THE ROAD TO SUSTAINABILITY FOR MEGACITIES

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The urban century and the rise of megacities
Challenges and opportunities
A road for sustainable megacities
Cities and complex systems and urban metabolism
KPI for sustainable megacities
Work in progress
The Rise of the urban century

Source: UN world Urbanization prospects, 2014
Urbanization: challenges and opportunities

Our Challenge

- Urban population is expected to be over 60% by 2050.
- 2.5 billion people in developing countries will be urban by 2050 (Angel, 2012)
- Reduce the impact on the environment (70% of GHG emissions are from cities).

Our Opportunity

- 2.5 bi. People will need basic services, especially in Latin America and Africa
- Access to electricity and clean water means:
  - Rely on cleaner energy sources
  - Economic development of low-income areas
  - Reduce emissions (Lighting, cooking, mobility)
- Paradigm shift: sustainable development

Source: Courtesy of C. Kennedy, University of Victoria.
The rise of megacities

- Metropolitan regions with more than 10M inhabitants
  - Considered engines of global growth
  - Paradigm of fast urban evolution
  - Accumulation points for population, especially in dev. countries
  - Significant global impact for resource consumption and source of economic power.
    - huge concentration of skills, knowledge and technical resources
  - Hub for the global network of cities

Study megacities means understanding:
- how cities grow and consume energy and materials
- mechanism of efficient use of resources
- the transformative role of utilities, governments and policy makers in driving a sustainability transition.

Megacities amplify negative aspects of urbanization:
- Inequalities and slums
- Pollution
- inadequate infrastructures (water, energy, mobility)
- Land degradation and consumption

Source: UN world Urbanization prospects, the 2014 revision
The global network of cities

Megacities as hubs

Source: http://www.lboro.ac.uk/gawc/visual/globalcities2010.pdf
The global impact of megacities

Infrastructural challenges in megacities

- **Infrastructures as** enabling factors for sustainability and efficient provision of services
- Especially in fast growing megacities, the *infrastructures need a deep rethinking and adaptation* in order to cope with the fast growth, climate change, and to ensure the quality of services for all the citizens.

- Transportation
- Waste
- Electricity
- Sanitation
- Water
- Security

A strategy is required for financing, managing and maintaining environmentally sustainable infrastructures
Quantity and quality
Urbanization in semi-arid regions
Inadequate infrastructures
Competition with energy and urban population

Other aspects:
- **Floods**: An estimated two billion people live in areas at risk
- **Climate change** and sea level rise
- **Pollution of rivers**
Water risk and megacities

Source: http://www.wri.org/our-work/project/aqueduct
✓ Traffic congestion
✓ Pollution of water and soil
✓ Degradation of green areas
✓ Air quality and GHG emissions
✓ Waste

Every year thousands of people die from lung diseases linked to pollution.
Most obvious expression of urban poverty
People in the lower income bracket are the most exposed to climate change issues.

They are characterized by the lack of:

- access to basic services (energy, water, improved sanitation, waste, etc.)
- Sufficient living space
- Durability security of dwellings

- Over 830 million of people live in slums.
- Every year about 1.3 million people (mostly women and children) die prematurely because of domestic air pollution by biomass
- More than 1.3 billion people will need access to electricity in the next 20 years.

Source: UN-Habitat
We expect in the next future an increase of megacities

Impact on the environment.

A road to sustainability is needed to cope with the challenges of the next future

- Identify structural changes and pressure factors (e.g. climate change, migrations, etc.)
- Cities as complex multi-layered systems
- Understand energy and material flows
- Low Carbon electric city
- Provide policy makers with decision supporting tools
Cities as Complex Systems

- Systems composed by many interconnected parts
- The whole is more than the sum of the parts
- Analogy with living organisms
- Role of cultural and technical evolution

- Multiscale Flows of energy, matter, and information;
- Emergence and formation of organized structures
- Growth Vs development

Energy flows in an industrial and post-industrial urban system

Cities as complex systems

- Urban infrastructures: Hard, soft, intangible.
- **Multilevel network**

- Integration of the layers of the city connecting physical and social layers.

- Understand this ML network means:
  - Accurate measures and monitoring for risks management
  - Improved resilience measures and adaptation to climate change
  - Social connection and inclusion of the citizens
  - Improving efficiency by means of awareness: new services and new business models for citizens
  - Enabling social innovation
Urban Metabolism: energy and material flows

- The aggregate of the technical and socio-economic process that occur in cities
- Analysed through the energy and material flows crossing the boundaries

Why Urban Metabolism?

- Gives measures of urban resource efficiency
- Connections to quality of life in cities
- Required input for city GHG inventories
- Framework for sustainable urban planning/design
Tailored low carbon infrastructure strategies

BIPV = building integrated photovoltaics,
DE = district energy,
EV = electric vehicles,
GSHP = ground source heat pumps,
HRT = heavy rapid transit,
IRE = import renewable electricity

Shares of metabolic flows in megacities

- Rank according to descending GDP
- Equal share of GDP (e.g. New York and Los Angeles - Mexico city, Moscow and Seoul – Paris and London) do not always lead to similar share of resource consumption
- Energy and water in Guangzhou and Shanghai suggest further investigation
- Jakarta, Mumbai, Istanbul, and Cairo, that show a significant difference between the GDP and waste collection share
Low carbon electric cities

Source: C. Kennedy, I. Stewart, A. Facchini, R. Mele. The role of Utilities in developing low Carbon, electric megacities, Energy policy 2017
<table>
<thead>
<tr>
<th>Key Performance Indicator (KPI)</th>
<th>Units</th>
<th>Time period</th>
<th>Urban dimension</th>
<th>Sub-Dimensions</th>
<th>Other supporting indicators in the megacities dataset</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Electricity use per capita</td>
<td>MWh</td>
<td>Annum</td>
<td>Energy</td>
<td>Air pollution, global warming, service delivery, physical infrastructure, innovation, urban form, economic development, social equity</td>
<td>CO₂ intensity of electricity; percentage of total energy use from low-carbon electricity</td>
</tr>
<tr>
<td>2. Percentage of households with direct access to drinkable water</td>
<td>%</td>
<td>---</td>
<td>Water</td>
<td>Sanitation, service delivery, physical infrastructure, social equity, economic development</td>
<td>Water line losses as a percentage of total water consumption</td>
</tr>
<tr>
<td>3. Solid waste production per capita</td>
<td>Tonnes</td>
<td>Annum</td>
<td>Waste</td>
<td>Subsurface pollution, global warming, material recycling, consumption, urban form, economic development</td>
<td>Wastewater volume per capita</td>
</tr>
<tr>
<td>4. Percentage of population with access to internet</td>
<td>%</td>
<td>---</td>
<td>Information &amp; communications technology</td>
<td>Connectivity, information access, innovation, service delivery, digital infrastructure, economic development, social equity</td>
<td>Percentage of population using mobile phones</td>
</tr>
</tbody>
</table>
Electricity consumption is an important driver for economic development, especially in fast developing countries.

In Rio de Janeiro both electricity consumption and GDP grew 10 times faster than population.

London managed to reduce its per capita electricity use for 2001-2011, while growing its GDP, but it is an exception.

Superlinear scaling is always observed.

Correlation between per capita electricity consumption and GDP.

Important insights for infrastructure resilience and climate change.
P.C. Electricity consumption

- Low consumption: people rely on less efficient (and more polluting) fuels in the energy ladder.
- Especially in Asia and Africa large share of people lives in slums
- Carbon intensity does not appear related with PM2.5 pollution
- Access to infrastructure is a crucial topic
Hard infrastructures (e.g. water, gas, electricity) are directly related to GDP.

Logistic model

\[ f(x) = \frac{100}{1 + ae^{bx}} \]
- One of the most important environmental issues facing megacities today;
- Critical function of the urban environment.
- Indicator of a healthy and resource-efficient city.
- Implicates urban form, wealth and poverty, over- and under-consumption, material recycling (both formal and informal), and subsurface pollution of water and soil.
Access to internet & Mobile phones

- Digital information is an essential function of everyday life in megacities.
- Access to digital infrastructure (e.g., internet) is improved thru access to grid electricity.
- This implies economic development and existing infrastructure for basic services such as sewerage, drinkable water, and solid waste removal.
- Enabling factor for digital infrastructures integration.
- Difference between hard and soft infrastructures.

![Bar chart showing the percentage of population with access to internet in different cities.](image1)

![Scatter plot showing the percentage of population using mobile phones vs. GDP per capita.](image2)
Analysis of KPI: communities in megacities

- Provide policy/decision makers with tools to:
  - Understand the actual situation.
  - Suggest action to move among communities

Develop supporting tools for policy makers

- Actual tools are not capturing the complex nature of megacities
- Need methods for modelling:
  - Hard infrastructures
  - Soft infrastructures
  - Intangible factors

- Models based on synthetic interacting populations may be exploited to:
  - Simulate the behavior of people reacting to different policies (intangible factors)
  - Analyze infrastructural changes (e.g. position of new power plants, electric mobility, TLC networks, etc.)
  - Simulate new policies and analyze their strengths and weaknesses (soft infrastructures)

- Some examples regarding water and CO2 Emissions
Policies influence water flows

Growth ratios for water use to population, 2001–11

- Growth ratios for water use to population, 2001–11
- Water conservation policies (post-2001)
Case study: CO2 Emissions in Lima

- Change in the electricity mix of Lima
- Increasing use of natural gas
- BAU scenario results in a relevant increase of CO2 emissions
- Which is the optimal policy.

Of course I’m not alone...

- Program started in 2013 by Enel Foundation
- Data Collected by a network of 28 researchers based in the megacities

The research network is now composed by:

- **Chris Kennedy**, Uni. of Victoria, Canada
- **Iain Stewart**, World Resources Institute, USA
- **Guido Caldarelli & Fabio Saracco**, IMT Lucca
- **Renata Mele**, Enel Foundation
- **Antonio Scala**, CNR-ISC
- **Ramzy Kahat**, Cath. University of Lima, Peru
- **Jonathan Barton**, Cath. Univ. Of Santiago, Santiago de Chile
- **Isaac Dyner**, University JT Lozano, Bogota
- **Clara Pardo**, Univ. Del Rosario, Bogota
- **Ted Endreny**, Syracuse Uni. NY, USA