KITEnrg
ALTITUDE WIND GENERATION

KITEnergy Project

Renewable Energy Cheaper than Oil

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High Altitude Wind (HAW) technologies

- At present, over 80% of the world electric energy is produced from plants making use of **fossil sources**
- The **economical and geopolitical problems** related to such sources are becoming everyday more and more evident
- **Climate change** is one of greatest threats facing the world and the electric generation sector accounts for over 30% of CO_2 emissions
- Aim of AWEC attendees: demonstrate that **HAW technologies can largely contribute to invert the split between non-renewable and renewable sources**

Challenges	Targets
■ Energy production costs lower than fossil sources	■ < 50 €/MWh
■ Power density comparable to nuclear plants	■ > 20 MW/Km²
■ Source available anywhere	■ CF > 0.5
■ ……	■ ……

High Altitude Wind (HAW) Technologies

- **Pioneer works in the '70:**
  - **Manalis, "Airborne windmills", J. Aircraft, 1976**
  - **Loyd, "Crosswind kite power", J. Energy, 1980**
  - **……**
- **Renewed interest in last 5-6 years with technologies of different features:**
  - **altitude: BL (200-1000 m); JS (8000-10000 m)**
  - **aircraft lift: AD (wing-kite); RC (helicopter); AS (aerostatic)**
  - **energy generation: OB (on board); GL (on ground)**

Kitenergy project

- The project started in 2005 at Politecnico di Torino in collaboration with small hi-tech companies
- It has been supported by Regione Piemonte, Ministero della Ricerca, Europe Union
- Advanced modeling and computer simulations have been performed for assessing the energy generation potentials
- From September 2006 a prototype able to generate energy with 1 Km cable length have been tested to experimentally verify the simulation results
- In 2010 KITEnrg srl is established with the aim of further developing Kitenergy technology towards the industrialization phase

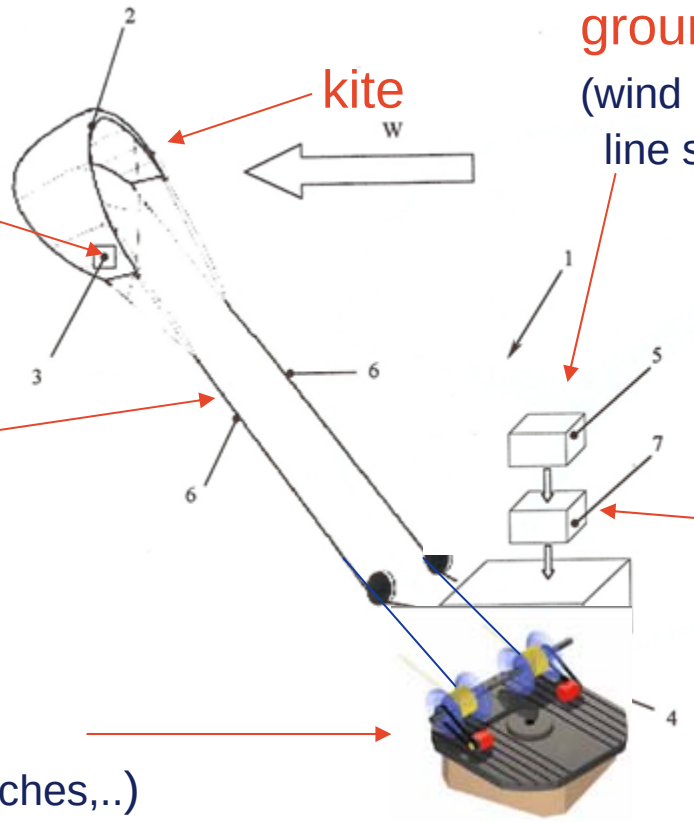
Kitenergy project

- **The basic features are:**
  - **altitude: BL (200-1000 m)**
  - **aircraft lift: AD (wing-kite)**
  - **energy generation: GL (on ground)**
- **Wind power is already extremely promising at 200-1000 m over the ground, where the wind power is about 20 times of the overall mankind energy needs**

  (Archer-Caldeira, "Global assessment of high-altitude wind power", Energies, 2009)

Kitenergy technology

- **The core is the system of automatic control of the kite flight, called KSU (Kite Steering Unit)**



kite

ground sensors

(wind speed and direction, line strength ,…)

on board sensors

(kite position and speed)

cables

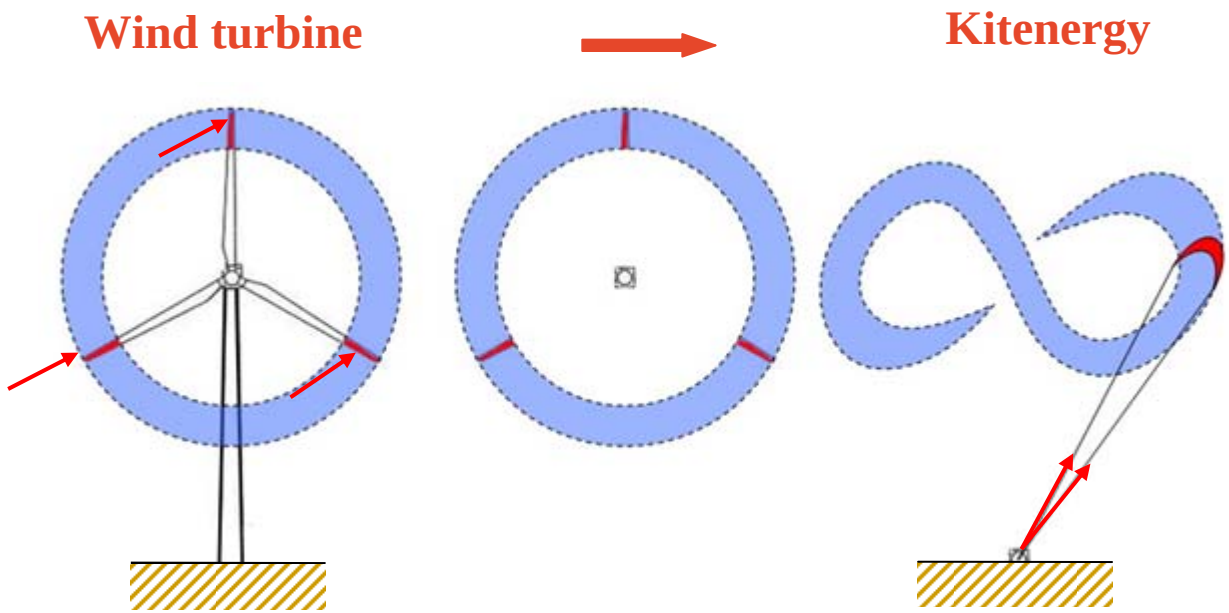
control software

actuation unit

(electric drives, winches,..)

Kitenergy technology

- In wind towers, the outermost 20% of the blades contributes for 80% of the power



- The kite acts as the outermost part of the blades without requiring the heavy tower

In the air: power kites

- In the air, to extract energy from the wind, power kites, air foils with high aerodynamic efficiency automatically driven

In the air: light cables

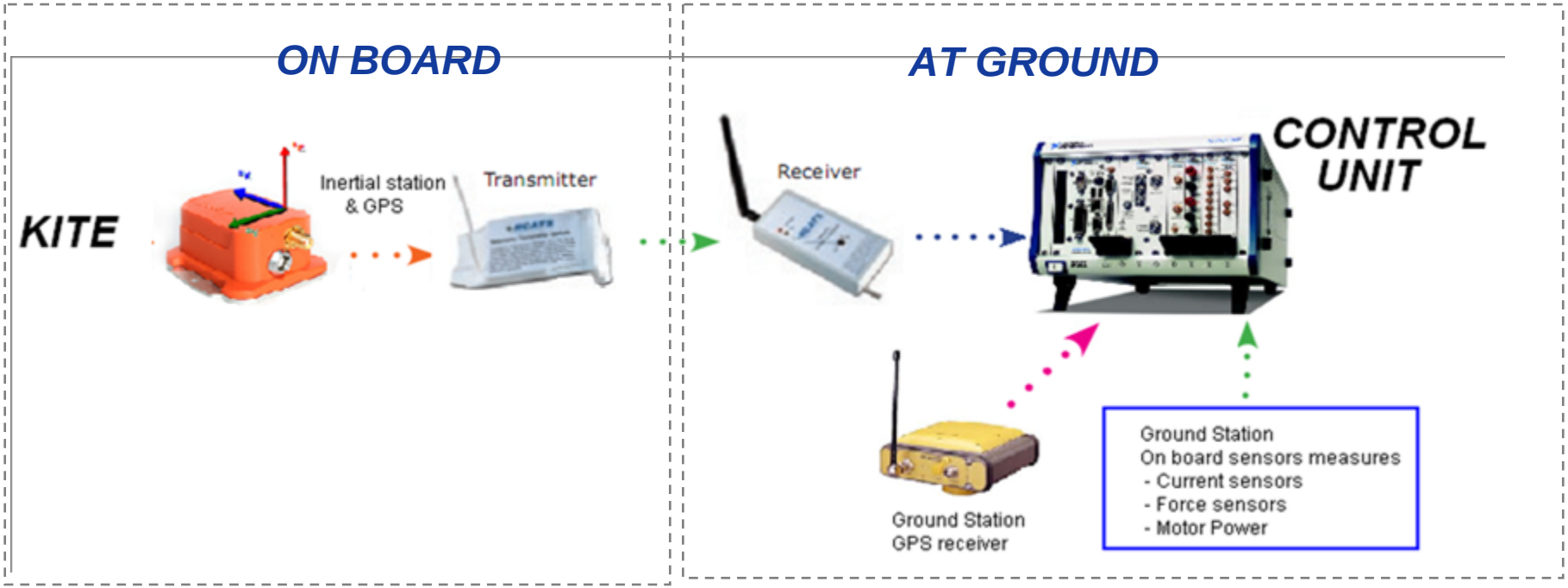
- **Connecting power kites to the units at ground level for power generation, 2 composite cables transmit the traction force and are differentially adjusted for manouvering**

Traction resistance:
10 tons / cm^2

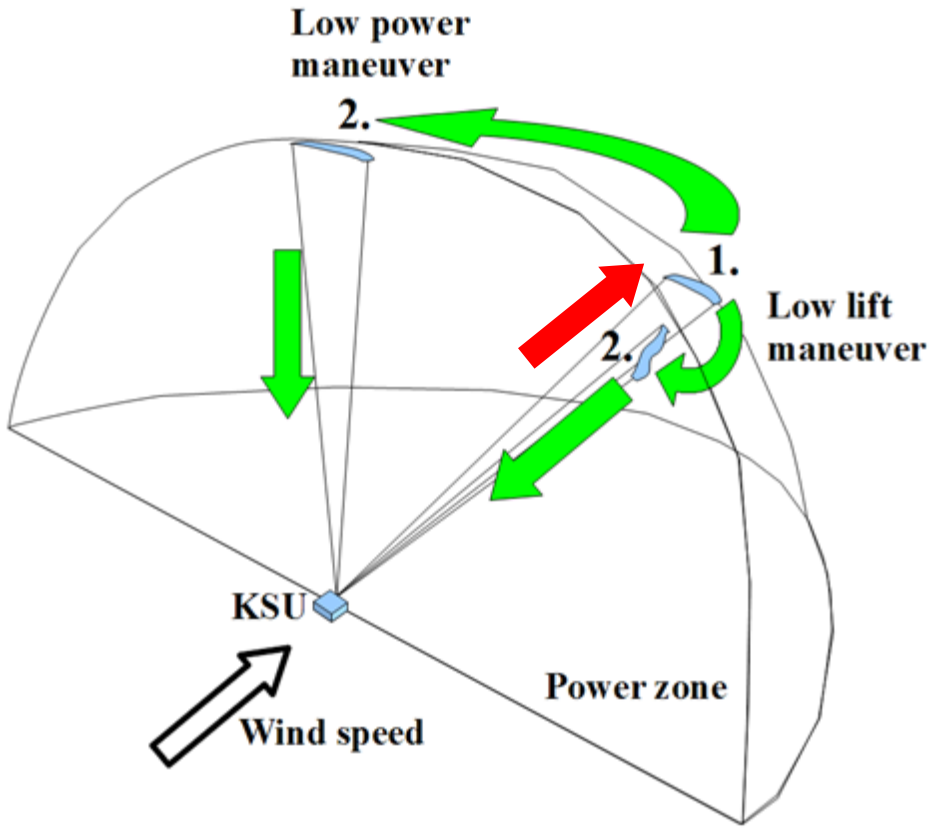
Weight:
100 kg /km*cm^2

The intelligence

- At the very core of the project stays the control flight system that autonomously drives the kites, maximising the energy production
- Modeling, control and sensors fusion techniques have been one of the main Kitenergy focus of research



KE-yoyo configuration

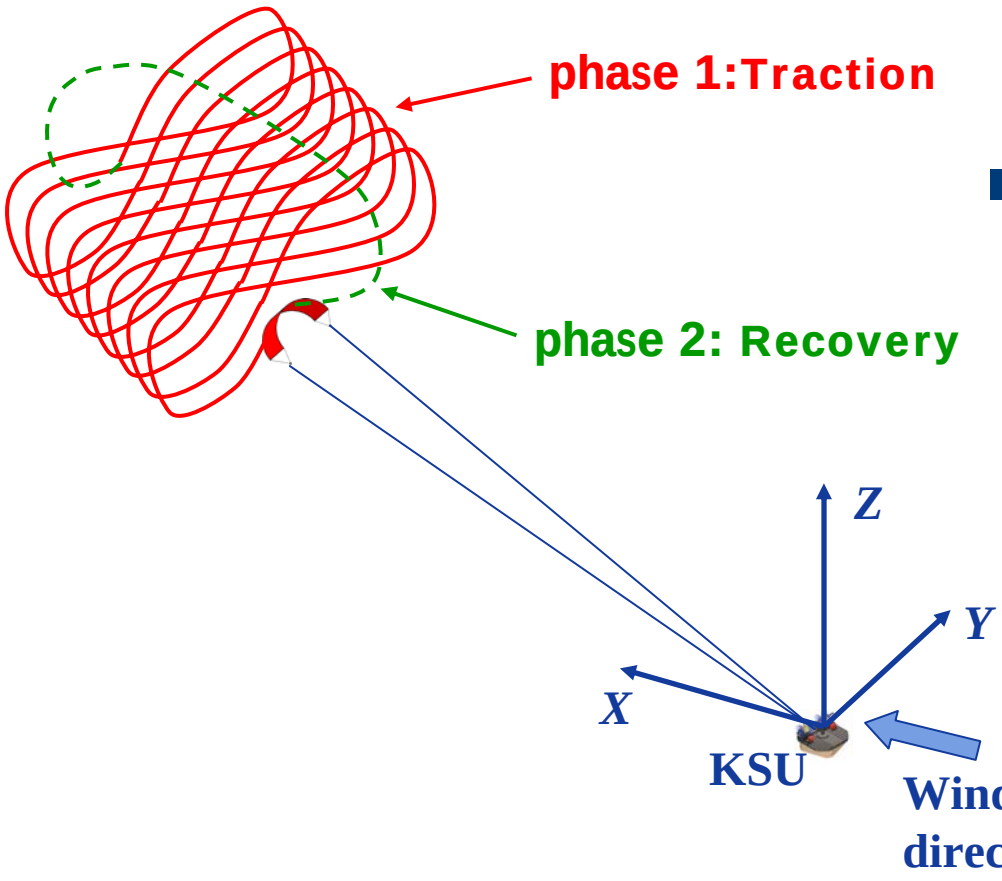


1. **The power kite pulls the cables producing rotation of winches which is transmitted to the electric drives for the production of electricity**

2. **Cables are recovered by the electric drives, with a minimal power consumption**

- **POSITIVE BALANCE** (~92%): **Energy produced during phase 1 is more than the energy spent in phase 2**

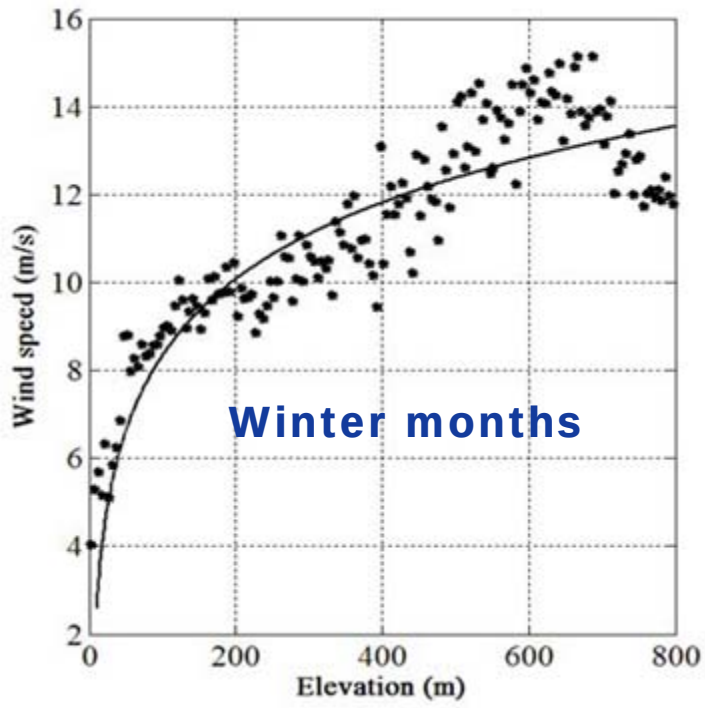
Flight control

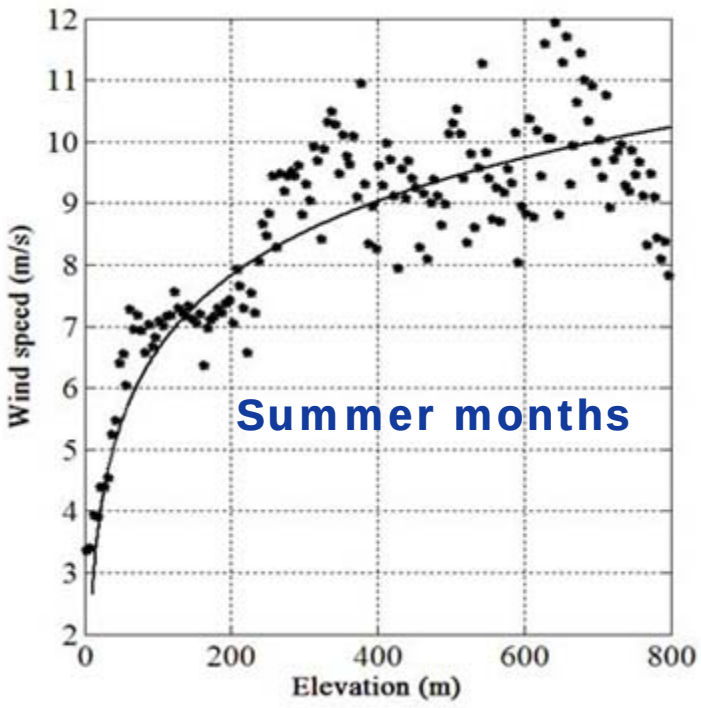


- The kite is driven to fly fast in crosswind direction, with "figure eight" trajectories
- Model Predictive Control techniques are applied to:
  - keep stability of the airfoil
  - maximize the net generated energy
  - satisfy physical constraints (keep the kite far from the ground, avoid line entangling, maximal cable strength, ...)
  - attenuate the effects of wind turbolence

Computer simulation results

Wind shear model using wind data collected at De Bilt(NL)





Wind data taken from the NOAA/ESRL Radiosonde Database

CFD evaluation of kite polar curves

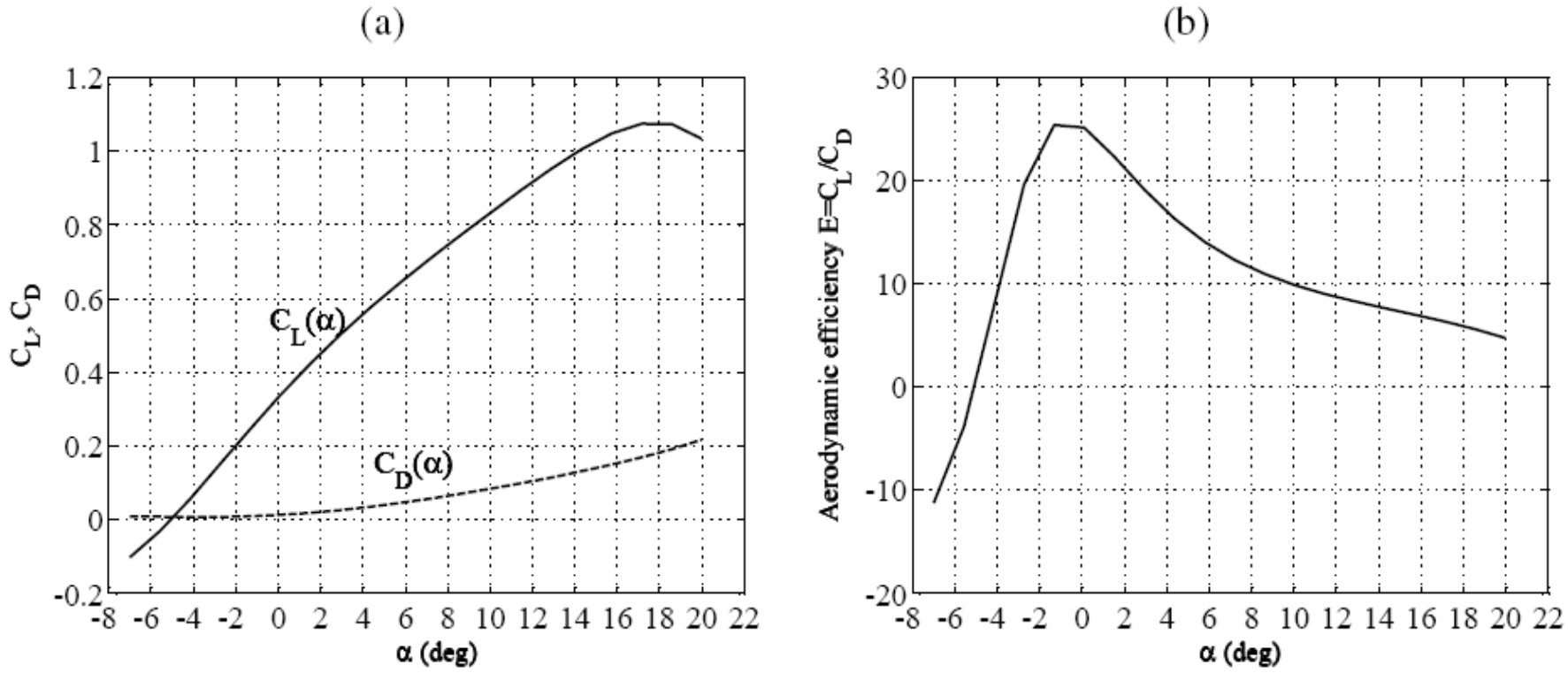
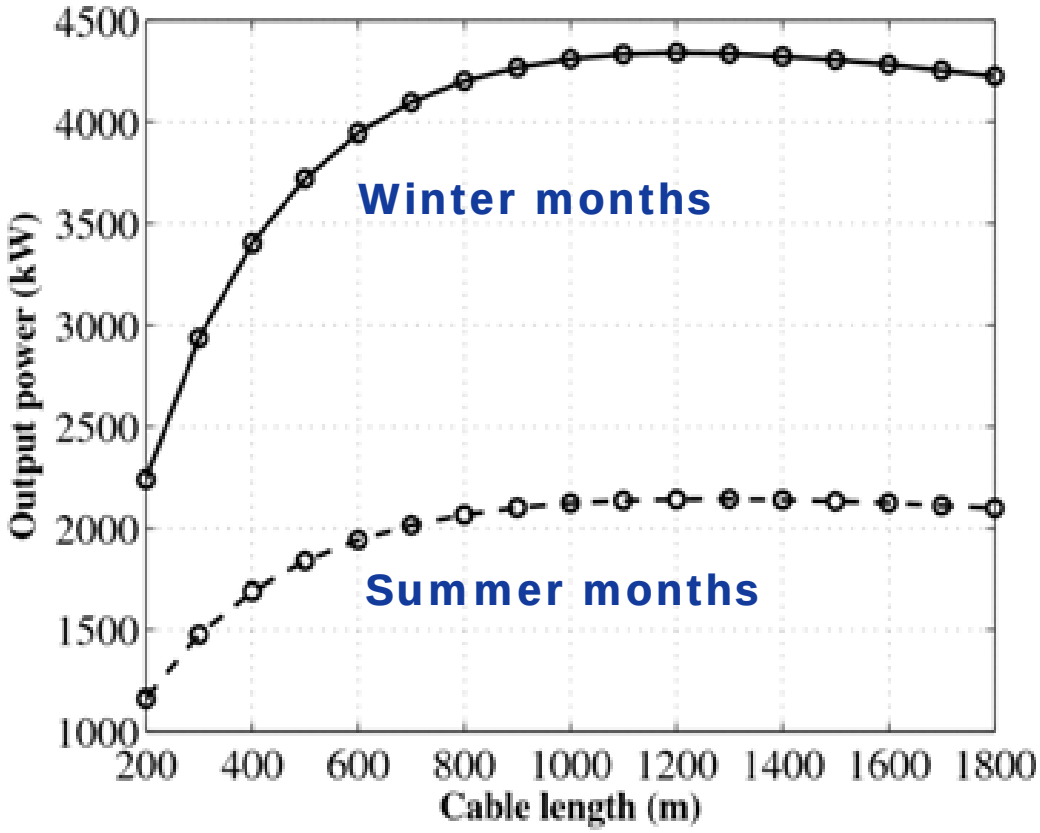


Fig. 5. (a) Kite Lift coefficient C_L (solid) and drag coefficient C_D (dashed) as functions of the attack angle α. (b) Aerodynamic efficiency E as function of the attack angle α.

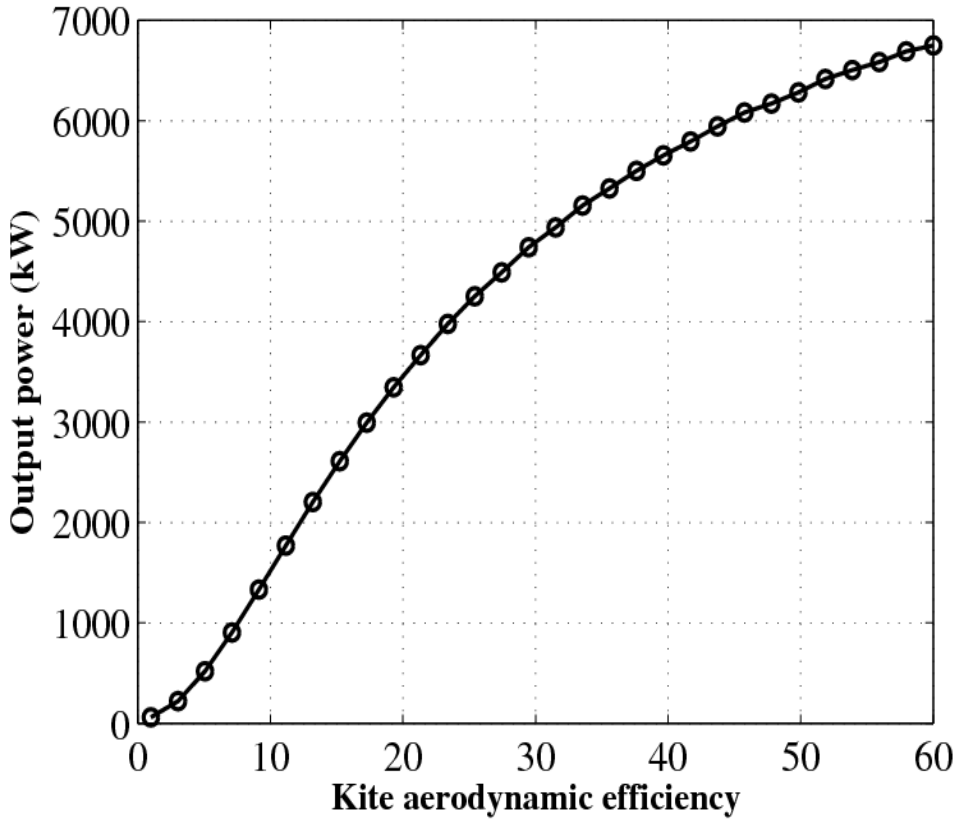
Generated power vs. cables length

- **Kite area: 500 m²**
- **De Bilt wind share model**



Generated power vs. aerodynamic efficiency

- **Kite area: 500 m²**
- **Wind speed: 9 m/s**



Capacity Factor

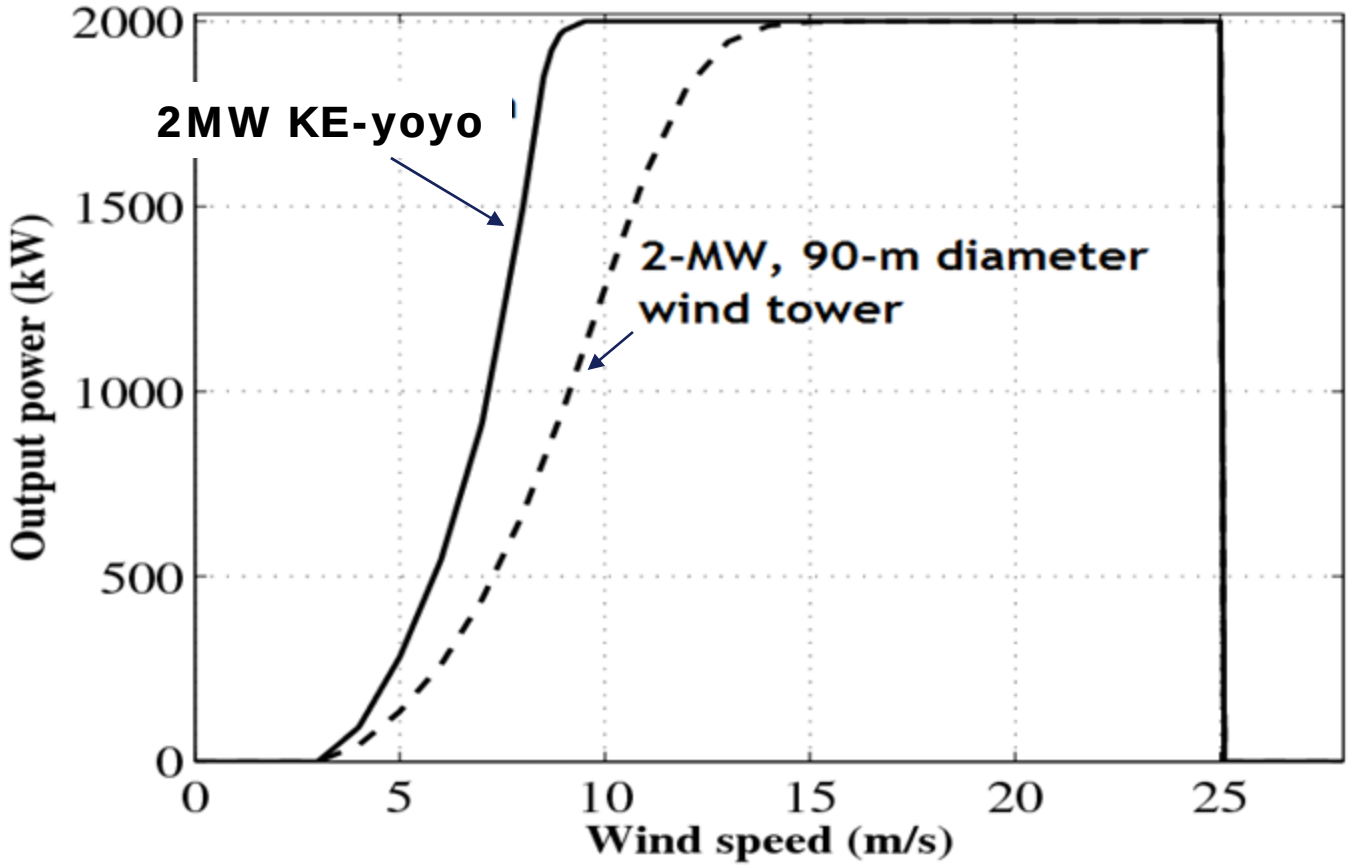
- Due to wind variability, a wind generator is able to produce in average only a fraction of its rated power, called “Capacity Factor”

$$P_{av} = P_{max} \cdot CF$$

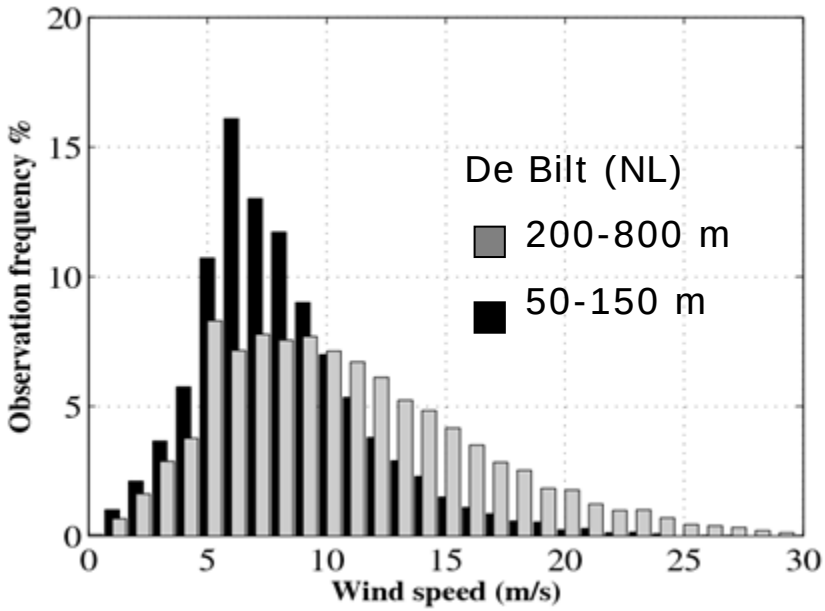
- The Capacity Factor depends on:
  - power curve of the generator
  - probability distribution of wind speed

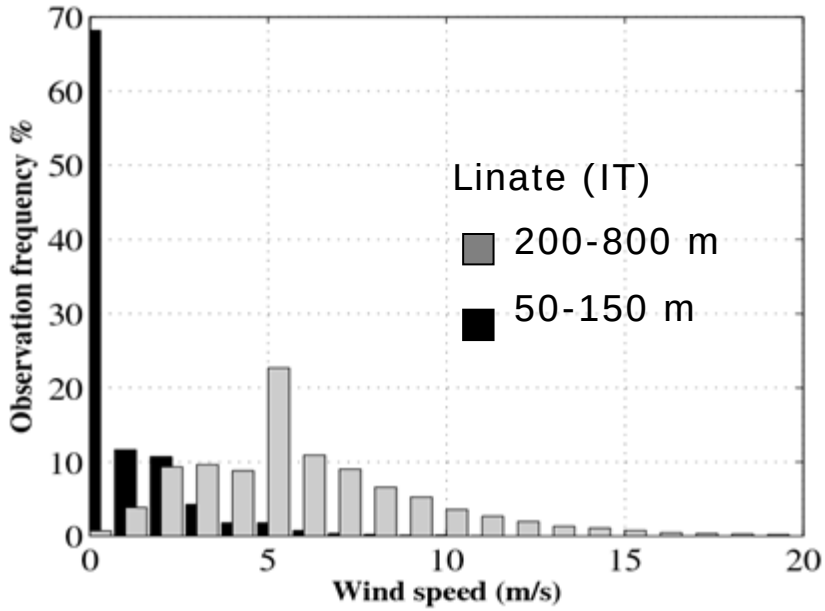
Power curve

Power curves of 2 MW rated power generators



Capacity Factor examples





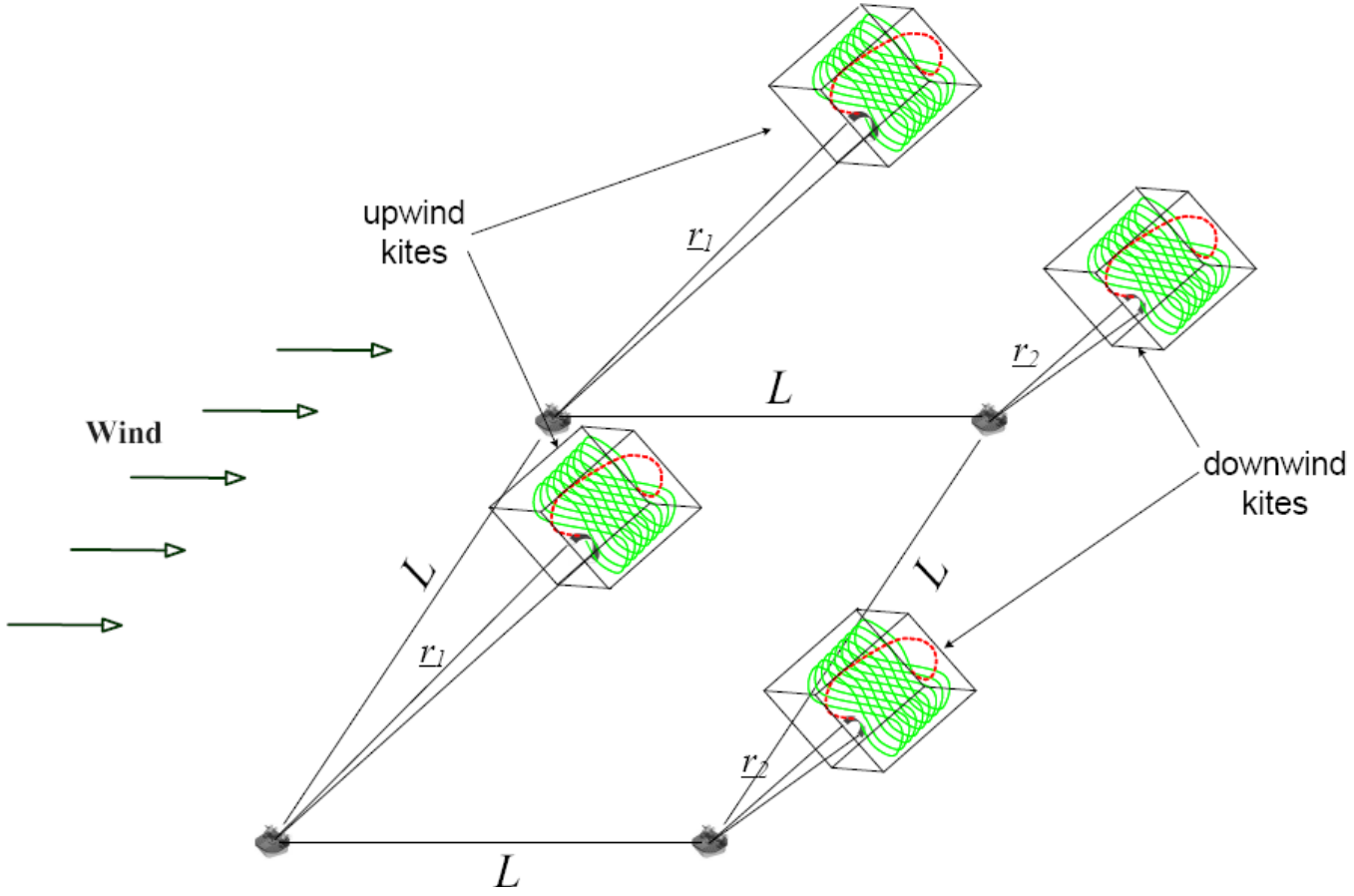
Linate (IT)	B. Aires (AR)	Misawa (JP)	Leba (PO)	Brindisi (IT)	De Bilt (NL)
0.006	0.18	0.11	0.32	0.31	0.36
0.33	0.63	0.50	0.68	0.60	0.71

Capacity factors of wind tower (black) and of KE-yoyo (red)

Wind data taken from the NOAA/ESRL Radiosonde Database

KITEnrg Farm

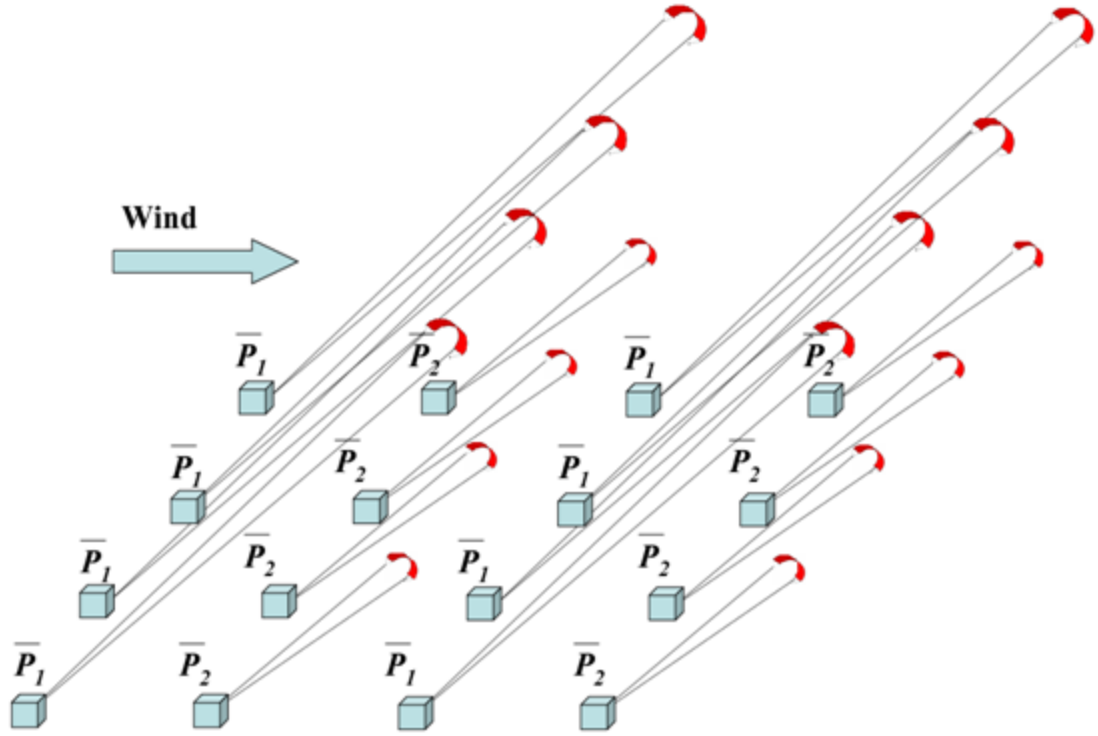
- **In a farm layout, several KE-yoyo are displaced in order to avoid kite collision and aerodynamic interferences**



Power density of KITEnrg Farms

- **Kitenergy Technology**
  - 16 KE-yoyo/km2
  - 32 MW/km2 (rated)
  - 22 MW/km2 (average)

- **Actual wind technology**
  - 4.5 towers/km2
  - 9 MW/km2 (rated)
  - 3.4 MW/km2 (average)



Energy production costs

- **Kitenergy technology has the potential of generating renewable energy at lower cost than energy generated from fossil sources**

Source	Minimal estimated ($/MWh)	Maximal estimated ($/MWh)	Average estimated ($/MWh)
Coal	25	50	34
Gas	37	60	47
Nuclear	21	31	29
Wind	35	95	57
Solar	180	500	325
KITEnrg	10	48	20

Projected cost in 2030 of energy for different sources (IEA Pubblication, 2008) compared with the estimated cost of Kitenergy

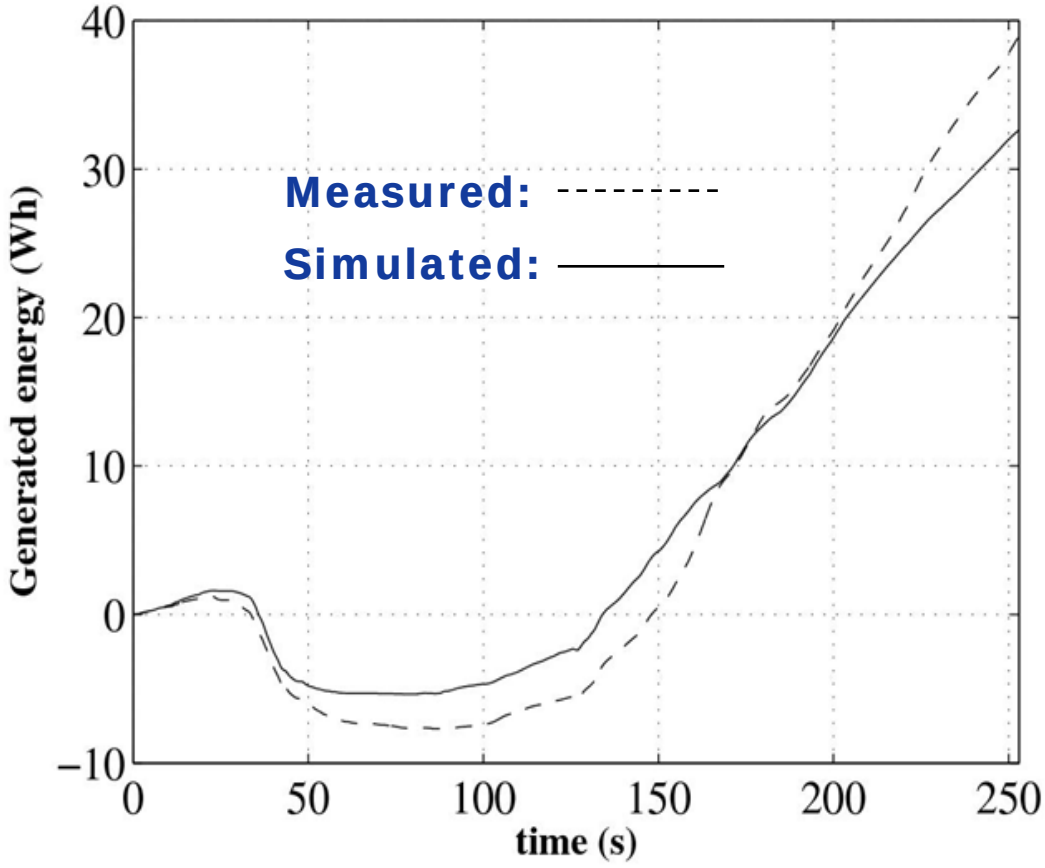
KITEnrg-yoyo prototype

- A prototype has been tested to produce energy in KITEnrg-yoyo configuration
  - max power: 40 kW
  - lines length: 1000 m
  - kite area: up to 20 m2

- It allowed to exprimentally confirm the computer simulation results

Experimental vs. simulation

- Kite area: 10 m²
- Wind speed: 1-3 m/s
- Max cable length:
  800 m



Future development plan

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

1. The first phase is on-going and will be focused on completing the experimental tests on the existing prototype implementing the full automatic control. The output expected by March 2011 will be energy generation for periods exceeding the 24 hours with minimal human assistance
2. The second phase 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.
3. The third phase will be focused on the industrialization of the KE yo-yo plants. The third phase will require the establishment of robust industrial partnerships.

References

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Info

www.kitenergy.net

Thank you!