Switching Gears

Enabling Access to Sustainable Urban Mobility

SUSTAINABLE ENERGY FOR ALL

CONTENTS

LIST OF FIGURES AND TABLES

Figures

Tables

LIST OF CASE STUDIES AND BREAKOUT BOXES

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FOREWORD

The nexus between energy and mobility has never been more pertinent. Fossil-fuel based transport is contributing to the ongoing climate crisis and to the poor air quality observed in approximately 90 percent of cities worldwide. Meanwhile, there are millions of people who lack access to energy or mobility services.

Several Sustainable Development Goals (SDGs) and the Paris Agreement emissions targets hinge on a rapid evolution of the transport sector and how it is powered. Yet opportunities for securing sustainable urban mobility for all in lock-step with the transport sector's need to decarbonize remain underexplored.

Switching Gears: Enabling Access to Sustainable Urban Mobility addresses this oversight. It explores how sustainable energy access and low-carbon mobility can be developed together to deliver new sustainable services for those previously underserved.

For those at the base of the pyramid, access to any type of energy or mobility services, let alone sustainable ones, is currently often out of reach. However, as this scoping report makes clear, there are untapped solutions that could arise from a holistic analysis of both transport and energy sectors. Now is the time to link these sectors.

Switching Gears: Enabling Access to Sustainable Urban Mobility makes the case for what can be achieved with closer partnerships, torn-down silos, and innovative financing to enable access to sustainable urban mobility.

Fast-growing, small-to-medium-sized cities are a focus of this report since these are places that need innovation to create efficient transport and equitable mobility while avoiding a future of gridlock. Collaboration, forward-thinking and technology can support this effort and ensure mobility projects get the political and financial support they need.

Using geographic information systems and data to map mobility demand, stakeholders from the energy and mobility sectors can work with urban planners to target solutions for different areas and population subsets.

Public transport, walking and cycling, together with adequate pricing of car usage, can help deliver sustainable urban mobility to citizens of the cities evaluated in this report.

Electrification is at a welcome tipping point pushing the sustainable energy and mobility sectors closer together. Vehicle electrification is often used to refer to electric passenger vehicles, but *Switching Gears: Enabling Access to Sustainable Urban Mobility* shows that electric two- and three-wheelers and electric minibuses can provide significant efficiency and accessibility gains. Scaling up these electric vehicle options calls for reliable and accessible power supplies, whether on-grid, mini-grid or by developing remote solar photovoltaics.

Of course, electrifying transport is not always the answer. Through mobility demand-side mapping, hot spots and high-impact locations can be identified where services can be provided closer to the source of demand, reducing people's travel needs altogether. This report highlights how this is already being put into practice through innovations like demand-side mapping used to determine where the highest demand is for pharmaceuticals in South Africa and electric drones delivering vaccines in Malawi.

Turning concepts and ideas into reality is what this scoping report set out to do, and it has identified not only what the solutions can be, how to implement them and how to finance them, but also where the best places are to start. Now that the puzzle pieces are on the table, I urge you to use this report as a springboard to help put different options together.

Sincerely,

Glenn Pearce-Oroz
Director of Policy and Programs

EXECUTIVE SUMMARY

Energy and mobility are critical sectors for achieving the Sustainable Development Goals (SDGs). Mobility impacts people's social and economic opportunities, making it a key sector for helping reduce inequalities. Meanwhile, many modern mobility services are dependent on reliable access to energy. Given that the transport sector is the fastest growing emitter of global Greenhouse Gas (GHG) emissions, the challenge the world faces is to provide access to energy and mobility while avoiding an increase in local and global pollutants.

SEforALL's new report – *Switching Gears: Enabling Access to Sustainable Urban Mobility* – brings together the energy and mobility sectors to explore pathways that enable us to achieve the SDGs.

This scoping report is the first of its kind to examine the baseline and potential for improving energy and mobility access for the world's most underserved people: those at the base of the pyramid. For these people, access to any energy or mobility services, let alone sustainable ones, are often out of reach; however, there are untapped solutions that can be achieved through a holistic evaluation of energy and transport sectors.

This report is the accumulation of data, analysis and interviews assessing the status of the energy-mobility nexus, and how to scale sustainable urban mobility access as rapidly as possible. It identifies 19 countries around the world – encompassing 13 in Sub-Saharan Africa as well as Bolivia, Honduras, India, Indonesia, Nepal, and Philippines – and an accompanying set of 260 fast-growing small-to-medium-sized cities where the highest impact might be anticipated.

The criteria for identifying locations with high potential to improve access to sustainable urban mobility include:

- Cities with a population between 300,000-1,000,000 (2018 data)
- Population growth expected at an average of more than 50 percent by 2030
- Locations with more than 5 percent of the population at the base of the pyramid
- Locations not in conflict areas
- Locations ranking higher than 2 on the Good Governance Index[1]

The countries and cities identified have a strong potential for energy efficiency and renewable energy coupled with mobility solutions. *Switching Gears: Enabling Access to Sustainable Urban Mobility* groups the cities to highlight similarities in challenges and potential for developing sustainable solutions, and highlights the top 20 cities that best fit the criteria for each group.

City type 1: Efficiency Opportunists

The first group includes the fastest growing cities in the world by 2030, and it is perhaps no surprise that 19 of the top 20 cities here are found in India, with Gwagwalada, Nigeria, completing the list. India accounts for 121 out of a list of 260 cities. This indicates that India would be a good target to support early-intervention and tracking tools for air quality, energy efficiency, and spatial planning to incorporate the energy and land-use sector.

City type 2: Digital Disruptors

The second group looks at populations that have the opportunity to gain efficiency through their significant access to communication and digital technologies. Furthermore, these cities are positioned to derive additional co-benefits of sustainable energy and improved mobility, such as improving harmful air quality and unsafe roads. This city group is the most diverse top 20 of all four groupings with a range of countries and cities ranked, from Tamale, Ghana to Pokhara, Nepal. These 20 locations share a common denominator of having high access to communication technologies and have the opportunity to use digital tools to access sustainable urban mobility.

City type 3: Electric Vehicle Leapfroggers

The third group includes locations where electric mobility is best deployed. Windhoek, Namibia is at the top of the list, with cities in the Philippines taking up the other 19 spots. In these locations the road infrastructure is considered relatively good, and the share of renewables in the electricity sector is high, both key requirements for electric mobility.

City type 4: Renewable Drivers

The fourth group focuses on renewable energy opportunities, looking at the full range of fuels available to drive sustainable transport and ranked cities based on their CO_2 emissions from transport relative to GDP. The list finds three African countries topping the list: Nigeria, Ethiopia and Zambia. This city group includes those locations that have renewable energy resources available to support access to sustainable urban mobility, biofuels, hydrogen, and electricity generated from renewable sources.

Three Solutions for Delivering Sustainable Mobility in Cities

We need the services and access that mobility provides: access to quality food, health care, employment, etc. Linking and mapping the demand for energy and mobility can support the development and implementation of sustainable mobility solutions, providing underserved groups with new mobility access. Three solutions show great potential for making this happen. These three solutions are not distinct, but operate across a shared spectrum, and in certain aspects there is more potential for overlap than others. The key is to find these areas and to utilize them as enablers of sustainable urban mobility.

Solution 1: Integrated energy, land-use, and mobility planning

Tying together land-use and transport planning has long been a worthwhile action of sustainable transport practitioners. Land-use planning can promote compact cities and enable public transport that better uses scarce land. In this context, public transport in the form of buses, while not a new technology or innovation, can be essential for transforming smaller cities with scant budgets into thriving cities. Integration of energy planning with transport planning and land use would allow for increased deployment of renewable energy and electric vehicles and provide services through energy supply that can improve demand-side management while reducing the need for travel. A side topic of this is Mobility as a Service (MaaS), which enables a new type of thinking that can be action oriented to deliver sustainable urban mobility as a service.

Planning options include addressing the massive informal mobility sector in the 19 countries and 260 cities in this report where public transport systems are often run informally. Finding ways to finance more sustainable systems will require new conversations, some of which have already begun.

Another option includes developing Sustainable Urban Mobility Plans (SUMPs), or on a national level, National Urban Mobility Programs (NUMPs), to leverage integrated land-use and transport planning approaches.

While this solution can and should be successfully applied to the different groups of cities identified, the first city type, *Efficiency Opportunists*, would particularly profit from integrated energy, land-use, and mobility planning due to fast growth projections.

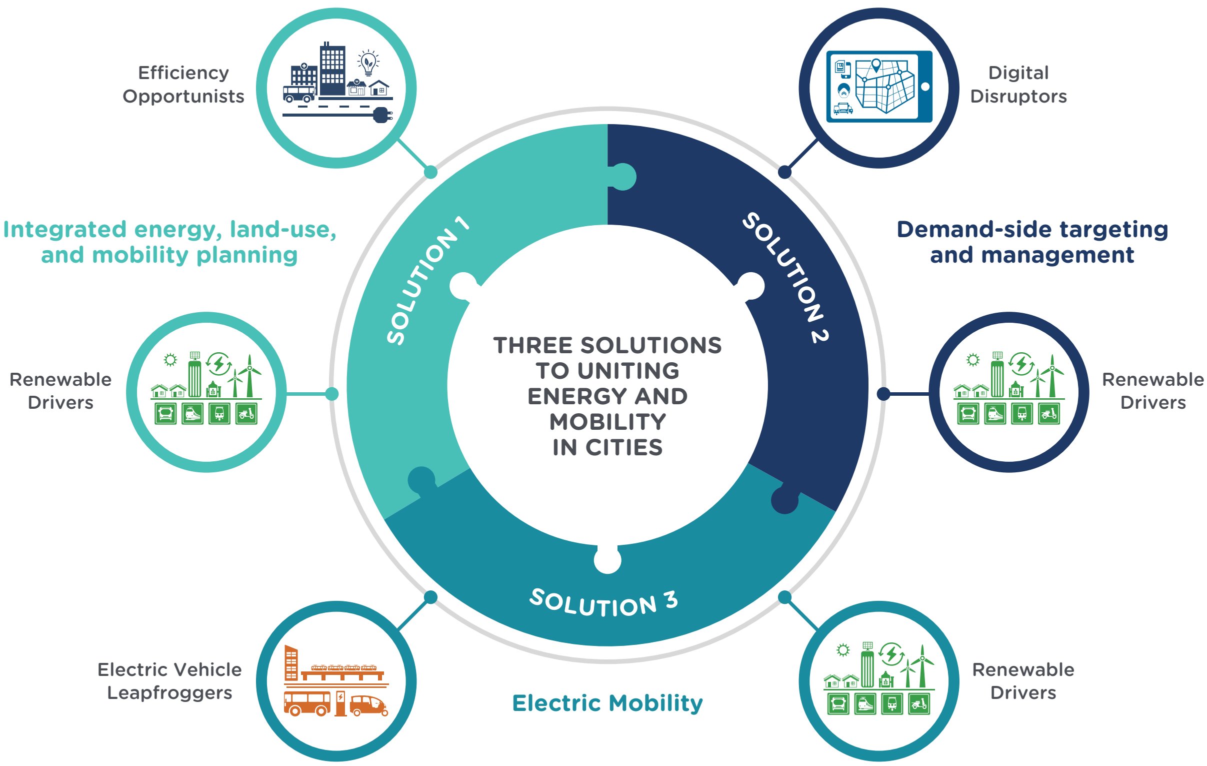
Solution 2: Demand-side targeting and management

From a sustainable transport point of view, a useful tool is the traditional *Avoid/Shift/Improve* approach: where you first *Avoid* unnecessary travel by providing the services closer to the source of demand through, for example, integrated land-use and transport planning; then *Shift* to more efficient modes of transportation, from individual car use to, for example, mass transit options such as buses; and then *Improve* the efficiency and lower the carbon intensity of the fuel used, be it gasoline, diesel, biofuel, hydrogen, or electricity. In other words, from an energy and emissions point of view, the best trip is the one not taken, especially considering time spent and services reached. Otherwise, when taken, the best trip is the one taken most efficiently.

Every day people use spatial mapping, perhaps without even realizing the data sets underpinning the ability to identify nearby services, find directions or use a shared form of mobility. What is often less considered is how spatial mapping can be a tool for city governments to assess the

Figure ES1

Three solutions to unite energy and mobility in cities



source of transport demand for services, whether education, the need to reach medical facilities or to buy goods. By better understanding what the derived energy and transport demands are and mapping them out, there is an opportunity to see where they overlap and to achieve synergies in efficiency.

The use of drones is an interesting example, albeit currently for niche purposes, yet it helps illustrate the larger point. Rather than looking for solutions to bringing services to remote locations at a high cost, drones have the potential to reduce costs by delivering services directly. They can be on standby mode and used for multiple locations and multiple purposes, according to need.

Links exist not only between energy and mobility, but also reflect benefits for and potential impact on gender equality, health, cooling, and education. These are crosscutting themes that require crosscutting ways to address them.

The second city type, *Digital Disruptors*, could particularly profit from demand-side targeting and management. Digital technology is an opportunity that, if harnessed correctly, can deliver a significant increase in mobility while consuming less energy. For example, demand-side mapping can help determine where smartphones, an increasingly accessible tool for all urban populations, might be useful in eliminating unnecessary travel through functions like mobile payments or communications.

Solution 3: Electric Mobility

Electric vehicles come in all shapes and forms, but all have the common ability to eliminate tail-pipe emissions and shift the emission reduction burden to the electricity supply provider. A few types of electric vehicles are particularly suitable in the context of this report. Specifically, electric-two wheelers and electric minibuses could yield substantial efficiency benefits and enable sustainable urban mobility when powered by renewable electricity.

In regions without access to electricity or with fossil-fuel dominated electricity, pairing remote solar photovoltaic with electric two-wheelers or electric buses can provide sustainable urban mobility directly.

By applying vehicle electrification to shared mobility and public transportation, the population at the base of the pyramid may have access to electric vehicles sooner than to passenger electric cars, which often begin their penetration into the higher income groups, with efficiency benefits taking some time to filter down.

The third city type, *Electric Vehicles Leapfroggers* would particularly see value from an increased penetration of electric buses, electric-two wheelers and electric minibuses.

Recommendations and Next Steps

Achieving the three proposed solutions requires several key steps.

1. **Focus on public transport, walking, cycling, land use, and adequate pricing of car usage** as key variables to enable a sustainable urban mobility for those at the base of the pyramid.

2. **Improve available data and metrics**, to quantify and track access to sustainable urban mobility. Number of hours wasted in traffic tracking time going to and from a destination can be used to quantify cost in terms of time, economic opportunity, air quality, and energy and can help identify the most urgently needed actions and quantify improvements to attract investments.

3. **Support the achievement of multiple SDGs.** When considering energy and mobility, the potential for achieving other SDGs multiplies**.** Other dimensions such as education (e.g. energy needs of schools or mobility patterns of teachers and children), health (air quality as well as access to health services), water, food, gender, and safety must be incorporated into energy and mobility planning.

4. **Address policy gaps through concerted efforts for tracking relevant policies and regulations** in key countries. Multiple organizations[2] have started such tracking for energy and other relevant aspects of the transport sector, including for example whether a country has renewable energy targets for its transport sector, or overall renewable power targets, especially relevant for electro-mobility. This work can further enable increased tracking of efforts in secondary cities to capture the expected growth.

5. **Create alliances between partners who may not have crossed paths before.** This includes

industry partners, real estate stakeholders, cities, and banks that can support common efforts to provide innovative and feasible sustainable urban mobility.

6. Increase capacity building in **spatial planning** for government agencies to maximize the synergies for energy and transport solutions at an early stage of urban planning.

7. Facilitate and enable **investments in renewable energy** and sustainable transport to decarbonize the grid and support the growth of new mobility business models.

8. Identify and foster **champions**, including mayors, for intangible aspects including behavioral and cultural shifts that can support overall improved access to sustainable urban mobility.

Energy and mobility linked together have the potential to offer even more for secondary cities and those at the base of the pyramid. In smaller cities there is an opportunity to have a significant and immediate impact on sustainable energy and mobility planning, spatial mapping of mobility demand, and financing energy and mobility projects combined. National policies can and should play a role, but not at the expense of cities being laboratories for energy efficiency and mobility. Transport planning should not undermine the ability for sustainable cities to direct existing transport funding for walking and cycling infrastructure.

Building and supporting cities across multiple ministries and organizations will require thinking outside silos and across sectors, but the cost of inaction is immense. If done well, the untapped sustainable urban mobility potential can be used for the benefit of those at the base of the pyramid, achieving not only access to energy and sustainable urban mobility, but also targets across all SDGs.

LIST OF ACRONYMS AND ABBREVIATIONS

$	United States Dollar
BRT	Bus Rapid Transit
CAPEX	Capital Expenditure
DRE	Decentralized Renewable Energy
EV	Electric Vehicle
GFEI	Global Fuel Economy Initiative
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GIS	Geographic Information Systems
GMF	Global Maritime Forum
HITS	Hierarchically Integrated Transit Systems
IEA	International Energy Agency
IMO	International Maritime Organization
IRENA	International Renewable Energy Agency
LRT	Light Rail Transit
MaaS	Mobility as a Service
MAC	Mobile Air Conditioners
NDC	Nationally Determined Contribution
NUMP	National Urban Mobility Program
OPEX	Operating Expense
PPM	Parts Per Million (of CO_2)
PPP	Purchasing Power Parity
REN21	Renewable Energy Policy Network for the 21st Century
PV	Photovoltaic
RE	Renewable Energy
SDG	Sustainable Development Goal
SUMP	Sustainable Urban Mobility Plan
TCO	Total Cost of Ownership
TOD	Transit-oriented development
TTW	Tank-to-wheel
UNSD	United Nations Statistics Division
WB	World Bank
WEF	World Economic Forum
WHO	World Health Organization
WRI	World Resource Institute
WTW	Wheel-to-wheel

1. INTRODUCTION: HOW ENERGY CAN TRIGGER ACCESS TO SUSTAINABLE URBAN MOBILITY

Transport enables workers to access their jobs and farmers to get their goods to market, but the growth of the sector needs to be well managed to avoid polluted gridlock. In the same way, increasing energy access has enabled people to reach services including communication and cooling,[3] but this too has led to increases in local air pollution and GHGs. The challenge is to increase access sustainably, but the question is: how?

"By 2050, both urban transport energy consumption and emissions are expected to double. Public transport is on average 2.5 times more energy efficient than private cars transport and only 10 percent of urban transport energy consumption is linked to public transport."[4]

This scoping study aims to identify opportunities for the energy sector to trigger access to sustainable urban mobility.[i] Solutions aim to accelerate on the ground action and ready to go finance. *Switching Gears: Enabling Access to Sustainable Urban Mobility* seeks to briefly outline what is currently being undertaken in the energy and mobility sectors, what is working and what is not – or at least not fast enough – and to delineate options. The report targets those populations that have the largest need and the biggest gap in access to services enabled by sustainable mobility and energy.

The scope of the report is centered on the population at the base of the pyramid, that is, those living on less than USD 1.9 per day (adjusted for PPP),[5] a number that has decreased in recent years, but still stands at an unacceptably high 736 million people,[6] with a current and increasing concentration of base of the pyramid population in Sub-Saharan Africa containing 27 of the world's poorest 28 countries in 2015.[7] The focus is on urban and peri-urban areas in fast-growing small-to-medium-sized cities defined as an average 50 percent growth projected by 2030 with a 2018 population between 300,000 and 1,000,000. Beyond these criteria, the study ultimately aims to bring the energy and transport communities closer together to enable otherwise dormant synergies.

There exists a real opportunity not only to switch out a combustion engine as part of vehicle electrification, but also to ensure that efficiency and sustainability are considered by both energy and mobility sectors from start to finish and to move them out of silos and into synergies. Energy and mobility are two sectors that can be likened to cousins, while they should in fact be siblings. Together they may be linked in a meaningful way to achieve more SDGs and faster than if implemented separately.[8]

Hundreds of local councils have declared a climate emergency, and on May 1, 2019, the United Kingdom became the first country to do so.[9] GHGs continue to rise in our atmosphere, and in May 2019, the Mauna Loa Observatory in Hawaii registered 414.7 ppm of CO_2.[10]

The challenge is to provide access to energy and mobility and the services enabled by them while avoiding an increase in local and global pollutants. The transport sector is the fastest

i Mobility and transport are often used interchangeably. In this report, transport mostly refers to both passenger and freight traffic, whereas mobility refers more to the opportunities and services that mobility provides access to.

growing emitter of global GHG emissions yet only 8 percent of 166 nationally determined contributions (NDCs) submitted set targets for the sector in 2018.[11] The context here does not only concern climate change, but also more broadly the SDGs. There is a growing demand for energy and mobility, which puts pressure on meeting the SDGs. Access can be achieved, but if it is done so unsustainably, not only will the SDGs not be met, but the access enabled will be one choked in air pollution and gridlock. For fast-growing cities, there is a chance to do something impactful now and enable access to energy and mobility to expand in parallel with population growth and urbanization so that, rather than hampering each other, each spurs the other on.

According to REN21, 3.3 percent of transport is RE-powered, which makes it the energy use sector with the least progress in terms of decarbonization.[12]

While electric mobility and solar power[ii] are improving by leaps and bounds in terms of decreasing costs and increasing efficiency, insufficient action has been taken to integrate the two at the planning and financing stage. The opportunity in this overlap is largely untapped, yet has the transformational potential to enable not just access to energy and mobility but to attain many of the SDGs. The key is to find ways to link energy and mobility in a useful and implementable manner.

Traditionally, transport can be made more sustainable through an approach embodied by three components: the so-called *Avoid/Shift/Improve* approach (Figure 1)[13] whereby you can *Avoid* unnecessary travel by providing the services closer to the source of demand through, for example, integrated land use and transport planning; *Shift* to more efficient modes of transportation, from individual car use to, for example, mass transit options such as buses; and *Improve* the efficiency and lower the carbon intensity of the fuel used, be it gasoline, diesel, biofuel, hydrogen, or electricity. Together, these encompass the approach to sustainable transport. The energy sector has no exact equivalent, and similarly approaches decarbonization of the energy sector from both a supply-side perspective (building renewable power generation such as wind or solar power) and a demand-side perspective (implementing demand-side management, improving grid networks, etc.), yet both lack the vision to link across sectors; an untapped potential that will be explored in the next chapter.

From the *Improve* perspective, several options exist for making the transport sector more energy efficient and cleaner, including biofuels, hydrogen, and electricity. This report will first consider vehicle efficiency. Efficiency should always be considered as a "first fuel",[14] and in the energy/mobility nexus there are several ways in which efficiency can be approached.

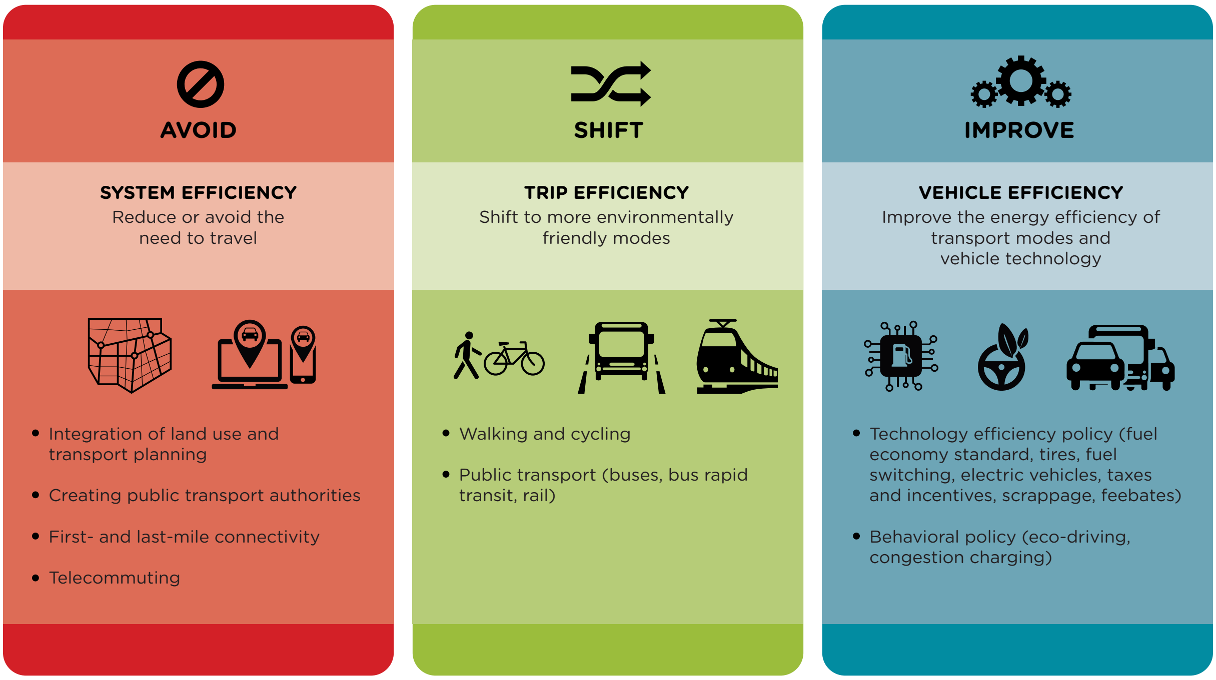
Efficiency on a vehicular level can either be enhanced through improved fuel economy standards (usually on a national level) or through deploying electric vehicles; electric motors convert energy into motion at an efficiency of around 60 percent versus 20 to 35 percent for conventional combustion vehicles. Efficiency can also be applied at a systems level whereby, for example, a bus system that is poorly planned can increase efficiency through better routing and integrated schedules or fare systems. Any one of these low-cost but planning-and-coordination-intense measures would have a high impact at a systems level. Finally, the report considers urban efficiency.[iii] This

ii All types of variable renewable energy generation are considered in this report, although solar photovoltaic – often generalized as solar power in this report – is likely to play a strong role, albeit not exclusive, in relation to electric mobility.

iii Energy efficiency is also considered at a national level in a variety of metrics, including "Energy consumption of transport relative to GDP (PPP)" or "Energy intensity (MJ/USD 2011 PPP)", but we return to these in more detail in Chapter 3.

Figure 1

Avoid/Shift/Improve framework for the transport sector



Source: GIZ, team elaboration

will be covered in more detail in the next chapter, but there are ways to measure and *improve* urban efficiency from a system level for the benefit of a city's energy and mobility systems and its citizens.

The Global Fuel Economy Initiative (GFEI) is a global partnership of expert groups that have come together to support governments around the world to set policies for cleaner and more efficient vehicles of all classes. Around 70 countries have received support from GFEI, to shape fuel economy policies and measures.[15]

There are many ways to approach the energy and transport fields, but recurring key themes that emerge are:

- Energy and mobility are a much-talked-about synergy, but not yet realized
- There are opportunities available to use energy as a lever to enable access to sustainable urban mobility for those with the highest needs (base of the pyramid population)
- Fast-growing cities present an opportunity to avoid grid-locked growth patterns and to take advantage of predictable growth patterns
- Secondary cities, defined in this report as cities with a population of less than 1 million inhabitants, have been so far relatively overlooked, but have enormous potential and will account for a substantial share of population and economic growth in the next 10 years[16]
- There are innovative options available to jointly finance energy and mobility projects as well as to bring secondary cities and funders together

"Electric mobility projects are planned as transportation projects, and clean electricity projects are planned as energy projects. The question is: how to get a project that considers both from the outset? It doesn't necessarily mean the electric mobility project will have as a main objective or outcome a cleaner electricity system, but rather that the planning considers both."

–Nathan Moore, GIZ

In Chapter 2, the opportunities and risks for sustainable development are delineated to provide the relevant context in relation to the SDGs and the urban context especially, capturing topics such as gender, education, and mobile applications. Chapter 3 presents the data findings and analysis of cities considered for this report. Chapter 4 looks at three sets of solutions, following the *Avoid/Shift/Improve* approach, examining not only technological solutions, but also digital tools enabling system efficiency through improved and integrated planning. Chapter 5 of the report looks at the status of financing flows, gaps, opportunities and methods. Finally, the report closes with recommendations, next steps, and conclusions for the key question: how can these solutions be implemented?


X-160

2. A FRAMEWORK TO INTEGRATE ENERGY AND MOBILITY IN THE URBAN CONTEXT

Cities account for 70 percent of worldwide GHG emissions and 50 percent of the world's population, but only 3 percent of Earth's land area. For this reason, cities have received growing attention[iv] in recent years as areas with high impacts. SDG 11 seeks to *"Make cities and human settlements inclusive, safe, resilient and sustainable"*, and while some progress has been made in sectors like municipal waste management, other indicators show that energy and mobility are lagging far behind their goals.[17] The share of people living in cities with polluted air has now reached 91 percent.[18] This is largely due to emissions from power generation, industry, and transport, and underscores the importance of connecting mobility and energy in order to foster sustainable cities.

Transport shapes cities, but often does so incrementally and organically rather than deliberately and efficiently, in some part due to market failures. In turn, transport is shaped by how cities are formed.[19] Both are interconnected, and react to each other. A car-centric approach has long ruled planning and policymaking. Furthermore, urban and public transport planners and policymakers do not often integrate or coordinate their efforts: their cooperation would create better planned cities and set the basis for 50-100 years of positive effects of good urban planning.

> *"Successful Indian urbanization is critical not only for the well-being of all people in India, but for the sustainability of the entire planet. We cannot afford to fly blind through this momentous transformation."*[20]
>
> *–Luís M. A. Bettencourt, Mansueto Institute for Urban Innovation at the University of Chicago*

iv While cities are the focus of this report, rural areas are essential to consider in the context of SDGs as well, and the link with rural transport as a service is an important research area moving forward: http://www.fao.org/sustainable-agricultural-mechanization/hire-services-as-a-business/rural-transport-as-a-service/en/

Transport Status Quo and Technologies

Most of the focus and funding to date has been on the *Improve* in *Avoid-Shift-Improve*, even though *Shift* arguably has wider applications for the base of the pyramid population and *Avoid* remains relatively untouched (Figure 1). While there is a strong focus on technology in the sustainable transport field including, for example, autonomous vehicles, its expected and potential applications are found mostly in wealthier cities and countries. In developing countries, initiatives aimed at increasing access to sustainable transport are often developed in the capitals, near decision makers. The bus rapid transit (BRT) system in Dar es Salaam, electric trolley bus system in Quito, and the light rail system in Addis Ababa are all good examples of sustainable transport. Quito has a comprehensive BRT network that will be physically and fare integrated with the first subway line, currently under construction. While BRT and metro lines are both part of the solution, the real solution applied here is Hierarchically Integrated Transit Systems (HITS), where high capacity modes such as metros and medium capacity modes such as BRTs are integrated both physically and with fares to serve the user better. In principle HITS can serve all needs, including for the base of the pyramid population. The Quito system however, as well as those of Dar es Salaam and Addis Ababa, serves a central corridor and might not be able to reach the base of the pyramid population, which still relies on informal and unreliable transit that may – as it is in Cape Town, South Africa[21] – or may not be well-connected to these types of high-capacity systems.

Positive developments include, for example, the case of Jakarta, a megalopolis with over 10 million inhabitants finally getting an urban mass rapid transit metro – suitable and needed for this population size – complementing other sustainable transport options including BRT.[22] However, there is a continuing focus on technologies and high-cost systems, which are not as feasible in developing countries, and even less so in secondary cities. The informal sector plays an important role in secondary cities in boosting livelihoods.[23]

Technology bias can lead to less transformational transitions than may otherwise be possible. For example, making all personal vehicles electric would have a major positive effect on emissions with a decarbonized grid, but mobility-wise it would result in a "green" traffic jam, keeping cities gridlocked and inefficient from an urban point of view. Solving the whole puzzle necessitates a broad perspective and a balance between *Avoid*, *Shift*, and *Improve* measures.

Nevertheless, technology has an essential role to play, and there are several technologies in place as well as some that are relatively untapped that should be explored to enable energy to trigger access to sustainable urban mobility (Table 1). One such example is geographic information systems (GIS), which allow for various data sets to use spatial data mapping to better understand energy and transport systems within the urban context, including for example traffic flows and demand-side mapping (see Chapter 4 for more details).

Policies for sustainable transport tend to have a bias focusing more on "carrot" policies (incentives) rather than "stick" policies (regulations) such as increased fuels pricing, taxation of jet fuel, or parking restrictions. This skewed policy bias is often politically easier to pass than other legislation, but a combination of "stick" and "carrot" policies can lead to a faster transformation. This was a critical lesson learnt from Norway's electric vehicle (EV) experience, which has the world's highest market share (58 percent of all new cars sold in March 2019 were electric).[24] In short, financial incentives alone yield results, but pairing them with non-financial incentives such as free parking, free use of high-occupancy lanes, and so on can lead to an enhanced outcome.

A good example of non-technological implementation of sustainable transport can be seen in Praia, Cape Verde, where the country's first restricted paid parking spots are starting to be implemented in high-density and high-volume areas. While there was initial resistance, as is common in all parts of the world, there is greater understanding now of the high environmental cost of free parking.[25] Parking alone may seem unexciting, particularly from a technological point of view, but it opens another revenue stream for cit-

Table 1

Technology options and their suitability for target cities

Technology options	Suitability for target cities
Electric two-and-three wheelers	High
Electric buses	Medium
Electric minibuses	High
Electric cars	Low
Electric taxis	Medium
Hydrogen vehicles	Low
Biofuels	Low-to-medium, depending on feedstock

Cooling and mobile air conditioning (MAC)

When examining the nexus between energy and mobility, it is important to account for the cooling needs of transport, both for mobile air conditioning and for goods such as medicines, healthcare products and food. SEforALL's 2019 *Chilling Prospects* report underlines the need to bring attention to this overlap.[26]

In its latest report *Cooling on the Move*, the International Energy Agency (IEA) addresses the energy consumption of and emissions caused by MAC. Currently MAC consumes almost 2 million barrels of oil equivalent per day (Mboe/d), ranging from a 3 percent to a 20 percent share of fuel consumption depending on climate, and one that could peak at over 40 percent in warm climates and congested traffic.

Without further policy intervention, MAC energy consumption may rise to over 5.7 Mboe/d by 2050. This near tripling of consumption would be driven by an increase in the number of passenger cars on the road, from around 1 billion today to over 2 billion, with a greater proportion of the increase in warmer climates. The overall expected increase in global ambient temperatures will drive further demand for air conditioning.

While MAC in public transport systems would need to be a priority to create comfort for passengers and avoid shifts to other modes in hot countries, this might pose challenges when considering e-buses due to their decreased range when utilizing AC.

ies, which can then be allocated for public transportation (see Chapter 5 for more details).

Digital solutions are already making parking a much more innovative tool for sustainable transport than previously thought.[27] Such solutions encourage drivers to drive less and *shift* to more efficient modes of transportation, such as buses. In addition, having desirable yet restricted parking spots in place can allow a municipality to consider applying free parking policies for electric vehicles as a non-financial incentive to support vehicle electrification at a low cost for an initial period.

The Role of Energy

While there is generally strong support for the energy and transport sectors to coordinate, little has been achieved on the ground. However, the developments in solar power and vehicle electrification (Chapter 4) may be at a tipping point, which can empower the role of energy in transport to become more clear-cut and impactful. While there is no exact *Avoid/Shift/Improve* framework equivalent in energy, we can say that energy currently supports sustainable transport in three ways:

- Energy fuels transport; a shift towards cleaner, renewable fuels[v] and clean electricity for electric vehicles, enables transport decarbonization
- Energy demand from transport can be decreased through improved efficiency at a vehicle, systems, and urban level
- Energy can power services earlier along the service chain, thus avoiding unnecessary travel e.g. off-grid solar powering a rural hospital and thus obviating the need for travel to another town/city for health services, as successfully implemented in Ethiopia.[28]

While the energy sector has seen significant improvements in increased energy access (especial-

v Referring to "fuels" in a general sense, including electricity. "Liquid fuels" will be written when only referring to liquid fuels.

ly electricity)[29] in recent years, 840 million people still do not have access to electricity.[30] Expanding this access is crucial, as energy is a thread that connects all the SDGs.[31] Currently, 26.2 percent of the global power sector is renewably powered.[32] Falling prices of solar panels is one trigger aiding this trend, and while wind power, and off-grid solar are all expanding among other renewable energy technologies, a bias in favor of centralized grids prevails. Similarly, while energy efficiency is gaining traction as a "first fuel", most of the world still has a supply-side mindset.

Within the urban context, energy implications are varied; the difference between a dense city and a sprawling one can affect energy infrastructure and opportunities in different ways. For example, a densely built environment might make centralized electricity generation more appealing or incentivize rooftop solar photovoltaic (PV), whereas a sprawling city might make large wind turbine installations more feasible. Electricity distribution matters as well, especially in relation to electric mobility, which necessitates a range of technical considerations, such as providing sub-stations for electric bus chargers that may rely heavily on the built environment and perhaps limit options or drastically raise installation costs. Existing tools that assess how "EV ready" a city is can help guide policymakers in this respect.[33]

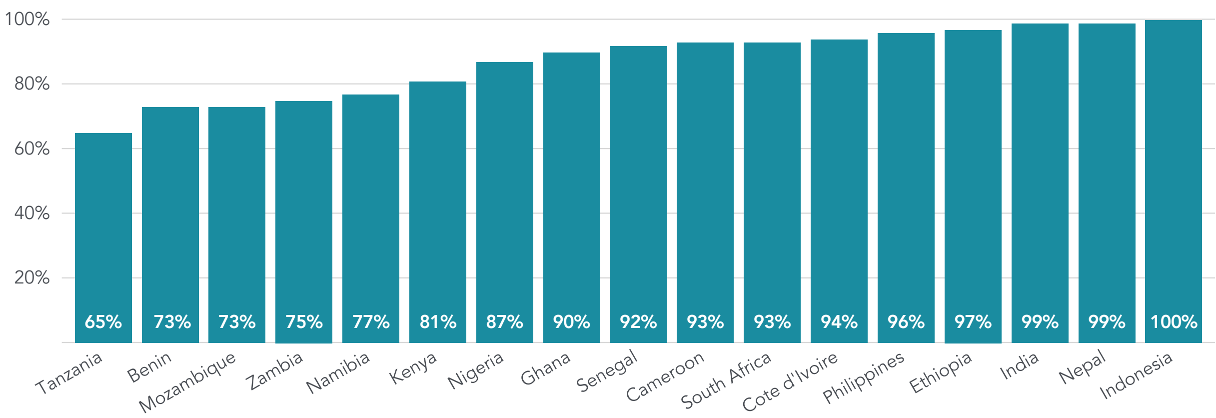
Urban Context and Public Transportation

According to the World Bank, if China were to focus on increasing the density of its cities rather than building new ones, it would save USD 1.4 trillion in infrastructure spending alone. Indonesia provides a useful case study in this respect as urbanization drove its energy intensity down 23 percent between 2000 and 2011.[34] This is the logical consequence of travel as a derived demand. Done well, transportation can accelerate the efficiency of cities, as density is a prerequisite for successful public transport. Cities that are very dispersed present major issues in their development and run the risk of becoming stagnant. According to the World Resources Institute (WRI), 80 percent of cities are expected to increase in size (spatially) through sprawl between 2018 and 2030, a statistic that has harmful consequences for urban efficiency gained from increased density.[35]

> *"Given that a large share of future urban growth is projected for small-to-medium-sized cities, bus-based forms of smaller-scale transit-oriented development interlaced by high-quality infrastructure for pedestrians and cyclists holds promise in many global settings."*[36]
>
> *–Robert Cervero, UC Berkeley College of Environmental Design*

Figure 2

Urban access to electricity as a percentage of population (2017)[37]



Source: IEA, IRENA, UNSD, WB, WHO

Urbanization is overtaking economic growth, and as research into urban development patterns has shown, there is a tipping point after which urban efficiency falls apart.[38] There is a need to better understand the push factors behind those leaving their villages for booming towns and cities. By conducting demand-side mapping for basic services such as medicine, food, and water,[39] there is a chance to slow down dispersed urban growth scenarios.

This report therefore looks not only at needs at a city-level, but also encompasses peri-urban areas as well as smaller cities, where tremendous gains can be reaped by effectively coordinating transportation and urban development.[40] Peri-urban areas are of special interest as they present an opportunity to provide access to the opportunities of cities, but possibly without the ardors of commuting.[41] There is also an opportunity for multi-modality as many at the base of the pyramid do not have direct access to high-quality and high-capacity public transportation, but by connecting informal services to these corridors, multiplier effects are possible.

Most target cities have informal transport, which often emerges because of over-regulation that makes formal services difficult to provide. Informal transport organized around competition in the market has major externalities such as too many small public transport vehicles, often in the form of mini-vans. Competition in the market leads to driving behavior that results in high numbers of fatalities and injuries. Only coordinated public transportation has the potential to move a large number of passengers in a highly dense context. For this to happen, human capacity is needed, coordination in planning needs to take place, and infrastructure and operations need to be funded.

Extensive research has been conducted on best practices for integrating public transport systems, with customers benefiting from several aspects including integrated fares and integrated information across operators.[42] The tools for – and case studies behind achieving these successes – are abundant, but are often neither prioritized nor properly funded in the context of sustainable transport implementation. One first step is to create a "transit alliance", a group of the key stakeholders – both formal and informal and across city boundaries – to effectively advance towards an efficient public transport system.

Chapter 5 looks at financing this infrastructure, but it is a simple truth that bad roads ruin vehicles, and overloaded vehicles ruin roads. Antiquated vehicles also harm air quality by using dirtier fuels and more of those fuels, increasing the overall energy demand. Breaking this pattern is paramount.

Freight and Logistics – Breakout Box

The focus of this scoping report is on public transportation and not the freight sector, but derived freight demand can and should be considered. Freight often operates in the shadows; we have more awareness of passenger transportation since we all use it. This does not mean however that freight does not have large impacts on emissions (the freight sector accounts for 42 percent of global GHG transport emissions according to the IEA) and on urban form and energy use, and it would be remiss not to incorporate it. In the maritime sector, the International Maritime Organization (IMO) has adopted regulations to address the emission of air pollutants from ships, including mandatory energy-efficiency measures to reduce emissions of greenhouse gases from international shipping.[43] The Global Maritime Forum (GMF), in partnership with Friends of Ocean Action, and the World Economic Forum, launched their Getting to Zero Coalition at the Climate Action Summit in New York, a coalition that is committed to getting commercially viable deep sea zero emission vessels powered by zero emission fuels into operation by 2030 (Breakout Box – Activities that are accelerating actions).

At the urban level, a recent white paper by the Transportation Decarbonisation Alliance (TDA) explores pathways to achieving zero emission urban freight,[44] underscoring the point that this is achievable, and advocating a starting point of asking not only how we get to the shopping center, but how the goods get there?

If we consider an apple getting to a store, one might be tempted to begin with a technological solution, such as electrification of the delivery vehicle. This is a worthwhile consideration and is being deployed with much success around the world with concomitant decreased local air and noise pollution. But in the context of the cities we are considering, it may not be the first nor most cost-effective solution. Rather, by using available data sets and mapping, one can better understand where agricultural goods are headed, to which markets, and for which customers. With this in hand, a map of demand for services and products may provide a sustainable solution earlier along the service chain. Blockchain technology is already enabling freight solutions and could be transferred to the passenger sector as well.[45]

From a fuels perspective, the freight sector is the hardest to decarbonize, largely due to the heavier weight of the vehicles and the fact that they use more energy, and the fact that there is a small market offering of low-carbon freight vehicles. Biofuels and hydrogen both have a role in the freight sector, as does electric mobility, but the application needs to take the full well-to-wheel emissions and efficiency and infrastructure requirements into account when pursuing a fuel option.[46]

Barriers, Challenges and Opportunities

Providing sustainable urban mobility without heating the planet and creating gridlocked and polluted cities is the main challenge and one not easily undertaken successfully. This is especially true for small-to-medium-sized cities vis-à-vis more visible and studied larger cities, for which more information is often available. This information gap, together with a possible lack of cooperation between the Ministries of Energy and Ministries of Transport, and a disconnect between the national/local level on both the energy and transport sides, make it even more important to identify the barriers and challenges to enabling access to sustainable urban transport and to overcome them with affordable and feasible solutions. Also, taking adaptation and resiliency into account is essential in order for solutions to truly be effective and sustainable. By considering climatic effects, there is an opportunity to ensure the siting of, for example, EV charging infrastructure and solar panels, is in optimal locations.

Five main barriers to enabling access to sustainable urban mobility are identified here, with opportunities considered in detail in Chapter 4:

- Barrier 1: **Human capacity** (technical skills and knowledge) is needed for better planning, which may be especially lacking in smaller cities with limited experience. Strong institutional frameworks with the capacity to set this up and financial capacity to make it sustainable are missing.
- Barrier 2: The level of **political support** is key. However, the ability to quantify and track down opportunities is challenging. Similarly, **political consistency** is key; long-term support is needed and not always available.
- Barrier 3: **Policy changes** are not always easy and often require cultural and behavioral changes.
- Barrier 4: **Economics and finance**: high upfront costs of efficiency technologies with zero-to-little credit lines available for customers.
- Barrier 5: Providing **access to sustainable urban mobility** without the right support policies and pricing may limit the ability for the base of the pyramid population and informal actors to gain effective access to sustainable mobility.

High-Impact Dimensions and Concepts

> *"Unfortunately, most cities have not prioritized children in their planning and design. We should move beyond designing our cities for the 30-year-old athletic person and think about the needs of our most vulnerable users: children, older adults, and the poor."[47]*
>
> *–Gil Penalosa, Founder and Chair of the Board of 8 80 Cities*

The reality on the ground in terms of energy and mobility is that access to mobility, let alone sustainable mobility, is out of reach for the vast majority of the base of the pyramid population, especially if sustainable is defined as entailing reliability and safety. There are risks and opportunities with the current approaches to sustainable development. Focusing on the connections between SDGs, which tie in not just transport, but also energy, can enable a better understanding of how the two interrelate and can help or hinder each other. An ecosystem approach is thus necessary to adequately map out high-impact dimensions and concepts relevant to the energy-mobility nexus (Figure 3).

These high-impact dimensions are not meant to cover everything, but rather consider those factors that are cross-sectional and could benefit from better integration. While all dimensions here are worthwhile, it is worth noting that choices need to be made to ensure the best use of the financial resources of a country or a city, and of course those of a given household at the base of the pyramid. The ten dimensions considered here are:

Figure 3

Sustainable energy and sustainable mobility and their links to achieving the SDGs

Source: United Nations, team elaboration

Disproportionality	Food	Road safety	Air quality and health	Education
Gender	Water	Infrastructure	Social equity	Digitalization

Disproportionality

The dimension of disproportional impacts is relatively unexplored despite its being the very definition of high impact. In Kathmandu, Nepal, approximately 1 percent of motorcycles were found to be high-emitting, having a disproportionate impact on the already poor air quality in Kathmandu, where over 80 percent of the vehicle fleet are motorcycles.[48] Efforts now include targeting and addressing the emissions of these motorcycles, which can be extremely cost efficient. Similarly, in Accra, Ghana, minibuses account for more than 50 percent of traffic violations and 22 percent of accidents, despite being a fleet of just around 6,000 vehicles (in 2004).[49] These two examples underscore the importance of understanding the impacts and using tools like GIS (Chapter 4) to map out disproportionate activities.

Food

Food security has many links to the energy and mobility sectors, including in delivering goods, in keeping food and drinks nutritious in the course of delivery and providing access to markets. However, what is less explored is the link with food security and mobility access within cities themselves. Work by the University of Cape Town has looked at how urban planning affects food systems in relation to urban poverty with a pertinent focus on secondary cities.[50] The research underscores the importance of better understanding the informal sector and its links to minibuses, and the fact that informal markets are often near high-density locales and can thus be serviced better with appropriate energy and mobility mapping and planning.[51] According to Sustainable Mobility for All (SuM4All), sustainable mobility has the potential to support a regional food market in Africa worth USD 1 trillion.[52]

Road safety

Road safety for cities can be looked at from a range of aspects, but they all include identifying so-called hot spots where a disproportionate number of accidents happens that can be targeted cost-effectively for a high-impact reduction in numbers and associated injuries and fatalities. Children are especially vulnerable, and it is worth noting the important work being done to highlight not only the role of children in urban spaces, but also in terms of solutions including helmets and child-sensitive urban planning, among other initiatives,[53] as well as ready-to-use tools for making cities child friendly.[54] From a planning point of view, many secondary cities have their urban cores sliced in half by large roads transporting goods and people between major cities, but this also amputates the city as well as creating a dangerous situation for many simply trying to cross the main road. While fatalities are three times higher in Africa compared to Europe despite its having a much smaller vehicle fleet in relation to the population, there are fortunately several interventions that can have a measurable impact.[55] One of those is improving access to public transit, another is to build the capacity of road users and regulators.[56] A key starting point for all measures and gaining welcome attention are data that can be used to identify high-impact cities and hot spots.[57]

Air quality and health

Nine in ten people worldwide breathe polluted air, with children bearing disproportionate exposure and effects.[58] Worldwide in 2015 385,000 people died of premature deaths due to vehicle exhaust emissions.[59] In India, schools reported 28 times the recommended levels of particulate matter, which led to 1,800 schools being closed for three days in 2016.[60] In some ways, poor local air quality has become a strange partner in the efforts to make cities more sustainable and to achieve the overall impetus to reduce GHGs. The reason for this is quite simple: we all need to breathe air, and we (mostly) live in cities. However, while quick fixes exist to tackle local air pollution to varying degrees, only a systematic citywide approach will yield long-term and sustainable results, entailing meeting not just one goal, but also several co-benefits simultaneously. Tracking local air quality early in smaller cities is wise so as to identify problems before they become overwhelming. The World Health Organization has an excellent database in place, but more data are needed for secondary cities to better assess their baseline and progress.[61] Cities can be places where air quality, health, and climate goals co-exist for the benefit of the base of the pyramid population but only if the right strategies are in place (see Table 2 below).

Table 2

Actions to foster synergies between sustainable mobility, health and climate gains[62]

Strategy	Key pathways
1. Land use systems that increase density and diversity of uses	• Increases proximity of destinations, reducing need for car travel and reducing distance travelled • Improves access to walking, cycling and rapid/public transport
2. Investment in and provision of transport network space for pedestrian and cycle infrastructure	• Improves access to walking and cycling • Encourages shift from car use to walking and cycling, reducing distance travelled
3. Investment in and provision of transport network space for rapid transit/public transport infrastructure	• Improves access to rapid/public transport • Encourages shift from car use to rapid/public transport, reducing distance travelled
4. Engineering and speed reduction measures to moderate the leading hazards of motorized transport	• Reducing speed improves safety of walking and cycling • Increasing separation of vehicles from walkers and cyclists improves safety of walking and cycling • Removing safety barriers encourages walking and cycling • Technological improvements reduce production of hazards from vehicles (greenhouse gases, pollutants, noise)

Education (children and teachers)

While children and youth have long been acknowledged as disproportionately affected by lack of access to sustainable urban mobility, until recently, little had been done to connect this with education. That is strange given that children – and teachers– have a predictable mobility pattern for, in the case of children, around 15 years to get to school and back. This presents an opportunity in terms of planning. UNICEF has risen to this challenge and is supporting "child-responsive urban planning" with helpful guidelines, tools, and a planning handbook, as well as raising awareness of the challenges and opportunities of being a child and young in a city setting as it relates to urban and transport planning, including planning of energy systems.[63,64]

Gender

Women must often endure the hardships of spatial isolation since they may be expected to remain close to home to raise children and carry out household chores;[65] this has important implications for energy and mobility access. The organization Urban95 tries to tackle issues concerning cities and mobility by recognizing that transport planners tend not to recognize "trips made while caring for others" as a distinct category (often women, often off-peak and often with more stops). Access to mobility can provide access to opportunities for women, especially to employment, help strengthen women's autonomy, and advance gender equality.[66] Accessible, efficient transportation can reduce time wasted on unnecessary or congested travel, time that if freed up, can enable women to put to use in other more productive ways.

Water

Access to clean drinking water is paramount, and with changing weather patterns due to climate change, it is critical to take a systems perspective to water and to understand where it intersects with energy and transport. The link between energy and water is relatively well established.[67] An interesting example comes from India where electricity access was increased with an eye to keeping groundwater levels stable.[68] Consideration and integration of mobility into the water nexus should be a next step, including the role transport plays in water quality, delivering water or providing access to it. A transition to a cleaner transport sector would help keep water clean, avoiding air pollutants emitted, and minimizing the risk of oil and gas leakages into ground source water reservoirs.

Infrastructure

Transport and energy infrastructure are utilized and shared by all urban residents. Both energy and transport infrastructure should fulfill the needs of different income groups. In fast growing cities, considerable investments will be necessary to meet the needs of an increasing population (see Chapter 5). A combined planned strategy can help define these needs, e.g. while leveraging SUMPs, or on a national level, NUMPs, for developing integrated land-use and transport planning (Chapter 4).

Moja Cruise – Case Study

eThekwini Municipality, of which Durban is the main city, launched a minibus reward program in October 2017, which uses digital tools to enable more sustainable shared mobility.[69] The concept is similar to the many rating tools that exist today, for example for restaurants and hotels, but what makes this tool different is that it gives passengers more power than what is usually seen in public transport systems, and it was drawn up collaboratively with an overall goal to improve public transportation.

The rating system includes ratings for safety, cleanliness and efficiency, all to build driver accountability and reward the best performers. The program, titled Moja Cruise, is a voluntary program of 500 taxi drivers that started in October 2018 as a pilot with 150 taxis and has a final goal of 6,000 minibus taxis.[70] Moja Cruise was conceptualized as being part of an overall drive towards a more sustainable city and developed under GO!Durban, a public transport vision and action plan. This plan includes walking, cycling, rail, and buses, and uses digital tools to enable access to sustainable urban mobility in an inclusionary manner for the benefit of all, including those at the base of the pyramid who often use minibuses.

Social equity

Social equity is a key dimension especially in regard to the base of the pyramid population. Achieving universal access to sustainable energy is necessary for a just energy transition that leaves no one behind. Providing and enabling access to sustainable urban mobility should increase overall accessibility in every sense of the meaning. For example, "grey mobility solutions" for the elderly population, follow a specific logic in terms of affordability and mobility patterns, providing discount fares for senior citizens. One way to assess such solutions according to this metric is the share of income spent on transport (and transport energy, further explored in Chapter 4). Accessibility has previously been defined largely in the context of disabled and vulnerable populations. It has to date not included energy in a significant way, except in relation to efficiency as part of the New Urban Agenda supporting, "A significant increase in accessible, safe, efficient, affordable and sustainable infrastructure for public transport, as well as non-motorised options such as walking and cycling, prioritising them over private motorised transportation"*[sic]*.[71] For the sake of equity, energy should be better incorporated into considerations of sustainable mobility.

Digitalization

Digital solutions are increasingly moving from buzzwords to reality, with the potential for the base of the pyramid population to technologically leapfrog to more effective solutions. Digital tools can support other high impact dimensions, such as allowing citizens to monitor air quality using a wide array of monitoring stations, meaning that they no longer need to rely on a single entity, which may have its own definitions of healthy air quality that differ from internationally accepted standards.[72] Another digital trend relates to MaaS,[73] which is an increasing focus of the International Association of Public Transport (UITP), with the aim to combine various transport offers into one service, crucial for enabling system level efficiency. Digital solutions also include using geospatial data (see Galileo 4 Mobility)[74] to combine key stakeholders who have otherwise been in silos at great cost and inefficiency. Shared mobility (see Case Study below) is equally enabled by digital technology, with significant positive effects on urban space and human health.[75]

Activities that are accelerating actions – Breakout Box

The **Global Fuel Economy Initiative (GFEI)** was founded in 2009 with the purpose of promoting and supporting government action to improve energy efficiency of the global light--duty vehicle fleet.

GFEI is the centerpiece of the SEforALL vehicle efficiency accelerator and has set global targets to double the average light-duty fuel economy by 2030 and increase it by 90 percent by 2050. GFEI is based on detailed data and technical analysis published through a working paper series of technical papers. It has also established the only regular global monitoring of fuel economy trends.

GFEI's in-country support started with four pilot countries, and has expanded to over 70 countries, with a target of working in 100 countries announced at COP21.

Sustainable Mobility for All (SuM4All) is a consortium promoting sustainable mobility focused on the pursuit of four concurrent policy goals: universal access, efficiency, safety, and green mobility. In October 2019 SuM4All published a Global Roadmap of Action toward Sustainable Mobility (GRA). GRA is a tool that will enable any country in the world to measure how far it is from achieving sustainable mobility, explore more than 180 policy measures that have been tested around the world, prioritize those that are most impactful, and lay out a path forward. The GRA Report is complemented by six policy papers, a private consultation summary paper, and an online, interactive tool toward sustainable mobility.

Transformative Urban Mobility Initiative (TUMI) is a leading global implementation initiative on sustainable mobility formed through the union of 11 partners. TUMI is based on three pillars: innovation, knowledge, and investment. It supports innovative pilot projects around the world, shares knowledge with planners about modern mobility concepts in workshops and conferences, and invests in the construction and modernization of sustainable urban infrastructure. TUMI supports up to 10 cities each year in achieving their sustainable mobility goals with up to EUR 200k for an urban mobility pilot project.

The World Economic Forum (WEF) and the Energy Transitions Commission launched the Mission Possible Platform to achieve net-zero carbon emissions by mid-century from a group of traditionally "hard-to-abate" industry sectors at the Climate Action Summit in NYC, in September 2019. The initiatives focused on transport are:

- **Clean Road Freight Coalition,** a platform for multi-stakeholder collaboration along the trucking value chain for advancing a net-zero CO_2 emissions goal.
- **Getting to Zero Shipping Coalition**, a coalition across the maritime, fuels and infrastructure value chains committed to getting commercially viable zero emissions vessels into operation by 2030. The Getting to Zero Coalition is a partnership between the GMF, the Friends of Ocean Action, and the WEF. The Coalition is supported by more than 70 public and private organizations including several shipowners and equipment suppliers.
- **Clean Skies for Tomorrow**, an initiative of high ambition CEO champions convened by the WEF and Rocky Mountain Institute to accelerate the energy transition to sustainable aviation fuels towards carbon-neutral flying.
- **Circular Cars Initiative,** a cross-industry alliance to advance shared, electric, and automated mobility.

vi Asian Development Bank (ADB), BMZ – Federal Ministry for Economic Cooperation and Development, C40 Cities – Climate Leadership Group, CAF – Development Bank of Latin America, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, ICLEI – Local Governments for Sustainability, ITDP – Institute for Transportation and Development Policy, KfW – Kreditanstalt für Wiederaufbau, SLoCaT – Partnership on Sustainable, Low Carbon Transport, UN-Habitat, WRI – World Resources Institute

3. DEFINING AND QUANTIFYING: THE SUSTAINABLE URBAN MOBILITY GAP

Setting the Scene

Switching Gears: Enabling Access to Sustainable Urban Mobility applies a quantitative approach to map out the availability of relevant city data and indicators. First, the report looks at key criteria and filters, including detail on the types of data that are available. Second, it takes a closer look at specific data for vehicles and fuels. Finally, it filters the data findings to define four types of high-impact cities to get a representative picture, with some cities scoring high enough to appear in more than one city group. These city types are inherently abstract, but nevertheless crystallize the potential for a given set of solutions; cities in each of these groups could likely benefit from the suggestions for other groups. This makes sense given the crosscutting themes of electric mobility and digitalization among other themes covered in this report.

While national-level indicators, such as GDP per unit of energy use or energy per distance travelled are useful metrics, they are less helpful in contexts where there is no energy access.[76] City-level data, especially quantitative data for smaller cities, are quite hard to come by, but population data are available, as are geospatial data, and some data for government budgets for energy, transport and urban planning.

On data availability, while there tends to be a bias in favor of larger cities, in recent years there have been efforts to try to fill the gap of data and indicators for medium-sized cities, so that there can be comparable data sets when comparing medium-sized cities.[77]

Other cities that do not fulfill the criteria of this report, from cities larger than one million inhabitants to growing megacities, would profit from the solutions proposed, which are aimed at improving sustainable mobility and at connecting energy and mobility in a meaningful way. By targeting these secondary cities (defined in this paper as cities with a population of less than 1 million people) for assessment and implementation, there are three opportunities to take advantage of:

- A theoretical lower complexity, thus easier implementation
- Growth enabled efficiency (from an urban/system level) to avoid future gridlock or other lock-in effects
- A chance to leapfrog technologically and developmentally

Key Criteria and Filters

Two levels were used to find cities with high potential for energy to improve access to sustainable urban mobility: criteria and filters. The criteria used were:

- Cities with a population between 300,000-1,000,000 (2018 data)
- Population growth expected at an average of more than 50 percent by 2030 for the group of cities
- The exclusion of locations with less than 5 percent of the population at the base of the pyramid
- The exclusion of locations in conflict areas
- The exclusion of locations with poor governance (1s and 2s according to the Good Governance Index)[78]

The effort to determine what level of access to sustainable urban mobility exists for the base of the pyramid population began with assessing income levels. The first step was thus to find which countries have base of the pyramid populations, and a minimum threshold of 5 percent was applied, meaning at least 5 percent of the population of a given country makes less than USD 1.9 per day adjusted for PPP, per World Bank definitions. Around 59 countries were excluded due to a lack of data availability, although this includes regional groupings, war zones, microstates, and countries that are not independent by UN definition. Applying these initial criteria, 70 countries were identified.

Subsequently, countries with no cities in the 300,000-1,000,000 range were excluded (seven in total) as well as countries with no agglomerations of 300,000 (projected) in 2030 (six additional). This left 57 countries (38 in Sub-Saharan Africa, five in South Asia, five in Latin America and the Caribbean [LAC], six in East Asia, two in Europe, and one in the Middle East). Measuring by population of the base of the pyramid by region and excluding countries at war or in conflict, 50 countries remained.

Applying SuM4All data, including the key metric of energy consumption data from the global tracking framework,[79] a number of countries were removed due to lack of data, bringing the number down to 27 countries and 939 cities. Applying the Good Governance Index (1-7 with 7 being the best) and taking out 1s and 2s, this further reduced the list to 22 countries and 870 cities. Applying population growth data to weight rates, three more countries were removed, resulting in 19 countries and 260 cities (Figure 4).

Vehicles and Fuels

Across the 19 priority countries, assessing the level of access to sustainable urban mobility is to date quite difficult; there are for example urban/rural splits for energy access, but not for access to sustainable mobility. However, there are some tools available to help advance the state of knowledge. BRTdata.org shows BRT systems in Sub-Saharan Africa in Nigeria, South Africa and Tanzania. However, none of these are in the cities meeting the criteria of this study, as they are major population centers. In Asia, there are none either in Nepal or in the Philippines, but there is one BRT system in Jakarta, Indonesia, which is 207 km long and carries 370,000 passengers per day. In India there are seven BRT systems that, when combined, are 174km long and carry 340,000 passengers per day (Table 3).

There are only two urban rail systems in Sub-Saharan Africa: one is the Gautrain in Johannes-

Figure 4

19 priority countries identified

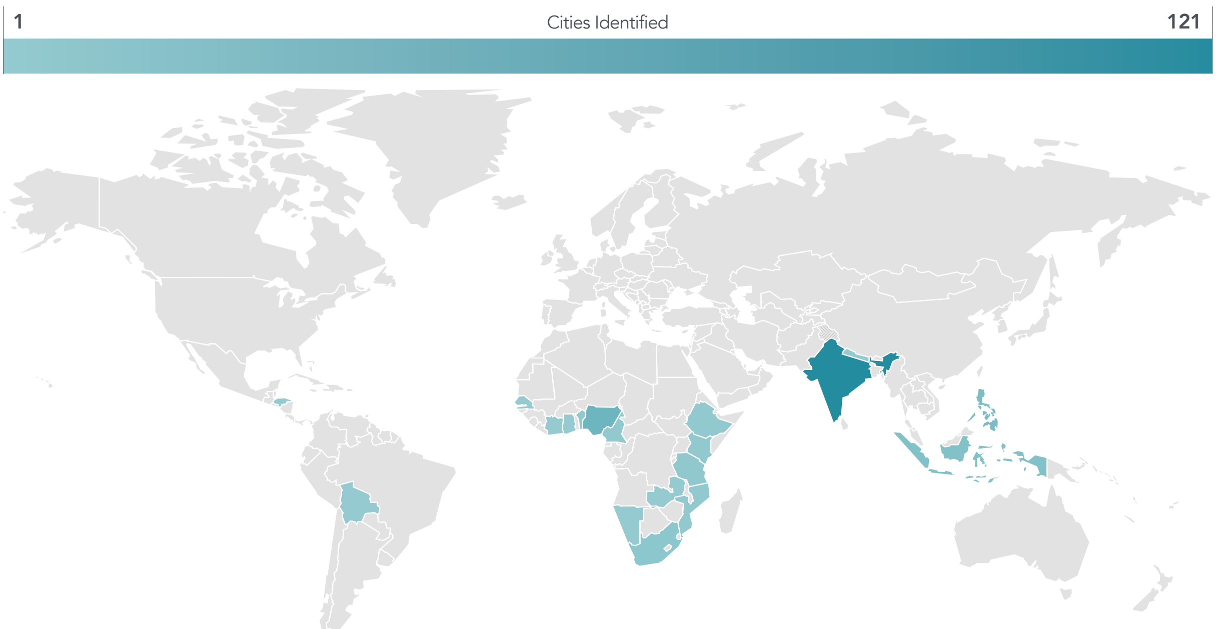


Table 3

Indian BRT systems

Cities	Passengers per Day	Number of Corridors	Length (km)
Ahmedabad	130,000	1	82
Bhopal	70,000	1	24
Indore	45,500	1	11
Jaipur	6,622	1	7
Pune – Primpi-Chinchwad	67,000	3	29
Rajkot	7,500	1	11
Surat	13,500	1	10

burg, South Africa and the other is the light rail in Addis Ababa, Ethiopia, built in 2015. In Indonesia there is a new mass rapid transit metro system in Jakarta. In Manila there is an old overground urban rail system. Nepal has no urban rail. Meanwhile, India has 515 km of operational urban rail in 12 cities with a further 604 km under construction,[80] however none of these cities meet the population size criteria of this report.

From a renewable liquid fuels perspective, data reveal that of the 19 countries meeting the criteria, four have some liquid biofuels share, with most located in Asia (percentage share of liquid biofuels out of total final energy consumption in 2016) [81,82],except for Ethiopia:

- Philippines (1.50 percent)
- Indonesia (1.40 percent)
- India (0.10 percent)
- Ethiopia (0.01 percent)

Up-to-date data on modal splits are hard to capture but should be the starting point for any mobility intervention. Similarly, the percentage of roads that have sidewalks is a key metric for understanding how people move around, and what access is available to them. Measuring the length of bicycle lanes is another way to assess access to sustainable urban mobility. Together, these data points and indicators help paint a picture of mobility, and with the urban/rural split available for energy access, mobility and energy data can be merged for an accurate assessment. Without this picture, any intervention will likely be inefficient or ineffective.

Another strategy is to use co-benefit indicators in relation to access to sustainable urban mobility. Using air quality as an example, if a

Atlas of Urban Expansion – Breakout Box

Recent improvements in data collection and geographical mapping have enabled analysis of city growth patterns in ways that were previously not possible. One such initiative is the work by a group of universities, the Lincoln Institute of Land Policy, and UN Habitat among others, which has resulted in the Atlas of Urban Expansion.

The data were collected in three phases across 200 cities, including historical data from before 1900, and allow for an understanding of how cities grow and perhaps help anticipate future growth. The list of 200 cities overlaps with 18 of this report's target cities (Table 4).

Table 4

Parameters from Atlas of Urban Expansion for 18 fast growing cities

City	Country	Walkability Ratio (1990-2015)[vii]	Built-up Area Density (persons/ha)[viii]	Average Road Width (meters in 1990-2015)
Bacolod	Philippines	2.2	0.10%	5.7
Pematangtiantar	Indonesia	1.8	-1.30%	5
Port Elizabeth	South Africa	1.8	0.10%	7
Gombe	Nigeria	1.7	-3.00%	8.2
Hindupur	India	1.7	-6.10%	5.1
Nakuru	Kenya	1.7	-4.40%	5.5
Ndola	Zambia	1.7	0.30%	4.9
Parbhani	India	1.7	0.60%	3.8
Pokhara	Nepal	1.7	2.50%	4.8
Singrauli	India	1.7	-4.30%	6.2
Arusha	Tanzania	1.6	-0.60%	4.7
Belgaum	India	1.6	-5.40%	8
Jalna	India	1.6	-1.00%	7.2
Oyo	Nigeria	1.6	0.30%	6.7
Parepare	Indonesia	1.6	-1.00%	6.3
Beira	Mozambique	1.5	-3.10%	6.5
Malegaon	India	1.5	-2.90%	4.6
Sitapur	India	1.3	-1.50%	5

city hypothetically has urban rail and BRT, but is choked in air pollution, we can assume people do not have complete access to sustainable urban mobility. This assumption would need to be grounded in some evidence, showing that the pollution does not emanate solely from industry for example.

Classifying cities

The second level used was filters, which included mostly country-level data and indicators such as energy intensity (national), and share of base of the pyramid population, as well as urban-level data including urban access to electricity, air quality, and urban population data including projected growth rates. With this data in place, the following city types were created (Figure 5):[ix]

The cities identified are those with the potential to implement high-impact and affordable solutions.

City group 1 includes some of the fastest growing cities in the world, and it is perhaps no surprise

vii Defined as, "The average ratio of the beeline distance and the street travel distance for 40 pairs of sample points within the locale that are more than 200-meters apart."

viii Annual change. Each city has different time periods, but this refers approximately to the annual change between 2000-2014.

ix Note that average yearly growth rate (percentage) projection until 2030 are data at the urban level and the other indicators are data at national level that 19 of the top 20 cities here are found in India, with Gwagwalada, Nigeria, completing the list. India accounts for 121 of a list of 260 cities. This indicates that India would be a good target to support early-intervention and tracking tools for air quality, energy efficiency, and spatial planning to incorporate the energy and land-use sector.

City group 2 is the most diverse top 20 with a range of countries and cities ranked, from Tamale, Ghana, to Pokhara, Nepal. These 20 countries have high access to communication technologies and the opportunity to use digital tools to enable multiple co-benefits of access to sustainable urban mobility, including air quality and road safety.

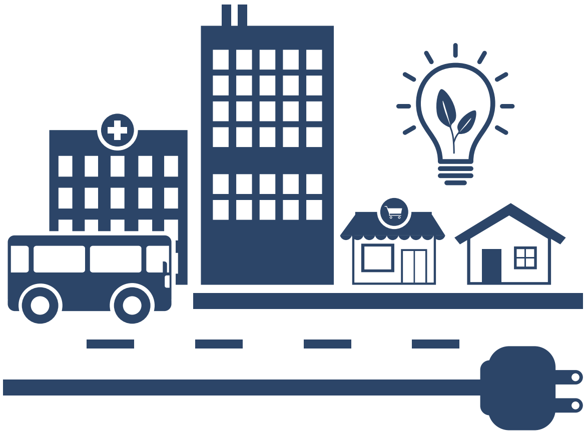
City group 3 highlights where electric mobility is best deployed. Windhoek, Namibia, tops the list, with the Philippines taking up the other 19 spots. The road infrastructure is considered relatively good, and the share of renewables in the electricity sector is high. The air quality is considered poor however, which, given the high urban access to electricity, indicates that there is a significant opportunity to consider electric mobility.

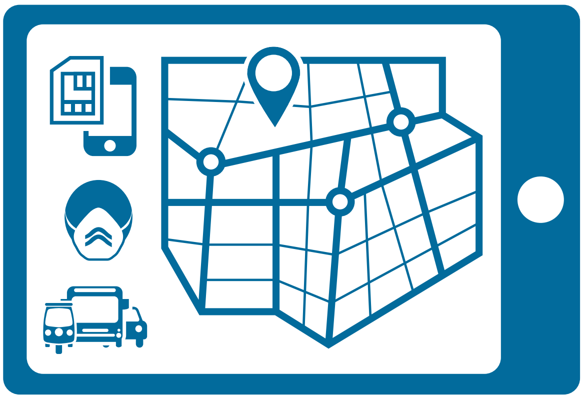
City group 4 focuses on renewables, looking at the full range of fuels available to drive renewable and sustainable transport, whether biofuels, hydrogen, or electricity. Three African countries top the list: Zambia, Ethiopia, and Nigeria. The grouping also ranked cities with CO_2 emissions from transport relative to GDP, with a higher figure giving it a higher ranking. This was done to identify those cities and countries where GDP is being created with high CO_2 intensity, but where there is renewable potential to grow sustainably.

It should be noted that the same city can be identified with more than one city type, as it can fulfill different criteria (and thus can profit from several solutions).

Figure 5

City types





Mobility A

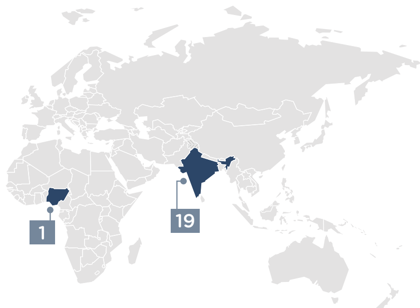
Efficiency Opportunists

- Fastest growing cities in the period 2020-2030, with a time sensitive opportunity to act on their mobility needs
- Indicated for interventions that reap the benefits of energy efficiency
- Present a special opportunity for countries where fuel economy policies are in place

Indicators and data used

- Average yearly growth rate projections
- Energy intensity
- Energy consumption of transport
- Fuel economy policies in place

Top 20 identified Efficiency Opportunist cities



India *(19 cities)*

Kottayam
Begusarai
Raniganj
Deoghar
Cherthala
Dhulian
Hosur
Kayamkulam
Ottappalam
Gandhidham
Purnia
Roorkee
Kanhangad
Karur
Tirupati
Muzaffarnagar
Siliguri
Agartala
Haldwani-cum-athgodam

Nigeria *(1 city)*

Gwagwalada

Mobility B

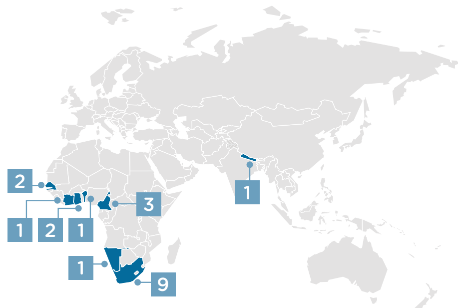
Digital Disruptors

- Cities that can gain significantly from potential co-benefits of improved energy and mobility
- Population exposed to air pollution and at risk due to unsafe roads
- Utilize digital technology as a solution to gain access to mobility

Indicators and data used

- Mobile cellular subscriptions
- Population exposed to air pollution
- Mortality caused by road traffic

Top 20 identified Digital Disruptor cities



South Africa *(9 cities)*

Rustenburg
Polokwane
Witbank
West Rand
Bloemfontein
Soshanguve
East London
Pietermaritzburg
Vereeniging

Cameroon *(3 cities)*

Mbouda
Bamenda
Loum

Ghana *(2 cities)*

Tamale
Sekondi Takoradi

Senegal *(2 cities)*

Rufisque
Thies

Namibia *(1 city)*

Windhoek

Côte d'Ivoire *(1 city)*

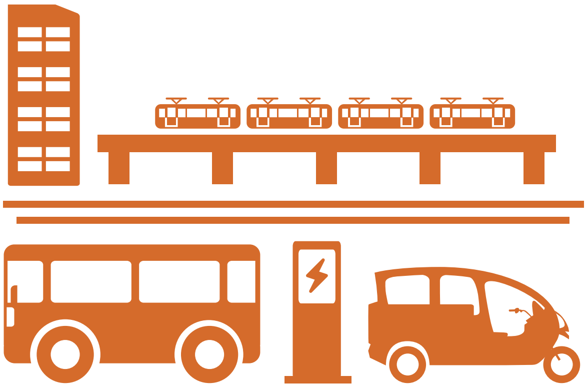
Bouake

Benin *(1 city)*

Abomey-Calavi

Nepal *(1 city)*

Pokhara



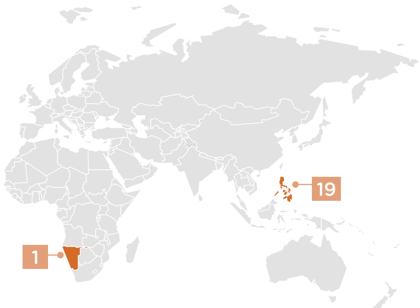
Energy A
Electric Vehicle Leapfroggers

- Cities that can profit from vehicle electrification, as they have urban access to electricity, especially renewable electricity
- Population exposed to air pollution
- Factor in quality of roads

Indicators and data used

- Population exposed to air pollution
- Urban access to electricity
- Quality of roads
- Use of renewable energy in electricity

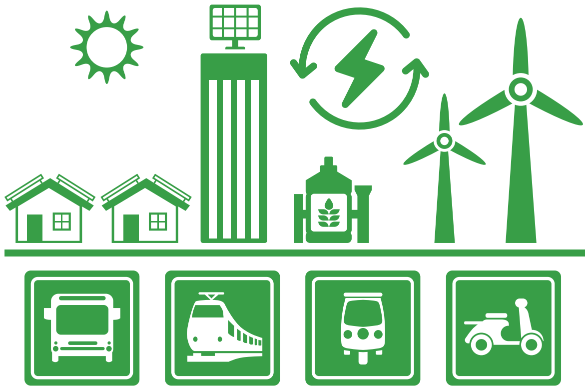
Top 20 identified Electric Vehicle Leapfrogger cities



Philippines *(19 cities)*

Imus	Binan	Bacoor	San Pedro
General Trias	Basilan City	Antipolo	General Santos City
Angeles City	Lipa City	Dasmarinas	Cotabato
Cabuyao	Calamba	Cagayan de Oro City	Bacolod
Santa Rosa	Lapu-Lapu City		Mandaue City

Namibia *(1 city)*
Windhoek



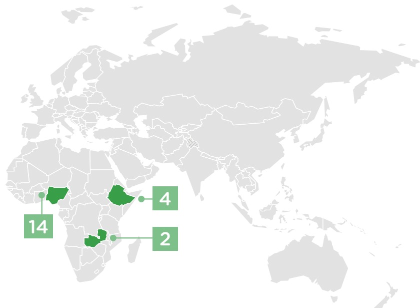
Energy B
Renewable Drivers

- Cities that have renewable resources available
- Look at renewable energy indicators, including use of biofuels, renewable energy in transport and renewable electricity
- Support access to sustainable urban mobility through renewable energy

Indicators and data used

- CO_2 Emissions from transport
- Use of renewable electricity
- Use of renewable energy in transport
- Use of renewable energy

Top 20 identified Renewable Driver cities



Nigeria *(14 cities)*

Gwagwalada	Uyo	Warri	Calabar
Lokoja	Umuahia	Saki	Ikot Ekpene
Potiskum	Ikorodu	Okpogho	
Nnewi	Abakaliki	Ogbomosho	

Ethiopia *(4 cities)*

Dire Dawa	Nazret
Gondar	Mekele

Zambia *(2 cities)*
Kitwe
Ndola

Latin America – Breakout Box

Only two cities in Latin America and the Caribbean met the criteria to be included in the list of cities considered: San Pedro Sula, Honduras, and Oruro, Bolivia.

San Pedro Sula has a projected growth rate by 2030 of 51 percent, from today's 767,000 inhabitants. Meanwhile, Oruro's corresponding numbers are 37 percent and 282,000. Both currently have public transit served by formal and informal buses and taxis, but no mass public transit systems are in place. On a national level, Bolivia presents a case for innovative public transit, namely for cable cars. Cable car systems are present in other areas in South America such as in Colombia, but the one in La Paz, Bolivia is particularly interesting given that it is an example of providing access to sustainable urban mobility at an affordable rate.[83]

Public transportation and electric vehicles are two significant trends sweeping across Latin America. More than a quarter of primary energy comes from renewables (with high dependence on hydropower), twice the global average,[84] and the region has both a fast-growing number of cars, and a high use of buses per capita, providing a sizeable opportunity for the electrification of bus systems.

According to UN Environment,"…[if] *the current fleet of buses and taxis of 22 Latin American cities were replaced with electric vehicles right now, the region could save almost US$64 billion in fuel by 2030, avoid the emission of 300 million tons of carbon dioxide equivalent, and save 36,500 people from premature death*".[85]

One on-going trend across Latin America is the electrification of public transit.[86] There are catenary electric buses in Quito, battery electric buses in several cities in Colombia, and in Santiago, Chile the largest purchase outside China has been made for 200 electric buses, with a goal to have 80 percent of public transportation be electric by 2022.[87] Electric utilities (Enel and Engie) will lease the buses to public transport operators, and provide the energy—renewable in the case of Engie in order to increase the value proposition to its clients—as well as install and maintain the charging infrastructure. Training has been incorporated as part of a program developed with support from the Energy Center at the University of Chile.[88]

In Uruguay, the first "country-wide electric corridor" was launched in 2018 with over 300 kilometers of EV infrastructure in place covering the full length of the country.[89] This is part of overall national efforts to improve planning by integrating the energy sector. Uruguay is therefore working on what may be the world's first "e-NUMP", an electric NUMP, which incorporates energy from the outset in national and urban planning, including for secondary cities.[90]

In Brazil, the Chinese manufacturer BYD is opening an electric bus factory in Campinas with an eye towards the sizeable Brazilian bus market, which only recently started to incorporate electric buses into its fleet.[91] A recent report by ICCT[92] shows that even with Brazil's favorable biofuel supply and usage, battery electric buses would result in much lower GHGs due to the supply of hydropower in Brazil as well as the associated emissions from biofuel production and land use.


72
METRO CABLE

4. THREE SOLUTIONS TO UNITING ENERGY AND MOBILITY IN CITIES

Asking the Right Question

The *Avoid/Shift/Improve* framework approaches sustainability and transport by looking at types of solutions available. However, we need to better understand how it can be implemented, how it can it be financed, and how it can be made sustainable.

For the energy sector there is no exact equivalent, but if we ask a different question, we can unite energy and mobility in a new way. This question is: when? When along the chain of a service can an intervention be most impactful and effective?

The theory underpinning this framework is the understanding that transport is a derived demand. In itself, transport serves little to no purpose, but the access it provides allows for the movement of people and goods. The same can be said for energy. Flowing electrons is not the end goal, but rather the means to services.

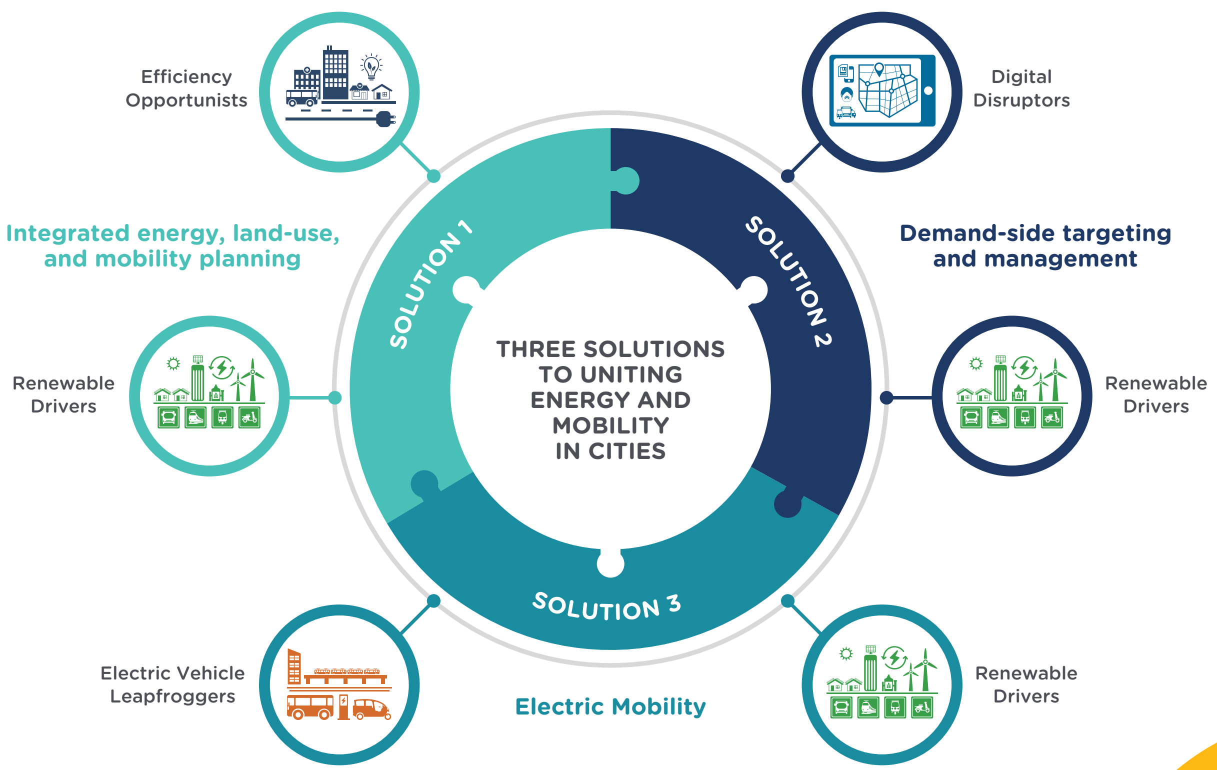
We need the services and access to opportunities energy and mobility provide, and by linking the two and mapping the demand, we can improve the effectiveness of implementation by ensuring three things:

1. We integrate not just land use and urban planning, but also the energy sector and energy efficiency, reaping multiple benefits of a systems approach.
2. By using demand-side management mapping of mobility and energy, there is a greater chance to efficiently utilize both, by avoiding unnecessary travel and energy use.
3. We ensure that the energy supply for mobility is as clean as possible; this will be more effective when the energy sector for electric mobility is included from the outset.

These combined approaches can be represented in a three-solution figure (Figure 6). It is worth underscoring first that the *Avoid* in the *Avoid/Shift/Improve* framework is the true untapped potential and by focusing on the *Avoid* we can get to *Shift* and then *Improve*, and preferably in that order: "first burn less, then burn clean".[93]

Figure 6

Three solutions to unite energy and mobility in cities



Solution 1: Integrated energy, land-use and mobility planning

Tying together land-use and transport planning has long been a worthwhile goal of sustainable transport practitioners, urging a holistic approach to urban planning and transport. Concepts including compact cities, transit-oriented development (TOD)[94] and new urbanism[95] stem from this effort, as well as SUMPs. Setting the basis for compact cities, which could allow for efficient integrated energy, land-use and mobility planning, might need stronger regulations, or in some cases for counter-productive regulations to be amended. For instance, regulations that could be relaxed to promote compact cities and allow for higher density include minimum lot size, maximum floor area ratio, minimum parking requirements and prohibition of mix land uses.

Bringing land-use and transport planning together is essential for sustainable cities and SDG 11 (Make cities and human settlements inclusive, safe, resilient and sustainable). Adding energy planning would increase the overall system efficiency.

The two main barriers to this integrated approach are the silos in which ministries operate – whether they are ministries of energy, planning, transport, or water – and related to this, the lack of available information. The key is to encourage stakeholders to plan jointly, rather than try to react. This is not a second order effect or an abstract notion, but in fact the very underpinnings of efficient public transportation, and in a sense, urban efficiency.

Public and Informal Transportation

In the absence of formal transport systems, informal ones materialize. Uber is an example – albeit unconventional – of such a service filling a market demand, and such informal transport is filling demand for public transportation around the world. The key question is whether regulation needs to follow, or lead, concerning the separation of formal and informal transport. There are case studies pointing in both directions, and there is a strong undercurrent of sentiment that informal transport should not be unfairly targeted or discriminated against, but rather incorporated into existing transport systems.

In the absence of any coordination, there can be great inefficiencies with negative consequences. A concrete example of this is the lack of fare integration. A system without fare integration discriminates against customers who are paying to be brought from Point A to Point B, and who find themselves negotiating different payment systems, fares, and schedules. Thanks to digitalization there is a way for informal transport to become more accessible, efficient, and sustainable (see Moja Cruise Case Study above). Using a single payment platform can enable access through several operators to a destination. This has been done in Berlin where both public and private operators have joined forces to further enable MaaS for customers,[96] and similarly in South Africa and Kenya where mapping technologies and digital payment platforms have enabled access to mobility.[97]

Thematically this points to another area of concern, namely operations. While infrastructure receives most of the attention and investment, building up the capacity of operations is equally important, and more likely to lead to a long-term and sustainable success.

Nevertheless, there are low-cost solutions available, but they require or at least encourage some integrated planning and discussions. For example, in Manila there are point-to-point buses, which target high populations (including base of the pyramid) in peripheral areas, transporting people directly with fewer stops to job centers.[98] Done well, this has the potential to

Bhubaneswar Bus Modernization – Case Study

The city of Bhubaneswar has a population of around 1 million and is the capital of Odisha state in India. Public transportation was formalized in 2010, however until recently it was served by only a few bus lines, which were infrequent, provided limited accessibility, and had a growth in ridership at just 2 percent per annum. This changed in 2018 when the Men's World Cup in (Land) Hockey was held in the city, spurring the city to act quickly to implement the first phase of a long-planned modernization effort, in part led by the Vice Chairman of the Development Authority.

In a short time, the city aimed to have a fleet of electric buses, a bike sharing system, and a public transport system resilient against climatic risks.

CRUT is the primary agency overseeing the bus operations within its jurisdiction area of the Development Authorities of Bhubaneswar, Cuttack, Puri & Khurda. Restructured in 2018, CRUT now operates around 200 buses through two private operators on a gross-cost model. CRUT started its new buses under title `MO BUS' which means 'my bus' on 6th November 2018. CRUT also launched MO CYCLE, the state's first public bicycle sharing (PBS) system on 26th November 2018, with 2000 bikes.[99] The role envisaged for CRUT is one of an 'integrated mobility provider' for its jurisdiction area, overseeing operations of various modes of transport – bus, cycle and electric cars.

The authority set out its ambitions in a well-considered 2017 modernization plan, including several phases as well as an overall ambition to increase access to sustainable urban mobility using mode share targets, going from a baseline of 10 percent moved by public transportation to 20-40 percent by no later than 2030. The effort was financially supported by local authorities, who took advantage of the timing as the main public transportation concession from the national government was coming to an end, and instead invested in buses themselves.

In April 2019, a devastating cyclone hit the region with 89 deaths, costs of over USD 1 billion, and significant infrastructure damage. In order to improve resiliency, CRUT is aiming to incorporate the following lessons:

1. keep power back-up ready
2. ensure network connectivity (during the cyclone it was difficult getting in touch with staff)
3. get depot infrastructure ready (as during cyclone buses were being kept at Kalinga stadium)
4. ensure a stock of physical tickets in case of non-usability of electronic ticket machines
5. have available funds to support affected staff and family
6. improve inter-departmental coordination to ensure route clearance and other necessities

The Bhubaneswar Bus Modernization case study shows that moving from a lack of public transportation to a well-integrated public transportation system, including a significant bus fleet, bike sharing, and other elements, can all be done in a city of around a million in the near term. The World Cup spurred action, but a well-considered 2017 modernization plan and political leadership all moved Bhubaneswar to a bus system with 190 buses being run by CRUT with a frequency of 15-20 minutes during peak hour. The next step will be bus electrification with purchasing in sight for 100km range electric buses in order to decrease local air pollution and increase energy efficiency.[100]

provide access to mobility, done poorly, it can cause more traffic and more delays, making joint planning again the key to successful implementation.

Walking and Cycling

Walking and cycling suffer from a lack of policy attention and funding, but it is nevertheless essential to incorporate them into any efficiency framework. Improved urban planning can support walking and cycling, but there is a lot that can be done in terms of training, capacity building, digital tools, and infrastructure, including for dedicated bicycle lanes.

High usage of walking and cycling with dedicated infrastructure comes with significant health and spatial benefits by avoiding polluting car traffic, for example, but for those who have no choice but to walk or bicycle in areas with high traffic mortality and poor air pollution, it is not fair to prescribe walking and cycling as a panacea.

Particularly in Africa, cities lack pedestrian sidewalks and bike dedicated lanes. In the absence of sidewalks on most urban roads, pedestrians walk on the carriageway, with terrible road safety implications. In addition, poor parking policies lead to cars being parked on the few sidewalks that do exist. Parking management emerges as a key area for ensuring walking and cycling each has its proper space. For this reason, walking and cycling should not be viewed in isolation, but as the underpinning of a multi-modal mobility system. Even the best bus or the fastest train is only so useful if one cannot get to the station itself, or if the station is in an inconvenient location. Planned together, the potential for walking and cycling to transform cities is immense.

In Quelimane, Mozambique, bicycling has gained increasing popularity thanks to a variety of factors, including a mayor who cycles himself.[101] The TDA has recently welcomed Maputo, Mozambique and Quelimane as its first African cities.[102] In Zambia, bicycles were given to farmers, which had a quick and measurable impact in terms of improved accessibility to, for example, health services, as well as a decrease in time spent traveling.[103] In many cities, steady investment to create a network has led to significant increases in the number of people using bicycles, even for longer trips.

Leapfrogging with SUMPs and NUMPs

Urban growth patterns tend to follow a somewhat predictable growth curve, but there is a way to leapfrog and avoid the worst parts of inefficient urban growth.

Urban researcher Dr. Robert Cervero points to the importance of SUMPs, or on a national level, NUMPs, in leveraging integrated land-use and transport planning. This has been done in Brazil with promising results and could be taken further by integrating energy into the mix. This is currently being undertaken in Uruguay where a so-called "e-NUMP" is being developed, incorporating elements of electric mobility into a NUMP, an opportunity that will drive multi-sector planning and tear down silos if done right, or be hampered by the lack of coordination if done poorly (Latin America Breakout Box).

India and Colombia also already have something similar in place. India (India Breakout Box) has a National Urban Transport Policy (NUTP),[104] while Colombia has a multi-tier public transit system depending on the size of the city,[105] which can also be used to meet certain criteria consistently established at a national level, following best practices not only within the country, but from around the world.

Bremen, Germany has won many accolades for its SUMP, including winning the European SUMP of the Year Award in 2014. While it may be considered less applicable to cities outside Europe, it is nevertheless worth delineating a key reason why it won the award and why the SUMP was ultimately considered so successful: public participation.[106] The city used online and visual mapping tools to engage the public to understand the priorities as well as to conduct a SWOT analysis, using the public's help and input to fill this matrix out. The result was increased public awareness and engagement, not only in the early preliminary planning stage, but also during rollout and subsequent evaluation. By doing it hand-in-hand with the public, and using this participatory approach, there is a key lesson that other cities in this report can take forward: digital tools in conjunction with a participatory approach may yield the best results.

While this solution can and should successfully be applied to the different groups of cities identified, Group 1, *Efficiency Opportunists*, would particularly profit from integrated energy, land-use, and mobility planning due to their fast growth projection.

Solution 2: Demand-side Targeting and Management

The best trip is the one not taken, at least from an energy and emissions point-of-view, especially considering time spent and services reached.

This "death of distance" is something that the communications field has spoken of. To avoid achieving one goal at the expense of another, it is key to start with demand-side management first, and then consider technological solutions.

While Solution 1, *Integrated planning*, has a lot to offer and is integral to long-term planning of urban form, ideally taking energy and transport sectors into account, there are new options emerging thanks to several concurrent trends: Urban access to electricity and communications, including a high penetration and usage of smartphones, has long since surpassed 50 percent and is already 99 percent in most of the 260 cities assessed here.

- Data collection systems have been established in the last two decades for urban, energy, and transport planning, but it is only now that access to these data is widely available
- Spatial mapping and geographic information systems (GIS) are more widely available, including the ability to track lights at night (as a proxy of population), IPs, remote sensing, and satellite data, and using geo-fencing as a tool for sustainability[107]
- Increasing research into how urban growth happens, both predictable linear developments, as well as non-linear and allometric development paths[108]
- MaaS has gone mainstream though various mobility services, driving home the point that you do not necessarily need to own your means of transportation to enjoy mobility services

> *"Satellite data are now available to a 30 meter extent, down to an object level. The urban scale is available."*[109]
>
> *–Luís M. A. Bettencourt, Mansueto Institute for Urban Innovation at the University of Chicago*

Together, these trends have the potential to foster transformational change while allowing for improved demand management and a decreased need for trips. These trends can also support Solution 1, *Integrated planning* and Solution 3, *Electric mobility*, by providing better data for urban planners and enabling technical transformations, for example by supporting charging solutions for electric vehicles. Solution 2, *Demand-side management*, however, focuses on a different notion, namely that it is possible and worthwhile to tackle demand at its source.

Open Data, GIS and Spatial Mapping

Every day many of us use spatial mapping perhaps without even realizing the data sets underpinning the abilities to order delivery food, find directions, or use a shared mobility service. What is less considered is how this can be a tool for city governments to tackle demand for a service at its source, be it education, health, the ability to work online, or ship local goods to market. By better understanding what the derived energy and transport demands are and mapping them out, there is an opportunity to see where they overlap and to achieve synergies in efficiency.

Other examples include innovative companies such as Conveyal that layers population, street, and transit data to help measure potential effects of urban and transport planning.[110] For the energy dimension, Lawrence Berkeley National Laboratory and the Institute for Transportation Studies at UC Berkeley have created "BEAM", a modeling framework that incorporates energy and mobility among other dimensions.[111]

Besides remote spatial mapping, how can spatial mapping be carried out on the ground? Mapping the overlap in demand is possible through energy use surveys using social science survey methods, or through stated preference surveys using mobile apps, online questionnaires, or door-to-door surveys. Similarly, this presents a good opportunity for the inclusion of relevant spatial questions into a census.

The World Bank has introduced an open-source web-based tool to link accessibility, spatial and networking mapping, with an aim to better understand the links of, for example, public transportation and links to employment centers and health services.[112] This tool has subsequently been used to map out potential employment growth based on various BRT corridor-planning scenarios in Kigali, Rwanda.[113]

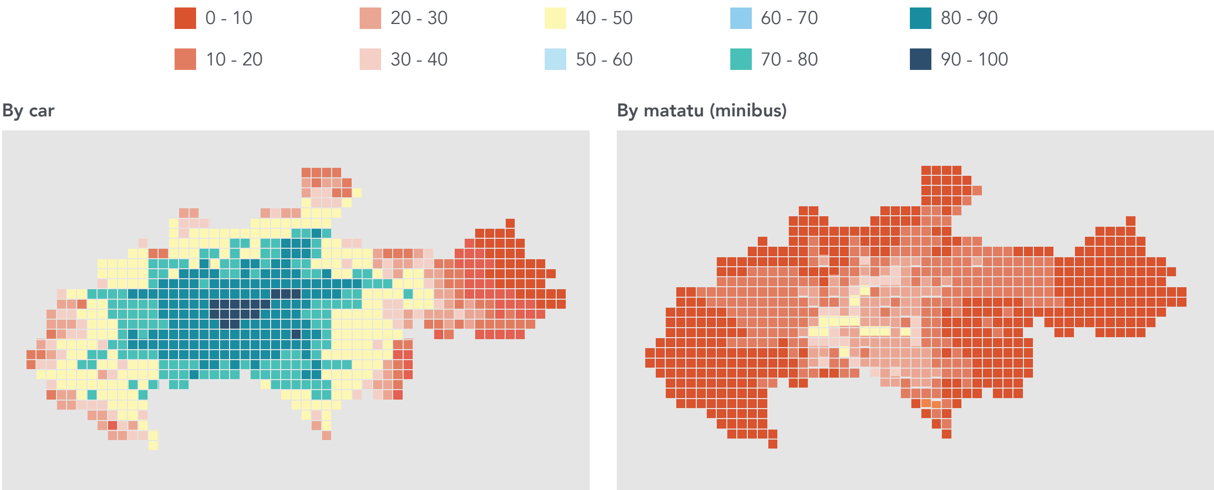
Demand-side mapping of companies and institutions can have higher impacts and likelier spill-over effects on surrounding communities.[114] Low-cost solutions include the companies providing transport shuttles themselves to avoid traffic and delays, or cities working with the largest companies to space out starting and end times of working shifts, something done successfully in San Francisco and London.

This is particularly relevant for the population at the base of the pyramid, as according to the "spatial mismatch hypothesis",[115] there is often a mismatch between the location of low-income households and appealing job opportunities. This manifests itself especially in larger cities where many migrate to the cheaper outskirts of the cities to have access to the services and jobs available in the larger city, only to get stuck in traffic for hours each day, spending upwards of 50 percent of their household income on commuting alone.[116] This is why something as straightforward as fare integration and information integration can be the difference between poverty and affluence.[117]

According to mobility research in Cape Verde, *"Accessibility is evaluated in terms of the number of bus trips required to access work places and the walking times to bus stops. The results show that deprived areas are at a disadvantage in the access to formal employment opportunities when comparing with more affluent areas."*[118]

Figure 7

Shares of jobs accessible within an hour by car or by matatu in Nairobi[119]



Source: WB

There is no quick fix to this issue, but more can be done, and new tools are available. When planning for public transportation, demand-side mapping can better support integration of equality considerations, including gender, by considering energy and mobility demands. This can be done using spatial technology coupled with on-the-ground data collection to ascertain types of settlements and potential spaces for informal trading, and the all-important area of public transport performance.[120] When measuring the performance of public transport – be it in terms of energy efficiency or delays – a key lesson internationally is to be sure to incorporate customer feedback for a reality check, which can be especially useful to flag burgeoning issues before they become critical and expensive.

This type of work is being done by South African company "WhereIsMyTransport" and Slum Dwellers International (SDI) in Harare, Zimbabwe, among other locations in Sub-Saharan Africa.[121] The end result and goal is to incorporate informal settlements into transport planning, but there is further potential to include energy demand. A key finding of the work so far is that even informal transport can be incorporated into a regulatory system, akin to what has now happened with Uber.[122,123]

Similarly, the Center for Neighborhood Technology in Chicago has built a "H+T index", calculating the combined costs of household and transportation for people to make better decisions when deciding where to rent or buy a habitation and what type of transportation mode to pursue. When thought of separately, many make the mistake of buying or renting a cheaper house or apartment only to find themselves spending a higher amount (and more time and with higher opportunity costs) on transportation. This index presents both as a percentage of household budgets.[124]

Finally, a third and similar concept is that of an "energy burden", which is the percentage of a person's or household's income spent on energy (electricity, home heating, and transportation), and is arguably one of the better metrics we have to measure affordability.[125] This opens up interesting opportunities such as, how can public transport infrastructure investment improve the energy cost burden for the base of the pyramid?

These data sets can give a sense of the variability within a given city and state, and can lead citizens, investors, and decision makers to search out high-impact hotspots for intervention.[126]

In the 19 priority countries identified in this report, some key data points are needed to start mapping out these demands, noting that data sets do not start out perfect, but rather are built up and improved over time:

- How many hours does it take to get to work, noting the origin and destination?[127]
- How many kilometers of formal (and informal, differentiated) public transportation are available?
- Transport modal splits (i.e. what share of travel is used by which type of travel mode) for some cities exist, but it is a worthwhile investment to conduct updated modal split assessments, since most cities either do not have them at all or have outdated assessments. In many of the 260 target cities, the modal share of walking and cycling is relatively high, which represents an opportunity to increase overall mobility.

Digital Disruption

MaaS is enabled by better access to and collection of geospatial data over time for both land use and transportation patterns. For example, UNICEF has collected data through its Multiple Indicator Cluster Surveys (MICS) for over 23 years in more than 317 surveys.[128] While these data, as one example, may not have been collected for the purpose of sustainable energy and mobility, they can be used in coordination with other data

sets to better understand MaaS business opportunities. In Kenya, two companies (Angaza and Uber Kenya) partnered to provide off-grid solar to Uber drivers.[129] This successful combination will lead to cost and energy savings, as well as improvements in access to energy services.

With GIS and other public transport data feeds,[130] we now have increased access to more data sets than ever before.

An interesting example of using GIS and customer data, which has potential for other secondary cities, comes from a secondary city in Sweden, where some long-distance and commuting buses are only put in operation if a reservation has been made.[131] This may or may not have a large energy impact in other cities, but can be done quite cost-effectively and applied to base of the pyramid as the only technology device needed by users is a mobile phone.

Digital tools can impact energy use in the transport sector (Figure 8).

Digital tools can support different needs for each sector. In the following two sections, the impact from digitalization for energy and transport for health and education sectors are discussed in more detail.

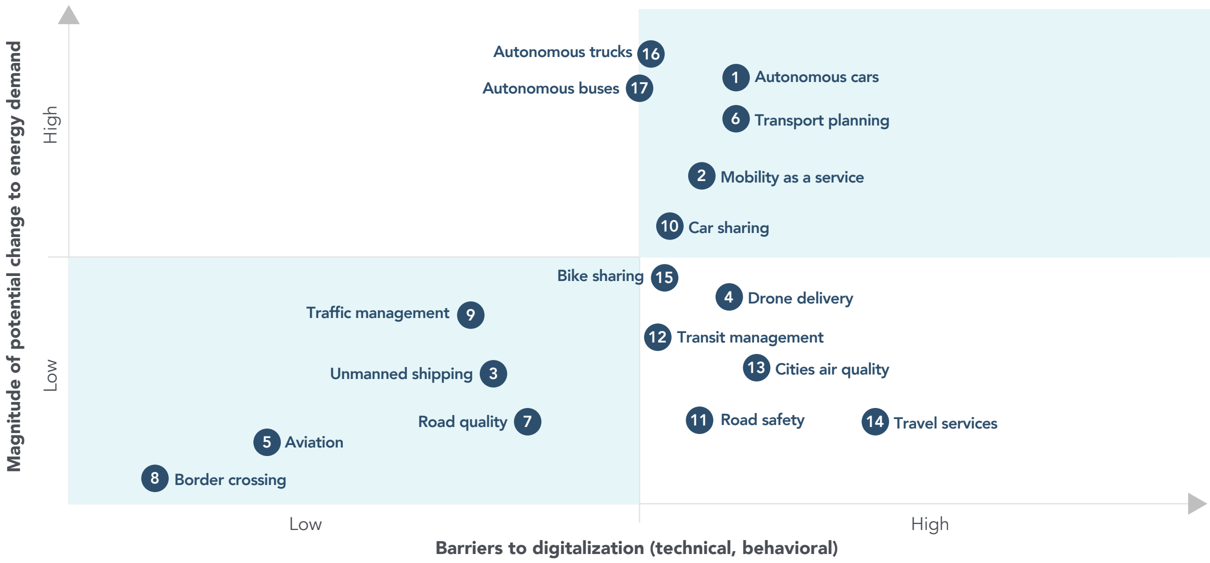
Energy and Transport for Health

Health is a fundamental right and is addressed in Sustainable Development Goal, SDG 3 "Ensure Healthy Lives and Promote Wellbeing for All at All Ages."[132] Health features here both in the sense of prevention of health issues and to provide health services. In terms of prevention, energy and mobility can support SDG 11 by improving air quality and can support SDG 3.6 to reduce global deaths and injuries from road traffic accidents by providing access to sustainable urban mobility, including public transit, safer transport, and more proximate access to services.

Besides prevention, demand-side mapping can reduce energy and mobility emissions that impact health, while still providing the same or bet-

Figure 8

The potential impact of digitalization on transport[133]



1. **Autonomous cars**
2. **Mobility as a service** (see chapter 2)
3. **Unmanned shipping**
4. **Drone delivery** (see case study)
5. **Aviation**, e.g. rely on real-time weather updates to direct planes to avoid turbulent skies, and save on jet fuel
6. **Transport planning**, track where base of the pyramid people live and where they need to go
7. **Road quality**
8. **Border crossing**
9. **Traffic management** through intelligent transportation systems, collecting data from the cars that are in the roads on accidents and congestions to help users avoid traffic jams and authorities start to plan traffic management better.
10. **Car sharing**
11. **Road safety** using street cameras, data analysis and artificial intelligence, to evaluate accidents and near misses to measure risk and road safety.
12. **Transit management** through open source data, to map movement and provide instant information to drivers, and others, in real time. Provide users with information in one site to see how different transport modes are interlinked.
13. **Cities air quality**: cities can use predictive models to alert residents to high levels of pollution, while taking steps to mitigate it.
14. **Travel services** using digital tools to track different travel patterns (e.g. women) and provide ad hoc services.
15. **Bike sharing**
16. **Autonomous trucks**
17. **Autonomous buses**

Source: IEA, team analysis

ter level of service in a more sustainable manner. Three examples are worth exploring:

- In Zambia, remote solar has enabled access to health services that were not available previously.[134] If there were access to the same services in other cities, the emissions avoided would be significant.
- In India, remote health services or "telemedicine", has proven to be a success, especially in the field of eye care. While health services require specialized equipment and in-person visits, remote eye care has proven to be effective and cost lowering.[135]
- In South Africa, demand-side mapping has been used to determine where the highest de-

mand is for pharmaceuticals, and "pharmacy vending machines" have been subsequently deployed.[136] This provides the service closer to the person needing it, thus reducing energy and transport emissions.

According to a World Health Organization study covering over 4,000 clinics and hospitals, about one in four health facilities in 11 countries in Sub-Saharan Africa had no access to electricity in 2013, and most facilities with access had an unreliable supply.[137] Transport-related health risks are significant, including 3.2 million deaths globally per year from physical inactivity, 1.3 million deaths per year from road traffic injuries and 1.3 million deaths per year from urban outdoor air pollution (mostly PM10 and PM2.5).[138]

While energy and transport may not be the foremost consideration in these examples, it is worth studying the reverse-engineering solutions where possible to identify options that are more energy and cost efficient for the health sector, such as remote solar-powered health facilities or telemedicine.

Energy and Transport for Education

While the demand for health is arguably unpredictable, education is quite predictable for at least a decade (primary to secondary school), if not more. This predictable demand holds true for students and employees of schools, including teachers and other staff.

For teachers, the need to take a day off to simply pick up their paycheck can cause missed classes and unnecessary travel.[139] Mobile payments such as those introduced in Kigali, Rwanda,[140] can represent a high-impact solution for the benefit of teachers, children and overall sustainability. The mobile payment system in Kigali has since spread to other parts of Rwanda and can now be used as a mobile application.[141]

Many children are exposed to harmful pollution either walking or taking the bus to school and are disproportionately affected by pollution from older buses.[142] To provide options in terms of better planning of school location for each student, we need to know where prospective students live, something that can be done through demand-side mapping. One solution that presents itself is that of solar-powered schools, meaning that schools can be in more remote locations, closer to the children going to the school, and at the same time providing the services that solar power can provide, including electricity[143] and cooling. This is being carried out in Kenya with success, noting that as electricity prices are often factored into school fees, the lower electricity costs make the school more affordable. This sector, as with health, is a high-priority area for achieving multiple SDGs with one intervention, and the collection of data is an important starting point.[144,145]

Digital Disruptors cities could profit from demand-side targeting and management. Digital technology is an opportunity that, if harnessed correctly, can be more than the sum of its parts. For example, demand-side mapping can help determine where smartphones might be useful in eliminating unnecessary travel through functions like mobile payments.

Solution 3: Electric Mobility

Electric vehicles (EV) have been around for over a century, but recent technological and market advances are shifting the value proposition of EVs quickly. Advances in both batteries (Figure 9) and solar photovoltaic panels have been key to enabling EVs to compete cost effectively with traditional combustion vehicles. While vehicle electrification may increase efficiency and solve local air and noise pollution, the shift to electric mobility can also be used to support the clean energy transition and mobility transitions to shared mobility and autonomous vehicles. [146,147,148]

Beyond market developments, there are also increasing data and information on best practices around the world; how can the base of the pyramid benefit from these transitions, especially given the current higher upfront costs of EVs and other potential solutions?

The 19 target countries have some automotive manufacturing, but most are the targets for imports of secondhand, often dirtier and antiquated vehicles. Solutions for this include import restrictions and fuel economy standards (see GFEI, the SEforALL Accelerator for fuel economy standards), but these are only part of the puzzle and mostly relevant at the national level with scant options for cities to act upon. To provide affordable mobility to the base of the pyramid, new car ownership is unlikely to be one of the first solutions; rather, vehicle electrification is an opportunity that needs innovative approaches.

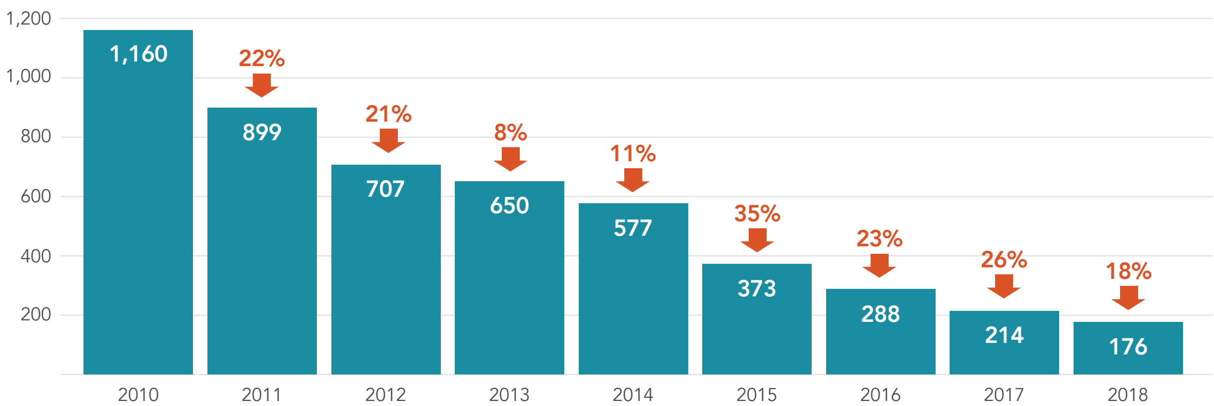
An increasing number of countries and cities are banning internal combustion engine (ICE) vehicles after a certain date in the near-to-medium future as a signal to automakers (Table 5).[149,150] Universities and companies are asking how electric mobility can serve the base of the pyramid,[151] and how we can leverage the phase-out of ICEs for the benefit of those at the base of the pyramid. According to the World Bank and UITP, *"electro-mobility fails if it doesn't serve disadvantaged communities, since the TCO [Total Cost of Ownership] is lower and the benefits should be distributed through e.g. sharing models."*[152]

By applying vehicle electrification to shared mobility and public transportation, those at the base of the pyramid may have access to shared or public electric vehicles sooner than to privately owned electric passenger ones, which often begin their penetration into the higher-income groups.

Electro-mobility is an opportunity that will drive multi-sector planning or be hampered by the lack of it. The challenge is to provide certainty for consumers, public transit authorities, companies, and infrastructure providers.

Figure 9

Battery pack prices decreased by 85% from 2010 to 2018 (real 2018 $/kWh)[153]



Source: BloombergNEF

Table 5

Overview of government commitments to the phase-out of internal combustion engine technologies[154]

Country/Cities	Example of targets
United Kingdom	Ban on new sales of petrol or diesel vehicles after 2040. London will impose an Ultra-Low Emission Zone (ULEZ) from April 2019
Norway	All new passenger cars, light commercial vehicles, and city buses should be zero emission by the year 2025
South Africa	5% reduction of greenhouse gas (GHG) emissions in the transport sector by 2050 [Draft Green Transport Strategy]
People's Republic of China	Considering a ban on the sale of new petrol and diesel vehicles
Denmark	Ban on new gasoline and diesel cars by 2030
Germany	1 million electric vehicles on the road by 2020
Ireland	No new internal combustion emission vehicles sold after 2030
India	15% of vehicles to be electric by 2023 [proposal]
South Korea	Government to supply 1 million electric vehicles by 2020
Scotland	No new petrol or diesel vehicles by 2032
Netherlands	All new vehicles emission free by 2030
France	No new petrol or diesel vehicle sales after 2040
Slovenia	New sales of vehicles to have less than 100 grams of CO_2/km by 2025; only low-emission cars (50 grams of CO_2/km) by 2030
Mexico City, Paris, Madrid	End use of all diesel vehicles by 2025
Copenhagen	All city-owned vehicles emission free by 2025
Brussels	Ban diesel vehicles in the capital by 2030
Barcelona	All new buses procured will be zero emission from 2025
Cluj-Napoca	By 2025, the city's whole public transport fleet will be zero emission
Copenhagen	From 2019, all new buses procured in Copenhagen will be zero emission vehicles
Quito	After 2025, all new operation contracts signed between public transport operators and the municipality will require only electric bus fleets
Paris	Becoming the world leader in green technology with a fleet of 4,700 clean buses by 2025
London, Paris, Los Angeles, Copenhagen, Barcelona, Quito, Vancouver, Mexico City, Milan, Seattle, Auckland and Cape Town	Only electric buses will be bought after 2025
Moscow	Diesel buses to be substituted with electric buses from 2021
London	By 2037 all buses in London (about 8,000) will be zero emission
Amsterdam	All bus fleet of public transport operator GVB will become electric by 2025
Flanders	By 2025, all urban buses operated by De Lijn will be only battery electric and plug-in hybrids
50 European Cities and Regions	Increase the share of zero emission vehicles in the EU to 30% by 2025 and contribute to the deployment of at least 2,000 zero emission buses by the end of 2019

Drones – Case Study

UNICEF is using drones (long-term plan to be locally piloted and 3D-printed) in Malawi, Ghana, and Vanuatu[155] to *improve* transport efficiency by reducing transportation time and ensuring that children who require treatment can receive it on time, especially important in areas without electricity and refrigeration.

By using drones to deliver vaccines, travel to health facilities can be reduced by providing the vaccines closer to the destination at a lower energy cost than that of a bus. Drones could also be used to deliver spare parts for EVs or indeed solar power.

Drones are certainly an innovative example of *Improve*, and while not a panacea to all issues of the transport sector, they have an important role to play by providing critical services closer to the source of demand. They can be electrically powered, and thus have the potential to be renewably powered.

From a Demand-side Targeting and Management (Solution 2) perspective, drones have the potential to reduce costs by delivering services directly. They can be on standby mode and used for multiple locations and multiple purposes, according to need.

From the energy side, there has been widespread progress with solar power and decentralized renewable energy. While progress in terms of price drops and implementation has been noteworthy, there are barriers including the lack of on- and off-grid data, potential for increased blackouts, difficulties in grid regulations and interconnections, and the lack of a widespread enabling regulatory and policy framework. Each of these needs to be taken into account when considering vehicle electrification, and a good step forward is for governments to develop a national-level guiding document. Nepal launched its National Action Plan for Electric Mobility in 2018, connecting it to its NDC, and including not only electric cars, but also multiple transport modes and electrical infrastructure.[156]

There is potential for governments at all levels of capacity to engage with electro-mobility. This report looks at the three main areas of potential for vehicle electrification for those at the base of the pyramid in the target cities, namely electric cars, buses, and two-wheelers.

"The transformational nature of eMobility opens opportunities for other evolutions in transport and other sectors such as energy. International experience suggests that this can be used to support important objectives such as increasing female participation, improving access to public transport, and the development of new -markets in the energy sector. The new value and supply chains underpinning eMobility offer a new opportunity for embracing principles of social and environmental sustainability in a way that goes beyond what has been achieved for ICE vehicles. Governments should think of eMobility as a lever that can affect broader change in addition to the reduction of emissions."

-World Bank and UITP paper on eMobility[157]

Electric Cars

Individual electric car ownership is not particularly relevant for those at the base of the pyramid given the current higher up-front price. However, exceptions could provide potential opportunity for this part of the population:

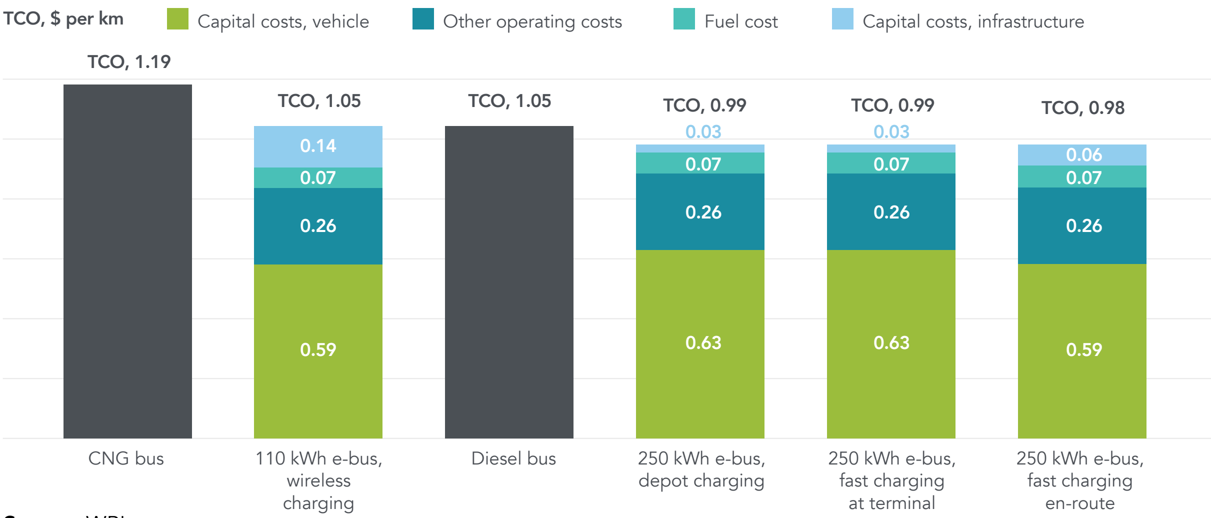
1. There is an increasing trend towards shared mobility, which could manifest itself through, for example, electric taxis, meaning that more passengers would get exposure to electro-mobility than a given individual owner. Electric taxis can improve local air and noise quality, as seen in Nairobi.[158] Electric shared mobility has the benefit of higher utilization, which means a faster payback on the investment, but higher use might also come with battery range limitations depending on the distance and use time required and battery size.
2. Secondhand EVs are starting to find markets in developing countries, which is an opportunity for advanced technologies to be experienced sustainably by all, including those at the base of the pyramid. An interesting example comes from Jordan, where about 7,000 EVs are plying the roads, 88 percent of them secondhand Nissan LEAFs, using just the seven charging stations that exist in the country.[159] How did this become such a big EV market?[160] For one, there was an exemption on import duties, which the government eventually altered. However, another interesting part of this story is that an online support group was created where EV owners could share best practices and in effect crowd-source charging stations, by owners offering their homes and outlets and eventually repair skills to troubleshoot subsequent questions and issues. If nothing else, this may have kicked off the first steps of a new ecosystem[161] that is needed for electro-mobility to prosper.

Electric buses

Electric buses are already saving more oil than electric cars. Electric buses in China displace more than three times the total amount of oil than the world's fleet of passenger electric vehicles.[162] Cities are quickly seeing electric buses as a relatively easy entry point into vehicle electrification with quick and concrete improvements in sustainability (Latin America Breakout Box).[163] Electric buses come in a variety of lengths, as well as with a variety of charging solutions. Given that the majority of informal transit is via minibus, it is almost shocking how little attention is given to the potential of their electrification. With high usage and low electricity costs, some electric bus lines are already cheaper from a total cost of ownership perspective (Figure 10).[164] While en-route charging may be the best from a system cost perspective, as suggested for India,[165] many bus op-

Figure 10

Total cost of ownership comparison for common e-bus configurations in a medium city



Source: WRI

erators in Europe, South America, and elsewhere are opting for overnight depot charging at bus terminals, in some part due to the issue of finding appropriate land and infrastructure for safe and secure charging stations.

While the vehicle level is well considered, that of the corresponding infrastructure is often not. The costs of finding the appropriate land for charging stations and electricity infrastructure expansion or upgrades need to be factored in before electric bus deployment begins.

To date, little has been done in Sub-Saharan Africa outside university campuses for electric buses. Of the 19 target countries in this report, only India and Nepal have electric buses in regular service.[166,167,168]

Electric two-wheelers

Electric two-wheelers (see Electric two-wheelers in Sub-Saharan Africa – Case Study) are one of the more overlooked solutions for sustainable transport. Policymakers often assume that support for electric two-wheelers implies a promotion of this mode over other modes, when in fact the goal is to improve both sustainability and mobility. Electric two-wheelers may not solve every issue or be suitable for every purpose, but they can play a meaningful role.

In China, there are more than 200 million electric two-wheelers plying the roads, a shift away from ICE fostered by cities and the national government through a two-stroke engine ban first, and eventually a ban of all combustion two-wheelers from urban centers, to improve local air and noise quality. With the success of the regulation and the scale of the market, the cost of electric two-wheelers has come down to equal in cost to—or even cheaper than—conventional powered two-wheelers.

India has 1.5 million electric rickshaws, albeit with three wheels, with significant energy savings (Table 6).[170]

Table 6

Diesel versus electric rickshaws in Udaipur

Parameter	Diesel Rickshaw	E-Rickshaw
GHG emissions per unit per year	Tank-to-wheel (TTW): 0.97 tCO_2 Well-to-wheel (WTW): 1.19 tCO_2	TTW: 0 tCO_2 WTW: 1.05 tCO_2
GHG reductions per year per fleet: 6,000 units	-	TTW: 5,800 tCO_2 WTW: 850 tCO_2
Capital expenditure per unit	$3,400	$4,900 including charger and two times battery replacement
Operational expenses per unit annually	$440	$250
Government subsidy	-	$650
Total cost of ownership per kilometer[x]	$0.63/km	$0.61 per kilometer with subsidy $0.68 per kilometer without subsidy

Note: E-Rickshaw is a 6-seater with a Li-ion battery unit and a 1,500-watt engine[169]

x Considering a vehicle lifetime of 6 years for rickshaw and a battery lifetime of 2 years.

Electric two-wheelers in Sub-Saharan Africa – Case Study

In Namibia, a local company, SunCycles, is producing electric two-wheelers powered by solar power.[171] In some cases the two--wheelers have proved more popular than cars, and fill gaps and ranges that conventional bicycles are not able to fill. There are over 100 SunCycles on the road in Namibia today.

In Rwanda, an electric bike company is conducting trials to support motorbike taxis and delivery services carried out electrically, with four types of motorcycles being trialed.[172] According to the company Ampersand, the vehicles are 75 percent less polluting in terms of GHGs and will save each driver around USD 900 per year.

In Kenya, a Swedish company is working to retrofit vehicles with batteries and electric motors, pairing this vehicle electrification with on- and off-grid solar PV solutions.[173] It has converted a safari vehicle into an electric safari vehicle, adding eco-tourism as a potential co-benefit for interested operators and drivers. The company is also cooperating with a Kenyan delivery firm, Get Boda[174], to produce over 3,000 electric motorbikes per month.[175]

While electric two-wheelers have received minimal attention to date, more is now being done, including by United Nations Environment Programme (UNEP), which is calculating the costs and benefits of the electrification of two-wheelers.[176]

As technology improves and the life of both vehicles and batteries increases, the cost effectiveness of e-rickshaw will further improve.

Electric two-wheelers, physically much smaller than cars, also provide a high efficiency gain when compared to conventional vehicles. Their versatility and lower price when compared to electric cars make them suitable for several applications in developing countries (Case Study below).

EV Leapfrogger Cities would particularly profit from an increased penetration of electric buses, electric-two wheelers and electric minibuses.

A Summary of the Three Solutions

The three solutions are not distinct, as they operate across a shared spectrum, and in certain parts there is more potential for overlap than others. The key is to find these areas and to utilize them as enablers of higher provision of public transportation. The overlap can take the form of the following interventions:

- By mapping energy and mobility demand, electric mobility can be provided in the right places for children, teachers, and parents going to and from schools.
- By using drones to deliver vaccines – as seen in Malawi, Ghana, and Vanuatu – health facilities can be avoided by providing the vaccines closer to the destination at a lower energy cost than that of a bus. Drones could also be utilized to deliver spare parts for EVs or indeed solar power.
- Vehicle electrification can focus on electric two-wheelers and buses, as seen in China, Kenya, and Malaysia, and when paired with off-grid solar, a whole community can become sustainable.

In short, energy can now play a key role in transport and mobility that it could not before. It can do so by powering EVs and mobile devices (and thus MaaS), and powering all of them renewably, in addition to powering services that obviate transport and meet multiple SDGs at the same time.

5. THE FINANCING GAP

Investing in energy efficiency is a well-researched field in which many case studies have identified opportunities and barriers.[177] To achieve energy efficiency in small-to-medium-sized cities it is important to identify and overcome the relevant barriers and challenges by utilizing affordable solutions.

A key role is played by data. The energy sector has a well-documented flow of funds and an identified gap.[178] The value of tracking funding flows can highlight trends, gaps and potentially the barriers to the investment needed for sustainable transport. The Africa Mini-grid Developers Association has underscored the importance of the link between data and finance.[179] Data are essential for financiers in determining whether to fund a particular activity, i.e. to assess the risks involved in that activity. Data are needed to understand the budgetary resources that cities and countries have to work with, as well as for an individual person, such as the cost of transport fares, not only in nominal terms, but also in relation to PPP and as a share of household income. A study from 2011 analyzes how urban household budgets are spent or needed for transport in 11 Sub-Saharan African countries.[180] This study shows that on average, the budget spent is between 5 and 15 percent of the total, a figure that increases for households in the bottom quintile where the budget needed for two trips per day is on average 40 percent of the total household budget ranging from 15 percent in Dakar, Senegal to 105 percent in Lagos, Nigeria.

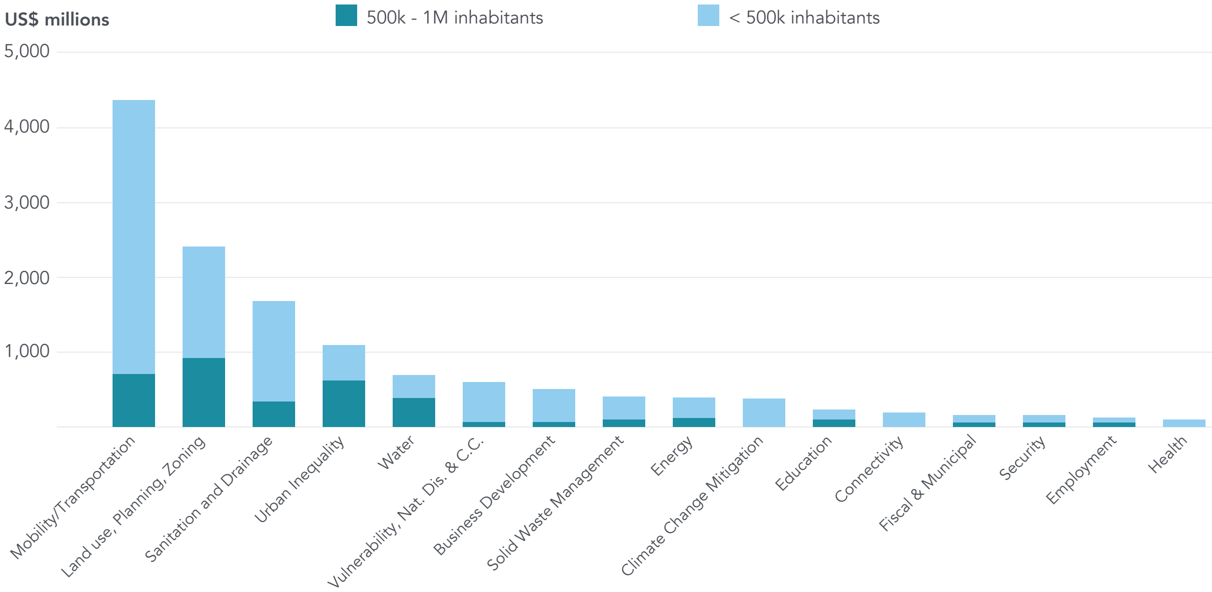
In total, the base of the pyramid represents a USD 5 trillion market according to the World Bank Group, of which:

- USD 2.3 trillion is in food and nutrition
- USD 508 billion is in housing
- USD 405 billion is in clothing and personal care
- USD 317 billion is in **energy**
- USD 298 billion is in **transport**
- USD 243 billion is in health
- USD 206 billion is in information and communication technology
- USD 193 billion is in education
- USD 32 billion is in water

In many regions, including Latin America (Figure 11), while transport and energy may be seen as priorities for investment, funds tend to be spent

Figure 11

Total indicative investment needs by sector (USD Millions): Cities of different sizes need different investments[181]



Source: Inter-American Development Bank

on infrastructure for cars and not on public transportation. This has to do with transport projects belonging to several sectors across several levels of government. It is also challenging as many transport projects have enormous positive societal effects that are much harder to measure than other sectors e.g. the difference between building a school (education) versus improving sidewalks (transportation) to get to the school. The new school has a quantifiable number of students in attendance, especially if there was no school before. However, an improved sidewalk or overall improved accessibility to walking and cycling is much harder to quantify and to "prove" what emission or safety savings took place.

An important principle for servicing the population at the base of the pyramid is that margins are not high, while so-called "unit sales" can be very lucrative,[182] yet this only applies if scale can be reached and if services are affordable, something still elusive for the energy and mobility service markets.[183] Public investment is needed to leapfrog new technologies into the market and avoid common problems with new technologies not trickling down to the base of the pyramid.[184]

Incentives for purchasing or operating EVs are available in many countries, but for some countries the options to support the transition might be costly in national budget or political terms. Besides importing vehicles, companies are emerging in Kenya, Namibia, and Rwanda to start manufacturing EVs at a low cost, which has benefits in terms of employment, mobility, and sustainability (Electric Two-wheelers in Sub-Saharan Africa Case Study). Moving forward, electric two-wheelers can now be 3D-printed, providing the opportunity to enable momentous changes if relevant parts become cheap enough.[185]

Cities have received just 11 percent of multilateral climate finance for mobility projects,[186] and while there is a major, overarching issue about accessibility of climate finance generally (including multiple climate financiers, and complex application procedures that differ from one to the next), this is exacerbated in the case of small jurisdictions with limited institutional capacity to raise climate finance. Furthermore, municipalities may not see the link between, for example, climate change financing and their local priorities, nor may it be under their purview and thus it may not be their responsibility. From a budgetary point of view, there may not even be a budget in place for transport at all, which may be allocated at a national level and become a problem if there is a disconnect between national transport planning process and local users' needs.

Public transportation needs to be convenient for the population at the base of the pyramid and for a growing middle class. Financing and subsidies in financially stressed countries and cities might be difficult, but available funding should take into account not only infrastructure and capital costs, [187,188] but also the sustainability of finance operations in the long-term, which means funding the cost of proper operations and maintenance (O&M) over the lifecycle of the assets.

Other barriers and challenges include:

- The total cost of ownership for electric vehicles is already lower[xi] in many places and for many vehicle classes, but the upfront cost is nevertheless higher, and with low awareness, capacity, and infrastructure installed, the market uptake is sluggish.
- There is a mismatch between climate finance and *Avoid* implementation measures, to some degree *Shift* as well, but not *Improve*. In other words, it is perhaps not surprising that technology solutions are more easily funded for the transport sector since the implementation period is clearer and shorter. However, for transformational effects, this should be reconsidered, and at the very least, supplemented with *Avoid* and *Shift* investments.

Equally, a range of opportunities exists to overcome barriers:

- There is potential for text-based data and information solutions given widespread cellphone, but not necessarily smartphone, penetration.[xii,189]
- Funding can go directly to local levels, but an alternative is to provide national funding with a pool for application by cities with plans for sustainable urban mobility. This has been done successfully in countries where a NUMP was supported with SUMP criteria for candidate cities.
- Similar to the SUMP criteria, there are many good ideas for how to support financing for sustainable mobility and improving energy efficiency, including attaching criteria for funding walking and cycling.[190] This could be expanded to make sure that energy and mobility projects consider each other where relevant, something pertinent in the electro-mobility space. Toolkits for developing sustainable energy and mobility plans are available from UN Environment.[191]

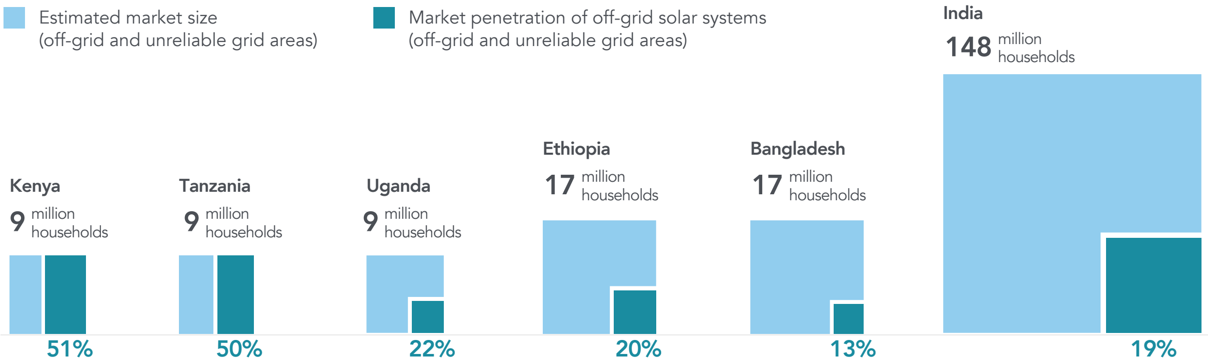
It is important that the percentage of population with access to sustainable urban mobility is given a baseline number so that this can be tracked and targeted with investment and financing. Without knowing the current status and the associated gap, we cannot begin to deliver a tracking mechanism for finance of access to sustainable mobility.

xi Several numbers weigh into this calculation, including electricity and diesel prices, but as a general trend, the TCO for EVs is improving across vehicle classes.

xii Research shows that while the penetration of communication devices might be overstated, the growth is quick, and the potential is bigger than previously considered.

Figure 12

Market size and current penetration of off-grid solar systems in selected countries, 2017[192]



Source: REN21

Another data point needed is the current and projected cost of inefficiency in the urban energy and transport system. If we have better data on this, Solution 1, *Integrated planning,* can help quantify the costs of inaction and make a clearer case for investment.[193]

The nexus between energy and mobility has the potential for transformational change, but there is much to be done to determine how it can be done, and how it can be paid for. By better understanding where the opportunities are for energy financing, and coupling this with mobility financing, we may arrive at areas of overlap that would be considered good investments. As an example, it may be worth considering Solution 2 and 3 for target cities in the East African region. Could these countries be well positioned for demand-side mapping of services in the energy and transport sectors based on their off-grid solar progress? Might they be an opportune place for electro-mobility investments, coupled with off-grid solar? One potential measure would be to consider subsidies for installing EV home chargers with an off-grid solar panel. These are the opportunities that are starting to be assessed,[194] and need to be better understood and explored by understanding existing examples.[195]

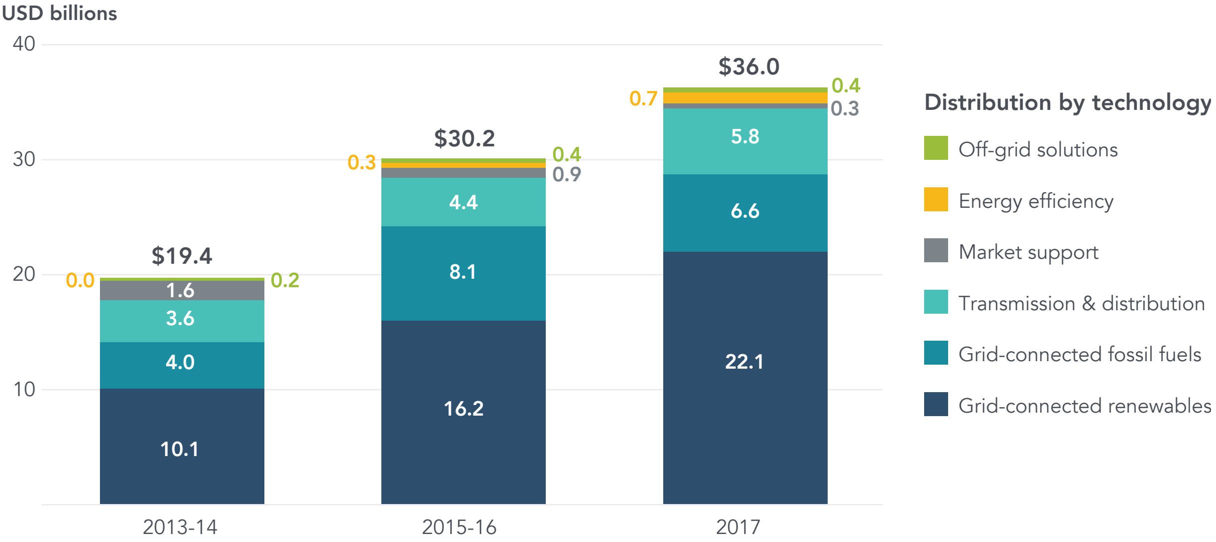
Similarly, there are financing models that have proven successful and innovative in the mobility and energy sectors, but little discussion has taken place as to what can be shared across areas, with the possible exception of energy service company (ESCO) financing.[196] An example of a new model for financing is Crowdfunding: for instance, the TRINE platform has been establishing Crowdfunding campaigns for off-grid renewable energy solutions in developing countries and could similarly address mobility projects.[197] Using results-based financing has supported the uptake of off-grid solar in Bangladesh and East Africa and could be considered for the mobility sector as well.[198]

Research into financing renewable energy has shown the potential of cross-country learning from other countries' financing models, including for off-grid solar.[199] Financing for renewable energy in 20 developing countries analyzed in SEforALL's *Energizing Finance* series[xiii] has been constantly increasing in recent years due to the economic competitiveness of renewable energy compared to fossil fuels (Figure 13). Four coal plants were financed in two of these 20 countries, Bangladesh and the Philippines, down from 17 plants in 2015-16. Financiers of mobility projects should analogously focus on cleaner and renewable sources of energy, even more when planning for new infrastructure projects.

xiii Afghanistan, Angola, Bangladesh, Burkina Faso, Congo (DR), Ethiopia, India, Kenya, Korea (DPR), Madagascar, Malawi, Mozambique, Myanmar, Niger, Nigeria, Philippines, Sudan, Tanzania, Uganda, and Yemen. For clean cooking access findings, the countries are: Afghanistan, Bangladesh, China, Congo (DR), Ethiopia, India, Indonesia, Kenya, Korea (DPR), Madagascar, Mozambique, Myanmar, Nepal, Nigeria, Pakistan, Philippines, Sudan, Tanzania, Uganda, and Vietnam

Figure 13

Finance for electricity in the 20 HICs (USD Billions): both off- and on grid renewable increased in 2017 compared with 2015-2016, while fossil fuels investment has gone down (%)[200]



Source: SEforALL

6. RECOMMENDATIONS AND NEXT STEPS

The aim of this scoping report is to suggest ways forward, not only in terms of "what?" but rather "how?" and "how can it be financed?" The potential *synergies* between energy and mobility are ignored at a cost both monetary and in terms of efficiency. By better quantifying and mapping out the demand side of energy and mobility services, and to view a given implementation from an urban efficiency point of view, the chance of an electro-mobility project being successful is that much more likely.

1. Focus on public transport, walking, cycling, land use and adequate pricing of car usage as key variables to enable a sustainable urban mobility.
2. Improve available data and metrics, to quantify and track access to sustainable urban mobility. Number of hours spent in traffic tracking time going to and from a destination can be used to quantify cost in terms of time wasted, economic opportunity cost, air quality, and energy and can help identify the most urgently needed actions and quantify improvements to attract investments.
3. Support the achievement of multiple SDGs. When considering energy and mobility, the potential for achieving other SDGs multiplies**.** Other dimensions such as education (e.g. energy needs of schools or mobility patterns of teachers and children), health (air quality as well as access to health services), water, food, gender, and safety must be incorporated into energy and mobility planning.
4. Address policy gaps through concerted efforts for tracking relevant policies and regulations in key countries. Multiple organizations[201] have started tracking for energy and other relevant aspects of the transport sector, including for example whether a country has renewable energy targets for its transport sector, or overall renewable power targets, especially relevant for electro-mobility. This work can further enable increased tracking of efforts in secondary cities to capture the expected growth.
5. Create alliances between partners who may not have crossed paths before. This includes industry partners, real estate stakeholders, cities, and banks that can support common efforts to provide innovative and feasible sustainable urban mobility.
6. Increase capacity building in spatial planning for government agencies to maximize the synergies for energy and transport solutions at an early stage of urban planning.
7. Facilitate and enable investments in renewable energy and sustainable transport to decarbonize the grid and support the growth of new mobility business models.
8. Identify and foster champions, including mayors, for intangible aspects including behavioral and cultural shifts that can support overall improved access to sustainable urban mobility.

Energy and mobility linked together have the potential to offer even more for secondary cities and the base of the pyramid. In smaller cities there is an opportunity to have a significant and immediate impact on sustainable energy and mobility planning, spatial mapping of mobility demand, and financing energy and mobility projects combined.

National policies can and should play a role, but not at the expense of cities being laboratories for energy efficiency and mobility. Transport planning biases are undermining the ability for sustainable cities to direct existing transport funding for walking and cycling infrastructure. Building and supporting the cities from across multiple ministries and organizations will require thinking outside silos and across sectors, but the cost of inaction is immense. If done well, the untapped sustainable urban mobility potential can be used for the benefit of those at the base of the pyramid, achieving not only access to energy and sustainable urban mobility, but also targets across all SDGs.

METHODOLOGY

The priority countries were identified through filters applied in multiple steps.

In the first step, countries with less than 5 percent of their population living under USD 1.9 per day were excluded. Then, countries with no cities in the 100,000-1,000,000-population range were excluded (seven in total: Belize, Comoros, Kiribati, Micronesia, São Tomé and Príncipe, Solomon Islands, and Vanuatu). In a third step, countries where no agglomerations of 300,000-5,000,000 inhabitants are expected by 2030 were excluded (6 additional countries: Cabo Verde, Eswatini, Guyana, Lesotho, Maldives, and Suriname). After these three steps, 57 countries remained (38 in Sub-Saharan Africa, five in South Asia, five in Latin America, six in East Asia, two in Europe, and one in the Middle East). Then, countries for which there was no key information available were excluded: first, countries lacking data on energy consumption from the SuM4All Global Tracking Framework, then countries for which population growth data were missing. The total number of countries after these filters were applied is 19 countries, with 260 cities.

City type 1

Cities were ranked by energy intensity and growth rates. Indicators and data used are:

- Average yearly growth rate (percentage) projection to 2030
- Energy intensity (MJ/USD 2011 PPP)
- Energy consumption of transport relative to GDP (PPP) (GOE per dollar)
- Fuel economy policies in place (GFEI data)

City type 2

Cities were ranked by cell phone penetration, air quality, and road safety and road mortality. Indicators and data used are:

- Mobile cellular subscriptions (per 100 people) [2017 data from WB]
- PM2.5 air pollution, population exposed to levels exceeding WHO guideline value (percentage of total)
- Mortality caused by road traffic injury (per 100,000 people), 2013 data

City type 3

Cities were ranked by air quality, urban access to electricity, road safety, and final use of renewable energy. Indicators and data used are:

- Air quality, PM2.5 air pollution, population exposed to levels exceeding WHO guideline value (percentage of total)
- Urban access to electricity (percentage of population) in 2017
- Quality of roads [value: 1 = worst to 7 = best], 2015 data
- The final use of renewable energy (petajoules) in electricity as a percentage of the total, 2016 data

City type 4

Cities were ranked by CO_2 emission from transport and renewable energy. Indicators and data used are:

- CO_2 emissions from road transport relative to GDP (PPP) (kg per dollar), 2013 data
- Three indicators were used to create an index, which was weighted accordingly:
  - (1x) Renewable electricity (petajoules) as a percentage of total final energy consumption
  - (1.25x) Final use of renewable energy (petajoules) in transport as a percentage of total final energy consumption
  - (1.5x) Overall renewable energy as a percentage of final energy consumption

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