The environmental impact of the ISIS-II Neutron and Muon Source

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JAI Fest | University of Oxford

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ISIS Neutron and Muon Source

Overview

1) Introduction
2) Environmental Impact & Life Cycle Assessment of ISIS-II
3) Methodology
4) First Results

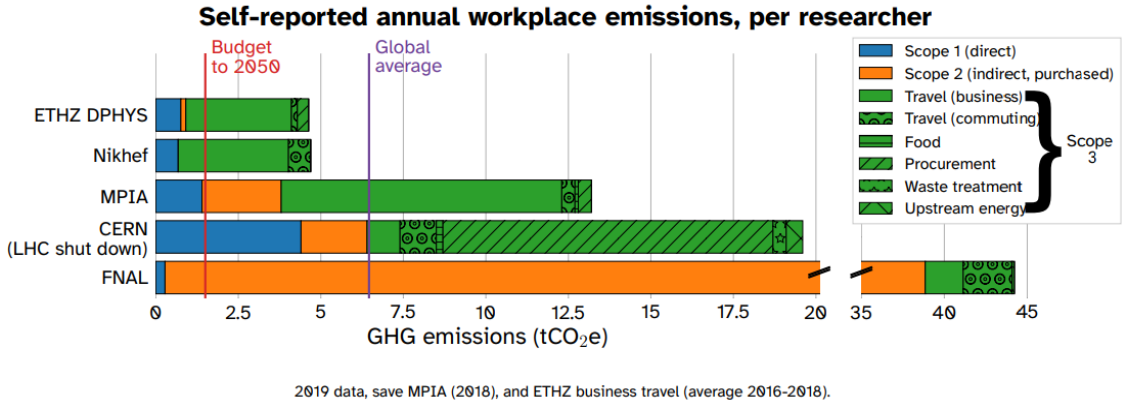
The environmental impact of particle accelerators

Large accelerator facilities are:

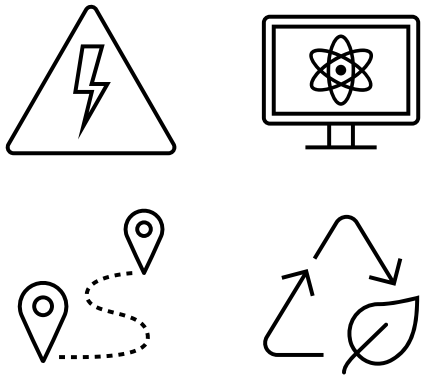
- resource consumptive, and
- growing in size and/or power, and therefore (generally) consumption.

Many efforts ongoing around the world:

- Carbon emissions and impact reports,
- R&D for increased efficiency of machines (klystrons, cryo., etc.),
- Reduction in resource consumption (helium, etc.),
- Sustainability guidelines,
- Air-travel reduction,
- And more...



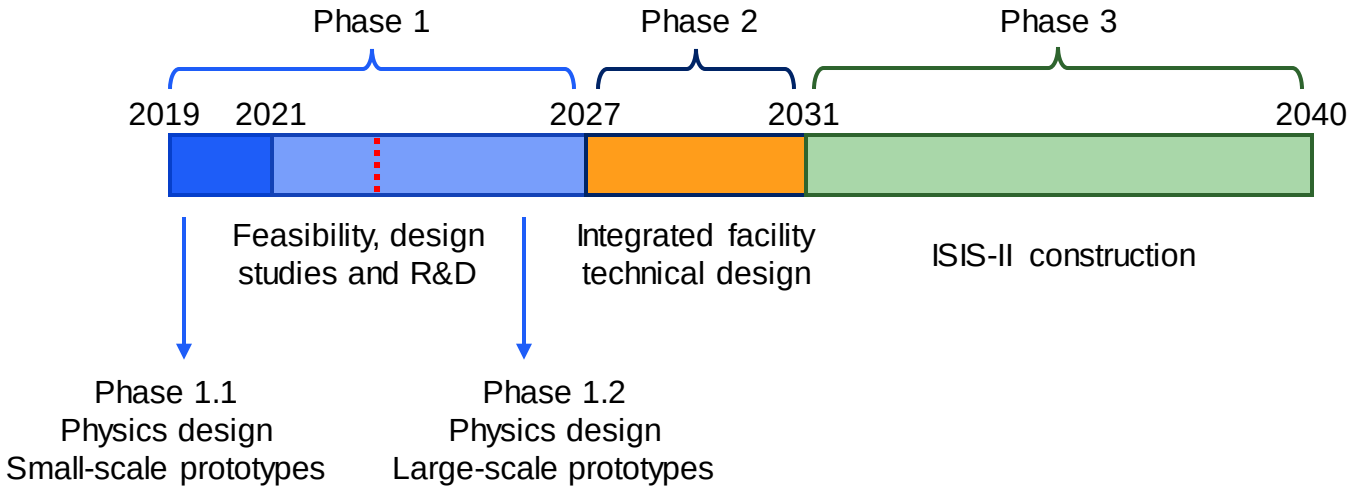
Reported workplace GHG emissions[1].



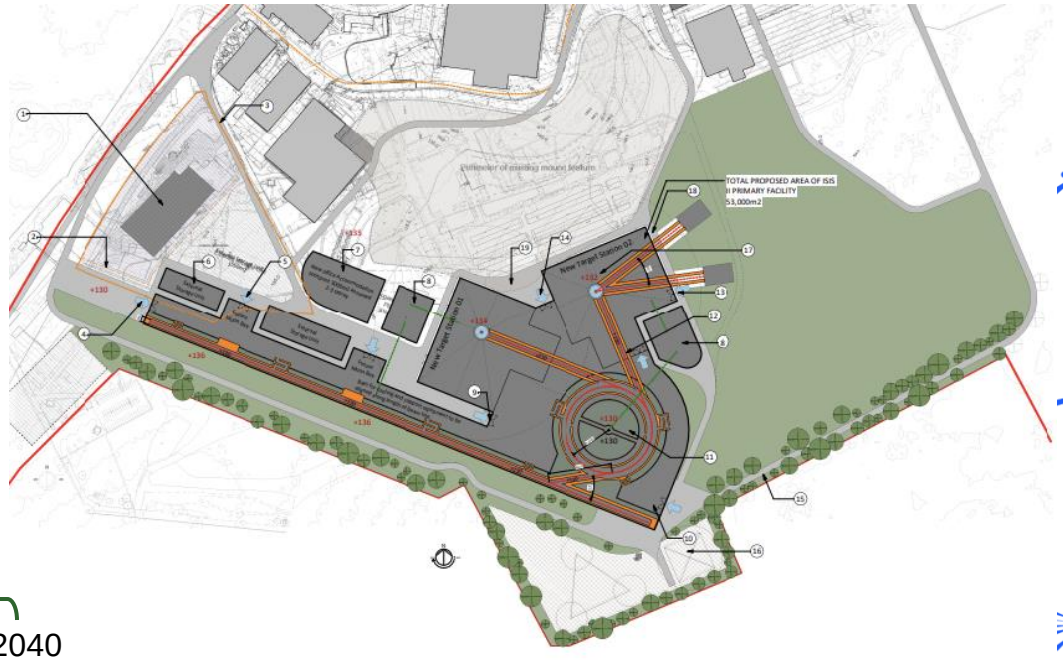
[1] Environmental sustainability in basic research: a perspective from HECAP+

The ISIS-II Neutron and Muon Source

- The proposed 1.2 GeV beam upgrade to the ISIS Neutron and Muon Source.



Proposed timeline.



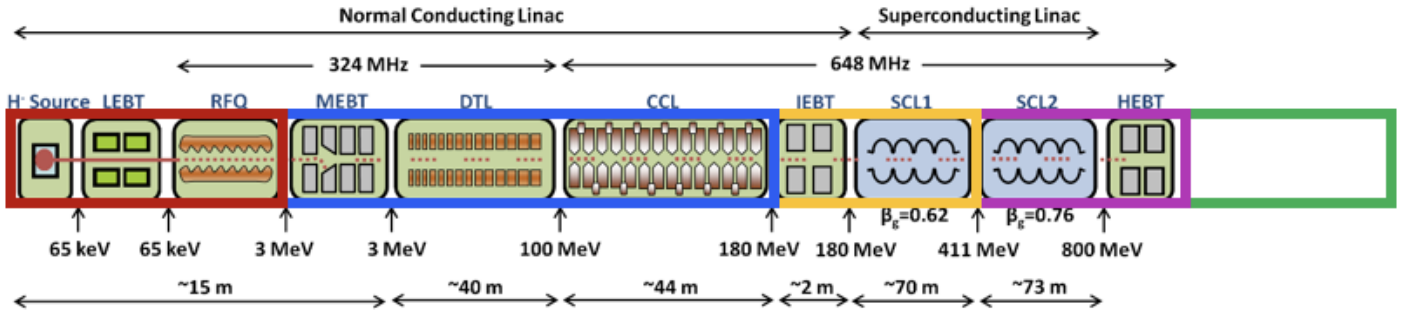
One proposed design option.

Progress on Design Studies for the ISIS II Upgrade (2019)

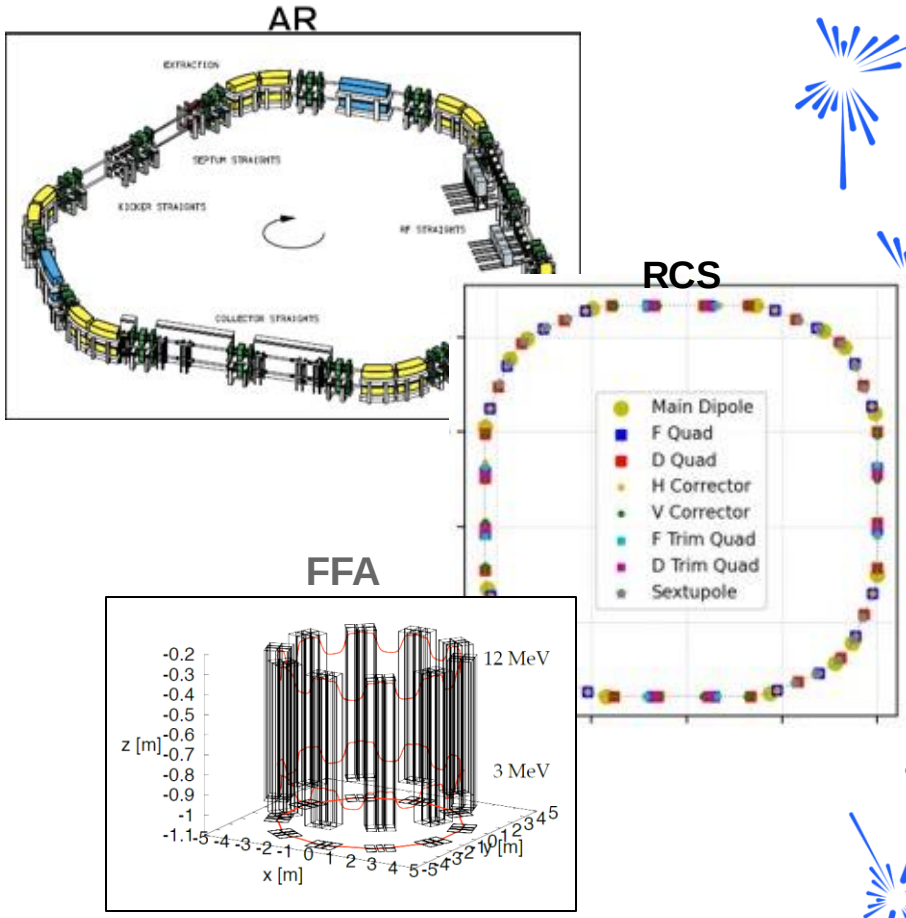
Environmental Impact and Life Cycle Assessment of ISIS-II

Two key stages to the analysis:

1. Core components of ISIS-II and their environmental impact.
2. Life cycle assessment to compare the various ring options for ISIS-II.



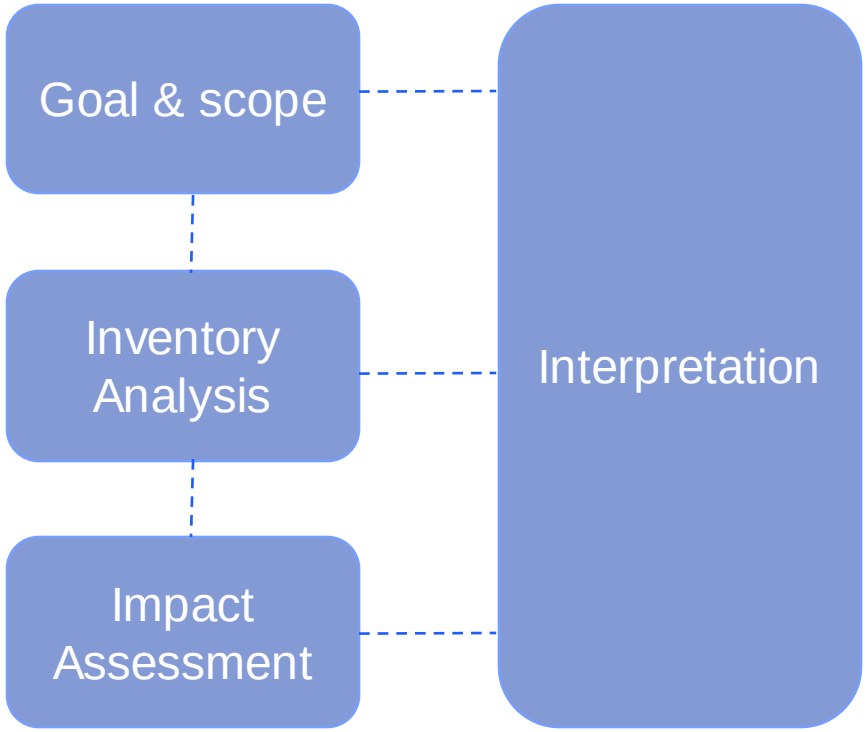
LINAC design proposal.



3 ring options for ISIS-II.

Life Cycle Assessment of ISIS-II

Life Cycle Assessment/Analysis (LCA):



LCA steps.

Environmental Impact and Life Cycle Assessment

Goal

- To report on the full lifetime environmental impact expected at ISIS-II.
- To investigate the broad question "Can ISIS-II be made more sustainable?".
- To evaluate and inform the design options for the rings of ISIS-II.

Scope

- The full ISIS-II facility.
- CO_2eq as assessment parameter but other environmental impacts not ignored/deemed negligible.
- RCS, AR and FFA and impacted components (LINAC,…)
- Currently the functional unit is "ISIS-II", with the view to update this in the future to, e.g., "user hours".

Inventory Analysis

Data collection and quality control:

- **Construction**
- Facility
- Machine
- Shielding
- Computing
- Location

- **Operation/Active life**
- Energy consumption
- Resource consumption inc. leakage
- Failure likelihoods/risks inc. replacement/repair

- **Decommissioning**
- Storage of radioactive materials

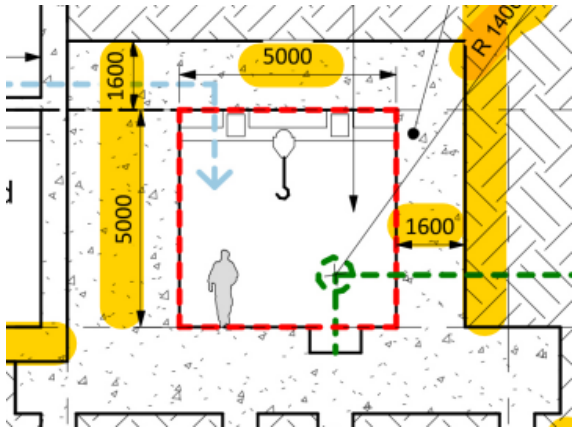
Input
(resources, materials, semi-products, products)
vs.
Output
(emissions, waste, valuable products)

A first look at the overall environmental impact of ISIS-II

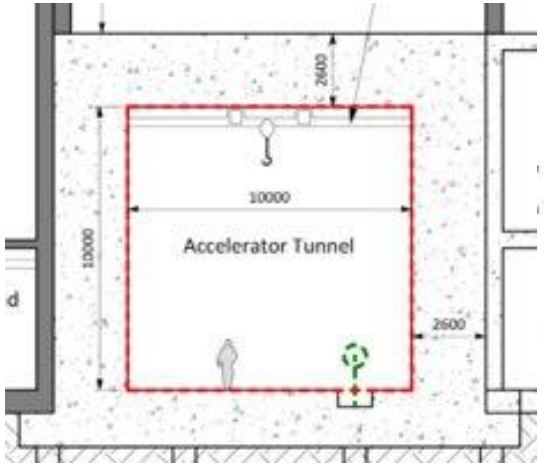
Disclaimer:

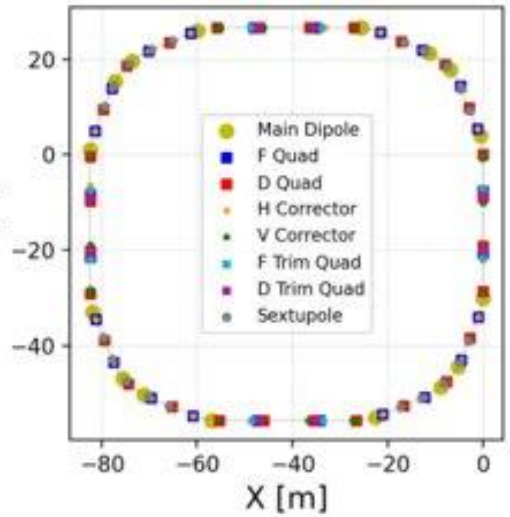
- Assumptions, assumptions, assumptions!
- Data coming in every day to update the models
- Future studies to come!

Construction

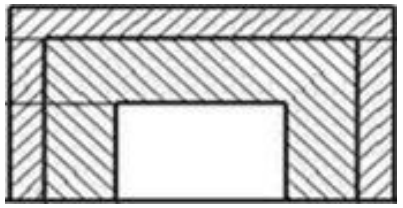


10s ktCO$_2$

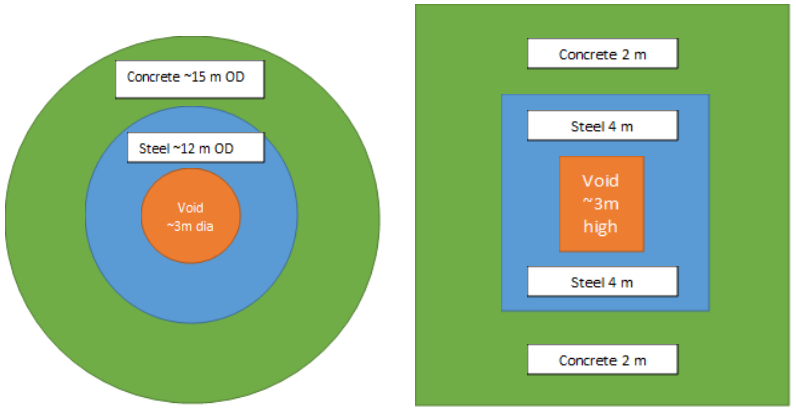




10s ktCO$_2$



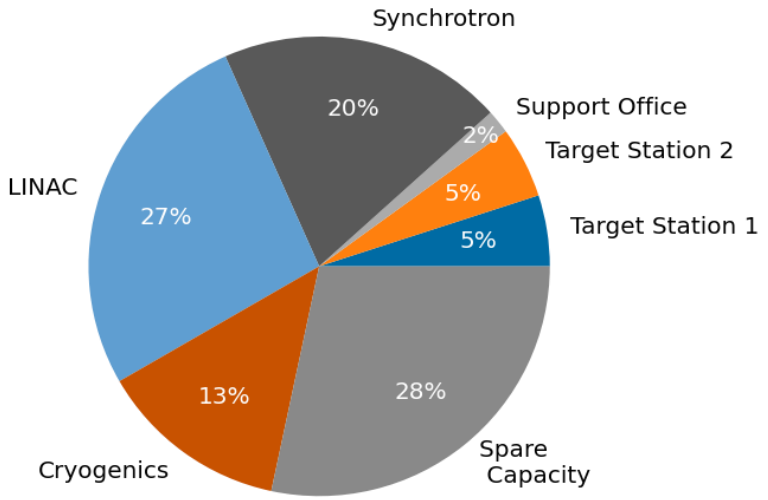
100s ktCO$_2$



10s ktCO$_2$

Operation

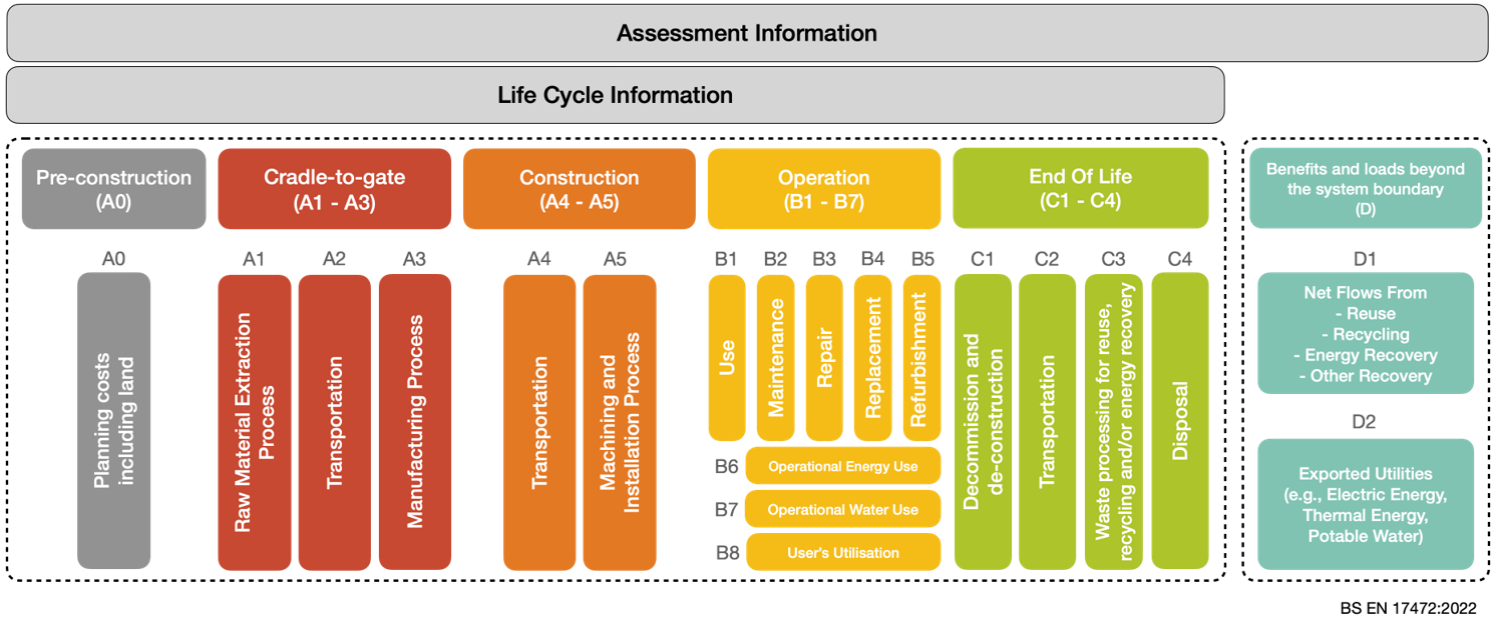
Power	Big Science Scheme	
	[MVA]	[tCO2e]
Target Station 1	1.5	30,156
Target Station 2	1.5	30,156
Support Office	0.5	10,052
Synchrotron	6	120,625
LINAC	8	160,834
Cryogenics	4	80,417
Spare Capacity	8.5	170,886
TOTAL	**30**	**603,126**



The power values are assumed to reflect the beam on/off ratio of ISIS-II and present the 60-year operational lifetime impact of ISIS-II, including presently known "decarbonization of the UK grid" estimates.

Decommissioning

Impact Assessment



BS EN 17472:2022

A. Construction
B. Operation
C. Decommissioning

- Following the EN 17472:2022 standard as a basis.
- Using the ReCiPE:2016 Midpoint (H) Life Cycle Impact Assessment Method.
- Using openLCA with the Idemat database (currently, fluid!)
  - One good outcome of this: naturally creates a database with key particle accelerator components such as magnets.

A first look at the overall environmental impact of ISIS-II

Area	Total estimated power [tCO_2e]	Embodied carbon from buildings [tCO_2e]	Tunnelling [tCO_2e]	Shielding materials [tCO_2e]
Target Station 1	30,156			~15,000
Target Station 2	30,156			~15,000
Support Office	10,052			-
Synchrotron	120,625			~10,000
LINAC	160,834		~10,000	~40,000
Cryogenics	80,417			-
Spare Capacity	170,886			-
Other (inc. support hall, EPBs)	-			~150,000*
TOTAL	**603,126**	**~100,000**	**~10,000**	**~230,000**

NB: Rest to come!

* Recent update – please take with bag of salt.

Thank you for your attention, questions welcome!

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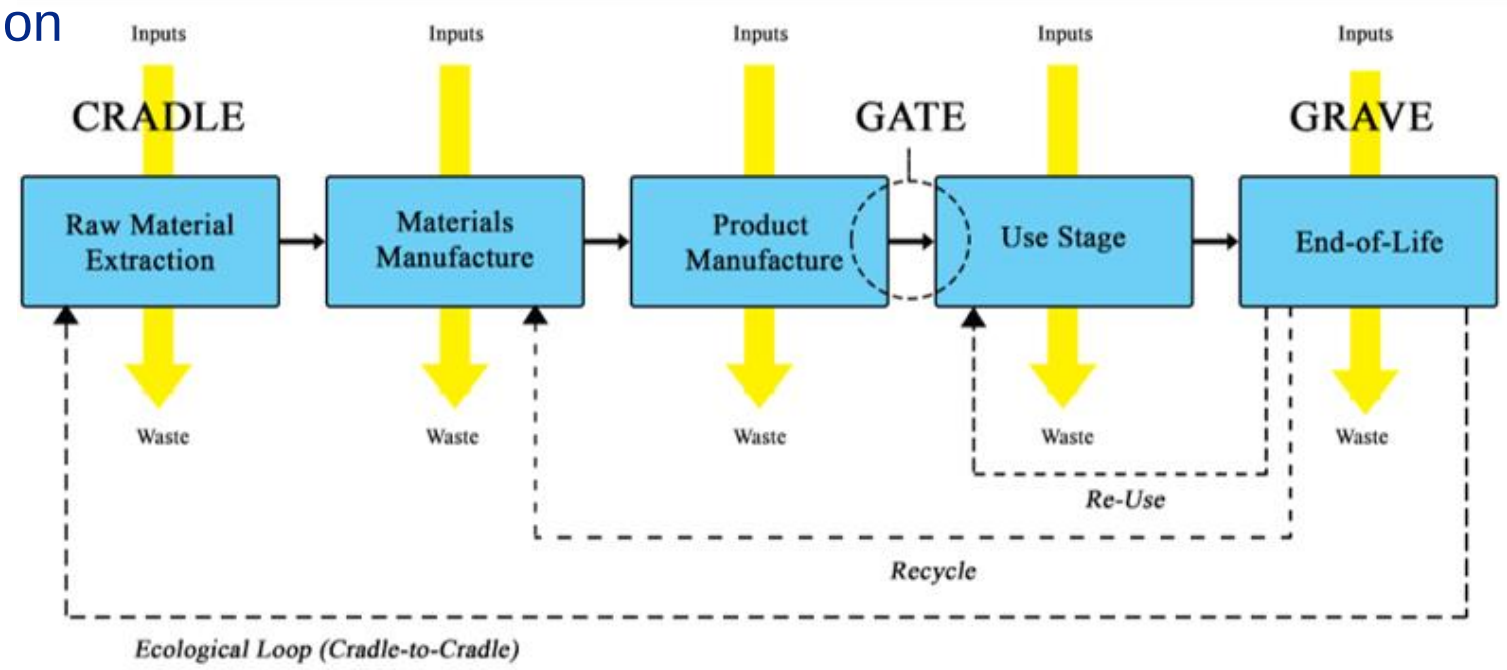
Life Cycle Analysis (LCA)

1. Goal & scope
2. Inventory analysis
3. Impact assessment
4. Interpretation

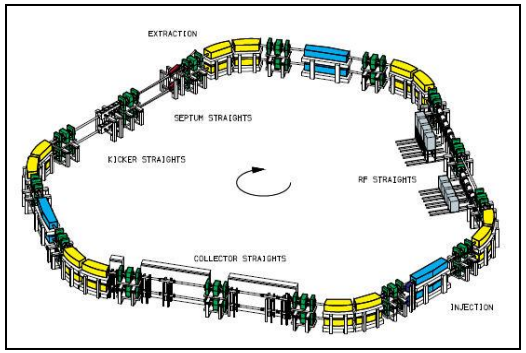


Options analysis

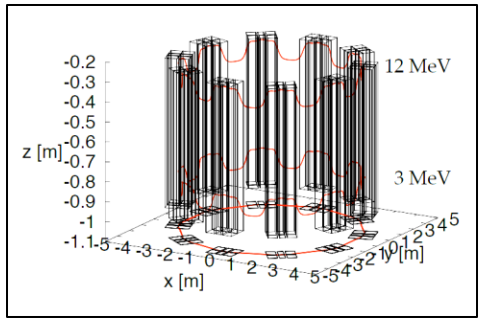
Once methodology established:

- Options-based LCA
- To inform ISIS-II phase 1.2b bid of compression ring options
    - Low energy linac with RCS
    - Low energy linac with FFA
    - Full energy linac with AR
    - Fall back option: 180 MeV linac upgrade to ISIS
- Timescale of 1 year.

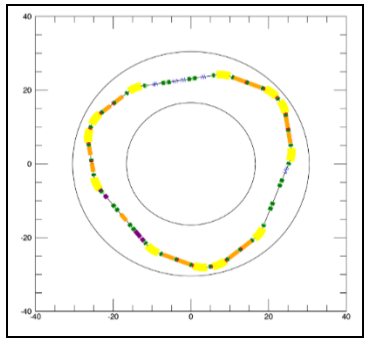
AR



FFA



RCS



High repetition rate target options

New 30 Hz 1.6 MW target station

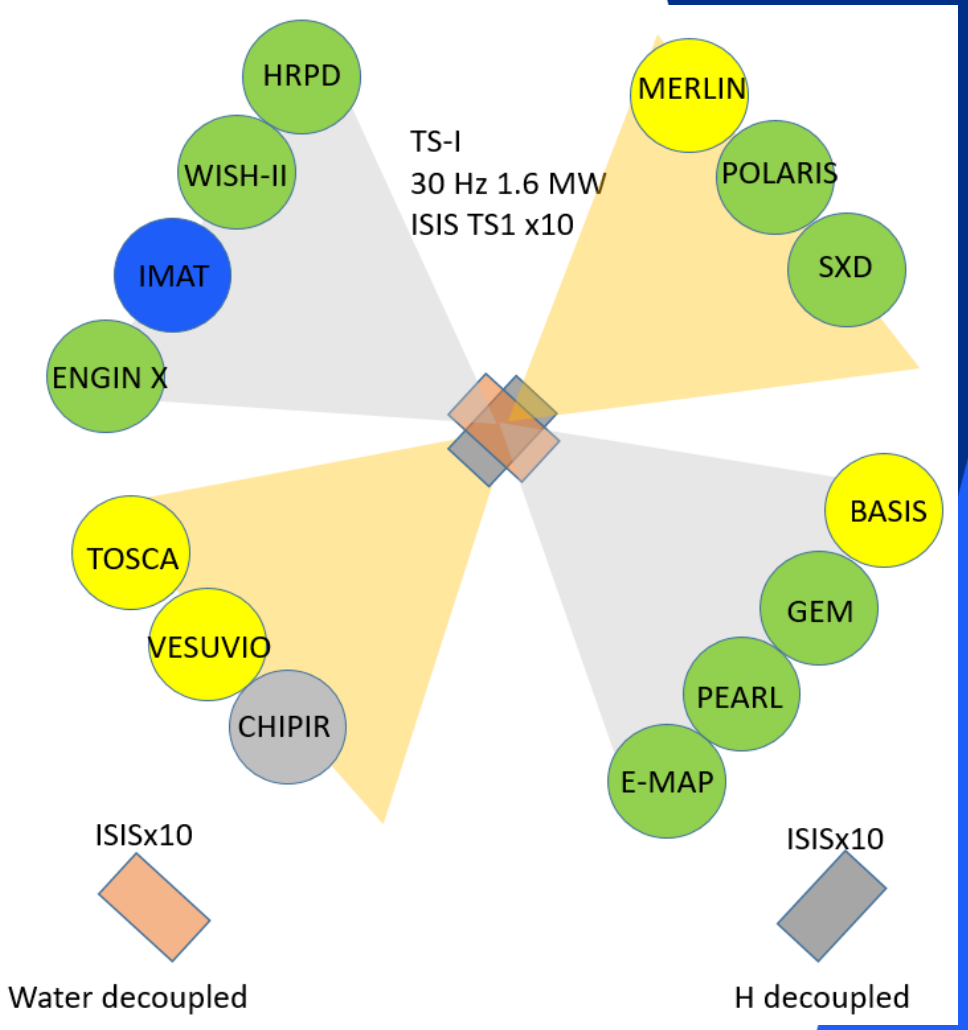
High resolution target station

Same or better resolution as current TS1

Expect gains to be proportional to power

Decoupled Water and Hydrogen moderators

Flux gain of 10 over current TS1 at same resolution.



Low repetition rate target options

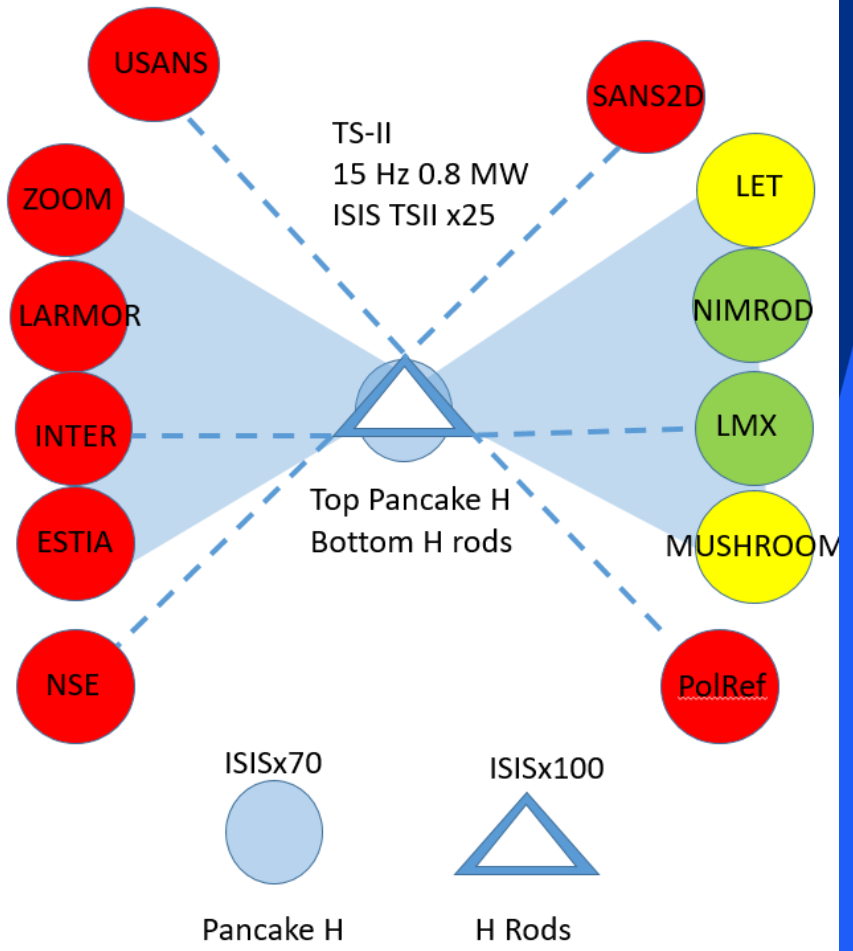
TS2 - 15 Hz 0.8MW

TS2 would focus on cold neutrons and high brightness

The preliminary concept looks a lot like SNS Second Target Station.

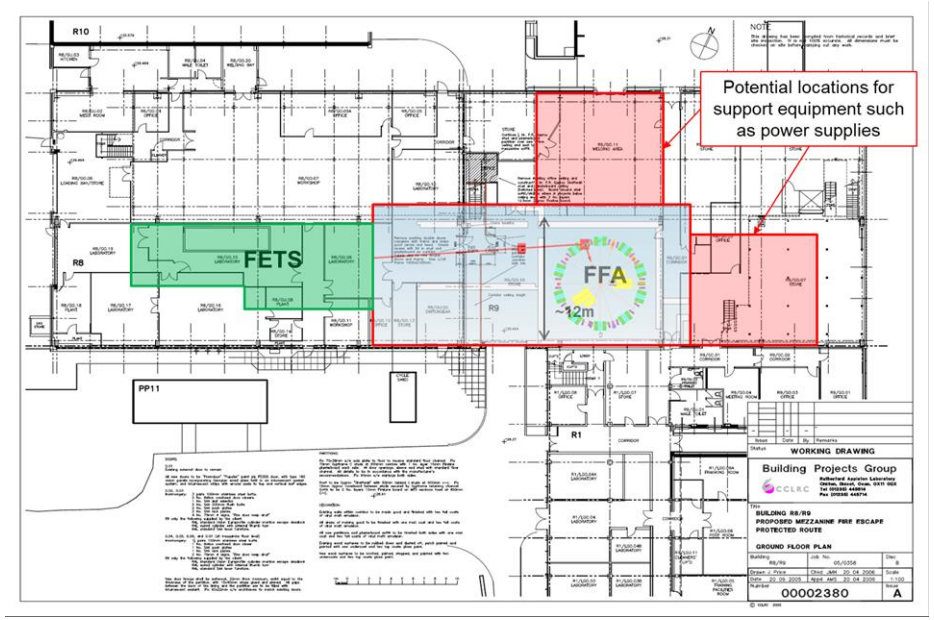
This would give gains of 70-100

For a green field facility there are several options for muon production, such as intermediate targets or stand alone stopping targets.



ISIS-II project phase 1.2b plan

- Construction of a small FFA test ring on the end of the Front End Test Stand (FETS) at RAL in order to explore the beam dynamics fully.
- Completion of compression ring designs.
- Linear accelerator design integrated with choice of pulse compression ring.
- Completion of target, moderator and shielding design for high and low repetition rate neutron targets and a muon target.
- Production of an optimal concept design with credible initial cost estimates.



What might ISIS-II look like?

Science and Technology Facilities Council

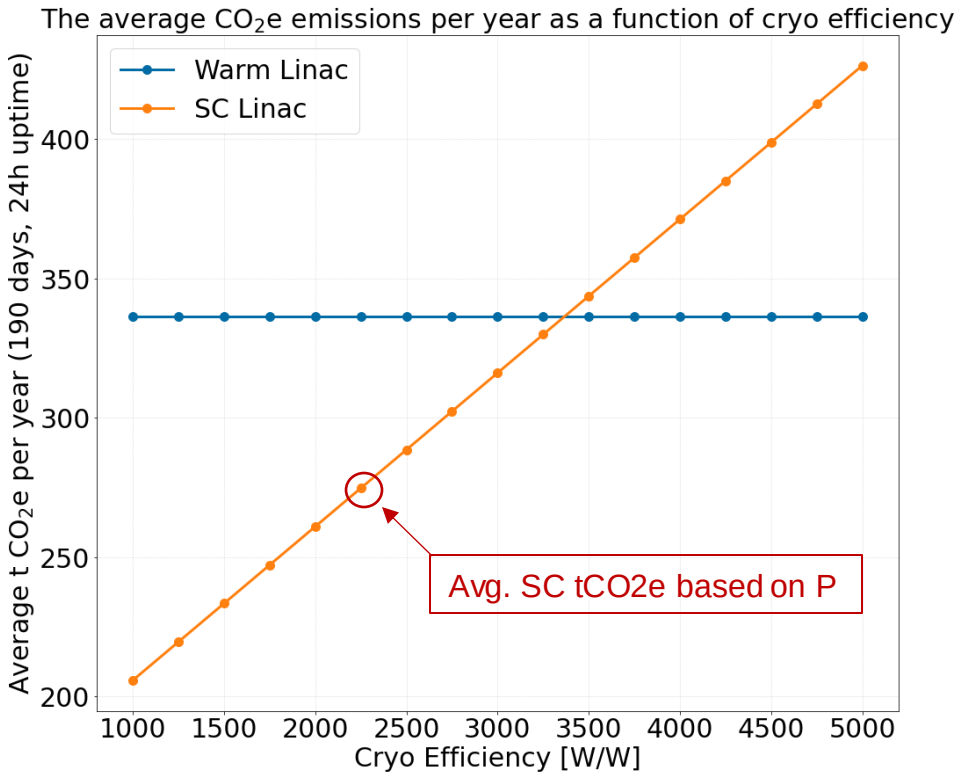
ISIS Neutron and Muon Source

www.isis.stfc.ac.uk

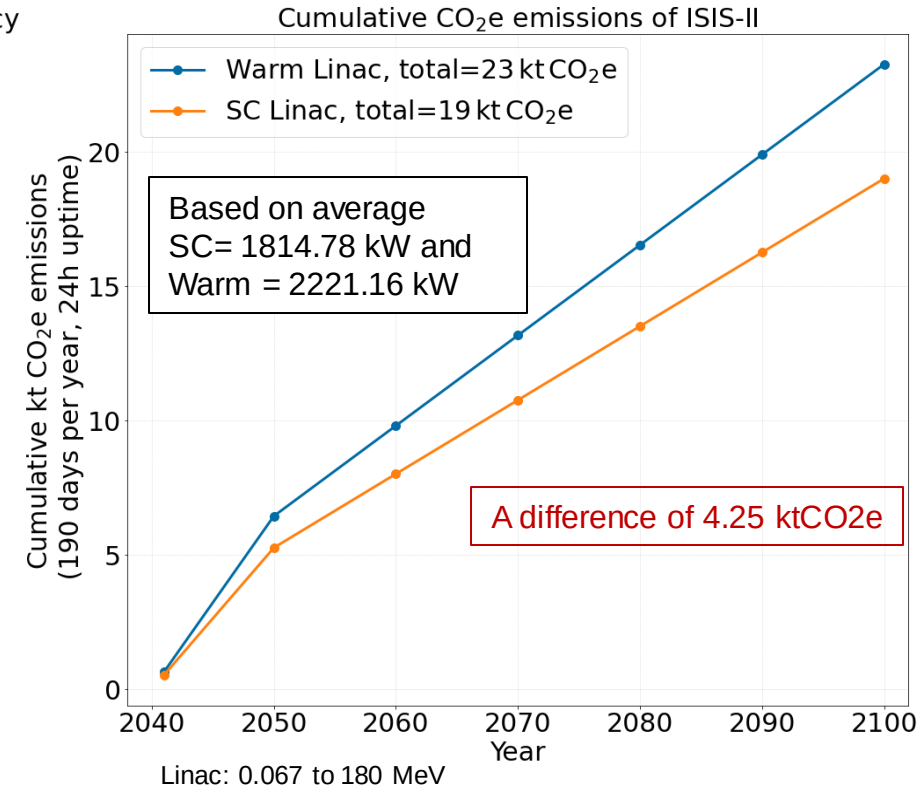
@isisneutronmuon

uk.linkedin.com/showcase/isis-neutron-and-muon-source

Operation: a comparison of warm LINAC and SC LINAC
(From A. Letchford's efforts)



Comparison of warm and SC LINAC as a function of cryo efficiency
(using 2050 energy CO2e emissions per kWh)



Cumulative CO2e emissions with comparison of SC vs. warm LINAC using total wall plug power (note **k**t CO2e)

Year	CO_2 emissions [t CO_2/kWh]
2020	1.415×10^{-4}
2030	8.51×10^{-5}
2040	6.36×10^{-5}
2050	3.32×10^{-5}

Aurora Energy Research