French Institute
of Science and Technology
for Transport, Development
and Networks

Reliable nanosensors for sustainable cities: from research to real-life deployments

Project Sense-City - Ifsttar, ESIEE, LPICM, CSTB, Inria, UPEM)
Project PLATINE - Ecole Polytechnique (LMS, LPICM, LSI), IFSTTAR

IFSTTAR

Singapore THz Workhsop

October 16th, 2014

IFSTTAR ESIEE LPICM CSTB Inria UPEM

Over 40 people throughout France

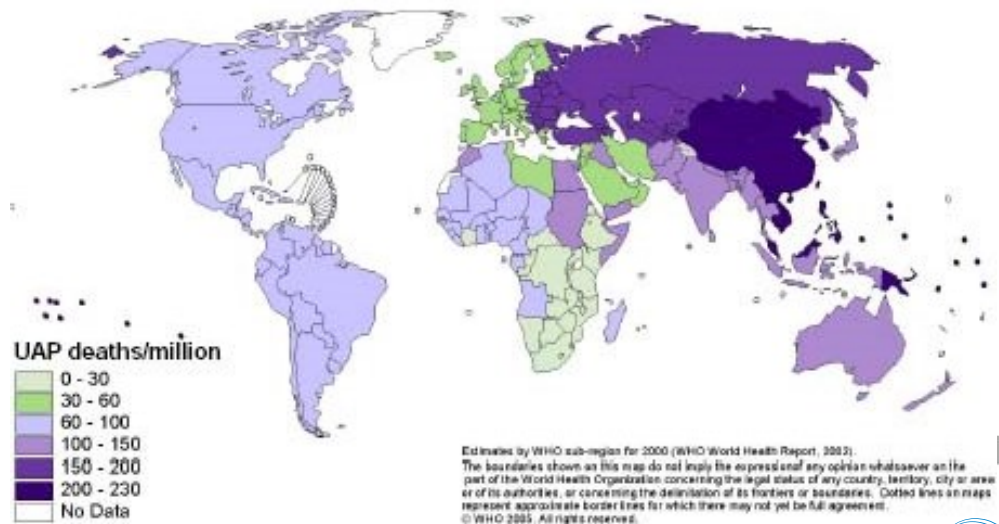
- Covering the whole chain of values for nanosensors prototyping
- From Nanomaterials to Big Data

Goals

- In 2050, cities will *welcome* 75% of the World population
  - Degradation of everyday life conditions
  - Variety of nuisances (pollution, traffic...)
- **Toward Sustainable Cities** we propose

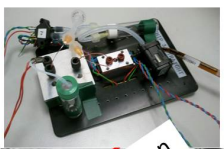
  Decision-support tools based on micro&nano-sensors, physical models, data management and representation

- *Environmental quality*
- *Eco-building & Ecodistrict*
- *People exposure & health*
- *Infrastructure and network durability*

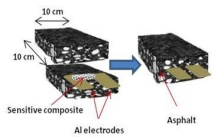


Decision-support tools: from sensors to users

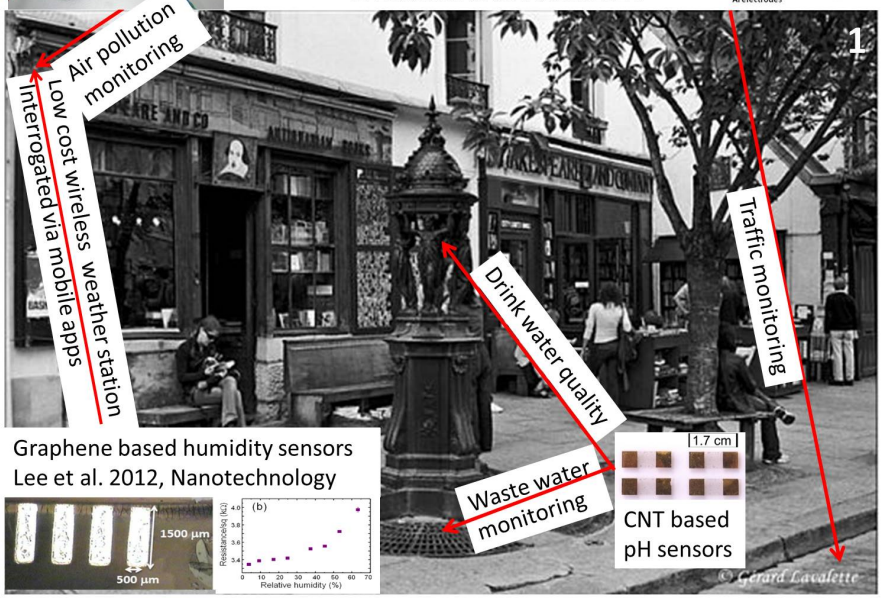
1. Repertoire of *reliable, networked micro&nano-sensors*
2. COMBINED with *advanced modeling* (inverse methods)
3. COMBINED with *contextualized visualization* (awareness of needs)



Microchromatograph
Cesar et al., IEEE MEMS 2013

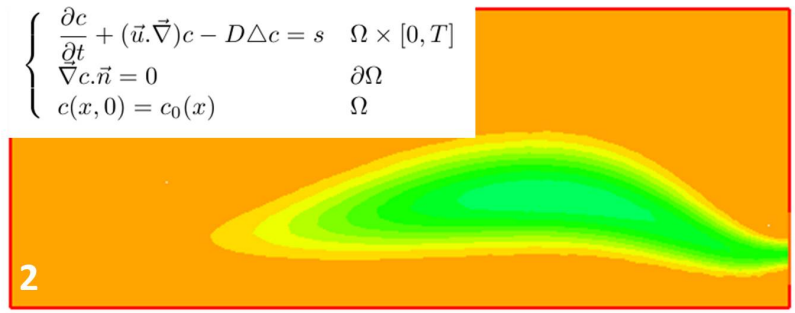


Smart asphalt
B. Lebental et al. Patent 2014



Graphene based humidity sensors
Lee et al. 2012, Nanotechnology

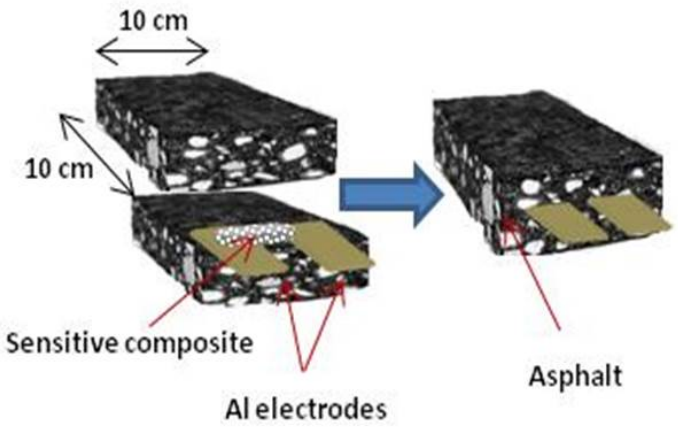
$$\begin{cases} \frac{\partial c}{\partial t} + (\vec{u}.\vec{\nabla})c - D\triangle c = s & \Omega \times [0,T] \\ \vec{\nabla} c.\vec{n} = 0 & \partial\Omega \\ c(x,0) = c_0(x) & \Omega \end{cases}$$



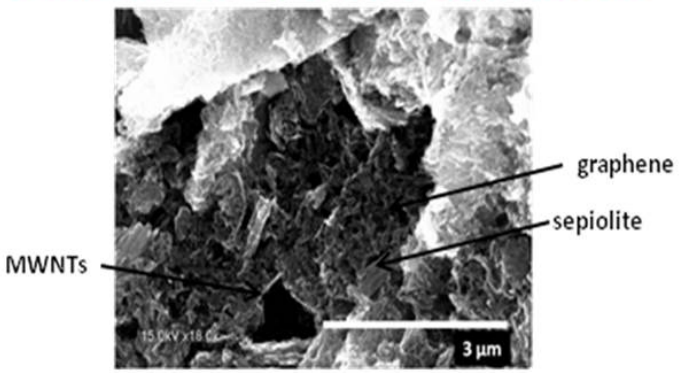
New sensors for sustainability

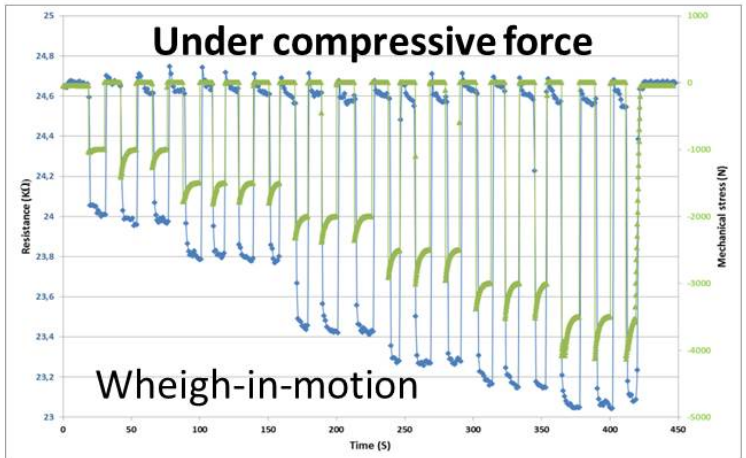
- Why do we need new sensors?
  - Progress in sustainability relies on **Big Data** analysis
  - Data provided by the **Internet of Things**
  - IoT addresses only few parameters at **affordable costs** (temperature, humidity, GPS data, accelerometers...)
  - **What about next generatation observables? improved quality of data? lower device cost?**
- Two routes for sensor prototyping
  - **Silicon route**: innovative technologies building upon traditional, silicium-based electronics; low cost in mass production, high cost in development; high accuracy and complex observables
  - **Low-cost route**: innovative material on low cost substrates (paper, plastics, glass...); printing, roll-to-roll technologies; moderate accuracy and simple observables

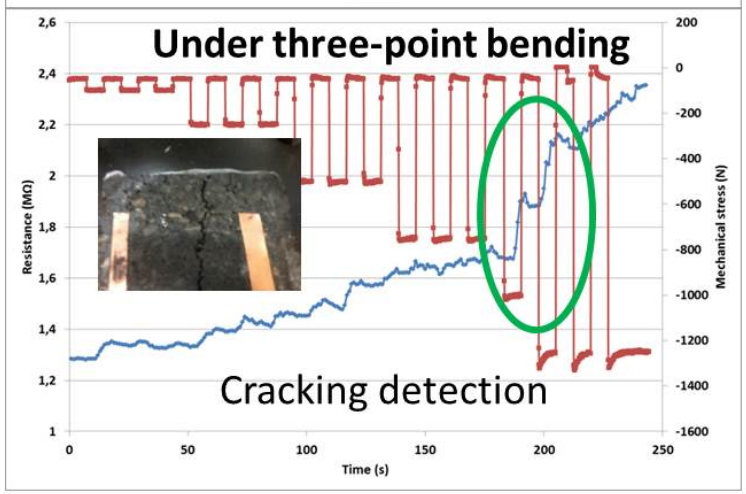
Clay-carbon Nanocomposite for Smart Asphalt



A clay-graphene-MWNT nano-composite in a percolating network

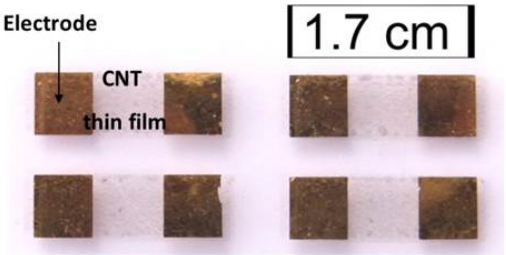




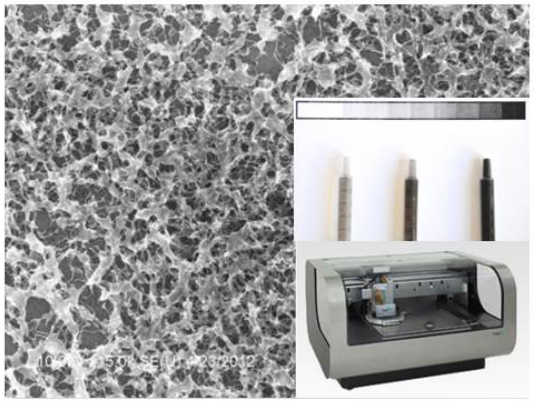


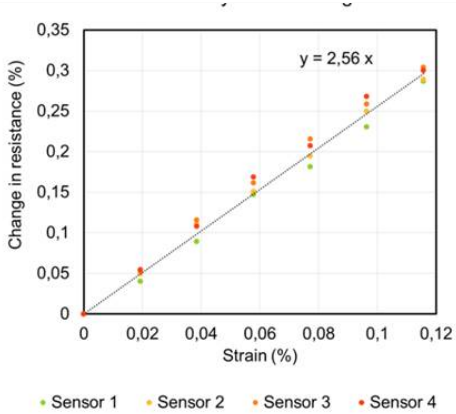
B. Lebental et al., Patent FR14 52842

Highly reproducible CNT network strain sensor

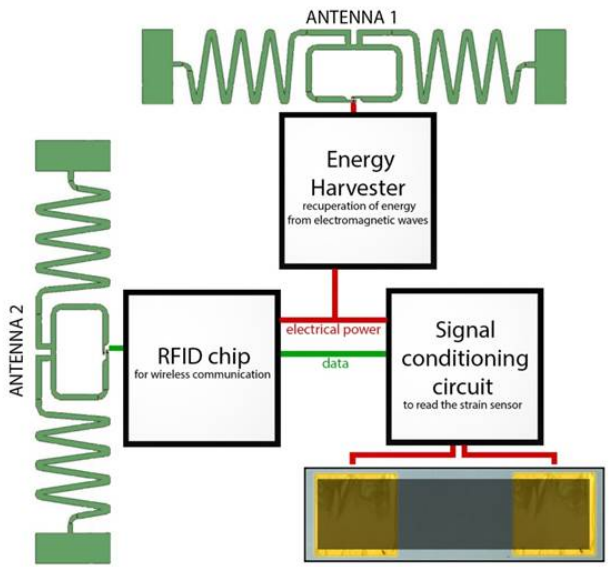


Resistive devices batch-fabricated by ink-jet printing of CNT

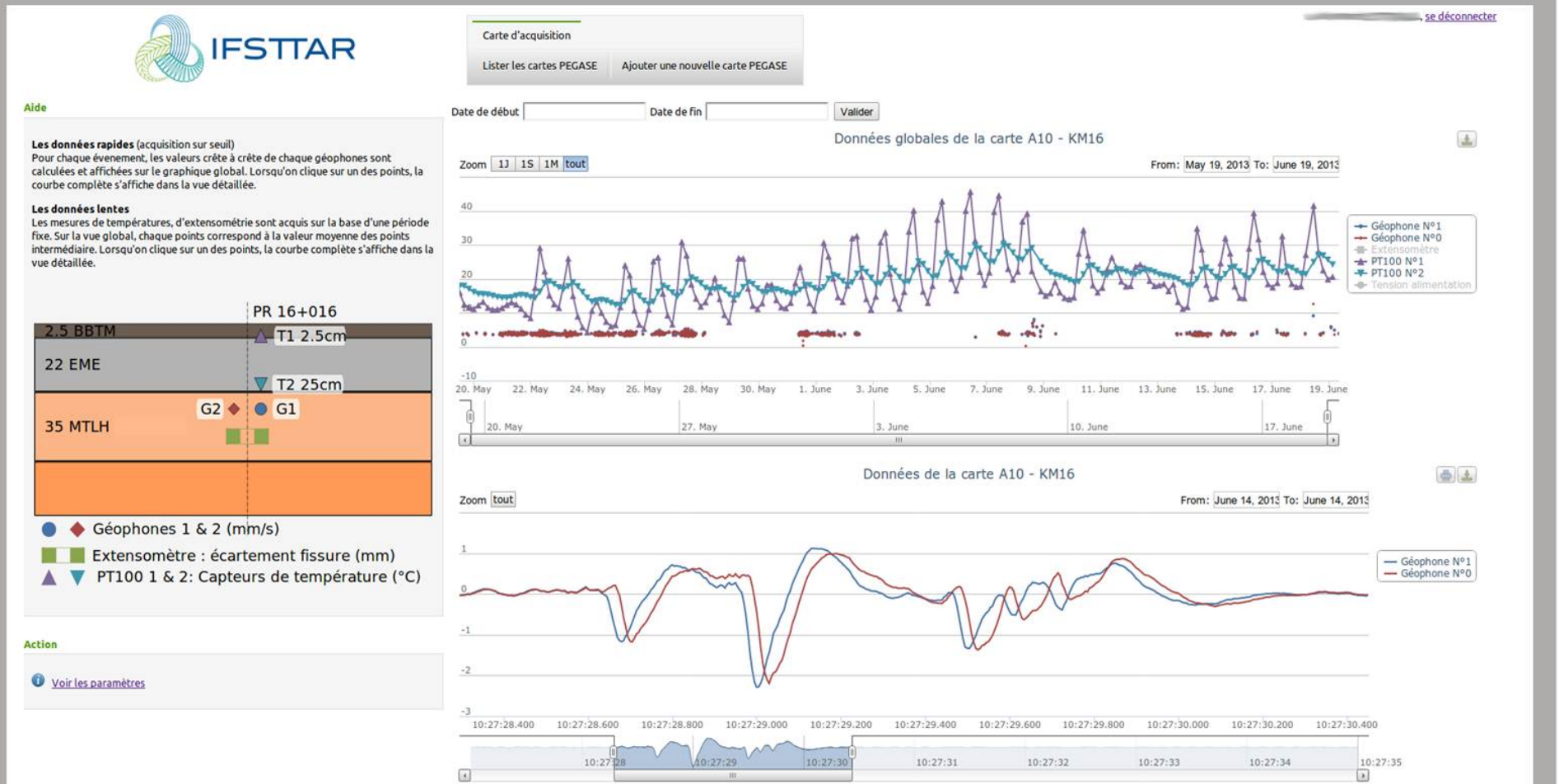




reproducible sensitivity to strain (strain gauge >2)



Wireless sensor network for infrastructure monitoring

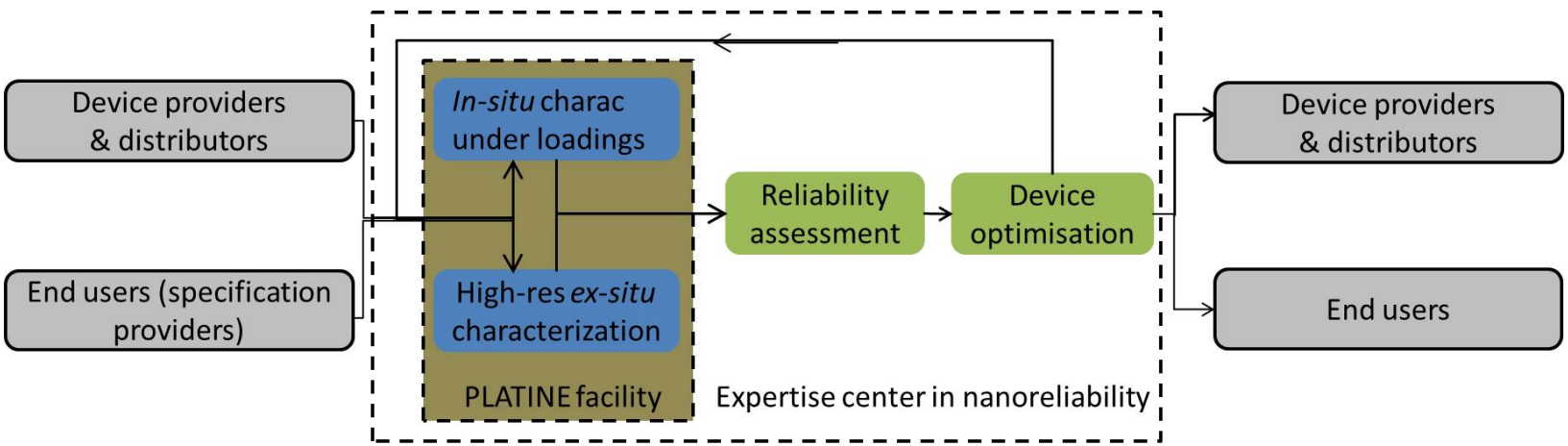


Potential of THz technologies for Smart Cities

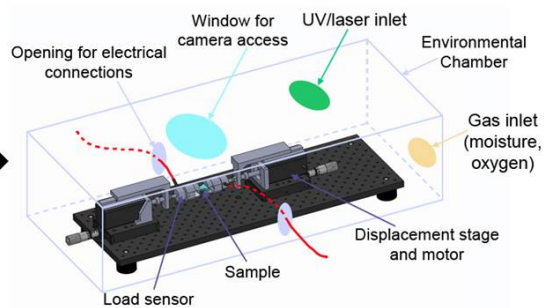
- Sensing and imaging
  - Gaz or liquid or solid phase spectroscopy (civil or militar)
  - Non-destructive testing of materials (defect detection)
- Communication
  - Ultra-small antenna
  - Low power, directional communication
- Requirements:
  - Adequation to the field: compact? low cost?
  - Level of maturity: reproctibility? reliability?

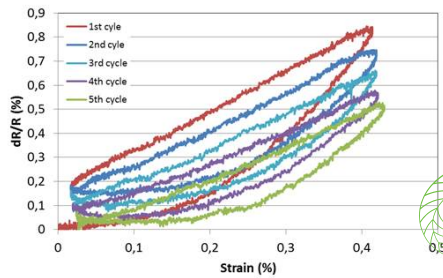
Nanoreliability assessment: an open platform

- Overcoming the 'valley of death' by building confidence in nanodevices
  1. Coupled characterizations under multiple loadings (mechanical, electrical, optical, thermal, hygrometry, chemical)
  2. In-situ/ex-situ analysis of damage mechanisms (from mm to nm)
  3. Lifetime assessment via multi-scale modelling



Evolving toward

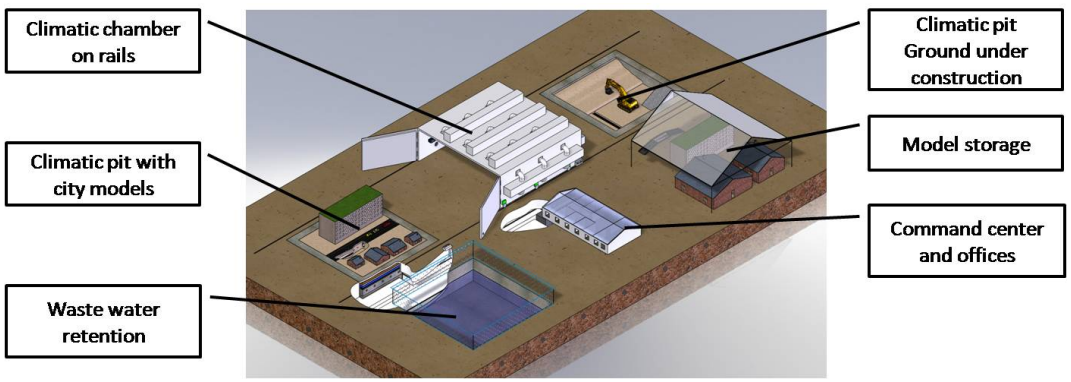




Urban deployments for nanosensors

- What next? Real life is way more complicated than the lab...
- Urban deployments essential to demonstrate industrial readiness
  - provide accurate benchmark for new devices
  - debug small series and develop deployment strategies
- But always **slow going process**
  - legal issues and access to infrastructures
  - reluctance from urban managers
  - highly complex, uncontrollable loadings

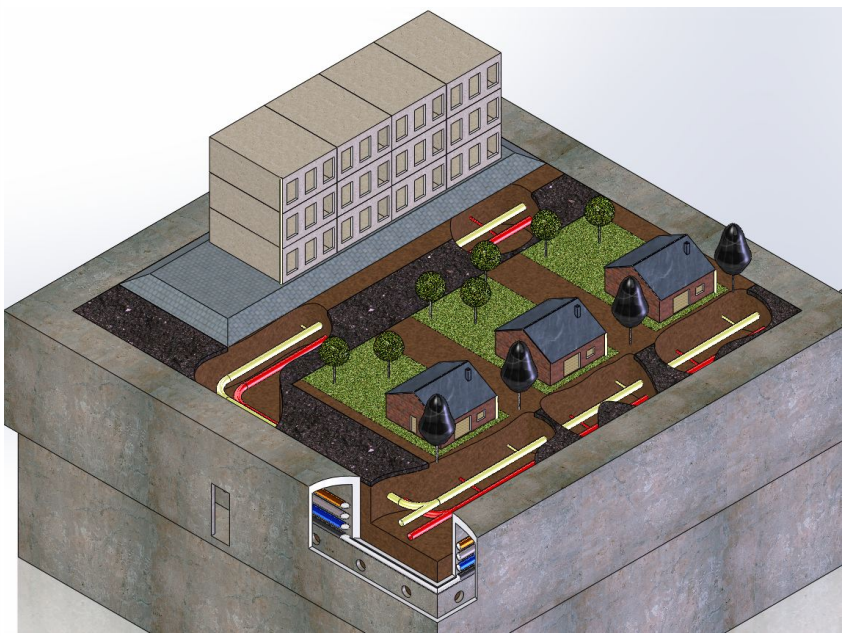
$\Rightarrow$ Sense-City mini-city: 400 m^2 for model urban deployments



Sense-City mini-city

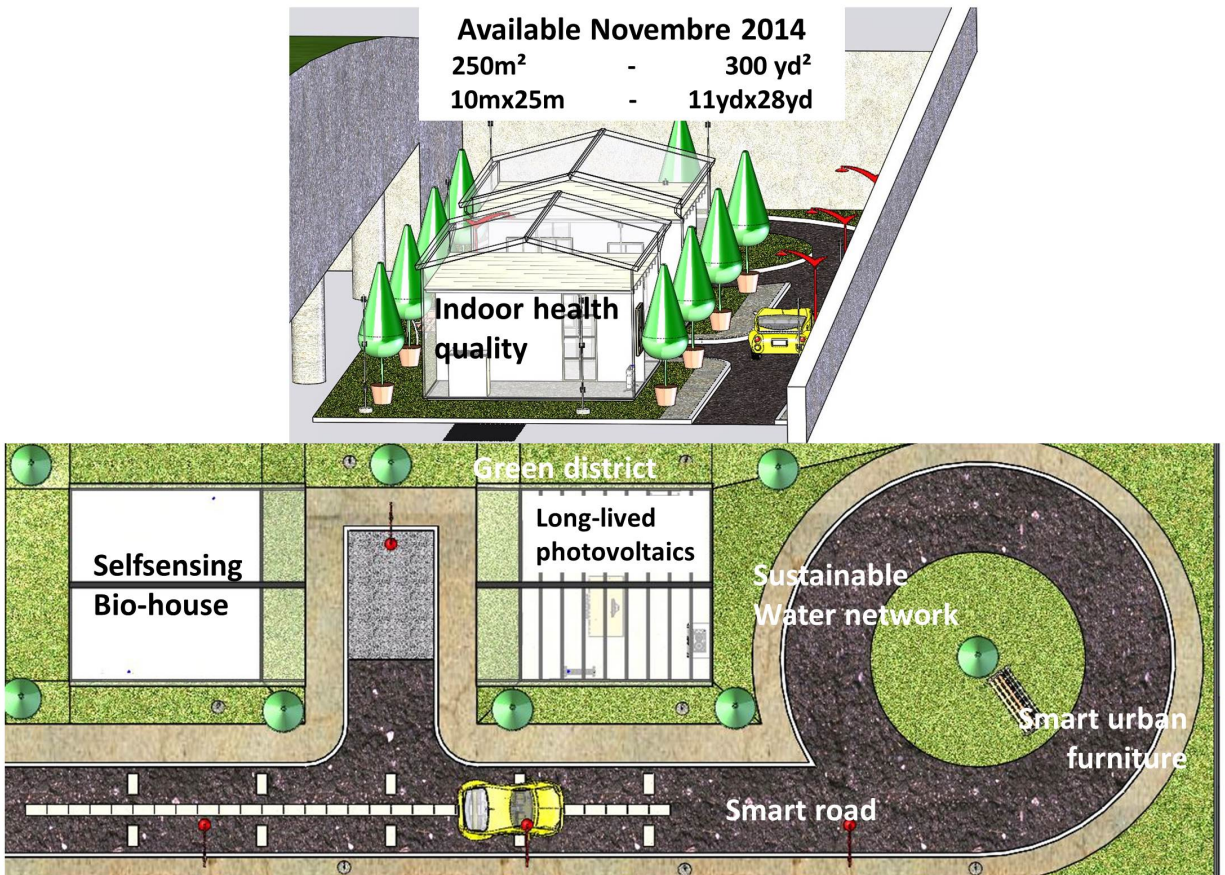
- 400 m^2 mobile climatic chamber with 3m-deep pit
- A tunable district with typical urban features
- From humid winter conditions to dry heat wave to rainstorm

$\Rightarrow$ Time-to-market accelerator



Sense-City mini-city

- First models available by end of year 2014
- Multidisciplinary initiatives
- Additional experiments are welcome



Summary

- Decision-support tools for Green Cities
- Open platform for nanotech reliability assessment
- Open platform for urban deployments
- Contributors
  - IFSTTAR: F. Derkx, F. Bourquin, H. Van Damme, A. Ruas, J. Dumoulin, E. Merliot, S. Buttigieg, F. Bouanis, J. Waeytens, R. Chakir, V. Le Cam, A. Nassiopoulos, E. Merliot, D. Siegert, W. Moujahid, F. Michelis, B. Ghaddab, W. Cesar, R. Kuate, W. Martin, L.-L. Sorin, H. Wu, M. Berbineau, W. Martin, S. Marceau, C. Chevalier, J.-M. Auberlet, F. Vienne, N. Hautière...
  - ESIEE: T. Bourouina, D. Angelescu, P. Basset, B. Mercier
  - Ecole Polytechnique/CNRS (LPICM, LMS, LSI): C. Cojocaru, P.Roca, Y. Bonnassieux, G. Rose, E. Caristan, L. Bodelot, A. Constantinescu, J.-E. Wegrowe, M.-C. Clochard, T. Gacoin, A. Rowe, D. Marcillac
  - CSTB: E. Robine, T. L. Ha
  - Inria: Hervé Rivano, Cedric Adjith, Stéphane Ubéda, Nathalie Mitton
  - UPEM: Jean-Marc Laheurte, Odile Picon