Photovoltaic for low power Telco devices: an opportunity for Orange

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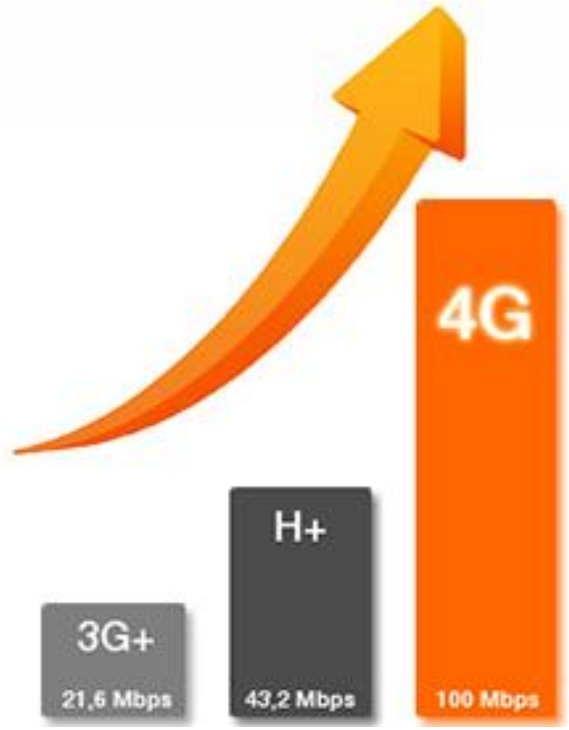


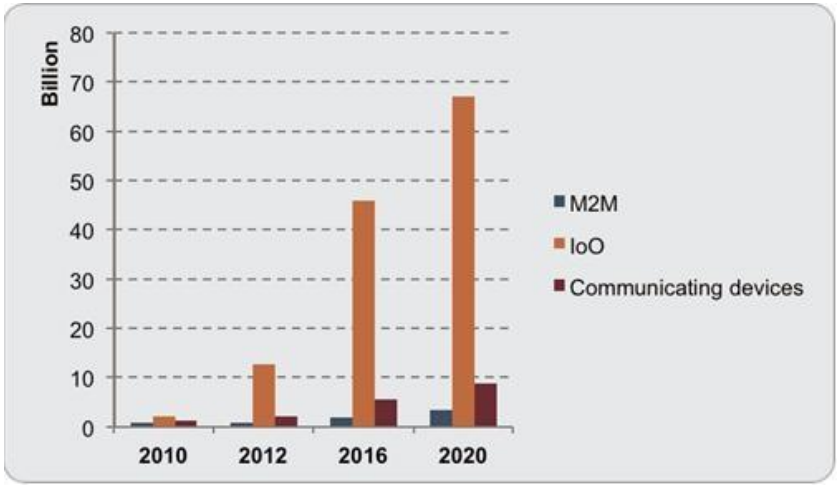
TELECOMS GLOBAL CONTEXT AND ECOSYSTEM BEFORE 2020

Global strategy adopted by Orange

- Objective
  - Reduce the ITN (IT & Networks) energy consumption (electricity and fuel)
- Challenge
  - Between 2006 and 2020, the challenge for the Group consists in reducing our carbon footprint by 20% as a whole
- How
  - Measuring and monitoring our energy consumption
  - Identifying potential reductions and launching operational programs in various countries
  - Integrating existing projects with an impact in terms of energy consumption
  - Carrying out the studies that will enable us to realize savings over the short or medium term
- The Scope
  - All countries

Telecoms global context and ecosystem before 2020

- Evolution of Telecoms by 2020
  - Generalization of the Internet of things
  - Explosion of the traffic on the M2M networks
  - 80 billion connected objects (IDATE)
- Energy cost is an issue
  - The energy consumption of the Orange group must be optimized.
- Opportunity of business for Orange group
  - Orange wants to be a leading player
  - “Smart cities” are based on this type of network
  - All these objects communicate and should be autonomous in energy



FOCUSED TOPIC : GREEN ENERGY FOR LOW POWER TELCO DEVICES

Low power Telco devices scope and goal

- Low power Telco devices enable Internet access for customer and operator
  - Smartphone, Internet box are low-power Telco devices for residential services
  - Sensors, repeaters, M2M gateway and Wi-Fi access points are low-power Telco devices too
- Range of power: from mW to a few W
  - All small Telco devices are electrically powered
    - for a consumption above 2 W (router, Wi-Fi access point, Internet box) power is supplied by the main (AC)
    - if the consumption below1 W (M2M repeaters, smartphones, sensors) power is provided by batteries
- Our goal is to self-feed most of these devices using green energy

Main green energy suitable for low power devices: An overview

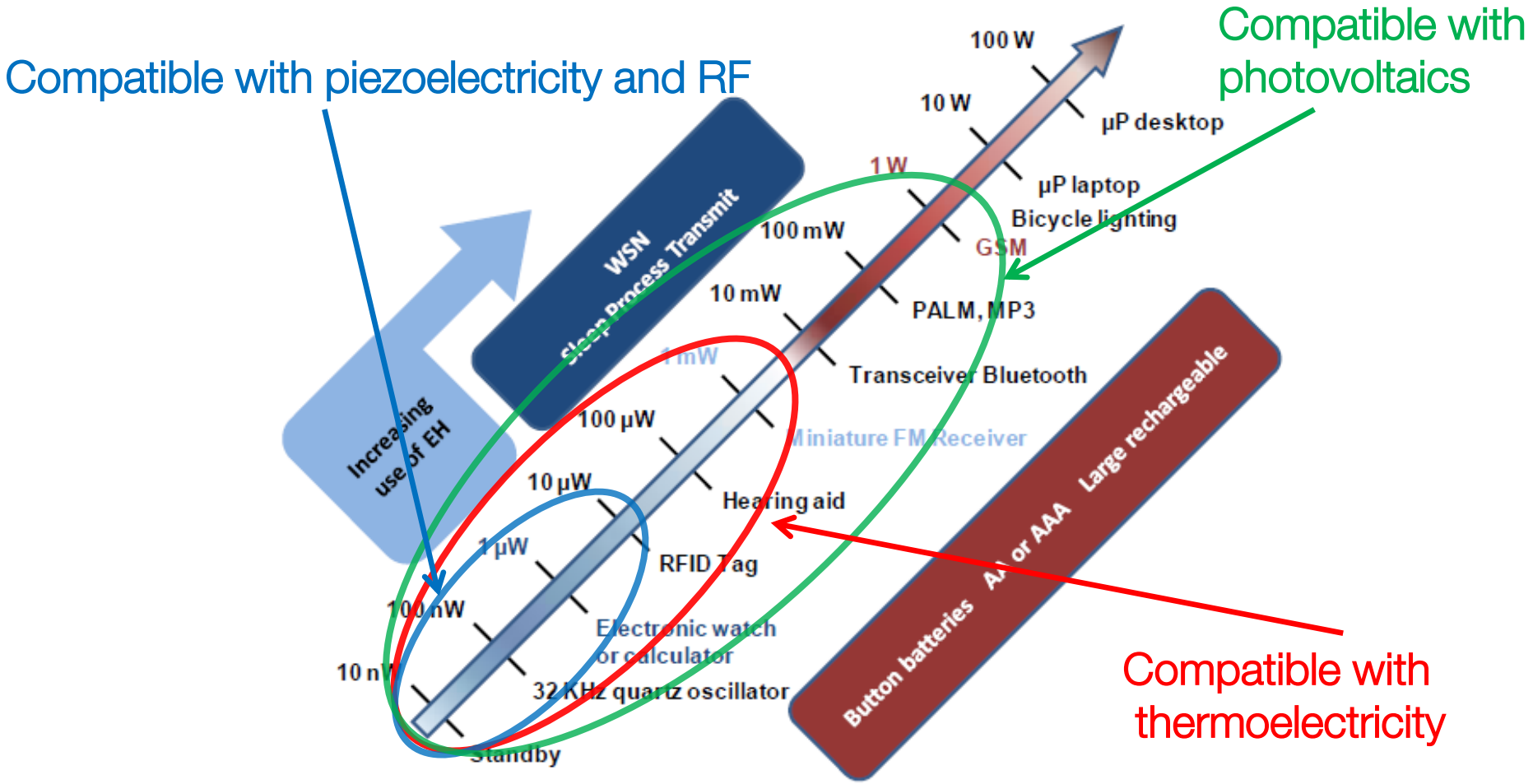
- Four physical effects can potentially be used to self-feed low power Telco devices because they produce electricity directly:
  - RF conversion (RFID)
  - piezoelectricity (vibration conversion into electricity)
  - thermoelectricity (heat conversion into electricity)
  - photovoltaic effect (light conversion into electricity)

- These physical effects have a range of use depending on
  - Level of generated power
  - Specific conditions (see following slide)
  - Technology's state of the art
  - Compatibility with Telco applications/power device

Main green energy suitable for low power devices: A summary

Physical effect Efficiency	Range of power	Specificity	Potential Telco applications
RF η = 50 %	GSM 900 MHz 0.1 µW/cm^2 Wi-Fi 0.001 µW/cm^2	Needs EM emission	Only devices with a very low duty cycle (sensors)
Piezoelectricity η = 25~50 %	Human 4 µW/cm^3 Industrial 800 µW/cm^3	Needs constant vibration	Devices with low duty cycle
Thermoelectricity η = 0.1~3 %	Human 60 µW/cm^2 Industrial 1~10 mW/cm^2	Needs hot and cold sources	Sensors in indoor locations without light (basements or cellars)
Photovoltaics η = 10~35 %	**Outdoor** **100 mW/cm^2** **Indoor** **100 µW/cm^2**	Needs light (natural or artificial)	Sensors , repeaters, gateway, routers, smartphone ….

Typical electric consumption of the main devices used in ICT
Domains of use of "green" energies



Source IDTechEx report "Energy Harvesting and Storage for Electronic Devices 2009-2019".

Photovoltaics is the best choice for self-feed low power devices

- A lot of Telco devices can already be self-fed by photovoltaic solar cells like sensors, repeaters, routers or wireless gateway in sunny areas.
- More than 2000 solar base stations (from 100 W to 1.5 kW) have been deployed in the world by Orange

- Advantages
  - Abundant worldwide energy (sun and artificial light)
  - Compatible with almost all Telco devices
  - Lifetime compatible with wireless network lifetime > 10 to 15 years
- Drawbacks
  - Panel surface is much too large for small Telco devices > 3~5 W
  - Low efficiency with indoor lighting ($\eta \approx 10\%$)
  - High efficiency solar cells are currently too expensive

Research on photovoltaics at Orange

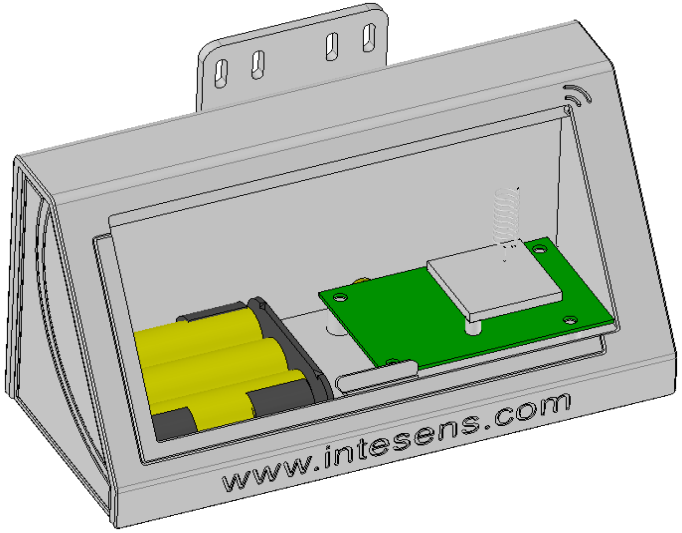
- Targets
  - Reduce the energy bill of our access networks
  - Spread our networks in areas without energy infrastructure or remote areas (Southern Europe and Africa)
  - Spread the deployment of wireless networks from outdoor to indoor
  - As "end user ", Orange must interact with manufacturers in order to adapt their solutions to our needs.

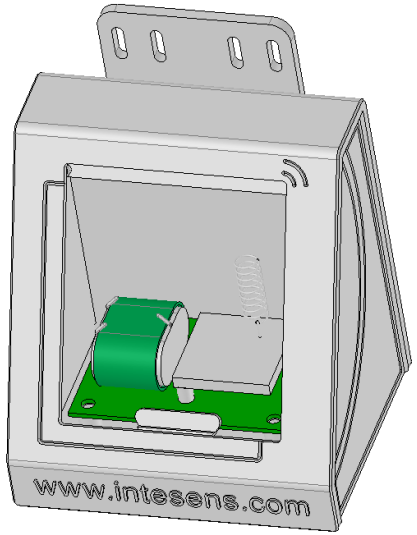
- Main areas of research in renewable energy
  - Outdoor supply of our networks and our residential low power equipments (from mW to tens of W)
  - Indoor supply of wireless sensors (ZigBee) thanks to artificial lighting (e.g. white LEDs).

Technological approaches depend on environment, device power and "use case"

- Outdoor applications
  - Definition : Classic photovoltaics having the sun for main light source:
  - Target technologies → technology optimized with respect to cost and a high efficiency > 30-35 %
  - Applicable for devices consuming a few W, up to approximately 50 W

- Indoor applications
  - Definition: Photovoltaics using artificial light (LED, fluorescent and halogen lighting) and/or diffuse sunlight:
  - Target technologies → very low cost technology with a reasonable efficiency > 12-15 %
  - Applicable for devices consuming a few mW up to approximately 100 mW





EXAMPLE OF INDUSTRIAL COLLABORATIONS

Industrial and academic collaborations

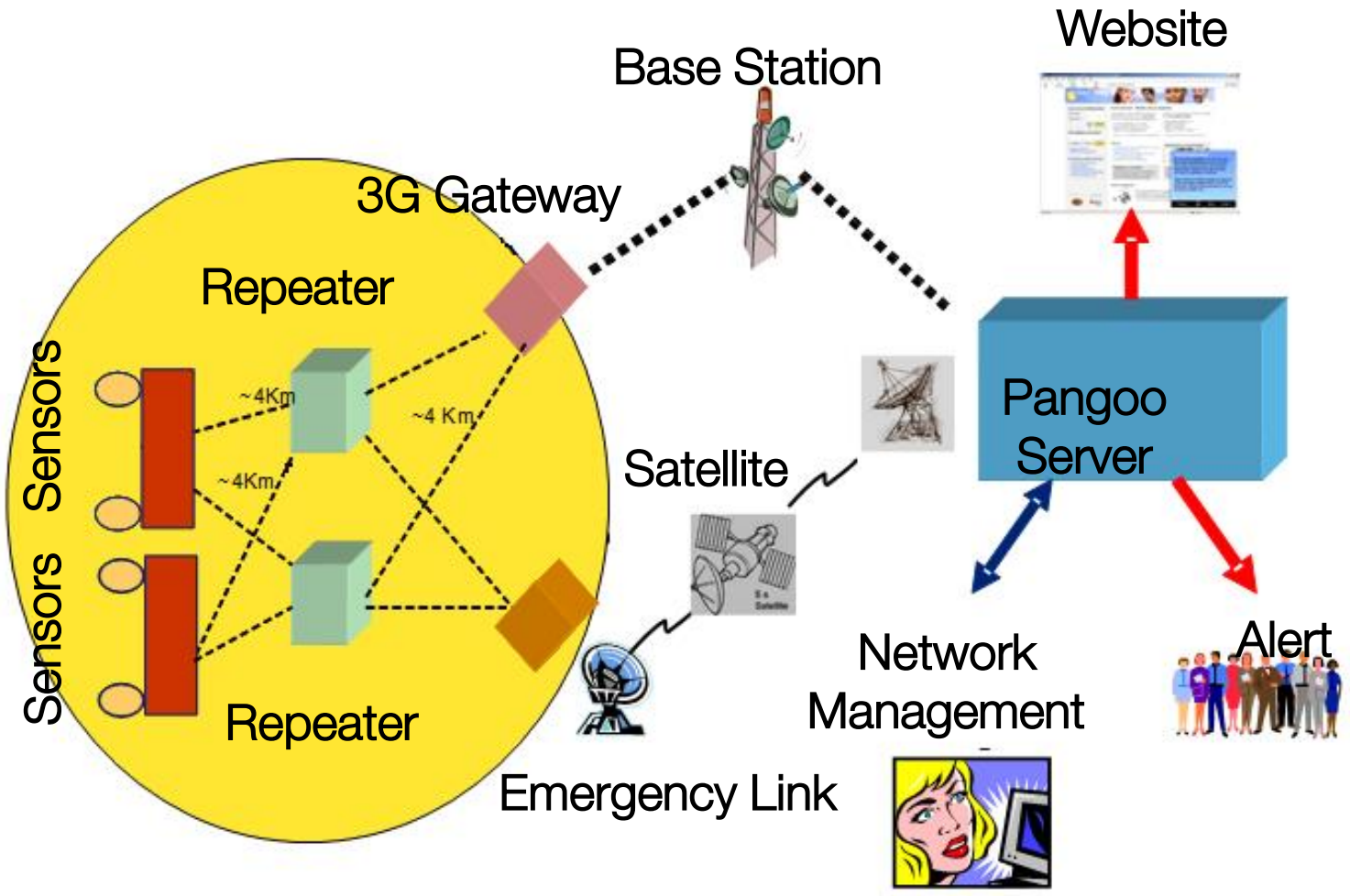
- Orange works in open innovation mode with industrial partners:
  - CORONIS/ELSTER: M2M networks sensors, repeater, gateway
  - Kyosemi/Solar Power: Innovative solar cells
  - Intesens: Ultra low power electronic for energy harvesting
  - SAFT: Secondary batteries (NiMH Technology)

- Orange collaborates with academic laboratories
  - CEA Grenoble/INAC (InGaN high efficiency solar cells)
  - Bordeaux I /CNRS (optimized indoor light photovoltaics)
  - GeorgiaTech Lorraine (bulk InGaN solar cells)
  - Institute of nanotechnologies from Lyon (optimized indoor light photovoltaics)

Industrial collaboration with Intenses/SAFT/CORONIS
Solar M2M network for sustainable city

- **Potential Use and Benefits**
  - 50 million potential urban equipments (sensors, repeaters, gateways) according to M2M Urban Objects Management project (District administration, Traffic regulation, Environment data monitoring, metering and distribution management).
  - Business plan 3.6 G€/yr for France residential and corporate markets.

Typical Machine To Machine Networks at Orange

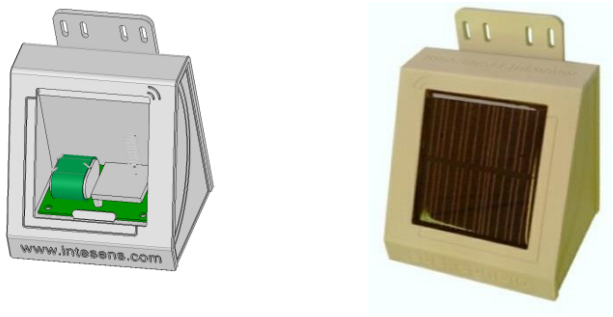


http://www.cagnes-sur-mer.fr/

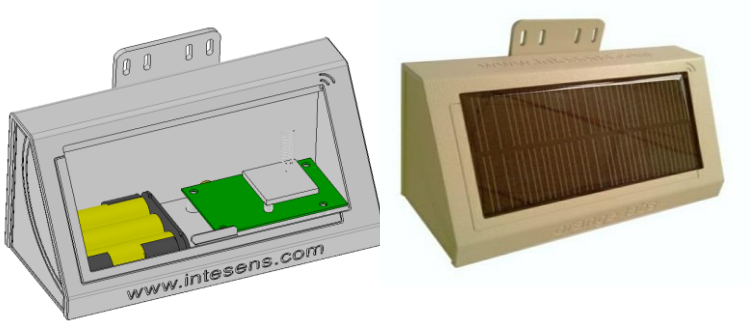
Constraints and limitations of the solution using primary batteries

- Constraints linked to primary batteries, in particular for repeaters and sensors
  - Maintenance costs (replacement of batteries)
  - Autonomy
  - Limitation of the number of requests thus limitation of future services
  - Batteries and equipment recycling
- Solution: “energy harvesting“
  - Renewable energy using photovoltaic cells
  - Associated with a rechargeable battery (NiMH)

M2M Self-Feed wireless repeater autonomies deployed at Cagnes sur Mer and Nice (France)



25 mW Solar repeater



500 mW Solar repeater

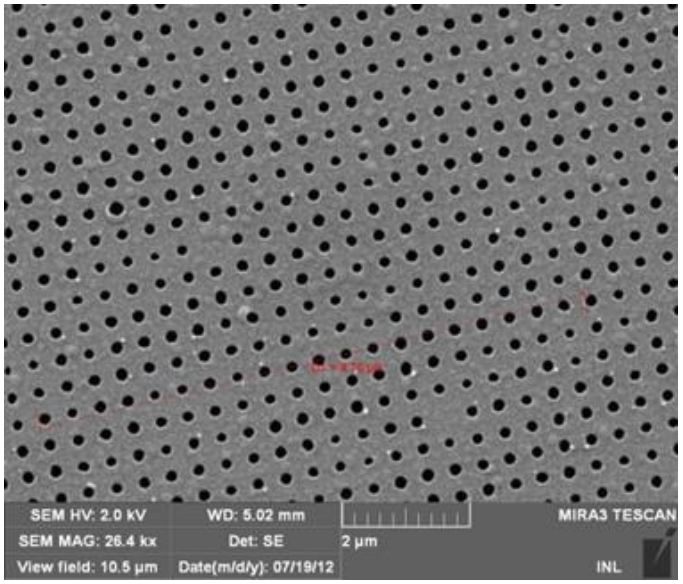
- Lifetime increased by at least a factor 8 with respect to a repeater using primary batteries
- The number of interrogations may be raised up to 800 per day

	Daily consomption (mA.h)	Batteries Capacity (mA.h)	Autonomy
25 mW	**4,85**	**110**	**> 6 days (15 in nominal)**
500 mW	**31,85**	**1100**	**> 10 days (23 in nominal)**

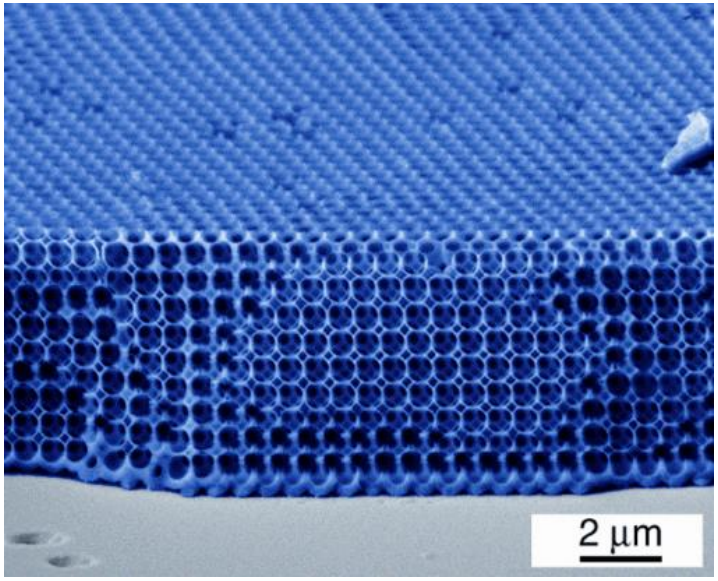
Solar M2M network for sustainable city

- **Innovative Breakthrough**
  - Drastically increased autonomy of M2M networks devices using rechargeable batteries and solar panel, maintenance-free networks, high-performance sustainable services.
  - Simplified outdoor network deployment (no AC mains required)
- **Results**
  - Full solar outdoor M2M network
  - Ruggedized and long life time (10 to 15 years)

EXAMPLES OF ACADEMIC COLLABORATIONS



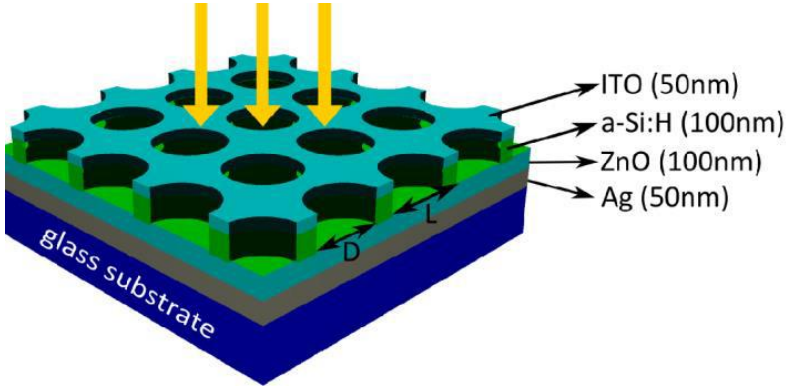
Photonic Crystal solar cell
Top down approach
Courtesy of INL

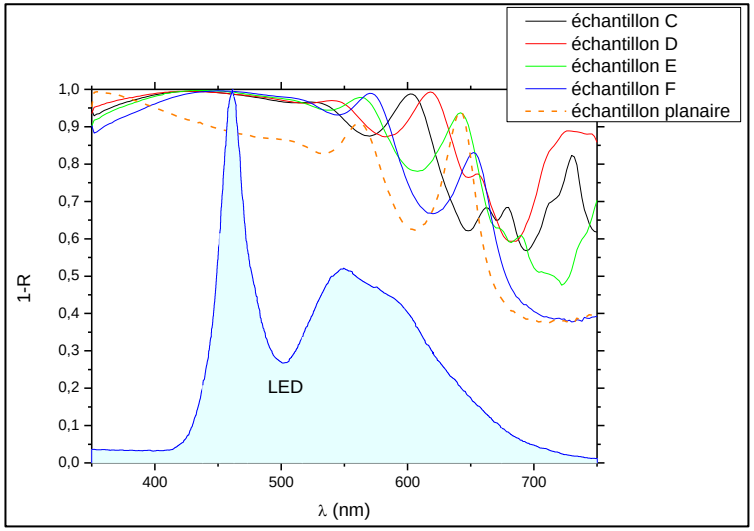


Photonic Crystal for indoor solar cell
Bottom up approach
Courtesy of Bordeaux I/CNRS

Photovoltaic sensor optimized for indoor light using photonic crystals (Top down approach).

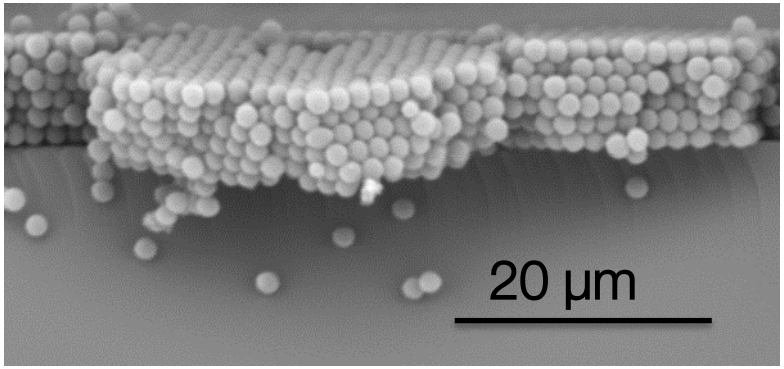
- Purpose:
  - Increase the efficiency of low-cost photovoltaic cells under artificial light (white LEDs)
- Objectives:
  - Increase the absorption of visible light
  - Convert reflected light more efficiently (grazing incidence)
- How:
  - Thanks to nanotechnologies and the use of photonic crystals (nanostructured materials)
- Results:
  - Experimental validation for a PV cell structure absorbing 80 to 85 % of a white LED spectra.

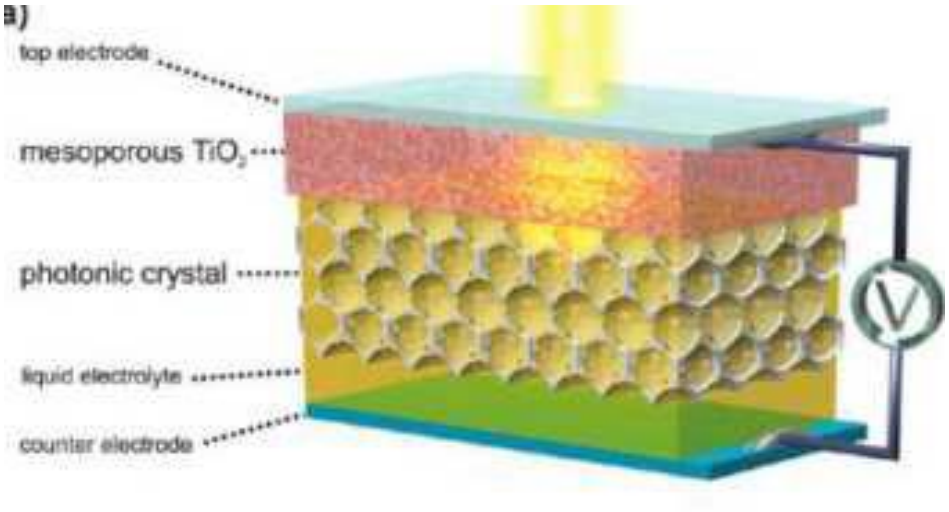




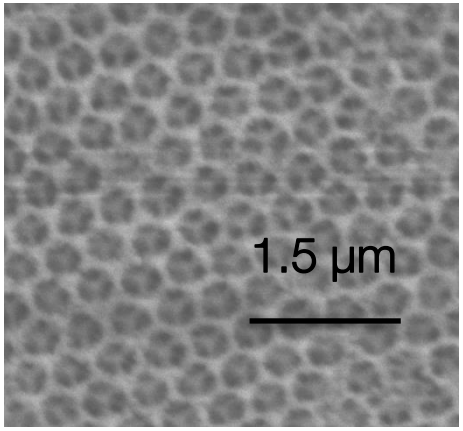
Very low cost approach using self-assembly materials: Inverse opals (bottom up approach) Bordeaux I / CNRS

Multilayer of silicon beads





Cross section of an opal inverse PV cell



Photonic crystal after processing
Honeycomb structure

Conclusion and outlook

- Future Telco networks will be deployed in a constellation of low-power devices
- Solar energy and artificial light are abundant, available worldwide, and suitable to self-feed low-power devices
- Issues are still remaining for Telco devices requiring more than 3 W
  - Router, Internet box and wireless access point power consumption must be reduced below a few W
  - Low-cost and high-efficiency solar cells have to be developed for Telco devices using more than 3 W
  - Indoor solar cells efficiency must be improved using recent developments in nanotechnology and new very low-cost materials (organic or semiconductors).
- A close collaboration between academic laboratories, industrials and Telco companies is essential for success

Industrial contributors

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ありがとうございます

thank You