

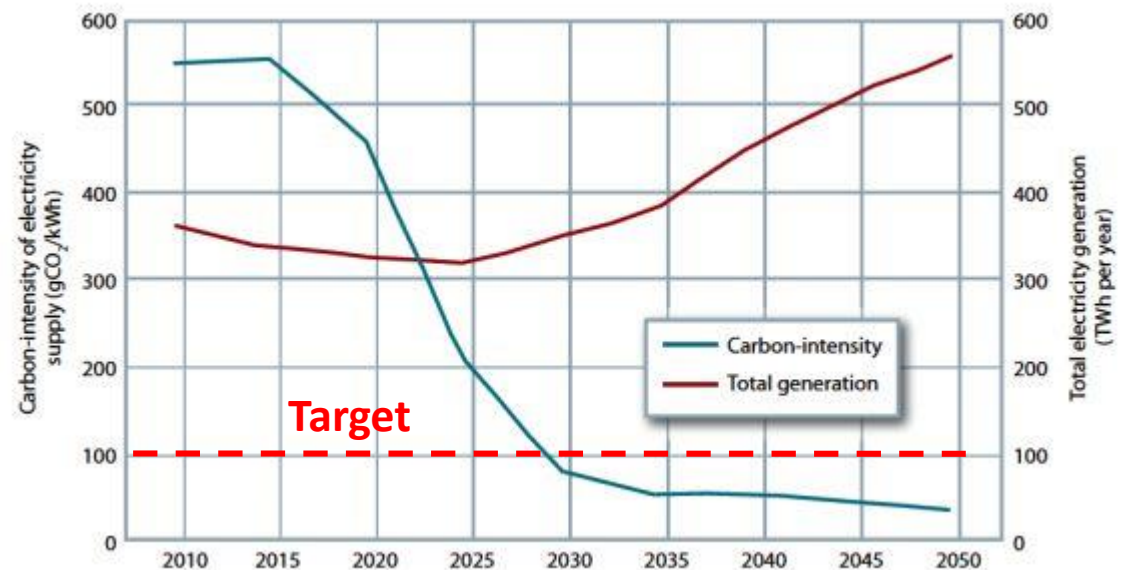
Nuclear Energy Education and Research

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UK Case

- ❑ Cut carbon intensity of power generation by 80-90%
- ❑ While the demand is expected to double
- ❑ Need for massive move to cleaner fuels ($< 100 \text{ gCO}_2 / \text{kWh}$)
 - Renewables
 - Nuclear



UK Case – Current plan

- ❑ Meeting the projected ($\times 2$) demand
 - 30,000 windmills ~ 80 GWe (nominal) or 20-25 GWe (average)
 - $\times 8$ increase over the current capacity
 - CCGT (gas) – fill the gap and assure grid stability
 - 20-30 GWe of new nuclear
 - $\times 3$ increase over the current capacity
 - One new nuclear plant each year (!) starting 2020

DECC Calculator



Nuclear New Build Sites



Reasons for Nuclear Education

- ❑ **UK is planning to build 16GWe of new nuclear power stations by 2030:**
 - **Using private funds – with guaranteed electricity prices;**
 - **Three consortia with three reactor designs in the market;**
 - **First project – EDF Energy with EPR – 3.3GWe twin at Hinkley Point in SW.**
- **New nuclear engineers required to construct, commission and operate these reactors;**
- **New UK interest in nuclear research;**
- **Many of current nuclear staff in UK are approaching retirement;**
- **Many other developments around the world require well-trained nuclear engineers.**

Nuclear Energy Education in Cambridge

❑ Undergraduate

- Introduction to NE, Nuclear Materials, Reactor Engineering, Advanced Systems/Fusion, Medical Physics
- Over 150 students took NE introductory module last year
- 10 – 20 fourth-year Engineering Projects were offered

❑ Graduate

- NE MPhil – one year full time masters course
- 15 PhD students in Engineering/Physics, Waste/Materials and Business/Policy
- Centre for Doctoral Training (CDT) – jointly with OU and ICL

Nuclear Energy Research Community in Cambridge

- ❑ **Cambridge Nuclear Energy Centre**
- ❑ **Coordinates cross-discipline collaboration**
- ❑ **About 15 academics are actively engaged in NE related research**
 - **Department of Engineering: Physics and design of advanced systems**
 - **Department of Earth Sciences and Department of Materials Science & Metallurgy: Waste and decommissioning, high temperature reactor materials, fuel reprocessing, fracture mechanics and steels**
 - **Judge Business School: Economics, technology policy**

MPhil in Nuclear Energy - Overview

- ❑ **Taught 1 year MPhil in Nuclear Energy (runs October – August each year)**
 - **20 -25 top students from around the world each year;**
 - **Five core nuclear engineering modules;**
 - **One core nuclear policy module;**
 - **Elective modules from masters teaching in Engineering, Materials Science, Chemical Engineering, Physics and Judge Business School;**
 - **Long project & dissertation – four months research project in the Summer on either:**
 - **Cambridge research topic or**
 - **Industry partner research area.**



Nuclear Energy MPhil - Core Scope

Core Topic	Scope
Reactor Physics	Core physics & shielding – steady state power & shapes, depletion control elements & use of poisons, core kinetics & system control.
Reactor Engineering & Heat Transfer	Coolant types, thermal cycles, heat transfer, thermal limits – reactor systems, their optimisation and operating characteristics including normal operation & how to address main types of fault condition.
Fuel Cycle, Waste & Decommissioning	Whole fuel cycle: mining to waste & how waste is managed, decommissioning principles.
Fuel & Reactor Materials	Fuel and reactor materials – including selection, safety and life issues – radiation behaviour & damage, structural integrity & fracture mechanics, EAC.
Safety & Advanced Systems	Safety philosophies, impact on design, justification approaches, control & reliability, advanced systems including Gen IV, Thorium & Fusion
Nuclear Technology Policy	Energy studies & climate change, economics of energy, nuclear politics, proliferation & physical security.

MPhil – Breadth & Depth of NE Education

❑ Breadth:

- Teaching a wide range of nuclear engineering and policy topics
- Visits & experiments: Sizewell B, Culham Fusion R&D lab, Research Reactor
- External lectures by leading figures from the nuclear industry

❑ Depth:

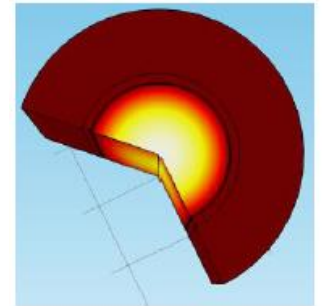
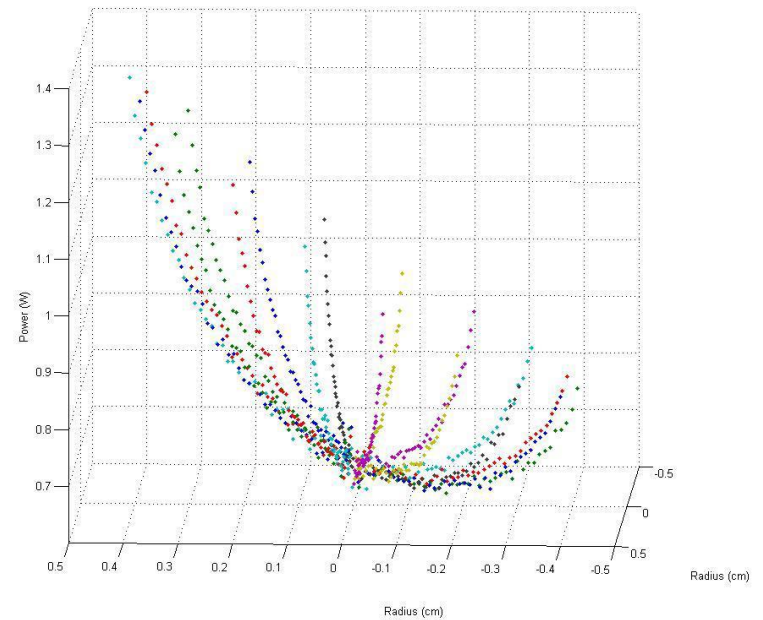
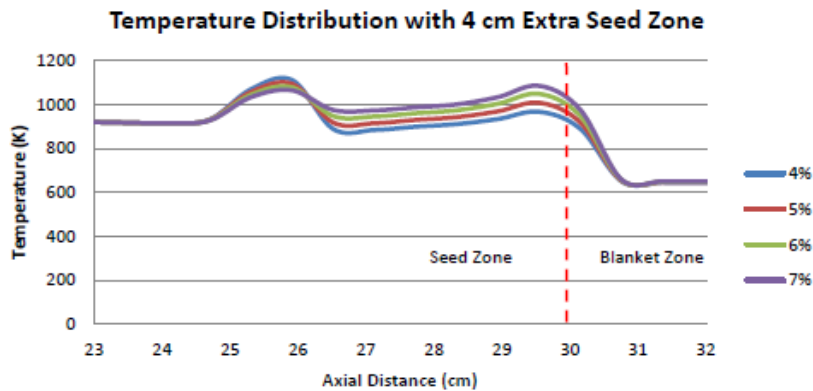
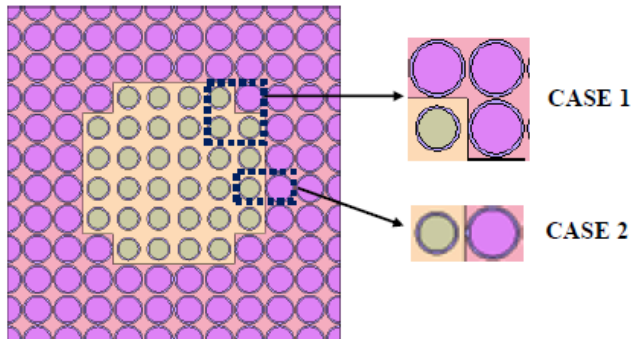
- Choice of optional/elective courses;
- Long research project and dissertation.
- Offer projects from industry – addressing a real issue with supervision by industry.

Examples of MPhil Projects

Title	Student
WIMS/ PANTHER model for a start-up EPR Core	Jinfeng LI
Economics of SMRs – design options	Inkar Yertayeva
Managing power peaking at fissile-fertile interface in HC LWRs	Cuicai Dong
Ethical Principles & Values in Nuclear Safety	Annie Bonaccorso
Accelerator Production of medical isotopes	Tianyi Wang
Commercial Nuclear Marine Core Design	Hao Sun
Electron Beam welds in nuclear pressure-vessels	Chris Duffy
Waste glass dissolution modelling	Rui Guo
Modelling of Fast Reactor transients	Xinyu Zhao
Energy group structure optimisation for fusion reactor applications	Michael Fleming

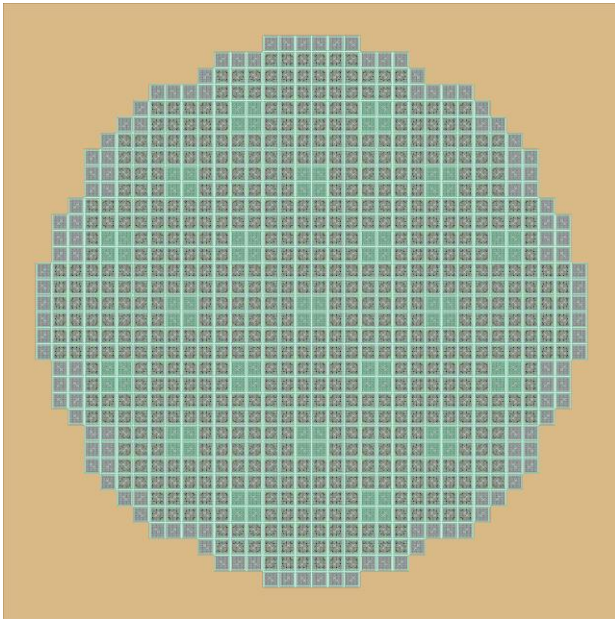
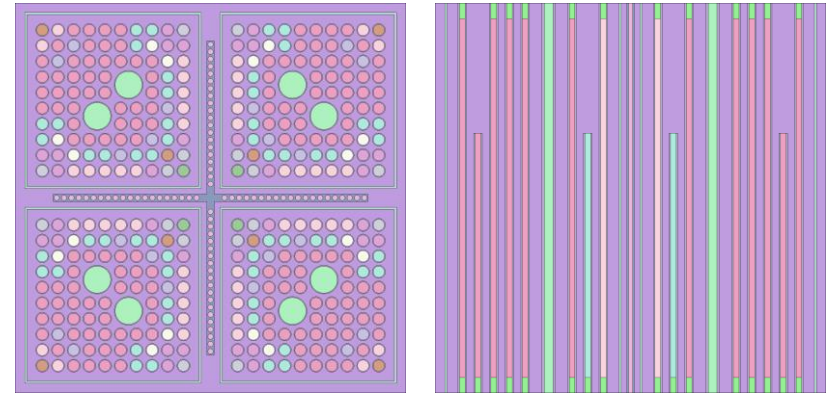
Examples of using Serpent

❑ Seed-blanket interface multi-physics modelling

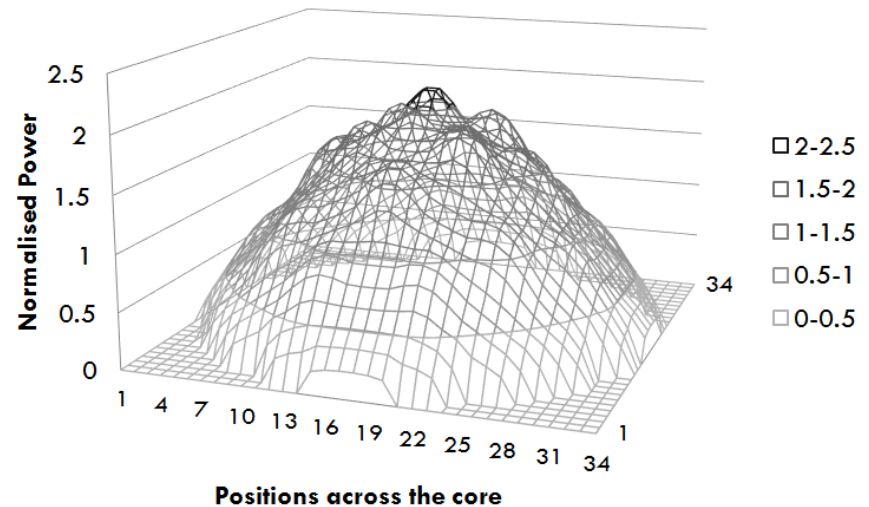


Examples of using Serpent

- ❑ ABWR modelling
 - Serpent XS + PANTHER
 - Thermal feedbacks included



Core Radial Power Distribution -BOC

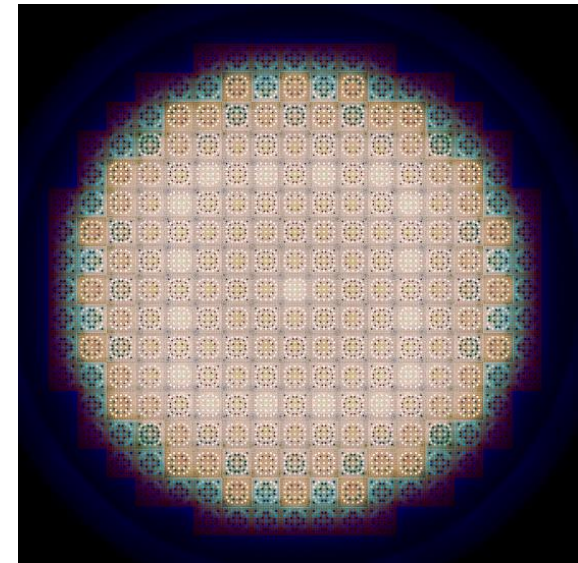


Examples of using Serpent

❑ EPR startup core modelling

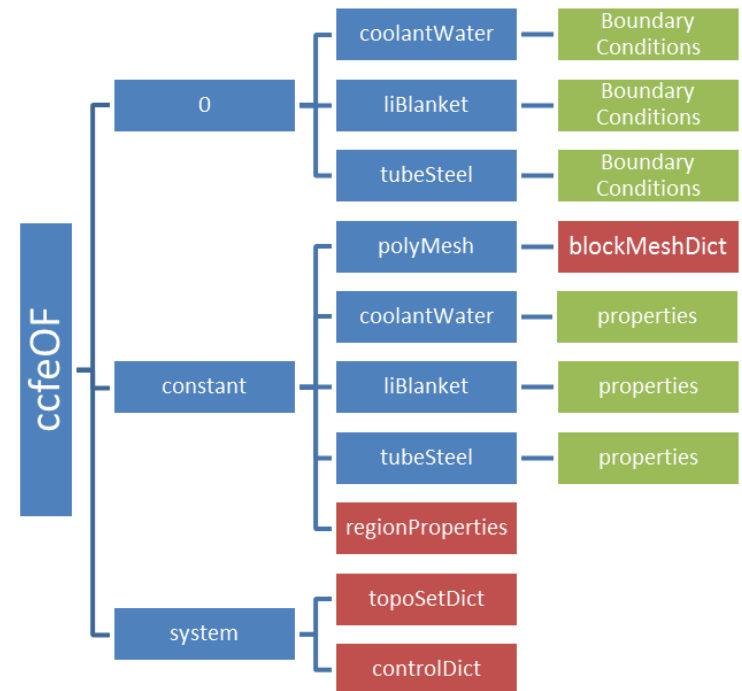
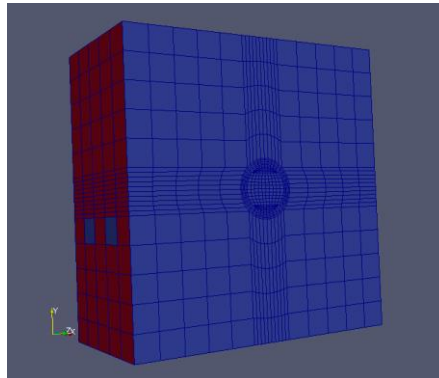
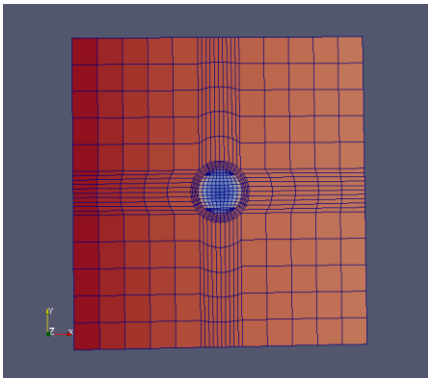
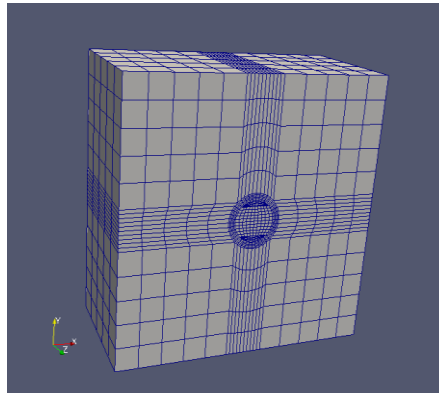
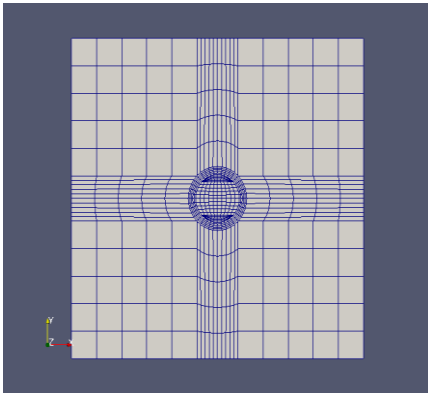
- WIMS/Serpent XS + PANTHER
- Thermal feedbacks included

		This work	ONR report	Difference
Critical Boron Concentration (ppm)		1029	1026	0.3 %
Total Heat Flux Hot Channel Factor		2.69	2.82	-4.8 %
Hot Channel Factor		1.63	1.61	1.2 %
Doppler Coefficient (pcm/K)	BOC	-2.90	-2.93	1.0 %
	EOC	-3.17	-3.21	1.2 %
MTC (pcm/K)	BOC	-13.7	-13.0	5.4 %
	EOC	-64.2	-60.6	5.9 %
Boron Worth (pcm/ppm)	BOC	-9.1	-9.3	2.2 %
	EOC	-9.4	-9.7	3.1 %



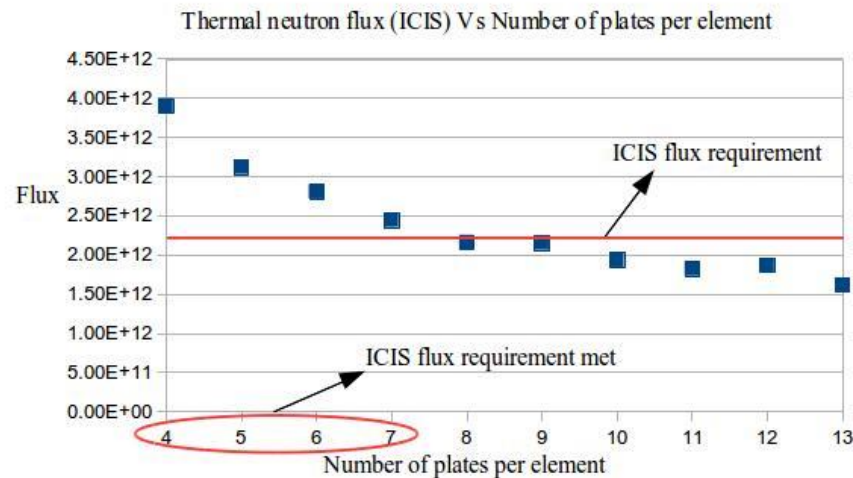
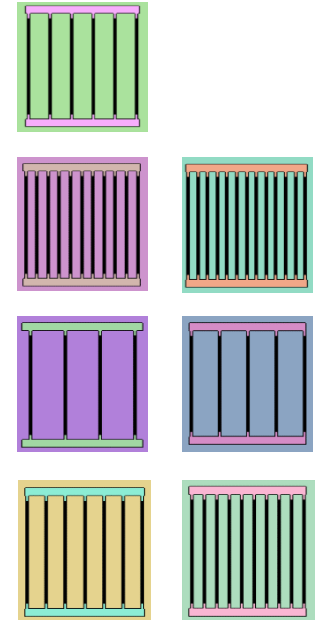
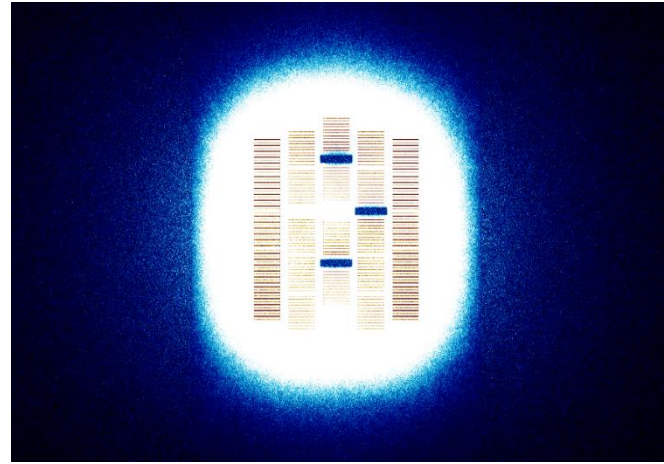
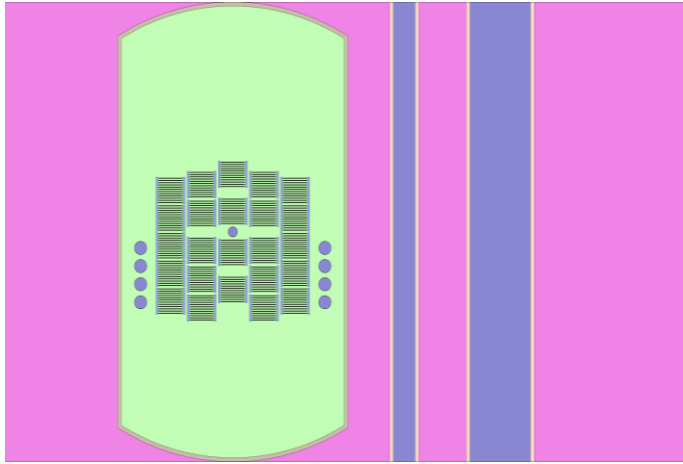
Examples of using Serpent

❑ Multi-physics modelling of fusion breeding blankets



Examples of using Serpent

❑ HEU to LEU fuel conversion of CONSORT reactor



Thank you