

A. Company

Kitenergy Srl was established in 2010 to respond to one of the main challenges that all developed and developing countries will be facing in the near future. This challenge is represented by the production of energy from renewable source at lower costs compared to fossil sources in order to satisfy on one hand the increasing world energy demand and on the other the increasing pressure on the energy industry in relation to climate change issues. Kitenergy's main objectives are the development and management of know-how and intellectual properties related to the high-altitude wind energy technology denoted as Kitenergy. The company is selling licenses of the Kitenergy technology and is providing consulting services to operators wishing to build and operate wind farms implementing the company-owned technology.

Kitenergy is composed of a group of professionals ranging from a variety of disciplines including engineering, physics, mechanics, environmental science, business management. Kitenergy professionals have worked at the development of high-altitude wind technologies for more than five years and are recognised at international level as pioneers in this field.

The company's plan is to consolidate and test the Kitenergy technology over the next two years in order to validate the concept for industrialization. A first small scale prototype has been built and operated successfully. Whilst some specific tests are still to be performed on the existing prototype, an industrial prototype is being designed to achieve the industrialisation scale.

Kitenergy will focus its development activities in Europe and North Africa over the next two years. From the third year onwards Kitenergy will expand its market worldwide starting from Asia and North America which are the most promising markets in the mid-long term.

B. Technology

This section provides an overview of the Kitenergy technology.

1. High altitude wind: an unexploited energy source

The power of sun radiation on the earth is estimated to be 174.000 TW. The wind is heat transformed by the atmosphere in kinetic energy. According to relatively recent studies, global wind power has the potential to supply the whole global energy need. It is estimated that the total wind power available is between 1.700 and 3.500 TW, being 14 TW the mankind primary energy need.

The highest average wind speed, i.e. about 30 m/s, can be harvested at 12.000 m of altitude between 30° N and 45° S. The wind speed and related energy decreases from such altitude towards the ground due to the friction of air streams among themselves and with the orography of the ground. At 80 m of altitude from the ground, which is the operational height of actual commercial wind turbines, the average wind speed is estimated to be 4,59 m/s, which is not sufficient for industrial exploitation; at 10 m from the ground is 3,31 m/s^[1].

¹ Source: *Evaluation of global wind power*, Archer, Cristina L. - Mark Z. Jacobson, Journal of Geophysical Research – Atmospheres, 2005

The advantages of harvesting high altitude wind become even clearer when comparing wind power density at different altitude and it emerges that the available power is extremely interesting already at 800 m where the average wind speed is 7,2 m/s^[2].

Altitude from ground	Av. Wind speed	Wind power
800 m	7,2 m/s	205 W/m ²
80 m	4,6 m/s	58 W/m ²
10 m	3,3 m/s	22 W/m ²

The wind power available at 800 m is about 4 times the power available for current wind turbines.

2. Kitenergy Radical Innovation

Kitenergy is a radical innovation in renewable energy and it originates from a radical change of perspective. The vision is to create light, dynamic and intelligent machines in order to reach and exploit the high altitude wind. It is the recipe for a major breakthrough in wind energy generation that will result in “renewable energy cheaper than oil”.

In the air, airfoils or power kites automatically controlled to harvest high-altitude wind. At the ground, the equipments required to generate electricity. Two cables link the kite to the generator and transmit the traction forces which are converted into electrical power.

The “core” of the system is the software that automatically controls the flight of the kite in order to optimise the energy generation.

The Kitenergy technology introduces important improvements and advantages compared to current wind turbines.

Improvement	Advantages ✓	
High altitude wind	✓	Increased average wind power
Larger wind swept area	✓	Increased total wind power
Increased relative speed of airfoil	✓	Increased energy efficiency

The details of the above mentioned improvements and advantages are clarified in the following paragraphs. However, it is necessary to emphasize that **Kitenergy does not require basic research or new technology invention** but the optimization of existing knowledge and applications in various engineering fields together with a relevant design effort.

In the simplest configuration of the Kitenergy technology the Kite Steering Unit (KSU) is fixed on the ground. The KSU can autonomously perform a two-phase cycle, simply acting on the two lines that connect the airfoil to the fixed steering unit. The lines are connected to two alterno-motors by means of wrapping drums. In the traction phase, the airfoil is driven to fly fast in crosswind direction, with “figure eight” trajectories and generates high traction forces that unroll the lines.

The drums are put in rotation and the alterno-motors produce energy. When the maximal length of the lines is reached, the control enters into the recovery phase, where the wing is driven to a region where the lines can be pulled by the motors until the minimal length is reached, spending a small fraction of the energy generated in the traction phase and a new traction phase is undertaken. The energy balance between the traction and recovery phase is approx. 90% (i.e. only

² Source: Kitenergy elaboration of data from *NCEP Reanalysis*, NOAA/ESRL Physical Sciences Division

10% of the energy generated during the traction phase is then spent during the recovery phase). The energy produced is stored in batteries and then directed to the electric grid.

It is possible to obtain continuous energy production by installing several generation units operating in different phases of the yo-yo cycle.

3. Capacity factor

Due to wind intermittency the average power produced by any wind generator over the year is only a fraction, often indicated as “Capacity Factor” (CF), of the rated power. For a given wind turbine on a specific site, the CF can be evaluated knowing the probability density distribution function of wind speed and the generator wind–power curve. For example, in Table 1 the CFs of a KITEng–yoyo and of a wind turbine of 2–MW rated power are reported, considering some Italian sites and one location in The Netherlands.

	De Bilt	Linate	Brindisi	Cagliari
Wind turbine	0.36	0.006	0.31	0.31
KITEng - yoyo	0.71	0.33	0.60	0.56

Table. 1 Comparison of capacity factors

In windy sites, the **Kitenergy technology has capacity factors about two times greater** than the present wind power technology.

4. Energy production costs

The production costs for Kitenergy and current wind turbine technologies are related essentially to the amortization of the CAPEX costs. Thus, the main differences between the two technologies are related to their structures, foundations and required land, whose costs are significantly lower for Kitenergy. In fact, the heavy tower and the rotor of a wind turbine are replaced by light composite fibre cables and the kite in a KITEng–yoyo.

All the aspects described so far have been considered to estimate the cost of energy produced with Kitenergy. Indeed, the obtained results indicate that Kitenergy has the potential of generating renewable energy with **production costs lower than those of fossil energy**.

Source	Min. Estimated cost (€/MWh)	Max. Estimated cost (€/MWh)	Av. Estimated cost (€/MWh)
Coal	23	46	31
Gas	34	56	44
Nuclear	19	29	27
Wind	32	88	53
Solar	167	463	301
Kitenergy	14	46	24

Table 2. Projected cost in 2030 (levelised in 2003 Euros per MWh) of energy from different sources³ compared with the estimated cost of Kitenergy

³ Source: International Energy Agency (IEA), Projected Cost of Generating Energy – 2005 update. Paris, France: IEA PUBLICATIONS, 2008

C. Kitenergy development status

The Kitenergy team and partners started working in 2005 at the development of the technology. During the past years excellent results have been achieved. One of the main achievements is the Kite Steering Unit (KSU) prototype that was developed in collaboration with Politecnico of Turin and with the financial support of Piedmont Region. The KSU prototype is one of the few existing and operating high altitude wind energy generators in the world.

The prototype is equipped with two Siemens permanent-magnet synchronous motors/generators with 40-kW peak power. The energy produced is accumulated in a series of batteries that have a total voltage of about 340 V. The batteries also supply the energy to roll back the lines when needed. The prototype is capable of driving the flight of 10–30-m² kites with cables up to 1000 m long. The various experimental tests performed in different Italian locations (note that the prototype is placed on a van and therefore can be transported via road) showed a very good matching between the computer-based simulations and the numerical results of tests in the field. The experimental results give a strong confidence in the numerical and theoretical tools, which can be therefore employed to perform a realistic study of the energy generation potential of large KITEnrg-farms, composed of several KITEnrg-yoyo generators.

D. Future development plan

The future development plan of Kitenergy is composed of 3 main phases.

The first phase is completed and was focused on completing the experimental tests on the existing prototype implementing the full automatic control.

The second phase, just started, will last 20 months and will be focused on the design, development and construction of an industrial prototype with 500 kW nominal power. The output will be the industrial prototype successful tests and operation.

The third phase will be focused on the industrialization of the KITEnrg yoyo plants.