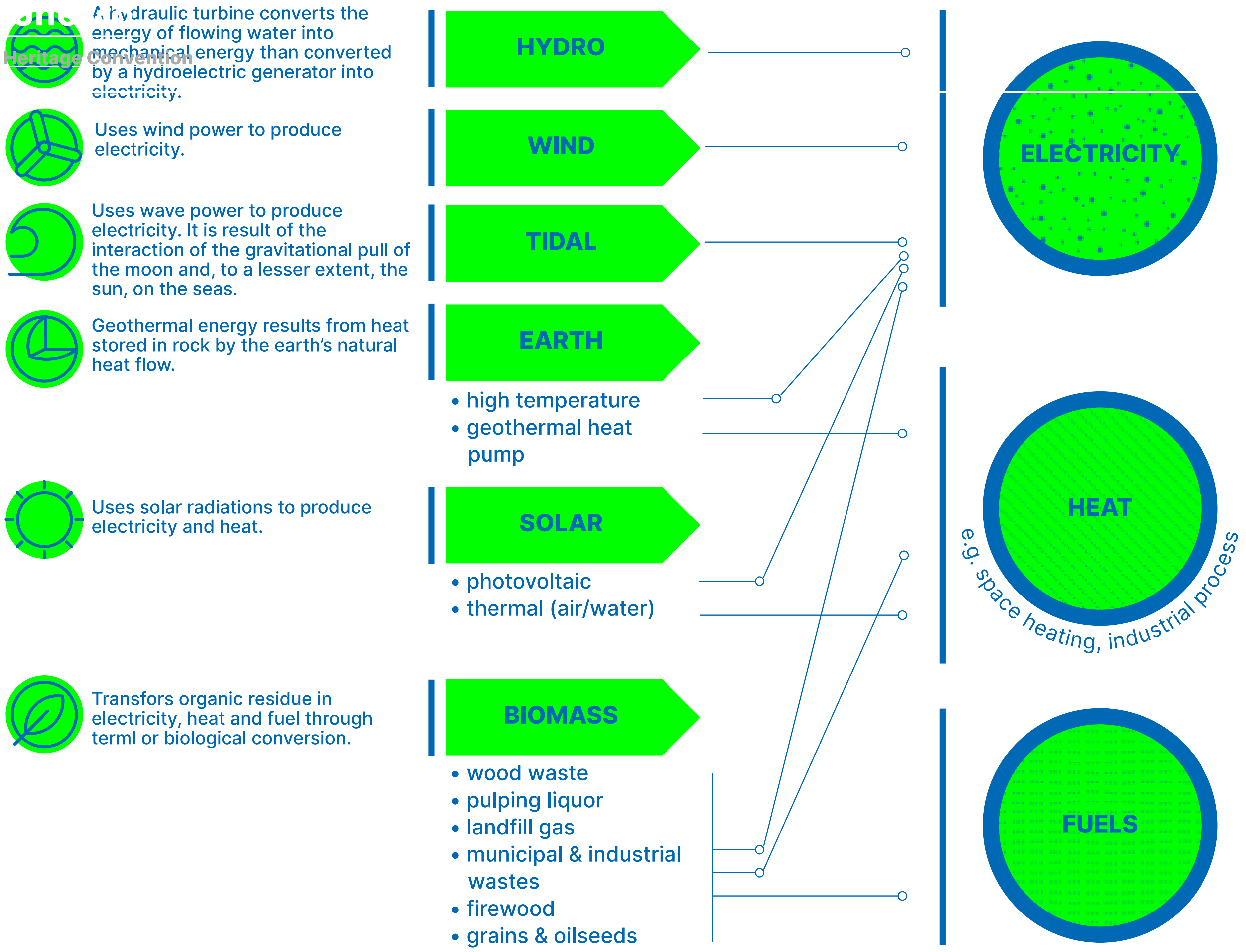
Wind Energy Essentials

This part of the Guidance offers an overview of wind energy related information primarily for heritage practitioners and decision-makers not familiar with this field. A brief overview of the main technical features and processes behind wind energy planning will allow a more effective understanding of their potential impacts on World Heritage and catalyse more efficient dialogue between stakeholders to seek solutions. In addition, this section approaches this field with a focus on World Heritage matters, highlighting sensitive conservation issues.

What is renewable energy?

Renewable energy is energy that is derived from natural processes (for example, sunlight and wind) that are replenished at a higher rate than they are consumed. Solar, wind, geothermal, hydro, tidal, and biomass (as defined in the figure below) are common sources of renewable energy. These resources are continually replenished by nature and are thus sustainable thanks to their:

- capacity not to be substantially depleted by continued use;
- minimal pollutant emissions and environmental problems;
- minimal health hazards;
- contribution to overcoming social injustice in relation to accessibility to clean sources of energy.



Types of renewable energy, their source and 'end product'

Further details on renewable energy production in Europe, the USA and Canada

Climate commitments regarding wind energy in Europe, the USA and Canada

What is wind energy?

How is energy generated by the wind?

Wind energy is electricity created from the naturally flowing air in by wind turbines. As the wind moves the turbine's rotor, it captures the movement through its blades and transforms the kinetic energy of the wind through rotation into mechanical energy. This initiates the spin of internal shafts. These are, in most cases, connected through a gearbox that spins a generator to produce electricity, which is then transformed into higher voltage electricity and transported through connected storage as well as distribution facilities and cable systems.

Wind energy technology is evolving rapidly. Whereas wind turbines originally required a placement on mountains and hilltops, today, thanks to technological developments, they can be installed in more diverse settings. Wind farms can both be constructed onshore (on the terrestrial areas) and offshore (constructed on water, dominantly in seas and oceans). Higher towers and longer blades make them increasingly cost-efficient (especially offshore) and allow a broader extension.

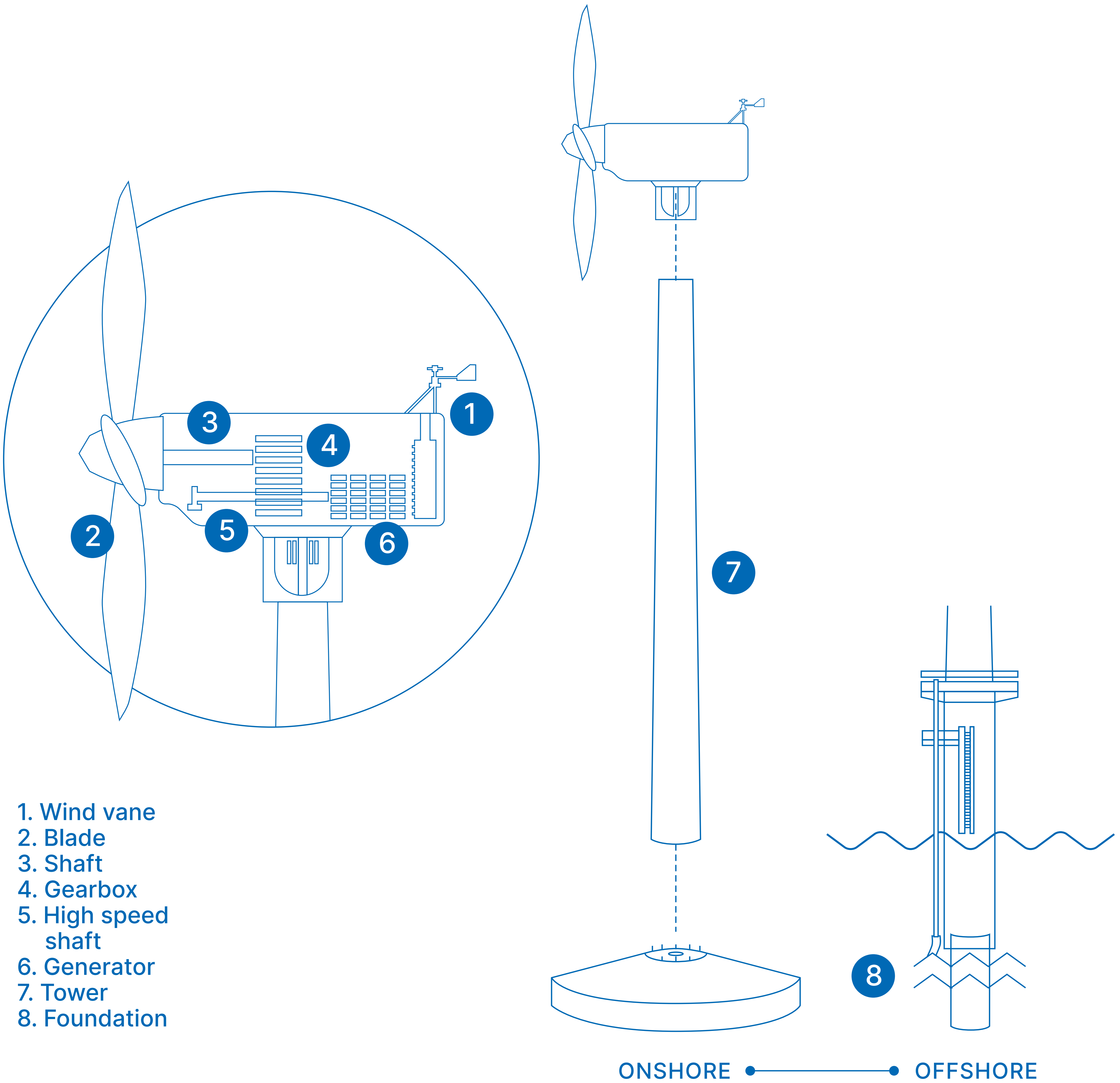
Components of wind energy infrastructure

Wind Turbines

Wind turbines have towers made of steel and/or concrete and are crowned by a hub connecting to blades of composite materials, a nacelle with the rotors, cables, a generator and a central computer system. At the bottom of the tower is a transformer, which connects the turbine to the power connection and distribution grid.

A wide range of possible designs exist for wind turbines to adapt to different areas and conditions regarding transportation requirements or technical and commercial necessities of the developer. Turbines with larger rotor diameters increase the captured energy, and higher hub heights have access to higher wind speeds. They can reach a total height of 246.5 m *(Source (Nicole): Gaildorf, Germany (Max Bögl Wind AG)*, although the weighted average of onshore wind turbines in Europe in 2020 is just below 120 m including some 16 m high turbines. The average height of onshore turbines has steadily increased since 2010 (in 2020, the total height of offshore wind turbines could reach up to 260 m).

(See wind basics and offshore Wind Europe key trends and statistics 2020 by WindEurope)



Main elements of onshore and offshore wind turbines (source: *Wind Europe*)

The foundation of wind turbines bears the load transmitted from the wind turbine tower and the turbine on the top, especially the huge overturning moments. Careful planning therefore is needed to choose the right basis for these constructions. Foundations of wind turbines can be of different types and depths depending on their location (onshore or offshore) additionally, there are multiple criteria related to their construction needs (these include the structure and height of a turbine, the wind intensity, the characteristics of the soil/seabed at the construction area and the likelihood of disasters in the development area, like earthquakes).

For **onshore** wind turbines, 5 common types of foundation are used today:

- the shallow mat extension
- the ribbed beam basement
- the underneath piled foundation
- the uplift anchors and
- the 'new type'

Each of these types could be round shape or octagonal shape. The average diameter of the foundation ranges from 15 m to 22 m.

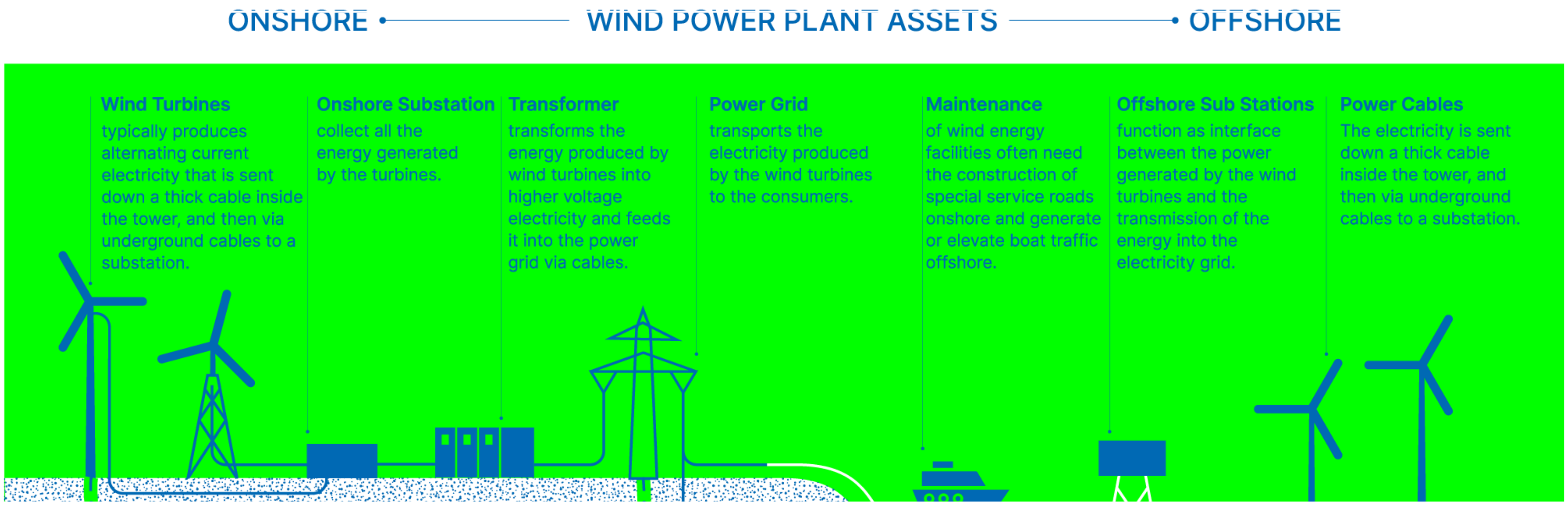
For **offshore** wind turbines, there are several types of foundations depending on the depth of water at the site of the wind farm:

- Fixed foundations
  - gravity-based foundation
  - monopole foundation
  - triple foundation
  - tripod foundation
  - jacket foundation
  - pile cap
  - suction bucket
- Floating foundations
  - spar buoy foundation
  - tension-leg platform (TLP) foundation
  - semi-submersible foundation
  - barge
  - multi-platform.

The technology related to the construction of wind turbines is rapidly evolving. Therefore, the most up-to-date information about the characteristic and dimension of onshore and offshore wind turbines and the types of their foundation would need to be checked in the relevant literature, of which many is available with a free access on the world wide web.

Ancillary infrastructures

World Heritage Convention



Wind energy facilities in a schematic landscape/seascape (sources: *WindEurope* and *Canadian Wind Energy Association*)

Sub-stations

Sub-stations are essential annexes of wind farms and function as interface between the power generated by the wind turbines and the transmission of the energy into the electricity grid. Sub-station compounds normally include:

1. control, protection, and metering system that allows the correct operation of the wind farm according to local regulations and grid requirements;
2. communication system made of optical fibre or wired cable – it guarantees the correct communication with the nearby substations and with the grid control centre;
3. protection systems against fire and intruders – it includes detectors, sirens and fire extinguishing tools.

Specificities concerning offshore substations

Access roads and tracks

The transportation, construction, maintenance and decommissioning of wind farms require access tracks. Wide and sturdy roads or tracks are needed to provide access to substations and to the base of the wind turbines. They are usually created either by improving the capacity and width of existing road infrastructures or by building new access roads.

The technical requirements may vary for these tracks during the different lifecycles of wind farms. For example, the transportation of wind turbine components such as blades requires wide, straight roads without swellings or collapses on the track, and there are specifications on the type of materials needed for construction. Offshore wind energy projects will require the establishment of marine routes for the vessels involved in the operation including the maintenance of turbines and ancillary facilities.

Why special attention is needed for the design of access roads and tracks from a World Heritage perspective?

Transformers

The transformer is a station that transforms the energy produced by wind turbines into higher voltage electricity and feeds it into the power grid via cables. The transformer is connected via cables to one or more sub-stations. The size and type of a transformer depends on the type of the sub-station and of the energy capacity of the wind energy project.

There are different types of transformers, among others: GEAFOL cast-resin transformers, liquid-immersed distribution transformers and power transformers. In the case of offshore wind energy projects, the transformer (also called the converter station) can be a medium to large offshore or onshore infrastructure, usually connected to one or more sub-stations.

Cables

Cables are a key element in the electrical system of wind turbines. The installation and use of a multitude of cables is required: some are used to transmit the electricity produced to sub-stations and the power grid (transmission cables), others connect turbines (inter-turbine array). They can be installed underground or overhead, depending on the topography of the area and legal requirements (including heritage related regulations).

Why special attention is needed for the design of cables from a World Heritage perspective?

Power grids

A power grid is the distribution system that transmits the electricity from a wind farm to the users. It involves a series of electricity pylons or transmission towers, connected by multiple cables that can extend to long distances (super grid).

Why special attention is needed for the design of power grids from a World Heritage perspective?

Potential impacts of wind energy projects on World Heritage

The potential impacts of wind energy projects on values of World Heritage properties strongly depend on the specific characteristic of the proposed project itself. In this respect, projects should be considered with all their elements and with all project phases. Any potential impact of projects needs to be measured in relation to the OUV of World Heritage properties they might affect. This includes potential impacts on the attributes that convey the OUV and the site’s conditions of integrity and authenticity, as well as its protection and management requirements, if the World Heritage status is to be respected.

For this reason, wind energy project proposals that might affect World Heritage properties should only proceed after their potential impacts have been assessed. In a World Heritage context, impact assessments (that are often categorized as Environmental and Social Impact Assessments or Heritage Impact Assessments) need to include the assessment of impacts on the OUV of the World Heritage properties concerned. As by definition the OUV of World Heritage properties is considered unique and irreplaceable, any potential irreversible negative impacts on the OUV should be avoided altogether. Potential impacts on other heritage values need to be mitigated. If mitigation or alternatives that pose no harm to the World Heritage property are not possible, the proposed project should not proceed, and project alternatives (including choosing a different location) need to be considered. The impact assessment should also consider the cumulative impact of already implemented or already known potential future projects (including other wind energy or other renewable energy projects).

➔ See the impact assessment process in Impacts of Wind Energy projects and their assessment.

Regarding potential impacts, the following aspects of wind energy projects are surely relevant in a World Heritage context:

(1) **placement and design** – the siting/location, layout and extension of a wind farm, the number, height and design and model of the turbines, the type of foundation, the placement and dimensions of the ancillary facilities are all factors that play a role in an assessment;

(2) foreseen actions within each phase of the facility's **lifecycle** – a systematic assessment should consider all phases within the lifecycle and identify potential impacts on the OUV of World Heritage properties for each of them.

➔ See Impacts of Wind Energy projects and their assessment

Further considerations for wind energy project planning and design in protecting World Heritage

Siting and design of wind energy farms

The selection of appropriate sites for wind farms from the wind industry's point of view will depend on multiple elements including landscape features, wind characteristics, location of the distribution grid, of residential and industrial areas, of nature protection and military areas as well as of other service infrastructures.

Further to these elements, in a World Heritage context the project proponents need to also consider the compatibility of their plans with the protection and management goals and needs of World Heritage properties. There are several tools that can help distinguish between 'suitable' and 'non-suitable' locations for wind energy projects in this respect, such as:

- Consulting the results of existing vulnerability assessments and sensitivity maps (➔ See Note 2) assisting in the selection of sites for wind energy projects, with information on the OUV, including the characteristics and the location (if possible) of attributes (such as habitats and on key views, vistas and panoramas). The preparation of such studies and the provision of relevant data are proactive and efficient actions before actual wind energy developments are proposed.
- Strategic Environmental Assessments (SEAs) can be carried out at the national or regional level to assist informed decision-making related to wind energy installations. The SEAs take into account existing policies and restrictions. They enhance a strategic approach to wind energy development and could help to identify suitable areas for development and so-called exclusion zones where no development should take place. Individual wind energy projects would, nevertheless, require a dedicated Environmental and Social Impact Assessments (ESIAs) to decide on their appropriateness in a specific location. ➔ See Impacts of Wind Energy projects and their assessment
- Environmental and Social Impact Assessments or ESIAs (in some cases Heritage Impact Assessments – HIAs) are usually a mandatory part of the planning process for specific wind energy projects. The result of the impact assessment can propose alternative project locations or reveal early in the planning phase if the construction of a wind energy project in a certain location is not possible from a World Heritage perspective (this could concern the area of the property, its buffer zone or its wider setting). ➔ See Impacts of Wind Energy projects and their assessment

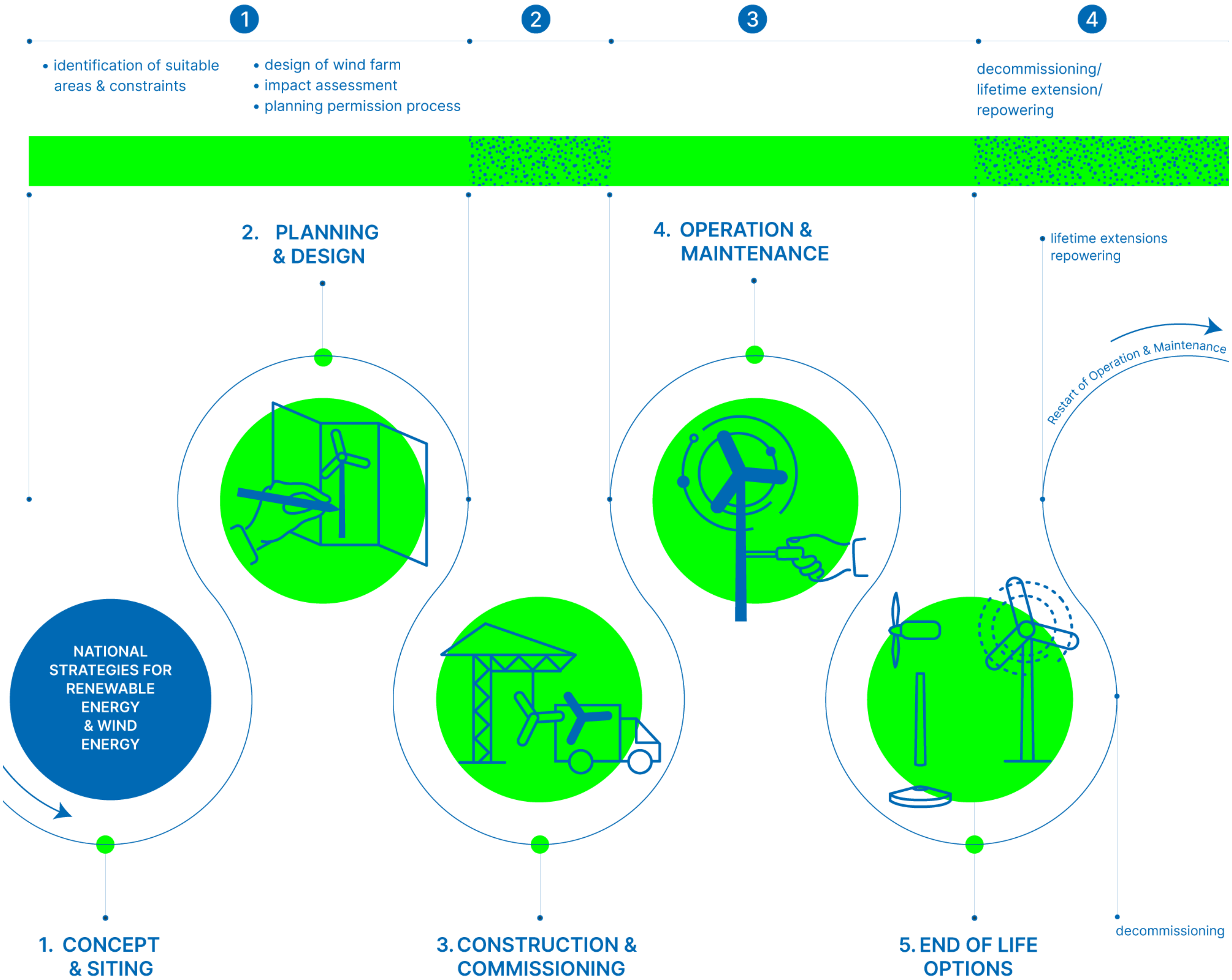
Further considerations in siting of wind energy projects to protect World Heritage

Why attention is needed for the scale of the wind energy projects from a World Heritage perspective

Wind energy life cycle

Potential impacts of wind energy projects on World Heritage properties need also to be assessed with regard to the different phases of a project life cycle. Impacts may differ from phase to phase, some may occur throughout the lifecycle of a project, others only for a short period of time, or at seasonal intervals.

➔ See [Impacts of Wind Energy projects and their assessment]



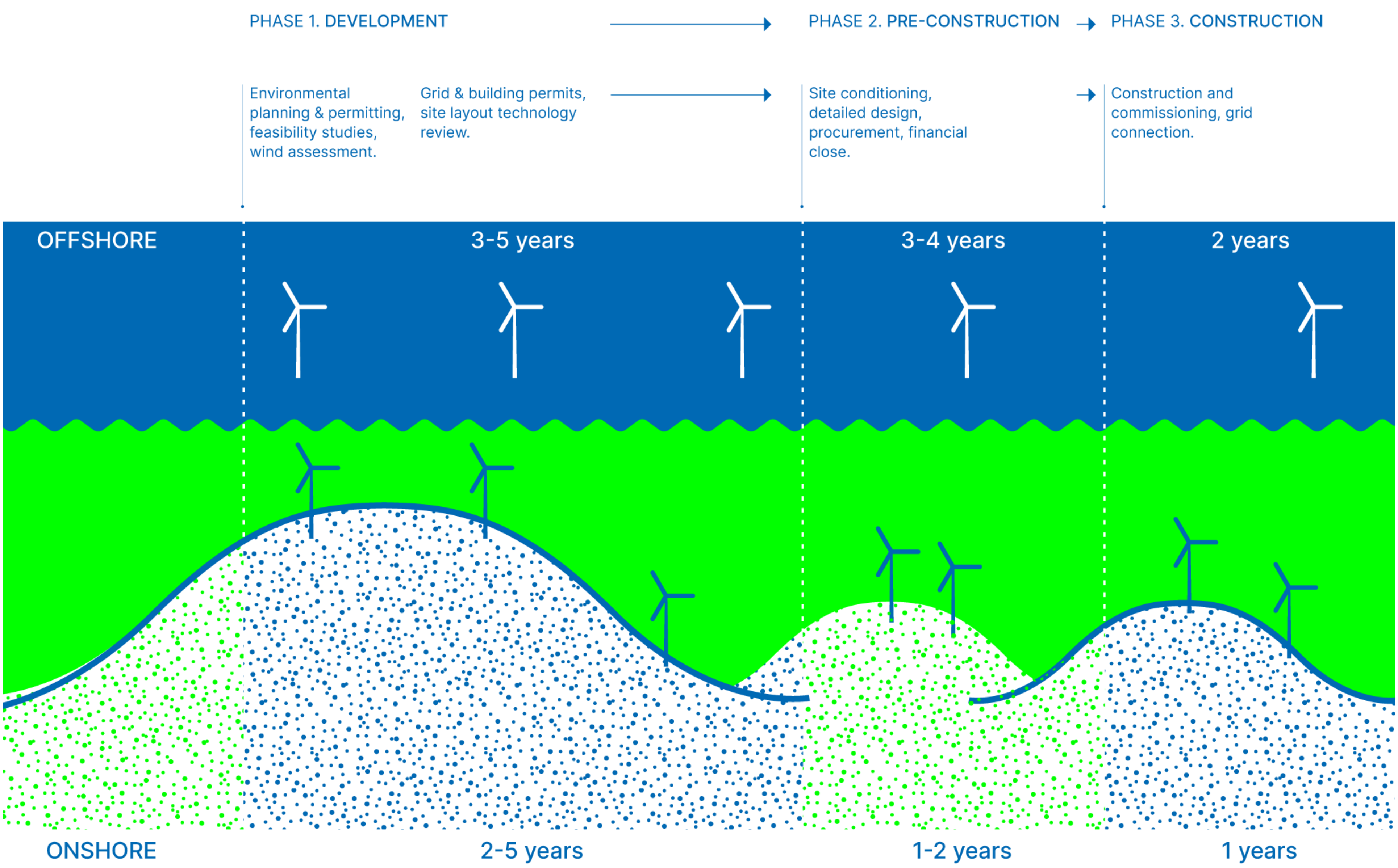
Schematic lifecycle depiction of wind energy facilities

From planning to commissioning

This project phase includes both strategic and detailed planning for the development of a wind energy instalment (usually the construction of several wind turbines or a wind farm) and the commissioning of the project (which is a set of activities performed before an operation permit is provided to confirm that the wind turbines have been correctly installed and that they are ready for energy production). It is characterized by a significant lapse of time and there can be several years between the planning and the operational phases.

This phase includes several activities:

- Compliance with spatial planning regulations,
- Assessment of resources and wind potential,
- Identification of land available (purchasing or leasing),
- Identification of potentially suitable areas for the development,
- Consultation with rights-holders and stakeholders,
- Site analysis through calculations and digital modeling that allows for the identification of the most appropriate location and type of wind turbines (height, diameter of the rotor, capacity, etc.),
- Early assessment of the technical feasibility of the project,
- Identification of regulatory constraints,
- Design of the wind farm (including size, model of wind turbines, technological characteristics, electrical design, infrastructure plan),
- Impact assessment and other technical studies (e.g. risk screening, biodiversity sensitivity, sensitivity mapping, setting studies),
- Preparation of the planning permission process,
- Securing financial mechanisms,
- Construction of the wind farm (including wind turbines and ancillary facilities),
- Commissioning (which covers all activities after the installation of the wind turbines is completed).



Average timespan requirement of each step in the planning to commissioning process
(Source: WindEurope)

When does impact assessments need to be prepared in the lifecycle of wind energy facilities?

Case studies

Operation and maintenance

The operation and maintenance phases of wind farms generally amount to a 20 to 25 years standard lifetime with a possible extension of up to 10 years. It starts after a testing period and upon approval of the purchase contract for the produced electricity by the relevant national, regional, or local authorities. This phase includes the routine servicing and repairs that are required to achieve a wind turbine's designed lifetime and to ensure the compliance with financial, safety, security, and leasing agreements.

What are the potential impacts of a wind energy facility in the operation and maintenance phase from a World Heritage perspective?

End of Life Options

Lifetime Extension

Through the partial replacement of components (for example, blades, gearbox), the lifetime of wind farms can be extended by 10 years to a total of up to 30 to 35 years. To prolong the already approved and licensed lifetime, a 'remaining useful lifetime assessment' (i.e., a fatigue load analysis) needs to be undertaken in combination with a site inspection and review of the maintenance framework. As a result, the developers may be required to undertake certain repair works and to reinforce or renovate certain areas.

Repowering

Repowering means replacing, in the same designated area, older wind turbines with taller and more powerful ones. Usually, the increase in energy yields allows deploying fewer facilities in the same zone.

The main factors for the decision on whether to repower or simply decommission a wind energy plant depends on:

- the performance of the wind turbines and the cost of operation and maintenance;
- the length of the support frameworks (generally 20 years);
- the evolution of the wholesale electricity market prices; and

regulatory framework and environmental restrictions.

Policies around repowering may vary considerably on the national levels. Whereas it may require a whole new permission process including impact assessments (usually as part of an Environmental and Social Impact Assessment processes) and the (re-)examination of the suitability of an area in one country, it may only take a 'fast-tracked' permission request in another country. In addition, not all previous wind farm areas remain necessarily eligible for repowering in which case an alternative end-of-life scenario will need to be considered (i.e., lifetime-extension or decommissioning).

Reversibility, lifetime extension and repowering from a World Heritage perspective

Case Study

Decommissioning: dismantling, removal, recycling

The decommissioning is the process of removing all wind turbines from an area. This phase consists of the dismantling and removal of the turbines and all other connecting infrastructures, including the treatment and recycling of waste and materials. Following this process, the area needs to be fully cleaned and the land restored to its original condition. The implementation of this phase depends to a great extent on the respective national policy in place and whether specific national guidelines are available for the dismantling and demolition of wind turbines and other project-specific infrastructures. If not specified otherwise, the decommissioned site must be restored to greenfield.

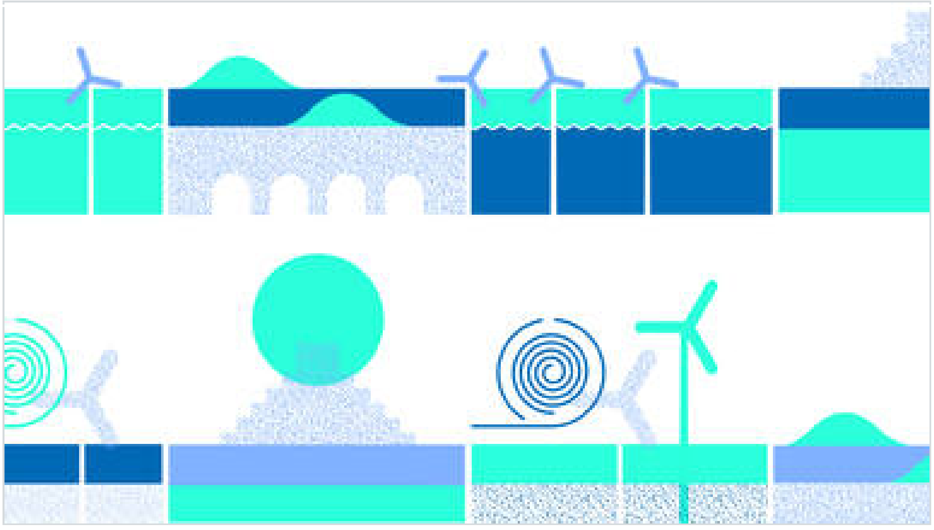
A detailed decommissioning plan is normally a mandatory part of the wind energy project proposal, which is examined and approved as part of the application process. This plan will later guide the removal of the wind farm, ensuring and specifying also that all related costs are to be covered by the developers. The plan usually reflects contracts regulating the land use and the grid connection points and refers to the conditions imposed by local authorities through the building or demolition permits as well as to relevant national, regional, or local legislation. Accordingly, wind energy licenses, contracts and plans need to include provisions for the complete removal and restoration of the land to the original state after the permanent decommissioning of the wind farm and, if relevant, the ancillary facilities as well.

Guidance for decommissioning

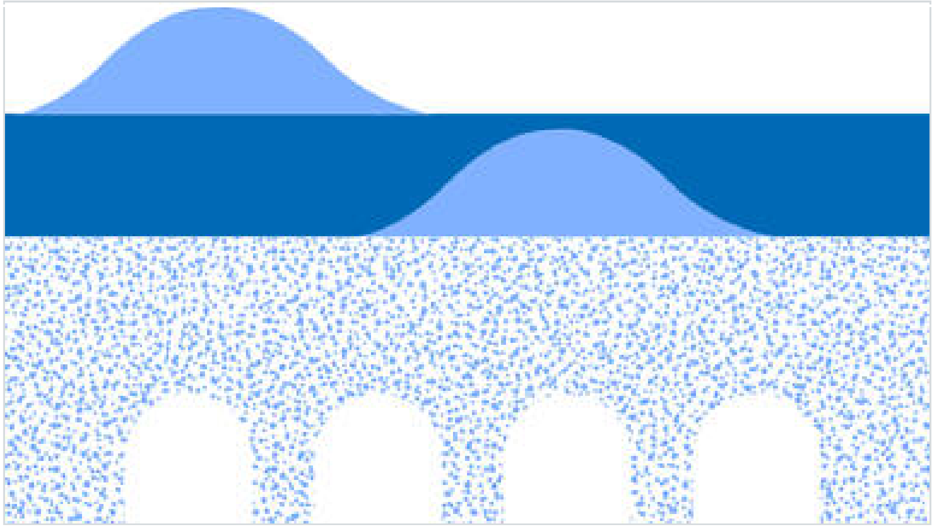
Removal of wind energy facilities and restoration of the land to its original state from a World Heritage perspective

World Heritage Convention

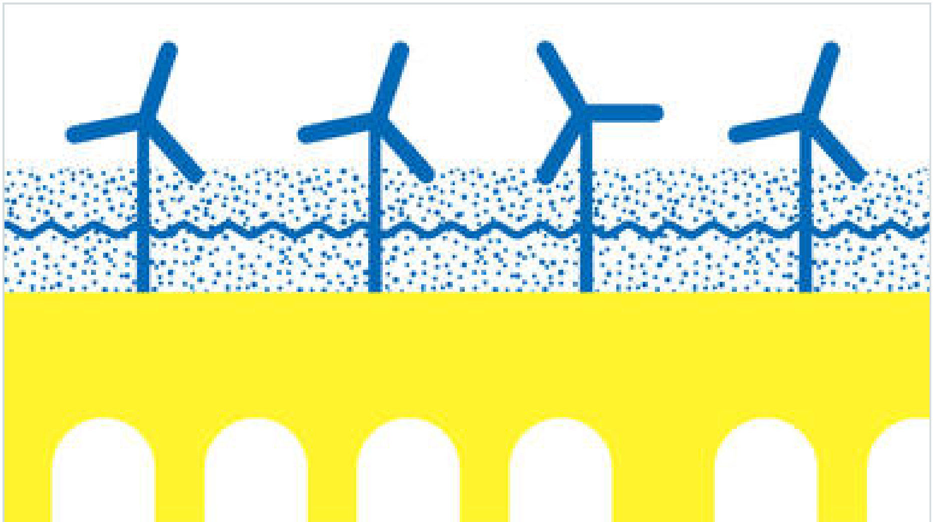
Other activities (4)



Wind Energy



Guidance for Wind Energy Projects in a World Heritage Context



Impacts of Wind Energy Projects and their Assessment

World Heritage and wind energy planning

Keywords (2)

Wind Wind energy

Partners

Government of the Netherlands