Bringing Nuclear Energy to Maritime and Onshore Users

The Allseas HTGR Journey

Allseas – Who are we?

- A world-leading contractor in the offshore energy market, with dynamism, rapid progress and pioneering spirit at our core.
- Experts in the design and execution of large and complex offshore projects; specialised in pipelay, heavy lift, subsea construction and deep-sea mineral collection.
- Designed and optimised in-house, our fleet of record-breaking construction and support vessels exceed the limit of what is possible above and below the water surface.
- Develop state-of-the-art equipment and specialised tools to improve safety, efficiency and productivity of our vessels.
- Responsible family company that ensures its people can work safely and passionately to be productive in a sustainable way.

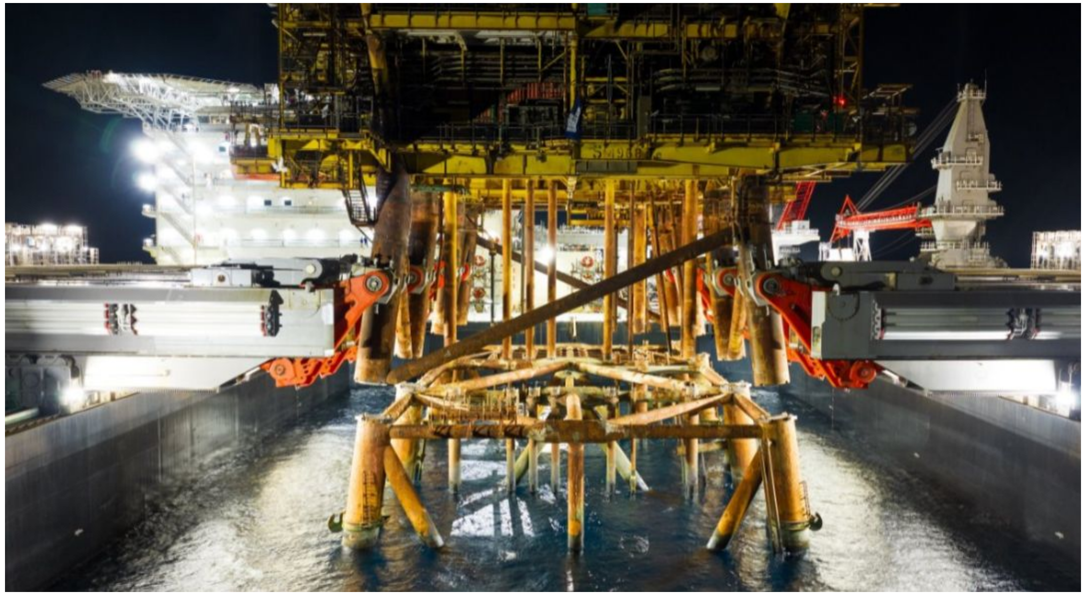
Pipelay

Pipelay

Solitaire averaged a 3 km/day production rate in the Baltic Sea while working in frozen seas

Heavy Lift

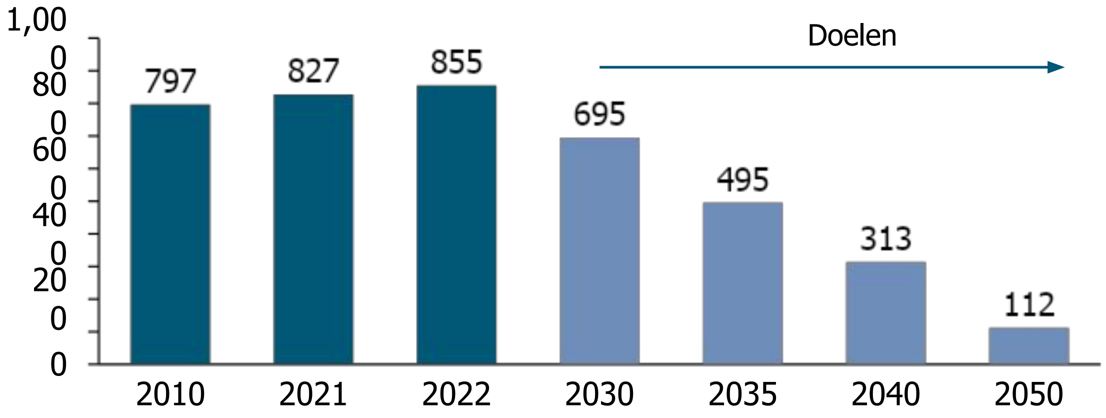
Heavy Lift



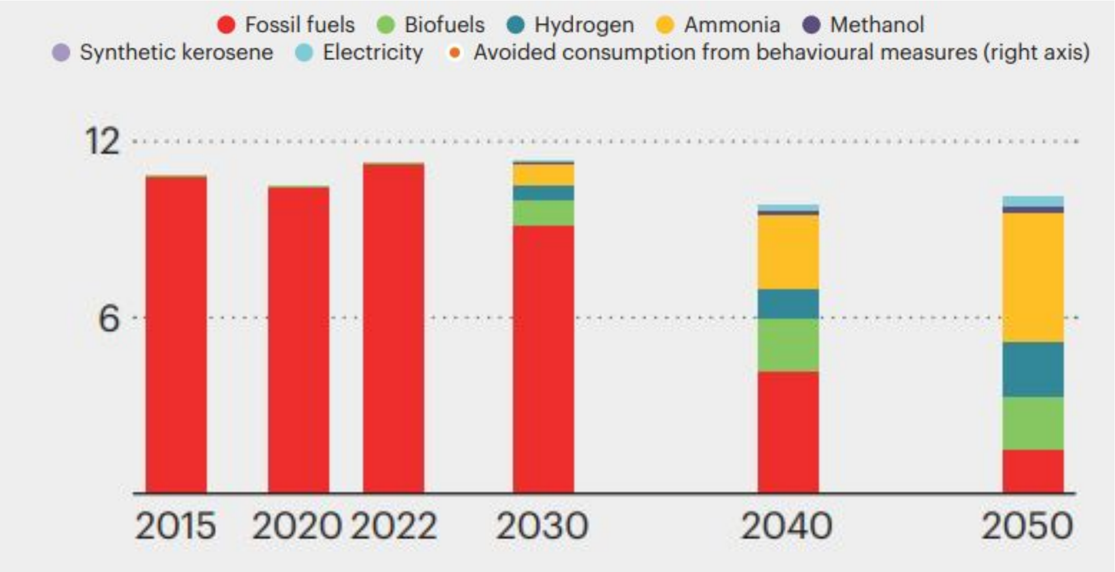
Nuclear

Nuclear power is needed to achieve maritime decarbonization goals

Emissions of international shipping (Mt CO2)



Energy usage of shipping (EJ)



2023 IMO STRATEGY ON REDUCTION OF GHG EMISSIONS FROM SHIPS
IEA| Net zero roadmap |Table A.4: World CO2 emissions

- International shipping: 3% of global CO_2 emissions
- 80% of emissions come from 13% of the fleet
- IMO reduction targets: −20% by 2030, −70% by 2040 (compared to 2008 levels)
- Energy density of alternative fuels is too low
- Availability of alternative fuels equals 2.7× the total electricity produced in the EU in 2022
- No realistic energy mix without nuclear

SMRs can significantly alleviate grid congestion and enable economic growth

Rotterdamse haven op kantelpunt: investeringen stromen weg, Den Haag moet versneld ingrijpen

Gemeente Rotterdam

22-09-2025

nieuwsuur

Nederlandse industrie kampt het meest met stijgende energiekosten

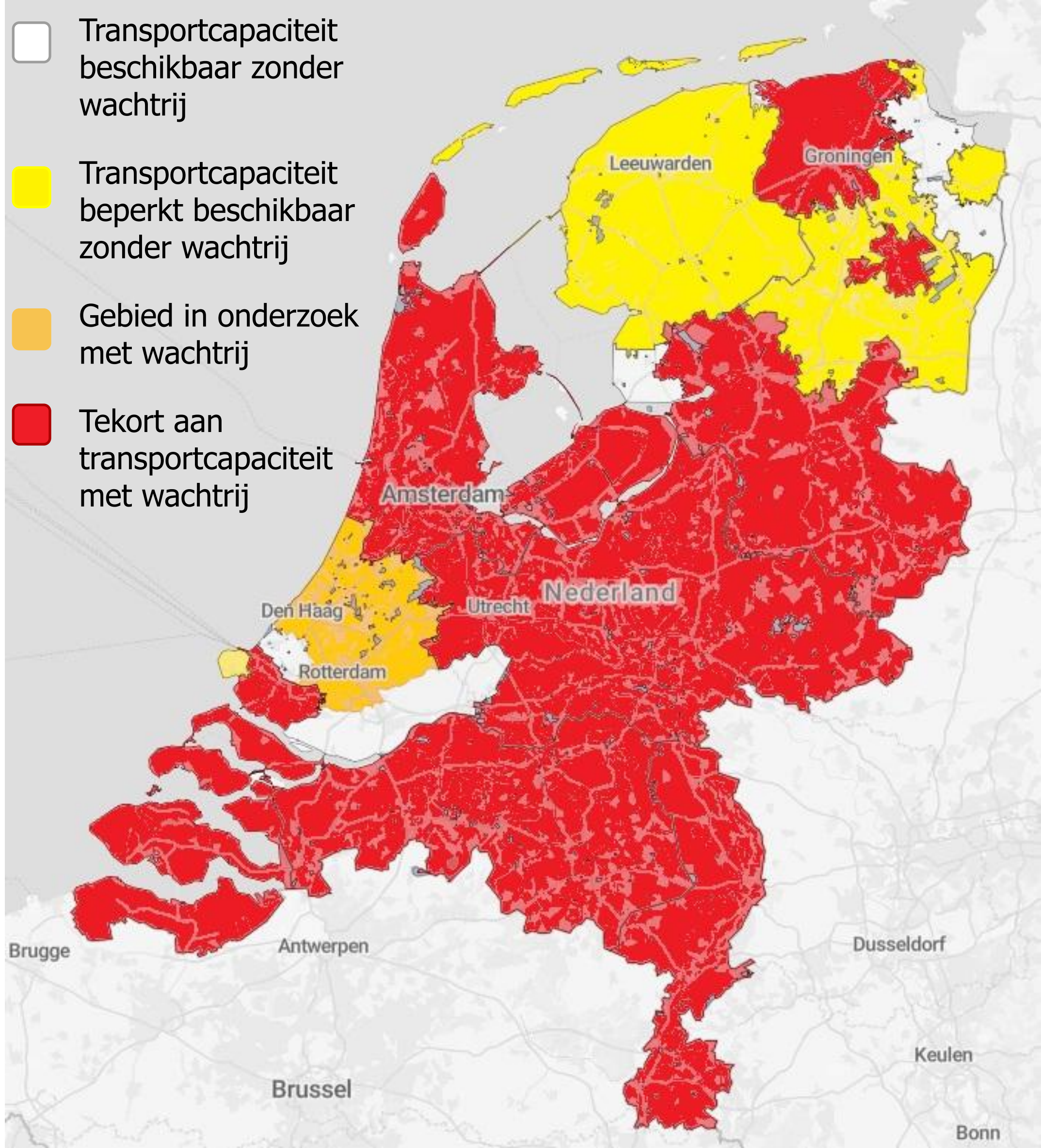
nu.nl

02-04-2025

'Vol stroomnet kost jaarlijks tot €40 mrd, ingrijpendere maatregelen nodig'

fd. het financieele dagblad

11-09-2024



Bron: TenneT, nieuws artikelen

Target System Design Requirements

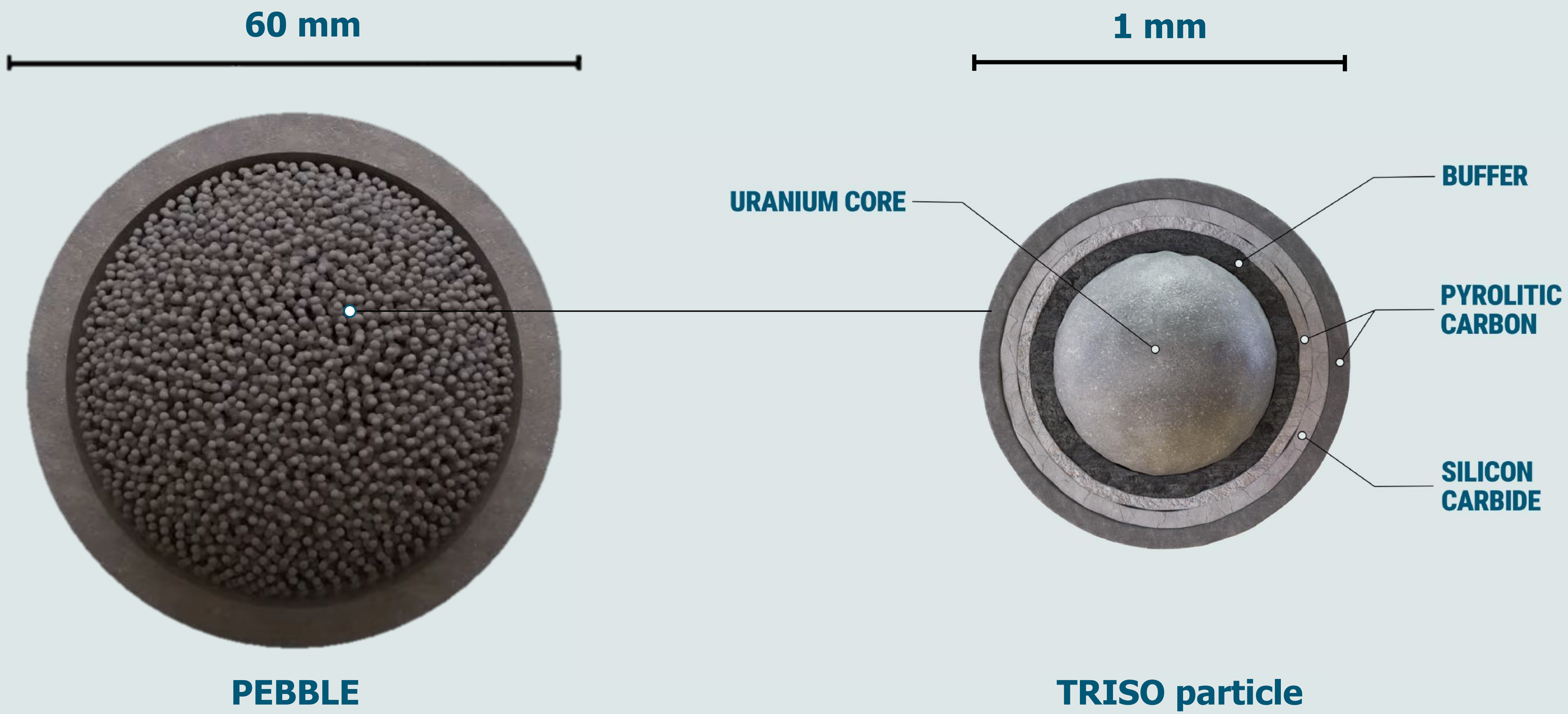
- **Inherently safe:** reactor should cool down itself in case of malfunction
- **SMR (Small Modular Reactor):** target 20-30MW electric
- **High technology readiness level (TRL):** no major scientific challenges, only engineering
- **Size of reactor:** should be workable on vessel as a modular system
- **“Plug & Play”:** Connection to existing infrastructure of the engine rooms and the power distribution systems/switch boards.

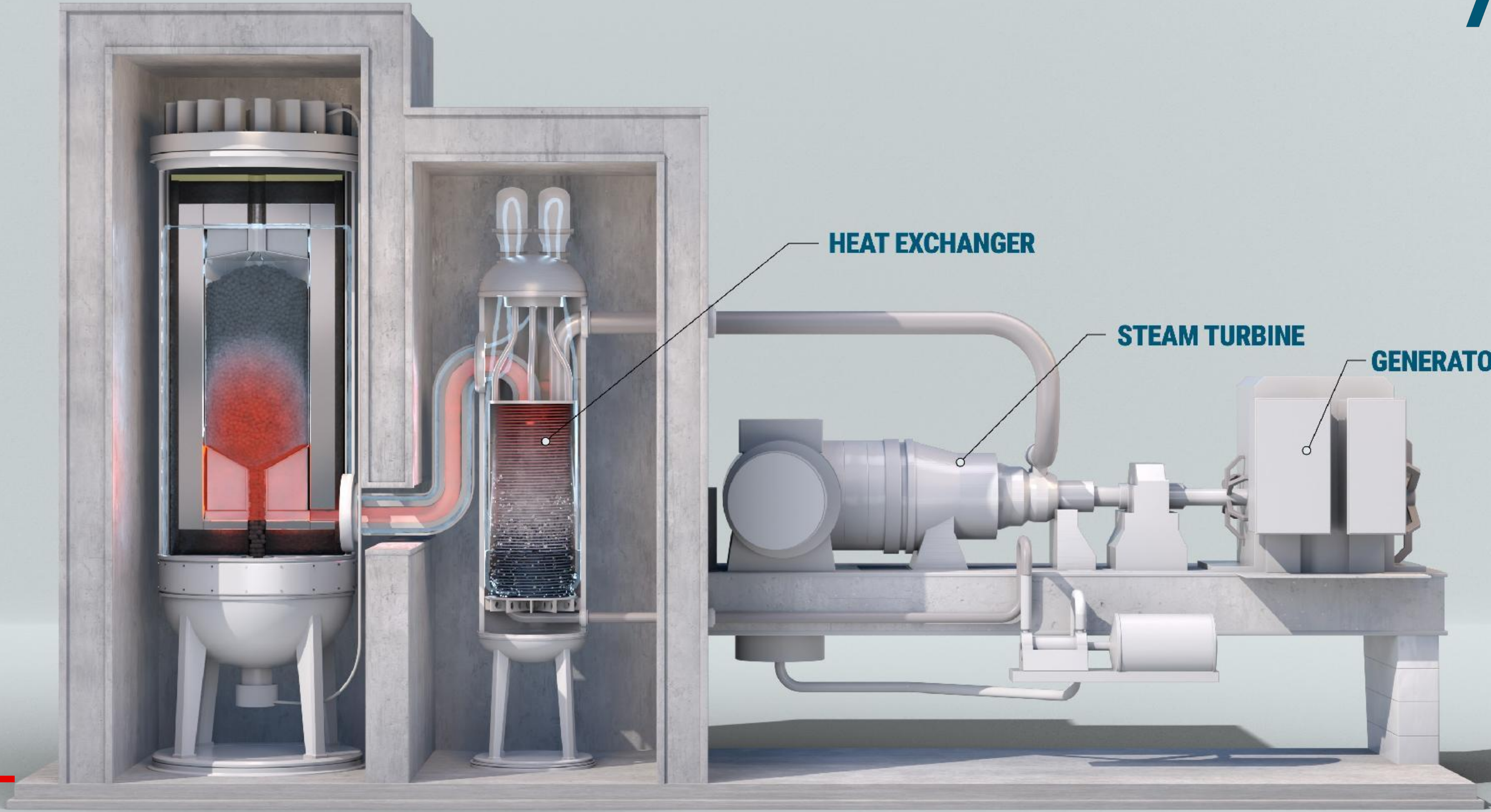
e believe HTGR is the way to go

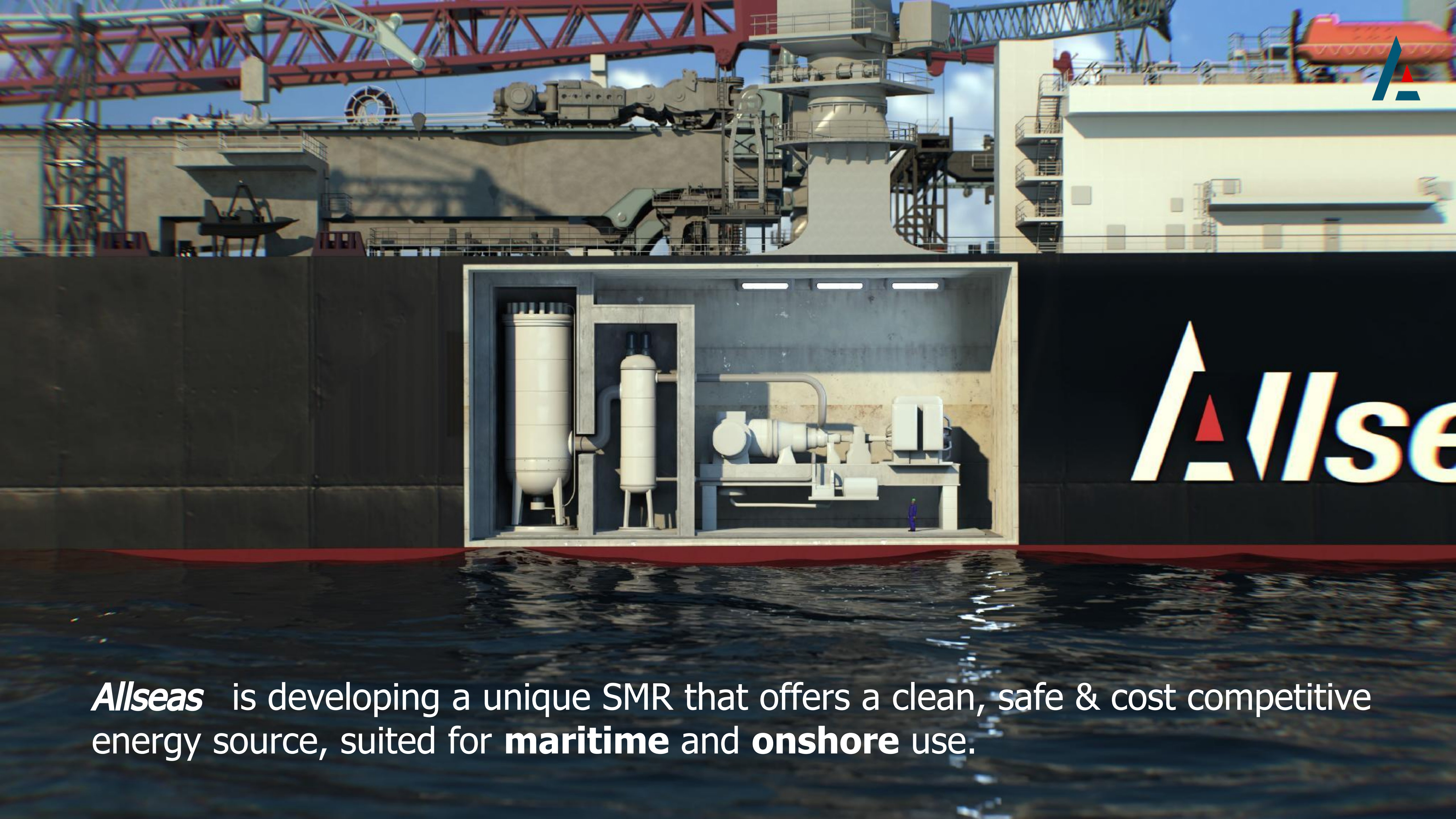
erent safety and security features:

- Small containment building (TRISO) to contain fissile material.
- Negative temperature coefficient of reactivity.
- Passive cooling.
- Coolant decoupled from neutronics.

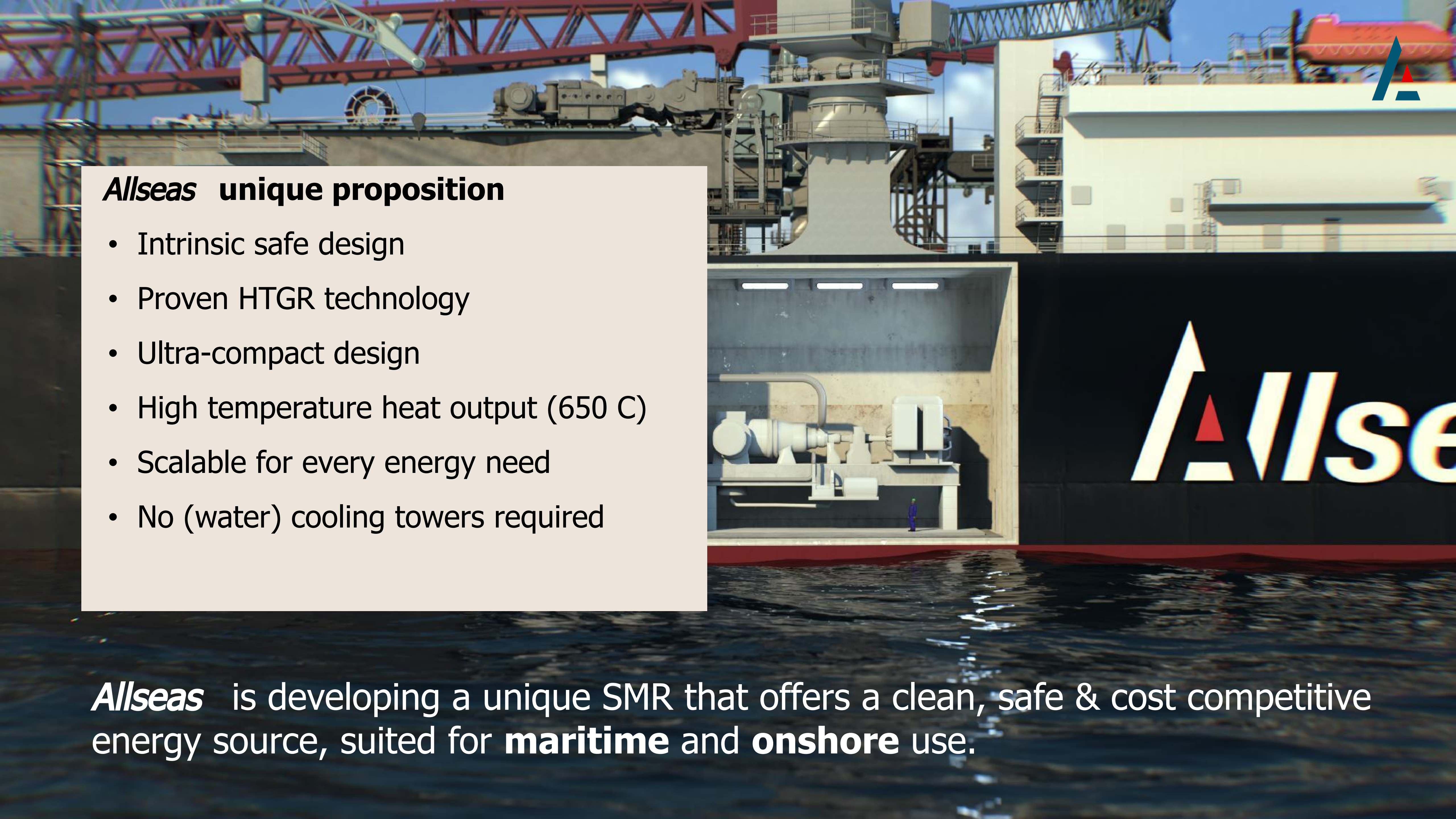
Fuel


60 mm
1 mm
URANIUM CORE
BUFFER
PYROLITIC CARBON
SILICON CARBIDE
PEBBLE
TRISO particle


HEAT EXCHANGER
STEAM TURBINE
GENERATOR



Allseas is developing a unique SMR that offers a clean, safe & cost competitive energy source, suited for **maritime** and **onshore** use.



Allseas **unique proposition**

- Intrinsic safe design
- Proven HTGR technology
- Ultra-compact design
- High temperature heat output (650 C)
- Scalable for every energy need
- No (water) cooling towers required

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- Intrinsic safe design
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Safety considerations

- Negative temperature coefficient
- TRISO fuel
- Helium coolant
- Passive heat removal
- Low power density

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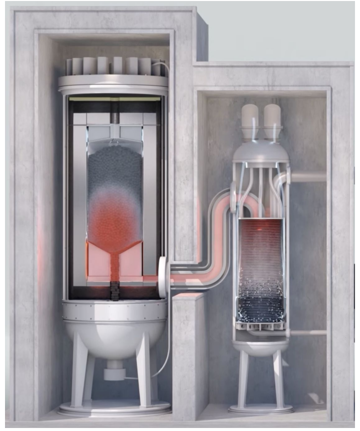
What Goes Into Such a Project?

Nuclear Engineering Analysis

Mechanical and Structural Analysis



Thermal Hydraulic Analysis

Detailed CFD Analysis

Maritime Implementation

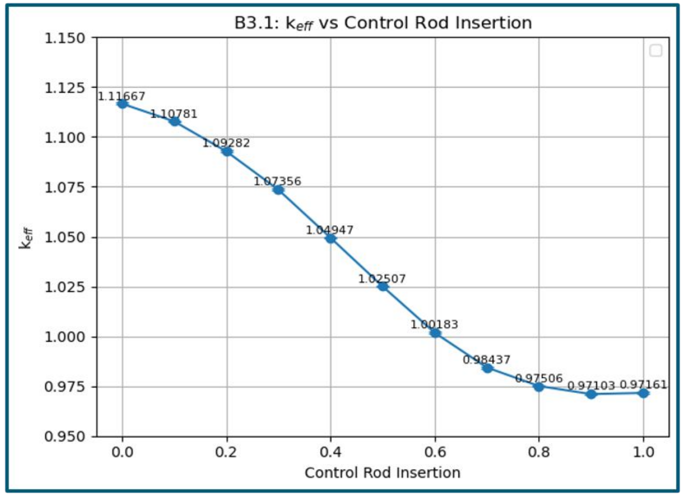
Maritime, Nuclear and Maritime Nuclear Regulation

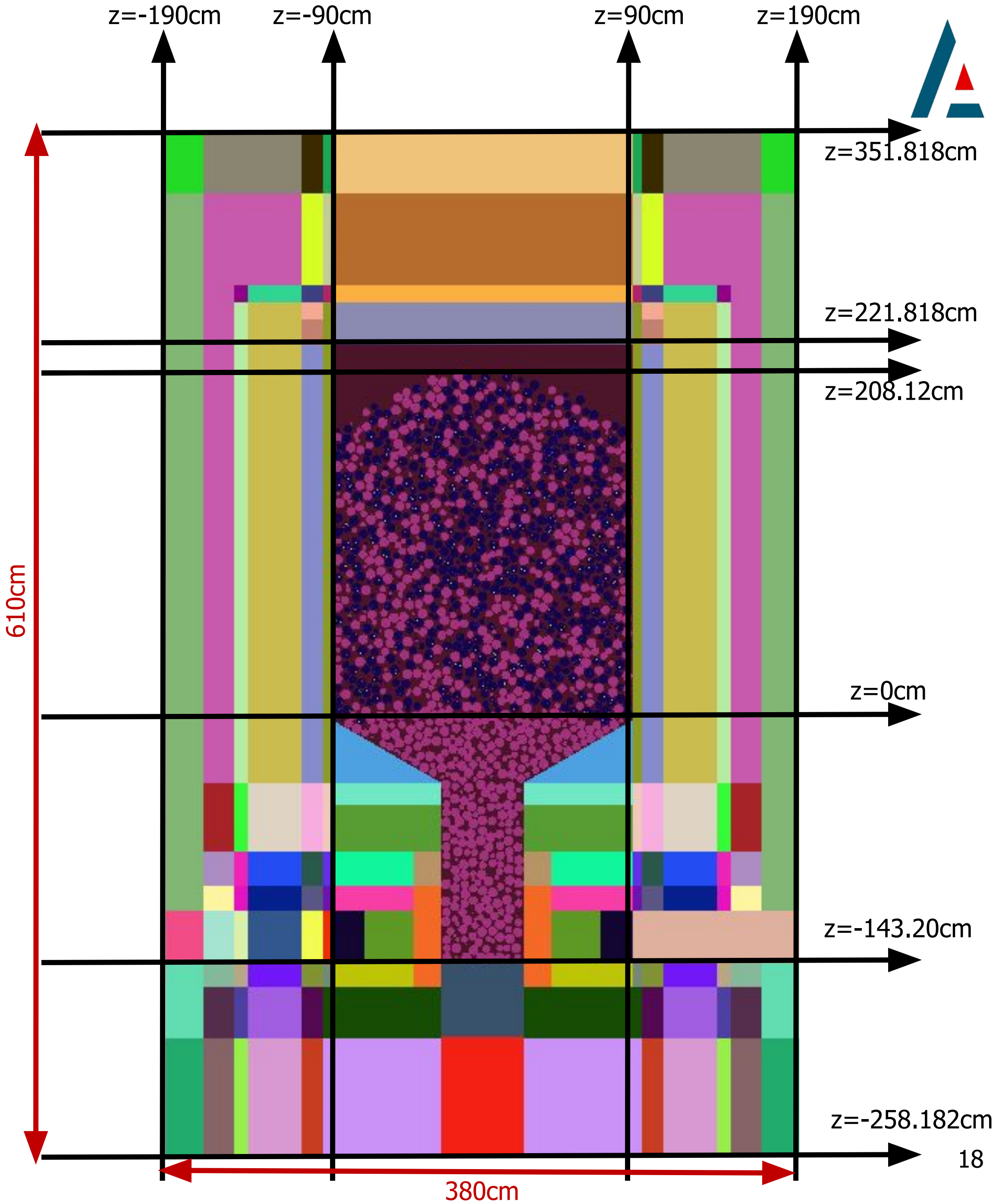
Basic Neutronics Example

- **Monte Carlo** simulations:
  - Using statistical means to determine the behavior of millions of neutrons in the reactor.

- Build **reactor model:**
  - Select appropriate material definitions, geometries, configuration, pebble fillings etc.

- Need to ensure that we can make the reactor subcritical with **control rods**

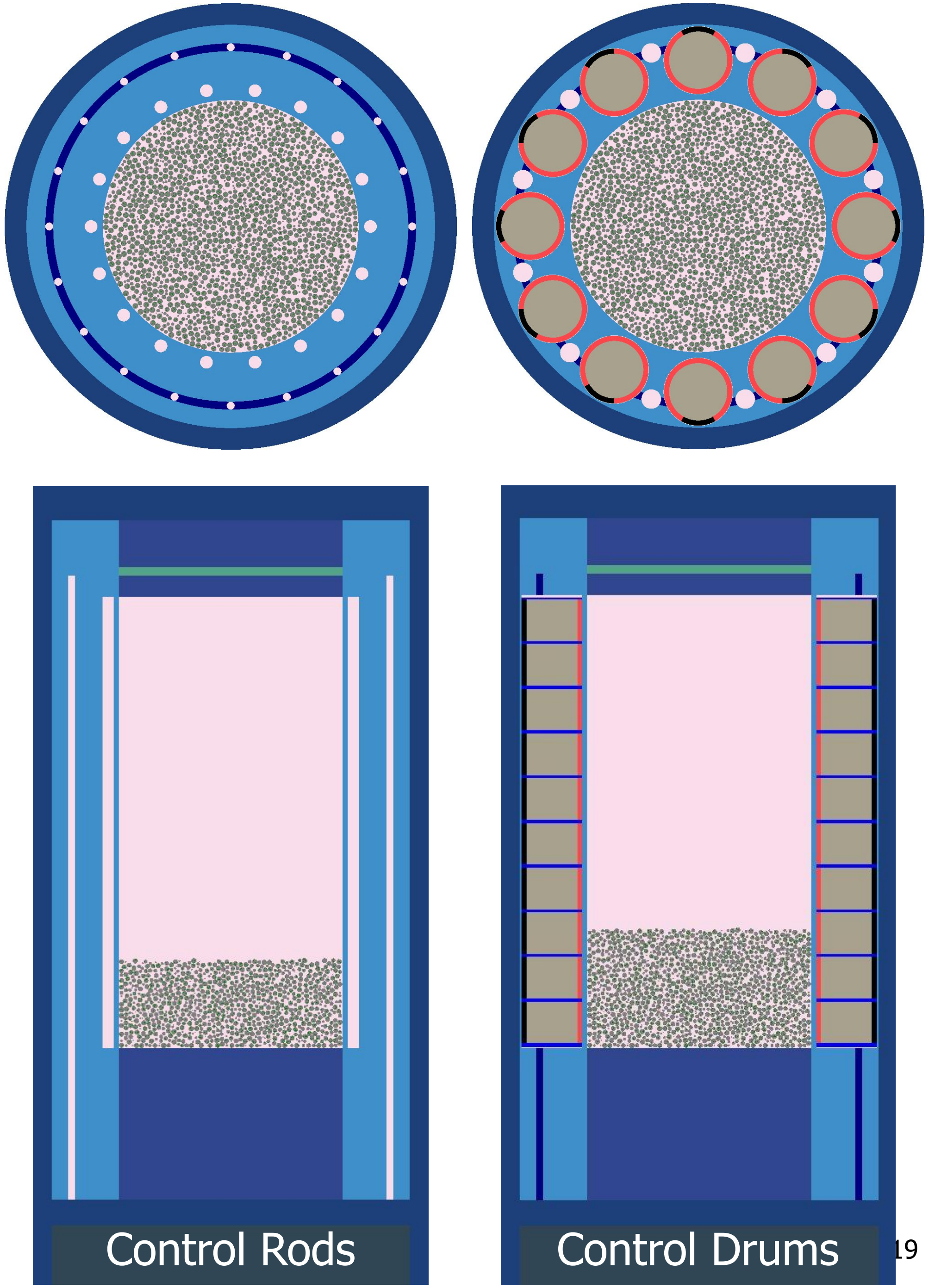




Detailed Geometry Studies: Control Rods vs. Control Drums

Feature	Control Rods	Control Drums
Function	Absorb neutrons to control reactivity	
Positioning	Inserted/withdrawn vertically	Rotating cylindrical components
Material	Neutron absorber	One side absorber, other side reflector
Gravity Reliance	Relies on gravity for emergency shutdown	Rotation is motor-driven
Reactivity worth (OpenMC)	~10%	~5%

- **Reactivity Worth** – The change in reactivity produced by inserting or withdrawing a control rod (or a group of rods), indicating how much that rod can increase or decrease the reactor's multiplication factor (K_{eff})

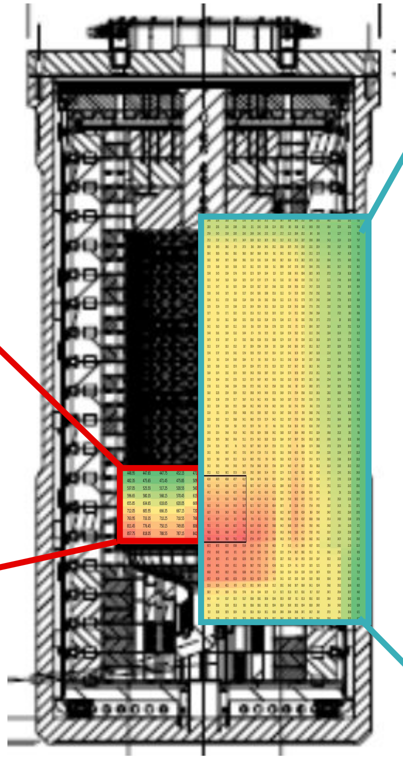


Sample Calculation with Coupled Programs

- With HCP we **couple thermal-hydraulic** analysis with **neutronic** analysis - to obtain detailed profiles of reactor behavior under operating conditions guiding design/modeling decisions
- Example: Temperature distributions over core at power, with coolant inlet/outlet temperatures

Core Materials Temperature (°C)

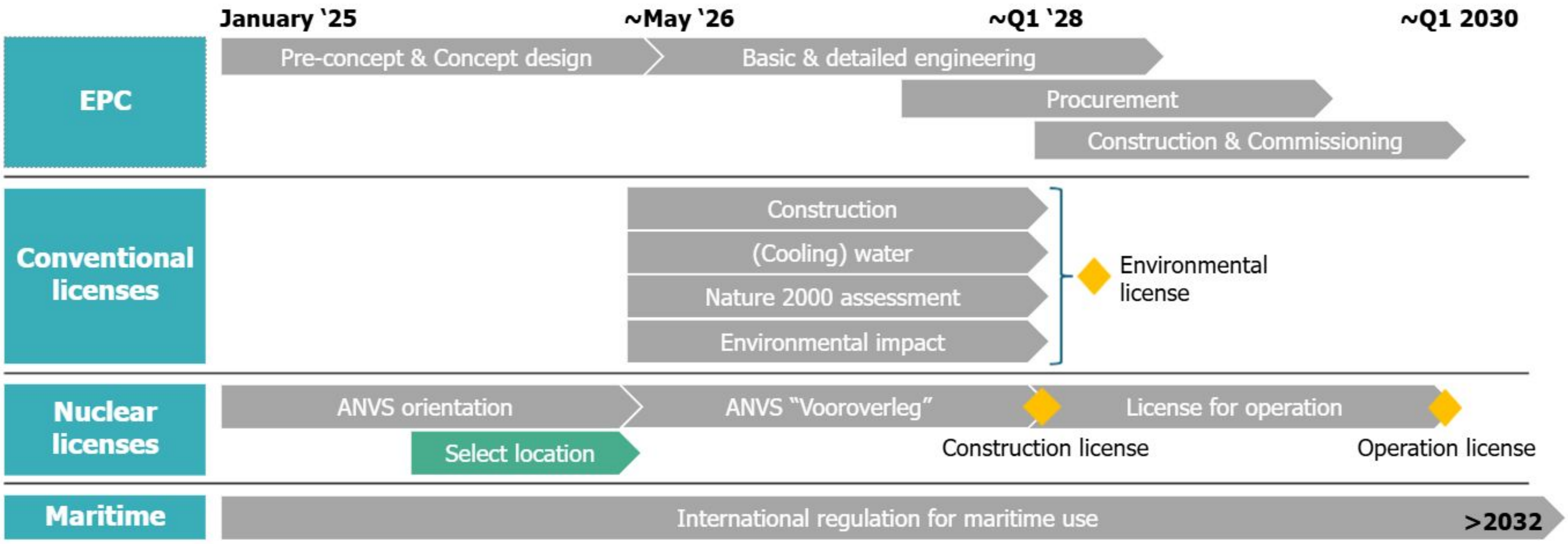
		CORE MESH 1	CORE MESH 2	CORE MESH 3	CORE MESH 4	CORE MESH 5	GAP	GRAPHITE	ROD	GRAPHITE	He RISER	GRAPHITE	BRICKS	BRICKS	HELIUM	BARREL	HELIUM	RPV	AIR GAP 1	AIR GAP 2	COOLER
	Z_cm	**41.11**	**71.2**	**91.92**	**108.77**	**123.33**	**130.5**	**133.32**	**138.63**	**145.14**	**165.38**	**184.64**	**198.43**	**219.18**	**239.69**	**250.76**	**262.3**	**275.78**	**287.99**	**366.81**	**436.11**
TOP PLATE	**-430.95**	224.69	221.42	218.16	214.83	211.42	209.5	208.73	207.23	205.27	198.77	190.63	184.35	173.27	160.46	153.51	146.05	138.12	129.31	75.02	50
TOP REFLECTOR GRAPHITE	**-403.45**	228.93	225.91	222.92	219.89	216.81	215.1	214.42	213.08	211.34	205.52	198.5	192.88	182.2	164.58	155.93	140.64	125.54	120.21	74.58	50
TOP REFLECTOR GRAPHITE	**-348.45**	237.04	234.33	231.69	229.05	226.42	224.99	224.42	223.32	221.87	217.17	212.13	208.49	203.22	184.5	169.9	145.4	122.77	117.35	74.19	50
TOP REFLECTOR GRAPHITE	**-283.45**	275.15	272.87	270.42	267.72	264.74	262.89	262.15	260.76	259.22	252.27	241.51	232.41	218.57	195.69	180.98	154.18	129.24	123.24	75.97	50
TOP REFLECTOR GRAPHITE	**-223.45**	300.09	299.35	298.62	297.9	297.19	296.8	296.64	294.91	293.22	292.06	290.79	279.35	253.65	222.01	203.54	170.95	141.07	133.88	78.91	50
TOP REFLECTOR GRAPHITE	**-175.95**	306.42	306.58	306.61	306.61	306.63	306.67	306.69	306.76	306.2	304.52	300.15	297.51	269.26	235.21	215.79	181.1	149.27	141.36	81.3	50
TOP REFLECTOR GRAPHITE	**-120.95**	310.02	309.87	309.75	309.69	309.81	310.19	310.61	310.49	309.92	308.27	308.24	307.28	280.23	245.78	226.23	190.48	157.51	148.95	83.91	50
TOP REFLECTOR GRAPHITE	**-70.95**	317.35	316.89	316.55	316.38	316.72	318.11	319.55	318.58	316.2	309.99	314.07	327.09	295.93	258.49	237.81	200.01	165.17	155.92	86.15	50
VOID	**-29.23**	313.48	314.53	315.84	317.46	319.43	321.76	326.74	326.44	322.9	311.57	318.88	343.41	308.48	268.35	246.78	207.35	171.06	161.26	87.85	50
CORE MESH 1	**6.62**	313.31	314.67	316.29	318.24	320.53	322.47	327.67	327.79	324.2	311.92	320.5	348.92	313.63	272.92	251.17	211.25	174.46	164.39	88.96	50
CORE MESH 2	**19.88**	313.31	314.77	316.5	318.55	320.94	322.93	328.27	328.37	324.68	312.02	320.99	350.56	315.23	274.37	252.58	212.52	175.59	165.43	89.34	50
CORE MESH 3	**33.12**	313.36	314.92	316.75	318.9	321.37	323.43	328.91	328.98	325.16	312.12	321.4	351.93	316.59	275.63	253.82	213.66	176.62	166.38	89.7	50
CORE MESH 4	**46.38**	313.46	315.11	317.03	319.28	321.84	323.96	329.6	329.62	325.66	312.21	321.76	353.11	317.78	276.75	254.92	214.69	177.56	167.25	90.04	50
CORE MESH 5	**59.62**	313.59	315.34	317.35	319.69	322.35	324.54	330.34	330.31	326.19	312.29	322.09	354.19	318.86	277.76	255.91	215.63	178.42	168.05	90.36	50
CORE MESH 6	**72.88**	313.77	315.6	317.71	320.15	322.91	325.16	331.15	331.05	326.76	312.37	322.4	355.21	319.85	278.69	256.84	216.5	179.23	168.8	90.66	50
CORE MESH 7	**86.12**	313.97	315.9	318.11	320.65	323.52	325.85	332.02	331.84	327.36	312.46	322.71	356.2	320.81	279.58	257.72	217.33	180	169.52	90.96	50
CORE MESH 8	**99.38**	314.21	316.23	318.55	321.21	324.19	326.6	332.95	332.66	327.98	312.55	323.02	357.2	321.76	280.45	258.57	218.14	180.75	170.21	91.24	50
CORE MESH 9	**112.62**	314.48	316.61	319.04	321.82	324.94	327.4	333.8	333.35	328.5	312.64	323.34	358.23	322.71	281.32	259.42	218.94	181.49	170.9	91.53	50
CORE MESH 10	**125.88**	314.79	317.02	319.57	322.5	325.82	328.62	332.88	333.16	328.68	312.74	323.67	359.3	323.69	282.21	260.28	219.74	182.23	171.59	91.82	50
CORE MESH 11	**139.12**	315.12	317.47	320.15	323.23	326.7	329.54	333.84	333.99	329.3	312.84	324.03	360.41	324.71	283.12	261.17	220.57	182.99	172.29	92.11	50
CORE MESH 12	**152.38**	315.49	317.97	320.78	324.01	327.64	330.58	335.03	335.07	330.14	312.97	324.41	361.59	325.77	284.07	262.09	221.43	183.78	173.02	92.42	50
CORE MESH 13	**165.62**	315.9	318.5	321.46	324.85	328.64	331.7	336.3	336.19	331.14	313.11	324.82	362.84	326.9	285.07	263.06	222.33	184.6	173.79	92.74	50
CORE MESH 14	**178.88**	316.35	319.09	322.21	325.76	329.74	332.94	337.72	337.52	332.19	313.27	325.27	364.17	328.1	286.13	264.1	223.29	185.48	174.61	93.08	50
CORE MESH 15	**192.12**	316.84	319.74	323.02	326.76	330.93	334.28	339.28	338.97	333.33	313.44	325.74	365.58	329.37	287.28	265.21	224.32	186.43	175.48	93.44	50
CORE MESH 16	**205.38**	317.38	320.44	323.91	327.85	332.23	335.75	340.97	340.55	334.56	313.62	326.25	367.08	330.75	288.51	266.41	225.44	187.45	176.44	93.83	50
CORE MESH 17	**218.62**	317.98	321.21	324.88	329.04	333.66	337.35	342.81	342.25	335.89	313.82	326.81	368.7	332.24	289.85	267.72	226.67	188.58	177.48	94.26	50
CORE MESH 18	**231.88**	318.63	322.05	325.94	330.34	335.23	339.08	344.76	344.04	337.28	314.04	327.41	370.44	333.86	291.33	269.16	228.02	189.83	178.64	94.73	50
CORE MESH 19	**245.12**	319.35	322.98	327.09	331.77	336.97	341.16	346.12	345.56	338.61	314.29	328.07	372.33	335.65	292.96	270.76	229.53	191.21	179.92	95.24	50
CORE MESH 20	**258.38**	320.15	323.99	328.36	333.33	338.84	343.22	348.38	347.66	340.25	314.56	328.8	374.41	337.64	294.8	272.56	231.22	192.76	181.36	95.79	50
CORE MESH 21	**271.62**	321.04	325.1	329.74	335.03	340.88	345.51	350.95	350.07	342.14	314.87	329.63	376.73	339.9	296.88	274.61	233.13	194.51	182.98	96.41	50
CORE MESH 22	**284.88**	322.03	326.32	331.25	336.88	343.11	348.03	353.78	352.74	344.25	315.22	330.57	379.36	342.49	299.28	276.96	235.31	196.49	184.8	97.08	50
CORE MESH 23	**298.12**	323.13	327.66	332.89	338.9	345.55	350.79	356.9	355.7	346.6	315.62	331.66	382.42	345.51	302.06	279.67	237.81	198.74	186.87	97.81	50
CORE MESH 24	**311.38**	324.39	329.14	334.68	341.09	348.21	353.82	360.34	358.98	349.22	316.08	332.97	386.04	349.09	305.32	282.84	240.68	201.28	189.2	98.6	50
CORE MESH 25	**324.62**	325.81	330.76	336.62	343.46	351.11	357.14	364.13	362.63	352.18	316.64	334.57	390.47	353.41	309.18	286.55	243.99	204.14	191.82	99.45	50
CORE MESH 26	**337.88**	327.44	332.56	338.72	346	354.25	360.77	368.33	366.74	355.56	317.31	336.56	396	358.64	313.74	290.88	247.78	207.36	194.74	100.35	50
CORE MESH 27	**351.12**	329.32	334.56	340.97	348.71	357.62	364.74	372.99	371.42	359.51	318.16	339.09	403.05	365.04	319.13	295.94	252.09	210.94	197.97	101.29	50
CORE MESH 28	**364.38**	331.53	336.8	343.39	351.52	361.16	369.05	378.21	376.9	364.31	319.26	342.35	412.14	372.8	325.41	301.74	256.93	214.86	201.49	102.26	50
CORE MESH 29	**377.62**	334.13	339.33	345.96	354.38	364.75	373.66	384.08	383.53	370.46	320.74	346.53	423.77	382.07	332.6	308.28	262.24	219.05	205.23	103.23	50
CORE MESH 30	**390.88**	337.22	342.23	348.72	357.19	368.08	378.03	389.93	391.44	378.75	322.74	351.78	438.27	392.81	340.57	315.43	267.92	223.43	209.11	104.19	50
CORE MESH 31	**404.12**	401.69	400.78	400.88	403.77	416.27	360.46	384.78	398.16	390.33	325.44	358.12	455.41	404.7	349.03	322.94	273.77	227.85	212.99	105.09	50
CORE MESH 32	**417.38**	431.15	426.76	424.06	427.25	449.46	390.72	416.37	425.95	412.01	328.99	365.29	474.15	417.07	357.53	330.42	279.51	232.11	216.72	105.91	50
CORE MESH 33	**430.62**	474.17	466.42	460.98	463.75	490.93	425.47	453.3	458.43	437.02	332.85	372.64	492.79	428.96	365.49	337.41	284.8	236	220.11	106.61	50
CORE MESH 34	**443.88**	521.34	510.1	501.92	504.28	535.66	462.83	491.69	491.32	461.99	336.54	379.43	509.52	439.37	372.32	343.37	289.3	239.29	222.96	107.15	50
CORE MESH 35	**457.12**	569.32	554.45	543.49	545.59	580.77	501.71	530.17	523.05	485.44	339.73	385	522.69	447.33	377.44	347.85	292.67	241.78	225.1	107.51	50
CORE MESH 36	**470.38**	616.57	597.98	584.29	586.21	624.61	541.18	566.17	551.79	506.01	342.25	388.77	530.95	452.04	380.4	350.43	294.67	243.31	226.43	107.65	50
CORE MESH 37	**483.62**	662.1	639.77	623.41	625.2	666.06	579.6	601.2	578.13	523.63	343.82	390.24	533.24	452.87	380.86	350.86	295.14	243.83	226.89	107.56	50
CORE MESH 38	**496.88**	705.51	679.51	660.56	662.15	704.42	616.33	633.08	600.27	536.88	344.25	388.98	528.73	449.41	378.65	349.01	294.08	243.4	226.56	107.2	50
CORE MESH 39	**510.12**	748.36	718.52	696.88	697.97	740.2	650.18	659.75	615.57	543.14	343.18	384.58	516.92	441.57	373.85	345.01	291.67	242.24	225.63	106.57	50
CORE MESH 40	**523.38**	795.08	760.98	736.03	735.12	774.15	677.44	674.77	616.6	536.86	340.18	376.74	497.91	429.63	366.82	339.22	288.33	240.79	224.42	105.63	50
BOTTOM REFLECTOR GRAPHITE	**558.42**	692.72	667.92	652.05	650.86	651.99	613.65	589.36	535.03	468.26	327	351.92	431.3	388.99	342.87	320.52	278.63	238.01	221.56	102.19	50
BOTTOM REFLECTOR GRAPHITE	**593.46**	677.45	654.92	640.98	637.1	628.47	595.37	582.84	533.95	461.97	322.35	337.44	386.27	360.81	332.11	318.2	296.86	278.25	201.42	90.58	50
BOTTOM REFLECTOR GRAPHITE	**614.08**	672.64	650.72	637.2	633.03	623.39	590.23	577.72	528.7	457.13	320.17	330.13	362.4	345.53	325.93	316.47	303.23	291.93	192.34	81.29	50
BOTTOM REFLECTOR GRAPHITE	**638.08**	670.49	649.01	635.66	631.11	620.46	586.57	573.82	524.16	452.48	318.11	323.74	341.1	331.07	318.55	312.31	303.78	296.37	190.57	74.69	50
BOTTOM REFLECTOR GRAPHITE	**655.58**	669.88	649.35	636.25	630.81	618.86	584.51	571.55	519.61	444.59	316.26	320.14	328.14	322.09	313.36	308.79	302.36	296.85	189.23	71.33	50
BOTTOM REFLECTOR GRAPHITE	**668.08**	670.17	652.09	640.01	632.28	615.04	592.29	582.78	513.23	414.8	314.11	318.72	320.05	316.59	310.05	306.38	300.48	296.54	188.27	69.51	50
BOTTOM REFLECTOR GRAPHITE	**694.08**	522.19	502.39	483.21	457.9	421.71	395.51	384.76	361.63	331.23	303.01	304.63	306.77	306.69	304.11	302.49	299.86	295.92	186.46	66.35	50
BOTTOM REFLECTOR GRAPHITE	**720.08**	388.33	366.17	360.09	350.16	337.46	329.6	326.46	320.35	312.9	301.72	302.16	302.71	302.81	301.7	301.07	299.72	295.64	185.57	64.83	50
BOTTOM REFLECTOR GRAPHITE	**746.08**	344.14	314.4	301.87	301.33	301.07	300.88	300.81	300.66	300.48	300.19	300.87	301.2	301.18	300.61	300.33	299.64	295.38	184.82	63.58	50
BOTTOM REFLECTOR GRAPHITE	**772.08**	326.54	305.26	301.98	301.18	300.8	300.66	300.61	300.52	300.44	300.24	300.43	300.52	300.44	300.09	299.95	299.4	294.85	184.25	62.99	50
BOTTOM REFLECTOR GRAPHITE	**798.08**	313.3	302.89	300.76	300.34	300.2	300.16	300.14	300.11	300.08	299.99	299.94	299.88	299.71	299.27	298.5	297.35	294.1	183.68	62.51	50
BOTTOM PLATE	**834.08**	308.1	303.88	302.23	301.35	300.79	300.58	300.49	300.34	300.17	299.67	299.19	298.82	298.12	297.15	296.45	295.69	294.65	183.81	62.29	50



Fuel Temperature (°C)

Z_cm	41.11	71.2	91.92	108.77	123.33
404.12	448.95	447.65	447.75	452.15	471.65
417.38	482.35	475.65	471.45	475.85	509.65
430.62	537.05	525.55	517.25	520.55	560.55
443.88	596.65	580.35	568.15	570.45	615.55
457.12	655.85	634.65	618.65	620.05	669.65
470.38	712.05	685.95	666.35	667.15	720.55
483.62	763.95	733.35	710.25	710.55	766.45
496.88	811.45	776.45	750.15	749.85	806.75
510.12	857.75	818.05	788.55	787.15	842.75
523.38	913.75	868.55	834.35	829.25	878.55

This summer we will select the FOAK site and start pre-licensing



“When will be the first nuclear powered vessel in a Dutch port?”

NS Savannah @ Rotterdam 1964