Small Modular Reactors – What, Why and When?

Modular Stable Salt Reactors - a simpler way to use molten salt fuel

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moltex energy
safer, cheaper, nuclear

SSR Development Team

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Development Partners

MANCHESTER 1824 The University of Manchester — *Neutronics Simulations, Corrosion and Heat Transfer Experiments*

ATKINS — *Plant Cost Estimating & Safety Assessments*

Institution of MECHANICAL ENGINEERS — *Venue Use & Communication Support*

NUCLEAR AMRC — *Prototype Fuel Assembly Fabrication and Manufacturing Reviews*

FRAZER-NASH CONSULTANCY — *Licensing & Controls Support (C&I)*

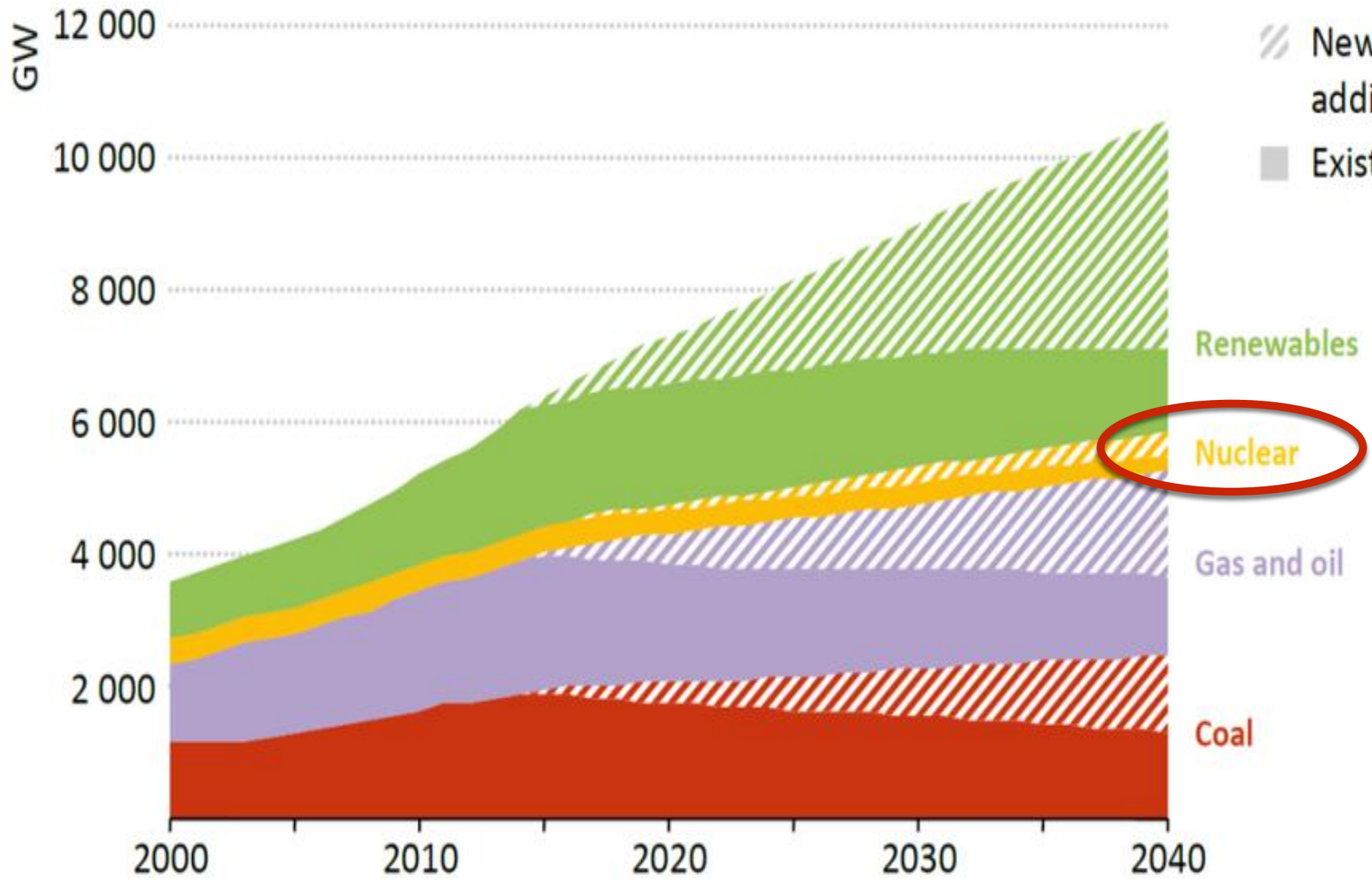
Wilde — *Computational Fluid Dynamic and Heat Transfer Simulations*

NATIONAL NUCLEAR LABORATORY — *Key Claim Validation*

SOLIDSOLUTIONS SUPPORTING EXCELLENCE — *CAD Modelling*

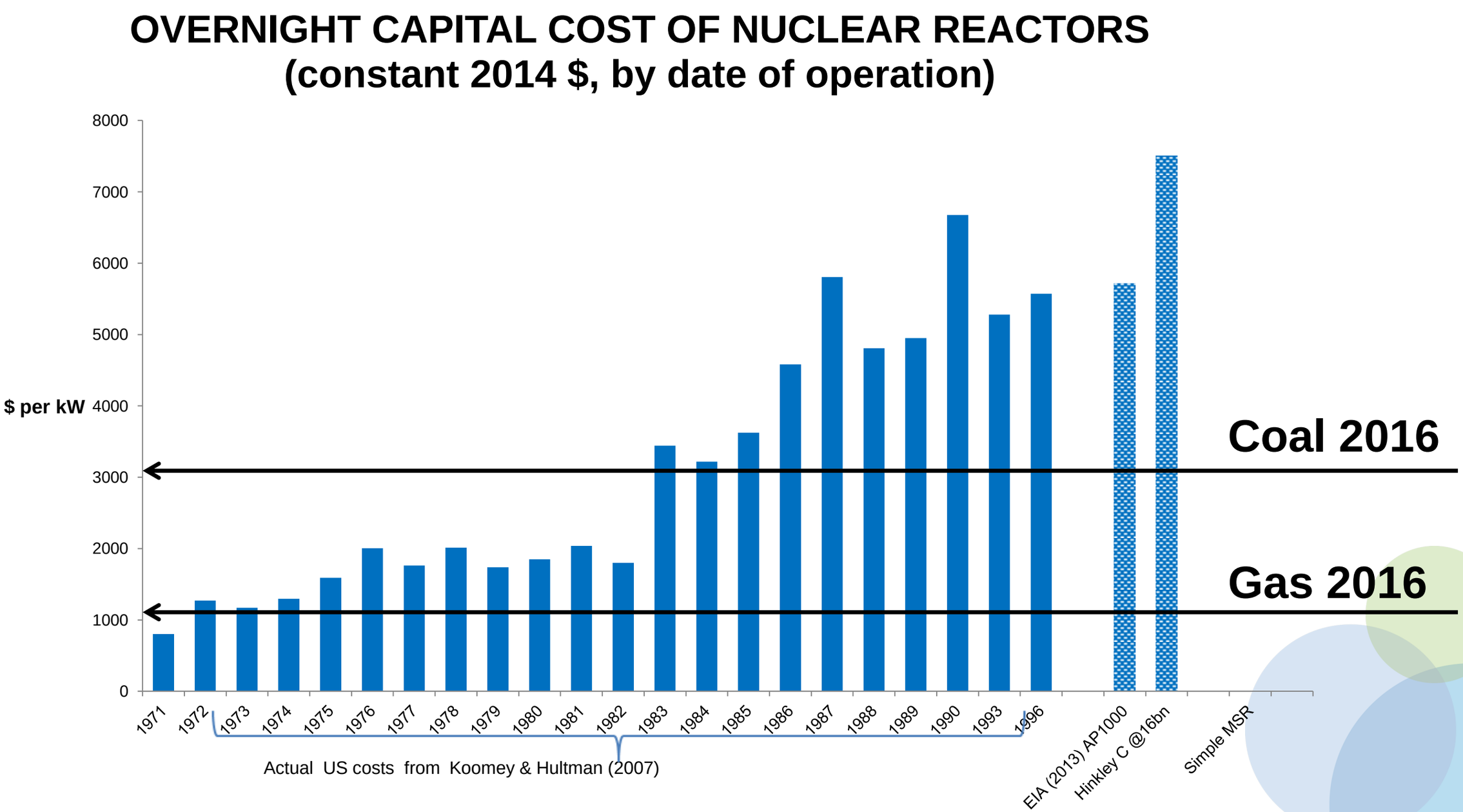
The Future of Nuclear Energy

Figure 8.4 ▷ Global installed capacity by source in the New Policies Scenario



International Energy Agency's World Energy Outlook 2015

Nuclear Energy is too Expensive



The Basic Hazards of Nuclear

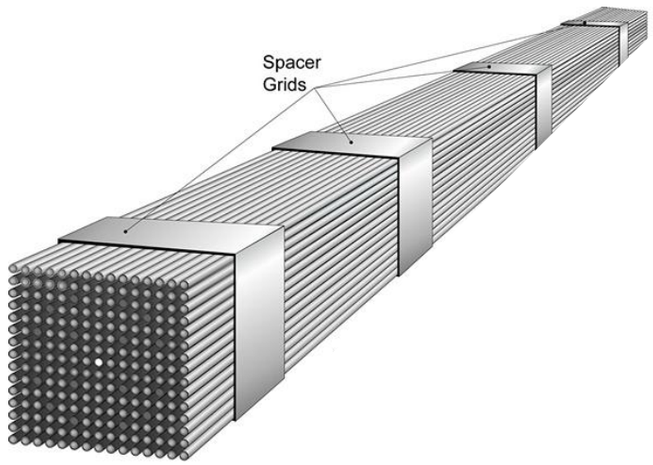
Volatile Caesium and Iodine gasses

High Pressures in Reactor Core to drive release

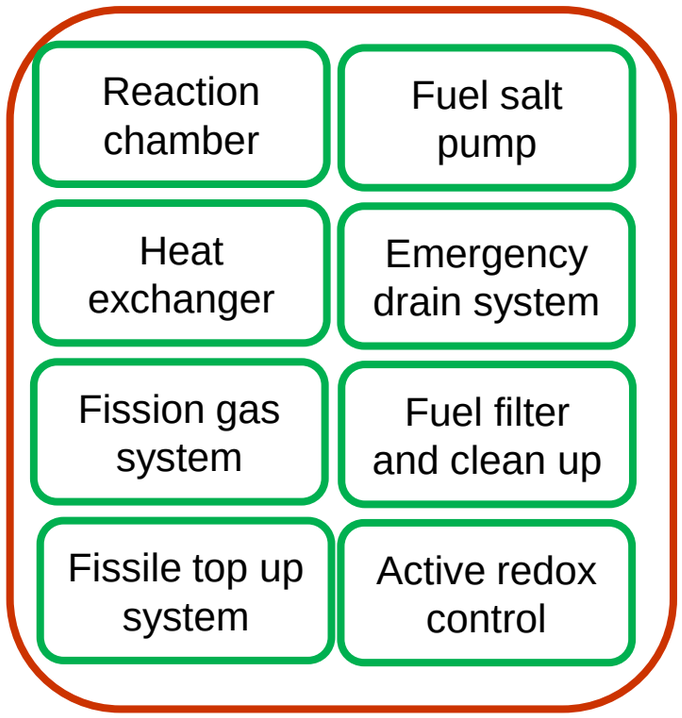
MOLTEN SALT FUEL ELIMINATES BOTH HAZARDS

Stable Salt vs Pumped Salt Reactors

A.R.E. 1949
STATIC FUEL SALT

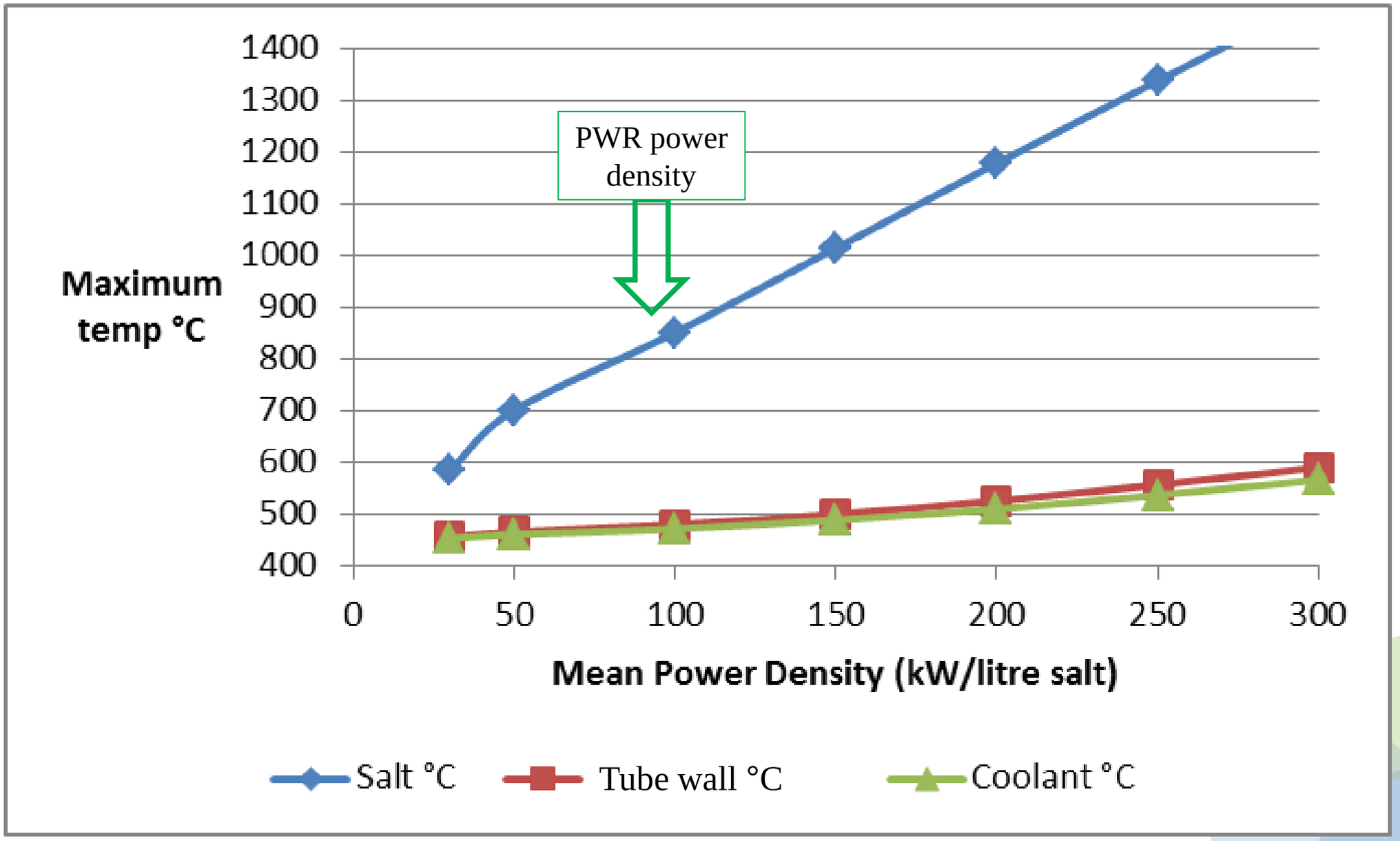


A.R.E. 1950
PUMPED FUEL SALT

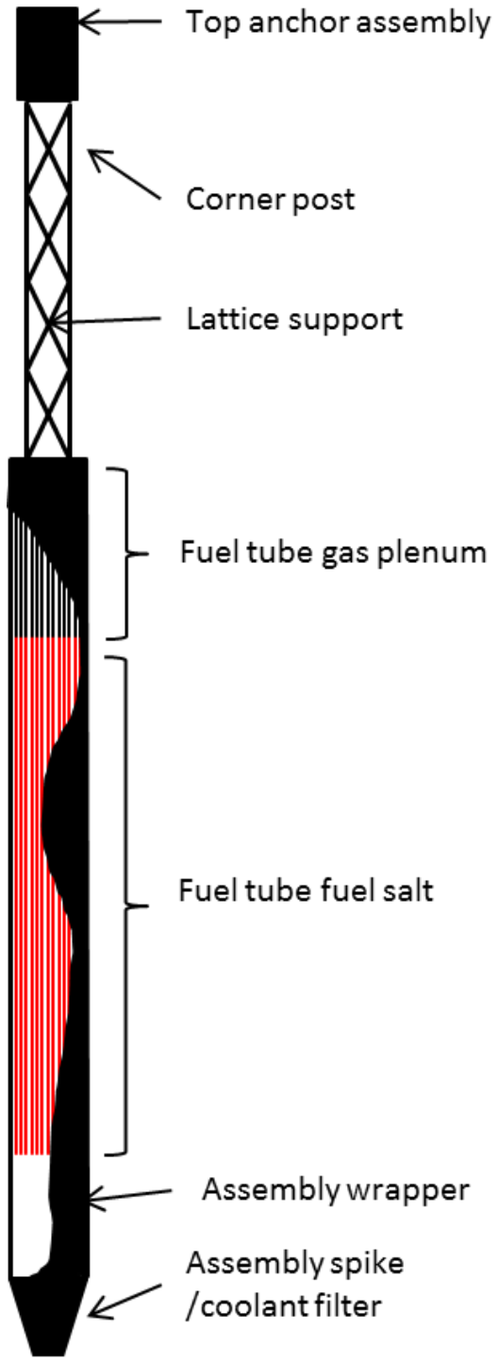


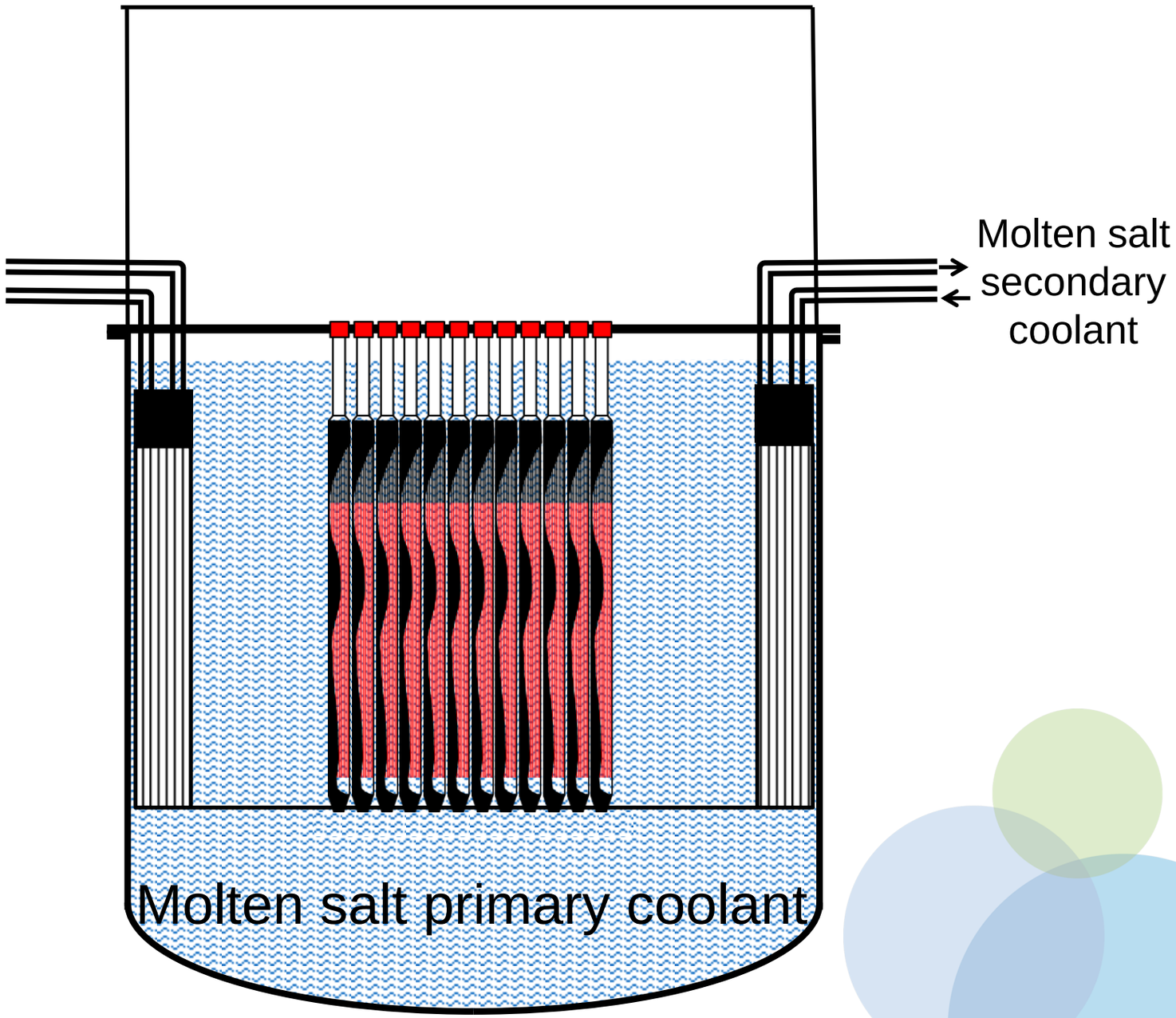
Aircraft Reactor Experiment decision to abandon simple static fuel salt concept has been the basis of every MSR design from 1950 to 2013

CFD Calculation of peak temperatures

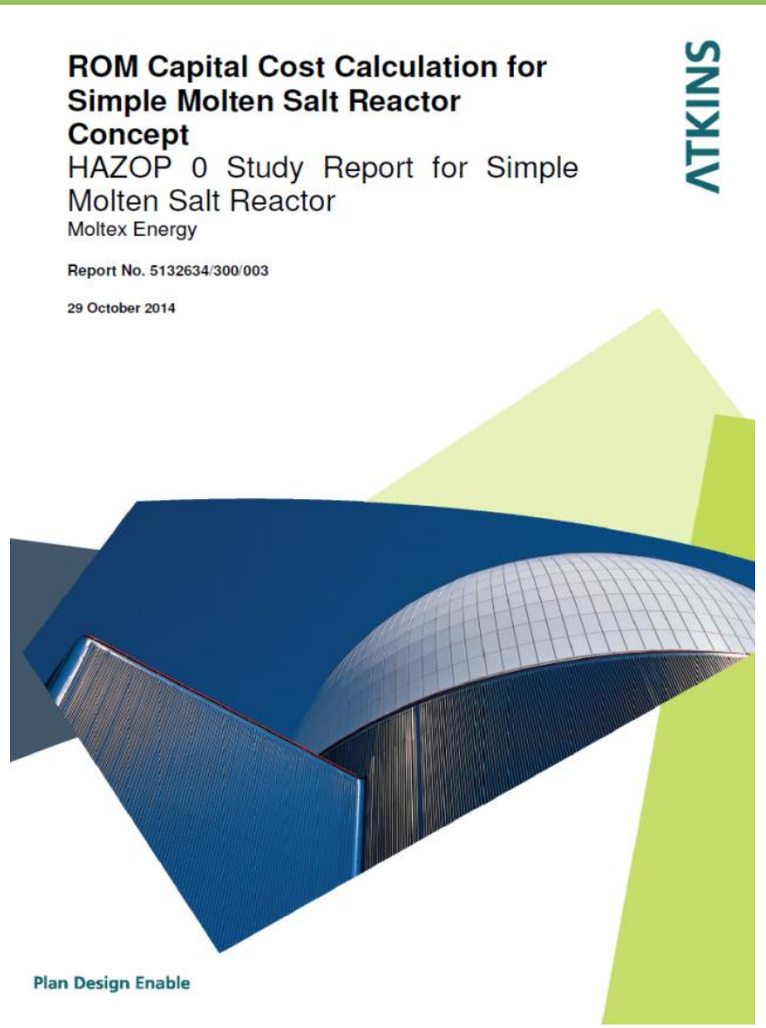


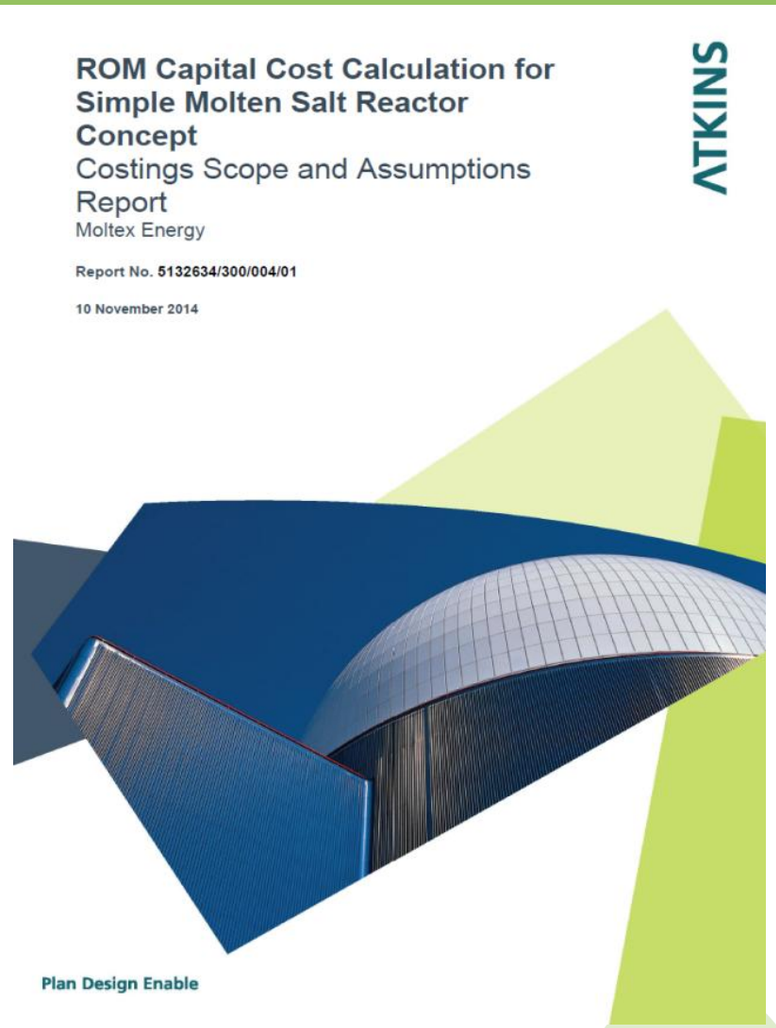
Basic Stable Salt Reactor Design





Cost Estimate by Atkins Ltd



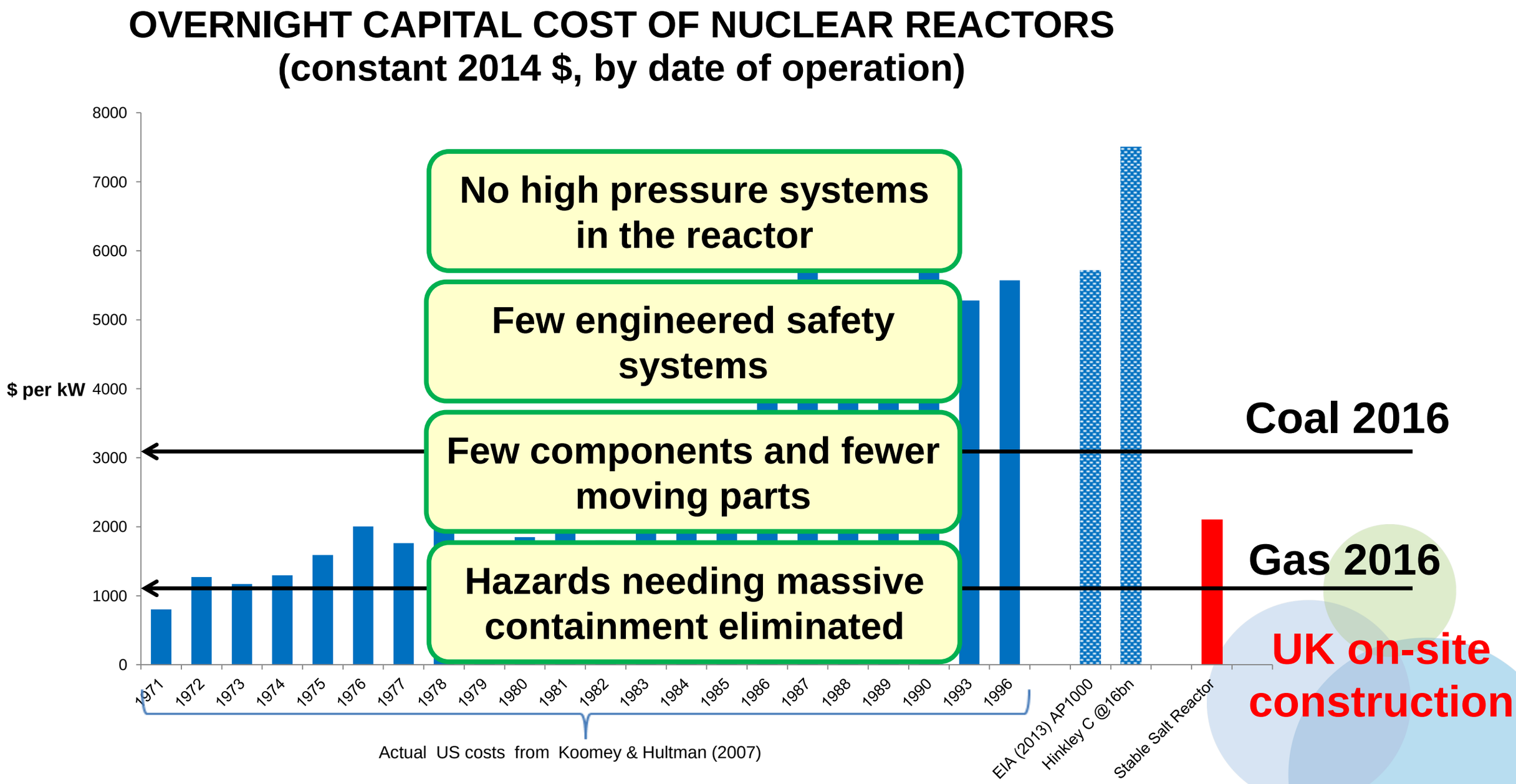


Review conceptual design against UK SAP's (Safety Assessment Principles) from Office of Nuclear Regulation

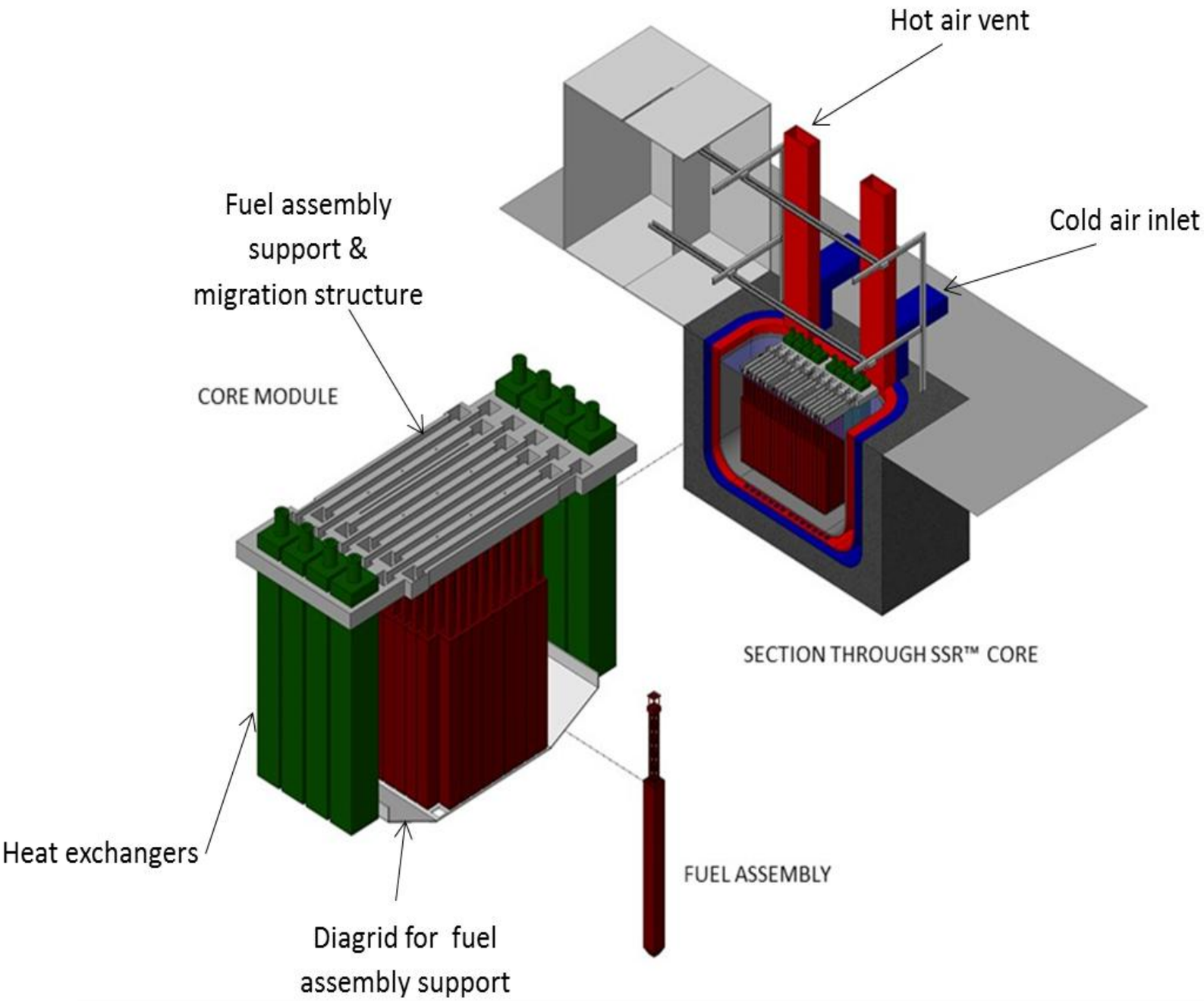
Carry out HAZOP 0 analysis identifying essential structures, systems and components required for safe operation

Calculate approximate capital cost of the nuclear and electrical generator islands of an Nth of a kind Simple MSR

Stable Salt Reactor Capital Cost

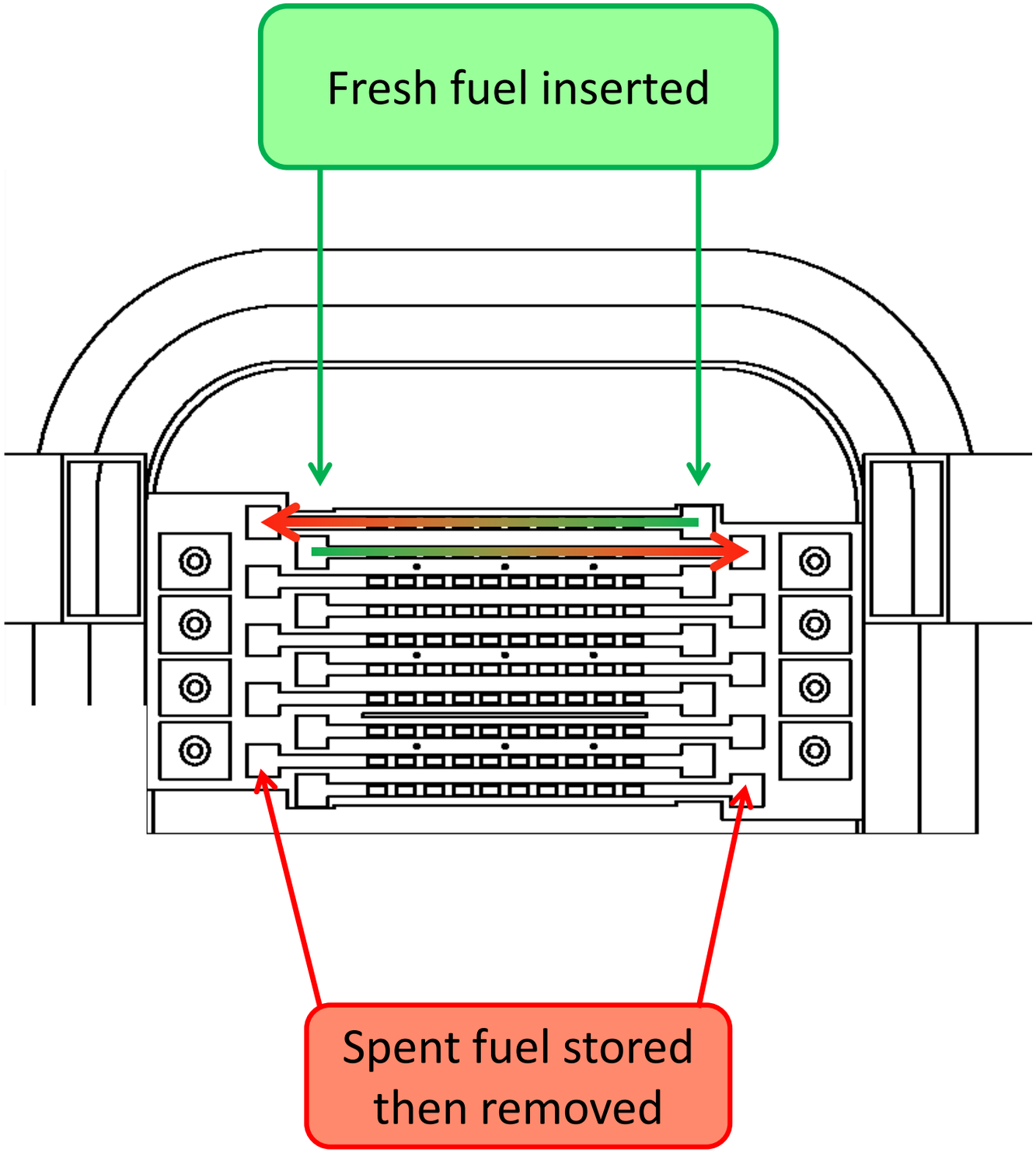


Modular SSR construction



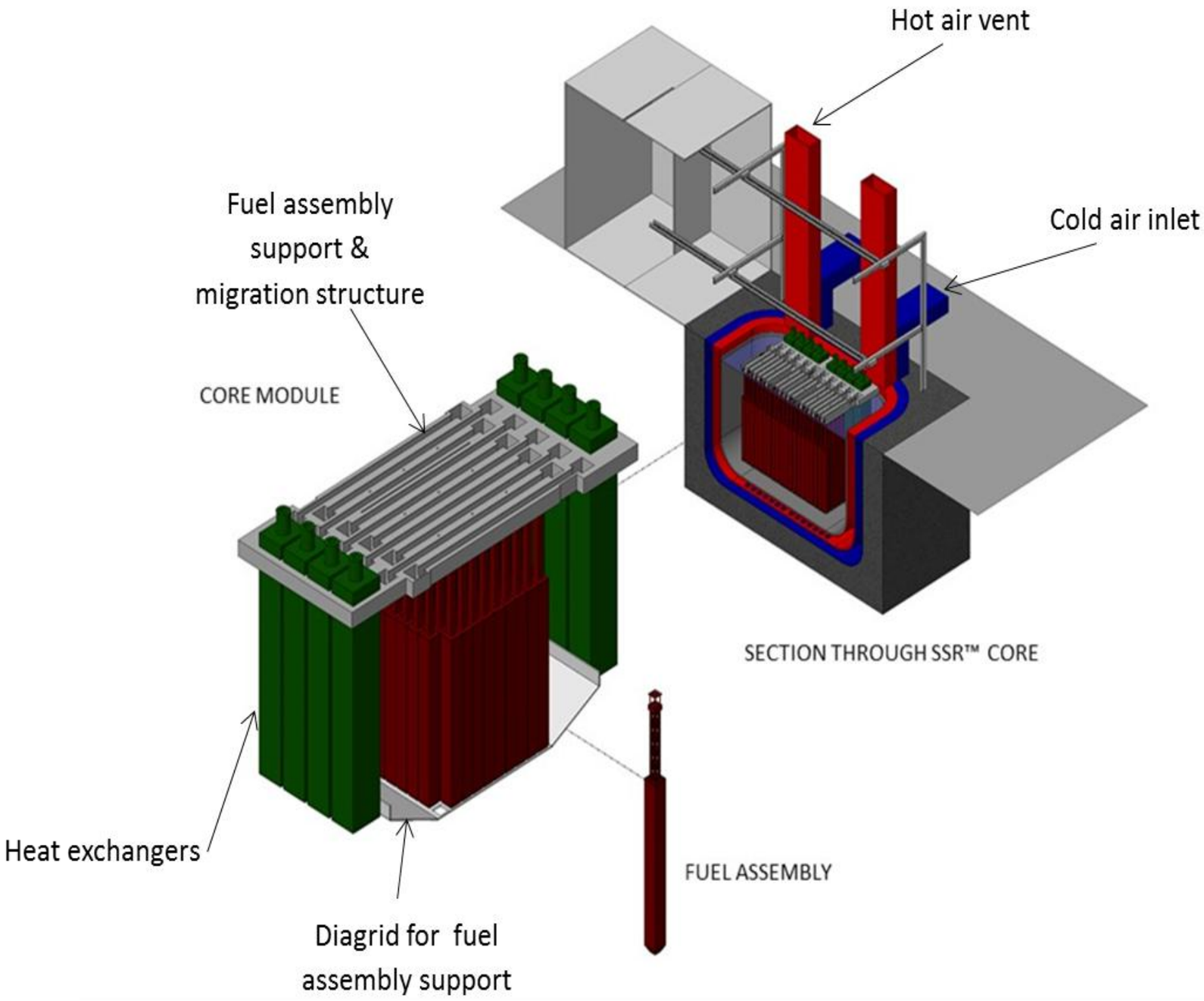
- Core module 150MWe
- Up to 8 modules
- Road transportable

Fuel Management



- Rectangular core allows counter-flow migration of fuel assemblies while on power
- Spent fuel cooled in reactor until it will freeze on withdrawal

Modular SSR construction



- Core module 150MWe
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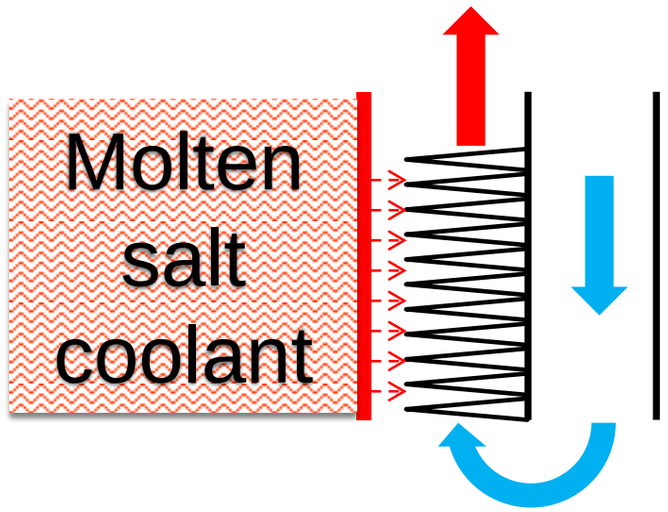
- **Passive air cooling for decay heat even at 1200MWe**

Modular SSR construction



- 1200MWe reactor just 5m x 4m x 18m cannot handle decay heat by air convection – even with fins added
- High temperature (~750°C) makes thermal radiation the dominant heat loss mechanism
- Large surface area “thin fins” collecting radiant heat allow air convection to be effective

- Core module 150MWe
- Up to 8 modules
- Road transportable
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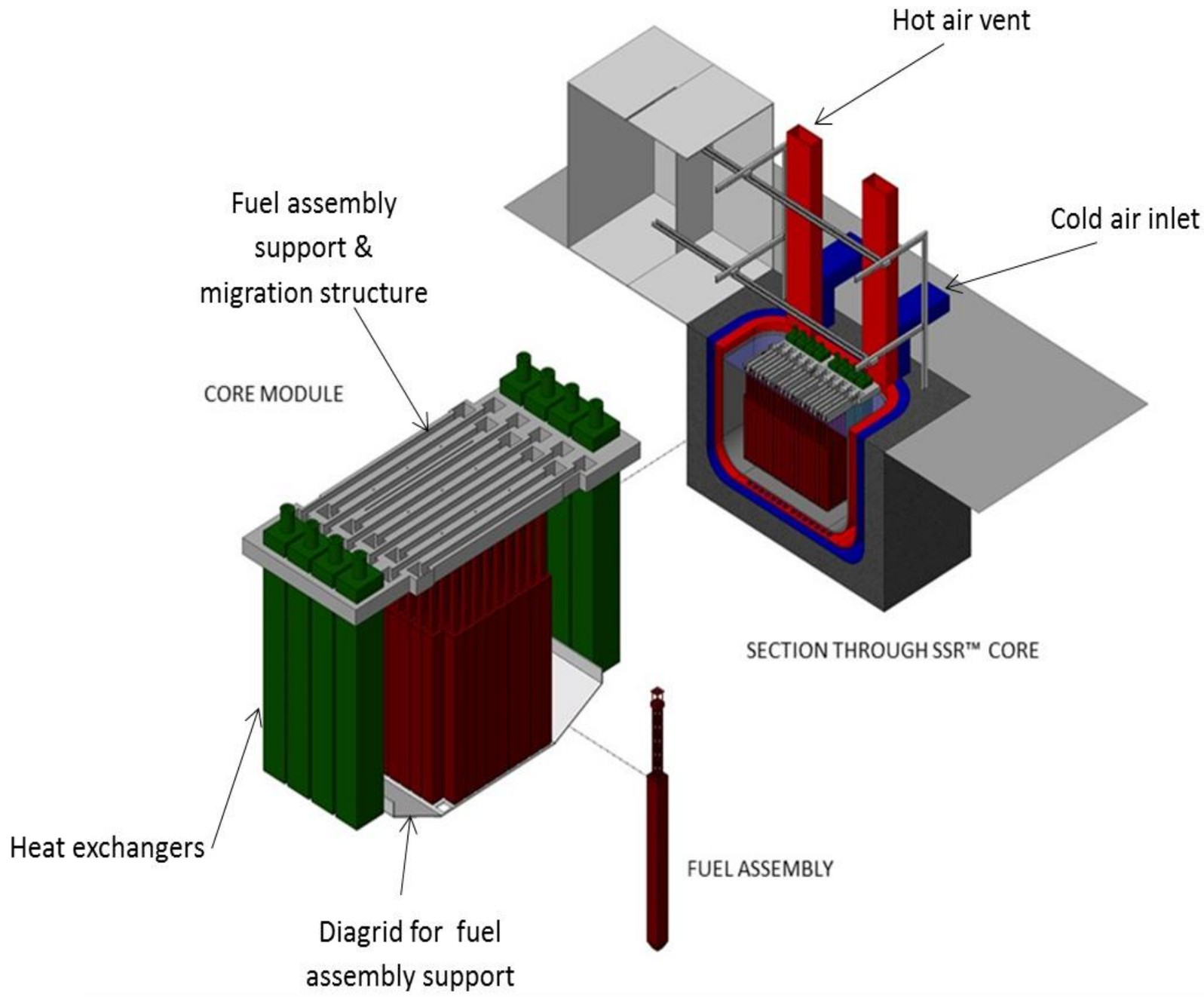
Modular SSR construction



- Core module 150MWe
- Up to 8 modules
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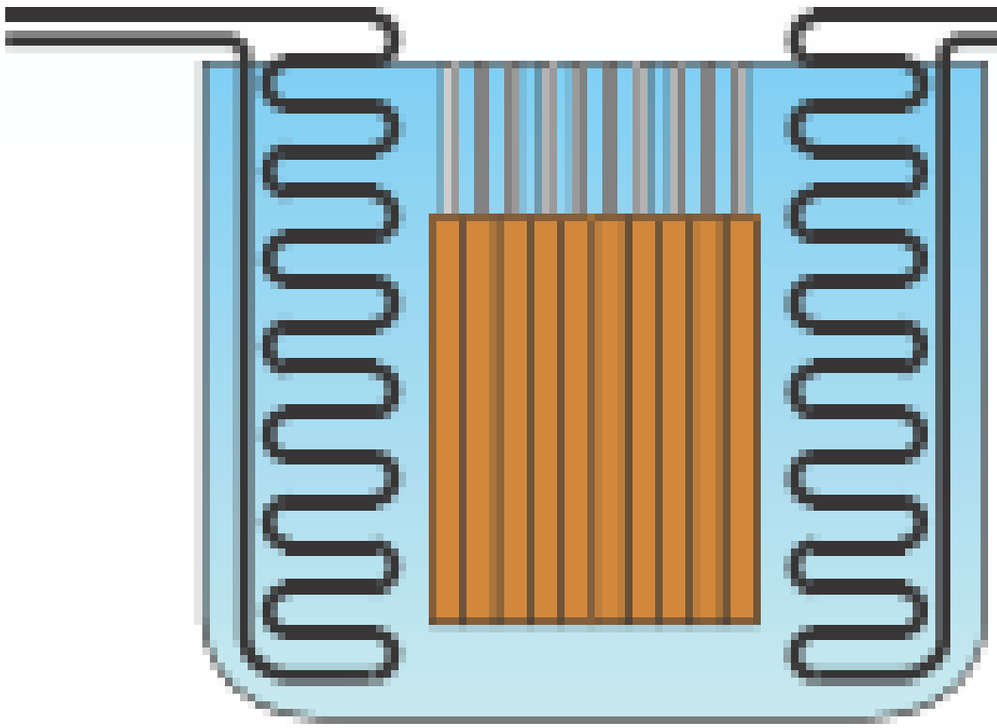
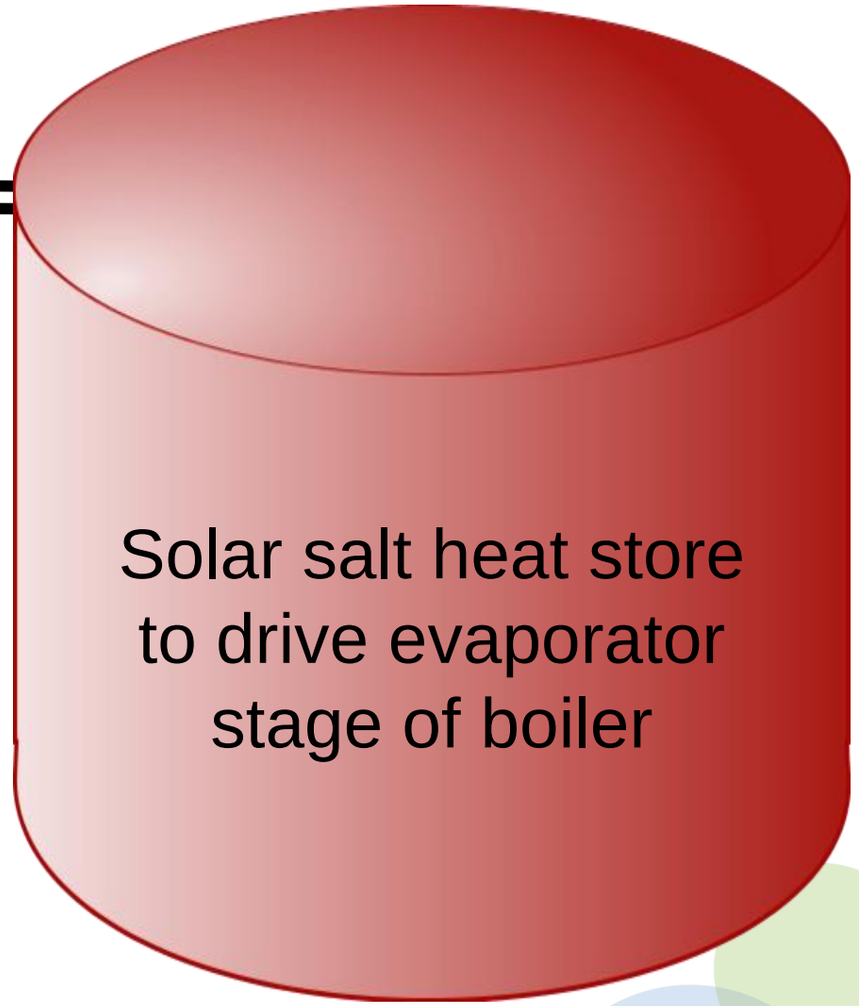
- Passive air cooling for decay heat even at 1200MWe
- **Output temperature 650°C – heat storage**

Energy Storage

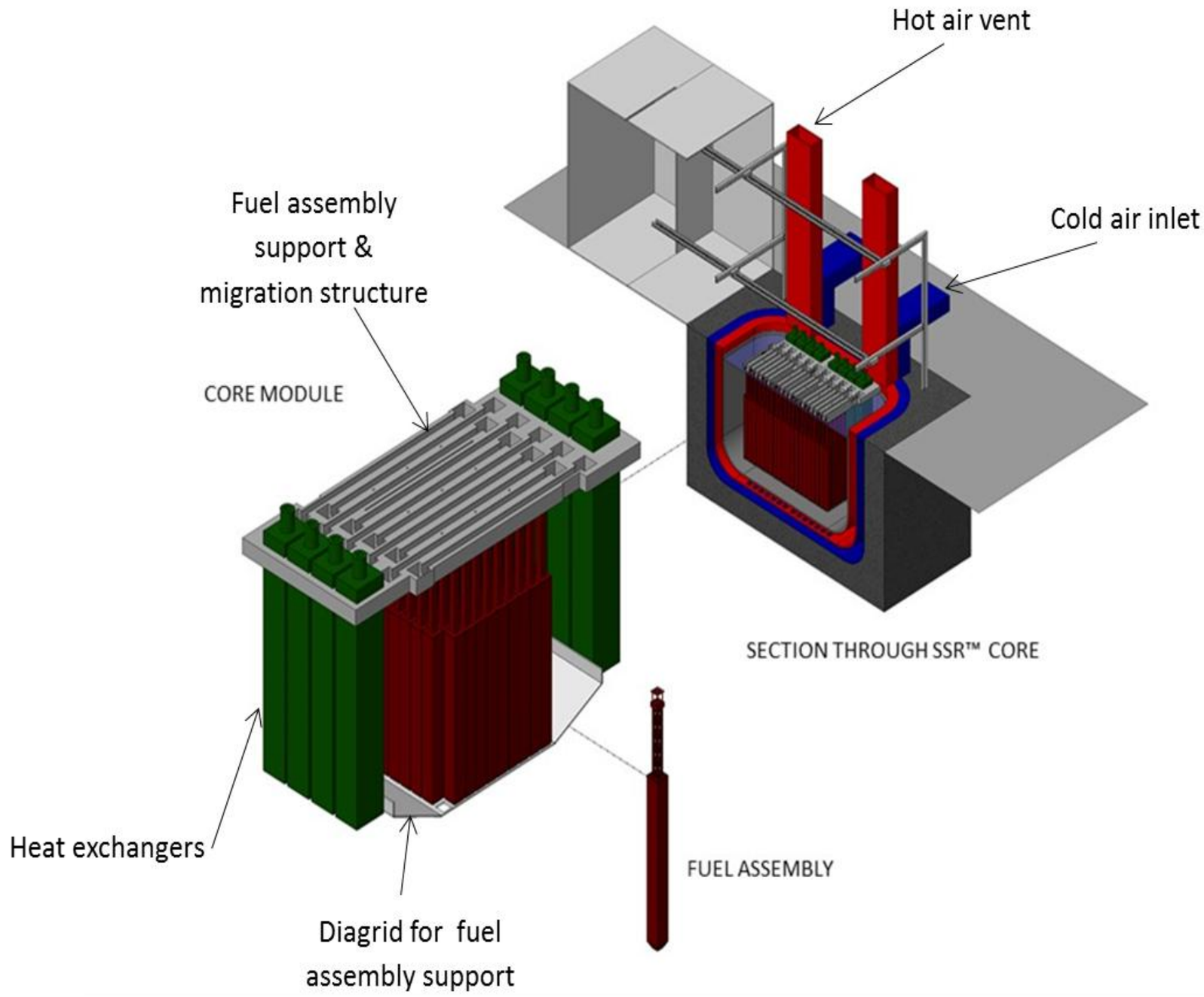
Secondary coolant ZrF_4/NaF/KF
Melting 385°C Output 600-650°C
Drives superheater and reheater stage of boiler





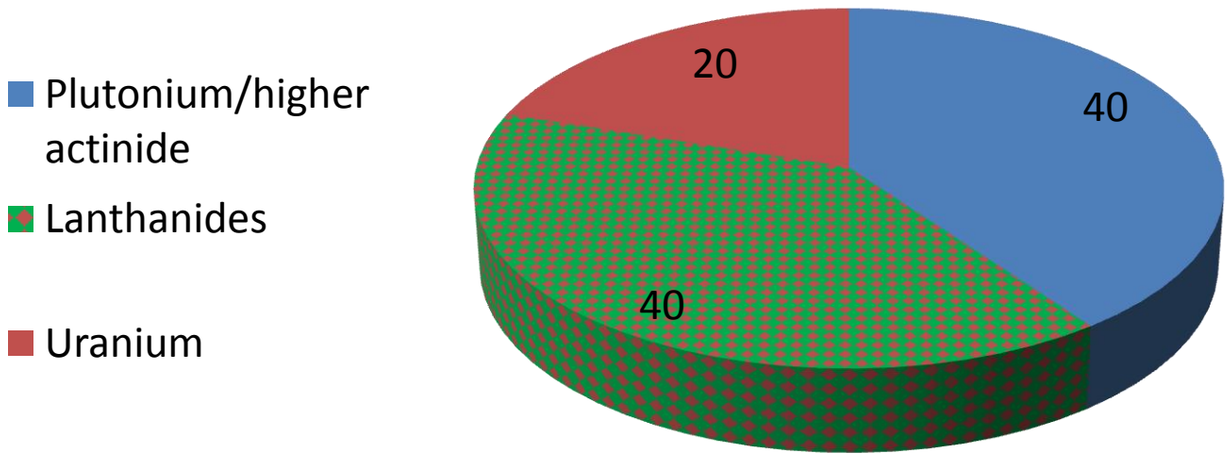
Reactor operates at constant power 24/7 but electricity generation can be varied over day from 0-200% of reactor power

Modular SSR construction



- Core module 150MWe
- Up to 8 modules
- Road transportable
- Passive air cooling for decay heat even at 1200MWe
- Output temperature 650°C – heat storage
- **Fuelled by low purity plutonium/actinides**

Reprocessing of spent oxide fuel and spent fuel from the SSR



Chlorine decladding and HF conversion converts zircalloy into SSR coolant salt and HCl

Patented electrochemical reduction converts UNTREATED pellets to molten uranium alloy

Patented electro-refiner separates pure uranium from U/Pu/Lanthanide alloy ready for use as SSR fuel

Actinide free waste streams

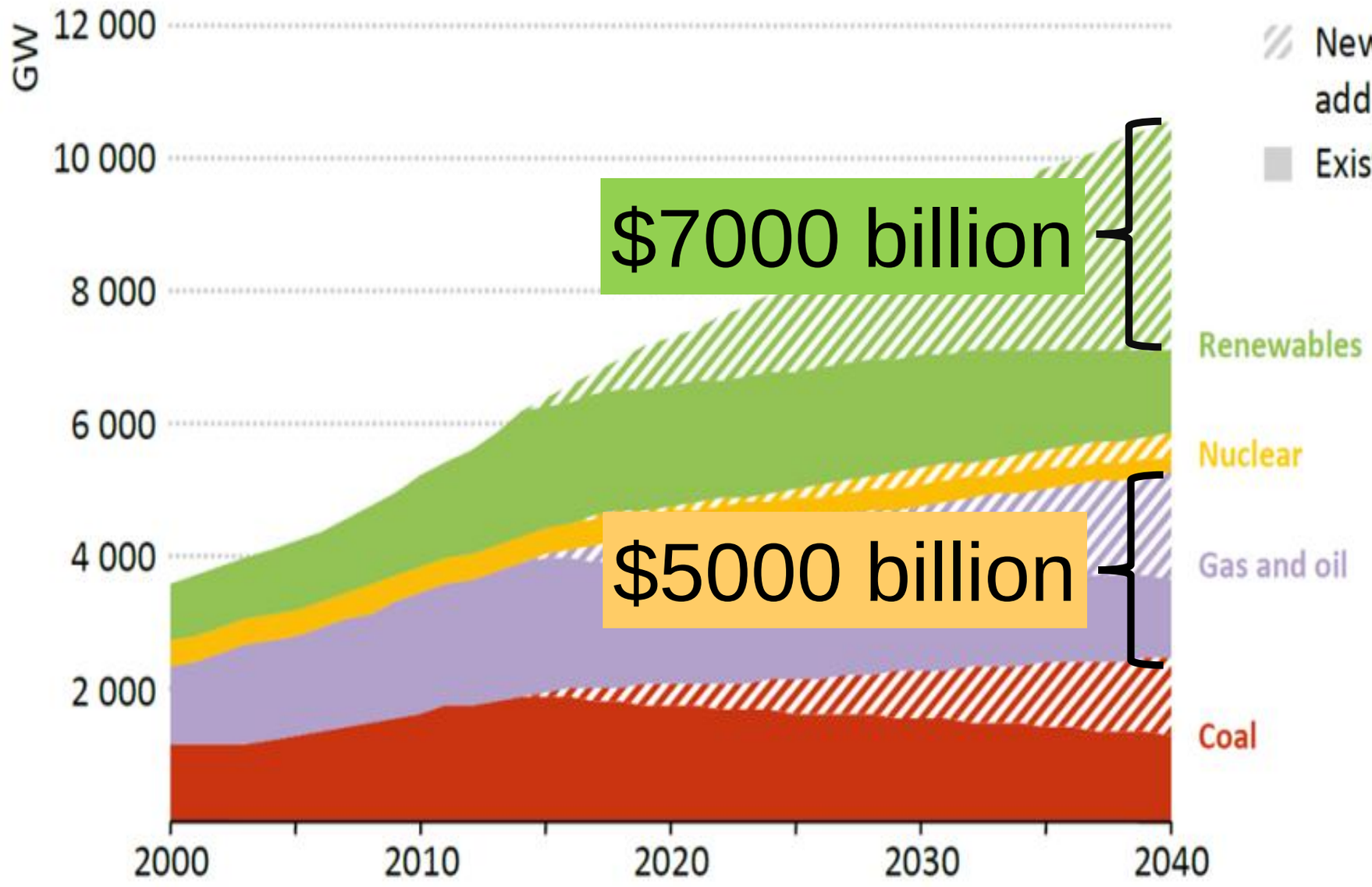
- Noble metal alloy
- Lanthanide metal alloy
- Other fission products for vitrification

Advantages of the Stable Salt Reactor

- Credible capital cost estimate lower than coal
- Can vary electricity output from zero to 200%
- Intrinsically much safer than uranium oxide fuel – liability limit and proximity to population for CHP
- Passive decay heat removal to air
- Passive shut down even if all control systems fail
- Modular, road transportable, rapid construction
- Consumes existing plutonium stock
- Consumes long lived waste from existing reactors without costly THORP and MOX plants

The Market Opportunity for Low Cost Nuclear Energy

Figure 8.4 ▷ Global installed capacity by source in the New Policies Scenario



International Energy Agency's World Energy Outlook 2015

Intellectual Property

- Feb 2014 > **Master patent on un-pumped molten salt fuel** - Granted in UK, pending in PCT nations

- Molten salt chemistry control allowing use of standard steels without corrosion
- Rectangular counter-flow reactor core design
- Passive air cooling for modular reactor
- Simple cheaper oxide fuel reprocessing
- 7 other patents
- Major opportunities for supply chain partners to develop IP

Why the UK?

- Moltex Energy is a UK company
- Supportive government and public opinion
- Regulatory system compatible with non LWR
- Large need for new cost effective generation
- 120 tonnes of plutonium
- Experience in reprocessing and no local support for geological repository
- Vendor capability sold off so little “sunk capital”
- Good base for international sales of reactors

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Thank You

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