

# MEMS Energy Harvesting Devices, Technologies and Markets

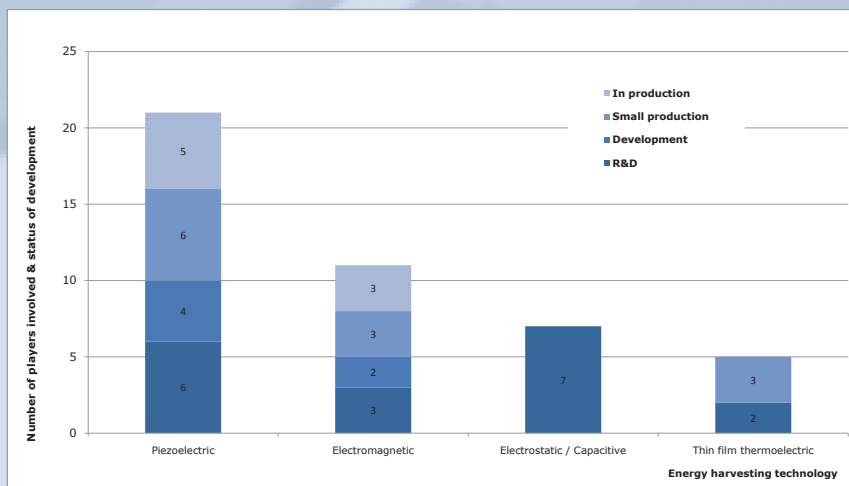
*Market driver analysis for challenges that go beyond energy density!*

## OBJECTIVES OF THE REPORT

**This report focuses on MEMS energy harvesting devices from both technology and market points of view.**

Special attention has been given to the market drivers for adopting MEMS energy harvesting devices in different market segments, factoring the progress of competing technologies and cost constraints.

It appears that the numerous opportunities for energy harvesting devices must be analyzed carefully, taking into account all aspects of the final application from power consumption profiles to lifetime and size constraints. Applications screened cover automotive, medical, industrial machine monitoring and process control, home automation and defense. The main developments in MEMS energy harvesting



*Number of developments for the main energy harvesting technologies (2009)*

devices are described and compared to fuel cells and micro-batteries. The report also describes the challenges facing the current players and the current market trends and business models.

## MAIN CHALLENGES

**Within an environmentally conscious world, MEMS Energy harvesting devices promise in principle a cleaner and almost perpetual solution to powering small systems avoiding the use and waste of polluting batteries.**

Ever optimistic market projections are predicting billions of dollars in revenue for ubiquitous sensor networks in the next five to ten years and derive from these numbers large energy harvesting sales and volumes.

And indeed, MEMS energy harvesting devices have been a hot topic in MEMS R&D for some years with spectacular developments driven by DARPA programs within the Hi-MEMS cyborg insects.

The reality is that beyond the technological buzz, commercial applications are slowly starting to get to market for industrial applications and home automation appliances. This is driving the first volumes for energy harvesting applications, but

not necessarily at the micro scale. Hot market segments in 2007 and 2008 such as tire pressure monitoring systems where batteries are currently the dominant solution have driven enormous efforts but the market dynamics have not made it possible to accept a premium price for alternative solutions.

We have focused our efforts in this report into a fine analysis of the market drivers for using MEMS energy harvesting devices, in comparison to micro batteries, micro fuel cells, or even solar cells. Different application fields from medical to home automation, industrial process control, machine monitoring or automotive have been analyzed in this report.

The challenges facing this technology were examined in a broad view, from a technology but also from a whole product point of view. There are needs for better power density but also for less power consuming electronics and wireless communications!

## MARKET METRICS

**Market acceptance of MEMS energy harvesting devices is a function of several parameters that are studied in the report.**

These parameters include, but are not limited to: size, cost, amount of power generated versus amount of power needed by the system and projected lifetime for the energy harvesting device compared to the system parts lifetime.

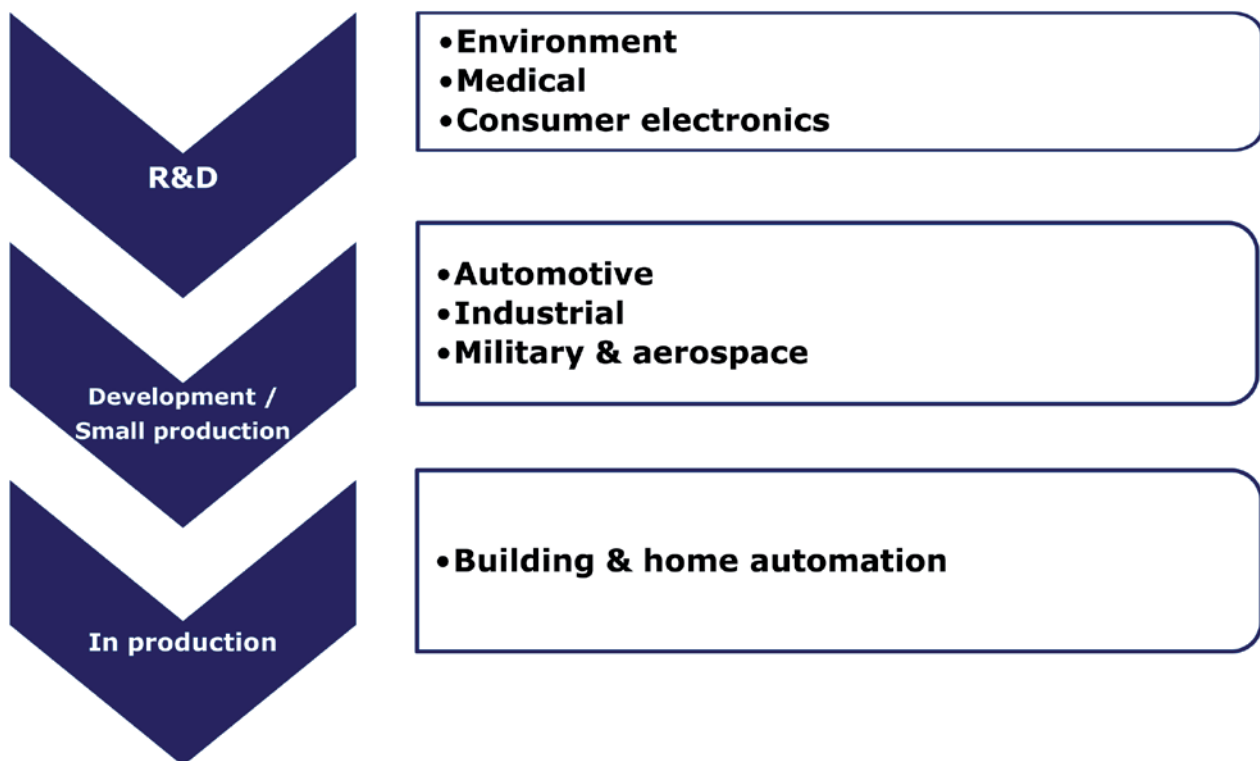
A major factor to be taken into account is whether there is enough power harvested for a particular application from a particular environment, and

whether the scavenged power needs to be stored. As piezoelectric MEMS energy harvesting devices can currently power sensor nodes requiring 60 uW according to the latest developments, a companion energy storage device would be necessary for most applications.

Commercial success will come from a full understanding of all aspects of the system to be powered and of the data receiver nodes.

Challenges include ultra low power electronics and wireless data transmissions rates and standards.

### STATUS OF ENERGY HARVESTING DEVICES\* IN THE DIFFERENT APPLICATION FIELDS, 2009



\* Only vibration and thin film thermal energy harvesting technologies are considered; Photovoltaic is not taken into account

## REPORT HIGHLIGHT

- 21 applications evaluated
- Global overview across 7 fields : automotive, industrial, building & home automation, environment monitoring, military & aerospace, medical, consumer electronics
- 14 company profiles
- 180 + slides
- Analysis of piezoelectric, capacitive, electromagnetic vibration energy harvesting and thin film thermal energy harvesting
- Review of the latest developments in energy storage devices (microbatteries...), wireless communication technologies and wireless sensor networks

## COMPANY PROFILES

### Main players and status

AdaptivEnergy, EnOcean, Holst Centre, Lumedyne Technologies, MEMS@MIT, Micropelt, Microstrain, Morgan Electro Ceramics, Piezo TAG, PMG Perpetuum, Thermo Life, TPL Micropower, Transense Technology, Visityre.

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- Potential for MEMS in the automotive field
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- Potential for MEMS in the environment monitoring field
- Potential for MEMS in the military & aerospace field
- Potential for MEMS in the medical field
- Potential for MEMS in the consumer electronics field

- **Conclusion**

## BIO



**Ridha HAMZA** joined Yole Développement in April 2007, as Project Manager MEMS devices and Technologies.

He has been involved since 1998 in MEMS EDA developments with various companies. He earned a Master of Science in Electrical Engineering.



**Laurent Robin** works at Yole Développement on marketing & technology analysis in the fields of MEMS and advanced packaging.

He earned a master degree of marketing and technology management and a science master degree in physics, with a specialisation in micro-technologies.

## YOLE IN THE PRESS



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Our commitment is to facilitate market access for innovative technology, devices, equipment and materials in the disruptive semiconductor businesses. Founded in 1998, Yole Développement is involved in the following fields, with strong leadership worldwide:

- MEMS Devices and Equipment & Materials for MEMS manufacturing
- Compound Semiconductors
- Nanomaterials
- Photovoltaic
- Microfluidics
- 3D IC/TSV & Advanced Packaging

Our services and publications:

- Market research
- Technology analysis
- Strategy consulting
- M&A support and due diligence
- Magazine Publication Micronews (print version and on line services)
- Exclusive newsletters in MEMS, 3D IC, photovoltaic, compound semiconductors and microfluidics
- Market reports & Database

Yole Développement is the world leader in the analysis of disruptive semiconductor applications and markets. Each day, Yole Développement's team of 20 market analysts is in contact with industrial companies, R&D institutes and investors worldwide in order to help them understand the market and technology trends. In its analysis, Yole Développement takes into account the complete value chain including materials, equipment suppliers, device & system manufacturers and end users.

# TERMS AND CONDITIONS OF SALE

Definitions: "Acceptance": Action by which the Buyer accepts the terms and conditions of sale in their entirety. It is done by ticking the box "I accept the conditions".

"Buyer": Any business user (i.e. any person acting in the course of its business activities, for its business needs) entering into the following general conditions to the exclusion of consumers acting in their personal interests.

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"Intellectual Property Rights" ("IPR") means any rights held by the Seller in its Products, including any patents, trademarks, registered models, designs, copyrights, inventions, commercial secrets and know-how, technical information, company or trading names and any other intellectual property rights or similar in any part of the world, notwithstanding the fact that they have been registered or not and including any pending registration of one of the above mentioned rights.

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## 1. Scope

1.1 The Contracting Parties undertake to observe the following general conditions when agreed by the Buyer and the Seller. ANY ADDITIONAL, DIFFERENT, OR CONFLICTING TERMS AND CONDITIONS IN ANY OTHER DOCUMENTS ISSUED BY THE BUYER AT ANY TIME ARE HEREBY OBJECTED TO BY THE SELLER, SHALL BE WHOLLY INAPPLICABLE TO ANY SALE MADE HEREUNDER AND SHALL NOT BE BINDING IN ANY WAY ON THE SELLER.

1.2 This agreement becomes valid and enforceable between the Contracting Parties after clear and non-equivocal consent by any duly authorised person representing the Buyer. For these purposes,

the Buyer accepts these conditions of sales when ticking the box "I accept the conditions". This results in acceptance by the Buyer.

1.3 Orders are deemed to be accepted only upon written acceptance and confirmation by the Seller, within [7 days] from the date of order, to be sent either by email or to the Buyer's address. In the absence of any confirmation in writing, orders shall be deemed to have been accepted.

## 2. Mailing of the Products

2.1 Products are sent by email to the Buyer:

- within [1] month from the order for Products already released; or

- within a reasonable time for Products ordered prior to their effective release. In this case, the Seller shall use its best endeavours to inform the Buyer of an indicative release date and the evolution of the work in progress.

2.2 Some weeks prior to the release date the Seller can propose a pre-release discount to the Buyer

The Seller shall by no means be responsible for any delay in respect of article 2.2 above, and including incases where a new event or access to new contradictory information would require for the analyst extra time to compute or compare the data in order to enable the Seller to deliver a high quality Products.

2.3 The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in article 3.

2.4. The mailing is operated through electronic meanseither by email via the sales department or automatically online via an email/password. If the Product's electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that it is informed of the defective formatting within 90 days from the date of the original download or receipt of the Product.

2.4 The person receiving the Products on behalf of the Buyer shall immediately verify the quality of the Products and their conformity to the order. Any claim for apparent defects or for non-conformity

shall be sent in writing to the Seller within 8 days of receipt of the Products. For this purpose, the Buyer agrees to produce sufficient evidence of such defects. .

2.5 No return of Products shall be accepted without prior information to the Seller, even in case of delayed delivery. Any Product returned to the Seller without providing prior information to the Seller as required under article 2.5 shall remain at the Buyer's risk.

## 3. Price, invoicing and payment

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3.3 Payments due by the Buyer shall be sent by cheque payable to Yole Développement, credit card or by electronic transfer to the following account:

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To ensure the payments, the Seller reserves the right to request down payments from the Buyer. In this case, the need of down payments will be mentioned on the order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except in the case of a particular written agreement. If the Buyer fails to pay within this time and fails to contact the Seller, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the «BC» + 7 points, in accordance with article L. 441-6 of the French Commercial Code.

3.4 In the event of termination of the contract, or of misconduct, during the contract, the Seller will have the right to invoice at the stage in progress, and to take legal action for damages.

## 4. Liabilities

4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for choosing the Products and for the use and interpretations he makes of the documents it purchases, of the results he obtains, and of the advice and acts it deduces thereof.

4.2 The Seller shall only be liable for (i) direct and (ii) foreseeable pecuniary loss, caused by the Products or arising from a material breach of this agreement

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4.4 All the information contained in the Products has been obtained from sources believed to be reliable. The Seller does not warrant the accuracy, completeness adequacy or reliability of such information, which cannot be guaranteed to be free from errors.

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