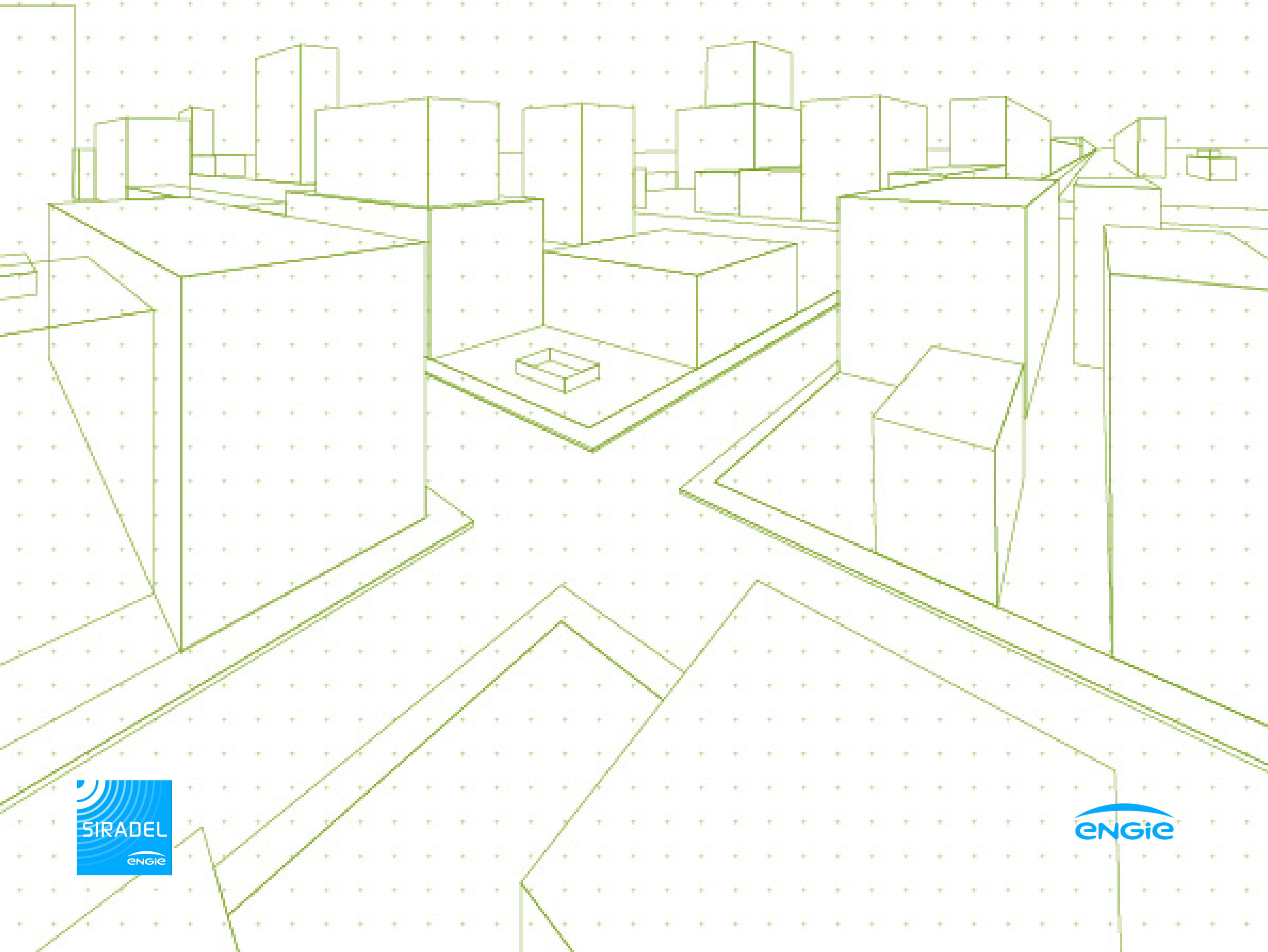
Understanding Resiliency: What It Means to be a Resilient City and Tools to Support



Co-authors

Christophe Papin
VP Business Developer, SIRADEL

George Reed
SVP Sales and Marketing NORAM, SIRADEL

Olivier Grandamas
Risk Management Expert, SIRADEL

Laurent Bouillot
CEO, SIRADEL

Sylvain Chapon
Marketing & External Relationships Executive
Key Expert, ENGIE

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More than 40% of the world's cities are developing in areas subject to major direct risks: floods, coastal areas, seismic activity, heat waves, disruption of essential services... In addition, cities continue to face threats from nefarious actors through overt actions and, more surreptitiously, through disruptive web-based activities. Furthermore, cities are perpetually working though the chronic stresses brought about by their own organizational, aging infrastructure, societal and equity-based issues. And let's not forget the devastating impacts of pandemics such as COVID-19.

So, what can cities do considering these various natural and man-made issues? How can cities successfully anticipate, prevent, react to and rebound from such wide-ranging disasters?

Fundamentally, cities must protect themselves from such issues and the way to do is to embed resiliency capabilities within the city's ecosystem. **Having a well-designed, comprehensive urban resilience management solution is mandatory** for every city to enable every citizen to live well, safely and connected in a city in the face of environmental disasters, pandemics, terrorist and cyber-security threats, and chronic internal issues.

This white paper will provide an enhanced discussion around why resiliency is required and key elements of resiliency in a city, territory or similar ecosystem. These elements include the definition of a resiliency/resilient cities, describe resilience challenges and highlight tools designed to implement resilient solutions and more.

With such knowledge, tools and solutions, cities can begin to identify their shortcomings regarding resiliency and implement specific programs and plans to become more resilient cities.

While not the main purpose of this paper, it is important to note that resiliency is only one key element of a comprehensive plan for a smart territory's ecosystem. **Cities and territories need to understand, define and support resiliency initiatives via an integrated approach** as the different measures and projects across the territory's ecosystem will invariably have mutual interdependencies. To intelligently accommodate the interplay, a transversal vision of all the territory's challenges must be adopted.

As technology plays a major role in the building of more resilient cities, **the redesign of some organizations, promotion of sustainable processes, development of innovation and collaboration between all stakeholders are necessary**. In that regard, both Siradel and parent, ENGIE, offer solutions worldwide for the building of transversal, resilient and sustainable territories as shown in Figure 1 below.

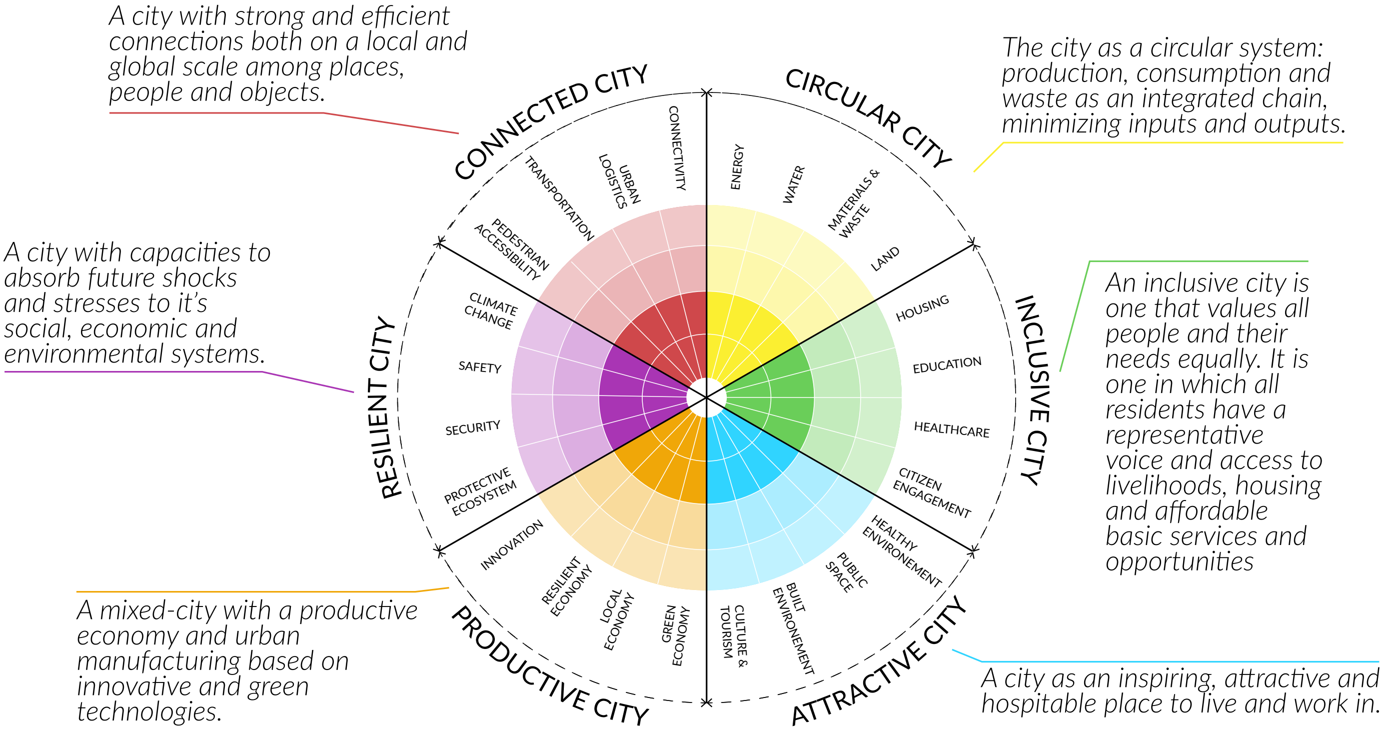

Figure 1 Credit - ENGIE - Tractebel

The Need for Resiliency

Some simple statistics and data points provide eye-opening information and the increasing necessity for a strong resiliency management plan to be an integral aspect of a city's budget and plans. For example, there is an ongoing migration of people to the world's cities such that by 2050 66% of the world's population will be living in cities vs 54% of people living in cities at the end of 2018. Another example: the average number of weather-related disasters per year between 2005 and 2014 is 335, an increase of 14% from the period 1995-2004. And more than 91% of the world's population live in places where air quality exceeds WHO guideline limits.

Individually, and collectively, these events or conditions lead to systematic stress in the urban ecosystem or cause immeasurable financial and personal strain. Without a strong, well-crafted resiliency plan, such suffering and stress will continue unimpeded. Figure 2 below, provides additional statistics that makes it easy for all of us to understand the necessity of resiliency plans.

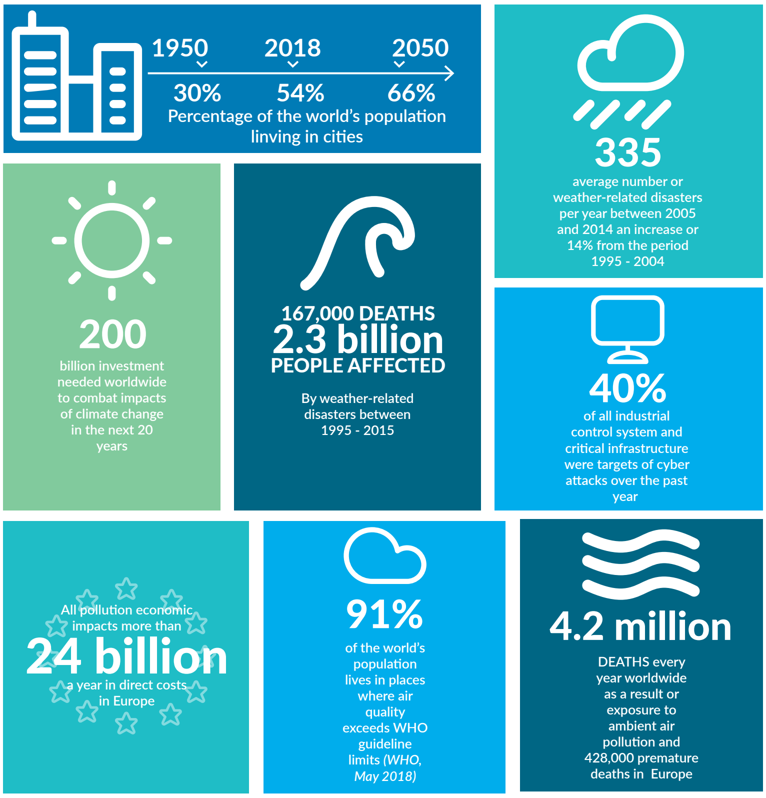

Figure 2

In this context, how can cities and territories prepare and adapt their infrastructure and services to guarantee the safety and well-being of their local population?

How can cities manage sound transformations and urban resiliency required in energy, mobility, security, infrastructure, social inclusiveness and involve all the relevant stakeholders?

Resiliency and Resilient Cities and Territories

Resilience is defined by the capacity of individuals, communities, territories, institutions and enterprises to resist, adapt, moderate the impact and anticipate the reconstruction of (whatever their level of severity) the dysfunctions, chronic stresses and/or the immediate, acute or latent shocks, predictable or not, avoidable or not, with which they are confronted.

In the urban and territorial context, in addition to fundamental safety and security aspects, priority is given to specific topics such as reducing air pollution, preventing and adapting to the effects of climate change, risks of low water levels or flooding, as well as improving modes of governance and the necessary cooperation with all stakeholders and peripheral territories as well.

As noted above, the range of issues that resilient cities must understand and work with are many and diverse. Topics cover societal items as well as issues brought about by environmental or natural disasters. These topics can be categorized in many different ways and for purposes here, these topics have been segmented into acute stresses (e.g. earthquakes, flooding, terrorists attacks) and chronic shocks (e.g. mobility, pollution, housing). Figure 3 below captures the broad range of topics for which cities must be aware.

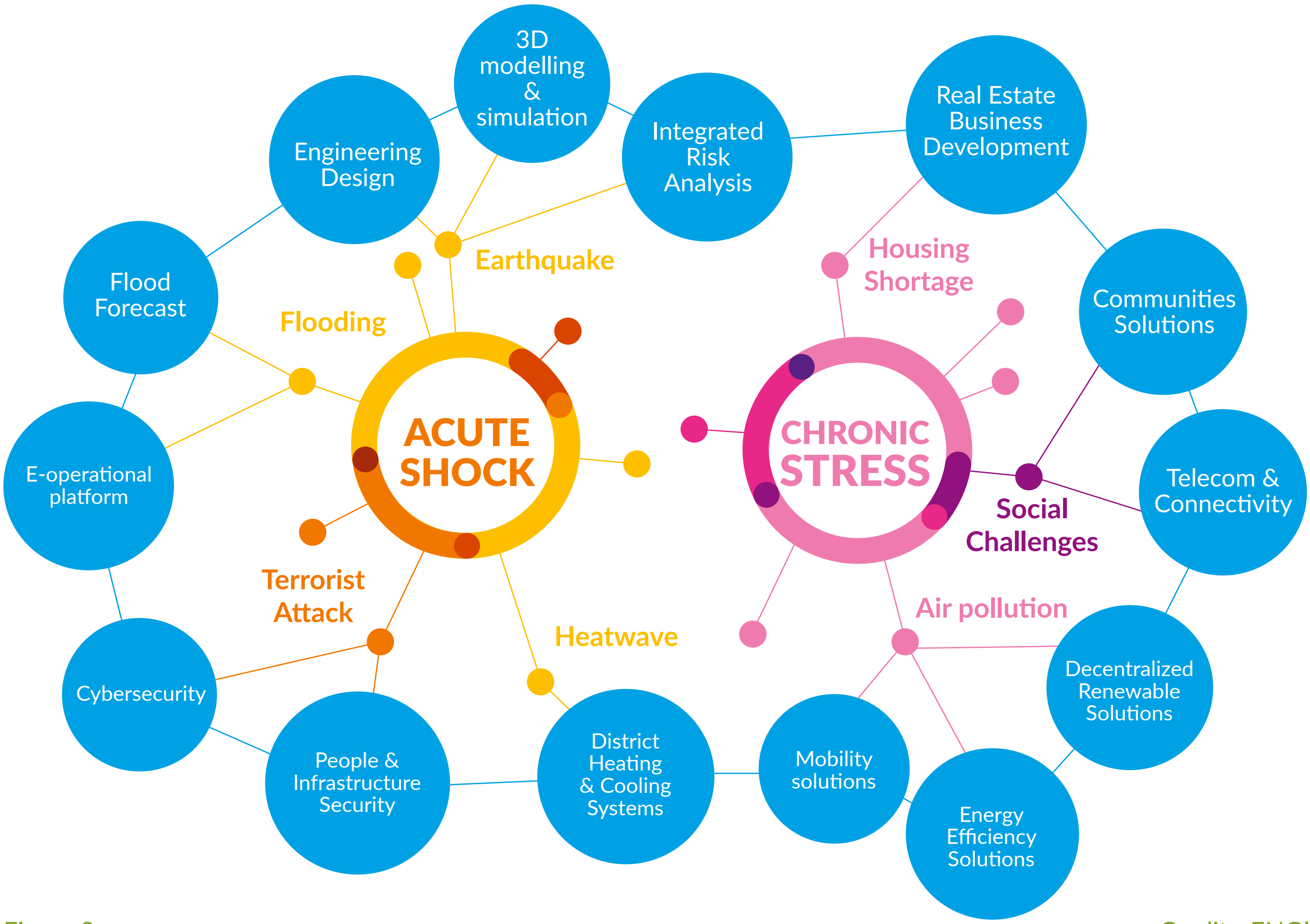

Figure 3 Credit - ENGIE

Having a resilient city means thinking about the city in a holistic way because the "bricks that make the city" are interdependent, like the flows that animate them.

Four main steps to integrating resiliency, as described here and captured in Figure 4 below, are:

- **Anticipating** extreme events by performing localized, relevant risk analyses and proposing the most appropriate recommendations
- **Preventing and mitigating** impacts by implementing actions to improve energy supply autonomy, enhance the security in the city, optimize mobility, etc.
- **Managing** crisis by contributing to the emergency organizations and saving of human lives
- **"Building back better"** by designing and implementing sustainable city and territory developments including planning, engineering, renewable energy, connectivity, infrastructure, security, electric mobility solutions, ...

All these solutions must be gathered in an integrated plan developed for each single city addressing its specific resilience challenges.

ANTICIPATION

Risk Analysis
Organisation
Especially for utilities, cyber and, energy networks

Public + private
Transportation

Preparation, storage of vital raw materials of crisis response resources (drugs, energy, human expertise, emergency communication resources, etc.)

PREVENTION

Impact and dysfunction limitation plan.
Organization and expertise planned by/to

Govermment authorities (incl. State agencies, civil protection & defense, army, police, health agencies...)
Private bodies (citizens, companies...)
Local authorities at all levels

CRISIS MANAGEMENT

Continuation Plan Deployment
Organization and adaptation of critical infrastructures (energy, water, sanitation, etc.) with a particular focus on transport networks and associated devices (fuels, electricity, communication systems, digital, etc.).

BUILT BACK BETTER

Drawing lessons from feedback to best rebuild and reorganize for future crises and shocks.

Rethinking infrastructures, construction, economic circuits, major ecosystems (food, education, etc...).
Taking better account of environmental and geophysical realities (flooding, seismicity, fire, pandemics, sol sterilization, etc.).

Use case example: Resilient mobility in normal operation and in times of crisis and post-crisis is not limited to the use of alternative fuel solutions to fossil fuels.

Mobility is inseparable from resilience: it constitutes a continuous flow, involving a diversity of individual and collective behavior, strengthening or weakening the ecosystem.

Even if the reduction of emissions by alternative fuels allows the reduction of air pollution and dependency for non fossil energy producting countries, the implementation of electric mobility - individual or collective - or hydrogen mobility, implies upstream the implementation of means of production, distribution networks and a significant digital management and potentially vulnerable to risks.

Figure 4 Credit - ENGIE

Challenges with Integrating Resiliency:

There are numerous challenges that arise when incorporating resiliency strategies in a city's plans. These challenges strongly relate to organizational aspects such as intra- and inter-departmental relationships, processes and the positive and, potentially negative, effects of resiliency plans. Furthermore, **sustainability of solutions** plays an integral part in resiliency integration. A short list of challenges include:

- **Designing adapted organization** with individual and collective responsibility of solutions for increased flexibility in ecosystems

- **Complementarity of solutions** for increased flexibility in ecosystems

- **Searching for autonomy** – reducing chain reaction and "domino effects" and diversified solutions sustainability

- **Promoting sustainable materials and processes** with optimized resource management.

These challenges can be addressed through many approaches incorporating both public and private sector engagement. These solutions span:

- **Accelerating innovation and deployment, at large scale**, of resilient centralized and decentralized systems addressing energy, mobility, efficiency, etc.

- **Strengthening research cooperation** and supporting the private sector as a beneficiary and a partner in PPP (or JV...) with national and local authorities and international organizations (OECD, UN ...)

- **Making full use of digital tools**

  - 2D/3D Digital Twins – digital territory replicas with aggregated, geo-referenced data
  - CIM and BIM scenario simulations

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- Dashboards for easy status and results visualizations
- Hypervisors for real-time assessment and operational control
- Sensor capture for various types of pollution, water levels, security, ...
- Traffic regulation and incident detection
- Solutions for cyber vulnerabilities
- New 5G opportunities
- Point solutions addressing specific resiliency requirements.

As the utilization of digital tools are foundational to successful implementation of smarter, more resilient cities, further discussion here is warranted. The next section will focus on Digital Twin and other digital tools usage with example uses cases shared.

Utilizing Digital Twins for Territorial Resilience Planning

A city 3D Digital Twin (DT) **integrates 3D modeling of the city** (terrain, land use, buildings, trees, etc.) **and their main urban infrastructures** (roads and public transport, public lighting, connectivity, water, etc.). The 3D model is **enriched by geo-referenced data** from various public and private sources (GIS, sensor networks, GPS, results of studies or calculations, management and maintenance of infrastructures, open data, citizen data, etc.). See Figures 5 and 6 below.

It also includes simulation (or prediction), artificial intelligence, data analysis and visualization functionalities to help cities, regulators and operators measure the impact of new technologies, of an urban development project, new policies or investments, or new social habits (teleworking, multimodal mobility, new modes of consumption of urban services, etc.).

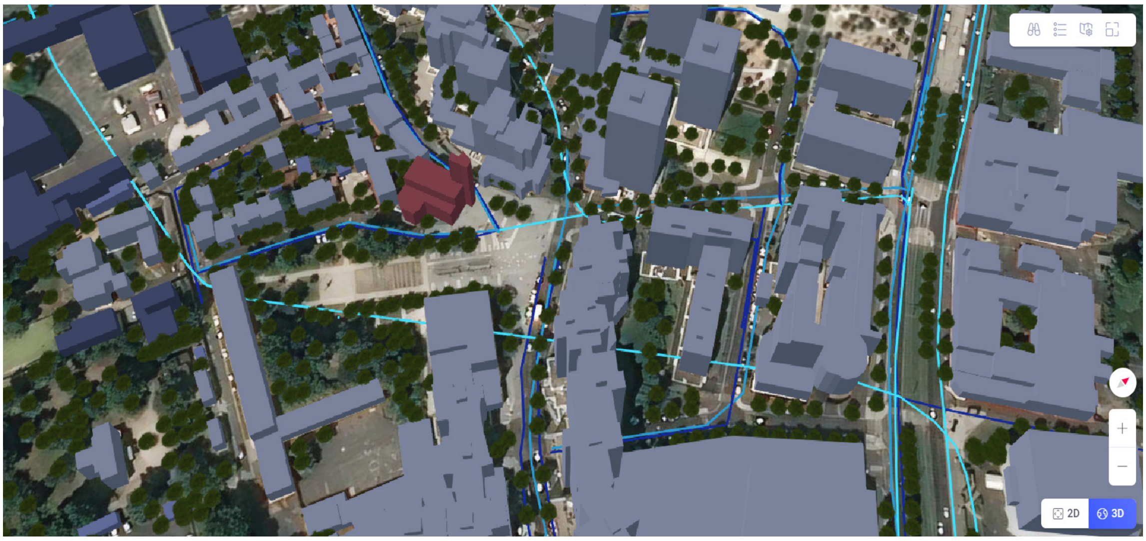


Figure 5 *Digital twin in support of the development of a greening strategy of a city near Paris*

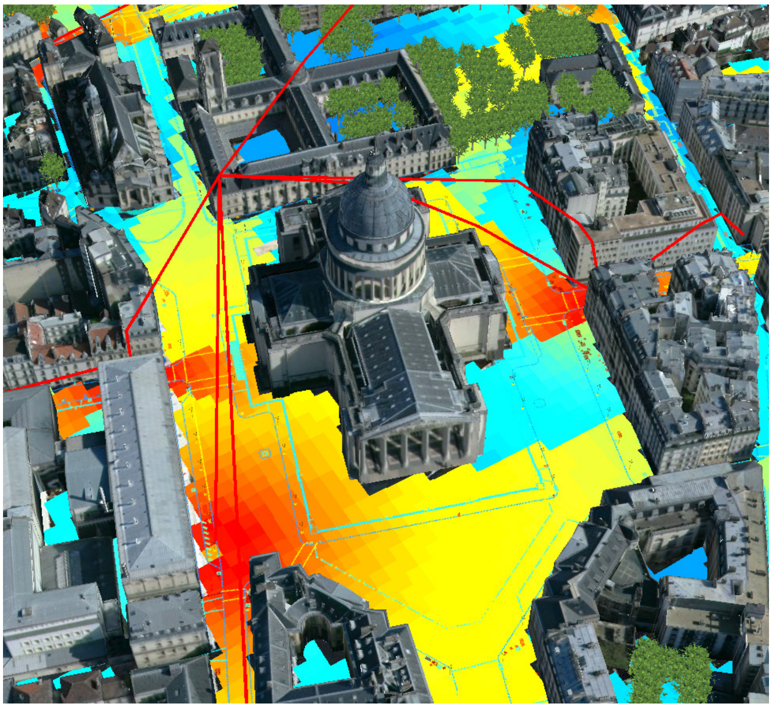


Figure 6 *Example of the use of a Digital twin (Paris) to design infrastructures according to criteria of performance, cost and resilience (environment, energy...)*

Thus, digital twins are by design much more than a common database or just a 3D model of the city.

The digital twin is a "living" tool that allows to a better understanding and the ability to monitor the performance and level of resilience of a territory, through the characteristics and functioning of its critical infrastructures, its industries, its flows (mobility, logistics, digital, energy, etc.) and the way in which the inhabitants "live" in their territory.

The digital twin is therefore used in both upstream aspects of a project to make a diagnostic of a territory or an infrastructure, carry out master plans, design infrastructures and plan urban developments, and also, in real-time, to hypervise, manage and maintain the territory and its infrastructures.

To assess the level of performance and resilience of a territory, which can be seen as a set of systems interacting with each other, it is therefore necessary to have a holistic approach capable of modeling behaviors and interactions between physical and intangible assets constituting a city.

While each infrastructure provides specific services, their operation is generally not independent of each other. An event (fire, cyber-attack, strike, etc.) that occurs in one infrastructure can have consequences on another. We are referring to **domino effects.** It is therefore essential to **model these interactions to better anticipate the risks.**

SIRADEL, a global provider of 3D Digital Twins of cities and expert in Smart City planning, has developed a risk scenario engine based on digital twins. The solution evaluates risks, virtually implements barriers, and dynamically computes their benefits.

More precisely, **this engine models the inter-dependencies between each asset geolocated in the digital twin** (buildings, urban equipment, public transport systems, etc.), which are therefore linked by relational, or logical, links. These ontologies are of different types: geographic relationships (distance between objects), physical or business relationships (different equipment that ares part of the same system)... These links enable modeling of cause and effect relationships associated to a risk or an event as shown in Figure 7 below.

Additionally, the model takes into account the probability of an event or a risk occurring, and the impact of barrier measures (access controls, environmental sensors, equipment maintenance, revegetation, etc.) which may actually exist or be virtually integrated in the digital twin.

However, this is not enough to make a territory resilient. To be resilient, **it is necessary to have planned risk control measures that will minimize consequences,** and those that will allow each of the impacted infrastructures to return to normal operation. Our approach enables identification of these measures, to identify any gaps (action plans) and, to propose solutions to ensure their sustainability over time.

By using the digital twin, the idea is not to modify the way infrastructures are actually managed, but to assess each of them with a same global reference, guaranteeing transversality and territorial resilience.

Such a transversal approach also makes it possible to save money, by avoiding resource duplication and enabling resources mutualization (data collection and processing...).

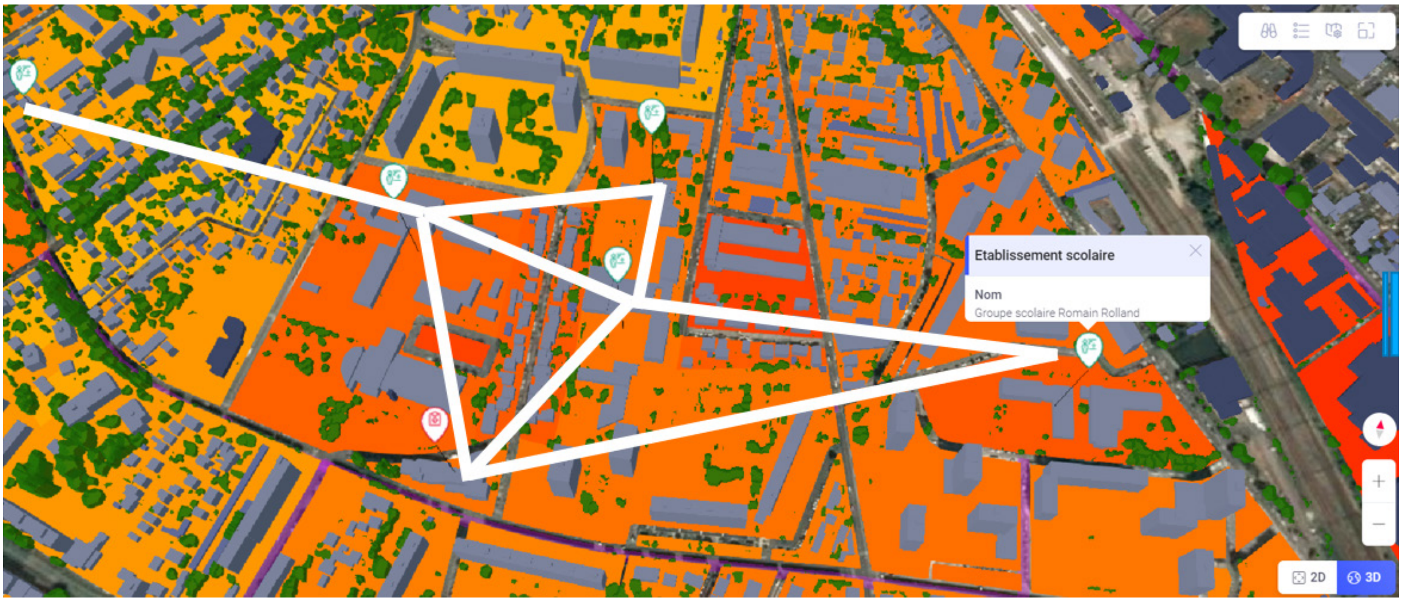


Figure 7 *Modeling of relations between objects in the digital twin. The rule engine models the propagation of effects (cause-consequences) and the barriers to minimize risks.*

Territorial resilience must be addressed at different scales: industrial sites, urban infrastructure, territories, citizens, and in collaboration with all local, public, and private actors and stakeholders.

To carry out a referential of territorial resilience, it is required to build and make widely available resilience indicators that are not only dynamically updated from information collected from the infrastructure themselves, but also in a declarative manner by operators (e.g., during maintenance), and more generally by all people in charge, or having an interest in **making their premises, their service, and their environment safer, pleasant, and more resilient.**

As an example, let us speak about the revegetation of cities to fight against urban heat islands. Revegetation must be taken in the broad sense here: more trees with strategies to select species to resistant to climate change and promote animal and plant biodiversity. Vegetation also means making soils more permeable for the benefit of nature in the city, for improvements in rainwater sanitation networks (less maintenance, less need for new equipment, etc.) and the fight against flooding.

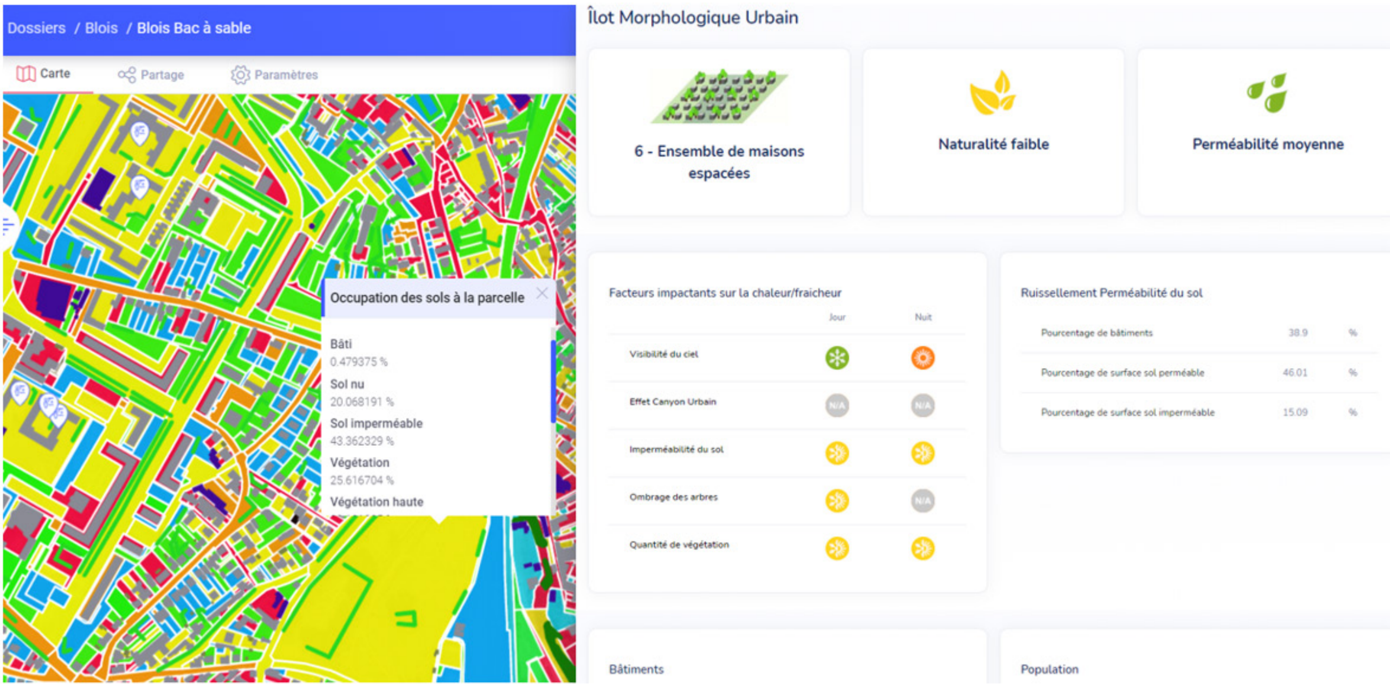


Figure 8 *Example of classification of a city according to its ability to absorb water and to fight against urban heat islands. The dashboard allows ranking and deciding about the appropriate measures for each urban island*

Another example including heat islands, and through the engine developed by Siradel, is to build scenarios to show the impact of a heat wave on all the schools in an urban area. By associating the frequency of occurrence of these heat waves with the scenarios and by weighting it against the risk control measures, we obtain a resilience indicator for each school. This first result allows us to see if this indicator is acceptable or not (see the figure 9 below).

If the indicator is unacceptable, the solution developed by Siradel makes it possible to choose the right measure to implement to make it acceptable, taking into account its impact on the indicator and its cost.

If it is acceptable, this same solution allows the following of the state of operation of the existing means and, in case of dysfunction of one of these means, to recalculate in real time the new indicator. The managers then have a real time means of monitoring the efficiency of their investments.

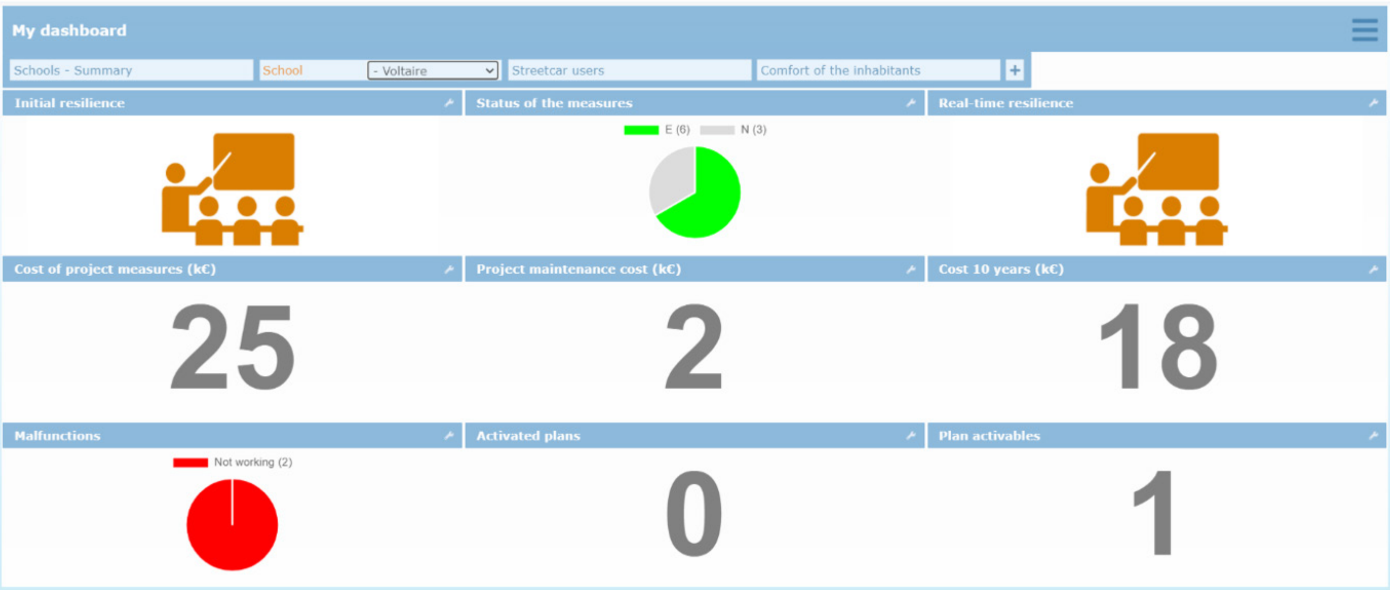


Figure 9

Utilizing a Real-Time Hypervision Platform for Urban Resiliency

Urban resiliency is easily supported with real-time hypervision. In this context, a hypervisory platform is a platform that is an open and digital supervision and control platform. Architecturally, it sits above and interacts with and consolidates all existing operational systems and management tools into one powerful, intuitive and infinitely scalable platform.

It allows real-time decision-making and/or automatically triggering pre-defined actions for managing and controlling operations across a city's ecosystem.

Livin' is a digital tool, developed by Engie that can be integrated into a city's existing IT ecosystem. It makes it possible to **transversally exploit urban data**, too much of which is still managed in silos and by individual departments in ways that neglect potential stores of value. This tool helps cities to **shape and enact a global vision for their infrastructure** (public lighting, signage, atmospheric pollution, safety, traffic management technology, etc.) and to **make appropriate decisions, in real time.**

Livin' fully meets the definition of a resiliency solution as it can be used to anticipate, prevent and react to urban stressors. It can be used to build back better within a city and regional information and infrastructure ecosystem.

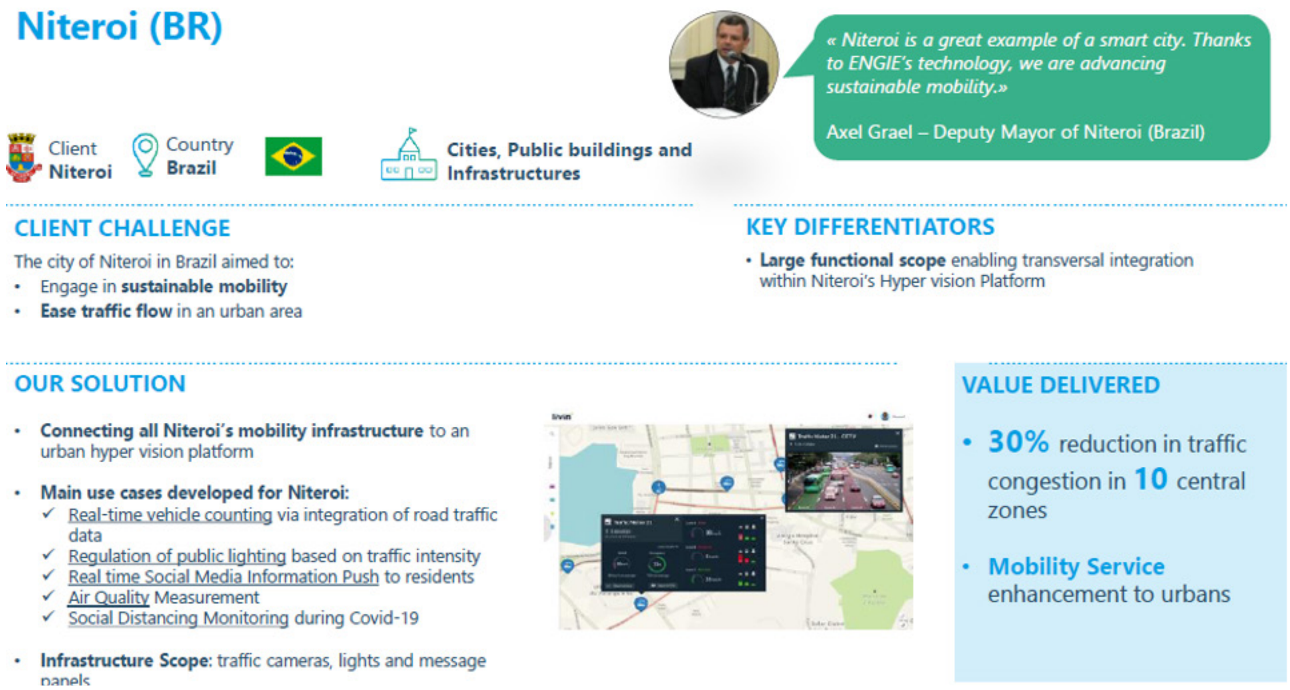
Livin' integrates with Siradel's Digital Twins and Smart City Explorer solutions and into the global offers of ENGIE.

In figure 10 above, an example of the easy-to-use, graphical interface of the Livin' solution is shown, including benefits for multiple levels of city personnel.

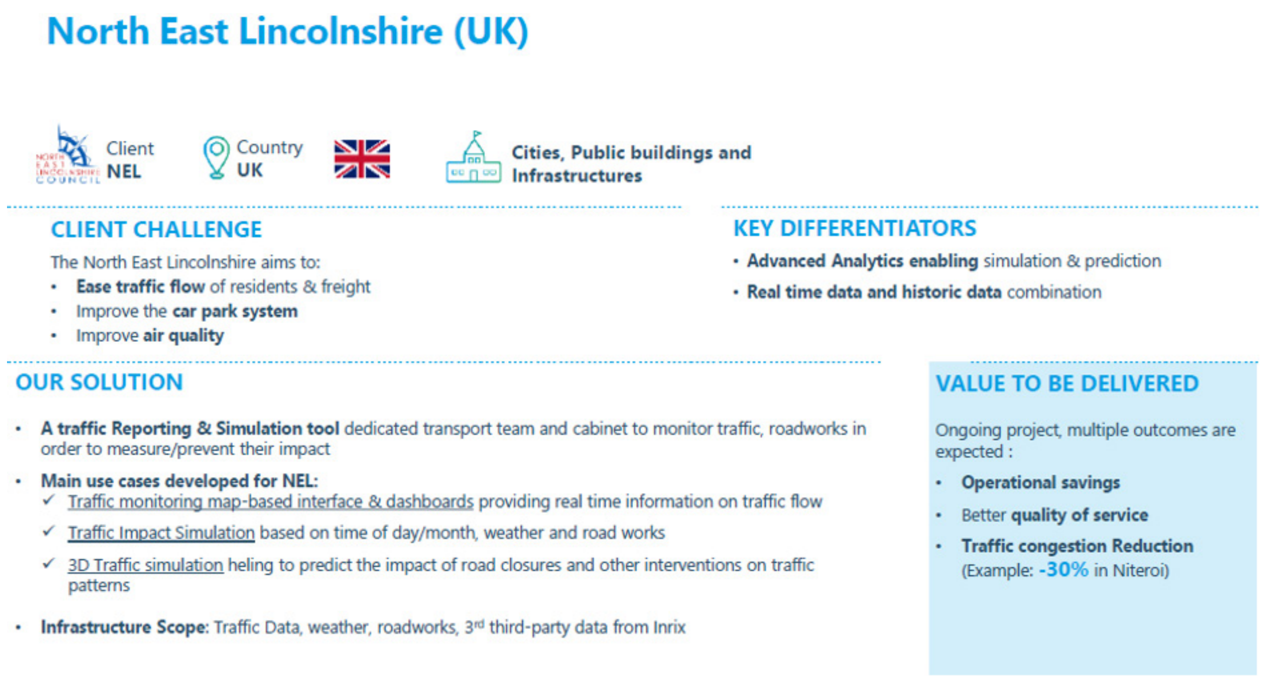
In the following figures 11, 12 and 13, the Livin' platform is used to address chronic, inherent stresses that have developed over years within a city/territorylocal area.

In Figure 11, the city of Angers, France, is using Livin' to develop and offer new services to citizens and substantially improve energy and utility performance across multiple infrastructure assets.

Figure 11 Credit - ENGIE - Livin'



In figure 12 (credit ENGIE - Livin'), the city of Niteroi, Brazil, has focused its use of Livin' on its mobility infrastructure, promoting resiliency and sustainability by integrating and controlling multiple infrastructure elements. Clear improvements are provided in reduced traffic congestion, reduced pollution and citizen well-being. Furthermore, the real-time control aspects offer instantaneous responses to any environmental or manmade system shocks encountered.



In figure 13 (credit ENGIE - Livin') above, North East Lincolnshire, United Kingdom, is using Livin' to address systematic stresses brought about by traffic issues with the resultant improvements in improved traffic management, improved real-time parking management and improved air quality.

Conclusion

The COVID-19 pandemic and the trend of increasing weather-related catastrophes, social crises and systematic stresses have demonstrated a clear need for resiliency plans for cities. Currently, few cities are sufficiently prepared to anticipate such shocks, manage the immediate response reactions and have any kind of strategy (or capabilities) to re-build infrastructure better after such shocks.

And because we live at a time when there are many technologies, digital tools and solutions available to better address these issues, we now have to work together, as government actions or individual initiatives alone will not be enough. **All stakeholders need to be involved, to be able to do better and face this resiliency challenge effectively**. This challenge will require:

- Sound transformations in the infrastructure, energy, mobility, security design and more relevant city management
- Appropriate involvement of the stakeholders to enable each citizen to live free, safe and connected
- Development and implementation of new methodologies
- Innovative solutions to better understand, anticipate and manage risks.

For resiliency itself, digital tools are fundamental elements of the solution and there are mature tools and methods from Siradel and Engie to enable cities and territories to travel the path of building resiliency into the fabric of the city's ecosystem.

Furthermore, Siradel offer tools that integrate resiliency solutions as part of a comprehensive and transversal vision of the city.

Given the urgency identified by the trends above, isn't now the time to make your territory more resilient and to simultaneously face climate, economic and social transition?

Please feel free to contact us at resiliency@siradel.com to share experience and know more about our solutions for the building of more resilient, sustainable territories.