Fast reactors as a solution for future small-scale nuclear energy

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SMR – Possible platform of the decentralized energy system

In the 21st century safe and sustainable development of the world's economy largely depends on the ability to build a better energy infrastructure:

- Provision of efficient access to the energy resources
- Reduction of greenhouse gas emissions
- Levelling of the fossil fuel cost growth
- Flexibility (manoeuvrability, modularity, complementary products).

Possible option is Small and Medium reactors (SMR)

A dozen of SMR with prospects of pilot unit construction by 2020 can be marked out from some 30 of SMR projects under development …

Korea	SMART	In July 2012, the Korean Nuclear Safety and Security Commission issued the Standard Design Approval for the 100 MW(e) Na SMART
USA	NuScale mPower W SMR	US-DOE support of SNR (decision on mPower funding was made)
Argentina	CAREM-25	Site excavation for CAREM-25 was started in September 2011
Japan	4S	Toshiba had promoted the 4S for a design certification with the US NRC
Russia	KLT-40s SVBR-100	2 modules marine propulsion-based barge-mounted KLT-40s are under construction, 90%. The lead-bismuth cooled SVBR-100 is planned to be launched by 2018

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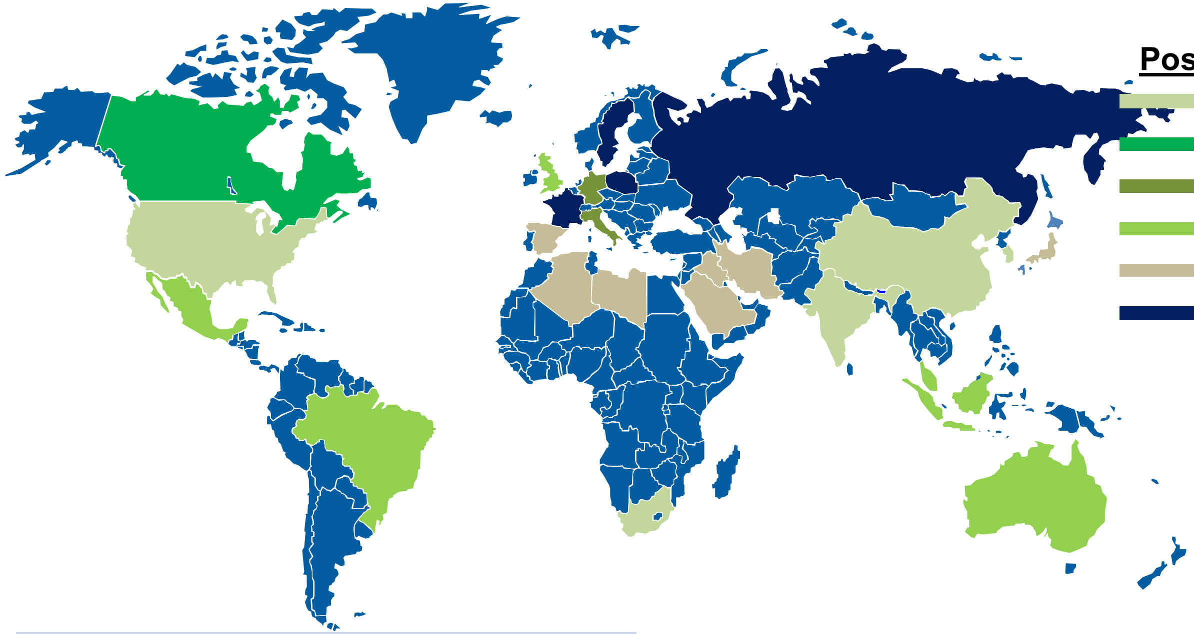
SMR potential market



Possible complementary products:

- cogeneration/desalination/hydrogen
- oil sands/hydrogen
- cogeneration/hydrogen
- hydrogen
- desalination
- cogeneration

Source: *"Building the value chain for SMR", 18-20 October 2010, Washington (USA)*

World's SMR potential by 2030 can be estimated as 30-35 GW, or 150-200 B$

BRICS SMR market evaluation

Country	Total Planned Capacity of Energy System 2030 (GW)	Nuclear Capacity 2010	Nuclear New Builds 2013-2020 (GW)	Nuclear Units Share 2030 Evaluation	SMR 100-400 GW Potential (GW)
China	2890	9,3	110,3	4,6%	14,0
India	686	4,6	29,5	6,1%	8,4
Brazil	251	2,0	5,2	4,0%	2,9
Russia	409	22,3	42,1	13,1%	5,5
S. Africa	95	1,9	4,8	8,8%	1,6

Source: *RolandBerger*

SMR key deployment drivers

At the beginning of 2011 the world-wide number of operating SMRs was about **125** (based on 1970-80s technologies) with about 57 GW(e) generation capacity. The number of countries with SMR was **28**.

Source: *IAEA - INIG Workshop on Topical Issues of Infrastructure Development, 24 – 27 January 2012*

Nuclear pros and cons

+	-
supply stability, zero-carbon emission, low operation costs	higher capital costs, non-proliferation resistance, spent nuclear fuel (SNF) and radioactive wastes management

To compete against alternative solutions new SMRs must exhibit some evident technical and economical advantages

Major drivers that can accelerate new SMR deployment:

- Reactor inherent safety (based on natural physical and chemical principles)
- Economical efficiency: LUEC competitiveness within its market niche
- Non-proliferation resistance, proven technology, SNF and radioactive waste management, operational and maintenance simplicity

Inherent safety

Growing number of active and passive safety systems and defense-in-depth barriers mitigate the probability of NPP accidents and their consequences.

- ✓ The crucial reactor coolant characteristic is a value of potential energy stored in a volume unit of coolant
- ✓ Potential (non-nuclear) energy cannot be changed by engineering solutions
- ✓ Non-nuclear energy “stored” in the reactor and associated with reactor coolant is a dominant factor determining the nuclear power plant safety/hazard performances - **inherent safety** feature

Coolant type	Water	Sodium	Lead, Lead-Bismuth eutectic
Parameter	P = 16 MPa, T = 300ºC	T = 500ºC	T = 500ºC
Maximum potential energy, GJ/m3, including:	**~ 21,9**	**~ 10**	**~ 1,09**
– Thermal energy	~ 0,90	~ 0,6	~ 1,09
– Potential compression energy	~ 0,15	None	None
– Potential chemical energy of interaction	~ 11,4 (with zirconium)	~ 5,1(with water) ~ 9,3 (with air)	None
– Potential chemical energy of interaction of hydrogen	~ 9,6	~ 4,3	None

LUEC competiveness

- ✓ SMR is not a competitor of large scale power source of any type of generation, and its competiveness should be measured in LUEC terms within **its market niche.**
- ✓ However SMR in its future mature state (serial production) can possess practical advantages: modularization, factory readiness, learning curve, match of supply to demand, shorter construction period, affordability ... that can smooth the difference between capital cost (per kW) for large scale (1 GW) and small reactors (different estimations show 5-20%)

Potential market for SMR - different than those for large scale reactors: decentralized grids, remote areas, co-generation & fresh water production, industrial heat

Country	LUEC*, $/MW·h	Competiveness range
China	60-70	CHP coal plants 100-300 MW(e); co-generation, desalination, renewable energy - wind
India	80-100	Coal plants, Solar PV
Brazil	60-70	Coal plants 100-600 MW(e), Gas CCGT, Solar PV
Russia	60	Coal plants 100-400 MW(e), co-generation/municipal heat, desalination, renewable energy - wind
Turkey	80-100	Coal plants, Gas CCGT, co-generation, desalination, renewable energy - wind
Indonesia	100-120	Coal plants, Gas, desalination, renewable energy – wind, Solar PV
South Africa	100-120	Coal plants, Gas, renewable energy – wind, Solar PV

**Discounting rate is taken as 10%*, Source: *RolandBerger*

SVBR-100 Project Case

- ✓ SMR deployment technical and economic challenges potentially addressed in nuclear power complexes based on SVBR-100 reactor –integral type 100 MW(e) lead-bismuth fast reactor with inherent safety and high proliferation resistance features
- ✓ Planned to launch the first pilot unit by 2018 in Dimitrovgrad (east to Moscow)

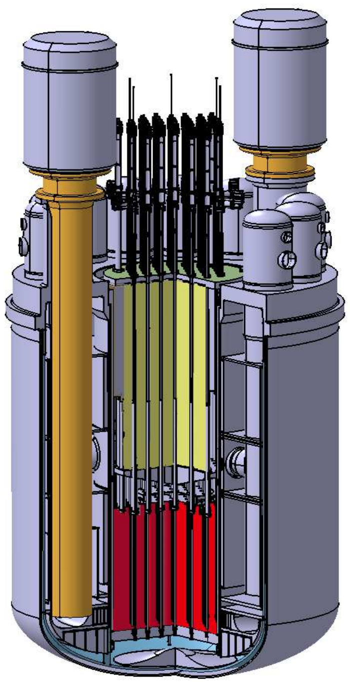
SVBR can potentially become world's first innovative commercial SMR reactor

Background

- Advanced lead-bismuth fast reactor technology with 80 reactor-years operational experience

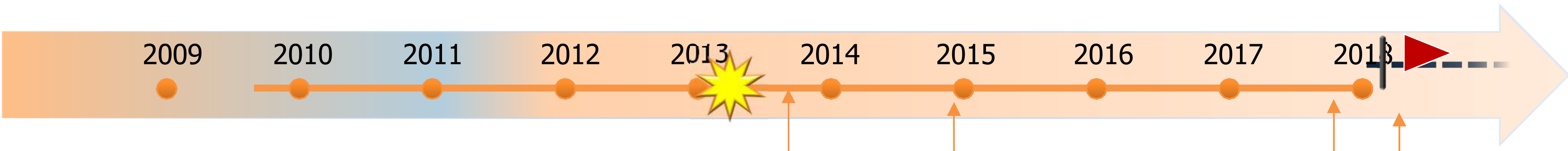
About the Project

- Public-private partnership, aimed to develop a business with competences in design, engineering, manufacturing, construction and operation of SVBR small and medium-sized nuclear power plants
- The project is managed by JSC "AKME-engineering" - a 50/50 joint venture of the Stat Russian Atomic Corporation "Rosatom" and private partner En+ Group, which is a subsidiar of the Basic Element Company
- Federal Target Program "Nuclear Power Technologies of the New Generation for 2010 - 2015 and until 2020"



Coolant	Lead-bismuth
Thermal output	280 MWt
Power plant output (with one reactor module):	
Electricity	100 MWe
Heat (optional)	70-100 Gkal/hour
Power plant efficiency	36%
Design availability factor	90%
Fuel campaign	7-8 years (with standard UO_2 fuel 16.3%)
Steam parameters	Saturated steam, p=6.7MPa, T~282.9°C
Load following capability	+-0.5-2% N_{nom} per minute in 70%-100% power range
Reactor module weight	~235 ton
Reactor module dimensions	4.5 / 8.2 meters (diameter/height)
Reactor module design lifetime	60 years

SVBR Project schedule and key milestones



Current status

- AKME is an **operating organization** and a "holder" of nuclear installations and fissile materials
- **Site selected and authorized**
- **Public hearings** successfully **passed**
- **Pilot plant design and site-specific works** are under way
- Reactor module design and **R&D to support licensing** is under way
- **Quality management system certified** (ISO 9001)

2013 Goal

- Siting license obtained

2014 Goals

- Construction license obtained
- Design completed

2018 Goals

- Operating license obtained
- Pilot plant commissioned
- **Manufacturing and servicing infrastructure for commercial modules**

Start of serial production of commercial modules

Concept design → **Design and engineering** → **Construction** → **Operation and Commercialization**

SVBR-100 non-proliferation features

Due to the physical principles and design SVBR reactor possess excellent non-proliferation protection that minimizes the risk of unauthorized access to the fissile materials during reactor lifetime

SVBR lifetime non-proliferation features :

Fresh Nuclear Fuel & re-fuelling	Operation	Spent Nuclear Fuel
Though SVBR possess fuel universality, only UO2 is considered as an export option	Reactor design excludes breeding blankets, where plutonium can be accumulated	Radiotoxic fission products in SNF allows controlling transfer by gamma-radiation detectors
UO2 fuel enrichment is 16,3% on average, and no fuel pellet has enrichment above 19,5%. Fuel breeding ratio is below 1	Possibility of the access to the fuel assemblies during fuel campaign is technically eliminated	Spent nuclear fuel (SNF) contains highly radioactive minor actinides (2%) that serve as additional intrinsic barrier in plus to safeguard and IAEA inspection
Refueling is performed using special heavy equipment, which remains the property of supplier	Partial refueling during the operation is impossible	Spent fuel assembly after cooling is transferred to the supplier country
Reactor refueling is performed very seldom (once a 7-8 years) and can be easily inspected by IAEA		

SVBR-100 key performance indicators & conclusions

Generation type	Overnight capital costs, $/kW	LCOE, $/MWh	Construction period, yrs
Coal-fired (US/USC)	650-800	40-80	3-4
Gas-fired (CCGT)	600-700	45	2-3
Nuclear (large plants)	2000-2900	50	4-5
On-shore wind	1300-1700	100	1-2
PV Solar	2900-3700	230	1-2
SVBR-100 * 4 (400 Mw)	**4000**	**60-70**	**3-4**

Source: : *IEA. KPMG India Electricity Market Outlook, Roland Berger*

- ✓ Small nuclear power plants can provide a future platform for decentralized energy supply providing better levels of accessibility, safety and environmental friendliness.
- ✓ The optimal solution for SMR deployment is fast reactors with inherent safety.
- ✓ To compete alternative solutions SMRs must exhibit some evident advantages in: safety, technology, and economic.

Small modular reactors with lead-bismuth coolant (SVBR-100) under development in Russia can be a prospective solution for future small and decentralized energy

Thanks!

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