Built Environment

- Rooftops fitted with low cost solar panels to become power sources for public or private use
- Incorporate automated management systems to control heating, cooling, lighting and emergency response
- Capture, detain and slow storm water and runoff by integrating green spaces with waste water management systems and underground parking, and by deploying porous surfaces, tree trenches and site grading
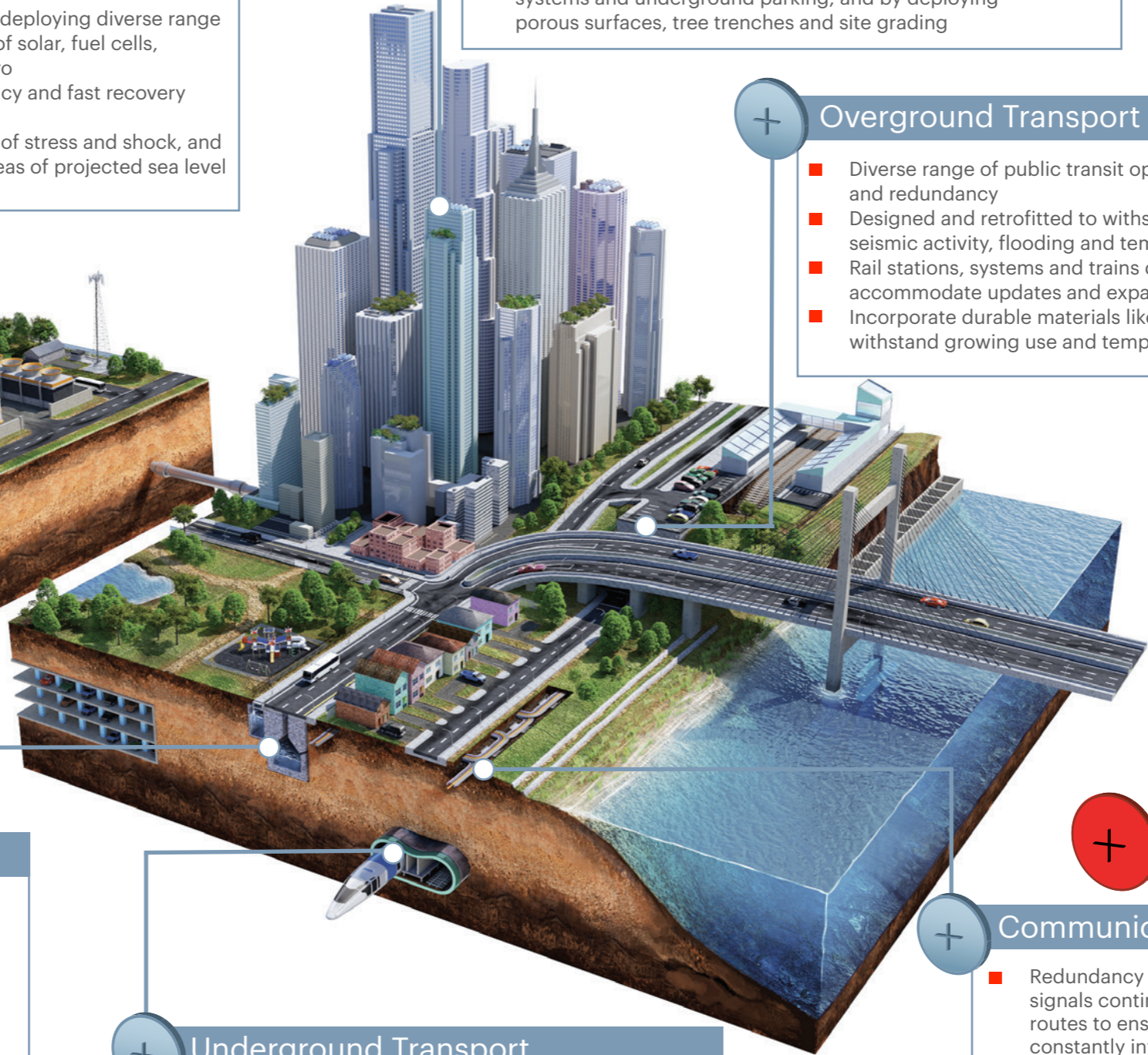
Energy

- Decentralize and offer redundancy by deploying diverse range of power types, such as combination of solar, fuel cells, combined cycle gas turbines and hydro
- Use smart grids with in-built redundancy and fast recovery capabilities
- Facilities hardened to withstand force of stress and shock, and located away from flood zones and areas of projected sea level rise

Overground Transport

- Diverse range of public transit options to maximize capacity and redundancy
- Designed and retrofitted to withstand adverse events like seismic activity, flooding and temperature extremes
- Rail stations, systems and trains designed to be upgradable to accommodate updates and expansions over many decades
- Incorporate durable materials like split mastic asphalt to withstand growing use and temperature extremes

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Water Management

- Waste water management systems integrated into all infrastructure, and installed underground to discharge storm water
- Flood defenses reinforced, preserved and bolstered, buffer zones created, and sea walls built outside existing walls to act as barrier system against sea level rise and storm surges
- Decentralize waste water treatment to provide recycled water close to local demand, and harden structures to withstand adverse events

Underground Transport

- Incorporate passive space into rail tunnel upgrades to accommodate future conditions like increased urbanization and climate change
- Excess hot air from cooling systems channeled to surface to heat buildings
- Extensions built according to projections of population mobility and growth

Communications

- Redundancy built into fiber deployment, with signals continuously routed through alternate routes to ensure communication remains constantly intact, and into wireless through overlapping spectrum coverage
- Modular network deployed to enable adaptation to growth demands
- Networks designed to mitigate cyber attacks
- Structures built to withstand adverse weather including hurricane-force winds and extreme snow and ice loading

How to transform your city with smart, resilient infrastructure

City Infrastructure: "Physical and organizational assets providing services to citizens"

1 Change the way you think about infrastructure

The first step to transforming your city is to change the way you think about infrastucture.

Consider it a system of integrated structures rather than projects operating in silos. The structures work both independently and together, as an integrated whole.

Designed to address multiple objectives, the systems are so integrated that changes to one part can sometimes create complex interactions within and between the other parts. Resilient infrastructure systems are sometimes geographically remote from the cities they serve.

Resilience cannot be achieved by merely scaling or replicating systems across different geographies. Each system delivers the greatest value when it is designed to be specific to each site, community and impact.

Advantages of smart, resilient infrastructure systems:

- Generate multiple benefits and capture value across sectors and geographies

- More efficient and robust in the face of shocks and stress

- Continue to provide a level of essential services to communities during, and in the aftermath of, adverse events

- Faster to recover after disruptions

2 Formulate your strategy

Formulate a strategy in which many infrastructure elements must be completed in order to achieve an overall goal. Each infrastructure element is an essential component, and omitting any will reduce the infrastructure system's value.

The completion of each infrastructure element is a milestone on the journey to creating the total solution.

The system only works if the investments in all the component infrastructure elements go forward in concert with one another. Building just one piece of the system fails to meet the overarching need.

Ensuring systems are not divided into small parts and built in silos is essential to create infrastructure where the whole creates more value than the sum of its parts.

3 Ensure your city's infrastructure systems span multiple sectors

Build your city's infrastructure systems across sectors.

When an infrastructure system spans numerous sectors so too do its benefits and savings. Any project confined to a single sector misses out on the opportunity to create cross-sector benefits like energy and water savings.

Success in resilient infrastructure means prevention of negative impacts. The storm arrived but the city did not flood and the power supply did not get cut off.

Capturing these benefits and savings across sectors over time requires thoughtful design and advance planning.

4 Identify breakthrough resilience opportunities for your city

To find breakthrough resilience opportunities that will transform your city, you must drop preconceived ideas about solutions and instead zoom out. Risks and needs are sometimes framed too narrowly whereby cities solve one problem only to create another.

Rather than wondering what type of structure you need to solve your city's sector-specific challenge, ask questions that are sufficiently broad to identify opportunities for innovation across sectors yet specific enough to be implemented in a formal planning process.

Ask these questions:

■   Where is your city losing money or incurring increased costs?

■   What is your city's greatest unfunded need or mandate?

■   What are the specific hazards, risks and threats to your city?

■   What do these risks and issues have in common? Are they the root cause of several problems or a symptom of another underlying problem?

■   If there was one thing you could start to build or change in your city in the next two years, what would it be?

5 Build redundancy into your city's infrastructure

Advance plan the critical level of services essential to your city both during and in the aftermath of an adverse event. Then design systems that ensure your city's infrastructure is capable of providing that level of service regardless of the magnitude of the adverse events to which it might be exposed.

Careful integration, coordination and sequencing are essential to ensure that when one structure fails, it does not take down the entire infrastructure system.

Resilient infrastructure goes beyond 'hardening' of structures to withstand the force of extreme events. Redundancy and decentralization must be built into infrastructure systems.

It means planning and building a diverse and decentralized collection of structures that back up each service within every infrastructure system. If one structure is disrupted, the others continue to provide the service. It also means provision of a variety of public transport options, power from multiple sources, and a series of measures to manage flood water.

Resilient systems are built to expand, adjust, enable repair and recovery, and continuously provide services to the community in the face of changing needs and conditions.

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