

# Innovative Pathways to Thermal Energy Storage (INPATH- TES) project

Gabriel Zsembinski<sup>1</sup>, Gundula Weber<sup>2</sup>, Luisa F. Cabeza<sup>1,\*</sup>

<sup>1</sup>GREA Innovació Concurrent, Universitat de Lleida, Edifici CREA, Pere de Cabrera s/n, 25001, Lleida, Spain. Email: lcabeza@diei.udl.cat

<sup>2</sup>AIT Austrian Institute of Technology GmbH/Energy Department, Vienna, Austria

**Abstract:** Following the EC SET-Plan Education and Training Roadmap, the goal of INPATH-TES is to create a network of academia, research institutes and small and medium-sized enterprises (SME) to implement a joint PhD programme on Thermal Energy Storage (TES) technologies. The project consortium consists of 22 partners from 14 different countries consisting of 14 universities, 3 research institutes, 3 industries, and 2 SME. The final result of such a network is to educate professionals on these technologies for the European research and industry institutions. Some of the main challenges identified so far consist of the development of the programme, the implementation of the programme in each country/institution, the development of a Master degree programme (MSc) in Thermal Energy Storage, and to ensure the continuity of the programme after EU funding ends. A total of 14 courses were proposed and defined in detail, which are currently being developed. These courses can be classified in three main groups, so that there are 5 basic common PhD courses, 4 common technology specialisation courses, and 5 research management, dissemination, and communication courses.

**Keywords:** thermal energy storage, PhD programme, e-learning.

## 1. Introduction

The European Strategic Energy Technology Plan (SET-Plan) was established as a strategic plan for energy technology policy in Europe, which comprises measures related to planning, implementation, resources and international cooperation in the field of energy technologies. The European Commission (EC) SET-Plan Education and Training (E&T) Roadmap (JRC Coordination, 2014) is targeted at bringing a structural change in the EU educational landscape by enhanced integration and coordination of the business and the research environment, and it has identified clear gaps and needs for more efficient PhD education in the area of thermal energy storages (TES).

To meet the needs and fill the gaps identified by the SET-Plan E&T Roadmap, the project “Innovative Pathway for PhD research in Thermal Energy Storage” (INPATH-  
TES), coordinated by the University of Lleida, Spain, was launched in May 2015 ([www.inpathtes.eu](http://www.inpathtes.eu)). The project is funded within the framework of the research and innovation programme Horizon 2020 by the EC.

The goal of INPATH-TES is to create a network of academia, research institutes and small and medium-sized enterprises (SME) to cooperate in defining and implementing a joint PhD programme on TES technologies. The final result of such a network will lead to the qualification of professionals in these technologies for European research and industry institutions. The specific objectives and outcomes of INPATH-TES project are:

- to establish a unique joint PhD programme in the field of TES starting year 0+2,
- to develop at least 20 ECTS equivalent common training modules,
- to develop four technology oriented PhD courses,
- to establish one annual joint workshop for PhD students,
- to aim at graduating 28 PhD students per year at year 0+6, and
- to exchange at least 14 PhD students per year between industry and academia.

The INPATH-TES consortium gathers 22 partners from 14 European countries, and consists of 14 universities, 3 research institutes, 3 industries, and 2 small and medium-sized enterprises (SMEs). Currently, they are the core of a future larger network of excellent R&D institutions, and industries for co-funding and industrial placement, sharing infrastructure capacities, and enhancing mobility of students.

## 2. Methodology to establish a joint PhD in TES and main results

The overall approach of INPATH-TES involves a work plan divided in six work packages (see Fig.1), being either coordination or support activities. The main coordination activities contain the development, maintaining and updating of the PhD programme in TES and the implementation of the PhD programme. Main support activities are stakeholder involvement, expansion of partnerships, framework for monitoring and evaluation of INPATH-TES as well as intellectual property rights, and regulatory issues.

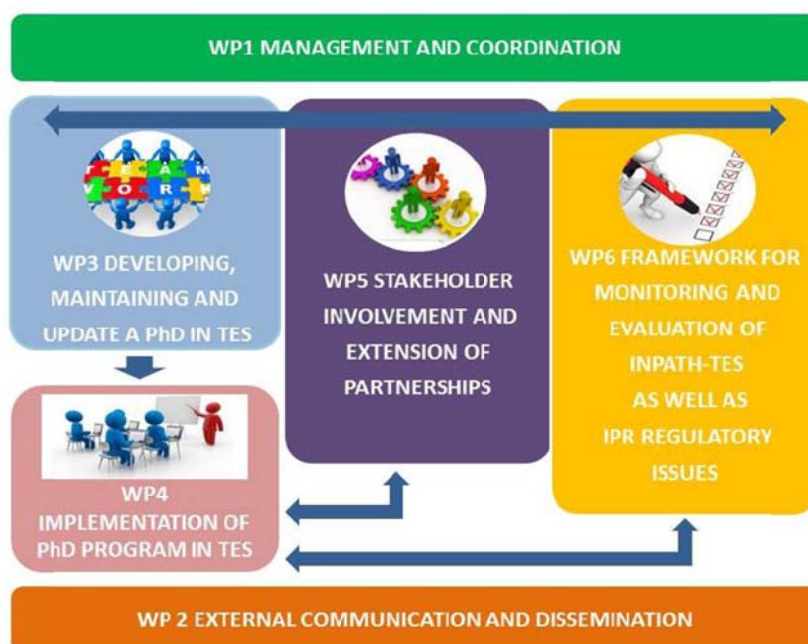


Fig.1 Pert diagram of INPATH-TES project

For the development, maintaining and updating of the PhD programme, a benchmark on PhD level education in the field of “energy storage” was first made, which reconfirmed and consolidated the findings from the SET-Plan E&T Roadmap (JRC Coordination, 2014). In the area of Thermal Energy Storage (TES), the best known practice and knowledge expertise among the 22 consortium members have been identified. Specifically designed PhD curricula serve the purpose of educating and training experts in the field of TES.

Next, a curriculum that can be implemented from a global perspective in ECTS awarding institutions was suggested. There are a total of 14 courses that are currently being developed by the consortium, which can be grouped as follows:

- Basic common PhD courses: Research and PhD, Introduction to thermal energy storage, Thermal energy storage materials, Testing and characterisation of energy storage materials, and Heat and mass transfer and sizing of energy storage devices.
- Common technology specialisation courses: Thermal energy storage applications for buildings, Demand side management concepts and energy storage, Large scale and industrial energy storage, and Energy policy and market development.
- Research management, dissemination, and communication courses (“soft skills”): Intellectual property and patenting ideas, Idea to product development, Dissemination of research results, Funding of research: writing proposals, and Management and entrepreneurship.

Each of these courses is composed of various topics of the fields. Each topic is then composed of different lessons. The lessons can then be “tailor-packaged” to meet the needs of each of the PhD supervisors for their PhD candidates. The concept is to build up small and easy to manage “learning modules” that in different ways can be “packaged” towards courses that the respective PhD supervisors, and their respective universities, can adapt to their own needs with approval of the PhD programme board (see Fig.2). The developed learning material is implemented in the constructive alignment perspective in the EIT (European Institute of Innovation and Technology)/KIC InnoEnergy pedagogical methodology of student-centred learning, aligned teaching, and active learning (Biggs and Tang, 2011).

All the learning material developed during the project duration period should also give the possibility of implementation of a Master of Science (MSc) degree. Among the different types of MSc degrees that could be established, the consortium is considering the possibility of implementing an interuniversity master’s degree at some of the partner universities.

The consortium has identified a Training Advisory Board (TAB) that will, within reasons, review, give advice and recommendations to the course developers related to the course content as well as the methodology used and the presentation of the material.

One of the most important duties of the TAB is to provide a quality control of the PhD programme.

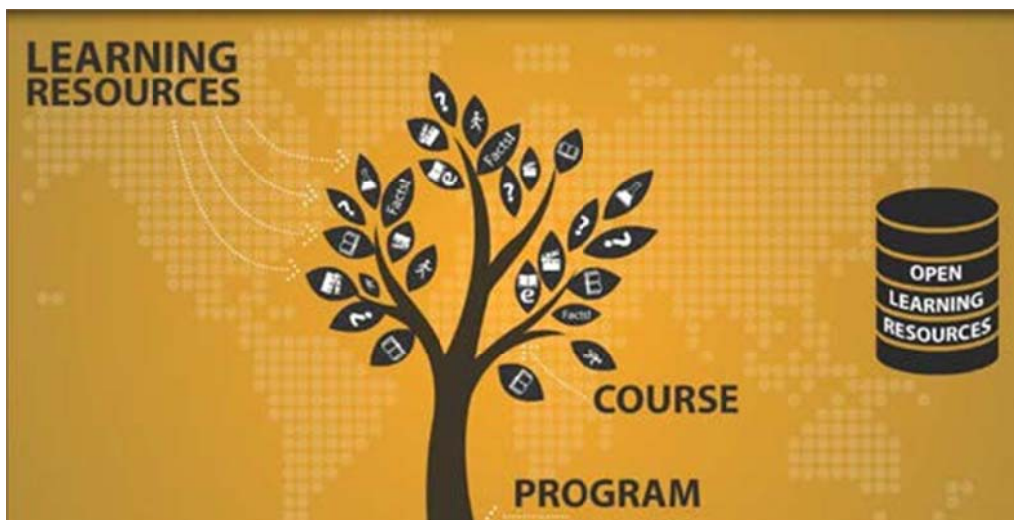


Fig.2 Example of e-learning material in the form of “learning modules” (Fransson 2014)

An e-learning repository platform has been commissioned to host all the learning materials that will be delivered in the PhD curricula. The use of online learning concept is the basis for the “flipped classroom” education. Here, the pedagogical methodology in student centred learning consists of careful design by the teachers of the intended learning outcomes (ILOs) assessed with the achieved learning outcomes (ALOs) assessment questions (EIT handbook, 2016). The online learning platform self-learning section consists of recorded learning videos cut into short segments for efficient learning. In order to get hands-on practice of the crucial technologies students will get access to remote lab exercises and also interactive simulations. Other parts are filmed study visits and online literatures. Each section is followed by tracked self-assessment where students’ performance can be followed up continuously and serve for pedagogic purpose. Randomized automatically corrected calculation exercises are to be programmed so that students may test their skills and knowledge at their convenience.

Another crucial coordinating activity is the implementation of the joint PhD in the partner countries, as it is a key success factor for the future of the PhD Programme. The different legislative barriers and the composition of a PhD programme in the partner countries were evaluated. Main differences were found in the regulation and scope, the structure of the PhD programme, potential doctoral training, skills to be acquired by the student, access to a PhD programme, admission criteria, and the PhD programme requirements. Among the European participating countries in the joint PhD programme, namely Austria, Belgium, France, Germany, Ireland, Israel, Italy, Latvia, Netherlands, Poland, Portugal, Spain, Turkey, UK, the duration of a PhD varies from 2 to 5 years. PhDs are offered in all countries in the framework of a full or part time study. In most of the countries, the supervisor assumes the main role in determining doctoral training curriculum. In most of the participating countries, a Master degree is mandatory to access a PhD programme (exceptions in Ireland, UK and Poland). Hence for the implementation of the joint PhD programme a common approach in line with the

legislative framework in each country must be defined and agreed on. The consortium decided that the simpler strategy to achieve cooperation between partners' universities is to start joint supervision PhDs (co-tutelle).

For the development and implementation of the PhD programme, the presence of a wide range of relevant stakeholders ensures inclusion of knowledge, experiences and needs in the project for high impact visibility. Stakeholders are providing input to the training agenda from a user and societal perspective and help define urgent training and R&D needs. Communication with stakeholder is also important to raise awareness of the importance of INPATH-TES across the EU. A Stakeholder Advisory Board (SHAB) was established during the first 6 months of the project duration, the knowledge and experience of its different members covering all relevant technological aspects for thermal storages: from storage materials to storage unit level up to system integration of storages in buildings, industry, power plants and heat networks for all thermal storage technologies. The SHAB members are contributing to the content of training materials, training needs and research agenda, provide recommendations to the project activities, assist local or European authorities and players and disseminate the results on national and European level.

The relevant stakeholders to engage were identified by the consortium, which included policy makers, industry, small and medium-sized enterprises (SMEs), academics, and non-governmental organisations (NGOs). On the other hand, the target groups for the PhD programme were identified, consisting of undergraduate and MSc students, academics potentially interested in supervising future PhD candidates, and policy makers comprising those bodies that may grant funding to the future PhD students. A general communication strategy was agreed and implemented which contains communication on a regular basis via newsletter and information materials, the organization of events such as breakfast meetings and conferences for policy makers and scientists. At least one international workshop and 14 national workshops are planned in each of the participating country. The focus of the workshops is a transfer of knowledge concerning the current status of the technologies, technical and regulatory aspects, supporting measures, and to increase the level of awareness of INPATH-TES.

Besides these main activities, an online based questionnaire was developed and completed by the stakeholder groups mainly industry, research centres and small and medium-sized enterprises with regard to expectations, needs and future demands of the industry involved in TES technologies. The questionnaire encompassed 14 courses corresponding to the main aspects of the joint PhD programme (thermal energy storage, research management, dissemination and communication and thermal energy storage specialisation), the content of which was evaluated along with the curriculum relevance. The results showed that over 85% of the survey participants were satisfied with the proposed content, and 67% of the participants would host a student in their company. Expectations from industry and research institutes on PhD students can mainly be summarized in:

1. Personal abilities e.g. multidisciplinary, creativeness, impact awareness;

2. Social, economic and technical abilities e.g. understanding of the fundamentals of relevant technological aspects of thermal energy storage, R&D, applications and markets, modelling, system integration, testing and characterisation of products.

The most attractive technical and non-technical topics reported by the industry were taken into account within the process of defining the courses.

Many industrial responses reported the most attractive technical topics as being research methods, thermal energy technologies, the role of thermal energy storages in an energy system, development of new thermal materials, experimental testing, design, modelling, and optimization of thermal energy storage systems. The most interesting non-technical topics were beside energy policies in Europe and international, the basics of patents, the technical implementation of an idea to a product and the publication in a scientific journal.

To reach the stakeholders and target groups identified by the consortium, an external communication strategy has been developed, which sets out a plan to maximise recognition of the project externally using a series of communication tools. The strategy has been designed to involve and engage those actors on a national and international level who can have an impact on the aims and objectives of the project and to spread, the findings, new knowledge, events and initiatives, outputs and results achieved by the consortium. Project branding, a website ([www.inpathtes.eu](http://www.inpathtes.eu)), press releases, bi-annual newsletters, social media platforms and public events such as conferences are the main tools for external communication of the project. In order to promote the INPATH-TES to society, special events such as breakfast meetings, small workshops and seminars were arranged. The 1<sup>st</sup> breakfast meeting was held during the EU Sustainable Energy Week in June 2016 in Brussels in order to reach EU politicians and EC decision makers. Furthermore, to bring together stakeholders from different sectors, such as architects and engineers, industry, scientists and policy-makers, at least two conferences focusing on specific themes within INPATH-TES have been planned. For this purpose, a conference was already held in Beer-Sheva, Israel in February 2016, in addition to a conference for policy makers and stakeholders that was held in June 2016 in Brussels. New types of social media are also being used for communication with the general public, for example collaborative projects, blogs and microblogs (e.g. Twitter: @inpath\_tes), content communities (e.g. YouTube: Story board video), and social networking sites (e.g. LinkedIn: <https://ie.linkedin.com/in/inpath-tes-7bb09b110>).

### **3. Conclusions**

Following the EC SET-Plan E&T Roadmap, the concept of the project INPATH-TES is to establish a joint PhD programme between universities and research centres, on the topic of Thermal Energy Storage. The PhD courses developed by the consortium strengthen PhD study through providing specialist underpinning.

The global curriculum that is to be implemented in ECTS-awarding institutions is composed of five engineering courses, five soft-skill courses and four advanced energy storage courses that can be combined to form PhD curricula.

Out of the PhD programme development, these courses will allow the development of an international Master degree programme (MSc) in Thermal Energy Storage. Wider dissemination access with direct industrial relevance and deployment aspects focussing on developed future markets is expected.

Through active engagement with different stakeholder groups in the project, research and market oriented inputs to the PhD topics were set up in the training courses.

All the leaning material is being implemented in the “flipped classroom” perspective in the EIT/KIC InnoEnergy pedagogical methodology of student-centred learning, aligned teaching and active learning. An e-learning repository platform is being developed, which has the functionality of hosting recorded learning videos for efficient learning, knowledge materials such as e-books, presentations, animations, diagrams, pictures and texts, as well as assessments such as multiple choice questions, fill in the blanks, right/wrong questions, sorting order and others.

The main challenge that has been identified is the implementation of the joint PhD programme in each of the participating countries. Although all participating countries in INPATH-TES are within Europe, differences in the regulatory framework for establishment of PhD programme subsist. The structure, the programme requirements and the admission criteria vary. In order to overcome this problem, the consortium decided to start by defining some bilateral agreements, in which a PhD could be supervised by two partners, being awarded by both institutions, such as Marie Curie EJD projects. This kind of PhD is well recognised in most of the partners’ regulations.

By creating further synergies between INPATH-TES and other global organisations and initiatives, extension of the partnership and exchange of students are foreseen. A strategy and platform for communication and dissemination was developed, to increase the visibility of the project and to support the task of achieving the long-term goals of the project.

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