NEW APPROACHES ON THE ENERGY STORAGE TECHNOLGIES IN ROMANIA

Ioan ȘTEFĂNESCU[1,2], Mihai VARLAM[2], Elena CARCADEA[2]

[1]Corresponding Member of the Academy of Technical Sciences of Romania
[2]National Research and Development Institute for Cryogenics and Isotopic Technologies, ICIT Rm. Vâlcea

Abstract: Critical issues related to the availability of energy sources and their efficient use has quickly become vitally important. Population growth combined with growing demand for energy and materials in order to increase the standard of living is actually the main cause of this concern. All this requires not only an increase in available energy sources, but also a more efficient way to use this availability. As a result, energy storage has become vital both for the efficient use of renewable energy sources and for the transmission and distribution of safe and efficient electricity. In this context, a new vision about future technological research in energy storage sector in terms of a new research facilities being developed by ICIT Rm. Vâlcea is addressed in this paper. Energy storage research laboratories will be developed in order to lead to new approaches to energy storage technologies, the new research facility aiming to "activate" in the scientific limitations area of chemical, electrochemical and thermal storage technologies, applicable in electrical networks, residential, transport and commercial. The paper presents some aspects of the declared mission of the new laboratory, the one to become a catalyst and an integrator of the results of this area with a strategic importance for the energy sector. ICIT Ramnicu Vâlcea aims to become a reference point and a developer in the field of energy storage technologies, being thought to become an open experimental platform for national and international partners.
Keywords: energy, storage, research laboratories.

1. ENERGY STORAGE PROBLEM

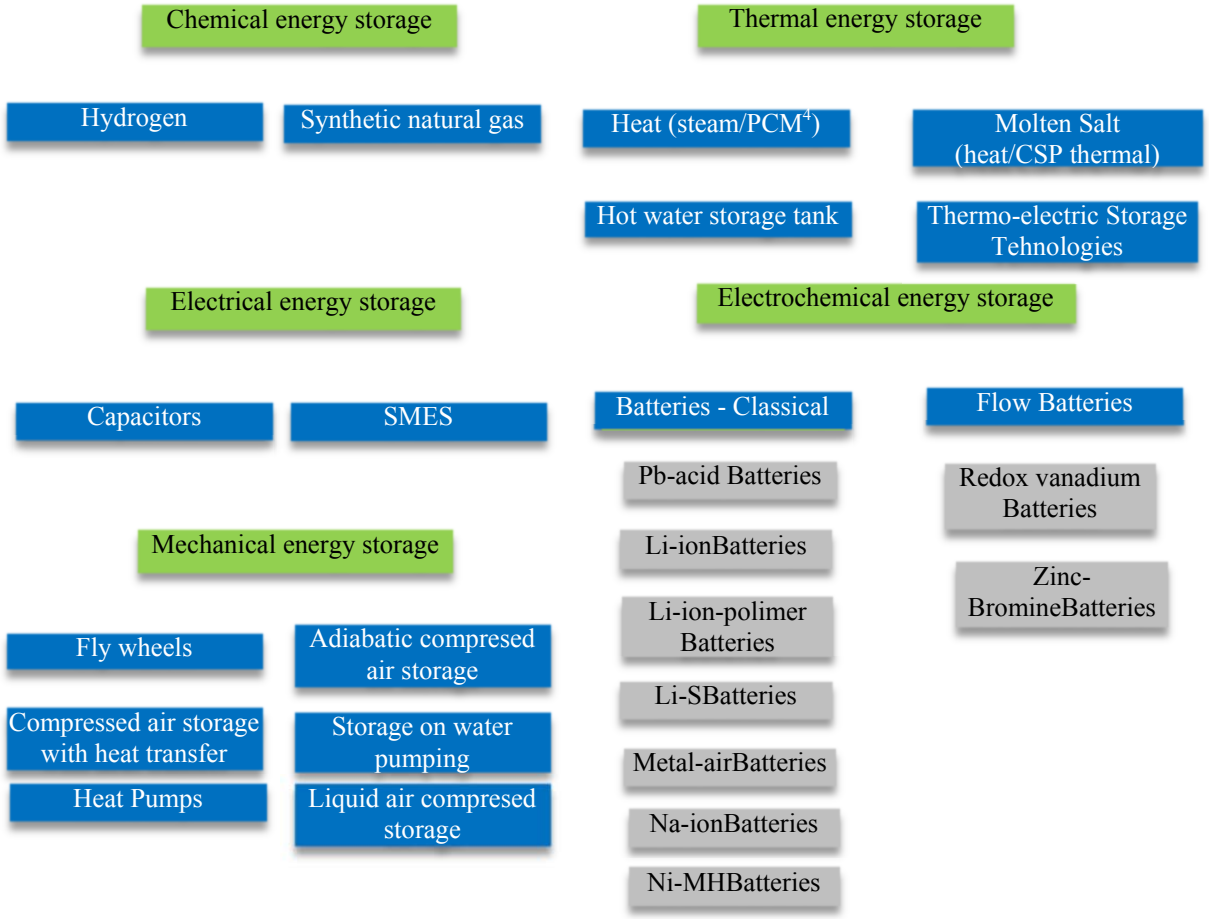
Energy plays an important role in the modern world. How energy based on fossil fuels can not be considered an option, finding alternative technologies to produce and store the energy is necessary. The energetic technologies based on renewable sources and hydrogen have a huge potential and can play a major role in the global energy system. In terms of energy production, we can say that currently several renewable and environmentally friendly technologies are available, such as: solar energy, wind and tidal power, but because of their intermittence cannot meet the demand for energy required at any moment. The big disadvantage that limits the use of renewable energy for electricity production is given by their fluctuating and intermittent nature. Thereby, the declared mission of worldwide researchers from the energy sector is to develop storage environments that allow solving these disadvantages and can close the global "chain" in terms of energy supply from renewable sources.

Due to intermittencies in electricity production and because a centralized system requires constant energy supply we can say that the ability to store efficiently and cheaply the energy can solve one of the greatest challenges of renewable energy. Energy storage would allow "flattening" power peak and "fill" the gaps occurring in the use of energy from renewable sources. In reality, this means that electricity is stored when too much is produced, in order to be consumed later when not sufficient energy is available.

Energy storage is vital for the efficient use of renewable energy sources and for the safe transport of electricity, for network applications. Since these applications are stationary, the technological "engines" are totally different from those needed for the transport or portable applications. The increased capability for electricity storage from the renewable energy and for network applications is a fundamental criterion for the applicability of these systems. The use of such advanced energy storage systems can have a significant impact on the reliability and stability of the network.

Efficient energy storage is becoming one of the most spectacular and sensitive domain, the development of processes, equipment and storage and conversion technologies being an exclusive condition for the competitive use of all renewable energy sources. At international level, many types

of energy storage technologies are available, depending on the energy production method. A summary of the key technologies addressed for each category and method is shown in the next diagram:



Currently there are a limited number of energy storage systems in the European Union (around 5% of total installed capacity), based almost exclusively on hydropower, especially in mountainous areas. Other forms of energy storage mentioned above such as: batteries, electric cars, flywheels, hydrogen, chemical storage are at a minimal level, or in an early stage of development.

2. THE DEVELOPMENT AT INTERNATIONAL LEVEL

It must be underlined that the UE energy policies have identified the energy storage technologies as an extremely important areas for research, due to their potential to contribute to energetic system security and to reduce the greenhouse gas emissions. Moreover, the European Commission has defined two priority areas for the applicability of energy storage technologies:

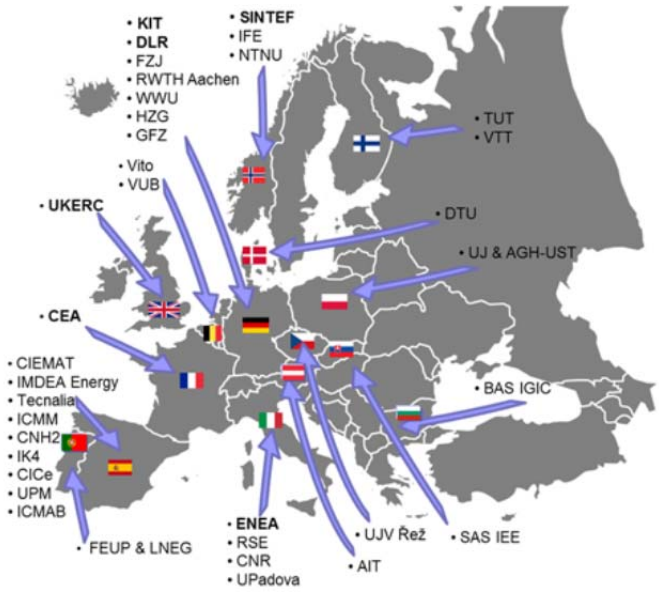
- The electricity distribution sector
- The transport sector.

EU official documents specify that energy storage technologies will play a key role in developing a low carbon electricity system. The energy storage can provide greater flexibility and can balance the network, providing a buffer system for intermittent renewable energy. Locally, these technologies can improve the management of distribution networks, reducing costs and improving energy efficiency. In this way, an easier integration of renewables can be achieved, accelerating the decarbonisation of the electricity network, increasing the security level and the efficiency of the distribution, stabilizing the market electricity prices, while ensuring greater security for the power supply.

It should be noted that the FP7Programme has included the electrical storage and thermal storage as specific objectives in the energy topics. In 2011 call on the thermal storage, were submitted and approved several proposals for systems with capacities under 70 kWh/m^3 for seasonal storage. Most electrical storage projects were focused on balancing the networks. Throughout the calls FP6

and FP7 research programs, 11 projects were funded under the European energy storage category, five of them were focused on hydrogen technologies and two were related to lithium-ion batteries.

To integrate the research efforts in this domain, in the European Alliance for Energy - EERA, the first pan-European joint program JPES – Joint Programme on Energy Storage have been developed. Its goal is to bring together all major research areas in the energy storage. JPES therefore represents a unique opportunity to align the research and the development activities in the field and is clearly intended to integrate and complete the national research programmes in the energy storage European level, in order to optimize the resources and the efforts. The basis of this program is represented by the SET – Strategic Energy Technology Plan. Also JPES established the road and paths for research needed in Horizon 2020 and even beyond this, and develop consortia and partnerships with industry in well-defined projects. One of the thematic priorities is hybrid energy storage development. The vision of this program is to establish an online platform for Simulation of Energy Storage and of an integrated European Virtual Laboratory for Energy Storage taking into account the connections between this program with the European Programme for Hydrogen and Fuel Cells and with the Smart Cities Network.



Participants in EERA Joint Program in Energy Storage-30 participants and 6 associated partners from 15 Member States.

Several European countries(Germany, UK, etc.) have developed research centres in the field of energy storage. For example, a recent study on new energy storage technologies revealed that only in the last two years, nine universities have received more than 10 million £ for projects in this area, the first that should be mentioned being Super Gen Energy Storage Consortium. These researches have been focused mainly on Li-air batteries with a target to achieve energy densities of 8-10 times higher than usual redox electrolyte flow batteries and supercapacitors. The same study reveals the existence of a large number of "high-tech" companies active in the energy storage field, among: Atraverda, Isentropic, Plurion, Nexeon, etc.

In Germany, there are many research laboratories (78) specialized in the development of energy storage technologies, many included in the Fraunhofer research network, but also under University of Stuttgart umbrella. It should be mentioned the European Institute for Energy Research in Karlsruhe with a department specialized in energy storage, the Fraunhofer Institute for Solar Energy Systems and the Institute of Technical Thermodynamics DLR's (thermal energy storage).

Meanwhile, in the USA, the research and development activities in the field of energy storage are more advanced and regarded as national priorities in energy policies. For example, recently, was adopted the Strategy 2020 for energy storage in California. This strategy stipulates that the California State progressing rapidly towards the target of 33% electricity generation from renewables, so the potential of energy storage to support the integration of renewable resources and to maintain a reliable and efficient electricity grid becomes very important. In this context, some goals for the technological development of energy storage systems were set, and various policies directed towards promoting

their implementation are discussed. In 2011 was created the Joint Centre for Energy Storage (JCESR) as a research partner that integrates the USA government authority, the academic and industrial research organizations from several disciplines, in order to overcome the scientific and technical barriers and create new storage technologies. Hosted by the Argonne National Laboratory, JCESR attempts to combine the expertise that sweeps across an entire range of activities that precede the technological development in the field, from basic research up to prototypes and commercial systems development.

Similarly, national programs and research centers focused on developing new energy storage technologies exist in Asian countries – China and Japan, and for many of these technologies, the research is considered to be the most advanced worldwide (Japan develops the most advanced electrochemical storage technologies). It should be noted that the research programs in the field of energy storage systems are mainly carried out by industrial companies so there is no national public strategy. Nevertheless, Japan is the only country that produce Redox flow batteries.

Basically it can be concluded that worldwide there is a real revolution regarding the energy system. It is already clear that the energy system has become the "backbone" of modern society and that the transition to a carbon-based system to an environmentally friendly technologies is vital. The trend of decreasing the energy consumption on the medium and long term, does not mean that we become less dependent on it, and, in this context, the energy storage technologies are a priority.

3. THE DEVELOPMENT AT NATIONAL LEVEL

From the point of view of the necessity of development of such technologies on a national scale, it is worth mentioning that Romania has one of the most prominent power penetration rates for renewable energy - wind and solar, and their integration requires attention. The problem of efficient management of the power grid becomes more complex, together with the potential development of new nuclear plants, which requires the implementation of a hydro storage system (Tarnița project).

The research facility described in this paper can solve the problem of energy storage. It complements the research already developed in energy storage area by the ICIT Rm. Vâlcea, which has a National Centre for Hydrogen and Fuel Cells (CNHPC) and a Low Temperatures Laboratory for energy applications [3,4].CNHPC is a governmental investment, relatively recent, having the mission to develop, promote and implement the energetic technologies based on hydrogen. The activities are interdisciplinary, being related to the whole chain of hydrogen technologies, from its production and to the core of this system – the fuel cell. One of the main applications of hydrogen, very active in the last year, is the integrator of energy carrier having the function of energy storage. Moreover, there are well-known studies and demonstration projects for storing the renewable energy by transforming it into hydrogen (PEM electrolysis) and reconverted into electricity (fuel cells) when is required. In parallel, a low temperatures research laboratory for energy applications. The Laboratory team is currently involved in the development of energy storage systems based on the superconductivity phenomena (SMES). Considered to be a potential and revolutionary solution for energy storage, the SMES technologies have been investigated a lot lately, because provides instantaneous discharge rates and an infinite number of recharge cycles. Until recently, SMES system-related material costs were prohibitively high, but with the development of new materials exhibiting the phenomenon of superconductivity at higher temperatures, they began to fall so that they become attractive for new solutions.

In this context, the new research facility ROM_EST (Energy Storage Technologies) would complete the range of research and development in the field of energy storage, thus creating a local R&D hub and covering many possible topics- cold storage, hydrogen, thermal, electrochemical and chemical storage [1, 2].

Also, it should be underline that at national level there is a scientific capability to approach such research topics, many of Universities and Research Institutes having some notable results in characterization and development of new materials with applications in electrochemical storage. In addition, there are few Romanian brands of batteries manufacturers that even if they are focused on classical technologies could be the beneficiaries of such technology transfers in the field.

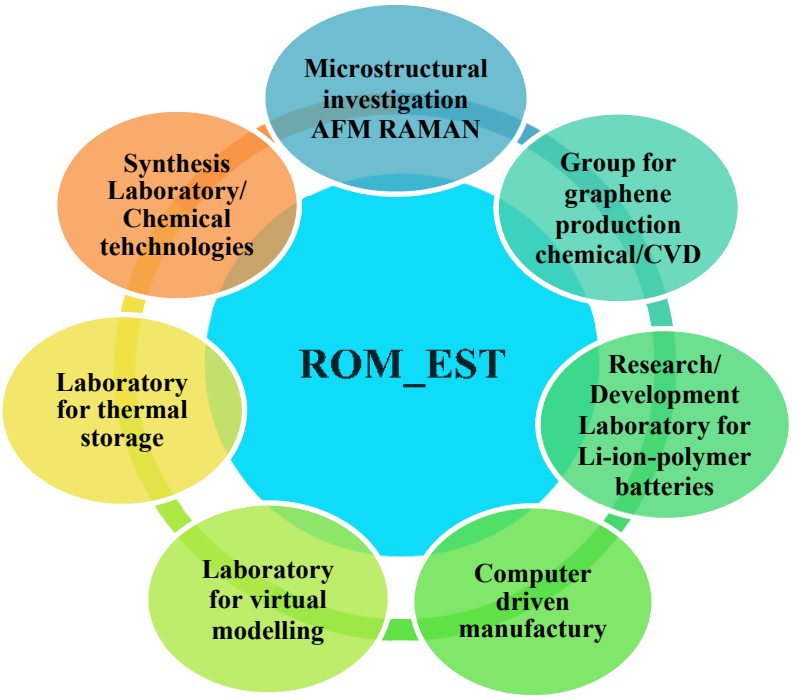
4. RESEARCH DIRECTIONS IN THE ICIT RM. VÂLCEA

ICIT Rm. Vâlcea has initiated since 10 years ago research and development activities in this area, based on two energy carriers: hydrogen and electricity. Together with its partners, has been involved in research regarding the production, purification and storage of hydrogen from biomass gasification, in the development of hydrogen storage material to develop a thermal compressor for ultrapure hydrogen required for fuel cell and hybrid vehicles, the development of a superconductor system for storing electric energy as magnetic or the development of new nanostructured materials for hydrogen storage.

The new research facility proposed to be developed at ICIT RM Valcea and discussed in this paper will "activate" at the boundary of chemical and electrochemical storage technologies with applicability for electrical networks, residential and transport. The basic mission is to understand the fundamental phenomena especially at the interface electrolyte/electrode that controls the electrochemical processes and allow a significant further improvement in the performance for the new materials and architectures developed. The laboratory is focused mainly on the type Lithium-Ion and Lithium-Polymer batteries, which are widely recognized to have potential for rapid technological advancement. Moreover, it is well-known that these energy storage systems are available in some form for some time, but the processes at atomic and molecular level that affect the operation and performance are not fully understood. It is expected to achieve a connection between the current technology and new innovations for fulfilling the targets established.

The proposed research infrastructure has defined its objectives in each action groups, as follows:

- Electrochemical Storage - development, characterization and implementation of new technological solutions for Lithium-Ion batteries and Redox batteries, for both stationary and mobile applications.
- Chemical Energy Storage - focused on new technologies for hydrogen storage in gaseous, liquid or metal hydrides. New standards and international cooperation are taken into account.
- Thermal Energy Storage - development of complex technological solutions as thermal energy storage for coupling with solar concentrators, based on molten salt materials.



Laboratories / / Workinggroups

The project is designed to create all the technological prerequisites for the development of new energy storage technologies (electrochemical and thermal) needed to be applied for stationary or mobile applications. ICIT Rm. Vâlcea aims to become the industry standard and promoter in energy

storage technologies and is designed to become an open experimental platform for national and international partners by creating a multidisciplinary research laboratory with several components related to new carbon materials, to specific microstructural investigation, to the development of lithium-ion-polymer batteries and to thermal/solar energy storage systems development.

The development of a research centre focused on creating new equipment and technologies in the energy storage field is a challenging task taking into account the requirements and features needed for such systems, the type and the particularity of each application. The "engine" of the research, development and innovation is represented by the economic benefit and related to this is the fundraising for projects. Besides the exploratory research activity, vital for accumulating the knowledge and the technological basis, the innovative type activities are considered to be the key to success of ROM_ EST laboratory. Based on this vision a small research group for technology transfer was set up, with the scope to take over the interesting results in terms of technology and filter them according to the requirements of potential beneficiaries or partners. From this point of view, cooperation with SME companies that are able to implement technologies developed is important in the laboratory activities.

In accordance with the activities designed to be carried out in this Laboratory, there are a number of services that are likely to be provided by the ROM_EST, towards two major categories of partners:

- **Research Centres and universities*:***
  - Development of new versions of Lithium-ion batteries, according to beneficiary requirements.
  - Development of new materials, new architectures (designs) and specifications (weight, volume, power) (a3D prototyping laboratory is available).
  - Experiments and tests for various electrochemical power sources. (for any electrochemical cell up to 20kW).
  - Mathematical modelling and simulation for various processes of heat and mass transfer in complex geometries.
  - Real-time simulations for grid and energy storage systems(a virtual laboratory with some hardware-software systems for real-time simulation will be available).
  - Microstructural and compositional analysis of surfaces and thin films by AFM-Raman system.
  - Analysis of thermal characteristics of materials.
  - Experiments and tests of thermal storage systems coupled with a solar power concentrator.
  - Production of graphene and carbon nanotubes using a CVD system.
- **Industrial companies (large and slam SMEs):**
  - Technological
  - consultancy for companies in the field of electricity distribution, for implementing and developing electricity storage solutions according to specific application requirements.
  - Design consultancy for electricity storage stations, based on hydrogen or thermal storage.
  - Feasibility studies for stations for power storage.
  - Development of prototypes for lithium-ion batteries for High tech companies.
  - Development of demonstration models for lithium-ion batteries for automotive applications.
  - Design and development of various experimental models by 3D prototyping
  - Providing technologies for ionic conductive electrolyte preparation for battery manufacturers
  - Testing and experiments for batteries
  - Giving new energy storage solutions based on the use of hydrogen.

ICIT Rm. Vâlcea believes that the development of a nationally supported research in the energy storage field is necessary. So, the development of a research centre with well-defined objectives, specific to Romanian economy, but in full compliance with existing targets at European and global level, will be an important step for energy sector and will contribute to the implementation of the strategy related to storage so necessary to ensure the sustainability of the energy sector [5].

5. CONCLUSIONS

The paper presented the strategy that led to the development of this investment and of a new research line, highlighting new opportunities for research and development in the field of energy storage offered by new ROM_EST laboratory. The aim of these activities, summarized in this paper, targets on one hand the development of partnerships with universities and companies for developing customized solutions for particular well-defined applications to be transferred to companies, and on the other hand the beginning of exploratory research programs which allow the development of new materials and architectures for the electrochemical and thermal energy storage.

Starting from the assumption that the technological research and development generally requires both national programs and national/international cooperation, the ICIT Rm. Vâlcea is seeking research topics of interest not only for Romania, this paper presenting one of the research topics of national interest for energy sector.

REFERENCES

[1] ROM-EST Feasibility study ″Research laboratories for energy storage″, 2013
[2] ROM-EST Funding application ″Research laboratories for energy storage″, POS CCE, O2.2.1, 2013
[3] The Strategy of the National Centre for Hydrogen and Fuel Cell, internal document, National Research and Development Institute for Cryogenic and Isotopic Technologies Râmnicu Vâlcea, 2009
[4] Feasibility study "CRYO-HY: Development of ICIT RD infrastructure by creating a low temperature laboratory for energetic applications of cryogenic fluids", 2009
[5] National Strategy for Sustainable Development, http://www.mmediu.ro/dezvoltare_durabila.htm

NOI ABORDĂRI ÎN TEHNOLOGIILE DE STOCARE A ENERGIEI ÎN ROMÂNIA

Ioan ȘTEFĂNESCU[1,2], Mihai VARLAM[2], Elena CARCADEA[2]

[1]Membru corespondent al Academiei de Stiinte Tehnice din Romania,
[2]Institutul Național de Cercetare-Dezvoltare pentru Tehnologii Criogenice și Izotopice - ICSI Rm. Vâlcea

Rezumat: Problema critică referitoare la disponibilitatea surselor de energie și utilizarea lor eficientă a devenit rapid de o importanță vitală. Creșterea populației, coroborată cu o cerere crescândă de energie și materiale, pentru a crește nivelul de trai este de fapt principala cauză a acestei îngrijorări. Toate acestea necesită nu numai o creștere a surselor de energie disponibile dar și o mult mai eficientă modalitate de a utiliza această disponibilitate. Ca urmare, stocarea energiei a devenit vitală atât pentru utilizarea eficientă a surselor de energie regenerabilă cât și pentru transmisia și distribuția eficientă și sigură a energiei electrice. În acest context, lucrarea prezintă o nouă viziune asupra cercetării tehnologice din domeniul stocării energiei prin prisma unei noi facilități de cercetare în curs de dezvoltare în cadrul ICSI Rm. Vâlcea. Laboratoarele de cercetare pentru stocarea energiei au fost gândite astfel încât să conducă la noi abordări în tehnologiile de stocare a energiei, noua facilitate de cercetare propunându-și să "activeze" în zona limitărilor științifice ale tehnologiilor de stocare chimică, electrochimică și termică, aplicabile în domeniul rețelelor electrice, rezidențial, transporturi și comercial. Lucrarea expune câteva aspecte ce țin de misiunea declarată a noilor laboratoare, aceea de a deveni un catalizator și un integrator de rezultate în acest domeniu de importanță strategică pentru sectorul energetic. INCDTCI Râmnicu Vâlcea își propune să devină standardul tehnologic si promotor in domeniul tehnologiilor de stocare energie, fiind proiectat a deveni o platformă experimentală deschisă pentru parteneri naționali sau internaționali.