ROSATOM

АТОМЭНЕРГОПРОМ ЦИПК

STATE ATOMIC ENERGY CORPORATION "ROSATOM"

The Concept of Training System for Newly Established Operator in Embarking State

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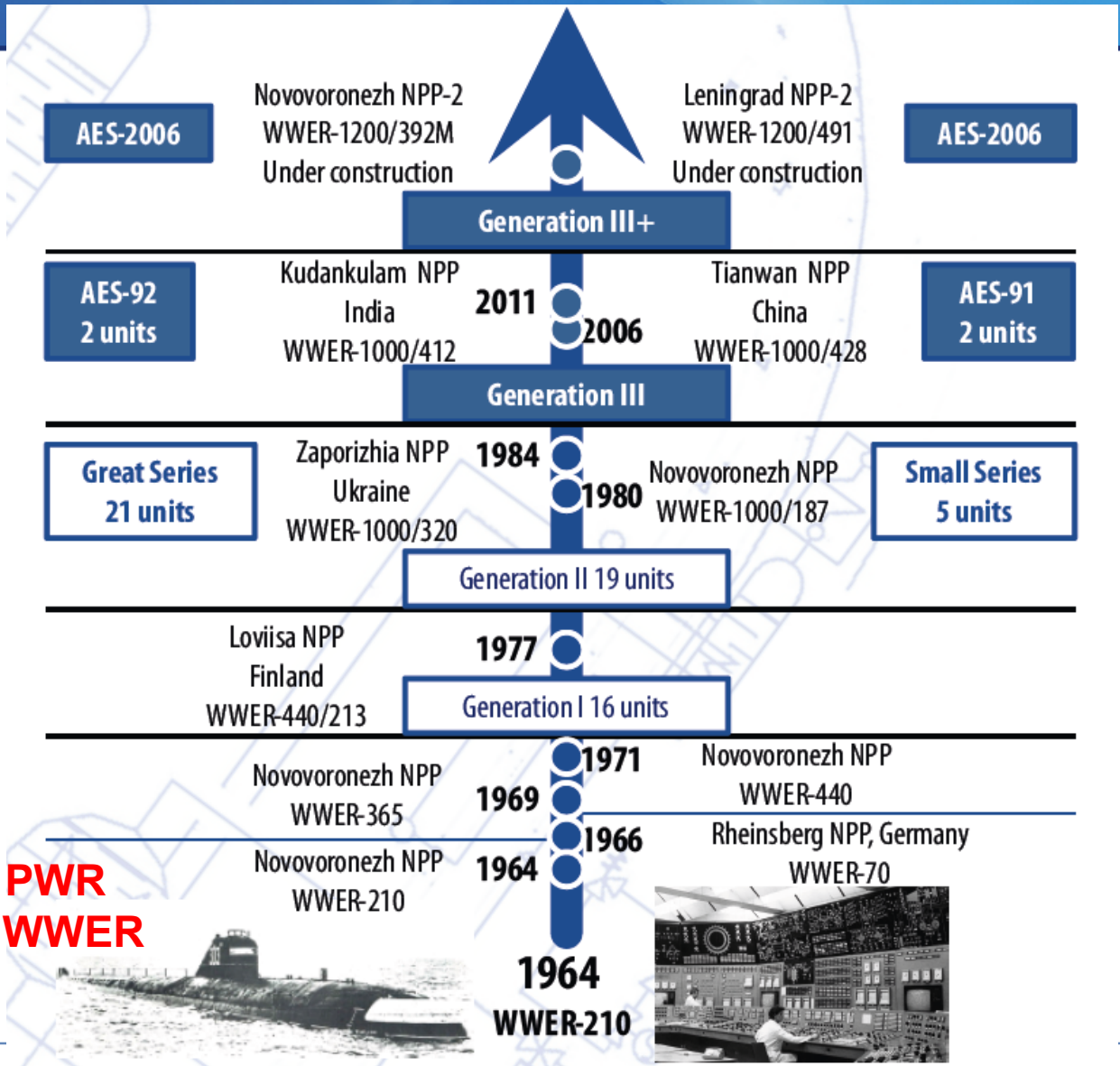
Contents

1. WWER Technology in a nut-shell
2. Training of NPP operating personnel
3. Training solutions for recipient countries

WWER Technology – History of Implementation

- **AES-2006** (WWER-1200, 60 years lifetime, 90% capacity factor)
- **WWER-TOI** (WWER-1300, Typical Optimized Informative-advanced project)
- **AES-91** (WWER-1000)
- **AES-92** (WWER-1000)

WEST: PWR
Russia : WWER

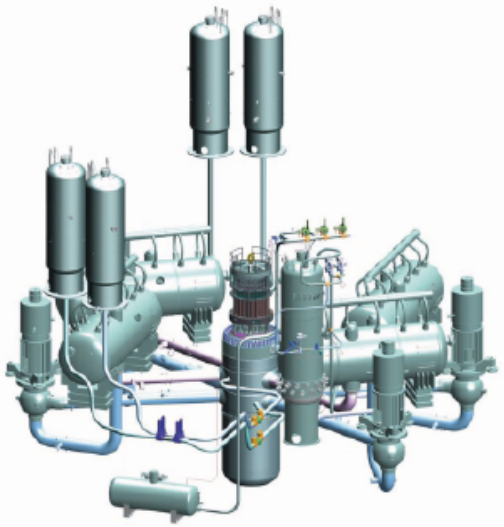


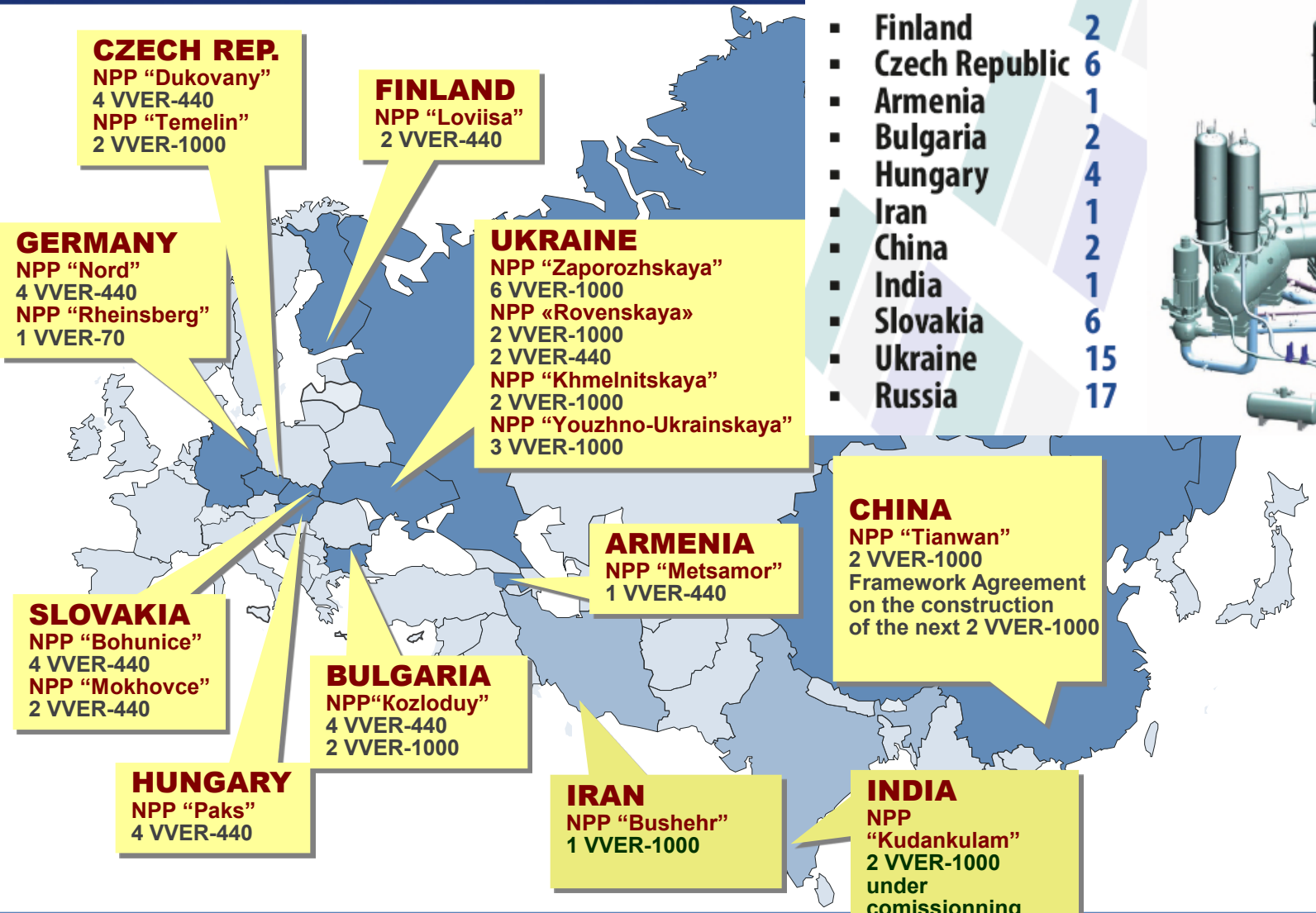
Water Cooled **W**ater Moderated **E**nergy **R**eactor

NPPs with WWER Type Reactors

At present more than 50 nuclear power plant units with WWER-type reactors are being operated around the world:

Finland	2
Czech Republic	6
Armenia	1
Bulgaria	2
Hungary	4
Iran	1
China	2
India	1
Slovakia	6
Ukraine	15
Russia	17





CZECH REP.
NPP "Dukovany"
4 VVER-440
NPP "Temelin"
2 VVER-1000

FINLAND
NPP "Loviisa"
2 VVER-440

GERMANY
NPP "Nord"
4 VVER-440
NPP "Rheinsberg"
1 VVER-70

UKRAINE
NPP "Zaporozhskaya"
6 VVER-1000
NPP «Rovenskaya»
2 VVER-1000
2 VVER-440
NPP "Khmelnitskaya"
2 VVER-1000
NPP "Youzhno-Ukrainskaya"
3 VVER-1000

ARMENIA
NPP "Metsamor"
1 VVER-440

CHINA
NPP "Tianwan"
2 VVER-1000
Framework Agreement
on the construction
of the next 2 VVER-1000

SLOVAKIA
NPP "Bohunice"
4 VVER-440
NPP "Mokhovce"
2 VVER-440

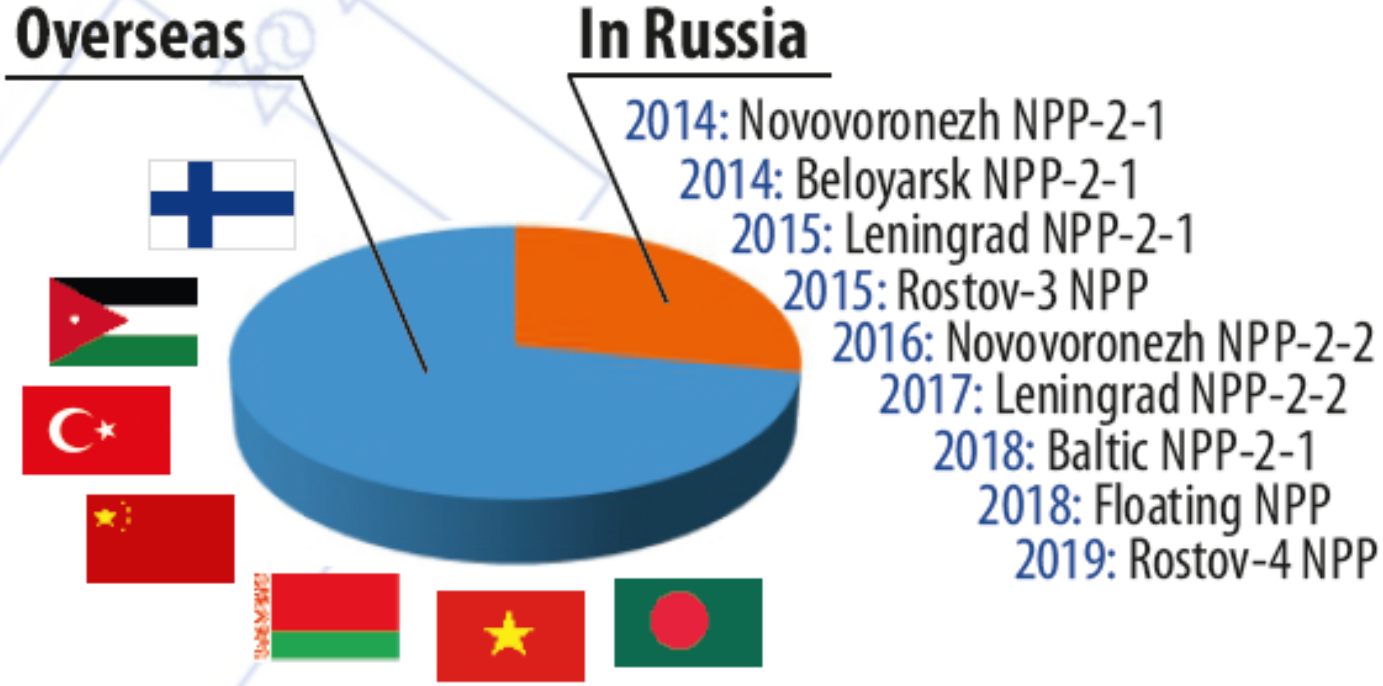
BULGARIA
NPP"Kozloduy"
4 VVER-440
2 VVER-1000

HUNGARY
NPP "Paks"
4 VVER-440

IRAN
NPP "Bushehr"
1 VVER-1000

INDIA
NPP
"Kudankulam"
2 VVER-1000
under
comissionning

Expansion of Russian NPP Technology



Currently Rosatom has negotiations over construction of 23 nuclear power units overseas. Nine power units are under construction in Russia

WWER vs PWR

TABLE V-1. Fuel Features

Reactor type	Fuel material	Fuel rod cladding[a]	Typical Assembly	Enrichment
AGR	UO_2	Stainless steel	Circular array of pins in graphite sleeve	2 - 4%
BWR	UO_2	Zircaloy-2	Square array	Up to 4.95%
Magnox	U metal	Magnox alloy	-	Natural
RBMK	UO_2	E110, E635	Circular array	Up to 2.8%
PHWR	UO_2	Zircaloy-4	Circular bundle	Natural
PWR	UO_2	Zircaloy-4	Square array	Up to 4.95%
WWER	UO_2	E110, E635	Hexagonal array	Up to 4.95%

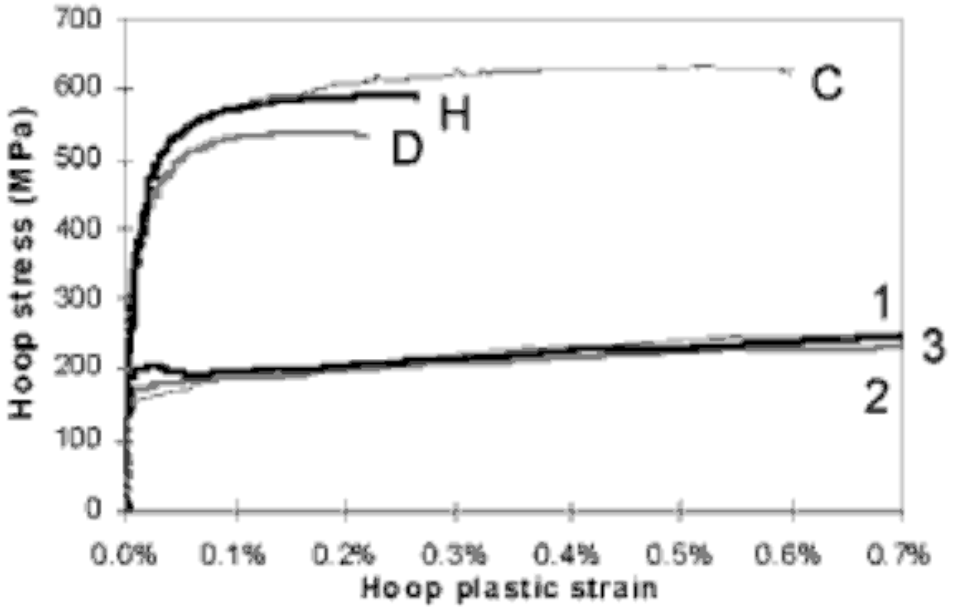
[a] Zircaloy-2 and -4 are alloys of zirconium with about 1.5% tin as the main alloying element. Magnox alloy is magnesium with about 1% aluminium or zirconium. Both E110 and E635 are alloys of zirconium with about 1% niobium.

Find difference!

NUCLEAR TECHNOLOGY REVIEW 2007

Specific of Cladding: long experience with Zr 1% Nb alloy

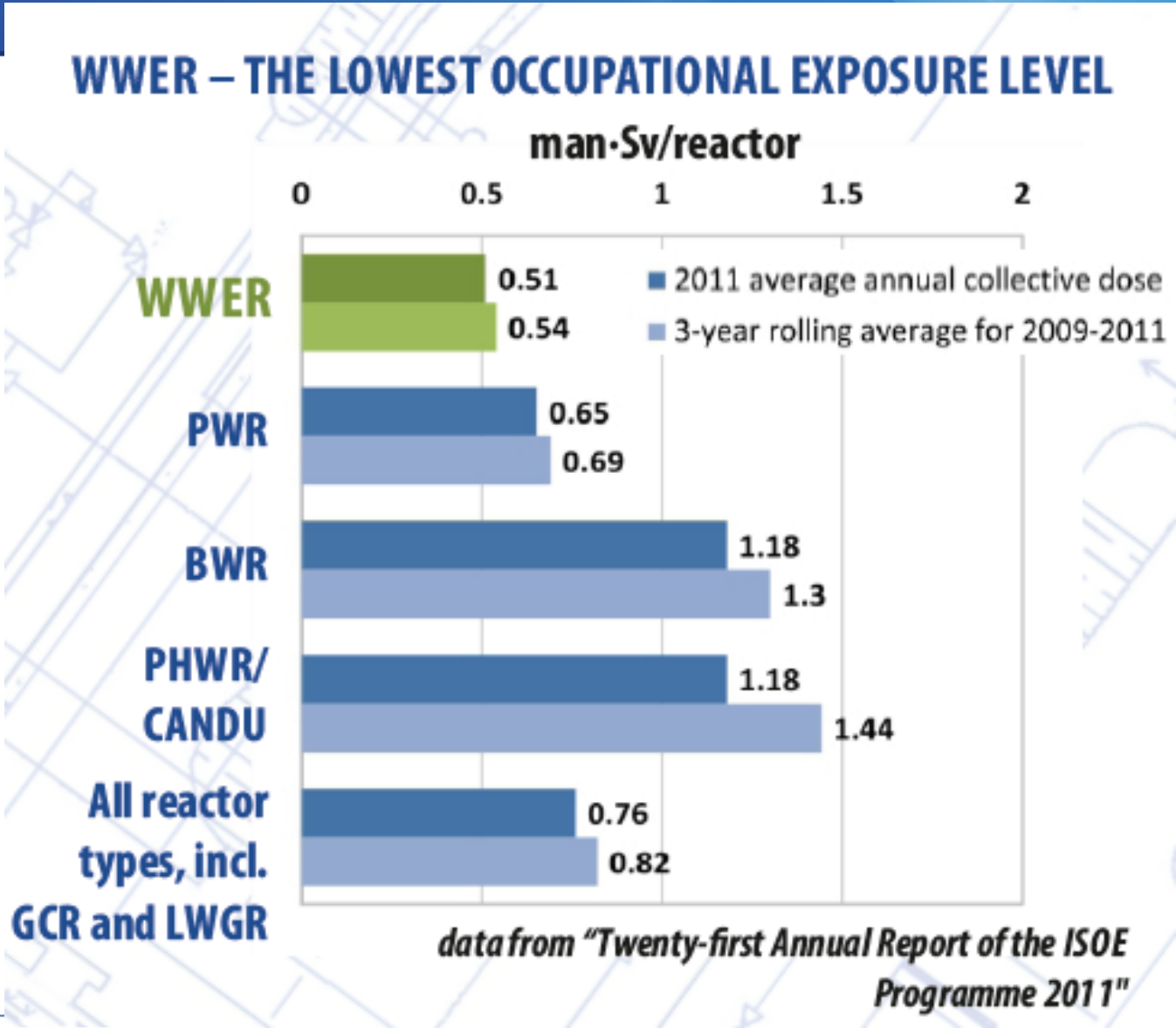
Extensive tests and over 20 years experience proved safe operation of cladding made of 1%Nb zirconium alloy E110 at temperature below 350 ºC. That value has been detected the lowest temperature for structural changes in material. Below 350 ºC there is no evidence of plastic deformation or any other mechanical phenomena. To improve plastic deformation resistance the E365 alloy (1% Nb, 1.5% Sn, 0.5%Fe) was introduced in 2000. Test results demonstrate that Zr1%Nb alloy in VVERs is more resistant to oxidation than Zircaloy (ZrSn alloy) in PWR.



Specimen	Material	Mechanical Test	Test Temperature
1	Zr-1%Nb-O	Internal pressure	350°C
2	Zy-4	Internal pressure	350°C
3	M5™	Internal pressure	350°C
C	Zr-1%Nb-O	Internal pressure	350°C
D	Zy-4	Internal pressure	350°C
H	M5™	Internal pressure (stress relaxation at E=0.8 %)	350°C

F.Onimus et al. "Plastic deformation of irradiated Zirconium alloys: TEM Investigations and Micro-Mechanical Modelling", J. of ASTN International, Vol.2, 2005

WWER Features



E&T Path for the Position of Control–Room Operator (in Russia)

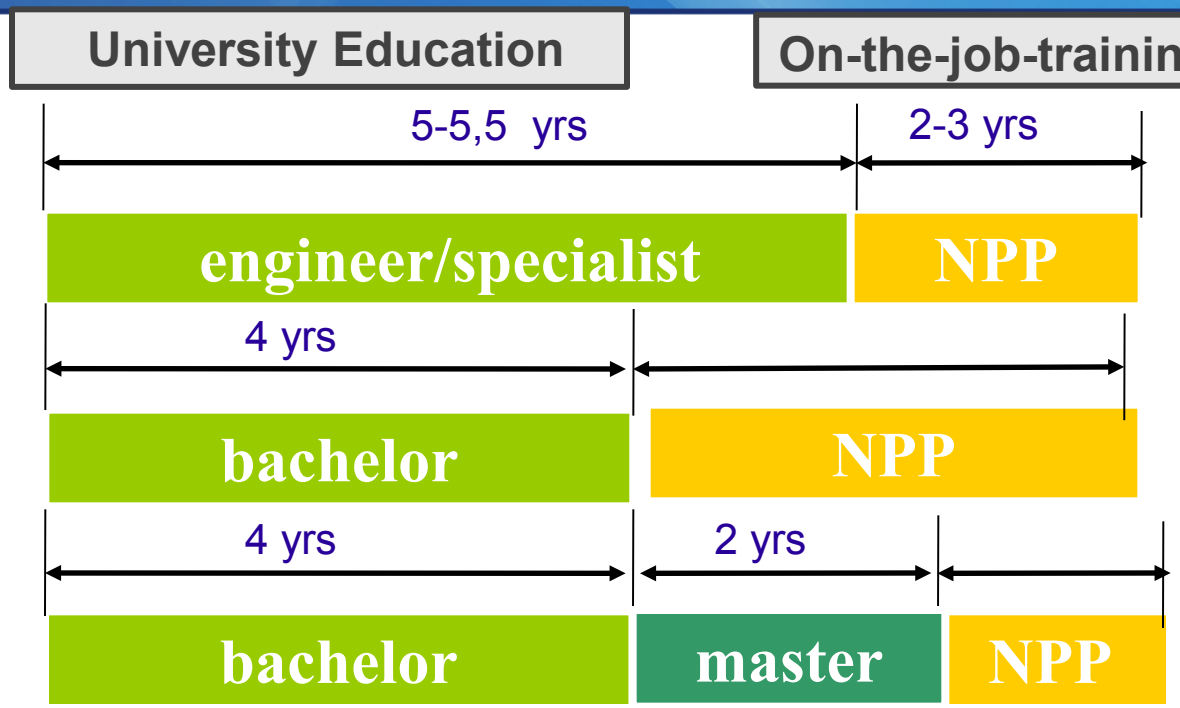
University Specialization

«Nuclear Power Plants and Facilities»

Fields of professional competences:

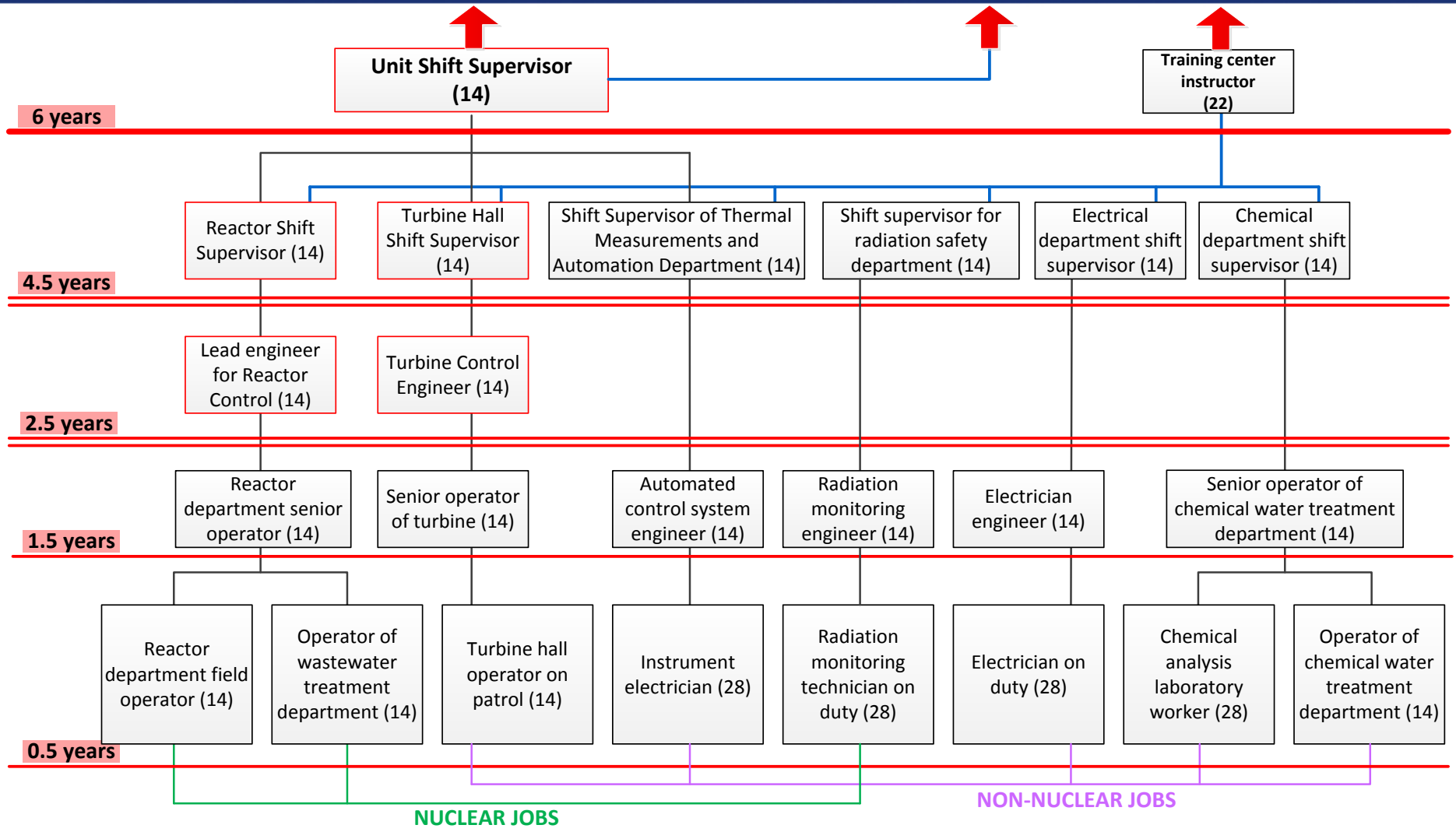
- Management
- NPP structure & design
- Commissioning & maintenance

4 yrs - Bachelor degree
2 yrs - Master degree
5.5 yrs – Specialist

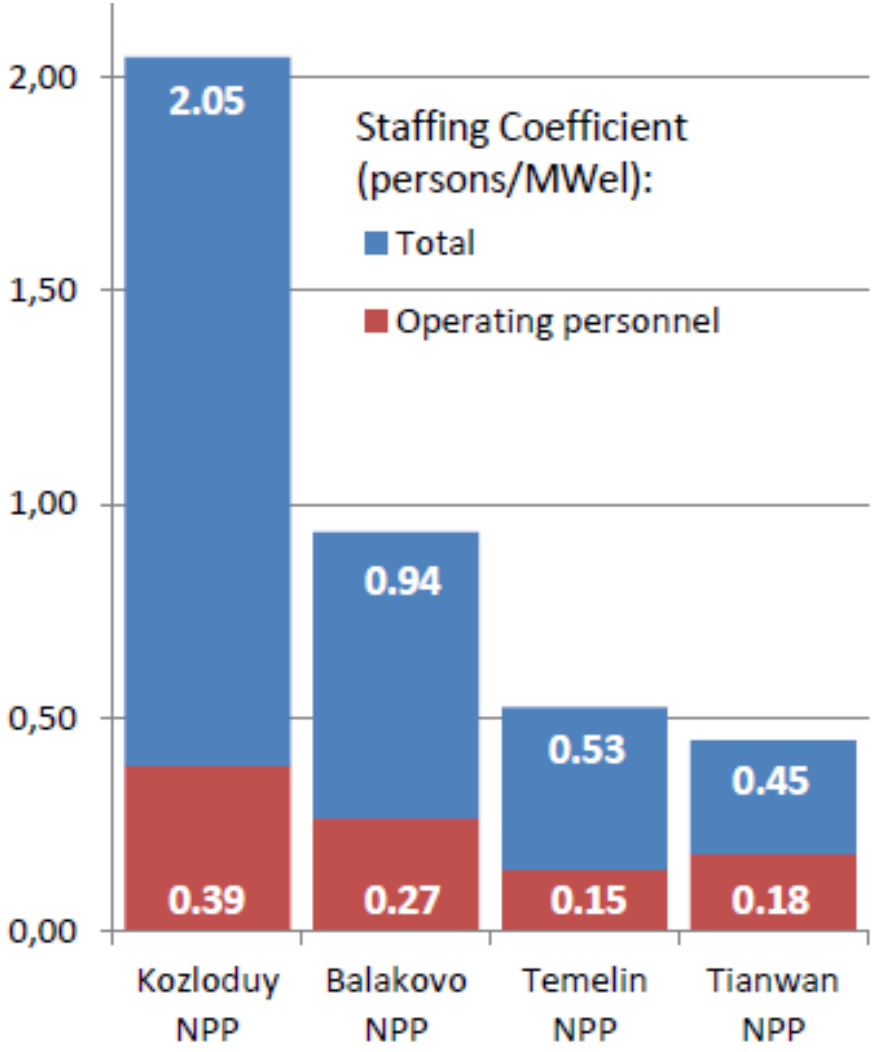


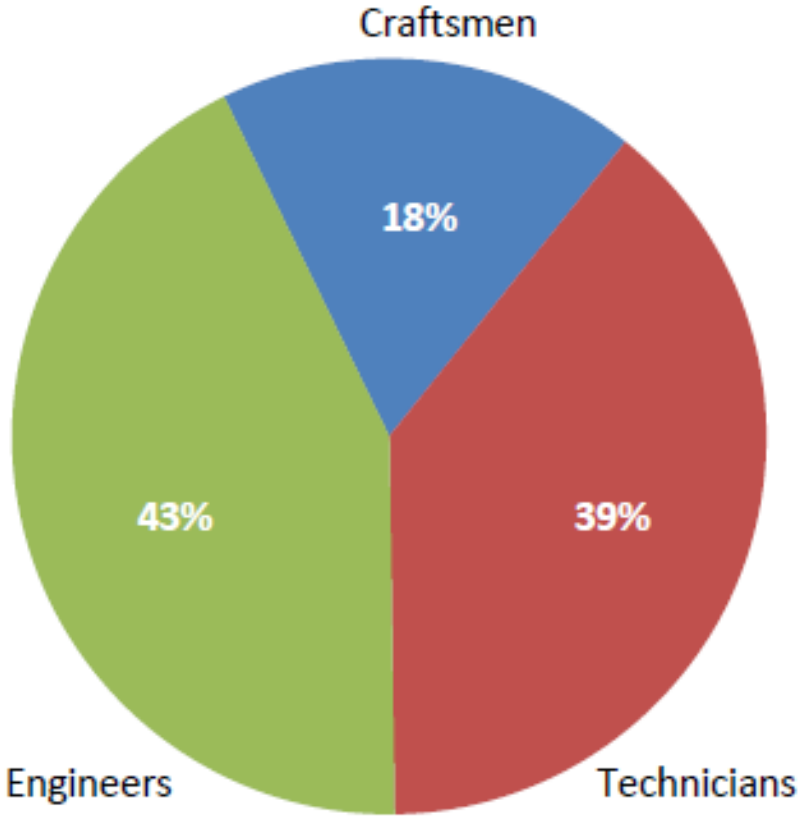
The specific of Russia is that, compared to western education system, there is a university specialty “nuclear power plant and facilities” especially focusing the staffing of Nuclear Power Plants.

NPP Personnel Development: Required On-The-Job Experience



WWER NPP Staffing





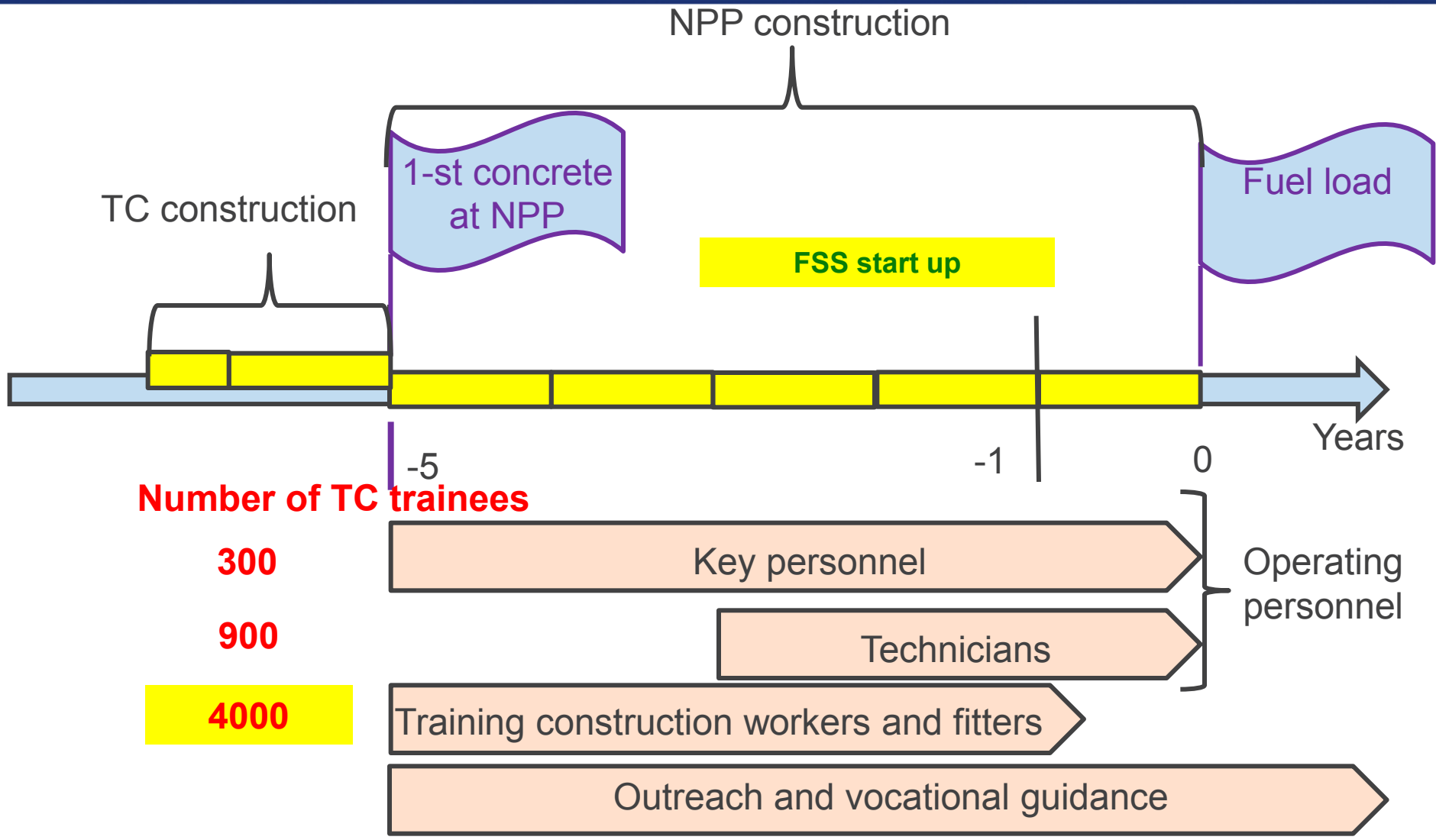
Job distribution (Russian NPP)

Number of construction workers and fitters by years for two units NPP

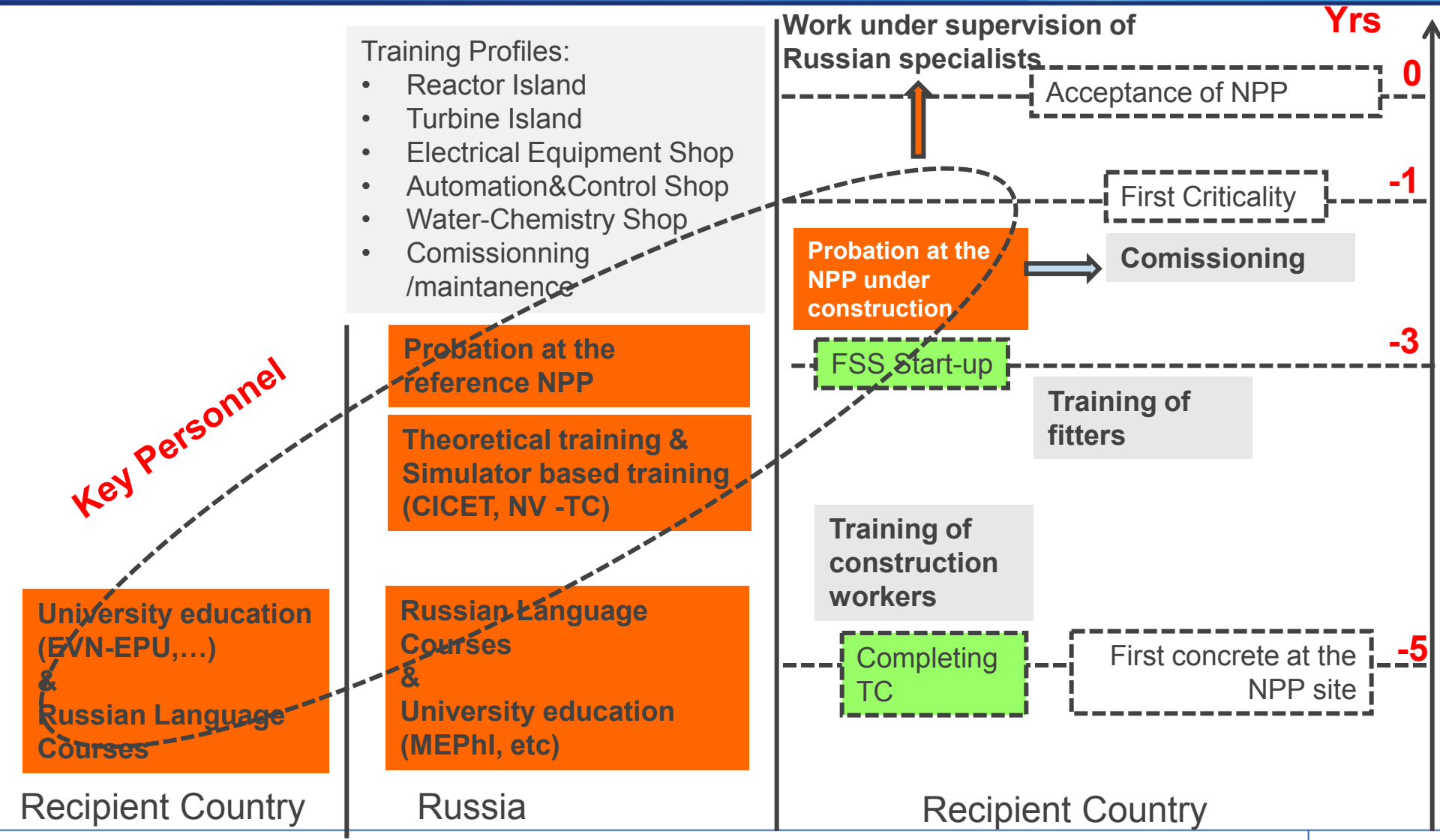
Example for Novovoronezh NPP-2 (by design documentation)

Jobs	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr
Construction workers	1085	2374	5341	5178	1625	209	10
Tele-equipment fitters		193	397	1451	1783	695	36
Ventilation equipment installers		35	51	106	64	12	
Construction electricians			283	1440	1700	600	
Insulation workers		7	82	182	228	184	
TOTAL:	1085	2609	6154	8357	5400	1700	46

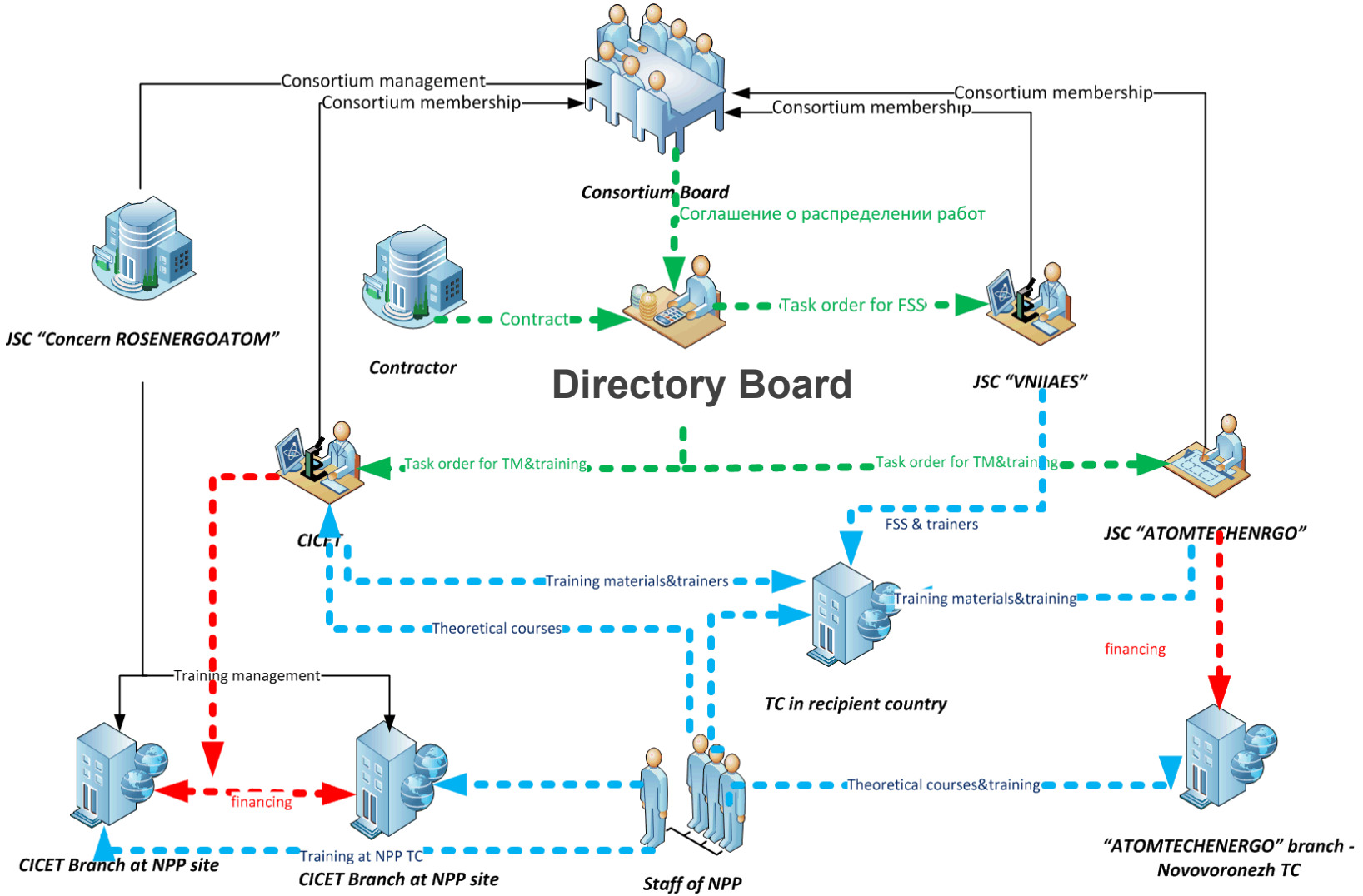
Role of a Training Centre in NPP Startup in Newcomer Country



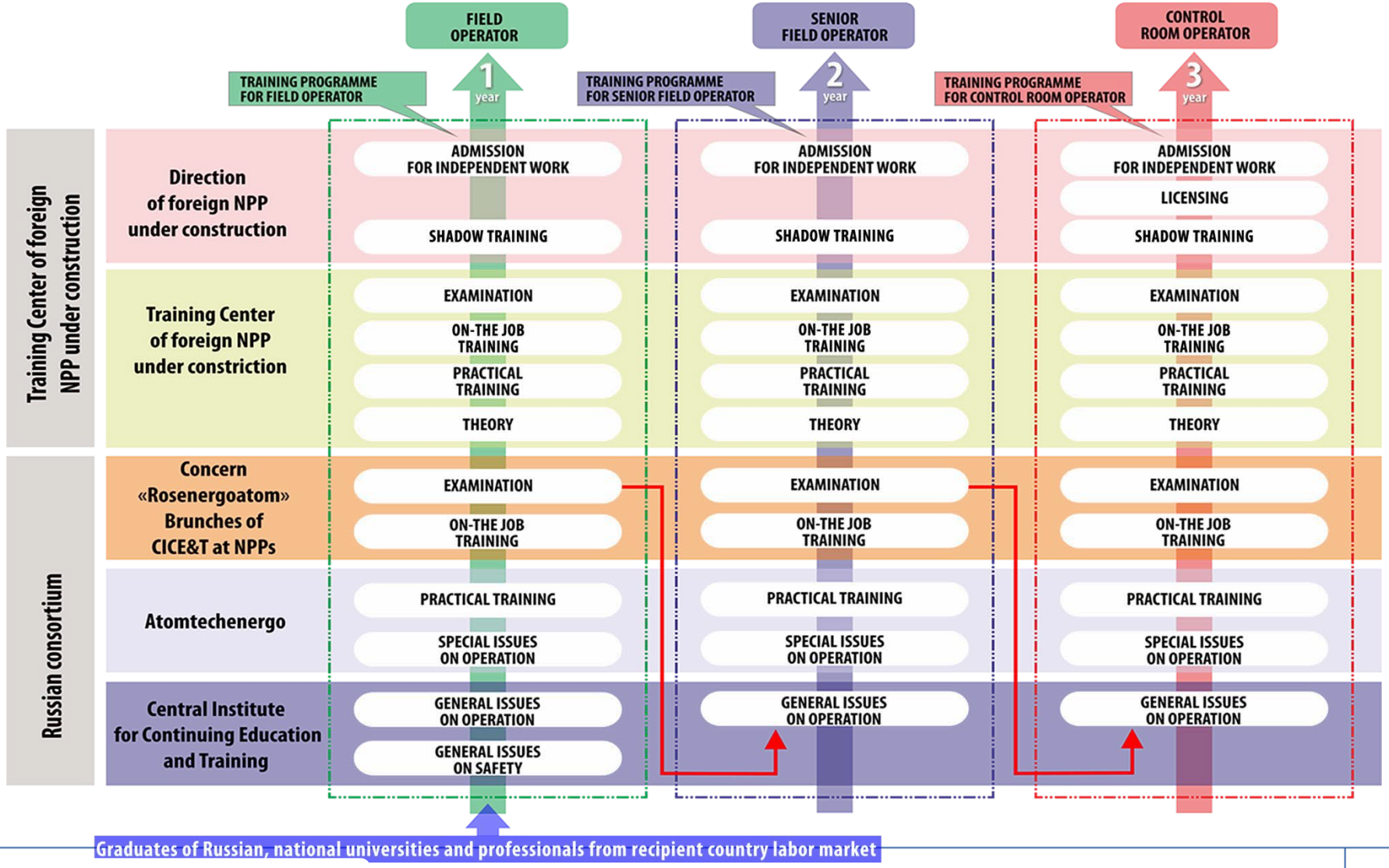
Stages of NPP Personnel Training: the case of recipient country



Configuration of the Consortium to Support the HRD Programme for NPP Staffing in Recipient Country

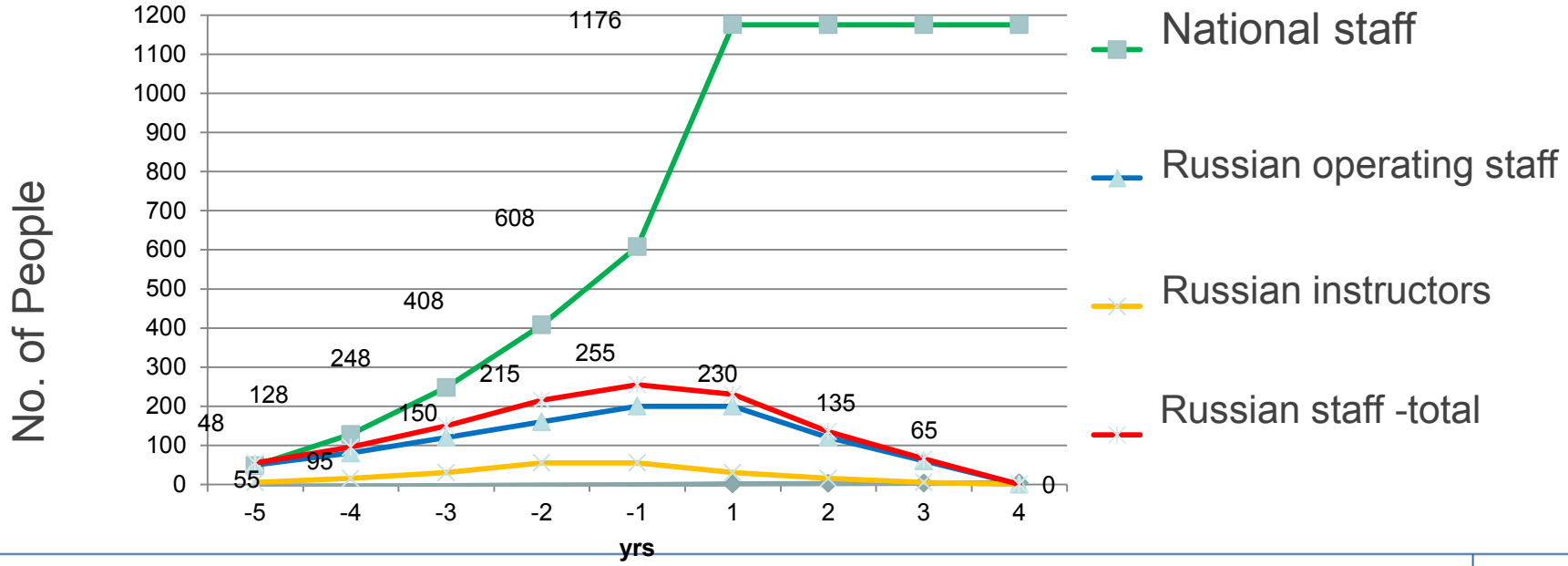


Stages of NPP Personnel Training: the case of recipient country



Staffing and Scheduling for VN NPP (2 units)

No of people / Yrs	-5	-4	-3	-2	-1	1	2	3	4
natonal staff	48	128	248	408	608	1176	1176	1176	1176
Russian operating staff	50	80	120	160	200	200	120	60	0
Russian instructors	5	15	30	55	55	30	15	5	0
Russian staff - total	55	95	150	215	255	230	135	65	0



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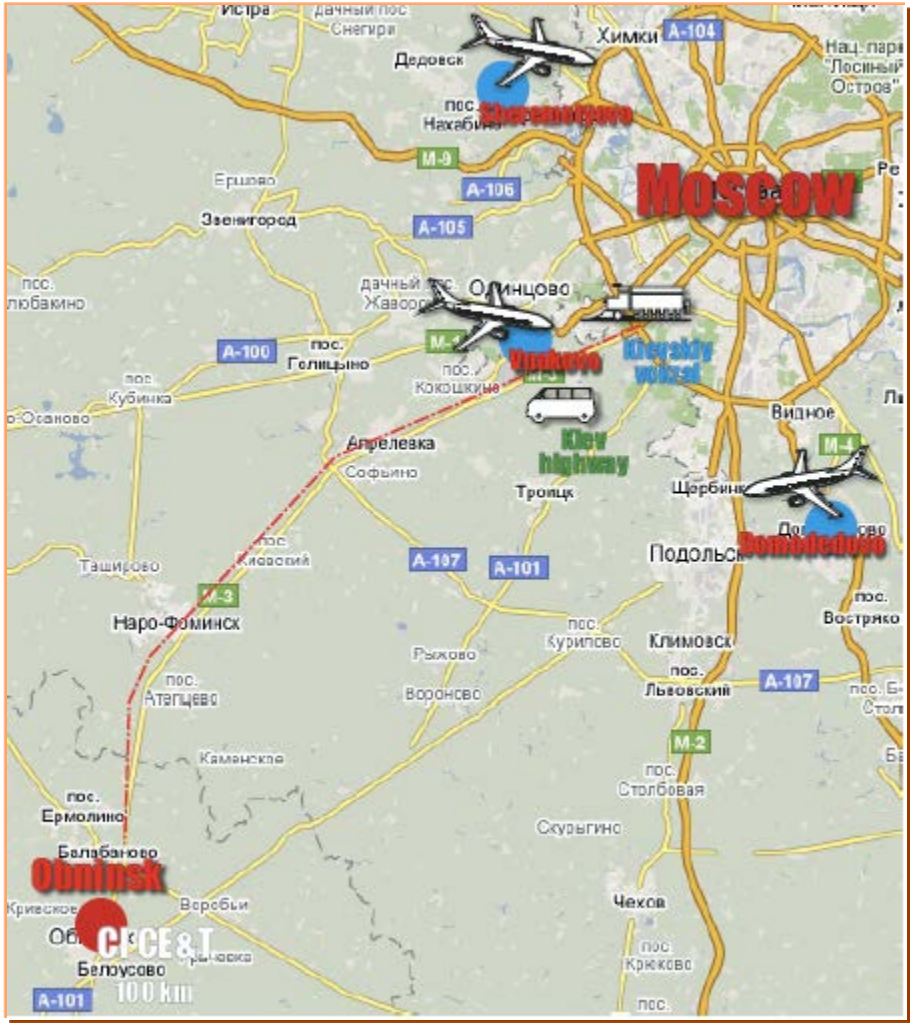

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Attachments

Nuclear Engineering Education in Russia

The main source of human resources for Russian Nuclear Sector is National Nuclear Research University MEPhI and the Consortium of universities supported by Rosatom

Universities supported by Rosatom

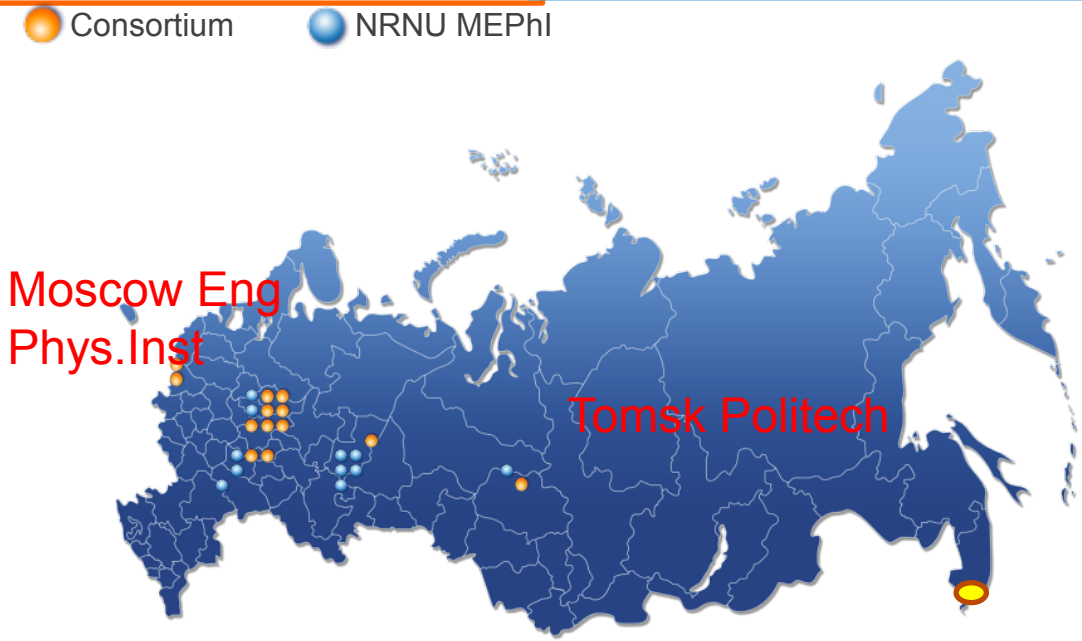
1. NNRU **MEPhI**
2. ISPU
3. MGSU
4. MSTU
5. MPEI
6. MISIS
7. NSTU
8. Lobachevsky UNN
9. Mendeleyev UCTR
10. SPSU
11. SPbSPU
12. TPU
13. UrFU

- 13 leading universities of Russia including a National University and 9 research universities
- Over 300 000 students and 50 000 lecturers in 23 cities of 19 regions of Russia, including all closed cities
- 56 scientific and educational centers with leading enterprises of the sphere

The share of Consortium universities graduates' in Rosatom graduate employment – 90%

NNRU MEPhI unites:

- 11 universities and 13 colleges
- Around 35 000 students
- Over 2000 lecturers
- Over 1600 professors and associate professors
- Over 500 000 m² academic area
- 60 higher education majors
- 45 secondary education majors



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ROSATOM CICE&T

STATE ATOMIC ENERGY CORPORATION "ROSATOM"

Ministry of Education and Science of the Russian Federation

OBNINSK International Campus

State Atomic Energy Corporation «ROSATOM»

PRE-UNIVERSITY EDUCATION (INCLUDING RUSSIAN LANGUAGE COURSE)

KEY UNIVERSITIES CONSORTIUM

- Ivanovo State
- National Research University
- Bauman Moscow
- National Research University St.
- National Research University
- National University of Science and
- Ural Federal University n.a. the
- St. Petersburg
- Nizhniy Novgorod State University
- Nizhniy Novgorod State Technical
- D. Mendeleev Moscow University

Obninsk Institute of Nuclear Power Engineering

National Research Nuclear University «MEPhI»

National Research Tomsk Polytechnic University

Central Institute for Continuing Education and Trainings

All-Russian Scientific Research Institute for Nuclear Power Plant Operation

ATOMTECHENERGO

«ROSENERGOATOM» CONCERN

- Balakovo NPP
- Rostov NPP
- Kalinin NPP
- Novovoronezh NPP

CONSORTIUM OF STATE ATOMIC ENERGY CORPORATION «ROSATOM» FACILITIES

EDUCATION

5 – 7 YEARS

CONTINUING EDUCATION

1 – 15 YEARS

NPP STAFF

Establishment of an international campus in Obninsk based on Obninsk branch of NRNU MEPhI and CICE&T

START: *2010*

Advance training of foreign specialists on the programmes of Russian nuclear education

Vietnam	29
Jordan	8
Mongolia	5
Total :	***42***

2011

Expanding the pool of countries-recipients of Russian nuclear education

Vietnam	99
Turkey	50
Kazakhstan	20
Jordan	10
Mongolia	9
Total:	***188***

2012

Formation of the interuniversity cooperation programme

Vietnam	169
Turkey	126
Mongolia	19
Jordan	10
Kazakhstan	20
Total:	***344***

2016

Implementation of a system of Russian nuclear education export in 25 countries

- Promoting Consortium of Rosatom's reference universities in international education market.
- Opening of International Nuclear Education Centers in the universities
- Nuclear power engineering training in the Obninsk International Center for ***1100 foreign specialists*** simultaneous.

Programmes of international cooperation in education and knowledge transfer:

- ENEN-RU project «Cooperation infrastructure development in the field of nuclear education" (Rosatom-Euratom agreement)
- Educational programmes of IAEA, WNU
- Working group on formation EurAsEC Cooperation Council
- Cooperation programmes with foreign universities (Turkey, Vietnam)

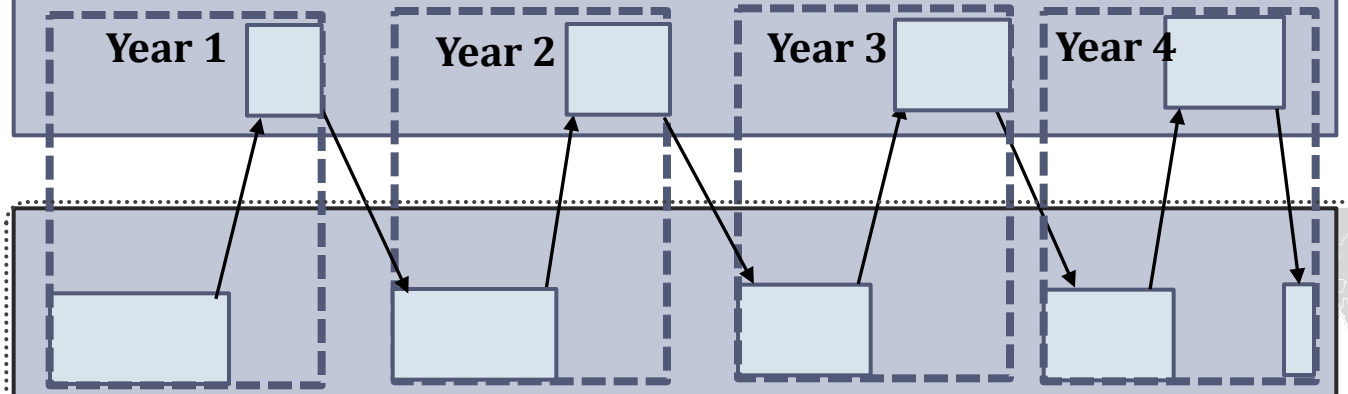
Potential market in Asia-Pacific

Potential market is estimated as 80 WWER units by 2030

FINPP – floating NPP

Scheme of Professional Education at Far-Eastern Federal University (FEFU)

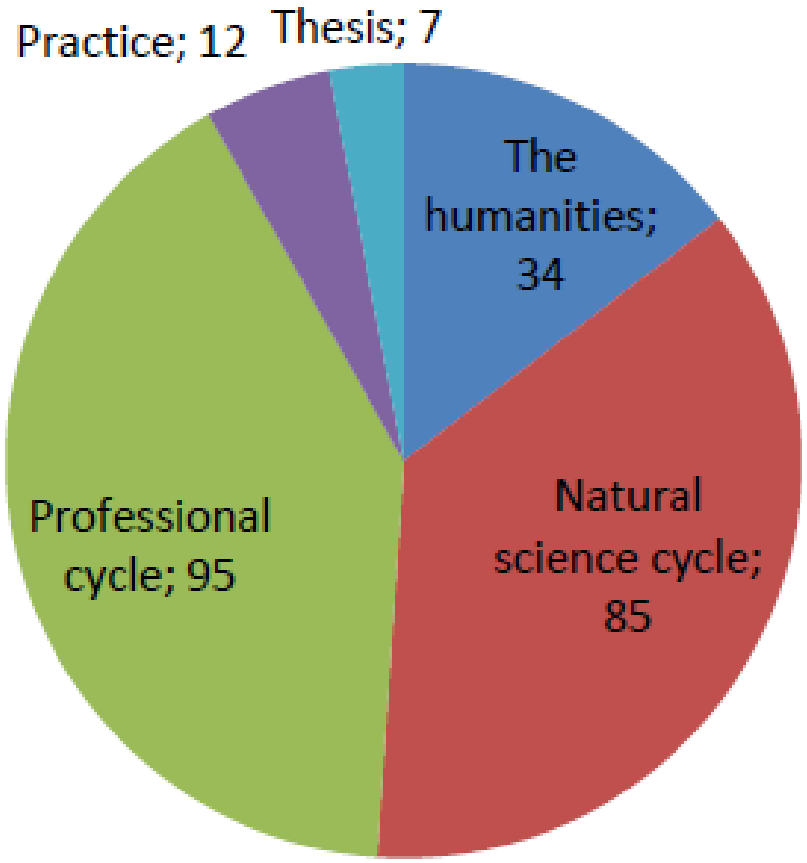
Professional education including special practical training and special courses at ROSATOM's enterprises and academic institutions including the use of 'Distant-education' technologies.



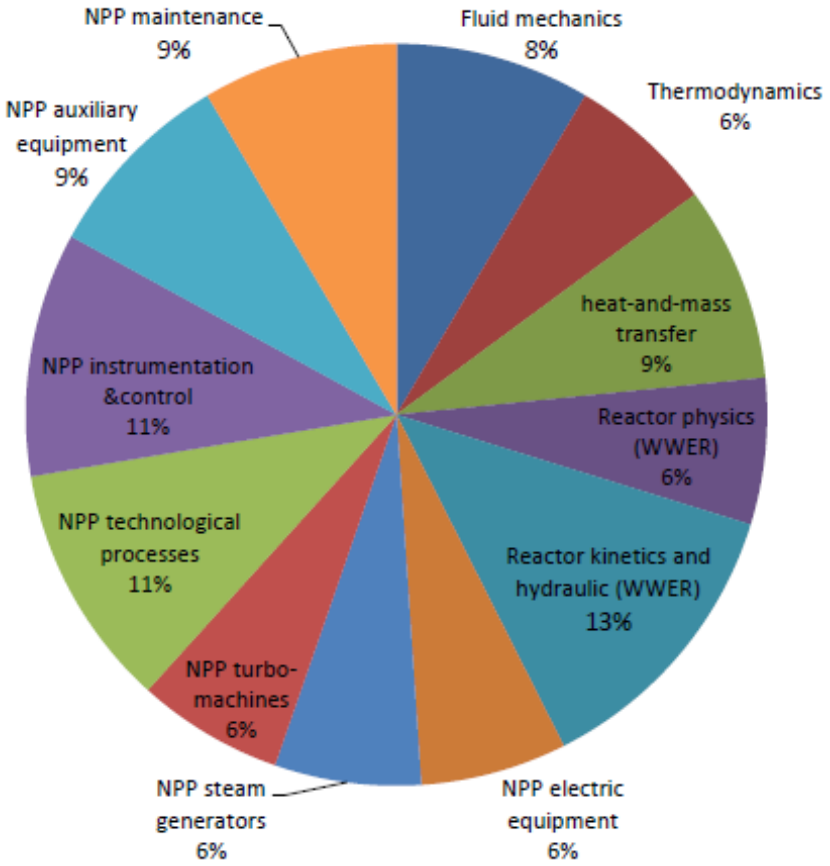
FEFU

Natural science and basic engineering education
Cross-culture education
Management

BS in Nuclear Enginnering



General structure of the BS programme (numers stand for credit units, 1 credit unit – 36 academic hours).



Distribution of NPP oriented disciplines in professional cycle (totally 55 credit units).

Simulator training in the Far Eastern Federal University (Sept 2013)

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