

Compilation of Available Information on Carbon-14 Releases from Different Types of Nuclear Reactors

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Relevance

- When ingested, carbon-14 is incorporated into various molecules and undergoes beta decay;
- IAEA recommends to control C-14 in gaseous releases of nuclear power plants*;
- In Russian Federation C-14 is included in the list of radionuclides for which it is necessary to implement measures of state regulation in the field of environmental protection**;
- At Russian nuclear power plants C-14 is included in the list of major dose forming radionuclides.

* INPRO Methodology for Sustainability Assessment of Nuclear Energy Systems: Environmental Impact of Stressors. IAEA Nuclear Energy Series. No. NG-T-3.15

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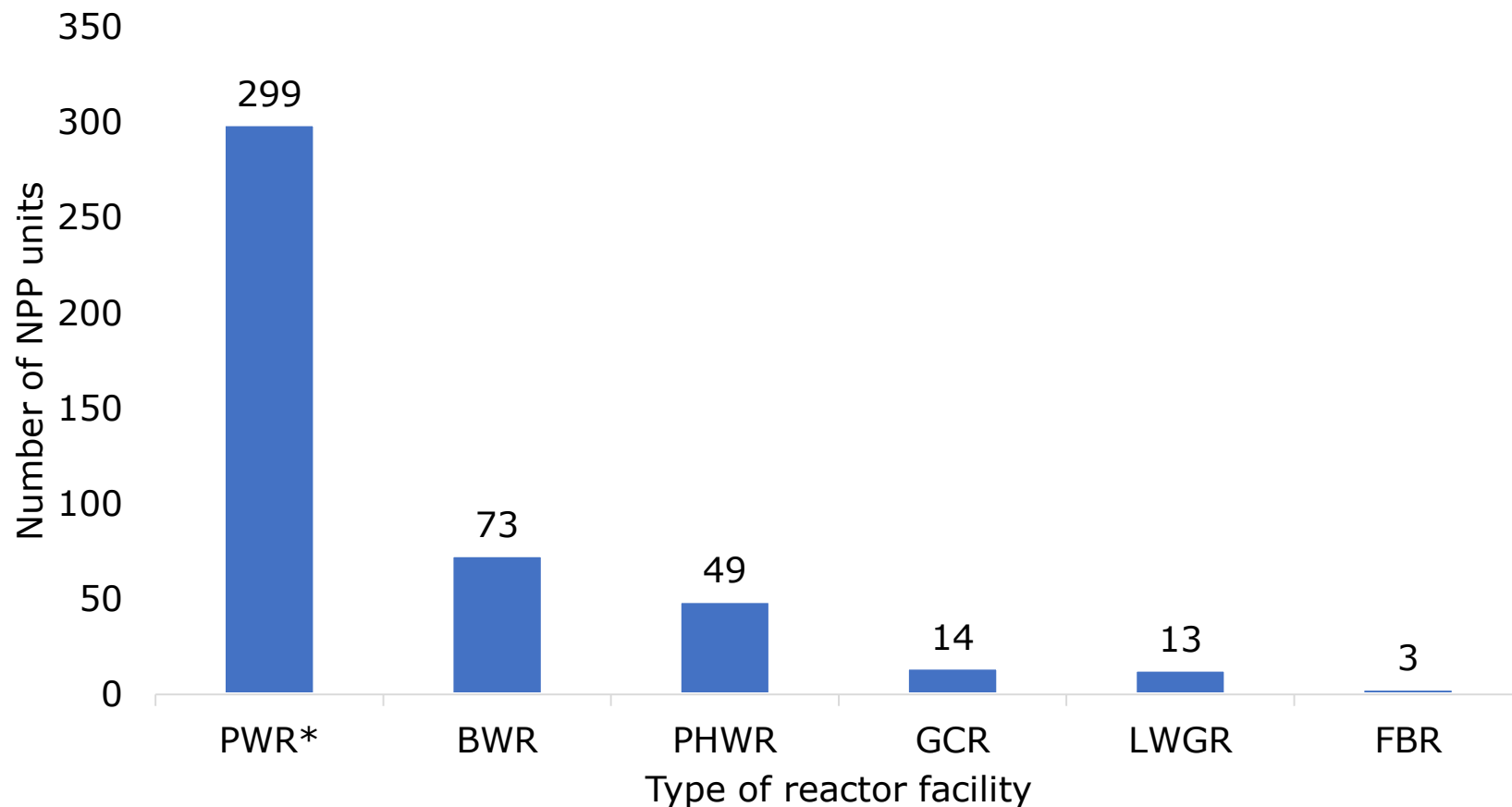
Purpose and tasks of investigation

Purpose: to assess the global contribution of NPP releases from various types of reactors to the carbon-14 activity in the atmosphere.

Tasks:

1. To determine the value of the carbon-14 specific release index in the atmosphere for each type of reactor facility on the example of European nuclear power plants;
2. To consider the dependence of the specific carbon-14 release index by NPP on the type of reactor facility;
3. To estimate the global accumulation of carbon-14 in the atmosphere from releases of nuclear power plants in the world.

Number of operating power units by reactor facility types



*Including 54 VVER

Mechanisms of C-14 production

Artificial:

- Releases of NPP

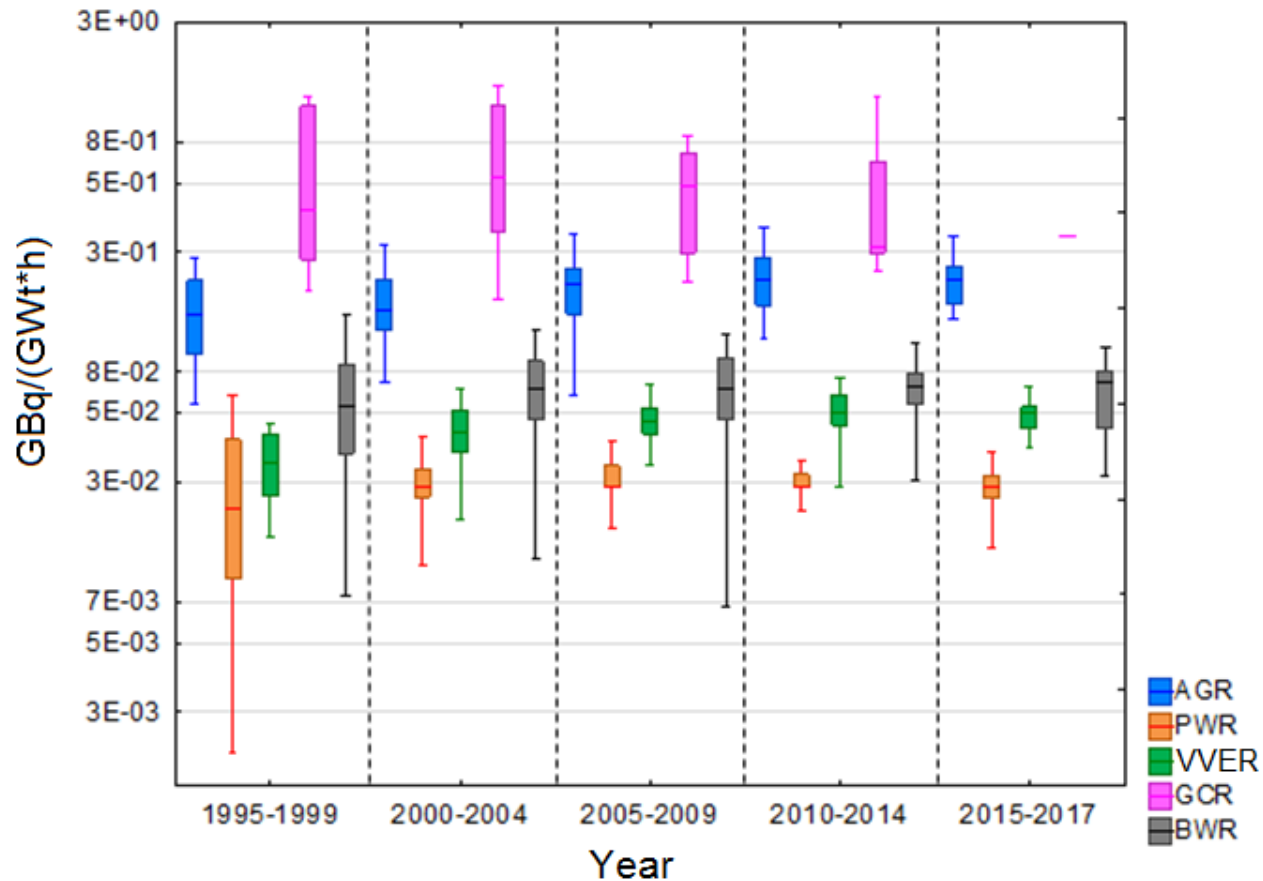
Type of RF	PWR	BWR	PHWR	GCR	LWGR
Main reaction	$^{17}\text{O}(n,\alpha)^{14}\text{C}$			$^{13}\text{C}(n,\gamma)^{14}\text{C}$ $^{14}\text{N}(n,p)^{14}\text{C}$	$^{14}\text{N}(n,p)^{14}\text{C}$
Coolant	H_2O		D_2O	CO_2	H_2O
Moderator	H_2O		D_2O	Graphite	Graphite

- Nuclear weapon testing in 1945 - 1980.
Total activity of C-14 - $3,5 \cdot 10^{17}$ Bq;

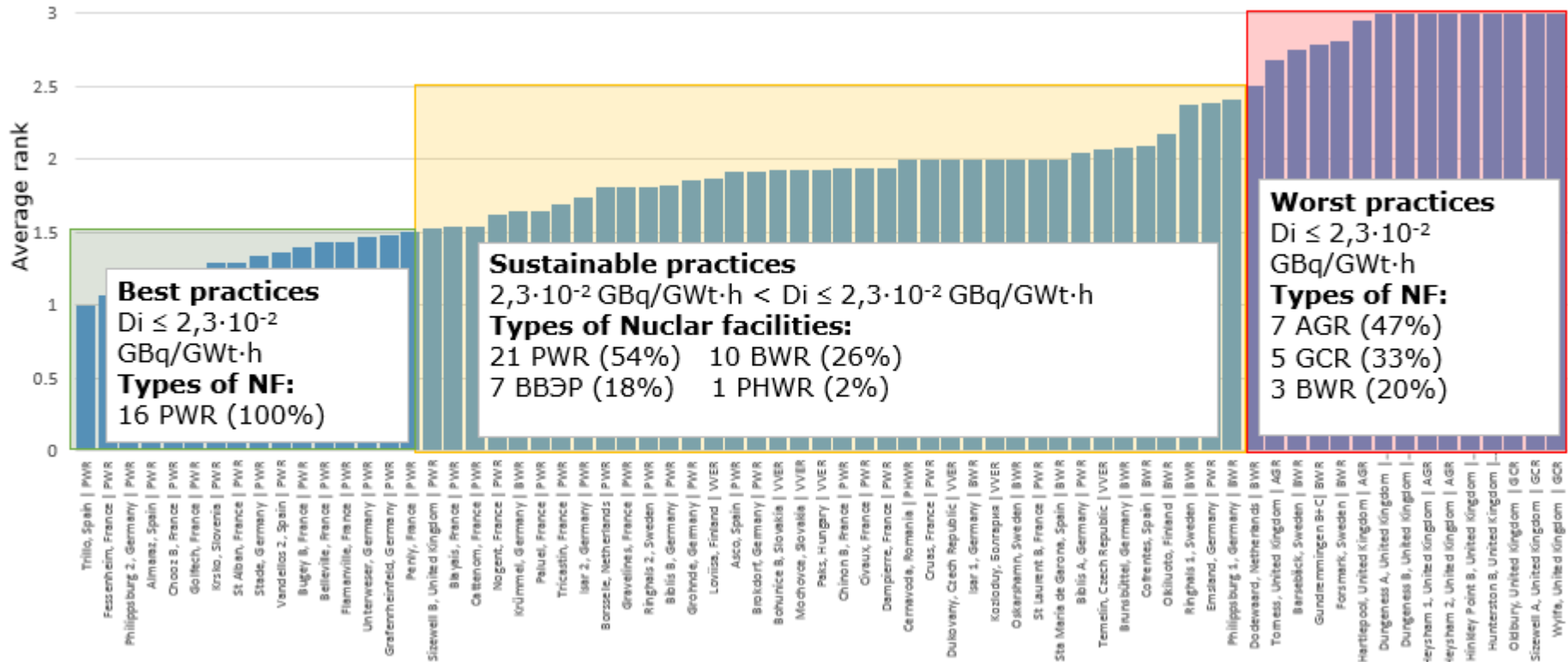
Natural:

- Cosmic neutrons acting on nitrogen atoms in the stratosphere and in the upper troposphere $^{14}\text{N}(n, p)^{14}\text{C}$. The annual production level is around $1.4 \cdot 10^{15}$ Bq.

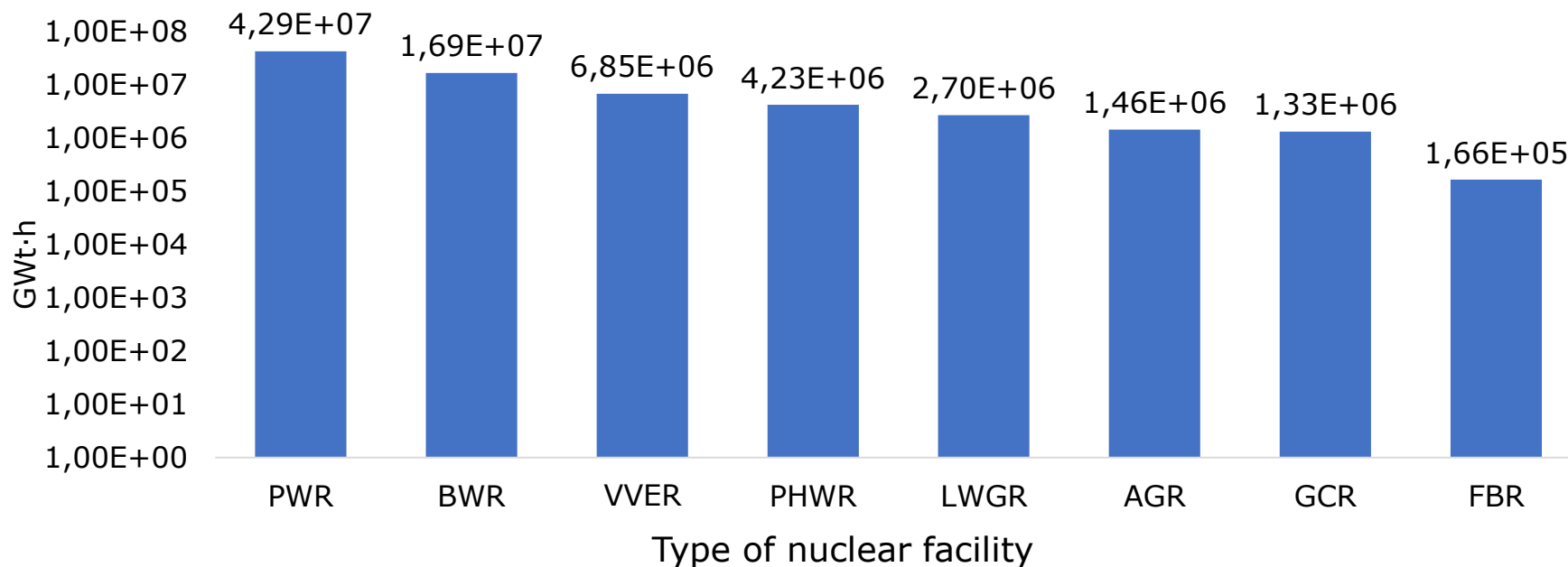
The dynamics of the specific indexes of C-14 releases for different types of reactor facilities



The best, sustainable and the worst practices of C-14 release for European NPP



Global power generation by various types of nuclear facilities

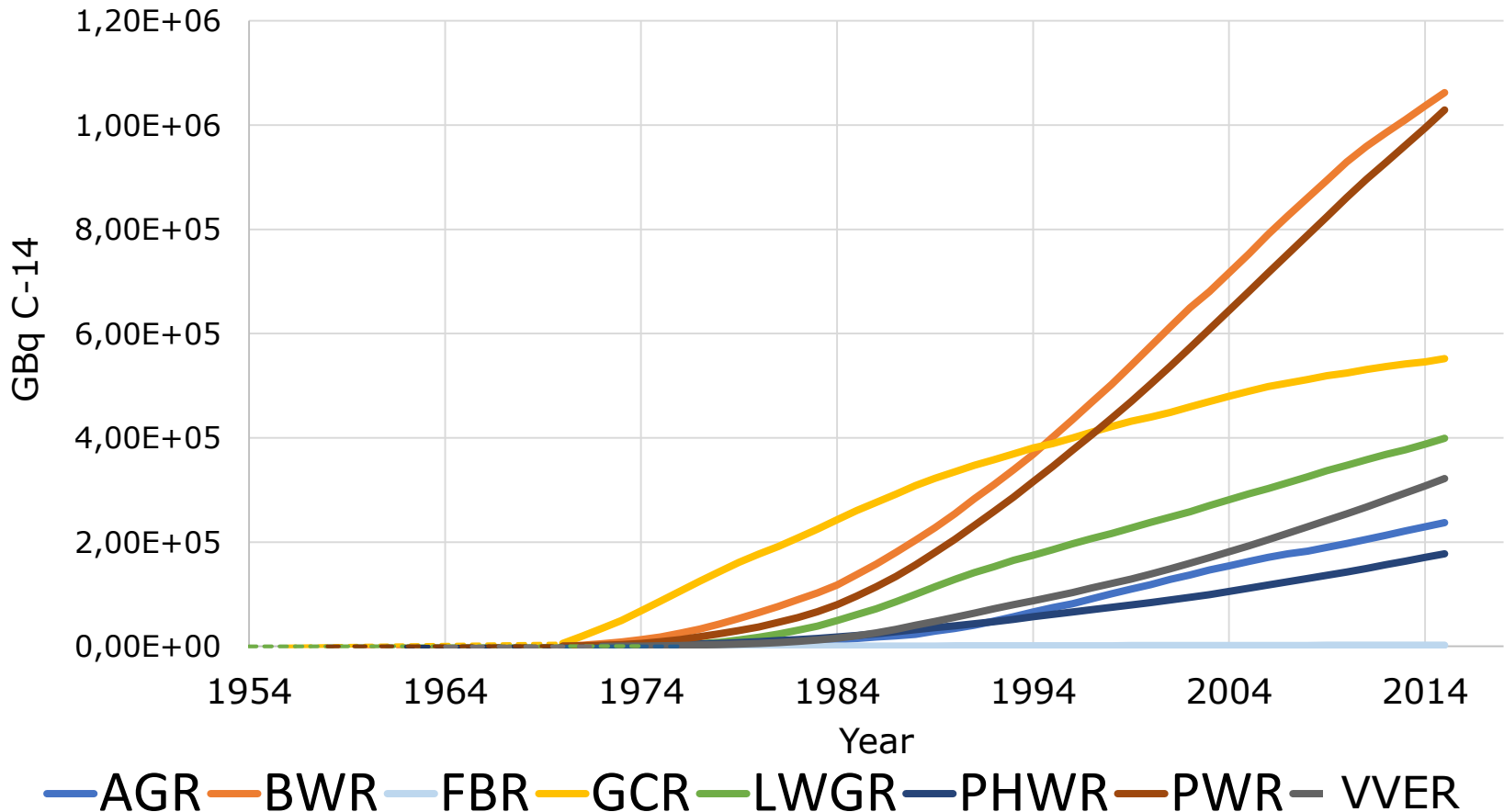


The Table - Specific index of C-14 emissions for various types of NF

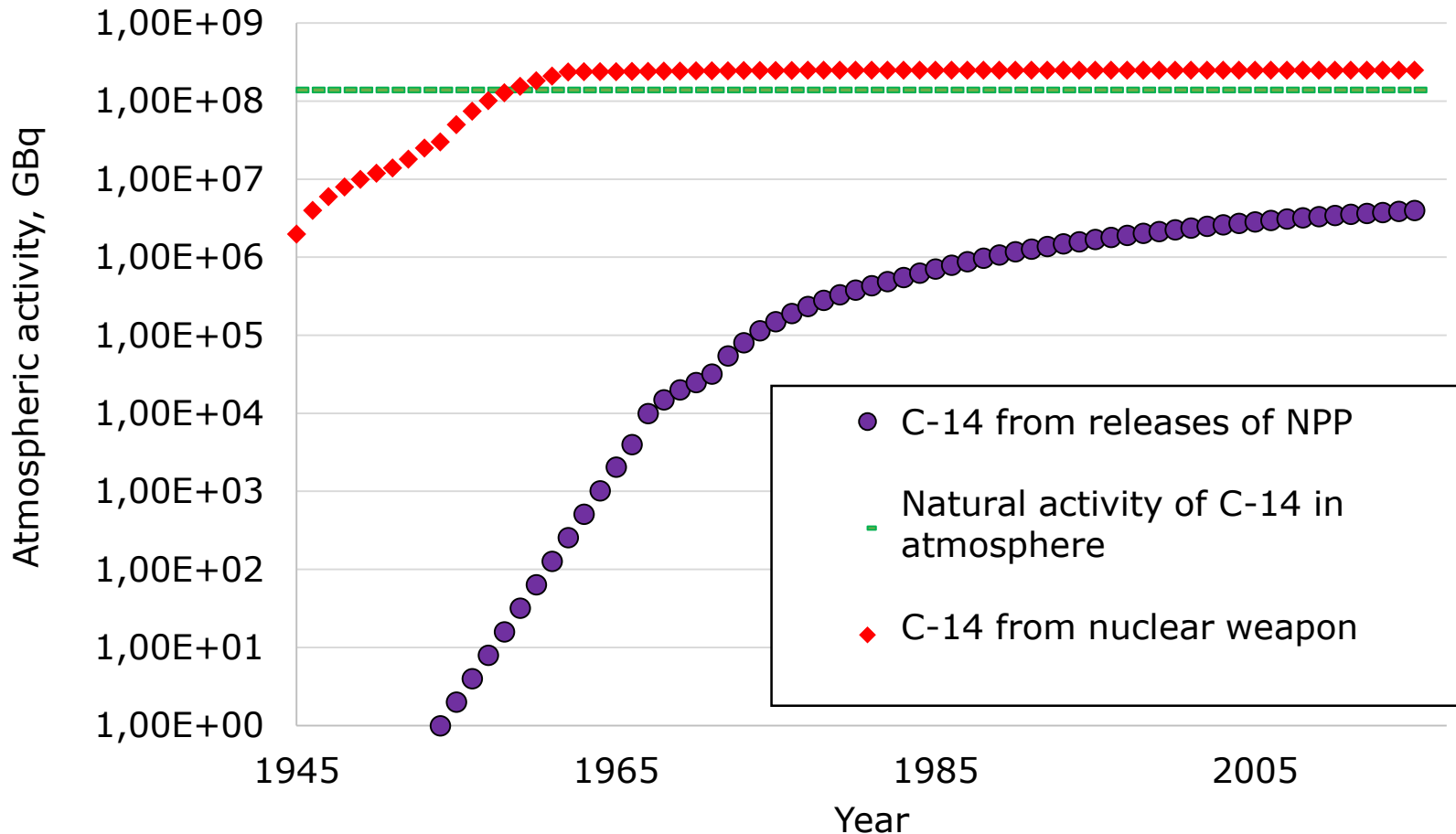
Type of RF	PWR	BWR	BBЭP	PHWR	LWGR*	AGR	GCR	FBR*
GBq/GWt·h	0,024	0,063	0,047	0,042	0,148	0,163	0,415	0,014

* IAEA. Setting Authorized Limits for Radioactive Discharges: Practical Issues to Consider. IAEA-TECDOC-1638

Integral values of C-14 emissions into the atmosphere from NPP with various types of reactor facilities



Conservative estimate of C-14 release to the atmosphere from various sources



Conclusions

- Specific indexes of C-14 release were obtained for various types of reactor facilities.
- Gas cooled reactors and their second generation, AGR, have the highest specific indexes of C-14 activity in releases to atmospheric air. Pressurized water reactors demonstrated the lowest specific index.
- Conservative estimate of the global contribution of NPP releases to C-14 activity in the atmosphere was made. It amounted to 2.8 %.