STREAMS LOGO

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STREAMS

Smart **T**echnologies for ene**R**gy **E**fficient **A**ctive cooling in advanced **M**icroelectronic **S**ystems

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Report on the business model concept definition as part of the Innovation management approach

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[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.

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Deliverable abstract

The objective of WP7 is to continuously monitor and provide means for the STREAMS partners to share their knowledge within the consortium and to integrate the research activities as well as to exploit the research results, and/or communicate and disseminate the results to the scientific community and to the wider audience. The goal of this deliverable is precisely to define the work needed to prepare and encourage the use and wide acceptance of project results after the end of the project. This deliverable will define the business model concept, explain the importance of choosing an adapted business model to capture value form innovation, and describe the main questions to be answered to conceptualize a business model for STREAMS main achievements. In the last section, an application of the “business model canvas” is proposed as result of a collaborative thinking on the possible exploitation of STREAMS developments.

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1 - Context

The objective of the innovation management and exploitation roadmap task is to identify, qualify and protect the results generated by the consortium. It includes the coordination of project intellectual property rights (IPR) issues with partners and the continuous benchmark, identification and assessment of the results that could be the subject matter of protection, use or dissemination based on publications and progress reports issued by WP leaders. In addition, the Exploitation/Innovation Manager is in charge of implementing the innovation management approach.

Implementing an innovation management approach within STREAM is crucial and appears as a Key Success Factor to achieve defined results and maximize the chance for future products developed to reach the market. A three dimensional approach is followed, working successively on collaborative strategy, exploitation strategy and knowledge management. This innovation management process aims at identifying key strategic and technological partners to address, defining precisely targeted markets and benchmarking the technological project ecosystem. Expected results will speed up the development and strengthen the link with the final market addressed.

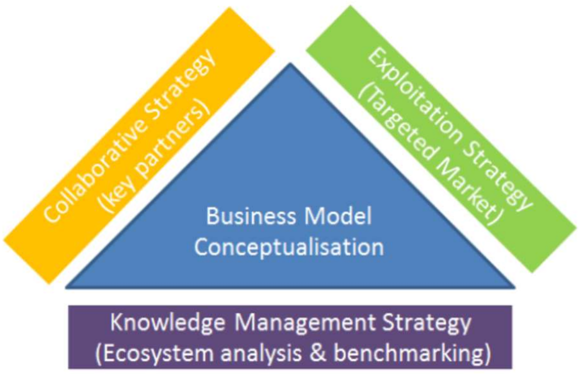

Figure 1: STREAMS project Innovation management

Innovation management implementation is conducted at the level of the General Assembly. Besides previous objectives, this work will provide several benefits to the project and partners, as for example:
- Brings fresh thinking and new value to the consortium,
- Helps identify and mitigate risks,
- Taps into the collective creativity and intelligence of the partners,
- Motivates partner involvement in the project success and fosters teamwork and collaboration,
- Proactively captures value from better understanding of future market needs and possibilities,
- Captures value from the collaboration with partners for innovation

The last two elements cited above are related to value creation from STREAMS innovations and partnership. They might be included in a more global approach that we will introduce as business model concept. In this deliverable, we will first define the concept of business models in general, then justify its interest for a project like STREAMS, and finally explore the practical questions to be answered toward a real business model for STREAMS innovations deployment.

2 – Business model concept definition

The term *Business Model* first came into widespread use with the advent of the personal computer and the spreadsheet [2] and became very popular since the development of the internet market in early 2000’s. The term is now very often used, but still remains seldom defined explicitly [1]. We here describe the concept, based on a review of articles dedicated to the business model definition and analysis. Large passages from these articles will be quoted in this section.

A business model is not synonym of strategy, it is more the managerial equivalent of a scientific method with a starting hypothesis tested in action and revised when necessary [2]. It describes how an organization creates, delivers and captures value. It must considers two types of activities: the ones associated with making something: designing it, purchasing raw materials, manufacturing, and so on, and the activities associated with selling something: finding and reaching customers, transacting a sale, distributing the product, or delivering the service. Figure 2 gives an overview of business model concepts. Several authors purely define a business model as a system for making money ("Economic concepts" column), some other considers that it is mandatory to capture also the created value ("Economic – valued concepts" column).

<table>
<tr><th colspan="3">Economic concepts</th><th colspan="2">Economic – valued concepts</th></tr>
<tr><td>Mullins - Komisar</td><td>A. Afuah</td><td>D. Watson</td><td>W. M. Johnson
C. M. Christensen
H. Kagermann</td><td>A. Osterwalder
Y. Pigneur</td></tr>
<tr><td>1. Revenue model</td><td rowspan="2">1. Position</td><td>1. Competitors</td><td rowspan="2">1. Value for customer</td><td>1. Customer segments</td></tr>
<tr><td rowspan="2">2. Gross margin model</td><td>2. Customers</td><td>2. Value proposition</td></tr>
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<tr><td rowspan="2">5. Investment model</td><td rowspan="2">6. Suppliers</td><td>8. Key partners</td></tr>
<tr><td>9. Cost structure</td></tr>
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Figure 2: Overview of Business Models concepts [3]

For Slavik and Richard, the business model is a system of resources and activities, which create a value that is useful to the customer and the sale of this value makes money for the company [3]. It generally answers questions such as "Who is the customer? What does the customer value? How do we make money in the business? What is the underlying economic logic that explains how we can deliver value to customers at an appropriate cost?" Chesbrough and Rosenbloom give an operational definition of a business model by means of elementary actions [4]:

- **Articulating a value proposition latent in the technology**. This requires a preliminary definition of what the product offering will be and in what form a customer may use it.

- **Identify a market segment**. The users to whom the technology is useful and for what purpose, and specify the revenue generation mechanisms for the firm. A customer can value a technology according to its ability to reduce the cost of a solution to an existing problem, or its ability to create new possibilities and solutions. A market focus is needed to begin the process in order to know what technological attributes to target in development, how to define and configure the offering

- **Define the structure of the value chain** within the firm required to create & distribute the offering, and determine the complementary assets needed to support the firm's position in this chain.

- **Define the "architecture of the revenues"** or how a customer will pay, how much to charge and how the value created will be apportioned between customers, the firm itself and its suppliers. Estimate the cost structure and profit potential of producing the offering. Describe the position of the firm within the value network linking suppliers and customers, including identification of potential complementors and competitors.

3 – Thinking Business Model concepts for STREAMS innovations

The article by Chesbrough and Rosenbloom is an interesting basis for reflection on STREAMS, as it describes the role of business models in capturing value of **path-breaking** innovations in an international business context (Xerox). Because discovery research often produces technologies that do not have clear path to commercialization, discovering viable business model is critical for creating value from technology. For six cases examined in their article, technologies were the result of inventions that did not have clear path to market within the company funding the research. They explain how this situation has been overcome by the implementation of alternative business models. A proposition now widely recognized is that technologies that make little or no business sense in a traditional model may yield great value when brought to market with a different model [4]. It seems notable that among examples of Xerox spin-off, while some business models were implicit from the outset in each of them, a different model was in place when the successful companies had demonstrated their viability.

We now discuss the method we should consider to build it in the next months with the fulfillment of main technological parts. We have chosen the comprehensive nine-part "business model canvas" established by Alexander Osterwalder, which constitutes a visual matrix of 9 blocks that describe the four main dimensions of an organization: customers, offer, infrastructure & financial sustainability. The canvas blocks are detailed here-below, based on a practical sheet proposed to start-up founders [5].

<u>Customer segments</u>
Groups of individuals or organizations that the company targets: mass, niche, segmented, diversified...
Do we know the entire customer chain from buyer to end user? Who are our non-customers?

<u>Value Proposition</u>
Product/service combinations creating value for each segment: novelty, performance, customization…
What value do we really bring to the customer? What do we not bring to our customers?

<u>Income flows</u>
The revenues generated: sales, subscription, rental/loan, licensing, brokerage fees and advertising
For what value are our customers willing to pay? How would they pay? How would they prefer to pay?

<u>Key resources</u>
Most important assets required to run business model: physical, intellectual, human, financial.
What key resources do our value propositions require?

<u>Key Activities</u>
Most important things to do to make its business model work: production, problem solving, network
What key activities do our value propositions require?

<u>Channels</u>
Channels to discover products & services, evaluate, distribute & purchase the offer, deliver proposition…
Which channels do customers prefer and give the best results?

<u>Customer Relations</u>
Relationships established on strategic objectives: acquire, retain, and achieve additional sales
What kind of relationships do our clients want? What kind of relationships have we established?

<u>Key Partners</u>
Key partners/suppliers through which the business model works: alliances, cooperation, joint ventures
Who are indispensable partners and suppliers? What key activities do our partners/suppliers conduct?

<u>Cost structures</u>
What are the most important costs inherent in our business model? Which key resources are the most expensive? Which key activities are the most expensive?

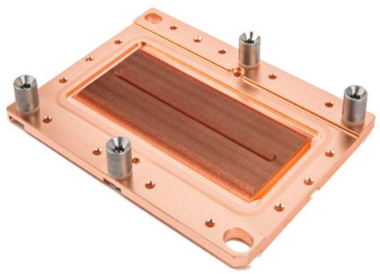
4 – Applying Business Model canvas to STREAMS Energy Efficient Cooling capability

This canvas could be potentially applied in the three fields explored in the project: self-adaptive cooling, temperature monitoring and energy harvesting, every time value can be created. It can deal with the technology itself or link to simulation and design methods associated to the technical developments. In this section, we practically apply the canvas to the asset we consider the most fertile in terms of business perspectives → **Providing a smart fluidic cooling system approach with a self-adaptive liquid cooling method that can be integrated in a micro fabricated chip**. We then try to give collective answers to the above-detailed canvas.

Customer Segments

- Microelectronics from high performance computing (HPC) & data centers to PC cooling

High-performance computing (HPC) infrastructures and state-of-the-art data centers require the deployment of very high-powered processor clusters including CPUs, GPUs and memory modules, with high interconnection densities. The rapid growth of structured and unstructured data and the growing demand for cloud computing are expected to drive data center growth over the next decade. Governments around the world have imposed environmental regulations on the efficiency of data center emissions and energy consumption. These regulations are driving a strong demand for environmentally friendly cooling solutions. Data centers often employ chiller-based air systems, which consume up to 50% of all data center power. Therefore, they are increasingly turning to liquid cooling, allowing efficient cooling without sacrificing density for performance, improving reliability and allowing bays to carry even more kW. Global data center cooling market was valued at USD 9.27 billion in 2018 and is expected to reach USD 17.39 billion by 2024 with an annual growth rate of 12.34% [6], and liquid cooling segment is expected to have the highest growth rate [7]. Rack and blade cooling will experience the strongest growth in this market due to the ability to provide cooling close to logic processors. North America is expected to lead the market in coming years due to presence of Facebook, Google and Microsoft. Key players in the global liquid data center cooling market include: 3M, AIRSYS, Alfa Laval, Allied Control, Asetek, Climaveneta (Mitsubishi Electric), Condair Group, Coolcentric, (Wakefield-Vette), CoolIT Systems, Daikin Applied, Data Aire, Delta Group, Green Revolution Cooling, Munters, Nortek Air, Pentair, Renovo Zhuhai, Rittal, Schneider Electric, Stulz, Swegon, Trane (Ingers Randoll), United Technology (Carrier), Vertiv, Vigil. Some of them could become targeted clients for STREAMS adaptations at interposer scale.



As an illustration, CoolIT Systems Inc. has revenues that increased by 60% in 2017 and backlog by 400% in 2018. Its Direct Contact Liquid Cooling platform (DCLC) uses a three-module approach with passive cold plate loops, rack manifolds and coolant distribution units. As key component, Split-Flow cooling plates use microchannel architecture to minimize pressure drops, maximize flow rate and direct coldest liquid to hottest area. The cold plates are compatible with compact blade architectures (figure 4). This device could typically benefit from a self-adaptive strategy.

Figure 4: DCLC coldplate (CoolIT) [8]

Cooling personal computers is another opportunity for STREAMS application. High-performance GPUs, for example, are sought after by gaming enthusiasts for their ability to deliver a visually rich and ultra-smooth experience. GPU liquid coolers are designed for high overclocking, increasing performance over air cooling solutions, while improving acoustics. Requirements are similar to those of HPC field, although the scale is not the same. It is therefore no surprise that many of the players of the HPC section, such as CoolIT Systems and Asetek, are part of this market. Closed-loop All-In-One (AIO) kits are ready-to-install liquid systems for high-density and high-performance workstations including water block, pump, radiator and quiet fans. They are fully autonomous and factory sealed, without filling or maintenance, and their installation is comparable to that of a standard heat sink. Tailor-made solutions are also common, and in this case STREAMS' objective would be the waterblock component. Current suppliers for AIO or watterblocks include Asetek, Corsair, DeepCool, Antec, EK Water Block, Thermaltake, Cooler Master, Bequiet !, Empire Gaming, NZXT for example.

AIO kits are sold between 50 and a few hundred dollars, for instance the Corsair Hydro series liquid CPU coolers, produced by CoolIT, or the Asetek 690LX-PN liquid cooler approved to cool the new Intel Xeon 28-core / 56-wire processor with a turbo frequency up to 4.3 GHz single core (figure 5).

Figure 5: Asetek 690LX-PN [9]

Those two domains could benefit from STREAMS approach where a higher efficiency is found by embedding the cooling even closer to the dissipatin CMOS devices. For those two domains, the cooling solutions are seen provided by third parties (heat sink, cold plate, All-in-One systems providers), and integrated into final systems by the system provider itself (Dell, HP, Apple, Asus, Acer etc… for personal computers and Atos, Cray etc… for High Perf Computing and data centers). The packaging house that assembles the chip in the module typically only provides an integrated heat spreader or other thermal interface for conductive heat transfer. Since STREAMS proposed technology is integrated into the packaging and needs fluidic interconnects at the package level, the packaging house needs to be involved in offering our solution. Furthermore, since it can be integrated at the chip level, in Si, this implies that the chip manufacturer could itself integrate the cooling solution. This is a major change from the current roles and responsibilities in microelectronics industry.

To offer our solution for the microelectronics industry, there ideally needs to be a joint effort from the chip manufacturer to the system integrator, which is not common. Companies such as IBM used to provide such a vertically integrated offering, but has moved away from this model. Other vertically integrated companies, such as Apple, could be good contenders to adopt and implement our cooling technology, although it does not currently have the need for liquid cooling.

- <u>High power electronics cooling and autonomous cars</u>

High power electronics for electric vehicles, for example, is increasingly requiring compact and efficient cooling. Upcoming firms operating in autonomous cars will require high performance computing and need to develop computing hardware solutions specific for their needs. Although most of these firms start by using commercially available chips and modules such as provided by Intel, it is expected that they may gradually go towards their own internally developed chips and modules. With the need to have compact and high performance computing, this appears to be a unique opportunity to position our cooling approach as an enabling technology. Power electronics integrators, such as Infineon, start from chips and do their own packaging and integration. They are therefore well positioned to bring such a technology to market. Furthermore, many power electronics are already liquid cooled, since this option is available onboard vehicles.

- <u>Medical systems cooling</u>

High-performance medical equipment, particularly imaging equipment, requires efficient cooling with unique challenges: cooling must be compact, quiet and has to be placed in the system chassis to avoid discomfort from wires and hoses. Liquid cooling is one of the technologies used to meet these challenges, providing high coefficient of performance (COP) for maximizing uptime and optimizing performance. Players include but are not limited to: Advanced Cooling Technologies (ACT) [10], Aspen

Systems, Boyd Corporation, Lytron, Laird... This latter, for instance, produces stand-alone liquid cooling systems for accurate temperature control in CT scanners, PET scanners and MRI scanners [11].

- Concentrated PhotoVoltaics (CPV) cooling

CPV are currently done using small, widely dispersed PV cells, operating at high solar concentration. Heat is current dissipated by ambient convection, so liquid cooling is not probable. Dense receiver arrays would however bring the need for active liquid cooling, but this market is not growing and the prospects for growth are not clear. This market is therefore not a priority.

Value Proposition

The self-adaptive cooling approach demonstrated in the STREAMS project brings the following advantages to the applications using it:

- Compact form factor (mm thin, no larger than the size of the heat source)
- Minimizes the power consumption required for liquid cooling
- Ensure temperature uniformity spatially as well as temporally
- Ensure higher performance for the full system
- Eliminates thermal cross talk between nearby chips, allowing dense integration and performance driven design (as opposed to thermal-constrained design)
- Improved reliability of interconnects with less thermal cycling
- Heat rejection can be delocalized from the heat source

Income flows

Since the self-adaptive fins/valves are ideally integrated with the chip, the chip manufacturer is best suited to implement the technology. Furthermore, the size of the cooling array needs to be adapted to the chip size. Also, the chip makers are well equipped to manufacture the proposed solution since it is based on standard microfabrication processes and materials.

Licensing of the cooling technology for integration into customer chips/packages is the most probable revenue stream. In addition, design services could be offered as an additional revenue stream. Since the chip companies do not typically have the thermofluids and thermomechanical expertise required to design our cooling solutions into their product, they would require support to facilitate their adoption. Engineering design services would therefore serve an important role, especially for the initial phase of the commercialization. Once the chip maker has developed its in-house expertise, only licensing fees would remain as a revenue stream.

Alternatively, a separate company could provide thermally adaptive interposers as a product. This market is however risky, since the standard interposer market is not well established today. Since out technology makes the interposers even more complex and expensive, it is unlikely that it would be of commercial interest until truly needed.

Key resources

Most important assets and key resources required to run the business model essentially includes in a first phase intellectual and human resources, especially in the perspective of developing extended technical expertise on the following topics:

- Thermal and fluidic design → Experienced engineers with strong background on thermal modelling, able to run complex convective/conductive heat transfer simulations

- Thermomechanical design → Experienced engineers with strong background on microelectronics able to simulate deformations of complex vertical assemblies operating with variable heat loads and temperature gradients. High reliability will only be achieved by mastering the mechanical stresses induced by thermal cycling and identifying potential failure points.

- MEMS fabrication capabilities → Experienced engineers with strong background in MEMS or 3D-IC, with solid experience on process flows including Deep Reactive Ion Etching, electroplating, wafer bonding techniques (direct bonding, adhesive bonding, anodic bonding…), etching for sacrificial film removal.

- System experts → Experienced engineers with background in system performance, especially in the fields of application such as HPC or PC. Able to give directions in system design to take benefit of the performance boost offered by STREAMS, able to supervise co-design.

- Establishment of standards for fluidic connectors → Persons able to link with standard organizations, engineers association… to make the adoption of the technique easier and with possible recognized quality levels.

Key Activities

The most important things to do to make its business model work are:

- Establishing partnerships across the required supply chain. Perfectly understand the specifications in terms of performance, environment, cost, physical integration and fabrication constraints.

- Co-design with chip maker, packaging house and system integrator taking into account previous specifications

- Support in defining the fluidic connecters standards

Channels

Channels to discover products & services, evaluate, distribute & purchase the offer and deliver the proposition include:

- Direct contact with decision makers and lead technological advisor.

- Demonstrator at technological shows (ECTC, ITHERM, Autonomous vehicle conference…)

- White papers on applications, to provide examples in the various areas of potential interest.

- Participate in a standards committee to introduce fluidics IOs and discuss certifications, labels etc… In relation with science societies, engineer association (ex. ASHRAE) and other fields requiring fluidic implementations (biology ?).

Customer Relations

Relationships established on strategic objectives are:

- Acquire: need to gain interest from system integrators, packaging firms and chips makers. Once a key partner has been established at one level, get them to bring in partners at the other levels.

- Retain: co-design to ensure appropriate integration of the cooling technology into their products. Demonstrate a performance improvement on client prototypes.

- Upsale: offer new IP on liquid cooling o other features that stemmed from the STREAMS project, such as intelligent pump control, energy harvesting, etc.

- Grow: publicize the results and implementation of the technology in one customer's product, to entice other potential customer to also want to adopt it.

Key Partners

Indispensable partners and suppliers include:

- Chipmakers: main customer, will manufacture the cooling components since they have the microfabrication expertise.

- Packaging house: needs to add fluidic interconnects in its packaging

- System integrators: needs to adopt liquid cooling, if not used already, and not rely on traditional add-on cold plates. Need to validate the reliability of the solution through standardized tests.

Cost structures

Since the business model is mainly based on licensing and engineering services, the costs are mostly limited to personnel and supporting resources. Simulation ressources cost might have to be considered if important. Important sales effort is required to get buy in from a chipmaker and the rest of the supply chain. Some engineering staff will also be required to work with the customers in the co-design effort to adapt the solution to the customer's chips and applications. Salaries will therefore dominant the cost structure.

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