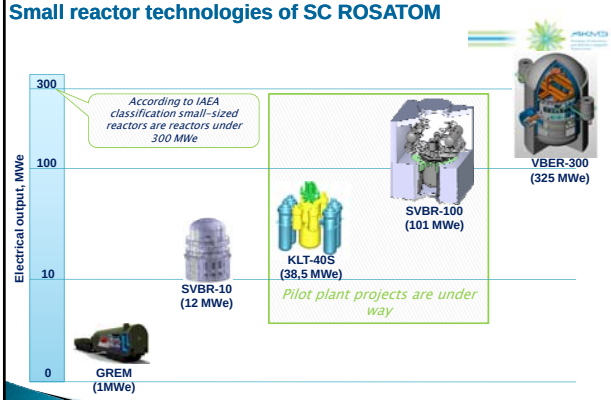
# Russian experience in SMR development and siting

## Small reactor technologies of SC ROSATOM




2

## Power modules with GREM reactor

| Key technical characteristics | |
|---|---|
| Reactor type | HTGR (helium-xenon) |
| Reactor thermal output | 2,6 MW(th) |
| Power plant output (with 2 reactor modules): | |
| Electricity | 2*1,0 MW(e) |
| Heat | 1,2 Gcal per hour (maximum) |
| Power plant efficiency | 38-45% |
| Design lifetime | 25 years |
| Fuel campaign duration | 10 years |
| NPP weight | 50 tonnes |
| Capital cost | ~15000 $/kW(e) |
| Operational costs | ~110 $/MWh |

**Current status and plans:**

- preliminary design is finished,
- a pilot plant could be commissioned by 2017,
- project is being reviewed for possible commercialization in Russia-Belarus partnership

3

## Power plants with VBER-300 reactor modules

| Key technical characteristics | |
|---|---|
| Reactor type | PWR |
| Reactor thermal output | 917 MW(th) |
| Power plant output: | |
| Electricity | 325 MW(e) |
| Power plant efficiency | 35,5% |
| Design lifetime | 60 years |
| Fuel campaign duration | 1-2 years (UO2 fuel) |
| Capital cost | ~3650 $/kW(e) |
| Operational costs | ~40 $/MWh |

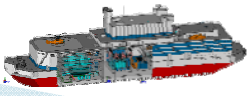
**Current status and plans:**
- feasibility study for Actau site (Kazakhstan) is finished,
- a joint venture between SC Rosatom and Kazatomprom (Kazakhstan) is established,
- a pilot plant could be commissioned by 2019

4

## Floating nuclear power plant with KLT-40S

| Key technical characteristics | |
|---|---|
| Reactor type | PWR |
| Reactor thermal output | 150 MW(th) |
| Power plant output (with 2 reactor modules): | |
| Electricity | 2*38,5 MW(e) |
| Heat | 146 Gcal per hour (maximum) |
| Design lifetime | 40 years |
| Fuel campaign duration | 2,5-3 years (UO2 fuel with 18,6% of U235) |
| Operating cycle between maintenance | 12 years |
| NPP (floating part) size | 140/30 meters (length/width) |

**Current status and plans:**
- Overall technical readiness is about 60%,
- a pilot plant will be commissioned by 2013 in Viluchinsk (Russia)



5

## Power plant with SVBR-10 reactor module

| Key technical characteristics | |
|---|---|
| Reactor type | liquid metal-cooled fast reactor |
| Reactor thermal output | 43 MW(th) |
| Power plant output: | |
| Electricity | 12 MW(e) |
| Desalinated water* | max. 30 000 tons/day |
| Load factor | 90% |
| Operating cycle between refueling and maintenance | 17-20 years (UO2 fuel with 18,4% of U235) |
| NSSS module weight | 310 ton |
| NSSS module dimensions | 8,0 / 11,2 meters (diameter/height) |
| Overnight capital cost | 5000-6000 $/MW(e) |
| Generating costs | 70-80 $/MWh |

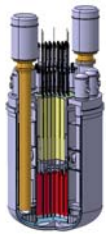
*- if water-desalinating equipment installed

**Current status and plans:**
preliminary design is finished,
a demonstration plant could be commissioned by 2015

6

## Power plants with SVBR-100 reactor module

| Key technical and economical characteristics | |
|---|---|
| Reactor type | liquid metal-cooled fast reactor |
| Reactor thermal output | 280 MW(th) |
| Power plant output (for power plant with one reactor module): | |
| Electricity | 101 MW(e) |
| Heat* | max. 70 Gkal/hour |
| Desalinated water* | max. 200 000 tons/day |
| Power plant efficiency | 36% |
| Load factor | 90% |
| Fuel campaign duration | 7-8 years (UO2 fuel with 16,3% of U235) |
| Steam parameters | Saturated steam, p=6,7MPa, T~282,9 C |
| Reactor module weight | 270 ton |
| Reactor module dimensions | 4,5 / 7,86 meters (diameter/height) |
| Overnight capital cost | 4000-4500 $/MW(e) |
| Generating costs** | 40-50 $/MWh |



* if appropriate equipment is installed
** including O&M, fuel, decommissioning costs

**Current status and plans:**
R&D and design engineering is under way,
**a demonstration plant will be commissioned by 2017**

7

## SVBR reactor modules - IV generation nuclear systems

- **Background:**
  - ✓80 reactor-years operational experience of the Pb-Bi cooled reactors for Russian submarines
- **Sustainability:**
  - ✓Minimal environmental impact (reduced spent fuel amount due to long fuel campaign (up to 8 years with UO2 fuel))
  - ✓Possibility to work in closed fuel cycle systems
- **Safety and reliability:**
  - ✓Inert lead-bismuth coolant
  - ✓Integral nuclear system design without high pressure in primary circuit
  - ✓Preferences to passive safety systems
  - ✓Factory assembly of reactor module
  - ✓Satisfy Russian regulatory requirements, basic EUR and NRC requirements
  - ✓Reduced "single-shaft" risk (through larger number of small units)

8

## SVBR reactor modules - IV generation nuclear systems

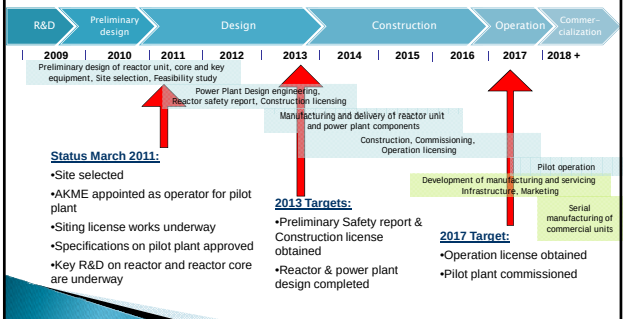
- **Economical efficiency:**
  - ✓Reduced financial risk during construction due to transportation and construction simplicity (factory-made ready-for-installation reactor module transportable by train, ship or vehicles)
  - ✓Flexibility for local energy needs due to scalable modular design (100-200-300-0-…MWe)
  - ✓Long fuel campaign and fuel universality (reactor core can be loaded with almost all types of nuclear fuel (UO2, MOX and other fuel types))
  - ✓Possibility of deployment near residential area (less than 1 km)
  - ✓60 years lifetime for reactor vessel and structures
  - ✓Broad range of products: electricity, heat, desalinated water, steam for some industrial needs
  - ✓Relative ease of system integration (less requirements towards local infrastructure)

| Temperatures needed for various types of industrial processes (Centigrade) | |
|---|---|
| Home and building heating | 100–170 |
| Desalination | 100–130 |
| Vinyl Chloride production | 100–200 |
| Process steam | 200–400 |
| Paper and pulp production | 200–400 |
| Oil refining | 200–600 |
| Oil shale and oil sand processing | 300–600 |
| … | |

9

## SVBR-100: current status and plans

- SVBR-100 project is managed by AKME-engineering – a 50/50 joint venture between SC Rosatom and EuroSibEnergo (En+ Group).
- Total investments are estimated at 16-18 bln.roubles ($500-600 mln.)




**Status March 2011:**
- Site selected
- AKME appointed as operator for pilot plant
- Siting license works underway
- Specifications on pilot plant approved
- Key R&D on reactor and reactor core are underway

**2013 Targets:**
- Preliminary Safety report & Construction license obtained
- Reactor & power plant design completed

**2017 Target:**
- Operation license obtained
- Pilot plant commissioned

10

## Licensing issues for SVBR-100

**RF regulations are sufficient to carry out activities regarding SVBR during it's lifetime and support innovative features of new SMRs**

| Key issues to be proved: | Solutions in Russian regulatory framework: |
|---|---|
| ? Operation staff requirements<br>? Emergency zone planning | Requirements are flexible and **depend on safety level** of NPP (proved by a SAR) |
| ? Distance from residential area | Requirement of the RF Ministry of Emergency is 25 km distance between NPP and residential area. But there is practice of reduction this distance **up to 3 km** by additional justifications |
| ? Safeguard requirements | Requirements are fixed and **depend on NPP technology and design** (results of a vulnerability analysis) |
| ? Liability insurance | Maximum liability for NPP operator is about **$195mln** and causes annual insurance payments which could not be a financial burden for a SMR operator, but can be additionally reduced for SMRs |

11

## Liability insurance issues

| Type of coolant | Water | Sodium | Lead/ lead-bismuth |
|---|---|---|---|
| Parameters | P=16 MPa, T=300 C | T=500 C | T=500 C |
| Max. potential energy, GJ/stere, incl.: | ~21,3 | ~10 | ~0,74 |
| Thermal energy | ~0,90 | ~0,53 | ~0,74 |
| Potential chemical energy of interaction | With zirconium ~11,4 | With water ~5,1<br>With air ~9,3 | NO |
| Potential energy of interaction between hydrogen and air | ~9,6 | ~4,3 | NO |

- According to RF regulations maximum liability (for one reactor) is $195 mln.
- Liability insurance fee is about $300k/year
- BUT maximum damage for new innovative SMR designs could be significantly less due to new safety features

IAEA ?

***Regulatory requirements towards liability insurance based on specific safety features of SMR designs (i.e. results of a SAR)***

12

## Globe market demand regarding regulatory issue

Key aspects to be considered by host countries:
- Ownership
- Operation
- Licensing
- Liability, etc.

Host countries for SMRs can chose different regulatory approaches based on:
- maturity of national nuclear regulation system,
- nuclear industry level of development, etc.

This leads to uncertainty for SMR vendors, investors and customers regarding regulatory approach which will be selected by the host country

Corresponding consequences:
- Infrastructural arrangements
- Timing (up to 5-10 years) and expenses

+Unsettled international rules (incl. transportation of fuelled reactors)

***Unified internationally accepted set of regulations for SMR market?***

Led by IAEA ?

13

## Contacts

***Anna Kudryavtseva***
*Project Director of SC ROSATOM*
*Director General*
*JSC "AKME-engineering"*
*Tel. +7 495 7307960*
*ak@svbr.org*
*www.akmeengineering.com*

14