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# Smart Energy Cities - Transition Towards a Low Carbon Society

Zoran Morvaj<sup>1</sup>, Luka Lugarić<sup>2</sup> and Boran Morvaj<sup>2</sup>

<sup>1</sup>United Nations Development Programme, New York

<sup>2</sup>University of Zagreb, Zagreb

<sup>1</sup>USA

<sup>2</sup>Croatia

## 1. Introduction

We are living in a fossil age. More than 90% of energy nowadays comes from fossil fuels. Fossil age still has some 100 years to go [1], but should we wait until the last moment before we make a switch? Population is increasing, urbanization is increasing, price of oil will be increasing, and eventually it will run out. The economies that delay transition to low carbon society, especially if dependent on import of fossil fuels, are risking major upheavals.

The transition policies should be crafted now - and implementation should follow without delay.

This of course entails a major shift in economies, and consequently there will be winners and losers. The losers in this shift of focus would be the existing pro-status-quo groups, lobbying to postpone changes. The winners may not even exist yet, which is why the ongoing political debates are unbalanced because the losers know they will lose and fight back now, but future winners still don't put up equally strong arguments.

The way out is by finding a long term roadmap, starting with national policies based on local resources which could drive the transition away from imported fossil fuels. Authors believe that this is a correct approach to a low carbon future, and should start in the cities - the places where most people live and use energy for everyday life and business needs.

A multitude of policy and technology developments have emerged in the last 10-15 years addressing sustainable development of cities, mitigation effects of climate change and creating better living conditions for citizens. Large cities are using their vast resources to search for their own development roadmap. However, a systematic approach does not exist yet and cities develop their plans individually.

Small nations and developing economies will be first to suffer if caught unprepared in the midst of the fast developing struggle for resources among the large players. Here it is where smart energy cities have a potential to lead the transition - from fossil age into a bio-age!

This chapter proposes a way for transition to sustainable energy development focusing on cities as implementing changes actors. The concept is created through the integration of

practical experience from on-going projects and research results towards development of energy resilient economies.

## 2. Definition of key terms and concepts

### 2.1 Pillars of the low carbon society

Throughout history, economic transformations occur when new communication technology converges with new energy systems [2]. New forms of communication and new sources of energy are cornerstones of managing complex civilizational challenges ahead. The fusion of Internet, information and communication technologies (ICT) and renewable energy sources (RES) enables development of nations toward a low carbon society, the focus of this chapter.

As outlined in Figure 1, there are 5 basic pillars of the low carbon society:

1. **Energy efficiency:** all energy losses must be either eliminated or minimized in accordance with best available technologies;
2. **Renewable energy sources:** solar, wind, hydro, geothermal, biomass, ocean waves and tides – their falling costs make them increasingly competitive;
3. **Buildings as active consumers:** Buildings that generate most of their energy needs from locally available renewable energy sources;
4. **Electro mobility:** Electric vehicles, once deployed on a large scale will serve both as means of transportation but also as energy storage units throughout the city;
5. **Developing smart energy cities:** An integrated effort of improving social, economic, environmental systems in cities, with energy infrastructure transformed first, as an enabler of further developments.

When these five pillars come together, they make up an indivisible sustainable development platform – an emergent system, whose properties and functions are qualitatively different than the sum of its parts.

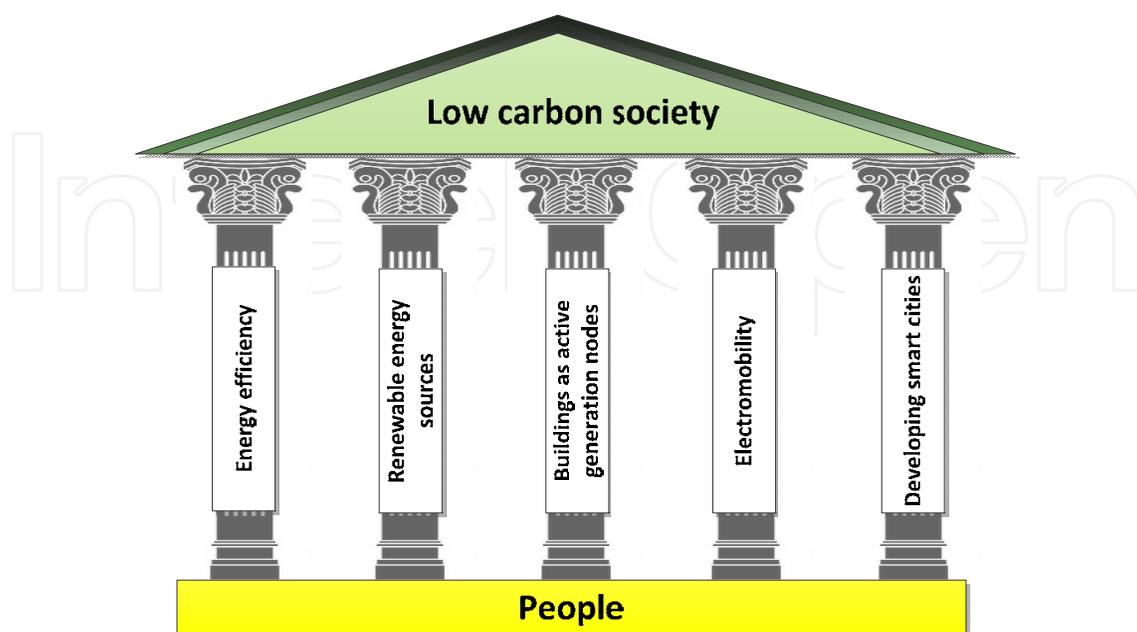


Fig. 1. Pillars of the low carbon society

Interconnectedness between the pillars creates cross-industry relationships, a system called distributed energy generation in which millions of existing and new businesses and homeowners become energy players to the advantage of final beneficiaries – the citizens.

The citizens – people as shown by Figure 1, are the foundation of the approach. Transition towards low carbon society must be consensual, involves change of behaviour and life style, thus people participation is essential.

## 2.2 Smart energy city

The United Nations estimates that already over 50% of the global population lives in cities [3]. Cities occupy only 2% of the Earth's surface but are the point of use of 75% of all resources required for everyday life and generate 75% of all waste [4]. Crucially, they produce 80% of global greenhouse gas emissions. Energy use is responsible for approximately 75% of these emissions, and 30-40% of that energy is used in buildings [5]. Sustainable future of the civilization depends to a great extent on changes in patterns of energy use and supply in cities.

Taking all this into account, for a city to become a smart energy city, it needs to evolve and address a multitude of technological and economic challenges in providing energy for basic needs of their citizens.

A smart energy city satisfies all energy needs of its citizens and goes beyond to provide innovative ways to increase the quality of life of its citizens in all areas. This is achieved by:

- Achieving the highest energy efficiency standards;
- Relying on local resources to provide for energy needs;
- Making all energy users active members of the local energy system;
- Developing smart homes and smart grids for demand management;
- Promoting electromobility;
- Using information to make insightful decisions on energy purchases or generation;
- Getting foresight to resolve problems proactively;
- Efficiently coordinating resources for effective operation of infrastructure systems.

An overview of key technologies and concepts which together comprise a smart energy city is shown in Figure 2.

## 2.3 Smart grids

The basic energy infrastructure of a smart energy city is the smart grid.

A smart grid implies integration of generation, transmission and distribution operations, monitoring and control functions, and suppliers and consumers through exchange of information in real time. Some of the widely quoted features are still under development while some have been implemented [6].

Buildings are the basic components of smart grids. The smart grid vision assumes all buildings will have a small renewable energy source installed and in case of increase of demand it can act as a small power plant, both externally to the grid and internally for its own consumption. Levels of observation at the new power grid, along with pertinent features are shown in Figure 3.

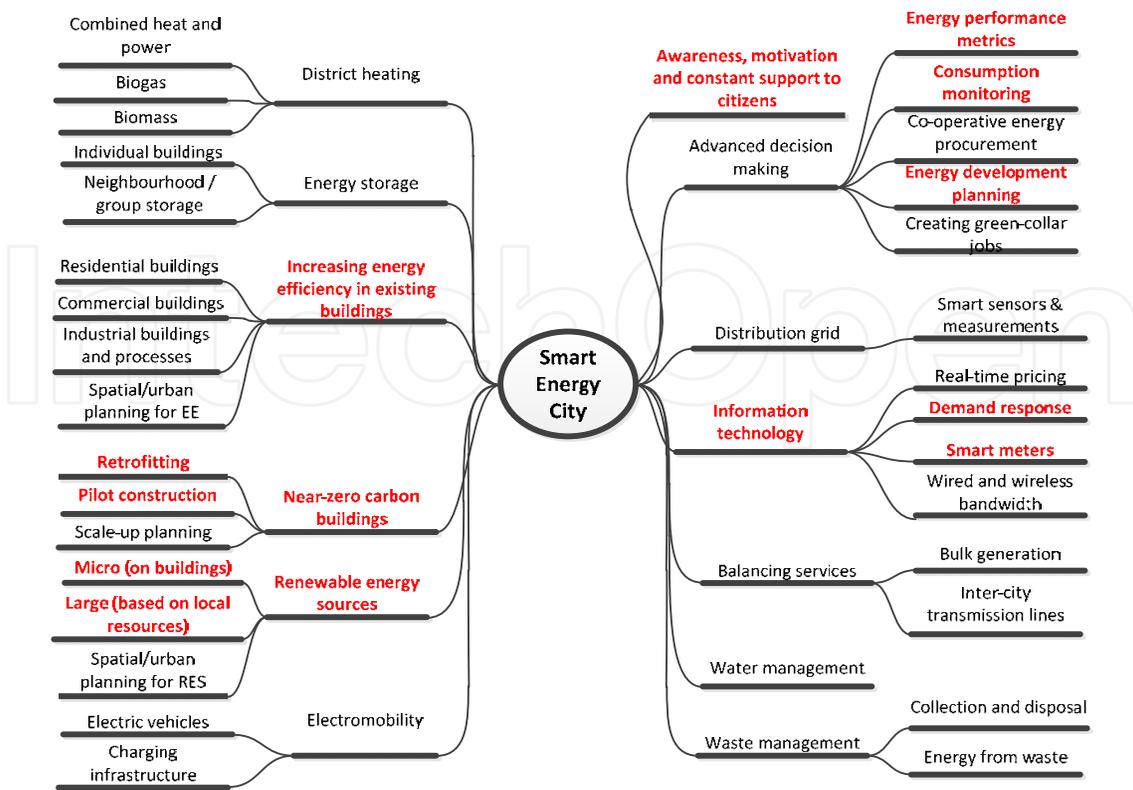


Fig. 2. Key concepts and technologies of a Smart Energy City

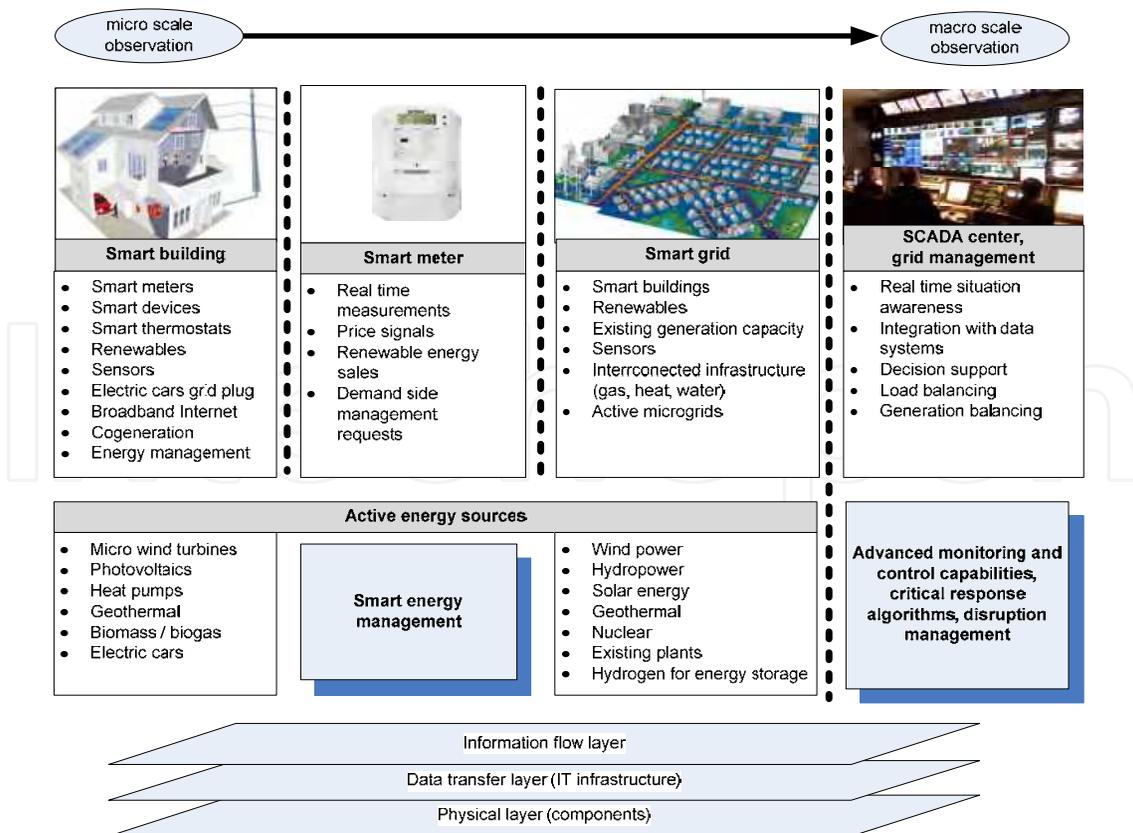


Fig. 3. Overview of the smart grid [7]

Vital to creation of smart cities is advancing infrastructural systems by using knowledge and technology in networking smart buildings.

## 2.4 Smart buildings

The definition of the term smart building has been used for more than two decades, and has been constantly evolving. In the 1980s "smart" was a building with implemented passive energy efficiency measures. In 1990s it was buildings with central, computer operated energy management systems. Today it includes all previous meanings with the addition of smart meters, networked appliances, advance energy management systems and renewable energy sources.

Smart buildings communicate with its surroundings (i.e. the energy distribution networks), and can adapt to conditions in the network, which building energy management systems can monitor and receive signals from. Smart buildings communicate between themselves, exchanging both information and energy, thus creating active microgrids . In general, the key components of a smart building are [8]:

- Local energy generation - producing energy either to be used within the building or injected to the grid;
- Sensors - monitoring of selected parameters and submit data to actuators;
- Actuators - which perform physical actions (i.e. open or close window shutters, turn on appliance, etc.)
- Controllers - monitoring inputs from sensors, managing units and devices based on programmed rules set by user;
- Central unit - used for programming and coordination of units in the system;
- Interface - the human-machine interface to the building automation system
- Network - communication between the units (RF, Bluetooth, wire);
- Smart meters - two-way, near or real-time communication between customer and utility company.

Capabilities and features of a model smart building are illustrated in Figure 4.

A smart building acts as a grid node as an energy producer through installed renewables or as an active participant in demand response management. Demand response (DR) programs can be classified into three groups [9]:

- **Incentive-Based:** represents a contract between utility and customer to ensure demand reductions from customers at critical times. This DR program gives participating customers incentives to reduce load during the agreed period which may be fixed or time-varying. Examples of the programs in this group are Direct Load Control and Interruptible & Curtailable Load.
- **Rate-Based:** a voluntary program where the customer pays a higher price during the peak hours and lower price during the off-peak hours. The price can vary in real time or a day in advance.
- **Demand Reduction Bids:** refers to relatively large customers to reduce their consumption. In this program customers send a demand reduction bid, containing demand reduction capacity and the price asked for, to the utility.

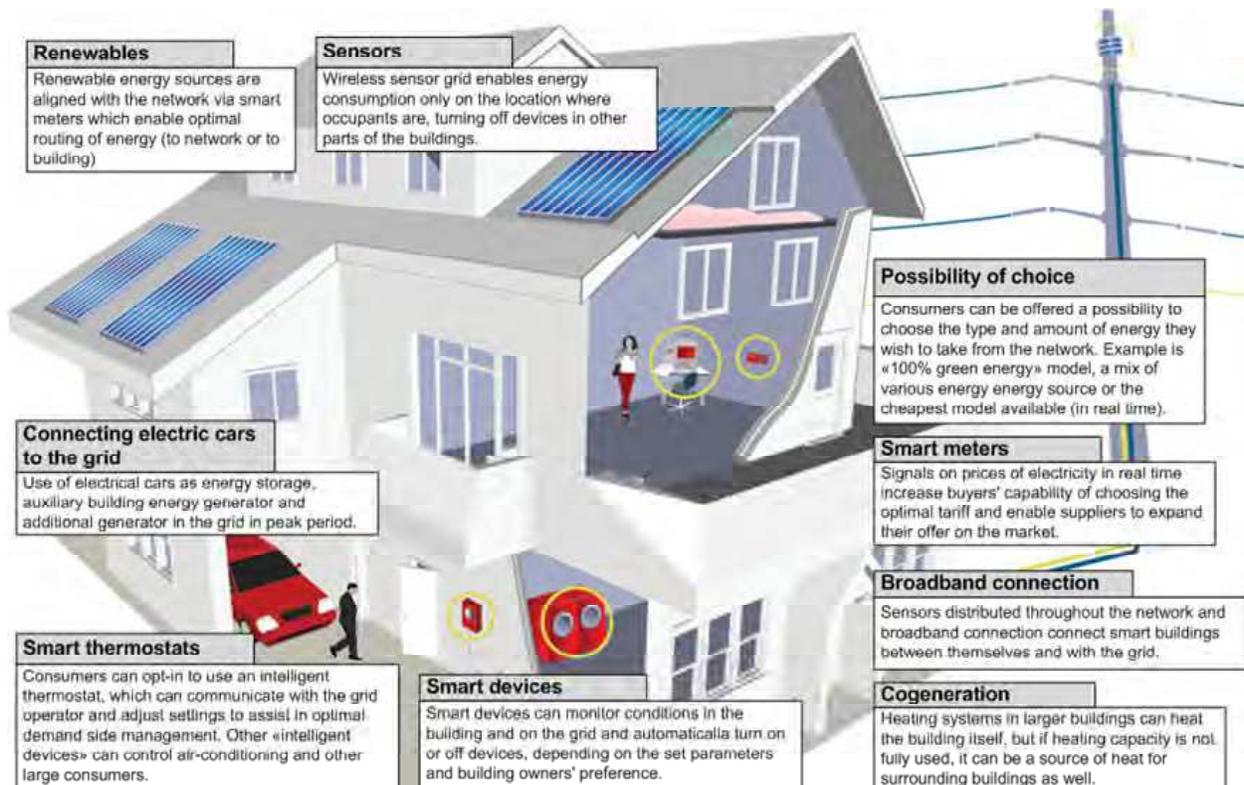


Fig. 4. Features of a smart building [6]

In an example given in [10], a demand response program based both on the price signal's value response and direct load control from the utility is considered. The imbalance of supply and demand is interpreted as the result of increased or decreased consumption and increased or decreased output of renewable energy resources. In case of shortage of supply, the price signal's value increases and buildings participating in the DR programme respond by turning off controllable load(s).

Algorithms for reducing energy consumption and regaining energy capacities are shown in Figure 5a and Figure 5b.

## 2.5 Energy management in cities

Energy management in cities can be defined as a continuous process aiming to [11, 12]:

- Avoid excessive and unnecessary use of energy through regulation and policy measures that stimulate behavioural changes;
- Reduce energy losses by implementing energy efficiency improvement measures and new technologies;
- Monitor energy consumption of all major users based on direct measurements of energy use (buildings, street lighting, water supply, public transport, etc.);
- Manage energy consumption by analysing energy consumption data and improving operational and maintenance practices.

To ensure continuity of energy efficiency improvements, energy consumption has to be managed as any other activity – an energy management system (EMS) must be implemented.

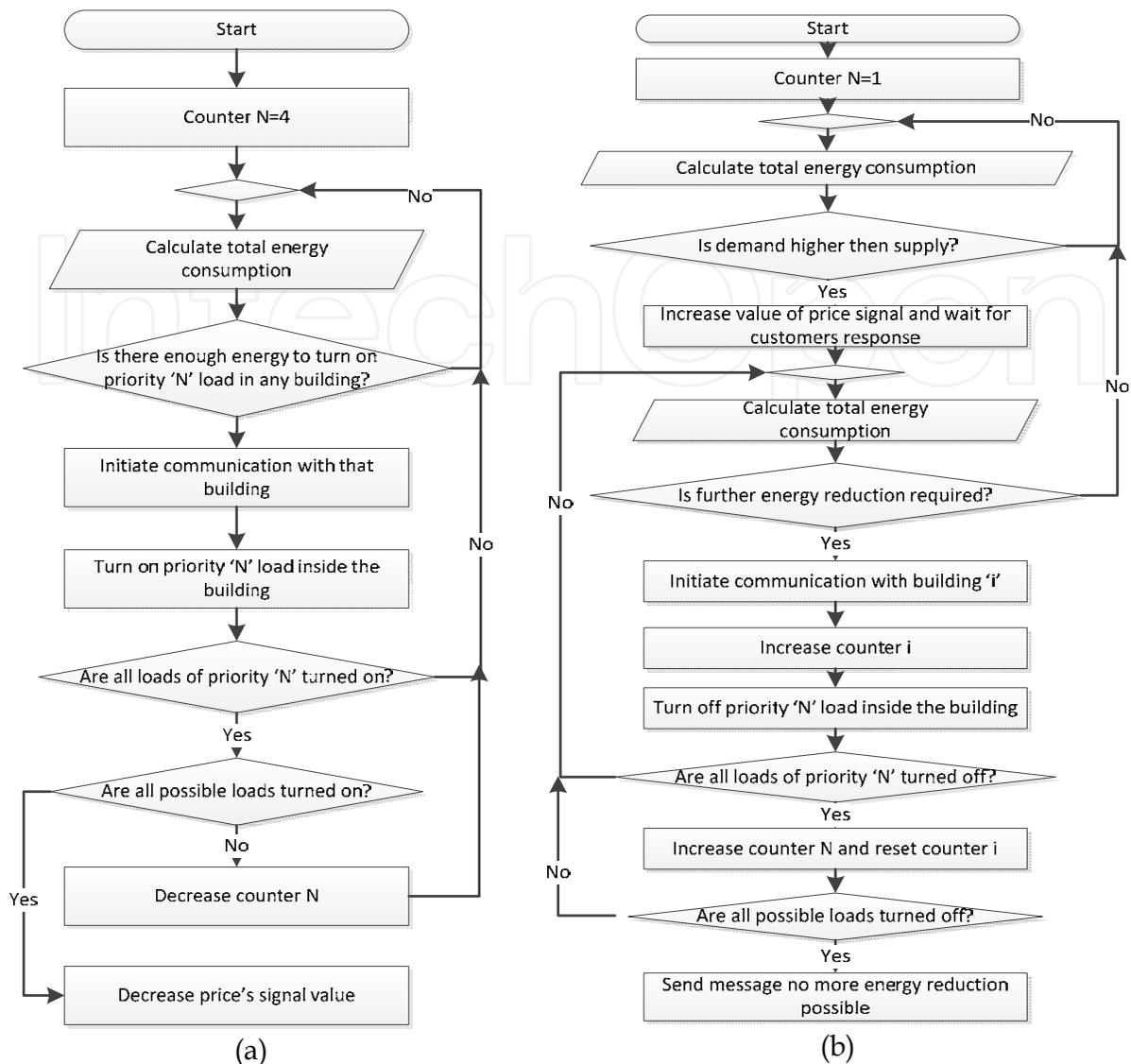


Fig. 5. Algorithms for reducing (a) and regaining energy (b) in a model (from [10])

Essentially, energy management can be defined as a framework for ensuring continuous improvement in efficiency of energy use. It is supported by a body of knowledge and supported by measurements and ICT technology [13]. It does not only consider techno-economic features of energy consumption but makes energy efficiency an on-going social process calling for changes in behaviour and life style.

The energy management system (EMS) is a specific set of knowledge and skills based on organizational structure incorporating the following elements:

- Motivated and trained people with assigned responsibilities;
- Energy efficiency monitoring procedures inclusive of:
  - establishing baseline consumption;
  - defining consumption indicators;
  - setting improvement targets;
- Continuous measuring of energy use and improvement of efficiency until the best practice is reached.

The basic EMS concept and its key elements are shown in Figure 6.

A city's energy management team is responsible for regular analysis of collected data individually per building and aggregated analysis for all public buildings. The process of regular energy use measurement and analysis, as shown in Figure 7, provides relevant indicators that are needed for identification of measures that will lead to improved energy performances of buildings.

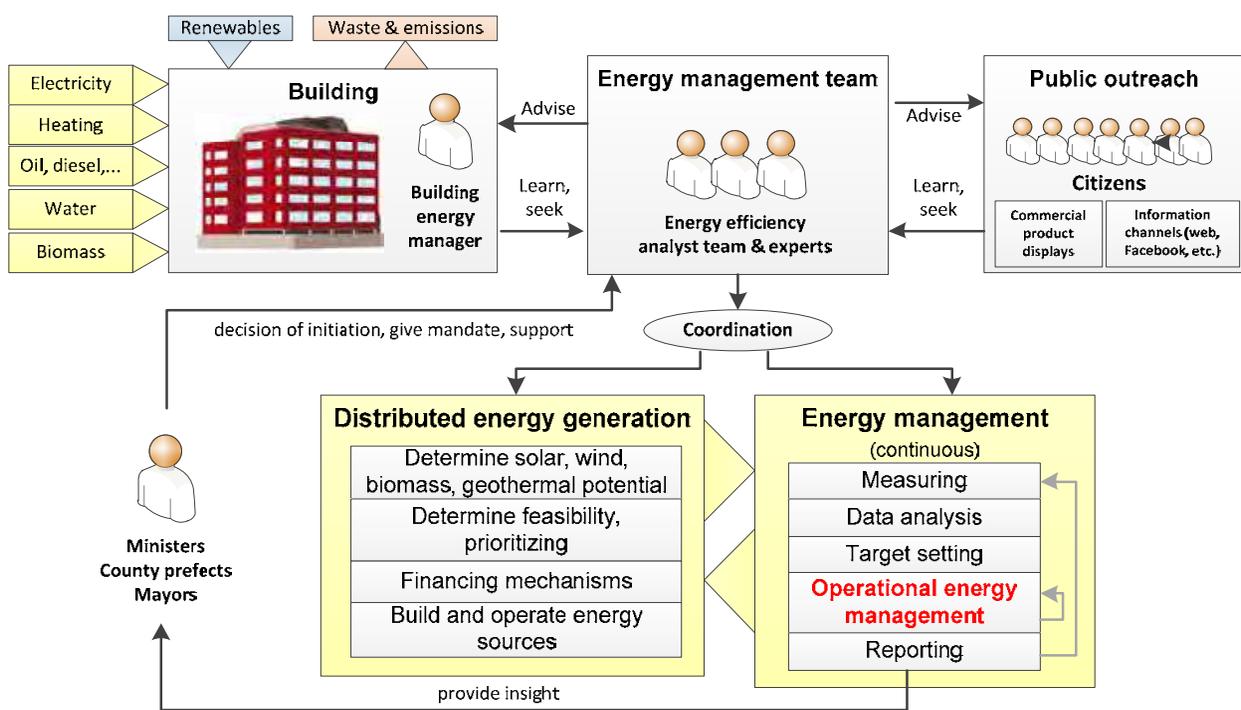


Fig. 6. Basic EMS concept in cities

## 2.6 Behaviour change

As said already, people are the foundation for introducing smart energy practices in cities because they will need to adopt their habits and behaviour to new realities of sustainable ways of energy use and supply.

The process of learning-while-doing and transfer of that knowledge from EE teams to the citizens and provision of essential information feedback from the implementation level back to the policy makers on national level in order to initiate policy adjustment is illustrated in Figure 8. The information feedback provided through EE teams is essential for accurate and objective analysis and evaluation of progress achieved and identification of needs for adjustment and adaptation of EE policies being implemented.

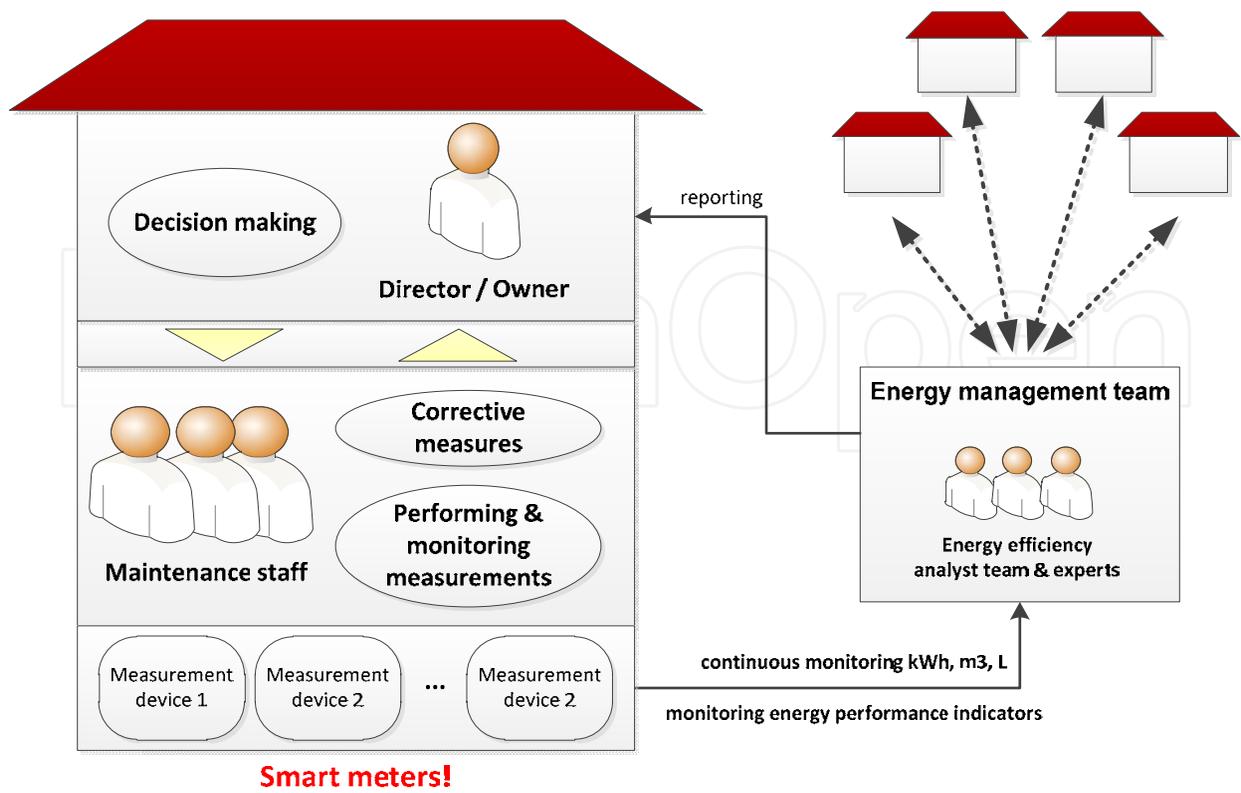


Fig. 7. Taking regular measurements – cornerstone of successful EMS practice

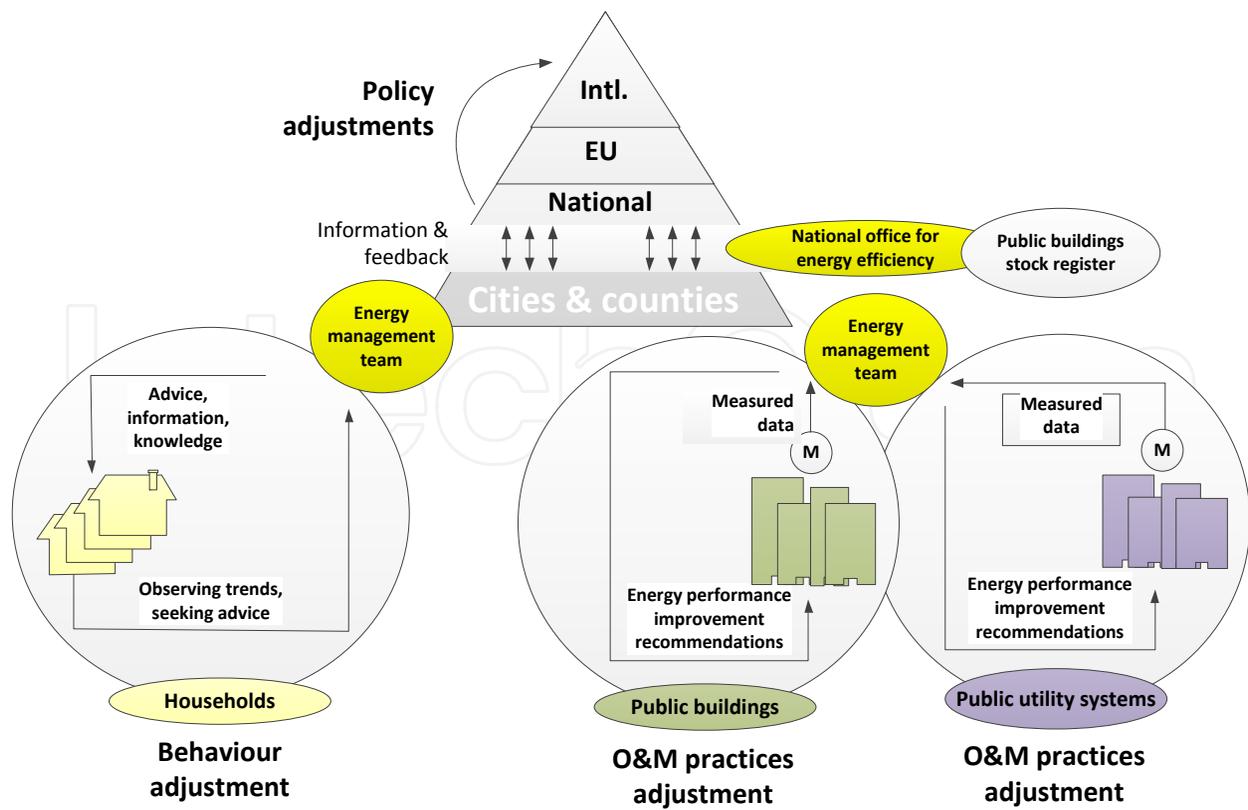


Fig. 8. Learning loops and knowledge transfer as part of EMS

### 3. The contexts

When discussing any of the above definitions, terms or concepts, it is vital to put them in the context of global energy supply situation, taking into account politics and technologies.

#### 3.1 Geopolitics of energy supply

Global energy consumption will continue to rise regardless of the developed countries' desire to see energy usage curbed. The reasons are that the population will continue to increase, and emerging economies (notably the BRIC group – Brazil, Russia, India, and China) would like to continue to grow. Available reserves of fossil fuels cannot grow at the same rate and are also limited; consequently resource scarcity, especially energy, will become an increasing reality.

In order to address this problem systematically, it is helpful to see [14, 15] what are the world's energy sources and energy sinks, and what are the underlying trends.

Figure 9 confirms the claim that we still live in a fossil age. Energy consumption is growing at an accelerating rate in Asia (Figure 10) mostly because of the fast developing economy of China and India. At the same time, these two economies are among the top 4 oil importers (Table 1).

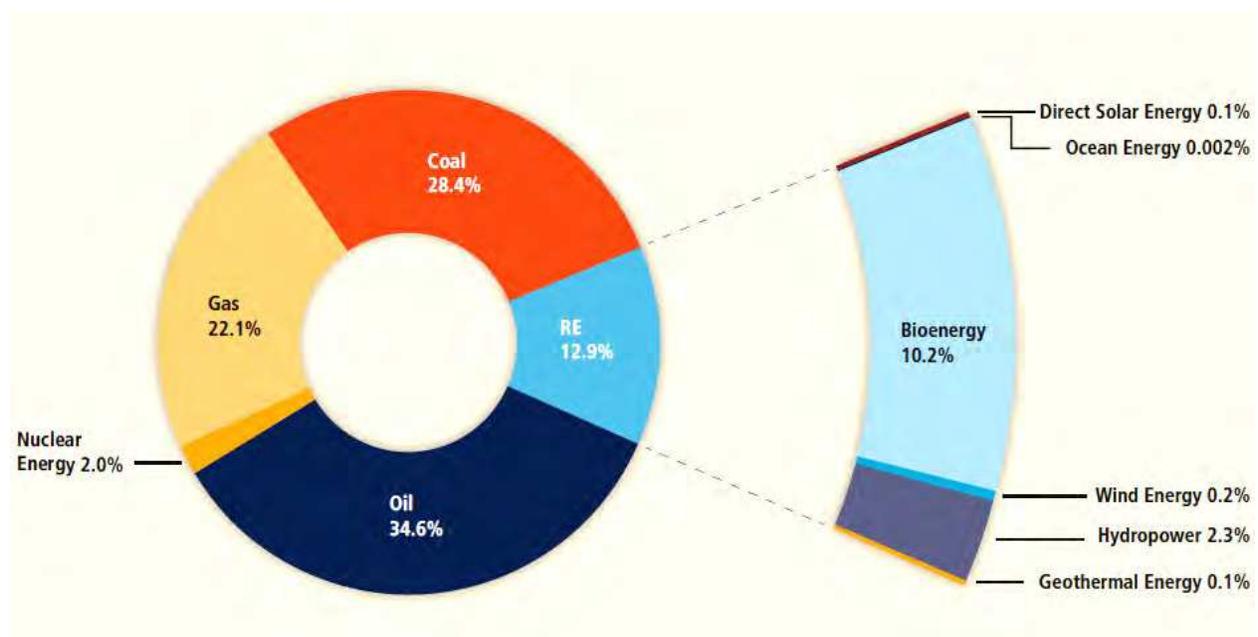


Fig. 9. Energy sources in total global primary energy supply [IEA, 16]

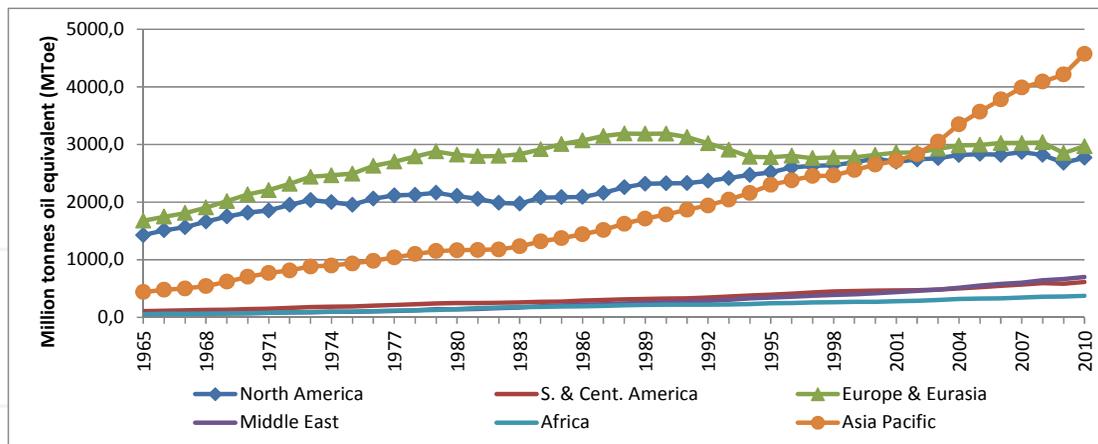


Fig. 10. Global primary energy consumption by geographic regions

Tables 1 and 2 show an imbalance between locations where the oil and gas resources are found and extracted and where the major demand for these occurs. As a consequence, there are a multibillion dollar international energy commodity market, sensitive to speculations, political manoeuvring, artificial intermittent shortages and gluts, conflicts and wars.

Most of the recent conflicts are caused by the desire to secure access to fossil fuels.

Producers	Mt	% of world total	Net exporters	Mt	Net importers	Mt
Russian Federation	502	12,6	Saudi Arabia	313	United States	510
Saudi Arabia	471	11,9	Russian Federation	247	People's Rep. of China	199
United States	336	8,5	Islamic Rep. of Iran	124	Japan	179
Islamic Rep. of Iran	227	5,7	Nigeria	114	India	159
Peoples Rep. of China	200	5,0	United Arab Emirates	100	Korea	115
Canada	159	4,0	Iraq	94	Germany	98
Venezuela	149	3,8	Angola	89	Italy	80
Mexico	144	3,6	Norway	87	France	72
Nigeria	130	3,3	Venezuela	85	Netherlands	57
United Arab Emirates	129	3,2	Kuwait	68	Spain	56
<b>Rest of the world</b>	<b>1.526</b>	<b>38,4</b>	<b>Others</b>	<b>574</b>	<b>Others</b>	<b>477</b>
<b>World</b>	<b>3.973</b>	<b>100,0</b>	<b>Total</b>	<b>1.895</b>	<b>Total</b>	<b>2.002</b>

(2010 data) (2009 data) (2009 data)

Table 1. Global top crude oil producers, net exporters and importers

Producers	Mt	% of world total	Net exporters	Mt	Net importers	Mt
Russian Federation	637	19,4	Russian Federation	169	Japan	99
United States	613	18,7	Norway	101	Germany	83
Canada	160	4,9	Qatar	97	Italy	75
Islamic Rep. of Iran	145	4,4	Canada	72	United States	74
Qatar	121	3,7	Algeria	55	France	46
Norway	107	3,3	Indonesia	42	Korea	43
Peoples Rep. of China	97	3,0	Netherlands	34	Turkey	37
Netherlands	89	2,7	Malaysia	25	United Kingdom	37
Indonesia	88	2,7	Turkmenistan	24	Ukraine	37
Saudi Arabia	82	2,5	Nigeria	24	Spain	36
<b>Rest of the world</b>	<b>1.143</b>	<b>34,7</b>	<b>Others</b>	<b>165</b>	<b>Others</b>	<b>253</b>
<b>World</b>	<b>3.282</b>	<b>100,0</b>	<b>Total</b>	<b>808</b>	<b>Total</b>	<b>820</b>

Table 2. Global top natural gas producers, net exporters and importers

Taking a longer term view, we are definitely facing two converging trends:

1. The consumption will continue to grow in most of the economies, including these that are net exporters today (Tables 1 and 2);
2. The reserves of fossil fuels will gradually shrink.

As a consequence, net export capacity will shrink as well, making oil and gas more scarce, thus more costly, and thus even more potent tool for political blackmailing. Key players in these games would be big economies who are still net importers (Tables 1 and 2). Small economies and particularly developing ones should seek not to be a part of these future struggles for resources.

But what are the alternatives?

### 3.2 Technologies

A view on current rising trend in utilization of renewable energy sources is given in Table 3. According to a 2011 projection by the International Energy Agency, solar power generators may produce most of the world's electricity within 50 years, dramatically reducing the emissions of greenhouse gases that harm the environment [17]. Renewable energy sources, although still only 1/10 of the global primary energy supply, are on the rise (Figure 11). At the same time the costs of these new technologies were rapidly falling (Figure 12).

Indicator		2008	2009	2010
<b>Global new investment in renewable energy (annual)</b>	billion USD	130	160	211
<b>Renewables power capacity (existing, not including hydro)</b>	GW	200	250	312
<b>Renewables power capacity (existing, including hydro)</b>	GW	1.150	1.230	1,320
<b>Hydropower capacity (existing)</b>	GW	950	980	1,010
<b>Wind power capacity (existing)</b>	GW	121	159	198
<b>Solar PV capacity (existing)</b>	GW	16	23	40
<b>Solar PV cell production (annual)</b>	GW	6.9	11	24
<b>Solar hot water capacity (existing)</b>	GW-A	130	160	185
<b>Ethanol production (annual)</b>	billion litres	67	76	86
<b>Biodiesel production (annual)</b>	billion litres	12	17	19
<b>Countries with policy targets</b>	#	79	89	98

Table 3. Selected global indicators of renewable energy sources [18]

The levelled costs of all RES technologies are approaching (some already are there) so called grid parity with conventional power plants based on fossil fuels (Table 4).

Levelled cost is often cited as a convenient summary measure of the overall competitiveness of different generating technologies. Levelled cost represents the present value of the total cost of building and operating a generating plant over an assumed financial life and duty cycle, converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation. Levelled cost reflects overnight capital cost, fuel cost, fixed and variable O&M cost, financing costs, and an assumed utilization rate for each plant type [19].

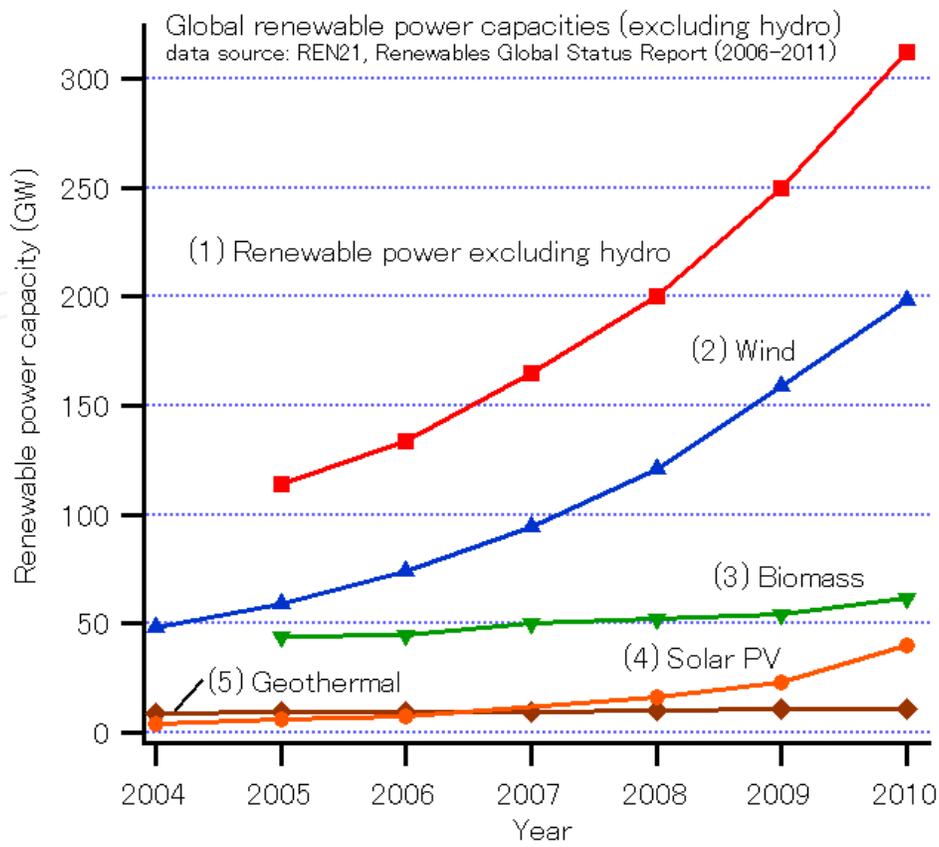


Fig. 11. Global renewable power capacity excluding hydro [18]

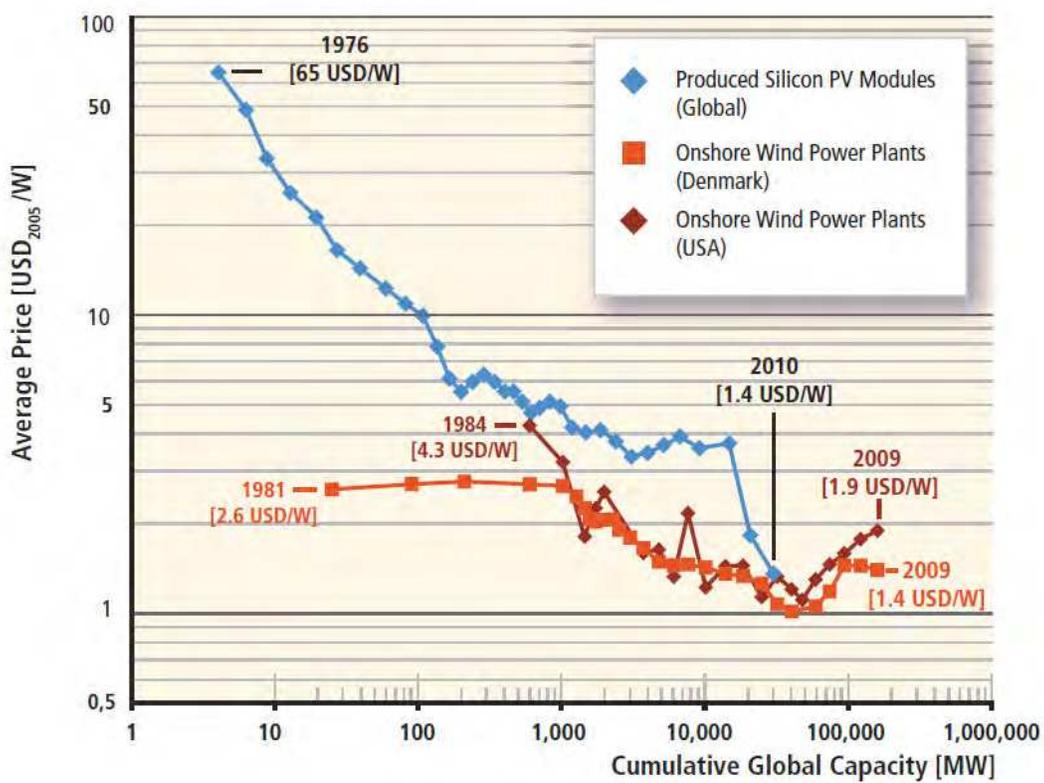


Fig. 12. Experience curves for PV modules and wind power plants [16]

Plant Type	Capacity Factor (%)	U.S. Average Levelized Costs (2009 \$/megawatt-hour) for plants entering service in 2016				
		Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Conventional Coal	85	65,3	3,9	24,3	1,2	94,8
Advanced Coal	85	74,6	7,9	25,7	1,2	109,4
Advanced Coal with CCS	85	92,7	9,2	33,1	1,2	136,2
Natural Gas-fired						
Conventional Combined Cycle	87	17,5	1,9	45,6	1,2	66,1
Advanced Combined Cycle	87	17,9	1,9	42,1	1,2	63,1
Advanced CC with CCS	87	34,6	3,9	49,6	1,2	89,3
Conventional Combustion Turbine	30	45,8	3,7	71,5	3,5	124,5
Advanced Combustion Turbine	30	31,6	5,5	62,9	3,5	103,5
Advanced Nuclear	90	90,1	11,1	11,7	1,0	113,9
Wind	34	83,9	9,6	-	3,5	97,0
Wind - Offshore	34	209,3	28,1	-	5,9	243,2
Solar PV <sup>1</sup>	25	194,6	12,1	-	4,0	210,7
Solar Thermal	18	259,4	46,6	-	5,8	311,8
Geothermal	92	79,3	11,9	9,5	1,0	101,7
Biomass	83	55,3	13,7	42,3	1,3	112,5
Hydro	52	74,5	3,8	6,3	1,9	86,4

Table 4. Estimated Levelled Cost of New Generation Resources [19]

For technologies such as solar and wind generation that have no fuel costs and relatively small O&M costs, levelled cost changes roughly in proportion to the estimated overnight capital cost of generation capacity. For technologies with significant fuel cost, both fuel cost and overnight cost estimates significantly affect levelled cost. The availability of various incentives including tax credits can also impact the calculation of levelled cost. The values shown in the table 4 do not incorporate any such incentives. As with any projections, there is an uncertainty about all of these factors and their values can vary regionally and across time as technologies evolve.

However, making a long term energy policy decisions based on the current levelled cost of technologies only is completely wrong.

Firstly, levelled will costs change in the future, but once we invested large amounts of funds in a technology, we are trapped by the need to return the investment! There is no cheap and easy way out.

Secondly, levelled costs do not show aggregated economic value of investing into local renewable energy sources in the context of the national economy (even though renewables are more expensive for the time being than fossil-based sources), especially against importing fossil fuels to the value of 5-15% of GDP annually over some 30 years. With the certainty of future price increases, prospects of insecurity of supply and eventual cease of supply, set of decisions to make becomes increasingly difficult.

#### 4. Proposed transition strategy for developing economies

The transition strategy proposed here addresses developing economies which depend on imports of fossil fuels. For these economies, annual cost of total final energy consumed is

generally above 10% of GDP, and very often around 20%. The cost of imported fuels is anywhere between 30 and 70% of total energy costs, which corresponds with 5 - 15% of GDP.

Introducing systematic energy efficiency increase programmes is the first step to be taken as the transition away from imported fossil fuels because it could reduce national energy expenditures by at least 20%. These significant funds can be reinvested back into the economy and for further transition strategy implementation.

Further, over the long term perspective, as the global availability of fossil fuels shrinks, prices of fuels will increase to unsustainable levels for developing economies, because the competition for the resources will intensify. This affects security of supply, also increasing the likelihood of international conflicts about resources would be more likely to happen, and where developing countries are more likely to be put down by more powerful players.

Taking everything presented under consideration, renewable energy sources should be seen nowadays as a credible alternative to the fossil fuels. Technologies are available, and prices are falling. Every country has at least some of the renewable energy sources in abundance. The basic development path to be taken is that local development must be based on local resources - natural and technological alike.

On the other hand, energy infrastructure development is time consuming and capital intensive. Therefore the transition away from fossil fuels should be planned right now in order to develop an energy resilient economy, able to face the more difficult situation emerging some 40 years from now.

Based on these considerations, simple transition strategy objectives can be proposed:

*Eliminate gradually the need for importing fossil fuels!*  
*Base local development on local resources!*

These goals can be achieved by most developing economies by 2050, if countries seriously embark on this journey now. The goals have to be translated into sound national policy with a perspective of supporting policy implementation on local levels, in cities, counties and regions.

Benefits from decreased energy consumption and decreased import costs for fossil fuels may not be obvious for many policy makers at the national level and even more so in the cities. Besides, eliminating imports of fossil fuels will require significant structural shifts in economies. Therefore an Energy foresight study will need to be carried out in order to charter a road map to a low carbon economy and elaborates impacts and necessary adjustments on various economic sectors in the country.

The vantage point for considerations is the current energy mix, both at the supply and demand sides (Figure 13). Total primary energy supply mix is taken into account, and shares of individual energy sources are presented. The supply mix is dominated by fossil fuels, which is still valid for all countries in the world. Increasing dependence on energy imports is also a major factor, and system losses and other inefficiencies are accounted for when determining final energy demand.

Further trends in both the supply mix and demand mix are calculated using traditional analysis.

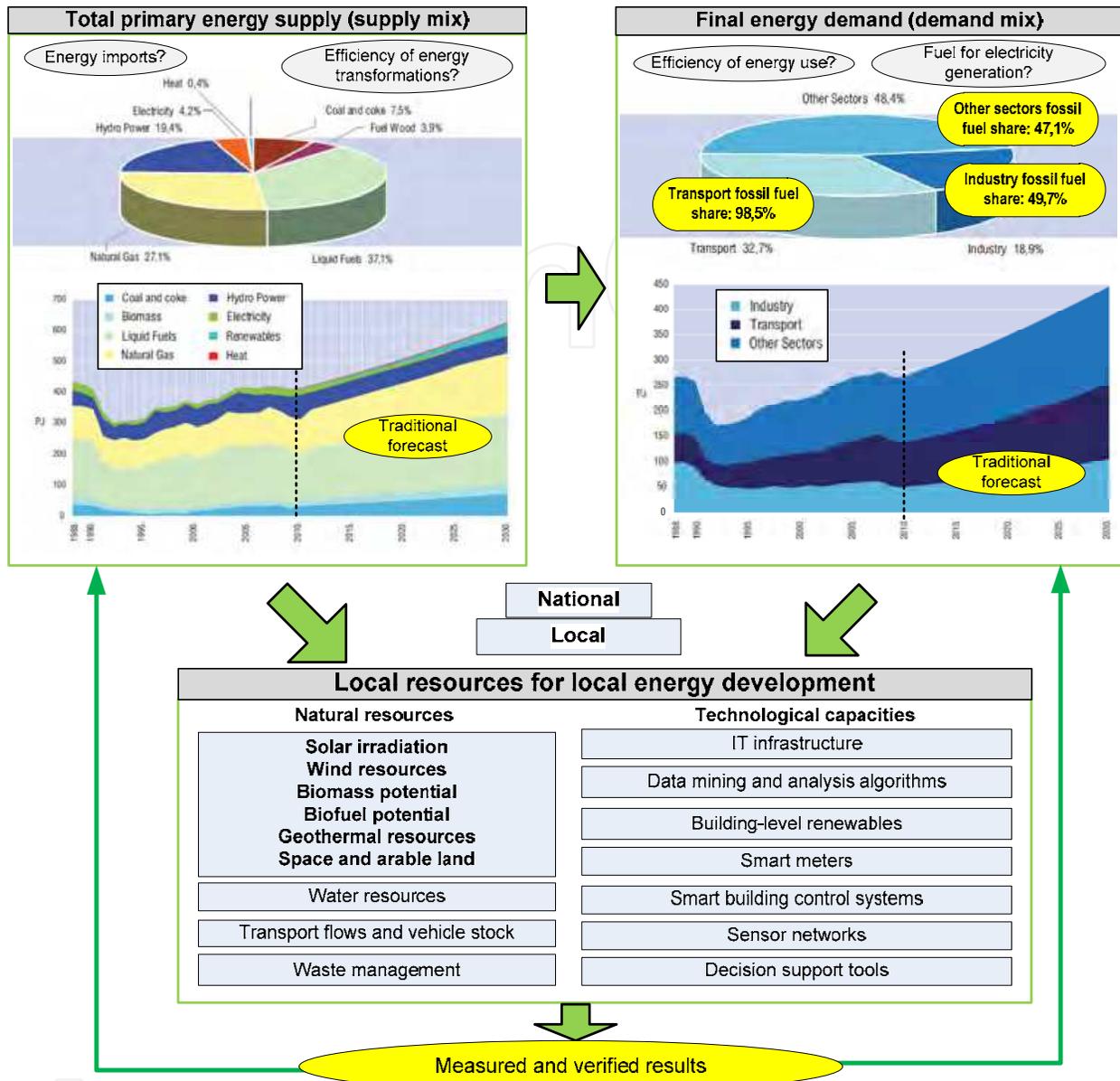


Fig. 13. Planning the utilization and development of local resources in alignment with national goals

Figure 13 represents a case that is quite common: 50% of total energy demands are fossil fuels from imports; industrial energy consumption is at 20% of the total, transport is at 30%, and buildings at 40% of total end use demand.

Targets for the transition strategy hereby are given as:

- implement a rigorous energy efficiency program aimed at improving EE in all sectors by at least 20%;
- identify local natural resources and developed related technologies so that the energy from RES can gradually eliminate all imported fossil fuels by 2050, which is 50% of current demand;
- define transition targets for particular energy end-use sectors (Figure 14).

We have underlined the word 'imported', because if a country has some fossil fuels of its own, they should be used with care and saved as a strategic reserve.

The obvious sectors to target first for the transition are buildings and transport where solutions are known and alternatives available. More difficulties are to be expected with industrial sector. But that is why we put development of an Energy foresight study as a mandatory step to get clear answers for structural changes in all sectors of the economy.

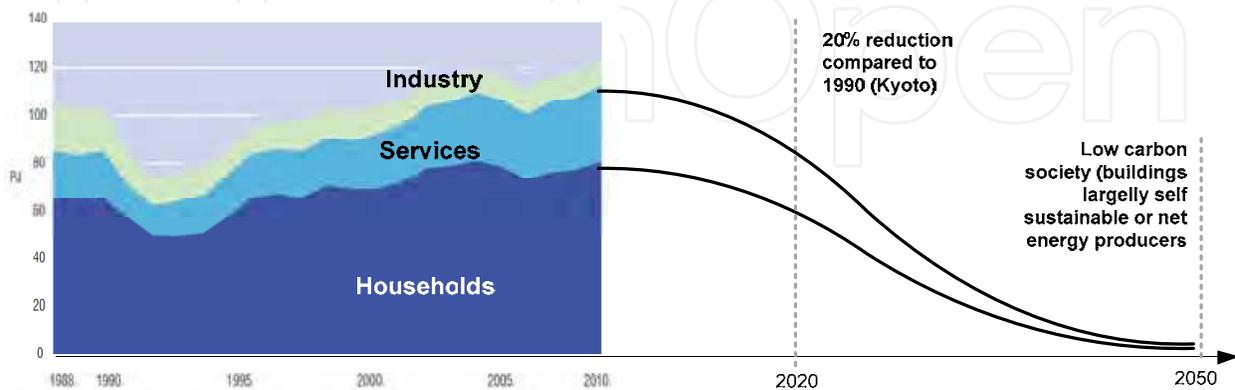


Fig. 14. Targets for transition toward a low carbon society in key consumption sectors for buildings

## 5. Smart energy cities - Implementation platform for transition

While concentrated action on the national level is required to develop and adopt energy policy, policy implementation has to be performed at the local levels in the cities where energy is consumed daily.

For cities which plan to apply local resource-based development approaches, the challenge will be to translate the national transition strategy into local-level projects. For this to happen, an effective participatory local, city-level planning methodology is indispensable. Through a consultative process, involving local stakeholders from the public and private sectors, a territorial diagnosis should be carried out to assess resources, capacities and economic opportunities that can facilitate transition process – a smart energy city action plan must be produced.

The process has to optimize utilization of locally available resources and make use of the competitive advantages of a locality to stimulate productivity in selected energy value chains while promoting economic development and creating employment.

From the technology viewpoint, transition towards the smart energy city can be summed up in three basic steps, as shown in figure 15:

1. Decreasing unnecessary energy losses by implementing an energy management system and implementing measures to increase energy efficiency;
2. Managing demand to avoid consumption peaks;
3. Promoting distributed generation from renewable energy sources.

By installing smart grid technology such as home area networks, smart meters and demand side management schemes, it is possible to control and optimize energy consumption so that

the maximum value of the peak demand is decreased. Smart meters along with energy management systems enable real time consumption monitoring both by consumers and utilities and enable use of smart appliances. After installing smart meters, demand response programs should be defined and implemented, which will enable an almost even consumption throughout the day.

The next step is installing renewable energy sources such as roof-mounted PV, wind turbines, biomass cogeneration plants, etc. as locally appropriate. They can be both local micro energy sources installed in the buildings and larger energy sources built in the city or nearby. This decreases losses in transmission since energy sources are situated near the consumption area. For installing smart meters and implementing demand response programs, ICT needs to be combined with the electric grid, so it will be possible to control and use the full potential of local distributed energy sources.

Cutting losses in buildings' consumption	Optimizing consumption of energy	Installing distributed, renewable sources
<ul style="list-style-type: none"> <li>• Energy efficiency</li> <li>• Cutting unnecessary waste of energy inputs (electricity, gas, heat, water)</li> </ul>	<ul style="list-style-type: none"> <li>• Installing smart meters</li> <li>• Implementing demand response program(s)</li> <li>• Decreasing needed capacity for peak demand</li> </ul>	<ul style="list-style-type: none"> <li>• Building-size renewable sources</li> <li>• Local distributed energy generation</li> <li>• Energy storage for power balancing</li> </ul>

Fig. 15. Three groups of activities toward smart energy city

Monitoring the progress and verifying results are of paramount importance because this should provide feedback data on success of the transition, and enable corrective policy measures to be defined if required. Key aspect of the monitoring system is definition of performance indicators to be measured. While the list of these could be quite extensive, key performance indicators (KPI) are here simplified to the following:

- KPI1: Total Energy consumption of building surface area (kWh/m<sup>2</sup>)
- KPI2: Thermal non-fossil energy produced locally compared to total thermal energy consumed in the city (MWh/MWh)
- KPI3: Electrical energy locally produced compared to total electricity consumed in the city (MWh/MWh)
- KPI4: Use of non-fossil fuels for transport (renewable electricity, bio fuels) compared to total energy use for transport in the city (%/%)

While other indicators are also important, these four serve to monitor two basic policy directions regarding smart energy – reducing energy consumption and increasing the share of renewable energy sources for electricity generation, heat production and transport. The presumed trend of change in accordance with the current policies in the EU of these KPI is shown in Figure 16.

Performance measurement in any process will not improve performance by itself. Performance data must be interpreted to plan and implement corrective policies and actions, and more than anything - to change the way people use energy in order to achieve lasting performance improvements.



Fig. 16. Presumed trend of change in accordance with current sustainability policies

Since increasing energy efficiency at all levels is by all means the first thing to do, and since it is only natural that the public sector takes the lead, introduction of systematic energy management in all public buildings should be the driver for implementation of transition strategy. This will create necessary capacities in terms of organization, institutions, skills, competencies, awareness, knowledge, IT and energy technologies infrastructure to serve as an implementation platform for furthering the transition strategy towards achievement of its objectives (Figure 17).

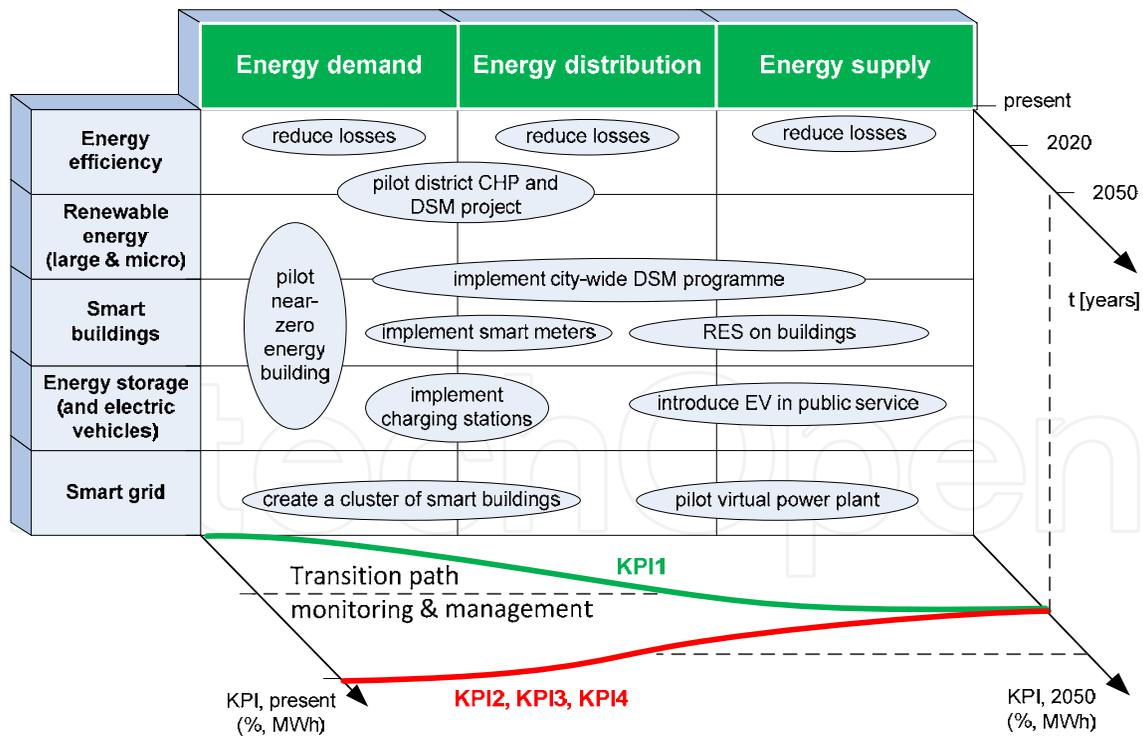


Fig. 17. Matrix structure of planning technology implementations for a smart energy city

Full implementation of energy management according to the smart building concept will gradually remove these buildings from demand for fossil fuels. This is illustrated in Figure 18.

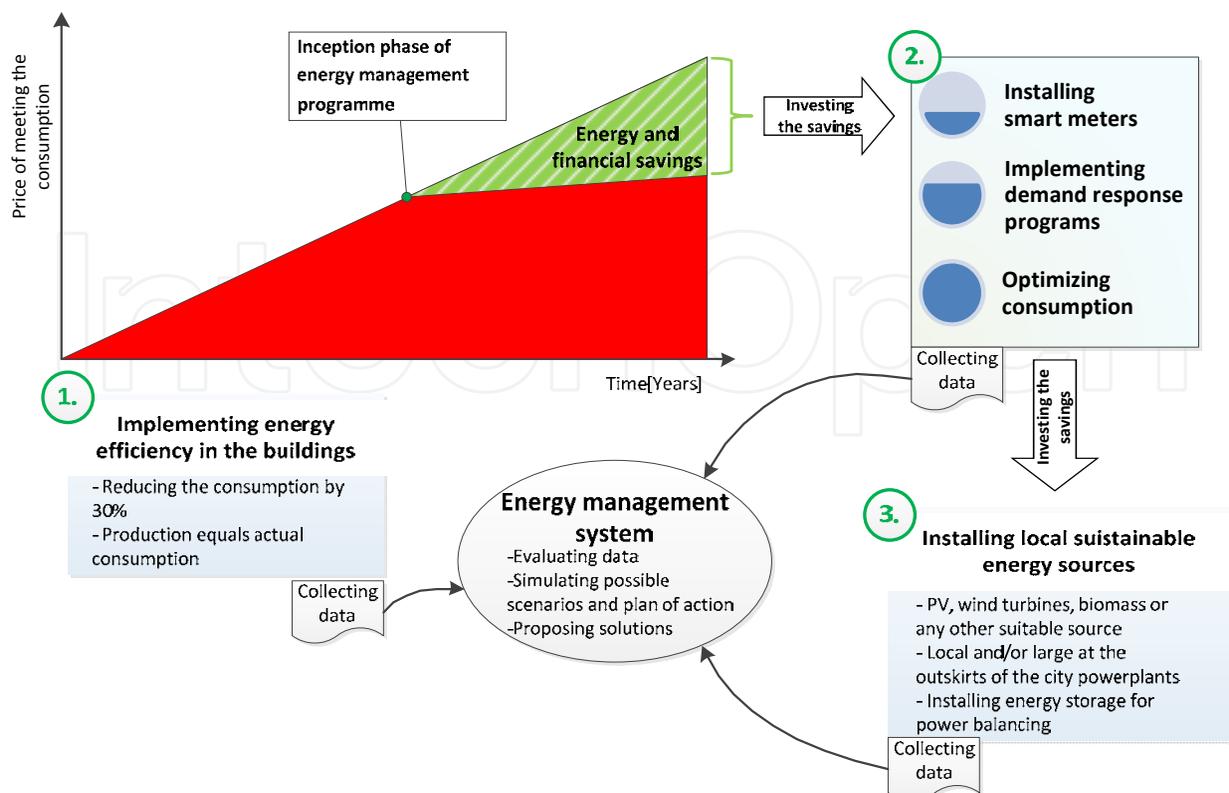


Fig. 18. Steps for transition to smart energy city with minimal initial investment

A well developed and functional energy management system in the city - inclusive of adequate organizational structures, institutional support, competent people and appropriate technology base, - presents a good foundation for transition towards the smart energy city and low carbon economic development.

## 6. Conclusion

We are living in an energy fossil age at the peak of its strength. There are various forecasts for how long it can still go on based on availability of fossil fuel reserves, but we believe this is extraneous. If we know that sooner or later we will run out of oil and gas, should we wait until the last drop dries out, or should we start acting earlier? Presumably, timely action is advisable, particularly in the case of the energy sector, where restructuring of energy infrastructure and changing of the energy mix is a time consuming and capital intensive process.

Nowadays there is a general awareness of the environmentally harmful side effects of using fossil fuels and geopolitical aspects of fossil fuel reserves and markets, inherent insecurity of energy supply and volatility of prices. The further we go towards scarcity of fossil fuel supplies, the greater the disturbances will be, and the higher the stakes in the struggle for securing supply.

Smaller economies and developing nations will be first to lose in this struggle if caught unprepared.

But there is also another aspect of this situation seldom emphasized: the cost of final energy in developing economies is usually more than 15% of GDP, and often more than 20%. The money which goes for import of fossil fuels is anywhere between 30 -70% of the annual energy bill which means around 5-15% of GDP. In addition, energy efficiency in developing economies leaves a lot of potential for improvement – at least 20%. These two facts are telling us that: firstly money is being wasted due to inefficient energy consumption, and secondly there are significant capital outflows for import of fossil fuels.

With all the other concerns about the fossil fuels, these are the additional which should kick us in the action – a transition towards low carbon economies, where imported fossil fuels have to be gradually replaced by locally available renewable energy sources.

Appropriate national transition policies are required for the period of up to 2050, and cities need to lead implementation of policies by transforming themselves into smart energy cities. The first step can start now – by implementing systematic energy management in cities, aiming at eliminating energy losses, further expanded by promoting distributed energy generation from locally available renewable energy sources and finally introducing smart meters, smart homes and smart grids.

Local natural and technological resources are the basis for local low carbon development – it cannot be based on resources and technologies we don't have. Charting the transition away from imported fossil fuels and towards low carbon development, in the long run, has no alternative.

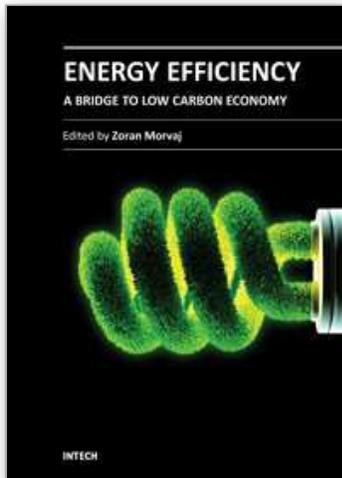
The sooner we start, the better off we will be, because there is only one thing more harmful than fossil fuels – fossilized thinking!

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## **Energy Efficiency - A Bridge to Low Carbon Economy**

Edited by Dr. Zoran Morvaj

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Energy efficiency is finally a common sense term. Nowadays almost everyone knows that using energy more efficiently saves money, reduces the emissions of greenhouse gasses and lowers dependence on imported fossil fuels. We are living in a fossil age at the peak of its strength. Competition for securing resources for fuelling economic development is increasing, price of fuels will increase while availability of would gradually decline. Small nations will be first to suffer if caught unprepared in the midst of the struggle for resources among the large players. Here it is where energy efficiency has a potential to lead toward the natural next step - transition away from imported fossil fuels! Someone said that the only thing more harmful then fossil fuel is fossilized thinking. It is our sincere hope that some of chapters in this book will influence you to take a fresh look at the transition to low carbon economy and the role that energy efficiency can play in that process.

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### **InTech Europe**

University Campus STeP Ri  
Slavka Krautzeka 83/A  
51000 Rijeka, Croatia  
Phone: +385 (51) 770 447  
Fax: +385 (51) 686 166  
[www.intechopen.com](http://www.intechopen.com)

### **InTech China**

Unit 405, Office Block, Hotel Equatorial Shanghai  
No.65, Yan An Road (West), Shanghai, 200040, China  
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元  
Phone: +86-21-62489820  
Fax: +86-21-62489821

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