Energy from the Sun and Nuclei

Royal Swedish Academy of Sciences
Food or Biofuel
Solar Energy
Continental Electric Power Grids
High Temperature Superconductor Grids!
Energy Amplifier and Waste Transmutation
Norweigan Thorium
Generation III and IV Reactors
Fusion Energy
0. Conclusions

Presentation at the 75th Birthday Celebrat

in the honour of Prof. Carlo Rub

CERN 7 April 2

Sven Kullan

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KUNGL. VETENSKAPSAKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

Nobel Prize 1984 to
Carlo Rubbia and Simon van der Meer, CERN,

r their decisive contributions to the large project, which led to the discovery of t
field particles W and Z, commmunicators of weak interaction

The Royal Swedish Academy of Sciences

- Promotes science in particular natural science
- Awards a number of different prizes
  - Nobel Prizes in Physics and Chemistry
  - Swedish State Bank's Prize in Economy
- Strengthens the role of science in Society
  - Energy Committee
  - Health Committee
  - Committee on Research Policy
  - Environment Committee
  - School Committee

Food or fuel?

1700 kJ/100g

Energy contents

Unit is mega joule (MJ)

1 kg	MJ
Sugar	17
Bread	12
Ham	11
Cucumber	0.6
Whisky	10
Ethanol	27
Gasoline	43

Daily need: 10 MJ

Global agriculture products in 2007

Cereals	2 228 million tonnes
Meat	265 million tonnes
Fruits/Vegetables	1 392 million tonnes
Roots/Tubers	712 million tonnes
Pulses	62 million tonnes
Oilseeds/Nuts	146 million tonnes
Sugar Crops	1 532 million tonnes
Tobacco	7 million tonnes
Fibre Crops	29 million tonnes
	6 373 million tonnes ~ **1 tonne/capita**

UN FAO data

Energy in all this biomass is 16 000 TWh!

Global energy supply 2007

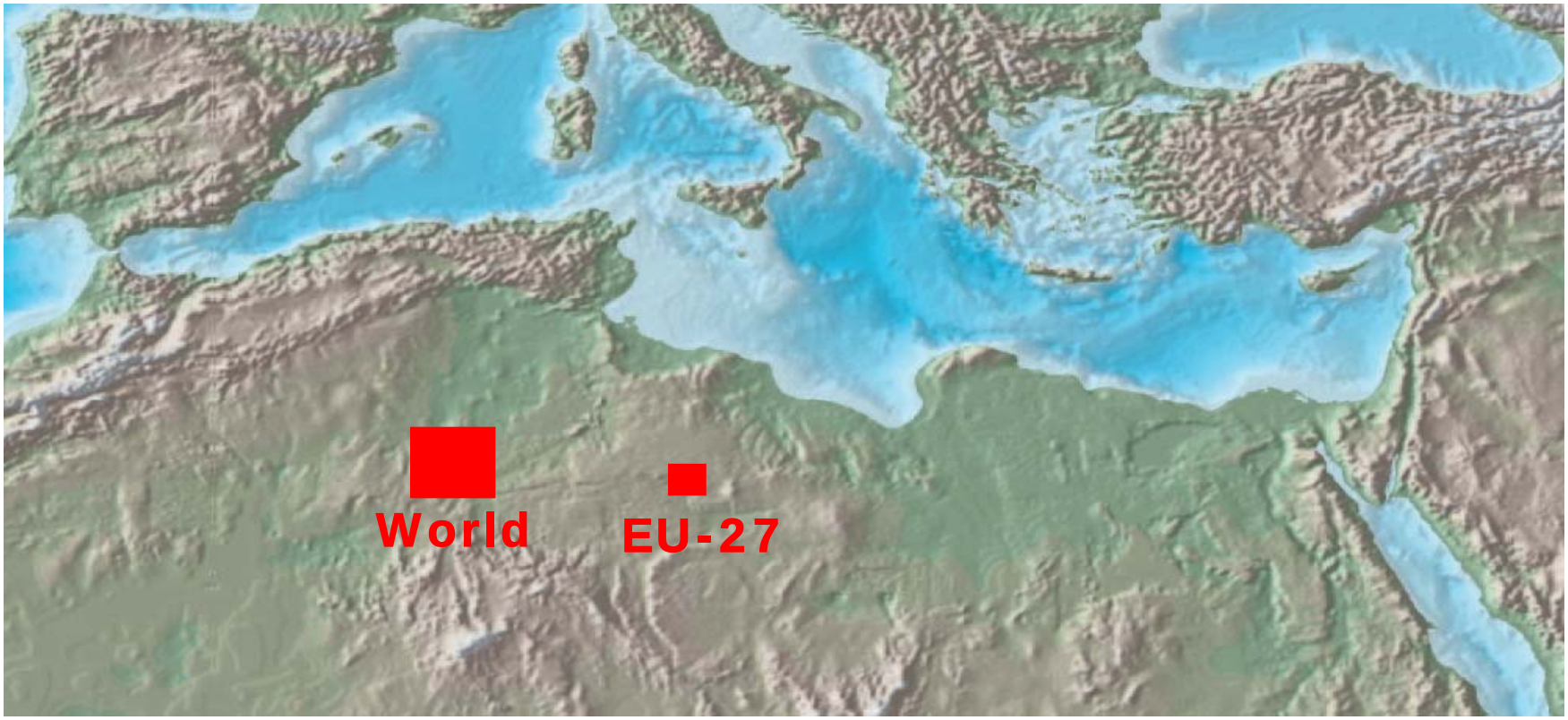
tal energy production	125 000 TWh	100%
ssil energy production	100 000 TWh	80%
agriculture products	16 000 TWh	12%
od for 6.7 billion people	7 100 TWh*)	5.7%
billion litres of biofuels	300 TWh	0.3%

od energy on all the world's tables
9 kWh/day x 365 x 6.7 x 10^9 = 7 100 TWh

Solar energy

+ Unlimited, renewable
− Intermittent, land requirements

Areas needed to capture solar energy

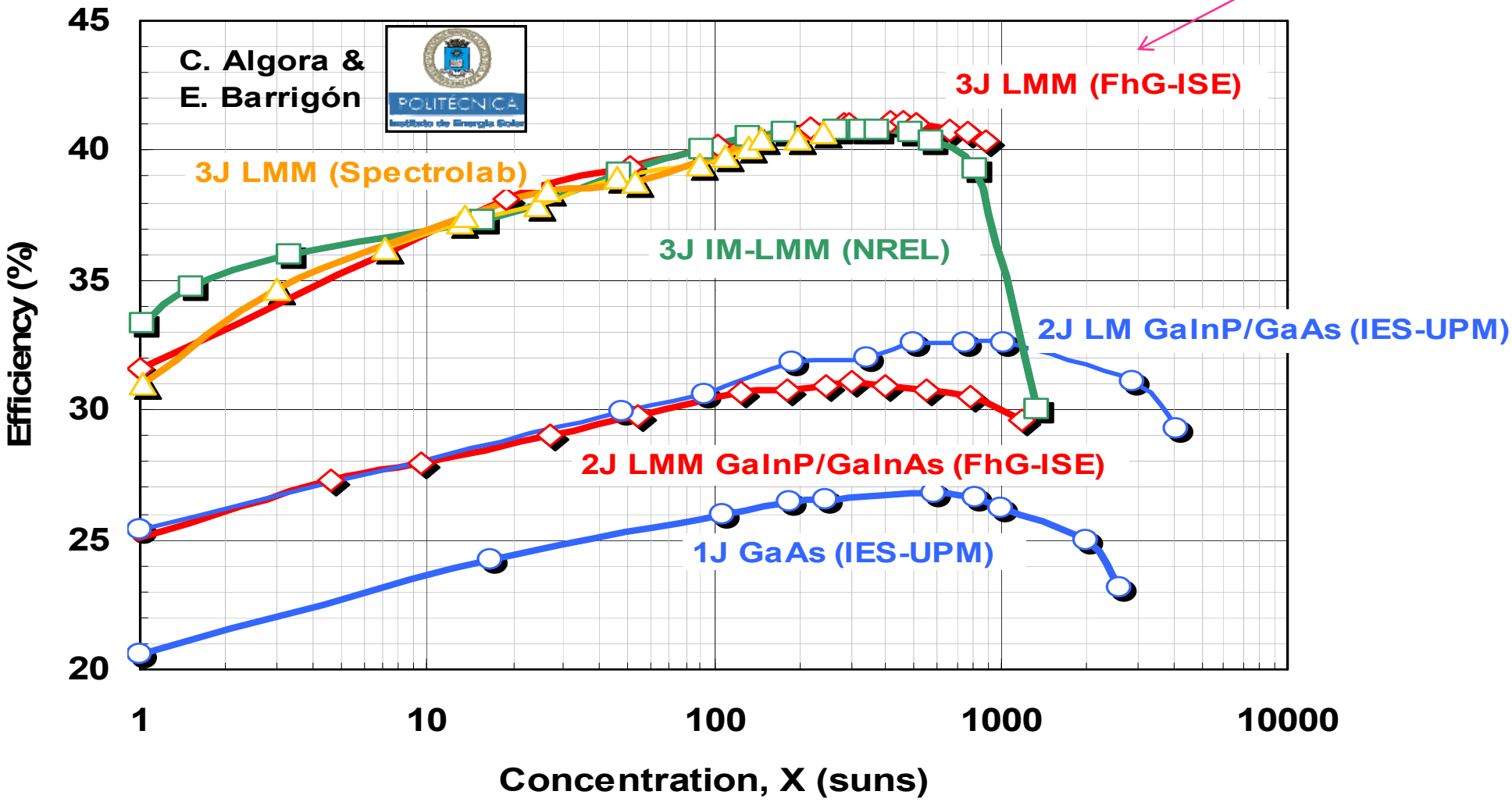


Concentrating PhotoVoltaics (CPV)
Concentrating Solar Power (CSP)

Concentrating sunlight with mirrors

Concentrating PhotoVoltaics

3-junction cells give 40% sun-to-electric conversion efficiency!



Concentrating Solar Power– a major option!

Sun light is concentrated by mirrors onto a liquid (top) which is heated to several hundred degree
The liquid is stored in tanks. Steam is taken out day and night to turbines for electricity generatio

olar Two in the Mojave desert, a prototype 10 MW CSP, operated between 1995 and 1999 using 1
eliostats. It used molten salt nitrates as an energy storage medium. Solar Two was decommissioned
1999, and was converted into an Air Cherenkov Telescope CACTUS.

The Archimedes CSP project on Sicily

Nobel Prize winning physicist Carlo Rubbia, president of the alternative energy agency ENEA opened the pilot of the Archimedes solar power plant in 2004. The prototype on industrial scale will supply energy to the town Priolo Gargallo

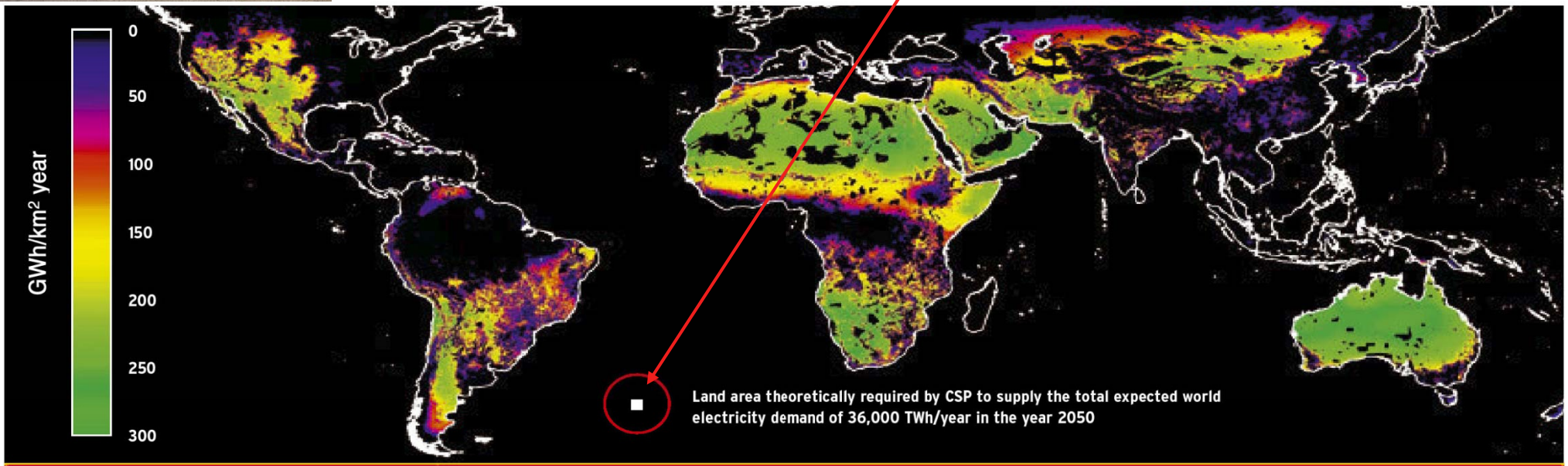
.

The solar plant consists of a solar field of 40 acres, a storage system and a steam generator. In the modular solar field, the solar energy is collected in 360 linear parabolic collectors. ENEA introduced a new fluid heat carrier (mixture of sodium and potassium) in order to increase the operating temperature and the possibility of storing heat. Another innovation is the design of a new type of concentrator based on thinner mirrors.

Concentrating solar power

From Carlo Rubbia's Nobel Symposium presentation, June 2005, Sweden

Land area theoretically required by CSP to supply the total expected world's electricity demand of 35'000 TWh/year in2050

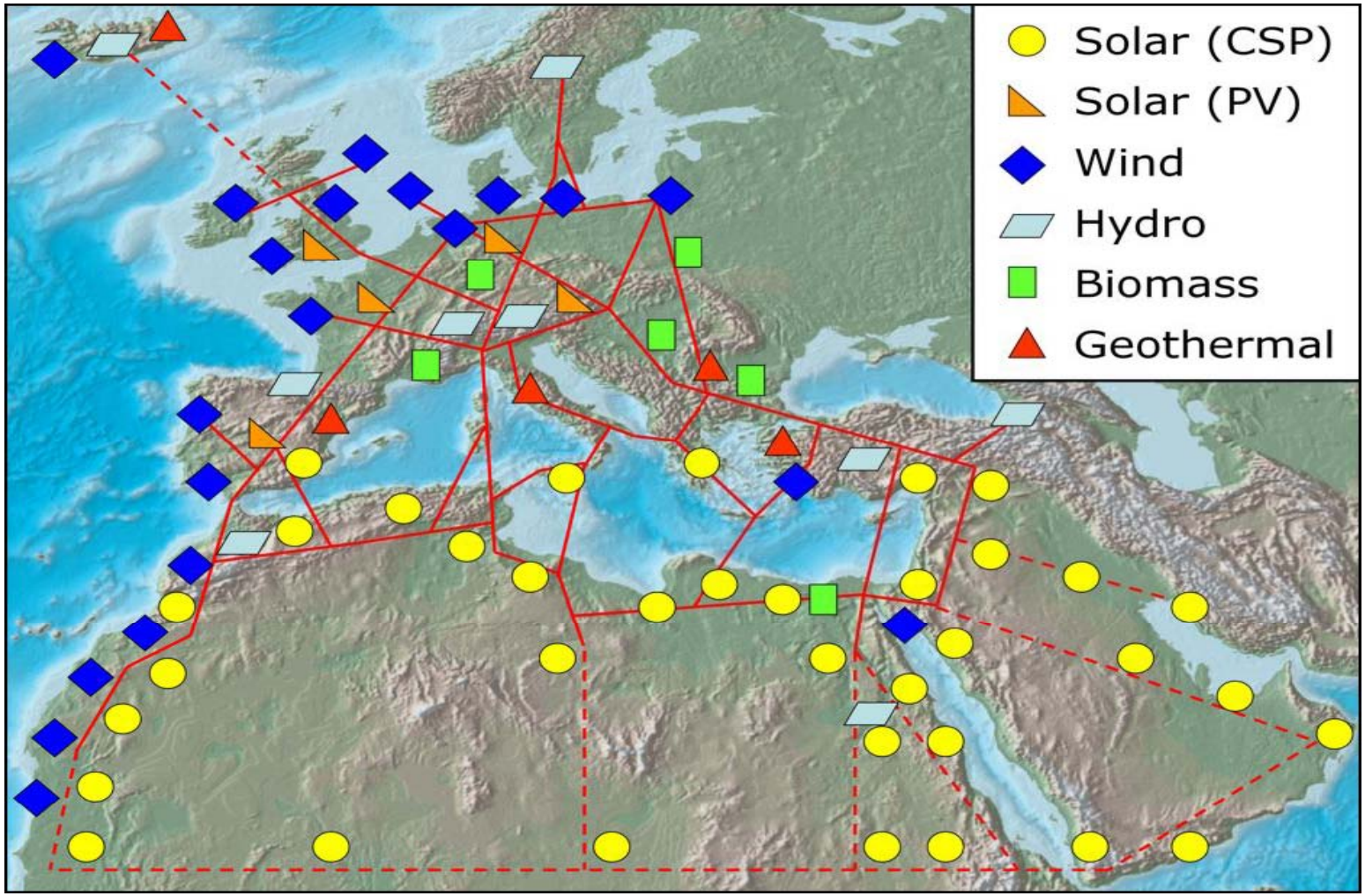


World wide potential of solar electricity generation by CSP in GWh/km² year (based on radiation data from G. Czisch, ISET).

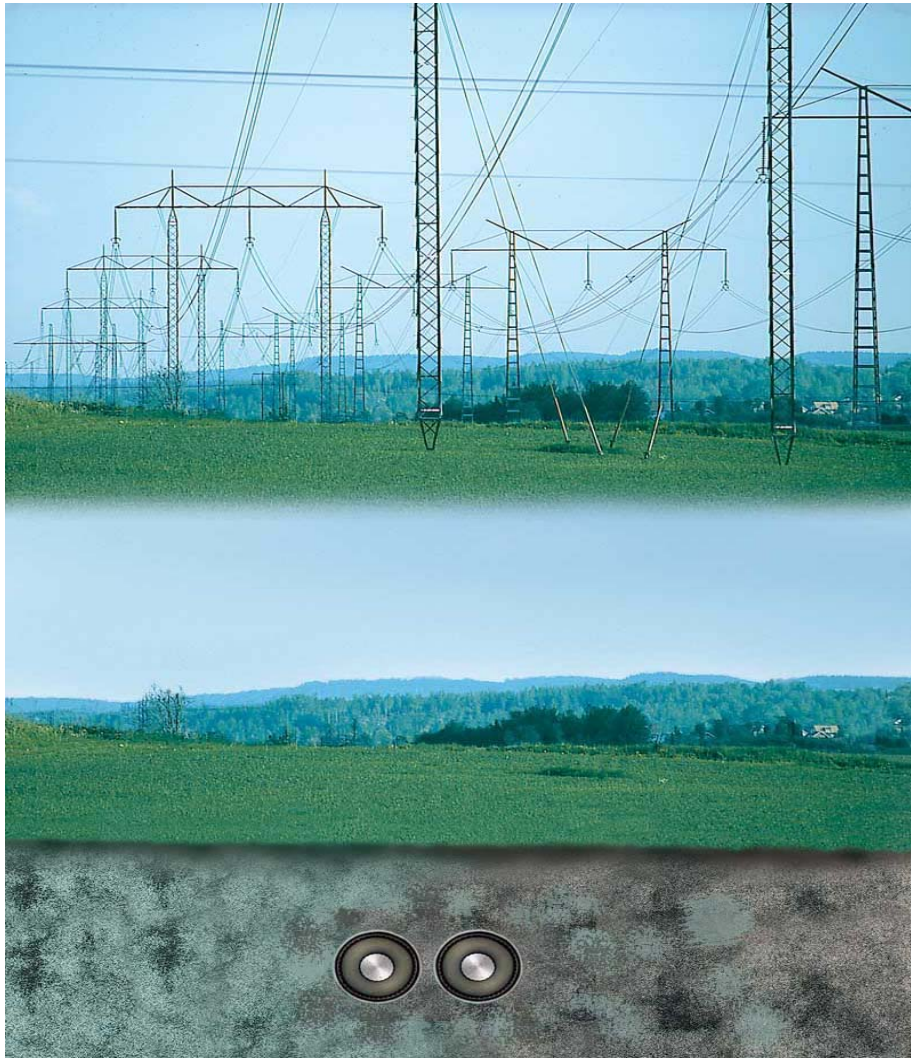
Gerhard Knies presentati
at the Solar energy sympos
In Stockholm, June 200

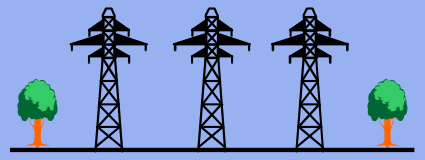
DESERTEC-project

Solar energy from the South



Corridor





Conventional HVAC

HVDC

HVDC – An alternative for power transmission?

High-temperature superconductors (HTS)

. Alexander Müller and J. Georg Bednorz 1987 Nobel Laureats in Physics fo
mportant break-through in discovery of superconductivity in ceramic materia

The best known high-temperature superconductors are bismuth strontium calcium copper oxide, BSCCO and yttrium barium copper oxide, YBCO.

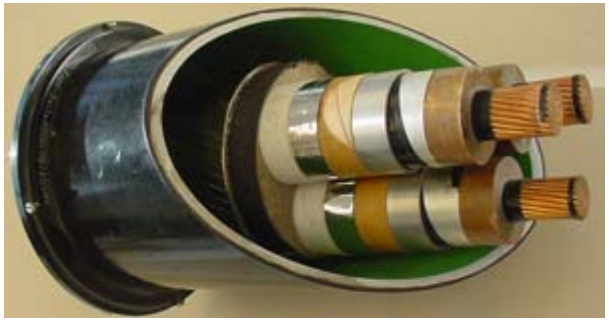
Liquid nitrogen can be used for the cooling!

High Temperature Superconductors (HTS)

In 2001, the first high temperature superconductior (HTS), a 30 meter cable, was installed into the Copenhagen electric power network.The purpose was to provide power (30 kV, 2.4 kA) to 50,000 customers on the island of Amager, (NKT Cables)

Results

After 2 years of autonomous operations in the utility substation, this project has successfully proven that HTS cables can operate in a utility environment.



WORLD'S FIRST TRANSMISSION VOLTAGE SUPERCONDUCTOR CABLE ENERGIZED IN LIPA'S POWER GRID

Hauppauge, NY - April 30, 2008

ong Island Power Authority (LIPA) and American Superconductor Corporatio
AMSC) announce operation of world's first high temperature superconducto
(HTS) power transmission system in a commercial power grid. The 574 MW
38 kV system consists of three individual HTS power cable phases running
parallel in LIPA's Holbrook transmission right of way. The cable utilizes HTS
re produced by AMSC and developed at **Brookhaven National lab**. The 60
meter long cable system is cooled by liquid nitrogen.

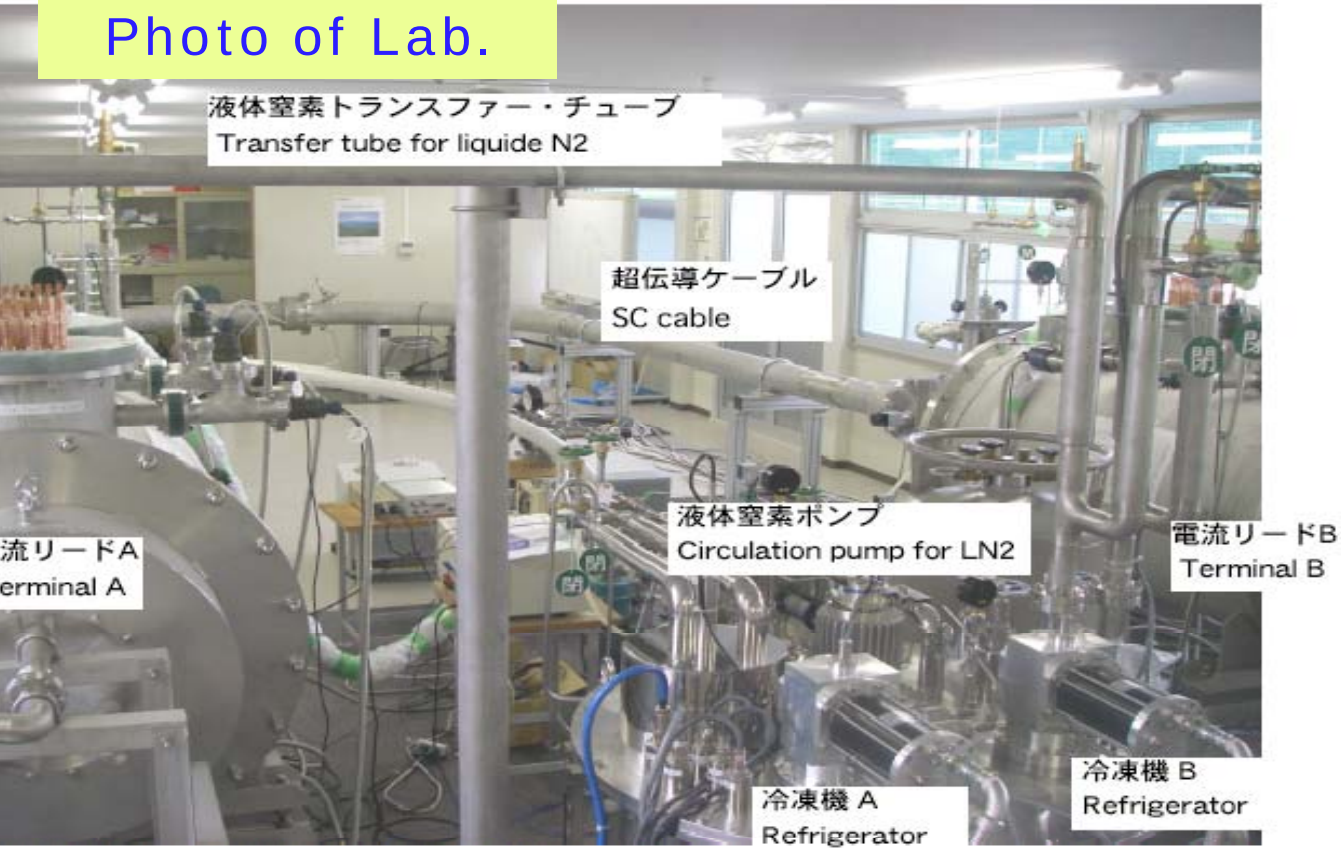
Major Step towards Electricity Superhighways!

Pipes containing HTS cables in Long Island

the pipes containing the HTS cables, capable of carrying 574 megawatts of power in a four-foot right of way.

First HVDC high temperature Superconductor (20 meter cable) in Chubu University

Photo of Lab.



20 meter: 2005 – 2009

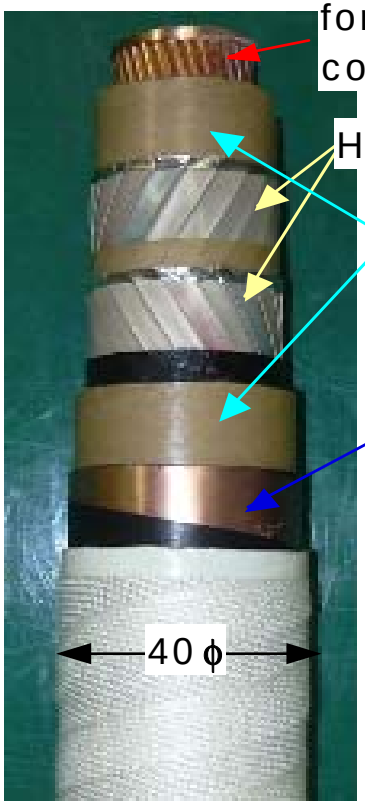
200 meter. Planned

20 kilometer: Final goal

Cortesy Satarou Yamaguchi

Cortesy Satarou Yamaguchi

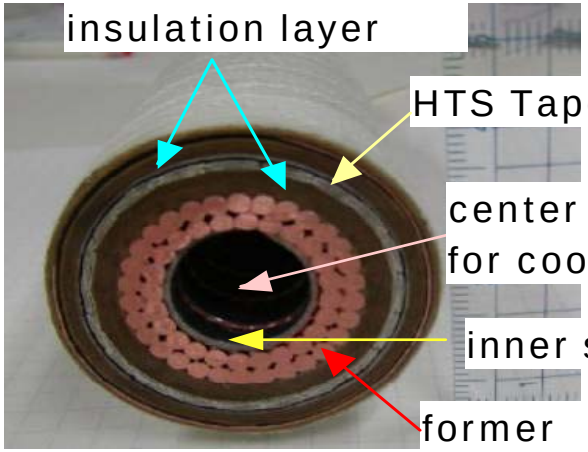
SC Cable, Photo & Spec.



Side View

made by Sumitomo

Photo of cross-section



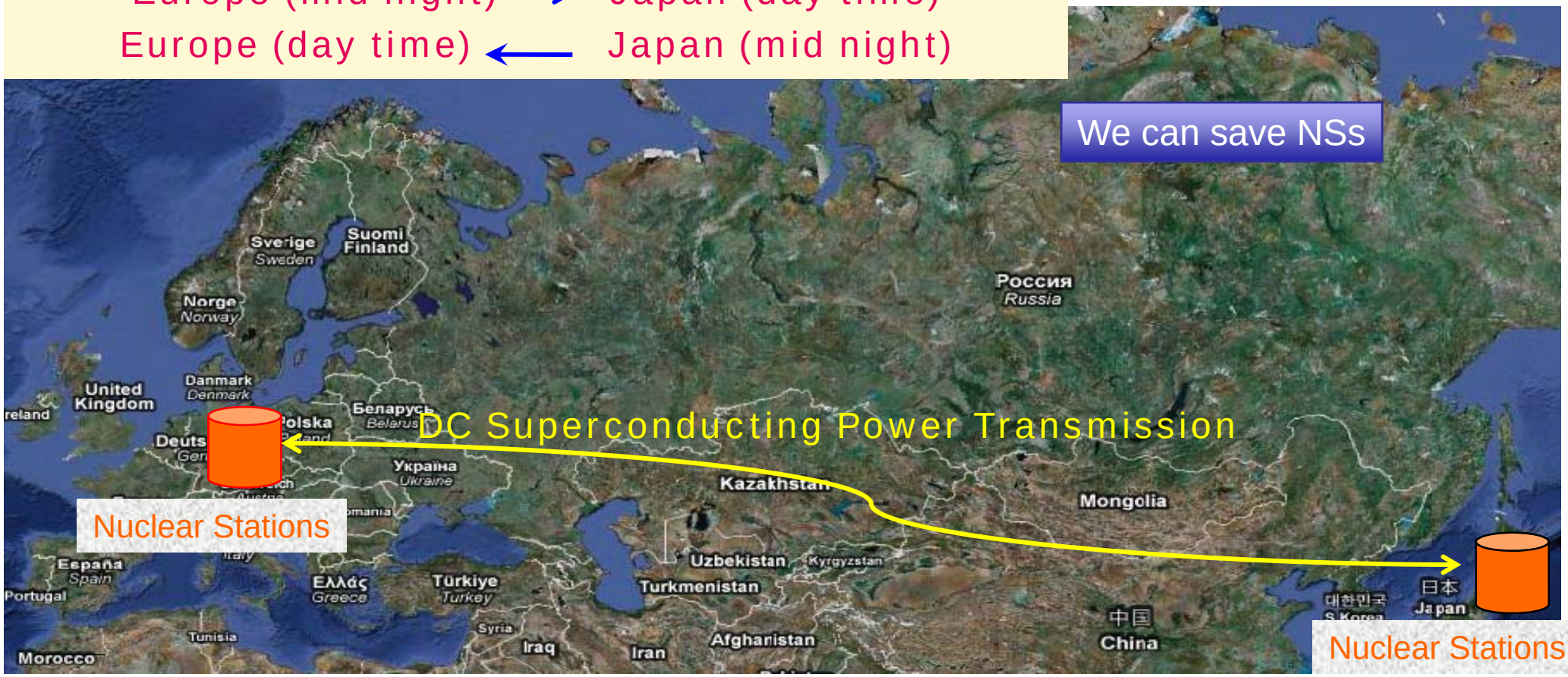
Tape conductor	**1st layer; 19 2nd layer; 20**	**Bi-2223/ 100A grade**
Insulation Volt.	**DC20kV**	**Insulator, PPPL**
Outer radius	**40φ**	**Center hole 14φ**

Satarou Yamaguch
Chubu University

A New Business with Nuclear Stations

Now we have ~350 Nuclear Stations in the World,
we will make ~2000 Nuclear Stations in 21st Century

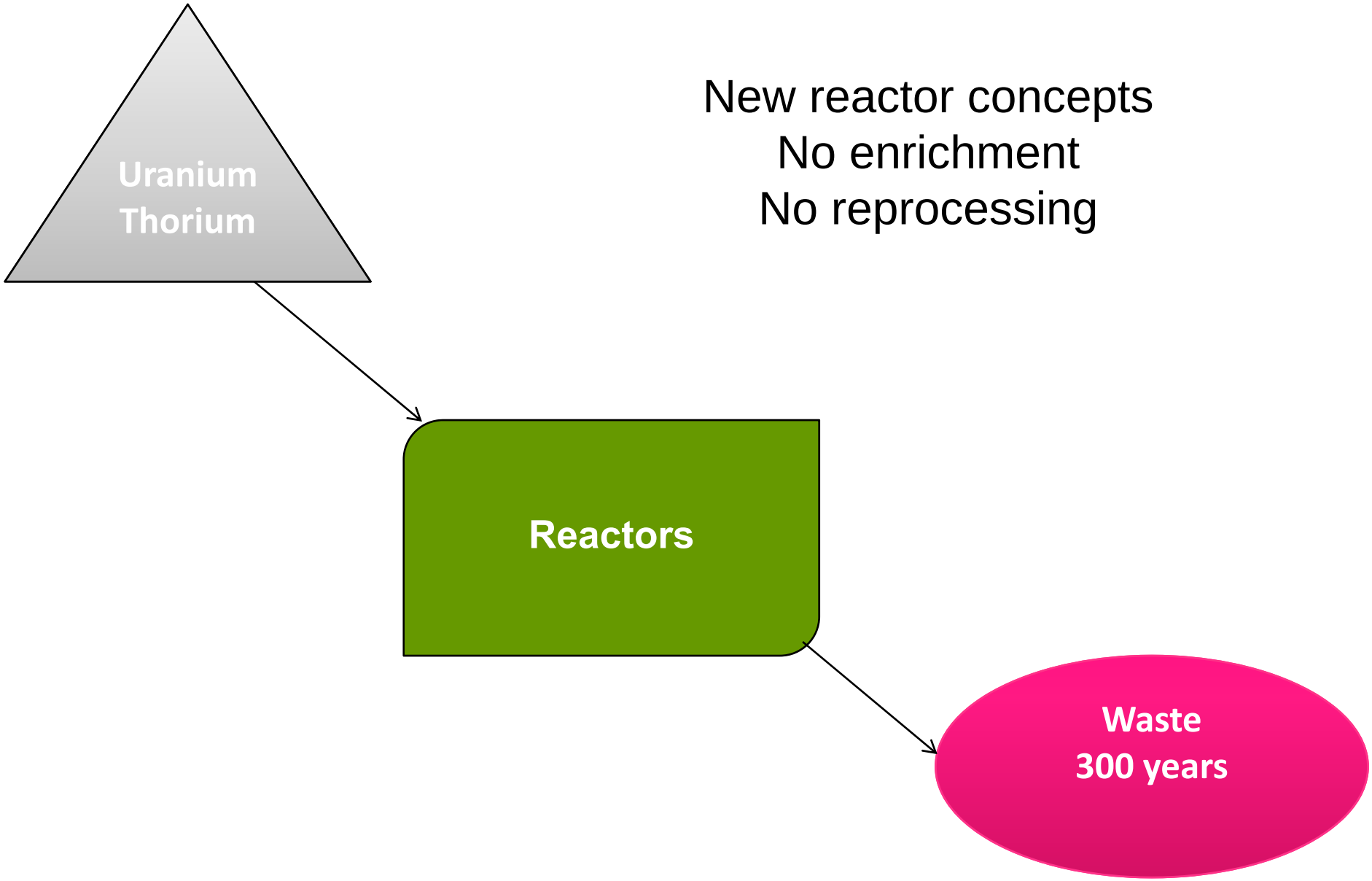
Europe (mid night) → Japan (day time)
Europe (day time) ← Japan (mid night)



Nuclear fission energy

+ sustainable, environment friendly, development potential

– long lived waste, operational safety, proliferation issues


Uranium
Thorium
New reactor concepts
No enrichment
No reprocessing
Reactors
Waste
300 years

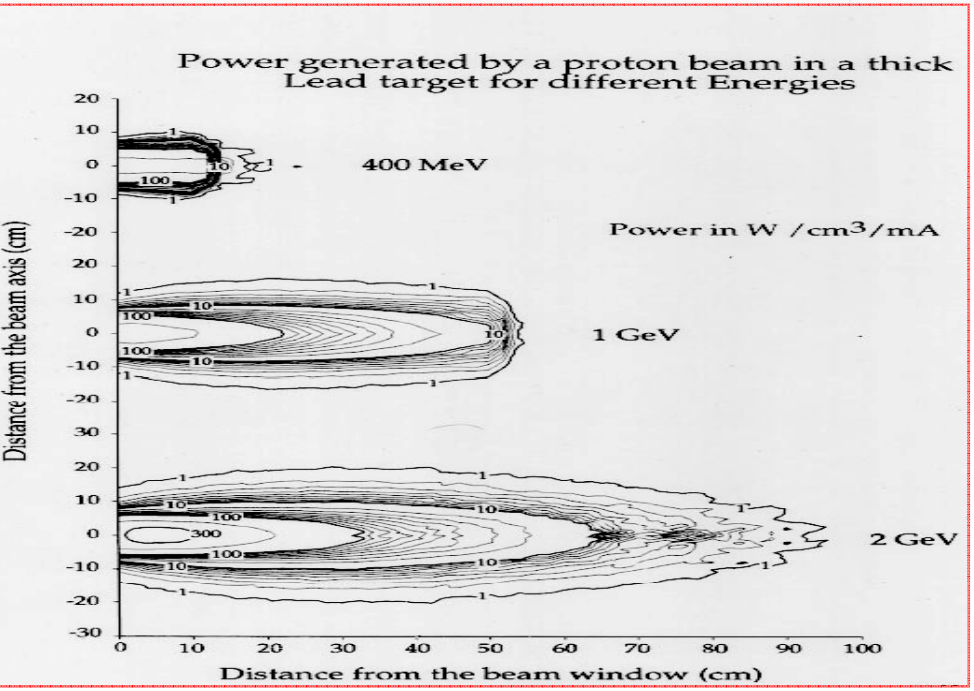
Principle of operation of the Energy Amplifier

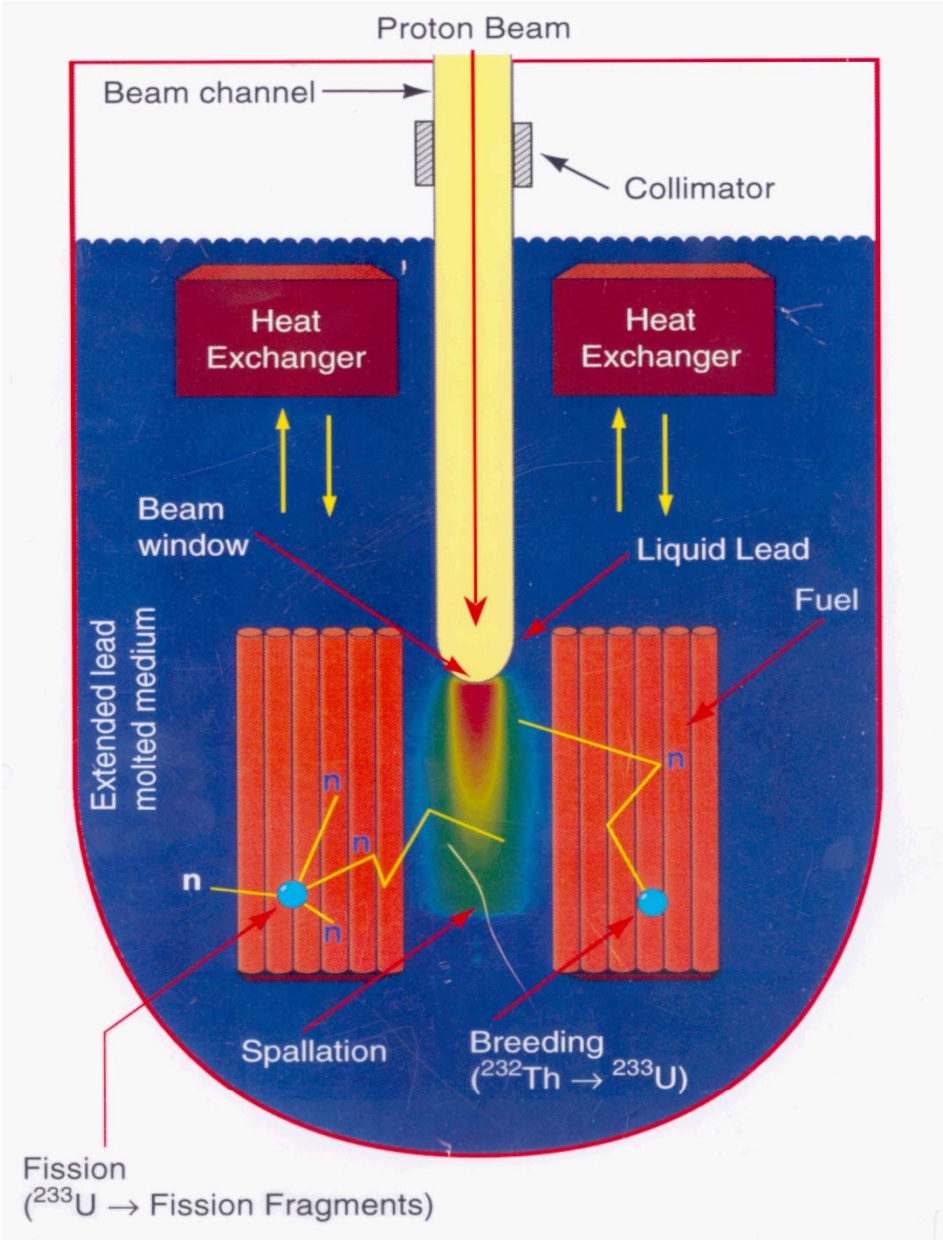
Thorium related Fission

$$^{233}_{92}U + {}^{1}_{o}n \rightarrow 2.53\left[{}^{1}_{o}n\right] + 2FF + 200\ MeV$$

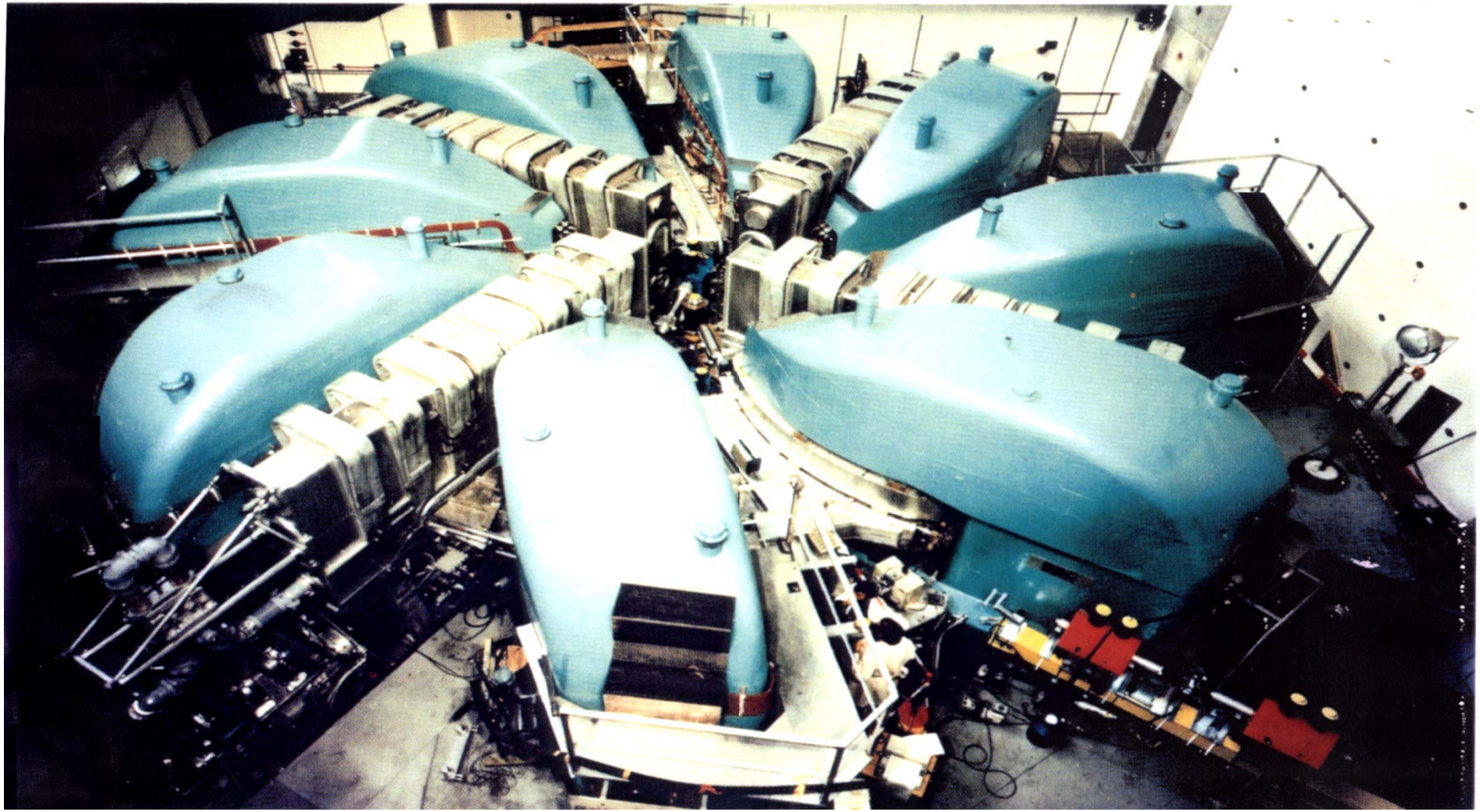
$$^{232}_{90}Th + {}^{1}_{o}n \rightarrow {}^{233}_{91}Pa + \gamma \xrightarrow[(27\ days)]{\beta-decay} {}^{233}_{92}U + {}^{o}_{-1}e$$

$$^{233}_{92}U + {}^{1}_{o}n \rightarrow {}^{234}_{92}U + \gamma$$





The 600 MeV cyclotron:PSI as a model



Present beam power ≈ 1 MWatt
Upgrade to about 3 x foreseen

The CERN TARC experiment

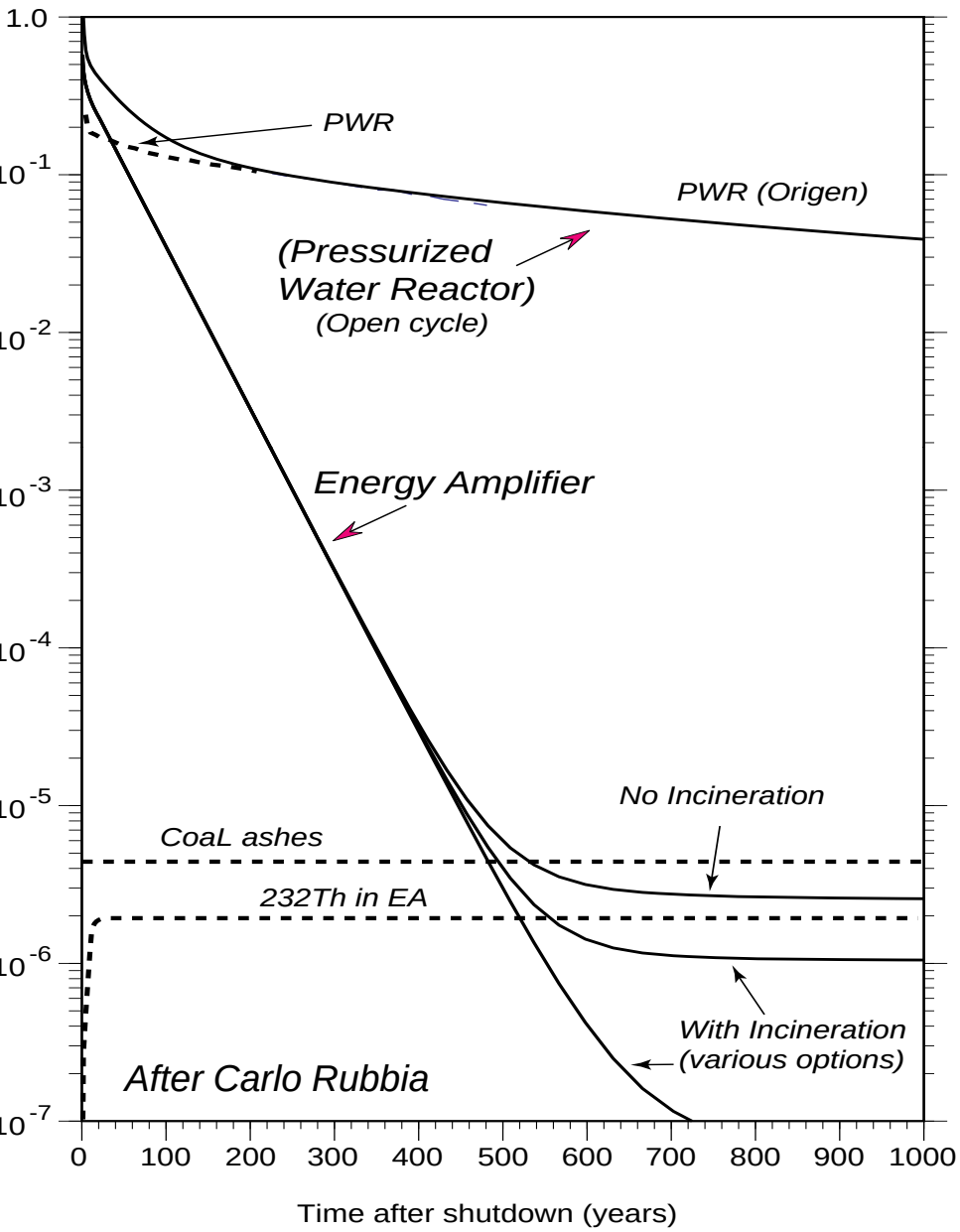
NIM 2002, vol. 478, nº3, pp. 577-730

The CERN TARC experiment demonstrated the possibility of using Adiabatic Resonance Crossing RC) to destroy efficiently Long-Lived Fission Fragments (LLFFs) in accelerator-driven systems and dated a new simulation developed in the framework of the Energy Amplifier programme.

Precision measurements of energy and space distributions of spallation neutrons
ng 2.5 and 3.5 GeV/c protons) slowing down in a 3.3 m x 3.3 m x 3 m lead volume and
eutron capture rates on LLFFs ^{99}Tc, ^{129}I and several other elements were performed.

t will be possible to destroy, in a parasitic mode, outside the Energy Amplifier core, large amounts of
c or ^{129}I at a rate exceeding the production rate, thereby making it practical to reduce correspondingly
existing stockpile of LLFFs.

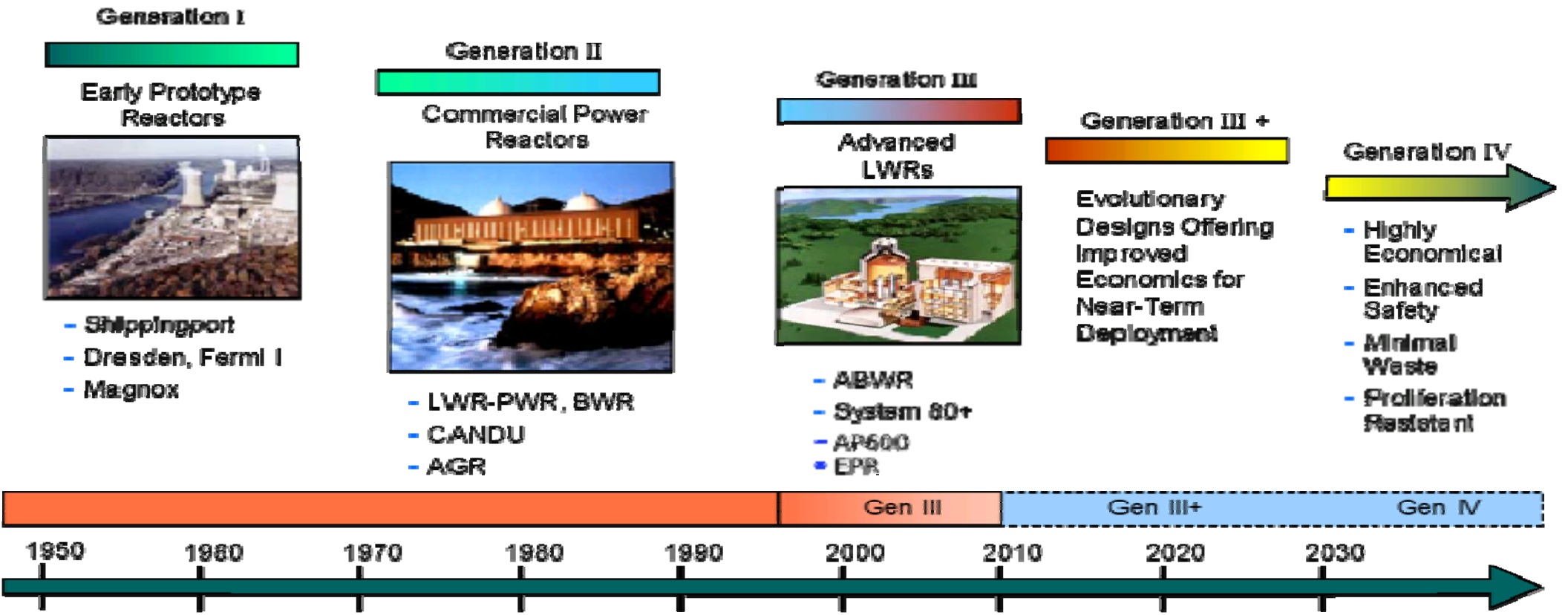
Radiotoxicity versus time for various transmutation alternatives using thorium and the Energy Amplifier



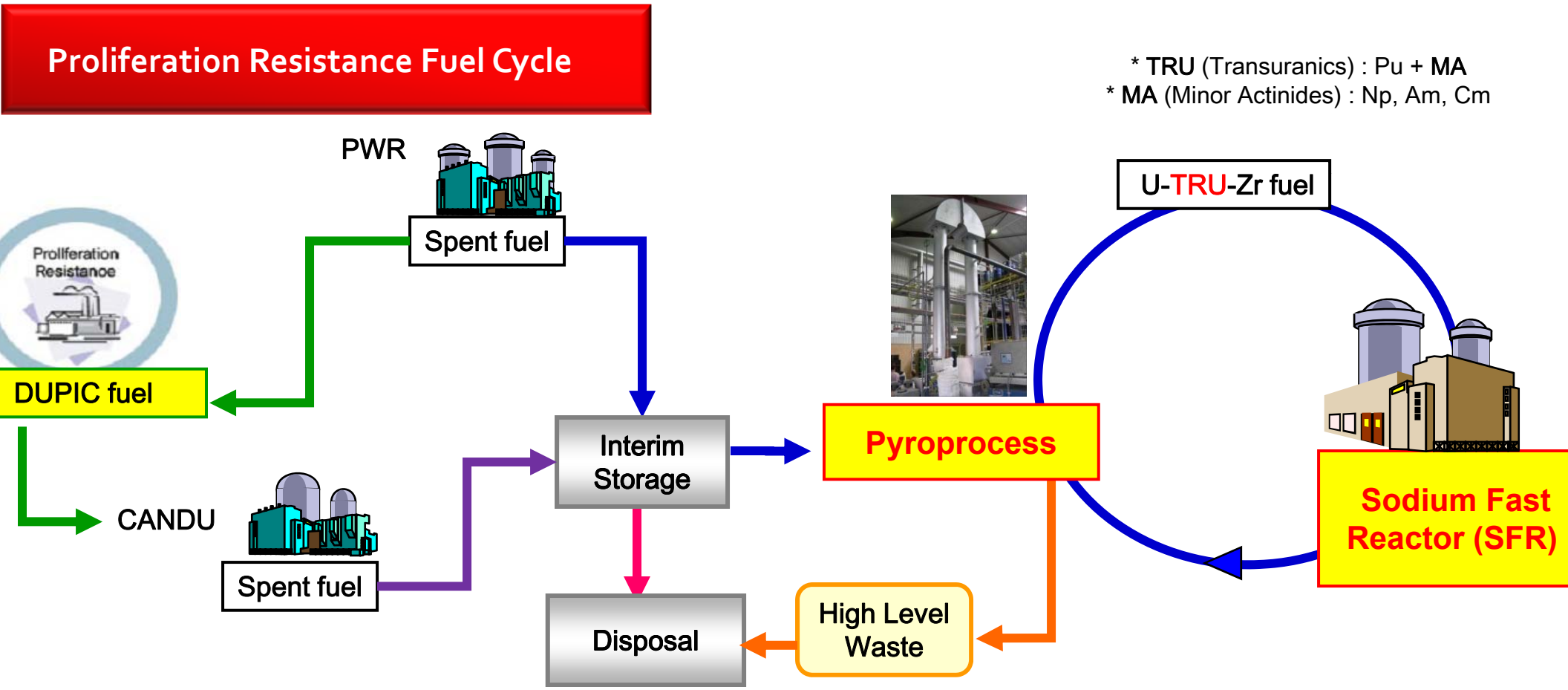
Evolution of the Potential Radiotoxicity of Nuclear Waste from a PWR, an Energy Amplifier and a Coal Burning Power Station.

In the Energy Amplifier, the long-term radiotoxicity can be 4 orders of magnitude smaller than in a PWR in open cycle. The flattening of the curves above 600 years is due to long lived fission fragments.

DEVELOPMENT IS TIME- CONSUMING



South Korea's Generation IV ready 2025



Thorium resources in Norway

Norway's energy resources of thorium are 200 times those of a oil produced as well as remaining!

Norway's thorium resources correspond to 500 years of globa nuclear energy at present production level!

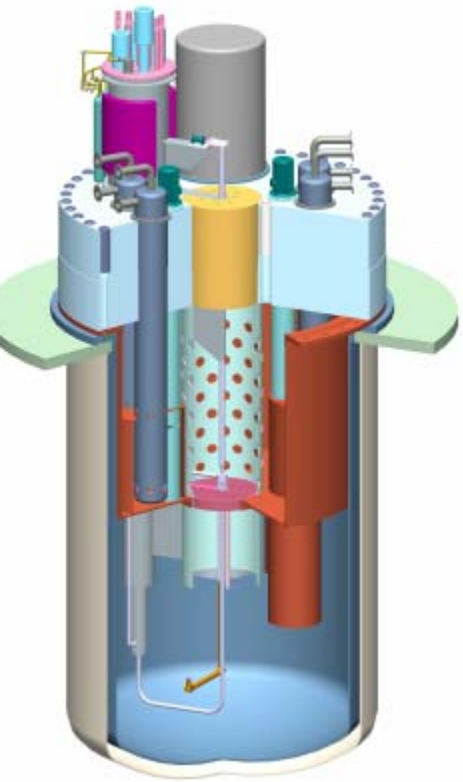
Location	% thorium	Mega tonnes
Stokkøy/Arøy, Vestfold	0.2	?
Sæteråsen, Vestfold	0.05	8
Høgtuva, Nordland	0.02	0.5 (+)
Ødegården, Aust Agder	0.1	?
Ytterøya,Nord-Trøndelag	0.2	?
Fen (iron ore)Telemark	0.2 - 0.4	?
Fen (iron rich) Telemark	0.1 - 0.2	A lot

Thorium resources

- Energy in Norway´s thorium is 200 times that of all their o
- Norway´s thorium enough for 500 years of world´s nuclear
- World´s thorium enough for world´s nuclear for 5 000 year

Recommendation 1:

Norwegian research groups should be encouraged to participate in relevant international ADS projects.



MYRRHA is an Accelerator Driven System (ADS) under development at Mol in Belgium. It aims to serve as a basis for the European XT-ADS(*) and to provide protons and neutrons for various R&D applications. It consists of a proton accelerator delivering a 600 MeV - 2.5 mA to a liquid Pb-Bi spallation target that in turn couples to a Pb-Bi cooled, subcritical fast nuclear core. The project started in 1997 and the aim is to put MYRRHA in service in 2016-2018.

Recommendation 2:

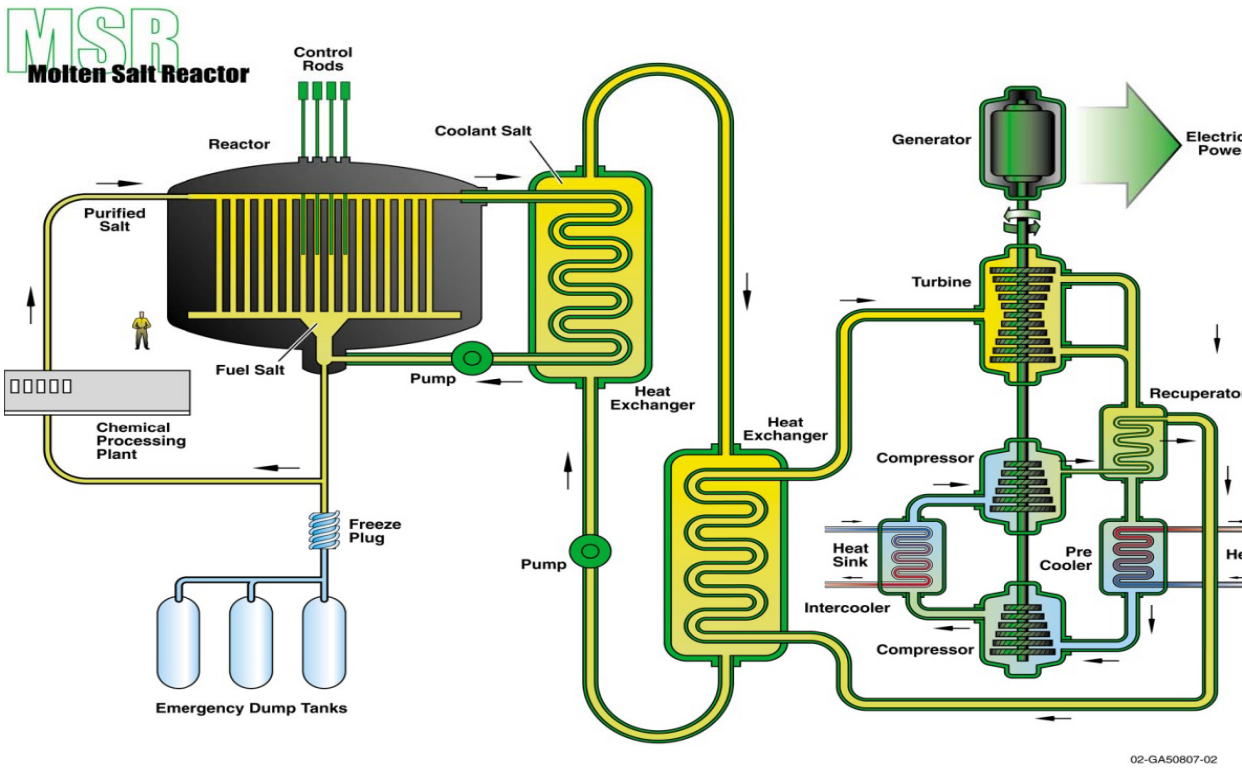
Norway should strengthen its participation in international collaborations by joining the GIF program on Generation IV reactors suitable for the use of thorium

racteristics:

uel: circulating liquid
Na, Zr, U and Pu fluorides
Low pressure (<5 bar)
00–800°C outlet temperature
000 MWe
Also for thorium fuel

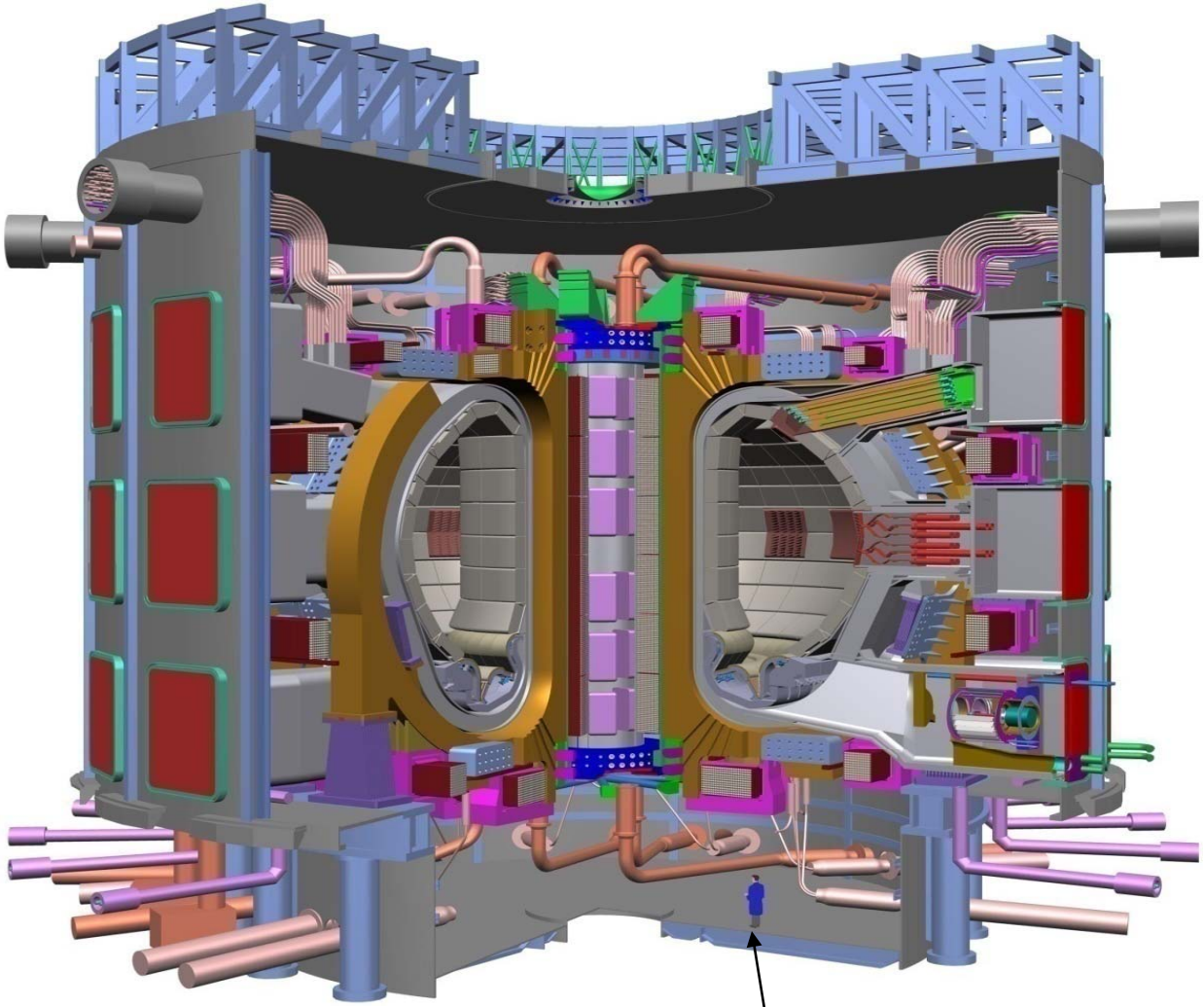
enefits:

Avoids fuel development
Proliferation resistant
Transmutation of waste



Molten Salt Reactor (MSR)

ITER - the next step in fusion



Location: Cadarache, F

Collaboration: World wide

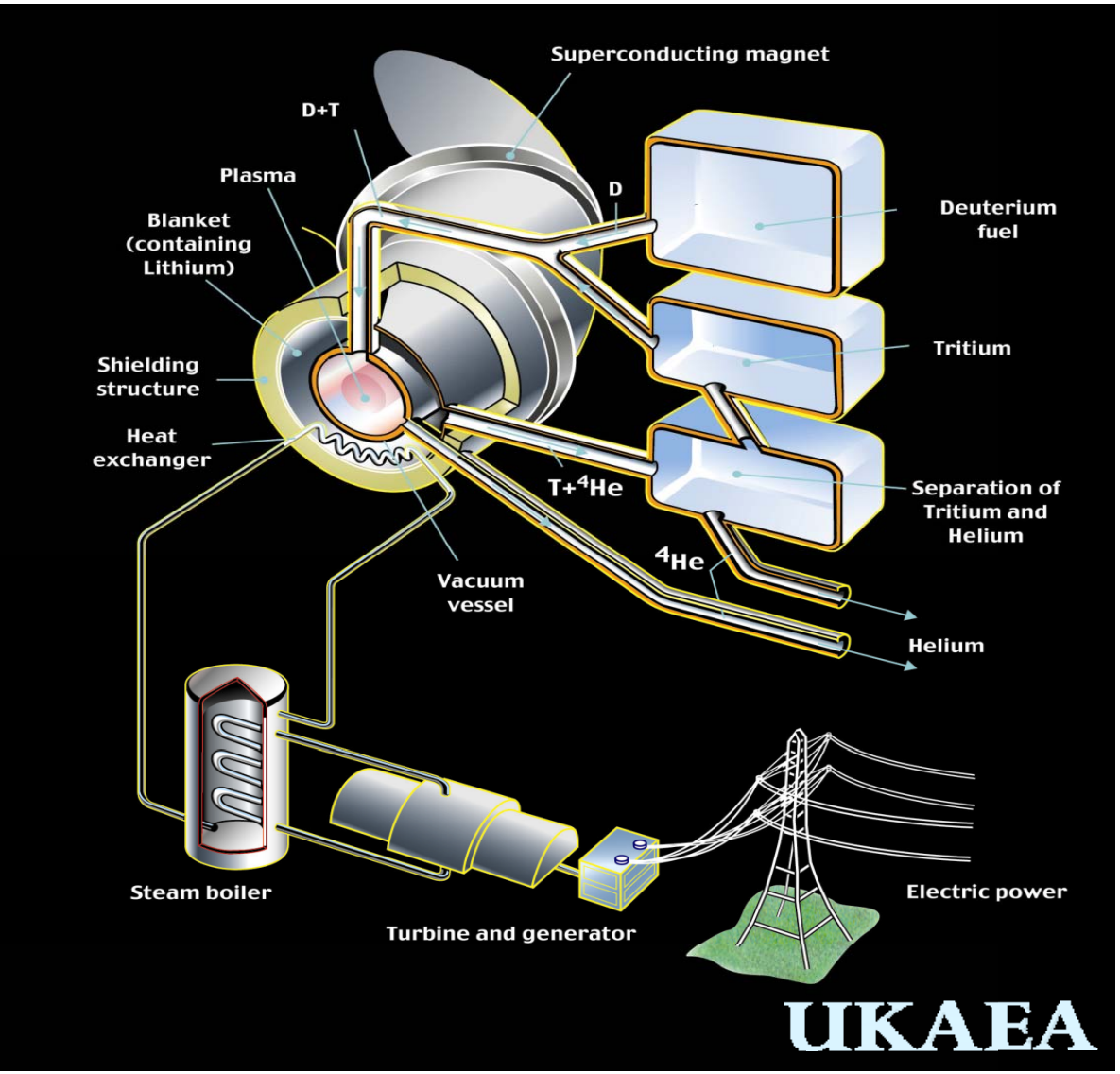
Status: Under construction

Cost: 5 B€

Goal is to keep

600 MW during 500 s

A Fusion Powerplant



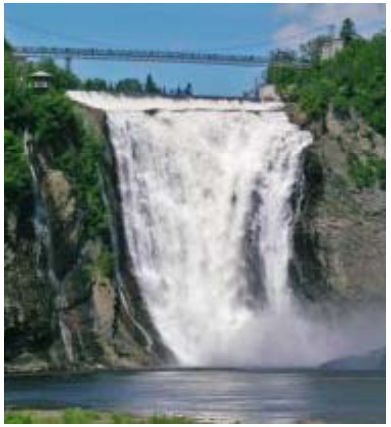
Lithium blanket captures energet neutrons from the fusion process a serves two purposes.

Boils water in a heat exchanger t produce steam to drive a generato

The Lithium and neutron react t produce Tritium, one of the prima fuels in the fusion process.

Conclusions on energy by 2050

- **Fossil fuels** -less than now?
- **Solar energy** -the major option!
- **Electricity from moving water** -the classical way, waves?
- **Electricity from moving air** -the option loved by politicians
- **Energy from nuclear fission** -a reincarnation!
- **Energy from nuclear fusion** -Tokamak or Stellarator?
- **Energy from biomass** -a doubling is possible; priority on food and rain forests
- **Energy efficiency** -electricity will help using energy much more efficiently



19–20 October 2009

The Royal Swedish Academy of Sciences

Energy 2050

Energy 2050 is an international symposium organized by the Royal Swedish Academy of Sciences in Stockholm 19–20 October 2009. The symposium is being held in association with the Swedish EU presidency in autumn 2009.

The symposium is focused on key issues emanating from the Academy's in-depth energy studies during 2005–2009. The goal is to provide a statement as a basis for the December 2009 Copenhagen meeting at which a post-Kyoto action plan will be discussed.

The symposium objectives are:

- to formulate an outlook for environmentally friendly energy by 2050
- to understand how and when the current dependence on fossil fuels can be replaced by a sustainable energy system
- to find ways to mitigate the effects of CO_2 emissions; e.g. efficient and clean use of coal
- to analyze how renewable energy sources with intermittent availability can be handled
- to understand the performance of the new generation of nuclear facilities with respect to fuel, waste and security
- to explore the best ways of increasing energy efficiency in transport, buildings and industrial production
- to indicate options for low-carbon vehicles
- to estimate resource requirements and the environmental impact of different energy sources over their life cycles

The symposium will have a number of distinguished speakers, among them Carlo Rubbia, 1984 Nobel Laureate in Physics and George A. Olah, 1994 Nobel Laureate in Chemistry.

A web page containing more information and registration forms is under preparation and will shortly be available at www.energy2050.se.

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Energy 2050

International symposium
19-20 October 2009
Stockholm

Associated event to the Swedish EU Presidency

Arranged by
Royal Swedish Academy of Sciences