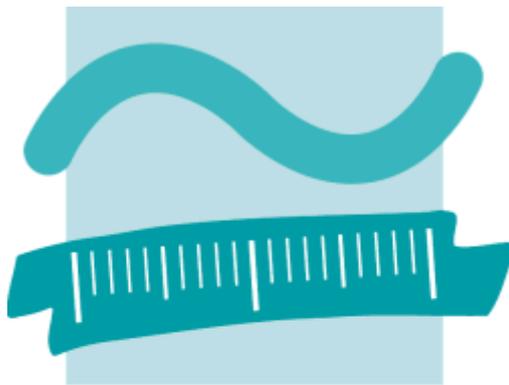


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# Ideas for Sustainable Cities of the Future

**E-mobility & Smart Grid**



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## 1 Introduction

“The 19<sup>th</sup> century was a century of empires, the 20<sup>th</sup> century was a century of nation states. The 21<sup>st</sup> century will be a century of cities.” – Wellington E. Webb, former Mayor of Denver, Colorado<sup>1</sup>

In economic, political and technological ways, cities have become more powerful than ever before. As the centers of a globally integrated, services-based society with great political influence and responsibility, cities are growing in both number and population, taking center stage for the entire world.

One hundred years ago, there were fewer than 20 cities with a population above 1 million. As of today, there are more than 450 cities worldwide with populations exceeding this number, and there is no end in sight for this growth.<sup>2</sup>

However, cities face enormous challenges on their way to becoming more sustainable. They are under pressure to act immediately. To reach its goals, a successful city must be effective and efficient with an integrated view and must use a variety of new technologies to achieve a “smarter” transformation.<sup>3</sup>

This text will focus on two systems, transportation/mobility and energy supply, as they relate to sustainable cities of the future. Today, wasted fuel and environmental pollution are major problems for transportation systems. Those burdens should be eliminated and sustainable new revenues should be generated: for example, by launching new drive systems in cars. Not every city has a secure and stable energy supply, and also sources are quite limited. Cities should have a stable and clean power source while lowering the consumption and giving the inhabitants the ability to give energy back to the city if it is not needed. Giving each household access to a smart grid, for example, would allow large disparities in energy usage to be compensated for today. The construction of a smart grid is complex and costly but the effort is well worth it. The intelligent energy network will be the guide for all renewable energies and for the integration of e-mobility.<sup>4</sup>

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<sup>1</sup> *A vision of smarter cities, 2009, p. 13*

<sup>2</sup> *A vision of smarter cities, 2009, p. 1*

<sup>3</sup> *A vision of smarter cities, 2009, p. 4*

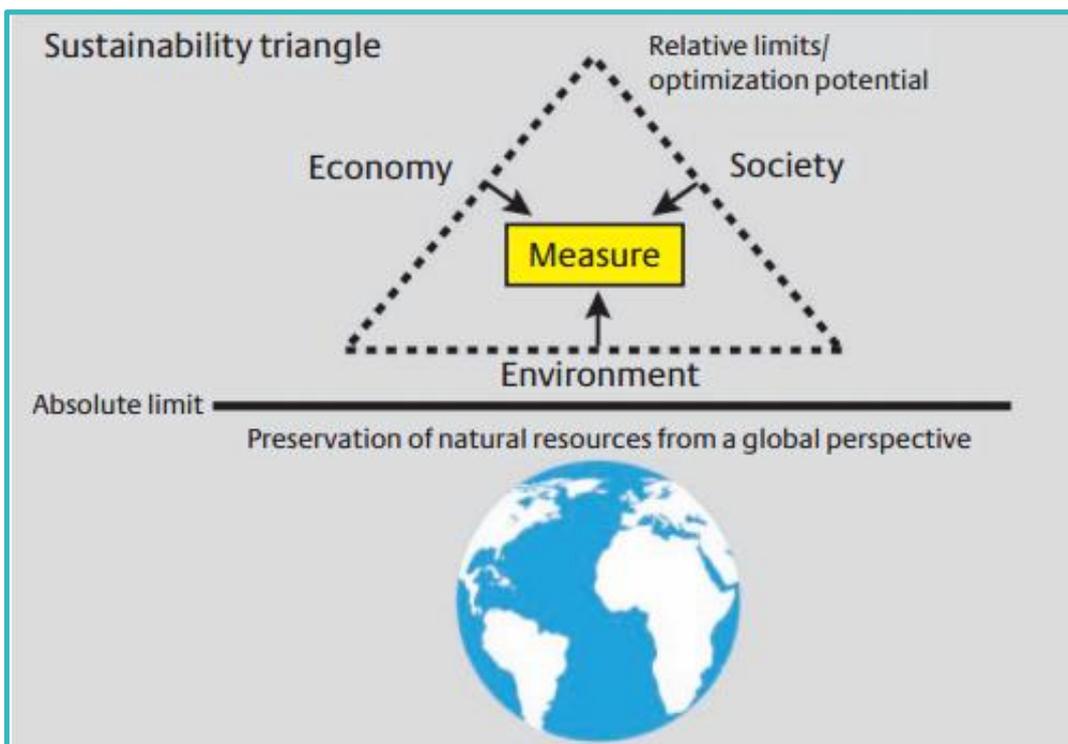
<sup>4</sup> *Sustainable Urban Infrastructure, 2011, p. 3*

It is important to keep in mind, however, that each city must work with what it has and not envision a total utopia.

### 1.1 Sustainability

Sustainable development has become a key role in policymaking since the United Nations Conference on Environment and Development, which took place in Rio de Janeiro in 1992. Sustainability<sup>5</sup>, from the Agenda 21 point of view, means sustainable economic growth, intergenerational equity, quality of life, social cohesion and international responsibility.<sup>6</sup>

There are numerous definitions for “sustainability” because everybody has a different idea of what it means and what to emphasize. Therefore, it is important to establish that, when this report uses the term “sustainability”, it refers to the following: sustainability is often depicted as a triangle representing the dependency of three key roles. Figure 1 shows this triangle.



**Figure 1 – Sustainability triangle**

Environmental sustainability means, that there will be no ruthless exploitation of nature. One should only use natural resources to the extent that nature can regenerate them.

<sup>5</sup> United Nations Framework Convention on Climate Change (UNFCCC) - Kyoto Protocol, 2011

<sup>6</sup> Shouldering Responsibility - Shaping the Future, 2011, pp. 4-7

A society should not live beyond its means, as this would invariably result in disadvantages for future generations – this is what is meant by economic sustainability.

Social sustainability refers to intergenerational consistency. A community should be able to develop processes and structures that also allow future generations to sustain a healthy community.

Cities are growing: they are the pacemakers of the future development, and more than half of the world's population lives in cities right now. Large cities cover only about 2 percent of the earth's total land surface, but consume around 75 percent of its resources. Decision-makers should make cities a better world, and a better place to live.

This text will focus on sustainable mobility, especially as it relates to electrification of drivetrains connected with the possibility of combining the electric supply network (smart grid management).

The key points of sustainable mobility are more efficiency, new technologies and the overall reduction in oil consumption. Along those lines, an efficient transportation infrastructure, a reduction in land take, more protection against traffic noise and the electrification of drivetrains are highly needed when pursuing sustainable mobility and in general for a sustainable city of the future.<sup>7</sup>

On the one hand, mobility is a prerequisite for welfare, personal freedom and employment, but on the other hand the energy and resources consumed and the pollution imposed by transportation have to be minimized. When changing main infrastructure systems, mobility should be still affordable for everyone and as safe as before.<sup>8</sup>

Due to the reduction of energy consumption and the impact of climate change and ecological factors, efficiency improvements in transportation systems have led to positive environmental effects. Not only can the costs of mobility for consumers and businesses be reduced, but also progress of in the sustainable transport sector can be achieved. This is why alternative fuels and drivetrains become very important in the near future to “move away from oil”.

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<sup>7</sup> Shouldering Responsibility - Shaping the Future, 2011, p. 5

<sup>8</sup> Shouldering Responsibility - Shaping the Future, 2011, p. 9

German inhabitants consider the noise caused by traffic to be one of the biggest environmental concerns. When planning sustainable cities for the future these impacts have to be taken into account when developing a livable city.<sup>9</sup>

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<sup>9</sup> Shouldering Responsibility - Shaping the Future, 2011, pp. 11-17

## 2 Ideas for sustainable cities of the future

Traffic and transportation are two of the greatest infrastructural challenges for city development. High growth rates (e.g., cars, commercial transport, flights, and trains) and, increasing requirements for lowering carbon dioxide emissions, combined with short-term limited availability of oil, leads to an extension of the traffic facilities, intelligent and more efficient traffic systems, new traffic- and vehicle concepts and more eco-friendly drive trains.<sup>10</sup>

As shown in figure 2 personal transportation has an annual growth of about 1,6 percent per year worldwide between 2000 and 2030.

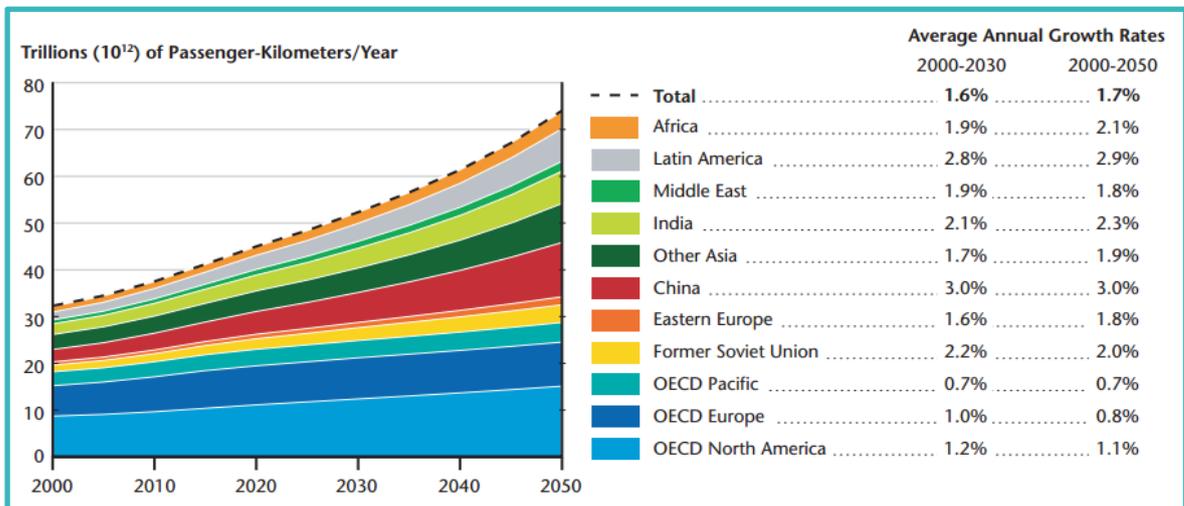


Figure 2 - Personal transport activity by region

In this section, two major ideas will be introduced, both of which can make the city a better and more sustainable place than it is now.

### 2.1 E-Mobility

Future mobility requires new innovative solutions for all kinds of vehicles and relevant infrastructure. The classic and most common way cars are powered nowadays is by using gasoline or diesel for the engine. To enhance efficiency in this field, one should think to the future and start to replace the polluting drive train with a more sustainable one.

<sup>10</sup> Mobility 2030: Meeting the challenges to sustainability, 2004, pp. 15-18

### 2.1.1 Technology

Although e-mobility also includes the loading infrastructure, this report will not go into more detail on this, and will instead continue to focus on the technology of the electronic vehicle itself.

There are different types of electronic vehicles and they all resemble each other in as much as all have batteries built in, but the usage for each is different.

Vehicles with a **hybrid drivetrain** are primary powered by a combustion engine and are also equipped with an electric motor. The electric driving mechanism is suited to very short distances only: for example, as a start-up process. The accumulator will be charged through energy recuperation while the break process when stopping the car. Those vehicles are not able to be charged at battery-charging stations. Figure 3 represents this schematically.

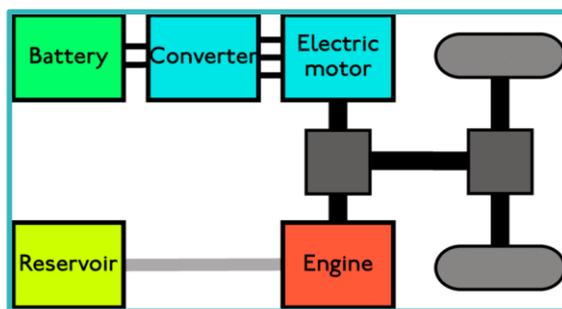


Figure 3 – Structure of a parallel hybrid electric vehicle

The **plug-in hybrid drivetrain** also uses a combination of a combustion engine and an electric motor. In comparison to the hybrid drivetrain, it is only possible to charge the battery at charging points.

**Range-extended electric vehicles** (REEV) are driven by an electric motor. The combustion engine is only used to charge the battery at a low capacity level while driving. This is why those vehicles are able to drive longer distances than “true” electric cars. While parking, the vehicle can be plugged in to a charging station.<sup>11</sup>

<sup>11</sup> E-on, 2012

Figure 4 represents this schematically.

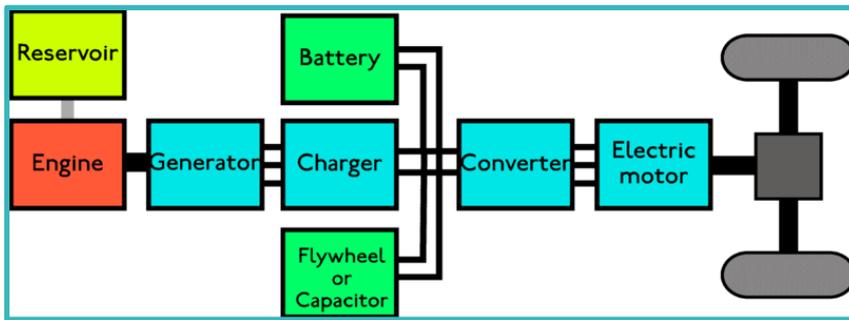


Figure 4 – Structure of a series-hybrid vehicle

In combination with renewable energy production technologies, the **Plug-in hybrid vehicles** (also known as vehicle-to-grid) come to the fore. Like the range-extended vehicles, they have a high voltage battery and an electric motor, but they are also equipped with a hydrogen tank and a fuel cell stack. The advantage of this technology is that it can either be plugged in to a charging station or store energy as hydrogen. When considering alternative energies, this technology seems best suited to goals of keeping carbon dioxide emissions to a minimum, or reducing them entirely for vehicles. This will be discussed in the following section.<sup>1213</sup>

Vehicles with an **electric traction only**, using one or more electric motors, do not have any combustion engine. As a matter of fact, the range of a vehicle with this technology is clearly limited, and the battery has to be charged at charging stations often. This technology distinguishes itself from all other technologies discussed in as much as this is the only system that is able to operate without emitting carbon dioxide, as long as the required energy is generated through renewable energy production.<sup>14</sup>

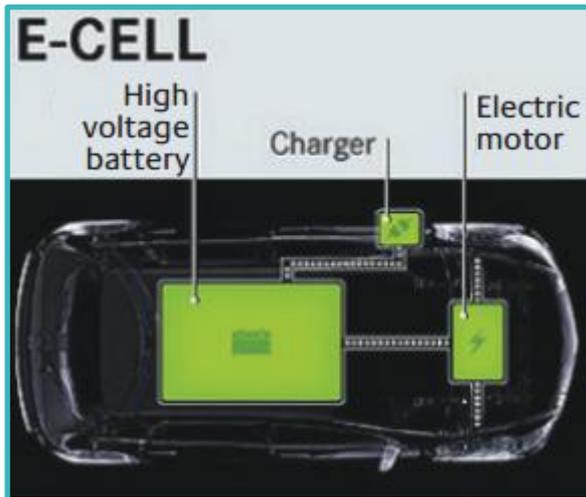
As shown in figure 5 the E-CELL car uses a high voltage lithium-ion battery connected to an electric motor. It is possible to drive a range of about 200 kilometers with this kind of drive train.<sup>15</sup>

<sup>12</sup> Reuters, Soyoung, K., 2008

<sup>13</sup> The New York Times, Motavalli, J., 2009

<sup>14</sup> E-on, 2012

<sup>15</sup> Shouldering Responsibility - Shaping the Future, 2011, pp. 11-13



**Figure 5 – Structure of a vehicle with an electric traction only**

In the end, it is clear that vehicles with a battery only are not the solution. As hydrogen is a flexible energy carrier not only useful for vehicles as motor fuel, but also to store energy in so-called salt caverns, hydrogen is becoming more and more relevant when discussing sustainable energy sourcing.

### **2.1.2 Pros and Cons**

There are several advantages and also disadvantages of e-mobility. This discussion will focus on plug-in hybrid vehicles with a hydrogen tank. Several advantages and disadvantages will be discussed below.

For the record, electronic vehicles have great potential to make the city more sustainable. These cars generate power by using a fuel cell that combusts liquid/gasoline oxygen and hydrogen without any emissions to pollute the environment.

Appropriate electronic vehicles do not have the disadvantages faced by conventional passenger cars, which pollute the environment with carbon dioxide emissions.

Moreover, another advantage is that hydrogen gained by water is more or less available worldwide when compared with oil.

However, there are also several disadvantages. Perhaps the biggest drawback is the lack of any area-wide filling station infrastructure. According to [h2stations.org](http://h2stations.org), there are only 39 hydrogen filling stations available in Germany at the moment.

Another disadvantage is the way that hydrogen has to be treated. It must be transported and stored at a temperature of about minus 253 degrees. Hydrogen is also an extremely flammable substance.<sup>16</sup>

## 2.2 Smart Grid

Nowadays energy is produced and transformed in industrial facilities - power plants. Mostly power stations burn fossil fuels, for example oil, coal and natural gas to generate the electricity people consume.

To achieve more sustainability in the energy sector it is of vital importance to generate the energy more efficiently. On the one hand power plants are and will be necessary in the future for the so-called base load, but on the other hand, new technologies such as wind power and solar cells offer ecologically friendly techniques to lead to more sustainability. They should therefore also be used in the energy sector. There is no doubt that with state of the art technologies and an integrated view on power supply for cities, one could obtain more efficiency and a more sustainable planet.<sup>1718</sup>

We live in an information era. Generated and shared information are the essence of a smart grid and an intelligent control system. Studies show, that, from now until 2037 it is possible to use 23 percent more renewable energy technologies in combination with a smart grid. The goal of a smart grid is not to replace any existing technologies, but to combine old with new. A smart grid links numerous energy consumers, such as electronic cars and energy suppliers, together. The aim is to buffer high power fluctuations of wind power and solar cells. The challenge of renewable energy technologies is to use all of the generated power.

The aim of all renewable energy systems is to use 100 percent of the energy produced. Reality shows different experiences. It is very hard to save all the energy generated during one time period of time to use later. As a result, the rotors must be throttled and developable clean energy remains unused. As it is possible to "store" energy as hydrogen in special types of electronic vehicles, this could be one solution to using a lot more of the energy generated by the nature

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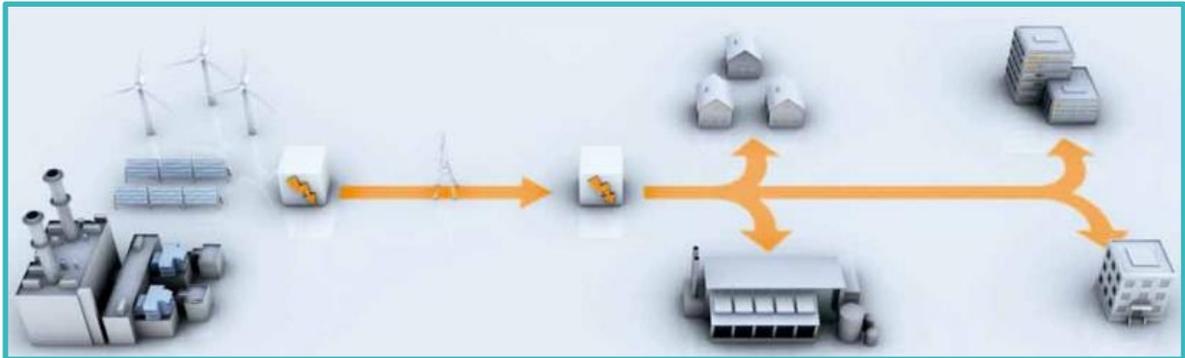
<sup>16</sup> [www.feelgreen.de](http://www.feelgreen.de), 2011

<sup>17</sup> Power Generation Technologies, 2005, pp. 1-13

<sup>18</sup> Smart Grids, 2006, pp. 3-21

than is possible today. A smart link between all is the key to success and more sustainability.

Figure 6 represents the current situation of the energy transport from the power plant (conventional/renewable) to the consumer.



**Figure 6 - Typical electric power supply**

In the future, various additional small energy producers and consumers will be connected to a smart grid as shown in figure 7.



**Figure 7 - Intelligent electricity network in the future**

Buildings, and moreover e-cars, will be the key elements in the smart grid. They are both energy consumers and producers. The intelligent control system contributes to a higher usage of green energy and can lower carbon dioxide emissions.<sup>19</sup>

<sup>19</sup> Sustainable Urban Infrastructure, 2011, pp. 5-7

### **3 Conclusion**

E-mobility and a smart grid seem to be the solution for a sustainable city of the future, but it is clear, that without any governmental/economic/private collaboration it is not possible to implement such a system. It will take several more years for everybody to understand how important a rethinking is.

Without any new storage technology, the smart grid will not succeed. The up- and downturns of the share from renewable energy is an enormous problem, because this makes the development of alternative energy sourcing impossible. Excess clean energy must be stored in times of low demand; otherwise it will be lost. There are already discussions on how to face this challenge, for example by building up huge salt caverns underground where hydrogen is stored. Hydrogen is also substantial in the previously mentioned electronic vehicle, which represents a multiplicity of small salt caverns.

Due to many factors of influence no one is able to tell when this kind of technology will be part of a usual day but one thing is for sure, something must happen – soon.

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Elektromobilität bei Daimler / Mercedes

([http://www.youtube.com/watch?v=lw1Kd\\_KEI6w](http://www.youtube.com/watch?v=lw1Kd_KEI6w))

Elektromobilität bei der EnBW / Forschungsprojekt Modellregion Stuttgart

(<http://www.youtube.com/watch?v=rvuqh4gyLK0>)

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**Figure 5** taken from: Federal Ministry of Transport, Building and Urban Development. Shouldering Responsibility - Shaping the Future.

**Figure 6** taken from: Müller, D. und Pokojski, M. Sustainable Urban Infrastructure

**Figure 7** taken from: Müller, D. und Pokojski, M. Sustainable Urban Infrastructure