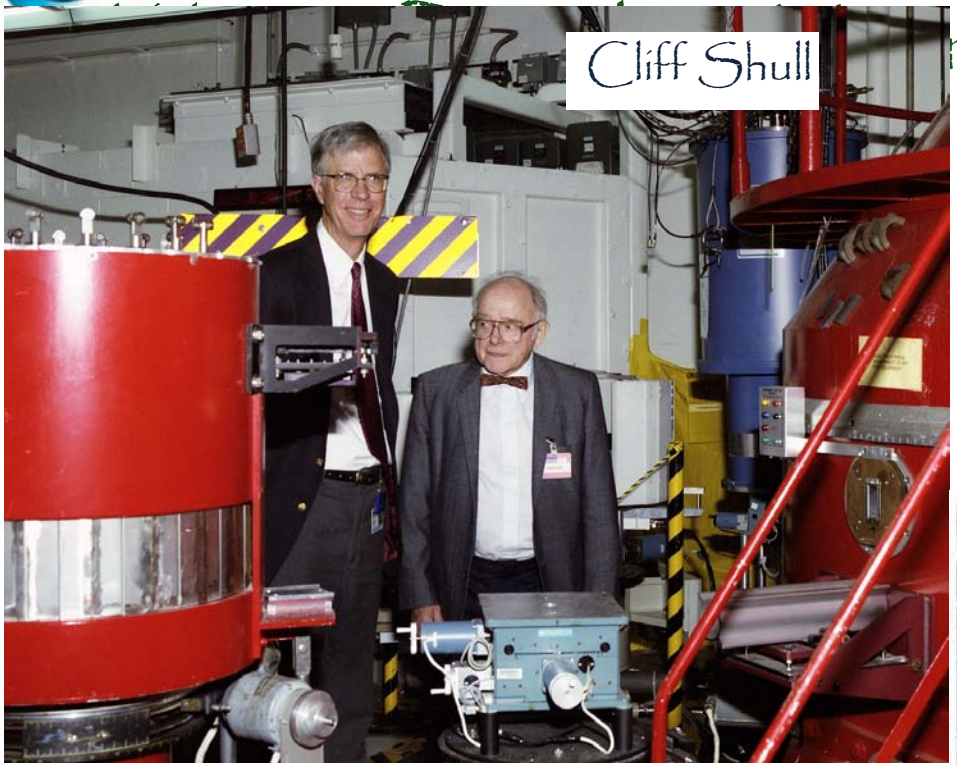
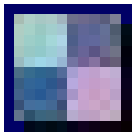
"The Road ahead for The European Spallation Source"

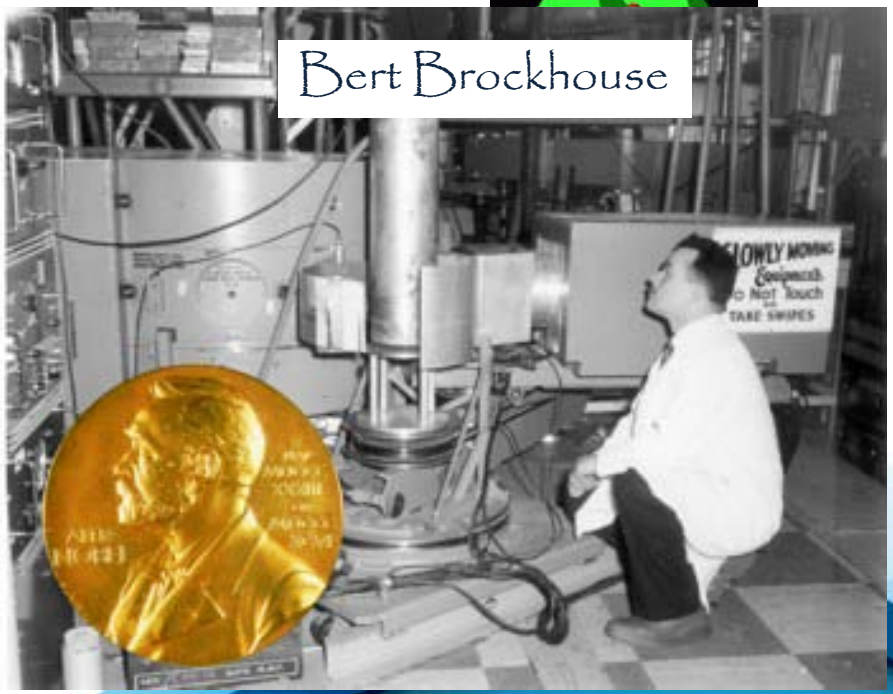
Colin Carlile, ESS, Lund, Sweden

Neutrons are beautiful !

netic moment Neutral







Spectrometers - Measure dynamics
- What atoms and molecules do

1 - 80 meV

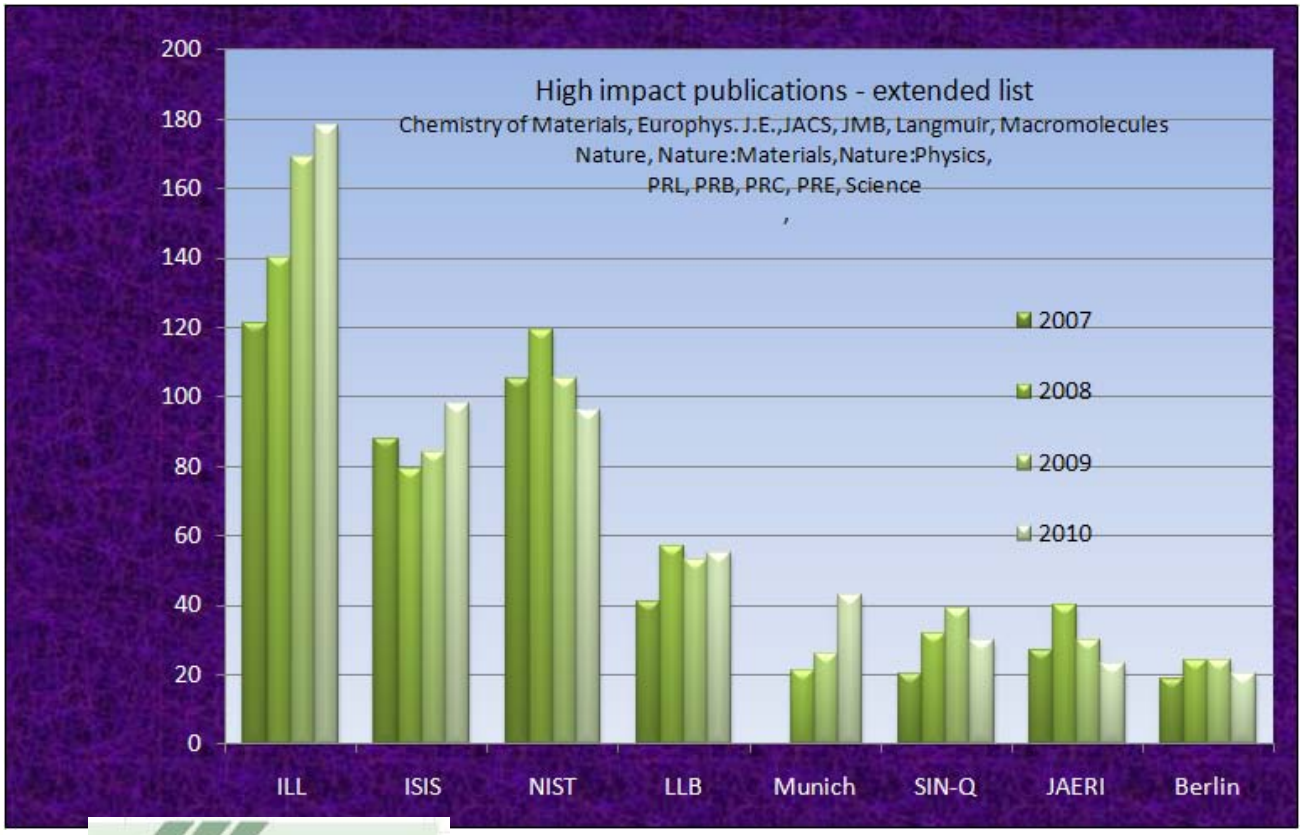
Neutrons are the Swiss Army Knife of Analytic techniques

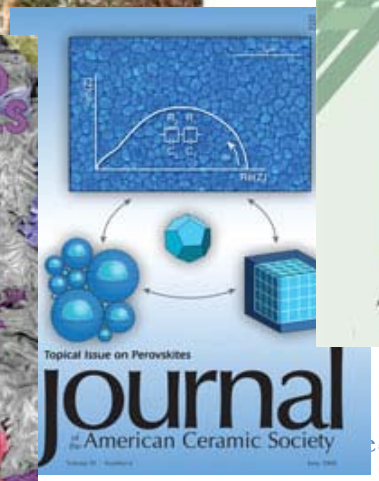
Thanks to Dimitri Argyriou

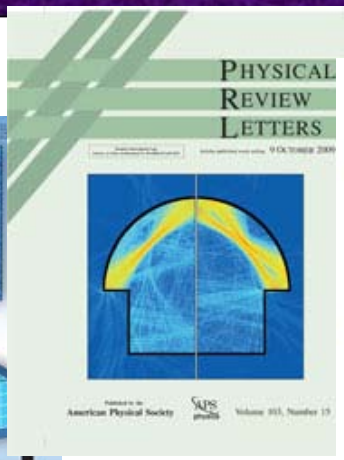
EUROPEAN SPALLATION SOURCE

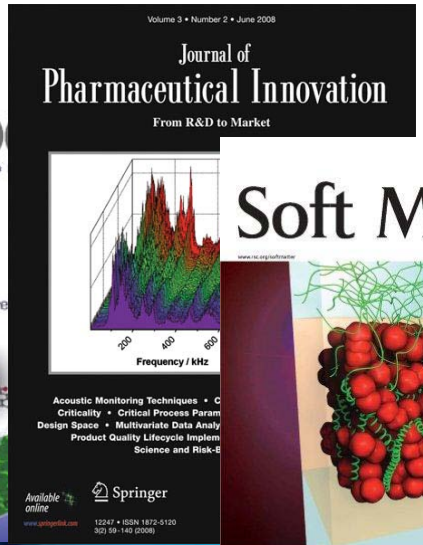
This is our primary product

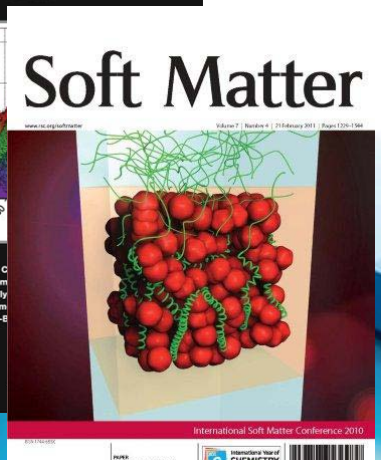
"Small science at big facilities"







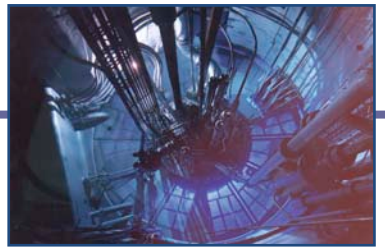




ecember 2011

But neutrons, like diamonds, are still rather rare...

Evolution of the performance of neutron sources



ESS

Effective thermal neutron flux n/cm^2-s

10^{20}
10^{15}
10^{10}
10^{5}
1

1930 1970 1980 1990 2000 2010 2020

Ch
Berkeley 37-inch cyclotron
350 mCi
CP-1
CP-2
X-10
NRX
MTR
NRU
HFIR
HFBR
ILL
ZINP-P
ZINP-P/
WNR
IPNS
KENS
ISIS
SNS
SINQ
FRM-II

Steady State Sources
Pulsed Sources

utron Scattering, K. Skold and D. L. Price, eds., Academic Press, 198

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We have to build the best facilities
with the best instruments
if we are to develop, understand, and harness
New Materials

"The stone Age didn't end for lack of stone"

Ahmed Zaki Yamani

my phone, my email, my notebook, my calculator, my atlas, my weather,
my camera, my star map, my music, my calendar, my address book...
& my training routine for Lundaloppet !

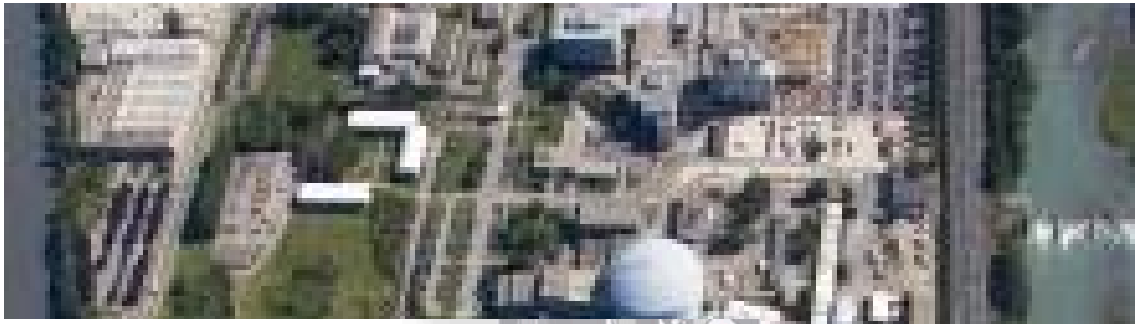
Packed with new materials !

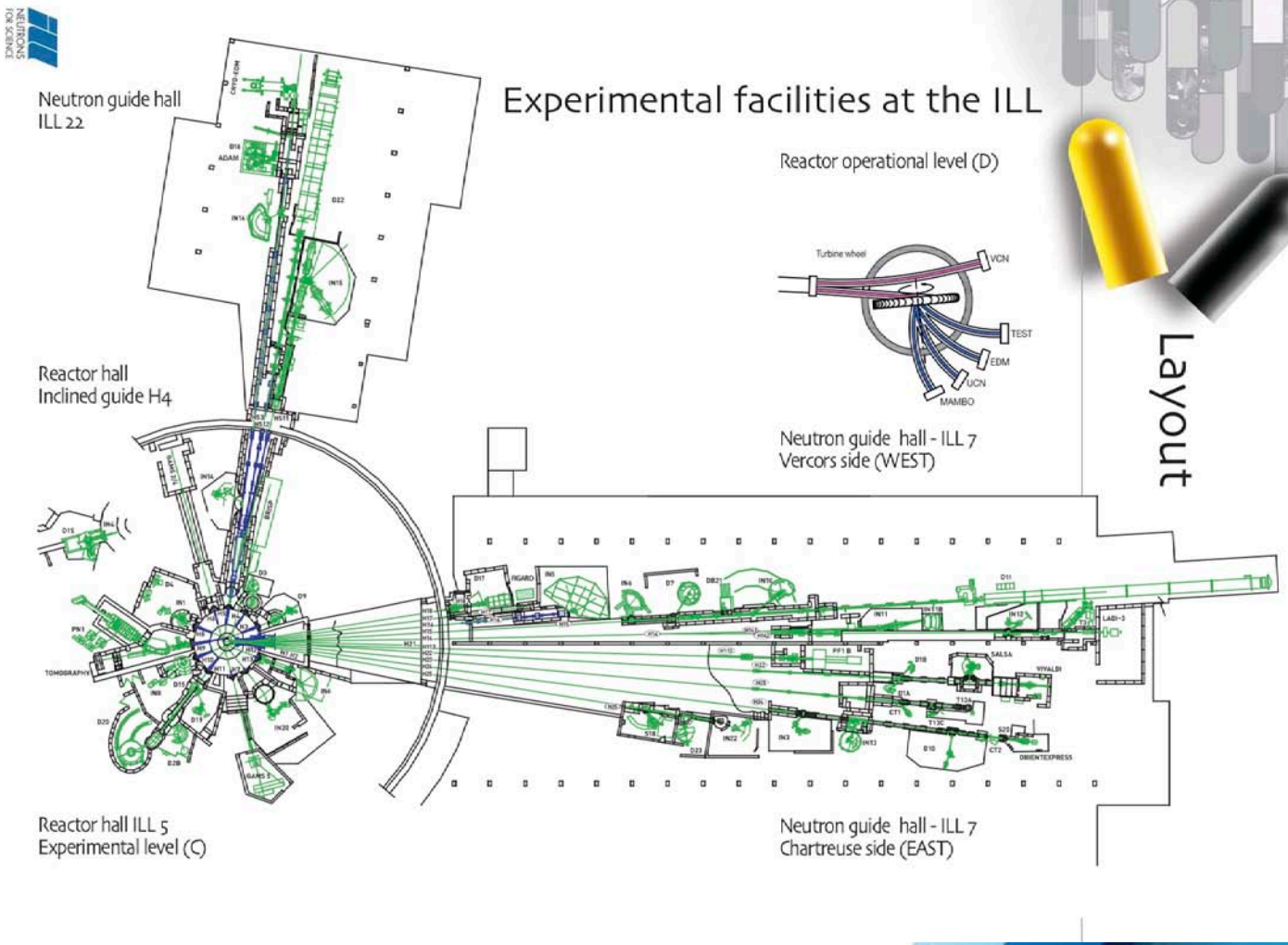
Neutron sources outside Europe

- There are 230 research reactors in 32 countries
- There are 5 spallation sources in 4 countries

EUROPEAN SPALLATION SOURCE

ILL





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SNS

Spallation Neutron Source at Oak Ridge National Laboratory

The world's most intense pulsed, accelerator-based neutron source

SNS SPALLATION NEUTRON SOURCE

Backscattering Spectrometer (BASIS) • BL-2
Dynamics of macromolecules, constrained molecular systems, polymers, biology, chemistry, materials science
Eugene Mamontov • 865.574-5109 • mamontove@ornl.gov

Nanoscale-Ordered Materials Diffractometer (NOMAD) • BL-1B (2010*)
Liquids, solutions, glasses, polymers, nanocrystalline and partially ordered complex materials
Joerg Neuefeind • 865.241.1835 • neuefeindjc@ornl.gov

Wide Angular-Range Chopper Spectrometer (ARCS) • BL-18
Atomic-level dynamics in materials science, chemistry, condensed matter sciences
Doug Abernathy • 865.576.5105 • abernathydl@ornl.gov

Fine-Resolution Fermi Chopper Spectrometer (SEQUOIA) • BL-17
Dynamics of complex fluids, quantum fluids, magnetism, condensed matter, materials science
Garrett Granroth • 865.576.0900 • granrothge@ornl.gov

Ultra-Small-Angle Neutron Scattering Instrument (TOF-USANS) • BL-1A (2014*)
Life sciences, polymers, materials science, earth and environmental sciences
Michael Agamalian • 865.576.0903 • magamalian@ornl.gov

Chemical Spectrometer (VISION) • BL-16B (2012*)
Vibrational dynamics in molecular systems, chemistry
Christoph Wildgruber • 865.574.5378 • wildgrubercu@ornl.gov

BL-16A

BL-1C

Spallation Neutrons and Pressure Diffractometer (SNAP) • BL-3
Materials science, geology, earth and environmental sciences
Chris Tulk • 865.576.7028 • tulkca@ornl.gov

Neutron Spin Echo Spectrometer (NSE) • BL-15 (2009*)
High-resolution dynamics of slow processes, polymers, biological macromolecules
Michael Ohl • 865.574.8426 • ohlme@ornl.gov

Hybrid Spectrometer (HYSPEC) • BL-14B (2011*)
Atomic-level dynamics in single crystals, magnetism, condensed matter sciences
Mark Hagen • 865.241.9782 • hagenme@ornl.gov

BL-14A

Magnetism Reflectometer • BL-4A
Chemistry, magnetism of layered systems and interfaces
Valeria Lauter • 865.576.5389 • lautervl@ornl.gov

Liquids Reflectometer • BL-4B
Interfaces in complex fluids, polymers, chemistry
John Ankner • 865.576.5122 • ankneri@ornl.gov

Fundamental Neutron Physics Beam Line • BL-13
Fundamental properties of neutrons
Geoffrey Greene • 865.574.8435 • greeneg@ornl.gov

Cold Neutron Chopper Spectrometer (CNCS) • BL-5
Condensed matter physics, materials science, chemistry, biology, environmental science
Georg Ehlers • 865.576.3511 • ehlersg@ornl.gov

BL-8A

BL-8B

Macromolecular Neutron Diffractometer (MaNDi) • BL-11B (2013*)
Atomic-level structures of membrane proteins, drug complexes, DNA
Leighton Coates • 865.963.8180 • coatesl@ornl.gov

Single-Crystal Diffractometer (TOPAZ) • BL-12 (2009*)
Atomic-level structures in chemistry, biology, earth science, materials science, condensed matter physics
Christina Hoffmann • 865.576.5127 • hoffmannccm@ornl.gov

Extended Q-Range Small-Angle Neutron Scattering Diffractometer (EQ-SANS) • BL-6
Life science, polymer and colloidal systems, materials science, earth and environmental sciences
Jinkui Zhao • 864.574.0411 • zhaoj@ornl.gov

Elastic Diffuse Scattering Spectrometer (CORELLI) • BL-9 (2014*)
Detailed studies of disorder in crystalline materials
Feng Ye • 865.576.0831 • yef1@ornl.gov

BL-10

Powder Diffractometer (POWGEN) • BL-11A
Atomic-level structures in chemistry, materials science, and condensed matter physics including magnetic spin structures
Jason Hodges • 865.576.7034 • hodgesjc@ornl.gov

Engineering Materials Diffractometer (VULCAN) • BL-7 (2009*)
Mechanical behaviors, materials science, materials processing
Xun-Li Wang • 865.574.9164 • wangxl@ornl.gov

* Scheduled commissioning date

LEGEND
- Installed, commissioning, or operating
- In design or construction
- Under consideration

06-G00400L/arm

OAK RIDGE National Laboratory

NEUTRONS.ORNL.GOV
NEUTRON SCIENCES

Carlile

EUROPEAN SPALLATION SOURCE

J-PARC

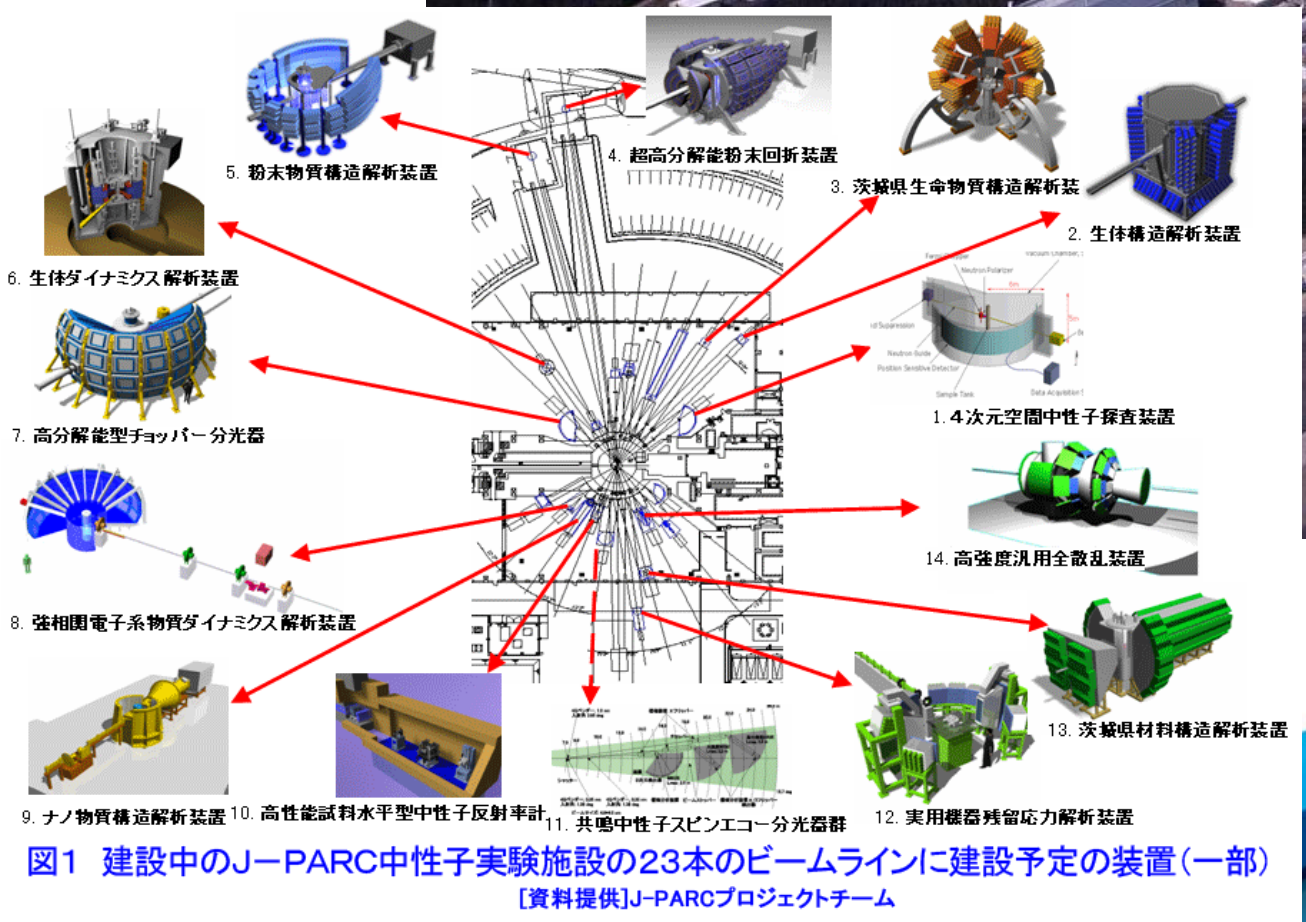


図1　建設中のJ−PARC中性子実験施設の23本のビームラインに建設予定の装置（一部）

[資料提供]J-PARCプロジェクトチーム

Malmö

Öresund bridge

Copenhagen

Lund

MAX IV
&
ESS

Fast forward
to this in 2019

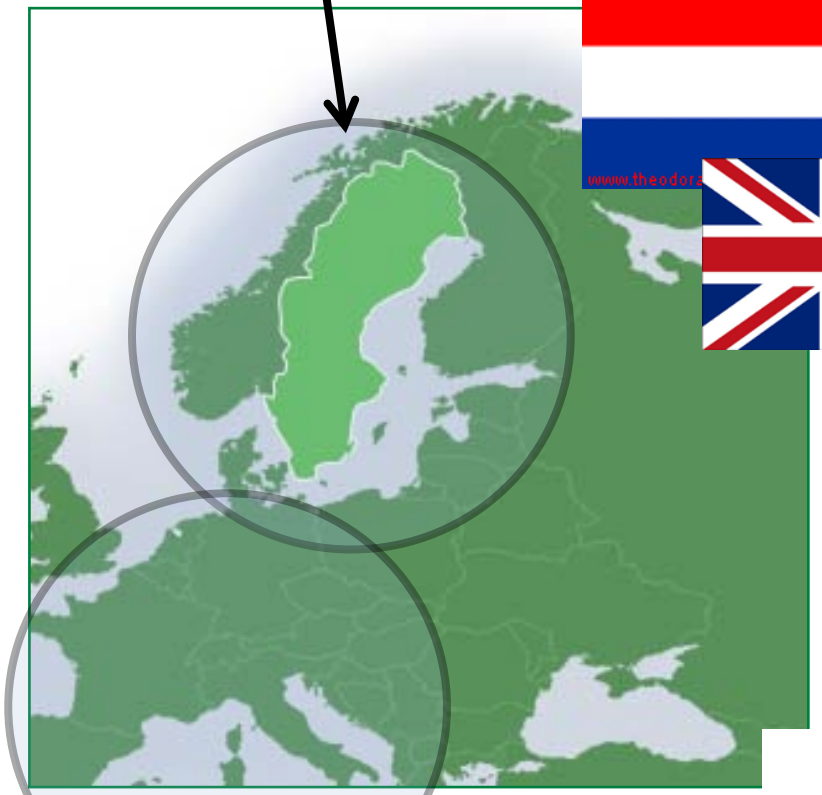
We have got the Partners

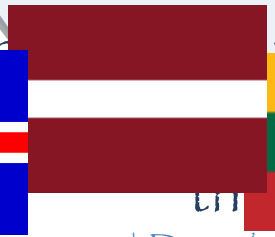
EUROPEAN SPALLATION SOURCE

Sweden, Denmark and Norway

50% of construction costs – 1479 M

17 Partners today





Spain, [illegible] Switze[illegible]zech Republic, Poland[illegible]ania, Iceland & UK

th[illegible]g 50%

The ESS Headlines

- ESS will be the world's best source of slow neutrons
- ESS will not produce its first neutrons until 2019
- ESS will cost 1479 M€$_{2008}$ to construct

ESS is different

- SNS, JPARC & ISIS produce neutrons in 1 to 100 µsec burs
- ESS will produce neutrons in 2.8 msec bursts
- ILL is a continuous neutron source

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The World's Ultimate Slow Neutron Source ?

LHC !

900 x SNS & 30 x ESS

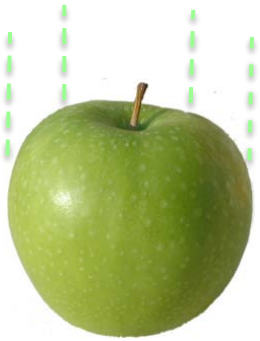
But not until 2050

...when they've found the Higgs boson.

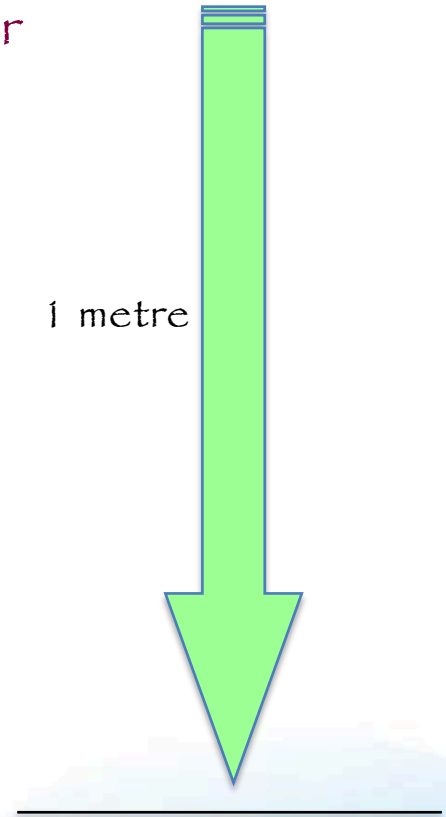
It must be somewhere

Colin Carlile & Ken Andersen

ESS – some numbers



- Superconducting Proton Linear Accelerator
  - 2.5 GeV Proton Energy
- 50mA (2mA) peak (average) proton current
  - 357 kJ/pulse
- 2.86 msec pulse length
  - 14 Hz pulse frequency
- 71.4 msec periods between pulses
  - 5MW proton beam power
- Single Target Station
  - Rotating Tungsten, helium cooled
- 22 instruments
  - High reliability, low losses



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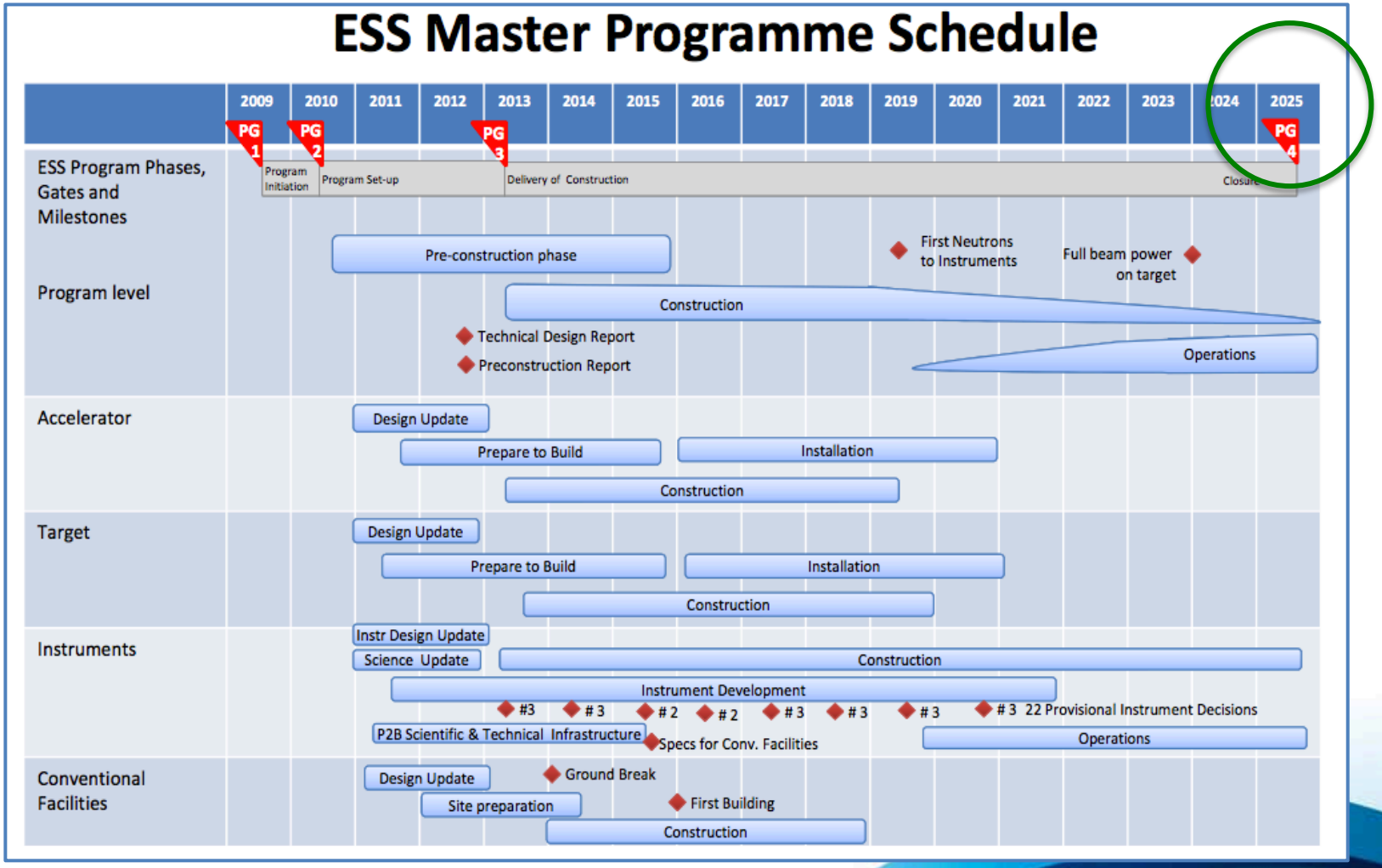
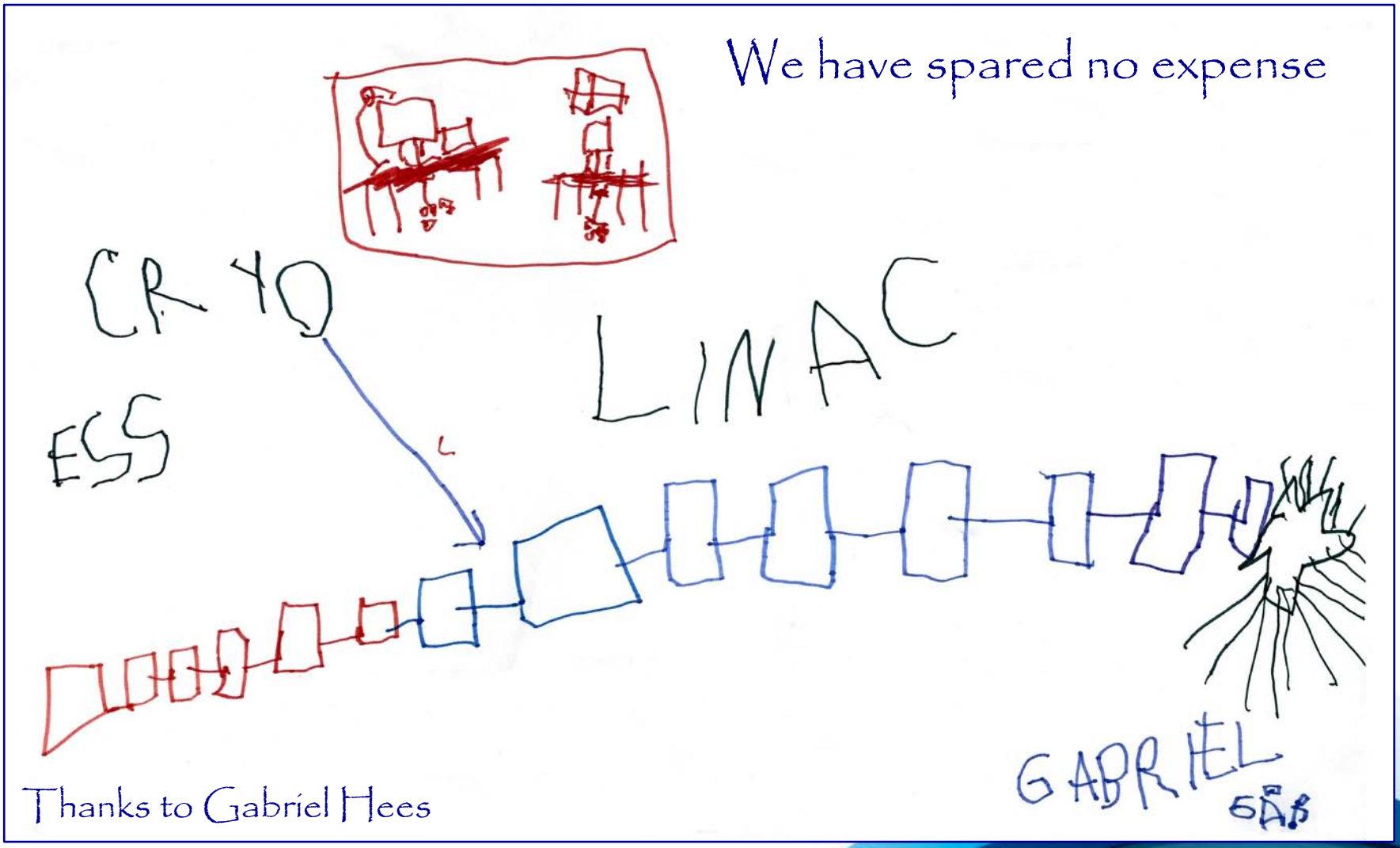
"If we wait for the moment when everything is ready, we shall never begin" Ivan Turgenev

Full Specification

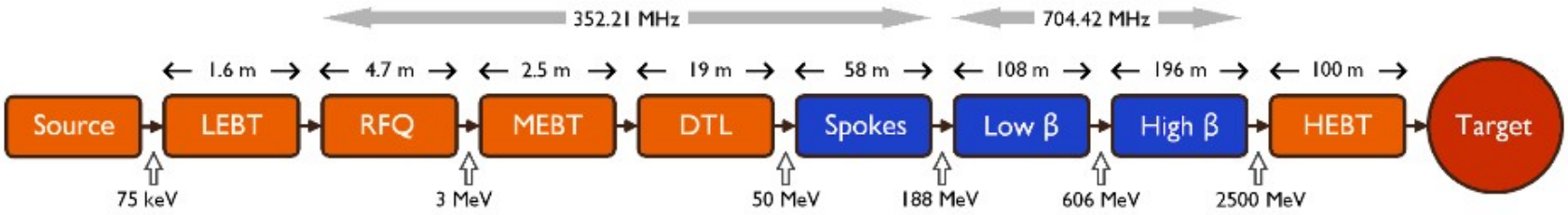


The ESS Design Update Phase 2010 - 2012



Thanks to Gabriel Hees

Linear Accelerator layout



	Length (m)	Input Energy (MeV)	Frequency (MHz)	Geometric β	# of Sections	Temp (K)
RFQ	4.7	75×10^{-3}	352.2	--	1	≈ 300
DTL	19	3	352.2	--	3	≈ 300
Spoke	58	50	352.2	0.57	14 (2c)	≈ 2
Low Beta	108	188	704.4	0.70	16 (4c)	≈ 2
High Beta	196	606	704.4	0.90	15 (8c)	≈ 2
HEBT	100	2500	--	--	--	--

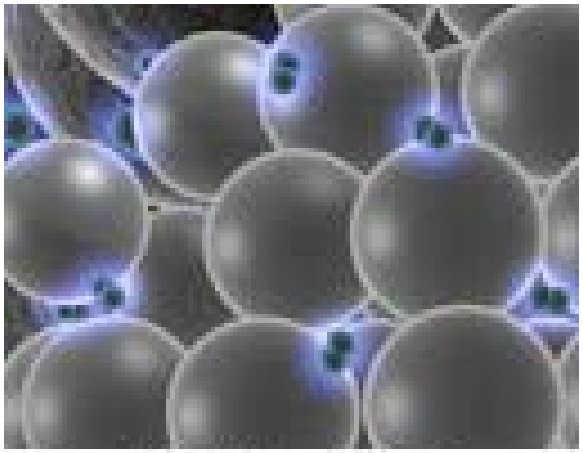
H. Danared, M. Eshraqi, A. Ponton, ESS

The Accelerator work is gaining momentum

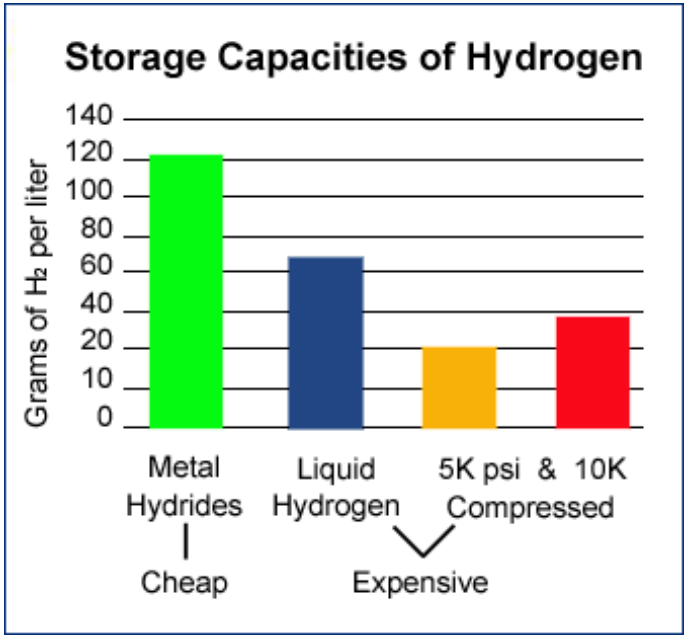
IPN Orsay – Mats Lindroos & Sebastian Bousson

Superconducting accelerating cavities

Hydrogen in Metals

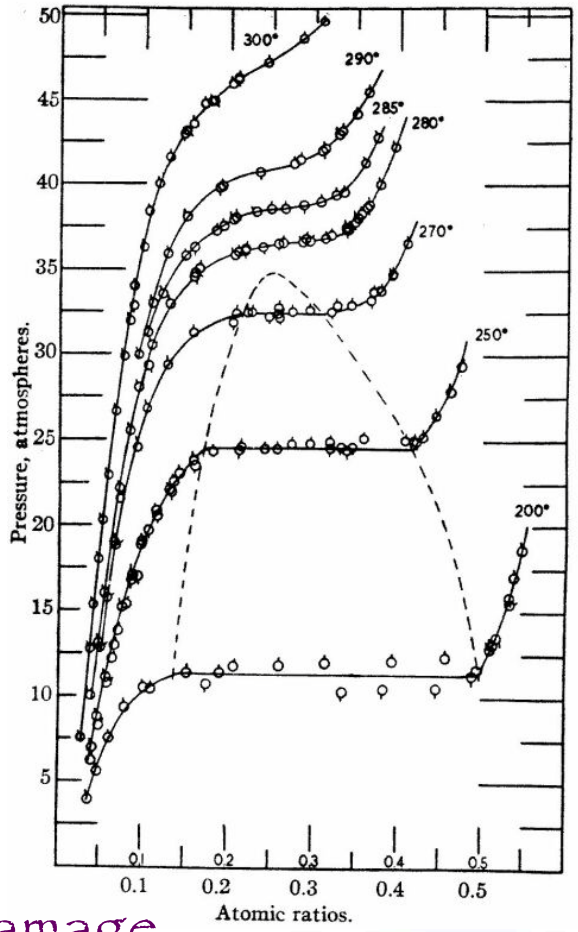


Spotlight on Science



- Interstitial
  - lattice gas
- Dense
- Mobile
- Easily poisoned
- Mixed phases
  - metallurgical damage

Hydrogen in Palladium



The 50K transition in β-phase palladium deuteride observed by neutron scattering

I S Anderson, D K Ross and C J Carlile
Department of Physics, Birmingham University, Birmingham B15 2TT, UK

Abstract
A first direct observation of the '50K' structural transition in beta -phase palladium hydride has been made using neutron scattering. This observation, of a superlattice reflection at (1/210), allows us to conclude that the transition is essentially an order-disorder transition involving a local rearrangement of deuterium atoms and vacancies between the eight indifferent interpenetrating FCC sublattices having twice the original lattice parameter. The low intensity of the reflection corresponds to a small value for the long-range order parameter and its dimensions in reciprocal space indicate that the long-range order only extends to about 25 Å.

Target Station Design Concept

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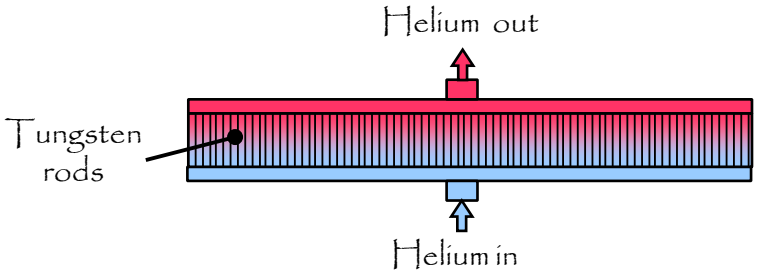
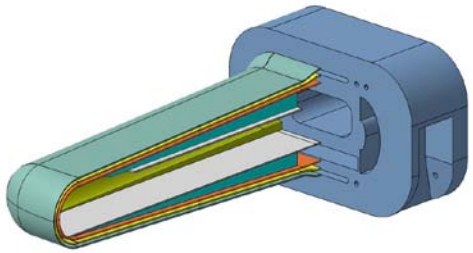
Three options which can work well.
A baseline and a comparative option are selected.

Rotating Solid		Liquid metal
Helium cooled Tungsten	Water cooled Tungsten	Lead Bismuth Eutectic

Hg as reference





University of Latvia Institute of Physics

PSI

Forschungszentrum Dresden Rossendorf

CRS4

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ESS bilbao

JÜLICH FORSCHUNGSZENTRUM

KIT Karlsruhe Institute of Technology

Possible Instrument Layout

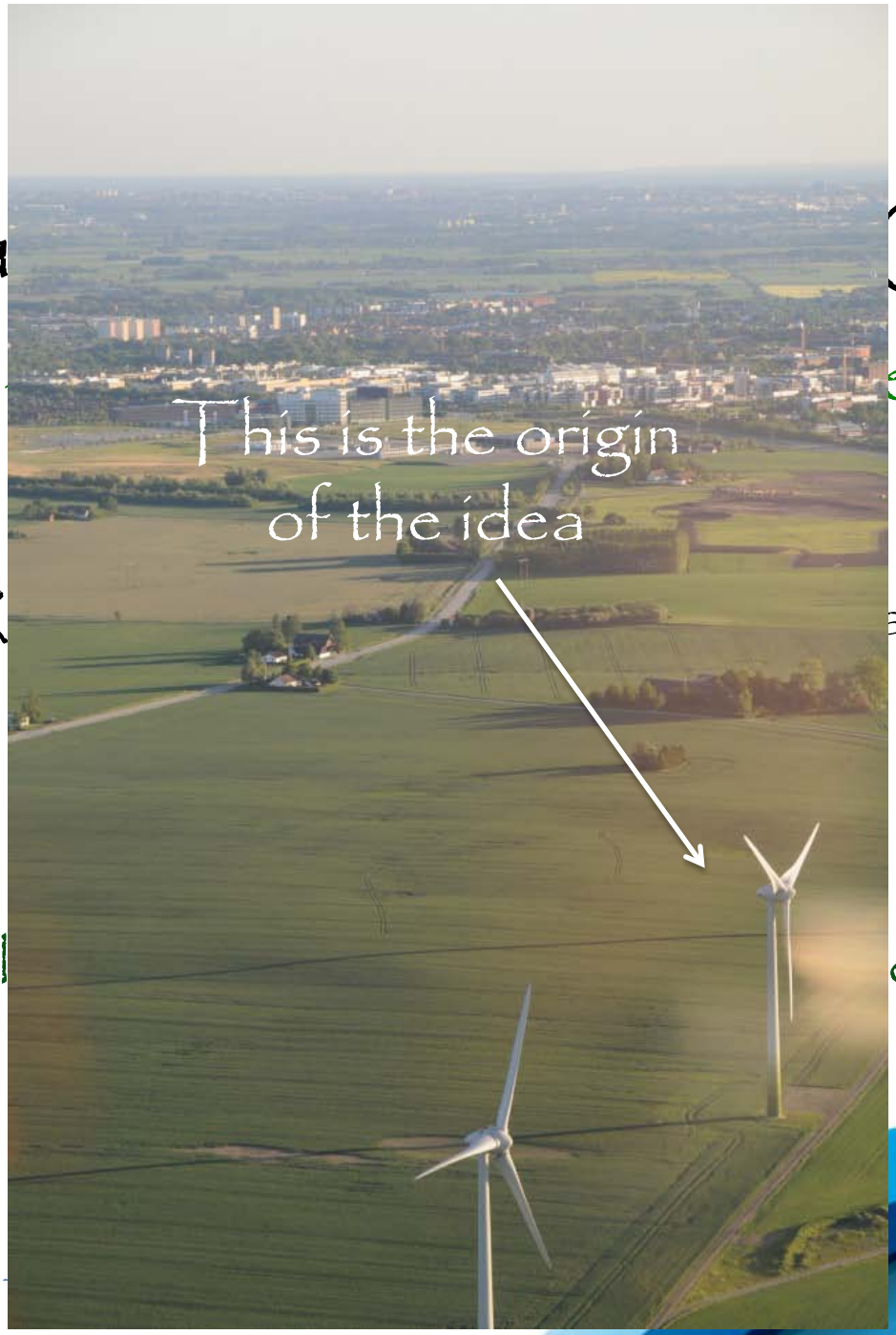
EUROPEAN SPALLATION SOURCE

The Su Centre

ESS eutron

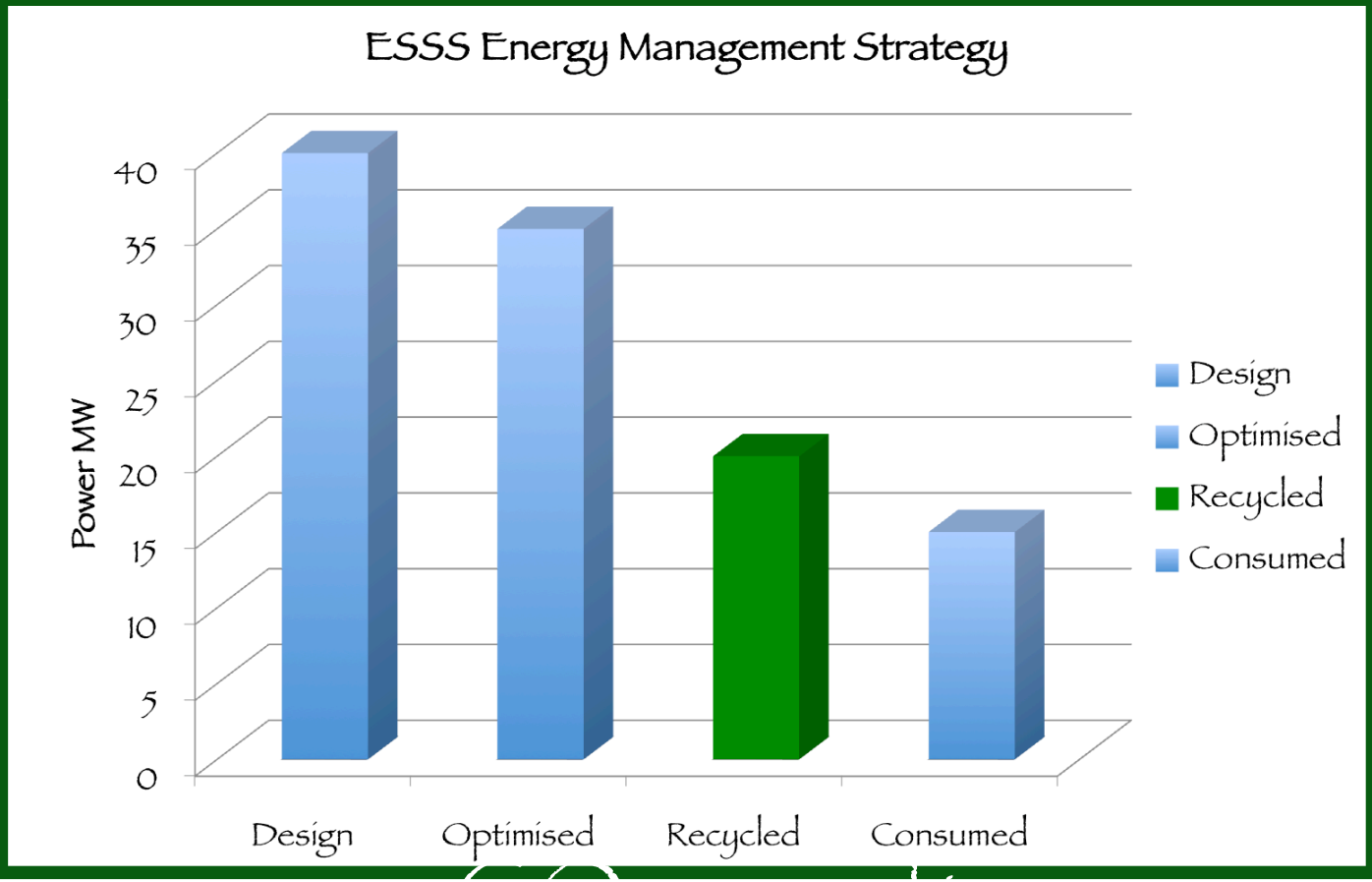
R able

incl e.



Innovative Energy Policy

ESS Energy Management Strategy



Aim to reduce operations costs by ~9 M€ p.a.

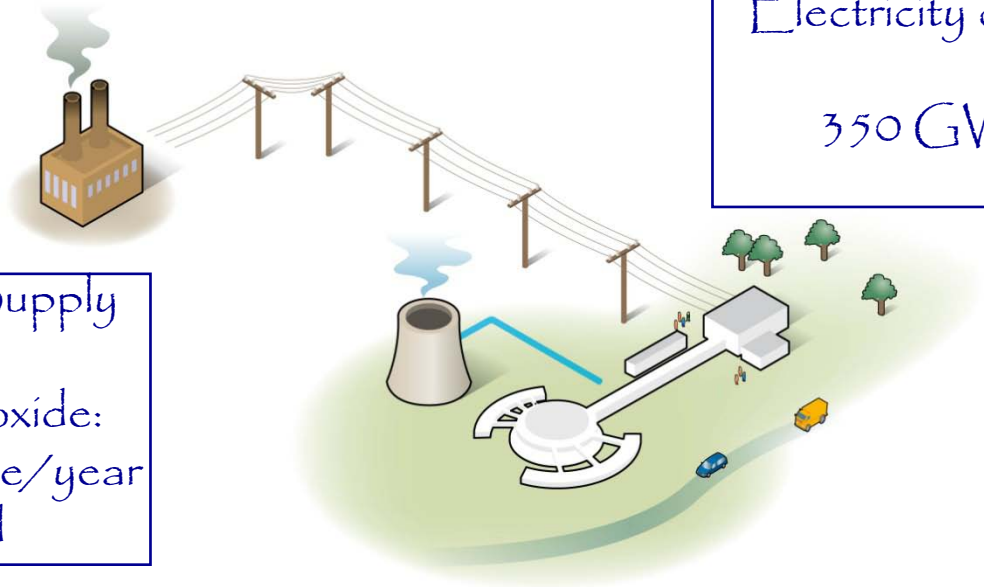
ADS and

Waste heat re-use

This is how it is usually done

Electricity consumption:

350 GWhr/year

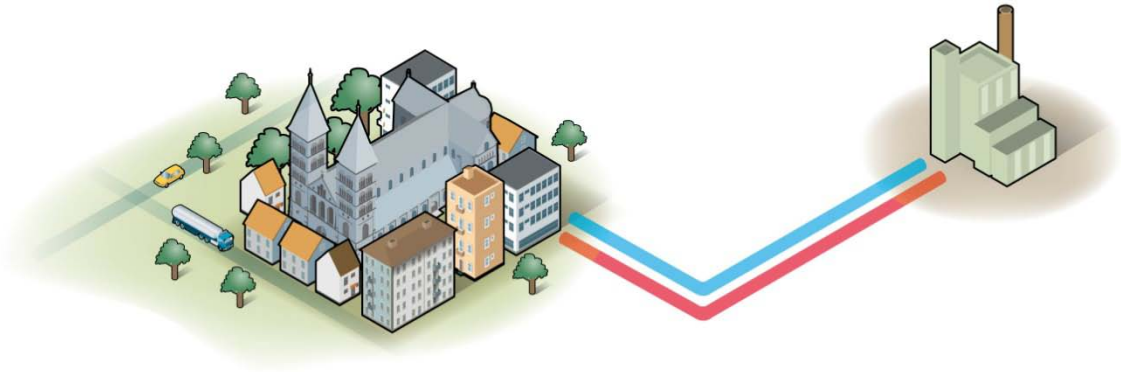


Electrical Supply

Carbon Dioxide:
150,000 tonne/year
emitted

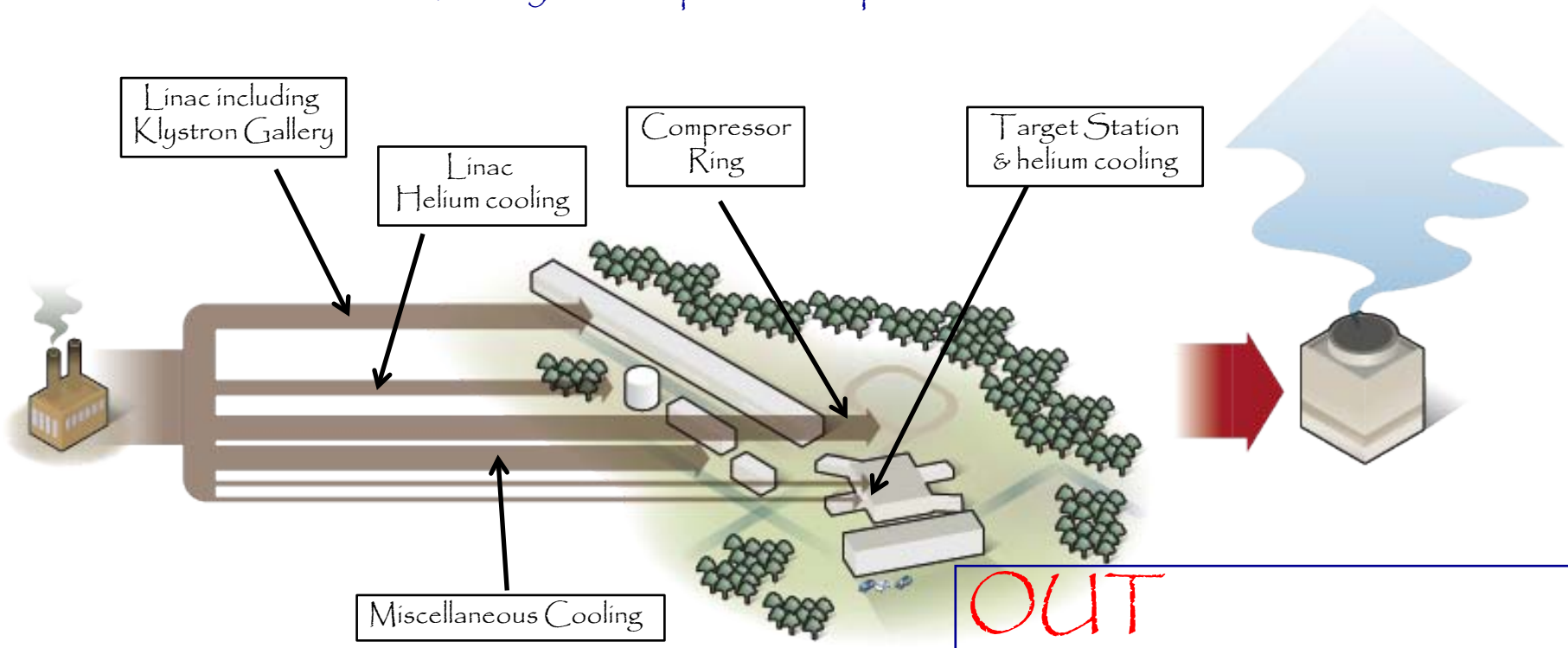
Heating Supply

Carbon Dioxide:
15,000 tonne/year
emitted



SNS Energy flow

Today's most powerful spallation source



IN
150 GWhr electricity
Much of it HEP

OUT
140 GWhr waste heat
Cooling Towers

This is how ESS will do it in 2020

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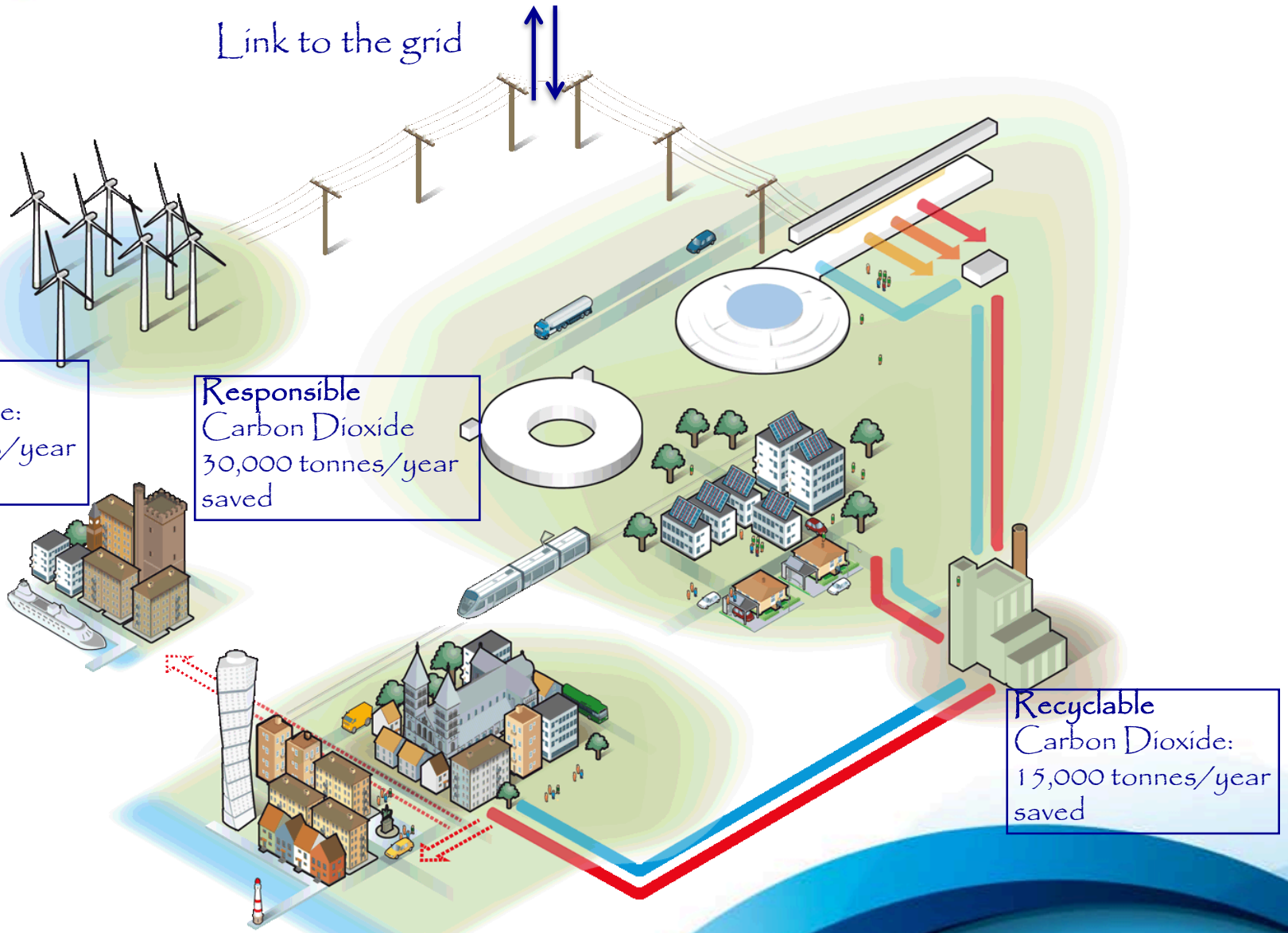
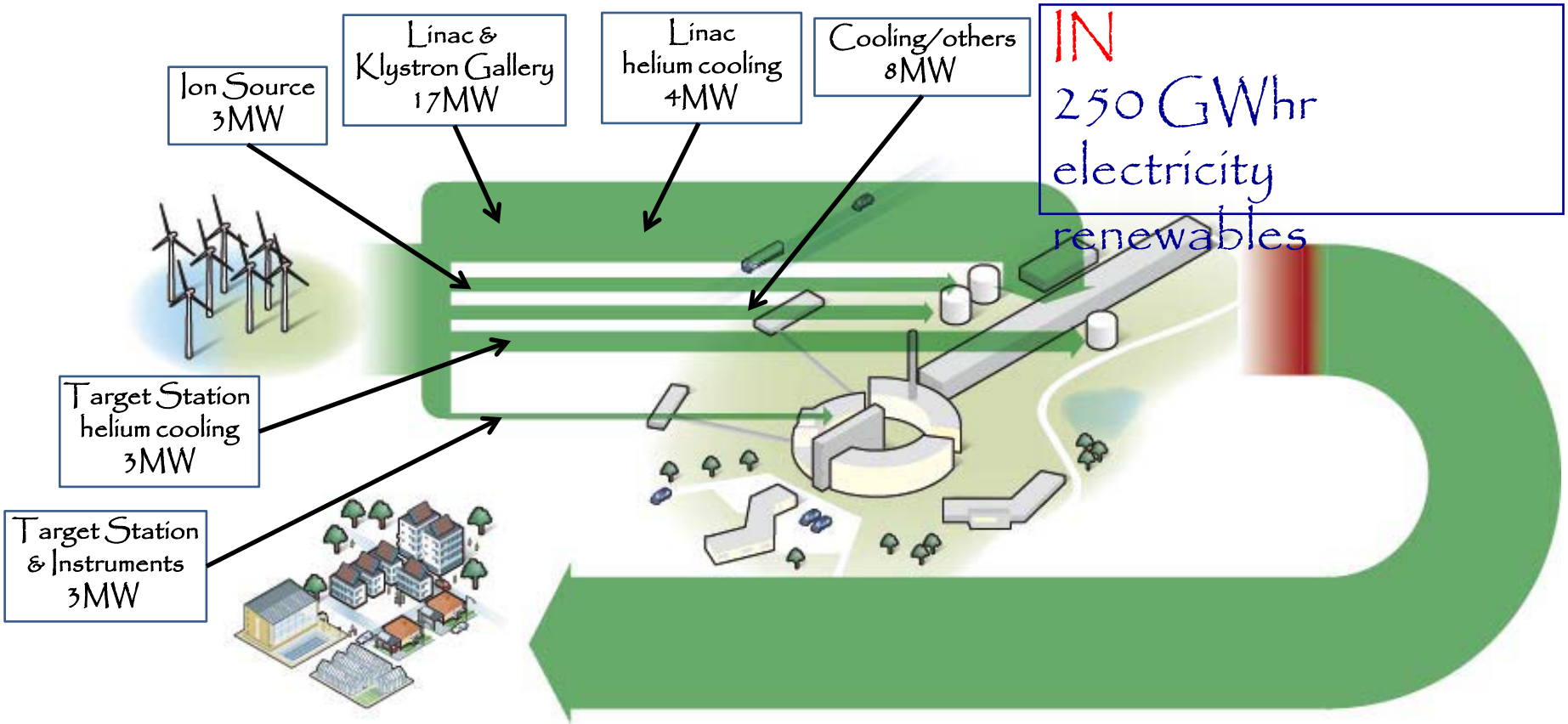


ESS Energy concept 2011

The world's first sustainable large-scale research facility ?



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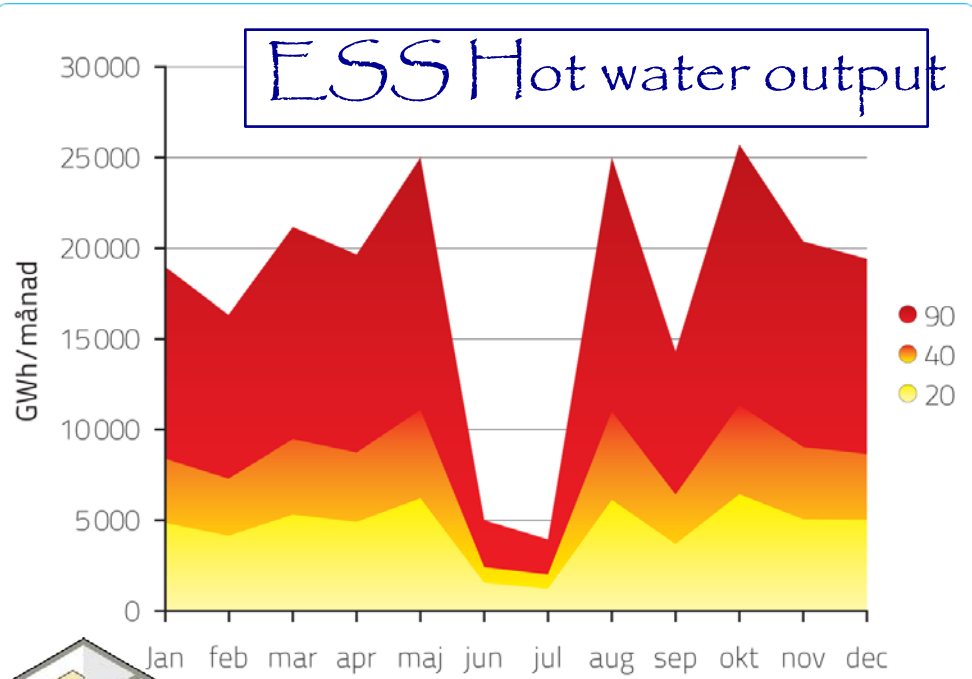
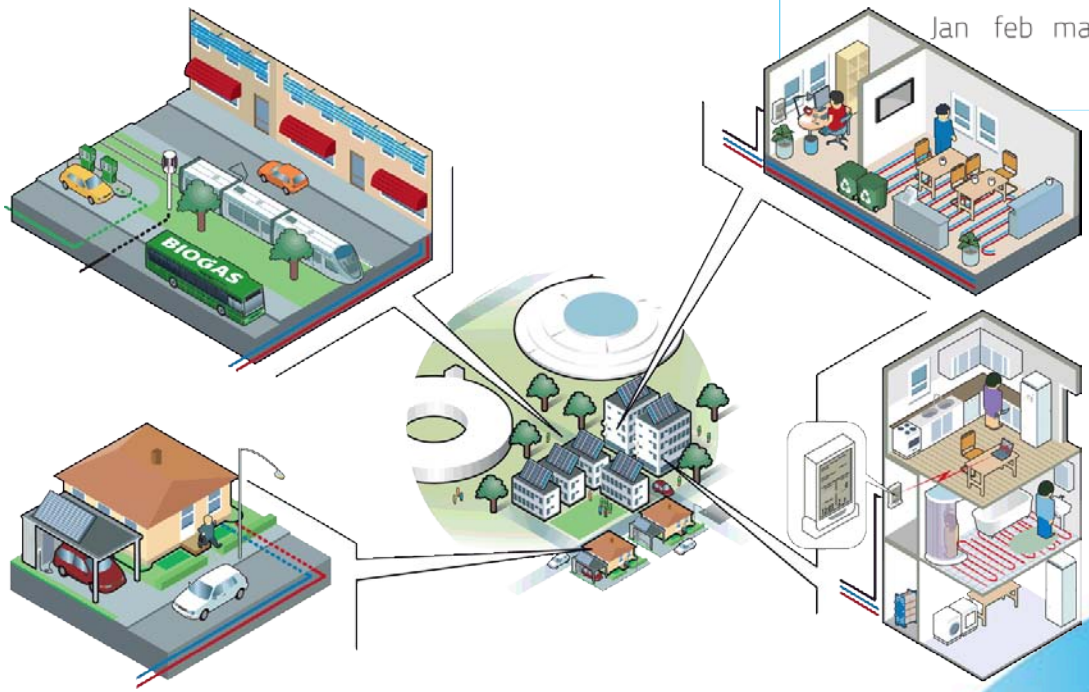
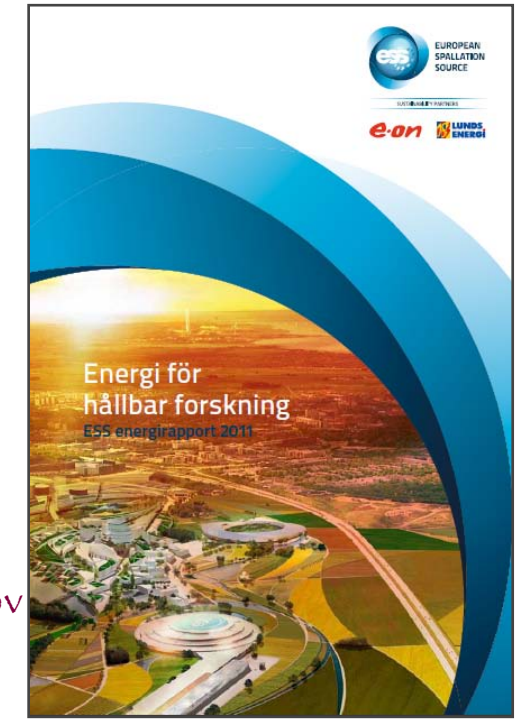
ESS's Cooling water becomes someone else's Heating water





Conclusions: ESS energy solution

- **Electricity consumption** is reduced from 350 GWh to 250 GWh, partly because of smart cooling systems and building technology.



n.

5M€/year.

na and Eslöv

ns

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Thank you for listening !