



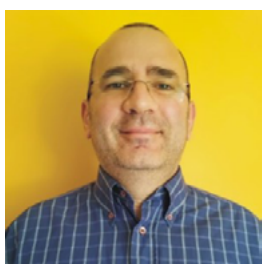
START

NEWSLETTER

RECOVER-REFORM-REUSE

for a Sustainable Future

EDITORIAL



Welcome to the fifth issue of the START project newsletter! In this edition, we're thrilled to present an exclusive interview with João Mascarenhas, the brilliant mind behind Starty, who shares insights into the creation process and future plans for our beloved character. Speaking of Starty,

don't miss the latest comic strip that cleverly demystifies life cycle assessment in a way only Starty can.

We've also got updates on the progress of our work packages, showcasing the collaborative efforts and milestones achieved thus far. The highlight of our year, the annual project meeting at SINTEF, was a resounding success, fostering synergy and innovation among our team members. Our commitment to spreading the word about START's mission continues with a roundup of our dissemination, communication, and clustering activities. Looking ahead, we're excited to announce the upcoming events that promise to further our reach and impact.

This edition features interesting interviews with two experts: one with Dr. Doris Hiam-Galvez, a senior Advisor at Hatch Consulting, who passionately advocates for sustainable development, and another with Hao Yin from TEGnology, discussing cutting-edge topics in the field of thermoelectric technology. Lastly, join us on a virtual tour to meet our partners GEO and MBN, whose contributions are invaluable to the success of the project.

We hope this issue of the newsletter provides you with valuable insights and keeps you informed about the exciting developments within the START project. Thank you for your continued support and engagement. Stay tuned for more updates and breakthroughs in our journey towards a sustainable future.

(F. Neves)

CONTENT

- Recover-Reform-Reuse	1
- STARTY – 5: Sustainable product design	2
- Interview with João Mascarenhas, author of Starty	6
- START Chronicles: Geology, thermoelectrics and more	8
* News from WorkPackages	8
* START Annual Assembly in Oslo, 6-7 June 2024	11
* START webinar #5	12
* START Industrial Workshop “Re-structuring of EU value chain on thermoelectrics - From supply chain to end user”, Kastrup (Denmark), 26th September 2024	13
* START online training course, 25th September-3rd October 2024	14
* START seeks synergies with the XTRACT project	15
* Other START dissemination events	16
- Register for the Clustering Event in Brussels!	19
- Technical pills	20
* Basic LCA Concepts and LCA in the START project	20
- Meet the experts	23
* Interview with Dr Doris HIAM-GALVEZ	23
* Interview with Hao YIN, published on the bulletin of Associazione Italiana di Termoelettricità (Italian Association for Thermoelectricity, AIT)	25
- Consortium tour	27
* GEO Unterweissacher (GEO)	27
* MBN Nanomaterialia (MBN)	28
- Bibliography	29
- Contacts	29

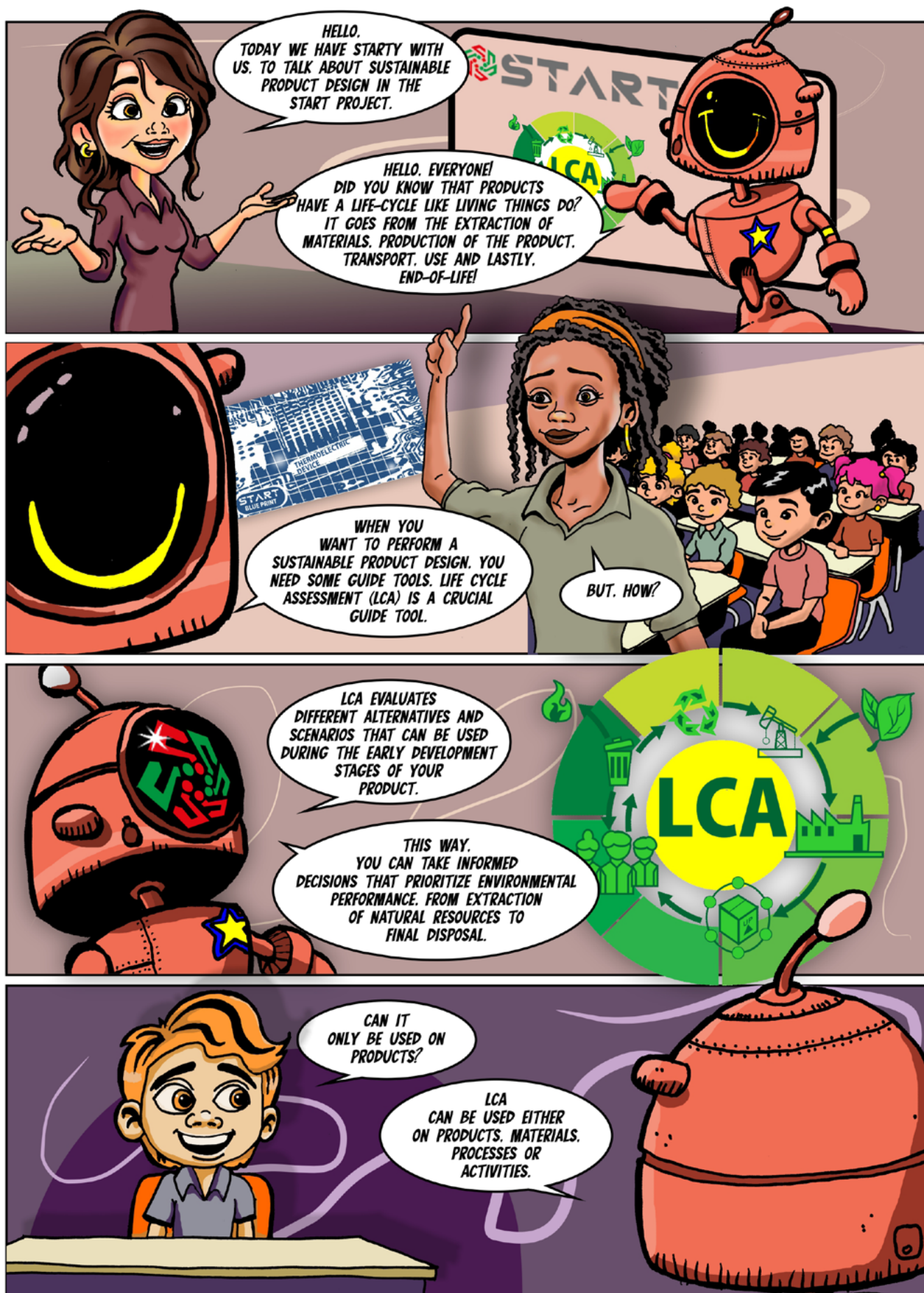


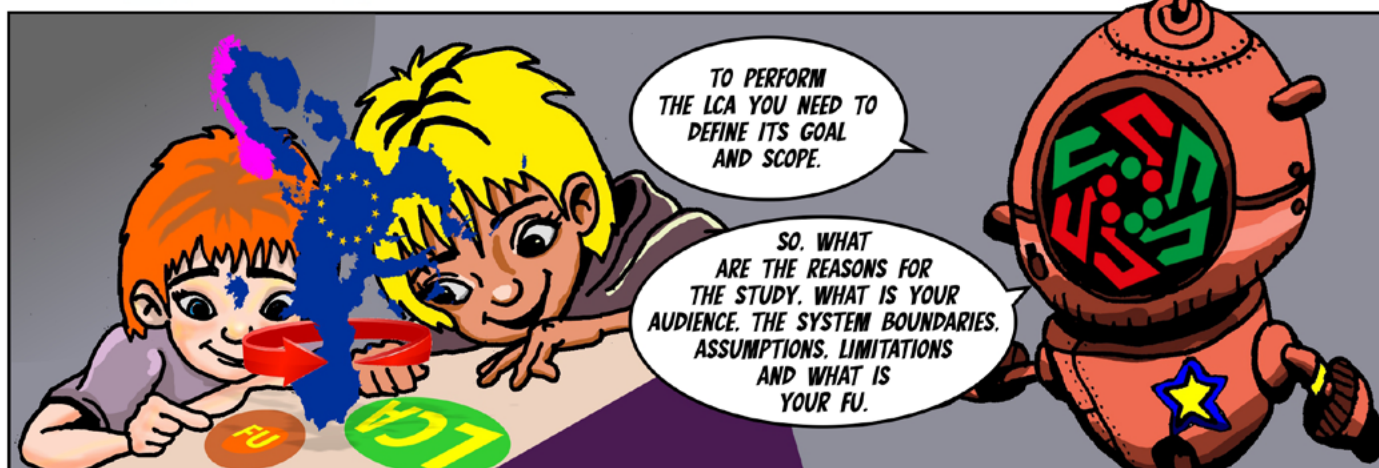
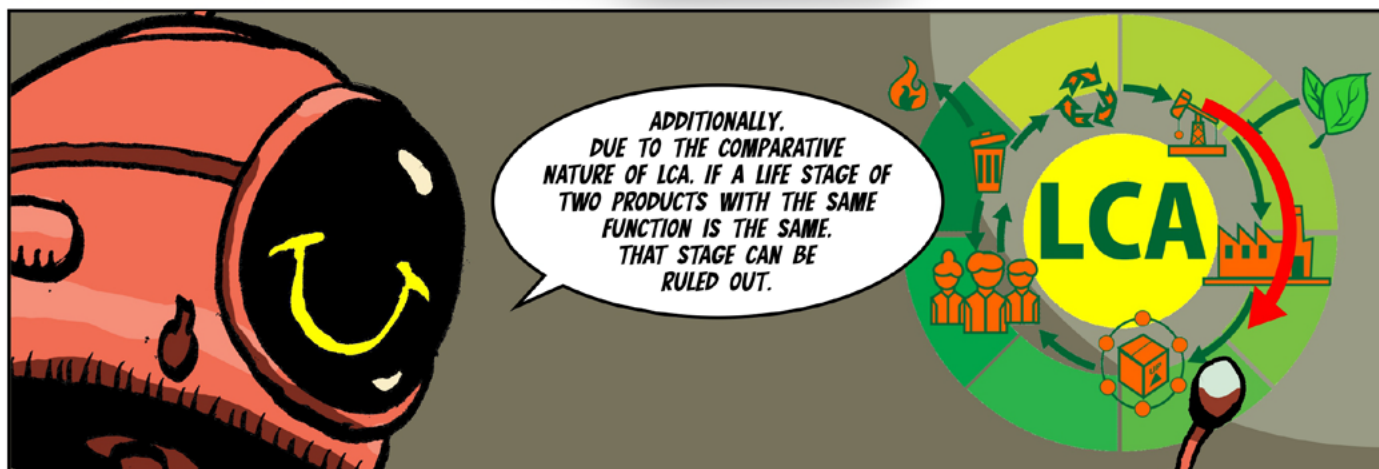
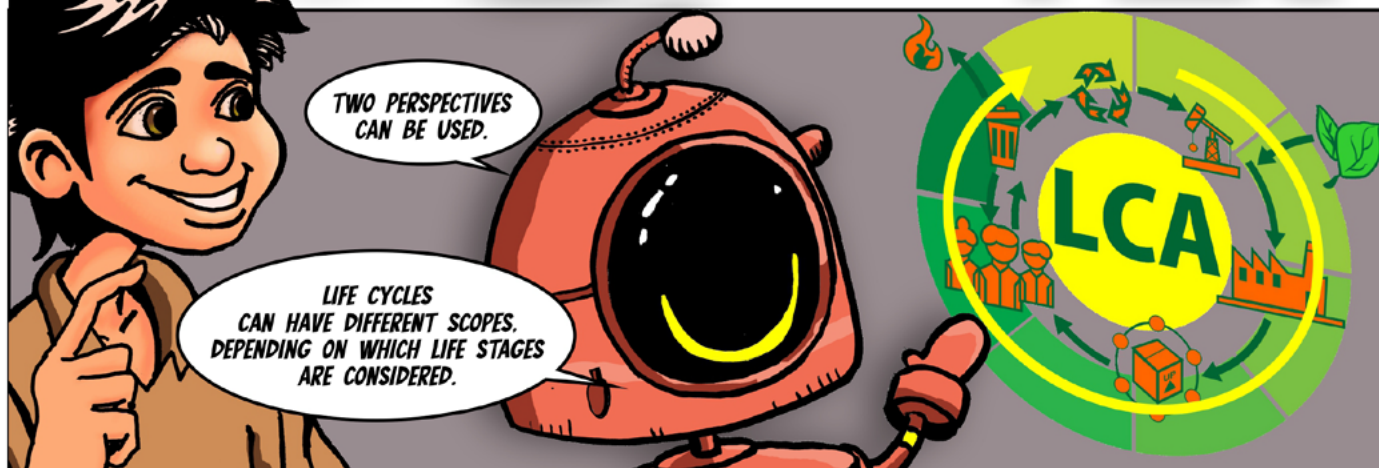
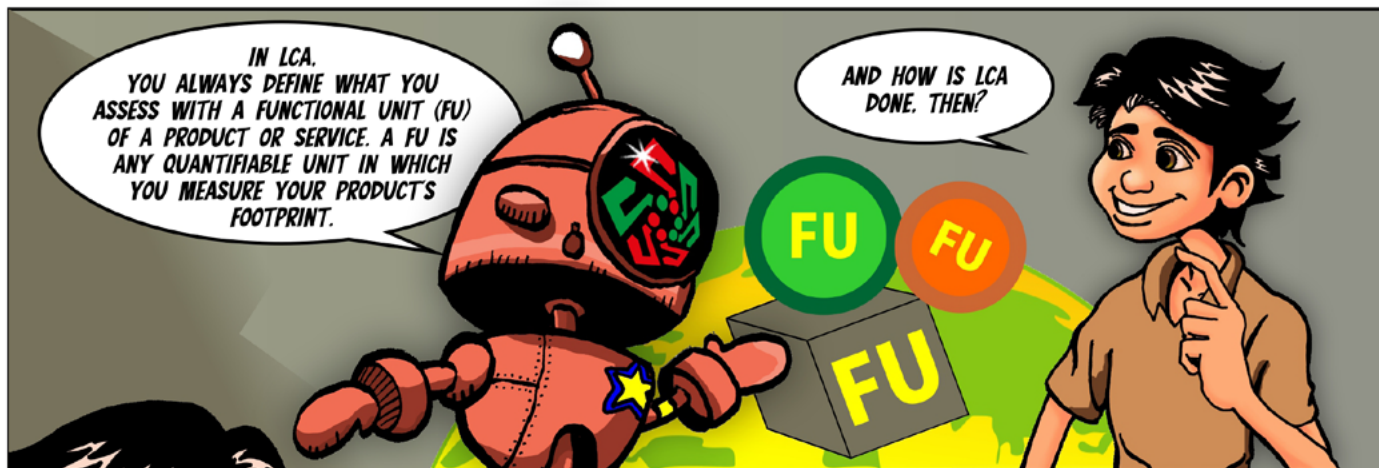
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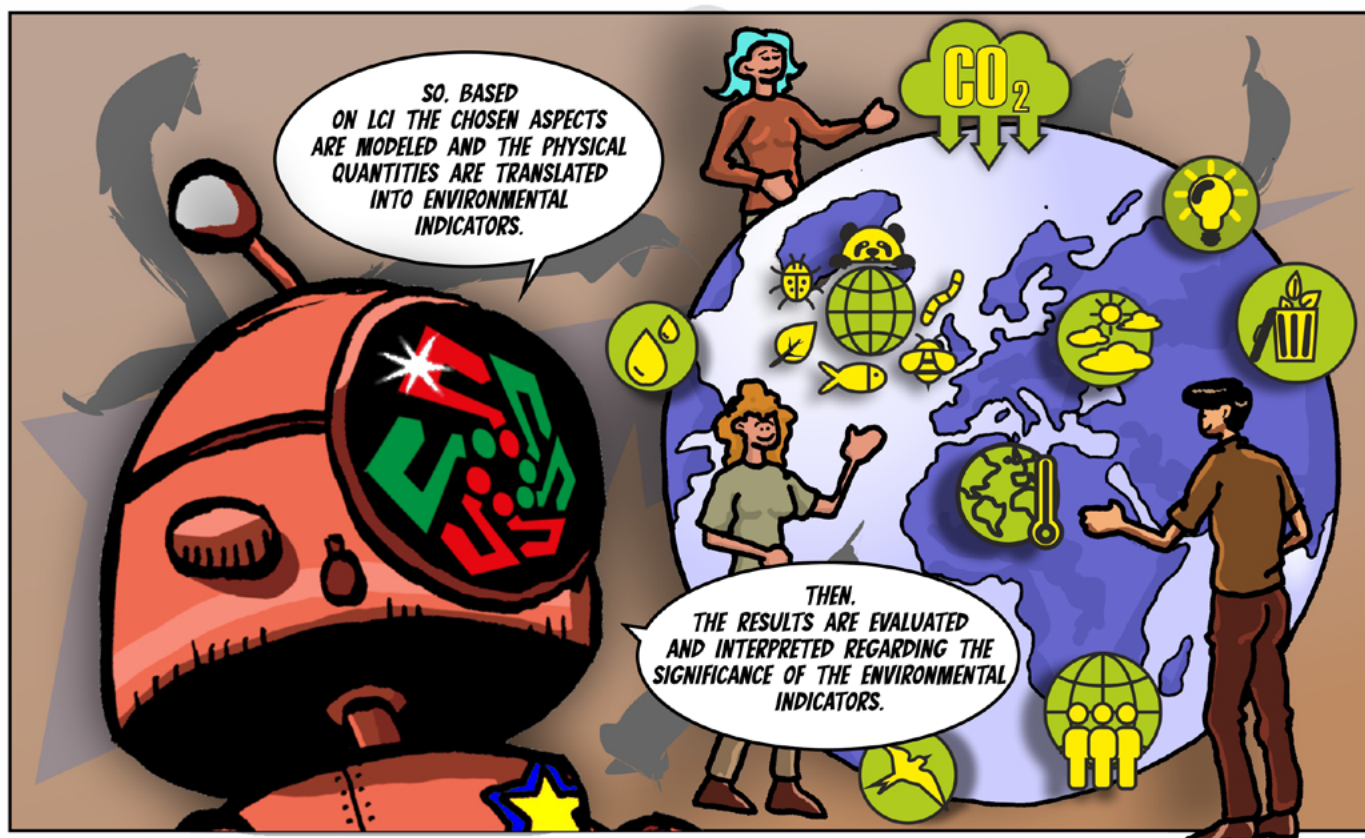
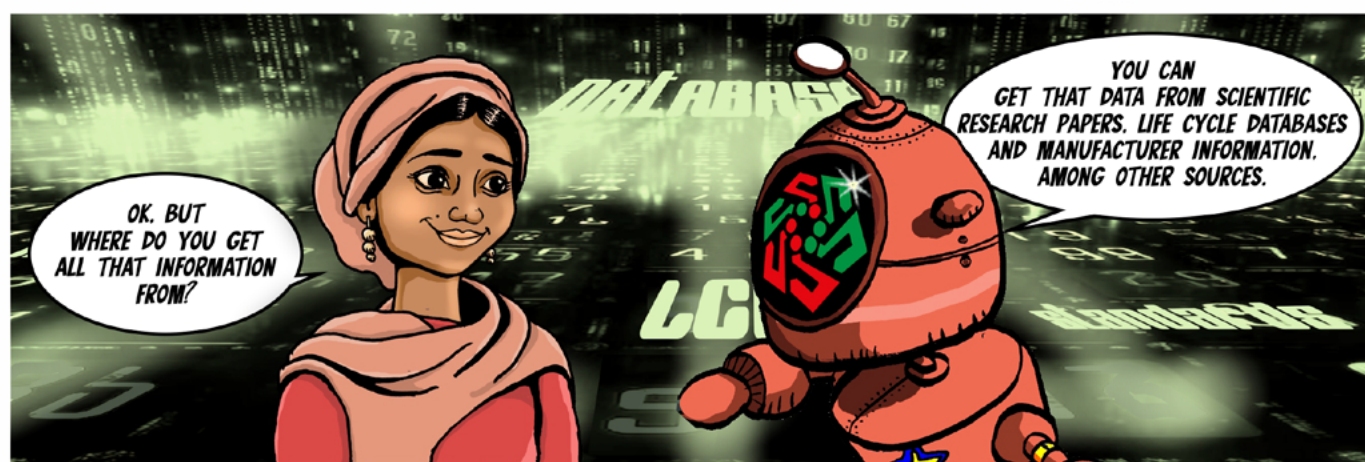
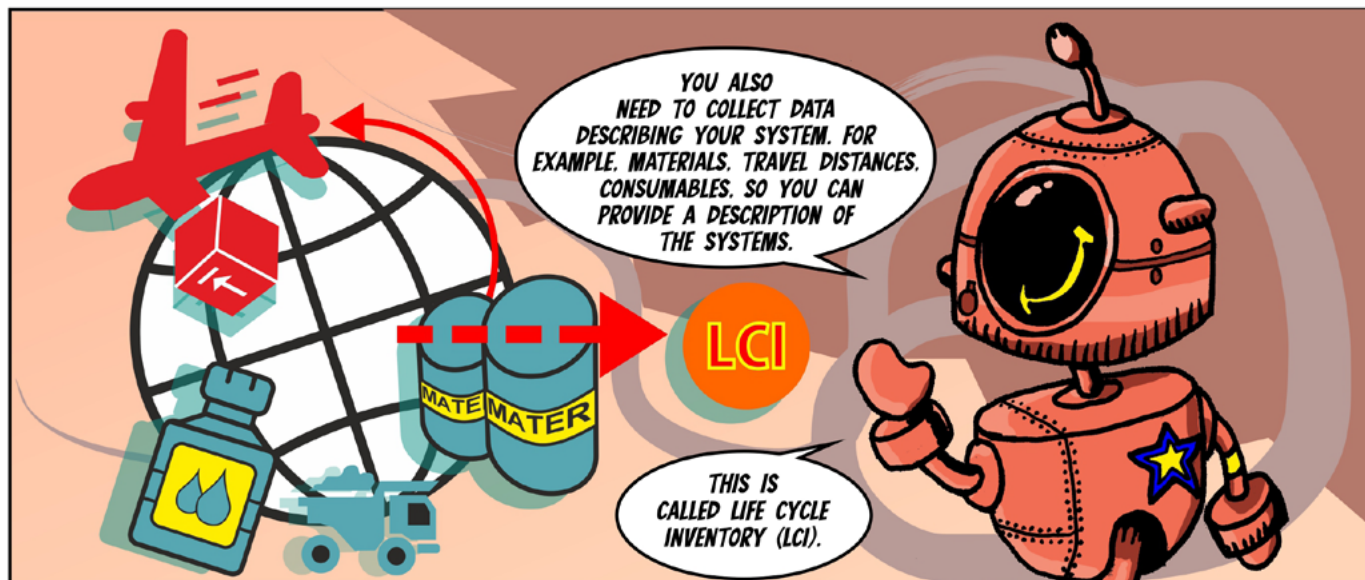
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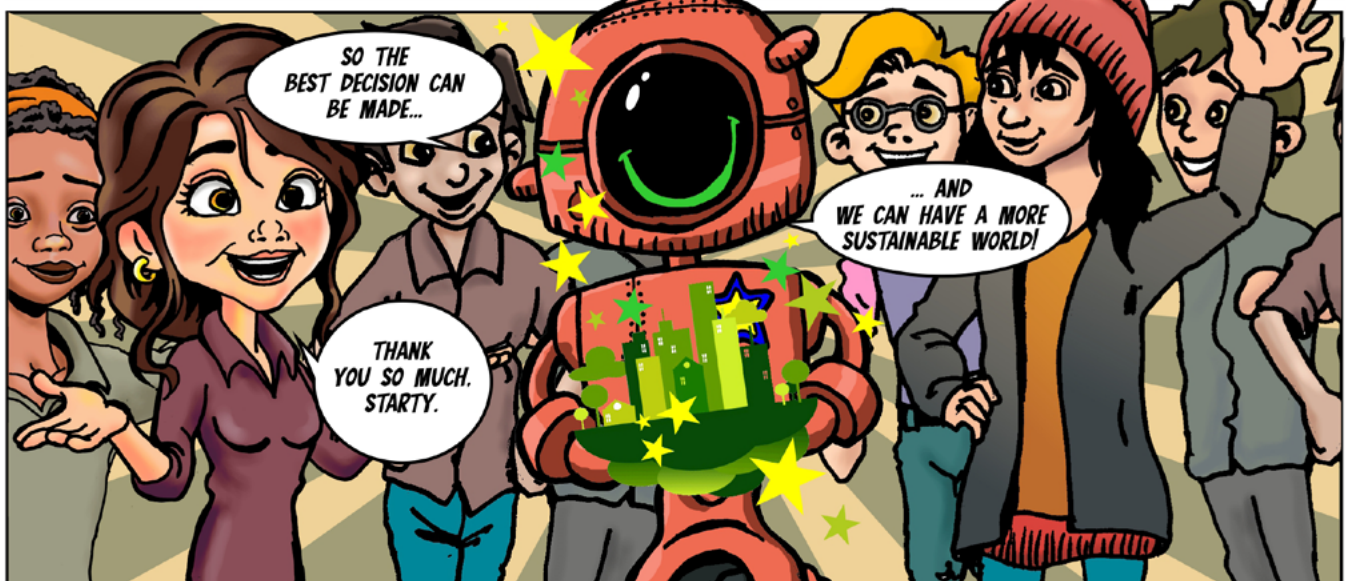
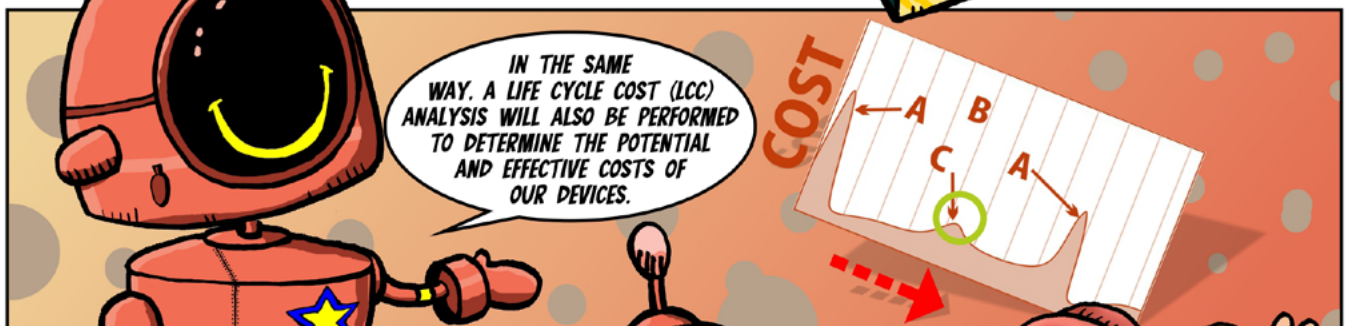
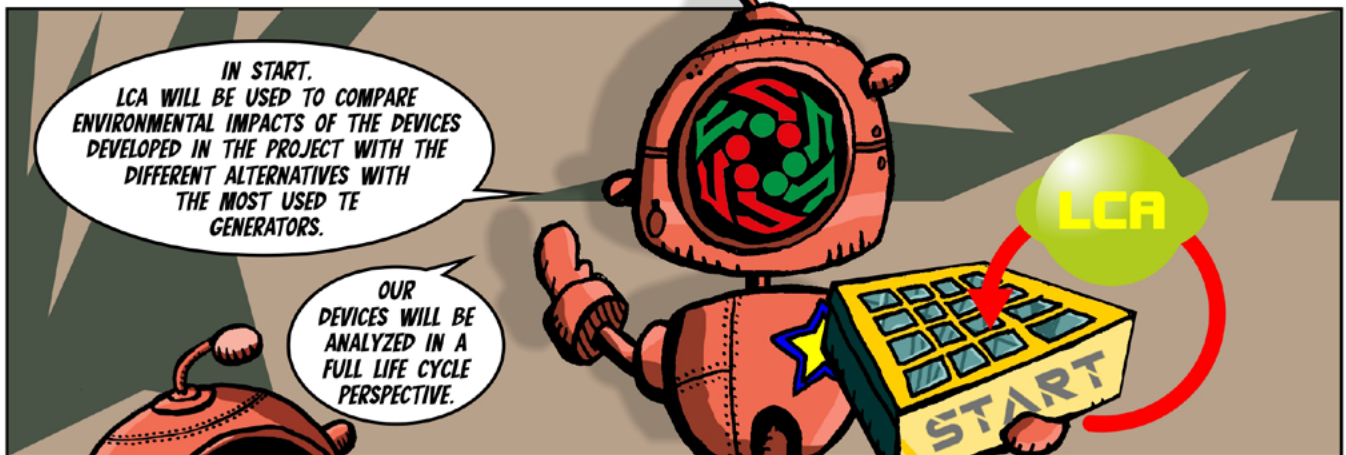
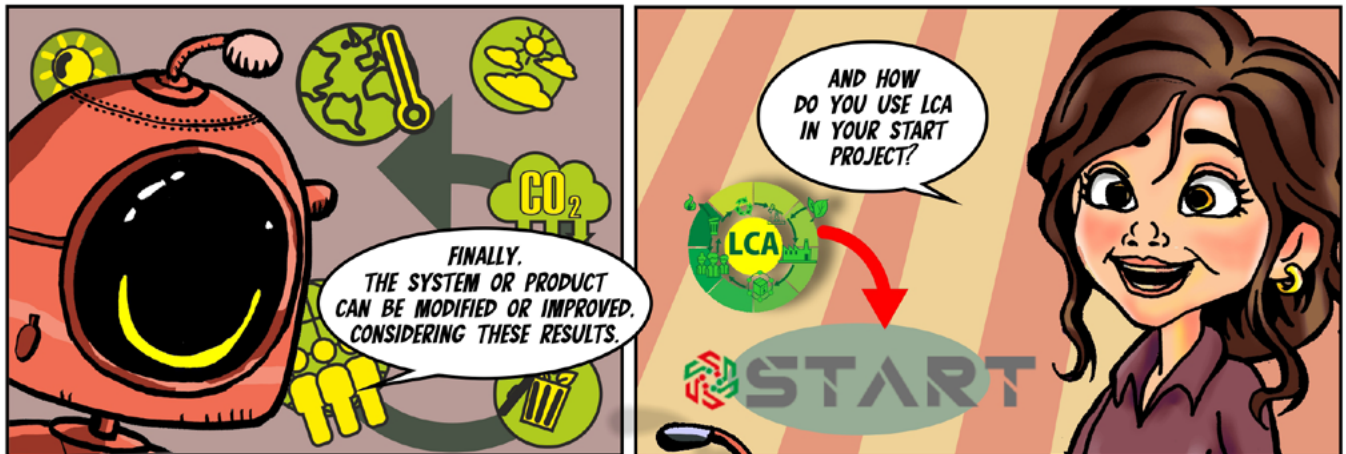
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STARTY - 5: SUSTAINABLE PRODUCT DESIGN









[TO BE CONTINUED...]

INTERVIEW WITH JOÃO MASCARENHAS, AUTHOR OF STARTY



Figure 1 - João Mascarenhas (LNEG), author of Starty and renowned cartoon author.

In this issue, we will take some space to recognize the huge work done by the author of Starty, João Mascarenhas, of Laboratório Nacional de Energia e Geologia, I.P. (LNEG), the coordinating partner of START. João is at the same time a well-known cartoonist and an experienced researcher at LNEG. In his professional career, he has been working on Powder Metallurgy and Materials Science since 1990, and more recently in Materials for Energy. As a cartoonist, he is an internationally awarded author, and his books published in several countries.

Every time a newsletter is prepared, João embarks in the preparation of some pages with Starty. Together with the text on the subject of each issue, he develops and draws the scenes alone. And each time we prepare a multilingual edition, he has to adapt all the dialogues to each language (we have 15 languages on board now!). A lot of effort, with quite good results, what do you think?

Here he will tell us something about his art, its connection to his engineering and research career, and some more details about the idea of Starty. We hope you will enjoy this interview!

Q: Hello João, thanks for accepting to reveal yourself to the readers of the newsletter! You have been working very hard to produce Starty's cartoons for the project, and we think that the readers might be curious to know who produced them. Can you tell us something about how you developed your passion and skills for drawing characters and stories?

João Mascarenhas: It's a pleasure to share some words with our readers. For as long as I can remember, I have always drawn something. But I only started as a comic professional author after my PhD (in 1997). My stories are based on Humanism, the preservation of Memory and the noble values of the Human being.

Q: People can Google your name and will find all the stories you have published. But let's list some of them here _ with some personal words on them.

JM: My best-known books, in national terms, is O Menino Triste (The Sad Boy). This is a character who is my alter ego. It's not about my life, but rather using it as a basis to later build stories, based on my childhood memories, and my experiences as a Human being. I also published a 200-pages book about science fiction, where I speculate about the use of memories that may be retained in our DNA. It's called The Butterfly Chronicles, and was initially published in Portuguese, English and Japanese. My most recent published book deals with a topic that is very much on the agenda, and it has to do with migrations. It is the story of an Arab musician, poet and perfumer who comes to live in Portugal in the 1980s.

Q: What are the tools a cartoonist like you uses nowadays? Supposedly, most of the work is now done digitally; tell us some of your secrets.

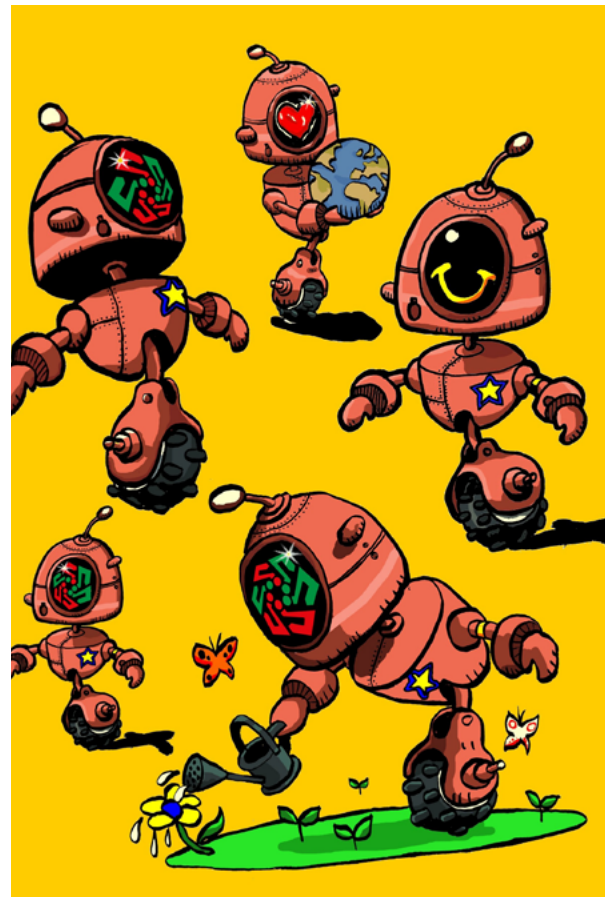
JM: I have no secrets . Normally, I draw in a traditional, conventional way, thatwhat is with the old blue colour pencil. Then I ink the drawings with black ink, using brushes or pens. The blue pencil is because when the drawings are scanned, the blue colour does not appear on the digital file, so it is not necessary to erase the pencil traces, as we need to do with the carbon pencil. These digital inked drawings are then coloured in the computer, that is a powerful tool, as it allows the author to change colours all over the process.

Q: You are an artist, but also an engineer, a scientist. People often think that scientists are “dry” persons, that just think by numbers and logic. I think you can object against this view!

JM: Yes. Normally, people have that idea. But it is not right. Even the more “traditional” engineers or scientists, they must be very creative to perform their work. We’ve all seen engineering work where we say, Wow, that’s a work of art! Personally, I do not know if I am an engineer that makes art, or an artist that does engineering. Whenever I can, I bring comics to Science, and Science to Comics. An example of the first case is our “STARTY”. An example of the second case is what I did a few years ago with a colleague of mine who is a biologist. He, using my hair, extracted my DNA. This DNA was multiplied and placed in an alcohol suspension, which I mixed with the ink with which I drew the autographs for one of my books.

Q: Let’s talk about Starty. You came up with this idea immediately, and everyone was enthusiastic about it. Let’s explain why we chose a robot, with a somewhat “steampunk” (please correct me if I am wrong, João!) appearance, as testimonial for START.

JM: The idea of making a comic book with the work we are developing in the START project occurred at the first project meeting. Some colleagues suggested creating a kind of dictionary with some of the main topics about thermoelectric materials and devices. The project leader immediately said that what would be done was a Comic Book, for the general public, and I would draw it. So, considering the nowadays reality, we decided to use a small robot, with the capacity of explain to everyone what we are doing. Not only explaining, but also answering to questions that someone could do. It’s natural AI



Q: What should people expect now? I think we will see Starty not only in the cartoons, but also elsewhere... who said “game”? Can we give some spoilers?

JM: Yes, our scientists are keen on showing the European (and not only) people what we are developing in the START project. So, various approaches can be taken. One is the STARTY comic book, and the other one is a Board Game, that can be played by up to four players or four teams. So, questions and answers are the way the players can go along the game, having fun and at the same time acquiring some knowledge about the area of our project, regarding the materials, the devices, the way they are manufactured, their use and some aspects of sustainability and circular economy. It will be possible to play this game on a board, or in digital format.

We are looking forward to Starty’s new adventures, and we hope that some readers can also be attracted by your other works. Thanks, João!

JM: I hope that both the Comics and the Board Game can help the public become familiar with the topic of thermoelectric devices and materials, as it will be something they will increasingly encounter on a daily basis. Thank you so much.

Well, stay tuned with us and you will have more from João!

START CHRONICLES: GEOLOGY, THERMOELECTRICS AND MORE

News from Work Packages

NEWS FROM WORK PACKAGE 4 "Maximising thermal stability"

A task force has been created within WP4 to specifically investigate how to maximize the thermal stability of the tetrahedrites through composition optimization, while mitigating any deleterious effects on thermoelectric performance. Keeping in mind that Fe substitution is to be maximized to take fully advantage of the high proportion of this element in the ore, two research lines are currently being pursued:

1. Substitution of copper by refractory metals to minimize sulphur sublimation and possibly promote the formation of a passivation layer through oxidation in service conditions.
2. Substitution of copper by nickel following the suggestion of the industrial consultant involved in the project.

Evaluation is carried out by screening the compositions through high energy ball milling followed by thermogravimetric experiments in inert and oxidative atmospheres. The best materials in terms of minimization of sulphur sublimation are subsequently sintered and tested to determine the power factors and thermoelectric figure of merits.

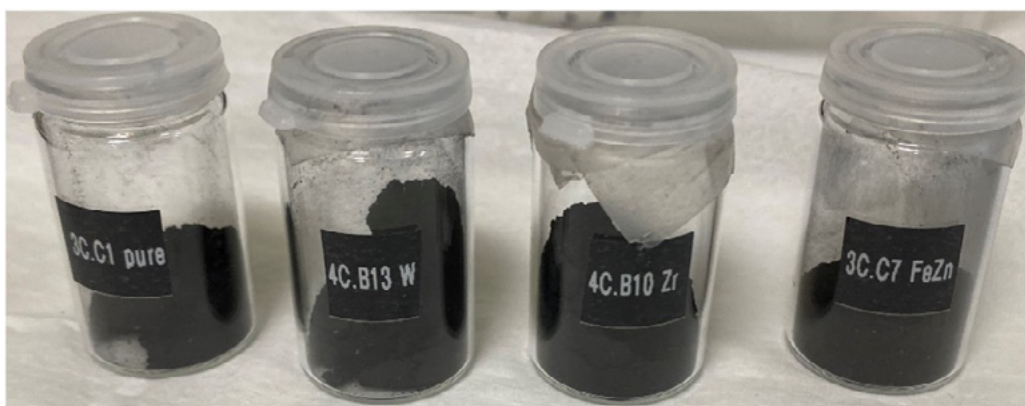


Figure 2 - Materials to be tested by thermogravimetry at 350 °C for 24h.

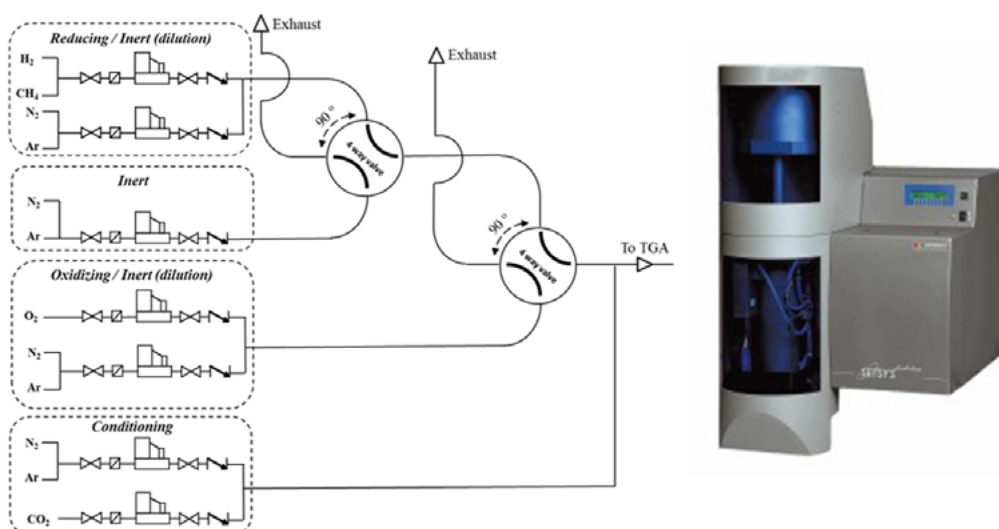


Figure 3 - Apparatus used for thermogravimetry measurements.

NEWS FROM WORK PACKAGE 5 "Design and construction of prototype TE modules"

In Task T5.1, the COMSOL model developed by RGS and SINTEF successfully incorporated the experimental data of the synthetically produced p-type tetrahedrite and the n-type magnesium antimonide material (Figure 4(a)). The temperature of the "Hot-Side" was fixed at 350°C to simulate the high-temperature application (Combined Heat and Power generation, CHP) and the fill factor (ratio of active thermoelectric material to uncouple surface area) was varied to optimize for maximum power generation (Figure 4(b,c)). In the following steps we will account for the electrical resistances of the interfacial materials (diffusion barrier layer, bonding material) and perform a detailed mechanical stress analysis of such a uncouple.

Task T5.2 focusses on the physical build-up of the module. A selected diffusion barrier layer was coated on both the p- and n-type materials as shown in Figure 5(a). Following this, the first dicing tests were carried out to obtain pellets (as shown in Figure 5(b,c)) to fabricate the first small tri-uncouple modules (Figure 5(d)). The electrical resistances of these uncouples will be measured, followed by a careful evaluation of the nanostructured silver bonds (cross-sectional imaging, shear tests). The next steps will involve the preparations for one-step bonding of the entire module (31 uncouples), including the design and fabrication of a stencil plate for silver paste application and of a brazing jig for holding the 62 thermoelectric pellets in place.

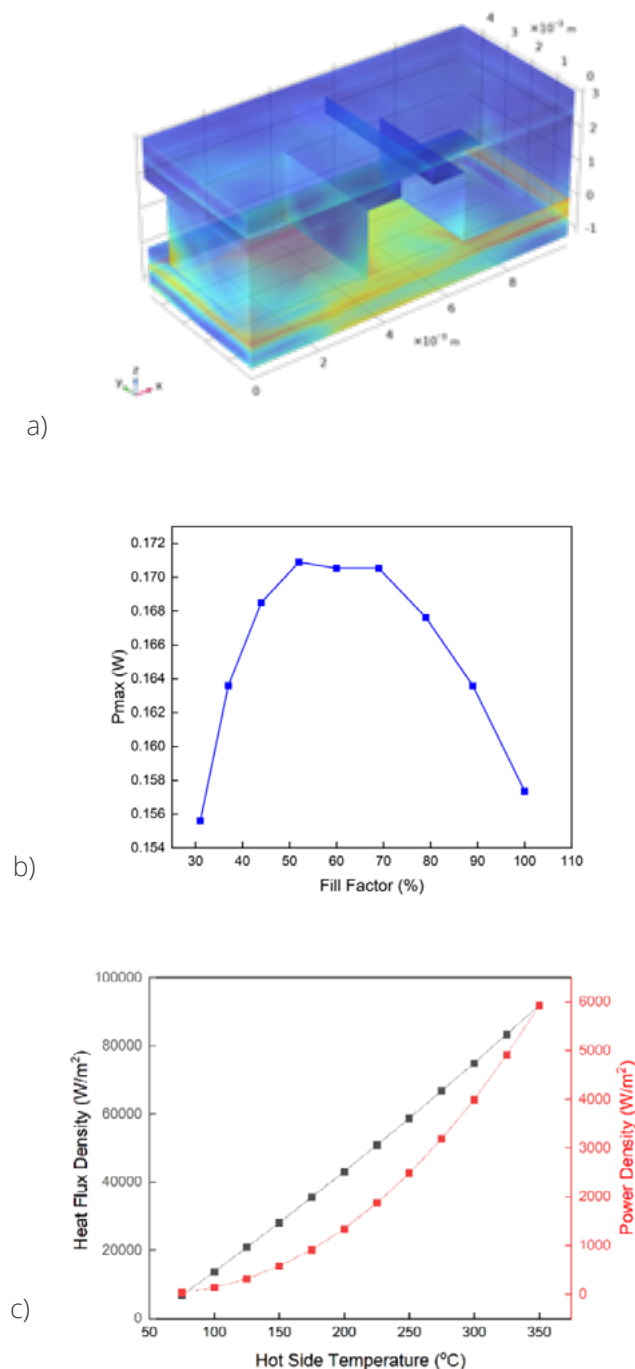


Figure 4 - COMSOL model developed by RGS and SINTEF: a) model, temperature of the "Hot-Side" fixed at 350°C; b) fill factor dependence of maximum power; c) hot side temperature dependence of heat flux density and power density.

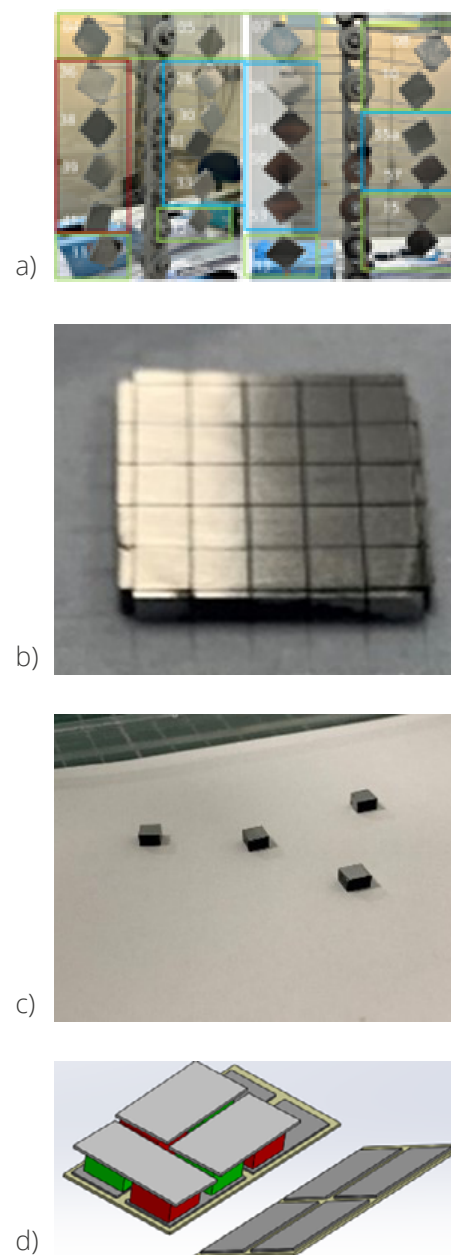


Figure 5 - Building a module. a) coating both p- and n-type elements with a diffusion barrier; b) slicing of the wafers; c) individual elements; d) design of the tri-uncouple module.

NEWS FROM WORK PACKAGE 7 “Preparing for the future”

In WP7 there are parallel activities going on for investigating and enhancing both the short/mid-term and the long-term future potentials of sustainable thermoelectric systems and applications.

During the 2024 Annual Assembly meeting (6th and 7th June 2024, Oslo), two workshops were held with the lead of LPRC. On Day 1, the focus was on data collection on commercial and feasibility aspects and key parameters of the START value chain that formulates the basis for assessing the industrial and economic viability of future technological developments. Day 2 included another workshop, this time dedicated to the sustainability of the START project itself after the funding period. During the event, participants contributed to the creation of a Lean Canvas of the START Service Company, that is to be established during the project lifetime to ensure that START results and findings are brought out to society and, more importantly, to potential businesses that will become the beneficiaries of a sustainable thermoelectric-based economic environment.

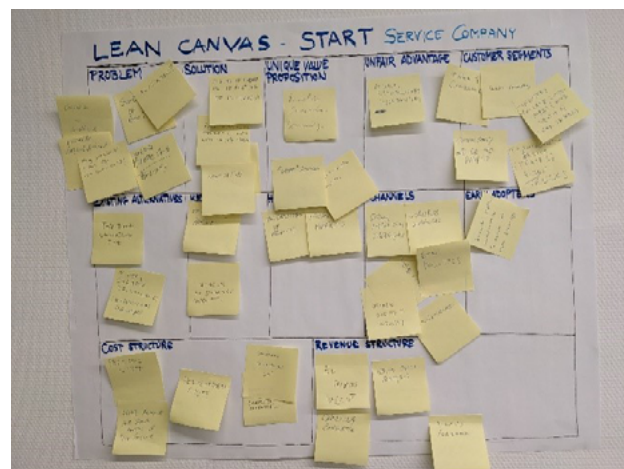


Figure 6 : Lean Canvas for the START Service Company developed during the workshop on sustainability of the START project.

In WP7 there are parallel activities going on for investigating and enhancing both the short/mid-term and the long-term future potentials of sustainable thermoelectric systems and applications.

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START Value Chain framework

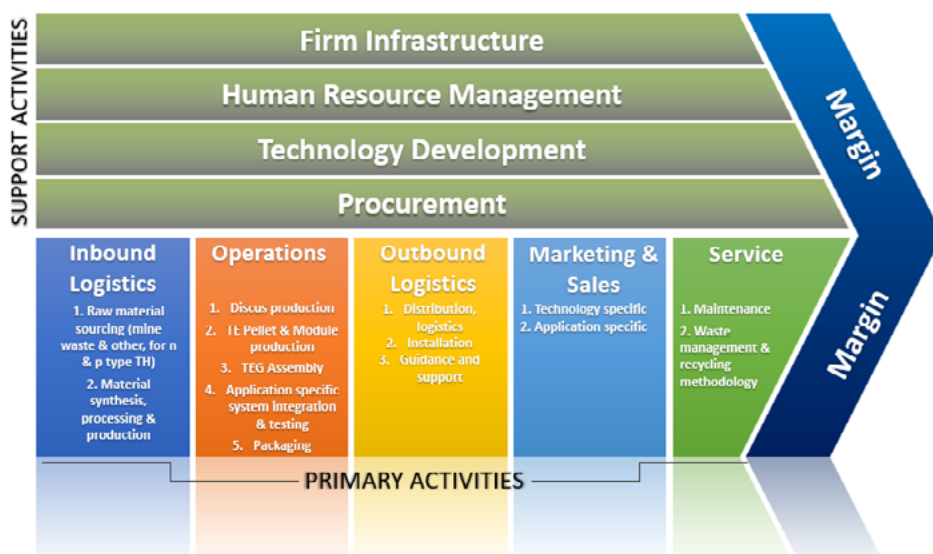


Figure 7 : START Value Chain framework developed for the START project.

START Annual Assembly in Oslo, 6-7 June 2024

On 6th and 7th June 2024, it was time to meet all together again for our third General Assembly. The host this time, in the fantastic city of Oslo, was the team at SINTEF, that let us use a very good meeting room in its great premises just some metro stops away from the centre of Oslo. Apart from some remarkably sunny Nordic weather (that you can see in [Figure 6](#)), the meeting was remarkable for the very interesting discussions among partners on the technical work done, and the challenges and opportunities that emerged from the various internal workshops organised within each work package. It was a time were all could review the results of the activities on minerals characterisation and concentration, preparation of tetrahedrite powders, optimisation of the composition, fabrication of samples and their characterisation, assessment of material stability, evaluation of sustainability, and dissemination and exploitation efforts. The activities were reviewed and discussed, and a plan for the next month was made for each task.

A lovely consortium dinner took place downtown Oslo on the night of the 6th.

During the second day the partners also actively took part in START's 5th free webinar (see the relevant news item below).

J.-Y. Escabasse was also involved in the meeting as a member of the Scientific Advisory Board (thanks Jean-Yves!) and spoke in the webinar as well.

We look forward to the next meeting in 2025!



Figure 8 - The START group at the third general assembly held in Oslo, at SINTEF's premises.

START webinar #5

As mentioned, we ran our 5th free START webinar during our Annual Meeting in SINTEF's facilities in Oslo (Norway), on 7th June 2024. The meeting room was fully equipped for hybrid meetings, thanks to SINTEF, so we had two speakers on site, and one connected remotely, and we had about 60 registrants for that part.

The hybrid event was dedicated to the important topic "Thermoelectric devices and applications": our two TE devices producers and industrial partners, RGS Development and TEGnology, presented on high- and low-temperature applications, with speeches by Maarten den Heijer and Hao Yin, respectively. Additionally, we announced a new project, STAR-TREC, involving J.-I. Escabasse, member of our Scientific Advisory Board, as a presenter.

We also used the webinar to advertise for the Industrial Workshop, very linked to the theme of the session, that we were organising for the next September in Copenhagen (see below).

This is the full agenda of the 5th webinar:

Webinar "Thermoelectric devices and applications" – Friday, June 7th (11:00 – 12:45 CEST)

- 11:00 Welcome and introduction by Bruno Vicenzi (European Powder Metallurgy Association) and Filipe Neves (LNEG)
- 11:00-11:30: "Thermoelectric Power Generation applications for Heavy industries and Combined Heat and Power" by Maarten den Heijer (RGS Development) [Slides only]
- 11:30-12:00: "100% Green Power for IoT sensors and industrial applications from low-grade excessive heat" by Hao Yin (TEGnology)
- 12:00-12:30: "Adding value to TEG design by Additive Manufacturing: illustration in STARTREC, a new HORIZON project" by Jean-Yves Escabasse (CEA-Liten and START's Scientific Advisory Board)
- 12:30-12:45: Q&A

The footage was unfortunately incomplete due to an IT issue, but the partially recovered video has later been made available in our website's Multimedia page, and of course on our YouTube channel¹. One of the presentations has been made available in the video only as slides and we apologise for that.

Thanks to the speakers and to all participants!



Project: 101058632
HORIZON-CL4-2021-RESILIENCE-01



Closing remarks

Sizeable Markets for Thermoelectrics can be identified. These are new markets, which require to be established across the value chain

The value chain development starts with raising end user interest and initiation of launching projects. Therefore the solution must be sufficiently mature (>TRL6)

All positions in the value chain will have to move simultaneously, hence share the recognition of future perspective



5th START Webinar, Thermoelectric devices and applications, June 7th, 2024
www.start-heproject.com

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Figure 9 - A screenshot from the 5th webinar footage.

START Industrial Workshop “Re-structuring of EU value chain on thermoelectrics - From supply chain to end user”, Kastrup (Denmark), 26th September 2024

Following several internal discussions on how to foster a quantum leap in the use of thermoelectrics, in particular in Europe, we came up with the idea of organizing an Industrial Workshop to try to re-structure an effective value chain in Europe. One of the objectives was also that thermoelectrics be recognized as one of the significant ways to make Europe more energy efficient in a sustainable way.

In coordination with the M-era.Net project THERMOS and the Eurostars project FLEX-TEG and based on the local efforts of our partner TEGnology, we invited all relevant stakeholders (all known companies using thermoelectric devices, those who are interested in introducing them, all industrial companies, startups and research actors in the field) by direct contacts and online advertisement.

The venue for the one-day workshop, that was totally free of charge, was the Clarion Hotel at Copenhagen Airport, a very convenient place as it is directly connected to the airport arrival hall, easy to reach for the participants from anywhere in the world. And in fact, we had speakers and participants even coming from Korea!

The agenda was split into two main parts: first a plenary part with several invited speakers, and in the afternoon, three different breakout sessions on different aspects, plus a specific time for networking and matchmaking, at the end of the event, during a break. H. Yin gave his closing remarks at the end.

Full details on the event, including the final programme with all speakers, can be found on our website, in a specific page² that was used to advertise the workshop and collect more registrations.

The participation was very good! Seventy people in the workshop, which is not easy for a relatively small community like that of thermoelectrics; and speakers from important actors in the field like the European Energy Research Agency, the Japanese National Institute for Materials Science, the Korea Advanced Institute of Science & Technology and the Hanyang University in South Korea, The German Space Centre (DLR), TUVienna, RGS Development, QuickOhm, DTP Thermoelectrics, Wideco, Fraunhofer IFAM, and many others in the breakout sessions. The three projects (START, THERMOS and FLEX-TEG) presented themselves. The breakout rooms in the afternoon, with four more speakers and a discussion in each room, allowed the participants to delve into more details for the respective competence areas, and during lunches and breaks they had the chance of meeting (or re-meeting) each other and establish connections. Very useful also for our consortium colleagues that are working for the future exploitation of the START results.

The meeting was a clear success and there may be a next edition in the future. START is keen on obtaining improvements in the supply chain, not only for the tetrahedrite solution it pursues, but for the whole industry.



Figure 10 - Group photo of the participants at the START Industrial Workshop in Copenhagen



Figure 11 - The full room in the plenary session.



Figure 12 - Our four speakers in the event, clockwise and “in order of appearance” in the workshop, starting from top left: Hao Yin (TEGnology), also local organiser and moderator of the plenary; Maarten den Heijer (RGS Developments); Filipe Neves (LNEG), our coordinator; Alvis Bianchin (MBN Nanomaterialia).

START online training course, 25th September-3rd October 2024

Between September 25 and October 3, 2024, the "Virtual Course: Mining Environmental Liabilities and Secondary Raw Materials" was held, organized by ASGMI³. This course was organized within the framework of the START project with the objective to provide participants a deep understanding of mining processes, their environmental and social impacts, and equipping them with the necessary tools for the identification, evaluation, and remediation of environmental liabilities.

The course, primarily aimed at postgraduate students, featured 7 experts from different fields who, in 6 sessions, delivered lectures on the following topics:

- Fundamentals of Mining Environmental Liabilities (MELs)
- Environmental and health risks related to MELs: From risk assessment to rehabilitation
- Remediation of Environmental Liabilities
- Reuse of Secondary Raw Materials
- Environmental Management and Corporate Social Responsibility
- Colleagues from IGME who are involved in the START project gave a presentation about the project.

The workshop had 419 registered participants, including 112 students from various countries in Europe and outside the European Union.

The materials (presentations and session recordings) are available on the ASGMI website³. Students requesting a certificate of completion were required to first complete an evaluation test.



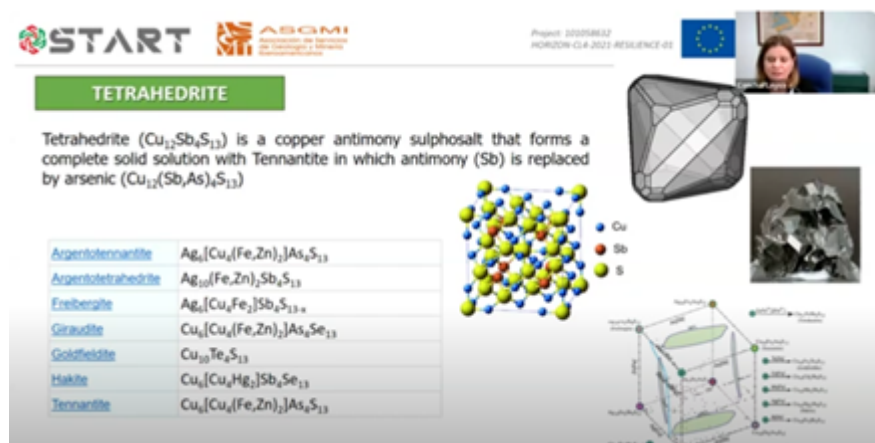
ASGMI | START PROJECT VIRTUAL TRAINING

25th Sept - 3rd Oct 2024 (10 hours)

"Mining environmental liabilities and secondary raw materials"

REGISTER NOW

Figure 13 - The advertisement used to collect registrations, on websites and on social media.



TETRAHEDRITE

Tetrahedrite ($\text{Cu}_{12}\text{Sb}_4\text{S}_{13}$) is a copper antimony sulphosalt that forms a complete solid solution with Tennantite in which antimony (Sb) is replaced by arsenic ($\text{Cu}_{12}(\text{Sb},\text{As})_4\text{S}_{13}$)

Argentotennantite	$\text{Ag}_{10}[\text{Cu}_2(\text{Fe},\text{Zn})_2]\text{As}_2\text{S}_{13}$
Argentotetrahedrite	$\text{Ag}_{10}[\text{Cu}_2(\text{Fe},\text{Zn})_2]\text{Sb}_2\text{S}_{13}$
Freibergite	$\text{Ag}_{10}[\text{Cu}_2\text{Fe}_2]\text{Sb}_2\text{S}_{13}$
Giraudite	$\text{Cu}_{10}[\text{Cu}_2(\text{Fe},\text{Zn})_2]\text{As}_2\text{S}_{13}$
Goldfieldite	$\text{Cu}_{10}\text{Te}_2\text{S}_{13}$
Hakite	$\text{Cu}_6[\text{Cu}_2\text{Hg}_2]\text{Sb}_2\text{S}_{13}$
Tennantite	$\text{Cu}_{10}[\text{Cu}_2(\text{Fe},\text{Zn})_2]\text{As}_2\text{S}_{13}$

Figure 14 - A moment of the course, where tetrahedrite, our material of election, was introduced.

START seeks synergies with the XTRACT project

In its clustering activities, START is getting in contact with other projects that share one or more topics with us. This is the case of XTRACT, another Horizon Europe project that was funded in 2023. Although XTRACT clearly focused on the improvement of mining and processing, in a preliminary meeting we had together we already identified the use of secondary raw materials (in our case clearly the mine wastes containing tetrahydrites) to extract useful materials for the EU industrial supply chains as a common ground.

We will surely do many things together with XTRACT in the near future! Stay tuned with us (next issues of the newsletter, news on common events and initiatives) and then for more details. Here follows a short description of XTRACT, but you can also find more information on the XTRACT project in the links⁴.

XTRACT (Horizon Europe, project number 101138432)

The XTRACT project aims to develop a sustainable ecosystem for innovative resource recovery and complex ore extraction. The goal is to reduce ore losses and mining waste through a novel system for controlling ore loss and dilution, thereby reducing overall mine emissions and economic loss. XTRACT will develop and validate innovative microinvasive

technologies and solutions tailored for remote, "hard-to-reach" locations and small quantities where extraction is typically unprofitable. The in-situ bioleaching process and membrane treatment will be optimized to achieve maximum metal recovery.

Launched in December 2023, XTRACT is a three-year Horizon Europe-funded initiative involving 14 partner organizations from 9 European countries. The project aims to contribute to the EU Climate Neutrality Goals by introducing low-TRL green technologies for mine waste remediation and the extraction of precious metals. XTRACT aligns with the European Commission's ambition for self-sufficiency in critical raw materials essential for the green and digital transition.

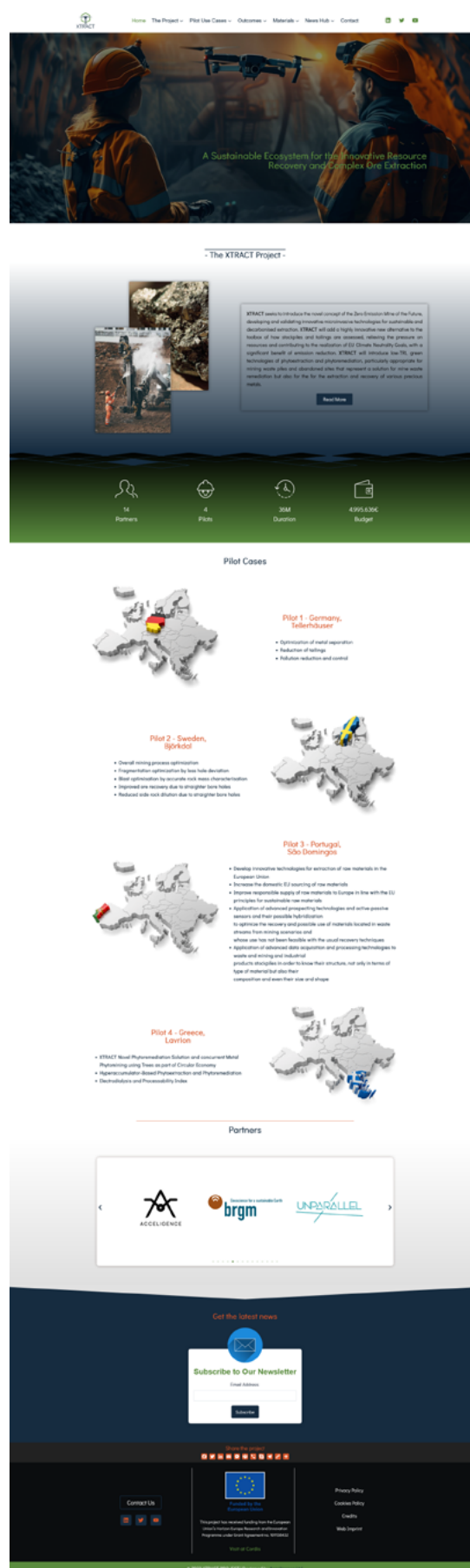


Figure 15 - The XTRACT homepage, where the main topic and the mines where they are actively working are clearly indicated.

Other START dissemination events

XXIX Ordinary General Assembly of ASGMI, April 2024., Huasca de Ocampo – Pachuca de Soto, Hidalgo, Mexico.

The XXIX Ordinary General Assembly of ASGMI⁵ took place in April 2024 in Mexico. The event was attended by Directors of the Geological Surveys from 15 different Ibero-American countries, as well as invited experts from the Geological Survey of Canada and the United States. During the event, a technical workshop was held in which the topic “the role of geological services in the energy transition” was discussed. This workshop highlighted the importance of sustainable mining activities, which involve the proper management of mining environmental liabilities



Figure 16 - Group of participants at the XXIX Ordinary Assembly of ASGMI, in Mexico.

and the reuse of secondary raw materials. In this context, a presentation was also made about the activities of ASGMI's Expert Groups, ASGMI's participation in European projects, and a presentation of the START project.

EPMA General Assembly, Brussels and hybrid, 16th May 2024

The 2024 EPMA General Assembly was celebrated on 16th May 2024 in a hybrid format and gathered many members of the association (about 30 considering on site and remotely connected participants). In the afternoon, a presentation of Serena Busatto (MBN Nanomaterialia SpA) was given, titled “START approach to powder metallurgy: Advanced materials for energy harvesting”.

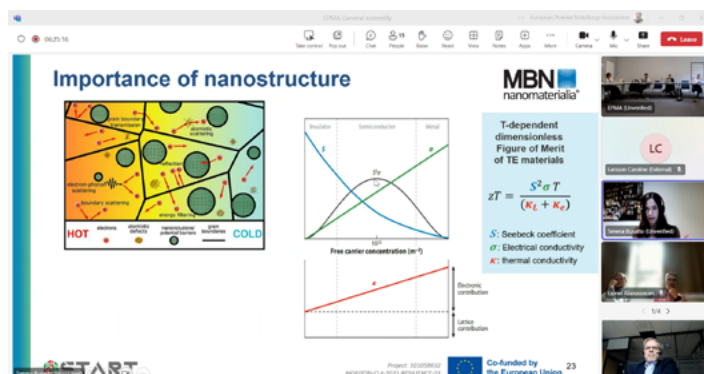


Figure 17 - A moment of Serena Busatto's presentation in the EPMA General Assembly 2024.

START at the 40th International and 20th European Thermoelectric Conference, ICT/ECT 2024, Krakow, Poland, 30th June - 4th July 2024



Welcome Conference Traveling Registration Thermoelectric School Login LOT Polish Airlines - Official Carrier

11:00-11:30	Coffee break	Large Hall A Session: TE systems Chairman: Jan KOENIG	Large Hall B Session: Cu-based chalcogenides II Chairman: Paz VAQUEIRO	Medium Hall Session: Composites Chairman: Xanthippi ZIANNI
11:30-11:45		M. M. Maia, A. L. Pires, Andre M. PEREIRA Wireless Energy Transfer using Photothermoelectric Devices	Filipe NEVES Tetrahedrite-based thermoelectrics: the START project's approach	Vijay VAIYAPURI, A. Jayaram, N. Mani Boosting the thermoelectric performance of HfMgSiCNF composites via thermally activated conduction and microstructure engineering
11:45-12:00		Álvaro CASI, A. Patricia, C. David, A. Rial, R. Antonio Thermoelectric Subcooling Optimization for Enhancing Vapour Compression Refrigeration Systems	Juliusz LESZCZYŃSKI, P. Leskisz, C. Candolfi, B. Lenoir, P. Nieroda, A. Koleszyski Thermoelectric properties of $\text{Cu}_{1-x}\text{Fe}_x\text{Mn}_2\text{Sb}_{2-x}\text{Te}_2\text{S}_3$ tetrahedrites	Van Quang Nguyen, Thi Huong Nguyen, Cheng Chang, Li-dong Zhao, Jungho Park, Jae Ki Lee, Su-dong Park, Sunglae CHO SnSe-SnSe ₂ & Bi ₂ Se ₃ -Sb ₂ Se ₃ Multilayered Composite Crystal: Growth and Thermoelectric Properties
12:00-12:15		David ASTRAIN, M. Araziz, L. Catalan, H. Pascual, P. Alegria Electric production from fumarols of volcanic origin in Antarctica by passive thermoelectric generators	Cancelled	Andrii BOICHUK, T. Boichuk, M. F. Changarath, M. Kreřmarová, J. P. Martínez-Pastor, J. F. Sánchez-Rayo Novel 2D materials with tunable properties for thermoelectric application
12:15-12:30			Tian-Yu YANG, Y.-X. Zhang, Z.-H. Ge Pseudomorphic Phase Engineering for Improved Thermoelectric Performance in Copper Sulfides	Peter BALÁŽ, M. Raják, M. B. Hudaib, L. Kubiřková, H. Daneu, P. Levinský, K. Křizek, J. Holmánek, R. Ůzunda, M. Achromovřová, M. Baláž Mechanochemistry in Preparation of Chalkalite/Stannite Nanocomposites: Kinetics of Synthesis and Thermoelectricity
12:30-12:45		Mykola MAKSYMUK, T. Parashchuk, A. Buribek, K. T. Wojciechowski High energy conversion efficiency realized by the thermoelectric converter with stepwise legs	Frantisek MIHOK, K. Sakai, M. Kruszewski, S. Michalik Polarity switch and thermoelectric properties of polycrystalline SnSe doped with Bi	Abinaya RENGARAJAN, M. Naveenath, J. Archana Enhanced charge transfer at zero-barrier injection of MoS ₂ -MoO ₃ nanocomposites for thermoelectric applications
12:45-13:00		Alaa ATTAR, A. Alharbi A New Design of a Geothermal Thermoelectric Generator System (GTEG) for Geothermal Heat Recovery	Sana SALAMI, S. Pailhes, C. Adessi, V. Giordano, H. Mahoezi, Z. Mihovski, S. Vignoli, R. Debord, R. Fulcrand, H. Blanchard, A. Every, S.R. Naidoo Phonon-drag in a graphite channel buried in diamond	Nouredine OUELDA, A. Portavoce, K. Houmada Crystalline Mg-Ag-Sb thermoelectric thin films for energy harvesting applications

Figure 18 - Programme of the ECT/ICT conference in Krakow, with F. Neves' presentation highlighted in orange (top center).

40th International Conference on Thermoelectrics - ICT/ECT2024START was present at the 40th International and 20th European Thermoelectric Conference, ICT/ECT 2024, that took place in Krakow, Poland, from 30th June to 4th July 2024. This is the main international event for thermoelectrics, that this year put together the European and the International events in the Polish conference.

The technical programme saw two presentations from START.

F. Neves (LNEG) presented as invited speaker in the session “Cu-based Chalcogenides II” on Thursday 4th July with the title “Tetrahedrite-based thermoelectrics: the START project's approach” (Figure 18), while A. Ray (RGS Developments) spoke on the same day on the topic “Thermoelectric Modules and Applications: An Industrial Perspective” in the session “TE Industry” (Figure 19).

THURSDAY, JULY 4, 2024			
	Large Hall A Session: TE Industry Chairman: Jean-Pierre FLEURIAL	Large Hall B Session: Zintl phases II Chairman: Franck GASCOIN	Medium Hall Session: Organic materials Chairman: Przemysław DATA
9:00-9:15	Vincent LINSEIS <i>Thermoelectric Metrology: A Comprehensive Review from a Manufacturer's Perspective</i> (Linsais Messtechnik GmbH, Germany)	Alexandra ZEWALKINK <i>Thermoelectric properties of layered AlX compounds with tunable vacancy concentrations and interlayer bonding</i>	S. Muhammad, D. Motta, M. Ronomo, F. Marchini, S. Carli, S. Caramori, C. Barolo, Andrea REALE <i>Deep eutectic solvents for thermoelectrochemical redox systems for waste-heat recovery applications</i>
9:15-9:30	R. Mohanramani, R. Lydland, Richard S. TULEY <i>Device substrates: high performance with low thermal conductivity</i> (European Thermodynamics Ltd, UK)		Kunusuke OCHI, Ryota MIYAKE, Yuki HANAMURA, Hirokazu IADA <i>Thermoelectric Properties of Ionic Liquids</i>
9:30-9:45	Alex GUREVICH, I. Steiner, Z. Dashevsky, S. Vitnuk <i>A High Performance Thermoelectric Modules with Substrates Made by Vapor Chamber Technology</i> (Double Check Ltd, Israel)	S. Baranets, A. Ovchinnikov, Svilen BOREV <i>Structural disorder in Zintl phases: The case of Yb₂MnSb₂ and Yb₂AlSb₂</i>	O. Calabrese, R. Cecchini, M. Ferri, F. Mancarella, D. Gentili, M. Cavallini, V. Morandi, Fabiola LISCIO <i>Enhancing Organic Thermoelectric Materials Through Local Control Wetting</i>
9:45-10:00	Aniruddha RAY, M. D. Hojer <i>Thermoelectric Modules and Applications: An Industrial Perspective</i> (RGS Development, Netherlands)	Amandine DUPRICHY, F. Kreps, E. Müller, J. de Boer <i>Unlocking the full potential of MgAgSb by unravelling the interrelation of phase constitution and thermoelectric properties</i>	Szymon GOGOC, P. Data, K. Wojciechowski <i>Influence of acidic p-type dopant on thermoelectric properties of conducting polymers</i>
10:00-10:15	Damian KARPOWICZ <i>Enhancing Thermoelectric Efficiency: The U-HAST Glovebox Solution</i> (Genicore, Poland)	Longquan WANG, W. Zhang, S. Back, N. Kawamoto, D. H. Nguyen, T. Mon <i>High-performance Mg₂Sb₂-based thermoelectrics with increased structural ordering and microstructure evolution</i>	M. Betty LINCOLN, R. A. Sujatha, P. Veluswamy, H. Ikeda <i>Flexible polymer based textile thermoelectric generator for wearable human body energy harvesting</i>
10:15-10:30	Uttam GHOSHAL, K. Kolle, A. Stautzenberger, M. Koelzer, J. Jamison <i>Large-Scale Integrated Microcooler Technology</i> (Sheetak Inc., Austin, USA)	Kejia LIU, C. Chen, H. Li, Y. Chen <i>Advancing thermoelectric performance in NaCdSb-based Zintl phase via the synergistic effect of Na deficiency and dynamic doping</i>	Sanyin QIU, Q. Xu, C. Ming, P. Olu, X. Shi, L. Chen <i>High-performance n-type Bi₂Te₃/PVDF/graphdiyne organic-inorganic flexible thermoelectric composites</i>
10:30-10:45	Marein BORCUCH, Michal MUSIAL <i>The performance study of the gas-liquid thermoelectric generator for waste heat harvesting</i> (TCEGOS, Poland)	Shunya SAKANE, A. Ayukawa, N. Kikidoshi, Y. Yamashita, H. Uono <i>Thermoelectric performance of epitaxially grown Mg₂Sb₂ thin films on sapphire substrates</i>	Sajid MUHAMMAD, M. Franzini, S. Galliano, C. Barolo, A. Reale <i>Printable thermoelectric devices based on organic semiconductor composites for low-temperature grade energy harvesting</i>
10:45-11:00		Hong-Jing SHANG, H.-W. Gu, F.-Z. Ding <i>Realizing ultrahigh zT values in Mg₂(Sb,Bi)₂ for superior thermoelectric power-generation</i>	Shun-ichiro ITO, K. Kanahashi, H. Tanaka, B. Chen, H. Ohta, T. Takanobu, Temperature Dependence of Thermoelectric Properties in Electrochemically-Doped Conducting Polymer PBTTT

Figure 19 - Programme of the ECT/ICT conference in Krakow, with A. Ray's presentation highlighted.



Figure 20 - Members of the START consortium at the booth in the ECT/ICT conference in Krakow

EPMA Powder Metallurgy Summer School, Alessandria (Italy), 15th - 19th July 2024

The 22nd EPMA powder Metallurgy Summer School was hosted in Alessandria (Italy) from 15th to 19th July. In this event, that has been running since 1998, more than 60 trainees coming from all over Europe (and even from outside Europe) are being taught by experienced lecturers from academy and industry the basics of powder metallurgy. In this edition, they were shown a small demonstration about thermoelectric devices. The demo was brought to the School by TEGnology, one of the partners in the project, and Hao Yin explained how these devices can be used for waste heat harvesting and other applications. This happened in two separate groups, one on Wednesday 17th and the other on Thursday 18th.



Figure 21 - H. Yin (TEGnology) addressing a group of students at the 22nd EPMA PM Summer School.

In addition to this, B. Vicenzi of EPMA gave some basic info about the project in the initial speech of the school, and START leaflets were available for the participants



Figure 22 - B. Vicenzi (EPMA) explaining the basics of START in the plenary session of the 22nd EPMA PM Summer School on Monday 15th July 2024.

START at the MacaroNight on 27th September 2024

In 2024 there was again a START presence at the MacaroNight event that LPRC organised in the Canary Islands as part of the European Researchers' Night. LPRC printed 100 copies of the START comic, which were given to the visitors at the EU Corner. In total, there were 762 students and 171 general public attending the event.

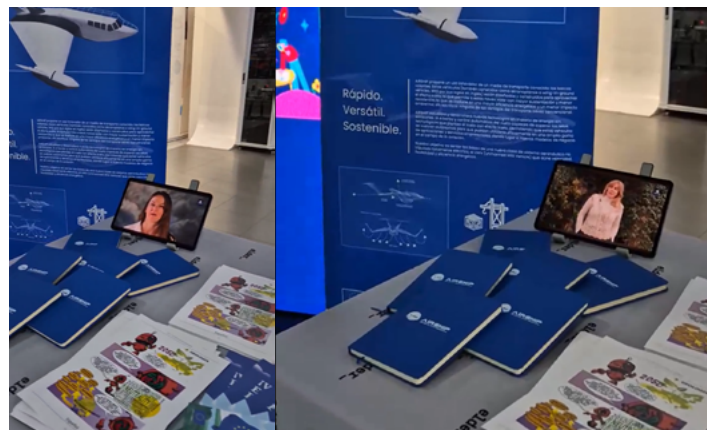


Figure 22 - START leaflets available at the 2024 Macaronight.

Euro PM2024 Congress & Exhibition, Malmö (Sweden), 29th September - 2nd October 2024



START took part with its own booth in the Euro PM2024 European Powder Metallurgy Congress & Exhibition, organised as usual by EPMA and taking place this year in Malmö (Sweden) from 29th September to 2nd October. The booth featured all materials about the project, posters, roller banner, leaflets, looping video with the Starty stories published to date, samples in the showcase, all available for the visitors of the large PM community. The thermoelectric device demo from TEGnology already taken to the EPMA Summer School was shown at the booth as well.

This year there was no presentation of START in the technical sessions, but there was again a visit of the so-called Young Engineers, a group of students that have a special care during the congress, and in particular visit the exhibition booths; D.; Karpowicz (GeniCore), A. Colella and E. Forlin (MBN) addressed them on the afternoon of Tuesday 1st October.





Figure 23 - The START booth at the Euro PM2024 Congress&Exhibition in Sweden.



Figure 24 - Detail of the START booth's showcase at the Euro PM2024 Congress&Exhibition in Sweden, with various materials, including the TE demo (visible on the wooden tabletop).

Future events

START is organizing its participation in several more events in the next months.

- XXX General Assembly of ASGMI: This will be held during the last week of March in Peru.
- First MERCOSUR Geology and Mining Meeting: ASGMI has been invited to participate at the main table, providing an opportunity to present ASGMI's activities, including a mention of the START project.

More events might see START participating in addition to these, and we will inform you in due time.

If you are from a similar initiative or project and would like to organise something together, please contact us!

REGISTER FOR THE CLUSTERING EVENT IN BRUSSELS!



As a result of its clustering initiatives, START is preparing a Clustering Event in Brussels, on 10th December 2024 from 14:00 to 17:30, at the Hotel Marivaux: it will be a Side Event of the well-known and established EU Raw Materials Week⁶, that will run from 9th to 13th December at the nearby La Plaza Hotel, also in Brussels, organized by the European Commission, and where START will also be visible.. The title of the workshop is "Supporting the Critical Raw Materials Act: Research Projects in the European Union"⁷. This event will bring together 8 European projects for presentations (and likely a contribution from EU officials) and a round table discussion.; The aim of the event is to create a space for exchange where project progress can be shared, common challenges identified, and collaboration and the creation of new partnerships fostered, and will include a networking session to explore synergies among them.

This is the list of projects invited to speak:

- - START
- - GSEU⁸
- - FutuRaM⁹
- - CRM Geothermal¹⁰
- - CIRAN¹¹
- - SUPREEMO¹²
- - REESOURCE¹³
- - REPTIS¹⁴

The workshop will be moderated by Thomas Unterweissacher, of GEO Unterweissacher, one of the partners of START (see its description in this issue of the Newsletter), and will include a panel discussion and a networking time at the end of the event.

Participation is free of charge, but registration beforehand is necessary, with a deadline on 25th November 2024. If you are interested, do not forget to register on our website by reaching the relevant page.



TECHNICAL PILLS

Some useful information that covers topics that are linked to our project! In this issue, we deal with the basics of Life Cycle Analysis and its use within START.

Basic LCA Concepts and LCA in the START project

Introduction

Life Cycle Analysis (LCA) is a methodology which aims at assessing potential environmental impacts of a product across its life cycle, from extraction of natural resources or raw material acquisition to final disposal (end-of-life). It is mainly used to compare impacts of different products with the same function or a product in relation to a standard and identifying the most impactful stages and processes of the products life cycle. Thus, LCA can also be an instrument for industry implying cost-savings and competitive advantages.

LCA evaluates impacts related to a functional unit (FU) of the product or service, defined according to the goal and scope of the assessment, and all inputs and outputs throughout the life cycle are related to the FU. LCA can be carried out from two perspectives, i.e. Cradle-to-grave, which includes complete life cycle stages, raw material extraction/generation, production, transportation/distribution, use and the end-of-life; and Cradle-to-gate, which concerns only initial stages of life cycle, raw material extraction/generation and production.

LCA involves several steps (*Figure 25* and *Figure 26*), which include:

- 1) Definition of the goal and scope – the reasons for the study, intended audience, system boundaries, assumptions, limitations and functional unit are defined.
- 2) Life cycle inventory (LCI) – data describing the system is collected (e.g. materials, travel distances, consumables) and converted to provide the description of the systems. Data can be retrieved from scientific research papers, life cycle databases and manufacturer information, among other sources.
- 3) Impact Assessment (LCIA) – in which material, energy and waste flows are modelled based on the LCI, and physical quantities are translated into environmental indicators.
- 4) Interpretation and improvement – the results are evaluated and interpreted regarding the significance and uncertainty of the environmental indicators. Based on these results, the system or product can be modified and improved.

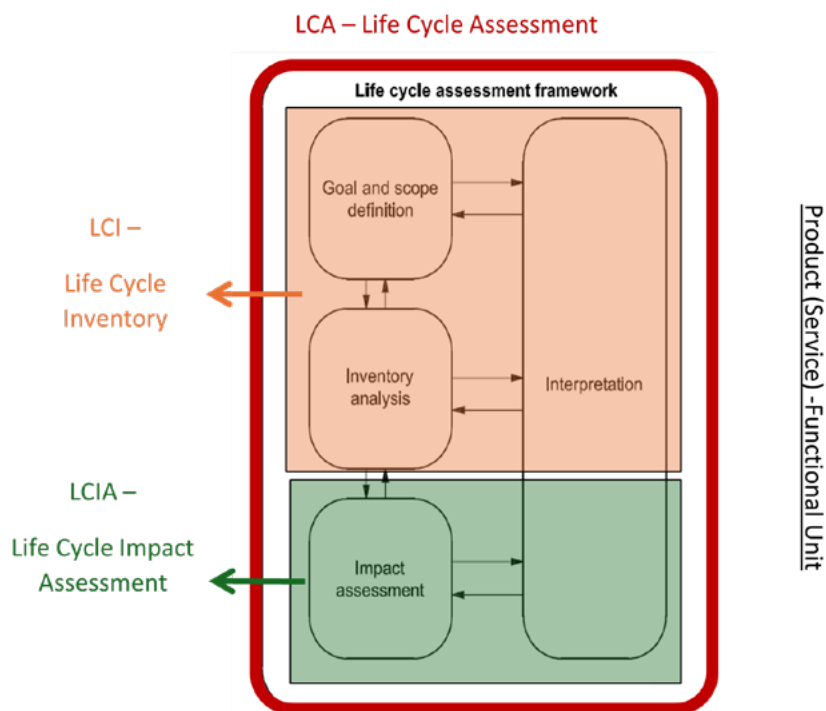


Figure 25 - LCA framework and simplified operational phases

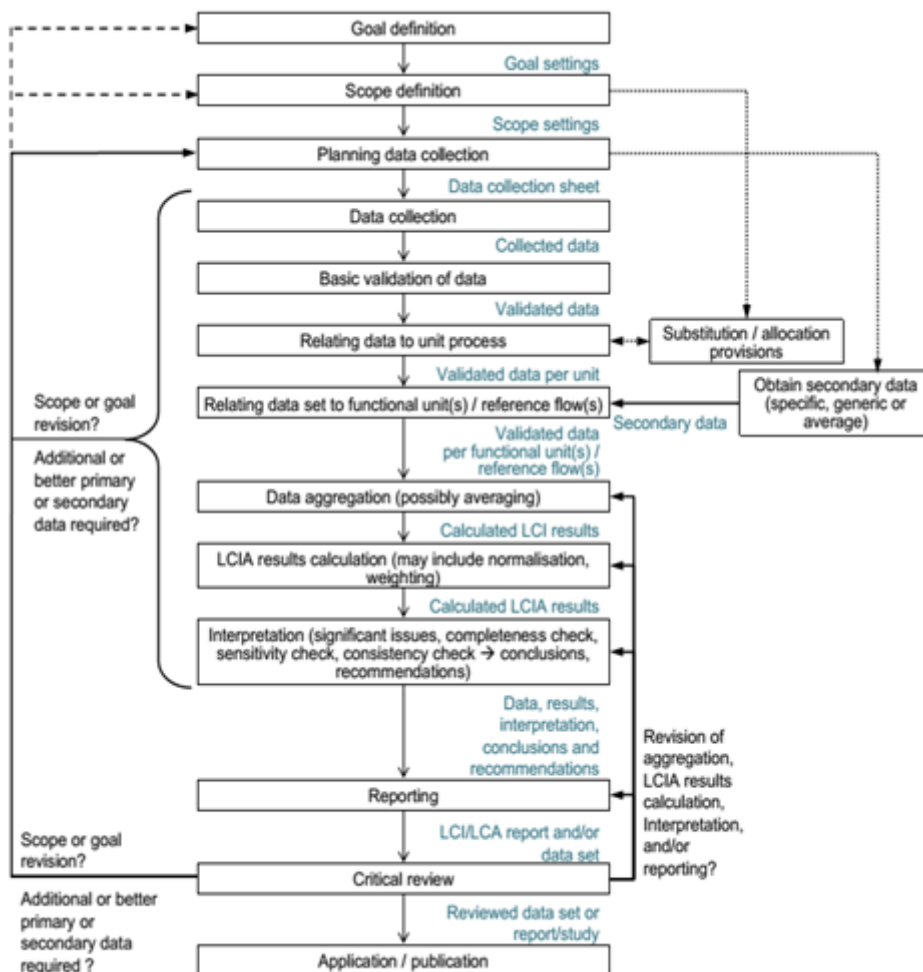


Figure 26 - Detailed overview on LCA approach.

It is worth nothing that LCA is not a substitute for location dependent assessments (e.g. Environmental Impact Assessments) nor risk analysis or strategic assessments, and it can be rather considered as a complementary tool. Furthermore, LCA can be paired with a Life Cycle Cost (LCC) analysis, which evaluates all the costs throughout the life cycle phases. The associated effective and/or potential costs (including e.g. capital investment, production costs, maintenance costs, capital replacement costs, operating costs, resale, salvage, or disposal cost) are considered within the LCC analysis.

A wider overview on the LCA basic principles and application on the project can be found both in the START website and the workshop uon LCA (available from YouTube¹⁵) presented by 3drivers in June 2023.

LCA in Start

In START, LCA will be used to compare environmental impacts of the mineral-derived sulphide-based semiconductor TE generators (TEGs) developed in the project based on tetrahedrites, obtained from mining waste (with a general formula of $(\text{Cu,Fe})_{12}(\text{Sb,As})_4\text{S}_{13}$, comparing the different obtained TEGs and the most commonly used, commercially available TE generators (e.g. based on BiTe - bismuth tellurite and PbTe - lead tellurite, for low and medium/high temperature applications, respectively). LCA analysis will be referred to a specific TEG module (n-type and p-type legs, interconnect and with ceramic plate); TE generators will be analysed in a full life cycle perspective (cradle-to-grave), from raw material extraction/processing, until the end-of-life. The functional unit was defined as 1 kWh of electricity produced by the TE generator. Furthermore, Life Cycle Cost (LCC) analysis will also be performed to determine potential and/or effective costs of these machines. The LCC model will include capital, facility & management (operation and productivity) and disposal costs, although maintenance costs for TEG use stage should not be considered, since this type of device has no interchangeable parts.

The environmental impact and costs analysis will be performed concerning scenarios with and without waste heat recovery and semiconductor material recovered from tailings (naturally formed tetrahedrite), and in comparison with semiconductor material based on synthetic tetrahedrite. A list of items for collection of data regarding the TEG life cycle inputs and outputs, as a result of recent implementation of the methodology specific for the LCA inventory development, is presented in [Figure 27](#).

Inputs (materials):
• Sulphides tetrahedrite for p-type formulation (kg)
• Cleaning products, other reagents and consumables (kg)
• n-type component base material (kg)
• TEG components (alumina plates, cooper interconnectors, others) (kg)
• Cleaning fluids, adhesives, solder, other consumables (kg)
• Water consumption (kg or m3)
• Diesel consumption (kg or m3)
Inputs (energy consumption):
• Mining activities (extraction, concentration, purification) (kWh, MJ)
• p-type production (powder technology, rapid solidification, layer deposition, others) (kWh, MJ)
• n-type production (kWh, MJ)
• TEG assembly production (kWh, MJ)
• End-of-Life technology (kWh, MJ)
Outputs:
• Electricity produced by the TEG (kWh)
• Wastes, leachates (kg or m3)
• Air emissions (kg)

[Figure 27](#) - List of input and output used in the LCA analysis.

MEET THE EXPERTS

In this issue we present you two interviews.

The first is with Dr. Doris Hiam-Galvez, of Hatch Consulting, who is a world-renowned expert, member of the Board of Directors of the prestigious PDAC (Prospectors and Developers Association of Canada). She tackles global challenges like the present warming and proposes a holistic solution to our current situation that is the DSP (Designing Sustainable Prosperity) method. Read more below!

The second interview is with our START member Hao Yin of TEGnology ApS and is a reprint of the interview given to the Associazione Italiana di Termoelettricità (Italian Thermoelectricity Association). Read Hao's ideas on thermoelectric applications from his own words!

Interview with Dr. Doris HIAM-GALVEZ

Question: The recently released report by the United Nations Environment Programme (UNEP) on greenhouse gas emissions ("UNEP Emissions Gap Report 2024") highlights that achieving a level of emissions reductions in line with the Paris Agreement target of 1.5°C is at serious risk of being compromised unless there is an immediate global mobilization and a six-fold increase in investment in mitigation actions. Dr. Doris, what are your thoughts on this and what strategies do you believe are most effective and realistic to be implemented in the short term so that the 1.5°C target can still be achieved?

Doris Galvez: Achieving the 1.5°C target calls for more than immediate innovation and investment; it requires societal transformation.



This means moving beyond isolated actions to designing integrated systems. Here, DSP plays a crucial role by creating ecosystems that balance development and sustainability, benefiting both people and the planet. Practically, each of us has a role- small shifts in consumption can collectively drive significant change, as seen during COVID. Meanwhile, we must urgently cut emissions by addressing major sources like fugitive emissions - leakage throughout the oil and gas sector - and accelerating the shift from high emissions energy sources to green energy such as wind and solar. This requires pressing both industry and governments to move beyond setting broad targets and commit to specific, actionable plans.

Q: You recently introduced the "Designing Sustainable Prosperity (DSP)" method, which focuses on long-term sustainable development. Can you describe this methodology and what contribution it can make to the active implementation of climate change solutions?

DHG: DSP is a holistic approach that unlocks untapped potential through system wide solutions to addresses climate change and regional resilience. By fostering economic diversification and scaling innovative solutions, DSP positions the regions as leaders in the knowledge economy, adapting educational systems to equip communities with future-focused skills that support long-term sustainable prosperity.

A key feature of DSP is how it frames the mining industry as catalyst for change, enabling regional prosperity by driving green innovation, circular economies, and lower impact mining methods. This approach aligns economic,

Figure 28 - Dr. Doris Hiam-Galvez is a senior Advisor at Hatch Consulting, Board Director, and an outspoken champion of sustainable development. She has a PhD in Metallurgy with broad senior level experience in leading organizations and driving significant expansion globally focused on value creation. For the past 16 years, her activities at Hatch involved leading regional operations and creating new and innovative businesses in Australia, South America, Europe & North America. Inspired by her work with global investors facing sustainability challenges, she developed "Designing Sustainable Prosperity (DSP)". A method to create resilient and sustainable regions. Her contribution to DSP has earned her the prestigious "CIM Distinguished Lecturer Award". Her book on the DSP method was recently published by Wiley. Designing Sustainable Prosperity (DSP) goes beyond just accessing and extracting the natural resources. It is an approach that unlocks the potential of resource-rich regions by integrating economic diversification, social well-being, and environmental sustainability. A systems design that leverages a multidisciplinary approach to co-create resilient regions and craft financially viable, environmentally responsible, and socially beneficial enterprises. This approach empowers local communities, fostering societal transformation and promoting a knowledge-based economy to meet market needs, all while aligning seamlessly with the United Nations Sustainable Development Goals (UNSDGs).

environmental, and social transformation, resulting in self-sustaining, climate resilient ecosystems. By integrating economic, environmental and social transformation, DSP helps build ecosystems where climate goals, community wellbeing and economic expansion reinforce each other, driving meaningful, long-lasting change.

Q: How do you envision the future of sustainable mining and what role does the DSP method play in this vision?

DHG: In the future of sustainable mining, I envisage a sector that not only minimizes its environmental footprint but actively contributes to regional resilience. DSP transforms mining into an enabler of regional prosperity that continues long after the mine has ceased to operate.

It positions sustainable mining as a key contributor to climate action and regional transformation, by balancing economic, social and environmental objectives, delivering enduring benefits for communities and ecosystems.

Q: Can you share some key milestones in your career that led you to focus on sustainable development and the creation of the DSP method? And what were the main challenges you faced while developing the DSP method?

DHG: Leading company operations around the world, I have witnessed the contrast between wealth and poverty in resource rich regions. Evidence that whatever we are doing is not working. For years, I have pondered if there was a better way to approach this complex situation. It has taken me 15 years to develop, implement and publish a book on a new way of achieving both development and sustainability.

One major challenge in creating DSP was helping people understand that real, lasting change requires a systems approach. We often work in silos, which limits our ability to tackle complex issues effectively.

DSP integrates scientific rigor with an emphasis on social transformation because regardless of innovative technologies or ideas, meaningful change occurs only when individuals are open and willing to collaborate. DSP employs a facilitated process in which key players co-create the future of their region through a structured seven-step process. The first two steps focus on preparing each individual and the team to broaden their perspectives about themselves and their region. This preparation enables them to progress to a stage where they can bring forth truly innovative ideas for system wide solutions, ensuring they are ready to create meaningful and specific action plans rather than general goals.

Q: What strategies do you recommend for fostering stronger partnerships between European stakeholders and other global regions to enhance sustainable development?

DHG: To enable Europeans to play a transformative role in fostering regional prosperity in resource rich areas, a strategic partnership is essential. Europeans' stakeholders can collaborate to build innovation hubs that address urgent climate challenges and position these regions as knowledge economy centres of excellence. By sharing expertise, Europeans can help create educational programs that equip local talent with skills to sustain these economies long after natural resources are exhausted. This cooperation should be done with developed nations especially with North America and China to drive global sustainability and strengthen long term resilience for these regions.

Q: The DSP method prioritizes waste reduction and the use of recycling and renewable resources. You have seen what the START project is trying to do in the field of thermoelectric device development, through a methodology that is based on "transforming mining waste into waste heat recovery materials". It is therefore a methodology that incorporates some of the ideas that were at the genesis of the DSP method. So, what is the aspect of the START project that you find more appealing, and why?

DHG: The START project redefines waste as a valuable resource by converting it into thermoelectric materials that capture waste heat and turn it into renewable energy. This approach mitigates environmental issues such as acid drainage, directly reducing the impact of mining on ecosystems, while supporting sustainable energy production. By creating new uses for mining byproducts, START has the potential to become an integral part of regional ecosystems, fostering circular economies that prioritize resource efficiency and environmental resilience.

Thanks for your views!

Interview with Hao YIN, published on the bulletin of Associazione Italiana di Termoelettricità (Italian Association for Thermoelectricity, AIT)



Figure 29 - Dr Hao Yin, CEO of TEGnology ApS, one of the partner companies in START, focused on TE devices production

With the kind permission of the Associazione Italiana di Termoelettricità (Italian Thermoelectricity Association), we share here the interview made by the AIT President Carlo Fanciulli to our partner Hao Yin, manager of TEGnology, published in June 2024 on the bulletin of AIT¹⁶. It contains interesting views about the thermoelectric industry and was also useful to attract participants to our Industrial Workshop in September.

Carlo Fanciulli: As a former researcher in thermoelectrics, Hao Yin started a company for designing and manufacturing thermoelectric generators for more than 10 years ago. Based on his observations and lessons, Hao agrees to share some personal thoughts, with the intention to accelerate the commercialization of thermoelectric generators. I want to thank Dr. Yin for accepting our invitation to share his vision on the market of thermoelectricity. What is your approach to the market development and what does drive you on the path of commercialization?

"Digging a tunnel" I have had a similar dream many times, when I'm stuck in darkness, trying to seek a tiny spot of vague light, which indicates the exit. If dreams only reflect reality, the reality is no less desperate. I usually compare the commercialization process to digging a tunnel from both ends. On one end, it's called technical "push" and on the other, the market "pull". When the tunnel finally got through, we call it a product-market fit. The situation when the market pull exceeds the technical push, often witnesses a new era of technology revolution, just as what is happening now in AI, the green transition and the climate change mitigation. However, it is not unusual during the technology commercialization, that the push exceeds the pull, which is also known as over-engineering. When a new technology doesn't have a market, it's often tempting to believe it is because the technology is not ready, yet. Well, this might often also be true. But the line between a perfect product (doesn't exist!) and a good-

enough solution (much desired) worths investigating. And the criteria should be defined more by what the market wants, other than what can be done in a lab.

CF: This is something many of us see every time a new project must be designed. For thermoelectrics, in most of the cases, technology suffers specifically because of the low performances in terms of efficiency. What is your approach to this critical issue?

"Efficiency. Efficiency! Efficiency?" It has been my first lesson when learning thermoelectrics, that the efficiency of TEG is (relatively) low. And most of the R&D in thermoelectrics has been focused on fundamental research and materials engineering in boosting the efficiency. In terms of energy conversion, it's of course crucial to have the efficiency as high as possible, period. However, the question is, does it mean that the efficiency of TEG is too low to be useful at all? Take the photosynthesis process for example. If we calculate the yield of biomass (dry weight over the solar energy), the plants are converting no more than a few percent of the energy into their leaf and fruits (3.5% for sugarcane, among the highest). But that a few percent are supporting the whole population on the planet, generation after generation. Also, I couldn't stop thinking of another example, combustion engines. Burning, one of the least efficient manners of utilizing the energy that is stored in the chemical bonds in fossil fuels, has been the driving force for human society for over two centuries, bringing us from iron age to steam and electric age, still continuing. The calculation behind is, the fossil fuel is (was) cheap, compared to the benefits it brings us (from A to B in shorter time). So, it is worth to accept the low efficiency of combustion engines (25-30%). (Oh, by the way, yes, we need to pay back for the benefits we've enjoyed, by reducing the Carbon from the atmosphere.) So, the absolute efficiency might not bring the whole picture. It would be more inspiring to think what can we do with the current efficiency of TEGs. If we couldn't get more electricity output from the heat input, maybe we should spend some time in finding the applications where the heat is available anyway and the electricity is so valuable, that people don't care about the efficiency?

CF: The key to thermoelectric technology is the materials. A lot of efforts have been and still are spent in developing new materials with improved characteristics. However, the effective impact of such improvements on the products accessing the market is negligible. Could you give us your comment on this?

"From materials (labs) to products (markets)" I used to be so excited over a new set of data, that shows the zT of a sample is X percent higher than the previous, until frustrating amounts of failures in bringing the state-of-the-art samples into a working module, that barely delivers some meaningful power. I will still applaud sincerely for any break throughs in thermoelectrics. But the lessons should be learnt. We can easily start from the best material but end up in nowhere. The evils are in the details. We need

innovative ideas and out-of-box solutions in the lab. That's the place where imagination should be set free. Science and technology are boundless. However, it doesn't hurt to come with a solution, you will still be the person who answers all the following questions. Nobody is there to do them for you. And the problems won't disappear by themselves. It is usually not the case, that you happen to use some spare time, between the intense brain sprints, to connect the new ideas to the industrial status quo. If you think the solution is still too early to answer the questions like "how to build a business on it", then try something easier, like "how to repeat the exercise 100 times by a less technical-savvy person", or "can the production be done without human intervention". Then start collecting some information that is required in the solution. It could be "the price/ availability/toxicity of the chemicals involved in the solution", or "the procedures of producing, say 100 kg of materials, or 10,000 modules", or "who should you talk to, after you've solved the problem", or simply, "what kind of people will eventually use the solution". These questions are most likely still there, when you assumingly can solve the current challenge. If you really are the first person answer the "last question" of a complex problem. If you can find some evidence that disqualify the argument, that "the solutions have been tried before and for some reason didn't work", it will make your solution more robust (and more likely, your funding application easier to get granted).

CF: All this is interesting. In your answer you are suggesting an approach often underestimated in lab. The shift of the focus from the improvement of the element of the chain to the design of a process capable to open the door to the product industrialization for such an element is a suggestion a lot of us are working on supporting the idea that an easier way could be better than a higher performance. But this opens the discussion about the availability of components and thermoelectric systems production worldwide. What do you think of this issue being on the "high readiness" side of the wall?

"Production & Supply-chain" It's not trivial to discuss where and how to get the TEGs produced. Without scalable production and reliable supply chain, we are still more or less creating visions only. Traditional commercially available Bi₂Te₃-based modules used to be produced in China, Russia and Ukraine, now mostly China. (BTW, the top three countries that produce Te are China, US and Canada). Several US, Japanese and European companies do design and post-manufacturing business of the modules. But it's not completely off to say, that the TEG market is dominated by a few non-EU producers. You don't feel the pressure? That's partly because TEG is still in a niche market compared to PV, batteries and PtX. But for us, including you my dear readers, who want to promote TEG as a unique and irreplaceable solution in the green transition, the task is tremendous. We need to:

Strategically choose the non-Te-based raw materials, which is abundant in EU.

Setup production procedures that are compatible to the European environmental and labour market legislations.

Design and setup production lines that are productive, flexible, and automated to compete with Asian producers.

To foster ecosystems in order to increase the awareness from politician, market and consumers.

The list continues.

CF: A lot of issues also common to other technologies! EU is supporting some steps out to escape these strategical limits but, as you state, the way is still long and hard to face. What is your vision for the future?

"A closing window" Thermoelectric has been a hotspot in academia for decades. And we don't have decades to catch up in commercialization. On one hand, we have competitors, solar panels (PV) being the most prominent one. You don't think so? Well, think about just 30 years ago, when the most useful application (if not the only one) for PV is the small window on a pocket calculator. Now, everyone wants PV panels on their roofs. Considering the sun is also providing heat (actually more than light, energy wise), that we potentially can use for thermal energy harvesting, PV has already taken the places. And there is no way we can take them back. On the other hand, we have nuclear power catching up, either SMRs (Small Modular Reactors) or fusion energy (I would rather believe it will take less than 50 years this time, maybe less than 30!). And even batteries(!) or some other science fiction-like solutions. Who knows which one will reduce the needs of thermoelectrics even more. When it will most likely go good for the society, it leaves us "TEGers" a closing window for commercialization.

CF: The scenario you are describing doesn't seem so promising. As the leader of a company working on thermoelectrics, do you still see a successful path for thermoelectric system? What are you planning in practice to further support and promote the growth of a market?

"Call for action" By bringing these concerns on the table, it is not to suffocate thermoelectric development by creating more constraints. On the contrary, it is the hope to set a better meaningful frame for innovation. We cannot build a car with a closed garage. By involving more people, especially stakeholders from the industry, we want to identify new applications, create new ideas, accelerate go-to-market. For that purpose, TEGnology is hosting an industrial workshop on thermoelectrics in Copenhagen on the 26th of September¹⁷. You will not only hear the latest development from several EU funded projects, but more importantly, requirements and wishes from the industry, if they are to integrate TEGs, as well as supply chains in EU. If you are interested, please preregister on the page.

CONSORTIUM TOUR

We continue our tour of consortium members: in this issue, meet GEO (Austria) and MBN (Italy).

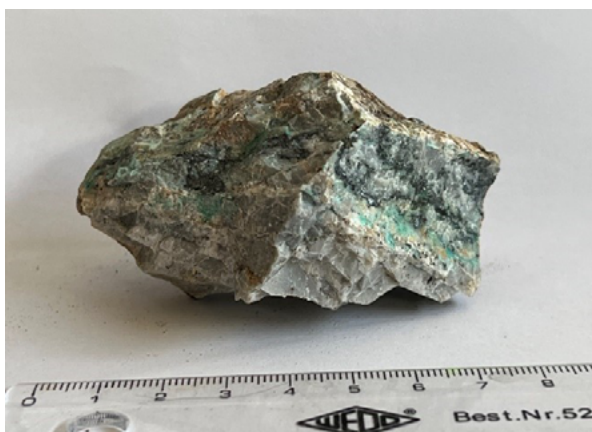
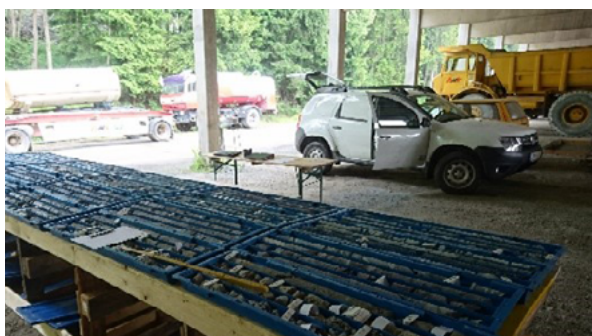
GEO UNTERWEISSACHER (GEO)¹⁸



GEO Unterweissacher GmbH is a geological consulting company based in Hochfilzen, Austria. The company's expertise extends beyond the assessment of natural hazards, hydrogeology as well as the research and analysis of geological raw materials. The company was founded over 20 years ago and has since developed into a leading expert in the field of raw materials geology.

The company GEO Unterweissacher GmbH focuses on four main pillars in its business activities: geological exploration, evaluation of raw material deposits, environmental impact assessment and consulting for companies in

the field of raw material geology. Thanks to the many years of experience and expertise of its employees, the company is able to carry out comprehensive geological investigations and make well-founded recommendations for the utilization of raw material deposits. The company has state-of-the-art laboratories and analytical equipment that enable it to examine geological samples precisely and obtain important information about the nature of raw material deposits. By using innovative technologies, the company can solve even complex geological problems and make well-founded decisions. Thomas Unterweissacher, the founder, has had a passion for historical mining ever since he was a child. His extensive knowledge of nearly every historical mine in Austria makes his company the perfect partner for the START project. With numerous mines and spoil tips scattered throughout the country, GEO Unterweissacher's ability to interpret natural signs has been invaluable in the project's success. The geology experts found several historical mine dumps, which contain the necessary mineral for creating a new and unique technological solution for thermoelectric elements.



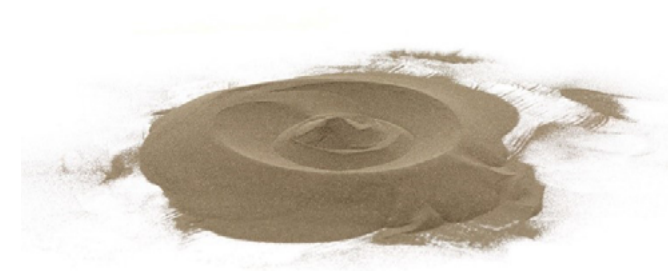


For over 30 years, MBN has been at the forefront of high-tech metal powder production, leveraging its proprietary Mechanomade® synthesis process to create materials with superior mechanical properties. Headquartered in Treviso, Italy, MBN operates across eight production plants, offering advanced alloy powders, nanostructured materials, ceramic-metal composites, and oxygen-sensitive materials for a range of industries. As a leader in the diamond tool industry, MBN specializes in cobalt-free, pre-alloyed metal powders. These innovative formulations enable the production of metal bonds that can be consolidated at lower temperatures and in shorter times, resulting in significant energy savings across various sintering methods, including graphite sintering, hot pressing, and HIP (Hot Isostatic Pressing).

MBN's expertise extends beyond sintering to support other cutting-edge manufacturing methods such as thermal spray deposition and additive manufacturing. MBN's approach to material development considers the final properties as a result of all the manufacturing processes that the material experiences and not only as intrinsic material characteristics. MBN's materials are designed with this concept in mind, and tested accordingly thanks to a well-equipped lab and extensive prototyping capabilities—including gravity sintering, press-sintering, and laser cladding—MBN offers customized solutions tailored to clients' specific needs, optimizing powder morphology and microstructure for superior performance.

In the START project, MBN is applying its Mechanomade® capabilities to transform mineral ore into high-performance thermoelectric materials. By mechanically alloying the tetrahedrite mineral with elements like Cu, S, Sb, Fe, Zn, and Ni, MBN can fine-tune the composition to maximize thermoelectric efficiency. The high-energy mechanical alloying process triggers the formation of tetrahedrite and incorporates dopants, creating a nanostructure that enhances thermoelectric properties by reducing thermal conductivity. The resulting tetrahedrite powder is then ready for sintering into p-type thermoelectric legs.

In addition, MBN plants provide the material for the n-type legs, utilizing direct mechanical alloying of elements to create Mg₂SbBi powders. MBN's teamwork advances material performance and supports a future where efficient thermoelectric technologies can be scaled up for practical applications.



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 - 4) <https://xtract-project.eu/>
- Social Media Links:
- YouTube: https://www.youtube.com/channel/UC9eNoqHV2BLXc37Q_CTWFuQ
 - X (Twitter): https://twitter.com/xtract_project
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 - 16) Il Bollettino, Anno 11, numero 2, Marzo-Aprile 2024. Available for members at <https://ait.icmate.cnr.it/>.
 - 17) See the relevant chapter; this interview was published before the event.
 - 18) <https://www.geo-unterweissacher.at/en/>
 - 19) <https://www.mbn.it/en/>

CONTACTS

START regularly updates its website and social media with news about its activities, but also with more general documents and info on the topics of relevance for the project. Thermoelectricity, waste heat recovery, mine waste remining, sustainability, raw materials and critical raw materials, energy efficiency, and many others.

If you are interested in receiving this newsletter and other special news from the project directly in your mailbox, consider subscribing our mailing list on the website ("Contacts" page, "subscribe" section)! Clicking on the "Subscribe" button, you will fill a form generated by Brevo, our mailing system, and will subsequently receive an E-Mail to confirm your address. Your data will be treated and stored in accordance with the EU GDPR Regulation. And do not forget to follow all our social media accounts! Here is the list of the important links to click to reach our news:

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LinkedIn: <https://www.linkedin.com/company/86266991/>

Twitch: https://www.twitch.tv/start_he_project

YouTube: <https://www.youtube.com/channel/UCHVjEhpVz9uaEgzICj2InPA>

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