# 1 General Description

EnerKite develops a new technology for more efficient use of wind power - using autonomous kites since 2004. With future electricity costs at 3-5 cents / kWh (at utility MW scale) and more than 4,000 full-load hours per year, AWES (EnerKites) will represent a cost effective alternative to the today's on- and offshore wind power plants as well es to fossile sources of energy. At flight altitudes of a few hundred meters, EnerKites are able to harvest more wind energy. Without heavy tower and foundation, EnerKites are representing a minimalistic approach.

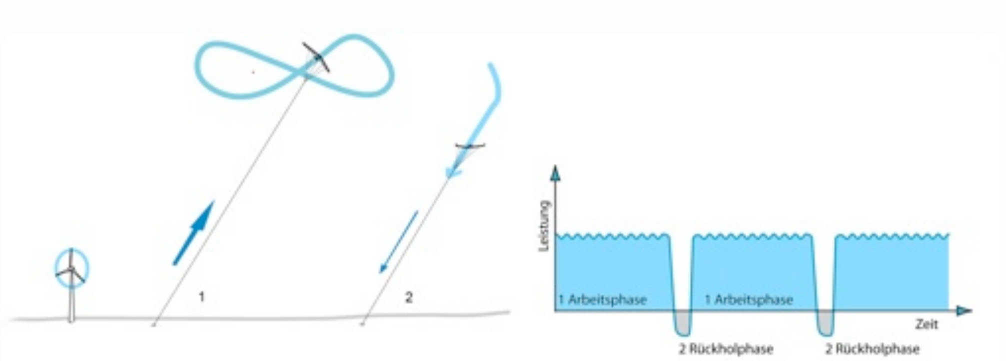


*Figure 1: Schematic depiction of energy generation with a kite in "Yo-Yo operation".*

EnerKite is a mobile system for power generation, which can be mounted on a 2-axle trailer. It mainly consists of a wing and a ground station. The system includes a tethered wing with a 3 line tether system, sensors and communication system. At the ground, the generator winch with controls, energy storage and energy conversion are positioned (see Figure 1, 2). The control during flight, at the start and the landing phase is carried out by the servo control from the ground - either automatically or manually by the pilot. The operating loads are set at 10 kN with automatic load limit. The mass of the trailer is about 2000 - 2500 kg. This is being protected from overturning by lateral arms or anchors, respectively.

Some hundreds of signals and system parameters, e.g. Forces, wind speed and direction, rope length, operating altitude and speed can be continuously monitored, recorded, analyzed and displayed. The system is also given a self-monitoring, which communicates with the safety systems and the pilot. Particularly in the stage of development, the pilot is able to override the autopilot by manually intervening.

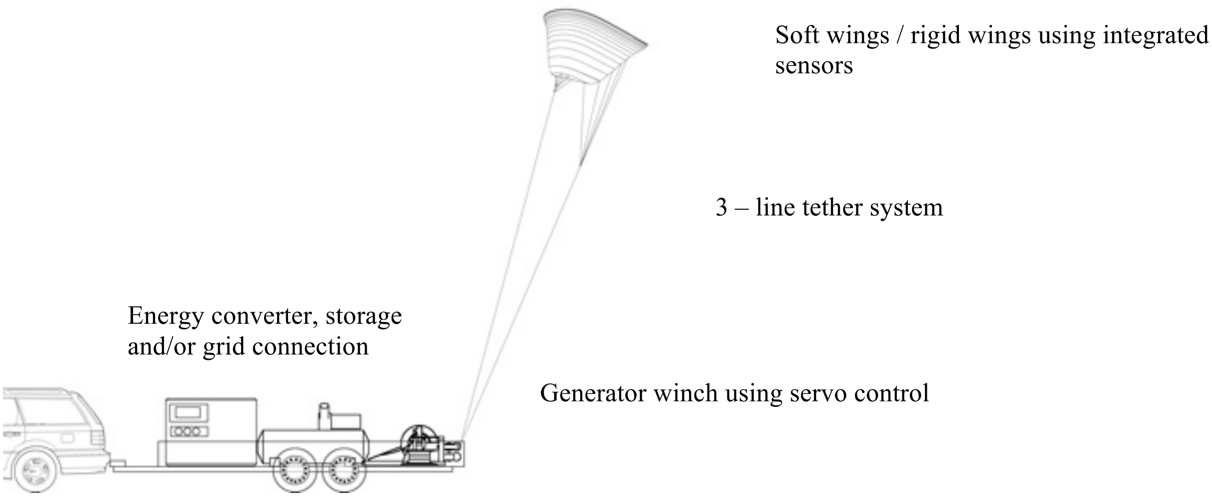


*Figure 2: Schematic diagram of a small mobile control unit for kites.*

EnerKite operations were approved by the German Authorothies such as described in chapter 2 – 4. Chapter 5- 7 refers to the policy and concerns of FAA.

# 2 Kite-System

## 2.1 Airfoil

The kites used with a tether system represent the actual aircraft in the sense of a kite. In the first phase flights are provided with fabric wings, which in areas of 15 - 21 square meters carry out a mass of 3 – 5 kilogram. The maximum speed of these wings is about 40 m / s . The rated forces in the system are about 12 kN.

**A) Soft Wings for a 30 kW**

- so-called ram air wings (similar to paragliders, kites)
- Surface Area of 15 - 21 square meters (sqm)

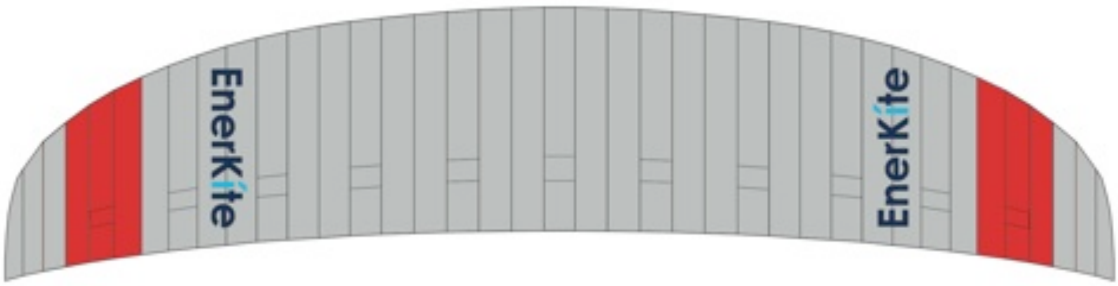


*Figure 3: Top view of a color-matched wing (for operation above 100 m), 21 sqm, 11 m span.*

## 2.2 Tether

The tether consists of a main tether attached on the wings leading edge near the center of lift and two control tethers, attached at the trailing edge. The tethers are 12-fold hollow braided, highly stretched polyethylene (Dyneema) fibers.

Minimum breaking load of the main tether: diameter 6 mm is 45 kN
Minimum breaking load of the control tethers: diameter 4 mm is 25 kN (total of the two)

Minimum breaking load of all ropes together: 70 kN

The ground station can be ballasted against the kite-traction and secured by ground nails additionally.

# 3 Operation and Safety

## 3.1 Operating Parameters

Locations providing a low roughness and low turbulences are selected as airfields. Similarly, in the stage of development places and operating hours with low thermals are preferred. For the operation an obstacle-free area on the ground (operating area) is required. In the air, the tether length and the tether angle determine the operating altitude or flight level. In addition, EnerKite defines a radius of action, which is within the maximum expansion of the airfield. (Figure 5).

**Operating Area**

As operating area, a field of approximately 100 m in diameter is required. The operating area is the ground area needed for the regular start and landing procedures.

**Radius of Action**

The radius of action of the wing represents a safety area at the ground, which won't be exceeded under any circumstances during operation, and which is having a sufficient distance to traffic areas and buildings. In this area, the kites can be operated safely and exceptionally be landed.

The radius of action is usually drawn as a circle around the centre of the operating area (B). This results in a radius of 100, 200 and 450 m for the glider airfield xyz, depending on the tether length in each phase of development.

**Extended Radius of Action**

In the presence a steady and appropriate wind direction, the operating area (B2) can be chosen so that the radius of action and the tether length are extended up to 600 m in a correspondingly smaller wind window (e.g. flight sector + / - 30 °). It is important to ensure that the operation takes place within the flight area and at a distance of approximately 100 m to traffic areas and buildings.

**Flight Altitude and Tether Length**

P1) altitude to 100 m - determined by the tether length (phase 1)
P2) altitude to 100 meters - determined by the control system with a tether length of 200 m (Phase 2)
P3) altitude: 100 m - 300 m - determined by the control system with a tether length of 450 m (phase 3) or 600 m (phase P3.1)

**Wind- and Load Range**

Wind speed: 0 - 20 m / s
Light to moderate turbulence / gusts

**Flying Schedule**

Out of duty times (while operation on an airfield)
In general, during the week.
During the day, during daylight hours (first phase)
Flight duration 24 - 72 hours or more (planned endurance flight record) (second phase)

## 3.2 Safety

Load limitation and control is done by pitch (angle of attack) or brake (butterfly rash) of the wing and / or by limiting the torque of the motor winch.

**Passive Safety**

Possible passive safety systems are weak links in the rope and on the wing. Further, increasing speed results in a wing deformation that degrades the glide ratio of the wing and thus limits the speed.

**Active Safety**

Fully automatic (without intervention of the control unit or the pilot) a torque or load limitation takes place.
Condition monitoring of the entire system controls sensors, operating parameters and functions.
Power control by

Automatic height control (the higher the kite the lower the load)
Pitch of the wing (also called depowering)
Emergency System

**Conspicuousness**

Kites are usually brightly coloured and are clearly visible in daylight. Special EnerKite wings may be made of metallised fabrics to improve durability and can be equipped with red markings.

For night flights, in coordination with the authorities, identifications can be implemented, either based on an illumination of the wing from the ground or on OBS-LED lights.

The identification of the tethers is described in Section 4.

# 4 Conspicuity

While the wing is clearly visible due to the area of 15 - 21 sqm, the main and control tethers could be easily overseen. An identification of the kites' tethers is prescribed in § 16 section 2 German air traffic regulations.

The efficient movement in the air and minimum weight are substantial to the efficiency of the system. Thus, large obstacle markings e.g. in spherical form are out of question. Also, flags usually generate considerable drag and complicate the dynamic extension and retraction of the system.

Therefore, EnerKite in coordination with the air traffic control is anxious to discuss the issue of conspicuousness in coordination with the DFS and the legislature.

Here we see the following options:

1. Conspicuity by a neighbouring marked obstacle
   see Figure 8
2. Conspicuity by the dynamic operation at variable tether length
   see Figure 9
3. Development of new ways to mark and make signs in terms of weight and resistance

**Conspicuity by a nearby obstacle**

A nearby obstacle can be:

A (not dynamic) kite system. In general, a one-tethered kite
A typical wind measurement tower reaching a corresponding altitude.

The adjacent obstacles are marked by day and by night using red / white flags or lights in line with Aviation Regulations.

When using a static adjacent kite as conspicuous marked obstacle, this kite has to be designed so that it remains in the vicinity to the dynamic kite system (EnerKite) without colliding with it. This is shown schematically in Figure 8. The angle $\alpha$ always has to be significantly greater than the angle $\beta$. The distance of the identification to the invisible dynamic tether should not be less than 100 m in turn.

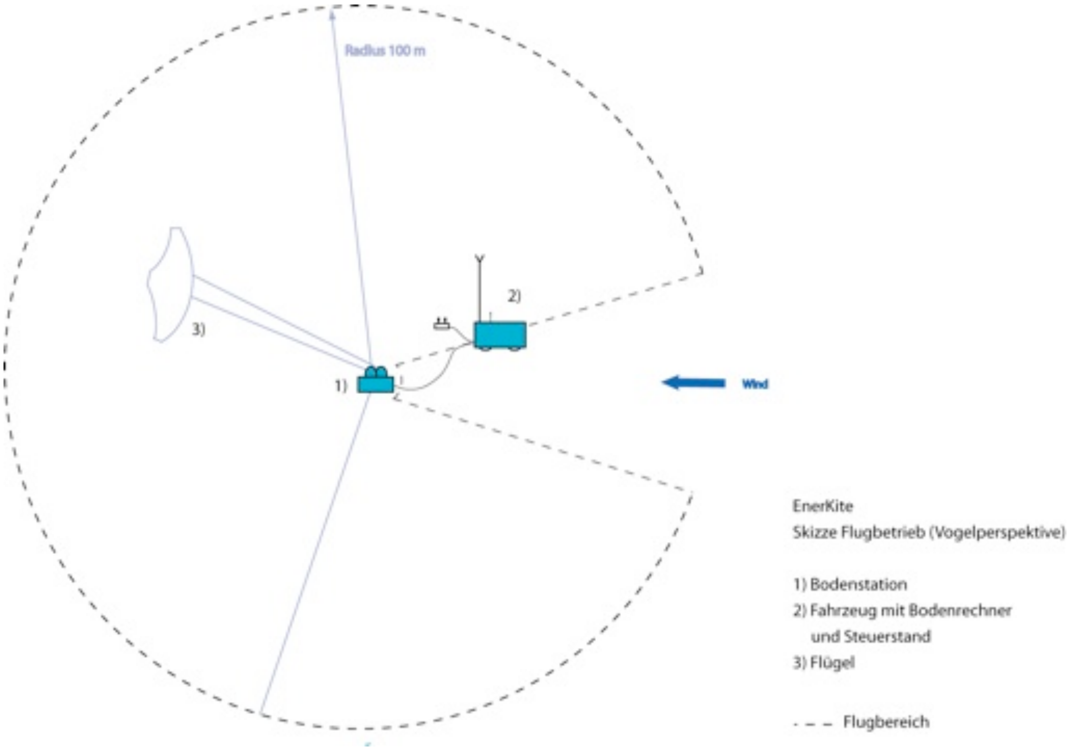


*Figure 4: Sketch of the arrangement on the airfield. Example of action radius $R_B$ = 50 m.*


*Figure 5: Top view of the airfield and placement of the Kite system during development*

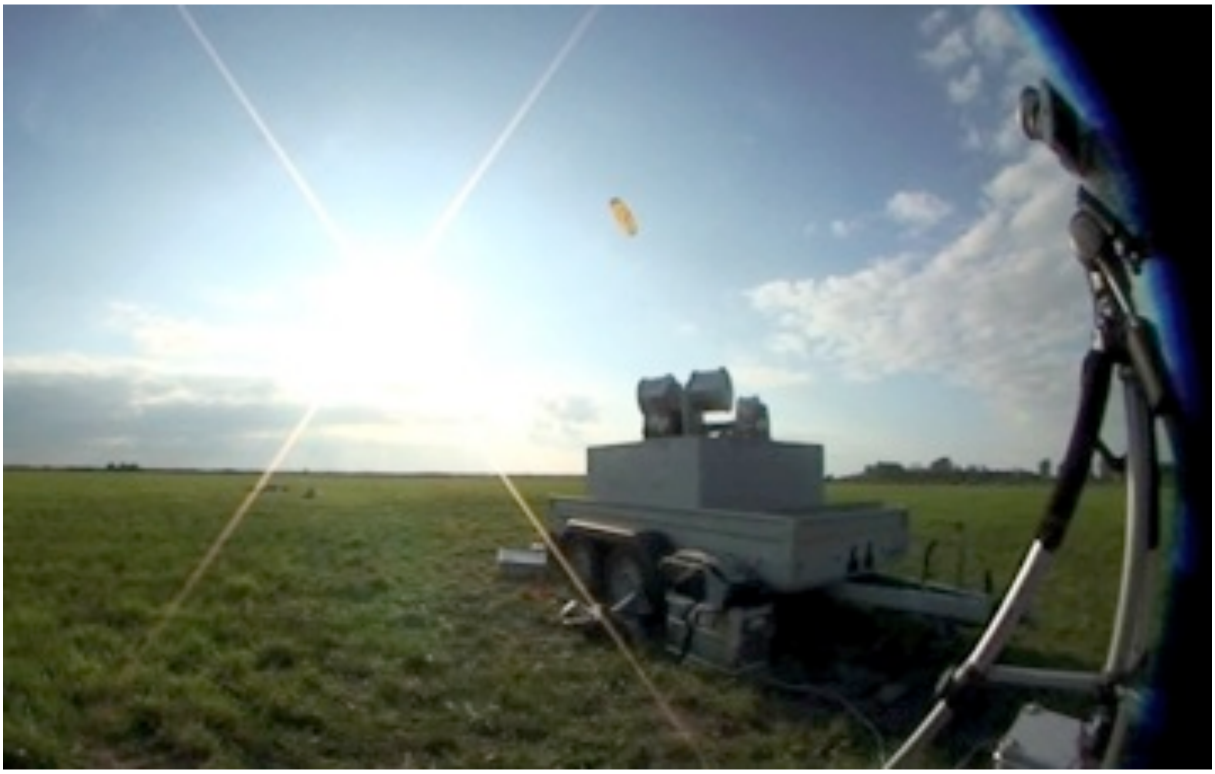

*Figure 6: A ground station in 2009, realized using 6 sqm wings. System with 4 winches, 2 main tether reels and two control tether reels.*

*Figure 7: Flight operations as part of the development of the autonomous kite control system.*

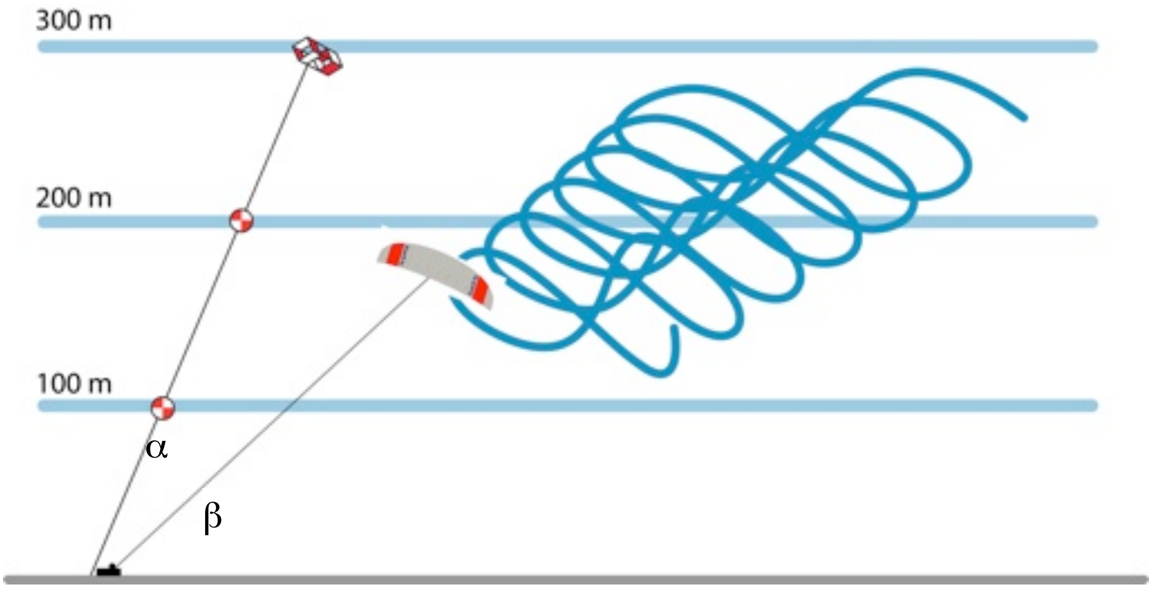


*Figure 8: Marking and lightning by neighbouring obstacle. Rope angle α = 60°–45°, β = 45 ° - 30 °. Positioning of the neighbouring obstacle upwind in direct distance (5 - 10 m) to the AWES.*

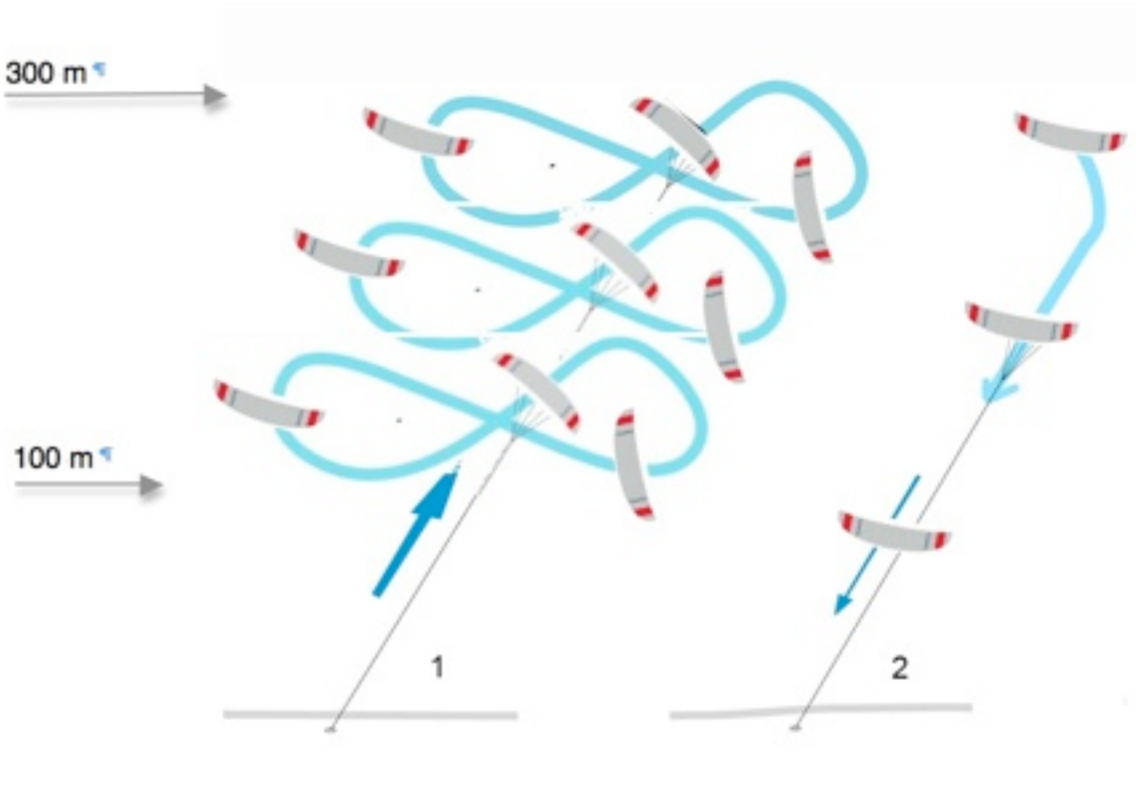


*Figure 9: Conspisuity by dynamic operation at variable pitch. Operational altitude above ground: 100 - 300 m. 1 - outlet, 2 - retrieval, cycle takes about 60 seconds.*

# 5 Proposed Restrictions

(1) Airborne operations of AWES should be temporary in nature for testing and data collection purposes only;

*Temporary operation shall include operations covering **day and night** cycles as well as uninterrupted operations with changing wind and weather conditions*

(2) Single AWES devices only (e.g.— no ''farms'' or multiple simultaneous testing);

*Operation in **farms** of 3 – 6 is **mandatory** in order to demonstrate that the systems fulfil the IEC feed in requirements on the electrical current without using expensive buffer systems.*

(3) AWES should be limited to a single fixed location (e.g.—no mobile ground facilities);

*Mobile/Portable ground facilities are a key advantage of AWES. We agree that each location may require a separate permit to ascent if required.*

(4) Testing is confined to heights at or below 499 feet above ground level (AGL);

*Testing of EnerKite was approved to heights of 300 m (985 ft).*

(5) Airborne flight testing of AWES will only occur during daylight hours;

*Uninterrupted 24 – 72 hours flights are essential in order to demonstrate the capabilities of autonomous controls.*

(6) AWES will be made conspicuous to the flying public.

*Please explain why AWES is considered rather an obstruction than an aircraft. Does Obstruction Marking and Lightning address any moving / flying objects?*

# 6 Answers to FAA concerns

(1) Impact(s) to various surveillance systems (radars);

*Please explain which radar cross section (e.g. in comparison to conventional wind turbines) are acceptable. By proper selection of size, material and surface treatments various more or less defined radar cross sections can be achieved.*

(2) Conspisuity to aircraft (marking and lighting);

*If operation is above 330 feet. Main focus should be on the tether. See chapter 4*

(3) Overall safety—safety to other airspace users, safety to persons and property on the ground, safety to the efficient and effective use of NAS facilities, safety to airports, safety to air commerce, and safety to the efficient operations and managing of the NAS;

*See chapter 3.*

(4) AWES fly-away protection (mooring cable is severed);

*Durability and damage tolerance of tethers is subject to further investigation. Multiple tethers acting from the ground may represent only temporary a safer but less efficient solution.*

*In case of severed mooring cables, automatic disconnection of the cable from the sail/wing is highly recommended in order to minimize risks.*

(5) AWES physical dimensions per unit and per farm;

*AWES are typically smaller than conventional wind turbines. Depending on the design and operation 1 – 4 kW of power output might be achieved per square metre wing.*

(6) AWES operating dimensions per unit and per farm (amt. of airspace it may require);

*Larger AWES may operate most efficient between 300 and 1000 feet, depending on the system size and site.*

(7) AWES mobility (potential for AWES to relocate from physical ground location to a different ground location);

*The capability to deliver mobile renewable energy is unique. However this concerns mostly the smaller AWES.*

(8) Wake turbulence or vortices of wind capturing component(s).

*This effect is directly related to the total force on the wing*

# 7 FAA Request for Information

**I) General Information**

1) What type(s) of mechanical devices are you employing to keep the system aloft?

*Mechanical energy may be introduced via tethers. However Propellers such as with propelled hanggliders are a possible option in the future.*

2) What are the physical dimensions of the device(s) with relation to the above?

*If so, less than 10% of the wing surface.*

3) What kind of materials will comprise this device?

*The lightest affordable materials.*

4) What are the operational dimensions (requirement for airspace) for the system?

*See above.*

5) Is there a requirement to operate more than one device in the air?

*Definetly yes. Multiple units however, may share the same airspace.*

6) What are your long-term plans for this system?

*Further develop and commercialize units up to 100 kW … 1 MW*

**II) Marking and lighting.**

1) Can you comply with marking and lighting requirements?

*No suited marking and lighting requirement seems to be defined yet. Marking and lighting by neighbouring obstruction – might be suitable for the development process.*

2) Can you identify any impacts to your system when complying with current guidance for marking and lighting standards?

*Weight matters. No directed and constant light propagation possible. Additional power consumption .*

3) What are your plans or how is your system designed to make the system conspicuous to the flying public?

*See chapter 4.*

**III) Safety to other airspace users and persons and property on the ground.**

1) What safety mechanisms or devices have you designed into the system to ensure all aspects of aviation safety?

*Redundant sensors, inertial navigation unit, health monitoring,*

2) What safety mechanisms or devices have you designed into the system to minimize or mitigate hazards to persons or property on the ground?

*Weak-links, pyrotechnical cutter, soft wings.*

**IV) Minimized impacts to NAS facilities.**

1) What are your plans or how is your system designed to reduce a large radar cross-section and become less conspicuous to surveillance systems?

*This has not become an issue with EnerKites current permit to fly. Radar cross-section is a possible subject to optimization. We wonder if the impact of conventional wind energy converters must be significantly higher.*

2) What are your plans or how is your system designed to reduce impacts to any communication or navigation systems supporting the NAS?

*AWES may have a very particular flight- / radar characteristic. In addition the actual position and orientation of the wings are well defined in their flight. We suppose that in the future*

**V) Final questions**

1) What safety implications do you foresee of AWES operations with respect to your use of the airspace or your interest to the NAS

*No safety implications are*

2) Would you have any concerns about AWES permanently operating at altitudes above 500 feet AGL, but, under 1,999 feet AGL? If so, what and why?

*Upper limit is fine. Lower limits might be lower.*

3) What other concerns and/or issues might you have with respect to AWES co-existing in the NAS?

*Where there's a will there's a way.*