Connected sustainable cities, which will evolve over the next decade, employ ubiquitous, networked intelligence to ensure the efficient and responsible use of the scarce resources – particularly energy and water – that are required for a city's operation, together with the effective management of waste products that a city produces, such as carbon emissions to the atmosphere.

Through a series of prospective scenarios, *Connected Sustainable Cities* illustrates some of the ways in which inhabitants may use and manage their living spaces, move around the city, work, shop, pursue their educational, cultural, and recreational interests, and make well informed, responsible personal choices. These scenarios are accompanied by brief sketches of the existing and emerging technologies, products, and systems that will support new, intelligently sustainable urban living patterns. In addition, there are short discussions of some of the theoretical, policy, and design issues that these scenarios raise.

Connected Sustainable Cities is a starting point for the investigations and debates that will be necessary as citizens, technologists, designers, policy experts, and political and business leaders begin to shape the new urban areas we urgently need to create in the near future.

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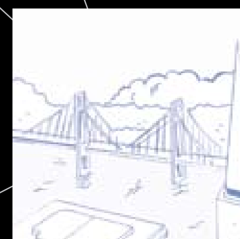

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MIT Mobile Experience Lab Publishing

CONNECTED URBANDEVELOPMENT

connected sustainable cities

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foreword to *connected sustainable cities*

In the 21st century, climate change, energy management and low carbon economics have emerged as major strategy and policy priorities among government and enterprise organizations globally. With their populations on the rise, cities are experiencing considerable increases in energy consumption. According to UN Habitat, cities are responsible for 75% of the world's energy use and for 80% of global greenhouse gas emissions.

Cities are also centers of innovation, economic growth, social transformation, healthcare, and education—and most are taking a proactive approach to address the urban sustainability challenge. The unprecedented development of new cities around the globe, however, and the need to renew outdated 20th century infrastructures in mature cities, requires innovative approaches in urban design, metropolitan governance, and infrastructure investment models.

Sustainability and information and communications technology (ICT) are emerging at the commencement of the 21st century as two sides of the same coin: both are innovations for cities seeking to improve their environmental effectiveness in the context of connected societies, global competitiveness, economic development, climate change, and demographic shifts. Today's cities are linked by a global information and communications infrastructure that facilitates communications, human interaction, collaboration, and mobility. Information is coming to people, rather than the reverse. As a result, cities are evolving into places where overlapping networks of companies, institutions, civil societies, and citizens are supported by ICT-enabled flows of people, materials, information, capital, services, and media.

The Connected Urban Development Program

The partners in the Connected Urban Development program believe that ICT networks, and the resulting knowledge-based economy, are as significant as the two major waves of "network" innovation that characterized 20th century urban development. In addition, the imperative to develop a new way of approaching the challenges of reducing carbon emissions and improving energy efficiency is critical, given the urgency posed by rapid climate change.

Connected Urban Development was born from Cisco's commitment to the Clinton Global Initiative. The first phase concentrated on building partnerships amongst Cisco and three cities: Amsterdam, San Francisco, and Seoul. In February 2008 the program was expanded to include the cities of Birmingham, Hamburg, Lisbon, and Madrid. Each of these cities is focused on excelling in one or two key areas. Areas addressed within the program are Green ICT, Connected and Sustainable Buildings, Connected and Sustainable Mobility, Connected and Sustainable Work, and Connected and Sustainable Energy.

The Connected Urban Development partner cities are jointly developing innovative approaches in the area of urban sustainability and ICT. In addition researchers from the Massachusetts Institute of Technology (MIT) are providing the globally recognized thought leadership on connected sustainable cities. The authors of this book, Professor William Mitchell, and Dr Federico Casalegno bring their innovative perspectives to the future of technology usability and applications, in particular to urban environments. Their contribution to the Connected Urban Development program has been to marry innovative practical solutions, which are core to the program, with a visionary perspective to the future of urban environments.

In this context the partners in the Connected Urban Development program are delighted to endorse this book, in recognition of its important contribution towards a blueprint of best practices and methodologies that can be implemented both within the cities in this program, and as a reference to scale the innovative pilot initiatives to other cities around the globe.

Signed;

John Chambers
Chairman and Chief Executive
Cisco Systems

Antonio Costa
Mayor of Lisbon

Job Cohen
Mayor of Amsterdam

Gavin Newsom
Mayor
City and County of San Francisco

Paul Tilsley
Deputy Leader of
Birmingham City Council

Mayor Oh Se-hoon
Mayor of Seoul

Ole von Beust
First Mayor of Hamburg

Alberto Ruiz-Gallardón
Mayor of Madrid

www.ConnectedUrbanDevelopment.org

December 2008

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introduction

What are connected sustainable cities?

Connected sustainable cities employ ubiquitous, networked intelligence to ensure the efficient and responsible use of the scarce resources – particularly energy and water – that are required for a city's operation, together with the effective management of waste products that a city produces, such as carbon emissions to the atmosphere.

How can they be achieved?

How can connected sustainable cities be achieved? It requires a combination of technologies and changed human behavior. Information and communication technologies (ICT) can be employed to help reduce energy usage and carbon dioxide emissions. Broadband-based applications and services can create links that make a city's buildings and infrastructure, mobility, work, and energy functions all more efficient and hence better for the environment. Pervasive connectivity and related services can encourage new ways of planning, working, and living that make social connections stronger and lead to cooperative sustainable behavior. ICT brings together previously disconnected operational programs and allows for coordinated, efficient, and sustainable urban policies across neighborhoods, institutions and, indeed, the entire social fabric of an urban area.

Background to the research

The Mobile Experience Lab, Design Lab, at the Massachusetts Institute of Technology has partnered with Cisco Systems and global cities in the Connected Urban Development program to research how information and communication technologies can support cities' sustainable development and improves citizens' lives.

The Connected Urban Development program is a public-private partnership focusing on innovative use of information and communications infrastructures to increase the efficiency of the flow of knowledge, people, traffic, and energy. This increased efficiency enhances how people experience urban life, streamlines the management of cities, and decreases the urban environmental footprint. Urban areas are responsible for a significant portion of carbon dioxide emissions, with transport-related activities accounting for the lion's share, followed by industrial and residential emissions. The Connected Urban Development program explores how the application of information communication technologies can promote innovative practices for reducing carbon emissions while fostering economic growth. The program's scope extends beyond the strictly environmental dimension to address innovative, sustainable models for urban planning.

This book

This book describes daily life in the connected sustainable cities we can expect to evolve over the next decade. It does so through scenarios that illustrate some of the ways in which inhabitants may use and manage their living spaces, move around the city, work, shop, pursue their educational, cultural, and recreational interests, and make well informed, responsible personal choices. It is important to note that these illustrations are prospective; they do not represent current reality in the cities named.

These scenarios are accompanied by brief sketches of the existing and emerging technologies, products, and systems that will support new, intelligently sustainable urban living patterns (web links are provided in the Index at the end of the book). These sketches do not attempt to provide a systematic, comprehensive overview, since the field is at a stage of rapid and often unpredictable development and any effort to do this would be premature. But they should suffice to ground the scenarios in technological and business reality.

Finally, there are short discussions of some of the theoretical, policy, and design issues that these scenarios raise. Again, we do not claim to be systematic and comprehensive. These are some starting points for the investigations and debates that will be necessary as citizens, technologists, designers, policy experts, and political and business leaders begin to shape the connected sustainable cities that we urgently need to create in the near future.

one/how cities have evolved

It is helpful to put the emergence of connected sustainable cities into long-term evolutionary perspective. For cities, like living organisms, have evolved from simple forms to more complex, internally differentiated, and intelligent versions.

Skeletons and skins

The earliest cities consisted of little more than skeleton and skin. They provided walls, floors, and roofs for shelter and protection, in combination with simple structural skeletons to hold them up. Climate control in building interiors was largely achieved by passive means, through the use of waterproofing, insulation, thermal mass, sunlight and shade, and ventilation. Water, food, and fuel were carried into cities with human and animal muscle power, and carried out in much the same way. The intelligence needed to operate these cities resided in the heads of their inhabitants.

Before long, though, primitive networks emerged to enhance operational efficiency and enable growth to larger scales. Roman cities, for example, had quite sophisticated water supply and sewage systems that served the urban fabric internally and connected it to increasingly distant sources and sinks in the surrounding territory. Similarly, street and road networks developed to enable the free circulation of people and to facilitate the supply of goods and the removal of waste.

Mechanical metabolisms

In the industrial era, urban networks multiplied, differentiated, and grew in scale. Furthermore, their operation was mechanized through the introduction of engines, pumps, and mechanically powered vehicles. Buildings acquired complex indoor plumbing networks connected to increasingly varied appliances and fixtures, heating, mechanical ventilation, air conditioning systems, gas and other fuel systems, electrical systems, movement systems, and safety systems. On urban and regional scales, cities developed massive infrastructures for water supply and liquid waste removal, energy supply, transportation, and solid waste removal. In other words, they added mechanical metabolic systems to the skeletons and skins that they had traditionally provided. These systems then became major consumers of energy and producers of waste and pollution.

Electronic nervous systems

At the dawn of the electronic era, buildings and cities began to develop primitive nervous systems. Telegraph, telephone, and radio communication systems provided the first artificial nerves. These allowed architectural and urban systems to develop simple reflexes and feedback loops. Thermostats controlled heating systems, elevators were called by push-button controls, and the telegraph system controlled the operations of the railroad. It became increasingly apparent that information and control were key to the efficient operation of buildings and cities.

In the Internet era, these primitive nervous systems rapidly evolved into something approximating the advanced nervous systems of higher organisms. Ubiquitous digital networks supplanted the older analog networks and formed a new kind of urban infrastructure. Distributed systems of networked computers and server farms became the brains of cities. Pervasive sensing connected vast, new streams of data about urban activities to these brains. The flows of resources into cities, the processing and distribution of materials, energy, and products, the coordination of the actions of individuals and organizations, and the eventual removal or recycling of waste were increasingly informed, coordinated, and sometimes controlled by the new, rapidly growing, digital nervous systems.

Working smarter

Throughout history, cities have grown larger and worked harder to meet the needs of their inhabitants. Now it is time for them to work smarter. The emerging conditions open up new opportunities for intelligently efficient, sustainable operation of cities. We describe these in the following pages.

two/moving around the city

In modern cities, the largest users of energy are the climate control systems of buildings (heating, cooling, and lighting) and the mobility systems people use to get around from place to place. In small settlements, the consumption of energy for mobility was much less significant, since distances were short and movement was mainly on foot. But in today's cities, the distances are much greater, there are many economic, social, and cultural reasons to move around, and the use of mechanized transportation – particularly the gasoline-powered private automobile – means that every mile of travel consumes a significant amount of energy, contributes to carbon emissions and global warming, and adds to road traffic and parking congestion.

Connected cities provide many ways to reduce the energy and other resources consumed in daily movement. The following scenarios illustrate a few of the most promising.

Scenario: more efficient commuting

How can we reduce the excessive, unsustainable consumption of time and energy spent in daily urban commuting? What can connectivity do to help?

Roads are often jammed during peak commuter hours, but have excess capacity at other times. By providing commuters with accurate and timely traffic information, creating incentives to travel when roads are less busy, and intelligently managing traffic, cities can reduce the inefficiencies of commuting.

Through commuter information and congestion pricing systems, alter the behavior of drivers. Create incentives to drive during off-peak hours and in less-crowded areas, and disincentives to drive during peak times and in particularly congested areas. In addition, create incentives for multi-passenger trips.

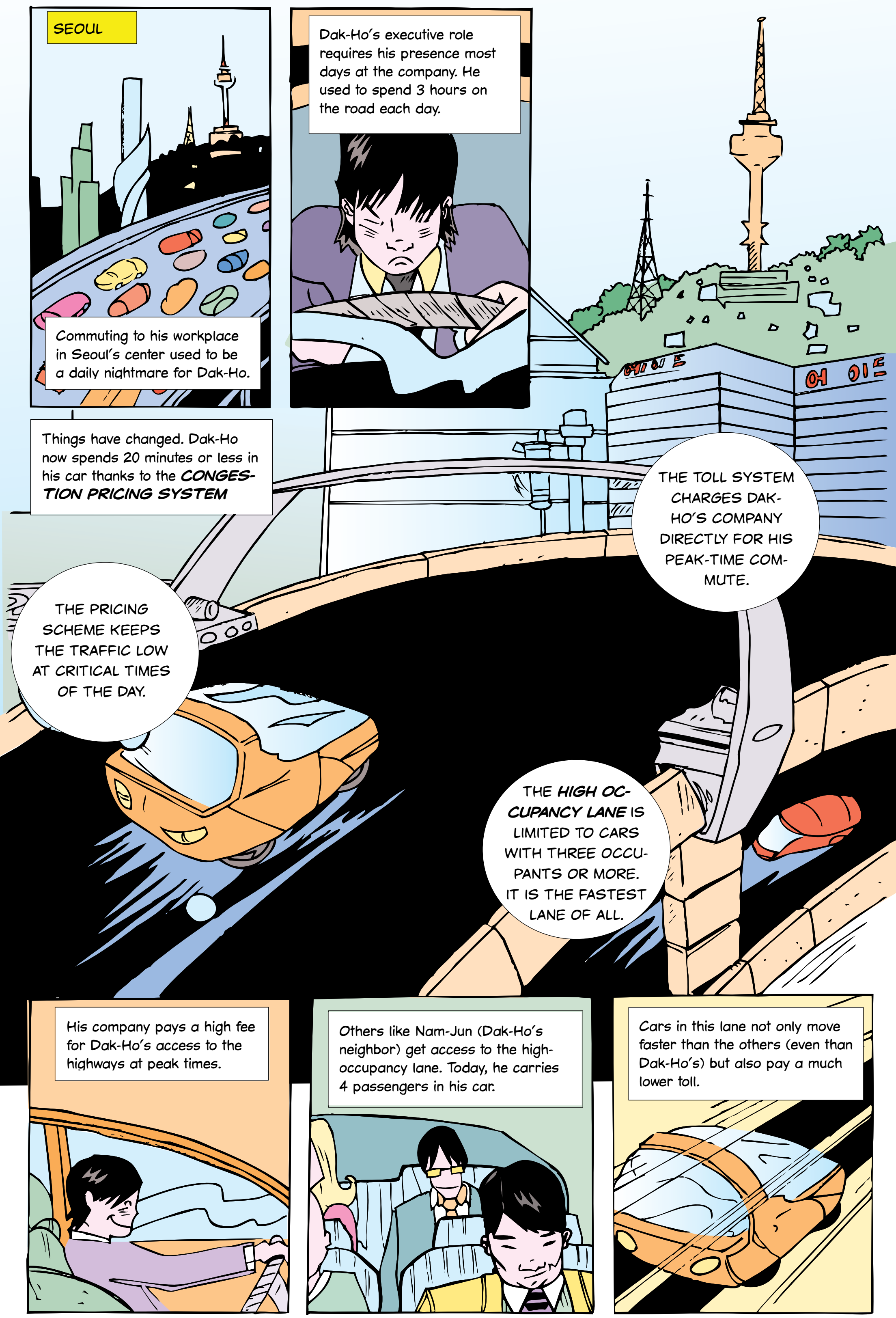
Dak-Ho's 20-minute drive from his home in the suburbs of Seoul to his office near the center of the city still defies belief, even after a year. For most of the decade he's worked at his company, his morning commute on the turnpike was 90 minutes of bumper-to-bumper traffic, honking horns, daring and dangerous lane changes, and a generally unpleasant experience from start to finish. The introduction of transponders a few years back, which made it possible to go through the toll gates without stopping to pay, only sped up the trip by about 10 percent. The entire experience was routinely so disagreeable that Dak-Ho attributes his prematurely gray hair, his once nasty disposition at the office for the first hour, and his seething hatred of all other drivers to his miserable former commute.

His particular executive responsibilities demand that he be at the office most days, so Dak-Ho can't take advantage of the telecommuting option many of his coworkers enjoy. Automobile is the only way he can travel from his home. His company is happy to help him get to the city each day during the peak morning commute, and get back home, by paying the higher toll on the road during those hours. It is those higher tolls that have brought Dak-Ho's commute from the depths of misery to the quick and even enjoyable ride it is today.

The toll differential is significant. On top of that, Dak-Ho's company pays a fee each day that he brings his car into the city, as part of the effort to keep congestion to a minimum.

Dak-Ho's neighbor across the street, Nam-Jun, has a very different story to tell. He, too, must travel to the city each day, and he works near Dak-Ho's office. He also commutes at roughly the same times of day. But he actually pays less – far less – than the charges incurred by Dak-Ho's commute. That's because he drives with four other people.

Alternating weeks, Nam-Jun and his friend and coworker Chan-sook, who lives about a half-mile from Nam-Jun, pick up the other and


SEOUL
Commuting to his workplace in Seoul's center used to be a daily nightmare for Dak-Ho.
Dak-Ho's executive role requires his presence most days at the company. He used to spend 3 hours on the road each day.
Things have changed. Dak-Ho now spends 20 minutes or less in his car thanks to the CONGESTION PRICING SYSTEM
THE TOLL SYSTEM CHARGES DAK-HO'S COMPANY DIRECTLY FOR HIS PEAK-TIME COMMUTE.
THE PRICING SCHEME KEEPS THE TRAFFIC LOW AT CRITICAL TIMES OF THE DAY.
THE HIGH OCCUPANCY LANE IS LIMITED TO CARS WITH THREE OCCUPANTS OR MORE. IT IS THE FASTEST LANE OF ALL.
His company pays a high fee for Dak-Ho's access to the highways at peak times.
Others like Nam-Jun (Dak-Ho's neighbor) get access to the high-occupancy lane. Today, he carries 4 passengers in his car.
Cars in this lane not only move faster than the others (even than Dak-Ho's) but also pay a much lower toll.

head for a park-and-ride lot about a mile away, near the turnpike. There they pull up in the line of cars offering rides, and each morning find three people looking for rides into the city. Entering the turnpike with five people in the car makes the vehicle eligible to travel in the high-occupancy vehicle lane, which moves even faster than Dak-Ho's lanes. They breeze through the toll plaza, where they pay a reduced fee, and they incur no congestion charge because of the number of passengers.

Once well within the city limits, Nam-Jun and Chan-sook drop their passengers off at a central location for them to find their ways the short distances to their places of employment. Nam-Jun and Chan-sook then finish the brief trip to their own workplace.

For Dak-Ho, Nam-Jun, and Chan-sook, reluctant automobile commuters, the schemes for paying less or paying more for using the roads have made once terrible commutes relatively easy, and even quick enough to be barely noticeable.

Enabling technologies

Congestion pricing

Dak-Ho pays more for his commute because he uses the turnpike during peak hours and brings a car into a city that prefers fewer cars. This is called congestion pricing, and cities around the world have implemented it in various ways. Congestion pricing schemes may be based on bringing any car into the city (as Dak-Ho experiences) or into just the city center, or impose charges for access to particular travel lanes or facilities.

In 1998, Singapore became the first city in the world to implement congestion pricing via an electronic road toll collection system. The system now includes all roads linking into the city's central business district, and can be expanded during peak hours to other roads with heavy traffic. Vehicles that wish to use the priced roads are equipped with stored-value CashCards that allow entry. No special charges are imposed during off-peak hours.

Stockholm levies a congestion tax on most vehicles entering and exiting the central city. It reduces traffic congestion and improves the environment, and funds are used for new road construction. The scheme in London, one of the largest in the world, involves a congestion charge on some motorists traveling within designated zones. Collected funds are used for the city's mass transit system.

Self-organized ridesharing

Nam-Jun and Chan-sook take advantage of a self-organized system in which those seeking a ride into the city and those with space in their vehicles can meet. Their experience is based on the unique form of commuting in the Washington, D.C., metropolitan area that combines ridesharing and hitchhiking and is known as "Slugging." It is a system of instant or casual carpooling. Slugging makes it possible for drivers to meet the requirements for traveling in the area's High Occupancy Vehicle lanes.

The simple system involves "slug lines" throughout the metropolitan area at bus stops, Park-and-Ride lots, and elsewhere (a full list and maps are available on the Slugging website). There, a driver needing passengers displays a sign with a destination, and those first in line get in the car if it is the destination they want. The system, which is completely independent of area governments and transportation authorities, is free to all, and includes about 10,000 riders each day. Estimates are that most of the 35,000 carpoolers who use the HOV on Interstate 95 in the D.C. area are "sluggers."

The MIT Mobile Experience Laboratory, in partnership with the Provincia di Brescia, Italy, is developing a ridesharing system for youth that utilizes wearable bracelets connected to GPS-enabled mobile phones. The system, with its main components of social networking, reputation management, referrals, and geopositioning, makes it possible to coordinate the matching of drivers and passengers with preferences entered online in user profiles. The system can detect successful ridesharing and will reward participants accordingly, thereby providing an incentive to continue using the system. In addition to promoting social sustainability, the system also serves to prevent driving under the influence of alcohol. The bracelet includes a breath analyzer that tells users when it is unsafe for them to drive, and then, by communicating to the mobile phone, allows users to find rides with drivers they trust.

Lessons

Roads need no longer be simple channels for the flow of vehicles. Information and communication technologies make it possible to implement radical new road pricing and traffic management strategies, with the result that available road space is used more efficiently and traffic flows more freely. Sophisticated congestion pricing systems can encourage efficient and cost-conscious use of roads by drivers.

ICT also enables highly effective and – perhaps most important – *self*-organized ridesharing. This means that the implementation of congestion pricing does not have to be seen as a "punishment" by the driver, but that she or he has options to carpool in ways that make it possible to take advantage of discounts that can be established for full cars under the new systems.

Further, ICT provides trust management tools that help overcome the traditional limitations associated with ridesharing among "strangers."

Key to these sorts of interventions is to create socially beneficial incentives that are promoted as an integral part of the public policy that brings such programs to fruition.

Scenario: more efficient parking

How can we reduce the total space devoted to car parking in cities, so that space can be devoted to more productive and human uses? How can we reduce the massive worldwide waste of fuel and time as people look for parking spaces in cities?

Generally, the market for parking in cities is very poorly structured; prices for parking spaces are mostly fixed, and buyers of parking spaces are connected to sellers through a process of randomly cruising around until an available space becomes visible. According to Donald Shoup in his 2005 book *The High Cost of Free Parking*, up to 30 percent of city traffic congestion can be due to cars "cruising for parking."

Reveal the availability of parking spaces online and via mobile devices, make it possible to reserve street parking, and add dynamic pricing to the equation.

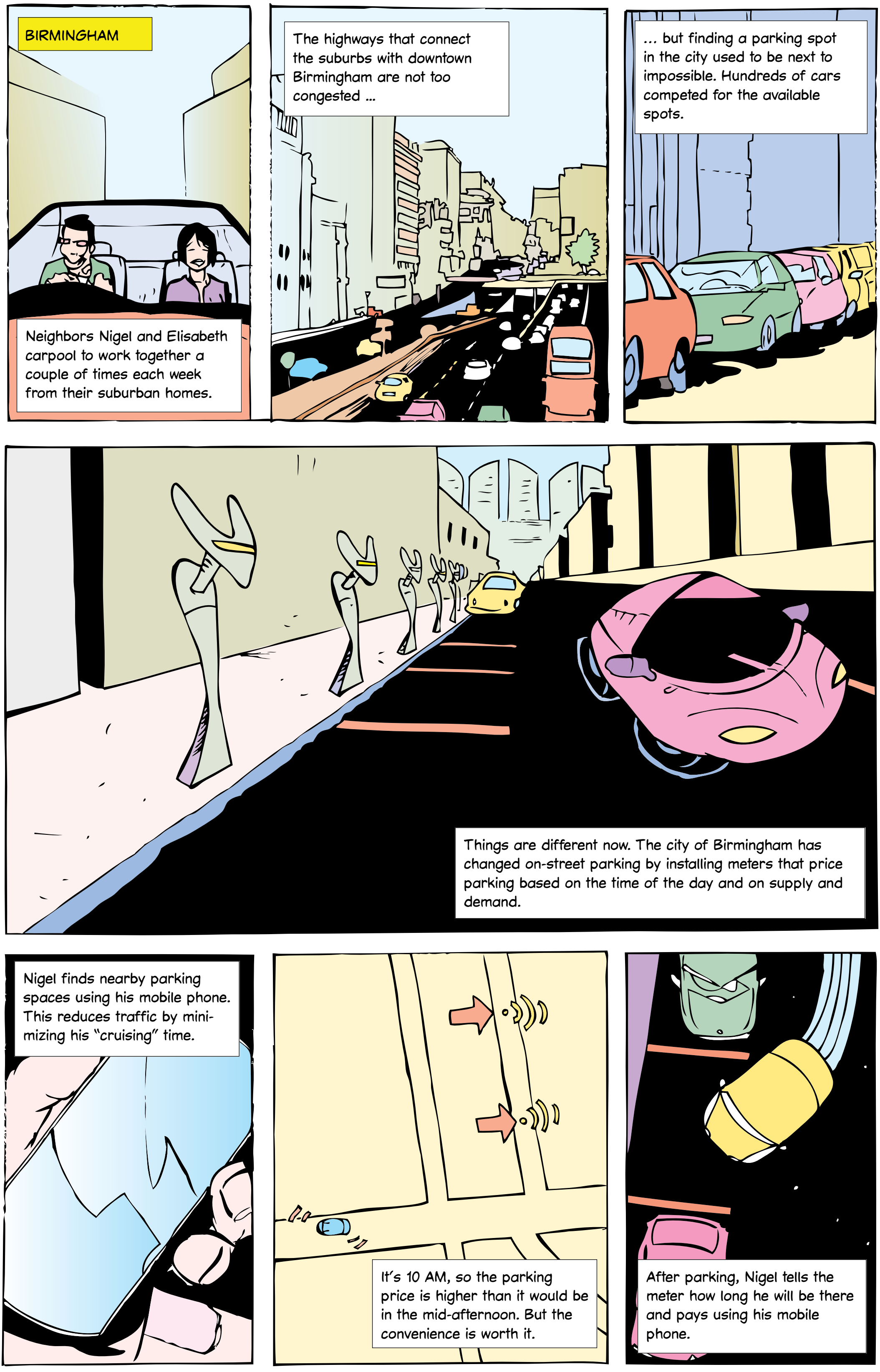
A couple of times each week for the past few years, Nigel and Elisabeth have carpooled together into the city from their suburban homes for the half-day they must spend at the headquarters of the company for which they both work. The drive is always pleasant: the highway portion hasn't been too bad, and they almost always have something interesting to talk about to pass the time. But until recently, the last part of the drive had been miserable. By the time they arrived in the city the parking lots were always filled, and finding an on-street parking space was next to impossible. They were downright miserable being part of the city traffic congestion that is so widely affected by cars cruising for the much-less-expensive parking spots on the street.

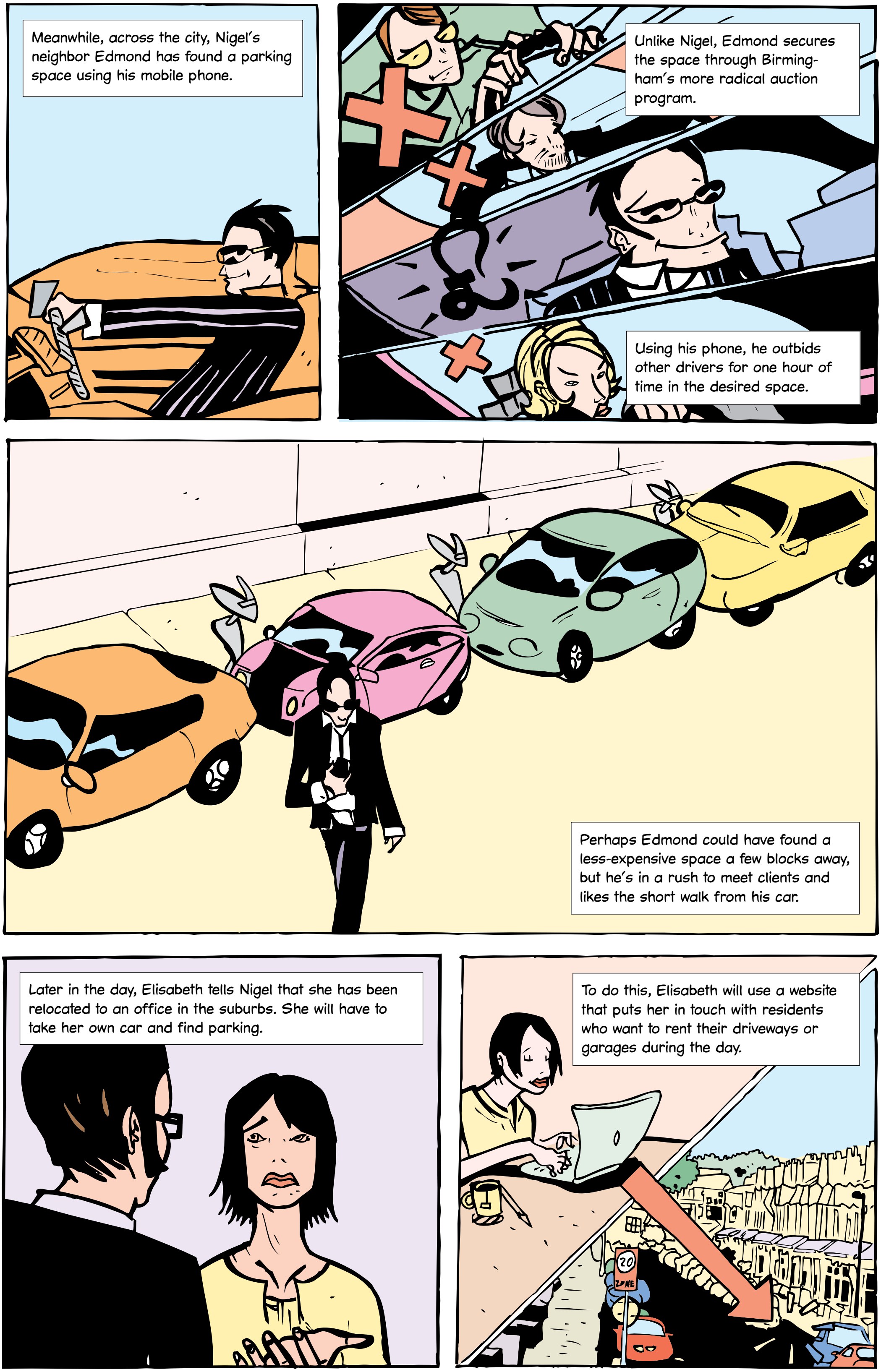
All that is different since Birmingham changed the way on-street parking works in the city. The first step the city took was to install meters that price the parking differently depending on the time of day – based on supply and demand. The initial reaction throughout the city brought talk of rioting in the streets, but pretty soon drivers figured out that it just made more sense to pay that way. After all, it's worked for years with carparks. Plus, the number of people cruising around dropped, and everyone was happy.

Birmingham, though, wasn't done with its transformation of on-street parking. The next step was to equip all the spots with in-street sensors that could tell whether the spot was occupied or available. On this particular day, Nigel checks on his mobile phone and – thanks to the sensor system – sees that there are four spots on the block behind the office building. That makes following the one-way streets around to get to that place worth the extra couple of minutes.

Nigel and Elisabeth find their spot and pull in. Since it's 10 AM, the price is much higher than if they had first taken the spot in the mid-afternoon, but the convenience is worth it. Using his mobile phone, Nigel tells the meter how long he will be parking and makes the payment through an automatic deduction from his bank account. If he comes back to his car early, he'll get an automatic refund for the difference in time.

Across the city, in another area with far less on-street parking, Nigel's neighbor Edmond is getting an on-street parking space through one of Birmingham's more radical programs. Using his mobile phone,


BIRMINGHAM
Neighbors Nigel and Elisabeth carpool to work together a couple of times each week from their suburban homes.
The highways that connect the suburbs with downtown Birmingham are not too congested ...
... but finding a parking spot in the city used to be next to impossible. Hundreds of cars competed for the available spots.
Things are different now. The city of Birmingham has changed on-street parking by installing meters that price parking based on the time of the day and on supply and demand.
Nigel finds nearby parking spaces using his mobile phone. This reduces traffic by minimizing his "cruising" time.
It's 10 AM, so the parking price is higher than it would be in the mid-afternoon. But the convenience is worth it.
After parking, Nigel tells the meter how long he will be there and pays using his mobile phone.


Meanwhile, across the city, Nigel's neighbor Edmond has found a parking space using his mobile phone.
Unlike Nigel, Edmond secures the space through Birmingham's more radical auction program.
Using his phone, he outbids other drivers for one hour of time in the desired space.
Perhaps Edmond could have found a less-expensive space a few blocks away, but he's in a rush to meet clients and likes the short walk from his car.
Later in the day, Elisabeth tells Nigel that she has been relocated to an office in the suburbs. She will have to take her own car and find parking.
To do this, Elisabeth will use a website that puts her in touch with residents who want to rent their driveways or garages during the day.
20
ZONE

he outbids another driver for one hour of time right in front of a client's office. While Edmond could probably find a spot further away at a lower price, he's on a very tight schedule today. From a business perspective, the extra payment is well worth it – he has to get to another client way out in the suburbs soon after this meeting.

At the end of the day, Edmond, Nigel, and Elisabeth head home to their suburb. Elisabeth gives Nigel some news: she's been put on a project team that will require her to be at another office four days a week, in a more residential part of the metropolitan area. They won't be able to carpool any longer. Nigel will surely compensate in some way, perhaps finding someone through the city's new slugging program. As for Elisabeth, she's planning to find a regular parking space online, through a website that puts city residents in touch with suburbanites who need parking in their neighborhoods, and allows them to earn some extra income by renting out driveways or garages. It gets around the neighborhood restrictions – so Elisabeth won't be facing a pile of parking tickets at her new work location.

Enabling technologies

Dynamic pricing for public parking

The price Nigel pays for the parking spot he finds is based on a "demand-responsive" pricing model like the one being implemented in San Francisco's SFpark program. It works by having multispace parking meters with variable pricing programmability; in-street sensors to determine parking spot occupancy and availability; remote monitoring of parking usage that is made available to parking enforcement officers through handheld monitoring devices; remote parking availability and price information that is made available to drivers through Internet-enabled devices and mobile phones; a remote payment and time-limit warning system for drivers using municipal parking; and dynamic signage. Sensors based on a technology called "smartdust" can detect vibrations, making it possible to know whether a car is occupying a spot.

The new parking infrastructure will allow the city to regulate the price and time limits for parking according to real-time demand and adjust parking prices such that demand is kept at or below 85 percent capacity at all times – the anticipated level that will make it possible for people who absolutely must drive to be able to find a spot wherever they need one, without having to "cruise."

Peer-to-peer parking coordination

Elisabeth will be visiting a website to find a more permanent parking space in the neighborhood where she will be working on her new project team. It's a system like YourParkingSpace, which began in London and has spread to other U.K. cities. YourParkingSpace provides a solution to the rapid rise in parking prices and the widespread implementation of resident parking restrictions in city neighborhoods. It offers a Web-based means by which residents can earn extra income by renting out their driveways or garages, either on a daily basis as needed (such as for events at a local stadium) or for longer terms (such as for commuters seeking parking near public transit terminals). It is also a way to find affordable, convenient parking where needed.

Lessons

As long as cities depend heavily upon private automobiles to provide mobility, there are only three ways for them to solve their parking problems. Unfortunately, the first two are not generally acceptable options: ban cars from entering the urban area where parking is a problem, or create more and more parking spaces, either on the street or in parking structures. The first is difficult to enforce, and the second runs counter to every effort to make cities more sustainable.

A third option is to make the use of existing parking spaces *smarter.* With wireless, sensing, and GPS technologies, a sophisticated system can be created that brings parking information directly to the navigation system in a car and eliminates the major problem, which is the incessant waste of time and fuel spent looking for a space.

Once cities have such systems, they will be ready to take the next step, which can happen only with information and communication technologies: implement different pricing models for different parking types and times. These systems will even make it possible to establish a kind of market for parking that is dynamic and, at the same time, equitable to all drivers irrespective of their financial means. This can include discounting linked to social policy. Ultimately, these systems will enable cities to manage parking space supply and demand in a way that truly serves the ultimate goal of minimizing city traffic.

Scenario: more attractive and efficient public transit

Public transit systems can be extremely efficient for moving people between stops, but their routes and timetables tend to be rigid and difficult to adapt to changing circumstances. They also have high infrastructure costs – often in the millions of dollars per mile to build and maintain. How can we take advantage of connectivity to enhance the attractiveness and efficiency of public transit systems?

Many of the world's cities are overcrowded, impoverished, and polluted. One of the most important ways to ease their problems is to establish good public transit. Mobility makes it possible for people to get to workplaces, which provides an economic benefit. And if the public transit system runs "green," it reduces pollution. But resources to create and operate transit systems are limited, and existing systems are often inadequate.

Make use of information and communication technologies to create efficient, flexible systems that can provide good service and operate sustainably.

Gabriela was excited, and quite nervous, as the plane began its descent into Curitiba, the capital city of the Brazilian state of Paraná. She had been out of her home city of Lima only a few times, and those times were all trips to small towns elsewhere in Peru. Now, as she arrived in one of Brazil's southernmost cities for an internship she had won through a university competition back home, she wondered whether she was making the right choice or whether homesickness would consume her every day.

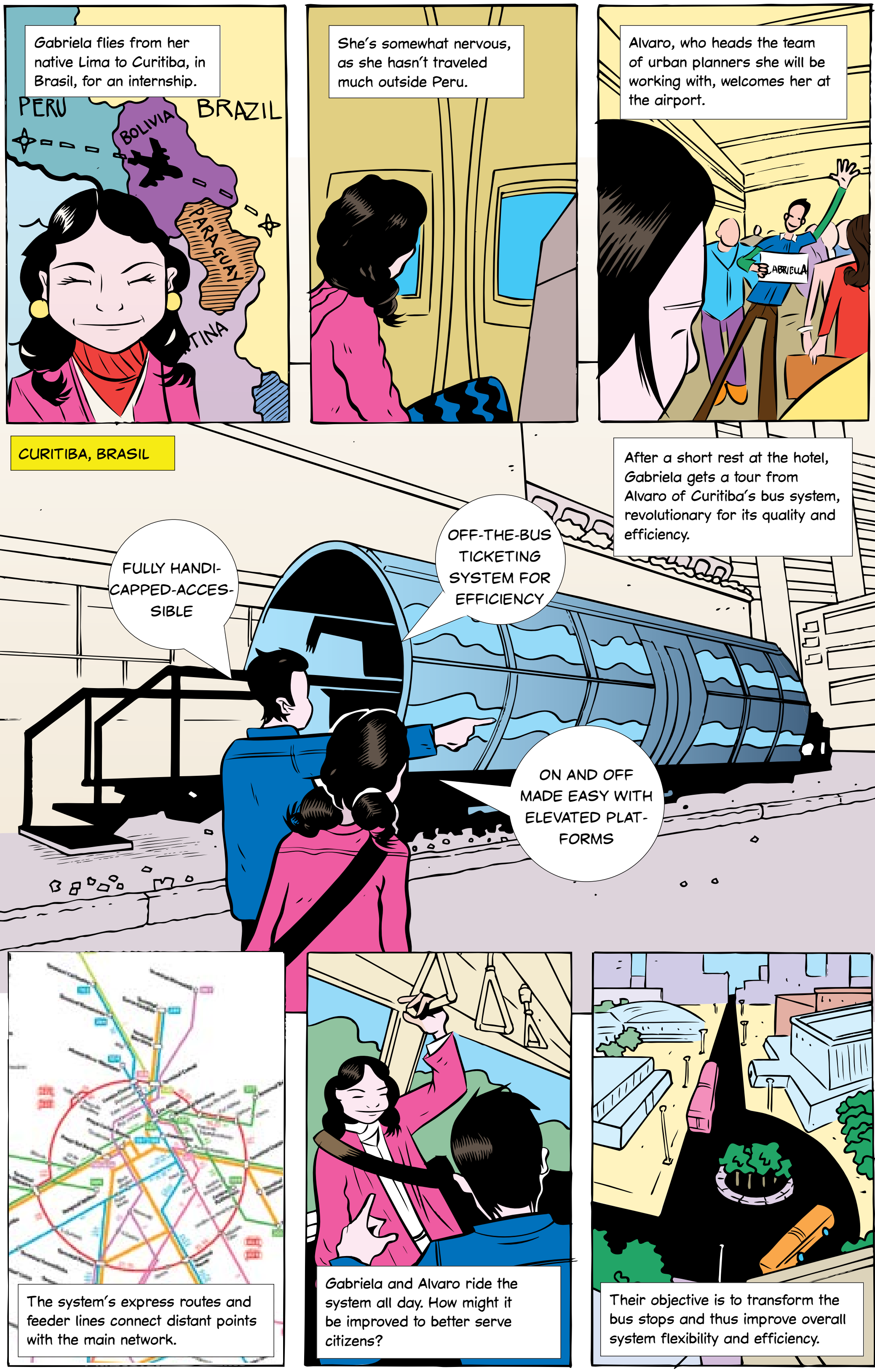
Moving easily through the baggage claim area, Gabriela felt much better when she saw a young man in the airport lobby holding a sign with her name and “bem-vindo.” She had been studying Portuguese and knew she was being welcomed. She moved quickly to the young man, who introduced himself as Alvaro. This really made Gabriela feel comfortable: he was the man she had been talking to on the phone after winning the internship.

“I’ll drive you to where you’ll be staying for the next three months,” said Alvaro, “and then come back and get you after you’ve rested a bit. I want to show you around the city.” Gabriela was exhausted, and took a quick nap until they arrived at her guesthouse.

Alvaro was an urban planner and worked for the *Rede Integrada de Transporte* [Integrated Transportation Network], which is responsible for the city’s remarkable public transit system. Gabriela would be working with him on some of his projects.

In the 1970s, Curitiba began a series of urban transit innovations that made it ahead of its time and have since won it worldwide renown. The first and most significant ones included the creation of the Rua Quinze do Novembro in the commercial center of the city; it was Brazil’s first pedestrian-only street. The Sistema Trinário road design established two-lane streets for buses and local automobile traffic in the middle of wider, faster one-way streets and eased city traffic considerably. Development of the “Industrial City” on the city’s outskirts began to attract businesses and jobs.

Even though Brazil overall faced a crippling economic recession in the 1980s, with a sharp upturn in poverty, Curitiba – with little money but a strong will – kept moving forward. Now a city of nearly 1 million people, Curitiba expanded public transit, set up a citywide recycling program, created parks, and established “green areas” to ensure that overdevelopment didn’t make the city unlivable. By 1992, with a population of more than 1.4 million, the city was tapped to host the World Cities Forum in advance of the United Nations Conference on the Environment and Development’s Earth Summit. Curitiba hit the world stage with a bang.



Gabriela flies from her native Lima to Curitiba, in Brasil, for an internship.
PERU
BRAZIL
BOLIVIA
PARAGUAY
She's somewhat nervous, as she hasn't traveled much outside Peru.
Alvaro, who heads the team of urban planners she will be working with, welcomes her at the airport.
GABRIELA
CURITIBA, BRASIL
After a short rest at the hotel, Gabriela gets a tour from Alvaro of Curitiba's bus system, revolutionary for its quality and efficiency.
FULLY HANDI-CAPPED-ACCES-SIBLE
OFF-THE-BUS TICKETING SYSTEM FOR EFFICIENCY
ON AND OFF MADE EASY WITH ELEVATED PLAT-FORMS
The system's express routes and feeder lines connect distant points with the main network.
Gabriela and Alvaro ride the system all day. How might it be improved to better serve citizens?
Their objective is to transform the bus stops and thus improve overall system flexibility and efficiency.


The team brainstorms about stations as social nodes that can provide more information to citizens.
How might the stops become part of the urban life beyond their role as mobility nodes?
INTERACTIVE SURFACES
MOBILE APPLICATIONS
Out in the field, Gabriela notes that pollution is a big concern for many bus riders. How can environmental conditions be made transparent?
She envisions bus stops as pollution sensors across the city that detect critical areas and make conditions explicit to citizens and government.
By turning bus stops into ENVIRONMENTAL SENSORS and displays, overall city awareness of pollution problems would rise ...
... and Curitiba's mobility system could become the envy of the world!

After the Forum, Curitiba continued to innovate. New jobs came to Industrial City, including good-paying ones at the automobile manufacturers Chrysler, Audi/Volkswagen, and Renault. And it was during this period that Curitiba radically transformed the way cities can plan urban mass transit. This was what Gabriela had arrived to work on and advance.

Curitiba could not afford the prohibitive costs of building any light rail lines, although the city desperately needed the kind of expansion of mass transit – and protection from pollution – that a subway or similar system would provide. So, the city's planners went in a different direction, introducing brand-new, red, bi-articulated buses into the city's already well configured transit system. These buses would travel between new tube-shaped bus stops.

When Alvaro picked up Gabriela a few hours later, she was anxious to see the system. She had missed everything on the ride in from the airport. She and Alvaro walked outside and down the block, and there Gabriela got her first look at one of the tubes.

"Wow!" Gabriela exclaimed. "I've only seen the pictures. This is remarkable." The tube was elevated off the ground, to make access into the bus easy. Passengers pay before boarding and can transfer within the system without paying again – which makes everything run quickly and smoothly. As she spoke, one of the buses pulled into the stop. She was equally impressed. She watched a woman in a wheelchair go from street to bus in a matter of seconds. Passengers walked right on and off the bus without any stairs.

"You know," Alvaro noted, "about 85 percent of our citizens use these buses. You can get anywhere in the metropolitan area. This one is an *Espresso Biarticulado* [express bus]; sometimes we call it the aboveground subway. The buses come very often and travel quite fast in special high-speed traffic lanes."

"There's an entire network, though, isn't there?" asked Gabriela.

"Yes, with color coding," answered Alvaro. "We have the green *Interbarrios* [inter-neighborhood] buses outside the downtown, circling in ever-larger radii. The orange *Alimentador* [feeding lines] link the express buses and others with neighborhoods. You can catch a silver *ônibus ligeirinho* [quickie bus] to go longer distances with fewer stops, and link with the tubes. Before coming to get you at the airport, I was doing some research by riding on one of the yellow *Convencional* [conventional] buses that radiate out from the city center. And downtown we even have the black *Circular Centro* [around downtown] buses that are the quickest way to get from one part of the city center to another."

Alvaro and Gabriela spent several hours that day riding the different buses and exploring Curitiba. Later, as Gabriela settled in for her first night of sleep in the city that would be her home for three months, she was eager to get started on Alvaro's project – to transform the bus stops and make them even better.

Alvaro came by bright and early the next morning to accompany her to the office for a project kickoff meeting. Gabriela met the rest of the team and, after a quick breakfast, they began to brainstorm. They had two objectives. One was to introduce even greater flexibility into the routes and schedules of the buses, so that the Curitiba citizenry could be better served. This was a challenge that would require introducing new information and communication technologies. The second had to do with the bus stops themselves: make the bus stops – not only the tubes, but also the stops for all the different lines – an organizing place for the city and its neighborhoods. Why couldn't the technology that provided schedules and arrival/departure information to riders at each stop also tell them about the concert up the street, the shops in the area, who needed childcare, what book club was being organized in the neighborhood, and so on?

These were the question that consumed the team for the first several weeks of Gabriela's stay in Curitiba. She enjoyed the discussions among this group of young planners, and she looked forward especially to the hours they spent riding the buses and talking to riders. Her Portuguese was getting quite good, and she was thrilled by the investment average Curitiba citizens would make in offering ideas to improve their already world-class transit system.

To address the issue of greater schedule and route flexibility, the team was looking at what was being done in some other cities, including using mobile technology to allow citizens to schedule bus trips along certain routes and at times precisely fitting riders' schedules. The rate of mobile phone use in Curitiba was growing, and the team felt confident that it could develop and implement some pilot programs to test out how the Curitiba system might be transformed in this way.

Gabriela participated in these discussions, but she was gravitating towards the bus stop aspect of the project. One day, while talking with a small group of men and women at one of the tubes, a truck went by and spewed a huge amount of dirty smoke into the air. A woman in the group commented that she had seen this happen every day for the past week, and she wondered aloud how she could feel comfortable bringing her young son, with asthma, down near the busy street. Gabriela had an idea.

"What if the tube could show you how much pollution was in the air nearby?" she asked. "Would that help?"

Not only did the woman think that would help, but she also suggested it would arm her and her neighbors to go to the city and demand that the trucks be rerouted.

Gabriela and her coworkers couldn't wait to get back to the office and brainstorm these new ideas with the team. It was a big order to fill, but they all felt that they were onto something that could make Curitiba again the envy of the world when it came to public transit that truly serves the needs of its citizens.

Enabling technologies

Interactive bus stops

Alvaro's project team is developing ideas for transforming Curitiba's bus stops into places for location-based information exchange. Gabriela hits on the idea of taking the concept even further. At the MIT Mobile Experience Laboratory, researchers and designers – working with the *Régie Autonome des Transports Parisiens* (RATP/Parisian Autonomous Transport Operator) in France – have developed the concept of the Interactive Bus Stop that can serve as an electronic "concierge" and digital gateway into the offerings of the neighborhood and the transportation system at large, giving passengers and residents the means to provide and access user-generated content.

Further, the physical bus stop itself can interact with the neighborhood. Inspired by the metaphor of a garden whose plants grow and react depending on environmental conditions, the bus stop's LED facade can display ambient information such as pollution. Alternatively, the display can be changed to show social interactions at the bus stop – such as those generated by newly uploaded user-generated content. Some of that content could be provided via a system such as Yelp, an online city guide with reviews of local businesses and services in city neighborhoods – all provided by the citizens.

Bus system

The technology behind the Curitiba bus system is a versatile, low-cost, and simple architectural intervention that creates closed spaces – accessible through turnstiles – where users can access to the transportation systems. The system allows a great deal of flexibility in designing the transportation solution for the city.

On-demand bus service

Alvaro's team envisions a time when riders can reserve space on a bus and set the schedule to get to work in the morning. The Drin Bus in Genoa, Italy, is a classic example of "demand responsive transport" – in this case, a flexible bus service that connects the hilly, low-density areas of Genoa through an operational model of "many to many" pickup and drop-off points. A riders can reserve the bus up to 30 minutes prior to his or her desired departure time via telephone, or catch it "on the road" if the bus has room.

Citizen reporting

Every city block can be seen as a system of interest in its own right that can engage users and the broader city directly in caring for the environment. Information and communication technologies at this level are the tools with which to involve local inhabitants in this way, for example, by providing specific news and information and by establishing a portal through which local concerns can be communicated.

Lessons

Curitiba has vividly demonstrated the advantages of innovative bus systems. With appropriate design and operating policies, bus rapid transit systems can combine the efficiency of rail systems with the flexibility and lower cost associated with buses. Now, through integration with mobile networking and information technology, advanced bus systems promise to become even more convenient and efficient.

Rethinking the bus stop is a good place to begin the process of enhancing bus systems through ICT. Prototype interactive bus stops have demonstrated the possibility of designing location-based services that increase local business activity while simultaneously promoting social connections at the local level, both among citizens and between citizens and institutions. The ability to produce user-generated content strengthens the local connection. Of course, enhanced access to local-level resources will alter mobility patterns.

Scenario: electronically integrated and coordinated transportation

Public transportation is often confusing and difficult to use. This makes it the least-desirable option for many people.

What can be done to integrate public transportation with other services in the city so that it attracts greater numbers of passengers? And how can social networking be used to enhance the experience of using public transit and making one's way around the city to take care of the necessities of daily life?

Integrate mass transit systems with advanced information services to create systems people want to use.

Anyone who has been to San Francisco knows that getting around can be quite a challenge. There's a lot of traffic, and public transportation, while ubiquitous, certainly doesn't hit every street. Then there are those hills – a challenge for anyone on foot or in a vehicle.

Lucia Mendoza, a 65-year-old diabetic living in the Potrero neighborhood, knows those hills well. They are a big part of why she always drove her car to run her errands. But now, in the spring of 2013, gas prices, impossible parking, and long waits in traffic have her taking the bus. What clinched her decision was her new *Passport* – a handheld electronic device from the regional transit authority. It's about the size of a wallet, with a touch screen, GPS, wi-fi, and a ubiquitous video connection.

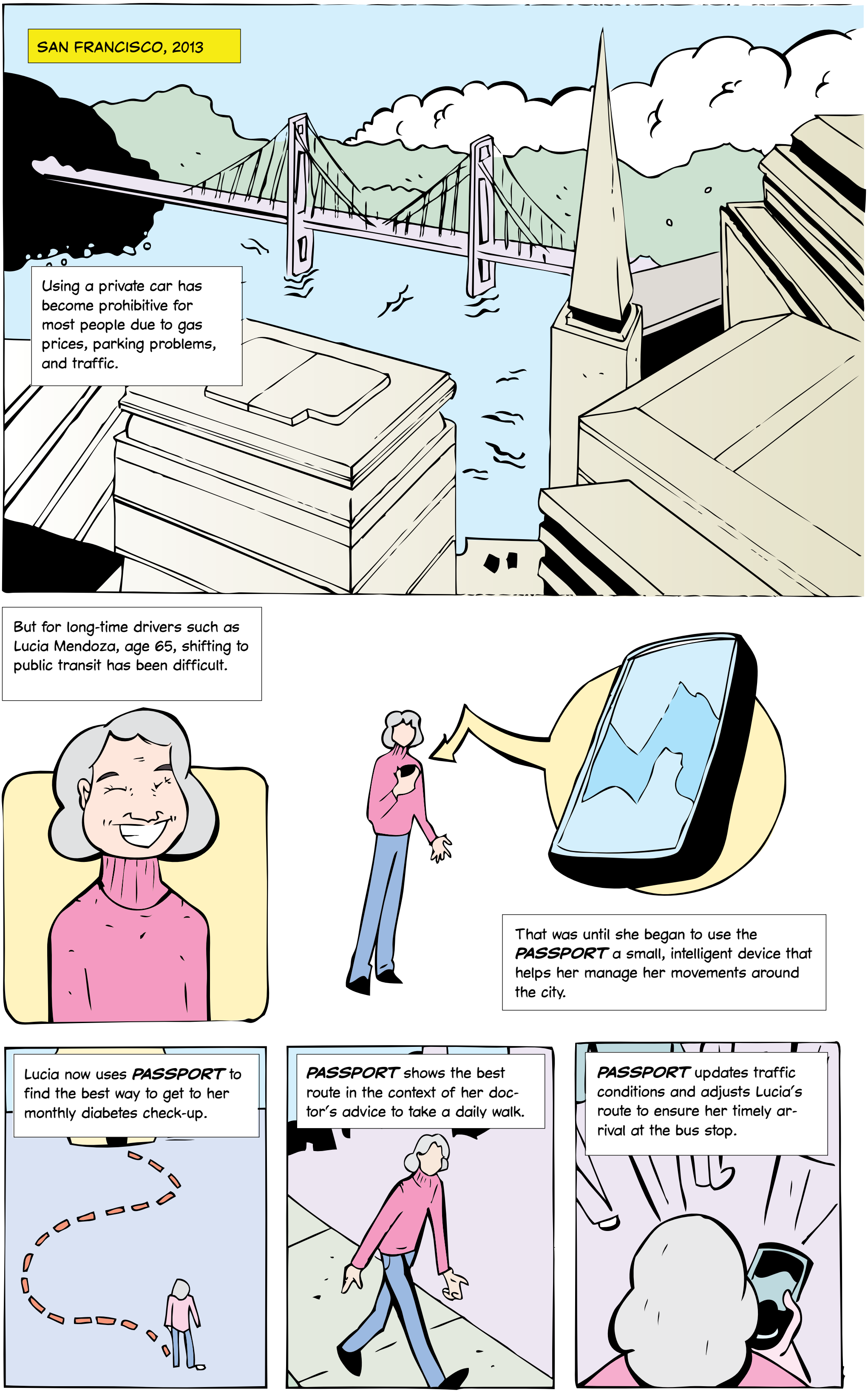
This day, Lucia has her monthly diabetes checkup at a downtown clinic. Normally, it would take about 10 minutes to get down the hill to her nearest bus stop, but Dr. Cole wants her walking more. So, her Passport gives her an itinerary: down the hill for one block, turn right, and head to the next street that goes down, to pick up the bus at a further stop. It's all part of getting in her 30 minutes of walking. The Passport tells her exactly where to be – and when.

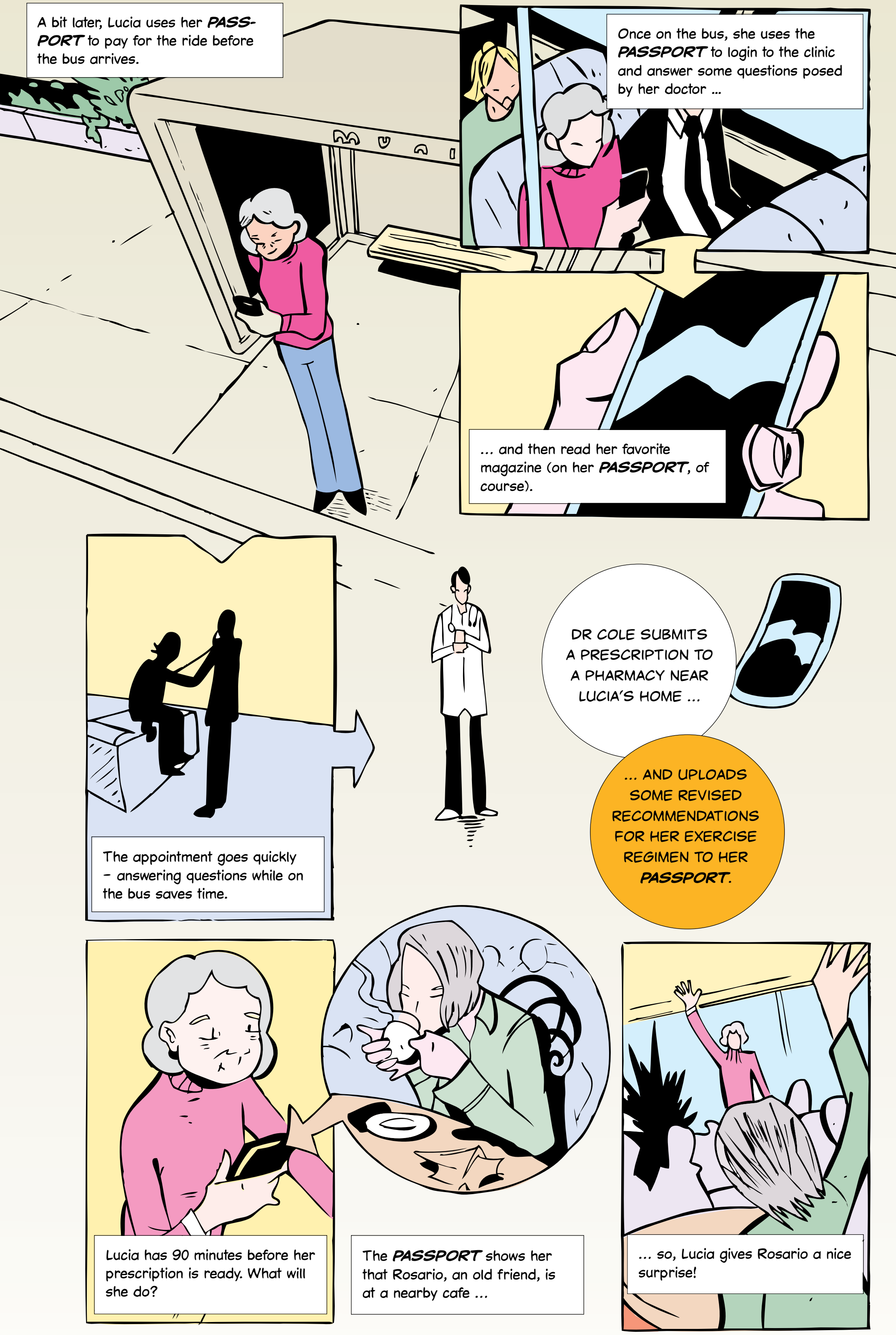
Logging how much time she's been walking, the Passport directs her to make a slight change in the route. The device has been monitoring traffic conditions and the estimated time the bus will arrive at the stop. The Passport also knows where the clinic is and when Lucia needs to be there, so everything is coordinated for maximum efficiency.

Lucia arrives at the bus stop just in time, and uses her Passport to pay for the ride. While seated, she uses her Passport to begin checking in at the clinic – even answering some questions Dr. Cole has posted for her. She then settles in for the ride uptown and reads her favorite magazine – on her Passport.

The bus is moving along at a good clip, and the Passport alerts Lucia that she can get off a few blocks before the clinic if she'd like to continue her walk. It also lets her know the estimated wait time at the clinic.

Lucia's appointment goes by quickly, thanks in large part to her answers to the posted questions on her Passport. Dr. Cole submits a new prescription to her neighborhood pharmacy, online, and Lucia gets a confirmation and pickup time sent to her Passport. The doctor also submits some revised recommendations for her exercise regimen, which


SAN FRANCISCO, 2013
Using a private car has become prohibitive for most people due to gas prices, parking problems, and traffic.
But for long-time drivers such as Lucia Mendoza, age 65, shifting to public transit has been difficult.
That was until she began to use the PASSPORT a small, intelligent device that helps her manage her movements around the city.
Lucia now uses PASSPORT to find the best way to get to her monthly diabetes check-up.
PASSPORT shows the best route in the context of her doctor's advice to take a daily walk.
PASSPORT updates traffic conditions and adjusts Lucia's route to ensure her timely arrival at the bus stop.


A bit later, Lucia uses her **PASS-PORT** to pay for the ride before the bus arrives.
Once on the bus, she uses the **PASSPORT** to login to the clinic and answer some questions posed by her doctor ...
... and then read her favorite magazine (on her **PASSPORT**, of course).
The appointment goes quickly – answering questions while on the bus saves time.
DR COLE SUBMITS A PRESCRIPTION TO A PHARMACY NEAR LUCIA'S HOME ...
... AND UPLOADS SOME REVISED RECOMMENDATIONS FOR HER EXERCISE REGIMEN TO HER **PASSPORT**.
Lucia has 90 minutes before her prescription is ready. What will she do?
The **PASSPORT** shows her that Rosario, an old friend, is at a nearby cafe ...
... so, Lucia gives Rosario a nice surprise!

are uploaded to the Passport system and will become factors in how the system recommends Lucia's walking routes.

With only a 20-minute bus ride back and 90 minutes to wait before her medication is ready, Lucia decides she'd like a coffee. She uses her Passport to search for whether any of her friends might be in the neighborhood, and finds that her neighbor Rosaria, who works nearby, is at a local café. The Passport gives her directions to walk the two blocks and shows her where the nearest bus stop will be. She enters the café and gives Rosaria a pleasant surprise.

Finally, it's time to head back home. Lucia boards the bus, takes a convenient ride to the stop near her home, and picks up her prescription. As she heads up the hill, she receives a reminder from her Passport that she needs to take her medication in 15 minutes.

Passport keeps Lucia in constant connection with the people, locations, and services that matter to her.

Enabling technologies

Schedules and fees via mobile devices

Lucia learns of schedule changes for her buses via her mobile phone. Air Canada makes check-in possible via mobile phones, with electronic boarding passes for its flights. The airline also offers a variety of other mobile services, including notification of changes in departure and arrival times, delays, and cancellations. With a prepaid package of flight credits, passengers can manage travel cost and increase flexibility in light of these notifications.

Lucia's mobile phone also provides her with a complete plan for her day's travel via public transit. Covering more than 50 U.S. cities and nearly 20 cities in other countries, Google Transit makes it possible to plan an entire trip using public transportation. It features step-by-step transit directions, walking maps to and from transit stops in a given area to beginning and ending destinations, and station information and schedules. The system links directly to the public transportation systems in the areas covered.

Commuter-friendly buses

Lucia relies on information provided to her by the bus system to ensure that her travel is as efficient as possible. In San Francisco, as part of the Connected Urban Development program, a pilot project was begun in 2007 to encourage people to use the city's Muni buses by improving ride quality. Using advanced Internet technology, the hybrid Connected Bus enhances the ride with onboard touch screens that provide information on bus arrivals and other Muni information, wireless Internet access from laptop computers or mobile devices, and external displays informing motorists about the environmental benefits of the vehicle. The objective is for rides to be safer and more reliable and for buses to spend less time in traffic and have lower carbon emissions.

Mobile social networking

Lucia meets her friend Rosaria at a local coffee shop, without having scheduled the encounter in advance. The online social networking site Dodgeball makes it possible to let friends know where you are, locate where friends and friends of friends are within a 10-block radius of your location, and find venue locations and broadcast messages to friends. Loopt alerts users where their friends are nearby and can show what they are doing via detailed, interactive maps on their mobile phones. The system also allows users to share a variety of information with designated friends in their mobile address book or through online social networks.

Lessons

In many cities, public transportation systems aren't as effective and desirable as they might be because they are confusing and unpleasant to use. So, instead, people choose the less sustainable alternative of the private automobile. As our scenario shows, however, information technology can now greatly reduce or even eliminate this barrier to more sustainable mobility.

There are three levels to applying information technology to create enhanced public transportation systems. First, the system must provide sufficiently comprehensive coverage of the city. Second, easy-to-use guidance systems, making use of GPS and (eventually) Near Field Communication, must be employed to make riding the system's vehicles simple, trip planning straightforward, and minute-by-minute personal scheduling possible. Finally, transit systems must embrace the software that *riders* use. This means going beyond guidance and scheduling systems to encompass online social networking, for instance, as a resource to help organize trips.

Scenario: productive commuting time

Time spent commuting is often time wasted. If people must commute, how can we employ connectivity to make their commuting time more productive?

Many drivers heading out to work each day stay in their cars despite the costs of fuel, parking, tolls, and maintenance. This is the case even in urban areas with terrible traffic congestion and many public transportation options. Ask these drivers why, and they're likely to tell you that it's a matter of control. They want to be in charge of when and where they go, even if the tradeoffs are substantial. They have other things to take care of on their way to work or back home. How can these work commuters be lured on to public transit?

Through the use of information technology, create vehicles, routes, and transit services that make commuting time available for work and play.

When Lars Ganesvoort bought his first car, back in 2008 when he was 25 years old, he certainly didn't think it would be the last one he owned. But it lasted a good while, and by the time he was thinking it needed to be replaced, he really had little use for it. Today, he rents a car when he wants to drive to the countryside. But to get to work and back from his Amsterdam suburb of Almere, this now 35-year-old tech professional uses public transportation.

And what a public transportation system it is. In many ways, there is little difference between the bus he rides and the car he used to own.

At least that's the case with respect to convenience and control. Lars is the master of his own fate when it comes to public transit.

This particular day is typical. At breakfast, Lars checks the bus system on the screen embedded in the table surface in his kitchen. The night before, he had reserved a space on a bus that would pick him up and get him to work within minutes of his preferred time. That bus was scheduled based on the requests of others in his neighborhood to adjacent areas of Amsterdam.

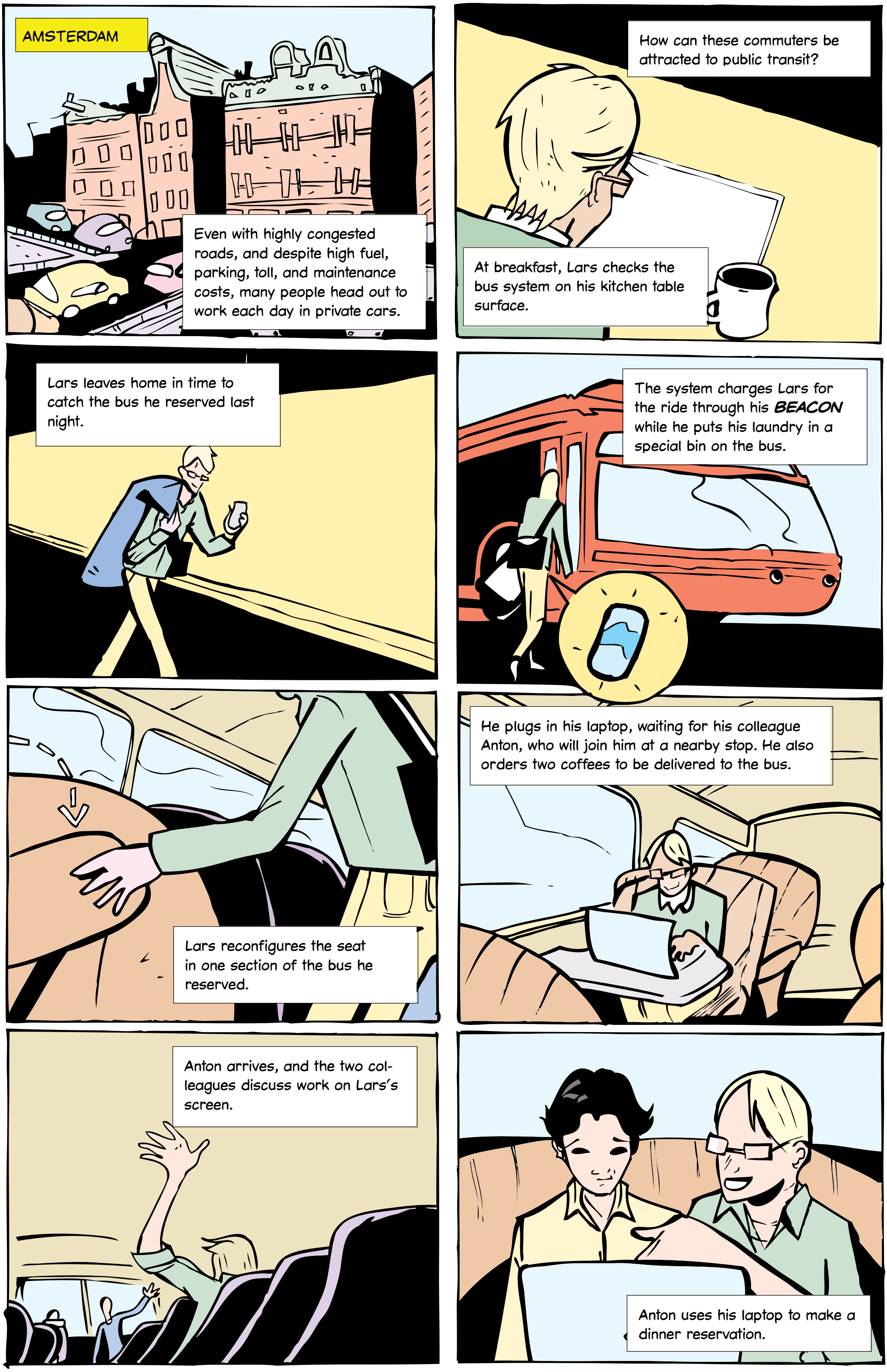
The map shows Lars what time he needs to be at the bus stop about five blocks away, and even suggests a time that he leave his house to ensure that he arrives on time. It also provides an estimate of the travel time based on current conditions. Today, everything is running smoothly. On other days, the system might have contacted him to let him know that getting to work at his preferred time might require a change in departure times, and offer him options in advance.

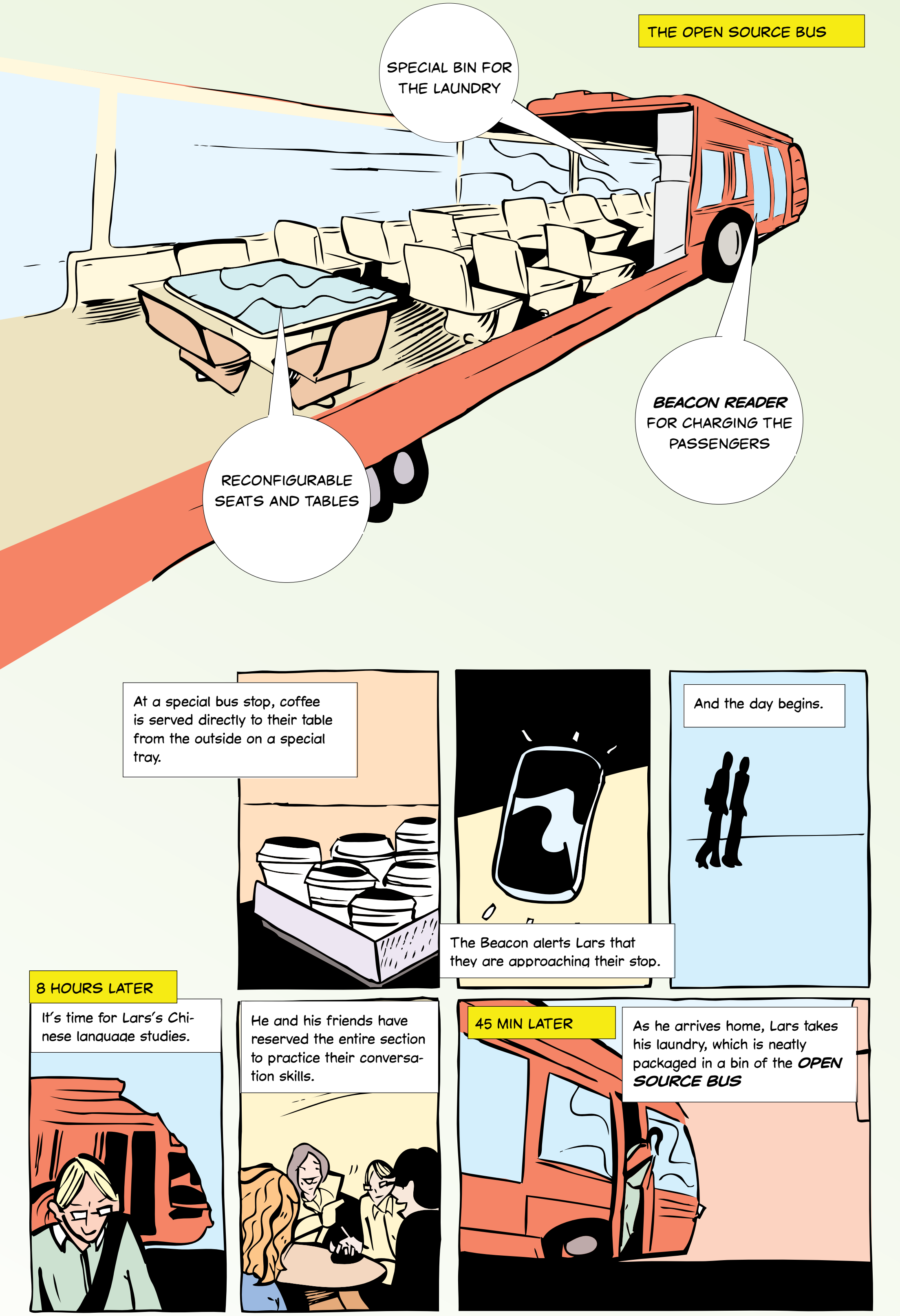
In the old days, Lars might have left even earlier to run some errands. Today, he has some laundry to drop off, but on his bus it's a simple matter of leaving it in the correct onboard bin and it will be ready for him on his trip home – or available at one of many pickup locations he can designate throughout the area.

Leaving the house, Lars activates the bus beacon application on his mobile phone. This makes his location visible to the bus, confirms his earlier reservation, and displays status information about the bus he's going to catch. When he boards the bus, he pays using his mobile phone, which also updates his status within the system to indicate that he is on board. He puts his laundry in the bin.

The ride to work is about 45 minutes – ideal time to get a head start on some work. Lars and his colleague Anton had arranged to meet on the bus and discuss a project they have in common, so before Anton boards a few minutes later Lars reconfigures the seats and a table in one section of the bus he reserved. He plugs in his portable computer and by the time Anton is on, the work is in front of them on the screen.

About 15 minutes into the trip, Lars and Anton are prompted electronically at their seats to order some coffee to be delivered at the scheduled coffee stop ahead. They place their orders, and when the bus stops


AMSTERDAM
Even with highly congested roads, and despite high fuel, parking, toll, and maintenance costs, many people head out to work each day in private cars.
How can these commuters be attracted to public transit?
At breakfast, Lars checks the bus system on his kitchen table surface.
Lars leaves home in time to catch the bus he reserved last night.
The system charges Lars for the ride through his BEACON while he puts his laundry in a special bin on the bus.
Lars reconfigures the seat in one section of the bus he reserved.
He plugs in his laptop, waiting for his colleague Anton, who will join him at a nearby stop. He also orders two coffees to be delivered to the bus.
Anton arrives, and the two colleagues discuss work on Lars's screen.
Anton uses his laptop to make a dinner reservation.


THE OPEN SOURCE BUS
SPECIAL BIN FOR THE LAUNDRY
BEACON READER FOR CHARGING THE PASSENGERS
RECONFIGURABLE SEATS AND TABLES
At a special bus stop, coffee is served directly to their table from the outside on a special tray.
The Beacon alerts Lars that they are approaching their stop.
And the day begins.
8 HOURS LATER
It's time for Lars's Chinese language studies.
He and his friends have reserved the entire section to practice their conversation skills.
45 MIN LATER
As he arrives home, Lars takes his laundry, which is neatly packaged in a bin of the OPEN SOURCE BUS

a few minutes later their orders are handed to them through the window by their seats. The coffee has already been paid for through the beacon.

Anton's computer is also plugged in, and as the two men review their work on Lars' screen the other screen shows continually changing information about the areas through which they drive. Anton – a "foodie" – is prompted to make a dinner reservation at a highly rated restaurant they pass, which he had added to his "hot list" that the system recognizes. With a touch of the screen, Anton has a table for a few nights hence, sends a message to his girlfriend to meet him there, and updates his calendar with the information.

Soon Lars and Anton arrive at their office. Their beacons warned them a couple of minutes in advance, so they've shut down their computers and are ready to get off the bus as soon as it stops. Their bus beacons turn off automatically.

For the trip home later that day, Lars has chosen a different bus. He's learning Chinese, and all the riders on his bus are also students at the same level. They arrange the seats in a circle and practice their conversational skills. As he nears his home, the bus beacon reminds him to take his laundry, which is neatly packaged and placed in a bin by the exit door. He disembarks, and again his beacon turns off automatically. There's no more need for the system to stay in touch with Lars tonight, until he logs back on and chooses his way to get to work for tomorrow.

Techies both, Lars and Anton have an ongoing friendly argument about what to call their bus. Lars calls it the "open source" bus; Anton refers to it as his "majordomo" bus – his chief mobility servant.

Enabling technologies

Social network ridesharing

Lars and others who are learning Chinese ride the same bus and take advantage of the time to work on their studies together. They set up their study group and meeting time via a social networking website. GoLoco is a ridesharing tool that taps into the social networking phenomenon to create a shared travel network. It facilitates the creation of personal transportation networks by transforming a social network into a traveling network. Users can post individual information, view the profiles of others, and then gain access to rides. The social networking aspect of GoLoco is its most unique feature: profiles users create allows for travel by riders with shared interests. Some examples include riders who want to enhance their skills with a foreign language, and so create a group to ride together and practice their conversational abilities. Other riders have created mobile book clubs, with reading assignments completed in advance of the ride and discussion ensuing *en route*. Parents use the service to arrange carpooling for their children's activities. Users can add GoLoco as an application to their Facebook profiles, which enhances the functionality.

Onboard ITC tools and user-configurable space

Lars uses onboard information technology during his morning trip into Amsterdam, which allows him to get some work done. On the trip home, he and the other students configure the space on the bus in a way that meets their group-learning needs. Serving the heavily traveled New York City-Boston route, LimoLiner is a luxury bus service that competes with the airline shuttles and Amtrak's Acela train service. A LimoLiner trip between the two cities takes approximately four hours, with the termini in midtown Manhattan and Boston's Back Bay. The roomy leather seats on the buses are billed as "mini workstations." There are several tables for work meetings, seatside outlets for computers, high-speed wireless Internet access, outlets for mobile phones, and back-of-the-seat videos screen showing televised financial and business news.

The Google Bus transports some 25 percent of the Google workforce in the San Francisco Bay Area to the company's headquarters. The fleet includes 32 shuttle buses, running on biodiesel fuel, that seat as many as 37 passengers each and are equipped with wireless Internet access, which allows Google employees to work while commuting. The buses serve approximately 40 pickup/drop-off locations in more than a dozen localities in six Bay Area counties, traveling more than 4,000 miles each day. Riders receive lateness alerts on their mobile phones or computers. A team of Google transportation specialists monitors the system regularly, examining traffic patterns and mapping out the residences of new hires at the company so that new routes can be plotted that better fit employee needs. Google has created as many as 10 new routes in a three-month period.

Onboard personalized services

Lars leaves his laundry on the bus and picks it up on the bus on his return trip. Services such as Laundry Locker allow customers to drop off laundry at unconventional locations and have it available for pickup at multiple sites according to the customer's choice.

Lessons

One of the great potential advantages of riding the train or the bus rather than commuting by car is that, in principle, it allows commuting time to become productive work time. The difficulty is that inflexible routes and schedules, together with the inadequate working conditions offered by train and bus stops and interiors, often result in this potential advantage going unrealized. Now, networked information technology can help to overcome this barrier – thus turning formerly unproductive commuting time into effective work time, recreational time, and time for shopping and transacting other business.

What draws commuters to private cars is the sense that they enjoy convenience and control by driving themselves to work. The sense of control is all about traveling on a schedule that meets the individual's real or perceived need. The sense of convenience comes from the idea that having one's automobile handy means that things other than getting to and from work directly can be taken care of *en route*.

In particular, ICT can enable public transportation that does not just provide a seat, but provides a convenient, personalized environment for doing whatever you may want to do in transit. This is partly a matter of interior design: a bus can be reconfigured with a conference table for work, or have stationary bicycles for exercise on the way home. It is partly a matter of providing mobile connectivity and services so that these interiors become more functional. And it is partly a matter of employing information technology to manage the complex logistics of such sophisticated, multifunctional combinations of movement systems and personalized spaces.

The open source bus concept is a platform for passengers to provide feedback to the bus system, and thus actively reconfigure the design of the bus to suit their particular needs. This makes the transit system more responsive to everyday passenger needs, which in turn leads to the delivery of highly relevant, high-quality services that address the specific needs of the community. This platform also enables the transit system to deliver service advisories and system information, and to propose and receive feedback on service changes.

The “majordomo” bus is a complementary concept. A bus that “works for” passengers – with onboard services such as the laundry delivery described in this scenario, package delivery, and other options – makes the lives of passengers more convenient and efficient, reduces the number of individual trips passengers might otherwise need to make, and enhances the overall attractiveness of public transportation.

Scenario: personal mobility-on-demand

For a century now, private automobiles have provided personal mobility within cities. But this is increasingly unsustainable as energy use, carbon emissions, and congestion due to the automobile continue to grow. Can connectivity enable a more sustainable alternative?

Recent research has opened up the possibility of advanced mobility-on-demand systems. These systems employ shared-use bicycles, electric scooters, and electric cars. Racks of vehicles are made available at convenient, closely spaced locations around the city. A user simply walks to the nearest rack, swipes a card to pick up a vehicle, travels to the rack nearest the destination, and drops the vehicle off. Use of networking and information technology enables real-time sensing and response to demand, efficient management of the vehicle fleet, and billing for use of the system.

Create multimodal mobility-on-demand systems to serve urban areas, and thus create a clean, convenient, efficient alternative to private automobiles.

She used to wonder when she'd ever find that extra time to spend with her young son, but today Joana's average weekday includes a couple of hours at home that she used to lose to travel. In her city of Lisbon, getting around – not just from work to home and back, but everywhere in the metropolitan area Joana needs to be – is more efficient than ever. And now seven-year-old Bernardo gets to see his mother almost as much as he sees his father Eduardo, who works at home.

Joana works at a shop down by the waterfront, but she lives with her family in the suburban area to the north. The train that takes her to work has always been convenient enough – a brisk and largely enjoyable 10-minute walk from home – but it used to be difficult to get anywhere else. Eduardo and Joana do not own their own car, so a trip to the doctor with Bernardo was once a real chore, taking up considerable time that both parents could ill afford to take from work during the week. Getting groceries from the supermarket was incredibly difficult with public transit: getting there could be arranged, but bringing the purchases home was downright impossible without spending a hefty sum of money on a taxi.

But all that has changed. Today, Lisbon is a city of mobility on demand. The ways in which this has changed the daily life of Joana and Eduardo are significant.

This particular Tuesday, mom and dad enjoy a breakfast with Bernardo before Eduardo walks him to the neighborhood primary school and Joana heads out to the train station for her trip into the city. They discuss what needs to get done that day in addition to their work, and make a plan. Eduardo will pick up Bernardo at the end of the school day and bring him to the dentist. Joana will run a couple of errands downtown during her lunch break, and do the grocery shopping on her way home. Satisfied that everything will run smoothly, they head out for the day, Joana turning right down their street on the way to the train and Eduardo and Bernardo going to the left, towards school.

At noontime, Joana leaves the shop where she works and walks to the end of the block, where she picks up a bicycle by swiping a special card that unlocks it from the rack that holds the 30 that are typically available at this location. She'll have plenty of time to pedal the six blocks to the hospice where she needs to sign some forms and meet briefly with the doctor who heads the team caring for her elderly mother; she'll spend more time with her over the weekend. The bicycle is available to her for an hour at no charge, so when she's done she's able to stop at a nearby vegetarian sandwich shop, have a quick lunch, and make it back to the bike rack with a few minutes to spare.

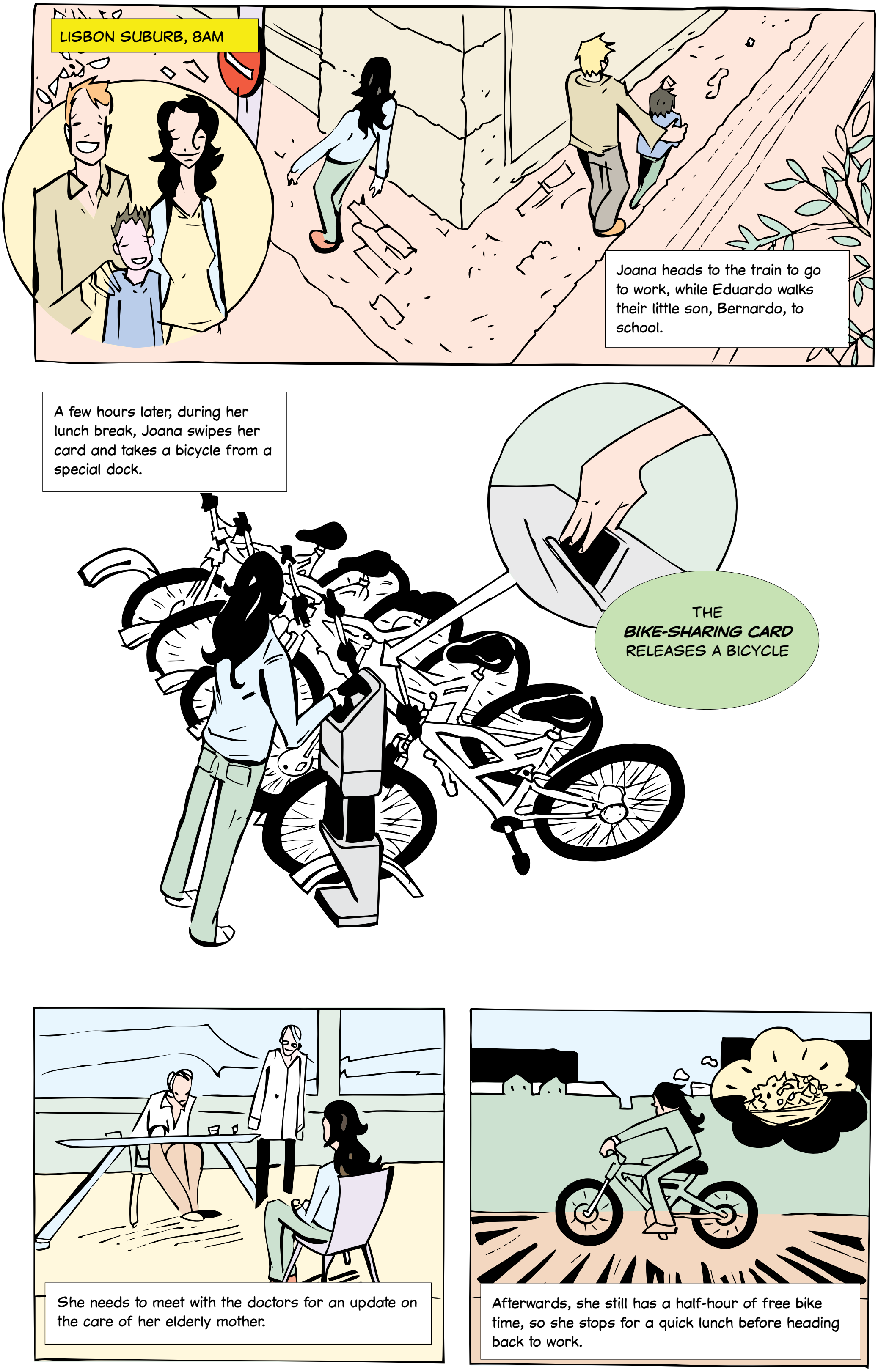
Back home, Eduardo is watching the clock. He wants to leave in plenty of time to get the electric scooter he's reserved and pick up Bernardo at school for the ride to the dentist, about four kilometers away. When it's time, he walks to the same train station Joana uses, swipes his card, and takes a scooter from the rack. He also takes one of the special sidecars specially developed for small children, and attaches it to the scooter. Then he heads to Bernardo's school.

When Bernardo is dismissed from classes, he runs to the curb where his dad is waiting. Strapped into the sidecar, Bernardo is so excited by the ride that he forgets how much he hates going to the dentist.

Once they arrive at the dentist's office, Eduardo waits with Bernardo until his son is called in, and – after checking with the nurse about how much time he has – walks across the street to a café with wireless access. He'll get some work done while Bernardo has his checkup.

A few minutes before Bernardo is done, Eduardo gets a text message on his mobile phone that he should return to the dentist's office. He arrives just as his son comes back to the waiting area, and they head out to the scooter for the trip back to the train station. There, they secure the vehicle and the sidecar and begin the short walk home – stopping for ice cream on the way, once dad has secured a promise from his son that mom will never know.

Meanwhile, Joana leaves work and heads for the train station for the trip back to the suburbs. When she arrives at the station, she walks a few blocks to the supermarket, spends about a half-hour doing her shopping, and heads outside with her packages. There are too many to carry,


LISBON SUBURB, 8AM
Joana heads to the train to go to work, while Eduardo walks their little son, Bernardo, to school.
A few hours later, during her lunch break, Joana swipes her card and takes a bicycle from a special dock.
THE *BIKE-SHARING CARD* RELEASES A BICYCLE
She needs to meet with the doctors for an update on the care of her elderly mother.
Afterwards, she still has a half-hour of free bike time, so she stops for a quick lunch before heading back to work.

4 PM. Eduardo goes to the train station and swipes his card to get a scooter. He'll pick up Bernardo for a dentist ap-pointment.
The ride in the sidecar is so much fun that Bernardo almost forgets where he's going.
Eduardo finds a nearby cafe to get some work done while his son sees the dentist.
On her way back from work, Joana stops by the supermarket to do some shopping.
She loads her packages in a small car in the parking lot and heads home.
Eduardo and Bernardo help with the bags; the car reports its location to the next user, who will pick up the car shortly.
After dinner, there's time for Joana to help Bernardo with his homework, and then father and son engage in a chess match. In the new, intermodal city of Lisbon, mobility systems help families spend more time together.

even if Eduardo met her, so she puts them in the trunk of a small car waiting in the parking lot for the quick trip home. She sends a text message to her husband, and as she turns onto her street she sees her family waiting to help with the packages. Once unloaded, the car is ready for its next use: a family outing to a favorite restaurant a bit outside the city that is inaccessible by public transit. After dinner, the car is dropped off at the end of the family's block in a specially designated space; the next person to use it will have been told just where to find the car.

In the "old" days, all of these daily activities would have meant just enough time left for dinner before Bernardo's bedtime, and no real family time together in the evening. Plus, it would have cost a lot more in terms of energy use and personal financial outlay. Joana would have had to visit the hospice after work and then get to the grocery store considerably later, or put it off until the weekend. But tonight there's plenty of time for Joana to help Bernardo with his homework, Bernardo to tell the epic tale of his dentist visit, and Eduardo to play a game of chess with his son – who is getting closer and closer to beating his dad.

Enabling technologies

One-way, shared-use, vehicles

The great family ending to the story of Joana, Eduardo, and Bernardo would have been impossible without access to the vehicles that took them to the hospice and the dentist. The Smart Cities group at MIT's Media Laboratory, working with partners Sanyang Motors and Taiwan's Industrial Technology Research Institute, has designed the RoboScooter to provide "clean, green mobility for today's crowded cities." Lightweight, folding compactly, and running quietly on an electric motor, the RoboScooter reduces the negative effects of extensive vehicle use, including carbon emissions, air pollution, traffic noise, road congestion, and excessive consumption of parking space. The same MIT group, in cooperation with engineers from General Motors, has designed a two-passenger electric vehicle – the City Car – for city use. Its unique design allows the vehicle to be stacked compactly at subway and bus stations, providing individual mobility to these locations of public transport. The stacks, which are similar to luggage carts available at airports, charge the vehicles.

Joana's bicycle is an ideal means by which to access individual mobility. Following on the heels of a highly successful initiative in Lyon, France, the mayor of Paris introduced Vélib' – a citywide communal bicycle program – in 2007. Rental is free for the first 30 minutes, and rates rise with longer use – encouraging quick rides to get from one place to another. The goal in Paris is to encourage bicycles as an alternative mode of transport throughout the city, with bicycle stations approximately every 900 feet, and realize a 40-percent reduction in automobile traffic by 2020. The program is enhanced by the creation of 125 miles of bike paths in Paris since 2001. There are nearly 20,000 bicycles available at 900 self-service docking stations. Paris anticipates 250,000 Vélib' trips each day, or 91 millions trips a year.

In Barcelona, a community bicycle program known as Bicing began in March 2007. Similar to Vélib', it is widely used to augment rides on public transport and thus represents intermodal use. Signs at Metro stations point to nearby Bicing stations from which users can easily complete trips to shops, schools, and home and find other Bicing stations where bicycles can be dropped off so that the final legs are one-way trips. Bicing works with contactless RFID cards that are swiped at stations to unlock the specially designed bikes.

Expanding to other types of shared-use vehicles, Paris is introducing a program like Vélib' – called Autolib' – that will allow users to pick up and drop off 4,000 sustainable electric cars at 700 locations in and around the city.

Distributed short-term vehicle rental

Joana brings the groceries home, and takes the family to a restaurant for dinner, in a car she has rented just for the time needed to complete these activities – thanks to a car-sharing service. ZipCar is the world's largest car-sharing provider, with more than 180,000 members sharing 5,000 vehicles that, the company estimates, each replaces 15 to 20 privately owned vehicles. Cars are parked in dedicated spaces throughout various cities, and are available for rental by the hour, day, week, or month, at any time of the day or night. Similarly, the U.K.'s Streetcar service makes vehicles available through online or by-phone rentals, and registered users use special cards and PINs to access vehicles.

Lessons

Bicycle-based mobility-on-demand systems have demonstrated their feasibility in Paris and other cities. We are already beginning to see, as well, systems based upon electric cars and scooters. These provide convenient, energy-efficient, carbon-minimal alternatives to the private automobile.

Although the idea of shared-use urban mobility systems has been around for a long time, information technology has recently made it much more practical and interesting. In today's systems, information technology is employed to make the transactions of picking up and dropping off vehicles as quick and easy as possible, to monitor and respond to patterns of demand for vehicles, to keep track of vehicles as they move around the city, and to handle the logistics of getting vehicles to locations where they are needed at times when they are needed.

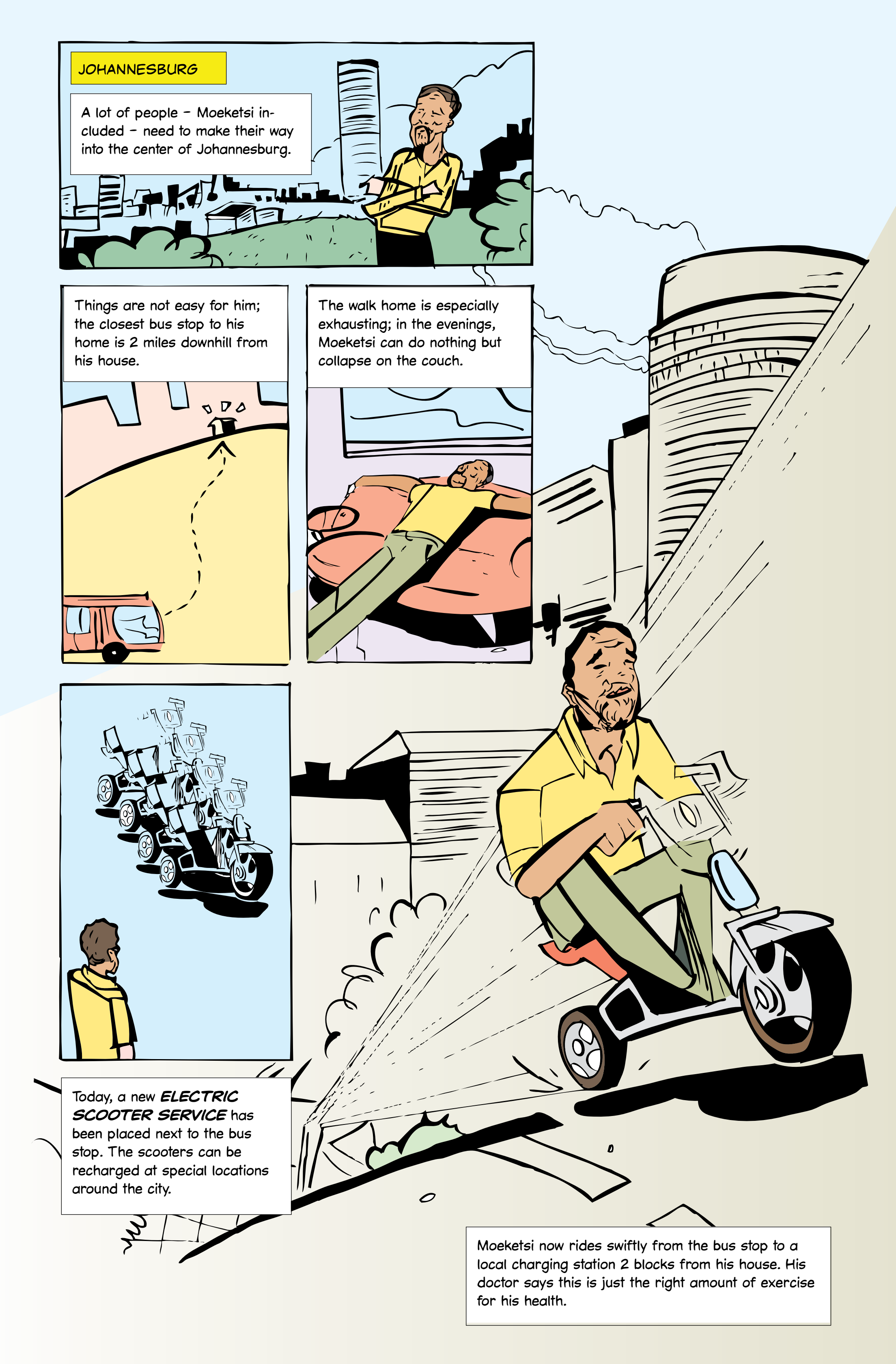
Scenario: solving the "last mile" problem

In public transportation systems, the density of transit stops typically diminishes rapidly with distance out from the center. This leaves a "last mile" problem: the system gets you approximately to your destination, but not quite, thus diminishing the practical effectiveness of public transportation.

Mobility-on-demand systems can now help to solve "last mile" problems by providing racks of vehicles at transit stops. For example, commuters might pick up bicycles or electric cars when they get off the train, use them over night, and then return them the next morning.

Create combinations of public transportation and mobility-on-demand systems to provide comprehensive mobility service in urban areas.

Even in the digital age, with telecommuting at all-time highs, a lot of people still need to make their way each day into the center of Johan-


JOHANNESBURG
A lot of people – Moeketsi included – need to make their way into the center of Johannesburg.
Things are not easy for him; the closest bus stop to his home is 2 miles downhill from his house.
The walk home is especially exhausting; in the evenings, Moeketsi can do nothing but collapse on the couch.
Today, a new ELECTRIC SCOOTER SERVICE has been placed next to the bus stop. The scooters can be recharged at special locations around the city.
Moeketsi now rides swiftly from the bus stop to a local charging station 2 blocks from his house. His doctor says this is just the right amount of exercise for his health.

nesburg. For Moeketsi and Samora, brother and sister, this used to be a challenge. Neither owns a car. Moeketsi lives about two miles over a very high hill from the nearest bus station, and on many days the trip by foot could be so exhausting that he barely felt able to work when he got into the city, or simply would collapse onto the couch at the end of the day when he got home. For Samora, who lives a similar distance from the bus in another part of the metropolitan area, the challenge was that there simply wasn't a convenient and safe place to walk to the station. Plus, her office in the city is quite a distance from the end of the line for her bus from the outskirts of the city, and even off the beaten path of the bus within the city itself. But that was then. This is now.

Today, when Samora commutes, she uses not only the bus but also a special car at both ends of her trip that takes her from the public transit termini. From home, she drives a special, small, two-passenger electric vehicle that charges directly from her home, is left at the bus station to continue charging, and is awaiting her return from work. Once in the city, she grabs a bicycle from the rack outside the bus station, rides to her office, parks the bike outside the building, and takes another one back to the bus at the end of the workday.

Moeketsi, who is older than his sister, suffers a bit from arthritis, so bicycling is a painful option for him. But he has easy access to special electric vehicles at both ends of his trip, and usually opts for a scooter. In his neighborhood, there is a local charging station for scooters, so he doesn't bring his home but leaves it two blocks from his home and walks the rest of the way. His doctor says the exercise is vital to his health.

Thanks to these multimodal options throughout the area, Johannesburg has solved the "last mile" problem – and the thousands of commuters who might otherwise be hard-pressed to get to their jobs efficiently are more than thankful.

Enabling technologies

The enabling technologies for this scenario are the same as those for the preceding scenario, employed in a different way depending upon a city's particular needs.

Lessons

Solving the last mile problem is often crucial to making public transit truly effective. If people must still drive private cars to the ends of transit lines to take advantage of the service, and park those cars in huge garages or lots, the goal of sustainable mobility is only partially addressed.

Shared-use vehicle systems now provide an effective solution to the last mile problem. In principle, these systems are similar to the inner-city mobility-on-demand systems described in an earlier scenario, but they are used in a different way to solve a different mobility problem. They similarly depend upon information technology, though, to provide the necessary tracking and management capabilities.

three/managing homes

A home is a kind of artificial organism. It has four basic input and output streams: energy, physical things (materials and goods in and solid waste out), fresh and waste water, and information. In earlier times, input streams mostly originated near to the home, and waste was also disposed of locally. Now, homes are connected to far-flung infrastructures and to supply and disposal chains that may extend deep into a hinterland, or even globally.

Today, connectivity is opening up the possibility of monitoring and managing these resource and waste streams more effectively, linking waste streams back to input streams so valuable resources can be recycled through the system, and shortening supply and removal chains so that less time and energy are expended in moving things through them. The scenarios that follow in this chapter illustrate some of the emerging possibilities.

Scenario: homes that produce and consume energy

The electric grids that currently serve our cities are centralized and asymmetrical. They serve primarily to distribute electricity from large, central power plants to the homes and businesses that consume that electricity. But connected sustainable cities will be better served by grids that are decentralized and symmetrical.

It is now possible for homes to serve not only as consumers of electricity but also as small-scale producers of electricity, by incorporating solar cells, wind turbines, fuel cells, and plug-in hybrid or battery electric cars that can pump electricity back into the grid. Such homes can be connected by a network that allows transfer of electricity among them, in any direction, as necessary to meet their needs. By analogy with the Internet, the Internet pioneer Robert Metcalfe has called such a system the Enernet.

Construction of something like the Enernet promises to make electric supply systems more redundant and reliable, increase the use of clean, renewable energy sources, and enable buildings to make more efficient use of energy in their daily operation.

Create and operate homes that plug into the Enernet.

It had been a long day at the hospital, and Dr. Alonso is glad to be heading home to his Madrid neighborhood. He rides a communal bicycle to the train station, locks it, and walks downstairs into the station. A few minutes later, he settles comfortably for the short ride to a stop a couple of blocks from his residence, reading the news on his laptop via the train's wi-fi.

Suddenly, Dr. Alonso remembers he has a phone call to return from earlier in the day. He pulls his mobile phone from his pocket, and the screen shows that his GPS is active and sending a signal to his apartment. That means his thermostat will be getting the message that he is on his way – with an estimated time of arrival. It is a very cold winter night, and the good doctor is heartened that his apartment will be warm by the time he walks in, after a day of little heat in that unoccupied space. Of course, he is scheduled to stop at the neighborhood council office next door to his building for a brief meeting before going to his apartment, but no worries: the system is linked to his calendar, so the thermostat will account for the fact that while is near, he isn't coming upstairs right away.

The GPS is also signaling Dr. Alonso's oven and stove to turn on and begin cooking the meal he left that morning. Everything is programmed to be ready about a half-hour after he walks in the door. The system also knows that his daughter will be home a few minutes before him to check on the meal.

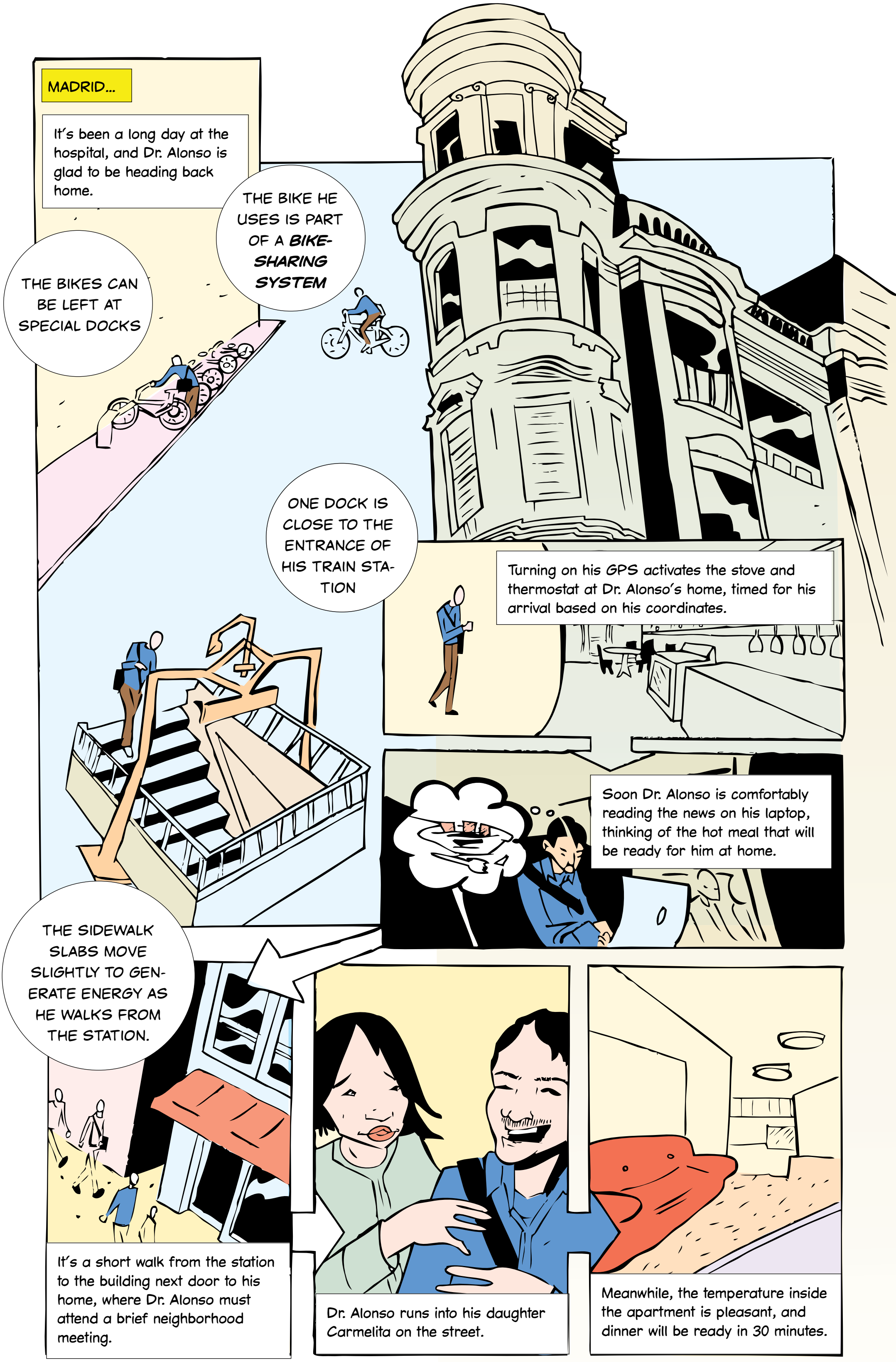
The train arrives at his neighborhood station, and Dr. Alonso makes his way up to the street. It's a three-block walk to his building through busy streets of shops and restaurants. He doesn't mind the crowds, because the more people who walk in his neighborhood, the more money he saves on energy in his building. The sidewalks are designed to move ever so slightly, unnoticed by the walkers but generating energy with each step. Beneath those sidewalks are pipes full of water that will be heated, pumped into the local buildings, and converted to steam for heat. It was this heat that his thermostat is accessing as he nears his front door.

Dr. Alonso attends his meeting at the neighborhood council for a brief half hour, and then heads back outside for the 20-meters walk to his building's front door. He sees his daughter Carmelita coming from the other direction. "Hi, Papi," she calls, running up and giving him a hug. "I'm sorry I didn't get home sooner, but I turned on my GPS so I'm sure the stove adjusted. Nothing will be burned."

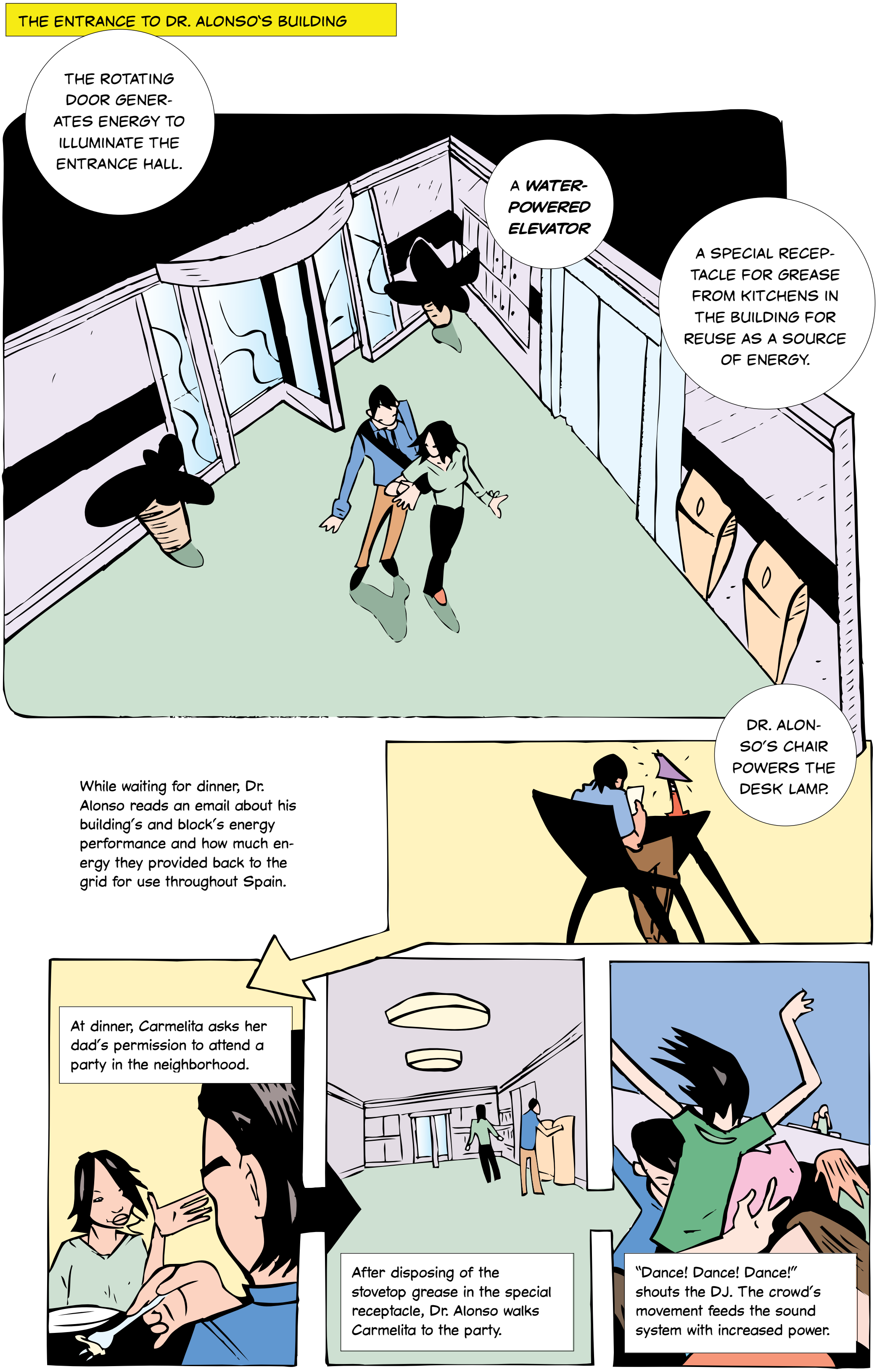
They enter the building together through the revolving door that keeps the cold night air out of the lobby. The low lights in the lobby brighten just enough for them to find their way to the elevator – thanks to the electricity generated by the revolving door itself. Carmelita pushes the elevator button and they hear a whooshing sound. Water stored in a huge tank on the building's roof works its way up and down next to the elevator car, powering each ride between the lobby and the building's three floors of apartments. Other than for the lights in the elevator car, no electricity is used – and the water also serves other needs of the building's residents.

When they enter the apartment, Carmelita rushes to the kitchen to check on the stove and oven. Both dishes look exactly as they should, and dinner will be ready in about 30 minutes. Dr. Alonso, meanwhile, heads for his small office to check his email. The floors they walk on function much like the sidewalk outside. The doctor enters his office and sits in his desk chair, powering a small lamp to come on.

His first email is a day's readout of the neighborhood energy network: how much power was produced, how much was shared within



MADRID...
It's been a long day at the hospital, and Dr. Alonso is glad to be heading back home.
THE BIKE HE USES IS PART OF A ***BIKE-SHARING SYSTEM***
THE BIKES CAN BE LEFT AT SPECIAL DOCKS
ONE DOCK IS CLOSE TO THE ENTRANCE OF HIS TRAIN STA-TION
Turning on his GPS activates the stove and thermostat at Dr. Alonso's home, timed for his arrival based on his coordinates.
Soon Dr. Alonso is comfortably reading the news on his laptop, thinking of the hot meal that will be ready for him at home.
THE SIDEWALK SLABS MOVE SLIGHTLY TO GEN-ERATE ENERGY AS HE WALKS FROM THE STATION.
It's a short walk from the station to the building next door to his home, where Dr. Alonso must attend a brief neighborhood meeting.
Dr. Alonso runs into his daughter Carmelita on the street.
Meanwhile, the temperature inside the apartment is pleasant, and dinner will be ready in 30 minutes.


THE ENTRANCE TO DR. ALONSO'S BUILDING
THE ROTATING DOOR GENERATES ENERGY TO ILLUMINATE THE ENTRANCE HALL.
A *WATER-POWERED ELEVATOR*
A SPECIAL RECEPTACLE FOR GREASE FROM KITCHENS IN THE BUILDING FOR REUSE AS A SOURCE OF ENERGY.
While waiting for dinner, Dr. Alonso reads an email about his building's and block's energy performance and how much energy they provided back to the grid for use throughout Spain.
DR. ALONSO'S CHAIR POWERS THE DESK LAMP.
At dinner, Carmelita asks her dad's permission to attend a party in the neighborhood.
After disposing of the stovetop grease in the special receptacle, Dr. Alonso walks Carmelita to the party.
"Dance! Dance! Dance!" shouts the DJ. The crowd's movement feeds the sound system with increased power.

the building and on his block, and how much was provided back to the grid for use throughout Spain. This includes the productivity of the solar power collectors on the roof and building sides that even store power on days when the sun is hidden in the clouds. As Dr. Alonso reads his last new message, Carmelita calls him in for dinner. As they sit and eat, she says, "Papi, there's a dance tonight at the neighborhood center at 9 PM. I'd like to go, if it's okay?"

"Absolutely," he says. "I'll walk you there. I'd like to get some air."

After dinner, Dr. Alonso reminds Carmelita to pour the grease from the stovetop pan into one of the special bags the city provides. In the lobby, they leave it in a special receptacle. The city will pick it up and converts it to biodiesel for use by Madrid's emergency vehicles.

They head down the street, arriving at the neighborhood center. Dr. Alonso gives Carmelita a peck on the cheek, tells her to have a great time, and heads home. She runs in, heading for the big room where she can already hear the music blasting. Dozens of young people are in the throes of a major dance party.

"Dance! Dance! Dance!" the DJ exhorts the crowd. After all, they more they dance, the more power he has for his audio system.

Enabling technologies

Smart thermostats

Many homes today have so-called "smart" thermostats with timers that can be set to adjust the temperature, but Dr. Alonso's knows when he'll really be home. In the future, via mobile technology, a thermostat will know when an occupant is approaching home and will begin the warmup process, making the time-related adjustment much finer. MIT researchers are exploring a "location-aware" thermostat system that can communicate with a GPS-enabled mobile phone. A next generation of thermostats will employ advanced sensing and control algorithms. For instance, a researcher at Carnegie Mellon University's Robert L. Preger Intelligent Workplace is designing a "smart" thermostat that adjusts a room's temperature according to a human body's "bio-signals," including skin temperature and heart rate. Sensors capture an occupant's need for thermal comfort.

A U.S. Department of Energy pilot equipped homes with meters that receive updates on energy prices every five minutes and devices that can regulate home heating systems. Programmed with ideal temperatures and an acceptable variance in response to price changes, this GridWise system switches the heating off and on in response to the information – saving the households 10 percent annually on electricity bills and reducing peak demand on the energy grid by up to 15 percent.

Cogeneration power plants

Some of the power in Dr. Alonso's building comes from unconventional sources, at least by today's standards. Beddington Zero Energy Development is the largest carbon-neutral "eco-community" in the United Kingdom. The community receives power from a small-scale combined heat and power plant that harnesses the heat that is a byproduct of generating electricity. This heat provides hot water, which is distributed to community buildings via super-insulated pipes. The cogeneration plant is powered by the waste from tree surgery that would otherwise find its way to landfill. When wood is burned, the CO2 released is equal to that absorbed by trees when they grow, hence the carbon neutrality of the fuel.

Smart appliances and devices

Dr. Alonso's mobile phone is in constant contact with appliances in his apartment. With special structured wiring in a building, occupants can control or program many different home devices from a mobile phone with a single command, including thermostats, appliances, lighting, security systems, and so on. Toshiba's "Femininity" line of home network appliances work with cellphone-based remote control that make it possible to set and control air conditioning, lighting, and alarm systems. The foodstuffs management functionality suggests recipes based on family preferences and allows for setting time and oven temperature in advance based on recipes. When appliance servicing is required, the user is informed by the appliance via the network.

Local energy networks

The building Carmelita and Dr. Alonso live in shares whatever energy residents generate both within the building and beyond. In a Local Energy Network, buildings – office or houses – are connected in a cluster via a mini-grid linked to the utility grid via one connection. This enables the exchange of electricity within the cluster and, if there is surplus capacity, it is sold back to the grid. On the larger grid, distributed energy exchanges can maximize effectiveness by creating demand-side management opportunities that address erratic consumption and leveling out the peak demand curve. GridPoint provides a "smart grid platform" that uses information technology to enable an intelligent network of aggregated distributed energy resources and then gives utilities a single Web-based interface that can function like central generation station controls. The system architecture also makes it possible to deploy new, sustainable technologies along with traditional electricity functions to ease and quicken the adoption of renewable energy.

Human-generated energy

Like the sidewalk in Dr. Alonso's neighborhood, power will increasingly be harnessed in the future via dispersed "micro-generation" – including from human movement. For instance, a chair might be fitted with a flywheel to spin from the weight of a body on the seat, powering a dynamo that lights LEDs. A responsive flooring system can be built of blocks that depress slightly from human steps, with that movement slipping blocks against each other and generating power though a dynamo assembled into the floor.

Electricity can even be generated by dancing. The Sustainable Dance Club uses a human-powered floor that captures the micro-generation of electricity in a club atmosphere – power that can be used for a wide variety of applications.

Or, by modifying a revolving door, the human movement and mechanical energy involved in its use can be harnessed and aggregated as micro-generated electricity.

Similarly, movement by large numbers of pedestrians through an occupied space can generate heat. In Stockholm, the movement of

250,000 persons passing through Central Station each day is generating heat that will warm water running through pipes and then be pumped to a new, adjacent building to provide some of the heat needed for interior spaces.

Biodiesel from cooking oil

After dinner, Carmelita recycles the oil used in the meal's preparation. Cooking oil used in homes and restaurants can be converted to biodiesel, an environmentally friendly alternative to petroleum diesel. In San Francisco, these oils are collected from restaurants at no charge and are being converted for use in the city's fleet of vehicles. This also eliminates the expense of clearing clogged pipes caused by these oils being poured down drains.

Storable solar power

The solar panels on Dr. Alonso's building are quite an advance from those typically in use today. They are part of a system that allows for storing solar energy affordably for use when the sun doesn't shine. Inspired by how photosynthesis works in plants, MIT researchers at the Nocera Lab have developed a process by which water can be split into hydrogen and oxygen gases, using the sun's energy, stored, and then recombined inside a fuel cell to create carbon-free electricity. The process transforms solar energy from a daytime-only energy source for most to one that allows for storage simply, inexpensively, and with high efficiency.

Lessons

For decades, the most people could do to make the heating and cooling of their homes more energy-efficient and hence more sustainable were things like insulating walls or installing better storm windows. Today, intelligent controls – powered by information and communication technologies – provide an effective new path to energy efficiency.

A particularly promising direction is to monitor, in fine-grained detail, the activity patterns of a home's occupants (rather than the temperature at a point on a wall, as a thermostat does), and to program heating and cooling systems to respond appropriately to those patterns.

This includes activities outside the home – such as initiating a trip home – as well as those within the walls. The more closely and directly the systems respond to actual, changing human needs, the more effective and efficient they will be.

These technologies are available now. With real-time coordination and location-based technologies, we have real opportunities to implement highly sensitive controls directly related to our energy consumption, with human and pattern recognition and the ability to gauge external and internal climate conditions all built in.

Scenario: homes that intelligently recycle waste

Over time, the supply streams coming into homes and the waste streams coming out have both grown. How can we take advantage of connectivity to manage these streams more efficiently and reduce their magnitudes?

Modern techniques of supply chain management, and of waste handling and recycling, have revolutionized business and industry in recent decades. There are now opportunities to apply the lessons of this at the domestic level. Homes can become electronically managed nodes in supply, removal, and recycling chains.

Employ electronic tagging, sensing, and tracking to facilitate efficient supply to homes and removal from them, and to enable effective recycling.

Friday afternoons are Dr. Alonso's time to take care of things at home. Typically, he puts in only a few hours at the hospital, starting very early in the morning. Arriving home close to 11 AM, he first brings his recycling bin down to the lobby dropoff point for the afternoon's pickup. This is the last Friday of the month, so soon Dr. Alonso will be receiving his recycling reward via email, adding to the total he already has from previous months.

Returning to his apartment, he changes clothes and heads to the roof of his building, where he meets his neighbor Sra. García de Guerrero.

It is their turn to harvest some of the vegetables grown in the aeroponic garden that the tenants share. They carefully divide what they have picked and drop some off at the doors of each of the building's apartments.

Of course, the rooftop garden grows only so much. Dr. Alonso, therefore, owns shares in a local farm on the outskirts of Madrid. Friday afternoon is when his delivery will arrive, and he looks forward to the meals he and his daughter Carmelita will prepare with the fresh produce that will be brought by the non-polluting delivery service the farm employs as part of the annual subscription to the harvest. By the time he and the señora have finished making their own deliveries, he receives a text message on his mobile phone that his share from the farm will be at the front door of his building in five minutes. He heads to the lobby to meet the cargocycle.

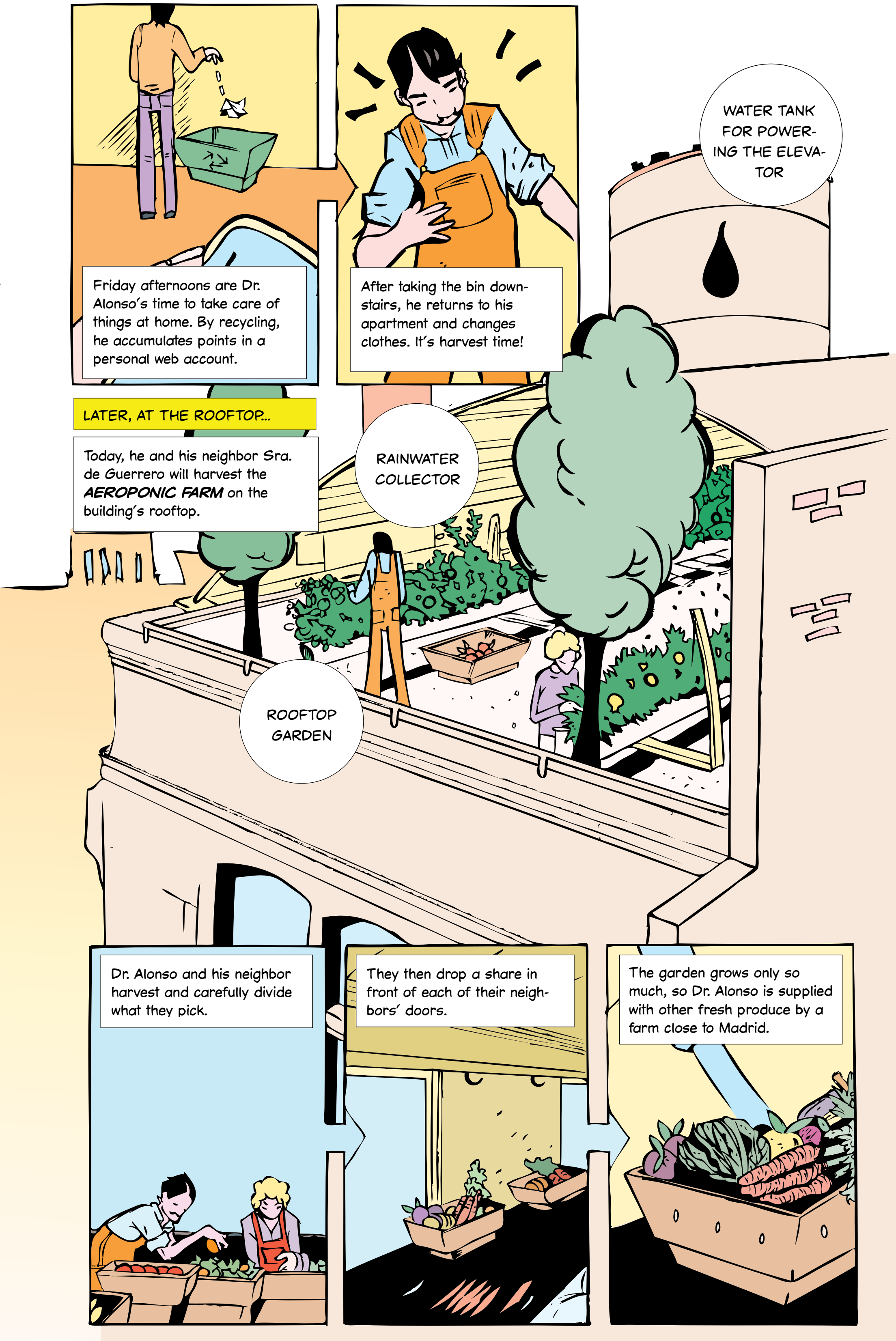
The afternoon will soon turn to evening, and Carmelita is on her way home. Along the way, she picks up a book she ordered online and that has been delivered to a dropoff point she selected earlier that day. She passes right by it on her regular route home from school, so it is very convenient and keeps the cost down – since no delivery truck has had to come specifically to her building.

Once home, Carmelita and Dr. Alonso prepare their evening meal and settle in to watch a movie they had decided to see while talking at breakfast. They log on to the movie service they use, stream the video from a computer, and project it onto one of the walls of their home. It's almost like going to the cinema. Dr. Alonso also receives a reminder on the computer that his subscription to the movie service is set to expire in a few days, but he doesn't worry. He plans to add that week's recycling reward to those he's been saving up and renew his subscription.

Enabling technologies

RFID waste management

Radio Frequency Identification (RFID), which makes it possible to improve the efficiency of waste removal and foster recycling, is key to the rewards program Dr. Alonso participates in with his own recycling. The technology provides a means to automate the collection of waste,


Friday afternoons are Dr. Alonso's time to take care of things at home. By recycling, he accumulates points in a personal web account.
After taking the bin downstairs, he returns to his apartment and changes clothes. It's harvest time!
WATER TANK FOR POWERING THE ELEVATOR
LATER, AT THE ROOFTOP...
Today, he and his neighbor Sra. de Guerrero will harvest the AEROPONIC FARM on the building's rooftop.
RAINWATER COLLECTOR
ROOFTOP GARDEN
Dr. Alonso and his neighbor harvest and carefully divide what they pick.
They then drop a share in front of each of their neighbors' doors.
The garden grows only so much, so Dr. Alonso is supplied with other fresh produce by a farm close to Madrid.


Each Friday, produce is delivered from the farm in a non-polluting cargo-cycle.
Just in time! Dr. Alonso can't wait to prepare a delicious meal with the fresh produce.
"YOUR DE-LIVERY WILL ARRIVE IN 5 MINUTES".
Meanwhile, Dr. Alonso's daughter Carmelita is heading home from school.
A few blocks from home, she stops at a neighborhood de-livery point to pick up a book she ordered online.
LIBR
This is an efficient approach to deliveries because no truck has to stop at her specific building.
When Carmelita arrives home, her dad is cooking. She helps prepare a fresh salad.
AT LAST! A FRESH, TASTY DINNER.
After dinner, Dr. Alonso and Carmelita project a movie on one of the walls. A service ex-piration warning blinks briefly on the computer screen.
The warning doesn't worry Dr. Alonso. Later, he will use his recycling points to renew his subscription to the movie service.

optimize truck use and routes, and (if applicable) streamline billing. Aspropyrgos, a municipality in the greater Athens metropolitan area, uses RFID to make its public garbage collection system more efficient. Data garnered from pickups (time, weight, etc.) allows the local Technical Department to organize collection in ways that provide better service at a lower cost.

In some cities, RFID tags are used for incentive-based recycling. For instance, through Philadelphia's partnership with Recycle Bank, residents are provided a recycling bin fitted with a low-frequency RFID tag that identifies the household. Recycling trucks with scales and RFID readers pick up the recycled material and track how many pounds the household produces monthly. The household then receives Recycle Bank Rewards Dollars that are redeemable at more than 300 retailers.

Local, sustainable agriculture

Dr. Alonso has many of his fruits, vegetables, and herbs delivered from a small farm on the outskirts of Madrid. This is an example of "community supported agriculture," where consumers share some of the risk their local farmers incur by purchasing a subscription or "share" of the produce harvested each week. Considering that in the United States, for instance, it has been argued that the average tomato purchased at a grocery store may have traveled upwards of 1,500 miles to get to the eater's home, the energy savings alone are enormous.

Getting so much food from local sources helps support the concept of "Slow Food," a movement founded to combat "fast food" and, in doing so, preserve the cuisine and associated food plants and seeds, domestic animals, and farming practices within a given region. Key to the movement's principles is that food should be produced cleanly, without harming the environment, animal welfare, or human health, and to make the consumers "co-producers" who are partners in the food production process.

Intra-city delivery services

The grocery delivery to Dr. Alonso's apartment is highly efficient. In France, La Petite Reine specializes in "intra-urban" transport of goods. The company also develops and markets its own innovative freight vehicles. La Petite Reine describes itself as the "ecological" freight carrier, concerned with "quality of life and respect for the environment." The focus is on deliveries within Paris. Vehicles are adapted to the specific "situations of urban hyperdensity" at any given time, with deliveries made – to the greatest degree possible – before rush hours. Specially adapted electric "triporteurs," electric bicycles, and – in particular – "cargocycles" are used whenever possible. Electric-motor cargocycles weigh upwards of 90 percent less than conventional delivery vans, can make deliveries faster than vans, and cost 10 to 20 percent less for customers.

Rooftop aeroponics

Dr. Alonso and his neighbors are growing vegetables and herbs on the roof, thanks to a new technology. In Singapore, food is being grown on residential and commercial rooftops. The technology is an offshoot of hydroponics called aeroponics and aquaponics. The former involves plant roots in lightproof containers; the latter results in ground-level production of fin fish, crustaceans, and mollusks in specially designed containers. One supports the other: the aquaponics technology also produces fish wastes that serve as nutrients for the plants grown with aeroponics. While the concept is still relatively small-scale in Singapore, one idea for the future is a "sky farm" of sunlit bridges between high-rise apartment buildings or office towers where aeroponic vegetable production could be expanded, with building tenants harvesting vegetables for their own use.

Home delivery of digital content

When it's time to watch a movie, Carmelita and Dr. Alonso simply bring it up on their computer. Today, DVDs can be delivered directly to the home by Netflix and other services, and a growing number of movies can be watched on computers without having to receive a physical DVD. More and more services like this are appearing, making it possible to bring content to the home in digital form and eliminating the need for buying or renting physical things that take up space and could ultimately become waste.

On-demand shipping and delivery

Carmelita picks up the book she ordered online with the utmost of convenience. DHL in Germany, in partnership with Deutsche Post, operates more than 1,000 standalone automated booths for package delivery and collection nationwide. Customers can register online with DHL to select whether parcels sent to them from within Germany will be delivered to their homes or offices or to a Packstation. The objective is to have a Packstation within 10 minutes of travel time for every customer in the country. Packstations are open around the clock and target busy professionals who cannot be at home to receive a package or cannot make it to the post office during normal business hours. In addition to convenience, the service promotes sustainability by centralizing pickup and delivery: Deutsche Post trucks make single trips to Packstations rather than traveling to multiple private locations. Text messages sent to mobile devices inform customers when their packages are ready to be delivered to any selected Packstation.

Lessons

In today's cities, the supply of necessities to homes and the removal of waste from them present a massive, daily logistical problem that has long been handled by very traditional means. Industry, though, has pioneered the use of information technology for efficiently managing supply and waste removal chains, and the lessons from this are increasingly applicable in the context of the home.

RFID tagging, just-in-time delivery with GPS coordination, and many other technologies offer ways to achieve more efficient domestic supply, waste removal, and recycling.

Scenario: homes that collect and reuse water

In many parts of the world, urban growth is putting water supply systems under severe stress and threatening the long-term sustainability of cities. Furthermore, water systems and energy systems are *often closely interconnected – as, for example, when desalination to increase water supply increases energy use. How can connectivity help with this pressing problem?*

In small settlements, water supply was typically local – from wells, rivers, or rainwater catchments – and wastewater disposal was local as well. As cities grew, they developed very large-scale water supply and removal networks that handled vast quantities of water, but were often inefficient and wasteful. Now, through utilization of sophisticated digital controls, there is an opportunity to return to systems of small-scale, efficiently managed water supplies and removal loops.

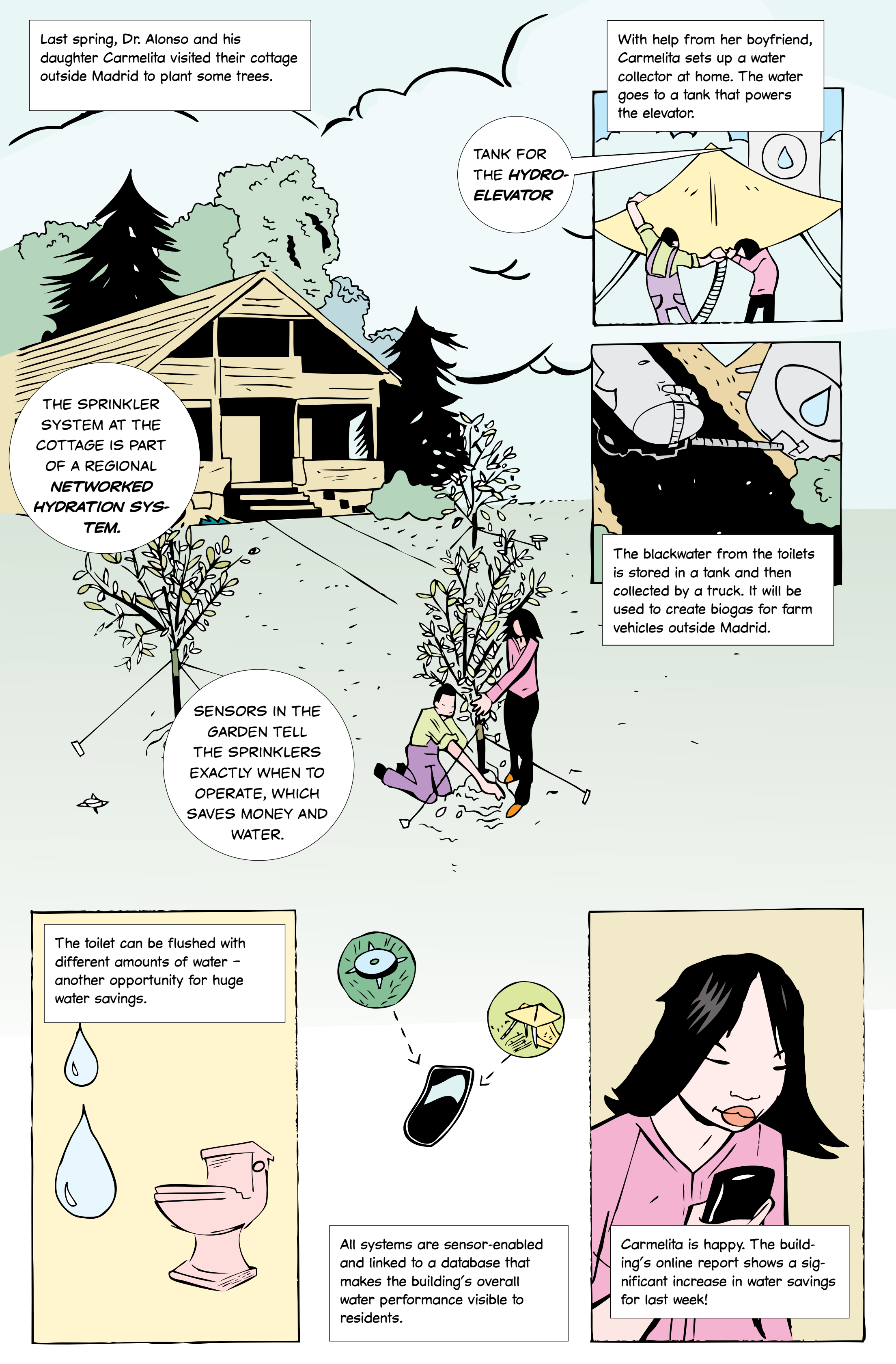
Create buildings that collect water locally, use it efficiently and responsibly, and effectively recycle wastewater – all under digital control.

As mid-summer nears, Dr. Alonso and his daughter Carmelita are getting more and more excited about their annual trip to the small summer cottage they have in the countryside, about 300 kilometers outside Madrid. Early in spring, they traveled to the cottage for a weekend and did some planting, and they look forward to sitting in the beautiful garden and whiling away their holiday time, free from the city's stresses.

It is some three weeks before departure time to the country, and Carmelita is reading her emails. One of them gives her the weekly update on the sprinkler system at the cottage, which is part of a networked hydration system in the region. The sprinklers, rather than turning on and off each day at the same time, work only when needed, based on real data from sensors in the garden. This saves a lot of money, and is similar to the system in the apartment building.

The roof, in addition to its aeroponic vegetable garden, is a green roof, with grass and other foliage planted across most of it. Having such a roof is part of a city program, and Madrid provides a networked hydration system for the entire neighborhood – which comprises quite a number of green roofs. There's never any need to water manually: the system knows when the water is needed.

Conserving water is a big part of what Carmelita focuses her attention on. A hydrology student at the local university, she also chairs



Last spring, Dr. Alonso and his daughter Carmelita visited their cottage outside Madrid to plant some trees.
THE SPRINKLER SYSTEM AT THE COTTAGE IS PART OF A REGIONAL **NETWORKED HYDRATION SYSTEM.**
SENSORS IN THE GARDEN TELL THE SPRINKLERS EXACTLY WHEN TO OPERATE, WHICH SAVES MONEY AND WATER.
With help from her boyfriend, Carmelita sets up a water collector at home. The water goes to a tank that powers the elevator.
TANK FOR THE **HYDRO-ELEVATOR**
The blackwater from the toilets is stored in a tank and then collected by a truck. It will be used to create biogas for farm vehicles outside Madrid.
The toilet can be flushed with different amounts of water – another opportunity for huge water savings.
All systems are sensor-enabled and linked to a database that makes the building's overall water performance visible to residents.
Carmelita is happy. The building's online report shows a significant increase in water savings for last week!

the building association's water conservation committee. She's turned the building into a showcase encompassing everything she can think of to save water. Residents receive real-time information about water consumption and Carmelita aggregates this information as part of a city-wide competition, wherein the buildings that do best at conserving as measured against like buildings have certain fees from the city waived. But there's more.

Amidst the greenery of the roof is a rainwater collector that Carmelita maintains. It collects water during the city's rainy seasons for use throughout the year. Some of the water collected is linked directly to a drip irrigation system that helps keep the garden watered. But also, with the help of her boyfriend, a civil engineer, Carmelita has rigged up the rainwater collector to provide most of the water needed for the building's unique hydro-powered elevator. What started as a school project for Carmelita has gotten a lot of attention throughout Spain, and her email inbox is always full of requests for more information about how she set up the system.

Inside the building, used washwater from sinks and bathtubs is piped into a city reclamation system, where it is filtered and then released into the groundwater table in parks and schoolyards throughout Madrid. In the building's basement, a blackwater tank collects whatever is flushed down the toilets in all the apartments, and as it gets close to full a sensor sends a message to a biogas fermenting company on the outskirts of the city, which dispatches a truck to drain the tank. The blackwater will be used to create biogas that fuels farm vehicles outside Madrid.

Carmelita comes back from a quick trip to the roof and needs to use the bathroom. When she's done, she's faced with a choice: which button to press on the dual-use toilet. One flush uses much less water than the other … yet another opportunity for big savings on water use in the Alonso household.

Enabling technologies

Networked hydration systems

Dr. Alonso's apartment building relies on a network system run by the city to keep the green roof watered and thriving. The system links together all the green roofs in his part of the city into one network. Wireless sensors on the roofs send moisture, temperature, and evaporation data about the plants to a central server, and based on these data automatically turns sprinkler systems on when the water is genuinely needed (rather than on a timer basis). Estimates are that such systems today can save one to two days of watering each week for some plants, which in turn saves millions of dollars in water and energy costs each year.

Water resource use feedback system

Carmelita chairs the committee in her building responsible for monitoring water consumption as part of the city's competition to encourage water conservation. At Oberlin College in Oberlin, Ohio, students in dormitories receive easily interpretable, real-time feedback on water (and electricity) consumption – via an information technology system – as well as information regarding the financial and environmental impact of this consumption. To motivate and empower conservation by students, the College sponsors conservation competitions between dormitories.

Water collection

The elevator in Dr. Alonso's building is powered largely from non-potable rainwater collected on the roof – which is where most rainwater collection systems used today are designed to capture the water. Water can be transported through gutters or other pipes into tanks or cisterns and stored until it is needed. There is typically some sort of filtering device. Uses for non-potable rainwater vary widely; increasingly, rainwater is being used in the developed world to meet potable water needs.

Dr. Alonso's building also collects greywater and blackwater. The greywater is collected in a cistern in the basement that is linked to a larger city system. Greywater comprises all wastewater other than toilet waste and food waste from garbage disposal systems in sinks; this includes water from laundering, dishwashing, and bathing. It can be filtered and then pumped back into the groundwater system. The benefits are not only to reduce demand for water needed for plants and vegetation, but also to reduce urban runoff and pollution.

Blackwater (more commonly referred to as sewage) describes water containing fecal matter and urine. While the process is much more difficult, and the pathogens contained in blackwater must decompose first, blackwater can be released safely into the environment as compost. Blackwater from toilets can be held in conservancy tanks and then transported to biogas fermenters, or toilets could be connected directly to biogas fermenters.

Drip irrigation

Carmelita uses a simple drip irrigation system to help water the roof garden. The simple technology of a special hose helps ensure that the rate of water is precisely what is needed for the garden – nothing more and nothing less.

Lessons

Cities have always depended for their survival upon efficient management of water resources. In the industrial era, cities developed massive, far-flung water collection, storage and distribution, and wastewater removal systems to meet their needs. But this neglected the possibilities of local rainwater collection and local wastewater processing, and entailed many losses and inefficiencies. (In some places, to eliminate competition to the water companies, domestic rainwater tanks were made illegal when the municipal piped water supply system was created.) Today, by providing electronic monitoring and automated management of flows, information technology is enabling the creation of extremely efficient "local loops."

four/managing workplaces

In communities, people tend to experience warmer, more satisfying personal relationships than they do in broader society as a whole. Imagine how much happier and productive we could all be if we could shift more of our work to the "warmer" location and away from the colder, less personal, more dehumanized location of the modern office building or factory.

Such is the idea of the "urban village" – a place where we broaden the local loop concept introduced earlier as a means to organize more sustainable behavior and use sustainable technologies while, simultaneously, capturing the opportunity to work, live, and play in that enhanced location, linking the best of a local community with the infrastructure of the modern work world.

It is possible only in our digital era.

Scenario: connected live-work villages

How can we take advantage of connectivity to create new, more sustainable land-use patterns in cities, and enhance the sense of community?

After the first decades of the industrial revolution, and for most of the 20th century, a typical urban pattern was to separate where people worked and where they lived. Huge office buildings sprung up in central cities, and when possible industrial facilities and huge office buildings were kept away from the leafy green suburbs where factory workers comprising the "middle class" aspired to reside. The result was excessive time spent commuting and lots of wasted energy. Now, with less industry and far more information- and knowledge-related employment – especially in the developed world – the pattern can change to one that is more sustainable and has some welcome social advantages. We can take advantage of the fact that information work can now be supported effectively in residential areas, and is not incompatible with those areas. The challenge is to transform land use patterns into ones that make sense in the new economy, and in doing so eliminate the energy sinkhole of suburb-to-city commuting.

Combine ubiquitous connectivity with live-work dwellings and new urban design principles to create connected live-work urban villages.

Sigrid works for a software development company in Hamburg, and lives in one of the suburbs out near the football stadium. When she first started in the workforce, she commuted every day in her car, first on neighborhood streets and then onto the congested autobahn, eventually finding herself on city streets maneuvering her way through traffic to the office building. She had to be in the office every day, because her boss expected to see her face – even though her job required little interaction with colleagues in person. The whole trip was unpleasant and wasted a lot of time and fuel.

Today, Sigrid's suburb has been transformed from what was once a bedroom community for people who commuted into the city to an "urban village" – and Sigrid can stay home and work much more efficiently. That transformation, thanks in large part to information technology, has made her home and the surrounding community an electronically supported live-work space, with ubiquitous wireless and mobile connections. In many respects, it represents a return to the preindustrial pattern of land use in a postindustrial world.

A typical day for Sigrid is a combination of work and non-work activities on a schedule that corresponds to the particular needs of her job and her family. She awakes each morning and checks her email to see whether anything has happened overnight on her main development project that requires her immediate attention. Her team members are dispersed throughout the world, including in the United States, India, Australia, and the United Kingdom.

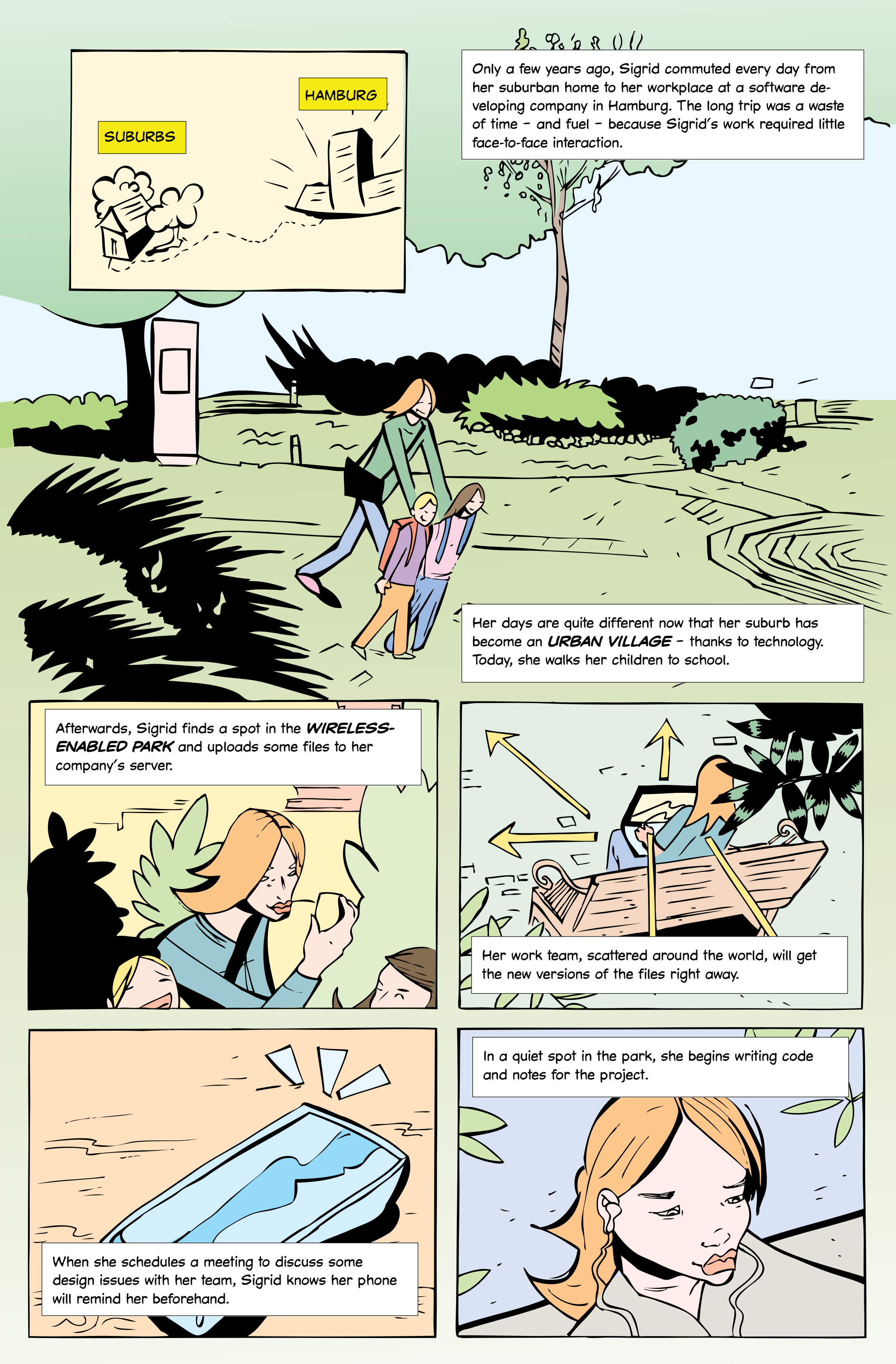
Sigrid likes to walk her two children to school, and always takes her laptop along. After Veronika and Franz enter the school building, Sigrid goes to the park next to the school and logs in to her company's server, where she can access applications that she and her team use throughout the workday. She goes into her calendar to set up a teleconference later that week, and the system automatically sends invitations to the designated invitees. That conference will take place at a "smart work center" in her neighborhood, where she can use the highest-end conferencing capabilities that are prohibitive for home use and, when necessary, rent a small, flexible workspace to augment what she has to use in her living space. When her children were younger, they could come with her to the smart work center and enjoy the childcare offered in the kindergarten. These days, she often picks up some groceries at the small store connected to the center – which eliminates the need for a separate trip to the market when she uses the facility.

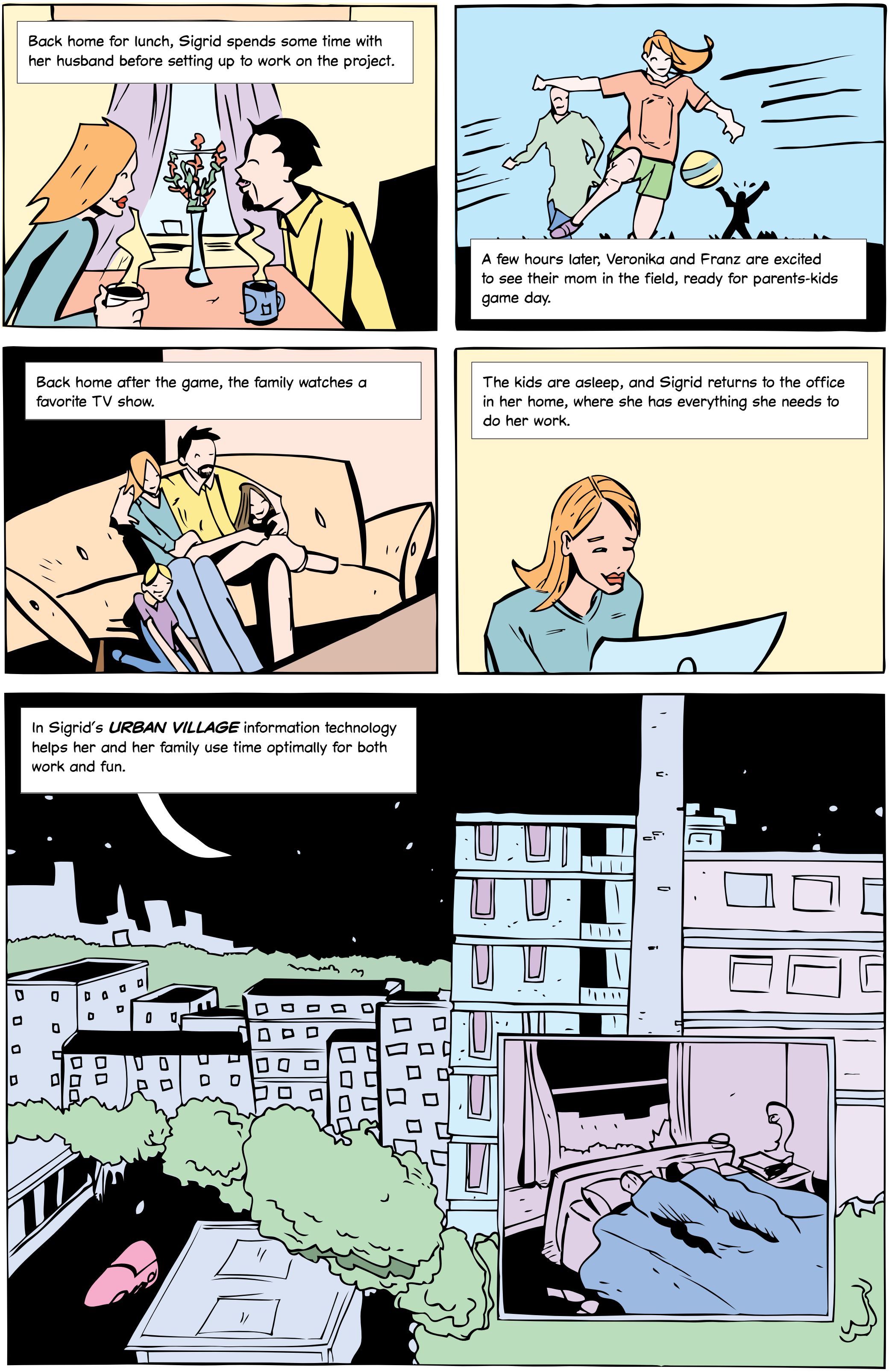
Once a schedule is set for next week's teleconference, Sigrid will receive a reminder on her mobile phone at the appropriate time.

Next, Sigrid heads down the street to her favorite café for an espresso. Again, she uses her laptop, this time checking her email and uploading some files she worked on the night before. Her mobile phone reminds her that she is to talk to Andrew in Minneapolis in 15 minutes, so she heads back to the park. Finding a bench away from others, she pulls out her headset and dials him up over the Internet, and they have a brief conversation about some design issues that are proving to be a challenge.

As lunchtime nears, Sigrid heads back home. She's planning to spend a couple of hours in the workspace she and her husband have created in their house, which is completely wireless and functions as well as any office she's ever worked in. She settles in with her project until it's time to pick up the children at school.

Veronika and Franz run out of the school, excited that this afternoon is their day to play in the parents-kids football game at the park. Although this will take up a couple of hours during what for most people is typical work time, Sigrid isn't worried. She's got all the flexibility she needs to arrange her work time around her life, as long as she gets


SUBURBS
HAMBURG
Only a few years ago, Sigrid commuted every day from her suburban home to her workplace at a software developing company in Hamburg. The long trip was a waste of time – and fuel – because Sigrid's work required little face-to-face interaction.
Her days are quite different now that her suburb has become an URBAN VILLAGE – thanks to technology. Today, she walks her children to school.
Afterwards, Sigrid finds a spot in the WIRELESS-ENABLED PARK and uploads some files to her company's server.
Her work team, scattered around the world, will get the new versions of the files right away.
When she schedules a meeting to discuss some design issues with her team, Sigrid knows her phone will remind her beforehand.
In a quiet spot in the park, she begins writing code and notes for the project.


Back home for lunch, Sigrid spends some time with her husband before setting up to work on the project.
A few hours later, Veronika and Franz are excited to see their mom in the field, ready for parents-kids game day.
Back home after the game, the family watches a favorite TV show.
The kids are asleep, and Sigrid returns to the office in her home, where she has everything she needs to do her work.
In Sigrid's URBAN VILLAGE information technology helps her and her family use time optimally for both work and fun.

the results she and her managers have agreed to in advance. She'll put in some time tonight, after the children are in bed.

After dinner, and when all the homework is done from school, Sigrid, her husband, and the two kids enjoy an hour watching a television show they like, which was broadcast the day before but they saved digitally for later viewing. Then, with the kids fast asleep, Sigrid heads back to her home office. She checks her email, responds to a few issues that have come up during the day, and uploads some notes on the development project for access by the other team members. Then she heads for bed.

In Sigrid's "urban village," enabled by information technology, Sigrid and her neighbors have opportunities for broader social interactions because they are around to have them, and can use their time optimally for both work and family. The entire community benefits.

Enabling technologies

Flexible work time

Key to creating urban villages is for employers to provide flexible work time so that village residents can work on their own schedules, not on arbitrary 9-to-5-type schedules imposed by companies. The "Results Only Work Environment" was first launched in the Minneapolis-St. Paul area in an effort to reduce traffic congestion by encouraging telecommuting and flexible work schedules. By defining a flexible, multimedia work-"place" as the norm rather than the exception, ROWE seeks to change the paradigm so that employees and managers alike are in the office only if and when it is helpful for their work, leaving them free to work and even attend meetings remotely. At Best Buy, where the company headquarters participates in ROWE, employees conduct work using company-provided mobile phones, laptop computers, and Blackberry devices, secure remote Internet links to company networks, and mandatory conference bridges at every meeting for employees to dial in. Most important, employees are evaluated only on their actual contributions to the company, not "face time" – which is a key cultural change that makes the ROWE business model possible.

Ubiquitous wi-fi access

One of the surest ways to keep people working in their urban villages rather than heading into a city office is to provide ubiquitous wi-fi access. It certainly makes a difference for Sigrid. In New York City, workers who want to get out of their homes or offices can take advantage of free, public wireless Internet access around the city, especially in open spaces. One of the best examples is the Bryant Park Wireless Network in midtown Manhattan. Located behind the main New York Public Library, Bryant Park is an oasis of calm and beauty in the middle of one of the world's busiest cities – and it's also a free wi-fi hot spot.

Cloud computing

Sigrid counts on her ability to collaborate with her coworkers who are dispersed throughout the world in their own urban villages. Given that her job is to design complex software systems, this collaboration can be a challenge, but Sigrid relies on a number of Web-based applications that can also be accessed by others. This so-called "cloud computing" concept involves providing information technology-enabled services in a "cloud" to users who require neither expertise with or even control over the infrastructure within which the applications function. Google Apps is an example of this concept: it provides word processing tools, spreadsheet applications, presentation tools, a shared calendaring system, and email addresses all in one place for multiple users. These are stored on remote servers hosted by Google and accessed via a web browser.

Coordination through mobile devices

Sigrid relies heavily on a mobile phone with which she not only makes calls, but also coordinates her schedule. Apple's iPhone provides the ability to coordinate calendars and contacts, receive push emails, quickly browse the web, and use GPS technology to find locations and track progress.

Internet telephony

Sigrid often talks with coworkers via computer-to-computer voice calls. Skype software makes it possible for users to make such calls free of charge. Using Voice-over-Internet Protocol (VOIP), the transmission of the voice is optimized through the Internet or other packet-switched networks.

Virtual meetings over the Web

Whenever necessary, Sigrid and her coworkers rely on web-based teleconferencing and other tools that make it possible for them to hold virtual meetings. Depending on the particular circumstances, these meetings may be over the web via personal computers or via special meeting centers in the communities where the team members live and work. GoToMeeting is an inexpensive tool that makes it possible for up to 15 people to attend virtual meetings online.

Smart work centers

When Sigrid needs the highest-end connectivity possible for a teleconference, she heads to the local smart work center. This is an office center in close proximity to her home that provides workspace that is fully enabled with all the latest information and communication technologies to make remote work the most productive. Cisco has opened just such a center in a residential area just outside Amsterdam.

Lessons

There is a huge difference between the commuter city, with workplaces in the center and bedroom suburbs in the surrounding metropolitan area, and the ICT-enabled urban village. In the latter, ubiquitous connectivity and new digital tools make it possible to live and work in the same place. They also enable a 24-hour community with local services that are both social- and work-related.

The concept of the urban village is simple but very powerful. The basic idea is of a community of people who, because they are able to live and work in the same place, can have richer services and richer social interactions than those that existed when they had to leave their suburbs to travel to their jobs. Within this concept we return to the local loop. The days of the extended loop can be put behind us and we can all benefit from local access to information, knowledge, services, and other people – our neighbors. This promotes sustainability not only with respect to resources but a kind of social sustainability that comes from our ability to remain closer to our families, to childcare and other social care, our schools, and so forth.

And it is all part of a structure that can work only with information and communication technologies.

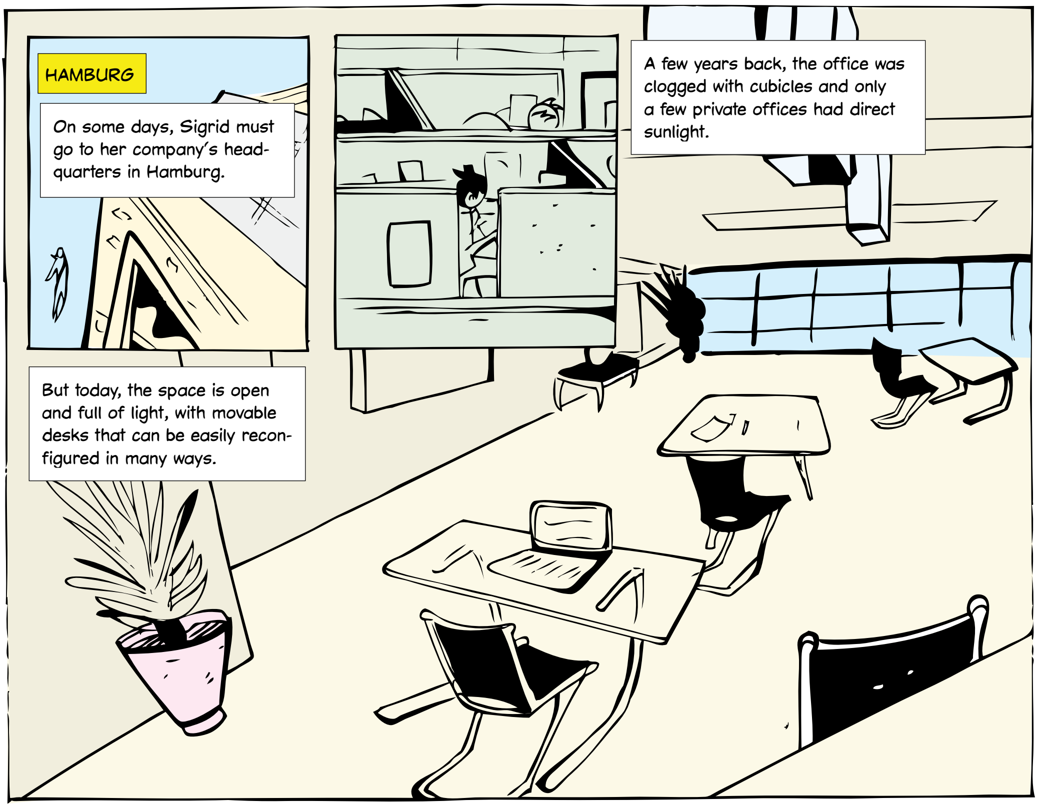
Scenario: intelligent workspaces

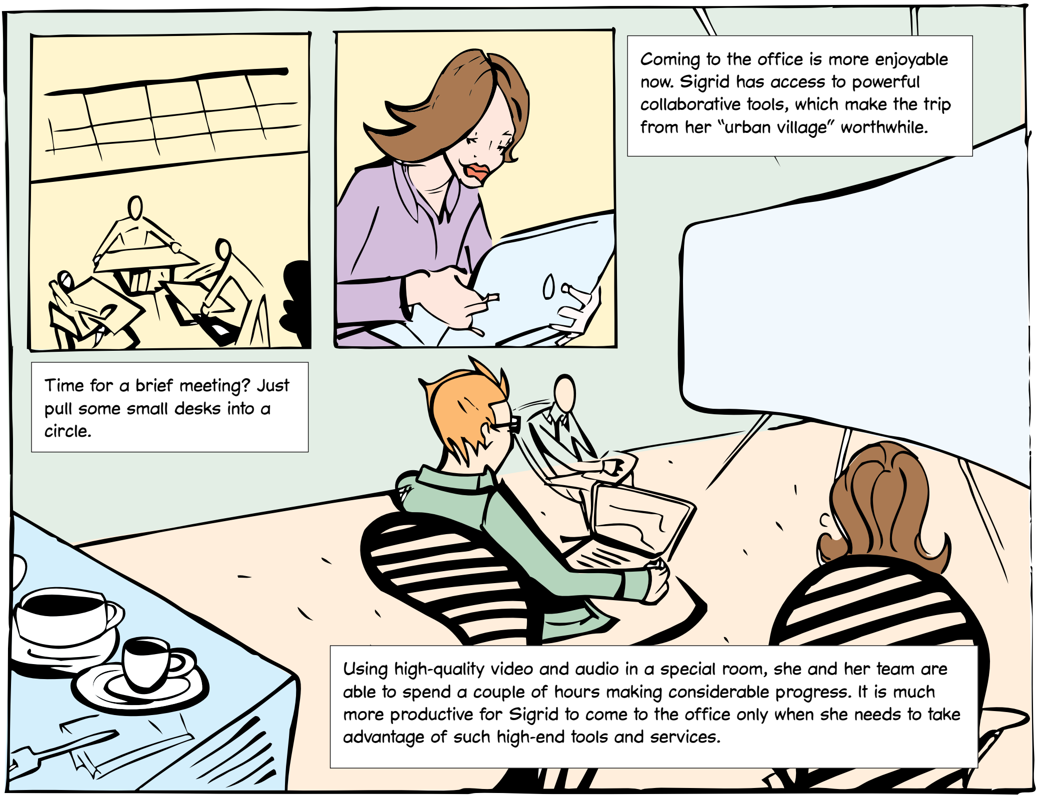
Traditionally, office buildings have consisted mostly of private offices and cubicles. But this no longer makes sense in an era of ubiquitous connectivity and the capacity to make a phone call, or sit down and work on a wirelessly connected laptop, just about anywhere. How can we now take advantage of connectivity to create more functional and efficient office workspaces?

There is nothing less productive than a private office or cubicle that sits dark and empty while its occupant is out on the road, in a conference room or cafeteria, or working with a customer or client at a remote location. At the same time, ubiquitous connectivity now allows effective work away from that office – in meeting rooms, social spaces, cafés, airport lounges, hotel rooms, and so on. Instead of devoting lots of space to private offices, it is now more efficient to create flexible interior landscapes in which office workers can appropriate space, in ad-hoc ways as they need it, for both individual and group work. This allows available space to be used far more intensively, and it makes the organization much more flexible in its responses to changing needs and conditions.

Create more flexible office space that can be reconfigured and reassigned as needed. Emphasize meeting space rather than private work areas. Take full advantage of the information technology tools that enable work anywhere, anytime, and that promote global collaboration.

When Sigrid does visit her company's offices rather than working in her urban village, it looks radically different than when she used to commute on a regular basis. The building itself is the same from the outside – except for the solar panels on the roof – but the inside is a new world.


HAMBURG
On some days, Sigrid must go to her company's headquarters in Hamburg.
A few years back, the office was clogged with cubicles and only a few private offices had direct sunlight.
But today, the space is open and full of light, with movable desks that can be easily reconfigured in many ways.


Coming to the office is more enjoyable now. Sigrid has access to powerful collaborative tools, which make the trip from her "urban village" worthwhile.
Time for a brief meeting? Just pull some small desks into a circle.
Using high-quality video and audio in a special room, she and her team are able to spend a couple of hours making considerable progress. It is much more productive for Sigrid to come to the office only when she needs to take advantage of such high-end tools and services.

The first thing she sees when she walks in is, well, everything. There used to be rows of offices along the outer walls, with many windows shut off except to those who occupied those private offices, and the minimum amount of window accessibility to all the rest of the employees as stipulated by law. The center of the one-floor headquarters comprised several rows of cubicles, with walls just high enough to make it nearly impossible to distinguish any one part of the space from another. Today, though, there are no private offices. The windows draw the light into a big, open space with a variety of workspaces, all of which are easily movable depending on the needs of employees. Time for a brief conference? Pull the small desks around in a circle, or move a larger table to wherever is best. Need some privacy for a phone call? Head into one of the small "booths" located in various places throughout the space. The executives, too, work in this space, and they can see – and be seen – by all.

When Sigrid goes into the headquarters, it's often to take advantage of the somewhat more "powerful" versions of the collaborative tools available to her in her urban village. This particular day, she needs to have a virtual meeting with collaborators working on one of her development projects, and they are widely dispersed around the world. Using high-quality video and audible capabilities installed in the office, she and her collaborators are able to spend a couple of hours making quite a bit of progress. In the "old days," at least a few of these coworkers would have needed to fly to Hamburg from considerably far away, using up a lot of energy resources and time that could be better spent working rather than traveling.

Of course, this is not to say that none of Sigrid's team members ever get on an airplane to attend a work-related meeting. In fact, Sigrid herself is planning just such a trip for a few weeks hence. It is a necessity to meet face-to-face every once in a while. But she is confident that the time she spends traveling will be just as productive as the time she spends in the meeting at her destination. The Hamburg airport is as functional as her urban village: she has a wi-fi connection while she waits for her plane to depart, and can even book a small room for a videoconference if her travel schedule demands it. At minimum, she can always keep in touch with her team and her office when she travels.

Sigrid's trip is to a metropolitan area where several of her team members reside and work from home. Her company has no dedicated office in that city, but Sigrid's team has a standing arrangement to use flexible office space at one of the area's on-demand facilities available without a lease. This minimizes the company's costs and is an environmentally sound way to do business – after all, resources are consumed only when the space is actually in use.

The availability of sensible office space on the road, and the changes at Sigrid's headquarters building, have spelled a big change in Sigrid's overall attitude about work. She used to hate coming into the office every day, finding the environment less than conducive to getting her work done in a way that made sense to her. She longed for the chance to work offsite, on her own schedule. She knew she would be more productive. Today, she is more productive, working most of the time in her urban village. And when she does come into the office, or must travel, it's on her own terms – because she and her team know it's necessary for the work. The space and tools she finds when she arrives makes it all worthwhile.

Enabling technologies

Collective intelligence

In Los Angeles, a group used collective intelligence and a powerful open-source design approach called BIMStorm (for Building Information Modeling) in a collaborative city planning demonstration project for a 60-block area. The team comprised more than 130 architects, planners, and others from 11 countries. The BIMStorm LAX open architecture project was a demonstration of the potential for real-time virtual collaboration in city planning using a central open-source online model. The demonstration employed a variety of different software, virtual imaging, and online meetings so team members could communicate with each other in a central planning system and complete the work. The "storm" part of the concept is to make all needed information for the project available all at once, as soon as it's created, to everyone involved. In such an environment, design occurs in real time in a central online model on which everyone is simultaneously working. A similar approach and tools are key to Sigrid's work.

Collaborative tools

Adobe's Acrobat Connect Pro makes it possible for multiple users to attend virtual meetings – even unscheduled meetings, thanks to always-available personal meeting rooms. These meetings replicate face-to-face meetings with shared screens, whiteboards, chat capabilities, and videoconferencing, all in real time. The tool also is widely used for online classroom education. WebEx is available on several platforms, is available for on-demand web meetings, and also functions with large, scalable online events.

Cisco TelePresence uses high-quality video and audio capabilities to replicate the experience of communicating in person, with visibility of expressions, gestures, and other nuances provided via specialized video monitors designed to make remote participants life-size on screen, in high definition. The tool works with enterprise groupware tools so that it can be available on-demand, with no advance scheduling or IT support required. The interface is via the telephone, which makes it easy for participants to use familiar phone functions such as mute, hold, and conference. HP Halo, which is similar to Cisco TelePresence, runs on a private network specifically designed for video collaboration.

On-demand urban office space

When Sigrid travels to see her team members face to face, they will work at an office they use only when needed – which results in considerable savings. The Cambridge Innovation Center in Massachusetts is an example of this kind of solution, offering flexible "instant on" facilities and office services when needed, replacing the need for companies with a distributed workforce to maintain underused offices in all locations.

Lessons

Old, inflexible designs for workspace result in many inefficiencies. Because space is assigned to individuals, it remains unused when those individuals are away from it. And because it is assigned to specialized purposes, it remains unused when the current need is for something different. However, the combination of ubiquitous connectivity with mobile and portable devices, online data, and sophisticated software tools enables much more flexible and efficient workspace designs.

When data, tools, and connectivity to collaborators are available anywhere and any time, any place potentially becomes a workplace as needed. This allows ad-hoc, temporary appropriation of shared-use space as needed instead of permanent occupancy of private offices or cubicles. And it allows many spaces other than formal workspaces – cafeterias, public circulation and atrium spaces, homes, hotel rooms, airplane seats, outdoor spaces in good weather, and so on – to serve temporarily as workspace as well. This enables more intensive, less wasteful use of available space resources, and it allows an organization to be more flexible.

Architects can take advantage of this new condition by designing landscapes of varied, shared-use space that can be appropriated and used in unplanned patterns as needed. They also need to rethink traditional ideas of net-to-gross ratios in buildings. There is nothing less productive than a locked, dark, private office – even though it would traditionally be counted as part of the net. And there is nothing more productive than an "amenity" space, such as a cafeteria table, that is being used for impromptu brainstorming by a group of engineers with their wirelessly connected laptops.

To manage workspace use under these conditions, and to make people findable, it is useful to have scheduling and tracking tools that are accessible from mobile devices. These enable, for example, the instant discovery and temporary claiming of a meeting space that is available and suitable for a particular purpose right now.

Under these conditions, workspace buildings and campuses don't have rigid floor plans, space assignments, and scheduled patterns of daily use. They become space-on-demand servers.

five/taking personal responsibility

The overwhelming majority of us in the developed world have individual carbon and water footprints well in excess of what the planet can sustain. What can be done, especially since what may be the biggest variable in sustainability is human behavior?

Scenario: knowing your carbon and water footprint

It is difficult to manage our individual carbon and water footprints if we don't know what they are and the effects of our actions on them. How can we take advantage of connectivity to supply the information that will enable us to make better resource-use choices?

It is a simple fact of human existence that we cannot solve our problems without knowing some details about their composition. Those details make it possible for us to put problems in context and begin to see how we might solve them – even if it requires altering our behavior to make different choices. Today, we lack sophisticated information about our individual carbon and water footprints and thus are missing a key part of what we need to solve a very big problem.

Electronically collect and distribute up-to-date, accurate information that enables and promotes sustainable personal choices.

Joe and Tom, both in their late twenties and both single, have been rivals since the beginning of high school. They battled for the varsity quarterback position on the football team. They competed for the affections of the same girl. They tried to outdo each other by having the coolest car.

After high school and college, both men returned to their suburban hometown and ended up working for the same company, where the rivalry continues over everything. However, no one ever expected these two to compete for who could have the most environmentally friendly carbon footprint. But since Joan, the high school girl they vied for (who is still single), moved back to town as the environmental coordinator for the local government, Joe and Tom have become the veritable poster boys for sustainability. Every day, they compete to impress Joan by sticking to their carbon budgets – which they do with clear, reliable information that helps them make the right choices.

These days, Joe and Tom both take public transit to their company office. Only on the weekends might they be found driving around town. A decade ago, a Saturday night for these two might have meant a drag race in souped-up, gas-guzzling monster cars out at the edge of town, but now both men drive highly fuel-efficient cars – and drive them as little as possible. This particular Saturday, Joe is feeling particularly good about driving because his car is sending data to his personal computer showing that he has probably bested Tom in fuel-efficiency for the month. He'll be sure to let Joan know the results when they have dinner next Tuesday.

Tom has spent the last week on one of those so-called "home vacations" – the kind where you have time off from work but don't go away. He's gotten a lot done around the house, gone to a ballgame, and taken in some of the area's nightspots (even getting Joan to join him once). As much as possible, he's taken the bus or train during the week, which has meant some walking as well. His personal travel assistant helped him track the time he spends traveling during the week, but more importantly it was key to monitoring his carbon footprint and energy budget during those travels. Each day he would log on to the website and specify his travel plans, which would generate a carbon, time, and energy budget for each trip. These would then be synchronized with his mobile device, and sensors throughout the area would continually monitor and update how he was doing with his budget. If he went over budget one day, he would adjust his travel plans for the next, to keep within his budget and show Joan what a good conservationist he is.

The week at home has also given Tom a chance to try out a new monitoring system he's installed that lets him know how much electricity he's using. Tom's house is pretty efficient, but the new system will let him see, in real time, just what his usage looks like and whether there are any patterns that suggest he's losing efficiency to particular appliances. He's hoping that he can tell Joan he doesn't need to replace his refrigerator because it's working so well.

Monitor, monitor, monitor ... that's a lot of what both men do. They realize that the key to winning Joan's heart is to show her they're making the right decisions, and that means they need a lot of clear information that is meaningful – and actionable.

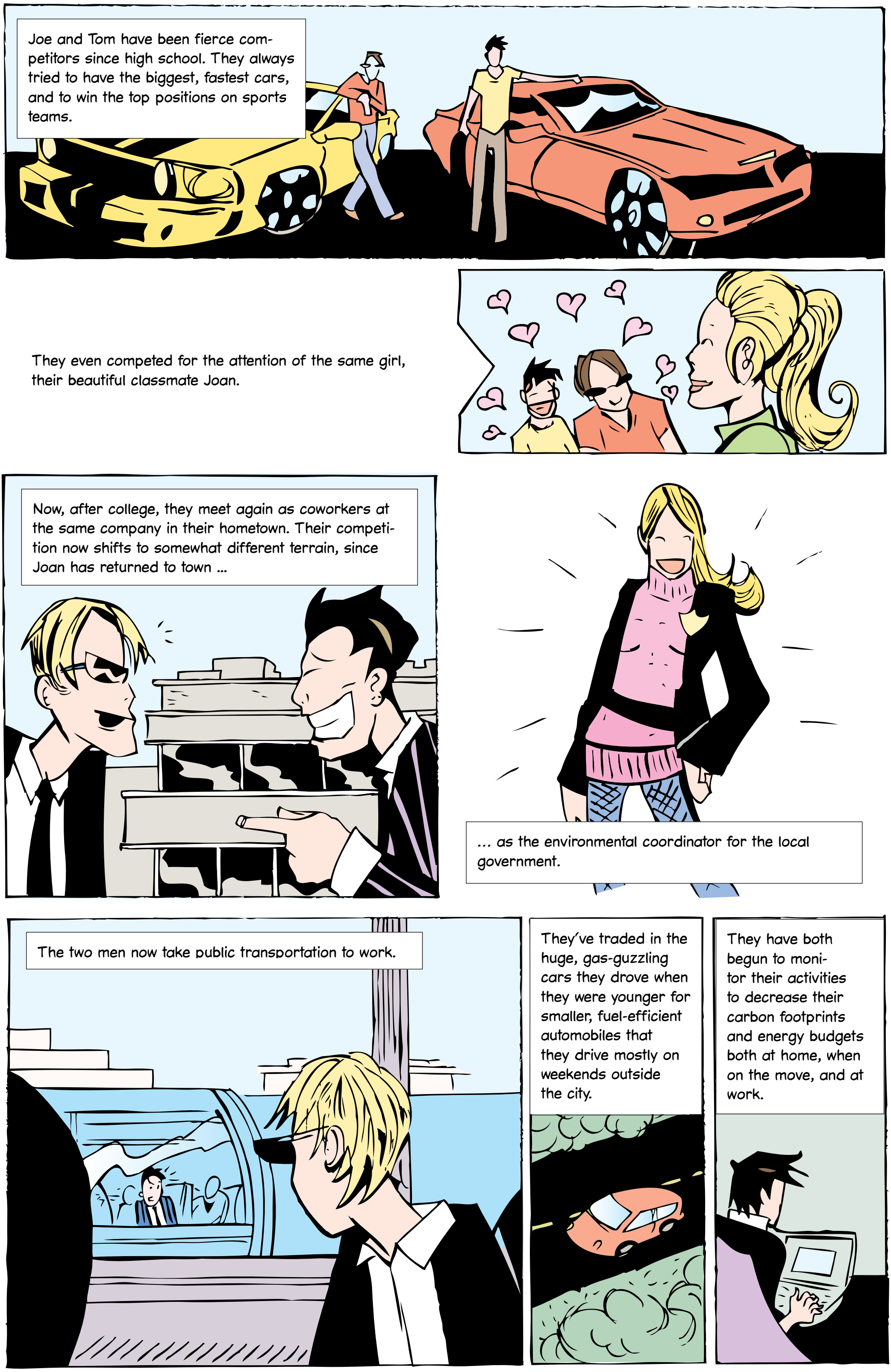
At Fred's house, the latest monitoring he's undertaken involves his water footprint. He has installed a device that tracks his water use in much the same way that his in-home system monitors electricity, and he's using a new hand-held device that allows him to monitor his water use when away from home. Soon he'll be able to boast to Joan that he's taken steps to conserve local water – something he's sure Tom has yet to catch up to.

The competition rages. Joe and Tom will do anything to win Joan the environmentalist's affections. We're not sure Joan benefits, but the earth certainly does.

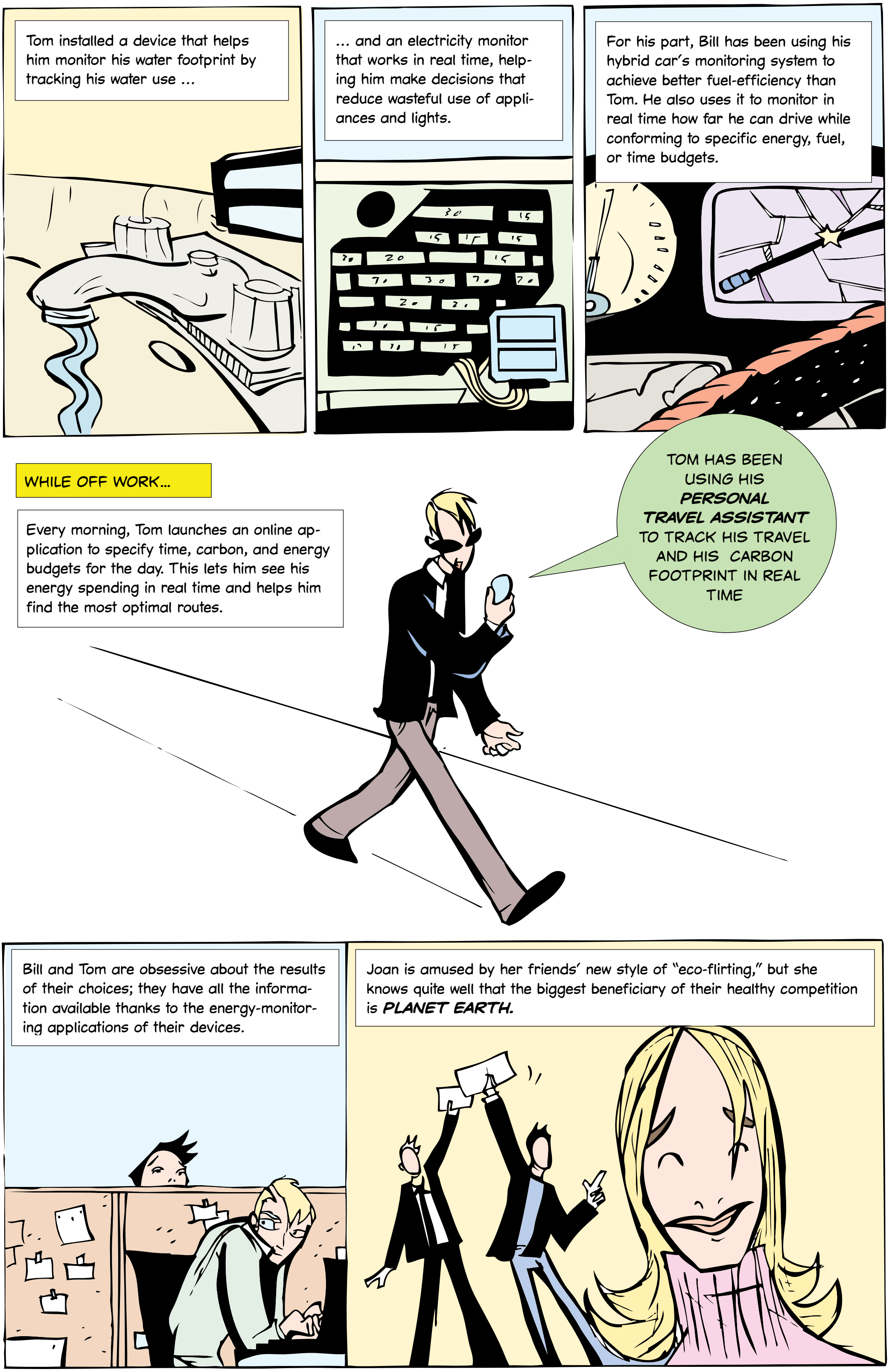
Enabling technologies

In-vehicle environmental performance data

One key to the ongoing competition between Joe and Tom is that they are continually aware of the contribution of their automobiles – when they do drive them – to their individual carbon footprints. For car owners in Japan, Nissan has introduced a function of the telematic in-car navigation system that, in addition to providing real-time traffic information and directions to drivers, also can show drivers their personal fuel consumption trends while they are on the road. The Nissan Eco-Drive software also provides a ranking of each driver's fuel efficiency relative to all owners of the same automobile model, and offers tips for reducing consumption – all of which help make sustainable behavior choices



Joe and Tom have been fierce competitors since high school. They always tried to have the biggest, fastest cars, and to win the top positions on sports teams.
They even competed for the attention of the same girl, their beautiful classmate Joan.
Now, after college, they meet again as coworkers at the same company in their hometown. Their competition now shifts to somewhat different terrain, since Joan has returned to town ...
... as the environmental coordinator for the local government.
The two men now take public transportation to work.
They've traded in the huge, gas-guzzling cars they drove when they were younger for smaller, fuel-efficient automobiles that they drive mostly on weekends outside the city.
They have both begun to monitor their activities to decrease their carbon footprints and energy budgets both at home, when on the move, and at work.



Tom installed a device that helps him monitor his water footprint by tracking his water use ...
... and an electricity monitor that works in real time, helping him make decisions that reduce wasteful use of appliances and lights.
For his part, Bill has been using his hybrid car's monitoring system to achieve better fuel-efficiency than Tom. He also uses it to monitor in real time how far he can drive while conforming to specific energy, fuel, or time budgets.
WHILE OFF WORK...
Every morning, Tom launches an online application to specify time, carbon, and energy budgets for the day. This lets him see his energy spending in real time and helps him find the most optimal routes.
TOM HAS BEEN USING HIS PERSONAL TRAVEL ASSISTANT TO TRACK HIS TRAVEL AND HIS CARBON FOOTPRINT IN REAL TIME
Bill and Tom are obsessive about the results of their choices; they have all the information available thanks to the energy-monitoring applications of their devices.
Joan is amused by her friends' new style of "eco-flirting," but she knows quite well that the biggest beneficiary of their healthy competition is PLANET EARTH.

easy and desirable. Knowledge of real-time fuel economy demonstrably encourages drivers to change their driving habits.

In Toyota's Prius hybrid, a touch-screen display "Energy Monitor" shows energy flow to and from the engine, battery, and regenerative braking system. The monitor not only displays the customary battery charge level, engine status, and outside temperature, but provides a dynamic bar graph of fuel efficiency for the trip, as well as current and accumulated miles-per-gallon data.

Individual carbon and water footprint tracking

Joe and Tom make responsible decisions each day based on information they receive in real time about their individual carbon footprints. This information comes from a variety of sources. Today, the Vulcan Project is working on a virtual carbon footprint map of the United States that will be able to identify sites of significant emissions at a much higher resolution than previously possible, including at individual factories and power plants as well as in neighborhoods and on roadways. When fully operational, the Vulcan Project mapping capabilities will provide real-time data updated hourly. The project is a North American Carbon Program initiative funded by NASA and the U.S. Department of Energy and involves researchers from several universities. The Vulcan Project makes these data available to anyone with an Internet connection, empowering individual citizens and interest groups to develop local sustainability programs based on these data.

Joe and Tom also keep track of their personal water footprints using online tools. Water footprint calculators allow individuals to figure out the water required to produce the goods and services they consume.

Home electricity monitoring

Both Tom and Joe are very conscious of their home electricity use, which they continually monitor with built-in devices in their homes. Kill A Watt is a monitoring tool for home use that helps users assess the efficiency of appliances. The display shows electricity consumption by kilowatt hours, and monitors voltage and line frequency. Electrical expenses can be calculated by any time measure, from day to year. Wattson is a system for the home that uses sensors that attach to cables or fuse boxes in the home, sending information to a transmitter. Output information includes the amount of electricity coming into the home and the cost of electricity in use at any moment.

Data from devices such as Kill A Watt and Wattson can be aggregated by Pachube, a web service wherein people share "real-time environmental data from objects, devices and spaces around the world." The result is a global picture of energy use.

Personal travel assistant

During his week off from work, Tom travels around the metropolitan area, always mindful of his carbon footprint and energy budget. He uses a personal travel assistant to keep track. The Mobility Opportunity Map concept developed at MIT is a mobile object available online, on a mobile phone, or even on a car dashboard, that makes it possible to track carbon, time, and energy budgets while traveling. A user can customize and adjust the budget. Carbon use is calculated based on the number of trips, distance, time, and other variables, according to a personalized schedule, which provides the information a user needs to make activity adjustments throughout the day to promote sustainability.

Lessons

In the end, there are just three fundamental ways to make cities more sustainable. We can increase the supply of the scarce resources cities need; we can, by introducing more efficient processes and other measures, reduce the demand of cities on those resources; and, through changing the behavior of individuals and groups who consume resources, we can try to bring supply and demand into better balance.

Regulation backed by enforcement is one way to change behavior. Governments can, for example, require that new homes have better insulation in order to reduce heating bills, or solar panels in order to reduce their external electricity requirements. An alternative is to provide citizens with data and analysis tools that allow them to keep track of their consumption of energy, water, and so on, and keep track of their production of greenhouse gases and other harmful products, and then to provide economic and other incentives to minimize their consumption and waste product footprints.

This latter strategy is attractive, and promises to be very effective in many contexts. However, it depends upon capabilities to track behavior electronically in real time, analyze and visualize the resulting data, and – via mobile devices and other means – deliver the results of analyses and visualizations directly into contexts where citizens are actually making decisions. Connectivity, together with new software tools, is now providing these capabilities.

six/conclusions

These scenarios have demonstrated some of the practical ways in which ubiquitous connectivity can help us to create and manage sustainable cities. From them, it is possible to draw some general conclusions.

Sensing and data mining

First, connected sustainable cities will depend upon continuous, fine-grained, electronic sensing of the human activities unfolding within them. Tiny, inexpensive sensors and tags of varied kinds are increasingly being mounted on buildings and infrastructure, carried in moving vehicles, integrated with wireless mobile devices such as telephones, and attached to products. These sensors are harvesting enormous streams of data that can be mined, by means of sophisticated software, to generate detailed, real-time pictures of evolving human activities, needs, and demands within the buildings and neighborhoods of cities. This provides the foundation for much more efficient response to mobility, space, environmental control, and other needs than has been possible in the past, and supports the optimal allocation of scarce resources – energy, water, materials, road space, and so on – to meet those needs.

Decentralized action

Ubiquitous networking allows the collection of this information everywhere and distribution of the information to wherever it may be needed – to the edges of networks as well as to central points. Further, distributed memory and processing capabilities enable effective use of this information in local contexts. Thus buildings, vehicles, and mobile individuals can become intelligently aware of the broader contexts in which they operate, can effectively manage their own actions – taking account of sustainability as well as other goals, and can begin to function as actors in larger self-organizing systems that respond to these goals on larger scales.

Electronic actuation

The responsiveness of connected sustainable cities can be achieved through well-informed and coordinated human action, automated actuation of machines and systems, or some combination of the two. For example, the entry of sunlight into a building can be controlled by manual operation of blinds and shutters or by sensor-controlled and electrically actuated blinds and shutters that respond automatically to changing external conditions and interior needs. Similarly, you can switch lights on and off when you enter and exit a room, or you can leave it to sensor-controlled systems to do this automatically. In both the manual and automated cases, resources are conserved by controlling the relevant systems attentively and precisely.

Human attention and cognitive capacity, however, are scarce resources, and generally it isn't effective to burden people with having to think constantly about controlling the systems that surround them. Furthermore, with the ongoing development of actuator technologies, it is becoming increasingly feasible and cost effective, in many contexts, to provide automated actuation. Therefore, in the connected, sustainable buildings and cities of the near future, we can expect to see increasing use of automatically actuated mobility systems, climate control and lighting systems, water and sewer systems, industrial plants, product supply and waste removal systems, appliances, and other elements and surroundings. Buildings and cities will evolve towards the condition of rooted-in-place robots.

Control systems and software

Just as online environments, such as retail sites, are now managed by extremely sophisticated software, so too will be the physical systems of connected buildings and cities. The standalone software that controls individual machines and systems at present will increasingly be combined into larger-scale, more broadly integrated systems. Widely accepted standards will be required to make this possible – much as with the integration of many smaller networks into the Internet.

This integration will enable efficiently coordinated responses to needs across different systems – as, for example, when the linkage of a home thermostat system to the GPS navigation system of an automobile enables the heating system to be turned down automatically when the inhabitants are out and then gradually turned up as they begin to return home.

These integrated systems will enable real-time response to dynamically varying conditions such as traffic and weather. The accumulation of data from their operation will also enable identification of long-term trends and patterns in urban activities for use in planning and design.

Local versus extended loops

Today's cities have very complex supply chains for the water, food, energy, materials, and goods that they require. These supply chains not only extend into their hinterlands, but also globally. There are also complex removal chains for the processing and elimination of waste products. Recycling of resources takes place when supply chains, consumption points, and removal chains are connected to form closed loops. In connected sustainable cities, entire supply and removal loops will be managed efficiently through electronic tracking and control.

Furthermore, there will be opportunities to achieve efficiencies by shortening these loops. In pre-industrial cities, for example, buildings often collected rainwater from their roofs, consumed it on the premises, and then disposed of wastewater locally – a low-tech solution, but one that entailed a very short supply and removal cycle. Similarly, food might be produced in a domestic garden, and then food waste mulched back into the garden. In the industrial era, though, growing cities sought economies of scale by vastly extending supply and removal chains. Thus, water might be transported from reservoirs hundreds of miles away, and then wastewater conveyed to regional-scale sewage treatment plants. Now, in connected sustainable cities, the combination of electronic monitoring, decentralized processing, and automated systems can enable efficient, high-tech versions of short supply and removal cycles – as, for example, in electronically managed, domestic-scale, rainwater collection, water recycling, and garden irrigation and management systems.

A particularly important instance of loop-shortening occurs when connected urban villages replace regional-scale workers. Here, the combination of connectivity with electronic devices and software tools allows the development of live-work dwellings organized into 24-hour neighborhoods. Rather than commuting to work at distant locations every morning and returning in the evening, inhabitants of these urban villages can travel much shorter daily distances – with resulting savings in energy use, carbon emissions, and traffic congestion.

Multitasking and spatial flexibility

In the pre-digital era, urban environments were largely subdivided into places for specialized uses. Homes were for living, offices were for working, cafés were for eating and drinking, and trains and buses were for traveling. When these spaces were not in use as intended, they mostly remained vacant. With the spread of wireless mobile and portable devices, though, the use of space began to become more flexible. Any place where you can sit down and get a wireless connection to your laptop now becomes a potential workplace, for instance.

In combination with architectural and vehicle design that responds appropriately to this new condition, this enables spaces to be more intensively and effectively used. In combination with scheduling and coordination software, it enables spaces to be allocated flexibly to meet needs as they arise. Further, from the perspective of mobile, connected inhabitants of a city, it means that "wasted" time – such as time spent sitting idly on a bus or train – can now be used for working, shopping, socializing, or entertainment. All this adds up to more flexible, effective, and efficient use of the real estate and the hours in the day available to city dwellers.

Informed, responsible choices

In our digitally networked, information-saturated era, ignorance of the consequences can be no excuse for ill-considered actions. It is increasingly possible to keep close track of our energy, water, and carbon footprints so that we can evaluate the sustainability consequences of our daily choices and actions. We have, at our fingertips, the tools and computation power to enable participation in sophisticated new markets, such as personal carbon trading markets. Connected sustainable cities will encourage new forms of personal and group responsibility, and will establish powerful incentives to meet those responsibilities.

Like individuals, government institutions and businesses – be they small or medium enterprises, or large corporations – also have responsible choices to make. The success of a connected sustainable city depends on coordinated policy and action in the development and introduction of information and communication technologies.

Businesses must commit to changes in how they work and to adopting sustainable technologies to use for that work. This is not only about the large-scale, systematic use of, say, renewable energy, but also about daily operational choices, from using recycled paper to replacing vehicle fleets with hybrid cars. Businesses must also promote a culture change that encourages remote work and virtual office solutions, as well as social networking within offices, without any of the drawbacks or penalties that often exist today for employees who engage in these activities.

Governments at every level (federal, regional, municipal) need to adopt policies and regulations that promote such choices. Worldwide organizations also play a crucial role, but local authorities – because they are in direct contact with citizens in the local loop – are especially important in fostering the development of connected sustainable cities and social sustainability.

The next generation of ICT tools

New tools and applications are becoming available that make it less-expensive, easier, and more effective than ever to coordinate collective action among people that can promote sustainable development and behavior. Often referred to as Web 2.0, these technologies allow easier knowledge- and information-sharing, both crucial to the development of connected sustainable cities. On these emerging collaborative platforms, people can share and capitalize on lessons learned from best practices around the world. These types of tools can advance the rise of a new bottom-up culture of decisonmaking and promote civic engagement on topics of great importance, encouraging people to get involved and take action locally and on a global level.

Advances in how the global ICT network will work in the future will fuel the changes. One is Internet Protocol version 6 (IPv6), which provides much more space for Internet addresses than is currently available. This enables far more things to be connected to the Internet and allows tremendous traffic routing flexibility. Another is the "Internet of Things," a concept in which all of the 50 to 100 billion objects of daily life (from a can of soda in your refrigerator to a city bus on the other side of the world) would have radio-frequency identification tags that make it possible for them to be managed by computers.

Education and new culture

A new dynamic of participatory citizenship dynamics can be leveraged on the emerging technologies described above. But it will not happen simply by putting the technological tools in people's hands. We also need to raise the consciousness about the issues and about the role individuals and communities must play. This will require a new literacy about connected sustainable development, one that shows people worldwide that the complex challenges we face must be confronted by us both as individuals and collectively. Education will be crucial to creating a new culture of sustainability based on responsible choices.

Inventing sustainable urban futures

Connected sustainable cities will not emerge automatically. We will have to use our imaginations to invent them, and we will need to be determined and resourceful in pursuing implementation. This book, we hope, has provided some starting points for the necessary debates about goals and priorities, and for the formulation and evaluation of technology, policy, planning, and design options.

The development of connected sustainable cities will, of necessity, be a broadly based, multidisciplinary enterprise. It will require researchers and technology companies to create and make available the necessary devices, systems, and software. It will demand the rethinking, by architects and urban designers, of some fundamental assumptions about the organization and use of space. It will need the clever integration of information systems with urban infrastructures of all kinds – mobility systems, energy systems, water systems, and waste removal and recycling systems. And it will depend upon the development of appropriate policy frameworks and business models.

The challenges are great, but there is no realistic alternative to confronting them. Cities will continue to grow in the 21st century, and the aspirations of their inhabitants will continue to rise, but the resources available to sustain them will be limited. To keep supply and demand in appropriate balance while preserving the quality of urban life and social equity, we must harness information, intelligence, and connectivity to create systems and patterns of urban life that manage those resources in the most efficient and responsible ways.

index of proper names

This index of proper names includes web links relevant to the scenarios and enabling technologies presented in this book. Boldface page numbers indicate material in illustrations. (All websites accessed October 29, 2008.)

A

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other relevant web links

biodiesel from cooking oil
www.sfgreasecycle.org/

citizen reporting
www.everyblock.com
www.fixmystreet.com

congestion pricing
www.lta.gov.sg/motoring_matters/index_motoring_erp.htm
www.tfl.gov.uk/roadusers/congestioncharging/
www.vv.se/templates/page3____17154.aspx

drip irrigation
cahe.nmsu.edu/aes/farm/drip-irrigation.html

dynamic pricing for public parking
robotics.eecs.berkeley.edu/~pister/SmartDust/

www.dustnetworks.com/
www.streetlinenetworks.com/site/index.php

human-generated energy
sap.mit.edu/resources/portfolio/crowd_farm/
www.fluxxlab.com/projects/
www.inhabitat.com/2008/01/13/hot-swedes-will-use-body-heat-to-heat-train-station/

local energy networks
www.citizenre.com/web/index.php?p=activities
www.qurrent.com/ENG/prodLocalEnergyNetworks.aspx

local, sustainable agriculture
http://www.sare.org/csa/

networked hydration systems
nicta.com.au/research/projects/water_information_networks

RFID waste management
www.ti.com/rfid/shtml/apps-waste-management.shtml

rooftop aeroponics
www.cityfarmer.org/singaporeroof.html

storable solar power
web.mit.edu/chemistry/dgn/www/research/e_conversion.html

water collection

www.greywater.com
www.nsf.org/consumer/rainwater_collection/index.asp?program=WaterTre

water footprint tracking
http://www.waterfootprint.org/index.php?page=cal/waterfootprintcalculator_indv_ext
http://www.h2oconserve.org/home.php?pd=index

water resource use feedback system
www.oberlin.edu/dormenergy/news.htm

(All websites accessed October 29, 2008.)

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