STREAMS

Smart Technologies for eneRgy Efficient Active cooling in Advanced Microelectronic Systems

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## Smart Technologies for eneRgy Efficient Active cooling in advanced Microelectronic Systems

Start date of the project: 01/01/2016
Duration: 42 months

# Deliverable D7.9

# Final Plan for Use and Dissemination of Foreground

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|---|---|---|
| **WP** | 7 | Exploitation & Dissemination |
| **Task** | 7.1 | Innovation management and exploitation roadmap |

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| **Dissemination Level**[1] | PU | **Due Delivery Date** | M42 |
| **Nature**[2] | R | **Actual Delivery Date** | 11/07/2019 |

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|---|---|
| **Lead beneficiary** | LN2 |
| **Contributing beneficiaries** | ALL |
| **Author** | Luc Frechette |

[1] Dissemination level: **PU** = Public, **PP** = Restricted to other programme participants (including the Commission services), **RE** = Restricted to a group specified by the consortium (including the JU), **CO** = Confidential, only for members of the consortium (including the Commission services).

[2] Nature of the deliverable: **R** = Report, **D** = Demonstrator, **O** = Other.

| Document version | Date | Author | Comments[3] |
|---|---|---|---|
| v1 | 11/07/2019 | Luc Fréchette (LN2) | Final version for evaluation |
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[3] Creation, modification, final version for evaluation, revised version following evaluation, final.

## Deliverable abstract

This document presents both the dissemination and the exploitation plans. The objectives to be met through dissemination are identified, as well as its content. The targeted audience is a subject of particular interest in order to maximize the impact of the project. The dissemination plan also highlights the actions taken in the STREAMS project. The plan emphasizes on the relevance of the publications. Finally, the plan describes how the consortium dealt with the networking activities related to the project.

The second part of the document presents the exploitation plan. It first clarifies the goals to be reached by such plan and presents the exploitable results. A special focus is brought to the intellectual property and know-how that was generated in this project and how to exploit it. The document concludes with the upcoming dissemination tasks.

With the proposed approach for both the dissemination and the exploitation plans, it is expected to maximize the impact of the project in order to increase the EU competiveness in microelectronics.

# Table of content

# 1. INTRODUCTION

The STREAMS consortium aimed at developing disruptive thermal management technologies in order to keep the EU leadership in microelectronic technologies. This project generated technological innovations in a wide range of domains, such as cooling design, microfabrication processes, energy harvesting at microscale and automation. In order to maximize the reach and benefits of such work, dissemination and exploitation plans were proposed. The former first specifies the objectives to reach and the content to be disseminated. It then focuses on the target audience and the potential publishers in order to reach them. The dissemination timeline issued from the consortium management is then presented before presenting the management organization for dissemination. The plan ends with its networking activities.

The later, which is the exploitation plan, first specifies the goals to be reached with it. It then presents the exploitable content. Its policies and rules are detailed and followed by the management of the result exploitation. Exploitation actions are then listed as well as potential follow-on projects that could come from the STREAMS results.

The final section summarises the actions that remain to be done to complete this final plan.

The present document is a final version of the plan, which is a follow-on to D7.5, “Preliminary Plan for Use and Dissemination of Foreground”. It summarizes the dissemination and exploitations actions done to date and describes the actions that will be done beyond the end of this funded project.

# 2. DISSEMINATION PLAN

The numerous partners working together in diversified technological domains on a 3 years project makes a considerable potential quantity of innovation that can be relevant for the industry. The dissemination plan includes the goals, means, approaches and logistics related in order to share the project innovation to reach the relevant audience.

## 2.1 – Objectives and content

The objective of the dissemination plan contains the expectations of the STREAMS consortium in regard of its capability of producing both valuable and original technological and scientific works. The objectives highlight to which ends such works should be disseminated, while the content presents the current and anticipated works that could be disseminated.

*Objectives*

The STREAMS objectives in dissemination are:

- To contribute to the scientific community global knowledge;
- To offer disruptive and relevant technologies to the microelectronic EU industry;
- To establish partnership with entities relevant to enhance the project;
- To develop expertise for highly qualified professionals in the microelectronic sector.

Therefore, the project objectives cover two global aspects, which are to increase the EU capability in microelectronics, and to increase its international reach.

*Potential content for dissemination*

The project generates several elements potentially valuable for dissemination. In order to evaluate the potential dissemination, they are presented and grouped into three categories. First, the project brings potential innovations through its expected proofs-of-concept:

- Themoelectric sensors;

- Themoelectric generators;
- Array of cooling cells;
- Microfins;
- Microvalves;
- Actively cooled interposer;
- Read-out circuits for thermoelectric sensors;
- Power management circuits for thermoelectric generators.

Second, those demonstrations are technologies that could find relevance in other microelectronic or MEMS devices, whether it is in a heat management context or not. In addition, the project can generate innovation through its developed tools and methods, such as:

- Microelectronic interposer assembly;
- Microelectronic packaging;
- Transient thermal simulation approaches;
- Process flows and unitary processes;
- Microelectronic thermomechanical insight
- Circuit design.

Third, those tools and methods could be relevant for subsequent projects. Finally, the knowhow developed by the partners will position them as a reference for the heat management in microelectronics and it might provide valuable asset in future project involving this aspect. It affects the following dimensions:

- Highly qualified professional formation;
- Networking activities;

## 2.2 – Target audience and communication channels

The potential audience for the beneficial impacts of the project is wide. It is relevant to identify in a first time the potential audience for each work to disseminate and to associate it with the proper communication channel. The potential audiences are:

*Internal*

Within the project itself, the partners can beneficiate from each other's work, as it can be complementary to theirs. To this end, the project documents produced by each member are shared in the online project portal. This includes reports, data, presentations, and other relevant documents. In addition, general assemblies and other work meetings allow the partners to be informed of each other's works. Regrouping EU industrials, academic and institutional entities, the dissemination through the STREAMS consortium covers a wide range of sectors. In addition to be beneficial to the project progress, internal dissemination can bring valuable knowledge to the partners. Furthermore, the collaboration between the partners involves an important networking between the institutions, making a synergy at the EU level.

*External*

As the external potential audience is diversified, so are the means. The targeted audiences are:

- Industries (R&D)
  - Microelectronics
  - MEMS
  - Power microelectronics
  - Optoelectronics and photovoltaics
- Research communities (Universities and Research Centers)
  - Microelectronics
  - Packaging and 3D integration
  - Thermoelectrics

  - Integrated Circuits and Systems
  - Thermofluids and microfluidics
  - MEMS Microfabrication
  - Concentrated PV
- Society in general

The scientific communities were reached through peer reviewed publications in Journals specific to the related communities. All the publications will be Open Access (Gold or Green open access). On their side, industries were reached by issuing patents and presentations at different conferences.
A workshop was held in partnership with the 24$^{th}$THERMINIC workshop (Thermal Investigations of ICs and Systems) in order to sensitize the microelectronic professional community to the issues of the heat management in microelectronic management and offer tools for it.

The open access STREAMS website completes the strategy by offering to the specialized and non-specialized public an overview of the project (D7.3). Such website is already online at website address: http://project-streams.eu, also available at http://project-streams.com.

A newsletter was also produced periodically (6 months) to inform the stakeholders and a generic audience with interest in microelectronics of our progress in the project (D7.1). Other than this, there were no plan to reach the general population by more generic medias (e.g. radio, magazines, etc.). However, if such occasion should happen, it would be a good opportunity to unveil the issues and potential solutions in relation to heat management in microelectronics.

## 2.3 – Management

The execution of the dissemination plan requires a proper management in order to be efficient. This section explains such aspect.

*Responsibilities*
The partner(s) producing a publishable result is in-charge of its publication. The dissemination manager is in charge of selecting with the related partners the material worth disseminating and to establish how this material should be disseminated. The dissemination manager assured the follow up of the dissemination plan. This role was held by:

**Dissemination manager**
Jérôme Barrau (UdL)

The dissemination manager held the following responsibilities:
- Establish and update dissemination strategy, plan and dissemination;
- Open access to publications;
- Support to exploitation communication activities;
- Networking and community building;
- Raise target groups awareness about project results.

## 2.4 – Publications and timeline

The publications were published immediately once the results are available. Therefore, the timeline remained flexible about the moment of their publication. Many publications have resulted from work done throughout the project, but more are to come after the end of the project based on the final results.

The completed and expected scientific publications for the project are summarized in Table 1, where both the content and the past or expected delivery time are shown. The table also shows the journals that has been identified has potential ways to reach relevant scientific and technical communities.

*Table 1 – Publication content and delivery time timeline.*

| Lead | Co-authors | Type [1] | Title | Time | Content |
|---|---|---|---|---|---|
| CEA | | Journal | Journal of Superlattices & Microstructures | M24 → M45 | Influence of annealing on QDSL structure |
| | IMTEK | Journal | Nanotechnology | M28 → M43 | Results of µTES |
| | IMTEK, LN2 | Journal | Journal of Micromechanics and Microengineering | M36 → M45 | Results of µTEG |
| | | Proceeding | H2020 European project STREAMS: General overview | M35 | H2020 European project STREAMS: General overview |
| | | Conference | EMN Summer Conference - Invited oral | M6 | Nanostructured thin films for thermoelectric applications |
| | | Conference | European Conference on Thermoelectrics - Oral | M9 | Presentation of CEA projects on Thermoelectrics |
| | | Workshop | French Research Group on Thermoelectrics - Oral | M11 | Presentation of CEA projects on Thermoelectrics |
| | | Conference | International Conference on Thermoelectrics - Poster | M19 | QDSL for integrated thermoelectric devices |
| | | Conference | COMSOL Conference 2017 | M22 | Thermal modelling for on-interposer thermoelectric sensors |
| | | Conference | International Conference on Thermoelectrics - Invited oral | M31 | Presentation of thermoelectric devices integrated in STREAMS project |
| | All | Workshop | THERMINIC Conference 2018 - Oral | M33 | H2020 European project STREAMS: General overview |
| | IMTEK | Workshop | THERMINIC Conference 2018 - Oral | M33 | Integrated Thermoelectric Sensors for Thermal Monitoring of Integrated Circuits |
| | IMTEK | Conference | European Conference on Thermoelectrics - Oral accepted | M45 | Presentation of µTES results |
| | | Lecture | PowerMEMS 2016 school | M12 | Thermoelectric materials at bulk and thin film scales |
| UdL | LN2 | Journal | Applied Thermal Ingineering- Accepted | M30 | Numerical parametric study of a hotspot-targeted microfluidic cooling array for microelectronics |
| | LN2 | Journal | Int. Journ. of Heat and Mass Transfer | M25 → M38 | D2.2 cooling solution |
| | | Journal | Solar Energy- Accepted | M30 | Assessment of the impact of non-uniform illumination and temperature profiles on a dense array CPV receiver performance |
| | LN2 | Journal | Journal of Micromechanics and Microengineering | M30 → M38 | Self adaptive fins |
| | All | Journal | Applied Thermal Engineering | M30 → M38 | WP2 PoC results |
| | LN2 | Conference | Global Conference on Applied Computing in Science and Engineering- Oral | M7 | Impact of inclined fins inside microchannels on the thermohidraulic performance |
| | LN2 | Conference | Global Conference on Applied Computing in Science and Engineering- Oral | M7 | Parametric study of a bimetal actuator submitted to convection |

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| | **LN2** | Conference | 13th International Conference on Concentrator Photovoltaic Systems (CPV-13) Poster | M17 | Distributed and Self-Adaptive Microfluidic Cell Cooling for CPV Dense Array Receivers |
| | **LN2, ST, CEA** | Workshop | THERMINIC 2017- Oral | M21 | Microfluidic cell cooling system for electronics |
| | **LN2** | Conference | JITH 2017- Oral | M22 | Thermohydraulic performance of an array of microfluidic cells in unsteady non uniform heat loads distributions |
| | **LN2** | Conference | 134h International Conference on Concentrator Photovoltaic Systems (CPV-14) Oral | M28 | Dense array CPV receivers: Impact of the cooling device on the Net PV output for different illumination profiles |
| | | Journal OA | Journal of Applied Fluid Mechanics | M37 | Impact of the Self-Adaptive Valve Behavior on an Array of Microfluidic Cells under Unsteady and Non-Uniform Heat Load Distributions |
| | **All** | Workshop | THERMINIC 2018 | M33 | Summer School organisation |
| | **All** | Workshop | THERMINIC 2018- Oral | M33 | Thermostatic Fins for Spatially and Temporally Adaptive Microfluidic Cooling |
| **LN2** | **UdL, ST, CEA** | Conference | ITherm 2017 | M18 | Microfluidic cell array cooling system for electronics (analytical modeling) |
| | **UdL** | Journal | Microfluidics and Nanofluidics | M45 | Microfluidic cell array cooling system for electronics with adaptive fins and valves |
| | **All** | Conference | TBD | M45 | WP5 demo results |
| | | Workshop | THERMINIC 2018- Oral | M33 | Thermoregulated Microvalve for Self-Adaptive Microfluidic Cooling |
| | **All** | Journal | Microfluidics and Nanofluidics | M45 | System integration and WP5 demo results |
| **IMTEK** | | Conference | IEEE International Conference on Circuits & Systems | M29 | Concept of energy harvesting using a single power management unit by means of multiplexing the generators |
| | **CEA** | Conference | European Solid-State Circuits Conference | M33 | integrated power management unit (depends on outcome of measurements) |
| | **CEA** | Conference | IEEE International Solid-State Circuits Conference | M38 | integrated power management unit (depends on outcome of measurements) |
| | | Journal(s) | IEEE Journal of Solid-State Circuits, IEEE Transactions on Circuits & Systems | ?? | power management unit or joint publication on final demonstrator ( both depend on outcome of measurements) |
| | **CEA LN2** | Workshop | THERMINIC 2018- Oral | M33 | Embedded Thermal Energy Harvesting – Challenges & Opportunities |
| | | Conference | European Solid-State Circuits Conference 2019 (ESSCIRC) | M45 (accepted M41) | Area Constrained Multi-Source Power Management for Thermoelectric Energy Harvesting |
| **HSG** | | Events | COMPAMED 2016 | M11 | Thermal flow sensor exhibition |
| | | Events | Sensor & Test 2017 | M17/M18 | Thermal flow sensor exhibition |
| | | Events | COMPAMED 2017 | M23 | Demonstrator variable flow pump module and electronic drive & presentation |

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| | **UdL, IMTEK** | Events | Sensor & Test 2018 | M30 | High dynamic thermal flow sensor and its integration in microfluidic cooling system |
| | **UdL, LN2** | Events | COMPAMED 2018 | M30 | High dynamic thermal flow sensor and its integration in microfluidic cooling system |
| | | Workshop | THERMINIC 2018 | M33 | Variable Pumping Control for Low Power Microfluidic Chip Cooling |
| | | Events | Electronica 2018 | M30 | Variable Pumping Control for Low Power Microfluidic Chip Cooling |
| | | Workshop | Hahn-Schickard | M36 | Variable Pumping Control for Low Power Microfluidic Chip Cooling |
| | | Events | 2019 Tranducers | M42 | Demonstrator integrated system & presentation |
| | | Events | Sensor & Test 2019 | M42 | Demonstrator integrated system & presentation |
| **STM** | **CEA, UdL, LN2** | Conference | 2018 Symposium on VLSI Technology | M30 | Shaping circuit environment to face the thermal challenge Innovative technologies from low to high power electronics |

## 2.5 – Networking activities

The main joint networking activities among the project partners were the regular General Assemblies, which allowed all the partners to share their activities, learn about those of others and interact to revise the upcoming activities. The main networking activity with the broader community was the Workshop organised in conjunction with Therminic 2018, which allowed extensive interaction of the project participants with the industrial and academic communities related to thermal management. In addition, the conference publications listed in Table 1 also consist of networking activities related to the project, initiated by the different partners participating in the specific publications. These allowed a broader scope of the target audience to be reached, notably the thermofluids, MEMS/microfabrication, thermoelectrics and circuits communities.

# 3. EXPLOITATION PLAN

The STREAMS project is expected to achieve several deliverables and other results that could be used outside of the project. This section presents the plan about how to deal with such elements. It starts with its objectives and the identification of the potentially exploitable results. It is followed by the policies and rules related to their use. It then ends with intellectual property rights (IPR) managements, including ownership of the IPRs anterior, within or ensuing from this project.

## 3.1 – Objectives and content

The objectives followed with the exploitation plan are:

- To enhance the commercialization of the project content in order to support EU microelectronic industry (or related);
- To manage the project IPR issues with partners

The foreseen exploitable content and IPRs are presented in Table 2 with the involved partners and means of exploitation.

*Table 2 - Exploitable results.*

| Partners | Co-authors | Exploitable results | Means of exploitation |
|---|---|---|---|
| **CEA** | **LN2** | Thermoelectric sensors arrays<br>Embedded µTEG on interposer | IP and know-hows<br>Licensing |
| **UdL** | **LN2** | Self-adaptive cooling device<br>Stepwise varying width microchannel cooling device for uniform wall temperature: (product) and design optimization process / service for a given heat flux distribution | IP and know-hows<br>Licensing |
| **LN2** | **CEA**<br>**UdL** | Surface TEG (STEG)<br>Thermally controlled cooling distribution array (with fins and or valves) | IP and know-hows - PATENT SUBMITED<br>IP and know-hows |
| **IMTEK** | **ALL** | read-out interface & power management unit<br>overall outcome of the project | IP, know-how, teaching, patent (depends on outcome of measurements)<br>follow-up proposal |

| | | | |
|---|---|---|---|
| **HSG** | | Thermal flow sensor for fluid flow measurement in high dynamic range<br>Smart and energy saving pump module | Know-hows<br>Know-hows |
| **STM** | | Performance improvements of future generations of chips | IP and know-how |

## 3.2 – Exploitation management

The management of the exploitable results from the project is essential to maximize the use of the project results. For this, two elements have been put in place, which are the nomination of an exploitation manager and the establishment of policies and rules to regulate such use.

*Exploitation manager*
To manage the results exploitation, the STREAMS consortium named a general exploitation manager. This person is responsible to make sure that the procedures are properly respected, that the selected results to be developed are so, and to make sure that the exploitation plan is followed or modified according to the situation. The general exploitation manager is:

**Exploitation manager**
Perceval Coudrain (STMicroelectronics)

He had the following responsibilities:
- Assessment and protection of IP (Pre-publication reviews, Access and usage rights);
- To manage the project IPR issues with partners;
- Project results identification to support the exploitation strategy;
- Scientific / Industrial & Commercial exploitation strategy (plan and implementation); - Business plan.

*Policies and rules*
The STREAMS consortium has agreed on some policies and rules in order set the result exploitation baselines. The policies and rules concerning the IPR are applicable to the elements to be disseminated. It is based on the Grand Agreement 688564, section 2.2.4 IPR rules. The baselines can be summarized as follows:
- Background IPRs: IP held by the partners before the project. They are shared for the purpose of the project, but remains the property of its owner.
- IPRs from the project results
    - If originating from a single institution: They remain the only owner of the patent, although all the partners must be informed of the intention to patent;
    - If originating from multiple institutions: The patent pending must be done in all the institutions of the inventors.

The partners are held by confidentiality agreement. Therefore, patent content can and should be disseminated inside the consortium. Partners are asked to keep the patent content inside the boundaries of the agreement. The partners must inform the rest of the consortium, including the disseminating manager, 3 weeks of pre-advice prior to start patent pending.

Another element is the coordination between the institutions in order to generate joint patents. To establish such coordination, when necessary, the partner(s) is/are responsible for providing their patent department contact persons.

In the case of publications, the following elements are considered:

- Prior to publication, a draft must be sent to all the partners having works related this publication. If a disagreement cannot be solved between the partners, the dissemination manager must be informed and can propose a solution. If the disagreement persists, the publication is holded until a solution is agreed.
- Authorship is naturally relative to the scientific contribution and not systematic for the whole consortium in all STREAMS publications.
- Additional publications within a partner's task can be published without other partner's advice if it has no element is in the publication plan and that all the work is from this partner.

## 3.3 – Commercial exploitation activities

An information packet of public information will be made available on the website and shared in the newsletter to facilitate access to the project contributions. It will contain a summary of the project contributions with examples of its applications, as well as links to the published material. This will be shared with potential industrial partners by directly sending them the information packet. It will specifically be shared with STMicroelectronics management to ensure internal broadcasting of the information to our main industrial partner. Other partners will also be invited to share this information packet internally and with their network of industrial collaborators. Finally, the business plan scenarios presented in D7.8 will be further explored by the relevant partners.

Foreground IP created by the STREAMS project will also be promoted. Specially, licensees for the IP on the microfabricated Surface Thermoelectric Generators held by CEA and LN2 will be sought by their respective IP offices and the inventors.

Background IP that has been further developed and demonstrated in the STREAMS project will also be further promoted. Specifically, the self-adaptive fins and valves approach was implemented and demonstrated during the STREAMS project, making this technology more mature and reducing the risk of adoption by the industry. A list of potential companies has been defined and contacts have been initiated. This effort will be pursued to further access the practical interest from industry.

## 3.4 – Potential follow-on projects

An information packet of public information will be made available on the website and shared in the
The STREAMS project generated significantly new knowledge and know-how that can be the basis for follow-on projects, listed in Table 3.

*Table 3 – Potential Follow-on Projects leveraging the project outcomes.*

| Potential follow-on projects | Exploitable results | Potential partners involded |
|---|---|---|
| Highly integrated high-power computing modules for AI or microservers | Thermoelectric sensor arrays<br>Self-adaptive cooling fins/valves | CEA<br>UdL<br>LN2 |
| Adaptive heat sinks for high power electronics, optoelectronics or CPV | Self-adaptive cooling array with fins and/or valves<br>Stepwise varying width microchannel cooling | LN2<br>UdL |
| Thermal energy harvesting for wireless sensors | Read-out interface & power management unit<br>Surface TEG (STEG)<br>Embedded µTEG | IMTEK<br>CEA<br>LN2 |
| Energy efficient servers | Smart and energy saving pump module<br>Self-adaptive cooling fins/valves | HSG<br>UdL<br>LN2 |

# 4. FINAL ACTIONS

To complete the dissemination and exploitation from the STREAMS project, the following actions are planned after the formal end of the funded period.

## 4.1 – Journal Publications and Conferences

According to Table 1, multiple journal publications and conferences are still planned, mostly to share the results obtained of the last 6 months of the projects. These include important achievements through the demonstration of the PoC of the functionalities, as well as the integrated demonstrator. These will ensure an archival contribution of the work done through the STREAMS project. They will also broadly disseminate the information about the project achievement in the research communities, including the industrial R&D sector.

## 4.2 – Website and Newsletter

The STREAMS website will remain active for a period of at least 5 years after the end of the funding and be updated with the follow-on publications and public results.

A newsletter will continue to be sent out every 6 months, as long as new publications or exploitation assets emerge from the project activities. A final newsletter will be sent once all the outcomes are generated to summarise the project outcomes and inform the connected community of the project completion.

## 4.3 – Commercialisation

Paths to commercialisation will continue to be sought for the IP and know-how generated in the project:

- Prepare and share information packet with potential users of the project results;
- Seek licensees for foreground IP: microfabricated Surface Thermoelectric Generator (CEA, LN2)
- Seek industrial users for background IP that has been mature and de-risked thanks to the STREAMS project: Self-adaptive fins and valves.