Floating Nuclear Power Plants /
Les Centrales Nucléaires Flottantes

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Introduction

- Floating Nuclear Power Plant (FNPP) is a new type of energy source based on nuclear shipbuilding technologies and designed to provide reliable year-round power supply to the industry and households in remote regions, lacking domestic fuel resources and not connected to major energy transmission lines.

- FNPP' central element is a floating power unit (FPU), a vessel with inbuilt power generating equipment. FPU is fully assembled at the shipyard and towed by sea to its operation site when it is ready to use.

- The other element of the FNPP is a complex of mooring and onshore facilities with energy transmission equipment constructed on site.

- FNPPs can be deployed in coastal areas to supply local consumers with thermal and electric power and operate as an energy source for water desalinating facilities.

Project goals

- Development of a mobile, safe, reliable, technically and economically feasible energy source for arduous regions and areas with decentralized power system
- Replacement of fossil power plants, reducing CO_2 emissions as well as the dependency on fuel market, and thus increasing the reliability and sustainability of energy supply
- Introduction of affordable energy sources and establishment of centers of growth for social and economic development of remote, isolated regions
- Stabilization of prices of heat, electricity and potable water for population and industries

UN Sustainable Development goals

Arts & Métiers ALUMNI

Power for water supply, desalination

Boost to science, knowledge transfer

4 QUALITY EDUCATION

6 CLEAN WATER AND SANITATION

7 AFFORDABLE AND CLEAN ENERGY

Affordable, clean and secure energy supply

Nuclear medicine

3 GOOD HEALTH AND WELL-BEING

8 DECENT WORK AND ECONOMIC GROWTH

Boost to GDP growth

Power for agriculture

2 ZERO HUNGER

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Boost to industry, technology transfer

Fights energy poverty, creates jobs

1 NO POVERTY

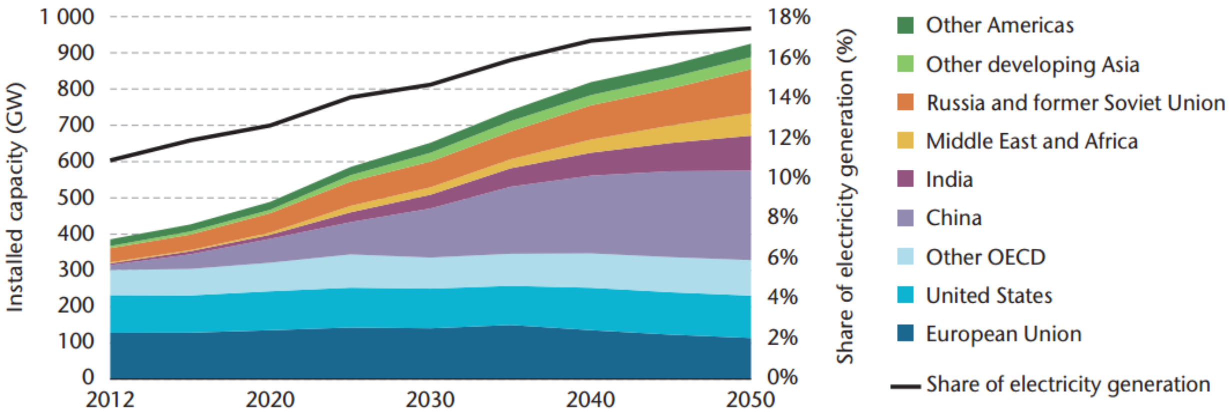
17 PARTNERSHIPS FOR THE GOALS

13 CLIMATE ACTION

Mitigates climate change

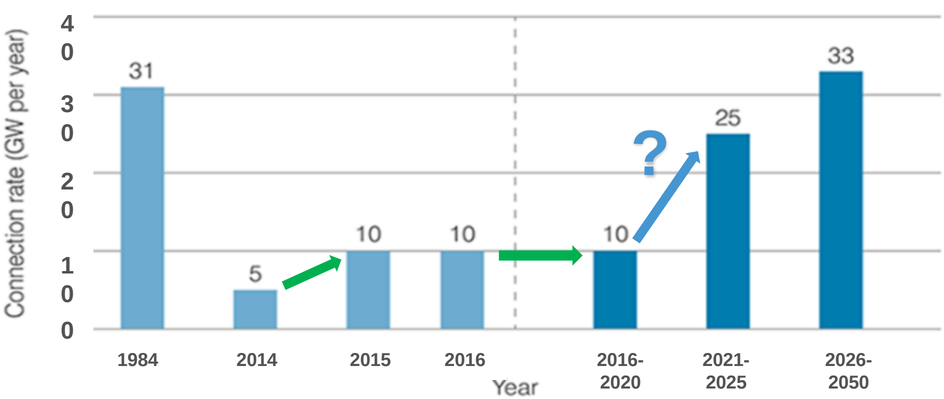
Needs for nuclear growth

Can we achieve it?



Source: International Energy Agency

Nuclear power needs to be more than doubled by 2050 to reach 18-25% of global electricity supply and to deliver up to 1000 GW of new capacity



Connection rate of 30-35 GW per year is required

Source: World Nuclear Association

Challenges of nuclear power development

COMPETITIVENESS	WASTE MANAGEMENT	PUBLIC ACCEPTANCE

These challenges can be addressed by:

- **Serial & sophisticated construction of NPPs**
- **New reactor technologies**
- **Responsible lifetime fuel cycle management**
- **International cooperation**

Can SMRs be an answer?

SPECIFIC CONDITIONS BRING DEMAND FOR…

GEOGRAPHIC CONDITIONS:
- Remote areas
- Islands, archipelagos, coastlines

→ **TRANSPORTABILITY & FLEXIBLE DEPOYMENT**

INFRASTRUCTURE CONDITIONS:
- Undeveloped power grids
- Energy storage is onerously expensive

→ **PLUG-AND-PLAY GRID CONNECTION**

MARKET CONDITIONS:
- Energy price volatility
- Fuel dependency

→ **COSTS PREDICTABILITY**

EXCESSIVE FOCUS ON RENEWABLES
- Balancing base load
- Small energy capacities

→ **STABLE GENERATION**

TES-3 nuclear power plant

Consists of 4 mobile, self-propelled modules assembled altogether on site

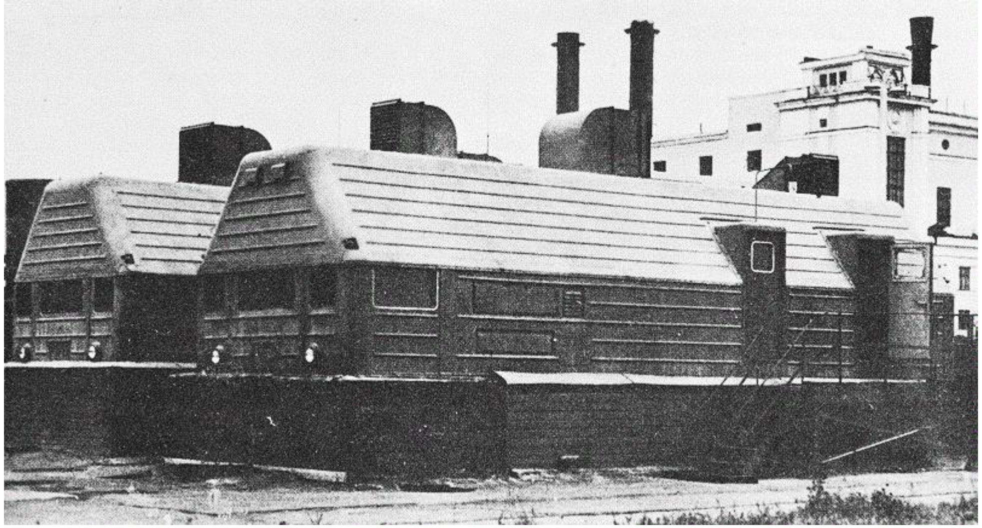
Single pressurized water reactor

8.8 MW thermal power

Installed capacity – 1.5 MW(e)

Designed and constructed at the IPPE (Obninsk, USSR)

Reached criticality in 1961



Source: https://igorpmigse.livejournal.com/130567.html

MH-1F “Sturgis” nuclear power plant

Based on a retrofitted Liberty-class cargo ship, the *Charles H. Cugle*

PWR MH-1A, 45 MW thermal power

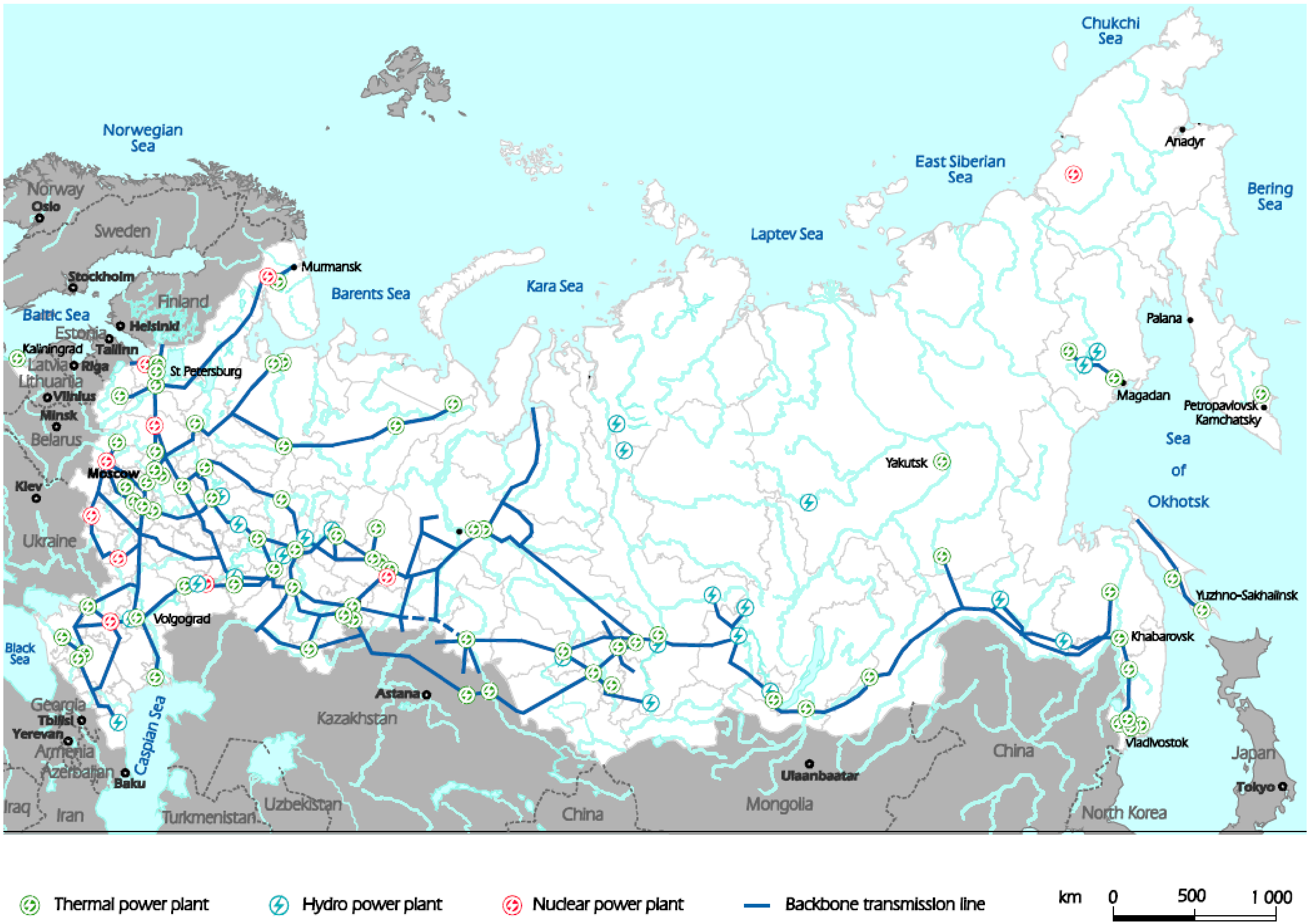
Installed capacity – 10 MW(e)

Reached criticality in 1967

Operated in 1968-1976 at Gatun Lake (Panama)

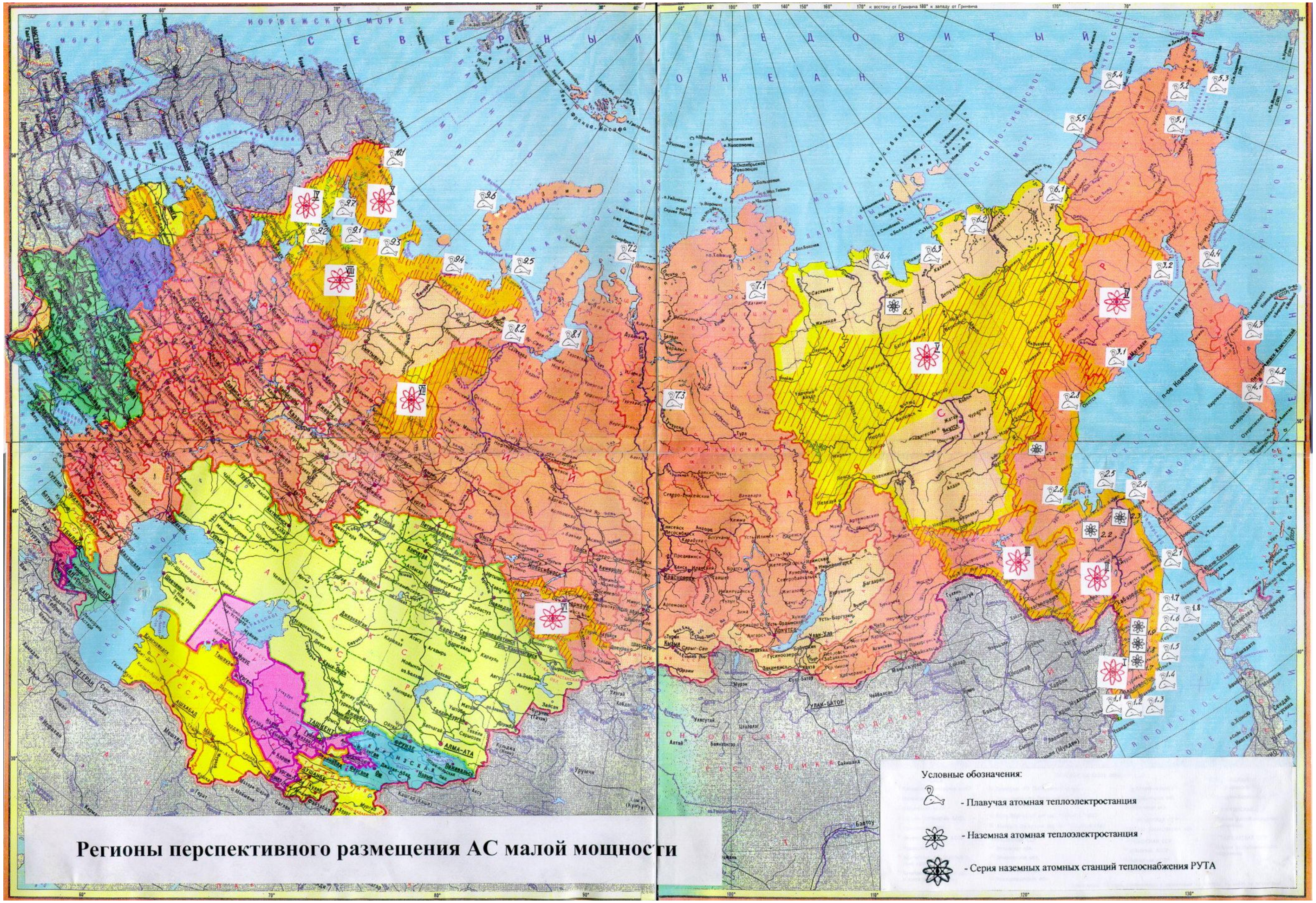
Source: https://armyengineerhistory.dodlive.mil/anpp/sturgis/

Major transmission lines in Russia



Source: IEA, 2014

SMR feasibility studies in the USSR



Source: IAEA, 2007

First-of-a-kind FNPP construction project

TECHNICAL FEATURES:	
Reactor module	2 x KLT-40S
Electrical capacity	77 MW (2 x 38,5 MW)
Refueling cycle	3 years
Design life	40 years
Displacement	21,150 m tons
Length	144 m
Beam	30 m
Draught	5.6 m

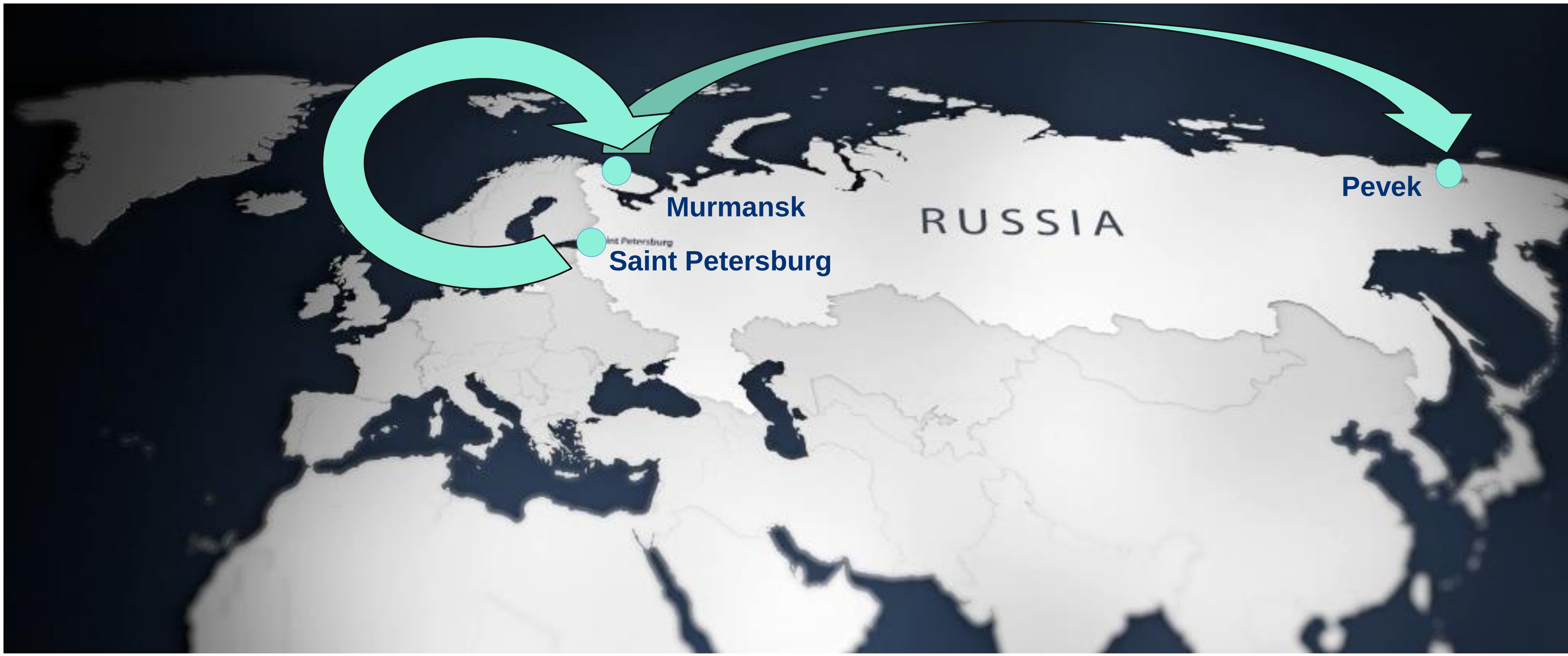
Construction started in April 2007

FPU launched in June 2010

Reactors reached criticality in November 2018

The plant is planned to be commissioned in 2019 (Pevek, Russia)

First-of-a-kind FNPP construction project



Source: RAOS, 2018

Work progress on the first-of-a-kind FPU

Source: Rosenergoatom, 2009

FPU launching

Source: Rosenergoatom, 2010

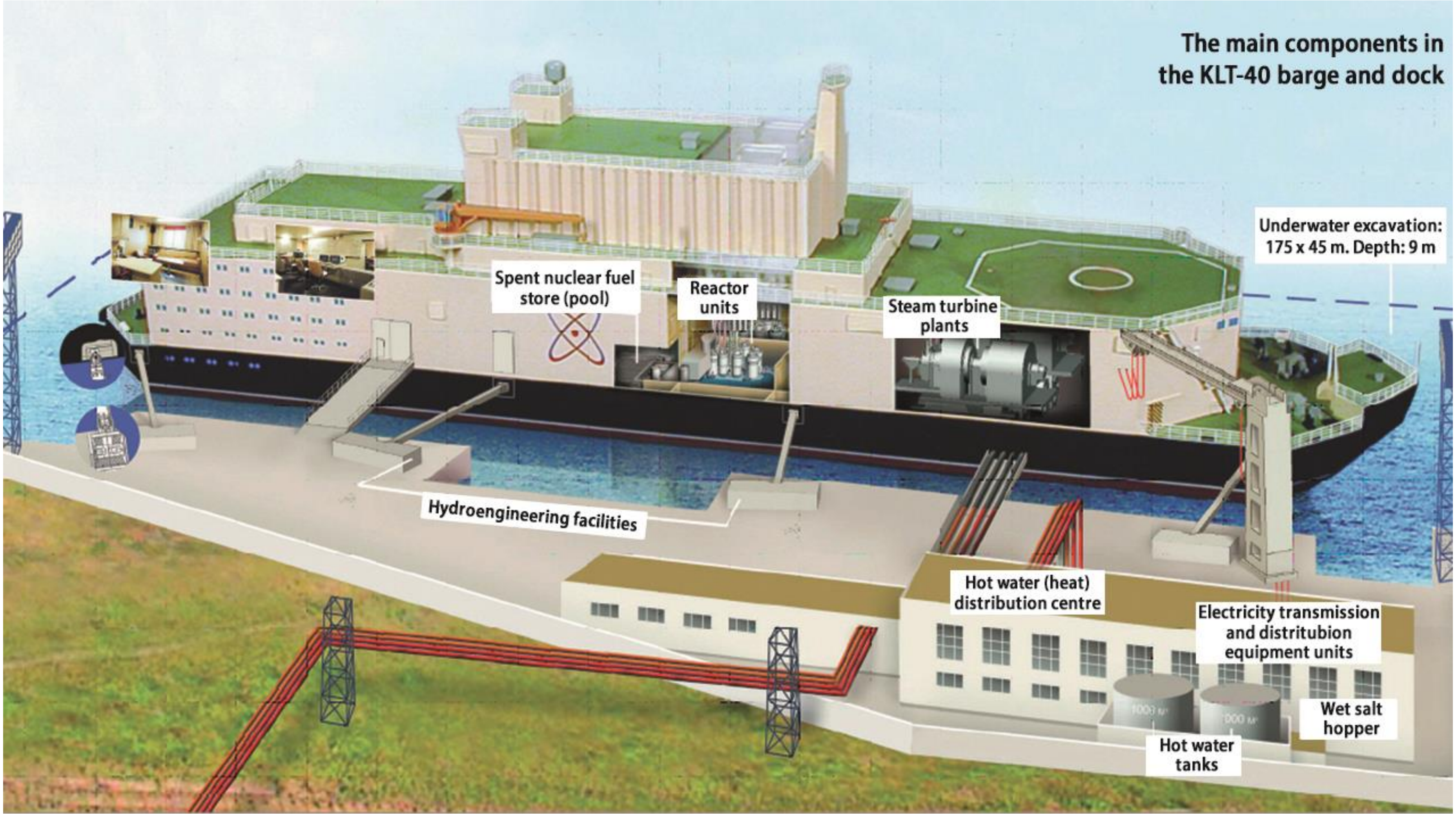
Fitting-out at the wharf

Source: Rosenergoatom, 2011

FPU «Akademik Lomonosov» in Murmansk, Russia

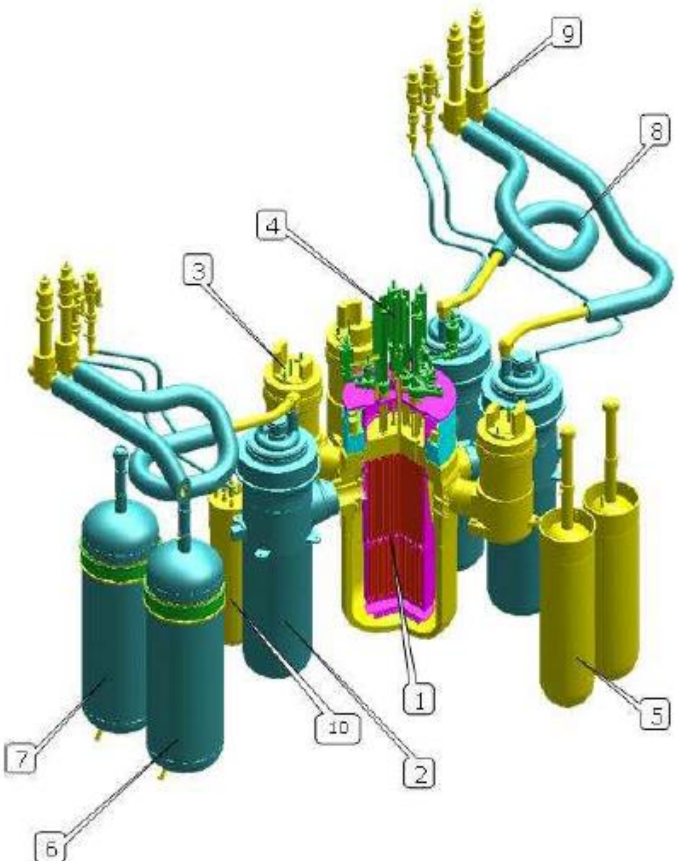
Source: https://energybase.ru/power-plant/floating-nuclear-thermal-power-plant-akademik-lomonosov

FNPP layout



Source: OKBM, 2016. See also: www.okbm.nnov.ru/english/lomonosov

KLT-40S reactor



Parameter	Value
1 Thermal power, MW	150
2 Number of FAs	121
3 FA across flats size, mm	98.5
4 Triangular lattice pitch, mm	100
5 Core diameter, mm	1220
6 Core height, mm	1200
7 FE dimensions across cladding, ∅×δ, mm	6.8×0.5
8 FE cladding material	Zirconium alloy
9 Absorber element layout in FA	Central absorber element
10 Number of control rods in the core	8 compensating rods + 3 emergency protection rods

1- Reactor
2- SG
3- MCP
4- Control rod drive mechanisms
5- ECCS accumulator
6- Pressurizer (1st vessel)
7- Pressurizer (2nd vessel)
8- Steam lines
9- Localizing valves
10- HX of purification and cooldown system

Source: IAEA Advanced Reactors Information System, 2013 (https://aris.iaea.org/PDF/KLT-40S.pdf)

Installation of a KLT-40S reactor

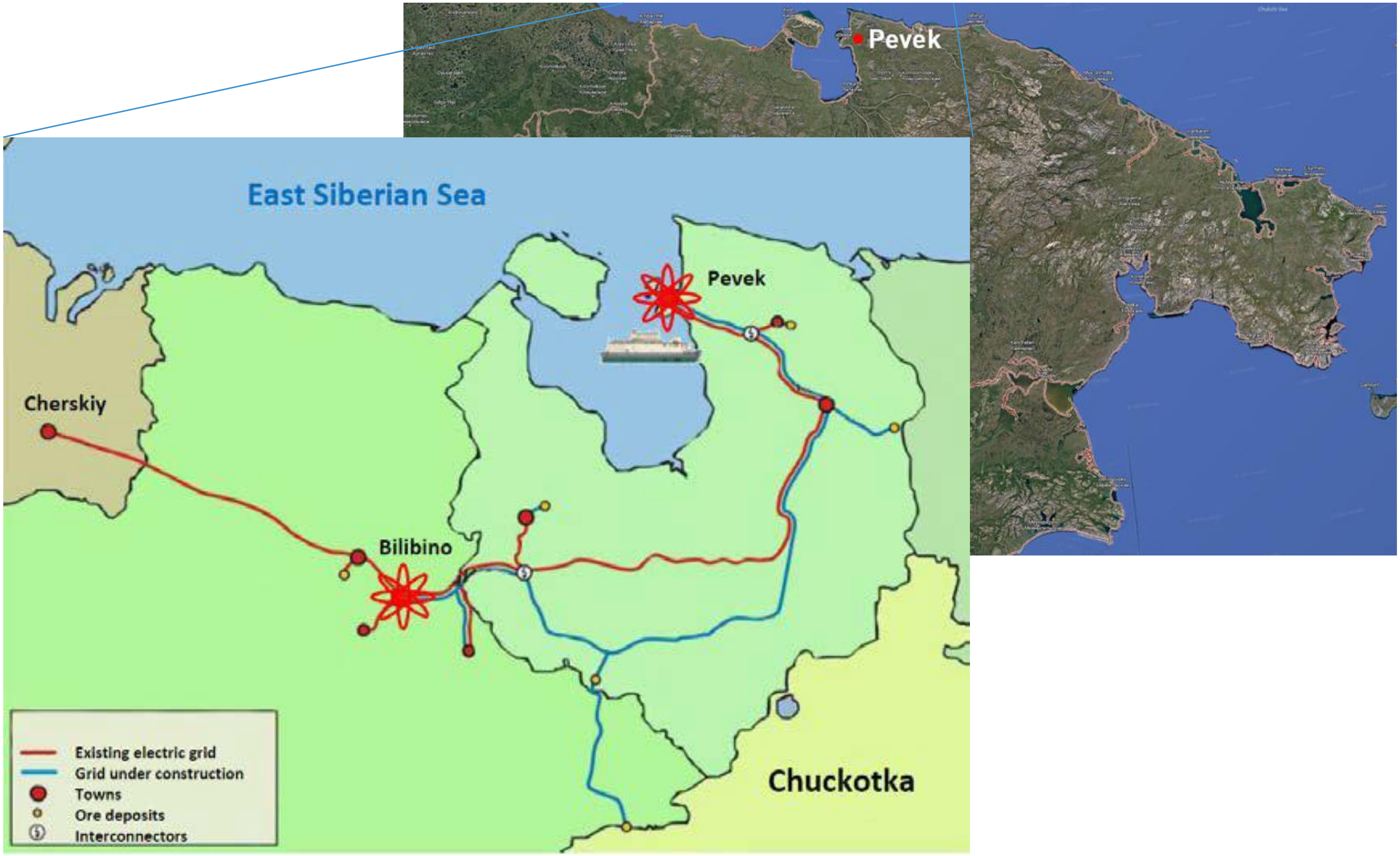
Source: http://www.atomic-energy.ru/news/2013/09/30/44078

Construction timeline

2007	**Construction started**
2008	Main contractor was changed from Sevmash to Baltiysky Zavod causing a delay in construction
2009	In mid-2009, turbines were manufactured and installed into the vessel
2010	In June 2010 the FPU was launched
2011	Delay in construction due to bankruptcy proceedings against the shipyard. A new contract was signed with the new owner of the Baltiysky Zavod shipyard
2012	
2013	In 2013, reactors were installed into the vessel
2014	Construction of on-shore facilities in Pevek started
2015	
2016	
2017	
2018	Construction completed. Reactors reached criticality
2019	Transportation to Pevek. The plant is planned to be commissioned in late-2019

Source: Rosatom, 2019 See also: http://www.rosenergoatom.ru/development/innovatsionnye-razrabotki/razrabotka-proektov-aes-s-reaktorami-novogo-pokoleniya/plavuchie-atomnye-teploelektrostantsii-pates/

Chaun-Bilibino local electric grid



Source: NEA, 2016 (http://www.oecd-nea.org/ndd/pubs/2016/7213-smrs.pdf)

Plans for FNPP deployment in Russia

Source: http://www.world-nuclear.org/information-library/country-profiles/countries-o-s/russia-nuclear-power.aspx

Next Gen FNPP with RITM-200 reactor

TECHNICAL FEATURES

Length	112m
Beam	25 m
Draught	4.5 m
Displacement	12 000 t
Design life	60 years
Refueling cycle	up to 10 years
Construction period	4 years

Reactors	2 x RITM-200M
Thermal power	350 MW (2 x 175 MW)
Electric power	100 MW (2 x 50 MW)

ELECTRICITY

HEAT

by-product district heating by the thermal power of the reactor plant

DESALINATION

an additional desalination module installed

Source: RAOS, 2018

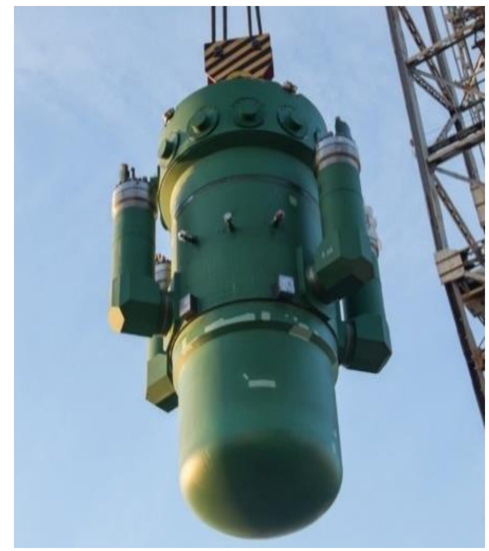
RITM-200 reactor

RITM Series Evolution

Further development of icebreaker reactors' family

50 Mw(e) rated power

MAIN TECHNICAL PARAMETRS:	
Design Life	60 years
Refueling Cycle	up to 6 years
Fuel Assemblies	199
Enrichment	Below 20%
Size, L x W x H	6,0 x 13,2 x 15,5 m



Six RITM-200's has been already manufactured

Four installed into "Arktika", "Sibir" icebreakers, which are expected to be in service in 2020
Two more will be installed in "Ural" icebreaker after 2020

Source: RAOS, 2018

First-of-a-kind FPU «Akademik Lomonosov» towed near Denmark