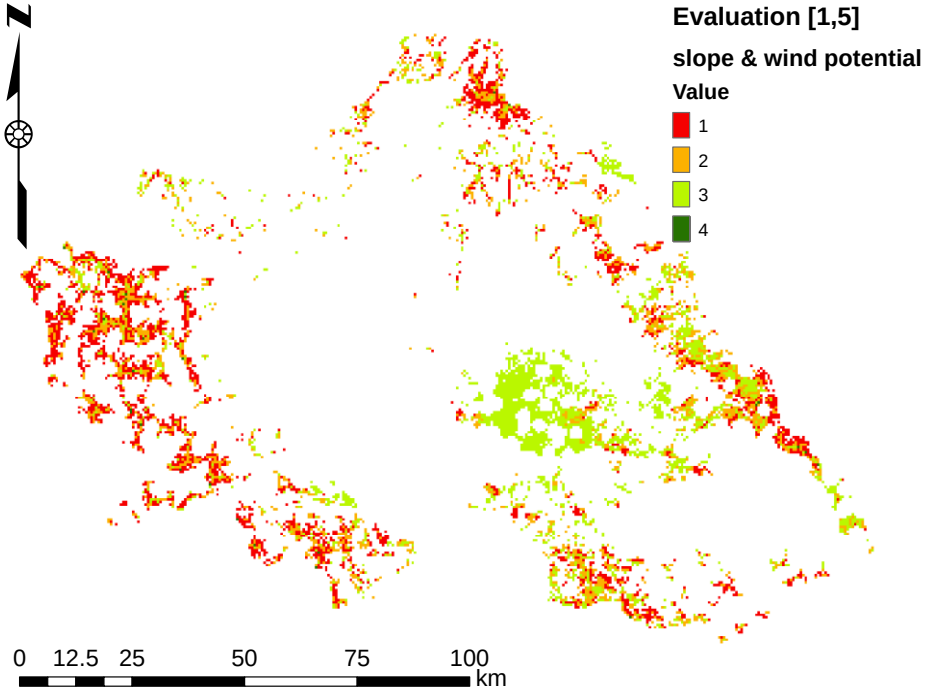
The analysis was computed with ArcGIS 10.3 software tool developing 2 independent models, 1 for the exclusion zones and 1 for the MCA analysis

Constrains - Exclusion & Buffer zones

- Protected landscapes [1000m buffer zone]
- Archeological sites [1000 buffer zone]
- UNESCO sites [3000m buffer zone]
- Historical sites (no buffer)
- Urban areas & Traditional settlements [buffer zones]
  - Population > 2000 inhabitants 1000 m
  - Population < 2000 inhabitants 500 m
  - Traditional settlements 1500 m
- Tourism facilities (hotels and guesthouses) [1000m buffer zone]
- Distance from roads & electrical grid (minimum distance) [150m buffer zone]
- Land use restrictions (no buffer)
  - Artificial surfaces (CLC: 111, 112)
  - Industrial, commercial and transport units (CLC: 121,122, 124) &
  - Mine, dump and construction sites (CLC: 131, 132,133)
  - Irrigated agricultural land. (CLC: 212)
  - Wetlands (CLC: 411, 412)
- Wind speed [Areas where average wind speed is lower than 4 m/s] 3000 m >25%
- Proximity to airports 3000m
- Slope (no buffer) 25%

Exclusion zones, evaluation and MCA GIS maps (Wind power)





- Area of feasible sites 2200km^2, 1100 MW max installed capacity
- There is no ideal wind installation area as the overlay of slope and wind potential is proving
- The best installation areas appear to be in the flat valley areas

Conclusions & Comments

- ✓A RES holistic spatial planning including all the possible feasible energy resources of an area might lead to a more feasible and sustainable development as both the restrictions and complementarity possibilities are tested
- ✓Potential of RES, electricity grid, pumping storage installations etc. are crucial for technically feasible RES planning
- ✓According to European – national experience spatial dispersion of wind energy installation, that are significantly variable, is the best way to increase the stability of the wind power in the electrical system (increase of operation hours versus decrease of max and zero wind energy frequency.) These matter is critical for large scale integration of wind power and could be particularly supported from such tools

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Thank you for your attention

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