**Vines and Turbines: Co-existence in nature**

Renewable Energy is a must for modern sustainable development. But when it is part of a natural landscape, there are two contradictory perspectives of sustainability - meeting the energy target as well as keeping the natural interface of an area intact keeping the disruption of the natural ecosystem to a minimum. Renewables should co-habit with the elements in nature and exist as part of the natural landscape rather than being dominant artificial entities. Like nature has least rigid elements, renewable energy should be a formless element that is sporadic, modular and easily modifiable.

Vines and turbines is such a simple system that can be placed anywhere on site and modified at will to suit the existing design elements. Vines grow as a function of multiplicity of a small element – turn and change direction fitting to whatever be the nature of the area. Keeping the concept in place, the system mimics green elements in nature that allow perforations for natural growth of other parts of natural ecosystem. There is no exact method as to how the overall form will develop. It will always be a function of the area under consideration. For the site context where no elements are fixed, the suggested installations would be peripheral to activity areas within the landscape formations. The structures will act as edges and boundaries and control human movement. Openings along these elements act as guidance for human traffic along specific routes. Due to flexibility of the structure the modules may be removed/ modified as per development plan or support any other aspect that may take precedence. Vines will terminate at top into wind turbines thereby utilizing wind energy. Turbines here will not be simple renewable elements. For a larger site their size and height/ cluster formation will change. They will become landmarks and direct movement towards specific zone or subzone. The developed structure will have spaces above ground that will be accessible for human activities. The simplest use will be that viewing terrace from where people can get different perspectives of the activity areas.

**Modularity of design- Leaf as the basic structure.** To allow equal development of all we learn from a leaf structure. It has veins that does the task of supplying essential nutrients without disrupting any other function of the leaf. The simplest modular element in design, The Leaf, mimics this pattern to supply the essential nutrient of energy to the human civilization. The perforations in between ensure that this essential tasks for human civilization does not disrupt any other activity of biosphere and allow all other elements of nature around to share the precious resource of sunlight.

**Basic structure and growth into patterns:** The Leaf has two equilateral triangular faces. They bend towards each other and are formed by three arms of a tetrahedron. This forms a structure that can be framed into large growth and can take a number of desired shapes. They can be formed into simple membranes with or without additional perforations (achieved by removing leaf element in between) The elements can be added or eliminated without affecting the structural integrity and hence having the ability to create large stable structures.

The leaf propagates and grow into vine structure taking organic path. Multiple vines can be connected making a much larger freestanding form.

**Use of technology in design:** The from allows use of two types of technology. Solar PV and Wind Energy. The vein structures are primarily designed to capture solar energy and the technology preferred would be Solar Mono PERC which allows better efficiency even in diffused conditions. This will ensure efficient production even when a complex shape or form is attained besides the fact that it is easily available. The vine elements grow to heights where threshold of wind production is achieved. At these heights horizontal axis wind turbines naturally become a part of the design. They are also natural landmarks.

**Design Achievements**: Vines and Turbines affects a sustainable development in more than one way. Besides producing renewable energy as a goal in sustainable development it produces minimum disruption to the existing ecosystem by sharing natural light with other elements of the system throughout hence rarely impeding their growth. The structure has a minimal contact with ground and hence allows easy ground water percolation. It breaks the tradition of conventional of Solar PV as continuous monotonous form and evolves into beautiful vines that imitate natural growth pattern rather than any natural human development. The conventional PV has been modeled as a leaf a form that is much more a part of the nature. Overall, the design in coherent with UN sustainable Goals 6,8,11 and 15.

The design element “The Leaf” also achieves the goal of scalability. It can be simply be a part of a normal garden or can be scaled to become parts of large landscaped areas. It can be a continuous membrane and equally conveniently it can take a linear or organic form. It doesn’t rely on complex forms that cannot be manufactured or mass produced. The simplicity of the design allows easy manufacturing using least complex technology and easy implementation.

**Environmental impact assessment:** The leaf module (two tetrahedron elements) with a total surface area of 2.5 sq m (production area of 1 sq m along with perforations) is expected to have a installed capacity of approximately 150 watts. It is expected that in an area of 1 hectare there will be 600-700 such modules having a total installed capacity of around 90 kilowatt. Assuming a production period of average six hours/ day with not more than 75 percent efficiency, a single hectare of area will produce around 145000 kwh of electricity annually.
Most wind turbine installations will be 4 m dia. having approximate capacity of 2 kwatt at 10 m/s speed. Presuming a mean wind speed of 6 m/s at installation height annual production per turbine will be around 3560 kwh hours of electricity per annum. With approximately 10 installations per hectare, total energy production per hectare would be 35600 kwh.

Total energy production per hectare of area can be approximated to 180000 kwh.
Hence 53 hectares will be around 9540000 kwh. Germany has 24% reliance on coal fired power plants. Assuming that the current installation replaces energy production across sectors uniformly (24% coal fired power in Germany ) the system will reduce around 2060 tonnes of CO2e of greenhouse gases (calculated at 0.9 kg CO2e average per kwh of electricity – various sources). If the production replaces only coal fired power, then the reduction of CO2e will 8586 tonnes annually. The design proposes use of recycled steel and aluminum for structural framing to further reduce the impact on environment.

Total installed capacity can be summarized as:

Solar PV – 4.7 megawatt

Wind Power 1 megawatt