European Research Reactor Position Paper

by

CEA, NCBJ, NRG, PALLAS, RCR, SCK•CEN and TUM

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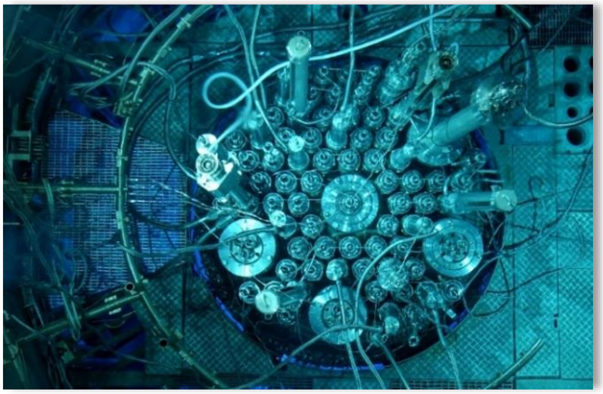
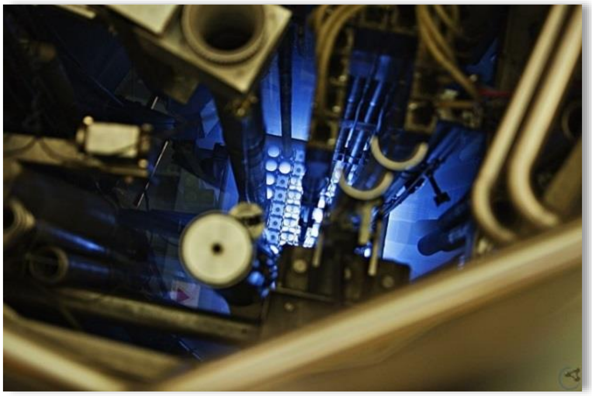
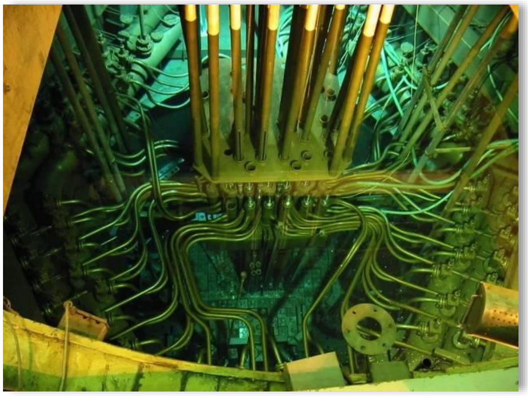
Jules Horowitz Research Reactor, JHR, Cardarache, France



Belgium Research Reactor 2, BR2, SCK•CEN, Belgium



Research Centre Rez, RCR, Czech Republic



MARIA, National Centre for Nuclear Research, Poland

TUM, Forschungsneutronenquelle, Heinz Maier-Leibnitz (FRM II), Germany

Nuclear Research and consultant Group, Netherlands

PALLAS, Netherlands

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EUROPEAN RESEARCH REACTOR POSITION PAPER BY CEA, NCBJ, PALLAS, NRG, SCK•CEN, TUM, AND RCR 15 JUNE 2018

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Scenario for sustainable Molybdenum-99 production in Europe

SUMMARY

- The European medical community and patients need a reliable continuous supply chain for Mo-99/Tc-99m. Since the 2008 crisis the OECD High Level Group on the Security of Supply of Medical Radioisotopes (HLG MR), the European Observatory and Association of Imaging Producers & Equipment Suppliers (AIPES) support and secure providing and sustainable production of Mo-99 based on research reactors. Europe plays the leading role in the supply of Mo-99/Tc-99m because it hosts the largest, most coherent and coordinated supply chain from the target manufacturing to medical applications.
- For Europe, the European Observatory is the leading body for this coordinated approach. Its main strategic objectives are: support a secure Mo-99/Tc-99m supply, ensure that the issue of Mo-99/Tc-99m supply is given high political visibility and establish periodic reviews of the supply capacities and demand. It is meant to provide the coordinated view of the Mo-99/Tc-99m irradiator facilities as a basis for the European decision-making process.
- In the next decade, it is expected that several European irradiating reactors will shut down. The upcoming capacities of FRM II (Germany) and JHR (France) will be urgently needed for the mid-term but to maintain a sustainable supply in the long-term it will be necessary to provide for further newly built Mo-99/Tc-99m irradiator facilities.
- To make this economically viable and to encourage investments, full cost recovery (FCR) within the production chain is an indispensable condition. For the irradiator facilities this means an increase of the price paid for the irradiation services. To strengthen the European network all stakeholders should actively participate in the coordinated actions of the European Observatory and AIPES.
- Diversity within the supply chain is another key impediment to sustainable supply. Further standardisation for target geometries, irradiation rigs, transport containers etc. will increase compatibility between the different irradiators and processors and improve sustainability.

- Highly radioactive irradiated targets have to be transported within six European countries. Closer coordination among the national licencing authorities for these transports should be part of the sustainable and diverse supply scenario for Europe.

FOREWORD

In 2008, a major supply crisis worldwide for the most used radioisotope Mo-99/Tc-99m raised awareness of the fragility of this relatively small (in revenue) but highly sensitive (in terms of public visibility) business. The activity rested upon few actors, aging facilities, and a precarious equilibrium.

As a consequence important work was carried out internationally to draw lessons from this failure. It was in particular identified that the supply chain was based on research reactors coming to the end of their lifetime, inadequate price breakdown and an insufficiently coordinated network.

The OECD/NEA High-Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR) was able to analyze in detail the causes of the 2008 crisis, emphasized the weakness of the supply chain, encouraged regional networks and, as a result of its work, came to an agreement among the stakeholders on 6 principles[1], which include the need for full cost recovery (FCR) and outage reserve capacity (ORC).

Even more important at a practical level, the Association of Isotope Producer and Equipment Suppliers (AIPES) set up an almost weekly coordination of all important irradiation reactors and processors worldwide, which forms the backbone of the currently continuous supply of Mo-99/Tc-99m to nuclear medicine, despite unforeseen temporary shutdowns of reactors and processing facilities in the last few years.

In both bodies European actors play a leading role as Europe is the largest, most coherent and coordinated network of suppliers. They are gathered in the European Observatory of the Supply of Medical Radioisotopes in which positions are synthetized and carried to the EU level.

Almost 10 years after the major crisis of 2008, the security of supply of radioisotopes has considerably improved, especially thanks to the work done by all the European stakeholders.

Nevertheless, to meet the challenges for the long run and to maintain the European sector as the world leader, further actions have to be undertaken. It is in particular important to implement a correct remuneration of the “upstream” actors (target manufacturers, irradiation reactors, processors and generator producers) in order to ensure the financing of existing and new infrastructures and back-ups.

The objective of this position paper is to present the progress made since the publication of the previous document[2] and propose ways to further improve the situation for a robust and sustainable production of Mo-99 required by the European medical community and patients. **Up to now, the Observatory has four general strategic objectives: to support a secure Mo-99/Tc-99m supply across the European Union, to ensure that the issue of Mo-99/Tc-99m supply is given high political visibility, to encourage the creation of a sustainable economic structure of the supply chain and to conduct periodic reviews of the supply capacities and demand.**

More specifically, in line with the six principles and recommendations established by the HLG-MR and agreed by the stakeholders, this position paper proposes actions to ensure:

[1] The Supply of Medical Radioisotopes, The Path to a Reliability, Nuclear Development OECD AEN NEA 2011
[2] European Research Reactor Position Paper by CEA, IRN, NRG, RCR, SCK-CEN, POLATOM and TUM, 10.03.2011

- recovery of all costs (including the investment costs) of new and existing infrastructures[3] and the establishment of a European level playing field for infrastructure investors,
- timely creation of new irradiation capacities in view of the age of the existing fleet of irradiation reactors,
- availability of "on call" reserve capacity with associated funding,
- upholding and tightening of the coordination between stakeholders,
- ways to improve security of supply through standardization,
- coordinated and transparent actions of the national authorities for transport licensing within Europe.

BACKGROUND INFORMATION

The reliable supply of Tc-99m, the daughter isotope of Mo-99 is an important public health issue since Tc-99m represents some 75% of all nuclear medicine diagnostics performed worldwide in more than 27 different applications representing 35 million medicine procedures every year, half of them for the US market and 8 million for the European market.

Due to the short lifetime of the main products Mo-99 and Tc-99m (66 hrs and 6 hrs respectively), the production of this radioisotope requires continuous processing and complex logistics, as they cannot be stockpiled.

1) The European picture

The European production of Mo-99 is based on the irradiation of HEU and LEU targets in four[4] - research reactors (BR2/Belgium, HFR/Netherlands, MARIA/Poland, LVR-15/Czech Republic), all of them operating for more than 40 years. The irradiated targets are processed in two facilities (IRE/Belgium, Curium/NRG/Netherlands). Once purified the Mo-99 is sold to worldwide generator producers (Curium, GE Healthcare, …) and finally delivered to radio pharmacies and/or hospitals.

FRAMATOME/CERCA (formerly AREVA/CERCA) produces 70% of the worldwide supply of targets. Like the research reactors, the facility was opened in the early 1960s. It is now undergoing a major refurbishment, which will ensure a reliable target production for the next decades. The new installation will be fully operational in 2022. FRAMATOME/CERCA will supply HEU and/or LEU targets according to the demand of its clients. It is foreseeable that the European supply chain will convert fully to LEU targets and processing in the next few years.

Besides the already mentioned four reactors, which are providing irradiation services for Mo-99 production, two other reactors will be available in the near future: FRM II/Germany will be able to irradiate uranium targets from 2019 on and JHR/France (in construction, intended to replace OSIRIS with twice the capacity) from 2022.

Furthermore, two other projects are in the pipeline. The most advanced one is PALLAS/Netherlands, which is planning to replace HFR from 2025. The second is MYRRHA/Belgium which should replace BR2, but not before 2030.

[3] Including waste management and high standard nuclear safety
[4] Since the publication of the previous position paper, Osiris/France has stopped operation by the end of 2015.

There are two Mo-99 processing facilities operated by NRG (Petten, The Netherlands) and IRE (Fleurus, Belgium). Both facilities made an important effort in converting the chemical extraction of Mo-99 and other radioisotopes for nuclear medicine from HEU to LEU targets. The Petten facility completed the conversion in early 2018, IRE conversion is due to be completed by the end of 2019.

There are also two important already mentioned technetium generator suppliers: GE Healthcare (UK) and Curium Pharma (The Netherlands, France).

This network is by far the largest existing regional network in the world. It is the only one, which is fully vertically integrated and as such has provided Europe with a high level of security of supply over the last decades.

2) Outside Europe

Since the shutdown of NRU/Canada in October 2016[5], there are two major suppliers of Mo-99 outside Europe: NTP in South Africa and ANSTO in Australia.

Russia and Argentina have a small production for the local or the regional market. Both countries aspire to become a global provider. Argentina has the RA-10 reactor in construction that should start production in the early 2020's.

Korea also builds a reactor (KJRR, start early 2020's) for the production of radioisotopes at a local and regional scale.

Although the USA absorbs half of the worldwide supply, they have no domestic production. Since 2009, DOE/NNSA is financially supporting projects based on different technologies (photon induced transmutation of Mo-100, neutron capture of Mo-98, and accelerator-driven subcritical assembly for neutron fission…). Some others projects without support from DOE are also underway[6]. But for the moment none of them have led to ponderable production.

SCENARIO FOR A SUSTAINABLE MO-99 PRODUCTION IN EUROPE

In 2011, the position paper listed 10 common principles that were agreed by the authors. Among those, five concerning coordination, reserve capacity, open access and HEU/LEU conversion can be considered as implemented or about to be implemented[7].

To maintain a reliable production of Mo-99 over the next decades and strengthen the European leadership it is necessary to maintain the effort and undertake the remaining actions.

1) Full cost recovery and European level playing field for infrastructure investors

Based on the experience of the past it is acknowledged that reserve capacity of at least 35% is needed to avoid a supply shortage and this has to be paid for. It is also expected that the needs will continue to grow slightly in Europe (aging population) and in the world (Westernised way of life, facilitated access to nuclear medicine for a growing part of the population…).

[5] In fact, in case of a new crisis NRU could be made available for medical isotope production until April 2018. Afterwards there will be a definitive shutdown
[6] Molybdenum-99 for medical imaging, the national academic press, 2016
[7] Vigilance is needed until the full LEU conversion to avoid shortage

In the past, research reactors have not been designed primarily for supplying medical markets with radioisotopes and the investment in these facilities largely precedes this application. To date the radioisotope supply has been provided essentially by existing governmental infrastructures. The market situation that has resulted is well documented by the recent OECD/NEA paper[8].

The result has been that the pre-existing excess capacity has allowed market forces to keep irradiation prices relatively low.

However in order to replace the now aging facilities in an economically sustainable way, it is necessary that the actors recover the full cost of the services rendered, including investment costs.

The current share of revenue and profit for irradiation services is only a small fraction of the final reimbursement rate.

The price paid for irradiation services has to be increased to at least the full cost recovery level in order to allow a robust business plan for maintenance, construction and safe operation of existing and new facilities in Europe.

The challenge of full cost recovery is to create a European level playing field for investors in the maintenance and development of infrastructure. To ensure markets are not distorted and markets operate efficiently full cost recovery at the European level should include important cost factors such as security, waste management, environmental protection and decommissioning. Europe may consider to work towards transparent and coherent government support for infrastructure developments, which does not jeopardize the required level playing field.

2) Need for new reactors in Europe

By the end of next decade, HFR and BR2 will be shut down. These two major reactors (each with an operating irradiation capacity higher than 100% of the European demand) will have to be replaced.

The new capacities which will arrive in 2019 (FRM II) and 2022 (JHR) are well below the combined capacities of HFR and BR2. They are needed for the mid-term but definitely not enough for the long-term (see Table 1).

It is necessary to anticipate the shutdown of several irradiating reactors in the next decades. To maintain redundancy and enough capacity, it is necessary to build at least one new reactor that is (at least partly) dedicated to target irradiations in the next decade and that has a significant number of normal operating days/year and a significant production capacity for Mo-99 production.

3) Upholding and strengthening the European network of stakeholders

After the 2008 crisis, important work was done to implement coordination at the European (European observatory) and international (AIPES) level through information exchange and planning.

[8] "The Supply of Medical Radioisotopes – An Economic Study of the Molybdenum-99 Supply Chain" NEA 2017 to be published.

Active participation of European stakeholders in AIPES and the European Observatory should be maintained and supported to continue to coordinate and anticipate the evolution of the nuclear medicine market.

Table 1: Existing and scheduled Production Facilities

Reactor	Com-missio-ning	Thermal powert (MW)	Start of 99Mo produc-tion	Normal operating days/year	Anticipated 99Mo production weeks/year	Expected available capacity per week (6-day Ci 99Mo)	Expected available capacity per year (6-day Ci 99Mo) by 2022	Esti-mated end of opera-tion
BR-2	1961	60	NA	147	21	7 800	163 800	At least until 2026
HFR	1961	45	NA	275	39	6 200	241 800	2024
LVR-15	1957	10	NA	210	30	3 000	90 000	2028
MARIA	1974	30	NA	200	36	2 700	95 000	2035
FRM-II	2005	20	2019	240	32	2 100	67 200	2054
JHR	2021	70-100	2023	220	24	4 800	115 200	2081

4) Standardisation in target and container design as well as in handling systems and other processes

Neither the actual targets nor the containers to transport them when irradiated (nor to a less extent irradiation setups) are compatible. It means that the processors can irradiate targets only in “adapted” reactors. This clearly limits the theoretical redundancy. A possible further improvement of the security of supply would be to consider more standardisation.

A first step has been achieved by a geometry of the LEU irradiation targets compatible with the irradiation rigs in European reactors. A second step should be a common container design. **To achieve both, fully exchangeable targets and a common container design European funding for the necessary R & D would be helpful. With a longer perspective, this European funding should include the development of an innovative target design that enables to compensate for the losses in effectivity due to the conversion from HEU to LEU targets**

5) Licensing of transport of irradiated targets through Europe

Existing and planned irradiators are located in six countries (Belgium, Germany, France, The Netherlands, Poland, Czech Republic), while the two processors are located in Belgium and The Netherlands. This necessitates transport of the irradiated targets through a total of six European countries. Timely licensing of the transports has been an issue in the past.

Coordinated and transparent actions of the national authorities for transport licensing are part of a sustainable and diverse supply scenario for Europe. Licensing of the transport containers themselves has to be included in this approach.

CONCLUSION

Since the publication of the previous position paper by the major research reactor operators, important work was done in order to implement the recommendations to secure the Mo-99/Tc-99m supply needed by the medical market.

An overall better coordination has allowed the effects of the final shutdown of OSIRIS (2015) and the cessation of Mo-99 production at NRU (2016) and the temporary shutdown of HFR (2013, 2014) and BR2 (2015-2016) to be mitigated.

The infrastructure is being improved. The refurbishing of the European target manufacturer (CERCA) is ongoing. The installation of the irradiation setup at FRM II and the construction of JHR to replace OSIRIS are underway. PALLAS is working towards obtaining a licensable design for the PALLAS-reactor. The Curium processing facility completed its HEU-LEU conversion in early 2018, the IRE conversion project is due to be completed by the end of 2019.

However to improve the security of supply in Europe in the mid- and long-term and to keep a leading role in the nuclear medicine market further actions have to be undertaken.

- It is of prime importance to obtain the full cost recovery for the front-end actors in order to be able to maintain and renew the facilities and support back-up capacities.

- One or two new (at least partly) dedicated irradiation reactors will be necessary in the next decade to replace the reactors expected to shut down.

- Improved standardisation of targets, transport containers, target handling equipment and transport licensing will improve efficiency and further increase the security of supply within Europe.

Abbreviations

AIPES	Association of Imaging Producers & Equipment Suppliers
BR2	Belgium Research Reactor 2
CEA	Commissariat à l'Énergie Atomique et aux Energies Alternatives France
FRM II	Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II)
HFR	High Flux Reactor, Netherlands, Netherlands
IRE	Institute National des Radioelements, Belgium
JHR	Jules Horowitz Research Reactor, Cadarache, France
LVR-15	Multi-purpose Research Reactor, Rez, Czech Republic
MARIA	Multi-purpose Research Reactor, Swierk, Poland
MYRRHA	Multi-purpose Hybrid Research Reactor for High-tech Applications
NCBJ	National Centre for Nuclear Research, Poland
NRG	Nuclear Research and consultant Group, Netherlands
RCR	Research Centre Rez, Czech Republic
OECD HLG MR	OECD High Level Group Medical Radioisotopes
OSIRIS	Material Testing Reactor, Saclay, France
PALLAS	Research Reactor, replacing HFR Petten, Netherlands
SCK•CEN	Studiecentrum voor Kernenergie, Centre d'Etude de l'Energie Nucléaire, Belgium
TUM	Technische Universität München, Germany

Annex

Literature

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