Guardian Angels
for a Smarter Life

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Outline: Guardian Angels

- **Concept and objectives**:
  @ the edge of the cloud
- **Zero-power technology platform:**
  the future of nanoelectronics
- **Applications and impact:**
  a more energy efficient and safer society
- **Instead of conclusions**

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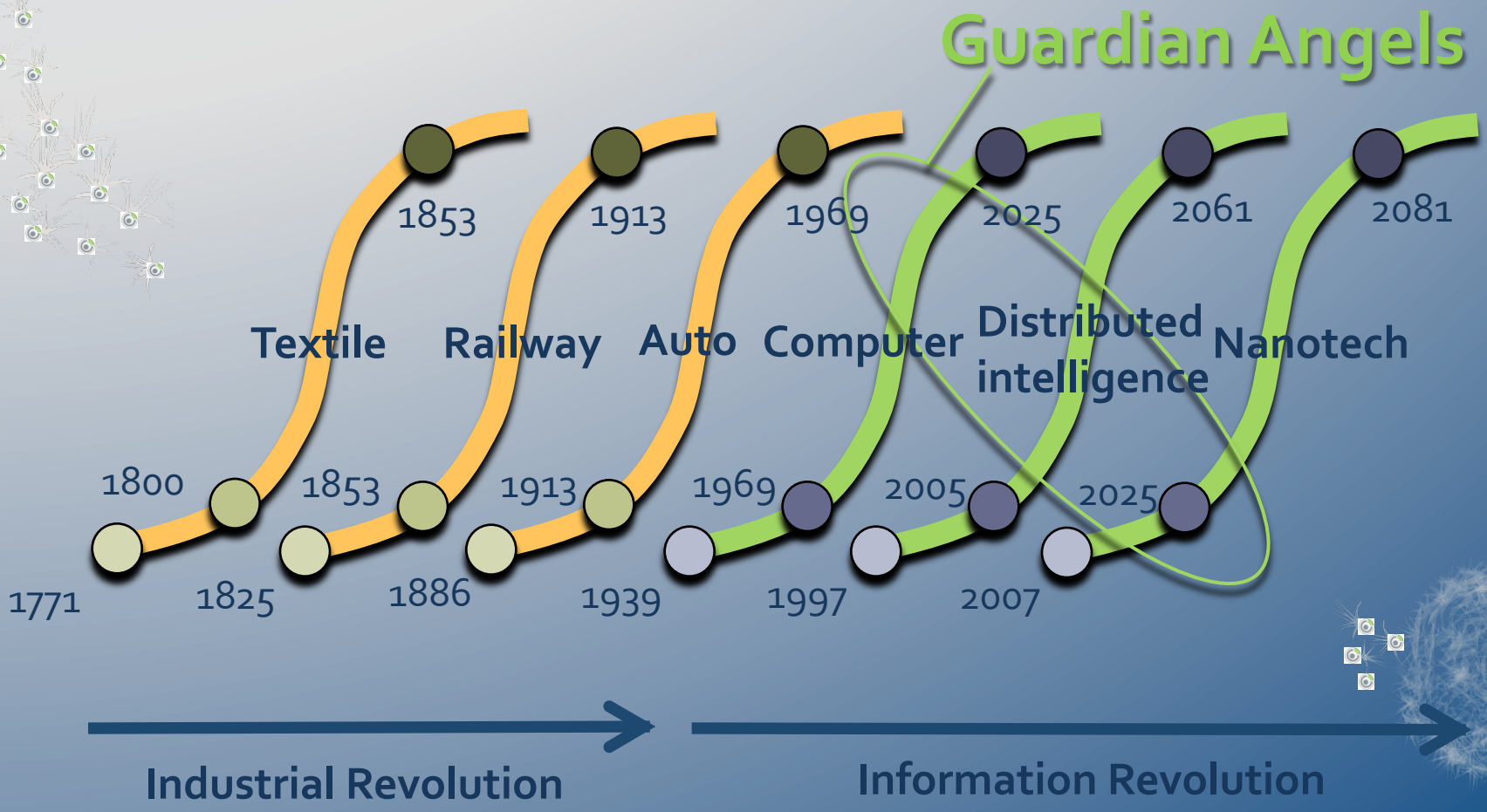
Innovation semantic waves



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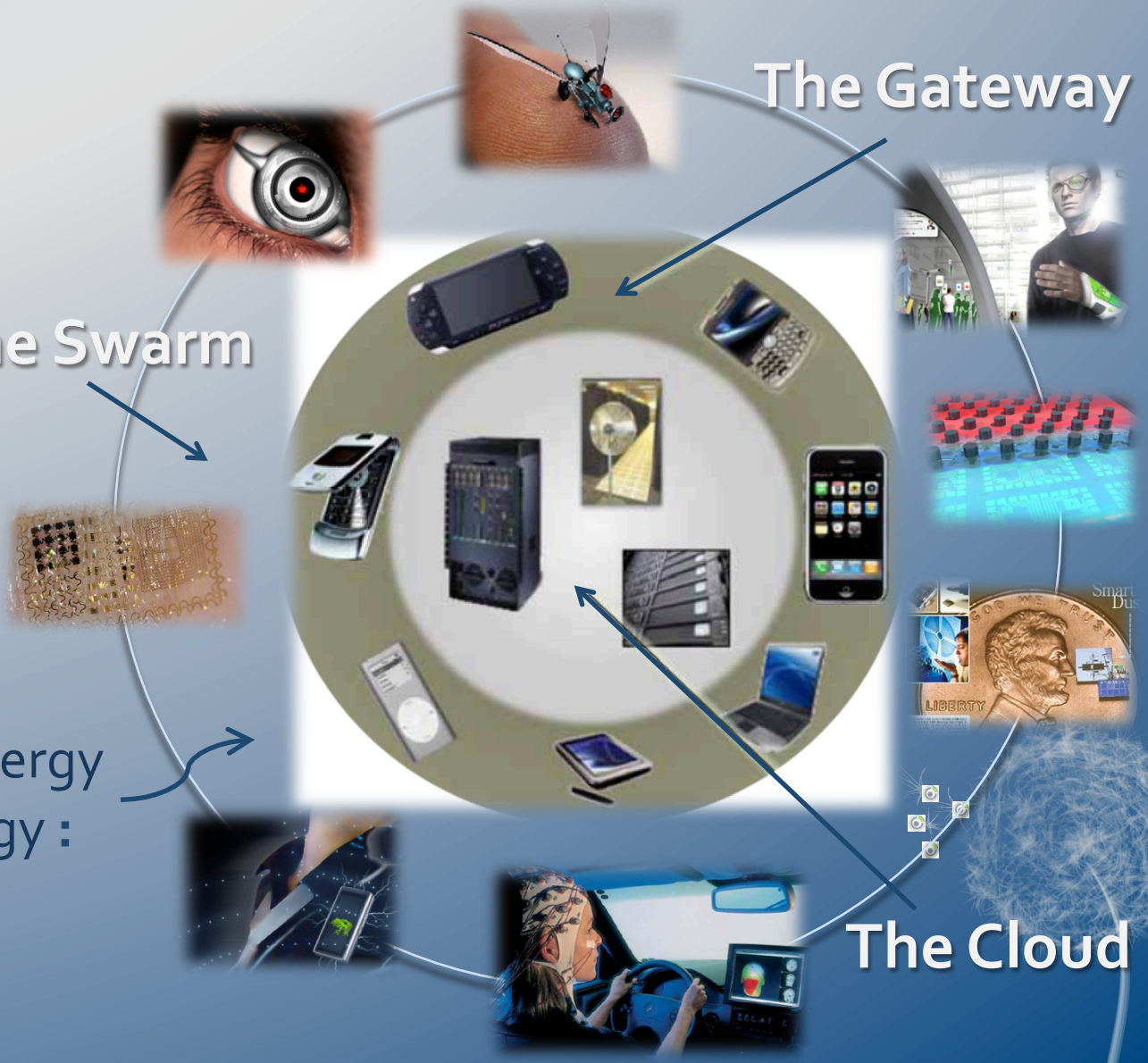
Beyond WSN and internet: GA…

Challenges:

- economy of scale
- interoperability
- energy
- reliability
- cost & easy to use



Interconnected smart objects enabled by energy efficient nanotechology : **the Guardian Angels.**

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Concept: Guardian Angels

- Guardian Angels are future **zero-power smart autonomous systems** featuring sensing, computation communication and energy harvesting features beyond human aptitudes.

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Enabled by zero power

- **Zero-power** is the system ability to harvest energy existing in dynamic environments (solar, thermal, vibration, electromagnetic) and power-up the system.
- **GA's are smart personal companions.**
  - They will assist humans from infancy to old age.
  - They are autonomous, straightforward and non-intrusive.
  - They are smart, controllable, secured and personalized.

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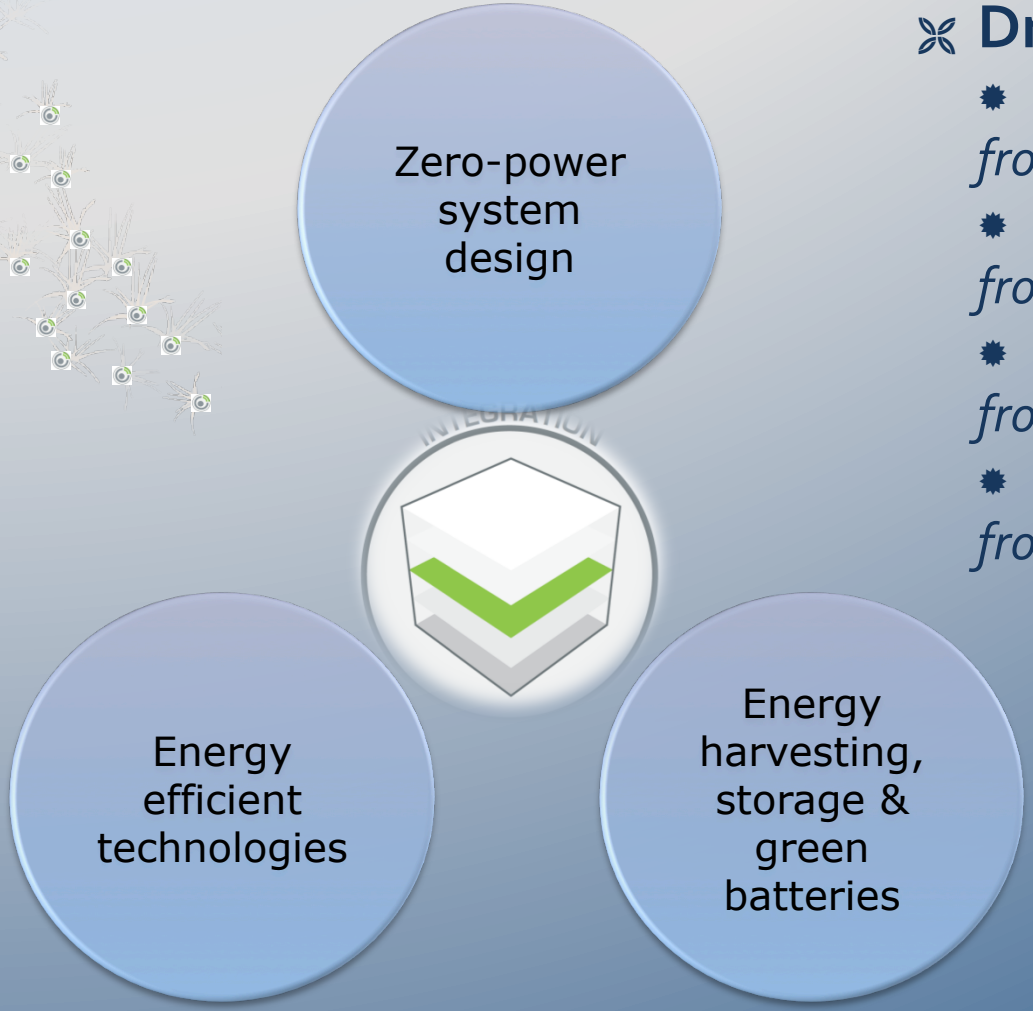
Zero power technology platform



- **Driven by energy limits**
  - Computation : 1000
    *from **100aJ/op** to 0.1aJ/op*
  - Communication : 1000
    *from **1nJ/bit** to 1pJ/bit*
  - Sensing : 1000
    *from **10µW** to 10nW*
  - Energy harvesting: x 100
    *from **100mW/cm²** to 10mW/cm²*

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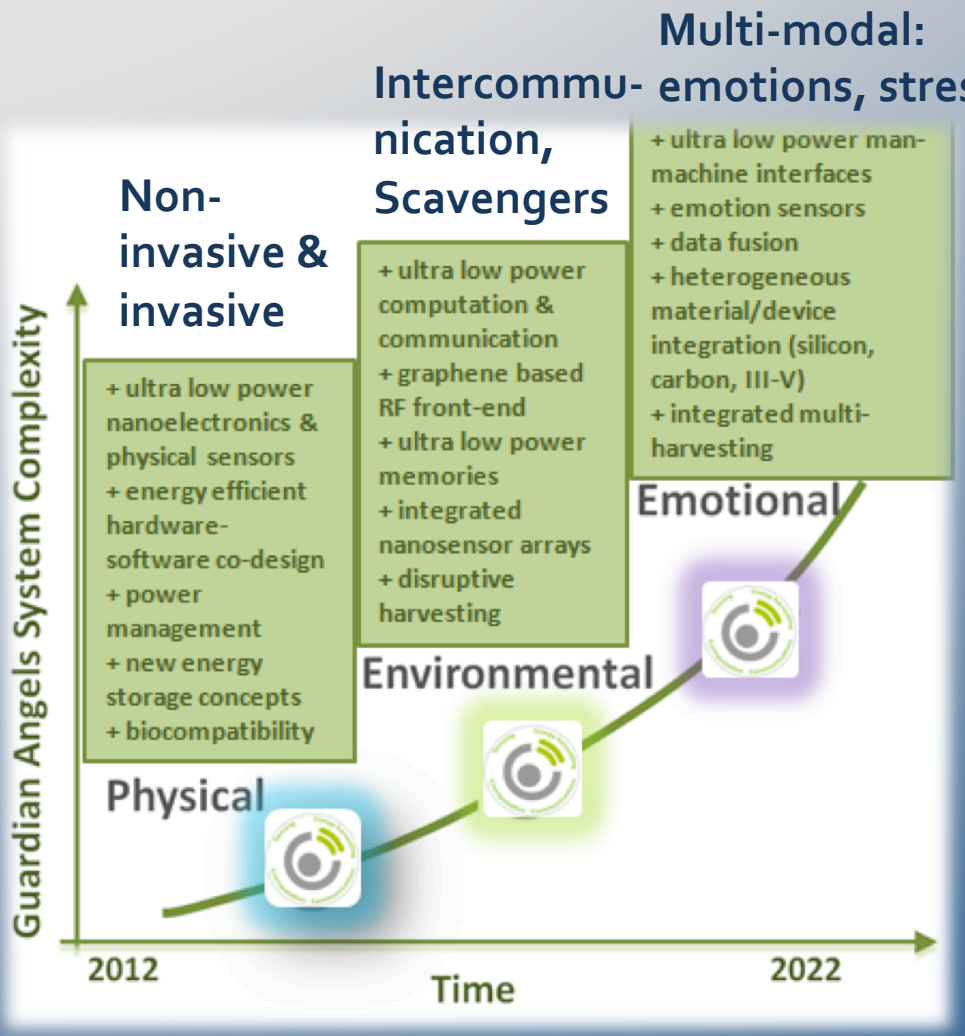
3 generations of Guardian Angels



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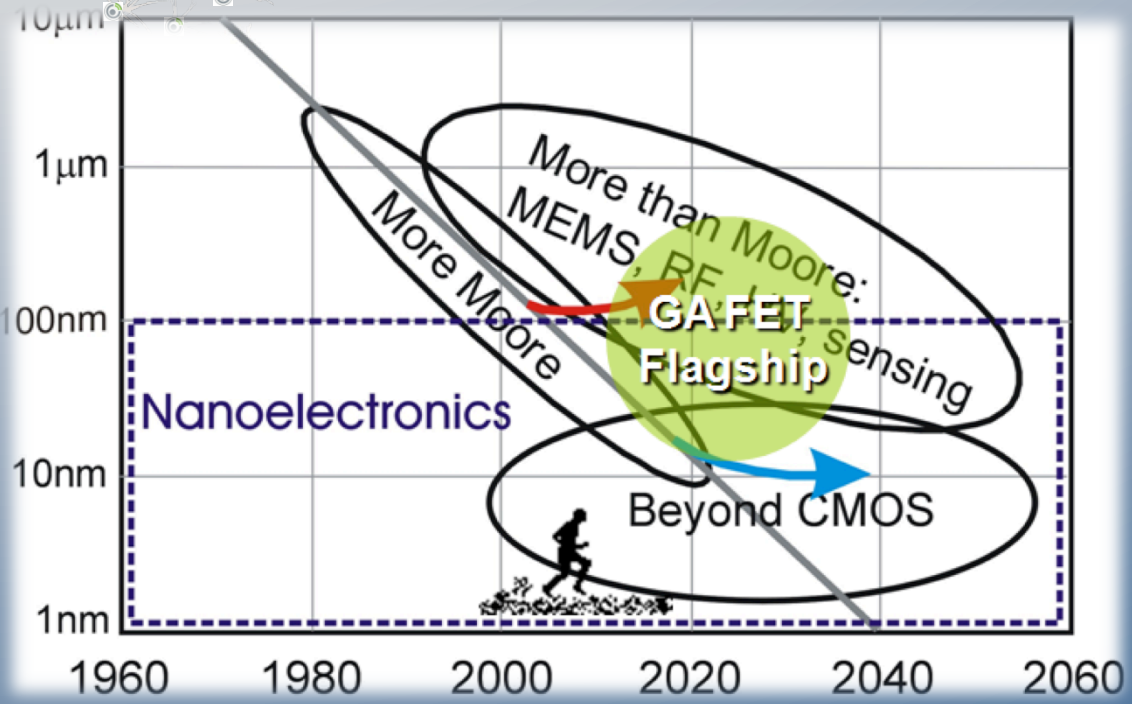
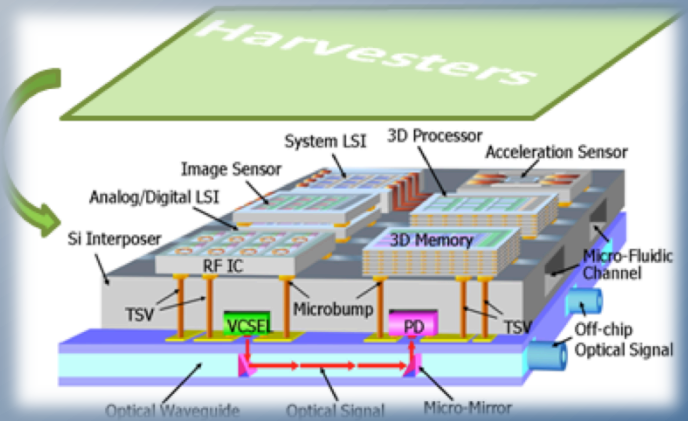
Nanoelectronics roadmaps & GA's

- **Heterogeneous integration** @ affordable cost
- Drivers: **power consumption** and **novel functionality**





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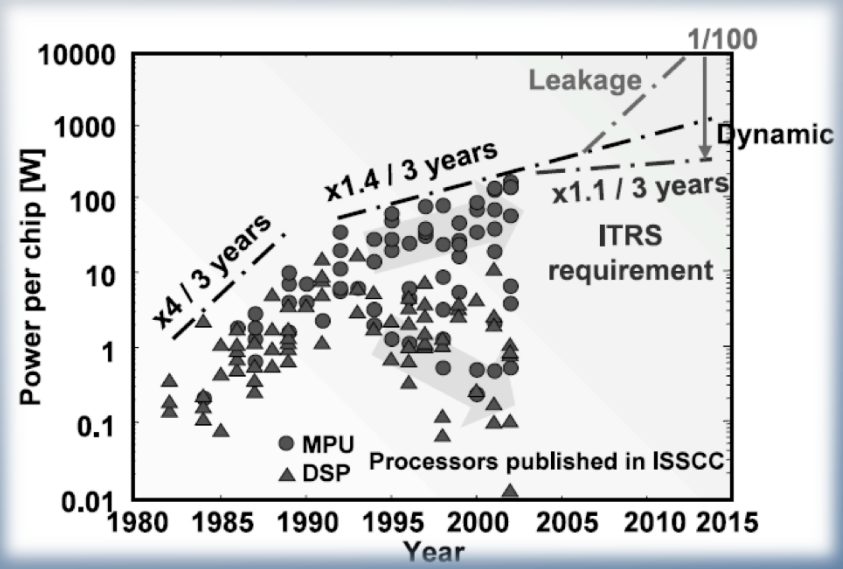
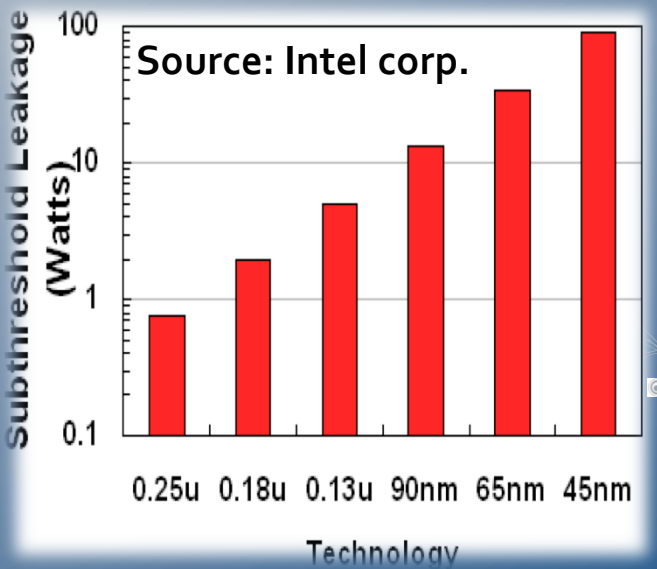
Power challenge in µprocessors

- **Power per chip continues increasing**.
- **Leakage power dominates** in advanced technology nodes.
- **Voltage scaling slowed**: 45nm=1V, 22nm=0.8V cannot go below 0.5V





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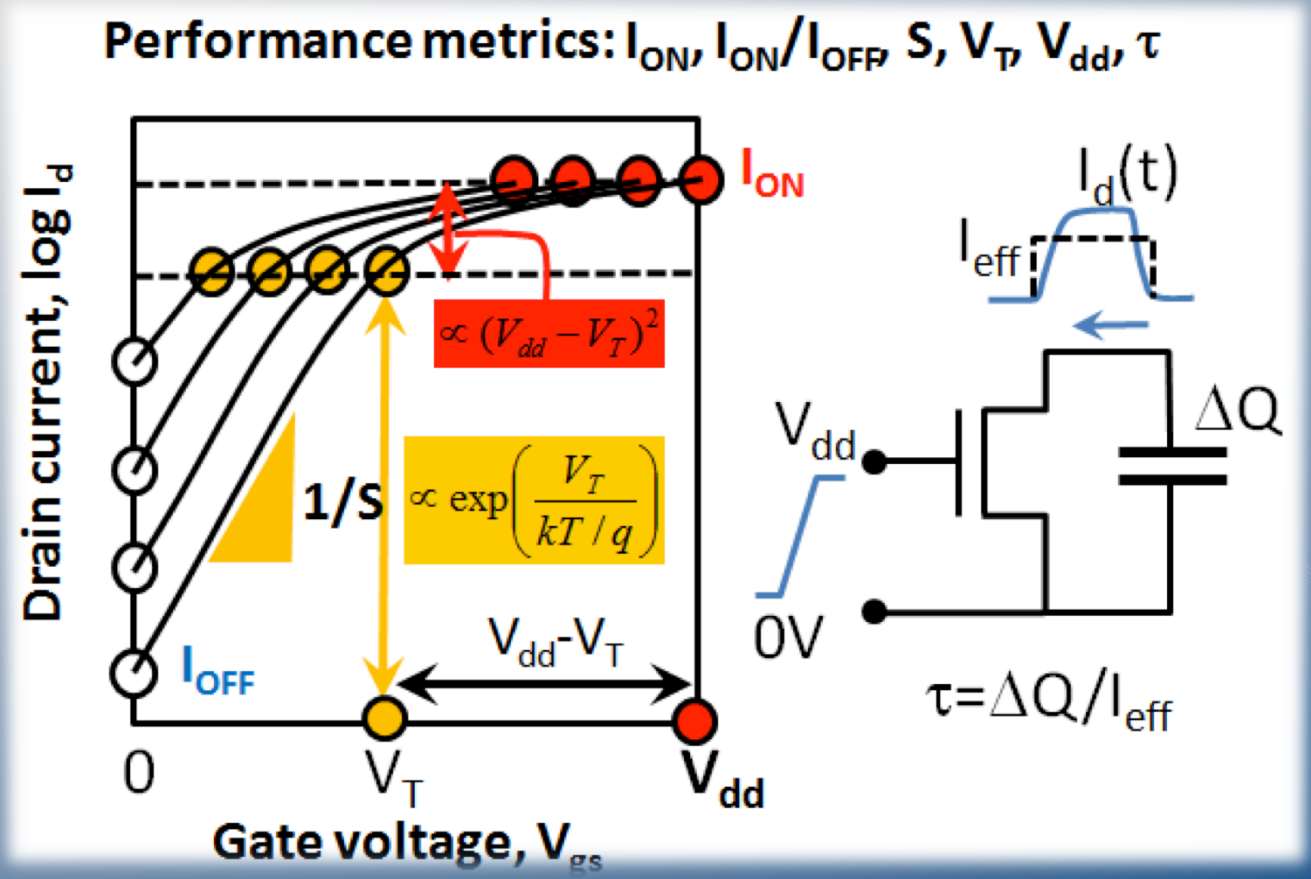
Limits of CMOS electronic switch

- Reducing threshold voltage **by 60mV** increases the leakage current (power) **by x10**



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Energy limits and swing

Power per binary switching event:

$$P = \alpha L_D C V_{dd}^2 f + I_{off} V_{dd} \approx K C V_{dd}^3 + I_{off} V_{dd}$$

a technology that would enable **a voltage scaling by a factor of 5 (from 1 V to 0.2 V)** with a negligible leakage power (with ultra-low I_{off} due to a small S) will provide **a power dissipation reduction of 125x.**

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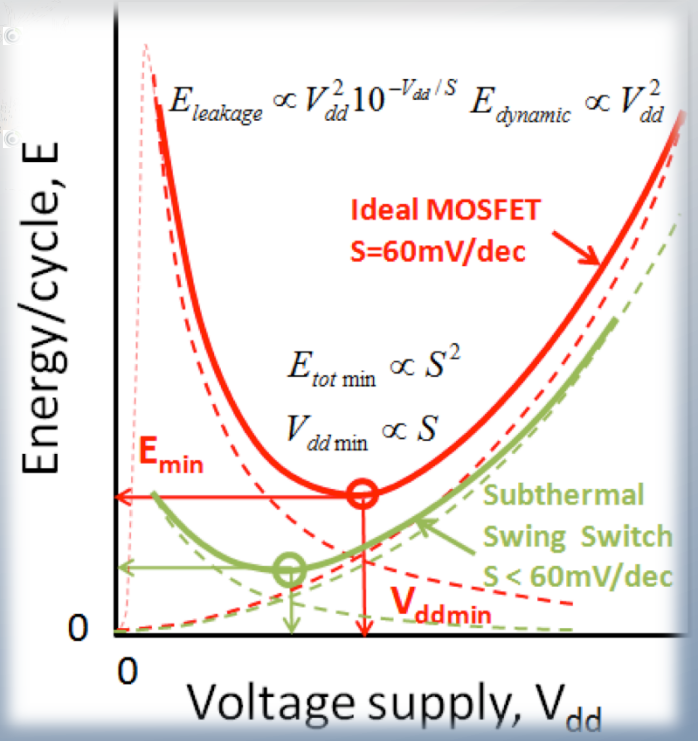
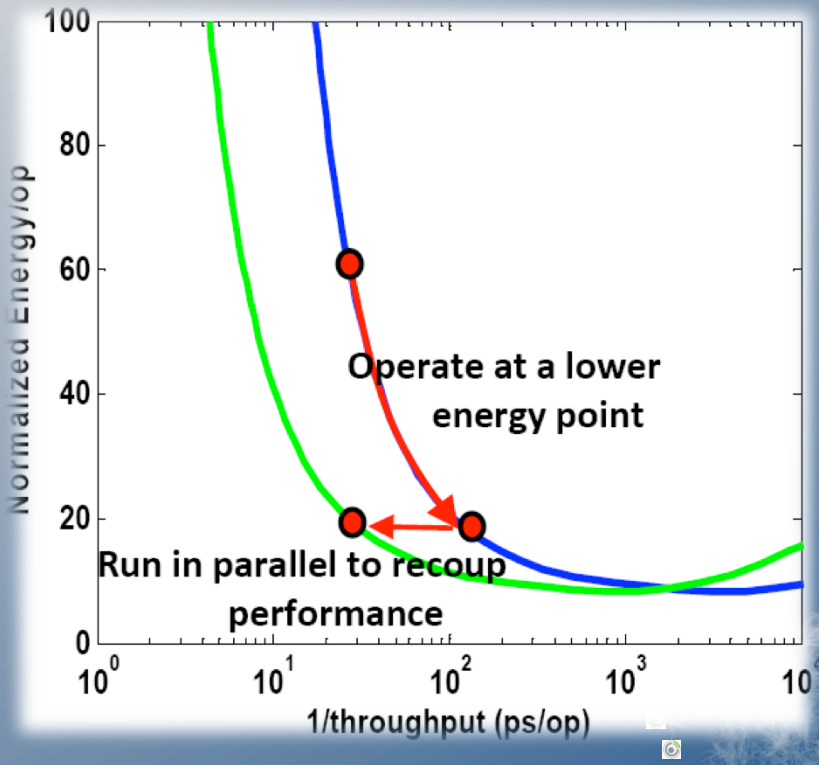
Solutions for lower energy

Subthermal swing S devices



Source: A.M. Ionescu, H. Riel, Nature, 2011.

Parallelism (multi-core)



Source: T.J. King, UC Berkeley.

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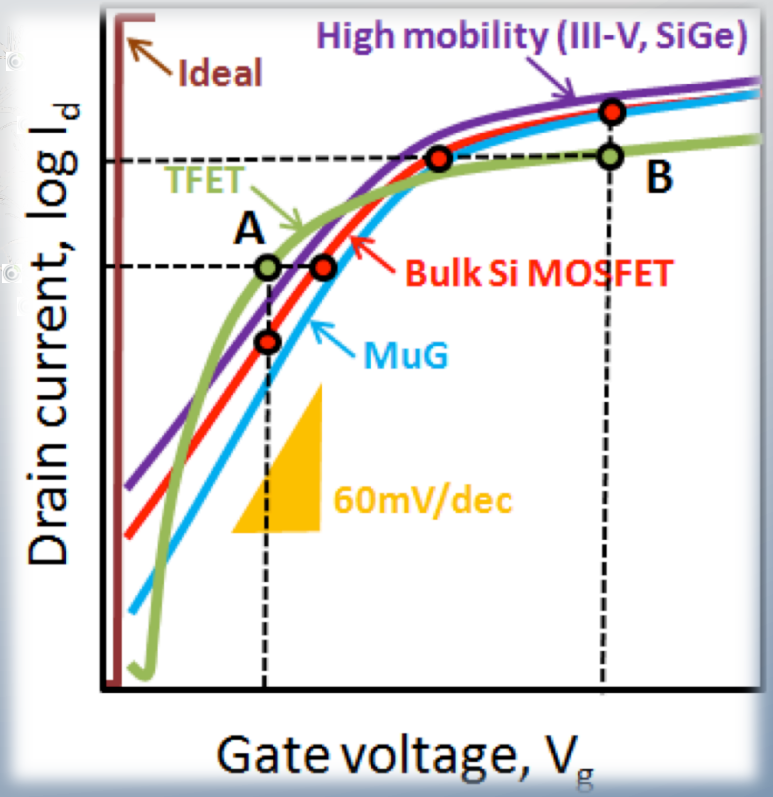
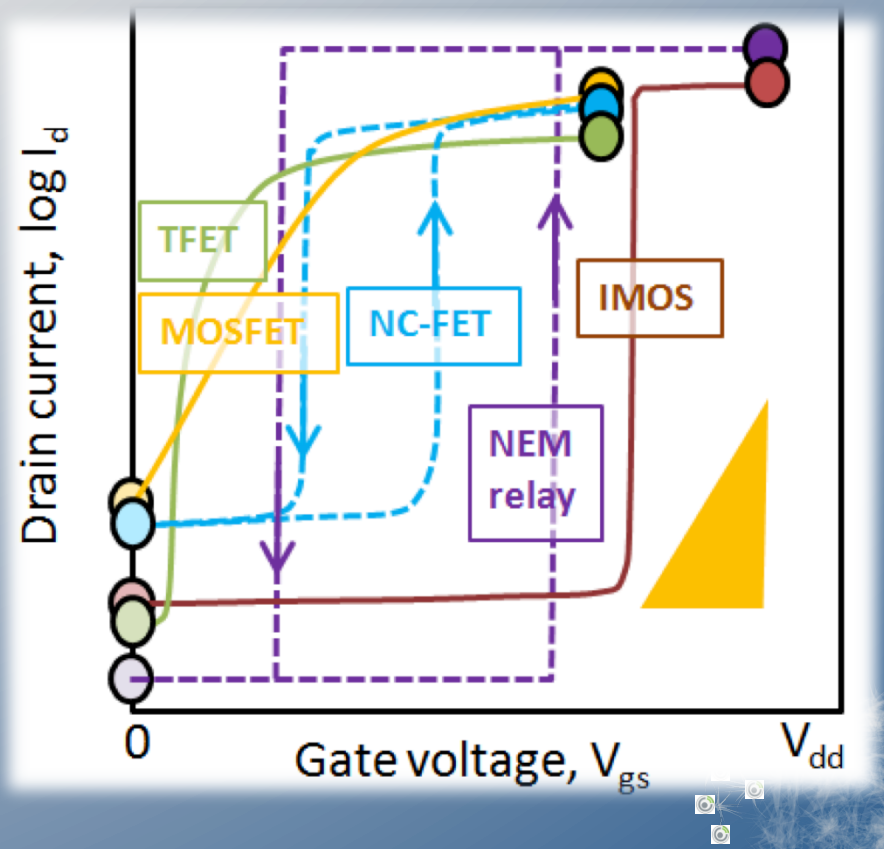
The Power Challenge
Steep slope switches





Tunnel FET is the most promising small swing switch for scaling the supply voltage and the energy per binary switching.

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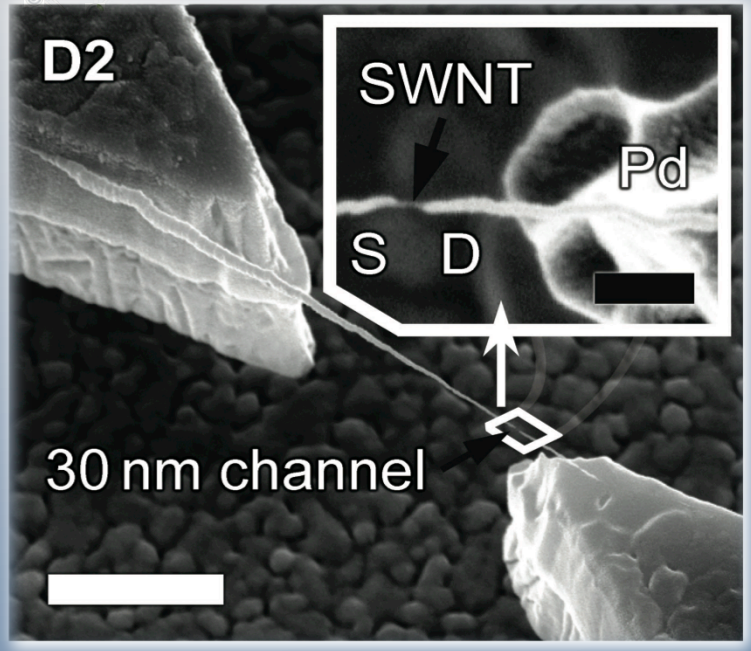
Ultra-low power nano-sensors

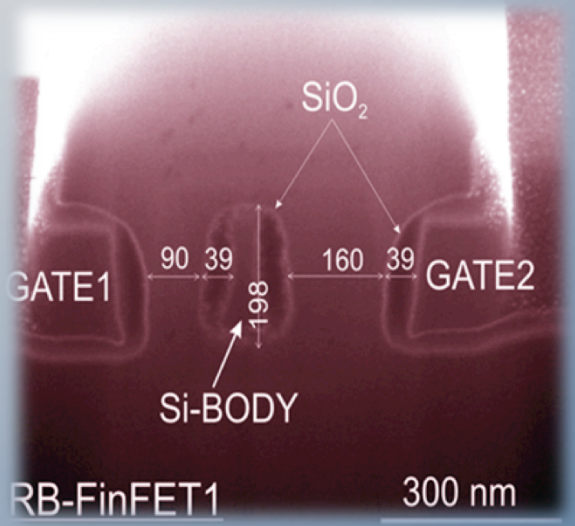
Mass-sensitivity below 10^{-19} grams and power consumption in the order of nW:
millions of sensors for 1mW!

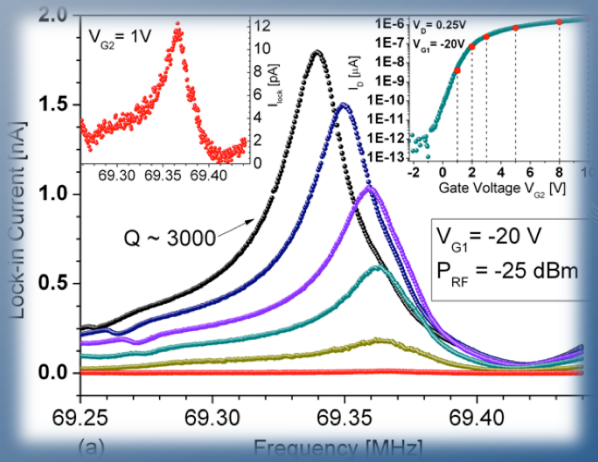
Carbon Nanotube Sensors



C. Hierold, ETHZ.

Silicon Nanowire Sensors





A.M. Ionescu, EPFL.

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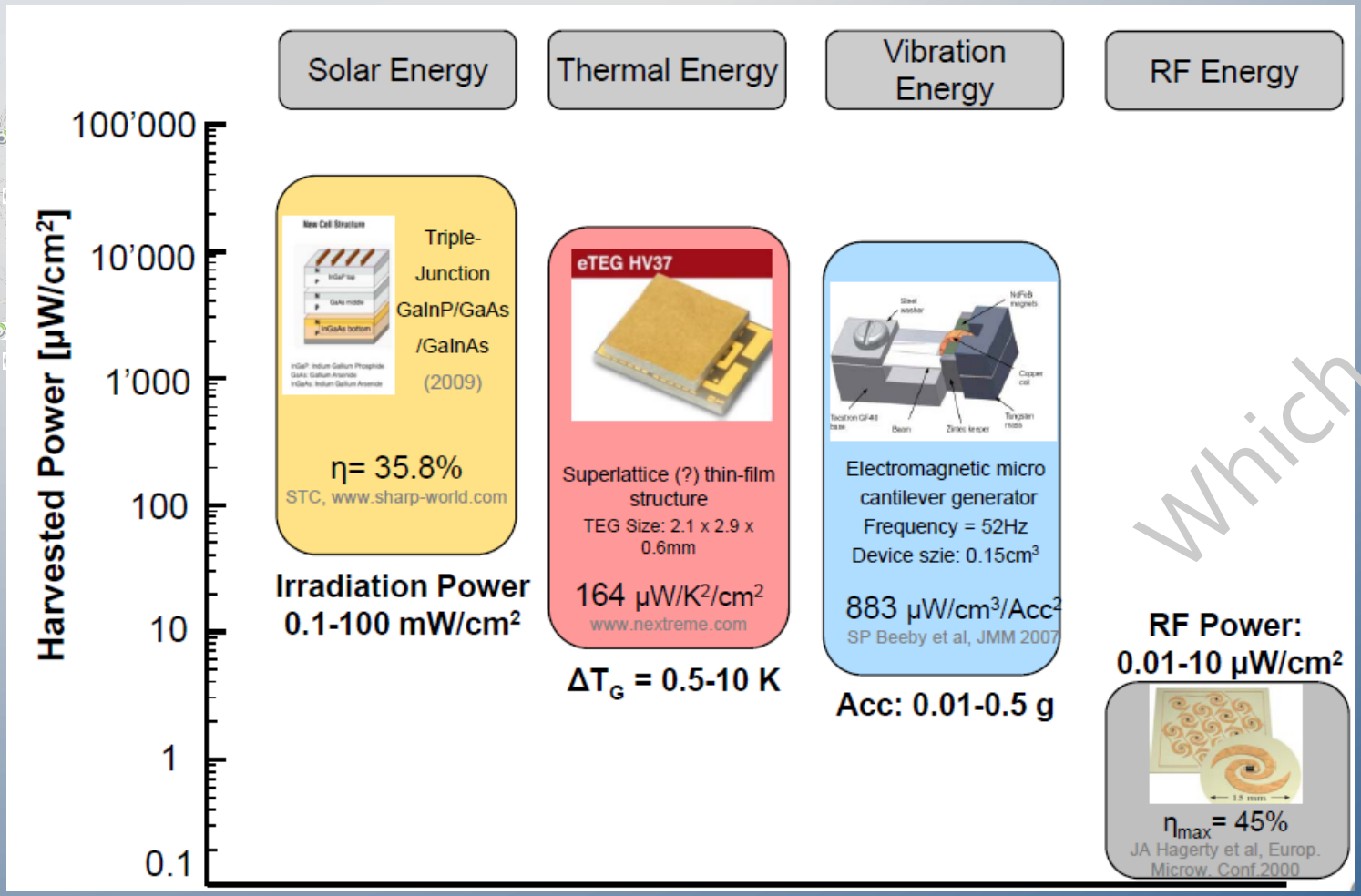
Energy scavenging systems



No winning concept: the analysis of the system specification defines the right type of harvester or combination of harvesters!

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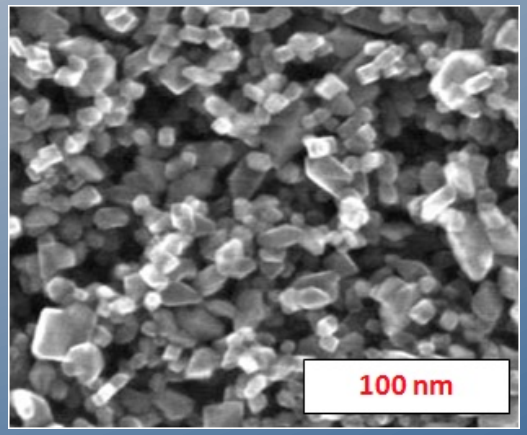
Bio-inspired energy scavenging

- Environmentally friendly materials
- High efficiency in-door & out-door
- Low cost processing @ on large size substrates



M. Graetzel, EPFL.

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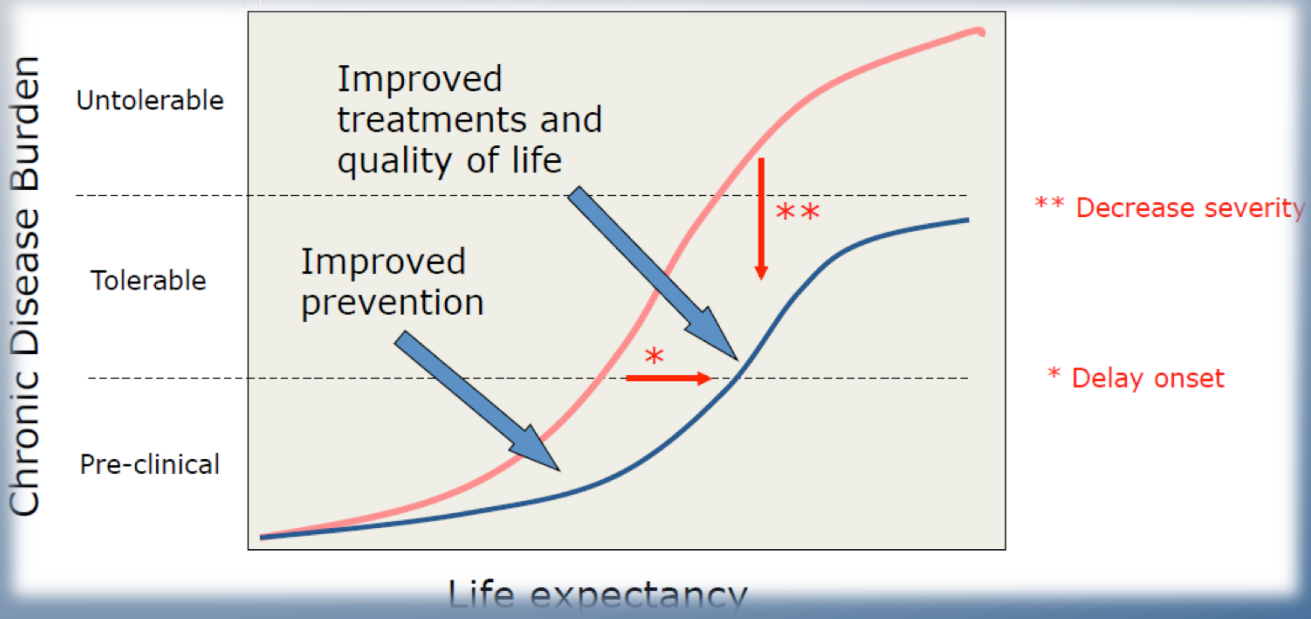
Prevention in bio-medical field

Pharmaco-therapy

early detection of treatment inefficiency or relapses.

Prevention/diagnostic

early signature of disease, metabolic and cardiac disorders.



Early detection of abnormalities continuous monitoring with energy efficient GA systems

– Homeostasis
  - Hormonal
  - Metabolic

– Compliance to treatments
– Biomarkers
– Physical parameters

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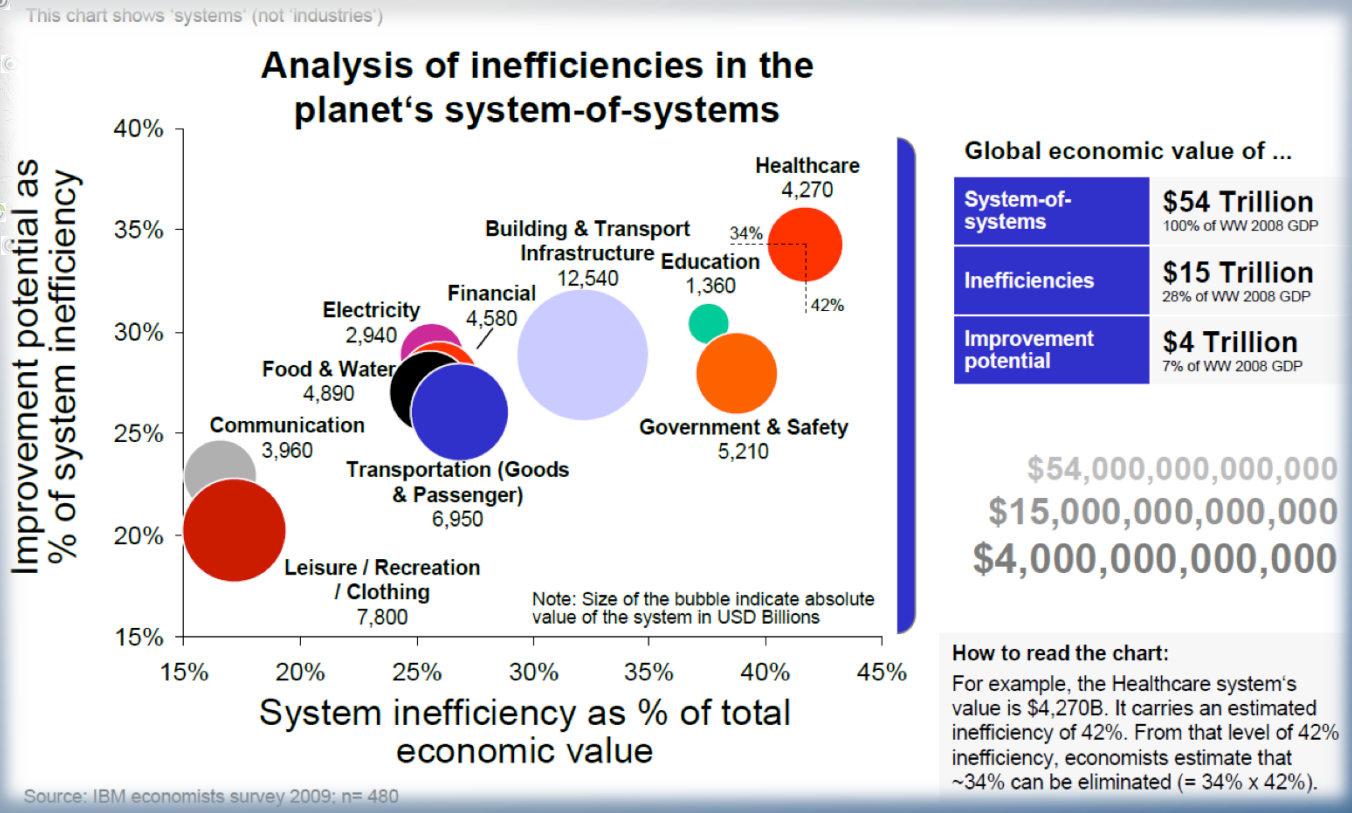
Energy (in)efficiency @ global scale

Improvement potential in system inefficiency up to 40%!



Global economic value of ...

System-of-systems	**$54 Trillion** 100% of WW 2008 GDP
Inefficiencies	**$15 Trillion** 28% of WW 2008 GDP
Improvement potential	**$4 Trillion** 7% of WW 2008 GDP

$54,000,000,000,000
$15,000,000,000,000
$4,000,000,000,000

How to read the chart:

For example, the Healthcare system's value is $4,270B. It carries an estimated inefficiency of 42%. From that level of 42% inefficiency, economists estimate that ~34% can be eliminated (= 34% x 42%).

Programs for improving the energy inefficiency of complex systems: IBM's Smarter Planet & Intel's Green initiative.

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Guardian Angels Consortium

For a bright future of energy efficient nanoelectronics and energy harvesters in smart personal companions!

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Expected impact of GA's

Society and life

- GA's will preserve human health and improve the quality of life for all categories of ages, in an affordable way.
- GA's will make our environment more energy efficient and safe.
- GA's will generate enhanced prevention based on augmented information for personal level decision.

Leadership in science and technology

- Leading role of Europe in zero-power novel technologies.
- Enabling a stronger role of manufacturing in Europe.
- Improving the competitiveness for leading energy, communication and medical companies.

Employment

- Creation of new employment in Europe in ICT domain.
- New business opportunities.

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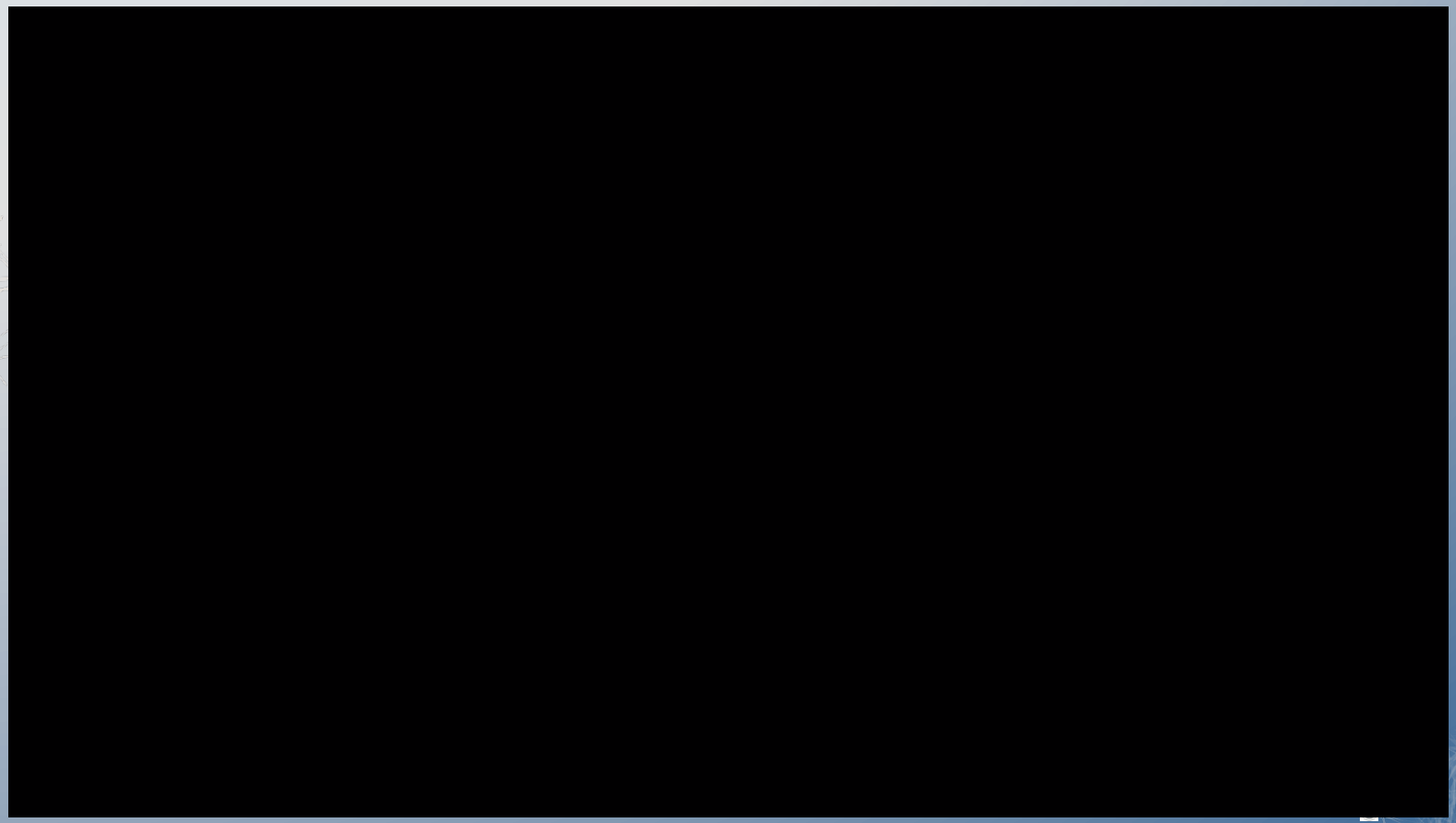

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