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A birds-eye view of thermoelectrics research within the EU - recent, past and prospective activities and developments

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Introduction

The collective term “thermoelectricity” summarizes various effects all of which were discovered in Europe starting almost 200 years ago. It took, however, until the early 1990s that significant research in the field could be observed. Today, industrial and academic institutions in almost every European country are dealing with thermoelectricity-related issues. We sketch the history of thermoelectric research in Europe and analyze the developments during the last decades.

History

Thomas Johann Seebeck (D)
discovers the effect named after him.

1822
1823

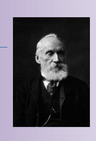
Hans Christian Ørsted (DK)
coins the term „thermoelectric“ for this effect.

1834
1838

Jean C. Athanase Peltier (FR)
introduces the reverse effect.

Heinrich F. Emil Lenz (EE)
uses the Peltier-effect to freeze water.

1854



William Thomson 1st Lord Kelvin (GB)
relates Peltier- and Seebeck-effect.

1909
1911

Edmund Altenkirch (DE)
characterizes the features of good thermo-electric materials and calculates their efficiency.

1929

Abram Fjodorowitsch Ioffe (RU)
- investigates semiconductors in search of materials with improved thermoelectric properties
- and formulates the thermoelectric Figure of Merit.

1949

Hiroshi Julian Goldsmid(GB)
Demonstrates thermoelectric cooling to temperatures below 0°C.

1954
1958

Ulrich Birkholz (DE)
Identifies the most suitable n- and p-type solid solution alloys of Bi_2Te_3 with Sb_2Te_3 and Bi_2Se_3.

1995

Formation of the “**European Thermoelectric Society**”

2005

Formation of the “**Deutsche Thermoelektrische Gesellschaft**”

2007

Formation of the “**Groupement de Recherche Thermoélectricité**”

2011

Swiss Thermoelectric Society

Formation of the “**Swiss Thermoelectric Society**”

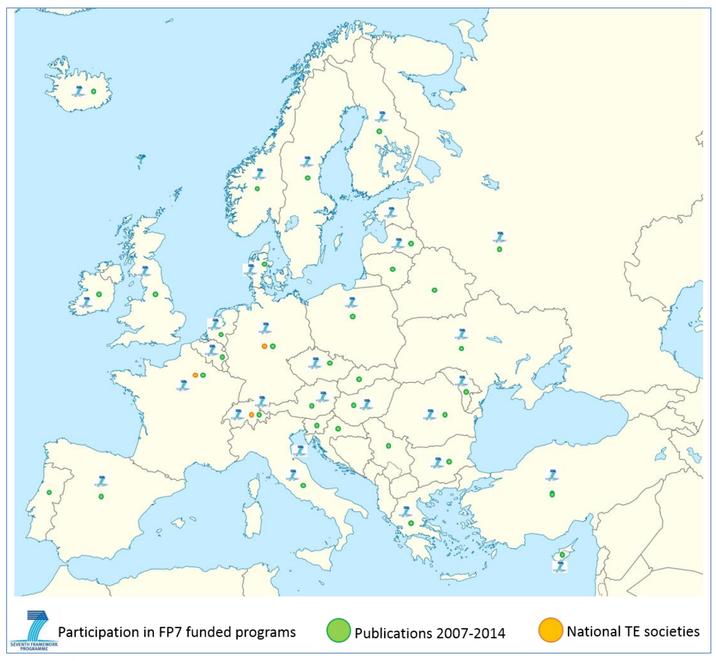


Fig. [1]: Current thermoelectric research in Europe.

Funding

The EU supports thermoelectric projects in Europe since the Fourth Framework Programme (FP4) [Fig. 2]. A pronounced increase in the number of projects can be observed within the just finished FP7 [Fig. 3].

During the course of FP7 institutions from 11 countries acted as project coordinators involving a total of 26 European states.

Projects

Projects cover all FP-programs (People, Ideas, Cooperation, Capacities) with “Cooperation” projects in the key areas **nanoscience** (NEAT, THERMOMAG, NEXTEC, IMAT, NANOHITEC, NANOCATE), **energy** (MERGING, GLOBASOL, H2ESOT, E2PHEST2US), **transport** (HEATRECAR, THETAGEN, SMARTTOP, GASTONE), **information technology** (GREENSILICON, SMARTPOWER) and **space** (SPACE TRIPS) leading the way.

Publications

The same basic trend can be seen with the number of publications on thermoelectric materials [Fig 4]. The intensified interest in materials research correlates with the emergence of new nanostructuring techniques to improve the material's transport properties. Papers on oxides and classic telluride materials show the most significant increase.

Patents

Patent filings of thermoelectric devices classified in IPC H01L35 almost doubled from 2008 to 2012. However, there has been a slight decline since 2010 [Fig. 5].

Developments

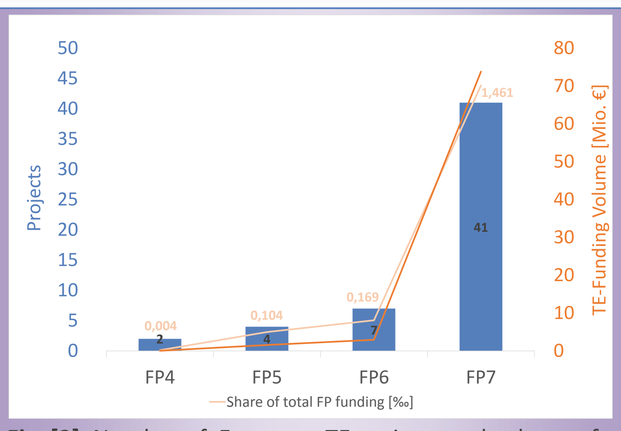


Fig. [2]: Number of European TE projects and volume of funding (cordis.europa.eu).

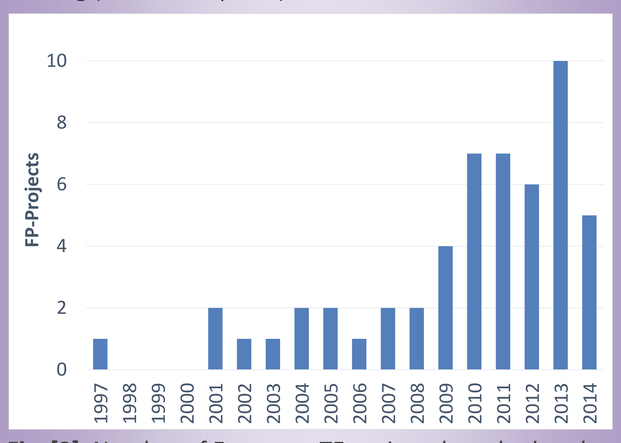


Fig. [3]: Number of European TE projects launched each year (cordis.Europa.eu).

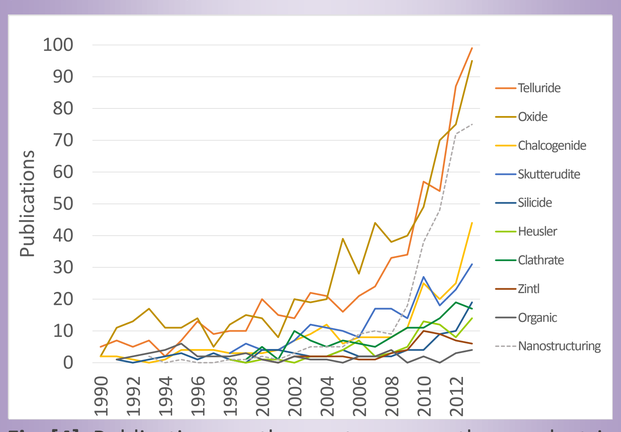


Fig. [4]: Publications on the most common thermoelectric materials (pcs.webofknowledge.com).

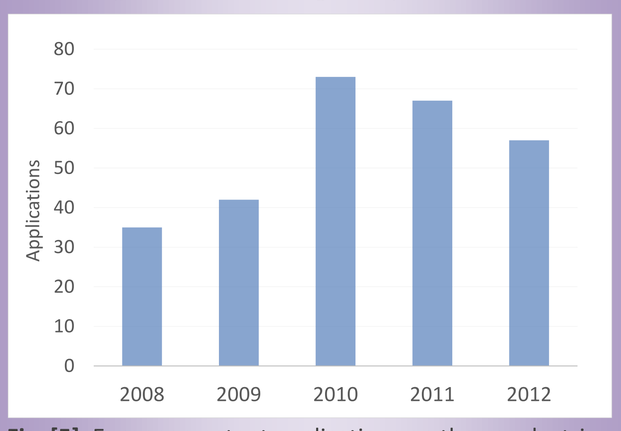


Fig. [5]: European patent applications on thermoelectrics. (by courtesy of the European Patent Office – J. Kirkwood).

Conclusions

The data illustrates that thermoelectricity has been a steady research topic in Europe for almost the past 200 years. The well-documented significant upturn starting around the year 2000 is associated with the finding that nanostructures provide an opportunity to adjust material transport properties. This has been particularly beneficial to the already then most efficient thermoelectric materials. Although a general breakthrough in this field is still pending, the developments show that the technique is definitely justified in selected applications.