

INTERNATIONAL MULTIDISCIPLINARY COMBINED EVENT  
"ACTUAL PROBLEMS OF LANDSCAPE SCIENCES: ENVIRONMENT, SOCIETY,  
POLITICS"

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# Renewable energy landscapes: typology and characteristics



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# 1. Introduction

Over the last two decades many countries have adopted and implemented policies in order to initiate a transition to more sustainable energy systems

The energy transition is based on different kinds of RE and associated systems.

Renewable energy systems have transformed land use and, in many cases, reshaped landscapes.

Landscape impacts of RE systems vary in nature and scale.

Impacts on landscape quality.

Local opposition.

Changing policy frameworks.

| Year   | Europe/Eurasia |        | World  |        |
|--------|----------------|--------|--------|--------|
|        | Solar          | Wind   | Solar  | Wind   |
| 2005   | 2335           | 40755  | 4214   | 59070  |
| 2006   | 3330           | 48303  | 5762   | 74008  |
| 2007   | 5376           | 57018  | 8323   | 94189  |
| 2008   | 11027          | 64923  | 14927  | 120747 |
| 2009   | 17533          | 76903  | 23018  | 151888 |
| 2010   | 30654          | 85804  | 39430  | 183872 |
| 2011   | 53390          | 96038  | 70182  | 224250 |
| 2012   | 70802          | 109689 | 98803  | 271817 |
| 2013   | 81836          | 120974 | 137005 | 304615 |
| 2014   | 89864          | 133937 | 177147 | 352831 |
| 2015   | 98630          | 147625 | 226380 | 418745 |
| 2016   | 105371         | 160530 | 301473 | 468989 |
| TC (%) | 4413           | 294    | 7054   | 694    |

Table 1. Evolution of installed capacity (Megawatts) of solar and wind energy– 2005 - 2016. Source: BP Statistical Review of World Energy (2017)

- Each type of RE system transforms the landscape in its own specific ways
- Direct and indirect impacts
- Positive and negative effects
- The impact varies depending on the context and scale of development and the methods used





## 2. Renewable energy landscape: theoretical background

Emergence of a new transdisciplinary field of sustainable energy landscape studies.

**Energy landscape** is defined as a **multi-layer landscape characterized by one or more elements of the energy chain** (e.g. energy extraction, assimilation, conversion, storage, transport or transmission of energy) **comprising combinations of technical and natural sources of energy within a landscape.**

Energy landscapes are not always distinct spatially bound landscapes, but represent “one of the many layers of complex, multi-faceted and heterogeneous landscape” (Stremke, 2015, 2).

Any energy landscape comprises landforms, vegetation, human-made structural elements, visual depth and breadth, but also a long list of other elements like water bodies, flora and fauna, etc.

It reaches beyond the expert view of landscape as a purely material entity.

It takes into account the importance of the perceptions of landscape by the people who share, value and use it.

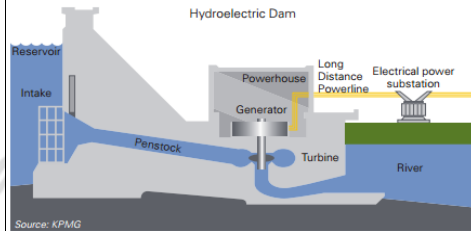
- Substantive and spatial qualifications (Pasqualetti and Stremke 2018).
- The substantive characteristic is based on the type of energy resource (e.g. hydro-, wind, solar, bio- and geothermal resources).
- The spatial qualifications are based it on amount of space required for energy development (energy density) and on spatial dominance (the degree to which energy infrastructure is affecting the landscape and the compatibility of energy with other land uses).
- Renewable energy infrastructure create a 'component' or 'layer' type and 'entity' type of energy landscape.
- An ensemble of auxiliary elements referred to assimilation, conversion, storage, transport or transmission of energy produced is considered as 'infrastructure energy landscapes' (expression of Uytterlinde et al. (2017)), spatially unique, largely empty entities within which other land uses are rarely possible (Pasqualetti and Stremke, 2018).

- RE landscapes are dynamic system.
- Evolving character of perceptions of RE landscapes.
- As any landscape, energy landscape is also shaped by the perceptions of the people who use, share and value them, and these perceptions have been evolving throughout of the history of RE development.
- Several studies showed that whether perception of this landscape will be positive or negative, depends not only on its characteristics, but also on the 'genius loci' shaped by relation between local people and their territory and resources, and reflect multiple layers, systems of values, aspirations and beliefs, associated to these landscapes (Frolova et al., 2015, Frolova 2017, Bevk and Golobič, 2018).

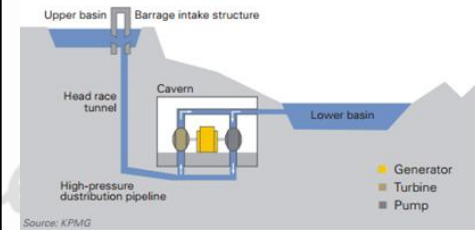
# 3. Hydroenergy landscape

## Types of large-scale hydropower plants

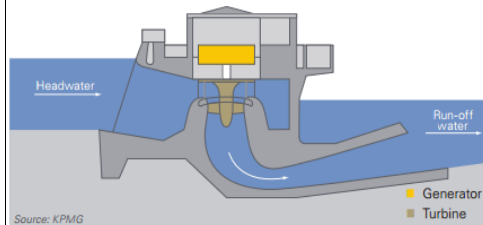
### Conventional hydroelectric dams



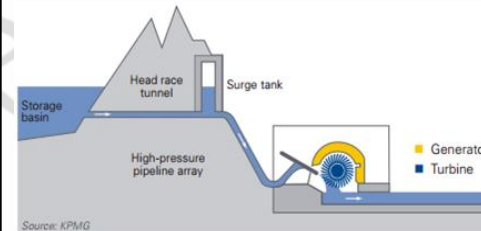
### Pumped-storage



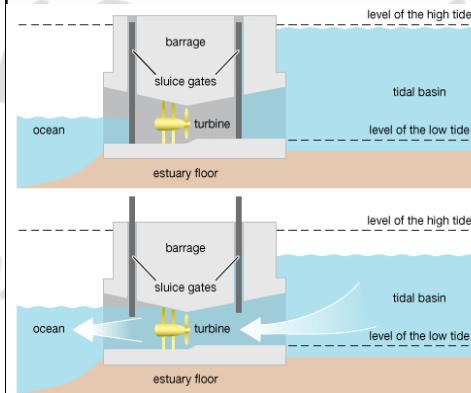
### Run-of-the-river



### Storage hydroelectric power plant



### Tidal

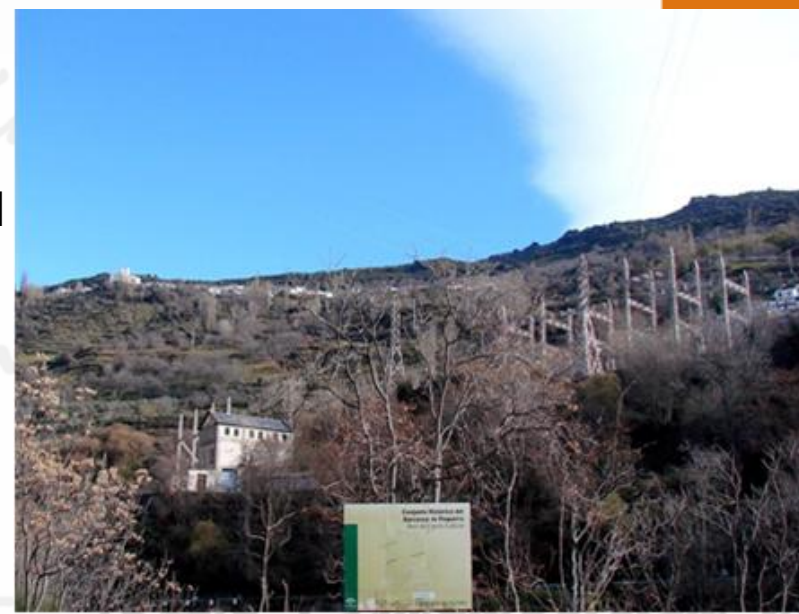


Small-scale hydropower definition varies from one country to the next (e.g. 50 MW in Spain, 15 MW in Greece, 5-10 MW in UK, 5 MW in Germany, 1-10 MW in Norway).





- Negative landscape effects of large facilities could derive from construction of power stations, damming rivers, and creating artificial reservoirs; and during their operation they can cause large fluctuation of the water level.
- Plants that rely on large water reservoirs require the flooding of huge areas. In addition LHPs, dams, power stations and transmission lines are huge structures and their presence constitutes substantial change in landscape features.
- Landscape impacts of smaller hydropower schemes are different, due to particularities of its characteristics, and considered relatively small.
- Nevertheless individual SHPs are spread out over large areas and most of their infrastructure is usually located above surface or visible from the surface.



Small-scale hydropower impacts 1. Pampaneira, Sierra Nevada Spain (M.Frolova); 2. Nethravathi, Western Ghats, India ([www.mangalorean.com](http://www.mangalorean.com))



- Negative impacts
  - Water diversion for electricity generation can lead to drying up of large watercourses and the damming of lakes and rivers can lead to the erosion of the shoreline.
  - Erosion.
  - Rapid flow variations due to hydropower plants can affect both physical and chemical qualities of water.
  - Threat to fish populations and various other species.
- Positive landscape impacts.
- Mitigation
  - Fish ladders help mitigate the impact on the species that would otherwise be threatened by the drastic changes to their ecosystems.
  - Power stations and lines as well as the accompanying infrastructure should be placed underground to reduce their visibility whenever feasible [26].
  - Utilizing existing old infrastructure like abandoned mills for the construction of SHPs
  - Establishing reservoirs from natural lakes, or by building large run-of-river plants .

## 4. Wind energy landscapes

- Wind energy landscape is based on using kinetic energy to pump water or process materials (wind mills) or to produce electricity (wind turbines)
- Consist of several individual wind turbines connected to the electric power transmission network.
- Onshore wind farms: large (one or more turbines,  $> 1$  MW), medium size (single turbine,  $0.5\text{--}1$  MW), miniwind (one or more,  $< 0.5$  MW), and microeolic (single turbine,  $< 0.01$  MW).
- The most prominent elements of wind energy landscapes are the towers and blades of wind turbines. Small or large WFs basing on the number of turbines and their capacity.
- Considerable height of wind turbines
- Strong visual impact of WFs is strongly influenced by size, design and layout of wind parks, make and model of the turbine proposed.



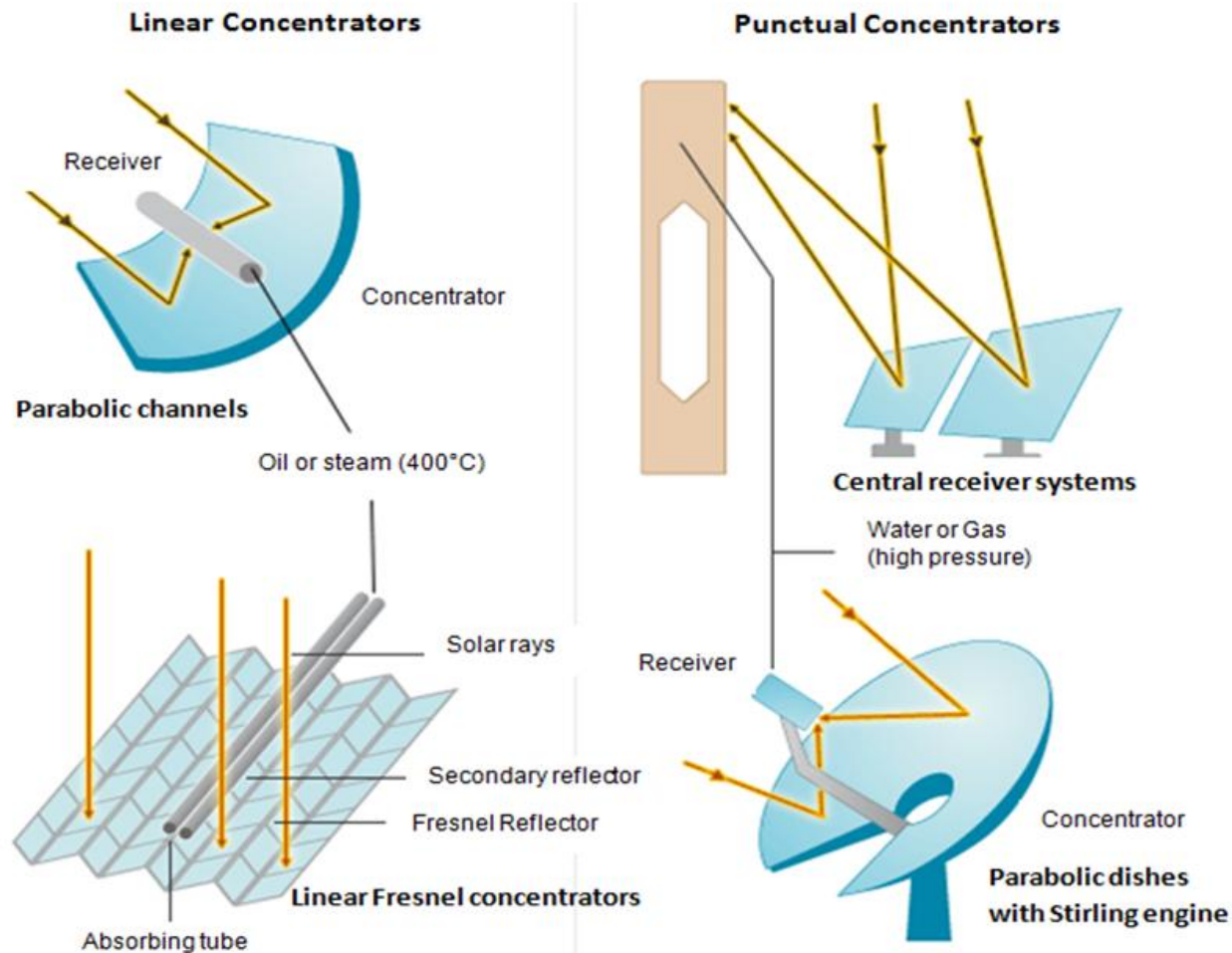
## 5. Solar energy landscapes

- Power generation, hot water production and space heating.
- The most common solar system for electricity production is photovoltaic (PV).
- Concentrated solar thermoelectric power (CSP) is still a minority solution.
- Solar thermal systems represent a mature market.
- Solar energy landscape is based on use of solar energy for electricity generation or heat provision.
- Solar PV landscapes include subtypes based on two principal types of solar PV topologies: on-ground PV (generally large systems) and building added/integrated PV (generally small systems).





- CSP landscapes include four types of systems: parabolic troughs, solar power towers, linear Fresnel concentrators and Stirling parabolic dishes



- Space heating and hot water production systems can be found in two topologies: in/on building mounted and on-ground solar thermal
- Typical in/on building systems consist mainly of flat plate solar collectors, a storage tank, a mounting base and the necessary piping.
- Can be seen both as 'component' or 'layer' type (e.g. small-scale solar PV, space heating and hot water production systems) or as 'entity energy landscape' (for large-scale solar PV and CSP systems), because solar energy landscapes may range from small components of the larger environment to distinct spatial entities.



Visually intrusive hot water production system



Aesthetically integrated solar PV system



- Solar energy sources have lower energy density and therefore usually require more land per final unit of power provided (Pasqualetti and Stremke 2018).
- The effects on landscape depend significantly on the size of the installations as well as on their concentration in a certain area.
- For on-ground PV and CSP systems the concerns about land use and visual intrusion are more pronounced, than for added and integrated PV systems
- The installation of PV on ground determines a land use change, therefore cultivated areas should be avoided





## Positive landscape impacts/practices

- PV can coexist with agriculture and grazing;
- The supporting structures of PV can be used as land stabilization elements;
- The pattern of the PV fields can be designed so as to ensure the spatial definition of a certain area (e.g. public parks, bike lanes, walking paths);
- PV modules can provide shade in spaces where this is needed;
- Solar PV farms can be also used for conversion of brownfield (underused, abandoned, and often contaminated land) in productive space.
- Utilization of large-scale solar parks as educational centres





## 6. Bioenergy landscapes

- Bioenergy is one of the most important RE sources and suitable forms to store energy, as no other can be available in liquid, gaseous and solid states.
- Low energy density which requires large areas for production and much energy for transporation of biomass.
- Public acceptance of bioenergy installations and landscape changes produced by them is related not only with its environmental and landscape impacts, but also with more global issues



- First-generation or second-generation technologies.
- Various types of biological material which can be converted into energy, a solid or liquid biofuel or other products.
- Three types of biomass materials:
  - Energy crops grown primarily for the production of energy (1),
  - Agricultural and forest residues that are generated when grains are harvested, trees pruned and cut down (2),
  - By-products and organic waste that is generated in the processing of biomass for the development of food products, from which energy can be recovered
  - There are two main types of bioenergy: biofuel and biomass for heat and power.





- Stationarity, low-energy density, scattering, direct and indirect land-use change, etc.) that characterize these power sources and, in particular, biomass waste.
- The most important landscape impacts are visual impacts on landscape and land-use change.
- Bioenergies induce direct land-use changes, with the important difference that the deployment of the latter also induces indirect land-use changes when pre-existing agricultural activity is converted into new, often more intensified forms of agriculture.
- Intensive monoculture practices.
- Landscape impact is scale-dependent.
- Even the small biogas structures, domes or cones covered with plastic foil and the silos required for year-round storage of the substrate, cause visual impacts and landscape change. Medium and large installations are comparable to regular buildings used in intensive farming and agriculture.
- Bioenergy landscapes may belong both to 'component' type and 'entity energy landscape'.

- Important re-surfacing of infrastructure and activity associated with biomass distribution and conversion.
- Biogas tends to be produced on a large industrial scale, which in some cases leads to important impacts on landscape character and its decoupling from the local community.
- Bioenergy environmental impacts: effect on soil, gaseous emissions, unfamiliar smell and possibility of water pollution.
- Plantations for bioenergy production can significantly alter the intervisibility in the landscape by replacing low-height crops above-eye-height-crops and changing formerly open landscapes to a different landscape character.





- Three principles of landscape design: conservation of ecosystem and social services, consideration of local context, and monitoring outcomes and adjusting plans to improve performance measures over time.
- To encourage or restrict the production of energy crops onto land considered marginal or abandoned for agricultural purposes, although this strategy in some cases has been proven to be problematic or even socially regressive.
- To favour development of advanced or second generation of biofuels that use a wider range of feedstock including lignocellulosic material, waste and residues or stimulate production of algae origin biodiesel and do not compete with food production.
- For more effective landscape management and protection the policies regulating the development of bioenergy should be integrated into agricultural, forest and environmental protection policies.
- Valorisation of domestic and forest waste.
- Positive experiences of eco-remediation of degraded land by growing energy crops (e.g., Mitrovica, Serbia) and visualization of bioenergy landscapes through using them as a part of nature trail (e.g., Boretice, Czech Republic) or incorporating bioenergy facilities into historical farm buildings

## 7. Infrastructure energy landscapes

- Ensemble of auxiliary elements referred to assimilation, conversion, storage, transport or transmission of energy produced.
- Although they may differ greatly across the different energy sources, in general terms infrastructure energy landscape' include ancillary buildings, substations and transmission lines, roads, tracks, canals and access tracks.
- They can have as much impact on the landscape quality, or more, than the very devices which produce power from renewable sources (Uyterlinde et al. (2017)].
- Associated hazards and needed accessibility, both directly and indirectly discourage other land uses along these infrastructures (Pasqualetti and Stremke, 2018).



- The auxiliary elements may have impacts on the materiality of historical and natural heritage, mainly when they interfere with archaeological sites or historical areas (excavations for foundations) or require deforestation of buffer zone (especially for power lines, due to their length).
- These elements may cause perceptual alterations or modification of the visual relations of scale and hierarchy between the different elements that compose a scene, as well as the legibility of the landscape.
- New roads and access tracks for the maintenance of facilities produce an increased accessibility (including motor traffic) in areas that often were previously difficult to access or inaccessible, in detriment of their wilderness.



## 8. Conclusion

- A great variety of RE landscapes.
- Hydro energy landscapes are the most well established among RE landscapes due to its long history of development and to the fact that hydro energy is the most important source of electricity production from renewable resources.
- Wind energy landscapes extension is also relatively high.
- Solar energy landscapes are constantly spreading over the world due to the boom of solar PV systems.
- Bioenergy landscapes are present in many countries and take very varied forms.
- Infrastructure energy landscape is very present, although further studies are necessary on its different subtypes.
- The impact on landscape quality is a widely discussed topic – especially so for wind turbines. The facilities do not merely represent new elements in the landscape, but often change the patterns of the landscapes concerned.

- RE structures may have a significant visual impact on landscapes, especially if they are high, large-scale and/or occupy large territories.
- The impact depends on the landscape type concerned, and may be relatively higher in rural areas with open or exposed views (along seashores, on hillsides and hilltops, arable lands etc.).
- Associated infrastructures may also have a significant impact and often form a different 'infrastructure energy landscape'.
- Direct land occupation of the facilities raises the issue of competing land uses.
- Beyond the direct visual impact of the facilities, potentially there are various negative environmental impacts with an influence on landscape character.
- Landscapes may benefit both from the socio-economic impacts of RE developments and new layers created by different RE technologies

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**Thank you for your attention!**

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