Design Studies of Innovatively Small Fusion Reactor Based On Biomass-Fusion Hybrid Concept: GNOME

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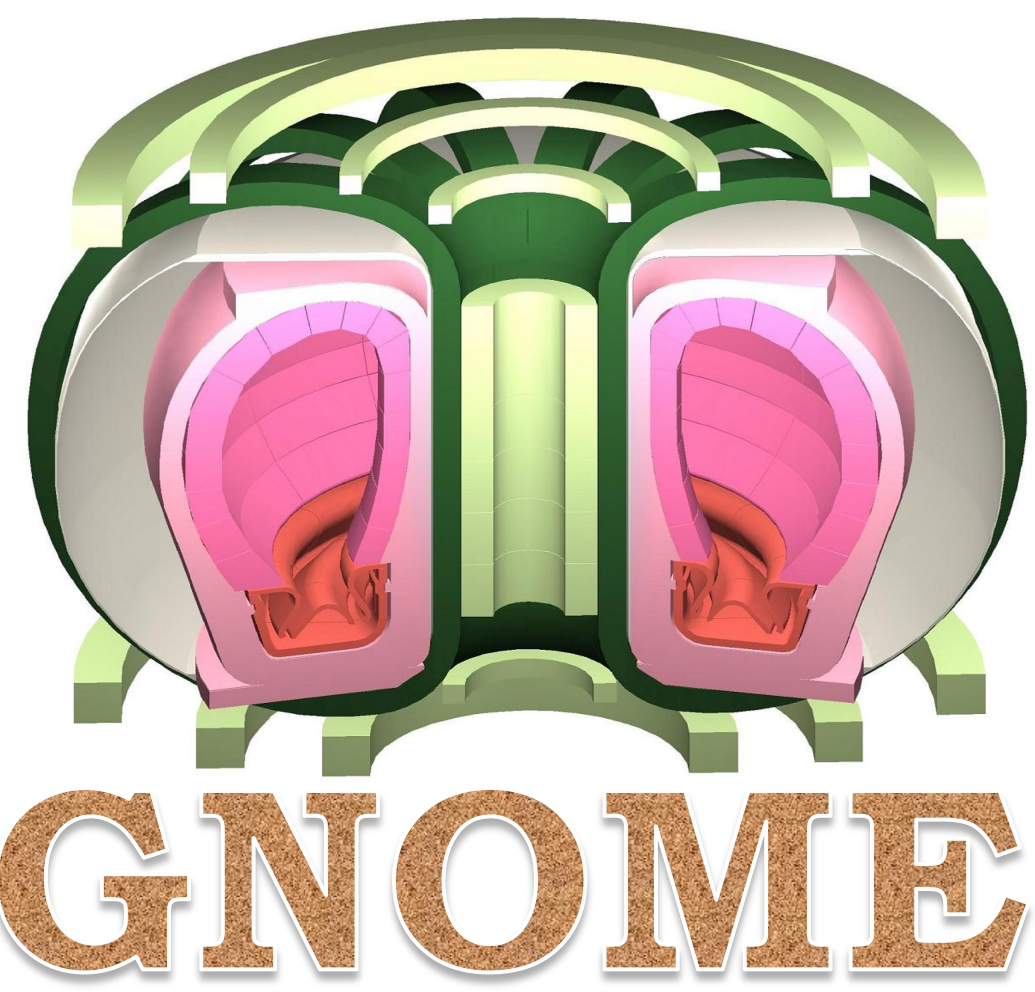


Hybrid concept for fusion to produce bio-fuels.

High-temperature heat for an efficient gasification of biomass can be provided from the nuclear fusion reactor.

High energy conversion efficiency of the gasification process reduces the requirement to ***Q* ~ 5**.

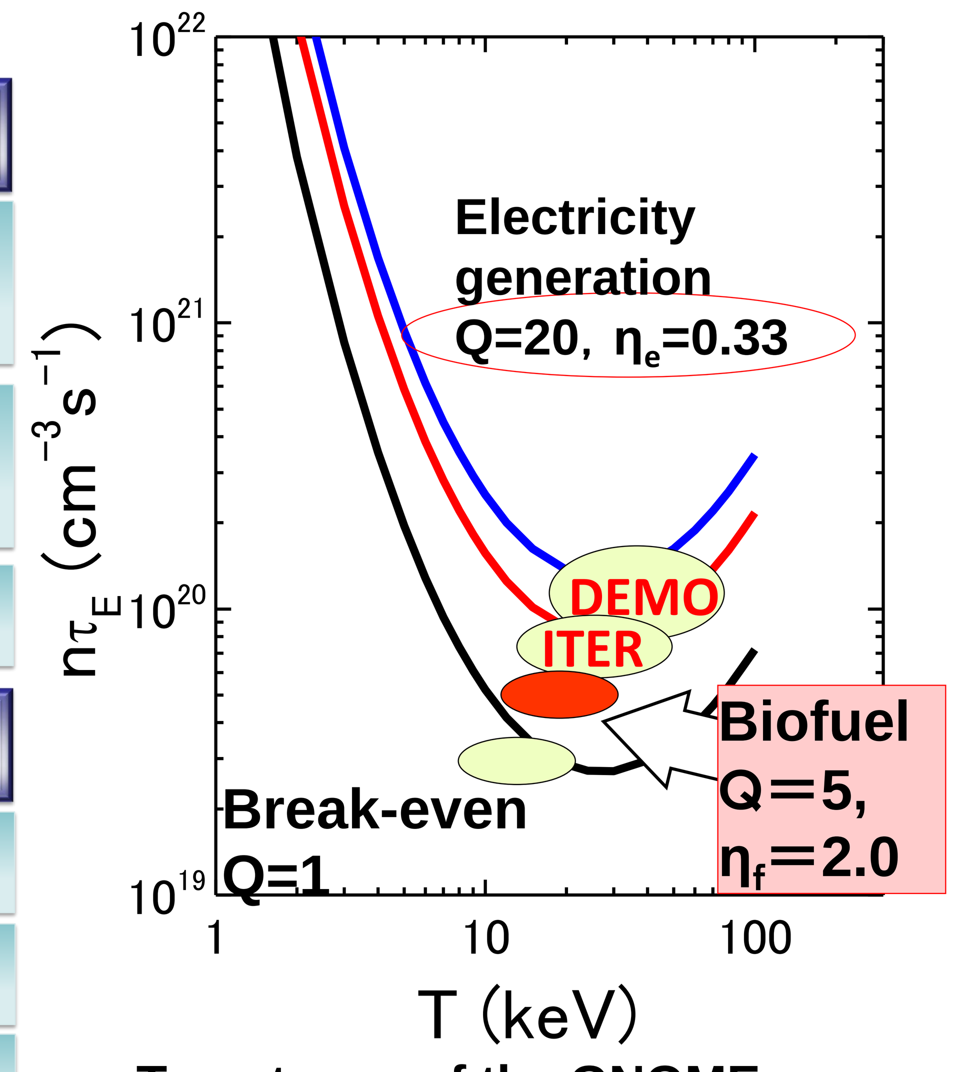
This small-*Q* reactor can be applied to the fusion-fission hybrid designs.

Design strategy

Enough space of BLK for TBR & CS (r = 1.5 m) for the start-up.

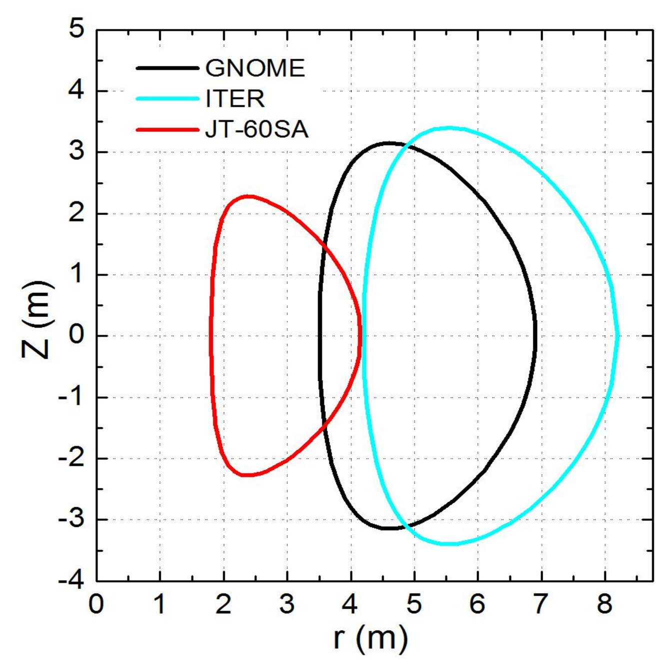
ITER-like Nb_3SnTF coil in order to reduce the construction cost.

Q ~ 5 with safety factor q_{MHD} > 3.

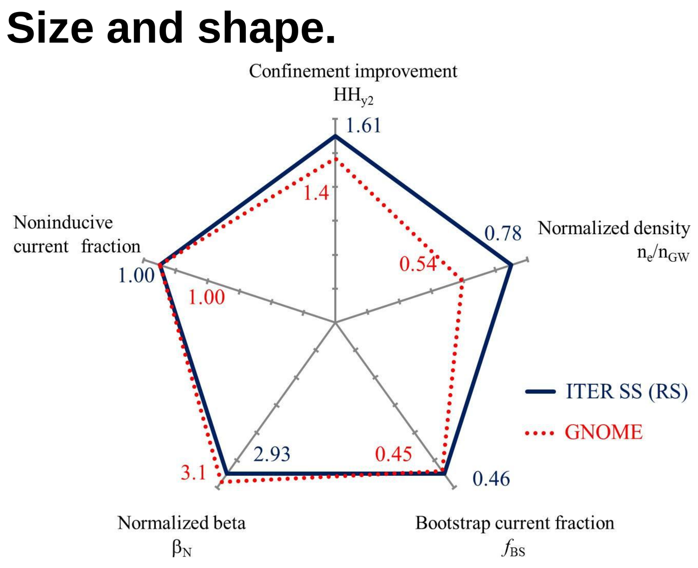


Target area of the GNOME reactor at the Lawson diagram.

Plasma parameter and designs



Comparison of plasma Size and shape.



Parameter comparison w/ ITER SS mode.

Designed plasma parameters

		ITER	GNOME
Major radius	R_p	6.2 m	5.2 m
Minor radius	a_p	2 m	1.7 m
Aspect ratio	A	3.1	3.1
Plasma volume	V_p	837 m³	547 m³
Plasma current	I_p	15 MA	10.4 MA
Toroidal field	B_t	5.3 T	4.4 T
Average temperature	$<T_e>$	8.9 keV	13 keV
Confinement improvement	HH_{y2}	(1.0)	1.4
Normalized beta	β_N	(1.5)	3.1
Normalized density	f_{GW}	(0.7)	0.54
Fusion power	P_{fus}	500 (250) MW	324 MW
External heating	P_{CD}	73 (20) MW	61 MW
Neutron wall load	P_n	0.57 MW/m²	0.48 MW/m²

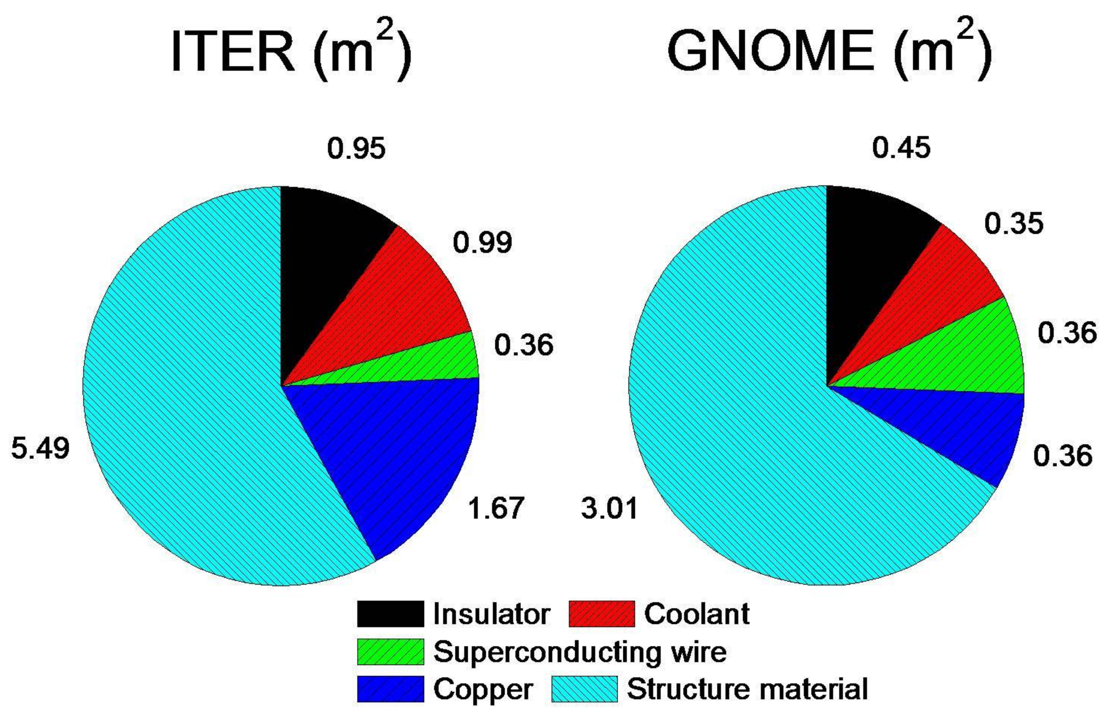
Neutral beam injection for the heating.

Smaller than ITER. About 2/3 in volume.

Relatively large improvement factor but small density.

Minimal technical extensions from ITER.

TF Coil designs

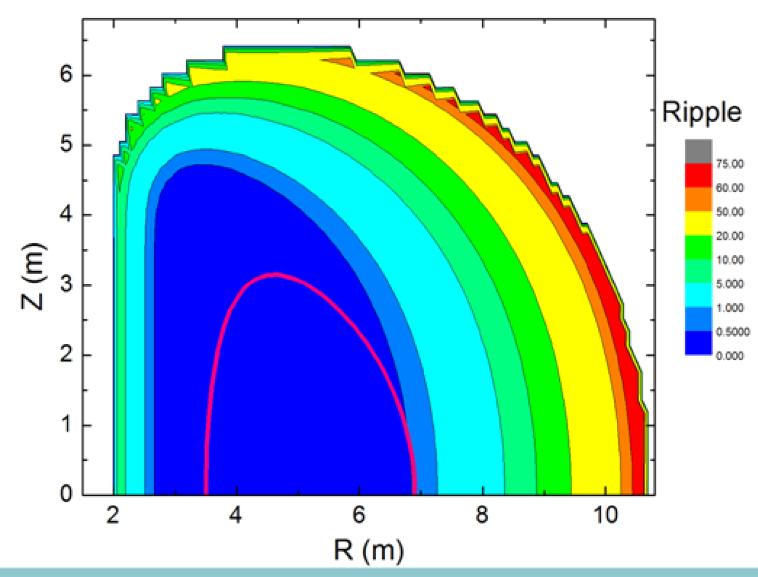


Coil Parameters		
	ITER*	GNOME**
# of TF coils	18	12
Type of SC strand	Nb_3Sn	Nb_3Sn
Maximum field	11.8 T	11.5 T
Operation current	68 kA	100 kA
Operation strain	~ 0.77%	~ 0.79%
Width	9 m	9 m
Height	14 m	13.3 m
Magnetic stored energy	41 GJ	29 GJ
Number of turns	134	96
Breakdown voltage	3.5 kV	20 kV
Allowable stress (S_m)	668 MPa	800 MPa

* ITER Technical Basis (2001)
** SCONE code,H. Utoh and *et al.*, JAEA(2009)

Composition of materials was determined through calculating the EM stress on materials and the heat balance at the quench.

Increased SC wire rate was achieved by assuming a slightly increased allowable stress.



Large size TF coils reduce their ripple. Thus, ripple < 0.5 % has been achieved w/ 12 TF coils.

Divertor

The two-point model suggests that the heat loads to the divertor tiles ~ 10 MW/m².

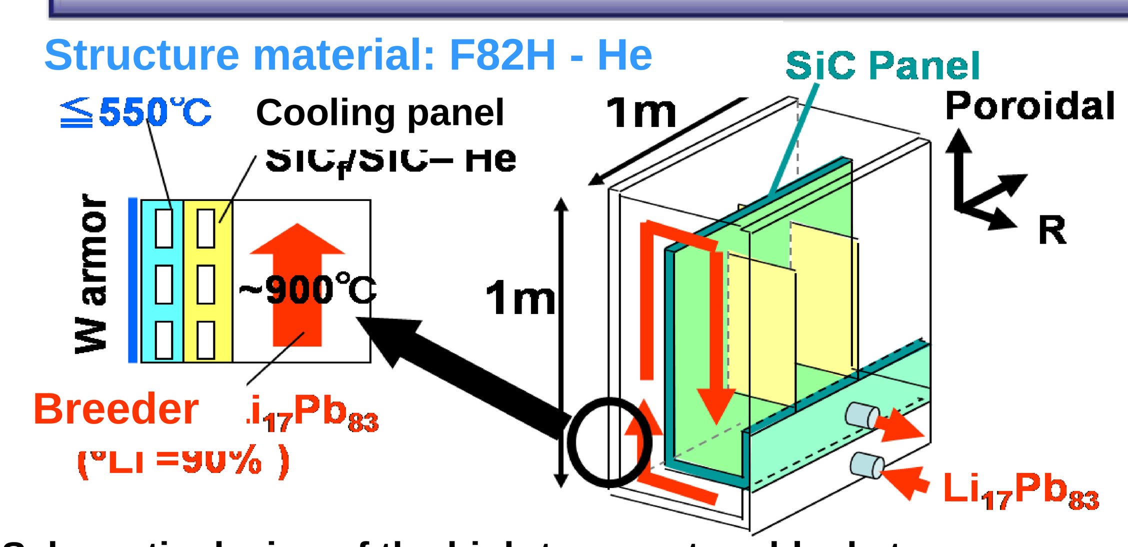
Attached high-recyling operation.

LiPb cooled Divertor

Local TBR around 0.5 is expected. (~ 0.05 contribution for net-TBR.)

Details will be given shortly in 19th TOFE.

Twin-He dual coolant blanket for the high-temp LiPb operation

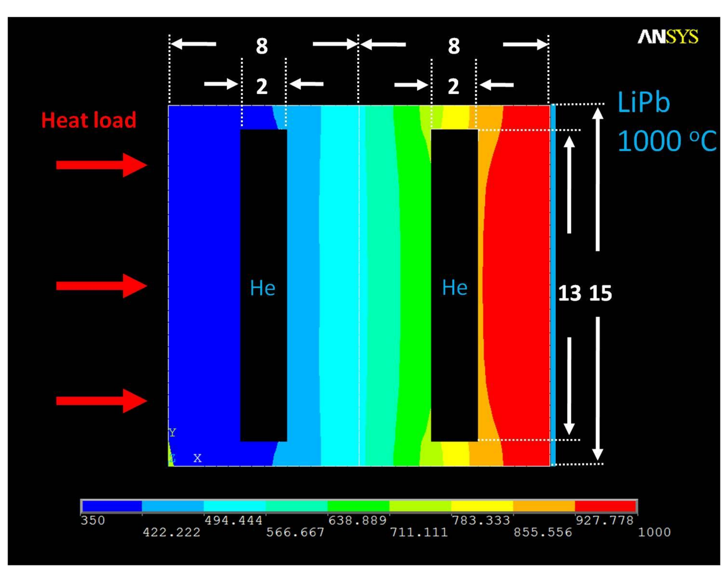


Schematic design of the high-temperature blanket.

Both He and LiPb work as coolant. (dual-coolant.)

In order to achieve a high-temperature LiPb operation, SiC insulator panel is needed.

Twin He channels for Steel and SiC panels are assumed which result a reduced wall thickness.



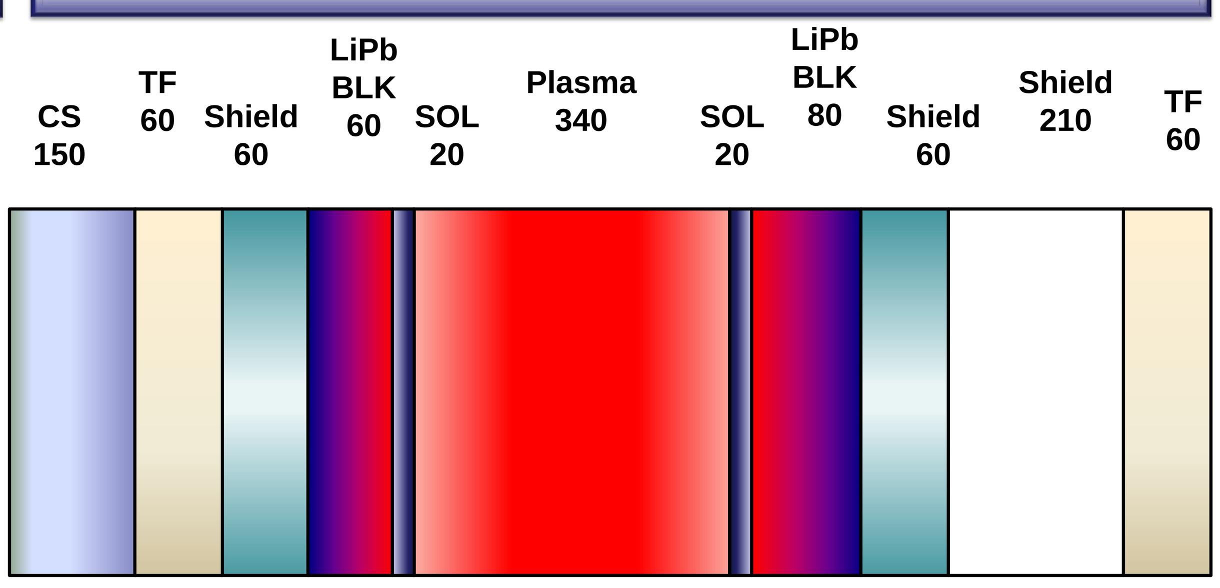
A calculated 2-D temp distribution of twin-He dual coolant Blanket wall.

Blanket parameters	
Heat flux to the FW	0.2 MW/m²
Neutron flux from the plasma	0.5 MW/m²
Boundary temperature at the LiPb/SiC interface	1000 ºC
He temperature at F82H channel	350 ºC
He temperature at SiC channel	850 ºC
Heat transfer coefficient of He coolant at F82H channel	10000 W m^{-2} K^{-1}
Heat transfer coefficient of He coolant at SiC channel	7000 W m^{-2} K^{-1}
Thermal conductivity of F82H	33.3 W m^{-1} K^{-1}
Thermal conductivity of SiC	20 W m^{-1} K^{-1}

Calculations by ANSYS show that the F82H steel vessel could be < 550 ºC during the operation w/ 1000 ºC LiPb.

A high temperature He output is achieved from the SiC_f/SiC panel.

Radial build, Tribtium breeding



Designed radial build of the GNOME reactor.

Liquid LiPb blanket with 90% Li-6 enrichment, the net-TBR of 1.05 achieves if the BLK coverage is >75 %.

Total irradiation will not reach 1*10^{22} neutrons/m² (ITER guide line value for coil life time) until 40 years.

Summary and conclusion

Based on the biomass-fusion hybrid concept, a Tokamak reactor without any major technical extensions from ITER was designed.

Equilibrium, stability and external heating analysis as well as its divertor operation and component designs will be given shortly.

Acknowledgement

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