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The European Nuclear Experimental Educational Platform – ENEEP: Progress, Prospects and Remote Education Capabilities

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***Abstract* — The European Nuclear Experimental Educational Platform – ENEEP is currently being established by five European educational and research organizations in the framework of a Horizon 2020 project, initiated in 2019. The ENEEP partner institutions are the Jožef Stefan Institute (JSI, Slovenia), the Slovak University of Technology in Bratislava (STU, Slovak Republic), the Czech Technical University in Prague (CTU, Czech Republic), Technische Universität Wien (TU Wien, Austria) and the Budapest University of Technology and Economics (BME, Hungary). ENEEP is intended as an open educational platform, offering experimental hands-on education activities at the ENEEP partner facilities. ENEEP education activities will be offered in different formats (group and individual) and are targeted at university students at all educational levels and young professionals in the nuclear field. This paper gives an overview of the ENEEP project activities and the progress achieved thus far, highlighting the experimental capabilities which will be offered. In the first implementation phase, ENEEP will be based on a comprehensive set of experiments comprising the basics in Reactor Physics and Nuclear Engineering curricula, as well as more specific experiments focusing on particular aspects – investigated phenomena, types and working principles of detectors, etc. Subsequently, novel education activities will be introduced and implemented in ENEEP, following scientific development in nuclear science and technology and nuclear instrumentation detectors, stemming from research activities. Attention will be devoted to the development and optimization of remote education capabilities at the ENEEP partner institutions, of particular relevance during the current Covid-19 pandemic, which is responsible for major changes in education activities worldwide.**

***Keywords* — Experimental Education activities, Nuclear Science and Technology, Remote capabilities.**

I. INTRODUCTION

EDUCATION activities in nuclear science and engineering are mainly based on theoretical lectures and exercises supplemented by modelling of real or simplified reactor systems by various computational codes. Nowadays, computer modelling is slowly replacing real experiments and, at most European universities, teaching of nuclear engineering is supplemented by the performance of only few basic experiments in radiation laboratories. This fact is very natural, as computer modelling is inexpensive compared to real experiments and it can be easily implemented into academic curricula without the need for complex laboratories requiring high operation costs and human resources. This trend is understandable, however, it should be considered that without real experimental education activities and without hands-on experience, the future nuclear engineers will suffer from a significant handicap in their professional careers. Experimental and hands-on experience is necessary to obtain high quality and complete nuclear education.

In nuclear education, research reactors are the most appropriate experimental facilities to achieve these goals. Critical and subcritical assemblies and training reactors are most suitable, as they are specifically designed for education and training. Research reactors in general are suitable for education activities at all academic levels, not only in nuclear engineering, but also in various non-nuclear engineering studies, such as power engineering, electrical engineering, natural sciences, medical sciences, physical sciences, etc. Experimental education at research reactors can significantly increase the quality of theoretical academic education and extend practical hands-on experience of students at real nuclear installations. In addition to research reactors, specific nuclear laboratories can be used to carry out experimental education and hands-on activities. In addition, it is also very valuable to have access to nuclear power plants, fuel cycle or decommissioning facilities where students can acquire experience with real nuclear installations, and obtain a full view on their complexity. Nowadays, for several reasons it is difficult to enable access to research reactors for students and their lecturers in order to provide them with a possibility of dedicated reactor physics experiments or hand-on reactor technology experience.

The mission of the ENEEP project [1-4] is to establish a platform at the European level which will fulfil the needs of European users. ENEEP – the European Nuclear Experimental Educational Platform – will contribute to significantly enhance the experimental education and hands-on activities in nuclear curricula, particularly in the fields of reactor physics, nuclear safety, radiation detection, radiation protection, spent nuclear fuel and radioactive waste management. The ENEEP platform will offer access opportunities to nuclear experimental facilities for university students at all academic levels (bachelors, masters and doctoral), professors, lecturers, experts in nuclear education, etc. It will allow specific nuclear training of professionals, particularly young professionals and post-docs at the beginning of their professional career, staff from governmental and non-commercially oriented companies, such as regulatory bodies, governmental organizations dealing with various aspects of peaceful use of nuclear energy, research institutions, etc. ENEEP is currently being established as an open platform for any European university, European research institute or nuclear training organization that is actively involved in experimental nuclear education, training and competence building. The ENEEP founding members are: the Jožef Stefan Institute (JSI, Slovenia), the Slovak University of Technology in Bratislava (STU, Slovak Republic), the Czech Technical University in Prague (CTU, Czech Republic), Technische Universität Wien (TU Wien, Austria) and the Budapest University of Technology and Economics (BME, Hungary) - institutions which are heavily involved in experimental nuclear education, training and competence building. Four institutions operate research reactors and the fifth one has access to specific laboratories for nuclear education and training. Fig. 1 – Fig. 5 display the facilities operated by the ENEEP project partners.

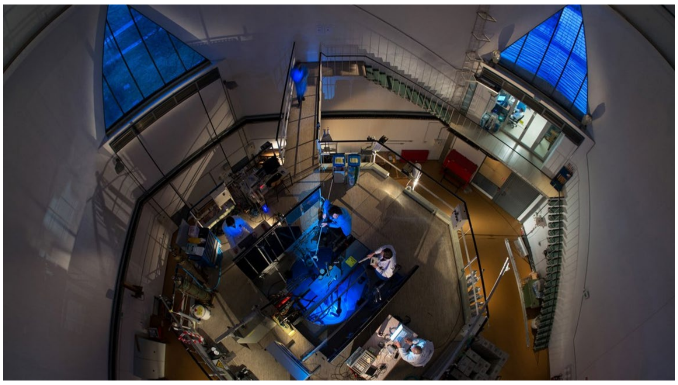

Fig. *1*. *JSI TRIGA reactor, JSI, Ljubljana.*

Fig. *2*. *Radiation Laboratory, STU, Bratislava.*

Fig. *3*. *Training reactor VR-1, CTU, Prague,*

Fig. 4. *TRIGA Mark II reactor, TUWien, Vienna.*

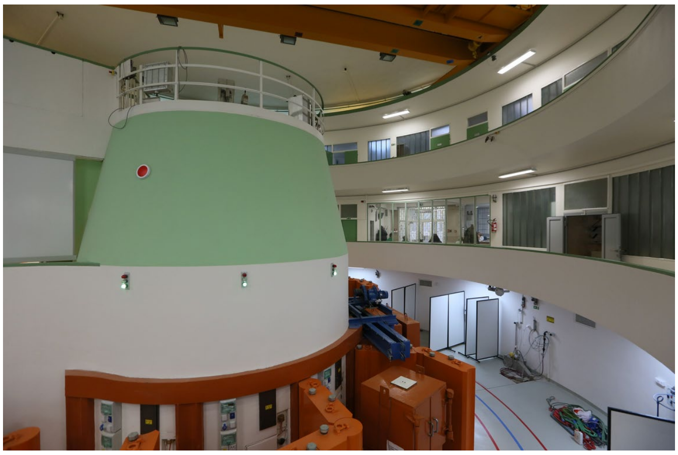

Fig. 5. *BME Training reactor, BME, Budapest.*

In the past, four ENEEP institutions, namely STU, CTU, TU Wien and BME, established in 2003 the Eugene Wigner course which connected three research reactors and offered experimental reactor courses for master students in nuclear engineering. The Eugene Wigner course ran annually for five years. Subsequently, four ENEEP institutions, namely CTU, TU Wien, BME, and JSI established in 2009 a Group Fellowship Training Program on Research Reactors which has been running under the Eastern European Research Reactor Initiative (EERRI). Training courses are performed regularly for International Atomic Energy Agency (IAEA) trainees. Up to now, 15 courses have successfully been accomplished and the 16th will be carried out in the autumn 2021. A six-week EERRI course is organised in two or three countries using two or three research reactors. ENEEP will be established based upon the existing experience of the current project partners originating from the Eugene Wigner courses, the EERRI courses as well as from the experience in experimental nuclear education, training and competence building activities carried out by the project partners. The 3-year ENEEP project was proposed in response to the 2018 EURATOM call for projects on the topic of "Availability and use of research infrastructures for education, training and competence building", and was kicked off in June 2019.

II. ENEEP Project – Progress and Prospects

The activities carried out within the ENEEP project are structured into work packages (WPs) devoted to distinct aspects:

- WP1: Post-grant requirements
- WP2: Consortium coordination and management
- WP3: Capabilities, users and SWOT analysis of ENEEP
- WP4: Establishment of ENEEP
- WP5: Demonstration of ENEEP
- WP6: Dissemination and feedback

WP1 and WP2, led by STU, are focused respectively on the Post-grant requirements set out by the European Commission (EC), and on the coordination and management of the ENEEP consortium and liaison with the EC.

WP3, led by TU Wien, covered the activities performed as a foundation of the ENEEP platform. The ENEEP partners have collected and compiled information in the form of databases covering the ENEEP facilities, the experiments to be offered within the ENEEP platform and the available instruments (e.g. detectors, equipment, etc.). A further important aspect covered in WP3 was the collection of information on potential ENEEP users in order to establish direct contacts, and for the purposes of promotion. Finally, a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis was performed, which allowed for the identification of key areas for the objectives of the ENEEP platform to be achieved, and thus providing directions for the ENEEP partners.

WP4, led by JSI, focused on the basis for the establishment of the ENEEP platform. The WP4 tasks are described in the following subsections.

A. ENEEP Agreement

The most important task of WP4 was achieving an agreement among the ENEEP partners, defining the platform's structure and legal status, the financial arrangements and responsibilities. The ENEEP partners have taken the decision to establish ENEEP as an association under the laws of the Republic of Slovakia. Work is in progress at present on the formal legal review of the ENEEP Statute and relevant documents. The ENEEP Association is expected to start running in mid-2022, following its formal establishment and the successful completion of the ENEEP demonstration.

B. ENEEP Application procedure

The purpose of the ENEEP application procedure is defining the application process and requirements, defining roles and responsibilities within ENEEP and criteria for application evaluation. The procedure will assist the ENEEP users in submitting applications to ENEEP; part of the content generated within this task will be made available publicly through the ENEEP web portal upon announcement of education and training activities.

C. Access requirement database

Access conditions to nuclear facilities are generally similar, however facility-specific regulations and procedures do exist.

An Access requirement database was created, synthetizing the access requirements and conditions for each partner-operated research facility, including facility-specific forms.

D. Procedures for group education and training activities

This task consisted in the definition of procedures for carrying out group education and training activities at the ENEEP partner institutions. Additionally, a dedicated template was created for the preparation of detailed instructions for each experiment, and presentation materials were created based on the outputs of WP3, providing a synthetic description of each experiment, including information of practical nature, e.g. education level, experiment duration, maximal number of participants, etc. ENEEP currently offers 61 experiments; the presentation materials are available on the ENEEP web portal at http://eneep.org/experiments/. Fig. 6 – Fig. 10 display examples of the presentation materials. It will be possible to prepare and implement additional experiments based on users' requirements.

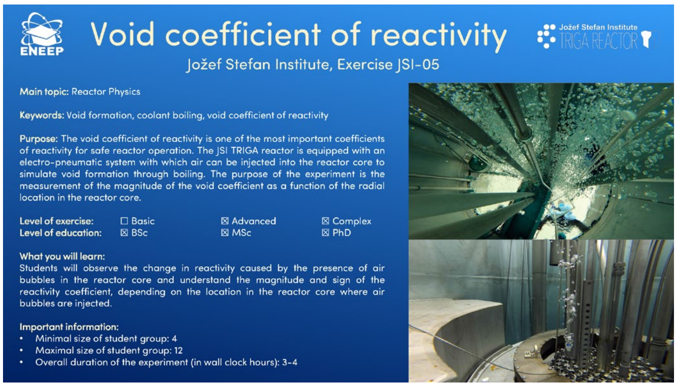

Fig. 6. Example of experiment presentation materials – JSI, Measurement of the void coefficient of reactivity.

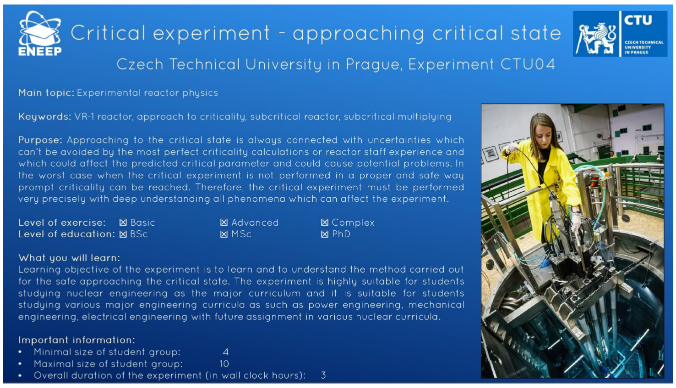

Fig. 7. Example of experiment presentation materials – CTU, Critical experiment.

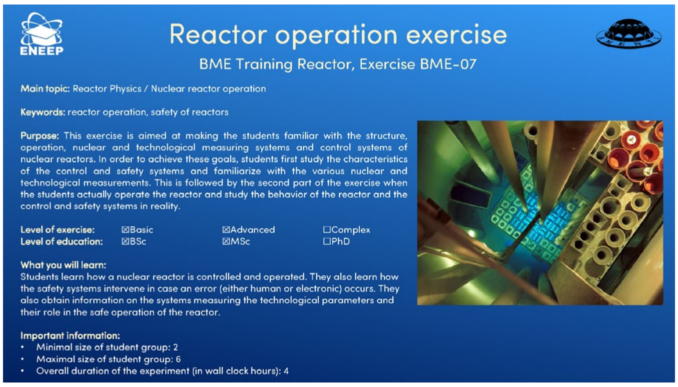

Fig. 8. Example of experiment presentation materials – BME, Reactor operation exercise.

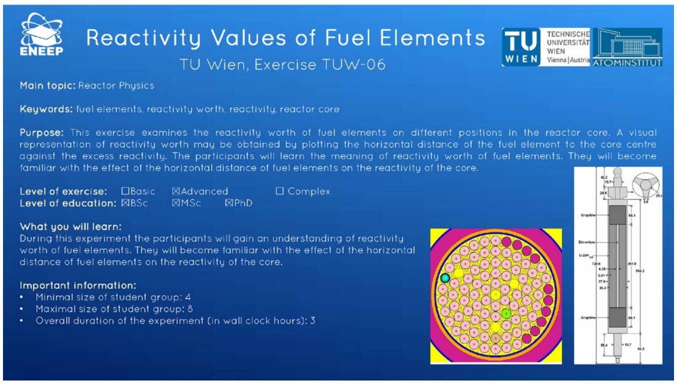

Fig. 9. Example of experiment presentation materials – TU Wien, Reactivity values of fuel elements.

Fig. 10. Example of experiment presentation materials – STU Wien, Measurement of the diffusion length and the Fermi age of neutrons.

E. Shortlist of novel education and training activities

Recognizing the need for updating the ENEEP education and training activities with regard to scientific advancement, a search was made for novel education and training activities with realistic possibilities of implementation at the ENEEP partner facilities. The search involved professors, operating personnel and students; in the resulting shortlist, 17 novel education and training activities were identified. Three novel activities proposed by the JSI were already tested in practice in collaboration with nuclear engineering students of the University of Ljubljana, Faculty of mathematics and Physics:

- Cherenkov light intensity measurements as a means of reactor power monitoring,

- Neutron detection with SiC semiconductor detectors,
- Measurement of self-powered neutron and gamma detector signals.

F. Synthesis of implementation workflow and conditions for novel activities

The implementation of novel, non-routine experimental education activities at nuclear facilities is generally subject to prior fulfilment of technical and administrative requirements. The technical requirements are determined by operational limits and conditions in place at the facilities, the administrative requirements are laid-out in operational procedures / legislation. A synthesis was made of the implementation workflow in place at the ENEEP partner facilities with the aim to support the implementation of novel activities. In addition to the activities identified in the Shortlist of novel education and training activities, the synthesis supports the implementation of experiments at the ENEEP partner institution facilities in the framework of individual education activities, e.g. M.Sc. or Ph.D. theses or other. The synthesis describes the administrative procedures, the operating limits and conditions and presents the relevant technical data, e.g. the neutron flux levels, neutron spectra, irradiation facility dimensions, neutron beam dimensions, gamma dose rates, etc.

G. Facility operation schedule

In order to assist in the time slot selection and the prior preparation activities, the ENEEP project partners agreed to establish a facility operation schedule, published as a subpage on the ENEEP web portal: http://www.eneep.org/schedule/. The subpage provides simple information on the availability of the ENEEP partner facilities in the time period approximately between three months and one year from any given date. The schedule states the periods in which the facilities are either available, available in part, unavailable or unavailable due to long-term outages (> 2 months).

III. ENEEP Demonstration and Dissemination Activities

The work package WP5 led by CTU concentrates on demonstration of the ENEEP educational and training capabilities and its real educational potential. In early 2022, the ENEEP partners will organize:

- a 2-week course involving two ENEEP facilities for 10 master students which will be held from January 24, 2022 till February 4, 2022 at STU in Bratislava (first week) and CTU in Prague (second week)
- a 1-week course for 10 trainees at JSI (Slovenia) on February 14-18, 2022
- two individual activities involving two ENEEP facilities for 1+1 Ph.D. students or trainees, both during February 7-11, 2022 at TU Wien and BME Budapest.

The experience gained by the ENEEP project partners during WP5 will represent the basis for the organization of education activities in future ENEEP operation. ENEEP will offer:

- **Package courses** with pre-determined content, targeted at Bachelor and Master students, on an annual or semiannual basis. The package courses will consist of selected experimental activities covering a specific topic, determined by the ENEEP project partners, e.g. experiments demonstrating the basic principles of reactor control, nuclear instrumentation, radiation dosimetry or other.
- **Custom courses,** organized on the basis of users' requirements, targeted at closed groups of Master or Doctoral students from one university or institution. Custom courses will be based on experimental activities already established at the ENEEP facilities or on activities implemented specifically for this purpose.
- **Individual activities**, targeted primarily at Doctoral students and intended as a means of deepening the knowledge in one particular field in nuclear science and technology.

WP6 coordinated by BME, covers the dissemination of the results of the ENEEP project and the promotion of ENEEP within the European nuclear community and worldwide. In the framework of WP6 a dedicated ENEEP website was created (www.eneep.org) and is being continuously updated. ENEEP is also being promoted on the social media platforms LinkedIn (https://www.linkedin.com/groups/13834594/) and Facebook (https://www.facebook.com/ENEEP-108437037552996).

IV. Remote Education Capabilities

The relevance of remote education capabilities in the field of nuclear science and technology has been increasing in the last several years, in the context of limited availability of research and training facilities for in-person activities, and with increasing possibilities of content broadcasting. Remote education activities have several advantageous aspects:

- possibility of wider coverage in case in-person attendance is not possible, e.g. due to no or limited possibilities of traveling,
- streamlining and increased flexibility: less time is spent on practical issues related to traveling (e.g. registration, access to facilities), remote activities can effectively be included into educational programs,
- some aspects may benefit from a remote format, e.g. ensuring all students are able to adequately observe the performance of a particular experiment.

However, it must be recognized that remote education activities can never completely replace in-person attendance, as several important aspects are lost, i.e. the actual experience of visiting a nuclear facility, observing the rules and regulations for access and work in a radiation-controlled environment, the possibility to perform oneself the experiment and interact on a more direct and more personal level with instructors or facility staff.

The global Covid-19 pandemic has imposed significant difficulties and restrictions in the performance of in-person education activities at all education levels, including nuclear science and technology. The reality we are currently experiencing has led to significant effort devoted to restructuring education activities and transferring them to a remote format.

At present two ENEEP partners, the JSI and CTU have fully operational remote education capabilities through videoconferencing solutions. Thus far, the JSI performed a dedicated remote course in reactor physics for students of the University of Uppsala in September 2020, practical exercises in the framework of two 1-semester courses for students of the University of Ljubljana and foreign students enrolled in the SARENA programme [5] in winter and spring 2021, and participated with a presentation of the JSI TRIGA reactor and a practical exercise in the MOBIL-APP mobility programme [6], organized for first year master students at the Aix-Marseille University in July 2021. Figs. 11 and 12 display students of the University of Uppsala and demonstrators from the JSI during the performance of remote education activities.

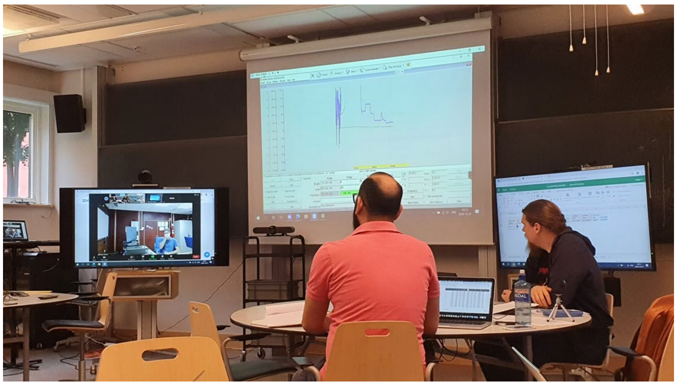

Fig. 11. *Students of the University of Uppsala on location during the performance of a remote experiment – September 28th-October 2nd, 2020.*

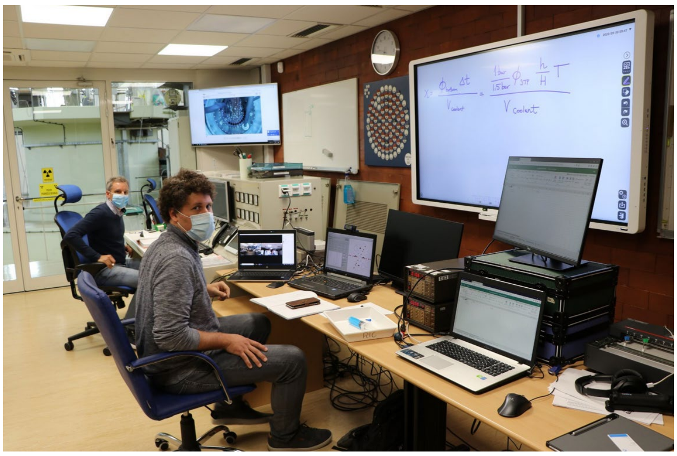

Fig. 12. *Reactor operator and demonstrator in the JSI TRIGA control room conductin an remote experiment - September 28th-October 2nd, 2020.*

In collaboration with the IAEA, the Czech Technical University in Prague developed the Internet Reactor Laboratory (IRL) instrumentation for distance education, which connects an operating VR-1 reactor, as a host reactor, with universities in other countries, as a guest institution. This IRL instrumentation offers the opportunity to add real reactor experiments to the academic curriculum, particularly nuclear engineering and reactor physics, where students access an operating research reactor is not feasible. The IRL is in operation in Europe and Latin America, and it is under implementation in Africa and Asia. In Europe, the Training Reactor VR-1 replaced French reactor ISIS as a host reactor this year (2020). The first broadcasting for IAEA to four European and African countries will start in September 2021.

Furthermore, during the first wave of the COVID-19 pandemic in Europe, the IRL instrumentation was upgraded to broadcast outside the IAEA IRL area for groups and individuals. The upgraded IRL system was frequently used during the whole academic year 2020/21 for remote experimental education of Czech students. In 2021 remote educational courses were also carried out for international students from the Middlebury Institute of International Studies at Monterey, California, USA and students from several British universities through NTEC (Nuclear Technology Education Consortium, http://www.ntec.ac.uk/consortium.html). The IRL system also allows carry out distance nuclear training and research.

Fig. 13. *Remote experimental education for students from the VR-1 Reactor to students from the Middlebury Institute of International Studies at Monterey, California, USA in January 2021.*

The remote education capabilities implemented recently primarily due to the Covid-19 pandemic will be maintained by the ENEEP partners in order to support the ENEEP activities.

V. Conclusions

This paper presents an overview of the ENEEP project, aiming at the establishment of a platform at the European level offering experimental nuclear education activities in order to enhance nuclear education curricula. The ENEEP project was initiated in 2019 and achieved significant progress, leading to the formal establishment of the ENEEP Association in 2022, which will be responsible for the organization of education activities. In early 2022 the ENEEP project partners will organize several demonstration activities (group and individual) at the ENEEP partner facilities. The increasingly limited availability in Europe of nuclear facilities suitable also for research and training purposes, in particular research reactors, and more importantly the Covid-19 pandemic, led to increased relevance of remote education capabilities. At present two ENEEP partners, the JSI and CTU have fully operational remote capabilities. ENEEP will offer package and custom courses as well as individual activities to students at all educational levels as well as young professionals from governmental or non-profit organizations dealing with the peaceful use of nuclear energy, starting from mid-2022.

Acknowledgment

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