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PARLIAMENTARY OFFICE FOR THE EVALUATION OF SCIENTIFIC AND TECHNOLOGICAL CHOICES

REPORT

on

The evolution of the micro and nanoelectronics sector

by

Mr. Claude SAUNIER, Senator

Filed with the Bureau of the National Assembly
by Mr. Claude BIRRAUX
Chairman of the OPECST

Filed with the Senate Bureau
by Mr. Henri REVOL
First Vice-Chairman of the OPECST

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A. A KEY ECONOMIC SECTOR

1. Omnipresent in day-to-day life

From the time we wake up until we go to bed, we're surrounded by objects that function thanks to electronic components.

This omnipresence of microelectronics in our daily life is to be explained by an extreme miniaturization supported by **exponentially decreasing production costs: between 1973 and the present day**, the price of one megabyte of electronic memory has fallen from €75,000 to one euro cent.

In addition, **the creation of new functionalities for integrated circuits has opened up new fields of application.**

2. Increasing economic weight in the global economy

The electronics industry has enjoyed spectacular growth, as measured by its worldwide turnover. **In 1965, the industry recorded a turnover of $1.5 billion, compared to $265 billion in 2006, a figure greater than the airline industry's.**

Up until the present decade, semiconductors enjoyed a growth rate twice that of the world economy.

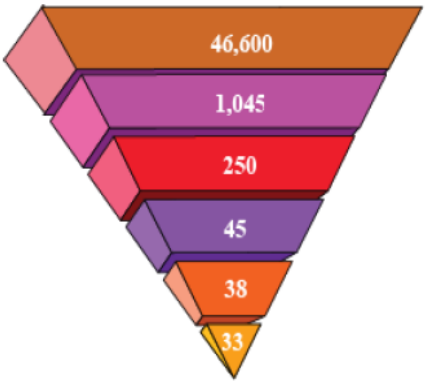
Today, the semiconductor market is being fuelled by the emerging countries. **In the medium term, China and Southeast Asia are expected to account for 75% of the semiconductor industry's worldwide growth.**

3. Tremendous leverage

In addition to this spectacular progress, we should also underline the **leverage** of semiconductors. Industry specialists refer to this phenomenon as the "upside-down pyramid" of the silicon sector, as illustrated in the following diagram:

With global gross domestic product estimated at $46,000 billion, the semiconductor industry accounts for more than 10% of the world's wealth.

The pyramid of good and wealth



US$ (billion)		2006 growth	Average over past decade
	World GDP	+5.1%	+3.4%
	Electronic equipment	+6.0%	+5.0%
	Semiconductors	$ +10.0% Units +18.0%	+14.0% +10.0%
	Capital spending	+18%	+14%
	SEMI equipment	+18.0%	+14.0%
	SEMI materials	+16.0%	+10.0%

Source: Medea +

4. A strategic sector for the competitiveness of businesses and national independence

With the increase in performance, the reduction in size and the reduced cost of integrated circuits, **semiconductors are no longer limited to their original field of application (i.e., military applications and large computers) and are conquering new areas, such as telecommunications, consumer products, the automotive sector and industrial control and automation systems.**

Today, **the omnipresence of microelectronics in all sectors forces companies to master the associated technologies in order to remain competitive.**

For instance, in the automotive sector, electronics play an ever greater role: while electronics represented on average only 22% of the cost of a motor vehicle in 2000, this figure is expected to rise to 35% in 2010 and 40% in 2015.

The semiconductors industry plays an essential role not only in business competitiveness, but also in the maintenance of national independence.

B. AN INDUSTRY FACING A TRIPLE CHALLENGE

1. Exploding costs

The increase in technological challenges has engendered an explosion in costs in terms of R&D, design, software and production.

Indeed, developing the technology to allow for a resolution of 90 nm cost $500 million. **Today, the development cost of technology allowing for a resolution of 45 nm and 32 nm is estimated at $750 million and $1 billion, respectively.**

What's more, costs linked to the functional design of integrated circuits increase by 50% for each new generation of technology.

Finally, the cost of production units is continually increasing. This figure has doubled since 2002, rising from $1.5 billion to $3 billion.

2. The shortening product life cycle

Product life cycle is shrinking. Indeed, portable-phone ranges change every six months. Manufacturers of semiconductors are therefore subjected to very short time limits.

In addition, the market very quickly absorbs new applications. For microelectronics manufacturers, this means that they not only have to be among the first to launch an adequate product, they also have to be able to very quickly increase their production volumes.

Finally, price constraints are huge. As the director of the STMicroelectronics site in Crolles pointed out: "We sell 1 mm^2 of silicon, no matter the technologies included". Semiconductor manufacturers must therefore constantly innovate without raising the prices of their products. **It is imperative to offset the minimal margin per production unit by a high production volume.**

3. A market nearing maturity

According to the information obtained by your rapporteur, the market for semiconductors grew by 8.9% in 2006. Growth slowed in 2007 (+3.1%) and the forecasted figure for 2008 has been readjusted downward to +5.2%. For 2009, a growth rate of +8.5% is expected.

Many industry specialists believe that this market is nearing maturity. If true, this would engender lower growth rates (between 6 and

8 percent, compared to more than 15% during the 1970s, 80s and 90s), as well as a less-cyclical sector.

C. A CHANGING INDUSTRY

1. An evolving global hierarchy

When one examines the evolution of the sector over a long period of time, one notices that no situation is permanently established.

- By large geographic regions: for instance, the United States, which once accounted for 55% of global transistor production in 1978, manufactured only 17% in 2007. As for Japan, this country produced 30% of the world's transistors in 1978, 50% ten years later, but only 25% in 2007. With regard to Europe, its share of global production has fallen from 15% in 2000 to 11% in 2007. However, Southeast Asia, which was almost absent from the market in 1985, manufactured 48% of the world's transistors in 2007.

- By companies: while, in 1990, of the 10 largest semiconductor manufacturers, 6 were Japanese, 3 American and 1 European, in 2007, only 3 were Japanese and 2 American compared to 3 European and 2 Korean companies.

2. The continuing "deverticalization" of the semiconductor sector

Considering the rise in costs mentioned earlier, fewer and fewer actors are capable of ensuring all research, technological development and manufacturing operations.

Today, **two other categories of actors are developing alongside the integrated companies:**

➢ **The "fabless" companies,** or those companies with no production capacity. They concentrate on those activities that are the most profitable and the least demanding in capital, such as the designing of new chips, marketing and distribution.

➢ **The foundries,** which are specialized in the manufacture of semiconductors.

3. The development of alliances as a result of rising costs

Semiconductor companies dedicate between 15 and 20 percent of their turnover to research and development. Nevertheless, considering the cost of developing a given technology ($750 million for the 45 nm, $1 billion for the 32 nm), no single company (with the notable exception of Intel[1]) is capable of providing the necessary financial resources.

As has already been pointed out, certain companies have given up trying to do so, turning their attention instead to design.

The other companies have been forced to form alliances, in order to share the costs.

- The Crolles 2 alliance

Such was the aim of the Crolles 2 alliance, created in 2002 for a duration of five years, between STMicroelectronics, NXP and Freescale. **A laboratory/shared research centre** was created to develop 90, 65 and 45-nm CMOS[2] technology and the by-products of great added value (analog, radio frequency, embedded memories). In addition, **a pilot production line for 300 mm wafers of silicon** has been completed in order to be able to produce sooner and in volume circuits made from these new technologies.

This alliance was a success to the extent that it met its objectives. However, it was not extended following the successive withdrawal of first NXP then Freescale in early 2007. According to STMicroelectronics representatives, the alliance had become too small to develop the 32-nm and 22-nm technologies and it would have been necessary to find two additional partners with whom to share the costs.

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[1] With a turnover of nearly $34 billion, Intel remains the undisputed leader in the semiconductor sector. In addition, it has succeeded in outsourcing a large portion of its "upstream" research by developing very close partnerships with universities, thereby allowing the company to limit its financial commitments to acceptable proportions.

[2] Complementary Metal Oxyde Semiconductor: a technology for the manufacturing of electronic components.

- The IBM alliance

This alliance was formed 15 years ago by Toshiba and Infineon in the DRAM sector. Today, the alliance is made up of 8 companies (Samsung, the world's 2nd largest manufacturer; Toshiba, the 3rd largest; ST, the 5th largest; Sony, the 8th largest; Infineon, the 10th largest; AMD; Freescale and IBM), for a total turnover of $60 billion. It constitutes a platform of cooperation for the development of 32 and 22-nm CMOS technologies.

4. The coexistence of three industrial models, each with its own constraints

a) The fabless/fablite companies[1]

The general increase in costs associated with a rising price pressure should engender a concentration of actors. However, just the opposite has in fact occurred, due to the increase in fabless companies.

In the short term, fabless companies enjoy two advantages.

Firstly, **the initial investment is not as great** as for the integrated companies, since the infrastructure needs are much more limited due to the absence of factories.

Secondly, at an equal turnover, **fabless companies can dedicate more funds to product development**; this constitutes a significant advantage for a market in which "differentiated" products yield greater profits than standard products.

However, in the medium term, the fabless companies could be directly threatened by the foundries.

Firstly, the development of a quasi-monopoly in the chip-manufacturing sector could **modify the balance of power between the principals and the subcontractors to the benefit of the latter.** The price of integrated circuits could therefore increase.

Secondly, the most important foundry, TSMC, has expressed its desire to increase its margins by rising in the value chain. **It could eventually design its own integrated circuits and directly compete with the fabless companies.**

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[1] A "fabless" has no production tool, while a "fablite" continues to produce a small portion of its own components.

b) The foundries

Shrinking product life cycles require a rapid increase in the volumes of integrated circuits manufactured, which in turn necessitates an excellent control of the manufacturing processes. However, the greater the volumes to be manufactured, the greater the opportunities for the engineers to improve output productivity and excel in this domain.

Such is the strategy of the foundries, the four largest of which account for nearly 80% of world chip subcontracting production and have acquired an unequalled savoir faire at particularly competitive prices.

By itself, TSMC produces 50% of the world's subcontracted integrated circuits.

The foundry model would seem to be well established and few integrated companies are capable of competing with them in their sector of activity.

However, not all foundries are optimistic regarding their chances of surviving in the long term.

According to the chairman and managing director of Chartered Semiconductor, the foundries suffer from constantly falling prices (-26% for 2006), resulting from excess production capacities for leading-edge technologies and a ferocious price war waging between TSMC, UMC and Chartered Semiconductor. In addition, for the manufacture of less technologically-advanced products, **competition is very hard due to the large number of 150 mm and 200 mm wafers fabs.**

Therefore, a consolidation of the sector seems inevitable, even if it will be insufficient to improve the foundries' margins. Indeed, in 2007, the production-via-subcontracting market grew by only 2.6% compared to 2006, for a total turnover of $22.19 billion. TSMC recorded a turnover of $9.8 billion, a rise of only 1.2% compared to 2006.

Therefore, the foundries are adapting their manufacturing policies, in order to improve their profitability.

In the short term, all of the foundries have reduced their investments, in order to put pressure on prices.

In the medium term, their strategies diverge between the leader, TSMC, and the other foundries, whose financial capacities are more limited.

TSMC is in the process of **diversifying its activities and developing an entire series of vertically-integrated services**: in addition to manufacturing integrated circuits, it offers pre-production tools for designing circuits and post-production services for testing and packaging.

It is also seeking to create an alliance to bring together components manufacturers and the large semiconductor manufacturers, in order to assert itself as **the unique worldwide hub for the manufacturing of circuits on 450 mm wafers.**

Due to their insufficient size, the other foundries plan on surviving by creating alliances allowing them to reduce the costs of investing in new technology.

c) The integrated companies

They must deal with competition from both the fabless companies, which, adjusted for turnover, invest more in integrated-circuit design, and the foundries, which manufacture better and for less money.

In order to mitigate their exploding costs, some integrated companies have joined a network of **"precompetitive partnerships" in order to develop such generic technologies as CMOS for digital applications, while often contracting out part of their production.**

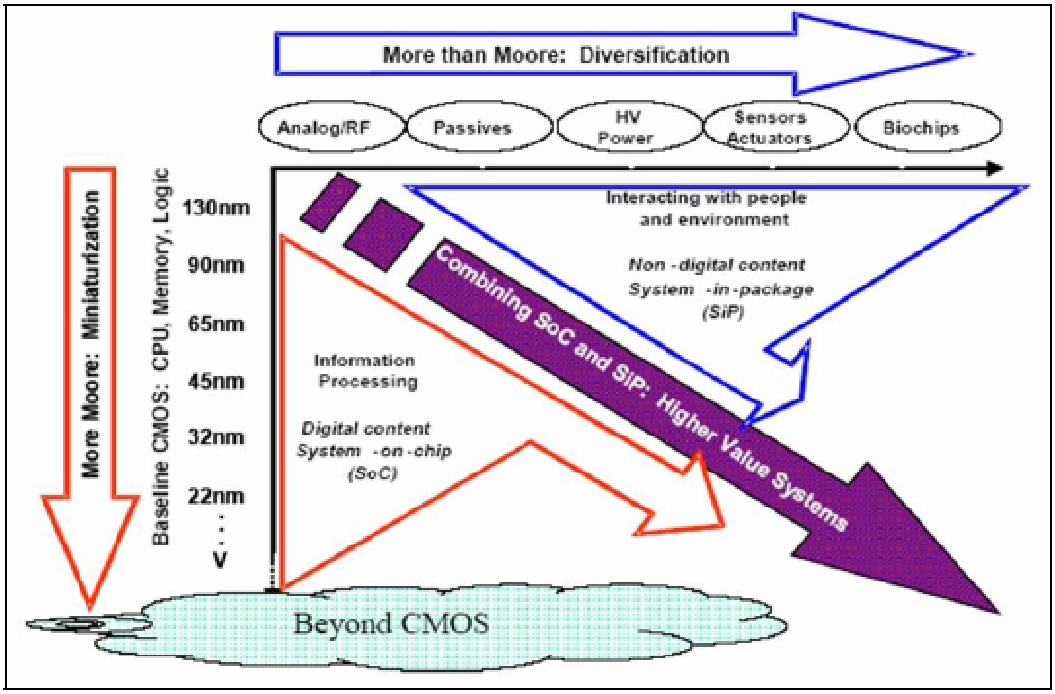
The scant differentiation by digital CMOS leads the integrated companies to seek competitive advantages via **the development of technological by-products of high added value**, allowing new functionalities to be added on to the integrated circuits.

Nevertheless, these companies would like to **retain their own production lines, in order to remain somewhat independent vis-a-vis the foundries.**

II. PROMISING SCIENTIFIC PROSPECTS DESPITE THE TECHNOLOGICAL CHALLENGES TO BE MET

A. THE THREE MAIN AREAS OF DEVELOPMENT FOR THE MICROELECTRONICS SECTOR

Semiconductor technology trends



Source: Medea +

1. "More Moore" or the pursuit of miniaturization

Miniaturization is significant for three reasons.

Firstly, by shortening the distance between the source and the drain, miniaturization accelerates the transfer of electrons, **thereby increasing the number of operations carried out per second while at the same time reducing the transistors' energy consumption.**

Secondly, reducing circuit size allows for **the collective manufacture of hundreds of chips per silicon wafer, thereby lowering their per-unit cost.**

Finally, miniaturization decreases the size of objects while increasing their functions.

In 2003, microelectronics became nanometric, with the production of transistor grids less than 100 nm wide (a node of 90 nm).

Since September 2006, integrated circuits have enjoyed a resolution of 65 nm and in early 2008, this figure descended to 45 nm for very fast microprocessors. At the same time, resolutions of 32 and 22 nm are already being developed, while in the laboratory, widths of as low as 6 nm have been obtained.

Discussion concerning the limits of Moore's Law is not new. Nevertheless, **a consensus is emerging that it is no longer possible to pass from one generation of transistors to the next by simply decreasing their geometric dimensions.** As an IBM representative succinctly put it to your rapporteur: "We can't shrink atoms!" However, this size has already been reached by certain transistor parts. Indeed, the very thin slice of silicon located between the grid and the channel is now much thinner than 1 nanometre, reaching widths of only a few layers of atoms.

Today, innovations in materials and architecture are what will allow for improved integrated-circuit performance.

2. "More than Moore", or the integration of several functions on a single chip

CMOS technology, which allows for the processing and memory functions, is not enough to explain the success of microelectronics. **It is the addition of non-digital functions (such as radiofrequency, high-voltage components, lighting electronics and battery chargers) that has played a decisive role in the omnipresence of microelectronics.** These are referred to as "more-than-Moore" or by-product technologies.

For example, portable phones now have a significant number of non-digital functions, such as a camera, a radiofrequency system for communication and an audio/video player.

While benefitting from progress made in microelectronics, these technologies come from various sectors of the microelectronics industry (mechanics, fluidics, acoustics, optics) and their performance is not directly correlated with etching size.

Your rapporteur insists on emphasizing the major economic changes linked to the development of by-product technologies.

On the one hand, the market for semiconductors is destined to diversify. Not only will new sectors appear alongside the classic silicon sector (such as organic electronics), but niche markets will also emerge.

On the other hand, the semiconductor market could open up to new players insofar as capital investment for the development of by-product technologies is significantly less expansive than for "more-Moore" technologies. However, the existence of industrial leaders in the application fields being considered and a proactive state policy of supporting these new markets can be determining criteria. In this regard, it is significant that Germany's early and massive commitment to solar energy has allowed for the creation of a strong national industry in this sector utilizing the by-product technologies.

3. "Beyond CMOS", or research on technological alternatives to CMOS

The combination of "more Moore" and "more than Moore" offers the field of microelectronics numerous opportunities for growth. Nevertheless, CMOS technology will sooner or later come up against a two-fold limit:

- **the physical limit** already mentioned above and which is expected to be reached around 2020. Today, in an integrated circuit, the insulating barrier separating the transistor grid from the channel is only a few atoms thick. By continuing with miniaturization, this barrier is becoming so thin as to allow for quantum tunnelling, creating a loss of power when the switch is set to the "closed" position. When the mechanism is in the "open" position, this leakage constitutes a significant fraction of the channel's current, thereby reducing the transistor's reliability.

- **an economic limit** that could be reached before the physical limit. The cost of developing a given technology increases by 30% with each new generation. Currently, only Intel, the IBM alliance and TSMC are capable of financing the research and development for the 32 and 22-nm generations. What does this mean for future generations?

In response to these two limits, manufacturers and the international scientific community, with significant state support, have been searching for the past several years for new avenues of development, which should prove less expensive thanks to the introduction of new concepts which do not utilize the classic architecture of the CMOS transistor and the manufacturing techniques of silicon microelectronics.

In his report, your rapporteur briefly presents four fields of research: spintronics, photonics, molecular electronics and quantum electronics.

While all of these avenues appear promising, for the moment they remain in the realm of fundamental research: not a single avenue has asserted itself as a credible alternative to silicon, neither in terms of performance, nor in terms of cost.

In addition, most persons interviewed for this report believe that we will not see a sudden break between the silicon industry and the "beyond CMOS", but rather a series of incremental changes.

B. THE OBSTACLES TO OVERCOME

1. Pursuing miniaturization via lithography

It should be pointed out that **the resolution that is currently being worked towards is far below the exposition wavelength**, which would seem to challenge the laws of physics.

Looking ahead, many researchers are betting on **the introduction of extreme ultra-violet radiation (EUV)**, whose wavelength is 13.5 nm. Even if it appears quite promising, lithography in extreme EUV encounters technological difficulties which remain insurmountable.

2. Disturbances to transistor performance

a) The growing complexity of the interconnections

One major problem in producing complex integrated circuits lies in the system of interconnected circuit blocks. **Currently, the average length of all the connections on a single chip is 8 km!**

IBM recently developed **microprocessors that use air to isolate the wires linking together the hundreds of millions of transistors ("air gap" technology).** This innovation reduces electrical interference, increases processor performance and reduces energy consumption.

b) Current leakages

To fight power leakages, researchers are turning on the one hand towards **replacing the layer of silicon dioxide with a dielectric material**

with a higher dielectric constant (referred to as "high k"[1]), and on the other hand towards **replacing the material currently used for the grid (doped polysilicon) with a metal with a lower resistance**, thereby allowing for a faster transfer of electrons and a minimum dissipation of energy.

c) Energy consumption

To increase the processing power of microprocessors, designers have long been satisfied with **making microprocessors work at a higher frequency** (megahertz then gigahertz).

However, the faster a microprocessor turns, the greater the amount of heat dissipated by the integrated circuit. To improve the power of microprocessors without increasing the amount of energy consumed, **manufacturers have given up targeting an ever-higher frequency and have instead turned to increasing the number of cores.** By using several cores instead of just one, more data can be processed simultaneously.

d) Fluctuations in transistor performance

The extreme miniaturization of transistors accentuates their heterogeneity. To mitigate performance fluctuations, manufacturers must develop **new architectures** (parallel, asynchronous) and **new design methods** (transistor redundancy, auto-detection of failures, methods for recovering from equipment failures and software errors).

e) The sensitivity of integrated circuits to radioactivity

Two sources of radioactivity disturb transistor performance:

- **Cosmic rays that can hamper the proper functioning of integrated circuits aboard satellites.**

- **The natural radioactivity of the materials used for the integrated-circuit bodies.**

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[1] The IBM alliance uses hafnium dioxide.

3. The growing complexity of the architectures

The continuing pursuit of circuit miniaturization entails a vertiginous rate of integration: currently, a circuit can contain more than one billion transistors. **The growing complexity of architectures engenders numerous challenges with regard to circuit modelling, performance optimization, etc.**

III. A SECTOR SUBJECTED TO SOCIETAL ISSUES

A. A POTENTIALLY CRUCIAL SECTOR FOR OVERCOMING THE SOCIAL CHALLENGES OF THE 21ST CENTURY

1. Exploding health costs

At the European level, health costs currently amount to more than €600 billion per year, or 9% of European GDP. However, health costs can only be expected to increase under the two-fold pressure of the technological evolution and an aging population.

Controlling health costs while ensuring the population access to a system that integrates the latest scientific advances demands that we make the health system more effective and efficient. To this end, microelectronics can play an important role.

Firstly, microelectronics can help **further prevention** by making it less expensive and therefore accessible to a large section of the population; it can also make it more reliable via the very-early detection of diseases.

In addition, **the use of less-invasive methods of diagnostics and treatment will allow for a reduction in the duration of hospital stays.**

Another avenue of cost savings resides in the development of at-home care and distance monitoring of patients.

Finally, **huge gains in productivity remain to be achieved in the administrative management of patient dossiers and the exchange of information between medical professionals.**

2. Costs linked to an ageing population

Considering the exorbitant costs linked to specialized senior-citizen housing and its negative psychological impact on the patients, **public officials are striving to develop solutions to allow the elderly to remain at home as long as possible.** To this end, microelectronics can play a central role.

For example, many seniors leave their home under the pressure of family members who fear their isolation in the event of a fall or a thoughtless act that can pose a danger to the person (especially in the case of Alzheimer's or senile dementia). **Distance monitoring of the elderly person who is still relatively able-bodied can therefore delay his/her entry into a specialized establishment.**

3. Improved energy efficiency

Within 20 years time, world electricity consumption is expected to double, thereby increasing price pressure even further. In addition, electricity production represents half of all carbon dioxide emissions, which are expected to grow by 55% by 2030 based on current trends. While the construction of new power stations is inevitable, microelectronics can provide solutions by increasing energy efficiency without questioning consumer habits.

Three sectors are particularly concerned: public lighting, residential services and transportation.

4. Road traffic management

According to a 1994 study commissioned by the German automobile manufacturer BMW, **the cost of traffic congestion in Germany amounted to €100 billion per year, with 12 billion litres of petrol being wasted.** For France, this cost is currently estimated at €30 billion, or 3% of GDP.

In addition, the economic cost of traffic accidents is estimated at €200 billion for Europe and €20 billion for France.

In the future, the increasing use of electronics in automobiles should contribute to an overall improvement in traffic and safety.

5. Safety issues

One of the fundamental responsibilities of the State is to guarantee the safety and security of its citizens. While objectively we may live in a safer world than was the case a century ago, **the need for security is increasing and takes various forms,** from the most basic concerning the safety and security of persons (namely, not being attacked in the street) and of property (such as not being burgled) to the security of networks, whether they be air, rail, telephone or computer for the transmission of data.

Microelectronics plays a preponderant role in the development of surveillance cameras, security systems utilizing badges or biometrics and cryptography, as well as optically-read passports and identity cards.

What's more, the Internet of Things should improve sanitary conditions and food safety, as well as help fight fraud and forgery.

B. A SECTOR THAT RAISES CERTAIN QUESTIONS

1. The environmental cost of the microelectronics industry

a) An industry that consumes a lot of natural resources

According to the chief representative of the association Vivagora[1], **a single computer chip requires 630 times its weight in fossil energy and chemical substances**, while the production of a single USB flash drive requires 250 litres of water.

The search for ever-greater performance and the multiplication of microelectronic applications also result in our **using an ever greater number of materials, some of which are rare (such as indium**, 50% of whose consumption goes to the production of liquid-crystal displays for flat-screen monitors).

In addition, **microelectronic applications use a lot of energy.** They currently account for **13% of global electricity consumption, the same amount as is used for public lighting**, and the medium-term previsions are alarming from a sustainable-development perspective.

In addition, a significant proportion of the energy consumed by electrical devices is used in standby or sleep mode, which constitutes an enormous waste. **In the United States, the proportion of electricity that supplies devices in standby mode is estimated at 24% of the overall electricity consumed by electrical devices (for the most part TVs, videorecorders and computers).**

b) An industry that produces a lot of waste

The omnipresence of electronics also raises the issue of waste management. According to the information obtained by your rapporteur, **waste from electrical and electronic devices amounts to between 1.7 and 2 million tonnes per year for all of Europe, or 16 kg of waste per inhabitant and per year.**

In addition, the total amount of such waste produced is increasing by 4% each year; this represents a much higher growth rate than for household waste overall.

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[1] Created in 2003, the aim of Vivagora is to promote a culture of debate on scientific and technological issues.

c) The development of green electronics

Nevertheless, **semiconductor firms have several reasons to design more energy-efficient products.**

Firstly, **the development of mobile products**, such as portable phones and computers, **requires greater energy autonomy**, which is achieved via more energy-efficient components.

Secondly, **increasing the power of microprocessors by raising their frequency has reached its limits due to the resulting heat dissipated by the integrated circuit.**

In addition, **the rarity and high cost of certain materials** used in electrical and electronic devices are **strong arguments in favour of recycling.**

Finally, microelectronic manufacturers have become aware of **the enormous potentials of the market for "green electronics".**

d) An industry concerned by the health and environmental risks linked to the development of nanomaterials

The electronics and communications industry will naturally make use of certain nanomaterials for high-density memories and miniaturized processors, solar cells, combustion batteries and cells, flat-screen monitors, etc.

In the short term, the needs of the microelectronics industry should be concentrated on carbon-nanotube production, which is estimated to reach 100 tonnes[1] per year between 2011 and 2020.

The predicted strong growth in the coming years in nanomaterial research and industrial applications is accompanied by **a fear that these materials could prove dangerous to human health, in particular for those persons working with these materials, but also for the population at large.**

In addition, **nanomaterials could prove toxic for the environment.**

However, if this new form of technology has only grown in popularity over the past decade, there is still not enough data regarding the behaviour of nanomaterials in the environment, as well as nanomaterial toxicity.

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[1] It should be pointed out that carbon nanotube production data is considered strategic information by national governments. As a result, this figure is undoubtedly an underestimation.

2. Protection of personal data

Because computers allow for the massive processing and cross-checking of data, they are liable to pose a threat to privacy and violate individual rights.

a) Developing the computer industry in a manner that respects privacy and individual rights

The law of 6 January 1978 (modified 6 August 2004) concerning computers, files and liberties created the Commission Nationale de l'Informatique et des Libertés or CNIL, an independent French administrative authority whose mission is to ensure that personal data is processed in such a manner as to respect privacy as well as individual and public liberties.

b) A principle increasingly undermined by the improvement and spread of traceability technologies

The omnipresence of microelectronics contributes to increasing the opportunities for the tracing of individuals. Indeed, most of our everyday objects contain microelectronic components, which result in our "leaving traces" more or less voluntarily.

The development of so-called "intelligent devices" capable of communicating amongst themselves without any direct human intervention could also prove quite intrusive and constitute a real threat to user privacy and peace of mind.

The development of invisible-marking technologies, such as radio-frequency identification (RFID) chips, and their pervasiveness due to their constant reduction in size and price also raise the issue of tracing and gathering information on individuals.

As a result, it seems increasingly difficult to maintain the balance between advances in microelectronics and computing on the one hand, and public liberties on the other.

IV. THE EUROPEAN MICROELECTRONICS INDUSTRY: AN INDUSTRY IN PERIL?

A. INFORMATION FROM THE WORLD MARKET

1. Demand fuelled by the Asian countries

Sales of semiconductors to the Pacific Asian States in 2007 amounted to $123.5 billion, or 48.3% of world sales and an increase of 6% compared to 2006.

Asia's preponderance in the purchasing of semiconductors is due to the fact that this region is the principal producer of electronic products.

2. A production mainly situated in Asia

Today, **45% of all semiconductors are manufactured in Southeast Asia**, compared to 24% in Japan, 18% in the United States and 13% in Europe.

In addition, according to the World Semiconductor Trade Statistics, 74 additional semiconductor fabrication plants or "fabs" are planned for construction in Asia in the coming years, compared to only 6 in Europe.

B. THREE EXAMPLES OF ASIAN PROACTIVENESS

1. Singapore

a) Key figures

Manufacturing represents 28% of gross domestic product, electronics 32% of global industrial production and semiconductors 48% of electronics production.

Holding a 10% share in the world market for the production of semiconductors, the city-state of Singapore (4.5 million inhabitants) is the **6th-largest country-producer of electronic components.**

b) Singapore's strategy

While Singapore is a first-rate financial centre and trade port, manufacturing remains an important pillar of its economy.

To attract multinationals, Singapore emphasizes three advantages:

- Its familiarity with the English language and a rather Western culture, which make Singapore an attractive destination for Western companies looking to gain access to the Chinese market.

- Its strict respect for intellectual property laws.

- Tax incentives and significant subsidies for high-technology companies setting up operations on its territory.

2. Taiwan

a) Key figures

The semiconductor sector represents 50% of Taiwan's industrial production, 12% of GDP and employs 80,000 people.

In 2007, Taiwan became the world's 2nd-largest producer of semiconductors (after Japan), with an 18% share of global production.

Via TSMC and UMC, it holds a 63% share in the world foundry market.

b) Taiwan's strategy

The success of the semiconductor industry in Taiwan is the fruit of the proactive policy of the government that decided to specifically encourage the development of those industrial sectors deemed of strategic interest during the 1980s, including the semiconductor industry. Taiwan succeeded in creating a very favourable environment for industrial investment via **the launch of successive, coherent plans with four pillars:**

- The creation of science parks gathering together on a single site universities, manufacturers and research centres.

- A concentration on advanced education, in order to provide itself with a workforce liable to satisfy the needs of future industrial developments.

- Providing technological support to companies, via the creation of several research centres working in close collaboration with the manufacturing industry.

- Very significant tax and financial incentives.

3. Mainland China

a) Key figures

Mainland China has made dazzling progress in the semiconductor sector. **While in 2000 China's share of global production amounted to only 2%, this figure had risen to 7% by 2007.** There are currently some one hundred functioning or planned factories located in China.

Likewise, in the encapsulation and testing sector, China's share had risen from 5% in 1999 to 23% in 2007.

b) China's strategy

In the 1960s, the Chinese government began attempting to develop its own semiconductor industry based on state-run companies. However, due to insufficient technology, the government modified its policy by favouring the importation of equipment and technology linked to semiconductors and authorizing foreign integrated companies to carry out joint ventures with national companies, and even to set up their own plants in China.

Up until the late 1990s, these set-ups essentially concerned assembly and testing operations for older generations of components.

In 2000, the Chinese company SMIC was created to develop a foundry industry in China. Highly subsidized by the Chinese government, SMIC now holds a 7.6% share of the foundry market.

What's more, **since 2005, China has progressively provided itself with companies covering the entire value chain** (equipment, materials, foundries, assembly and testing, design and integrated companies).

Due to a lack of know-how, experience and capital, as well as restrictions set up by the United States on the exportation of sensitive semiconductor-related technology, **mainland China remains positioned in the low- to mid-ranges for subcontracting, design, assembly and testing.**

Nevertheless, it is clear that Chinese companies will seek to position themselves higher in the value chain in order to increase their margins.

C. THE INFLUENCE OF THE UNITED STATES

1. A major actor in the semiconductor sector

The United States remains a major actor in the semiconductor sector, despite its eroding market share in world production. Indeed, **while the US is home to no more than 17% of global production capacity, American companies account for 49% of semiconductor production,** illustrating American leadership in the sector.

Similarly, American influence remains preponderant in the field of semiconductor design (34% of the world market), compared to 26% for Japan, 22% for Southeast Asia and 18% for Europe.

In the IT software and services sector, the United States enjoys a near monopoly, holding an 85.2% share of the world market, compared to 10.8% for Europe and 2.1% for Japan.

2. A significant programme in support of microelectronics

Research in the microelectronics sector is financed on three levels:

- **At the federal level:** the principal agencies concerned are the National Science Foundation (NSF), which finances basic-research projects, the Defence Department via the Defence Advanced Research Projects Agency (DARPA) and the Energy Department.

- At the state level: in order to develop economic activity in the high-tech sectors, **many American states invest in the construction of research centres.** For example, the state of New York has spent $2 billion to create the College of Nanoscale Science and Engineering at the University of Albany.

- **At the industrial-association level:** several associations allocate a budget to research and development in distinct technological fields. For example, **SEMATECH dedicates $150 million** to research programmes that are closely linked to short-term industrial developments.

D. MICROELECTRONICS IN EUROPE: AN INDUSTRIAL SECTOR AT A CROSSROADS

1. Significant advantages

a) European industrial leaders

In certain segments of the semiconductor industry, European companies hold the lead.

For instance, this is the case in the **automotive-equipment sector**, in which four European firms are among the world's top ten companies: Infineon, STMicroelectronics, Philips and Bosch.

Likewise, **several European companies have made a name for themselves in telecommunications:** STMicroelectronics, NXP and Infineon Technologies are among the world's top ten sellers of wireless semiconductors, while Nokia, Alcatel-Lucent, Siemens and Ericsson are giants of the electronic telecommunications industry.

In addition, certain European suppliers of equipment and materials have asserted themselves as world leaders. Within a period of 10 years, **ASML has become the world leader in the field of lithography**, holding a 50% share of the market.

As for **SOITEC**, between 1991 and 2007, it imposed a near-monopoly as a supplier of the microelectronics industry with the development and manufacture of an innovative material: the silicon on insulator (SOI), used in the manufacture of chips.

b) World-famous European research centres

In the microelectronics sector, three European research centres are considered competitiveness clusters at the international level: LETI, IMEC/the Holst Centre and the Fraunhofer Society.

c) Microelectronics clusters with a true critical size

- Dresden's Silicon Saxony

A few key figures: 243 companies, including AMD, Infineon and Qimonda; 16,000 direct jobs and 40,000 indirect jobs; €7 billion of private investments between 2002 and 2007 for €1.5 billion of public investments.

- Minalogic in Grenoble

A few key figures: 115 members, including 79 companies (STMicroelectronics, Schneider Electric, Soitec, Hewlett-Packard) and 13 research centres and universities; 21,700 direct jobs in the microelectronics and electronics sectors; 3,000 jobs in research; 1,200 graduates per year.

- Point One in Eindhoven/Nijmegen

In 2006, the Netherlands created **the Point One competitiveness cluster in the nanoelectronics and embedded-system field** that gathers together large manufacturers (ASML, Philips Semiconductors, etc.), renowned research centres (the Holst Centre and the Embedded Systems Institute) and SMEs.

d) A variety of European programmes

- **The EUREKA programmes** (JESSI, MEDEA, MEDEA+, CATRENE): the last MEDEA+ programme, for the period of 2001-2008, received €1.1 billion from the member states; the new CATRENE programme covers the period 2008-2011 with the possibility of being extended until 2016. The manufacturers hope that €6 billion will be set aside for the programme, a third of this amount coming from the states.

- Framework Programmes for Research and Technological Development (FP): the 6th FP, covering the period of 2002-2006, devoted €1.4 billion to the microelectronics sector. The 7th FP (2007-2013) enjoys a budget of €50.5 billion. It is divided into five programmes: cooperation (which accounts for 2/3 of the total budget), ideas, persons, capacities and nuclear research.

- The European Nanoelectronics Initiative Advisory Council (ENIAC): for the period of 2008-2017, the European Commission forecasts that €3 billion will be allocated to this joint technological initiative by the member states, the European Commission and manufacturers.

2. Worrisome insufficiencies

a) A European industry whose influence remains marginal compared to its Asian and American competitors

The global influence of the European industry remains marginal compared to its Asian and American competitors. For example, 41.3% of semiconductors are sold by American companies, 44.6% by Asian companies and only 14.1% by European companies.

In addition, **not a single European company is sufficiently large to pursue alone its own technological development.** For instance, STMicroelectronics and Infineon have joined the IBM alliance in order to share the costs of developing CMOS technologies, while NXP has dropped out of the race towards miniaturization, preferring instead to concentrate on "More-than-Moore" applications. Therefore, it is not certain that, in the medium term, European companies will continue to invest in "More Moore".

Your rapporteur **supports the specialization of the European semiconductor industry in "More than Moore", insofar as this avenue of research is better suited to its financial capacities and the applications that it is expected to develop are quite promising.**

Nevertheless, your rapporteur is uncertain regarding **the danger of dropping out of the miniaturization race**, insofar as those companies who will continue all the way to the end of the "roadmap" will benefit from a decisive technological advantage which they could then use to develop "More-than-Moore" applications.

b) The competitiveness of European companies hindered by a weak dollar

French and European sites are significantly impacted by the near doubling in price of the euro compared to the dollar since 2002 (from $0.81 to $1.56 in May 2008). **In the medium term, a continuing fall in the dollar threatens Europe's ability to maintain not only its production capacities, but also its research centres.**

c) A European industry penalized by competition laws that are overly strict compared to the rest of the world

The real competitiveness of manufacturing and R&D sites is greatly distorted by the weight of state subsidies.

For instance, the 2005 report on European competitiveness carried out by the European Semiconductor Industry Association shows that, more than disparities in wage costs, it is in fact state subsidies that have the greatest impact on a fab's profit levels. **Over a period of five years, the same factory can generate profits ranging from 100% to 200% depending on whether it**

is set up in Germany or in such countries as China, South Korea and Malaysia.

However, the severity of European regulations concerning the attribution of state subsidies penalizes those companies looking to set up operations in Europe and encourages European manufacturers to relocate their production activities.

d) A relative lack of political interest for the microelectronics sector, which prevents the establishment of an effective industrial strategy

The European Union finances numerous research programmes in the semiconductor sector, but **they are not part of any coherent industrial strategy**. There are several explanations for this situation:

- **A profound misunderstanding of the issues related to this sector** and its impact on the competitiveness of all companies.

- **The geographic concentration of the microelectronics industry in a small number of European countries**, thereby diminishing its interest at the EU level.

- **The illusion that Europe can give up producing electronic components and instead concentrate its efforts on R&D, even though production and R&D are very often interlinked in this sector of activity.**

e) Still imperfect scientific cooperation between states

The European programmes encourage cross-border cooperation between the various research institutes. Nevertheless, this cooperation could be improved. For example, your rapporteur observed that Europe's two largest research centres, IMEC and LETI, could cooperate more on fundamental-research subjects insofar as they often work on the very same subjects.

E. THE MICROELECTRONICS INDUSTRY IN FRANCE: AN UNCERTAIN SITUATION

1. The adoption of measures allowing for indirect but effective support of the semiconductor industry

a) The creation of ecosystems via the competitiveness clusters

In 2004, the government decided to launch a new industrial policy via the competitiveness clusters. Among the seven worldwide competitiveness clusters, three concern more or less directly the semiconductor sector[1], even if Minalogic, with its micro/nanotechnology cluster, is the only one directly dedicated to this sector.

The competitiveness clusters, by stimulating innovation and making the territory more attractive, create "ecosystems" that help limit relocations.

b) Reforming the research tax credit

The reform of the research tax credit included in the 2008 Finance Act seeks to do away with that portion of the research tax credit based on growing R&D expenditures, as well as the credit ceiling previously fixed at €16 million.

This reform is therefore of particular interest to large companies dedicating large sums to R&D, such as microelectronics companies.

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[1] These three clusters are: Systematic (Ile-de-France) for software and embedded systems; Solutions Communicantes Sécurisées (Provence Alpes Côte d'Azur), which seeks to design and develop new solutions that integrate components, software, networks and systems in order to share and process information in a secure, reliable manner; and Minalogic, with a micro- and nanoelectronics cluster and an embedded system-on-chip cluster.

2. Weaknesses to overcome

a) The absence of an industrial strategy

Competitiveness clusters are meant to embody France's new industrial policy. However, even if their creation does have a positive impact on the regions by encouraging a dialogue between representatives from the worlds of research, training/education and manufacturing, your rapporteur believes that there are too many such clusters and that they concern too many sectors to be of much use as a strategic industry tool.

In this regard, **your rapporteur disagrees with the current trend of questioning "large-scale programmes" in favour of non-targeted policies in support of innovation.** His travels around Asia and the United States confirmed that **the rapid development of leading companies in new industrial sectors is the fruit of proactive policies that require a selection of those sectors deemed of greatest importance combined with massive and sustained financial support.**

b) A continued lack of clarity with regard to public research

The setting up of a network of large technology centres has been positive, because it has allowed for the updating of research equipment and a greater structuring of public research. **Nevertheless, having visited four of the five sites, your rapporteur believes that public research still lacks sufficient clarity insofar as numerous laboratories continue to work on the same subjects without having first verified if the studies being carried out are competing or complementary.**

c) The future of Crolles

Freescale and NXP having ended their alliance with STMicroelectronics, **the future of the Crolles site is uncertain**, even if the directors of STMicroelectronics interviewed by your rapporteur insisted that STMicroelectronics remains committed to keeping this site.

CONCLUSION

THE MICROELECTRONICS SECTOR: A TEXTBOOK CASE OF GLOBALIZATION-INNOVATION-DEINDUSTRIALIZATION

The microelectronics industry is subject to worldwide competition. Regardless of the nationality of a given company, its location strategy is global and determined by the territories' general attractiveness and proximity to growth markets. **The impact of globalization on individual states depends therefore on their capacity to influence the creation of new markets and increase the attractiveness of their territory.**

Due to the absence of a strong industrial policy at the EU level and a low attractiveness linked to both its heavy tax system and competition regulations that penalize investments on its territory, **Europe would appear weakened by globalization.**

What's more, **innovation plays a decisive role in ensuring company competitiveness.** In the semiconductor sector, not only does technology evolve at a rapid rate, but the range of products is constantly being renewed. Considerable sums are therefore spent on research and development in order to encourage innovation.

Europe enjoys important advantages with regard to innovation, such as a qualified population, internationally-renowned research centres and competitive financial incentive tools for innovation. **Faced with globalization, Europe is endeavouring to position itself in those sectors of high added value (product design) and is tending to turn away from production.** For instance, in the electronics sector, production capacity no longer exists in the fifteen pre-1995 EU member states: televisions, computers, DVD players and portable phones are now made in the new EU member states, or even in Asia.

Will this trend towards Europe's deindustrialization extend to the microelectronics sector? Will Europe turn away from producing components and instead specialize in circuit design? **Your rapporteur believes that such an orientation would eventually lead to the disappearance of the European microelectronics industry and result in decreased competitiveness in entire areas of the economy.**

The development of applications connected to More than Moore constitutes an opportunity for Europe, but only if two conditions are met.

Firstly, **its industrial specialization must correspond to the new, rapidly developing markets linked to these applications.** Organic light-emitting diodes are a case in point. These diodes are expected to develop in two sectors: screens/monitors and lighting. However, European manufacturers have "lost the screen war", with all screens being designed and manufactured by Asian companies. With regard to lighting, while Philips is a major player, it faces especially fierce competition coming from China. Therefore, organic light-emitting diodes will only represent a growth market for Europe if a network of innovative SMEs develops in the lighting sector.

Secondly, while More-than-Moore applications could allow for **the reconversion of European manufacturing sites, these restructurations would prove expensive and necessitate state intervention.**

In addition, **Europe must maintain a minimum level of domestic production, in order to retain its technological expertise** and remain competitive in terms of innovation, even if it is not expected to compete with the Taiwanese foundries.

Indeed, in the More-Moore segment of the semiconductor sector, **"research follows production"**: in concrete terms, this means that tomorrow's research subjects are determined by the manufacturers' preoccupations. Therefore, it is to be feared that the relocation of production results in a relocation of research centres.

To conclude, Europe must continue its strategy to develop its competitiveness via innovation; therefore, the objective set by the European countries in Lisbon for setting aside 3% of GDP for research is more justified than ever.

Nevertheless, this policy must be accompanied by a proactive strategy to fight deindustrialization in Europe. **Therefore, public support of innovation must be better targeted, in order to encourage Europe's technological specialization in growth markets.**

As a result, Europe and France have no alternative but to pursue a proactive industrial policy which establishes a few sector-based priorities which they then commit to favouring by making available recurrent, medium-term loans.

PROPOSALS

I. Support the microelectronics sector

A. At the European Union level

RECOMMENDATION NO. 1: Launch a concerted effort at the European-Council level to bring the euro-dollar parity back into balance, in order to provide European manufacturers with a fairer competitive environment.

RECOMMENDATION NO. 2: Commission the World Trade Organization (WTO) with carrying out a study on the various practices of supporting the microelectronics sector pursued by both EU member and non-member countries. The results of this study would be used to establish, within the framework of the WTO, regulations to control the subsidies and tax exemptions granted to companies for the setting up of factories.

RECOMMENDATION NO. 3: Align European regulations on aid with policies outside Europe.

RECOMMENDATION NO. 4: Provide the European Union with a sector-based industrial strategy that recognizes the microelectronics industry's specificities and authorizes the co-financing of large-scale investment projects.

RECOMMENDATION NO. 5: Encourage the massive support by the European Union and its member countries of the five "lighthouse projects" put forward by the official report prepared by CATRENE - dealing with the autonomous car, controlling energy consumption, improving the healthcare system, strengthening security and improving the accessibility of broadband communication - and which are liable to create growth markets.

B. At the national level

RECOMMENDATION NO. 6: Commit, as of today, to the elaboration of pioneer programmes for innovation in the transportation,

energy, health and education sectors, while taking into account the specificities of French industry in the project-selection process.

RECOMMENDATION NO. 7: Lend coherence to public research by strengthening cooperation between laboratories working on the same subjects.

RECOMMENDATION NO. 8: Strengthen the links between the public laboratories and industry by creating within the research bodies "dialogue authorities" including manufacturers and by setting up shared laboratories.

RECOMMENDATION NO. 9: Commission an existing institution, that has already proven its competence with regard to the transfer of technology, with the development of public research. This institution would be mandated to develop the patents of a group of companies/institutions on a given geographical location.

RECOMMENDATION NO. 10: Encourage the hiring of researchers by manufacturers by promoting their skills and the statutory measures facilitating their mobility.

RECOMMENDATION NO. 11: Set aside specific funding from the National Research Agency budget for cooperative, cross-border projects for applied research with a view to industrial transfer.

RECOMMENDATION NO. 12: Increase the budget of the public interest group for the national coordination of microelectronics training, considered a strategic national training tool.

RECOMMENDATION NO. 13: Progressively bring France's normal private-sector tax rate into line with the European Union average (25%) within a period of five years, within the framework of a European strategy for the construction of a common tax zone.

RECOMMENDATION NO. 14: Reform the local business tax legislation by favouring a VAT base.

II. Reconcile microelectronics' rapid expansion with a respect for privacy and the environment

A. Reconciling ethics with microelectronics

RECOMMENDATION NO. 15: Adapt the staff and budget of the CNIL (French data-protection watchdog) to meet new needs generated by

the massive spread of monitoring instruments stemming from microelectronics.

RECOMMENDATION NO. 16: Introduce into the very heart of technology liable to threaten the protection of personal data a technical system for its neutralization and the strict regulation of personal-data use.

RECOMMENDATION NO. 17: Encourage the elaboration of an international agreement on the protection of personal data, defining international standards and rendering these same standards legally binding.

B. Encourage the development of "green electronics"

RECOMMENDATION NO. 18: Use government levers in the form of "model initiatives" and regulations to develop "green electronics" as part of an overall strategy of sustainable development.

RECOMMENDATION NO. 19: Inform users of the energy consumption of electronic devices via clear, standardized labelling.

RECOMMENDATION NO. 20: Raise public awareness of the environmental issues regarding the massive use of electronics, in order to develop "environmentally-responsible" behaviour.

RECOMMENDATION NO. 21: Provide sufficient funding for the carrying out of quality toxicological studies for the evaluation of risks linked to nanoparticles, in order to support preventive actions and training programmes centred around these risks and to encourage a responsible public-awareness campaign.

At the end of this study, European and French microelectronics would appear to be at a crossroads.

More than Moore offers Europe new opportunities. Indeed, this is a less capital-intensive avenue of research which should create numerous growth markets in the fields of energy efficiency, transportation, health and security. The excellence of European laboratories active in this field of research, the existence of European leaders in certain sectors of application, the close cooperation between European microelectronics manufacturers and the manufacturers of finished products, and the size of the domestic market are all advantages working in Europe's favour for it to become the world leader in More than Moore.

Nevertheless, certain indications are a source of concern with regard to the competitiveness of European microelectronics.

While the European market represents 20% of worldwide semiconductor demand, Europe attracts less than 8% of investment in production capacity. In its 2005 report on European competitiveness, the European Semiconductor Industry Association (ESIA) estimated that **between 1998 and 2003, 9% of European production capacity was relocated to other regions.**

In addition, the missions carried out within the framework of this study in Asia and the United States demonstrate that **Europe's competitors provide their respective microelectronics sectors with much greater support. Furthermore, this support is provided by clear strategies establishing a few priorities that the countries commit to encouraging via recurrent, medium-term loans.**

A similar system could be established for the French microelectronics industry.

Since the last report prepared by your rapporteur on this sector and adopted by the Parliamentary Office for the Evaluation of Scientific and Technological Choices in January 2003, **several reforms have been made that have directly or indirectly improved the competitiveness of France's microelectronics industry.**

For instance, the creation of a network of large technology platforms and the updating of its facilities, the setting up of worldwide competitiveness clusters, the instauration of a national research agency for the financing of research projects, the creation of OSEO and the reform of the research tax credit are all measures in support of innovation, considered a key factor of competitiveness.

Nevertheless, France's competitiveness in the microelectronics sector is weakened by both external and internal elements.

The external elements include, on the one hand, **distorted competition** linked to the massive support of this industry by Asia and the United States and, on the other hand, the continued rise of the euro against the dollar since 2002.

As for the internal weaknesses, they are above all linked to **the absence of a proactive industrial policy in the semiconductor sector**, to the mixed performances of public research programmes and to the inadequacies observed with regard to training.

Therefore, it seems that while certain measures could be carried out at the national level to improve France's competitiveness in the semiconductor sector, others are only possible at the European - or even the world - level.

Indeed, faced with a globalized industry, whose 2007 turnover amounted to $256 billion, France, which represents a market of $2.7 billion, carries little weight with which to enforce the basic rules of competition.

Likewise, the national champion, STMicroelectronics, represents only 4% of the world market, even though, with a turnover of $10 billion, it is the world's 5th largest producer of semiconductors.

When one considers that STMicroelectronics must be able to devote nearly 40% of its turnover to R&D and capital investments in order to maintain its competitiveness, one readily understands its desire to create alliances in order to both control costs and attain a sufficient size to allow it to assert itself in a given market.

The forming of alliances is also essential at the state level, if France desires, via Europe, to influence the running of the world market.

I. SUPPORT THE MICROELECTRONICS SECTOR

A. PROPOSALS AT THE EUROPEAN-UNION LEVEL

1. End the euro's overvaluation against the dollar

The nearly doubling in value of the euro against the dollar since 2002 (from $0.81/€ to $1.56/€ in May 2008) has strongly influenced the competitiveness of French and European manufacturers.

According to an STMicroelectronics representative, a variation in the dollar-euro parity of one cent costs this company €27 million. As a result, the **21-cent variation** in the dollar-euro parity between June 2007 (€1 = $1.34) and June 2008 (€1 = $1.55) **cost STMicroelectronics €380 million.**

In the medium term, the continued fall of the dollar threatens Europe's capacity to maintain not only its production capacities, but also its research centres.

Therefore, your rapporteur pleads for a concerted political effort at the European level in order to reestablish the dollar-euro parity to the benefit of European manufacturers. He would also like to point out that while the European Central Bank is responsible for interest-rate policy, exchange-rate policy falls under the aegis of the European Council.

RECOMMENDATION NO. 1: Launch a concerted effort at the European-Council level to bring the euro-dollar parity back into balance, in order to provide European manufacturers with a fairer competitive environment.

2. Ensure the basic rules of competition

The choice of where to set up a factory is determined by economic considerations; in other words, market proximity and site competitiveness.

In reality, the second consideration is largely distorted by state subsidies.

Your rapporteur is hardly naive and is perfectly aware that the setting up of each and every manufacturing plant is accompanied by the financial participation of the host country and/or region. The setting up of STMicroelectronics in Crolles and of AMD in Dresden were no exceptions.

Nevertheless, he questions the excesses of a system which, due to a lack of universally-accepted regulations fixed at the international level, results in overbidding between states, as well as a windfall for semiconductor manufacturers that are thereby able to pass off an ever-larger portion of their factories' construction – and even operating – costs to taxpayers.

RECOMMENDATION NO. 2: Commission the World Trade Organization (WTO) with carrying out a study on the various practices of supporting the microelectronics sector pursued by both EU member and non-member countries. The results of this study would be used to establish, within the framework of the WTO, regulations to control the subsidies and tax exemptions granted companies for the setting up of factories.

3. Adapt Europe's competitive rights to the world market place

European regulations seek to eliminate non-competitive practices within the European Union. Therefore, their application is centred on this zone. However, competition is global.

Therefore, the European Union should redefine the rules governing the attribution of state aid to the microelectronics sector, taking into account the reality of the world market.

For instance, one can question the pertinence of the "European Union Framework on Aid to Research and Technology", which lays down the applicable rules of European law.

The maintenance in the European zone of restrictive rules and procedures that apply principally to European companies and contrast with those of Europe's main competitors only results in penalizing our own industries. In addition, justifying this same maintenance by pointing to the need to enforce free competition makes little sense in an environment in which the pressure of research, development and production costs forces European companies to cooperate in almost every segment of the industry.

Therefore, new rules should be defined and practices should be recommended that take into account the two characteristics of the semiconductor industry:

1) It is **a sector which receives massive aid from the non-EU countries**, which consider this sector of strategic importance for the competitiveness of their companies while at the same time recognizing its massive needs in terms of capital in order to finance its manufacturing capacities and R&D.

2) It is **a sector in which competition plays a lesser role between companies of the EU member states than between European and non-European companies.** In this regard, it should be pointed out that the combined turnover of the three European companies listed among the world's 10 largest semiconductor manufacturers amounts to $22 billion, or only 8.5% of global sales.

RECOMMENDATION NO. 3: Align European regulations on aid with policies outside Europe.

RECOMMENDATION NO. 4: Provide the European Union with a sector-based industrial strategy that recognizes the microelectronics industry's specificities and authorizes the co-financing of large-scale investment projects.

4. Influence the creation of growth markets for the European microelectronics industry

As has already been pointed out, the microelectronics industry - particularly with the development of More than Moore – could contribute to the overcoming of certain societal challenges of the 21st century, such as exploding health costs, costs linked to an ageing population, increasing energy efficiency, managing road traffic and increasing security.

What's more, not only do these sectors represent growth markets for the microelectronics industry, but they will also have a ratchet effect on other industrial sectors, such as the automotive, medical-instrumentation, telecommunications and software sectors, as well as on services for both businesses and private individuals.

The following figures evaluate the potential of a few of these markets at the world level.

According to the estimates presented in the official report prepared by the EUREKA CATRENE programme, in 2011, **the world semiconductor market for wireless technologies** should total $21 billion, while the sales of related electronic devices are expected to reach $72 billion.

Likewise, **world semiconductor sales for the health sector** should amount to $10 billion in 2011, while the turnover of electronic medical equipment is expected to reach $87 billion.

Nevertheless, these markets will have difficulty developing without strong state support.

Firstly, the technological breakthroughs on which they are based demand the setting up of long and costly R&D programmes.

Next, these new markets often correspond to societal choices that the manufacturers cannot impose by technology alone, as illustrated by the following two examples:

- Energy savings

Improving energy efficiency requires not only the development and finalization of more energy-efficient technologies, but also their spread via their substitution of existing, less energy-efficient technologies. The main sectors targeted are lighting and electric and electronic equipment. Nevertheless, money is needed to invest in these new technologies. Via a policy of encouragement and/or regulation, government authorities can therefore speed up the "natural" replacing of older equipment.

- Telemedicine

The development of "distance medicine" associated with the computerization of the exchange of information between medical professionals should improve health services, while at the same time controlling costs. However, in addition to the technological challenges to be overcome, **these prospects represent a veritable revolution in the organization of medical treatments and raise numerous health and ethical questions.**

For example, a recent experiment in telemedicine carried out at a retirement home without medical care encountered the resistance of doctors who raised the question of their responsability due to their not being able to follow the rule of maintaining "direct contact with the patient".

Another difficulty resides in reconciling a respect for privacy with the processing and computerized exchange of a patient's medical information.

Similarly, telemedicine can only assert itself if it is socially acceptable and its funding is ensured by social security. Therefore, the setting up of telemedicine must enjoy support from the government, which will have to gather together the paying bodies, health professionals and patient associations in order to together define this new type of medicine.

In this regard, the importance of standards should be emphasized in ensuring that the chosen projects have a global impact. However, the establishment of standards necessitates close collaboration between the industries developing the products, the final users and the government authorities. With its 500 million consumers and great experience in dialoguing with both the manufacturers and the administrations of all of its members, the European Union enjoys significant advantages for the imposition of recognized standards at the international level.

As has already been pointed out, the official report prepared by the EUREKA CATRENE programme singled out five “lightlouse” projects capable of mobilizing both manufacturers and government authorities:

- Developing "autonomous" cars.
- Increasing the energy efficiency of common electrical devices by 20%.
- Improving the health care system.
- Strengthening security.
- Providing access to broadband communication throughout the European Union.

These projects seem to be a wise choice insofar as they satisfy the five conditions necessary for their success:

They meet a real – if, at times, still diffuse - demand and are expected to satisfy a global market.

These projects are meant to stand out for their technological innovation. They suppose important scientific breakthroughs or needs for integration between numerous, complex technologies.

They are based on a solid, industrial foundation and can be turned over to European manufacturers capable of their management and cofinancing and of becoming leaders in these newly-formed markets.

They are expected to improve European competitiveness in high-technology sectors and generate long-lasting, qualified jobs.

Finally, their success depends on government intervention on three levels:

- To improve coordination between the private players and public bodies (such as research laboratories).
- To help finance these projects' R&D.
- To ensure the commercial success of these projects via government orders or by regulations and/or tax incentives.

RECOMMENDATION NO. 5: Encourage the massive support by the European Union and its member countries of the five "pioneer projects" put forward by the official report prepared by CATRENE - dealing with the autonomous car, controlling energy consumption, improving the healthcare system, strengthening security and improving the accessibility of broadband communication - and which are liable to create growth markets.

Considering the slowness of the decision-making processes linked to the number of EU-member countries and their varying degree of interest for this sector of activity, a concerted effort between the five European countries having a real strategic interest in the semiconductor industry is recommended.

B. PROPOSALS AT THE NATIONAL LEVEL

1. Pursue the elaboration of national pioneer programmes

It seems most appropriate to support the five R&D projects presented above at the European Union level for at least two reasons:

- The large sums to be generated which exceed the financial capacities of any single country.
- The role of EU regulations, which can facilitate the creation of a European market and therefore provide the projects with a commercial dimension necessary for their then being able to conquer other markets outside Europe.

Nevertheless, your rapporteur is well aware of the slowness of the decision-making process of the 27-member European Union. However, the growth markets mentioned above also interest our Asian and American competitors, who benefit from the massive support of their respective governments, as well as a much more efficient decision-making process.

Therefore, your rapporteur believes that the French government must immediately commit to the elaboration of pioneer programmes without awaiting the outcomes of EU-level negotiations.

In addition, the choice of programmes must take into account the specificities of French industry.

The weaknesses of our industry have been cited in numerous reports.[1]

The causes of France's lag in private R&D merit a more detailed analysis. It is nevertheless clear that **the weak private R&D effort hinders the development and exploitation of research, for it directly influences the intensity of links between private companies and public research institutions and limits the latter's access to sources of private funding.**

In addition, the sectorial distribution of R&D questions the connection between the strong points of public research and the specialization of France's industrial fabric. The national companies' lack of critical size in certain sectors, such as biotechnology and software, slows down the dissemination of public-research results.

As a result, the selection of pioneer programmes must meet a two-fold concern:

- **Use those national manufacturing skills that already enjoy international recognition in order to create new markets.** For instance, taking into account France's excellence in the automotive industry, the project targeting the development of "autonomous" cars merits selection, because it can draw support from France's large national manufacturers.

- **Use these pioneer programmes to facilitate the rapid expansion of leading companies in those industrial sectors with little French presence.** For example, during his travels, your rapporteur observed that - contrary to the situation in Germany - the organic electronics and photovoltaics sectors receive little investment on the part of French manufacturers, even though they both represent very promising sectors. Establishing a pioneer programme in these two domains would allow France to make up for lost time and enlarge its industrial specialization by encouraging the SMEs active in these sectors to collaborate and attain critical size in order to be able to assert themselves at the international level.

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[1] Two such reports are:
- that of Jean-Louis Beffa (15 January 2005): *For a new industrial policy;*
- that of the Inspection Générale des Finances and the Inspection Générale de l'Administration de l'Education Nationale et de la Recherche (January 2007) on research development and exploitation.

RECOMMENDATION NO. 6: Commit, as of today, at the national level, to the elaboration of pioneer programmes for innovation in the transportation, energy, health and education sectors, while taking into account the specificities of French industry in the project-selection process.

2. Improve the performance of public research

a) Improve the clarity of public research

The setting up of a network of large technology centres has been positive, because it has allowed for the updating of research equipment and a greater structuring of public research. Nevertheless, having visited four of the five sites, your rapporteur believes that public research still lacks sufficient clarity insofar as **numerous laboratories continue to work on the same subjects without having first verified if the studies being carried out are competing or complementary.**

RECOMMENDATION NO. 7: Lend coherence to public research by strengthening cooperation between laboratories working on the same subjects.

b) Bring together fundamental-science researchers and industry experts

Bringing together public researchers and private companies is necessary for both parties for three reasons:

- Firstly, development work carried out in the companies' own laboratories primarily seeks to improve existing technologies and therefore rarely results in any technological breakthroughs, which are usually the result of fundamental research. However, in all countries, the constraints weighing on companies engender a progressive concentration of basic research in public laboratories. **Consequently, access to public-laboratory research results is strategic for companies which must retain their advantage by remaining at the forefront of technology.**

- Secondly, **the "outsourcing" of research to public laboratories can be decisive for those SMEs** unable to carry out their own research.

- Finally, maintaining links with industry allows public laboratories to remain abreast of the latest problems/developments and to develop specific qualities (meeting deadlines, maintaining high quality standards, defining minimum standards, etc.) without adversely affecting their research.

The creation of competitiveness clusters seeks to bring together the worlds of industry and research. Additional measures could be carried out to strengthen this trend.

The policy of setting up "dialogue authorities" which include manufacturers within the research bodies, so as to remain up-to-date regarding the manufacturers' needs, must be systematized. Every research laboratory that has established a long-term relationship with the private sector has adopted this policy, either by creating a "club of affiliated members" for its partner companies or by inviting manufacturers to sit on its scientific steering committee.

The creation of shared laboratories must also be encouraged, because they allow for close, prolonged cooperation between researchers and manufacturers and favour continuity between the accumulation of knowledge "upstream" and the resolution of finalized problems confronting the industry. In addition, they allow for the identification of new research topics linked to industrial concerns.

RECOMMENDATION NO. 8: Strengthen the links between the public laboratories and industry by creating within the research bodies "dialogue authorities" which include manufacturers and by setting up shared laboratories.

c) Professionalize development/exploitation measures

In order to have a positive impact on innovation, productivity and growth, public-research results must be developed and exploited; in other words, they must be used by the private sector to develop innovate applications.

However, the results of intellectual-property development in France vary widely depending on the particular institution/company.

Globally speaking, patent requests issued by public-research bodies have greatly increased over the past 10 years.

Nevertheless, **revenue from the development of intellectual property is relatively low** (1% of the domestic research budget, against 3% in the United States) **and highly concentrated: the CEA** (Atomic Energy Commission)**, CNRS** (National Scientific Research Centre) **and Institut Pasteur account for 90% of national earnings.** Universities account for less than 6% of the total, which contrasts sharply with their share of the public research effort (27% of domestic research funding in 2004).

The main obstacles to developing an effective development/exploitation policy are linked to the insufficient professionalization and size of those bodies responsible for the granting and development of patents.

RECOMMENDATION NO. 9: Commission an existing institution, that has already proven its competence with regard to the transfer of technology, with the development of public research. This institution would be mandated to develop the patents of a group of companies/institutions on a given geographical location.

At the same time, researchers must be made aware of the interest of filing patents. According to the director of industrial policy for the CNRS, only 3 to 4% of researchers are likely to file patents, even though at least 20% could have the opportunity to do so.

d) Encourage the hiring of researchers by manufacturers

The transfer of technology is not limited to joint research, intellectual property and the creation of start-ups. According to several studies carried out in the private sector, **the hiring of active PhD students, doctors and researchers is considered the principal mode of technological transfer.**

However, it appears that the hiring of researchers by companies not only remains largely insufficient, it is also declining. For example, while 50% of the 75,000 private-sector researchers are engineers, doctors represent only 12% of the total, with 4% being both engineers and doctors.

This "French exception" is partly due to the weakness of private-sector R&D, which discourages the hiring of doctors. But it is also due to the separation of the universities and the engineering schools within the higher-education system.

RECOMMENDATION NO. 10: Encourage the hiring of researchers by manufacturers by promoting their skills and the statutory measures facilitating their mobility.

Several measures have already been taken to this end, though they have had mixed results.[1] Nevertheless, via the previously-proposed measures (developing close links between manufacturers and fundamental researchers via the regular consultation of the former regarding their needs/expectations and improving the transfer of technology), manufacturers must come into greater contact with researchers and be made aware of their value and utility, thereby encouraging their hiring.

e) Encourage cooperation between the Carnot Institutes and the European research centres

The Carnot label was created to encourage joint research; in other words, public laboratories carrying out research in cooperation with companies. As a result, while at the same time carrying out research "upstream", Carnot Institutes also carry out applied research with a view to industrial transfer.

However, the development of partnerships with European research centres is also essential for this type of research, because it not only allows for an extension of the research offer vis-a-vis companies, but also an acceleration of the research process, which consequently speeds up the transfer of results.

Several cooperative projects have been launched by the Carnot Institutes, in particular with the Fraunhofer Institutes. Nevertheless, the number of such projects remains limited insofar as they are wholly dependent upon the Carnot Institutes' own funds. However, it should be pointed out that in Germany, on the contrary, the Fraunhofer Institutes are encouraged to develop this type of partnership by benefitting from specific funding which is added on to their initial grant.

This policy should therefore serve as inspiration.

[1] For example, the "Industrial Agreements on Training by Research" (CIFRE) and the funding provided by OSEO for the hiring of doctors.

RECOMMENDATION NO. 11: Set aside specific funding from the National Research Agency budget for cooperative, cross-border projects for applied research with a view to industrial transfer.

3. Increase funding for microelectronics training

The development of micro- and nanoelectronics companies depends on major and rapid technological changes: providing young engineers with practical, high-quality training is a determining factor for the success of this strategic industry.

The size of the investments to be granted, the necessary sharing of means and the taking into account of the geographical distribution of the industries, research laboratories and training establishments have led to the creation of a network that gathers together the twelve interuniversity clusters and the national departments for the computer-assisted design, testing and prototyping of integrated circuits.

This network is managed by the Groupement d'Intérêt Public pour la Coordination Nationale de la Formation en Microélectronique ("Public Interest Group for the National Coordination of Microelectronics Training" or GIP CNFM), which ensures:

- **a sharing of operational means** (the GIP CNFM clusters gather together production and specification equipment, computer equipment and software for the computer-assisted design and testing of integrated circuits and systems, as well as for prototyping);

- s**upport for educational and scientific innovation:** the GIP CNFM organizes working groups (multimedia, single-chip systems, nanotechnologies, etc.) and carries out studies on related trade and skill evolutions. It establishes the national training assessments and proposes programmes of action in micro- and nanoelectronics;

- **the propagation of knowledge:** the GIP CNFM organizes biannual training days, whose aim is to encourage exchanges between teachers in micro- and nanoelectronics. It helps organize "National Microelectronics Doctoral Network Days" (JNRDMs), as well as the European Workshop on Microelectronics Education (EWME). It publishes a newsletter (*La Puce à l'Oreille*) on the network's life and activities, on the future awaiting young graduates and on the various trades of the micro- and nanoelectronics industry;

- a permanent contact with the private sector: the GIP CNFM's network of universities and engineering schools maintains close ties with SITELESC, the professional trade union which represents all micro- and nanoelectronics companies. In 2002, SITELESC and GIP CNFM created the GIP CNFM public interest group. As a result, the national network's driving principles are jointly defined by the universities and companies.

The GIP CNFM carries out its tasks within the framework of long-term agreements signed with the ministry in charge of higher education and research.

The ministerial subsidies accorded to the GIP CNFM have greatly decreased over the past 12 years: while they amounted to €3.6 million in 1994, they totalled only €900,000 in 2007, or €100 per student, since the means of the CNFM network are used by 9,000 persons each year. However, quality microelectronics training requires high-performance equipment, as well as its regular renewal to provide the students with access to the latest technological tools.

RECOMMENDATION NO. 12: Increase the budget accorded to the GIP CNFM, considered a national strategic training tool.

4. Create a more favourable fiscal environment for companies located in France

The tax system plays a major role in avoiding pushing companies already set up in France from relocating their manufacturing and R&D activities abroad and for attracting foreign companies to set up on our territory.

However, France suffers from a handicap, considering its level of private-sector taxation compared to its European partners and the existence of the local business tax on fixed assets.

In 2008, while the nominal French tax rate for companies has been set at 33.33%, the European Union average is 25.8%. In Sweden, Finland and Denmark, the average tax rate levied on companies varies between 26% and 28%.

In addition, this rate disadvantage is not compensated for by tax-base effects: even if one takes into account effective (rather than nominal) rates, France levies some of the heaviest taxes on companies of any country.

A significant reduction in the private-sector tax rate would therefore greatly increase France's attractiveness.

What's more, **the local business tax considerably weakens the attractiveness of our territory**, as was pointed out in the report prepared by the commission on the business-tax reform[1].

Firstly, the local taxation of investments constitutes, within the European Union, **a French singularity**.

It **also raises production costs and penalizes new investments, hiring and growth**, in particular in capital-intensive sectors. For instance, the local business tax paid by STMicroelectronics at Crolles is around €28,000 per job, while the average amount paid by companies in the Isère *département* is around €1,800 per job.

Finally, it **increases the tax burden of companies vis-a-vis their foreign competitors**, particularly in those sectors exposed to the greatest international competition, which are also the most capital-intensive. It should be pointed out that this taxation is quite concentrated. In 2003, 10% of companies paid 90% of local business taxes and generated 75% of added value. 1% of companies paid 70% of local business taxes and generated 55% of added value.

It is true that the local business tax reform introduced by the Finance Act for 2006, comprising two main parts[2], should lighten the tax burden on companies. **Nevertheless, the local business tax remains a great hindrance for capital-intensive companies and greatly diminishes France's attractiveness to businesses.**

However, semiconductor plants have an enormous impact on the local job market. According to a 2007 study carried out by the consultancies Reverdy Associés and Christian Genthon Consultant, the Crolles site has allowed for the creation of 4,415 direct jobs and more than 22,000 indirect jobs.

RECOMMENDATION NO. 13: Progressively bring France's normal private-sector tax rate into line with the European Union average (or 25%) within a period of five years, within the framework of a European strategy for the construction of a common tax zone.

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[1] "Commission on the local business tax reform", chaired by Olivier Fouquet; report prepared for the prime minister's office, 21 December 2004.

[2] An unlimited extension on the possibility for companies to enter the "Tax-Reductions for New Investments" (DIN) system and an effective ceiling on the local business tax set at 3.5% of added value.

RECOMMENDATION NO. 14: Reform the local business tax legislation by favouring a VAT base.

II. RECONCILE MICROELECTRONICS' RAPID EXPANSION WITH A RESPECT FOR PRIVACY AND THE ENVIRONMENT

A. RECONCILING MICROELECTRONICS AND ETHICS

1. Provide the CNIL with greater means, allowing it to correctly carry out all of its missions

Since its creation in 1978, the CNIL has greatly expanded its activities, considering the dramatic rise in the processing of personal data recorded each year.

In 2007, it recorded 56,404 new files. Since 1978, the CNIL has processed a total of 1,213,404 files.

In addition, law no. 2004-801 of 6 August 2004 concerning the protection of an individual's personal data strengthened the CNIL's monitoring and administrative-sanctioning missions.

For the past 4 years, the CNIL's budget has regularly benefitted from additional funding[1] and the creation of new posts; however, with regard to the missions placed under its authority and compared to its European counterparts, this effort remains insufficient.

For example, the ratio of agents per one million inhabitants is 1.6 for the CNIL, which places it on the lowest rung among its European Union counterparts.

In terms of workforce, the CNIL will number 120 employees at the end of 2008, compared to 260 for its British counterpart, 400 for its German counterpart and 300 for its Canadian counterpart.

However, **the CNIL needs sufficient human resources for it to effectively carry out its missions.** For instance, one can question the actual effectiveness of its monitoring when one compares the 164 assessments carried out in 2007 by the 7 agents in charge of this task with the 56,000 cases filed during the course of this year.

Likewise, due to its insufficient workforce and budget, the CNIL is unable to carry out a veritable public-awareness campaign regarding the importance of privacy-protection issues. **As a comparison, the equivalent**

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[1] The CNIL's budget amounts to €11.4 million in the initial Finance Act for 2008.

English authority enjoys a communication budget that is 30 times greater than that of the CNIL, or €3 million compared to €100,000 for the CNIL.

Therefore, in order for the CNIL to be able to effectively ensure the protection of personal data, its budget must be significantly increased. To limit the impact of this increase on the public funds, companies could be required to make a contribution towards the file-registration fees.

RECOMMENDATION NO. 15: Adapt the staff and budget of the CNIL (French data-protection watchdog) to meet new needs generated by the massive spread of monitoring instruments stemming from microelectronics.

2. Integrate personal-data protection into technology

The continuing miniaturization of electronics already partially allows for - and will permanently allow for in the very near future – the massive development (because inexpensive) of perfectly invisible devices.

To prevent the resulting applications from threatening our privacy, the legal avenue allows for a firm framing of these technologies.

Nevertheless, according to numerous jurists interviewed by your rapporteur, laws and regulations are not enough. We would need to ensure that during the development phase of such technology, technological safeguards are introduced to guarantee certain fundamental principles, such as data security and confidentiality. In the RFID field, for example, a mechanism could be introduced which deactivates the RFIDs upon check-out.

RECOMMENDATION NO. 16: Introduce into the very heart of technology liable to threaten the protection of personal data a technical system for its neutralization and the strict regulation of personal-data use.

3. Encourage the signing of an international agreement on personal-data protection

Because the microelectronics industry is a worldwide industry, the resulting technologies spread rapidly all over the planet. However, the self-regulation of such technologies by their developers is today inappropriate.

Indeed, **the respect for privacy and personal data varies greatly between countries** and it is often those countries with the least amount of personal-data protection that are responsible for designing and manufacturing technologies capable of threatening our fundamental freedoms.

Nevertheless, **a more-or-less general consensus exists concerning the necessity of ensuring personal-data protection**, as much at the national level as at the level of such large IT companies as Google, Microsoft and IBM. Indeed, the latter are well aware that their continued commercial success depends on the social acceptance of information technology. In addition, because their market is worldwide, they favour a harmonization at the international level of personal-data protection laws.

However, differences arise concerning the minimal standards of personal-data protection to be established and their degree of restrictiveness.

Your rapporteur favours the elaboration of an international agreement on personal-data protection. Several bodies, such as the OECD or the UN, could be interested in launching such an initiative.

However, it should be pointed out that the European Union has provided itself - via the 95/46 directive relative to personal-data protection and the free circulation of information - with one of the world's most protective legislations. **As a result, we must ensure that an eventual harmonization at the international level of personal-data protection does not undermine the rules and regulations that have already been established in the EU-member countries.**

RECOMMENDATION NO. 17: Encourage the elaboration of an international agreement on the protection of personal data, defining international standards and rendering these same standards legally binding.

B. ENCOURAGE THE DEVELOPMENT OF "GREEN ELECTRONICS"

1. Using government levers to develop "green electronics"

The public authorities have two main levers with which to encourage the development of "green electronics": government orders and regulations.

- Government orders

The public services are large consumers of electronic equipment, such as servers, computers, printers, photocopiers and fax machines.

Their purchasing policies must therefore **favour the acquisition of more energy-efficient equipment**, in order to support this market segment and encourage its development.

- Regulations

In addition, public authorities can speed up the development of "green electronics" by imposing standards to strengthen energy-efficiency requirements for both electronic components and electrical/electronic equipment. For example, **the European Union could force manufacturers to discontinue the "standby" option** on TVs, DVD players, stereo systems and computers, insofar as this functionality is responsible for a huge waste of energy.

What's more, the installation of sensors for lighting, heating and air conditioning could be required for all new constructions.

At the national level, considering the omnipresence of microelectronics in our everyday lives and the fundamental role it can play in sustainable development, it would seem necessary to integrate "green electronics" into the Grenelle de l'Environnement negotiations.

RECOMMENDATION NO. 18: Use government levers in the form of "model initiatives" and regulations to develop "green electronics" as part of an overall strategy of sustainable development.

2. Raise awareness among users of the energy consumption of electronic devices

Strengthened regulations must nevertheless be combined with a raised awareness among final users of the energy impact of electronic devices. Following the example of household appliances, **the introduction of labels detailing the energy efficiency of equipment would allow consumers to directly compare the energy performance of the various products on display.**

In addition, public-awareness campaigns should be carried out to encourage more environmentally-friendly behaviour on the part of the public. Indeed, your rapporteur was informed of an experiment carried out within a French administrative department in which the employees committed to making such simple gestures as turning off their lights and electronic equipment when they left the office; this immediately lowered the department's energy costs by 30%!

RECOMMENDATION NO. 19: Inform users of the energy consumption of electronic devices via clear, standardized labelling.

RECOMMENDATION NO. 20: Raise public awareness of the environmental issues regarding the massive use of electronics, in order to develop "environmentally-responsible" behaviour.

3. Intensify research programmes to anticipate and prevent possible health and environmental risks related to nanoparticles.

Today, the semiconductor sector seems virtually unaffected by the risks related to nanoparticles.

Industrial component manufacturing barely uses this type of material, except for deposit operations, whereas the integration of carbon nanotubes in integrated circuits is still confined to research laboratories.

Furthermore, nanomaterials present in semiconductors do not come directly into contact with the population or environment insofar as they are encapsulated in other layers of metal.

As for the end product, it is housed in a package.

Nevertheless, as nanomaterial usage in microelectronics is likely to spread, we should now investigate the resources to protect employees who are likely to come into contact with nanoparticles and take an interest in their future when electronic products reach the end of their life cycle.

RECOMMENDATION NO. 21: Provide sufficient funding for the carrying out of quality toxicological studies for the evaluation of risks linked to nanoparticles, in order to support preventive actions and training programmes centred around these risks and to encourage a responsible public-awareness campaign.

The Parliamentary Office for the Evaluation of Scientific and Technological Choices had already carried out a report on semiconductors in 2002. An updating of this study seemed indispensable, considering the great changes that have since taken place at both the scientific and economic levels.

The scientific evolutions are of three types: the pursuit of miniaturization and the swing from microelectronics to nanoelectronics since 2003; the explosion of "More than Moore", or the integration of several functionalities onto a single chip; and the role of the nanosciences in developing tomorrow's electronics.

At the economic level, exploding R&D, design and production costs linked to technological advances engender profound changes in the semiconductor industry. While Europe and France enjoy real advantages, they are also hampered by their misappreciation of strategic issues linked to microelectronics and by the lack of proactive government policies in favour of maintaining manufacturing jobs in this sector.

Is the microelectronics industry doomed to fail in Europe? Such an evolution would have dramatic results, considering the fact that microelectronics has played a pivotal role in most innovations in such important growth markets as the automotive, health and energy sectors. Without a strong and independent French and European microelectronics industry, the competitiveness of entire sectors of our economy would be undermined and lastingly weakened to the benefit of our Asian and American competitors.

Finally, due to the omnipresence of semiconductors in day-to-day life, the hopes and fears that they arouse call for an ethical consideration of their role in society.

In addition to this general assessment, several proposals are formulated in this study, with the aim of strengthening the French and European microelectronics industry, as well as reconciling the rapid development of microelectronics with the respect for personal data and taking advantage of microelectronics' immense potential to further sustainable development.

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