

## START Project

Conversion of secondary mineral resources into value-added products for energy harvesting systems

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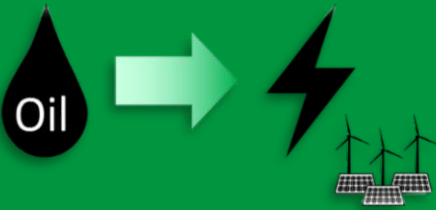
# 1. Motivation



**Combating climate change**


Climate change is one of the greatest challenges faced by humankind

- Fighting global warming is critically dependent on the rapid implementation of a green transition
- European Union (EU) is fully committed through the European Green Deal



Green transition

- Based on a shift from a fossil fuel-intensive to a material-intensive energy system, which implies an increased need of minerals resources
- This growing demand for essential minerals and the declining quality of ores is leading to a substantial increase in waste volumes from mining operations
- Use of mine wastes as valuable secondary raw materials for the development of advanced energy conversion devices creates an increased economic incentive to eliminate environmentally hazardous tailings



Current commercial thermoelectric (TE) devices

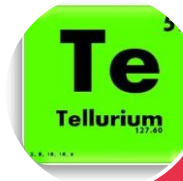
- Uses Te-based thermoelements (TE production accounts for  $\approx 30\%$  of its global consumption)
- Element derived or refined from minerals that are scarce in Europe, making the continent heavily import dependent

## 2. Overview of the START project

### Main objective

Create a sustainable supply chain for green energy harvesting products.

To develop sustainable TE devices, it is important to address the replacement of telluride-based TE materials



#### Current commercial TE devices

Cannot achieve a very low cost due to the scarcity and cost of Te.

Courtesy RGS Development  
B.V. (RGS), Netherlands



#### Thermoelectric (TE) technology / devices

- Scalable and modular, meaning they can be customized to fit different sizes and shapes of heat sources.
- Can operate in a wide range of temperatures.



#### Waste heat

A huge amount of the **primary energy produced** worldwide is **lost to the environment** as waste heat, which can be recovered.



#### Green energy harvesting

Is the process in which energy is captured from a system's environment and converted into useful energy (e.g., **thermal energy (thermoelectricity)**).

## 2. Overview of the START project

# START

## SUSTAINABLE ENERGY HARVESTING SYSTEMS BASED ON INNOVATIVE MINE WASTE RECYCLING

Innovation Action project co-funded by the European Union and its Horizon Europe programme  
(project number: 101058632)

- **Cluster 4: Digital, Industry and Space**

Topic: Building innovative value chains from raw materials to sustainable products  
(HORIZON-CL4-2021-RESILIENCE-01-07)

- **Duration**

48 months (1 June 2022 - 31 May 2026)

- **Total eligible costs**

9 194 441.25 €

- **Maximum grant amount**

7 667 878.00 €

## 2. Overview of the START project

### The Consortium



- **Coordination**

#### LNEG (National Laboratory of Energy and Geology, Portugal)



State Laboratory of the Ministry of Environment and Climate Action that makes R&D oriented to the areas of Energy and Geology. Is the National Geological Survey authority of Portugal. Wide expertise on mineral resources and minerals technology. In the START project, LNEG also leads the activities related to the selection of mine waste sites, physical minerals separation and concentration.

- **Multidisciplinary Consortium**

**15 partners** from 10 EU member states and 1 associated country, including **6 research organizations** with strong background and knowledge on geology, materials science and renewable energies, **7 SME's companies** that guarantee the entire supply chain, from production, exploitation and ecological footprint assessment, and **2 non-profit international associations** with a consolidated network of partners and stakeholders



## 2. Overview of the START project

### START approach to address the replacement of telluride-based TE materials

Production of advanced **sulphide p-type materials** that incorporates discarded waste secondary sulphides, mainly tetrahedrite.

Characteristics of commercially relevant TE materials and comparison with tetrahedrites ( $\text{Cu}_6[\text{Cu}_4(\text{TM})_2]\text{Sb}_4\text{S}_{13}$  (TM = transition metal))

Materials	$\text{Bi}_2\text{Te}_3$	PbTe	SiGe	Tetrahedrite
Current commercial materials				
<b>Figure of merit (<math>zT</math>)</b>	> 1	> 1	> 1	> 1
<b>Operational temperature</b>	< 300 °C	< 500 °C	< 900 °C	< 550 °C
<b>Toxicity</b>	■	■	■	■
<b>Environmental aspects</b>	■	■	■	■
<b>Raw materials availability</b>	■	■	■	■
<b>Large scale manufacture</b>	■	■	■	■
Positive assessment ■	Negative assessment ■	Less favourable ■		

(A.V. Powell, J. Appl. Phys. 126, 100901 (2019).; H. Huang, et al., J. Alloys and Compounds 881 (2021) 160546)

## 2. Overview of the START project

### START approach to address the replacement of telluride-based TE materials

Production of advanced **sulphide p-type materials** that incorporates discarded waste secondary sulphides, mainly tetrahedrite.

Tetrahedrite can be found all around the world



Tetrahedrite ( $\text{Cu}_6[\text{Cu}_4(\text{TM})_2]\text{Sb}_4\text{S}_{13}$  (TM = transition metal)) is relatively **abundant in some Cu mine tailings**



## 2. Overview of the START project

### START approach to address the replacement of telluride-based TE materials

#### Unique technological solution

START will transform waste secondary sulphide materials in sustainable high added-value components for tellurium-free thermoelectric devices.


#### Some of the environment and locations where samples were collected for the START project




## 2. Overview of the START project

### START approach to address the replacement of telluride-based TE materials

Unique technological solution  
START will transform waste secondary sulphide materials in sustainable high added-value components for tellurium-free thermoelectric devices.



**20%**




**80%**

**p-type tetrahedrite**


Seebeck	196 $\mu\text{V/K}$
Resistivity	58 $\mu\text{Ohm/m}$
Power Factor	0.67 $\text{mW/mK}^2$
Therm. Cond.	0.62 $\text{W/mK}$

**zT: 0.69 (364 °C)**





**50%**

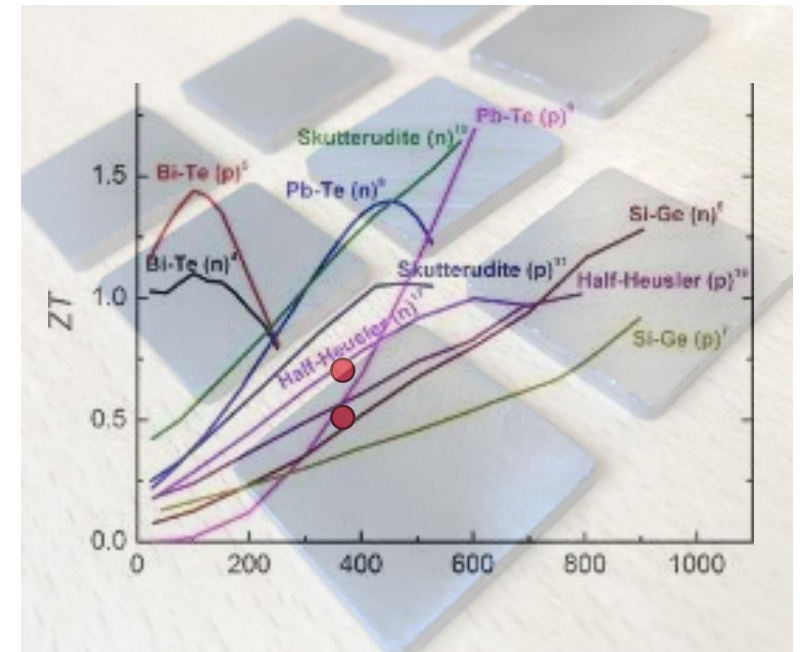


**50%**

**p-type tetrahedrite**

Seebeck	182 $\mu\text{V/K}$
Resistivity	62 $\mu\text{Ohm/m}$
Power Factor	0.53 $\text{mW/mK}^2$
Therm. Cond.	0.69 $\text{W/mK}$

**zT: 0.49 (362 °C)**



## 2. Overview of the START project

### START CONCEPT

Transform mining waste into waste heat recovery materials



Sulphide minerals: tetrahedrite series treated for TE supply chain (WP2)



DFT modelling, powder technology and rapid solidification (WP3)



Advanced characterization (WP4)



TE device design, simulation, production and characterization (WP5)



Mine waste

RECOVERY AND REUSE OF MINE WASTE

MATERIAL PROCESSING

DEVICE

SCALE UP

VALIDATION

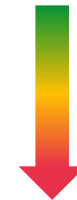
Technology demonstration in relevant environment (TRL6)



Waste heat



- Opportunity for an efficient use of resources and to decrease resource dependence and waste
- Diversification of the sources of renewable energy production systems using green energy harvesting through thermoelectrics

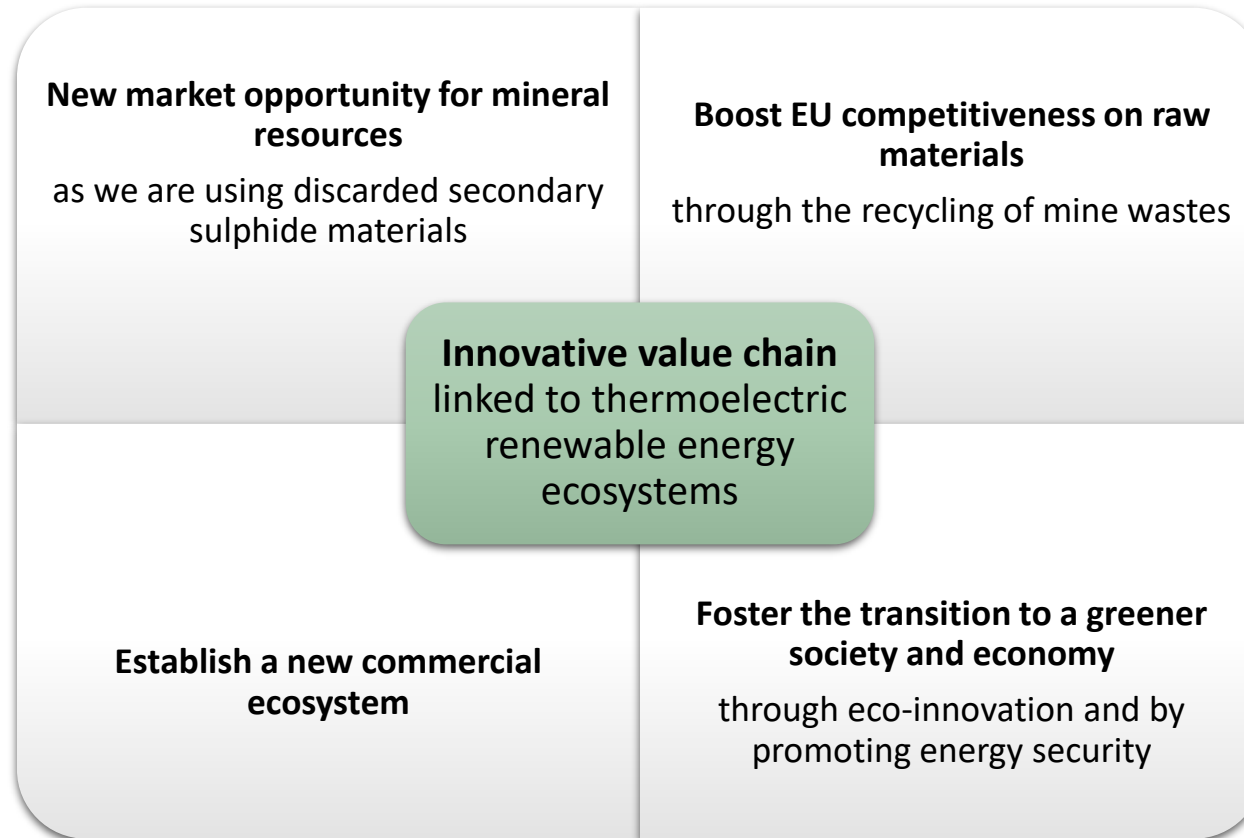


#### In line with:

- European Green Deal
- EU Action Plan on Critical Raw Materials
- EU Action Plan on Circular Economy

### 3. START relevance

#### Main Outcomes



## 3. START relevance

### Impact

#### Environment

- Reprocessing of sulphide-containing mining residues reduces the environmental impact of mining activities

#### Sustainable sourcing of raw materials

- Production of Te-free TE devices based on tetrahedrite, an earth-abundant mineral that is being sourced from European mining sites

#### Material and technology innovation

- Scalable methods for producing high-quality p-type tetrahedrite powder materials (High Energy Ball Milling)
- Innovations in assembling TE modules

### 3. START relevance

#### Impact

The START project contributes to the implementation of the following actions of the EU Action Plan on Critical Raw Materials



#### Action 3

Launch research and innovation on waste processing, advanced materials and substitution of critical raw materials



#### Action 4

Map the potential supply of secondary critical raw materials in Europe and identify viable recovery projects



#### Action 5

Identify priority mining and processing projects for critical raw materials in the EU



#### Action 8

Develop research and innovation projects to reduce environmental impacts of raw materials extraction and processing



#### Action 9

Develop strategic international partnerships to secure a diversified supply of sustainable critical raw materials, starting with pilot partnerships with Canada, interested countries in Africa and the EU's neighborhood (partially)

### 3. START relevance

#### Impact

and also...



## 4. How to follow START

- **Website**

[www.START-HEproject.com](http://www.START-HEproject.com)

- **Social media accounts**



[https://twitter.com/START\\_HEproject](https://twitter.com/START_HEproject)



<https://www.linkedin.com/company/start-he-project>



<https://es.slideshare.net/StartProject>

## 4. How to follow START



‘START CHRONICLES’: with news on the project’s activities;

‘COMIC STORY’: with Starty, our friendly robot that helps us explain the project scope;

‘TECHNICAL PILLS’: short technical documents;

‘CONSORTIUM TOUR’: meet the START partners.



[www.START-HEproject.com](http://www.START-HEproject.com)

### Subscribe

If you want to be kept informed about the activities in the project by receiving our news and our Newsletter, that will be published twice a year (every six months), fill the form here:

SUBSCRIBE

### Contact

If you want to contact us, you can send an E-Mail to one of the following contacts:

- [contact@start-heproject.com](mailto:contact@start-heproject.com)
- Filipe NEVES [filipe.neves@lneg.pt](mailto:filipe.neves@lneg.pt)
- Bruno VICENZI [bv@epma.com](mailto:bv@epma.com)

or you can send us a message using the form below.

Fields marked with \* are required

## SUSTAINABLE ENERGY HARVESTING SYSTEMS BASED ON INNOVATIVE MINE WASTE RECYCLING

*A Horizon Europe project*

To follow our activities don't miss  
**START Webinar #4 on 14<sup>th</sup> March 2024**

***“Powder technology for tetrahedrite p-type semiconductors”***

**[www.START-HEproject.com](http://www.START-HEproject.com)**

**Thank You For Your Attention**

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