Concept presentation: Conversion of old nuclear plants

Content

Introduction / Problem description

General problems in the nuclear energy sector in Germany and other countries.

- Many of the old nuclear power plants (NPPs) are shut down too early. Many parts of the plant systems can still be used for decades if they continue to be maintained.
- Even after the end of NPPs design life time (40-60 years), the majority of systems can still be operated in non-nuclear applications. NPPs life time in nuclear operation is mainly limited due to non-replacable components (e.g. reactor pressure vessel).
- The cost of dismantling old nuclear power plants is very high. In Germany alone, the cost is estimated at over 40 billion euro.
- The shift from conventional and nuclear energy to renewable energy is very costly while the available systems are not capable to provide stable and reliable base load electricity.

Introduction / Goal

Instead of the complete decomissioning and costly dismantling/destruction of the old nuclear plants, it was the aim to identify technologies to re-use those plants in modified ways. The focus was set on the sector of energy generation and storage as most plant systems had been designed for this purpose.

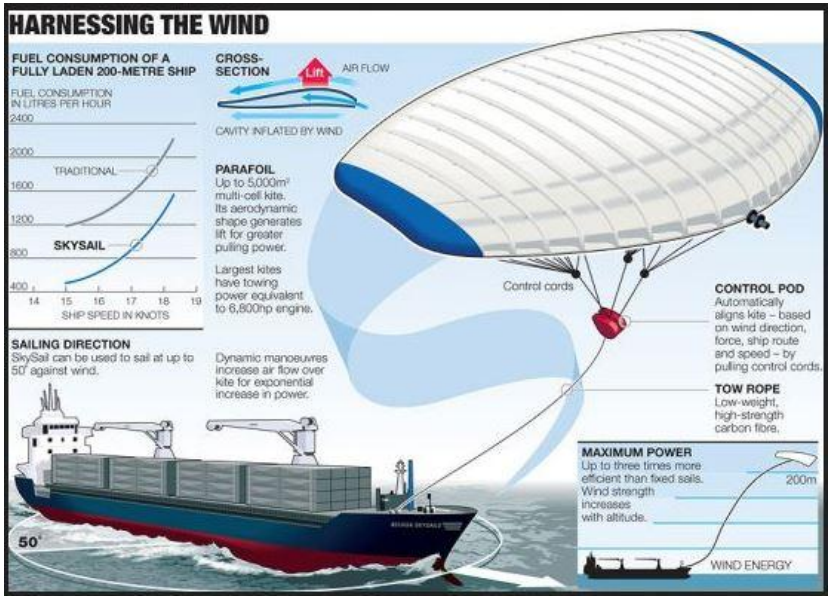
The following slides present technologies which could be applied on the mentioned plants in order fullfill the above described goal.

Technology 1: Kite power plants

Objective

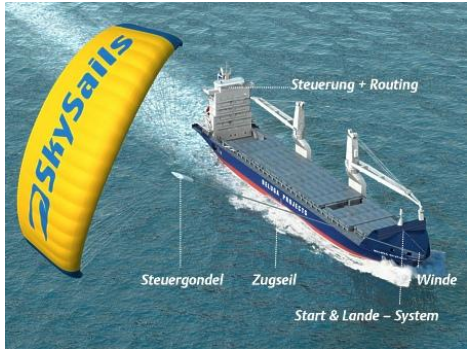
Continuous, baseload-capable, centralized energy generation

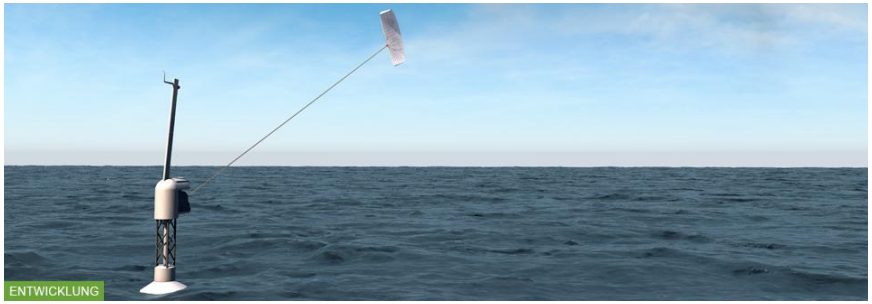
- Kites are not only used as sports equipment
- As so-called skysails, they serve as ship propulsion
- Kites work at heights of up to 400m (at these heights the winds blow much more steadily)
- The largest kites are in the 5MW range



Technology 1: Kite power plants

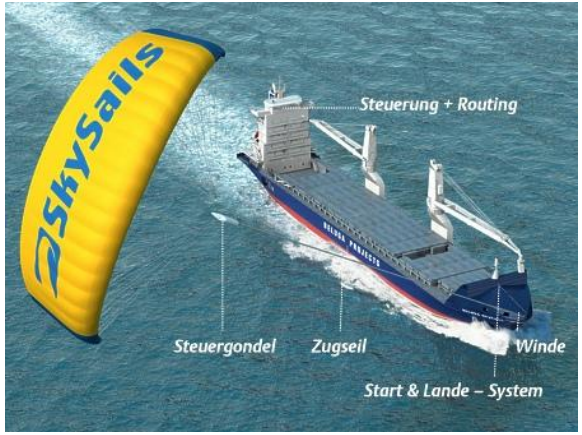
- The development was directed from ship propulsion to power plant application
- Enerkite, among others, is developing larger offshore systems
- Disadvantages include the location and the discontinuous working method





Enerkite Kite power plant

Technology 1: Kite power plants



Kites can be used to perform continuously circular/elliptical movement.

Technology 1: Kite power plants

Kite power plants on railways.

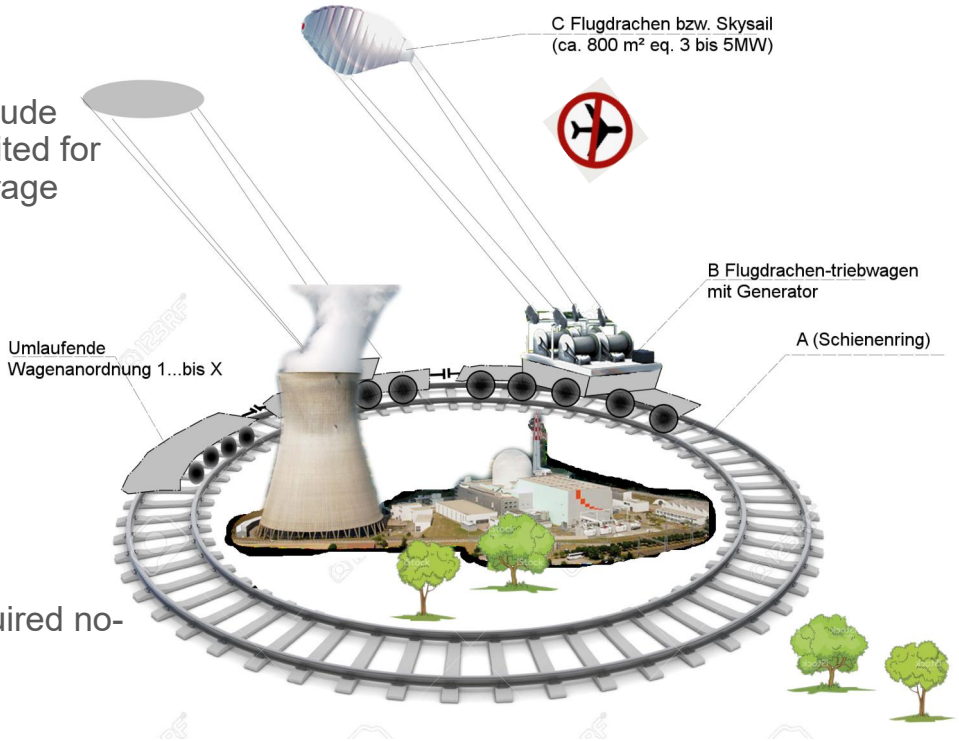
NTS energy and transport systems develops stationary systems.

NTS Energie- und Transportsysteme

Technology 1: Kite power plants

Advantages of this type of power plant

- Works with constantly prevailing high-altitude winds (H400m) and is therefore better suited for base load backup (avoids the energy storage problem of other renewable systems)
- Is suitable for large land based central application.
- Scalable to several hundred MW per unit.



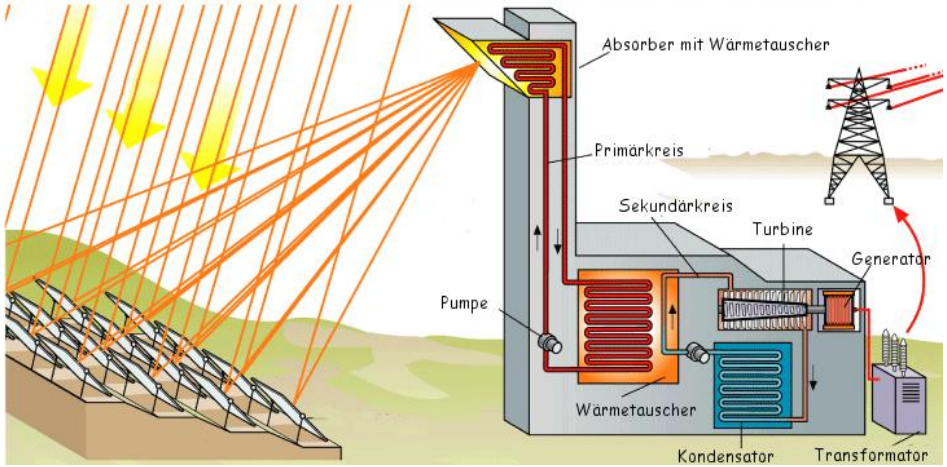
Specific advantages

- The location of a old nuclear power plant provides the central facilities and the required no-fly-zone.
- Usage of existing grid connection.

Technology 2: Solar thermal power plants

Objective:

Continuous, central energy production by bundling solar energy and transferring it to a water or steam cycle and converting it into electrical energy with the help of a turbine and generator.



Basic function of existing solar tower plants

Technology 2: Solar thermal power plants

Advantages

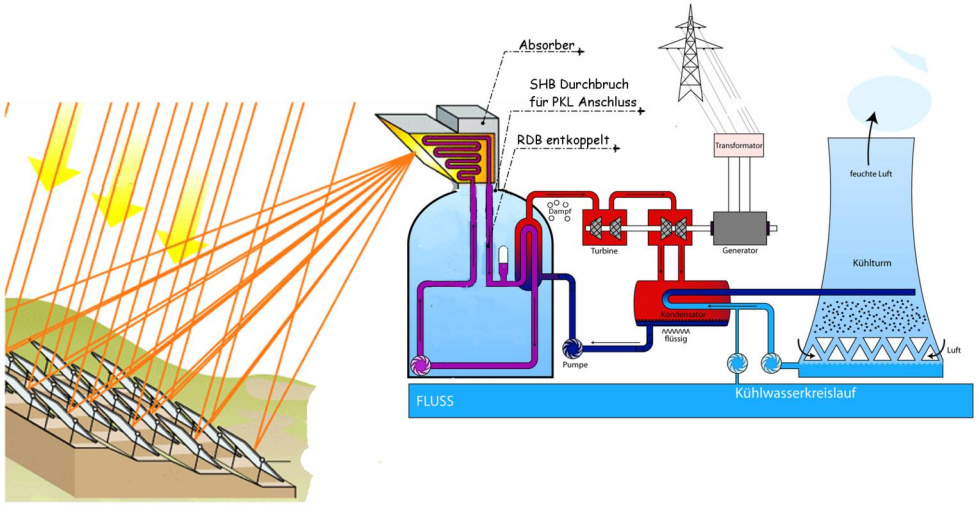
- Higher efficiency compared to photovoltaic systems
- By using heat storage, electricity production can continue even after sunset.
- In comparison to photovoltaic systems, the available residual heat can be used for other processes.

110 MWel plant USA (Crescent Dunes Nevada)

Technology 2: Solar thermal power plants

Integration of a solar thermal plant into a old nuclear power plant after core removal, decontamination of the primary circuit and connected system.

- The cooling circuits of the primary and secondary circuits are suitable for heat dissipation with high power density which is essential for solar thermal power plants
- The entire cooling chain and steam chain for energy production can continue to be used.
- The auxiliary systems can continue to be used



Primary-side integration into a PWR (secondary-side integration as an evaporator or primary side in the BWR is also an option). Solar absorber directly feeds into the primary system (core removed, containment penetrated).

Technology 2: Solar thermal power plants

Existing solar thermal power plants are focusing on molten salt and salt absorber due to high heat density and costly water systems. Those disadavantages can be solved by using old nuclear power plants as the systems are specifically designed for this application.

WT-Medium	Vorteile	Nachteile
Wasser, Wasserdampf	• thermische Stabilität • niedrige Viskosität (n < 1cSt bei Raumtemperatur) • hohe spez. Wärmekapazität (Wasser ca. 4,2 kJ/kgK) • hohe Verdampfungsenthalpie • hohe Wärmeleitfähigkeit • ungiftig • nicht brennbar • nicht umweltgefahrdend • preiswert • hohe Verfügbarkeit	• geringe Siedetemperatur bei p_{atm} • aufgrund von Korrosionsneigung und Wasserhärte (Mineralien) bei höheren Einsatztemperaturen teure Aufbereitung erforderlich • hohe Drücke bei Heißwasserkesseln mit hohen Vorlauftemperaturen
WT-Öl	• hoher Siedebeginn (Mediumstemperatur bin 400°C) Korrosionsneigung • keine Frostschäden	• Gefahr des Crackens bei lokaler Überhitzung, z. B. durch Ablagerungen oder durch zu geringen Volumenstrom • Alterung, thermische Zersetzung • Geringe Wärmeleitfähigkeit (ca. 0,1 bis 0,15 W/(m*K))
Salzschmelzen	• hohe Mediumstemperatur möglich (bis >800°C) • nicht brennbar • ungiftig • hohe thermische Beständigkeit	• nicht in Verbindung mit Gusseisen und Leichtmetallen einzusetzen
Metalle	• hohe Mediumstemperatur möglich (2000°C) • hohe Wärmeleitfähigkeit • hoher Siedepunkt • hohe Mediumstemperatur möglich (bis >800°C)	• Korrosionsgefahr • Umweltbelastung

Tabelle 3. 2: Vorteile und Nachteile von verschiedenen Wärmeträgermedien

Source: “Auslegung eines Solarturmkraftwerks mit überkritischem Dampfprozess (Saeed Dehghan Moeini/ DLR und Uni Kassel / 05-2007)”

Disadvantage of water cooling circuits for solar thermal power plants are neglectable when old PWRs are used.

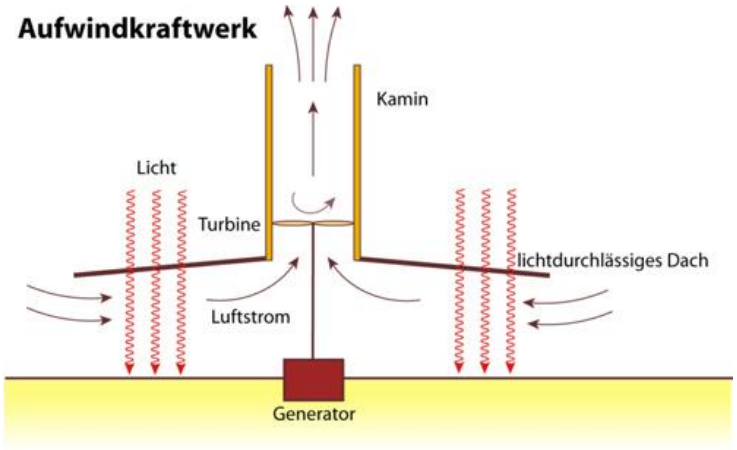
- Low boiling temperature at atm pressure
- Expensive aux systems required when operated at higher temperature/pressure
- High pressure has impact on system design and cost

Technology 3: Updraft power plant

Objectiv

Continuous, central energy generation using the buoyancy (difference in density) of warm air.

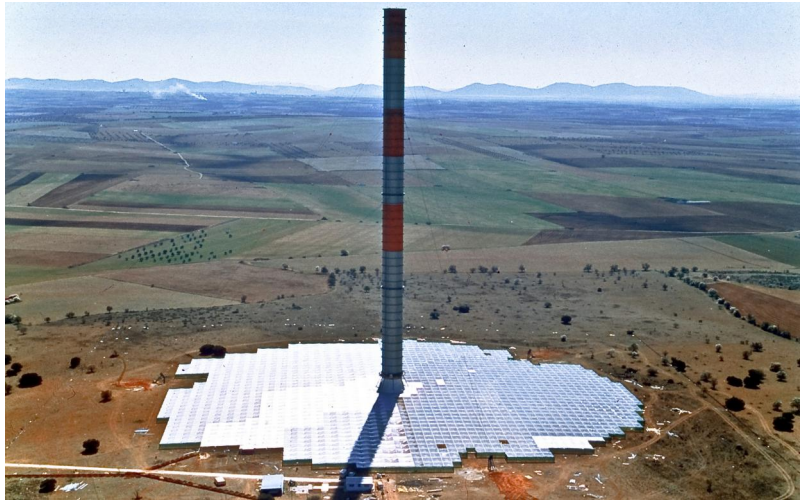
- Usage of low-temperature solar or thermal energy (e.g. residual heat of plant cooling chain)
- Low maintenance costs, simple technology
- In combination with heat storage, a updraft power plant can also be operated at low temperatures at night



Technology 3: Updraft power plant

Disadvantage of common updraft power plants

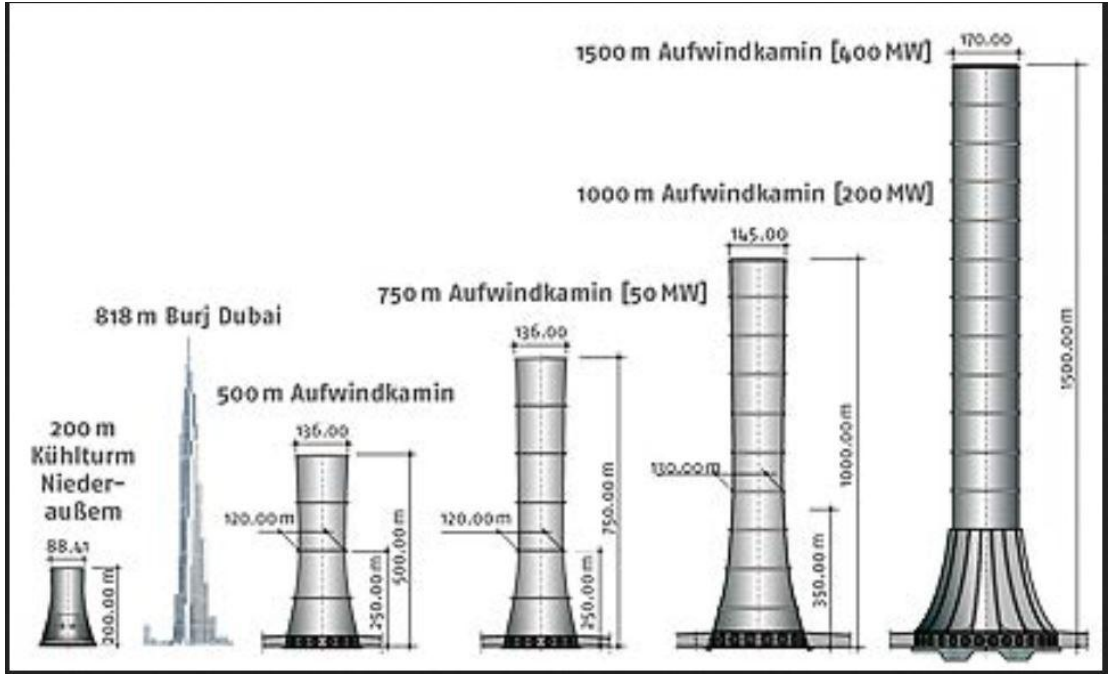
- Vulnerable to storms
- High construction heights are necessary for profitable systems, very costly
- Large areas required



Prototype Updraft plant in Manzanares power= 50 kW

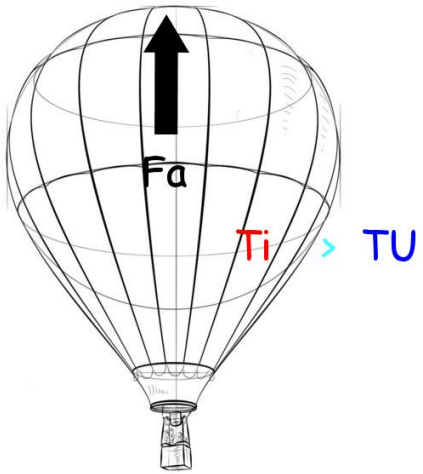
Technology 3: Updraft power plant

Power and building size

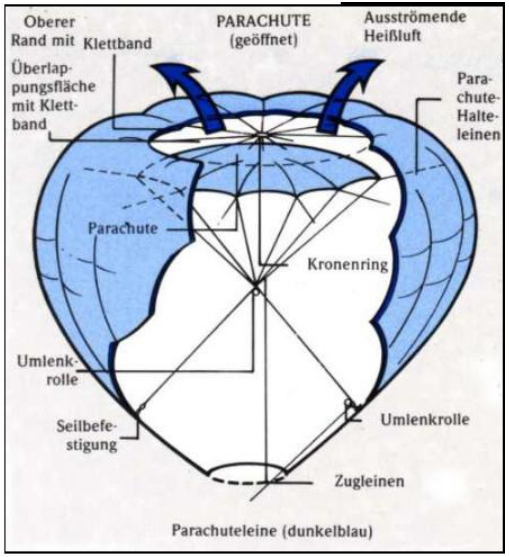


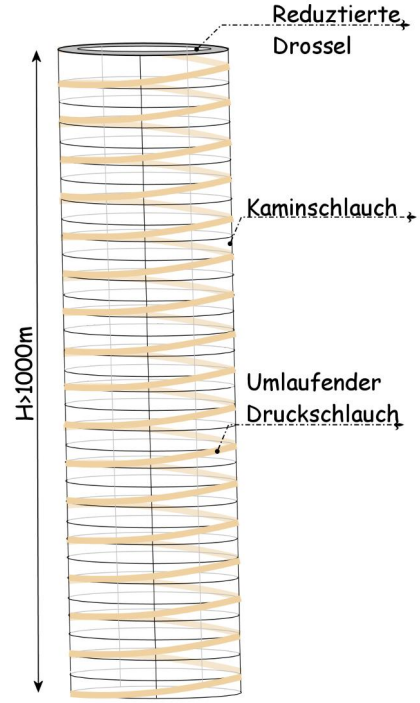
Technology 3: Updraft power plant

Design change suggestion for updraft channels



Principe of a hot air balloon

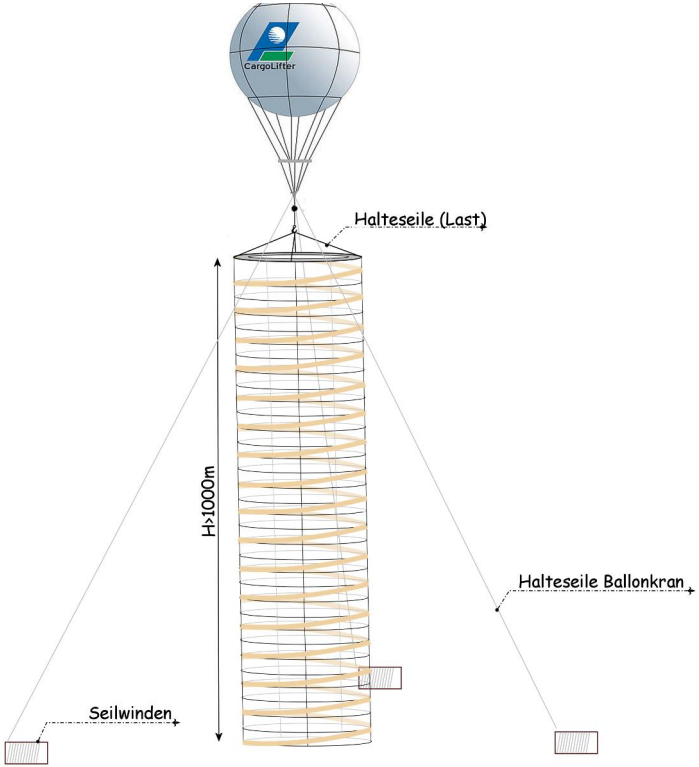




Flexible light weight (parachute silk) upwind channel with pressurized air spiral

Technology 3: Updraft power plant

Design change suggestion for updraft channels



Flexible upwind channel
with pressurized air spiral

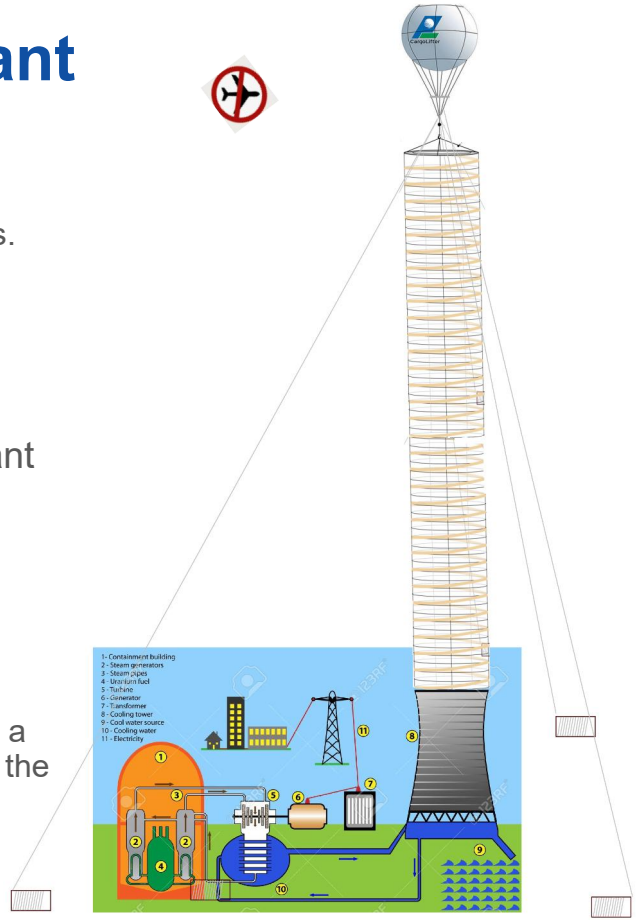
Technology 3: Updraft power plant

Advantages

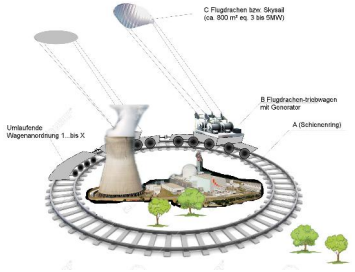
- The tower construction is significantly cheaper than rigid channels.
- Significantly higher tower height and performance is possible
- High tensile strength, high flexibility for strong winds
- Quick shutdown possible in case of strong storms

Specific advantages when integrated into a nuclear power plant

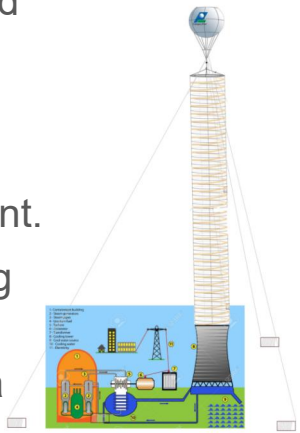
- Approval of a no-fly zone is easier
- The existing cooling tower of the PWR can be used.
- The heat exchangers in the cooling tower can be used.
- Existing grid connection can be used.
- When combined with a thermal solar power plant (see Section 2), a significant increase in overall efficiency can be achieved by using the low-temperature heat in the updraft channel.



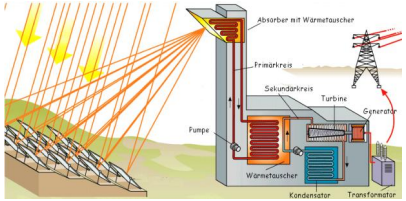
Our Vision
One research facility as an overall concept



Building one test and research facility, directly integrated in one old NPP, to test prototype technolgies for NPP conversion.



- Renewable energy sources are on the agenda in the next decades even if conventional energy sources stay most relevant.
- Sufficient old nuclear plants are available for de-commissioning due to ending liftime.
- Lifetime issue and high deconstruction cost of NPPs remains a major issue.
- A new pioneering position can be established when it comes to conversion and retrofit projects for old NPPs.
- The energy storage issue, which is very critical issue for the renewable energy sector, can be partially or completely solved if power generation is less interrupted.



Benefits of a research facility

- Know-how development in the area of renewable energy generation
- The continued operation of system components enables the test operation of new operating methods and arrangements
- R&D projects as well as product developments for international nuclear retrofit projects can be carried out.
- Improving plant safety through realistic tests, including accident tests are possible (because the decontaminated research facility provides ideal test boundaries for tests which are relevant for nuclear safety like e.g. loss of coolant accidents)
- If the conversion of NPPs can be done successful, the decommissioning and desctruction costs can be safed.
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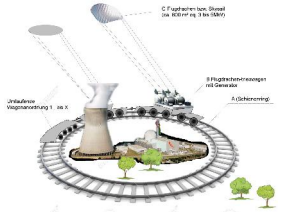

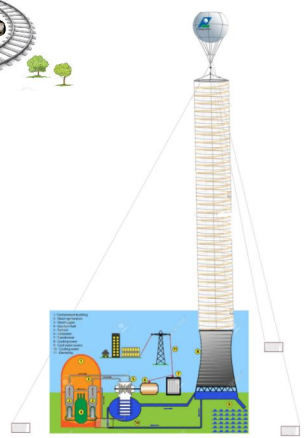

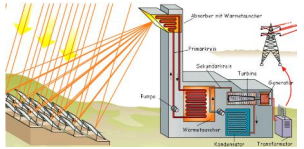

Thank you for your attention.