Clean Energy
EC-Link Position Paper

January 2018
What is EC-Link?

Europe-China Eco cities link project (EC-LINK,) is a European Union founded project, a key element of the EU-China Partnership on Sustainable Urbanisation, which was signed by the European Commission and the Chinese government in May 2012.

It aims to assist Chinese cities in implementing energy and resource-efficient measures by sharing European cities’ experiences in sustainable urbanisation. Meanwhile, EC-Link has created a platform of experience for easy accessible exchange between Chinese and European cities on low carbon/eco city development issues.

Enhancing communication and providing training to Chinese related organizations and its’ staff on policy making, giving technical advices on specific sustainable urban development projects will contribute a lot to China sustainable urbanization.

EC-Link has produced Eco city toolboxes, a Knowledge platform and is organising city-to-city cooperation in the frame of City Network Units’ activities (CNUs). CNUs activities are focussed on pilot actions implementation based on the joint work of Chinese and EU experts for a common objective, chosen in the frame of sustainable urbanisation issues.

Our aim is to increase learning curve from European cities’ good examples & techniques, strategy and methods. These activities enhanced the communication between Chinese cities and European cities, which formed a solid base for the further cooperation.  http://eclink.org/en/
PREFACE

China’s Commitment to Mitigate Climate Change

In 2015, China was one of the first Asian countries – besides Japan and South Korea – to come out strongly with a commitment to combat climate change, and to adapt to eventual future impacts.

Context. With its population of about 1,300 million people, China is one of the world’s major emitters of greenhouse gases (GHG), and at the same time it is also one of the most vulnerable countries to the negative impacts of climate change.

Commitment. In preparation for the 2015 United Nations Climate Change Meeting (COP21) in Paris, the government of China has announced that its GHG emissions will peak in 2030. Equally, it is committed to reduce by 2030 by 60-65% the intensity of its carbon usage in relationship to its gross domestic product (GDP), compared to 2005 levels. It will take on the responsibility to increase substantially its forest cover, and will ensure that by 2030 some 20% of its energy requirements will be covered by renewable energy.

Actions. The country’s measures will include mitigation of its contributions to GHG emissions, and it will introduce adaptations measures to cope with negative impacts of climate change in food production, protection of its population, and in climate-proof infrastructure. China aims at biding climate change agreements under the COP21. The international community sees the proposed measures as ambitious but achievable. Since several years, China has started with low-carbon development. Today it is working towards a full-fledged program of green development of its economy.

Eco-Cities and Climate Change

China’s activities to create eco-cities must be seen as part of its contributions to low-carbon development with aim to mitigate climate change. Among the various support mechanisms which exist, to support low-carbon development, the Ministry of Housing, and Urban-Rural Development (MoHURD), is being supported by the European Union (EU) through the Europe-China Eco-Cities Link Project (EC Link).

Background. The main objective of the EC Link project is to serve as a support mechanism to the Ministry of Housing and Urban-Rural Development to implement its sustainable low-carbon urbanisation agenda. The project will support the Ministry in 4 strategic areas:

1) Demonstrate best approaches to implement low carbon solutions by introducing appropriate urban planning tools. Best practice low carbon planning will be identified in both Europe and China and made available nation-wide to municipal governments. Advanced planning tools will be deployed at the local level with the support of the project, with a view to refining proposed low-carbon planning models and to scaling them up across Chinese provinces.
2) Serve as testing ground for innovations in specific low-carbon policies (e.g. energy performance labelling for buildings, intelligent transport systems, smart cities, GIS planning tools, eco city labelling schemes) and technologies (in the 9 sectors selected by the project: compact urban development, clean energy, green buildings, green transportation, water management, solid waste treatment, urban renewal and revitalization, municipal financing, green industries).

3) Improve Chinese Municipalities’ potential to finance low carbon solutions and notably their ability to attract private sector financing in the form of public private partnerships. The EC Link will support MoHURD to define innovative financial schemes, support feasibility studies and the formulation of finance and investment proposals, better coordinate and leverage investments undertaken by EU Member States, or to link projects to European financing institutions (e.g. European Investment Bank) and to European companies.

4) Establish knowledge networks and test the functionality of the support mechanism by leveraging, scaling up, and integrating transformative actions supported by the policy and technology tools developed under the project. The Knowledge Platform will demonstrate how strategic objectives have been translated at local level and how results have been integrated at national level for the definition of long-term best practices. Results will be shared via training and capacity building at local level, and via the knowledge platform set-up by the project at national and international level.

The EC Link Position Papers. MoHURD and the EC Link Technical Assistance Team (TAT) have identified 9 specific sectors for the deployment of technology based tool boxes. In all of these, Europe has a lot of knowledge and best practice to contribute to support the deployment of these solutions in China. These 9 sectors include:

- compact urban development,
- clean energy,
- green buildings,
- green transportation,
- water management,
- solid waste treatment,
- urban renewal and revitalization,
- municipal financing,
- green industries.

MoHURD’s Department of Science and Technology, EC Link’s direct counterpart, has issued targeted objectives for the deployment of policy, research and development and engineering agendas.

Users and Target Groups of Position Papers. The EC Link Position Papers will be utilized by personnel of the cities which are covered by MoHURD’s eco-city programme. This covers technical and managerial staff of these cities. Additionally, at central government level, MoHURD and other ministries may also make use of these position papers for the purpose of staff training and briefing.
Since these position papers are also going to be published in the EC Link website (www.eclink.org), also the general public is invited to make use of these position papers.

**Content of Position Papers**

**Sector overview:** The EC-Link position papers provide an overview of each thematic sector (compact urban development, clean energy, green buildings, green transportation, water management, solid waste treatment, urban renewal and revitalization, municipal financing, green industries). It begins with a state-of-the-art review of the sector, and presents sector challenges as development objectives.

**Sector policy analysis:** As part of the sector overview, the EC-Link position papers provide sector policy analysis, and a comparison of EU and Chinese sector policies.

**Comparison of European and Chinese experiences:** The comparison of real-life EU and Chinese project experiences are used to illustrate innovations and progress in the respective sector. Both for EU and Chinese cases, there is an overview of good practices, technologies and products, performance indicators, technical standards, verification methods, and lessons learnt from best eco-city practices.

**Tools:** This position paper contains three primary tools. Throughout the text of this position paper there are flags provided to point out these primary tools (→ Tool CE 1, → Tool CE 2, → Tool CE 3). At the end of the position paper there is an Annex with short summary descriptions of these primary tools.

The primary tools for Clean Energy (CE) are:

- → Tool CE 1: Technology options for decentralized new energy supply.
- → Tool CE 2: Decentralised micro-grids.
- → Tool CE 3: Sustainable energy action plans (SEAPs).

It is understood that these primary tools, do contain numerous secondary tools which cannot be elaborated in the context of this position paper.

**Position Paper - a living document:** This position paper will be updated based on city-level real-life project experiences in the EC-Link pilot cities.

**Possible misconceptions:** These position papers shall not be mistaken for ‘cook books’, or ‘how to do’-manuals like we know them from other subject fields (car repair, computer servicing, etc.). Urban development is too complex for such an approach.
Upon request of MoHURD these position papers are addressing good practices and seek to provide tools for complex issues of green urban development.

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CONTENTS

Abbreviations .................................................................................................................. 9
List of cases .................................................................................................................... 10
List of illustrations .......................................................................................................... 11
List of tables .................................................................................................................. 11
Glossary of terms .......................................................................................................... 11
1. THEMATIC BACKGROUND ..................................................................................... 12
  1.1 Content and Delineation of this Position paper ..................................................... 13
    1.1.1 Clean energy technologies, sources and options in the service delivery chain 16
    1.1.2 Integrated community (thermal) energy concepts ......................................... 20
    1.1.3 Comprehensive multi sector urban low-carbon concepts ............................. 21
  1.2 Role of municipality and other stakeholders, policy options and financing .......... 26
    1.2.1 Stakeholders and urban clean energy project organisation .......................... 26
    1.2.2 Institutions, organizational structure, process organization and participation mechanisms ............................................................ 27
    1.2.3 Financing of project preparation and implementation by projects ............. 27
  1.3 Competence and Policy Options ........................................................................... 28
    1.3.1 Policy mechanisms ....................................................................................... 28
    1.3.2 Policy objectives ........................................................................................... 28
  1.4 Spatial and temporal resolution of urban energy concepts .................................. 30
  1.5 Information and decision support ........................................................................ 30
    1.5.1 Analysis, forecasts and modeling .................................................................. 30
    1.5.2 Modeling Tools and Software ....................................................................... 32
2. DEVELOPMENT OBJECTIVES ............................................................................... 34
3. KEY ISSUES — KEY CONCEPTS ................................................................. 37
4. PERSPECTIVES FROM EUROPE ........................................................................ 38
  4.1 Sector Context and Policy Analysis ..................................................................... 38
    4.1.1 Importance of clean energy technologies ...................................................... 38
    4.1.2 Framework conditions: RE targets and obligations ..................................... 40
    4.1.3 Other framework conditions and trends ....................................................... 45
    4.1.4 European urban energy programs and associations .................................... 46
  4.2 Good practices .................................................................................................... 49
    4.2.1 Citywide comprehensive concepts ............................................................... 58
    4.2.2 Integrated community energy concepts (district and neighbourhood rehabilitation and greenfield projects) ........................................... 73
    4.2.3 Special clean energy technology applications ............................................. 87
4.3 Technologies, Products and Standards.................................................................93
4.4 Indicators..................................................................................................................104
4.5 Planning Models and Modeling Tools and Software .................................................108
4.6 Evaluation Methodology..........................................................................................112
4.7 Lessons Learnt from pilot projects ..........................................................................113
4.8 Outlook......................................................................................................................116
5. PERSPECTIVES FROM CHINA ..............................................................................117
  5.1 Sector Context and Policy Analysis..........................................................................120
  5.2 Objectives, Programs, Institutions and Sector Organization ..................................130
  5.3 Examples of interventions ......................................................................................135
  5.4 Good Practices - Illustrations ................................................................................148
  5.5 Technologies and Products, Standards ...................................................................149
  5.6 Indicators..................................................................................................................150
  5.7 Evaluation Methodology .........................................................................................151
  5.8 Lessons Learnt from pilot projects .........................................................................153
  5.9 Outlook......................................................................................................................157
6. VALUE ADDED and CROSS CUTTING THEMES ....................................................163
7. AVAILABLE RESOURCES AND TOOLS .............................................................164
8. RECOMMENDED READING ...................................................................................167
ANNEXES ......................................................................................................................168
  Annex 1: Tool CE 1 - Technology options for decentralized new energy supply ........168
  Annex 2: Tool CE 2 - Decentralised micro-grids .........................................................170
  Annex 3: Tool CE 3 - Sustainable energy action plans (SEAPs) ...............................174
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIPV</td>
<td>building integrated photovoltaic</td>
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<tr>
<td>CAS</td>
<td>Chinese Academy of Sciences</td>
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<td>CCHP</td>
<td>Combined Cooling, Heat and Power</td>
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<td>cCR</td>
<td>carbonn Climate Registry</td>
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<td>CCS</td>
<td>Carbon Capture and Storage</td>
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<td>CBDC</td>
<td>China Development Bank Capital</td>
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<td>CHP</td>
<td>combined heat and power</td>
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<td>CNREC</td>
<td>China National Renewable Energy Centre</td>
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<td>COP21</td>
<td>United Nations Climate Change Meeting</td>
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<td>CSUS</td>
<td>Chinese Society for Urban Studies</td>
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<td>DEMaP</td>
<td>Decentralised Energy Master Planning</td>
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<td>EC Link</td>
<td>Europe-China Eco-Cities Link Project</td>
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<tr>
<td>EEA</td>
<td>European Environment Agency</td>
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<tr>
<td>EIB</td>
<td>European Investment Bank</td>
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<td>ELENA</td>
<td>European Local Energy Assistance</td>
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<td>EPC</td>
<td>Energy Performance Certificate</td>
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<td>EU</td>
<td>European Union</td>
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<td>EU ETS</td>
<td>EU Emissions Trading System</td>
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<td>GDP</td>
<td>gross domestic product</td>
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<td>GEF</td>
<td>Global Environment Fund</td>
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<td>GFEC</td>
<td>gross final energy consumption</td>
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<td>GHG</td>
<td>green house gases</td>
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<td>HDD</td>
<td>heating degree days</td>
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<td>HRBEE</td>
<td>Heat Reform and Building Energy Efficiency</td>
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<tr>
<td>IEE</td>
<td>Institute of Electrical Engineering</td>
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<tr>
<td>INDC</td>
<td>Intended Nationally Determined Contributions</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>ISEP</td>
<td>Institute for Sustainable Energy Policies</td>
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<td>KPIs</td>
<td>Key Performance Indicators</td>
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<td>LDA</td>
<td>London Development Agency</td>
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<td>LIP</td>
<td>Local Investment Program</td>
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<tr>
<td>LCOE</td>
<td>Levelized Unit Costs of Electricity</td>
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<td>MEP</td>
<td>Ministry of Environmental Protection</td>
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<tr>
<td>MoHURD</td>
<td>Ministry of Housing, and Urban-Rural Development</td>
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<td>PV</td>
<td>Photovoltaic</td>
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<tr>
<td>SEAPs</td>
<td>Sustainable Energy Action Plans</td>
</tr>
</tbody>
</table>
List of cases

Case 1 Denmark: Three lessons for cities in Denmark’s clean-energy revolution .......................................................... 50
Case 2 Germany: Germany Overhauls its Flagship Energy Policy ........................................................................... 54
Case 3 Stockholm, Sweden: Energy Concept of Stockholm ....................................................................................... 58
Case 4 Växjö, Sweden: Fossil Free Växjö .................................................................................................................. 60
Case 5 Aarhus, Denmark: the Climate Plant ................................................................................................................. 61
Case 6 London, United Kingdom: Decentralised Energy Master Planning (DEMaP) Program .................................. 63
Case 7 Woking, United Kingdom: Renewable Energy at City Level ........................................................................ 65
Case 8 Tilburg, the Netherlands: Multi-Sector Network .............................................................................................. 65
Case 9 Freiburg, Germany: “Climate Change Action Scenario” until 2030 ................................................................. 66
Case 10 Nantes, France: Climate Plan ....................................................................................................................... 68
Case 11 Barcelona, Spain: Energy, Climate Change and Air Quality Plan (PECQ 2011-2020) ...................................... 69
Case 12 Almada, Portugal ........................................................................................................................................... 72
Case 13 Helsinki, Finland: Eco-efficient renewal and revitalization of Peltosaari neighbourhood .................................... 73
Case 14 Malmö, Sweden: Western Harbour (Västra Hamnen) Revitalisation .............................................................. 75
Case 15 Scotland: Sets Wind Record, Provides Enough Electricity for 3.3 Million Homes ........................................ 76
Case 16 Aarhus, Denmark: Low-Energy Neighborhood Project in Lystrup ............................................................... 77
Case 17 Stad van de Zon, the Netherlands: New District of Heerhugowaard ............................................................ 78
Case 18 Berlin, Germany: Science and Commercial Park Adlershof 2020+ ............................................................... 79
Case 19 Hamburg, Germany: Integrated Energy Network Wilhelmsburg Mitte (of Cities and Climate Change Programme) ........................................................................................................ 79
Case 20 Grenoble, France: Revitalization of Unutilized Military Baracks “ZAC de Borne” ........................................... 81
Case 21 Toulouse, France: Greenfield Development, ZAC Andromède ....................................................................... 83
Case 22 Salzburg, Austria: Revitalization and Heat Supply of Lehen District .............................................................. 85
Case 23 Linz, Austria: Solar City Pichling .................................................................................................................. 86
Case 24 Wieringermeer, The Netherlands: Wind power .............................................................................................. 87
Case 25 Leicester, United Kingdom: Reduction in energy usage of municipal buildings ........................................ 88
Case 26 Mannheim, Germany: e-energy model city MOMA .................................................................................... 89
Case 27 Heidelberg, Germany: Old Gasometer to be Transformed into Centre for Renewable Energy ................... 89
Case 28 Lille, France: Buses powered by biogas of the municipal wastewater ............................................................ 90
Case 29 Bristol, United Kingdom: Buses running on biomethane gas ........................................................................ 91
Case 30 Tianjin: an Emerging Eco-City .................................................................................................................. 135
Case 31 Anshan, Liaoning Province: Restructuring district heating with heat recovery .................................. 135
Case 32 Minhang District, Shanghai: Anting New Town with innovative energy and waste management .................. 137
Case 33 Hohhot, Inner Mongolia: various initiatives ................................................................................................. 138
Case 34 Dunhuang, Gansu Province: solar power ..................................................................................................... 139
Case 35 Datong, Shanxi Province: Solar-PV, driven by manufacturer in a coal mining city ........................................ 140
Case 36 Huainan, Anhui Province: The world’s largest floating solar power plant went online .............................. 140
Case 37 Hami, Xinjiang Autonomous Region: Changing energy mix ....................................................................... 141
Case 38 Rizhao, Shandong Province: Solar heat and PV Utilization ...................................................................... 142
Case 39 Dezhou, Shandong Province: Solar City ..................................................................................................... 143
Case 40 Rongcheng, Shandong Province: Wind energy city .................................................................................... 143
Case 41 Wuxi, Jiangsu Province: China’s First Zero Energy Building ...................................................................... 145
Case 42 Shanxi Province: Special Compensation Fund for Eliminating Inefficient Capacity

Case 43 Shanghai: An innovative green pricing mechanisms-the Shanghai Green Electricity Scheme

Case 44: Shenzhen: World’s Largest Waste to Energy Power Plant

List of illustrations

Figure 1: Delivery chain for thermal comfort service for the case of district heating........ 15
Figure 2: Conceptual Overview: Sectors of urban energy ............................................. 22
Figure 4: Conceptual Overview: Sectors of Urban Energy ........................................... 40
Figure 5: Self-Regulating Energy systems.................................................................. 111
Figure 6: Energy Sector Investment Demand Estimate in the 13th Five Year Plan (2016-2020) ................................................................. 125

List of tables

Table 1: Relationship between Smart and Green Guidelines ........................................ 127
Table 2: China’s Renewable Energy Targets Overview .................................................. 130
Table 3: Energy Sector: Key Performance Indicators for Tianjin Eco City ..................... 150
Table 4: Additional Quantitative Objectives of SSTEC’s Energy Sector Plan ................ 151
Table 5: Proposed Clean Energy KPIs ......................................................................... 152

Glossary of terms

Carbon emissions  Emissions of CO₂ = greenhouse gas (GHG).
Clean energy  Energy generated from clean sources (hydro, wind, sea, earth heat, solar, blo gas, methane gas, photo-voltaic, etc.).
District heating (and cooling)  Neighbourhood based heating (and/or cooling) stations which are more energy efficient than decentralized systems.
Energy-efficiency  Energy-efficiency describes the difference in performance of conventional carbon-based systems and new energy technologies (hydro, wind, sea, earth heat, solar, etc.).
1. THEMATIC BACKGROUND

Carbon emissions. The major portion (81% in 2011) of the carbon emissions in Europe is related to energy use in residential buildings, transport, industry and other sectors and to energy transformation, while in China that proportion was 80% in 2011. In China, the generation of electricity and heat emitted approximately 40% of all carbon while in Europe it was 33%. In China, industries have been responsible for 23% of all emissions.

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Image: AFP

Source: Gray, A. 2016. 5 Charts that explain the Paris Climate Agreement. World Economic Forum 4 November. https://www.weforum.org/agenda/2016/11/5-charts-that-explain-the-paris-climate-agreement/

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1 According to World Resources Institute the GHG emissions 2011 (latest available overall numbers all in MtCO₂ equivalent) for EU 28 were 3688 for energy (including energy sector and energy use) of 4541 (total) and for China 8392 of 10552 (energy related); http://cait.wri.org/
In Europe, transport and residential energy use emissions are much more important. The trends in China show that carbon impact of individual transport and higher living comfort are increasing, as do the respective energy use emission shares.

**Cities and carbon emissions.** Energy use and related carbon emissions are concentrated in cities. In China, cities concentrate energy uses and carbon emissions even more than population. This makes urban energy a principle concern in low-carbon strategies, in particular for China’s cities, and gives energy an outstanding position in the sustainable low-carbon agenda of MoHURD.

**Chinese cities are carbon-intensive.** One driving factor for higher energy use and carbon emissions in cities is the activity level, i.e. the higher degree of agglomeration of productive and consumptive activities in cities compared to rural areas. Another factor is the location of power generation and energy intensive industrial production within cities, which is particularly frequent in China. This raises the relative carbon emission (measured per capita) intensity of Chinese cities compared to similar sized cities in other countries, where large power stations and basic industries are only exceptionally situated within major cities. But also building and transport energy use, and related carbon emissions in large Chinese cities are already on a similar level per capita compared to cities to Europe in similar climatic zones.

### 1.1 Content and Delineation of this Position Paper

**Urban carbon emissions.** In the carbon statistics, the energy emissions are accounted where the CO\(_2\) and other green-house gas (GHG) emissions actually take place when energy is transformed. Thus, apart from the energy supplying industries, also the energy transformation GHG emissions of the energy use sectors are classified under the energy category, specifying (i) manufacturing and construction, (ii) transportation, and (iii) other fuel combustion including residential, commercial, public and other small sectors, mainly in buildings.

**Towards low-carbon urban development.** With respect to low-carbon urban development, manufacturing, construction, transportation, and buildings merit attention not only as source of GHG emissions from fossil fuel combustion but also as a user of secondary energy such as electricity, heat and cold, which are produced on-site or by the energy supply sector more or less carbon intensively.

**Scope of clean energy.** Clean energy covers a wide scope including the energy use as well as the energy supply sectors according to the pervasiveness of energy and the energy-related GHG emissions. This is necessary to capture the comprehensive nature of urban low-carbon emissions. The 35 largest cities in China, which contain 18% of the population, contribute 40% of China's energy uses and CO\(_2\) emissions”, S. Dhakal, Urban energy use and carbon emissions from cities in China and policy implications, in: Energy Policy, Volume 37, Issue 11, November 2009, Pages 4208–4219.


4 The IPCC Common Reporting Framework used by the UNFCCC subsumes under Energy (Category 1) all energy transformation emissions from 5 subsectors (Category 1A), i.e. Energy Industries, Manufacturing & Construction, Transportation, Other Sectors (CO\(_2\) emissions) and Energy-other (CH4, N2O) as well as Fugitive Emissions (Category 1 B, from gas venting & flaring, pipelines, etc.) see IPCC. 1996. IPCC Guidelines for National Greenhouse Gas Inventories. Understanding the Common Reporting Framework. Available at [http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ri.pdf](http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ri.pdf).

5 In the energy statistics, the overall term for these sectors is Gross Final Energy Consumption. The energy transformation in the energy (supply) industry is reported in the transformation part of the energy statistics.

6 Therefore, these three sectors are given particular attention in (other) EC Link position papers: Green Transportation, Green Buildings, and Green Industries. In addition specific position papers are also available for water management and solid waste management which is an important user of energy and also holds specific options for clean energy technologies for reducing GHG emission such as land-fill gas.
concepts, which follow the energy flows and include the energy use sectors. In addition, cleaner energy technologies are increasingly applied on site. Considering the energy interrelationships, cities have developed comprehensive low-carbon development concepts, covering all sectors which entail GHG emissions. In such a comprehensive approach, cities pull together all efforts related to reduce GHG emissions in a concerted and rational way.

**Overlap with other position papers.** To avoid duplication, this position paper defers for details to the green transportation, buildings, industrial, water and waste management position papers, which delve deeper into the specific aspects and the respective low-carbon measures.

**Complexity of low-carbon development.** Low-carbon options may be some of the low-carbon urban energy solutions, e.g. district systems for thermal comfort and other thermal services, are complex and consists of several successive and interrelated elements (see Figure below). A district thermal system also involves numerous users within reach of the grid. To conceive such systems in which economies of coalition operate, an integrated community energy concept is required. Such integrated community concepts for thermal energy encompass many buildings and other users as well as various sources, and provides the information for making rational use of the multitude of clean energy options. Clean options include efficient buildings, decentralized generation and storage, district grid and heat sources, for each of which there are technical alternatives with different economic, financial and environmental implications. To be able to identify preferable options for the low-carbon agenda, many cities have taken an integrated perspective and developed a very detailed view and model of the thermal energy system, when districts or urban areas are rehabilitated or new urban developments are planned.
Figure 1: Delivery chain for thermal comfort service for the case of district heating

Source: Chevron
Note: blue arrow indicates the steps where clean energy technologies are applied; red illustrates the steps of building technologies. Energy efficiency principles apply along the whole chain.

The recent rise of decentralized generation and mini grids for electricity is another example of the growing complexity and competing solutions in urban energy (decentralized and centralized) which are better understood and chosen on the basis of community concepts.

Focus of Position Paper. This position paper obviously also needs to address individual clean energy technology and sources. It regards, however, the energy technology or source always as part of a delivery chain for a service, be it thermal comfort, food preparation, transport, processing of a product or other services for which energy is required.

Summing up, this position paper addresses three levels of low-carbon clean energy concepts for cities:

- comprehensive multi-sector urban energy / low-carbon concepts;
- integrated community energy concepts; and
- clean energy technologies and sources.

Below explanations of these concepts starts from the detailed level of individual technologies and moves from upwards to city level technologies and approaches.
Clean energy technologies, sources and options in the service delivery chain

Definition. There is an official globally accepted definition of clean energy. In the framework of the urban sustainable low-carbon agenda, “clean” is understood as “low-carbon”. Carbon emissions are also a good indicator for other air emissions, and therefore low-carbon also corresponds to low air emissions in general.

Clean energy. Against this background, clean energy is the low-carbon subset of the energy technologies and sources. Of the many individual technologies and combinations which are employed to deliver energy services we consider those as clean energy, which are characterised by low-carbon emissions over the whole delivery chain. This delivery chain can be very long and involve all the steps from primary production and transport, central transformation, transmission and distribution to the end user, or short and involve only a decentralised provision of the respective energy service using ambient sources, or interim solutions.

Terminology of low-carbon. Low-carbon is a relative term. Therefore, we consider as clean energy in addition to zero carbon technologies also those which reduce significantly the overall GHG emissions compared to the alternative of “Business as Usual” (BAU). If for instance the alternative of a combined heat and power (CHP) station, fired by biomass, is electricity from a coal fired power station and decentralised fossil-based heat generation, this CHP is considered low-carbon, i.e. clean energy.

Clean energy technologies. In practical terms, we consider as clean energy all those technologies which reduce fossil fuel, combustion and GHG emissions, making use of

- renewable energy sources, including hydro, solar, wind, geothermal and bioenergy with exception of bioenergy which induces as much carbon emissions in the delivery chain as the main alternative fuel; but also
- passive solar energy;
- ambient energy, in particular with heat pumps;
- land-fill and sewage gases;
- solid waste (provided the combustion complies to low emission standards); and
- waste heat. ➔ Tool CE 1

We also include poly-generation technologies (combined heat and power [CHP] and combined heat cold and power [CCHP]), even when fired by a fossil fuel with specific carbon emissions coefficients on the lower side such as natural gas, provided that it replaces power and thermal energy from high emitting plants, and provided the overall carbon reduction is clearly positive. Poly-generation plants will become complementary cornerstones for energy systems with high renewable energy shares. Thus, district thermal (heating and/or cooling) systems are part of the clean energy technologies; provided they are they are fed from clean energy technologies.

Energy efficiency. Energy efficiency is another category which fulfils the criteria, reducing carbon emission, that can be considered clean energy technology. Energy efficiency reduces energy input in relation to the respective output. Energy efficiency is rather a principle than a set of specific technologies and can be applied in all stages, technologies and processes of the energy use and supply chain which can be demonstrated also along the links. Reducing carbon emissions actually begins with fitting provision of an energy service exactly to requirement, provide thermal comfort where and when needed, and avoid squandering of heat. In transportation avoid travel when possible, possibly substitute it by communication.

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7 Sometimes Carbon Capture and Storage (CCS) is included under clean energy, although the carbon captured is stored and leakage is a risk. In any case, the CCS development however is stalled and it is basically a technology related to large power stations or energy production. This is not the focus of this position paper. For similar reasons, nuclear energy is not included in clean energy.
In some energy use sectors, it is possible to apply different modes for the service which involves very different energy intensities. In transportation, shifting of modes from individual to mass transport or even to biking are very well established ways of reducing fossil energy consumption and related emissions. In thermal services of buildings, the choice of building types and density (urban morphology) can also be considered as a modal shift.

The next area with many options for reducing final energy consumption is the sector specific technology which is incorporated in buildings (orientation, compactness and envelope), appliances, vehicles, industrial equipment and processes. In other words, energy efficiency is an important feature of building technology, transportation technology, industrial process technology and other technologies which are not genuine energy technologies.\(^8\)

**Transformations in energy needs.** In-situ energy transformation technology needs to be conceptionally distinguished also. For example for thermal comfort, the options include a heat exchanger, a boiler, a heat pump, a solar water heater, micro-CHP or other technology. In case of transportation the options include different engines which for electric vehicles involve charging stations and batteries. In case of industrial process heat larger boilers and cogeneration plants are the main choices. In the sense of low-carbon, all this energy transformation technology should become more efficient, or use non fossil energy.

**Energy supply.** Next element upstream is the energy supply network, in case of thermal, gas and electricity actually in form of grids consisting of pipes and lines. In terms of low-carbon, the imperative is to reduce energy losses. The thermal or electrical energy lost in the grids would need to be produced, additionally causing respective additional CO\(_2\) and air emissions. In case of natural gas losses mean a release into the atmosphere of methane with high global warming potential (GWP).

**Energy generation.** The next upstream step, the generation of thermal energy and electricity, is the effective step in the chain in terms of a low-carbon strategy. Poly-generation is an efficient technology, and low-carbon if compared to separate fossil fuelled generation of heat and power. Here the choice of fuel is another key measure to reduce carbon emission, with natural gas emitting approximately less than half CO\(_2\) per unit energy generated than coal. In case of biomass the life cycle of the respective fuel must be considered for classifying it low-carbon.

Recently, local grids have become less unidirectional. In case of thermal grids, low-carbon sources have been added at different points and caused multidirectional flows. This is true for both, thermal and electricity grids and has allowed to incorporate clean energy technologies at the grid level. In case of thermal grids, solar water heaters, heat pumps, shallow geothermal sources may contribute, and in particular waste heat from industry or surplus from commercial users and buildings. In case of electricity, distributed generation situated at the consumer plant feeds into the grid. In some cases local micro-grids are established below the level of the customary low voltage distribution level.

Poly-generation plants are situated within or near city boundaries to reduce capital intensive pipeline investment and energy losses, whereas power plants without extraction of thermal energy are only occasionally located within cities. ➔**Tool CE 1**

**Renewable energy.** However, in addition to the traditional hydro power, other renewable energy technologies on utility scale including wind and solar have become available also for energy generation to be fed into the medium voltage and even high voltage levels, and

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\(^8\) End-use energy efficiency which is achieved by building, transport, or industrial technology is rather addressed in the position papers of those sectors, although the delineation is not always strict and overlap is acceptable.
replacing fossil-generated electricity, at increasingly competitive conditions. Worldwide, one is observing a rapid decline of the cost of renewable energy costs.⁹

**Solar Cost Hits World’s New Low, Half the Price of Coal**

“Chile awarded a contract to sell solar power for $29.10 per megawatt hour (MWh), the lowest ever across the planet. This surpasses the record set in May of a $29.90 per MWh bid in Dubai for an 800 megawatt (MW) solar project. ‘This is the lowest price ever seen, for any renewable technology,’ an analyst told Bloomberg. The low price is possible due to the rapid fall in cost of solar technology and the 12 MW solar plant’s location in the ideal conditions of Chile’s Atacama Desert.”

![Solar panels](https://example.com/solar Panels.jpg)

ACERA


Going a step further, also energy storage technologies may be considered as part of clean energy technologies, above all since storage permits to bring more renewable energy into the system instead of dispatchable fossil fuel generated power or thermal energy.¹⁰

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⁹ See also: Abudheen K. S. 2016. For the cost of an iPhone, you can now buy a wind turbine that can power an entire house for lifetime. [http://educateinspirechange.org/nature/environment/cost-iphone-can-now-buy-wind-turbine-can-power-whole-house-lifetime/](http://educateinspirechange.org/nature/environment/cost-iphone-can-now-buy-wind-turbine-can-power-whole-house-lifetime/)

Wind Energy – An Example of Renewable Energy


Availability and costs. In all these sectors, energy use and supply, the availability and cost of clean energy technologies has dramatically evolved and fallen respectively in recent years and continues. The most dramatic change has taken place in power generation, where solar power from photovoltaic technology is becoming competitive and offers the option of consumer site generation, i.e. inside urbanised areas.

Sometimes carbon capture and storage (CCS) is also included under clean energy, although the carbon captured is not definitely removed, and leakage is a risk. In any case, it is basically a technology related to large power stations or energy production, not for cities. However, this is not the focus of this position paper. For similar reasons, nuclear energy is not addressed in this clean energy position paper.
Integrated community (thermal) energy concepts

**Community-level energy.** Integrated community energy concepts are information, planning and decision support tools for local energy systems. These are prepared for areas of a city (district, urban quarter) or towns at the occasion of rehabilitation of an existing quarter or for a new urbanization.

Usually these concepts were established for the provision of thermal energy services within a defined boundary in order to capture the advantages of a joint concept, including the economies of coalition and the reduction of the number of stationary emissions sources, i.e. combustion of fossil fuels in the buildings.

### Modern district heating systems save money and CO2

Today, 40% of the energy consumed in Europe is for heating. All this energy can become sustainable through modern district heating systems collecting waste heat from power plants and industry, and working at low temperatures which minimises the heat loss and integrates more sources of renewable energy. … [T]he heat currently being wasted in Europe could heat all of our buildings if it was collected in smart district heating grids. … 40% of our energy use currently consists of heating. All of this energy can become sustainable through modern district heating systems, which collect excess heat from combined heat and power (CHP) plants and industry and work at low temperatures, which decreases the heat waste and enables more renewable energy sources to be used.

“Our research shows that there is great potential for expanding the district heating grid in Europe by 30-50%, and the political will to make it happen is growing in our surrounding countries,” says Brian Vad Mathiesen, Professor of Energy Planning at Aalborg University.

In recent years, district heating has gained significant political focus in e.g. the EU, which gives the technology a prominent place in its new heating and cooling strategy. District heating has also become an important part of the […] work to obtain climate and sustainability goals.

Source: Modern district heating systems save money and CO2. State of Green. 11 October 2016.

### Seasonal energy needs.

Customarily in cities in winter cold regions, households or businesses used individual solid or liquid fuel fired boilers or even stoves for heating. An environmentally preferable but capital-intensive line-bound system such as district heating could only become economically and financially feasible with a high load factor, thus high demand density, which in turn requires to include in the system as many users as possible. This has led in market economies to some kind of prioritization, in cases where the joint supply by district thermal scheme looked economically favorable. Frequently cities have ordered a limitation of choice of competing systems, also citing clean air motives. Such urban development decisions needed a systemic comparison as a decision support tool, for which integrated urban thermal energy concepts were developed.

Using GIS. These integrated concepts are modeled in great detail and the information is geographically referenced in geographical information systems (GIS). They use individual buildings (or even typified users) as basic unit, integrating demand along streets, blocks, or quarters according to information needs. Demand scenarios are elaborated, in particular for varying levels of energy efficiency in the building system and taking into account the user behavior, and appropriate alternative delivery chains are designed accordingly. The various options then are evaluated using ecological, economic, financial and also social criteria, for
information and decision making, depending on the competence and participation of the stakeholders.

Schematically, such community thermal energy concepts include a multitude of delivery chains presented in the Figure below. These are interconnected by grids upstream and being fed by one or several sources (see good practices from Europe).

Integrated community concepts. Integrated community concepts are designed for long-term implementation. Their time horizon of planning, therefore, corresponds to a development cycle of 10 to 15 years.

With growing climate change concerns on the one hand and increasing technology choices on the other hand the integrated community concepts have become even more relevant, every time when a new urbanization is developed or an existing urban quarter is rehabilitated.

More recently, with the rise of distributed power generation and enabled by information and communication technology (smart grids), such integrated concepts become relevant also for the design of local electricity systems. The decentralized generation offers clean energy contributions to the power supply, alternatives to central generation and possibly also grid configuration and cost. Again, the advantages may be captured best when an integrated concept is developed and alternatives are analyzed systematically.

Distributed renewable energy power generation, high building energy efficiency and ambient heat sources can be combined to new options of clean energy, at the building level but also at the local level, in particular new urbanizations. To realize such options, hybrid thermal and power energy concepts are being employed.

Integrated energy concepts for communities may also include local transportation schemes and connections, as well as water and waste management and other local concerns. Objectives often include more than energy and environmental aspects and extend to socio-economic aspects and quality of life in these communities. Such concepts resemble more and more comprehensive urban low-carbon concepts.

Comprehensive multi sector urban low-carbon concepts

Comprehensive concepts. Comprehensive urban low-carbon concepts encompass all urban activities which involve energy flows and entail (or reduce) carbon emissions.

In addition to the thermal energy and the local electricity system of the residential, commercial and public energy use sectors, which are subjects of the integrated community concepts, the comprehensive concepts also address other energy uses namely transportation and industry and the whole energy industry sector, including supply from outside city boundaries. It also includes the water, waste water and solid waste sectors. For a city the water and sanitation sector is an important activity in several respect including carbon since it discharges GHG emissions and in particular methane gas, and municipal solid waste can become sources of energy.

Strategy for comprehensive low-carbon urban energy. Below graph visualizes the most important sectors of a comprehensive low-carbon urban energy strategy. It is useful to distinguish:

- Residential, public and commercial sectors with two subsectors (building and other energy services), including distributed generation;
- Industrial energy sector, including auto-generation;
- Transportation energy subsector;
- Water, waste water and waste management sectors; and
- Energy supply sector, including electricity, heat and CHP plants (public plants as well as auto-producers), and refineries. Tool CE 1

It is important to consider the energy interrelations between the sectors. Such strategies also include more generic urbanization aspects such as the density or compactness of urban development and urban renewal and revitalization, which have a strong impact on carbon emissions via the transport and building sectors. Many European cities have started to implement such comprehensive strategies (see below good practices from Europe).

Figure 2: Conceptual Overview: Sectors of urban energy

Characteristics. These sectors may also be regarded as strata, or vertical layers of the urban energy system. In terms of planning this view connects to spatial conceptualisation in the planning and decision tools.

Sectoral interrelations. Many interrelations between these sectors or strata exist, in particular between the energy utilities as suppliers of power and heat in particular and their relationship to the building energy strata (i.e. residential, commercial, and public users, and industry). Energy intensive industry traditionally includes auto-producers and has strong interchanges with grid operators and power sector, increasingly also with heat utilities. Gas or power generated from municipal waste may add energy supply for the use sectors. Interchanges between these strata currently grow also because of the rise of decentralised generation with renewable energy, and potential interconnections multiply. The current disruptive change in the electricity sector with high renewable energy shares seeks opportunities for storage or other flexibility solutions in use sectors, such as heat storage, storage in batteries of plug-in electric cars, and transformation to gas (power to gas) which can be stored or used in premium applications. Comprehensive concepts comprise the area of the whole administrative city and may include the wider metropolitan area.

Comprehensive concepts usually have a longer time perspective (up to 30 years) than the integrated community concepts, but use intermediate milestones. They are less detailed than
Clean energy approaches and packages

1. **Thermal energy services in residential, commercial or public buildings:** heating and cooling; hot water

**Characteristics:**
- Provision of thermal energy services adds up to significant energy demand, and causes significant carbon emissions. Energy requirements depend on indoor thermal comfort purposes in cold climate zones (heating), as well as in hot summer climate zones (cooling);
- Major fossil energy combustion and carbon emissions, locally felt at the end user level; or indirectly in the form of power, heating or co-generation plants;
- Service demand is scattered over the city, with varying density according to building and activity concentration;
- Energy demand depends on behaviour of users;
- Need for active energy input (delivered energy commodities) can be reduced significantly by passive building technologies, including orientation, compactness, insulation and natural ventilation, which reduce energy requirements.

**Clean energy technologies:**
Clean energy technologies and sources, alternatively or in combination. Once energy demand is reduced by smart building technologies, the demand may be met by following low-carbon technologies:
- decentralised internal systems:
  - heat pumps, geothermal, solar thermal water heaters;
  - high efficiency boilers for solid biomass, biogas, bio liquids, co-firing with fossil fuels,
  - decentralised cogeneration (micro CHP);
  - use of accessory electricity, generated again by clean technologies including photovoltaics;
  - highly efficient devices and small air conditioning units specifically for small cooling seasonal demand, generated by clean technologies;
- grid connected external systems, involving or supplied by
  - heat exchangers, possibly heat storage on the building level;
  - chillers, gas-fired absorption or electric compressed-vapour, both supplied from local neighbourhood combined heat and power (CHP) or combined heat, cold and power (CCHP) (bioenergy or fossil co-firing);
  - waste heat;
  - central district energy network supplied from district CHP plants; or
- small efficient gas or electricity systems required for cooking and hot water in laundry and other cleaning purposes.

2. **Other energy services in the residential, commercial and public sector buildings:** light, communication and information, operation of pumps for water and air circulation and also include food preservation, dishwashing and laundry, food conservation and preparation, hygiene, laundry and other cleaning, dishwashing.

**Characteristics:**
- various cleaning purposes;
  - electricity demand reduced by building technologies (daylight), by energy efficiency of appliances, natural lighting, or by user behavior;
  - conventionally remaining electricity supply;
- the low voltage grid, clean energy rather through the way electricity is produced;
Clean energy:
- Clean energy produced within or outside city;
- Distributed energy generation at neighbourhood level (local or mini grid; virtual power plants);
- Renewables or poly-generation on-site; storage by electricity consumers (prosumer), in particular energy from solar photovoltaic rooftops, and wind energy.

3. **Industrial energy**: stationary and concentrated high energy use and transformation in designated urban areas.

**Characteristics:**
- Heavy industries: very energy and carbon emission intensive, using steam and other forms of process heat;
- Transformation in situ;
- Use of fuels or electricity in the process of energy generation;
- Punctiform concentration and point source of emissions
- Location dependent on urban land use planning and zoning;
- Opportunities for heat and process heat to interact with district heating and cooling supply, but also interactive lines in medium and high voltage.

Clean energy:
- industry cogeneration;
- may generate more energy than used or at other times so integration into heat, steam, gas or power grid;
- technologies: energy and resources efficiency in the process, heat recovery, poly-generation.

4. **The transportation energy**: small non-stationary energy services, provided on big scale for mobility, and the fuel for power loading stations.

**Characteristics:**
- Quantity of these services add up to significant energy demand;
- Energy use and emissions are all over the city (and beyond), but tank fuelling or battery loading is stationary.
- Air emission policy may require a spatial concentration of transport modes, but carbon emission issues do not require this;
- Mobility provided with different energy intensity, from zero in case non-motorized transit (walking and bicycling), low intensity in mass transit to high intensity (individual car-based transport). This emphasized the need for green transport and compact urban development highly relevant reduction of energy related carbon emissions in cities;
- Energy use and emissions can be reduced by energy-efficiency of specific equipment or motors; and also by behaviour, which in turn can be influenced by transport policy.

Clean energy:
- Technologies include electro-mobility, in particular if power is provided from renewables;
- Intra–urban rail transit which is mostly electric; bus transit (electric, or bio-gas powered); electric cars;
- For plug-in electro-mobility loading stations are necessary, which need provisions from the city and power grid.
- Required opportunities to store electricity in batteries and help balance demand and variable renewable energy supply.

Other clean energy technologies:
- Blended fuel (ethanol/gasoline);
- Biogas, bio-gasoline, and biodiesel, provided that the delivery chain and life cycle is low-carbon (and not competing against food and fodder production); intermediate technology is natural gas; and
- Low-carbon fuels from coal (coal to liquid or gas); and
- Fuel cell or hydrogen technology.

5. **Urban infrastructure services**: water management, waste water and municipal waste, street lighting

**Characteristics:**
- services as energy users: water pumping, distribution networks;  
- services as energy producers: waste water treatment gas, used for internal purposes or for external users (residential users, transport).

**Clean energy:**
- bioenergy from waste water in treatment plants; biogas used as such or transformed to electricity in situ;  
- municipal solid waste: heat and power from incinerators;  
- landfill gas capture; and  
- small solar applications in lighting of streets, parking areas, parking meters.

6. **Energy utilities and central energy transformation**

**Characteristics:**
- Highly concentrated punctiform energy transformation;  
- Point sources of emissions, important for local emissions, but not important for carbon emissions;  
- Cogeneration of heat products or cooling.

**Clean energy technologies:**
- Centralised and connected to distribution grids through middle or high voltage lines;  
- Cogeneration (poly-generation): combined heat and power (CHP) or combined heat, cold and power (CCHP);  
- In case of bioenergy fired utilities, or biomass co-firing to fossil fuel, natural gas is preferable. Note: bioenergy is storable, transportable;  
- Concentrated solar power technologies, in particular parabolic through thermal technology providing heat and power;  
- Hydropower or geothermal as non-variable renewable energy options for power depending on resources availability in or near the urban area;  
- Onshore wind energy;  
- Offshore wind energy;  
- Tidal, wave and ocean energy for coastal cities: variable renewable energy options depending on resources availability in the respective city;  
- Solar photovoltaic in central solar parks;  
- Natural gas, blended with biogas;  
- Future applications of power-to-heat, power-to-gas, to make use of surplus renewable energy power during low load; use of central power storage facilities. Synchronisation of demand and renewable energy supply may lead to power-to-heat or power-to-gas options.
1.2 Role of municipality and other stakeholders, policy options and financing

Stakeholders and urban clean energy project organisation
The concrete configuration of the urban energy systems are the result of a myriad of past decisions by many actors in each case. In order to redirect and implement the development towards a future sustainable low-carbon system several groups of stakeholders must interact.

The stakeholders groups are characterised by different levels of ability of decision making and different responsibilities. The distinction between private and public organizations is of highest importance, particularly with regard to social and economic responsibility:

- The political leadership, legislators and administration of the respective authority: depending on the location include regional, metropolitan, municipal or lower district authorities; or departments of public administration, i.e. environmental, energy, urban planning, housing, infrastructure, public spaces, etc.
- Funding and information agencies: public funding organizations and energy agencies, maintained entirely or partly by national, state/provincial or local governments. These organisations usually work with the local authorities.
- Energy supply, including energy service organisations (ESCO) and energy management companies: these may be municipal, private and mixed ownership companies; usually, the municipal owned utilities are more directly controlled by the public authorities.
- Water and waste management, transport organisations: public or private companies.
- End users and auto-producers, and associations: industry, commerce, residential; owners, tenants, employees, and facility managers.
- Developers and building owners: housing companies, social housing associations, other private or public developers.
- Design and consultancy: urban planning (and architectural) firms, transport engineering companies, technical consultancy firms, or universities, usually contracted to contribute their subject matter expertise.

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Institutions, organizational structure, process organization and participation mechanisms
A deliberate effort to develop and implement a clean energy concept requires a specific project organisation, led by the authority and involving the stakeholders concerned.

For the institution concept there are numerous options. Energy operators can be created with their own legal status and rules, own budget governance, and a formalised participation of stakeholders and hired management. Alternatively there can be temporary project organisations (non-institutionalised), with a professional project management and voluntary participation of stakeholders (non-formalised).

Organisational structures may include governing board, steering council, consultation groups, project management, technical support structures, and contracted consultants.

In the process, classic steps and specific mechanisms include:
- Preparation and decision making phase: objective setting, strategy formulation, establishment of targets, definition of delivery trajectory and tasks and operational mechanisms, business plan formulation, guidelines for safeguards, mechanisms for stakeholder and customer consultations;
- Implementation phase: concrete projects need their own organisations, possibly a public-private partnership body; tendering and award of concession to an existing or new organisation;
- Monitoring and supervision: review of performance, and continuous improvements and adjustments where necessary;\(^\text{12}\) and
- Information sharing: Internal training, external training and dissemination.

Financing of project preparation and implementation by projects
In the context of EU cities, comprehensive energy concepts are usually financed by city budgets, with possible contributions from regional and national programs. However, there is scope for participation from utilities and the energy industry in general. Within the sector there exist many public-private participation modalities. In the case of integrated land development projects, new districts or neighbourhoods, creation of energy utilities can be achieved through mixed financing, for instance through private investors with vested interest in a specific area development. The provision of public infrastructure can be supplied by the utility companies. Private developers may prefinance municipal facilities, as well as commercial and housing investments.

Public Private Partnerships for Renewable Energy Investments
Historically, PPP programs and frameworks have been focused on projects of national importance, which are politically riveting as well as, oftentimes, costly – involving central government agencies to assume liabilities or giving guarantees.

By comparison, PPPs at the municipal level tend to be less splashy, smaller projects that quietly improve citizens’ daily lives: better street lighting, improved parking, clean markets, and bus shelters that keep commuters out of the rain. While these projects may not capture national attention, they are worthwhile infrastructure.

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\(^\text{12}\) For environmental monitoring, real time (GIS supported) data disclosure is going to be utilized in future for public data sharing (i.e. citizens’ information) like in air quality data. This is expected to also be extended to other environmental sectors like the water sector (for instance water bodies, rivers, lakes etc.) and waste water management.
• **Street lighting** energy-saving agreements that give the private partner a share of savings on a municipality’s energy bill for street lighting in return for improved and well maintained street lighting.

• **Car parks and on-street parking schemes**, where a provider is given a share of revenues in return for building and maintaining the car park on municipal lands and operating fare collection.

• **Solar panels** on local or state government buildings that allow the developer to generate and sell power to a government off-taker or into the grid with some benefit to the government agency. These projects need careful crafting as there are often a number of public agencies involved, including state or even national-level utilities.

• **Bus stations** where the developer follows municipal specifications for layout as well as developing space for other commercial revenue-generating activities.


### 1.3 Competence and Policy Options

Energy policy is widely considered a national responsibility and competence, but cities do have many options to influence energy development in their sphere of authority, within the national framework and the competences of provinces or regions. Depending on the status and role of cities in different countries, cities wield varying influence over their energy systems.

**Policy mechanisms.**

The policy mechanisms available to cities may be categorized as follows:

**Target setting**

- Regulatory schemes, including spatial and urban planning, contractual agreements, building regulation, standards and labeling, organization of local markets; including penalties;
- Incentive schemes, in particular financial incentives such as tax reductions, tax credit, soft loans, capital investment support, or operating grants and subsidies, feed-in tariffs; but also other incentives; cities may be intermediates for investment financing, including guarantees;
- Rules that affect use and operation of clean energy equipment, including municipal assets, such as low-carbon buildings, decentralized facilities for clean energy generation, or a low-carbon vehicle fleet;
- Voluntary actions by agencies and government serving as a role model, promoter and / or facilitator of innovations; and
- Capacity development including awareness building, knowledge and information sharing, capacity building, training, awards, and demonstration projects.


**Policy objectives**

Quality of life objective. In view of the pervasiveness of energy services, use and transformation in all productive and consumptive activities, even leisure, energy development objectives relate closely to general urban development goals, in particular in the longer term. On the vision level, objectives like quality of life, attractiveness, and economic competitiveness,
quality of the environment, healthiness, and even social cohesion are set to frame the city’s future energy system into the overall vision for the respective city. More generally formulated, sustainable energy development is seen as a part of economic, environmental, social and even political sustainability of the city.

Low-carbon development as objective. Although carbon emissions are not felt on the local level, cities all over the world have embraced low-carbon as a long term objective, with strong implications for the energy system. Cities do so being committed and wanting to lead in taking on responsibilities in climate change mitigation, in view of the concentration of energy transactions and emissions caused by urban activities. In addition, low-carbon associates well with other urban development objectives. Carbon emissions correlate to locally felt air emissions such as SO$_2$, NO$_x$ and particles. Although there are specific means to reduce each of these, the general principle is, that reduction of GHG emissions (i) can only be achieved through systemic change; and (ii) brings reduction of other emissions as well, even noise emissions. Additionally, carbon capture and the reduction of carbon in the atmosphere can be done through CO$_2$ photosynthesis of the flora. Thus, the global objective of maintaining carbon concentration below certain limits associates well with maintaining green areas for quality of life and also for biodiversity in cities. Also ‘greenness’ bodes well with modernity, new technologies, high tech, and lifestyle. Finally, low-carbon constitutes a quite operational objective, since it can be measured by a scientific indicator (GHG emissions), it can be scaled over time, even attributed to sectors of sources or causes (i.e. energy services) which can be provided with value chains, i.e. energy technologies and sources of extremely different carbon intensity.

Energy efficiency as cross-cutting dimension. Instead or in addition to the low-carbon objective, cities choose energy efficiency, low energy intensity, low or zero fossil energy use, and certain renewable energy objectives. These objectives are generally in line with the low-carbon idea and correspond similarly to other objectives, in particular local atmospheric emissions. These objectives, however, do not need a justification from the angle of global climate change mitigation, but may be justified by the developmental interests of cities.

Classic objectives in the energy sector remain permanently important and include the two groups:

- availability, sufficiency and security of energy supply; and
- Cost efficiency, price of energy, competitiveness, energy budgets and affordability which are economic and financial concerns depending on the standpoint (overall energy system; city administration concerns; interests of industrial, commercial or residential users).

Need to balance objectives. Cities must not lose sight of these objectives and solve potential conflicts with other ambitious objectives within their strategy and in cooperation with concerned stakeholders. Thus, these aspects may be considered more like boundary conditions to be observed rather than objectives.

Cost of energy. With respect to the economic and financial implications, it is important to note, that the price of the energy commodity (electricity, gas or oil products) is not any more as important, when energy services are provided at very low energy input. The cost of the respective energy service is increasingly determined by capital cost, when highly efficient, renewable or other distributed generation technologies are applied.

Decentralized systems. These new more decentralized clean energy systems require a more qualified local workforce and intelligence in construction, engineering and operations. Therefore, qualified local job creation and business development become objectives in energy concepts. In addition, smarter management systems require higher education levels.

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innovation and research, and therefore, could influence curricular changes in local capacity building and research institutions.

Developing and implementing a clean energy concept strengthens local energy institutions, and improves the quality of municipal services, both short and medium term objectives.

1.4 Spatial and temporal resolution of urban energy concepts

Changing urban energy concepts. Obviously, changing the energy system and exploiting the clean energy potentials in a city needs time, in particular in an existing built environment, due to the technologies locked-in the capital stock of infrastructure, buildings, and industrial and power plants. Even when implemented in a smaller new greenfield development, the full implementation takes as long as new quarter is completed and the clean energy system operates. The transformation of the energy system of a whole city to clean energy is a matter of decades. ⇒Tool CE 1

Planning for clean energy. Correspondingly, planning horizons for a clean energy concept are set: Very long term, i.e. three to four decades for the completion of transformation of a complex city, medium term, i.e. approximately one decade for a greenfield or rehabilitation area within a district. Since a clean energy concept for a whole city also consists of many clean energy concepts within, a comprehensive city concept requires also medium and shorter term intermediate planning terms. The intermediate terms and milestones are also important to define, they need to be monitored to measure the overall progress. ⇒Tool CE 1

Establishing city-level energy objectives. Cities formulate vision-type objectives for the very long term, with measurable indicators. The vision is the end point of the strategy and provides an orientation for the urban development as a whole and includes clean energy prominently, if low-carbon is determined as a key element of a city’s vision. ⇒Tool CE 1

Tangible targets. The objectives for the shorter term are much more concrete and tangible. In part, they are milestones on the path to the longer term vision, but they also are subdivisions described quantitatively with indicators and add up logically to the milestone at a determined point in time. To a large extent, they include concrete objectives for focal areas of the city and specific projects. ⇒Tool CE 1

The objective system is embedded in a strategy, which again is more concrete for the shorter term.

1.5 Information and decision support

Analysis, forecasts and modeling

Situational analysis. A clean energy concept obviously needs a baseline study, an inventory of the situation, level of use, mix of energy sources, and the respective carbon emissions. The energy statistic of the city, if existing, would be a starting point. This top down view should be shored up by a bottom-up approach starting from service demand and patterns of use by sectors - buildings (residential, commercial, public), transport, and industry. An analysis should be performed which relates it to the driving factors such as population, income, economic structure, energy prices, urban form, built environment, climate conditions, and the availability of supply. Additionally important is a description, analysis, and diagnosis of the
energy sector itself and other utilities. Developing a profile and understanding the composite parts are the initial steps of sustainable urban energy planning.\textsuperscript{15}

Vision formulation. The long term clean energy vision needs forecasting, in order to check feasibility, at least a general scenario forecast. This can be based on the abovementioned analysis of the existing system, the driving factors and trends in particular long term urban development. Between these two poles (baseline study and long term vision) and in terms of specificity, there are many options for the information and decision support from planning, again depending on the scope and time horizon of the energy concept.

Energy concept. A concrete greenfield or rehabilitation project obviously needs a concrete energy concept, exploring clean energy alternatives early on in the planning process (pre-feasibility level), and when project becomes concrete (feasibility study level).

A longer term energy concept for a complex area like a city needs alternative scenarios, taking into account potential different developments in the external factors. Once a robust vision is formulated, the forecasted situation, say for 2050, can be backcasted through intermediate steps to the actual situation. Thus a set of key indicators can be defined over time from the baseline to the vision. For the short and medium term concrete planning is appropriate.

Short-term plan. For short and medium term concrete planning, modeling is applied, modeling the objects within the area.\textsuperscript{16}

Planning and respective modeling should be geo-referenced at least for those parts of the system, where local density of demand and local availability of energy sources play a role in the clean energy design, and when the conducting of the potential energy sources involves significant cost. These two factors, density and distance are cost factors, and important in particular for financial and economic analysis, and optimization.

Localisation of information is also important for other criteria, in particular local emissions, and transport issues also need localized (i.e. geo-referenced) considerations. Thus, already plain information and in particular simulation of urban development and choices in clean energy and transport and other are greatly enhanced by geo-referenced data.

Demand analysis. Therefore, it has become common to model the urban heating energy systems including the demand for the heating services, the current heating and energy supply systems. Modeling is used to project future demand based on the urban development plans. It takes into account changes in building technology, supply options, cost, emissions and other parameters. These maps have various levels of resolution: by apartment unit, building, block, or neighborhood, depending on the questions to be answered.

Efficiency for decentralized systems. Recent technology and cost developments in decentralized electricity generation, in particular from renewable energy, modified electricity demand patterns. Efficient applications, heat pumps, cooling systems, and the use of information and communication technology have led to radical changes in the configuration of low voltage electricity systems. This does affect also the higher voltage systems, in particular, where clean energy generation technologies feed into the medium voltage grid. These developments may make it worthwhile, to also create geo-referenced planning of the urban electricity system. This should be far more detailed than the usual electricity grid planning, which assumed a demand profile on the level of the distribution substation. In the future, with renewable energy feed-in, storage and other flexibility technologies, changes of the demand patterns at the end-user level will stimulate the creation of mini grids and smart grid technology. The local electricity system will become more important. Thus, a geo-referenced energy plan, on a resolution level of utility clients (or addresses) may become useful for the management


of a low voltage electricity system in the city. In view of the many interlinkages of the electricity with the heating and cooling system, geo-referenced hybrid or comprehensive energy plans are becoming relevant. \textit{Tool CE 1, Tool CE 2}

Mapping supply of heating energy. In the heating energy maps, industry and power plants figure rather as sources of heat supply.

Transport-related needs. Transport planning is considered in heating and cooling energy, and in electricity planning since roads are the main arteries for the heat, cold, gas and electricity conducts. When local emissions (CO\textsubscript{2}, NOx and particulates) are a main concern, geo-referenced emissions cadastres from traffic as well as from stationary sources (all kinds of combustion boilers or engines) are key information, and provide instruments for decision making, jointly with emission data at various points in the city.

**Modeling Tools and Software**

**Planning at different levels.** For urban energy planning, information and decision support many computational data processing tools and specific software have been developed. These may be applied for a building, for a defined area (high demand density), for an administrative district, or the whole city.

For large projects, custom-made models are designed and run by the research institutes or engineering consultants involved. In developing these models, standard software is applied.

The varying features of the tools include data and information of various disciplines: engineering, energy flow, and energy potential, economic, environmental and other data. The functional features of the tools may be information, interactive, simulation, or optimization. Optimization may operate according to one-dimensional objectives, e.g. minimal cost, under boundary conditions (e.g. a ceiling of carbon emissions), or allow multi-objective optimization.

**Optimisation.** Optimisation models deliver a description of the energy system integrating its technical, economic and environmental aspects. Usually both demand and supply side descriptions are included in the models. The resulting equilibrium system is then optimised towards a target function using mathematical approaches such as linear programming. Often the total costs of the system are used in objective function. Considering the technical description, optimisation models are usually designed as bottom-up approaches using detailed descriptions of technical components of the system.

In order to draw a realistic picture of the energy system, optimisation models include a number of additional or boundary conditions such as the availability of technologies. The definition of the boundary is of vital importance for the relevance of the modelling results, as is their documentation to the transparency of the overall modelling process.

**Simulation.** Simulation models usually apply a bottom-up approach to describe the energy system by adding single processes to process chains or networks. While optimisation models tend to focus on the cost function, simulation models are often applied to quantify the technical or techno-economic potential for energy savings or emission reductions. In the detailed description of simulation models expert knowledge replaces the mechanistic approach pursued by optimisation models. Technical measures can be discussed on a detailed level. In both cases, simulation as well as optimisation models, the quality and transparent documentation of the expert knowledge as the equivalent of the bounds can prove to be a main factor determining the model’s quality.

Depending on the questions and tasks, geo-referenced or summarizing tools may be applied. In large projects, different models and tools are combined, depending on the tasks and the scale of assessment. Detailed building simulation tools are used with other models representing the wider context in the assessment.
Summarizing or top down information does not need specific modelling, but may be done using standard software such as excel. Some excel based tools have been developed, which offer a user interface which allows simple simulations of main factors in a city in order to calculate overall impacts of variations on key indicators, e.g. for GHG emissions.
2. DEVELOPMENT OBJECTIVES

From vision to action. As discussed above, on the long term urban vision level, long term objectives like quality of life, attractiveness, economic competitiveness, quality of the environment, healthiness, even social cohesion are relevant to set a city’s energy framework.

Acting locally – for global impact. Although carbon emissions are not felt on the local level, cities all over the world have embraced low-carbon as a long term objective, for its own importance but also for its correspondence to many other objectives and for its practical operationally. Instead or in addition to the low-carbon objective, cities choose energy efficiency, low energy intensity, low or zero fossil energy use, and high renewable energy objectives. For the medium term, i.e. a decade or more, the low-carbon and energy intensity, renewable energy share objectives can be scaled as milestones.

Medium-term goals are more ambitious. More concrete, mid-term objectives may relate to the completion of specific clean energy area projects, renewable energy demonstration objects, implementation of clean energy in key or high profile urban projects, distributed generation and mini-grids, integration of clean energy in smart city concepts, network of electric car charging stations and similar smart technologies. Whether these are new greenfield or rehabilitation projects depends on the priorities of the respective city. In the medium-term, energy goals also affect job creation and business development.

Germany publishes 30-year climate change strategy

The final version of the German Environment Ministry’s Climate Action Plan has been published.  

However, “environmental organisations have responded to a government proposal to decarbonise the economy with outrage. They say the Climate Action Plan 2050 will fall well short of meeting climate targets, and accuse the environment ministry of caving in to pressure from the economics ministry and Angela Merkel’s Chancellery to water down ambitious plans and drop important details, like a deadline for the coal exit. But concrete targets included in previous drafts have been removed, prompting the Green Party to describe the document as an “admission of government failure”. The Climate Action Plan was announced at the Paris Climate Summit as a framework for how Germany was to reach its goal of cutting greenhouse gas emissions by 80 to 95 percent by 2050.

Germany is already struggling to meet its 2020 climate targets, and is under additional pressure after Chancellor Angela Merkel repeatedly said she would make climate policy a priority of Germany’s G20 presidency next year.

The environment ministry’s final version of the plan is still to be coordinated with other ministries. But critics say it had already been watered down under pressure from Sigmar Gabriel’s Ministry for Economic Affairs and Energy, which insisted on the omission of a date for the coal exit.

Environment minister Barbara Hendricks said Merkel’s Chancellery asked for further changes to the plan. “I have accepted these amendments to avoid further delays to the necessary discussions within the federal government,” Hendricks said in a statement posted on the ministry’s website. But the Green Party and environmental organisations said the Climate Action Plan has lost all power as a blueprint for decarbonising Germany.”

Source: Germany publishes 30-year climate change strategy. factorco2.com. 09 September 2016.

**Short-term plans are the “lower-hanging fruits”**. In the shorter term, say in 3 to 5 years the targets within a comprehensive long term projects may be related to laying the groundwork and have the strategy ready, and start the first implementation steps.

In addition the clean energy concept may have reached a number of concrete agreements with developers, industry and energy sector stakeholders on projects, including whole areas, new plants, plant closure, fuel switching, interconnections and use of waste heat, etc. As energy efficiency targets or compacts are established in the short term, and supply contracts are adjusted, short-term green energy supply targets are included. Low hanging fruits, i.e. actions and projects which are identified in the analysis as quick wins, are already harvested.

**How To Accelerate Energy Efficiency**

![Diagram showing how to accelerate energy efficiency](chart.png)
The latest United Nations report on energy-efficiency technologies\(^{20}\) shows that low-carbon technologies apparently aid clean air, save water and cut land use, and could reduce 25 billion tonnes of greenhouse gas emissions and 17 million tonnes of particulates a year. "We are on the right track. We know that cleaning up the air we breathe gives rise to huge benefits to both human and environmental health, and we know, too, that low-carbon energy efficiency technologies can help us reduce damaging climate change". \(^{21}\)


3. KEY ISSUES --- KEY CONCEPTS

<table>
<thead>
<tr>
<th>Key issues to be addressed</th>
<th>Key concepts recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attractiveness; quality of life</td>
<td>Energy services with low active energy input</td>
</tr>
<tr>
<td>Emissions and air quality</td>
<td>energy efficient building, appliances, transport and industrial technologies</td>
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<tr>
<td>Public health</td>
<td>Retrofitting</td>
</tr>
<tr>
<td>Climate change; carbon emissions;</td>
<td>Recycling of energy and materials</td>
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<tr>
<td>Sufficient energy</td>
<td>urban planning; integrated energy planning</td>
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<tr>
<td>Security of supply</td>
<td>Life cycle analysis</td>
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<tr>
<td>Cost efficiency; Price and affordability, energy poverty</td>
<td>Low-carbon energy, Renewable energy</td>
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<tr>
<td>competitiveness</td>
<td>Poly-generation (combined cold, heat and power-CCHP)</td>
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<tr>
<td>Technology &amp; innovation</td>
<td>waste energy</td>
</tr>
<tr>
<td>Capacity and job markets</td>
<td>distributed generation</td>
</tr>
<tr>
<td>Revitalisation and upgrade of urban districts</td>
<td>Local coalitions of users and producers (Mini-grids) = Prosumers</td>
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<tr>
<td>Connectivity</td>
<td>upstream grid integration; grid reconfiguration and Smart grids</td>
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<td>Regional low-carbon energy and flexibility markets</td>
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<td></td>
<td>Transport electrification</td>
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<td>Performance-based financial incentives</td>
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<td></td>
<td>Climate change mitigation</td>
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<td>International trading schemes</td>
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<td></td>
<td>GHG inventory</td>
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4. PERSPECTIVES FROM EUROPE

4.1 Sector Context and Policy Analysis

Importance of clean energy technologies

The growth of renewables. Wind, solar, biomass and other renewable energy technologies grow rapidly in the EU. According to European Energy Agency (EEA) approximate estimates, the EU-wide share of renewables in gross final energy consumption continued to increase from 14.1% in 2012 to 14.9% in 2013 from 8.5% in 2005. Overall statistics of the share of other clean energy technologies are not available. A rough calculation based on the percentage of CHP in power generation - approximately 12% and CHP derived heat (48 Million tons of oil equivalent -Mtoe) according to EUROSTAT would represent another 8% clean energy, which may be regarded as an estimate on the higher side. The total of clean energy technologies in the EU has been estimated at 20% in 2012.

50% of EU Residents Could Be Generating Their Own Renewable Energy by 2050

“A people-powered energy revolution—an era in which people can produce their own electricity—is possible, and could happen soon, according to a new report released Monday by the environmental group Friends of the Earth Europe (FOEE).

The report, “The Potential of Energy Citizens in the European Union”, finds that over half the residents of the EU could be generating their own renewable electricity by 2050. That's 264 million “energy citizens” meeting 45 percent of the region's energy demand through a democratized, citizen-owned system that allows people to be the operators of their own utilities—taking power away, in more ways than one, from a market monopolized by large corporations. "[People] have the power to revolutionize Europe's energy system, reclaiming power from big energy companies, and putting the planet first. We need to enshrine the right

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23 Kiss, C., Update on cogeneration in Europe, A view from the COGEN Europe National Associations; [http://www.endseurope.com/docs/130419a.pdf](http://www.endseurope.com/docs/130419a.pdf)

for people to produce their own renewable energy in European and national legislation,” Molly Walsh, FOEE community power campaigner, said. The report also found that overall, 83 percent of European households, whether individually or as part of a utility collective, have the potential to help create, store or help provide renewable energy.


**Dominance of the urban sector.** Most of the distributed generation, in particular when it involves cogeneration takes place in urban areas, whereas the bulk of energy production from renewable energy is situated outside cities. Hydro-power plants, which are still the most important contributors of RE in power generation, and other resource-dependent plants such as wind-parks and geothermal power stations, and area consuming solar parks are usually not situated within municipal boundaries. But all these may be taken into account in the cities’ sustainability goals since they contribute to their electricity supply. In Europe, decentralised solar PV on roof-top is up to now by far more important than ground mounted solar parks, which in terms of capacity and production remain below 50% even in some strong solar PV countries like Germany, Italy, Spain and UK.25 Roof-top PV generation is situated to a large part within urban areas, in particular those on commercial buildings. The residential roof-top systems are found massively on single family housing in low density urbanisations and villages.

**Growing importance of renewables.** Without the clean energy technologies, GHG emissions in the EU would be approximately 400 Mtoe, i.e. 10% higher. According to the recent European Environment Agency (EEA) report, RE have been important recent driving forces in reducing greenhouse gas emissions in Europe.26 Without the deployment of renewable energy since 2005, greenhouse gas emissions in 2012 could have been 7% higher than actual emissions. Thus, the recent surge of wind and solar energy in Europe has contributed massively to GHG reduction. Other more traditional clean energy technologies like bioenergy and CHP have also advanced, however less rapidly. ➔**Tool CE 1**

The main drivers for this shift to renewables are the increasing cost-competitiveness of renewable energy technologies and policies to implement other benefits such as improved energy security and decreased air pollution. Below graph27 shows the price development of Solar PV modules as one important factor.

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27Fraunhofer ISE; Aktuelle Fakten zur Photovoltaik, update 19.05.2015, www.pv-fakten.de
This has led to levelized unit costs of electricity (LCOE), calculated for utility scale PV systems in central and southern Europe at 5.4 and 8.4 ctEUR/kWh. Further cost reductions are expected to allow LCOE, in 2050, to range between 1.8 and 4.4 ctEUR2014/kWh, with locations in southern Spain at the lower end and southern Germany in the upper range.28 LCOE of roof mounted PV-systems, depending on the understructure, are clearly higher.

Framework conditions: RE targets and obligations

**Targets.** RE sources are expected to provide 20% of EU gross final energy consumption (GFEC) by 2020 and progress indicates that this objective will be achieved. In addition, other clean energy technologies will also grow, which means that a 30% clean energy target is achievable.

In the EU framework, member countries have agreed to overall RE targets for the power sector (20% in Gross Final Energy Consumption [GFEC]) by 2020 as part of the Renewable Energy Directive29. The countries do have individual targets agreed between them from 10% for Malta to 48% for Sweden, taking into account their status in 200530, the GEFC demand perspectives and the particular RE potentials and options. For the transport sector an overall minimum renewable energy (i.e. biofuel) share was set at 10%. Each country has submitted a National Renewable Energy Action Plan to the EU, explaining how they intend to reach their targets.31

**National policies.** The national policies vary between countries.32 All EU countries have some kind regulatory support policy for RE for the power sector, although distinct concepts, including

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30 Sweden and other countries including Austria exhibit high hydro-power shares already in the base-year.


32 For a detailed overview of RE support policies See REN 21 Global Status Report op.cit. in the above footnote.
• feed-in tariffs for electricity delivered to the grid, differentiated by technology and other criteria;
• obligations or quota for electricity suppliers, often combined with a tradable certificate scheme;
• tendering and bidding schemes or auctions, for individual sites or for defined quantities of electricity, differentiated by technologies; and
• net metering of electricity drawn from the grid, crediting surplus feed-in.

RE for heating and cooling energy. Some countries have started regulatory policies, i.e. obligations also for RE for heating and cooling energy. Scandinavian countries have a tradition of biomass use. Currently, the principle energy source for heating in Europe is natural gas, used in central building or apartment boilers, or for cooking. High efficiency boilers and heating systems are employed, and natural gas entails significantly less CO\textsubscript{2} emissions than coal or mineral oil products. This helps reducing the carbon footprint of a city. Nonetheless, natural gas fuelled systems are not considered clean energy systems. Transport fuel suppliers have blending obligations.\textsuperscript{33} Tool CE 1

Fiscal policies with EU countries. Within the EU there are also numerous fiscal support policies and public financing schemes. There is a decade long intensive exchange on policies and some convergence, but no harmonization of policies yet.

Cogeneration. With regard to poly- or cogeneration (Combined Cool, Heat and Power Generation [CCHP]), which constitutes is the second largest group of clean energy technologies, there are also various support policies in EU countries. Germany e.g. in pursuance of the fundamental energy transition (‘Energiewende’) provides a premium for power fed-in from cogeneration.

District heating. Due to the economies of density which are typical for the heating grids, district heating is traditionally an urban energy technology in winter cold regions. European cities have since long time used it in their energy strategy. Innovations and new circumstances make it even more versatile and important for cities’ low-carbon energy strategies. Cities in Scandinavian, eastern and central European countries including Germany have long standing district heating systems, some long distance and integrated grids, some only local, e.g. on block level. Simple heat generators have been replaced by heat from large CHP with external combustion and turbines increasingly from smaller plants driven by internal combustion engines, and waste heat from industry or others. Cooling grids are local, and connected block- or building level CCHP, or micro-plants. From the power sector point of view, cogeneration is considered to become the cornerstone for a low-carbon power sector (like the ones targeted e.g. in Denmark and Germany, which is principally supplied by RE technologies, but needs some technologies to balance the variable generation from fluctuating RE sources like wind and solar. Therefore, thermal storage will become more important in order to allow cogeneration plants running temporarily when thermal demand is low. Tool CE 1

Denmark’s first net-zero energy building - using VisBlue energy storage

Housing+ (BOLIG+ in Danish), an apartment building just outside Copenhagen, is Denmark’s first net-zero energy building. The owner is Realdania By & Byg and within the

\textsuperscript{33} See reference in the RE Directive.
building a VisBlue battery has been installed. In addition to being energy neutral, the building also produces electricity for the residents' use of electrical appliances such as mobile chargers, vacuum cleaner and lighting. The building consists of 10 apartments amassing approximately 1,200 square metres distributed across 4 storeys.

The project came about because Realdania wanted to tackle the challenge of building energy efficient housing. With Housing+, Realdania has managed to hit the actual zero in terms of energy in particular due to its partners, VisBlue being one of them. This means that the output from the building coming from the solar panels correlates with the electrical
consumption of the residents. The actual zero has only been reachable due to VisBlue’s Vanadium Redox Flow Battery. With the flow battery the output from the solar panels is doubled from 25 % to 50 % which means a great deal on the bottom line. Due to this doubling in output the residents will save around 10.000 DKK each year.

The sun doesn’t shine round-the-clock and therefore the output will differ throughout the day. Consequently, in order for the residents to have electrical power night and day the energy that is produced during the day has to be stored. In a Vanadium Redox Flow Battery, the electric power is stored in fluids in stead of solids. This means that the battery can be tailored and changed according to the needs of the housing. Furthermore, the battery has a life span of 28 years outliving the solar panels installed at Housing+. In addition to the economic benefits, the battery is also fire-resistant as well as environmentally friendly because most of the materials used for the battery can be reused when the 28 years have passed.


Obligations. Within EU, each country is required to carry out a comprehensive assessment of the national potential of cogeneration and district heating and cooling of all countries by December 2015, according to the Energy Efficiency Directive. 34 Hence, cogeneration is considered in the common framework of measures for the promotion of energy efficiency within the EU in order to ensure the achievement of the Union’s 2020 20 % headline target of energy efficiency. In terms of regulation, EU countries must ensure a cost-benefit analysis is conducted on the potential for using cogeneration when building or substantially refurbishing heat or electrical installations, industrial installations generating waste heat, or a district heating and cooling network. But in any case this regulation excludes small installations of 20 MW and below.

Since the 2015 Paris agreement on Climate Change (COP21), many cities have issued statements to pronounce ambitious targets to stop using coal altogether, or to become carbon-neutral. 35

However, the translation of political commitments into action is not always direct. A recent study tried to establish which of the EU countries would be most consequential in the implementation of their commitments. 36

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Source: https://cleantechnica.com/2017/04/12/european-union-countries-pursuing-policies-line-paris-climate-agreement/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+IM-cleantechnica+%28CleanTechnica%29
Helsinki: carbon neutral by 2050.

Helsinki has set itself a target of carbon neutrality by 2050. It plans to meet this predominantly through the supply of cleaner electricity and heating. Due to Helsinki’s cold climate, the share of total GHG emissions directly attributable to residential buildings currently stands at one megatonne, accounting for almost 42 percent of total emissions – considerably higher than in other European cities. The capital of Finland aims to become carbon-neutral by the middle of this century by switching to cleaner electricity and heating.


Other framework conditions and trends

EU emissions trading system. Another important framework for clean energy is the EU Emissions Trading System (EU ETS). Cities do not participate in the ETS. However, fossil power stations and industry within the cities are supposed to be penalized and clean energy favored by high carbon prices. The EU ETS is a cap-and-trade system for GHG emissions from power stations and industry, leading to a market for carbon and prices for Emission Allowances. It allows to a certain degree the use of Certified Emission Reductions (CER) from the Kyoto Protocol. The price for Emission Allowances (‘carbon price’) has fallen in the wake of the global economic crisis, which was not expected when the emission caps were calculated and allocated. Reforms of EU ETS are being discussed which target the reduction of allowances and the increase of carbon prices in order to make them sensitive to the cost of CO₂-intensive production.37

Effort Sharing Decision. Around 60% of the EU's total emissions come, however, from sectors outside the EU ETS. Under the so-called Effort Sharing Decision, member states have taken on binding annual targets for reducing their greenhouse gas emissions from these sectors, such as housing, agriculture, waste and transport by overall 10% by 2020 compared to 2005 levels,38 much of which is taking place in cities. The national emission reduction targets are differentiated according to EU member states’ relative wealth. They range from emissions reduction by the early member states (up to a 20% decrease in the richest) to some increase up to 20% by the by the least wealthy, mostly new member states.

Power and gas sectors’ institutional framework. The national power and gas sectors’ institutional framework and factual organization constitute another important set of condition for cities’ energy strategies. In most EU countries, the power sector is unbundled and vertically disintegrated: Power generation, transmission, distribution and retail are in principle separated

38 See for the effort sharing decision http://ec.europa.eu/clima/policies/effort/index_en.htm
and conducted by different entities. Generators, large users and retailers participate in wholesale markets, organized in form of energy exchanges. Also retail is organized to allow competition. Transmission and distribution are regulated. Similarly, the natural gas supply chain has been unbundled; in particular transmission cannot be controlled by large producers or large trading organizations. The details vary somewhat and not all countries have completed the reforms.  

**Important features of urban energy strategies.** For European cities’ energy strategies, the following features are important:

- Gas and power supply to customers is competitive: restrictions on customers from changing their supplier are removed from operation of networks (gas and electricity). Network operations are non-competitive and regulated, operators of these grids are obliged to allow third parties to have access to the infrastructure;
- Cities may participate in utilities but in a very different way than the old integrated patterns: city-owned utilities may run the distribution grids under regulation, based on long-term leases, and participate in retail supply of households, commercial and public customers. Cities may undertake these operations only in competition to alternative suppliers, which must have access to distributions lines. Cities’ utilities may run power stations and generations, also participate in generators outside frontiers, and participate in wholesale markets, etc. but again only in competition.
- Availability of different suppliers: Cities may buy ‘green’ electricity from external suppliers.

**Disruptive change of the power sectors in Europe.** Currently, due to distributed generation, fluctuating RE and smart grid developments, another disruptive change of the power sectors in Europe, which is very relevant to cities, is in the making. The RE and other feed from small producers or ‘posumers’ (which are consumers and producers at the same time) and potential local coalitions of mini and micro grids cause multidirectional electricity flows. New storage opportunity and distribution technologies may reduce the need to supply from higher voltage levels and allow different system network configurations. Proposals to create a regional market for specific energy services are on the table and may become very relevant in particular for cities, where these new forms of energy exchange (coalitions, mini grids, smart grids) are starting already (see examples below). Cities are expected to contribute, and are entitled to receive significant support which is financed by the EU.

**European urban energy programs and associations**

<table>
<thead>
<tr>
<th>Cities in 2050 – A European Vision</th>
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<tbody>
<tr>
<td>The city of the future is run by the energy subsidiary principle. In 2050, cities are highly energy efficient. The low energy demand (heating, cooling and electricity) will mainly be supplied by diverse local and regional renewable energy sources as well as co-generation. Smart grids will ensure decentralized solutions. New buildings do not consume fossil fuels; most of them produce electricity. They facilities to park soft mobility vehicles like bikes. They come with a user guide, which is obligatory when letting any kind of building. Older buildings are refurbished and do not exceed a consumption of 50 kWh/m²/year. Fuel poverty has dramatically decreased.</td>
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**EU CONCERTO and Smart Cities Information System.** CONCERTO is a European Commission initiative within the European Research Framework Programme (FP6 and FP7).  

39 The EU has played a pivotal role in the institutional reform of the power and gas sectors, because they are considered fundamental parts of the EU internal market. Following the first liberalisation directives adopted in 1996 (electricity) and 1998 (gas) and the second liberalisation directives adopted in 2003, the European Union has adopted the third Energy Package is a legislative package for an internal gas and electricity market in the European Union. It entered force on 3 September 2009. For an overview of the package and a reference to the five directives see https://ec.europa.eu/energy/en/topics/markets-and-consumers-market-legislation
It aimed to demonstrate that the energy-optimization of districts and communities as a whole is more cost-effective than optimizing each building individually, if all relevant stakeholders work together and integrate different energy-technologies in a smart way. The EU initiative under of the European Commission's Directorate General for Energy started in 2005 and has co-funded more than €175 Million in 58 cities and communities in 22 projects in 23 countries. Currently, CONCERTO is discontinued and its results and experiences will be documented in a user-friendly way in the Smart Cities Information System.40

**EU Smart Cities Initiative.** The smart cities initiative 2010 – 2020 has the objective to demonstrate the feasibility of rapidly progressing towards our energy and climate objectives at a local level while proving to citizens that their quality of life and local economies can be improved through investments in energy efficiency and reduction of carbon emissions. The initiative fosters the dissemination throughout Europe of the most efficient models and strategies to progress towards a low-carbon future, and builds on existing EU and national policies and programs, including CONCERTO and Intelligent Energy Europe.41

This Initiative will support cities and regions in taking ambitious and pioneering measures to progress by 2020 towards a 40% reduction of greenhouse gas emissions through sustainable use and production of energy. This will require systemic approaches and organizational innovation, encompassing energy efficiency, low-carbon technologies and the smart management of supply and demand. In particular, measures on buildings, local energy networks and transport are the main components of the Initiative.

**Energy Cities.** The network of ‘Energy Cities’ is the European Association of local authorities engaged in energy transition. It represents 1000 towns and cities in 30 countries. Its main objectives are (i) to strengthen the cities’ role and skills in the field of sustainable energy, (ii) to represent members’ interests and influence the policies and proposals made by EU institutions in the fields of energy, environmental protection and urban policy, and (iii) to develop and promote your initiatives through exchange of experiences, the transfer of know-how and the implementation of joint projects. Energy Cities is advocating decentralized energy production and a switch from the “big–scale infrastructure” perspective to one of “aggregating the small units” of energy producers.42

**The EU Covenant of Mayors.** This covenant is an initiative that created a community of local governments focused on climate protection, since the 2009 signature ceremony in Brussels, over two thousand local authorities have opted to join the Covenant. World-wide this has become a sort of movement propelled by the global climate change conferences, and the activities of the EU and International Coalition of Local Environmental Initiatives (ICLEI).43 An ever growing number of cities are preparing Sustainable Energy Action Plans (SEAPs).

Signatories of the Covenant of Mayors formally commit to achieve the ambitious targets set in the EU Climate Action and Energy Package. However, non-European cities may also join the covenant. The Climate and Energy Package aims to:

- Reduce EU greenhouse gas emissions by at least 20% from 1990 levels by 2020;

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40 The Smart City Information System will be visible in the concerto website. [www.concerto.eu](http://www.concerto.eu)
43 [http://www.covenantofmayors.eu/index_en.html](http://www.covenantofmayors.eu/index_en.html);
b. Increase the EU’s use of renewable energy to account 20% of total consumption; and
c. Reduce energy consumption by 20% through increased energy efficiency.

Upon signing the Covenant, local authorities commit themselves to submitting their Sustainable Energy Action Plans (SEAPs). Each SEAP lays forth in greater detail how each local government intends to reach its CO₂ targets by 2020.  

Signatories of the Covenant of Mayors

The European Energy Award. Since 1988 this award supports municipalities willing to contribute to sustainable energy policy and urban development through the rational use of energy and increased use of renewable energies. Members are 8 European Countries around Switzerland and some city and regional programs outside of these. There are more than 1,300 municipalities participating. At the European level, it is interlocked with other programs and activities, such as the Smart Cities Initiative and the Covenant of Mayors. The specific feature is the quality management and certification process. As per the end of 2014, 720 municipalities had been awarded the European Energy Award, 87 of which the European Energy Award in the ‘Gold’ category.

The Mexico City Pact. The Mexico City pact builds on existing regional action (e.g. Covenant of Mayors in Europe or the US Conference of Mayors Climate Protection Agreement) and the achievements of global advocacy through the International Coalition of Local Environmental Initiatives (ICLEI)’s Local Government Climate Roadmap. The Mexico City Pact goes even further through the introduction of the concept of globally measurable, reportable, and verifiable (MRV) local climate action. The Mexico City Pact was launched at the World Mayors Summit on Climate that was held in Mexico City on 21 November 2010.

The carbon Climate Registry (cCR). This registry is a global mechanism for cities and local government to make commitments to climate change. Article 4 of the Mexico City Pact envisages that signatories report their climate commitments, performance and actions through the carbon Cities Climate Registry. Developed by local governments for local governments, the cCR supports the global credibility of local climate action by ensuring transparency, accountability and comparability and presents the global response of local governments to climate change.

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46 for further information see  http://www.iclei.org/index.php?id=1197

47 To see the updated list of signatories and sign the Pact, please visit  www.mexicocitypact.org
measurable, reportable, verifiable climate action of cities, not only of Mexico City Pact Signatories.  

**Energy Agencies.** Energy agencies have been set up in many cities and regional governments. They serve an important role in introducing good energy management practices, promoting sustainability, providing quality information and guidance, and offering other services based on local needs. International co-operation, networking and peer learning among these actors is essential. Therefore an EU Energy Agencies Association was formed. ManagEnergy was established to enable local energy agencies to work together more effectively. The initiative provides a range of services for this purpose: directories and interactive maps, partner search facilities, information on successful projects, and regularly scheduled workshops.

### Innovative Funding Concepts

<table>
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<tr>
<th>Community-Funded Infrastructure Projects in the EU</th>
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<td>In the UK, Brixton Energy is a predominantly locally owned and managed London co-operative, that differs by including distant investors. They construct solar energy projects on state-owned housing blocks’ rooftops. To encourage investment from locals, i.e. the minimum contribution is £50. Return on investment is 6.11% derived from FIT’s, and indirectly from tax relief via SEIS. By contrast, Ecotricity places no emphasis on local installation or on the location of its shareholders. Their Eco-bond scheme allows an investor to contribute to mixed technology projects for a ROI of 6%. Typically the electricity generated feeds directly into the grid. Similar organizations have been emerging in recent times, suggesting that distant “crowd” funding may be an important trend.</td>
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In Germany, Citizen Energy Cooperatives (Bürgerenergiegenossenschaften) are a recent innovative idea to finance and operate energy supply and distribution networks locally. Such small-scale local networks are particularly suitable for decentralized supply systems in combination with smart grids, and they provide a strong incentive for the use of energy-efficient technologies, as the coincidence of investor and user in the same locality means that the additional investment can be offset with savings incurred on the investor. Around 600 energy cooperatives have been set up by the end of 2011. More recently, high-voltage lines in the German state of Schleswig-Holstein are crowdfunded to achieve higher acceptance in the communities affected by the overland lines, since they thus also receive a share in the profits.

### 4.2 Good practices

Several European capitals and large cities including Amsterdam, Berlin, Paris, London, Stockholm, Vienna have developed comprehensive energy concepts focused around clean energy and climate protection respectively. Many intermediate and smaller cities have followed suit. Far more than thousand European municipalities are members or participants of specific initiatives. The following selection of cases represents forerunners, salient features, and different climate zones, proceeding from North to South. The first group of cases includes comprehensive citywide concepts, which encompass clean energy jointly with building, transport and other sectors. The second group includes exemplary clean energy district and community projects, new areas as well as rehabilitation and revitalization of existing areas.

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49. cf. [http://www.managenergy.net/about](http://www.managenergy.net/about)
50. The Barcelona new energy plan PECQ document, see footnote below, gives a brief overview as benchmark, see page 46.
Case 1 Denmark: Three lessons for cities in Denmark’s clean-energy revolution

"Many of Denmark’s windmills are partially owned by individual investors in the community, which helps to fund projects while tempering opposition.

To find the world’s most aggressive clean energy targets, look no further than Denmark. The city of Copenhagen is working hard toward meeting a pledge to become carbon-neutral by 2025. A much smaller municipality near the German border, Sønderborg, wants to do the same by 2029.

The targets are not onerous national mandates imposed on unwilling local governments. Instead, in a mutually reinforcing cycle, robust action by municipalities to cut carbon and add clean energy to the grid begets ever-more ambitious policy at the national level. By 2020, at least half of Denmark’s electricity will be supplied by wind turbines. By 2050, the country intends to be free of fossil fuels... There is much city leaders across the globe can learn from Denmark, both in terms of novel clean-energy solutions as well as the creative thinking behind them. Here, distilled from the book, are three lessons Denmark has for cities around the world.

1. Unleash the creativity of public-sector entrepreneurs

Some of the most creative capitalists I’ve ever met work for Danish municipalities. Take Billund Vand, for example. Billund Vand is a local water services company owned by the municipality of Billund. For the past 16 years, the company has steadily improved its ability to make use of a renewable resource — wastewater — viewed nearly everywhere else as a problem to be managed. In particular, Billund Vand uses something called a bio-digester to turn wastewater and other organic material into fertilizer, heat and electricity.

There was a hurdle, however: Danish law does not allow drinking water or wastewater treatment providers to earn a profit in the delivery of those services. So Billund Vand spun off a second company called Billund Energy. The spin-off can make a profit selling surplus electricity, and by providing consulting services to municipalities in Denmark and beyond. The model is a win-win: Clean power is delivered to the electrical grid and customers enjoy rates that are 50 percent lower than elsewhere in Denmark.

The Billund BioRefinery near Grindsted, Denmark, turns wastewater into electricity.
Another example of public-sector entrepreneurship comes from the village of Dronninglund. Like most of Denmark’s cities and towns, Dronninglund has a “district heating” system — buildings get their heat from hot water or steam pumped through a vast network of insulated pipes. In Dronninglund, members of the local heating co-operative voted to establish what was until recently Denmark’s largest solar district heating plant.

Previously, Dronninglund relied heavily on natural gas to heat the water in its district heating system. Now, 40 percent of the energy comes from the sun, avoiding Denmark’s high taxes on fossil fuels. This works best during the summer months when the Nordic sun is strongest, but Dronninglund went a step further to extend the solar plant’s usefulness late into the year. Water heated by the sun is pumped into a retired gravel quarry lined with plastic. The water from this storage pit can be used to heat homes and businesses well into the fall and early winter. Customers are saving hundreds of euros annually on their heating bills while simultaneously slashing the village’s carbon footprint.

2. Reap the efficiencies of district energy

District heating systems like the one in Dronninglund are an indispensable element of Denmark’s energy transition. Almost two-thirds of Danish households are connected to such systems; in Copenhagen, the world’s largest district heating network serves 98 percent of the city’s buildings. Copenhagen also has launched a district cooling system that draws cool water from the city’s harbor to pre-chill water destined for buildings with large cooling loads. The city estimates district cooling reduces electricity consumption by 80 percent compared to conventional air-conditioning.

Denmark’s decision many years ago to deploy these kinds of shared heating systems represents an advantage. District systems are more efficient than the more common model of having every residence or business provide its own heat. District systems like Denmark’s are common in a handful of European countries, including Sweden and Finland. In the United States, district energy systems are often used to heat and cool college campuses.

Insulated pipes below Copenhagen provide heat to 98 percent of the city’s buildings.
Growing cities can replicate Denmark’s model by planning for district-heating systems in new neighborhoods. This is something Vancouver is doing, as Citiscope reported in 2014. Making such systems solar powered — like the one in Dronninglund — represents an exciting new frontier. Dozens more solar systems have been installed or are in the works across Denmark. Neighboring Germany, hungry for low-carbon heating solutions, is a likely market for the technology. And if solar-powered systems can thrive in cloudy Denmark, there’s no reason the sun’s power can’t be deployed elsewhere.

3. Give citizens a financial stake in clean energy

From the earliest days of Denmark’s energy transition, policymakers understood the importance of giving citizens a stake in clean energy projects.

A grant program launched by the Danish government in the early 1980s covered 30 percent of the initial capital cost of wind turbines. It was early days for the wind industry then; even with the grant, turbines were still quite expensive. So local cooperatives formed, giving individuals and households a chance to invest in wind energy projects.

By 1996, more than 2,000 such cooperatives had formed. Within five years, the cooperatives’ 100,000 investors were responsible for 86 percent of the turbines installed in Denmark. Investors in the Middelgrunden wind farm, which sits just offshore in shallow water of Copenhagen Harbor, were able to buy shares in 1,000 kilowatt-hour increments. After more than 10 years, not only do investors have their money back, they also receive a 7-percent annual return on their investment.
In Dronninglund, solar-heated water is stored in an insulated pit to use for heat later

Source: Justin Gerdes.

A program launched by the Danish government in 2011 built upon this legacy by requiring developers of most onshore and offshore wind projects to offer nearby residents shares worth 20 percent of the total project. Developers are not permitted to earn a profit on these community shares, which must be offered at cost. These shares must first be offered to permanent residents age 18 or older living within 4.5 kilometers (about 3 miles) of the project site. As Søren Thorpstrup Laursen, an engineer with HOFOR (formerly Copenhagen Energy) [informed], the rules are intended both to promote new wind projects while also tempering local opposition to proposed projects by turning neighbors into investors. In Sønderborg, as in Copenhagen, the push to go carbon-neutral is inextricably linked to larger efforts to drive sustainable economic growth and add good-paying local jobs. “We’ve adopted a holistic approach that’s bottom-up,” says Christian Eriksen, project director for Project Zero A/S, the private firm charged with implementing clean energy plans in Sønderborg. “It’s not just top-down, about planning and coming up with business and new technology to drive this forward. It’s also very much about participation, about learning, and empowerment of our citizens and local companies.”

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Case 2 Germany: Germany Overhauls its Flagship Energy Policy

"Germany promises more renewables but big utilities take back control. …

The Krughütte Solar Park - a 29.1-megawatt (MW) photovoltaic power station in Eisleben, Germany.

Source: Image by Parabel GmbH

Germany is a world leader in renewable energy deployment. Driven by a long-term renewable energy policy that dates back decades and, more recently, a nuclear power phase-out, the country is spearheading a transition to renewables commonly known as the Energiewende (energy transition).

For many years, the policy instrument of choice was a feed-in tariff (FIT). It guaranteed a fixed payment for (in most cases) 20 years and priority grid access for renewables. The policy provided high investment certainty and triggered tremendous growth in renewable power generation capacity.

When the initial law was introduced in 1990, the role of renewables in Germany’s power mix was negligible. By 2015, renewable electricity made up 32% of consumption and had grown at speed exceeding all expectations. The government repeatedly had to upgrade its targets to keep up with renewables growth.
But a couple of weeks ago, the German government put forward plans to overhaul the Energiewende’s flagship policy. The planned reform of the Renewable Energy Sources Act includes a switch from feed-in tariffs to auctions.

Sigmar Gabriel, Energy Minister and party leader of the Social Democrats, hails the reform as a paradigm shift in the way renewables are funded: “More competition, continuous growth with effective steering, restrictions on costs, stakeholder diversity and dovetailing with grid expansion - these are the coordinates for the next phase of the energy transition.”

With the reform, the government reiterates previously set goals to increase the share of renewable electricity to 40-45% in 2025, to 55-60% in 2035 and to at least 80% by 2050.

But to keep a steady hand on the rise in renewable power, a “deployment corridor” will set limits on how much renewables capacity may be added per year. These limits are set per technology: For onshore wind, a gross amount of 2,800 megawatts is to be auctioned each year over the next three years (2017, 2018 and 2019), increasing thereafter.

For solar, 600 megawatts will be auctioned each year, and the overall corridor of 2,500 megawatts per year will remain (the remainder being built under FITs). For offshore wind, the overall target is 15,000 megawatts by 2030.

For biomass, 150 megawatts are annually up for auction in 2017, 2018 and 2019. Small renewables installations like rooftop solar will continue to receive feed-in tariffs (with small changes). The government believes this will ensure that citizen cooperatives and project developers remain active in operating small renewables plants.

These limits have been attacked for protecting old coal power plants at the expense of renewables. But the government argues it is making renewables deployment more predictable, thereby facilitating grid expansion and improving planning security for Germany’s neighbours and for the energy industry. After all, Chancellor Merkel promised the Energiewende must not destroy German utilities.
Critics argue that the government is putting the brakes on the Energiewende. Green campaigners see the limits for onshore wind power, the most cost-competitive renewable technology, as a sign that the government is trying to slow the rapid growth of renewables.

In light of past growth rates, the concern seems justified. Since 2010, Germany has increased the share of renewables in electricity demand by annually 3.1% on average. If this growth path continued, the country would reach more than 60% renewables by 2025. With the new proposal, however, the government wants to ensure that renewables growth does not exceed its 2025 target of 40% to 45%.

Anna Leidtreiter of the World Future Council expects these changes will fundamentally threaten Germany’s leadership position within energy and climate politics, but also lead to significant job losses and reduce business opportunities for entrepreneurs.

The switch from feed-in tariffs to auctions would weaken investment opportunities for small investors, energy cooperatives, farmers and enterprises, she says. “Citizens are essentially the backbone of the energy transition in Germany. Energy cooperatives alone have invested about 1.3 billion euros (9.5 billion yuan) in RE projects, thus generating revenues for communities, regions and citizens,” Leidtreiter argues.

Indeed, the Energiewende has democratised Germany’s power sector in the last few decades. Due to its inclusive design, the policy has enabled new stakeholders to enter the market. They have leveraged significant private investment over the past decade.

More than 800 energy cooperatives as well as private investors, farmers, banks and enterprises owned almost 90% of total installed renewables capacity at the end of 2012. In contrast, traditional utilities and energy suppliers invested very little and thus lost market shares.
Up to now, the Renewable Energy Act has been a tremendous success story. As the International Renewable Energy Association (IRENA) says, Germany has shown the world that such a high level of renewables can be integrated without systemic problems, thanks to strong grid infrastructure and cross-border exchange links.

But the Energiewende as we know it is at a crossroads. So far citizens, communities and new investors have been the biggest drivers for the energy transition. If the caps and the switch from feed-in tariffs to auctions are implemented, large corporations will dominate the market.

The reform would exclude many potential investors, including citizens, whose billions of euros would be welcomed to finance the transformation to a low-carbon economy. A recent analysis by the Climate Policy Initiative (CPI) concludes that more than 30 billion euros a year could be available for investment in the expansion of renewable energy capacity in Germany as long as the country shifts policy effectively to deal with the next phase of the energy transition and keeps investment open. These concerns are being discussed in Berlin. For international observers, it is important that broad sections of the country know that ownership matters in the energy sector.

The law is expected to be passed before the summer recess by the Bundestag (lower house) and the Bundesrat (upper house). It will be the government’s final major piece of energy legislation before the federal elections in 2017. The Energiewende will move forward. Whether or not the reform puts Germany on track to cut greenhouse gas emissions by 40% by 2020 in comparison to 1990 remains to be seen. Either way, slowing down renewables growth to protect old coal plants is not what the world expects from a global climate leader.
Germany’s next government will have to address the challenge of a coal phase-out and how to expand the Energiewende to the heat and transport sector.  

“Europe’s energy utilities have rung a death knell for coal, with a historic pledge that no new coal-fired plants will be built in the EU after 2020. The surprise announcement was made at a press conference in Brussels on Wednesday, 442 years after the continent’s first pit was sunk by Sir George Bruce of Carnock, in Scotland. National energy companies from every EU nation – except Poland and Greece – have signed up to the initiative, which will overhaul the bloc’s energy-generating future. A press release from Eurelectric, which represents 3,500 utilities with a combined value of over €200bn, reaffirmed a pledge to deliver on the Paris climate agreement, and vowed a moratorium on new investments in coal plants after 2020.”

Citywide comprehensive concepts

Case 3 Stockholm, Sweden: Energy Concept of Stockholm

The city of Stockholm is a leader in design and implementation of a comprehensive energy concept including all sectors including transport. The coordination of long term vision, long term strategy and shorter term targets and implementation are good practice examples.

Stockholm counts a population of 0.85 million in the municipality (2010) and 1.37 million in the urban area (2010). Stockholm is a coastal city and has relatively mild weather compared to other locations at similar latitude (59°20′N). Its climate could be classified as cold marine with significant continental influence. Heating degree days (18/15) are on average at approximately 4100 with short days in winter, but many sunshine hours in summer.

“Stockholm is taking decisive action against climate change. We aim to reduce greenhouse gas emissions to no more than 2.3 tCO₂ equivalent per citizen by 2020, and to become an entirely fossil free-city by 2040. Stockholm will not be able to meet these objectives on our own – and collaboration is at the center of our climate change strategy. The city’s own operations contribute just 10% of Stockholm’s overall emissions. Our climate strategy depends on us finding ways to work with the majority privately owned local energy supplier, and with our partners in regional government, with whom we share responsibility for public transport in the city and beyond. And our strategy depends upon us finding ways to work with hundreds of businesses across the city, helping them to reduce their own climate impacts, and to find opportunities for new low carbon products and services.”

The energy and climate related long-term vision is to achieve a fossil free Stockholm area based on energy saving and renewable energy in year 2050. District heating plays an important role to reach this goal. However, in order to make the region fossil free, transport is the biggest issue. The overall vision for 2050 is to be the “most attractive Metropolitan Region of Europe” and indicates the direction for the total planning and development work for the next 40 years in the region. Backcasting is used for planning milestones at two intermediate times: 2020 and 2030. The city has set an intermediate goal of maximum 3.0


t CO₂e GHG emissions per inhabitant by the end of 2015, down from 5.4 tCO₂e in 1990. The specifications are made in the Environment Programme 2012–2015. Stockholm is using the principle of conceivable measures for selecting programs.

“In 2007, we launched the Climate Pact, a collaborative network that offers a forum for networking, development and sharing expertise. It was set up to break down the sense of ‘them and us’ that divided private companies from the city authorities, and to find common cause in reducing carbon emissions. The pact is open to every company – big and small, environmental leaders and those looking to learn. With more than 200 members, it is not restricted to those who are already doing well – only to those who want to do better. It provides a way for companies to share experiences with each other. Unlike other business forums, it is cross-sectoral, allowing construction firms to learn from transport companies, and energy firms to talk to IT companies. It also helps us, within the city, to develop climate policies and programs in dialogue with business. We can talk to each other to bring forward proposals that work, and that have buy-in from those who will have to deliver them. [Stockholm is] now deepening collaboration with those companies who are ready to go further, with the launch of a vanguard group. These companies will serve as an inspiration to their peers and be stretched to be even more ambitious and to report their climate work. The most important lesson from the success of the Climate Pact for other cities around the world is that collaboration can start small, and costs little. Networks can be established at little expense, and can grow and evolve as their worth is proven, and as needs are identified. The first step in addressing the challenge of climate change lies in understanding the nature of the problem, and the challenges faced by all the parties involved. Then, in a spirit of dialogue and collaboration, we move forward to begin to tackle it.”

Stockholm: Potentials and costs for different blocks of measures prior to 2015


The interim target for 2015 required that:

- Building stock of Stockholm be made 5 per cent more energy efficient by 2015; Stockholm’s city administration aims to reduce the energy use in its own buildings by 50% before 2050;
- Emissions from traffic be reduced by 15 per cent; and

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The utility for heat and electricity, co-owned by the city has an extensive program for conversion and extension of the district heating system and electricity production, including new waste-fired and a large forest biomass CHP unit. In the long run, a coal fired CHP unit will be closed.

**Hammarby Sjöstad.** Good practice neighborhood projects in the Stockholm area include the Hammarby Sjöstad project for revitalization, recovery of this contaminated former industrial area. In total 11,000 apartments will be erected in about 500 buildings. The urban concept is to minimize car use by mixing housing and business, short distances to work, public traffic and car pools instead of privately owned cars. Commercial centres are also within the area. New for Stockholm is the public transport by means of a tramway. The environmental feature is reduced emission from energy and waste. At least half of the energy is directly or indirectly produced on-site (solar energy and biogas from recycled waste). The energy supply is primarily based on cogeneration and district heating.

**Järva.** Through the city-owned real estate company Svenska Bostäder, Stockholm is also renovating Järva. The "Sustainable Järva" project aims to reduce energy use by 50% in the suburb, with 10,000 square meters of rooftop solar panels being installed. Sustainable Järva also serves as a demonstration project to the many suburbs in the rest of Europe, where suburbs are demanding in terms of energy consumption and are also in urgent need of renovation.

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**Case 4 Växjö, Sweden: Fossil Free Växjö**

Växjö is situated on an inland, but has oceanic climate. Average annual heating degree days are around 4000. Växjö counts 61,000 inhabitants. The "Fossil Free Växjö" is a programme initiated by the city of Växjö to reduce human impact on global climate change. In 1996, the city council of Växjö unanimously decided that local emissions of greenhouse gases should be cut by half by 2010, compared with the 1993 levels, and that the municipality shall become fossil fuel free. Between 1993 and 2003 CO₂ emissions from fossil fuel were reduced by 24% per inhabitants and the share of renewable energy is now over 50%. The Fossil Free Växjö programme incorporates different types of activities, such as biomass-based district heating and power generation, small-scale district heating, district cooling, biomass boilers for households, energy efficient street lighting, energy efficient building design and construction, solar panels, cycle paths, environmentally friendly cars, biogas production, etc.

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IEA Subtask A
The dedicated political leadership was the most important starting point for the programme. All political parties have unanimously supported the targets set, and researchers, private sector companies, and local policy makers collaborated to achieve the common goals. The programme has strengthened regional competitiveness and provided multiple benefits. The town has provided an important example to other municipalities in Sweden and abroad.

Case 5 Aarhus, Denmark: the Climate Plant

Aarhus is situated in Denmark, northern Europe but still in the humid continental climate zone, influenced and unstable by the ocean. Therefore it experiences mild spring, warmer summer, rainy and windy autumn and cooler winter months. Aarhus has on average approximately 3200 heating degree days. Aarhus is the seat of the council of Aarhus municipality with 314,144 inhabitants and 249,709 (1 October 2011) in the inner urban area. According to Aarhus municipality, the "Greater Aarhus" area has a population of about 1.2 million people. In 2007 the City of Aarhus set the political goal to become CO2-neutral by 2030. This is the objective for Aarhus, as one of the six official "Eco-Cities" in Denmark. Plans have led to a deliberate and productive course for tackling climate change in Aarhus. The city has been working with climate issues for a number of years, by means of environmental action plans, energy management systems, wastewater plans, green accounts and environmental impact analysis of construction projects. Furthermore, Aarhus is one of the leading cities in Denmark when it comes to the district heating supply, public transport possibilities and extended cycle path system. The City of Aarhus has committed itself in 2009 in various agreements to:

- reduce its energy consumption by more than 20 % before 2020;
- reduce the annual electricity consumption of the municipal buildings with at least 2% per year; and
- reduce CO2 emissions by 2% each year until 2030.

The approach in the City of Aarhus is an implementation by phases, mainly following a forecasting approach (from input to output) from: (i) set the goal and the vision; (ii) analysis

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of the potential and definition of the climate target, with regards to the quantitative target and the time frame; and (iii) implementation. The climate plan for the City of Aarhus consists of several generations of climate plans reaching towards 2030. The plans have generally a 2-year perspective in order to guarantee progress, adjustment and evaluation. The climate plans are versatile, and their priorities’ embrace the municipal organization, the business community and educational institutions. Good practices and factors for success are:

- Detailed CO₂ mapping: the municipal survey (carried out in collaboration with consultants, their own technical department, experts, representatives from business associations, and other stakeholders) of the CO₂ emissions in the municipal area, by sector and type of activities (transport, industry, trade, public and private buildings. This formed the basis both for understanding the carbon impact of the activities, assessing the saving potential, making a list of priorities, planning investments and actions;
- Highly committed management in the Municipality;
- Political commitment at the highest level;
- Separate groups with the necessary expertise are established to prepare energy plans, e.g. the “heat plan”;
- Introduction of Climate Partnerships with other cities;
- Existence of well-developed climate friendly technologies and businesses on site (e.g. district heating and wind energy);
- Monitoring and updating of projects and Climate Plans; every second year there is a new accounting of the CO₂ and adjustment of the data.

The Climate Plans are made based on the feedback from the CO₂ balance and the assessment of the projects, the budget of the municipality, and the discussion with all stakeholders. The municipality ideally wants to be less and less involved in financing, while keeping the role of assistance/guide in creating “Climate Partnership” with the private citizens/businesses. However, whether those plans are really in line with the goal of being CO₂-neutral by 2030 is uncertain.

Aarhus is also home of one of the biggest biomass-fuelled Combined Heat and Power (CHP) stations in the world. The Studstrup plant [is burning] wood pellets instead of coal… , bringing green heating and electricity to city residents and businesses whilst reducing CO₂ emissions by 1 tonne per resident. … The recently completed conversion of Studstrup is the biggest single event in the entire green revolution for Aarhus. The switch from coal to wood pellets at Studstrup not only gives the biggest total CO₂ reduction in Aarhus to date, but is also the biggest conversion to green energy in Denmark. The Climate Plan 2016-2020 will set the city's next climate target, and within the heating area, the new biomass-fuelled CHP station at Lisbjerg will also come on line within the next few months with green heating. The City Council will thus bolster green district heating again, ensuring green supplies for many years to come, as the Studstrup plant will supply 50% of the green district heating annually, and the biomass-fuelled CHP will supply 20% on an annual basis.
An excellent example. Apart from the switch from coal to wood pellets now completed, the city's Department of Waste and Heating built two massive electric boilers at Studstrup 18 months ago. They can generate electricity to produce district heating when wind turbines are running at full capacity, and electricity prices are low. Studstrup is an excellent example of how we make maximum use of our resources to the benefit of the climate, and ensure competitive prices for the consumer. We will use water, solar power and biomass and get the various technologies to work together to complement each other in the best way possible … The conversion, costing around DKK 13 billion, makes Studstrup one of the biggest biomass-fuelled power stations in the world. It is expected to produce district heating in the future based on biomass for around 106,000 homes, with green electricity equivalent to the annual consumption of around 230,000 homes.63

Case 6 London, United Kingdom: Decentralised Energy Master Planning (DEMaP) Program

Situated in the temperate oceanic climate zone; Annual Heating degree days are below 2000. The administrative area of Greater London counts 8.2 million inhabitants. London has developed a concept for decentralized energy unlike Barcelona and Stockholm not in a long term comprehensive plan, but rather in a step by step approach, involving heating and power sectors.64 Good practice features are cooperation with developers and financing. In 2007, the Mayor of London set an ambitious target to supply a quarter of Greater London's energy from decentralised sources by 2025; this amounts to over 10 GWh/year from distributed generation for the electricity sector.65 To assist with this goal, the Decentralised Energy Master Planning (DEMaP) programme was introduced by the London Development Agency (LDA) in 2009. The LDA allocated nearly £5 million towards decentralized energy (DE) over four years from 2009, to build capacity and catalyse the development of DE, specifically CHP for district heating networks in London.

The DEMaP programme was developed to enable boroughs to identify opportunities for DE, and to develop the capacity to realize those opportunities. This was based on a trajectory of work packages, broken down into the three energy strategy phases, from initial capacity building through to feasibility study and project delivery. This was further supported by the publication of a free toolkit known as Decentralized Energy Networks Masterplanning Guidance (DENet)66 which allowed local authorities and other stakeholders to rapidly carry out pre-feasibility stage assessment on potential district heating schemes, so removing some uncertainty and risk from the process. Following on from the successes of the DEMaP programme, the Greater London Authority moved to support further strategic development, and actively support the delivery of more DE schemes within London, through the Decentralized Energy for London programme.67 This was set up in late 2011 with €3.3m in funding, 90% of which was secured from the European Local Energy Assistance (ELENA) facility of the European Investment Bank (EIB), to provide project sponsors, particularly London boroughs, with technical, financial and commercial assistance in developing and bringing DE projects to market. London has been home to district heating networks for a number of years, and the City of London, set to be joined by many more in the near future.


66 ARUP. http://www.arup.com/Projects/DENet

67 https://www.london.gov.uk/priorities/environment/climate-change/decentralised-energy
Growth in interconnections between some of these existing schemes is anticipated, along with the potential development of a number of high-capacity strategic networks, transporting industrial volumes of heat from power stations over long distances, which could allow for truly significant carbon savings. Existing schemes and those planned for future development are shown in the London “Vision Map” or the London Heat Map’s vision layer.68

The London Decentralised Energy Vision Map, London, United Kingdom

Source: ARUP, London

68 www.londonheatmap.org.uk
Case 7 Woking, United Kingdom: Renewable Energy at City Level

Woking has 68,000 inhabitants and is situated close to London, UK in the oceanic temperate climate zone. The Woking Borough Council is at the forefront of decentralized city energy supply in the United Kingdom. It has pioneered the development of network of over 60 local generators, including cogeneration and tri-generation plants, photovoltaic equipment and a fuel cell station. These facilities have been established to power, heat and cool municipal buildings, and social housing. The council has achieved this through the establishment of two energy and environmental services companies, the Thamesway Ltd. and the Thamesway Energy Ltd which are solely owned by the Woking Council. In order to fully capitalise on its energy innovations, the expertise of the private sector was required to implement larger projects. Thamesway Energy Ltd. developed a private power network, and since this was done privately, it was able to avoid charges normally associated with the use of the grid. By circumventing these costs, it has been able to fund wires and generation to deliver low emission electricity in competition with conventional suppliers. This privatisation and decentralisation has enabled the cost of energy to be cut by nearly half. CO₂ emissions have been reduced by a massive 77.6% since 1990. The key to success has been technical innovation, such as combined heat and power generation (CHP), absorption cooling, private wire systems, and the partnership with the private sector, financial and commercial innovations, and the use of local electricity balancing and trading.

Case 8 Tilburg, the Netherlands: Multi-Sector Network

Tilburg has 206,000 citizens, situated in temperate oceanic climate similar to almost all of the Netherlands, receiving 1600 sunshine hours and rather high humidity. Average annual heating degree days are around 2700. Following industry's decline in the 1960s, the city and surrounding area succeeded in the development of a hugely varied local economy. City officials realized in 2006 that actions to protect the city should be handled in a thorough and structural manner. The city aims at being CO₂ neutral in 2045, and at the same time adapting to the impacts of climate change. In order to reach these goals a multi-sector network was formed involving all relevant parties, initiated by the City Council, with involvement of other organizations. Tilburg is since one of the frontrunners in municipal climate policy in the Netherlands. The city plans to transform the existing district heating network fed by a fossil fuel CHP plant, into a network supplied by distributed low-carbon sources and supported by heat and cold storage. The graph below is a schematic diagram of the long term plan, in which the existing CHP plant in the Northwest will have a balancing function and also switch to renewable fuel.

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http://media.except.nl/media/uploaded_files/asset_files/Visiebrochure_doorontwikkeling_WNT_v12_web.pdf
District Heating vision Tilburg, The Netherlands

As other salient features, the city uses heat and cold storage in the ground in several places, based on an agreement with social housing corporations which are steadily implementing energy efficient renovation, and also has a modern public lighting policy. Along with these energy reforms, Tilburg has implemented a new way of governance and creation of a regional network organization, organically growing with a Climate Board as central midpoint. The Climate Board consists of a multi-sector network where climate alliances and consortia are established to initiate projects based on green deal agreements. An innovative approach for existing private owned houses is carried out through local private parties. The municipality takes part in the newly established consortium. Other energy saving achievements includes district heating, waste heat recovery, as well as bicycle lanes and routes throughout the city to encourage a reduction in car dependency. An important bottleneck is that big energy companies won’t take the risk of investing in large scale sustainable energy. There’s no “issue owner” for implementing energy infrastructure on city scale.

Case 9 Freiburg, Germany: “Climate Change Action Scenario” until 2030

Freiburg is situated within the temperate oceanic climate zone. It is the warmest city of Germany despite winter cold and rain in summer. Heating degree days are calculated at around 2800. It receives about 1800 hrs/year of sunshine. Freiburg counts 210,000 inhabitants and is one of the fastest growing cities in Germany. Since the 1980s Freiburg and its inhabitants have been concerned with sustainable energy. The initial aim of moving away from nuclear energy towards the use of renewable energy sources (RES), expanded into a comprehensive climate protection approach. The city developed a vision for a sustainable city reliant on an ecologically-oriented energy supply and is today well known for its solar, energy efficiency and public transit programs. The targets of the City are a reduction of CO₂ emissions by 40 % until 2030, compared to 1992, the coverage of 10 % of the electricity consumption in the city by local renewable energies until 2010 and 100 % substitution of electricity supply from nuclear energy until 2010 for electricity consumed in Freiburg.

Concerning the use of local renewable resources in electricity supply the emphasis is on PV panels installed on public, commercial and private buildings, which is due to a long tradition of solar energy use in Freiburg. Another major focus in the supply are cogeneration plants in the periphery which are to be operated with biogas from farming, using new and existing gas supply lines. Most of thermal energy from renewables is provided by local biomass, utilizing biogas in cogeneration plants, fuel wood in major heating plants and wood pellet boilers in individual buildings. A big effort is devoted to solar thermal panels, but due to limited contribution of solar collectors during the heating period the overall contribution to cover the thermal energy demand will remain small. The municipality is using various planning tools: For long-term energy planning, an Excel-based “scenario model" was used, tailored to the existing demand and supply structure in Freiburg of 2005. Using known energy saving potentials for sector specific technical conservation measures and local supply potentials for renewables, and considering long-term municipal development plans, a consistent "climate change action scenario" until 2030 was defined in communication between the municipality, housing companies and local utilities which resulted in realistic combination of measures and time frames and corresponding targets. These targets were confirmed by the City Council. To derive concrete measures and investment plans on neighborhood level, supply alternatives have to be defined and compared. For local district heating projects using cogeneration or biomass, the simulation model “BHKW-Plan" has been used to analyze energy balances and economic results. In case of solar thermal projects, the planning package “T-Sol" is frequently used. The most relevant policies for the implementation of the described measures in the field of regulations are the self-commitment of the municipality for its own public buildings in terms of energy conservation and use of renewable energies as well as the prescription of low-carbon energy standards for new buildings.  

Important financial incentives are the municipal program for private home owners to support retrofit measures in residential buildings and the installation of a revolving contracting fund for economic energy investments.

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3D-Model of the Retrofitting area in Freiburg Weingarten-West


As part of the strategy, a neighborhood project Weingarten West is being implemented with the goal of a 30% reduction of primary energy consumption. This is an energy-oriented

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73 These buildings are constructed on estates sold by the municipality (using private contracts).
74 enEff
refurbishment of a Freiburg city district including the district heating. The passive-house-standard refurbishment is to be demonstrated with the example of a 16-storey high-rise building. One key objective is stronger networking of the parties involved: building society, energy supplier and tenants.

Case 10 Nantes, France: Climate Plan

Nantes is situated on the Atlantic seaboard, and benefits from an oceanic climate characterized by plenty of sunshine and gentle temperatures. Heating degree days are approximately 2000 and cooling need is low. After four decades of strong economic growth, the Nantes agglomeration it has now reached 580 000 inhabitants. Nantes enjoys high levels of industrial and tertiary activity (service industry). For Nantes, the central emphasis is to reduce GHG emissions on its territory by 50% by 2025. An ambitious target considering the 24 district authorities only directly control 6% of emissions. The cooperation of all the parties involved – private individuals, public and private companies – is thus essential. Nantes City is in the position to draw up a coherent and flexible energy policy. It applies to three areas:
- Coordination of energy use policy;
- Development of renewable energy; and
- Energy distribution.

The challenge for Nantes metropolis is to set objectives in line with the national targets and the international commitments, observing the regional climate energy plan, the main planning tool since 2006 in France. Climate plans are required by the government, and the local community has to define quantitative realistic goals in relation with national goals (Kyoto, Factor 4). The first step of Nantes district (not yet Nantes metropolis) was centered on ‘Agenda 21’ which was designed for sustainable development in general. The built up of competences resulted in a multi-year energy action plan (PPAE) in 2006 including the increase of renewable and heating networks. The next step was the climate plan in 2007 which led to considerations of climate and energy issues for the whole territory, including mobility, urban planning and housing. For this purpose, Nantes conducted a greenhouse gases emissions assessment and has the recourse of several tools made available mainly by the national Agence de l'Environnement et de la Maitrise de l'Energie (ADEME) to support the set-up of this local and global policy. Then arouse the need to translate the theoretical planning into concrete actions for local government in charge of them.

Nevertheless, the Nantes metropolis and its communities do not have all levers to act on major sources of CO₂-emissions. Neither does Nantes have all the necessary competencies to regulate energy in all its aspects. Thus, the local government created an energy and climate regulation and actions according to its competencies, including a massive deployment of solar panels on public buildings. Nantes was forced to leave energy reform actions to the discretion of users. Thus, the city’s role is that of a motivator, an organizer of the climate actors. Importantly, in Nantes such approach has come a long way due to the existence of committed elected representatives.

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76 IEA Annex 51 Subtask C DRAFT Version 2.0, op cit
http://www.annex51.org/media/content/files/casestudies/subtaskC/Annex-51-ST-C-v2.pdf
Solar Panels on public Buildings, Nantes, France

Source: http://www.nantesmetropole.fr/la-communaute-urbaine/institution/le-plan-climat-energie-territorial-de-nantes-metropole-50904.kjsp

Case 11 Barcelona, Spain: Energy, Climate Change and Air Quality Plan (PECQ 2011-2020)

Barcelona is an early leader in developing and implementing a comprehensive energy concept. Barcelona has a Mediterranean climate with mild, humid winters and warm, dry summers, with high solar irradiation. Heating degree days are below 1000 and cooling degree days above 1000. The very densely populated coastal municipality itself has 1.6 million inhabitants within an urban organized agglomeration of 3.2 million. The city incorporates solar thermal energy capture and use systems for the production of sanitary hot water in the city's buildings. This has been recommended in the city’s general environmental ordinance of 2000. The city broadened support for energy reforms through the modernization in 2002 of the Barcelona Energy Agency, now run by a consortium led by the Barcelona City Council, with the participation of the Metropolitan body for hydraulic services and waste treatment, the Catalan Institute for Energy and the Institute for Energy Diversification and Savings, the University of Barcelona, and the Catalan University Technical College. The City adopted the Barcelona Energy Improvement Plan (PMEB) as the general framework for matter of energy policy of the city. The PMEB was updated and expanded by the New Energy, Climate Change and Air Quality plan of Barcelona (PECQ 2011-2020).

77 This document uses approximate degree day numbers in order to indicate heating or cooling demand, not exact numbers for planning purposes. For many of the cases, see: IEA_ECBCS Annex 51 - Subtask A: Descriptions of state-of-the-art energy efficiency projects on the level of neighborhoods ; Koch, A., Kersting J., EIFER Karlsruhe 2011, http://www.annex51.org/media/content/files/casestudies/subtaskA/SubA_report_120405.pdf
78 See the respective page on the website http://www.barcelonaenergia.com/
The figure above documents Barcelona’s comprehensive view of the urban metabolism with energy as an input. The new energy plan includes a detailed assessment of the current energy situation, trends, as well as future scenarios. The PMEB had established a set of actions to achieve energy savings, and increase in the use of renewable energy, and increased energy efficiency. The PECQ updated and expanded the diagnosis and objectives and included implementation of 109 projects within the 2011-2020 period. The more specific objectives formulated in the PECQ are:

- Increasing the consumption of self-generated energy and the amount of energy produced from renewable sources (biogas, photovoltaic and solar thermal);
- Reducing emission levels of NO\textsubscript{2}, PM10 and PM2.5;
- Improving air quality levels in terms of other pollutants;
- Improving efficiency and the ‘environmentalization’ of transport in Barcelona; and
- Involving all agents and groups in reaching the PECQ’s objectives.

Another of the environmental objectives in the PECQ is to meet the Covenant of Mayors’ commitment to reducing GHGs by 20% by 2020, whilst increasing energy efficiency and the use of renewable energies. Barcelona is well on the way to achieve this. The PECQ is also an example of considering climate change impacts and adaptation. Barcelona is putting less emphasis on the long term objectives and dedicates much more work on the detailed diagnosis and projects in the medium term, with support from the research institutes. The plan distinguishes strategic actions for the city and the municipality. The city programme intends to:

- Influence the relationship between how people behave, how society behaves and how organisations behave in terms of energy consumption;
• Introduce the need to apply energy efficiency principles when rehabilitating buildings and refurbishing housing;
• Continue prioritising the use of the main renewable resources available to the city and incorporate high-efficiency technology;
• Reduce the presence of private vehicles in Barcelona - the cause of one of the main public health problems in Barcelona: air pollution;
• Reduce the environmental impact of large infrastructures and economic factors such as industry, the port and airport.

One of the concrete measures is the closing down of a thermal power plant unit and replacement by CHP units which supply electricity, heat and cold.

The energy, climate change and air quality plan of Barcelona (PECQ 2011-2020) New Energy Plan

The municipal programme’s strategic lines are to:
• Reduce the impact of transport in the city;
• Rationalise the use of energy in both new and existing facilities; and
• Lower the proportion of primary energy used by municipal services that comes from fossil sources.

Source: http://www.barcelonaenergia.com/
Case 12 Almada, Portugal

Located on the south bank of the Tagus River across from Lisbon, Almada enjoys Subtropical-Mediterranean climate with mild winters and warm summers. Heating as well as cooling needs are limited. Almada is one of 18 municipalities within the Lisbon Metropolitan Region, with 174,030 residents living in an area of 72 km$^2$. Almada City Council has been developing policies and strategies towards a more sustainable city launching several projects aiming at promoting public transport and soft transport modes, such as a light rail system and cycling, energy efficiency in municipal buildings and facilities, and public lighting. Almada is planning the orientation on a new urban development on the east side to profit from natural cooling and heating from wind and solar (see wind and solar map below) as well as green infrastructure.

**Eastern Almada Urban Plan - wind and solar energy use**


Another very important measure is the on-going implementation of a remote control system to manage the public lighting infrastructures of the municipality. Along these lines, the Municipality of Almada was among the first signatories of the Covenant of Mayors. The Almada Local Strategy for Climate Change contains a number of actions targeted at reducing the energy consumption of buildings and transport sector. To support these actions the Almada’s Carbon Fund “Almada Less Carbon”, was created in 2009. It supports local energy efficiency investments, serving as a benchmarking instrument for the actions of other key players in the mitigation of GHG emissions, whether from the public or private sector.

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80 For more information see http://www.energy-cities.eu/Almeda-Portugal
Integrated community energy concepts (district and neighbourhood rehabilitation and greenfield projects)

Case 13 Helsinki, Finland: Eco-efficient renewal and revitalization of Peltosaari neighbourhood

The Peltosaari neighbourhood is situated north of Helsinki. It is in the humid continental climate close to subarctic. On average the place has over 5000 heating degree days per year. It was built during the 1970s and 1980s next to Riihimäki city center about 70 kilometers inland from the capital. Peltosaari has today some 2,800 inhabitants compared to planned maximum occupancy of 3,600 inhabitants. The socio-economic situation requires radical action to prevent further social exclusion and segregation. The Peltosari project is rather small. But in a nutshell it has the elements of Eco efficient renewal and revitalization of a sunset neighbourhood by technical, architectural and socio-economic development, which is its vision and objective. It is an intensely analysed, research-led, and monitored pilot and demonstration project, with high level architectural and urban planning participation. The residents of Peltosaari are connected to the process. Important part was the financing and cost control in order to assure affordability despite improved quality and much higher energy efficiency.

A competition was opened for free ideas on the future with criteria including innovative planning, new urban design, energy-efficiency and eco-efficiency, transport system, and communal solutions for housing and development of existing environment and building stock. Tools available for the city administration are the master plan, rental agreements, other agreements between the city and site owners, organization of ideas and other competitions, co-operation initiatives with various stakeholders, and implementation of innovative development ideas from other projects. Some buildings were demolished and new building space added. The plan below shows the winning entry ‘Spinning Wheel’ with the renewed railway station left to the settlement. The red lines indicate buildings to be demolished.

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82 IEA -ECBCS Annex 51 Subtask B May 2012, Final report weiter sehr aufschlüsslich
http://www.annex51.org/media/content/files/casestudies/subtaskB/Case%20Studies/Endbericht_subtaskB.pdf
Location of passive house retrofit projects, Riihimaeki, Peltosaari, Finland


Passive house retrofit, Riihimaeki, Peltosaari, Finland


Energy efficiency and refurbishment of the existing district heating were the main features and accessibility of the railway station with connection to Helsinki improved to reduce transport time and energy.
Malmö is by Swedish standards a large city recording approximately 664,000 inhabitants in its Greater Malmö area. It is situated on the Oeresund opposite Copenhagen in Denmark, in the oceanic northern climate zone. Annual heating degree days (HDD) are on average 3470. As exemplary for sustainable city development, Malmö started the revitalization of a former industrial dockyard and creation of a seaside city area. The objectives of the project include an expressed environmental and low energy profile. The initial development area was a place for an international housing exhibition referred to as Bo01, which was devoted to sustainable cities. Around 30 construction firms participated with buildings demonstrating environmental and energy innovations. This development was thereafter successively extended to the total industrial area. The impression of a small town should be conserved through houses mixed with public spaces and green surfaces. Service areas, small businesses and schools are included in the area. The outer building front was designed to serve as windshield. Private car use should be minimized and public transportation was improved through buses powered by biogas. The energy goal was an energy use of 105 kWh/ (m²/a) gross area (jointly heat and electricity) based on 100% renewable energy. The energy is supplied by district heating and public grid electricity. A nearby wind power plant is producing electricity to the grid of the same amount as the consumption (on annual basis). Energy is delivered by a district heating system based on waste burning and sea water heat pumps. The energy use is visualized by means of measurement and a web interface. Due to the coverage of energy needs by the use of renewable resources the objectives energy efficiency goal were considered less important as the whole energy system including both electricity production and thermal energy provision is regarded.

In general, in most of the buildings, there is no special measure for reducing energy consumption other than mechanical ventilation system with heat recovery, since triple-glazing windows and high insulation thickness among other are standard in Swedish buildings. In the cases were solar collectors are installed on buildings; the energy is either directly consumed or fed to the district heating network. Similar is true for solar cells, which are supplying immediate needs of the buildings, the balance is fed into the grid. This kind of energy efficiency project must be seen as an important milestone to turn Sweden into a ‘energy-neutral’ country by 2045.

Western Harbour Revitalisation, Malmö, Sweden

A wind power plant operated by the local district heating company belongs to the Western Harbour (Västra Hamnen) area and is balancing the predicted electricity demand of the area on an annual basis. A general conclusion is that the supply of heat from central cogeneration power plants does neither economically nor technically stimulate low energy investments.

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83 IEA Subtask A
84 [http://www.innoventum.se/demosite/](http://www.innoventum.se/demosite/)
The project organization developed a quality plan for the area that regulates all energy and environmental guidelines together with the physical description for the development. All investors had to implement this quality plan in order to receive a building permit. Financing is based on private investments through housing companies. Municipality-owned companies are in some cases applying tenancy agreements, but in most cases a certain form of freehold property is applied. The price level is rather high (around 4000 €/m²). Malmö City contributed with subsidies for the Bo01-office and for parts of the infrastructure. The energy company is investing in the energy supply system, including district heating which is paid back through the energy sales. Governmental support was given for special environmental features within a local investment program for sustainability (LIP-program). The amount of the subsidies corresponds to about 3% of the total costs of the area development. For some selected energy projects, EU-funded subsidies were received.

Case 15 Scotland: Sets Wind Record, Provides Enough Electricity for 3.3 Million Homes

The skyline of Ardrossan, North Ayrshire, Scotland, is dominated by an enormous wind farm. (Vincent van Zeijst, CC BY)

"Now it has been reported that Scottish turbines provided 1.2 million megawatt hours of electricity to the National Grid—enough energy to meet the electrical needs of 136 percent of households in the country (or ~3.3 million homes). What's more, 58 percent of Scotland's entire electricity needs were met for the entire month. The Independent reported that on March 17 and March 19, enough energy was generated to power Scotland's total power needs for an entire day.

An analysis of WeatherEnergy data by the World Wide Fund for Nature (WWF) Scotland revealed that the amount of energy generated in March increased by a staggering 81 percent compared to the same month in 2016. … Now that Scotland has set an impressive new wind record, the WWF is calling on political parties to continue backing onshore wind power to help the country meet its carbon emission cut targets. One of the country's goals is to deliver
the equivalent of 50 percent of the energy required for Scotland’s heat, transport and electricity needs from renewable energy sources by 2030.” 86

Case 16 Aarhus, Denmark: Low-Energy Neighborhood Project in Lystrup

In Lysterup there is a Low-Energy Neighborhood Project with new development and integration of sustainable solutions both for the end-user side (building sector) and the energy supply side (district heating network). 87

A consortium among municipalities, industrial partners and research institutes was the main initiator of the “Lærkehaven” project for three building areas and new development for a total of 122 of low-energy row-houses. The construction technology is based on prefabricated house structures. In one of the areas, the energy is supplied by a low-temperature 55/25°C district heating system, in twin-pipe systems, unique in Europe. Hot water is produced either directly in heat exchangers or in accumulators in some cases. This system does not require a very high demand density to be competitive. See the screenshot from the Guidelines for Low Temperature District Heating. 88

Guidelines for Low Temperature District Heating: System Layout and pipe specifications


Case 17 Stad van de Zon, the Netherlands: New District of Heerhugowaard

This new district is energy-efficient and supplied by renewable energy. Stad van de Zon (city of the sun) is a new district built in the Alkmaar area, situated in temperate oceanic climate zone with approximately 2700 heating degree days. The new district is planned for a total of 1,600 homes located on the polders towards the North Sea. All new buildings were equipped with solar PV panels. When opened in 2009, this was the biggest urban PV project in the world.

Heerhugowaard, Stad van de Zon, the Netherlands

Three wind turbines ensure the area is CO₂ neutral. A 70 ha lake offers a natural and recreational environment as well as providing a water storage facility. A labyrinth of flowing water creates a natural purification system. Research by TNO (Netherlands Organisation for Applied Scientific Research) and ECN (Energy Research Centre of the Netherlands) has shown that a carbon-neutral City of the Sun was feasible, with almost 4 MW solar energy created by three major wind turbines. For the realization of the CO₂ target the energy demand is limited to the dwellings. The EPC (Energy Performance Coefficient) will be on average 0.8. EPC’s were mandatory. The solar energy performance was monitored according to a monitoring plan. The project was financed by the municipality of Heerhugowaard, the Province Noord-Holland, NUON (energy company) and the European Commission (5th framework programme, 2002). For one part also the Dutch government agency SenterNovem has contributed to the financing. A refined payback system based on the energy produced by solar, involving the utility NUON and a guarantee fund. Through this action the residents were stimulated to energy saving, because they could earn the deposit back through energy saving measures.

Copyright: Jan Tuyp

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89 EA IEA ECBCS Annex 51 – Subtask A; European Commission under the Fifth Framework Programme contributing to the implementation of the Key Action "Cleaner energy systems, including renewables" within the specific programme for RTD and demonstration on "Energy, Environment and Sustainable Development - Part B: Energy program”.

Case 18 Berlin Germany: Science and Commercial Park Adlershof 2020+  

Berlin has a decades’ long tradition of integrated energy planning, dating from pre-reunification. These efforts are focused on efficiency, district heating and also RE. Among those is the large science and commercial park Berlin Adlershof in Berlins Trento Koepenick District which offers approximately 14,000 jobs. Berlin has a continental climate, i.e. colder and warmer than the oceanic climate in western parts of Germany. With the cluster project High Tech – Low Ex, a concept for an energy-efficient development of the Berlin-Adlershof science park developed 2011 to 2013 with the aim of achieving 30% primary energy consumption compared with “business as usual” in 2020. The project is implemented in several sub-projects until 2016 with the objective to attain the goal in 2020.


Case 19 Hamburg, Germany: Integrated Energy Network Wilhelmsburg Mitte (of Cities and Climate Change Programme)

Hamburg’s International Building Exhibition (IBA) demonstrates through its Cities and Climate Change programme how major cities can grow in an environmentally friendly way by generating decentralized renewable energy and using their own resources efficiently. The Wilhelmsburg and other Elbe islands are industrial, harbor and working class neighborhoods with approximately 100,000 inhabitants in the southern parts of Hamburg, within the river Elbe also including nature conservation areas and even agriculture. Hamburg has oceanic climate, influenced by the North Sea. The Hamburg International Building Exhibition (IBA) from 2007 to 2013 was the location for 50 individual projects in the Wilhelmsburg district and on the neighboring Elbe Islands as well as at Hamburg’s inland port. The Cities and district Climate Change initiative has set the objectives:

- 100% renewable Wilhelmsburg in the long run;
- Localized energy: Elbe islands energy should become largely energy autarkic, heat pumps, geothermal, bioenergy, wind and solar, with local energy grids (mini-grids and virtual power stations);
- energy efficient buildings, highest standards, focus on existing building stock;
- climate change mitigation and adaptation as community concern.


A specialty is the parallel development of concepts (energy mapping and planning) and projects, due to the fact that the building exhibition requires visible objects. Some extraordinary projects which explore directions and symbolize the concepts:

- Energieverbund Wilhelmsburg Mitte: a heating energy grid and ‘virtual power station’ including some storage, connecting user and decentralized heat providers; buildings involved produce temporarily more heat than needed and feed into the grid; the aggregated and variable heat demand is covered by the variable inputs from heat pumps, solar thermal, geothermal and distributed cogeneration on the basis of biomethane; this system is called virtual power station since it reduces capacity requirements for the individual building; on the demand side low energy standards are attained.

**Integrated Energy Network Wilhelmsburg Mitte, Hamburg, Germany**

- Some extraordinary projects generate the heat; a building with a green solar thermal façade, (smart is green), the BIQ house which explores facades in which micro-algae generate heat and also the water houses built on water using geothermal heat, groundwater heat pumps and again, solar thermal elements;
- The energy bunker is a high profile building: it is a WWII high bunker, inside of which a CHP station is accommodated, and on which a roof of solar PV arrays have has been installed.
- The Georgwerder energy hill, which is a land fill mound, from which land fill gas is extracted, used also in an industrial plant nearby, as well as a field solar PV array and a wind turbine on top;

The Jenfelder Au demonstration and research project is aimed at finding holistic, innovative, exemplary and future-oriented solutions in order to intelligently combine urban wastewater management with energy provision and urban design requirements. Since the IBA exhibition ended, research and analysis continues. Today, the city and the district pursue the 100% renewable Wilhelmsburg concept more systematically. The success of the renewable energy programme of Germany became evident in 2016 when it was reported that the share of renewables in total energy balances had gone up so much that energy prices became negative (i.e below zero). This was possible due to the sale of energy generated to the grid of providers.  

"Energy Hill’ in Georgwerder, Hamburg


‘Energy Bunker’. Wilhelmsburg-Mitte Hamburg


Case 20 Grenoble, France: Revitalization of Unutilized Military Barracks “ZAC de Bonne”

Situated in the South-East of France and surrounded by mountains, Grenoble’s climate has extensive thermal amplitudes and high insolation as well. Average heating degree days are approximately 2,500 per year. The municipality proper has 156,000 inhabitants. The de Bonne Zone d’Aménagement Concerté (ZAC) is an eco-neighborhood in Grenoble built on 8.5 hectares of land previously occupied by army barracks. The area is situated near the city center and will in total provide for 850 apartments. In the context of the development the existing building stock was revitalized and new buildings with high energy efficiency standard were built with a total primary energy need below 50 kWh/(m²/a). In addition to the major objective of an increased energy performance in comparison to national legislation, passive solar gains had to be optimized in order to limit overheating during summer and enable the use of solar gains in winter. Use of recyclable materials was promoted throughout the whole project. A first application of a positive energy office building (positive energy balance and on-site generation of energy if measured over the year) was also implemented in the de Bonne district.

Overall the measures taken to increase building energy efficiency included compactness of buildings, reduction of thermal bridges, external isolation and mechanical ventilation systems with heat recovery. Concerning the use of renewable energy a central photovoltaic plant with 1000 m² surface on top of the district’s commercial center was established and 8 micro-cogeneration plants were installed. The engagement of all actors was formalized in a Charta (declaration of commitment) for high environmental quality (“charte haute qualité environnementale”) that was signed by the construction companies and developers to

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93 This country made so much clean energy it had to pay people to use it. 9 June 2016. https://www.weforum.org/agenda/2016/06/germany-made-so-much-clean-energy-it-had-to-pay-people-to-use-it/

ensure compliance after sales. In addition to general development planning documents
tender documents for high environmental quality were developed and applied throughout
the project. To ensure a high construction quality on all levels training modules for the
diffusion of new construction technologies and their application were developed. While no
overall monitoring scheme was implemented the measurement of energy consumption was
offered to the inhabitants on a voluntary basis. Large part of the financing was accomplished
through land sales by the city to private property developers. The ZAC de Bonne project has
participated in the European CONCERTO programme.
The urban community of Greater Toulouse is situated inland in southwest France, on the frontier between Mediterranean and Atlantic oceanic climate. It has less than 2,000 heating degree days per year, but may become hot in summer. The city has a population of 650,000. The rise of high-technology aerospace industry entailed a strong demographic and economic development in the second half of the 20th century. However, the strong growth brought about forms of urban sprawl which impedes sustainable urban development. Moreover the increasing land costs constitute a major problem enhancing the construction of housings on the outskirts of the agglomeration and thus act as driving force of urban sprawl. The city of Toulouse which responsible for urban planning wants to counteract this trend while developing a polycentric urban model, with new orderly developments. The urban (re)-development zone (’Zone d’Aménagement Concerté’ [ZAC]) “Andromède” is one of the projects which has been established 1999 when Airbus decided to locate factories for the construction of the A380 airliner near Toulouse. The three ZAC together correspond to 500 ha, 5,000 housing units and roughly 10,000 employments. In 2004 the city established an environmental observatory, serving as an instrument to inform and sensitize delegates and municipal institutions as well as the population. It is the first French project that includes the principles of sustainability. The strong significance attributed to landscape in the “Andromède” project is justified by the utilization of 70 ha arable area by the Constellation project. The mixed economy company Constellation has been established in 1999 and became general contractor for the ZAC. The project is composed of three phases and lasts altogether 20 years; it has exhibited some delay because of the economic crisis of 2008. The project pursues different objectives: A maximum green space should be preserved (70 ha) to compensate the arable area occupied by the Constellation project. In addition to a social mix, a functional mix is aspired in “Andromède”. Public institutions such as nurseries, schools, sport facilities and retirement homes should be established. Finally the extension of means of transportation like tramways and bikeways is central to the project. The biggest part of the residential units has been privately financed.

During the urban planning focus was on the active and passive use of solar energy. Also a low-energy elementary school was erected at the location. The solar district heating system consisted of flat collectors on three multi-family houses with in total 1,750 m² that fed the heated water into a 90 m³ buffer storage tank in the central heating station below the school. Whenever the required temperature cannot be reached through the solar system alone, the 3.7 MW central gas condensing boiler combination increases the heating water temperature. The residential buildings met the planned heating and domestic energy use which was calculated to be 30 % lower than the requirements for new buildings at that time. Each building had its own design and its own concept for the thermal insulation in order to meet the tightened requirements. Besides the solar array on the roof of three different houses for the central heating unit no other renewable measure (besides optimization of passive solar gains and daylighting) has been implemented.
Site Plan of Urban Redevelopment Area Andromede, Toulouse, France

Source: [http://www.lemoniteur.fr/article/inauguration-de-la-zac-andromede-pres-de-toulouse-77147](http://www.lemoniteur.fr/article/inauguration-de-la-zac-andromede-pres-de-toulouse-77147)
Case 22 Salzburg, Austria: Revitalization and Heat Supply of Lehen District

Salzburg is situated in western Austria, influenced by continental, alpine and oceanic climate. The north-western district of Lehen counts approximately 15,000 of Salzburg’s total 148,000 inhabitants. Revitalization of a rundown urban area with the intention to improve quality of life by creating a district aimed at environmental and social sustainability. Public, semi-public and private companies joined under the lead of the municipality of Salzburg for planning and developing new residential and commercial buildings, based on a political and social vision of the municipality. The project comprises an area of 105,000 m² for new buildings with 550 dwellings and refurbishment of buildings and 50,000 m² with 623 dwellings. About 20% of the new buildings were planned for commercial use. The criteria of sustainability are as follows:

- Low energy standard for new buildings and as economically as possible for refurbishment;  
- High rate of renewable energy supply for the whole area; and  
- Energy efficient components in the public electrical applications.

The targets for annual heat demand were set at 20 kWh/m² per year for new buildings and 35 kWh/m² for existing buildings. The requirement for a high amount of renewable energy resulted in a local (micro) district heat. Hot water DH (65/35°C) with 2.000 m² solar collectors, central storage tank of 200m³ and electrical heat pump resulting in a solar share of over 30%. Cooling is planned. Compared to natural gas use for heating, the CO₂ emission reduction is calculated at or 92%. The existing electricity is produced with 93% renewable energy, mostly hydroelectric. A backlash happened in spring 2011, when the investor decided for cost reasons to withdraw all innovative energy efficient refurbishment measures and plans now for renovation based on conventional refurbishment standards. The EU CONCERTO program was instrumental to start the project.

Heat supply concept with solar collector fields, storage tank and micro net for neighborhood scale heat supply, Lehen, Salzburg, Austria

Source: http://www.annex51.org/media/content/files/casestudies/subtaskB/Endbericht_subtaskB
Case 23 Linz, Austria: Solar City Pichling

Linz is situated on the Danube in central Austria, influenced by continental and oceanic climate. Linz municipality counts approximately 200,000 inhabitants. The Linz Pichling Solar City is a new development of a total of 1,317 homes and apartments, south west of the city beyond the Voest Alpine plant. In 1994 the city council of Linz and four social housing associations teamed up and confirmed their intention to fund the planning and construction of a new neighborhood consisting at low energy standard in Linz-Pichling. Later further 8 housing associations joined for the construction of apartments. Besides housing projects there were also projects for social infrastructure (e.g. school building, kindergarten). The main criteria for sustainability have a focus on low-energy standard (max. 44 kWh/ (m²a)), and use of solar energy (passive and active, for District Heating and Warm Water and also for electricity generation), public transport and other measures promoting walking. A connection to the district heating system of the City of Linz is also planned. The main focus of solar City Pichling was the integration of solar energy in the architecture of social housing projects. Energy criteria were not the main focus of the projects (at this time ‘passive house’ standard was at the beginning of its conceptual development).

Solar City Pichling, Linz, Austria

Source: http://www.annex51.org/media/content/files/casestudies/subtaskA/SubA_report_120405.pdf
Special clean energy technology applications
Case 24 Wieringmeer, The Netherlands: Wind power

Wieringmeer is ideally situated to wind energy, and in 1996 it already had 44 wind turbines scattered through its area with a capacity of 12.3 MW. 35 of these are small, privately owned turbines with an approximate size of 80 KW. In this location, 1 1.65 MW turbine will produce on average 3.300 MWh and thereby save 1880 tonnes in CO₂- emissions. There has, however, been considerable resistance in the Netherlands to the construction of a large number of turbines in this flat and open landscape. The municipality had originally prepared a special wind energy plan, but as wind energy technology developed, this became increasingly out of date. Therefore the opportunity was taken to review the plan for wind energy. In 1997 it was decided to account the results of the technical review and the public reaction to wind energy infrastructure, that only 5 out of 8 sites would be developed. By the end of 2002, only 31 new turbines with a capacity of 1.65 MW each were ready to operate. If all planned wind turbines are installed, the electricity production would be sufficient to supply approximately 50,000 average households. Although there are no financial incentives, the municipality actively helps citizens in their applications to erect wind turbines.⁹⁶

Windmills in the Netherlands


Case 25 Leicester, United Kingdom: Reduction in energy usage of municipal buildings

Leicester City Council has been at the forefront of the sustainable energy agenda since 1990 when Leicester’s first strategic energy action plan was developed. An energy audit conducted determined that offices and buildings owned by the municipality consumed over 170 GWh of energy each year. As part of the larger Energy Action Plan, in 1990 Leicester announced its commitment to reduce energy use by 50% by year 2025 through retrofit measures, design of new buildings with improved lighting, heating and ventilation standards. For example, the Town Hall which had been built in 1876 was retrofitted under the Council’s energy investment programme. As a result, the gas usage was reduced by over 20%, resulting in big savings, and 90 tonnes of CO₂ emissions slashed in just two years. Since then, Leicester has invested in intelligent metering systems, installed over 300 administrative buildings throughout the city to provide half-hourly monitoring of gas, electricity, water, and heat consumption data. This data is used to engage building users in changes in their behaviour as consumers. Responsibility for the initiatives is held by the Energy Efficiency Advice Centre which provides information and a range of energy-efficient products to the general public. The Leicester Energy Agency provides practical assistance to small businesses on energy-related matters. The agency aims to improve the energy efficiency of up to 5,000 businesses, and is planning to set up an Energy Services Company which sustains these efforts.  

Source: Leicester Town hall.  
https://www.leicester.gov.uk/contact-us/our-offices/town-hall

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Case 26 Mannheim Germany: e-energy model city MOMA

A pilot project for a smart grid combining active distribution networks and smart buildings was implemented in Mannheim Germany for 1000 participants, using a cellular model. It is expected that smart grids and distributed generation including other elements as variable renewable energy, storage, demand side management will constitute they future urban power energy world. Delivers practical lessons learnt for the new energy world of distributed generation and smart grids.

MOMA Mannheim Germany : e-energy model city

Source: http://www.coms4grid.de/155-0-Modellstadt+Mannheim.html

Case 27 Heidelberg, Germany: Old Gasometer to be Transformed into Centre for Renewable Energy

The Laboratory of Visionary Architecture has won the European Prize for Architecture 2016, by the Chicago Athenaeum Museum of Architecture and Design, and the European Centre for Architecture, Art, Design and Urban Studies. The 56m high refurbished building will become a monument of new energy technologies, an exhibition centre and educational tool for the citizens of Heidelberg.


97 For the time being, reports are only in German, see: http://www.modellstadt-mannheim.de/moma/web/de/home/index.html
Case 28 Lille, France: Buses powered by biogas of the municipal wastewater

The Urban Community of Lille (CUDL) is a public inter-municipal co-operation body that gathers 87 local authorities from the Nord-Pas-de-Calais Region. Its scope of competencies includes the provision of services and amenities to the urban community in the fields of town planning, road infrastructure, mobility and parking facilities, urban transport systems for passengers. CUDL is home to over 1 million inhabitants. The mobility policy is determined by the town planning and master plan. Priority is being given to public transport: (i) development of existing transport facilities (train, underground, tramway); and (ii) preferential urban development (ToD) in these areas serviced by such transport facilities. The Urban Mobility Plan, adopted by the Municipal Council in 1997, set the objective of promoting less polluting energy sources for private cars as well as for public transport, and for transportation of goods. By the end of 1990, the CUDL launched the innovative renewable energy project, to introduce biogas to power urban transport buses. The biogas is being produced by the Maquette sewage plant, in the suburbs of Lille. In 1990, 80% of the 15,000 m³ of biogas produced daily by the waste water treatment plan, i.e. the equivalent of 6,000 litres of petrol every day, was used internally to supply the treatment plant with heat and power, and the remaining gas was burnt. To make use of this resource, the CUDL decided to utilize the balance, some 1,200 m³ of biogas usable as fuel in public transport vehicles. The first bus operating on such biogas was introduced in March 1994. Further buses were introduced in the years thereafter, bringing the share of biogas fuelled vehicles to 50% of the entire municipal bus fleet.

Source: http://www.energy-cities.eu/db/lille_113_en.pdf

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Case 29 Bristol, United Kingdom: Buses running on biomethane gas

Britain’s first bus which runs on human and household waste – the "poo bus", has gone into regular service. Powered by biomethane gas, the Bio-Bus will use waste from more than 32,000 households along its 15-mile route. Operated by bus company First West of England, the bus will fill up at a site in Avonmouth, Bristol, where sewage and inedible food waste is turned into biomethane gas. The Bio-bus will use waste from more than 32,000 households along a 15-mile route. The bus, which can seat up to 40 people, was unveiled in the Bristol area last autumn. The bus operator company is considering introducing more "poo buses". The Bio-Bus has generated worldwide attention. The very fact that it's running in the city should help to open up a serious debate about how buses are best fuelled, and what is good for the environment."

Methane Gas Powered Buses, Bristol, United Kingdom

Source: [http://www.dailymail.co.uk/wires/pa/article-2995269/Poo-bus-set-passenger-service.html#ixzz3USs9mJx1](http://www.dailymail.co.uk/wires/pa/article-2995269/Poo-bus-set-passenger-service.html#ixzz3USs9mJx1)

99 'Poo bus' set for passenger service, 15 March 2015. [http://www.dailymail.co.uk/wires/pa/article-2995269/Poo-bus-set-passenger-service.html#ixzz3USs9mJx1](http://www.dailymail.co.uk/wires/pa/article-2995269/Poo-bus-set-passenger-service.html#ixzz3USs9mJx1)
### Good Practices - Illustrations

<table>
<thead>
<tr>
<th>Photovoltaic system in Berlin, Germany</th>
<th>Renewable energy in the city</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Image" /></td>
<td><img src="image2.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solar water heating panels similar to these now provide 60% of the hot water used in newly constructed buildings in Barcelona, Spain.</th>
<th>Photovoltaic technologies in buildings: HIT solar panels generate electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.jpg" alt="Image" /></td>
<td><img src="image4.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Private Sector Companies Preparing for Green Energy</th>
<th>Solar Powered Municipal Bus Fleet, Adelaide, Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5.jpg" alt="Image" /></td>
<td><img src="image6.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>
4.3 Technologies, Products and Standards,

**Diversity in Europe.** European countries have long and separate technical traditions, which have led to diversity in technical standards. An illustrative example is the electrical plug, for which different standards reign in UK, France, Italy and Germany. European technical standardization is, therefore, an important part of creating a European Internal Market.

**Going for standardization.** Energy efficiency and clean energy are relatively new themes and the systems and products which have respective features are introduced increasingly since the last four decades and innovations continue. Therefore, standardization has encompassed the various clean energy systems to a very different degree and made these obligatory.

**Building technology.** With respect to building energy, building technology products and procedures are – for various reasons - highly standardized, including those important for energy efficiency, such as windows. Energy policy has been interested in building system standards, as a means to reduce energy fossil energy consumption. Therefore, in European countries, technical standards for residential buildings as complex systems have been developed, characterized by various levels of energy requirements for heating, expressed in energy (per m² and year) required to balance heat and ventilation losses. Thus, low building...
energy standards were tested and defined (called low energy, zero energy or passive house) as well as less ambitious standards for common use in new buildings. Increasingly, energy efficiency standards were also developed for retrofitting.

**Mandatory standards.** Very important to note is the binding character of building energy standards in many European countries, in contrast to the US. The less ambitious but still effective standards were included as minimum requirements in building regulations. Over time, these minimum requirements were tightened substantially. The low energy standards remain voluntary, although they may be required by city ordinance or in specific developments (see above good practice cases) or made a condition in financing.  

**Certification.** Standards and even regulations also exist for the customary energy technologies within a building, in particular the boilers or heat exchangers and heating distribution systems. Overall building energy performance certification (EPC) and labeling for all buildings has been introduced in several European countries. The EU has made an effort to harmonize and EPCs were introduced in the Energy Performance of Buildings Directive (EPBD) and re-casted 2010. To date, all 28 EU Member states formally implemented the EPBD requirements in their national legislations. The EPC are considered instruments of market transparency, but some countries make them obligatory e.g. in case of selling.  

**Labelling.** A much elaborated European system of energy consumption labeling exists for almost all significant energy household appliances, including ductless split type air conditioning. With respect to lighting, Europe has, for energy efficiency reasons implemented a ban on incandescent lamps. This has led to a very strong growth of LED to the detriment of fluorescent lamps. For these and also for halogen lamps, technical standards exist. More important for energy policy however is the labeling.

**LED lighting retrofits: saving money to invest in low-carbon solutions**

“Daunting, futuristic innovations for nearly every aspect of urban infrastructure come to light every day, so it’s unsurprising that light itself can be a Smart City solution. A simple, effective investment, LED lighting is a simple way that a city can take a step towards sustainability and efficiency.

‘LED is a gateway technology for cities and companies,’ Revolution Lighting’s VP of Development and Communications Jay Black said. “They’re not overly sophisticated to adopt.’ An acronym for light-emitting diode, LED solutions present various advantages over existing systems, such as fluorescent and sodium lighting fixtures. For one, LED lights are substantially more energy efficient than current legacy lamps by an average of nearly 60 percent. This becomes more substantial when viewing an organization or building’s energy budget as a whole, as lighting on its own typically accounts for about 25 percent of total energy use, according to Black. LED fixtures manage to save this energy while providing longer-lasting, full-spectral light output without degradation over time.

Because of their efficiency and efficacy, LED lights offer a considerable ROI. As the lights have a greater lifespan, less time and money will need to be spent changing and replacing them, thus freeing up man-hours and reducing spending. New Bedford, Mass., is a living example of this; the city’s LED system reduced lighting energy usage by 50 percent and eliminated many maintenance costs. That now translates into $500 thousand in annual savings for the city.

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100 For more details see also the EC Link green building position paper.
101 For an overview of Energy Performance Certificates (EPC) across the EU, see Mapping of national approaches by the Building Performance Institute Europe http://bpie.eu/epc_2014.html#.VW1DMVJ_M_S8
'When I was brought in 2013, I looked at legacy utilities and lighting was an easy target,' New Bedford CFO Ari Sky said. The city’s first CFO, Sky faced a number of problems when he joined. The city was constrained in terms of resources and cases of deferred maintenance were beginning to compound. To save money, the municipal government took out a small bond to cover the cost of retrofitting their exterior lighting infrastructure. The plan paid off, and now the city is using the savings from the lighting retrofit to finance interior lighting and HVAC upgrades. By partnering with Revolution, the city has retrofitted seventeen of its municipal buildings, with more on the way.

‘LED streetlights and office fixtures are a no-brainer,’ Sky said. ‘They’re cheaper to maintain and operate and it helps us realign the city’s carbon footprint.’


Smart or intelligent homes. Smart and intelligent homes are characterized by massive use of automatic or remote controls of energy and other residential services, applications of from information and communication technologies. These concepts have not yet become integral part of urban energy concepts, but will effectively become very important, when decentralized and variable power generation from RE reach high shares and the time of use will determine the value of electricity. Then, households will need and get more options to control energy and in particular electricity consumption and possibly also storage. Smart home concepts have not yet been standardized. ➔Tool CE 1

Thin-film solar ‘wallpaper’ is light, flexible, and can be taped onto any surface

“These flexible CIGS solar cells don't require a mounting rack, weigh 65% less than conventional solar panels, and are said to generate 10% more energy. The next generation of solar looks to be a much lighter, more flexible, and more customizable experience than anything that's come before it, and thin-film CIGS (copper indium gallium selenide) solar
technology could offer a variety of benefits, such as a much lighter weight, simpler installation, and increased energy generation, to everything from buildings to vehicles.

According to the solar startup Sunflare’s founder, Len Gao, “the panels can be secured to any surface with a special double-sided tape,” and are flexible enough to conform to curves in applications, which could allow for a lot more solar surfaces on everyday items. The company claims to have "cracked the code" for manufacturing high quality CIGS cells with its proprietary Capture4 process, which would enable mass production of its SUN² solar cells at a competitive cost. Sunflare's solar cells are based on a stainless steel substrate, on which a thin film of the semi-conductor materials get silkscreened, in a process which is said to use just 50% of the energy of conventional silicon solar panels, and to require much less water and fewer toxic chemicals to manufacture. The result are solar panels that weigh 65% less than conventional panels, don't require a rack to install, and because of their higher efficiencies in both low-light and high heat conditions, are said to produce 10% more energy.

For the building industry, Sunflare could be light and efficient solar panel option as a Building-Integrated Photovoltaics (BIPV) installation on the skin of buildings, or as a rooftop array that could cover an entire roof without any concerns about added weight or more roof penetrations, and could allow for easier custom installations on complex residential roofs. For the consumer, these thin-film solar panels could be applied to the roofs of velomobiles, neighborhood EVs, golf carts, trailers, RVs, as a solar awning, or perhaps on electric cars and carports."


Smart grids. Smart homes correspond to smart grids. Smart or intelligent grids are electricity (possibly also heating) networks, in which control technologies improve flexibility, efficiency and security, but also communication technology is implemented to transmit information and signals, including meter reading and pricing (smart meter). Internationally, there are smart grid initiatives to include smart grid into the grid codes, following the standardization of connection and feed-in from distributed generation. In Europe, national governments and technical authorities are working on codes for smart grids. These smart grids include also the technologies to control power generation, control storage facilities integrated in the grid, and allow short forced lay-offs of distributed generation, or more feed-in to the grid from the low voltage side by variable local network transformers. All these smart grid technologies will become elements of the future decentralised power system, which will operate very differently from the conventional system. ➔Tool CE 2

Storage. In Europe, electricity storage will also become an integral part of the system. Whether it will be installed predominantly on the user side in smaller units or within the grid and with higher capacities on the utility side and how these may interact or complement, is still open. Recently, manufacturers have announced large scale production of smaller storage modules at falling prices, whereas larger installations have been assembled and are operational as pilot plants in Germany. It is also still open, which battery technologies will succeed. ➔Tool CE 2

Innovative photovoltaic Roofing Materials

After the introduction of its electric storage facility (Powerwall batteries), and electric cars (Tesla car), the same form has introduced new solar roofing shingles, which combine roofing tiles with the photovoltaic technology.
"[Tesla] has just introduced a new Powerwall with enough juice in it to run a two bedroom house (14 kWh) for a day, and hooked up to rooftop solar, can run indefinitely. (Although it will not charge the car, which needs 85 kWh or more) It is surprisingly affordable at US$ 5,500. This is a real game-changer, that erases so many of the problems I have had with rooftop solar and its dependence on the grid [is]... just gone.... But what is getting all the pixels is that Musk has introduced a new solar roof shingle, in four different styles. They are made of tempered glass so that they are stronger and more durable than clay or slate or just about any other roof. they have a "micro-louvre" layer so that when you look at it from the street, you just see roof, but when you look at it from above, you see the solar cell...

The slate roof tile is made so that every one is different, with randomly generated patterns that make it look very real... If you have a great solar roof, a big battery pack and an electric car, you can solve the whole energy equation." He does not say what it costs, but notes that it will have a "lower cost than a traditional roof when combined with projected utility bill savings.... Urbanistically, it promotes and justifies sprawl. ... "Rooftop solar disproportionately favors those who have rooftops, preferably big ones on one-story houses on big suburban lots."


Technologies. Among the clean energy technologies in a narrower sense proper, heat pumps provide heating, cooling, and hot water for residential, commercial, and industrial

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applications by drawing on one of three main sources: the ground, ambient air, or water bodies. Heat pumps transfer heat from a source medium to a service medium (air, water) using a reverse refrigeration cycle driven by external energy, either electric or thermal energy, such as gas. A typical input-to-output ratio for a modern electrically driven heat pump is 4:1, meaning that the heat pump delivers four units of final energy for every one unit of energy it consumes, which is also known as a coefficient of performance (COP) of 4. 800,000 heat pumps are sold annually in Europe, which is a significant (15%) share of European overall heating system installations. Approximately 86% of them are air-source heat pumps. Ground-source and water-source heat pumps are more attractive for large and very large buildings, and their contribution in terms of service is far higher than their market share in units.

The most significant trend related to heat pumps is towards the use of hybrid systems that integrate several energy resources with heat pumps for the range of heat applications. There is also growing interest in the use of larger-scale heat pumps for supplying district heating.  

Road paved with solar panels powers French town

In December 2016, "France … inaugurated the world's first "solar highway", a road paved with solar panels providing enough energy to power the street lights of the small Normandy town of Tourouvre." It’s only 1 kilometer long, but a two-year test of the solar road will help determine if a full rollout of 1000 km of solar roads in the country is worth pursuing.

Calculating energy outputs. In 2009, the European Commission set out to standardise calculation of heat pump output and to define the renewable component thereof. The Commission provided a formula for calculating the renewable component of heat pump output that took into account both the operating efficiency of the heat pump itself and the average ratio of primary energy input to electricity production across the EU. In March 2013, the Commission issued remaining rules for applying its formula, including default values for climate-specific average equivalent full-load hours of operation and seasonal performance factors for various heat pumps. The default values resulted in a minimum COP of 2.5 for electrically driven heat pumps in 2013, well below the average value of new units.

103 Solar thermal heating cases in this position paper include Tilburg, Malme, Hamburg, and Salzburg. Sønderborg, Denmark, and Drammen, Norway use absorption heat pumps for district heating.

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**Clean Energy – EC Link Working Papers - Draft Version 1.5**

98
**Geothermal direct use.** The term of geothermal direct use\(^{104}\) refers to direct thermal extraction for heating and cooling, excluding ground water heat pumps. Direct use refers to deep geothermal resources, irrespective of scale, as distinct from shallow geothermal resource utilisation, specifically ground-source heat pumps. The single largest direct use sector is estimated to be swimming pools and other public baths. The second largest sector is space heating, including district heat. Applications in urban areas can be numerous in places, where resources are particularly plentiful and where district heat systems are well developed, such as Iceland, where nine out of ten buildings rely on direct geothermal heat. Applications are increasing in other parts of Europe, including some district heat schemes in countries that have relatively few traditional high-temperature resources, such as Italy. When the circumstances such as temperature of the source, distance to heat market permit, direct use is combined with power cogeneration. Geothermal power generation is only by chance an option for urban clean energy, in case significant deep geothermal resources are situated within city boundaries.

Only when including Turkey European countries together use approximately the same capacity and heat from deep geothermal sources as China. Iceland, Italy and Hungary are advanced with Finland, Germany and France entering. Hybrid geothermal-fossil (natural gas) district heating is tried in the Paris region.

**Solar thermal technologies** (solar low temperature water heaters) contribute significantly to hot water production, but are also becoming an option for space heating and cooling as well as industrial processes, and are also included into local district heating schemes. By far the most new installations globally, where China is the uncontested market leader, are glazed water systems. Unglazed water systems are used mainly for swimming pool heating outside Europe and China. A tiny share is held by unglazed and glazed air collector systems. In Europe, glazed Flat Plate Collectors are by far the most common technology, different from China, where Evacuated Tube Collectors are prevalent, since they allow higher efficiency in colder conditions. For operation, thermo-syphon systems – common in China - are widespread in Southern Europe in particular Cyprus, which has the largest solar water heating capacity per capita world-wide, whereas pumped systems are especially common in Central and Northern Europe. Most solar thermal systems are used for domestic water heating, and they typically meet 40–80% of demand. There is a trend towards larger domestic water heating systems for hotels, schools, multi-family homes, and other big complexes. The use of solar thermal water collectors for space heating is also gaining ground, particularly in Central Europe, where 100% solar-heated buildings have been demonstrated (although typically solar meets 15–30% of space heating demand). Such “combi-systems”, are gaining ground in Europe (particularly in Austria, Germany, Italy, and Poland). Solar thermal can be combined with various backup heat sources, and hybrid systems with heat pumps, and become part of local district heating schemes. Advanced collectors can be used for solar-assisted district heating as well as for industrial and commercial applications with operating temperatures generally in the 60–120 °C range; they also can drive some cooling systems. An increasing number of district heating systems relies on solar thermal technology, often combined with other heat sources such as biomass, and increasingly with seasonal storage.

**Solar cooling** is a rather new technology, which is gaining ground, since cost of solar cooling kits continues to fall. This variety of thermal chillers continued to increase in 2014, as did their standardisation. In addition to new chillers, innovative technologies continue to emerge, particularly for large-scale and industrial systems. Due to improved efficiencies of chillers and increasing temperature range for solar thermal technologies, flat plate and evacuated tube collectors can drive air-conditioning and slab cooling systems in the 10 to -20 °C range, and solar concentrators such as parabolic trough and Fresnel collectors can drive refrigeration up to -20°C. \[\Rightarrow\text{Tool CE 1}\]

Concentrating solar power (CSP) systems actually are also thermal systems. They were developed principally for power generation in turbines. The solar radiation is concentrated by mirrors (parabolic trough or heliostats) and heats a medium such as an oil or molten salt, in tubes or a tower, to high temperatures, from which steam or a gas can be produced for a turbine and generator. Parabolic dishes and Fresnel concentrating systems are also in use, and used for industrial processes. In Europe, CSP systems are limited to the very southern areas in subtropical climate zones with high insolation. In addition, CSP systems need large surfaces which are not available with European city boundaries. Both conditions are different in China, in particular in cities in the Western China highland desert climate. 

Biomass. For heat purposes in urban areas, the most relevant biomass biomass for heating sources and technologies use solid biomass combusted to provide higher-temperature for use by industry, in district heating schemes, and in combined heat and power (CHP) plants as well as for use at lower-temperature heat (< 100°C) for heating water and for heating space in individual buildings. Solid biomass low temperature heat supply is traditionally strong in Northern European countries because of resource abundance but also in Western and Southern countries because of the limited heating requirements. The traditional use of split roundwood in open fireplaces is being replaced by more efficient technologies involving low temperature distribution and comfortable pellet systems. These individual technologies are, though, not promoted in densely urbanized areas, also for local air quality considerations.

District heating. For urban energy in Europe, the relevant biomass use technologies are boilers for district heating networks, where the share of heat derived from bioenergy has grown steadily in recent years. In particular in biomass rich Northern countries, biomass has become a source of choice for district heating and to replace coal in large cogeneration plants, with new 100% biomass or co-firing plants (case example Stockholm).

Waste-to-Energy. CHP has also become a technology to use heat from Municipal Solid Waste (MSW) incinerators. In spite of progress in environmental safeguards, new MSW combustion plants remain contested in European cities and recycling has reduced the need. 

Landfills. Landfills have become sources of energy, where landfill gas is captured, and in most cases used in reciprocating engines to drive small power generators, and electricity fed into the grid. When situation allows, waste heat may be injected into the district heating system.

Biogas. A similar technology is used in sewage treatment plants. Biogas produced in the sewage sludge treatment process with anaerobic digestion can produce enough energy to meet most of the electricity and heat energy needs of the sewage treatment plant itself. This technology is common in European sewage plants. Biogas from agricultural waste has become significant in Europe. Based on political support schemes it is mostly applied in small power or CHP units in rural areas, or is upgraded in quality and injected in natural gas networks.

District energy is a term coined recently as superordinate concept to include district heating and district cooling. District energy is a fundamentally urban energy technology. It is considered clean energy, if the sources are to a large part renewable or waste energy, possibly combined with natural gas and if the overall efficiency is high because of co-generation and low losses.

105 See also solid waste treatment position paper.  
District heating. The characterizing attribute of district heating is the conduct of a heat energy carrying medium in insulated pipe networks from one or many sources to many users. The common medium used for heat distribution is water or pressurized hot water, but steam is also used in DH systems consisting of feed and return lines. Originally the DH systems connected central heat providers with a multitude of buildings in dense heat demand urban areas which allowed the rapid amortization of high capital cost. In recent decades in European cities, the number and kind of sources have multiplied or diversified respectively, from fossil fired CHP and peak load boilers to heat extraction from power stations, biomass CHP, smaller CHP with district cooling facility, industrial or other waste heat, geothermal solar and thermal heat, heat pumps and other. On the downstream side, DH ends normally at the heat exchanger of the building. In some cases local heat grids are connected to the principle DH network or developed separately. Storage facilities are included which reduce the need for peak load plants and also allow a power load led operation mode of CHP. The reduction of energy demand density in cities by building and energy efficiency technology has challenged district heating distribution technology, which is very capital intensive. Apart from decentralization of heat sources and reduction of distance, the technology of low temperature district heating allows different and less costly conduct technology (see the case of Lystrup, Denmark). This may become a new additional standard. →Tool CE 1

Danish expertise in energy efficient district heating in high demand

China is the largest consumer of energy and coal in the world. The Chinese industry is based primarily on coal; the potentials for reduction of CO₂ through efficiency improvement are therefore substantial. The Chinese National Development and Reform Commission (NDRC) and China’s National Energy Conservation Centre (NECC) are in Denmark to get inspired by Danish solutions.

A large part of the potential for improved efficiency lies in the utilization of surplus heat from industries to district heating. NDRC and NECC are responsible for this focus area within Chinese energy policy, and the Danish Energy Agency (DEA) has therefore invited the delegation to Denmark to present how Denmark through decades has been improving the efficiency of district heating and industry.

Apart from the presentation of Danish experiences is the study tour part of a preparation of a Chinese/Danish pilot project on district heating in cooperation with Beijing District Heating Group DHG). The pilot project is included as a substantial part of the cooperation agreement between NECC and the Danish Ministry of Energy-, Utilities and Climate.

The inspiration for the pilot project is a project by Danfoss and COWI in the city of Anshan in north eastern China. The utilization of coal has in Anshan been reduced by extending the heat transmission system and by utilizing the surplus heat from the city’s steelwork for the supply of district heating. The project had a repayment period of around three years and it is estimated that Danfoss’ and COWI’s solution will contribute with CO₂-savings at around 240,000 tons annually.

Beijing has China’s largest system of district heating and has a long tradition of cooperating with Denmark. There is currently a Memorandum of Understanding between BDHG and Danish Board of District Heating (DBDH), and Danish Minister of Energy-, Utilities and Climate, Lars Christian Lilleholt, attended a major seminar on district heating with BDHG during his visit in China in January 2016.

Zhangjiakou north of Beijing is together with Beijing hosting the Winter Olympic Games in 2022 and will therefore be extending and upgrading their district heating system. Zhangjiakou has also by the Chinese authorities been selected for being a city of demonstration of renewable energy, which means that there are excellent opportunities for
testing new solutions. Zhangjiakou is therefore also a candidate for a Chinese/Danish pilot project on district heating.

... NECC shares this knowledge with their 1200 local Chinese centres of energy savings, thus has an extensive outreach in China.


District cooling. More recently, the district cooling concept has been developed for local neighborhoods or large complex facilities like e.g. universities with dorms or hospitals. In European climates these are fed by Combined Cooling and Heating Power Plants, i.e. poly-generating plants which allow high load factors and efficiencies. These are generally distributed generation plants involving reciprocation motors. These systems have become appropriate for climates which demand a year round cooling. ➔Tool CE 1

CHP generators, Distributed CHP generators are basically internal combustion reciprocating engines, which drive an electricity generator, and the (waste) heat of which is captured. The engines may operate with compression ignition (Diesel motors) or spark ignition (Otto motors). Such systems are available for sizes as small as 100 kW to as large as 85,000 kW (85 MW). They may be fired by biogas or biofuel instead of fossil fuels, among which natural firing is by far the least carbon intensive. Although not regarded as a clean energy source, the use of natural gas in distributed cogeneration may be considered under clean energy technologies, when it replaces not only heat from a boiler but also electricity from centralized fossil fuel power stations, and reduces the overall GHG-emission intensity in a double way: reducing losses and replacing a high emission fuel. The small capacity (micro CHP) products range around 100 kW (also called total energy systems). The technology is based on car engines. They are used internally in buildings providing heat and electricity, either for self-use or feeding back into the grid. The next range up to several MW is applicable in large residential buildings or blocks, feeding in heating and power micro grids, industry and similar. These are installed to use biogas from landfills, waste water treatment plants or agricultural plants. Finally, larger double digit capacity units or modular systems, which can attain more than 100 MW electric may be incorporated in larger power grids, providing electricity to the medium voltage level and heat to the district heating network, possibly also cooling energy. Several European manufacturers offer their specific range of products, based on their experience in engine manufacturing for cars, Lorries and ships. ➔Tool CE 1

Power generation

Photovoltaics. Within Solar Photovoltaic (PV) power, which converts light directly into electricity, technologies may be distinguished according to scale and ownership (utility solar parks, consumer and single use), base to which it is mounted (ground mounted, roof top or building integrated, individual stand alone or appliance integrated or even portable), and according to the solar cell technology. Multi-silicon has become the leading technology, replacing mono-silicon; thin film has global market share of approximately 10%. Concentrating solar PV is a niche technology. The PV system consist of the assembly of solar cells in solar modules, several modules to panels or arrays and the Balance of System (BoS), which includes all other elements including voltage inverters. In spite of the diversity and complexity, a high degree of standardization reigns in the principle technologies.

Systems suitable for cities. For urban energy, all systems are relevant, although large utility scale systems only where city boundaries include the appropriate land, which is not the case in European cities. Smaller ground mounted systems, like those called solar gardens in the US, would be possible, although the underlying third party supply option is not generally granted in Europe. Therefore, building integrated and roof mounted installations are the most
widespread in European cities. They can be found principally in commercial areas and single family housing in the less densely urbanized areas and are connected to the low voltage distribution grid. In addition, individual systems (city lighting with LED, parking meters etc.) are also widespread. ➔Tool CE 1, ➔Tool CE 2

**EU leadership.** The EU continues to lead the world in total regional operating capacity (87 GW) and in solar PV’s contribution to electricity supply. Statistics of the urban share are not available, but most of the capacity is in rural areas, roof-top as well as solar parks. In Europe roof top systems in rural areas are the mainstay, but utility size system grew faster since 2008. An analysis of German distribution grids indicates that urban grids have the lowest intensity of PV compared to load.108

**Photovoltaics in Europe.** The dynamic of new PV installation in Europe is decreasing, because of policy changes (whereas the dynamic in China is picking up due to positive policies). In 2014, the UK was still increasing the number of its installations, also for roof top and in particular flat roofs of commercial structures. Germany generated about 33 TWh with solar PV in 2014, and, at year’s end, it had the most solar PV capacity of any country by far. China, however, was moving very fast. Low module prices continue to challenge many thin film companies and the concentrating solar industries, which have struggled to compete. As costs fall, solar PV-generated electricity has become cost-competitive on a kWh base, not considering the fluctuating character, with fossil fuels without subsidies in an increasing number of countries. ➔Tool CE 1

Over the past decade, module production has shifted from the United States, to Japan, to Europe, and back to Asia, with China dominating shipments since 2009. Among the leading module manufacturers on markets in Europe there are several Chinese companies, including Trina, Yingli, Canadian Solar, and Jinko Solar.110 This indicates the global industrial standardization. Nonetheless, there are still quality concerns. Equally, inverters are being produced for the world market. Insurance companies are prepared to insure products from certified producers. ➔Tool CE 1

**Wind power.** Small wind power equipment for urban applications has not reached a maturity and noteworthy dissemination in Europe. Currently large wind power equipment offers peak capacity between 600 kW and up to 6,000 kW (6 MW) per unit. In arrays of typical 2 MW units in small wind parks these are possible within city boundaries. The European Union continues to install wind energy capacity, although less growth than in Asia, led by China. Germany and the United Kingdom accounted for 59% (46% in 2013) of new EU installations. In some countries in Europe, however, minimum distance rules from habitations like they exist in Germany make it practically impossible to install wind turbines in urban areas. In other countries on-shore wind power is specifically confined to industrial zones (Netherlands), which makes it more feasible. Shoreline cities use the opportunity to participate in close-by offshore wind installations if zoning allows (seen in Stad von de Zon, Wieringmeer, Netherlands; and Malmoe, Sweden). ➔Tool CE 1

**Hydro-power or deep geothermal power resources.** Hydro-power or deep geothermal power resources may be installed in an urban area, but this will only be applied exceptionally, in very specific situations. ➔Tool CE 1

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107 REN 21 GSR 2015
110 REN 21 GSR 2015
E-mobile charging technologies. Energy relevant standards in the transport system (see transport position paper). There seems to be standard yet for plug-in, batteries, and loading stations. Since most local clean energy concepts or programs are city specific and e-energy is bottom-up, there is no unified policy or established standard yet. There are efforts by engineering and software developers, however, to define IT planning tools and models used in urban energy planning as products. ➔Tool CE 1

4.4 Indicators

Emissions as overarching indicator. On the general level, where overall objectives are involved the most common is the GHG emission per capita, measured as CO₂ equivalent /inhabitant/year.

This indicator may be calculated in the following way:

a) over the whole chain of energy production and transformation to use (life cycle), i.e. including the emission induced in the steps of the energy chain outside of the city, or

b) only for the energy use and transformation which take place in the city.

On the other hand, GHG emission are taking place also in energy transformations (power plants) within city boundaries for the secondary energy used outside the city, and also in the production of goods and services exported outside the boundaries. Finally, the city inhabitants and actors also use imported goods and service which ‘embody’ GHG emissions. There is some value in taking into account each of these elements. Nonetheless, some are extremely intricate and time consuming to calculate. A practical manageable approach, taking into account the fact that GHG emissions are a global issue, would be a modified approach a), i.e. taking into account the GHG emissions in the whole energy chain and life cycle, but separating out the emissions caused by central power stations and large industry, which can be reported separately. This way, a policy of simply relocating a similar power stations or large industrial plants outside the city boundaries would – correctly - not count as a key measure to reduce GHG emissions.

Which method is being used to include or exclude ‘imported’ or ‘exported’ emissions, must be at least clarified in the definition of the indicator. This clarification is also extremely important for benchmarking with other cities. A good clarifying approach is the definition of a GHG emission indicator per capita for each end use sector. Residential, commercial, public may be summarized to building sector, transport and industry to be calculated separately.

Energy consumption by sectors per capita and year of a city. Similarly to per capita emissions, per capita energy consumption indicators may be used on the overall level. For these the same options are available. The same solutions are recommended. A small set of indicators of final energy consumption by sectors per capita and year of the city, which can easily be aggregated, using an energy unit like the more scientific Joule or more common units like BTU or kWh. With respect to energy indicators, some statistical issues need to be taken into account. Energy services may be calculated in engineering. However, energy statistics are based mostly on commercial energy (sales volumes) data, which are converted into energy units. Non-traded energy, i.e. some of the biomass, or solar gains or heat pumps gains should be included. This is generally achieved in European statistics of final energy demand. However, such final energy demand statistics (Gross Final Energy Consumption - GFEC) in Europe are not compiled for cities. This is different in China where such data exist. The data need to be raised and the statistics need to be calculated specifically for the energy concept and the indicators, also as a basis to calculate GHG emissions.
It is not recommended to use primary energy consumption or Gross Inland Energy Consumption (GIEC) indicators, because of misleading methods in the calculation. The primary energy data include losses incurred in transformation, in particular in electricity generation. Losses from fossil fuels pose no problem since they are real and cause emissions. The problems stem from the convention for the calculation of losses from nuclear and ‘primary electricity’ which include hydro-power, wind and solar power, which do not involve a thermal process. The IEA and EU energy statistical convention prescribes the inclusion of thermal losses ink case of nuclear power and practically no losses in case of hydro, wind and solar. This leads to the somewhat paradox result, that nuclear energy is recorded in the primary energy balance with a three times higher contribution than hydro- power even if they produce the same amount of electricity. Other conventions prescribe the calculation of hypothetical losses (similar to fossil fuel and nuclear) also for primary electricity. This method inflates numbers even further. Whatever convention is used, it is advisable to not use primary energy or Gross City Energy Consumption on the indicator level, because changes in the power sector outside the cities reach could be reflected by a significant change in the cities energy indicator, which would have little meaning in the energy concept.

Reykjavik, Island aims to be carbon neutral by 2040

“Reykjavik City, capital of Iceland and Member of ICLEI, has put forward a climate policy paper with an action plan aiming for a carbon neutral city by 2040. In Reykjavik, all electricity is produced with hydroelectric power and houses are geothermally heated. The release of greenhouse gases in Reykjavik is minor compared with international figures.

Transport is the main source of greenhouse gas emissions and is the largest challenge for the city. In the city’s Municipal Plan 2010-2030, the goal is to change travel modes so that public transport usage rises from 4% to 12% and the ratio of pedestrians and cyclists rises from 19% to over 30% in 2030.

In 2009, Reykjavik became the first municipality in Iceland to make a policy on reducing greenhouse gas emissions. In 2016, the Reykjavik City Council decided to go further and make even more ambitious goals: Reykjavik City will be carbon neutral by 2040. ‘Cities play a key role in the fight against climate change. They can react quickly and have many possibilities of enacting change,’ says Dagur B. Eggertsson, Mayor of Reykjavik.

The mayor adds that these goals for reducing green house gas emissions are in sync with what many of the world’s most ambitious cities are aiming for, but Reykjavik is in a prime position to follow through with them because of its renewable energy sources. Reykjavik began utilizing geothermal energy sources for central heating in 1930. In 1971 98% of homes were connected to geothermal water heating. Now all homes in the city and neighbouring municipalities are heated with geothermal energy.

Reykjavik’s goal is to increase the use of bicycles and buses as primary means of transport and to ensure that people have the chance of commuting to work on foot. With electric cars becoming more common, Reykjavik will increase the availability of charging stations – preferably at home, in parking garages and on specific locations within the city. These goals are intrinsically linked to urban densification which also produces opportunities for a more efficient public transport system through the use of either light railways or a bus rapid transit system.”

Objectives and indicators. Absolute reduction objectives and respective indicators (percentage of GHG emissions or total energy consumption in a city in a future year compared to a base year = 100) are acceptable in a rather stable urban entity, i.e. when population, building space or other activity factors do not change significantly over time. In view of the discussed statistical conversion issues, it is not recommended to use primary energy in the indicator. These considerations are even more relevant with respect to share indicators. In line with objectives, clean energy or of renewable energy shares in total energy aggregates are common indicators.

Renewables as indicators. RE sources’ shares in electricity generation seem relatively easy to identify and calculate. As seen above, RE shares in power generation are agreed as targets for 2020 in all EU member states. On a national scale, when almost all electricity is generated within the country with some cross-border exchange but a low net export or net import balance, this indicator is easily extracted from power generation statistics. On city level, however, the power generation may be dominated by power stations whose production is largely exported outside the boundaries. Therefore, it is more appropriate to relate the RE-based power production to the electricity consumption in the city, i.e. set the electricity consumption instead of production in the denominator. If the import of RE-based power is intended and understood as part of the objectives, this imported RE-power may be included in the numerator of the indicator.

Renewables in heating and cooling. For the reasons explained above, including the difficulties to include non-commercial energy or solar gains it is more complex to identify and calculate RE shares in heating (and cooling) energy, i.e. in the building sector. EU has developed methods to include those.

Renewables in transport. Again, calculation of RE shares in the transport sector is more straightforward.

Overall RE targets. Since EU and Member States have agreed to overall RE share targets, a convention was required on a method how to calculate and at which level to aggregate. For the reasons discussed above, the final energy consumption level was adopted instead of the primary energy level. This requires a method to recast the electricity consumption according to the generation mix, since the sources of electricity are not shown in the final energy statistics.

Distributed generation targets and indicators. When distributed generation including RES is matter of the target as in case of London, a straightforward indicator is the share of non-central generation in total electricity. For the same reasons discussed above for RE-shares it is more appropriate to use the city’s electricity consumption in the denominator than production. In the numerator of the indicator All electricity generated in CHP power stations,
self-generated by consumers or in renewable energy plants within the city boundaries could be considered as distributed or non-central generation, and added up in the numerator.

Another indicator would be the share of distributed clean energy production in the heating sector. To become a meaningful indicator, only the heat (and cold) generated in—clean - CHP plants or renewable heat would be included. Obviously, in any case for large complex entities, baseline values of the indicators for a recent year are required, and feasibility and ambition of potential future targets should be assessed in scenarios.

**Other indicators.** With respect to non-energy objectives on the general level, many more corresponding indicators are used; for air quality, job creation, etc. On a disaggregated level and for district or community projects, where building energy efficiency and low or zero fossil energy supply are part of the objective set, per floor area indicators become relevant and more appropriate than per capita indicators. These can be used also for new developments, for which baselines cannot be established, and are also appropriate for rehabilitations, where additions and demolitions changes of use are planned. When the structure and use remains basically the same, however, it is even very important to do an ex ante base line in order to be able to assess the success ex post.

In the absence of baselines, ambitious building energy standards, e.g. low-energy or passive-house standards are used as a benchmark to develop the project indicator, considering standards from other countries, if not available nationally. These are stated in the form of energy requirements per area per year (e.g. kWh/m²/a).

Traditionally, these requirements include the heating (and/or cooling) services only. Some clean energy concepts have included the total active energy use within the building, including the electricity consumption for appliances etc. in the indicator.

When engineering indicators are used, it is important to consider, that real life consumption almost always differs from the calculation. It must be expected, that the engineering indicators are missed regularly. This may be cause by the so-called rebound effect, which captures the experience that energy users behave differently in low energy buildings or using high-efficient appliances. The economic explanation is that the low marginal cost of increasing the energy service, for example heating a room somewhat longer and better, lead household to increase their comfort or be less careful.

Therefore, some measure of comfort should be included in the indicator sets.
4.5 Planning Models and Modeling Tools and Software

A number of current modeling approaches is provided and applied including both optimization and simulation models in Europe. In the thematic background, the principle features were already discussed. Some selected tools are presented here, both for integrated planning as well for specific object project planning, simulation tools as well as optimization tools.\(^{111}\)

**BHKW-Plan.** The BHKW-Plan (decentralized-CHP Plan) was developed by the Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW) (=centre for solar energy and hydrogen research) and the Institute of Technical Thermodynamics of the German Aerospace Centre (DLR). Further development is provided by the engineering office Steinborn Innovative.\(^{112}\) The software tool BHKW-Plan uses a data driven approach to estimate load profiles for typical building types which are put together in total sum of square meters to represent the demand side excluding spatial information. The overall system description, however, follows a steady-state forward approach. System losses are considered as the main focus of the tool is the assessment of district heating systems represented by the length of distribution lines. Solutions implementing CHP units are compared with central boiler systems only. To overcome this limitation a mayor update is currently under development to integrate individual heating systems. A simplified estimation of solar thermal potentials is included as well. Strength of the model is the economic assessment including the possibility to integrate various tariff systems adapted to the German regulation on feed-in tariffs (KWKG and EEG) but can be changed to represent different offers in the market. BHKW-Plan is a simulation tool. The system is based on Microsoft Excel and delivers the output files in the same format.

**CitySim.** The CitySim is a detailed bottom-up simulation program for simulating and optimizing the environmental sustainability of urban developments of various scales; from a small neighborhood to an entire city. It is developed and maintained by the Solar Energy and Building Physics Laboratory of the Ecole Polytechnique Federal de Lausanne.\(^{113}\) It currently focuses on simulating the demand of and storage and supply of energy to buildings in the urban context. For this the user prepares a 3D description of the urban scene under investigation, either using native 3D modeling tools or by importing 3D geometry prepared using 3rd party software. The buildings in this scene are then attributed according to their envelopes’ thermal and optical properties; parameters effecting the presence and behavior of occupants; the parameters describing embedded HVAC (in the case of mechanical ventilated buildings) and energy conversion systems (which may also be district-wide). This scene description is then parsed to a unique solver. This solver predicts the (sub-)hourly thermal and electrical energy consumption of each building within the development, accounting for: (i) occupants’ stochastic presence and behavior, (ii) the occlusions of adjacent buildings and ground to the sun and sky and their contribution to receiving surfaces’ reflected radiation, (iii) occlusions to the sun and sky from far-field obstructions such as mountains, (iv) the storage and supply of heat, (v) the supply of energy from a range of (non-)renewable energy conversion systems, etc. The CitySim may be coupled with a multi-agent transport simulation program called MATSim, It has also been combined with EnergyPlus, the building energy simulation program supported by the US DoE.\(^{114}\)

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112 Additional resources [http://www.bhkw-info.de/bhkw.html](http://www.bhkw-info.de/bhkw.html)
113 For more information see [http://citysim.epfl.ch/](http://citysim.epfl.ch/)
EnerGIS. Building on the work of the AGS Tokyo, the EnerGIS has been developed in France at the École Polytechnique Fédérale de Lausanne, at the Laboratory for Industrial Energy Systems (LENI). EnerGIS uses a classification of building types per use and building age to aggregate surfaces per area defined in a coupled GIS system. Energy requirements are based on measured data or in cases where no measured data is available. By an estimation of the heating system the model extrapolates temperature levels and compares composite curves for districts.

GOMBIS. The overall optimization model on the basis of an integrated system simulation („Gesamt Optimierungs-Modell auf der Basis einer Integrierten Systemsimulation“ - GOMBIS) was developed by Saadat, Korb Systemtechnik, Berlin. Despite its title the tool provides a comparison of different scenarios simulating the supply of a calculated demand using different supply options rather than performing an integrated optimizations procedure. The general purpose is to assess economic as well as environmental effects of CHP solutions and renewable energies as solar thermal and biomass in comparison to conventional supply options (reference case). The economic benefits can be assessed either from the perspective of end consumers, of contractors or of energy supply companies; therefore GOMBIS also seems a practical solution for the design of contracting schemes.

URBS (Polis). The model URBS (Polis) was initially developed by the Max-Planck-Institut für Plasmaphysik (IPP), Garching, Germany. An improved version is used by GEF Ingenieure AG, Leimen In the description of energy demand URBS uses a top-down approach distributing energy demand to representative hourly values, thus a data driven approach is taken. In four modules included in the model the urban development module describes a possible future development that is included in the scenarios. Eventually a linear optimisation is run based on
the energy demand and supply module. The mentioned urban development module delivers the boundaries. The model optimizes either costs or emissions. It is also used by the US Army to plan energy systems for barracks.\(^{115}\)  

**RETScreen.** The RETScreen Clean Energy Project Analysis Software is a decision support tool developed through the collaboration of numerous experts from government, industry, and academia. The software can be used to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). The software also includes default data representing product, project, hydrology and climate conditions. Technologies utilized within RETScreen include solar thermal, PV, heat pumps, cogeneration, district heating and cooling, refrigeration and many others.\(^{116}\)  

**GEMIS.** The Global Emissions Model for Integrated Systems (GEMIS). This system is a analytical tool, but also useful for urban systems.\(^{116}\) IINAS is the host of GEMIS (Global Emissions Model for integrated Systems), a public domain life-cycle and material flow analysis model and database that IINAS provides freely. GEMIS was first released in 1989, and is continuously updated and extended since then. It is used by many parties in more than 30 countries for environmental, cost and employment analyses of energy, materials and transport systems. IINAS continues networking with GEMIS users on the international level, and extending and improving the model, and its database.\(^{116}\)  

**New Tools under Development**  

**SimStadt** is the name of a new urban simulation environment, that will be developed until December 2015 within the project of the same name, involving HFT, Stuttgart, University of Nottingham, and the GEF engineering consultants. The goal of this urban simulation environment using virtual 3D city models is to carry out a variety of energy analyses for city districts, whole cities or regions. From heating demand diagnosis, to photovoltaic potential, via the simulation of building refurbishment and renewable energy supply scenarios, this urban simulation environment aims at assisting urban planners and city managers with defining and coordinating low-carbon energy strategies for their cities.\(^{116}\)  

**UMEM.** On the research stage, Urban Multiscale Energy Modelling (UMEM) is revisited for applications in retrofitting clusters of existing buildings, which is a key issue for sustainable cities and urban energy systems in Europe, using also energy from new buildings. New positive energy buildings provide energy production for the entire city quarter, while retrofitted buildings with renewable energy production limit their energy consumption and provide sufficient energy storage for temporal mismatches between energy production and consumption. The new urban energy retrofit scenarios’ have to take into account the impact of the urban heat island effect and the changing urban microclimate (e.g. heat waves) due to climatic change. The new concepts have to guarantee sustainable living conditions, comfort and health for their inhabitants in the urban and building environment.\(^{116}\)  

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\(^{115}\) For more information see [http://www.ccem.ch/science/umem](http://www.ccem.ch/science/umem)

\(^{116}\) For more information see [http://www.iinas.org/gemis-download-en.html](http://www.iinas.org/gemis-download-en.html)
ISIS. Furthermore, ISIS: an Integrated Semantic Information Model as a planning tool is developed by the Karlsruhe Institute of Technology. The idea is to provide tools which, from the earliest point possible, incorporate all aspects concerned with cities and energy as dynamic and highly emergent systems. Unlike with traditional geographic information systems (GIS), it should be possible to manage both explicit spatial information and intelligent semantic data. In addition to building energy data, it includes topologies for the integrated representation of municipal transport and utility networks, as well as information on the stakeholders in the systemic "city+energy" structure (consumers, users, suppliers, etc.).

HYPV. Still under development, is a Hybrid Heating and Power System Planning (HYPV) tool, which will respond to the increasing need to consider heating and cooling energy for urban quarters jointly with the electricity distribution system, which materializes already in urban micro-grids and virtual power station concepts. The concept is under development in Konstanz Germany by the HYPV consortium with funding from Federal Government. The conceptual scheme is presented in schematic diagram below. The colors represent heat (red), natural gas (yellow), electricity (blue) in supply and the mix in the building energy technologies including simple and combined technologies, including heat pumps, CHP and solar heating.
Hybrid Heating and Power System Planning tool

Note: HYPV uses a linear and nonlinear optimization model and process, in order to plan and implement hybrid network.

4.6 Evaluation Methodology

An objective system with appropriate quantitative measurable indicators is fundamental for monitoring within the energy concepts and programs. These need to be formulated for Intermediate milestones and not only for the end point. This way, the monitoring can rely on rather objectively verifiable data. External evaluation by regional or national authorities during project operations and ex post are desirable, but not always performed. In many of the pilot cases financing from higher level national budgets or national or EU funds or programs is involved, in which cases evaluation is the rule. These programs generally do have monitoring and evaluation procedures.

In addition to the quantitative data-based evaluation based on the indicators, other methodologies including interviews are employed to register the satisfaction of the concerned people. In addition to representatives and observers of the projects with the authorities and other stakeholders, structured interviews are conducted with inhabitants and observers. Such interview based evaluations help to get a deeper understanding of factors of failure and success and help improving the respective energy concepts and provide lessons learnt. In cases of long term comprehensive sustainable energy strategies, it is indispensable to revised the whole analysis and planning after a decade or so. This will not only allow adjustments because of progress diversion, but it allows including new external developments. As can be seen in case of distributed generation, innovation and cost-reduction of renewable energy technologies, storage technologies as well as information and communication control technologies, there are new opportunities and possibly also threats coming up, which may require revisions of strategies. EU and national finance programs require ex ante specified commitments, for which monitored, measured and verified (MMV) indicators for a future state or minimum standards are defined. Some groups like the Covenant of Mayors require the
subscription to a generic objective and to an action programme as an entry commitment. On
the contrary, some initiatives and award programs use a quality control and certification
process of the current situation and process. That is the case e.g. for the European Energy
Award which has two levels of certification. For rating, the EEA uses a point-system applied
by experts.\textsuperscript{120}

\section*{4.7 Lessons Learnt from pilot projects}

General lessons learnt over all the divers types of projects relate primarily to principles of
leadership, organization and processes.

In abstract terms, the obvious sequence must be: setting vision - analysis of status, future
development and potentials, scenarios – adopt goals and indicators for milestones in the
timeframe, – elaborate strategy and lines of action – implementation through policies and
projects– monitoring. A periodical updating and revision is recommended for long term
concepts and some flexibility to react to opportunities and threats.

More specific institutional and organizational success factors:

\begin{itemize}
  \item Political commitment at the highest level for the respective type of concept, e.g. the
        Lord Mayor for a comprehensive city plan;
  \item Strong commitment, capacity and competences on the management level, held or
        supported by the administrative authorities, all concerned departments;
  \item Coordination with national or provincial goals and programs;
  \item Cooperation, partnerships with other cities;
  \item Information, transparency and involvement of concerned and interested citizens;
        planning tools should public display; good communication;
  \item Inclusion of stakeholders; good coordination with energy utilities, equipment
        manufacturers, building and equipment trades, collaboration with commercial,
        industrial economic and financial actors; possibly in joint organization or public private
        partnership; and
  \item Involve local planning, engineering, technology and social expertise, research and
        higher education, Universities and Institutes and assure knowledge transfer.
\end{itemize}

Principles. As a guiding principle for the conceptualization of the specific energy approach:

\begin{itemize}
  \item \textbf{Study bottom up and address efficiency first}: starting from services provided with
        energy (domestic, commercial, public related to buildings; transport services; industry
        production), provide these services and products with little (active) energy supply
        needs. Focus on urban design, building and appliances technology, transport
        technology and modes, industrial process technologies (these are subject of other EC
        link Position Papers);
  \item \textbf{then consider clean energy technologies} (renewables, cogeneration, waste heat)
        on the potential levels - decentralized within/on top of buildings; mini grids, centrally
        supplied by grids from plants within city, including industry, power plants, waste water
        and municipal waste; and
  \item \textbf{acquire clean energy from outside} city boundaries.
\end{itemize}

The technology lessons learnt are rather more mixed:

Effective absolute energy savings and reductions are more difficult to attain than expected,
because of rebound and other effects. Nonetheless, energy efficiency is increased taking into
account the higher level of energy services provided. Therefore, energy reduction indicators

\textsuperscript{120}http://www.european-energy-award.org/fileadmin/Documents/Download/eea-optimising-activities-2012.pdf
should be formulated less ambitiously, but other wellbeing or activity indicators included in order capturing the higher energy service level.

**“Dutch Parliament Votes to Shut Down All Coal Plants.”**

The Dutch parliament voted Thursday to shut down its entire coal industry. The move is needed in order for the country to meet its 2030 goal to reduce carbon emissions by 55 percent. The action would put the Netherlands in position to achieve the goals of the Paris climate agreement. The 77 to 72 vote, while non-binding, comes on the heels of a recent confidential study, leaked to the Dutch newspaper Trouw, that one or more plants would have to be closed. The country has five coal plants currently in operation, including three that just came online last year. A recent five percent increase in emissions has been linked to its newest plants. In June, 2015, a court in The Hague ordered the Dutch government to cut its emissions by 25 percent within five years. The unprecedented ruling came in a case brought by the Dutch Urgenda Foundation. In a transcript from the reading of the verdict, the court said: "The state must do more to avert the imminent danger caused by climate change, also in view of its duty of care to protect and improve the living environment." … 

[T]he consulting firm CE Delft said that the Dutch government would need to quickly close one or two power plants to meet the court's order. They concluded that closing the plants would impose lower costs to society than other alternatives to achieve the court-imposed emissions target. The report estimated that the average household would save 80 Euros ($90 at current exchange rates) a year, against costs of 30 Euros ($34). The Dutch economic ministry estimated that the cost of closing all the country's coal plants by 2020 would total 7 billion Euros ($7.9 billion).


**UK unveils coal phase out**

“Business Green is reporting that Britain’s … government just unveiled plans for its phase out of coal, and new investments in renewables. Here are some of the details:

—The government reaffirmed its commitment to domestic climate goals;
—It promised £730m of annual support for renewable electricity generation over the course of this parliament;
—It appears the government is still committed to phasing out all remaining coal plants by 2025 at the latest.

All of these commitments are important steps in the right direction. At some point, renewables will simply be too competitive to derail. The work continues to get there fast enough."
UK Solar Beats Coal Over Half a Year

“Saturday, April 9 was the first-ever day where more electricity was generated in the UK by solar than by coal. May 2016 was the first-ever month. The three months from June through to September was the first-ever quarter. And now the six months to September is the first half year.

The UK's pioneering community energy project, Westmill Solar Park and Wind Farm in Oxfordshire, England. Richard Peat via Flickr (CC BY-NC-ND)

These firsts reflect the changing face of UK electricity supplies, with solar capacity having nearly doubled during 2015. They also reflect historic lows for coal-fired generation, driven by changes in wholesale energy markets and the carbon price floor. Carbon Brief runs through the numbers.

**Solar Six Months.** The UK’s solar panels generated an estimated 6,964 gigawatt hours (GWh) of electricity during quarter two (Q2) and three (Q3) of 2016, from April through to September. (See note below regarding data sources and methodology). The solar output was equivalent to 5.2 percent of UK electricity demand for the half-year period. It was nearly 10 percent higher than the 6,342 GWh generated by coal, which covered 4.7 percent of demand. Starting on July 1, there were 10 straight weeks when solar output exceeded that from coal. Solar output is strongly affected by the UK’s seasonal cycle. Roughly three-quarters of annual UK solar power is generated during the sunnier half-year from April to
September. In contrast, coal generation tends to increase in winter when electricity demand peaks.”


Innovation and cost reductions have allowed faster implementation progress for renewable energy and distributed generation than expected in the past. Technologies associated to these including storage, and progress in application of information, control and communication technology are enhancing opportunities for clean energy.

The skepticism towards clean energy as a principle concept for urban energy, based on fears of high cost and reduced security, has been greatly diminished in Europe.

4.8 Outlook

Clean energy will advance more and broadly in European cities. City governments embrace the concept of responsibility in climate protection, also because they can see the co benefits for quality of life and other key factors for the cities’ development.

EU must shut all coal plants by 2030 to meet Paris climate pledges, study says

“Europe will vastly overshoot its carbon emissions target for coal unless it closes all 300 power stations, says thinktank Climate Analytics … The European Union will “vastly overshoot” its Paris climate pledges unless its coal emissions are completely phased out within 15 years, a stress test for the industry has found. Coal’s use is falling by about 1% a year in Europe but still generates a quarter of the continent’s power – and a fifth of its greenhouse gas emissions…

The Belchatow power station in Poland is Europe’s largest coal-fired power plant. Photograph: Kacper Pempel/Reuters

If Europe’s 300 coal plants run to the end of their natural lifespans, the EU nations will exceed their carbon budget for coal by 85%, according to a report by the respected thinktank Climate Analytics. It says the EU would need to stop using coal for electricity generation by 2030. “Not only would existing coal plants exceed the EU’s emissions budget, but the 11 planned and announced plants would raise EU emissions to almost twice the levels required to keep warming to the Paris agreement’s long term temperature goal,” said Dr Michiel Schaeffer, Climate Analytics science director. The report will feed into
a review of the EU’s Paris targets next year, which could see the bloc's planned emissions cuts raised significantly, in line with an aspirational 1.5C goal agreed at Paris. …”

The distributed generation will become more and more common, which will disrupt fundamentally the operational pattern of electricity supply, in particular on the low voltage level, integrating power production by consumers (‘prosumers’) with mini-grids, storage, flexibility. If in the past, energy for heating services was the main concern and district heating expansion and refurbishment was the pivot factor in clean energy concepts, in the future the new electricity system will be the main and disruptive innovation sector.

It is therefore recommended to immediately ‘leap frog’ to hybrid heating, cooling and electricity planning and implementation concepts121, where both areas of building energy services are considered jointly, and strong interrelations to transport electrification as well as industrial development are be taken into account.

China is fueling a global decline in new coal power projects

“China's stronger environmental policies and weaker economic growth are driving a global decline in coal-fired power projects, a new report found. Since the start of this year, the world has seen a 14 percent drop in the total amount of coal-fired power capacity in early planning stages, from 1,090 gigawatts globally to 932 gigawatts in July, according to CoalSwarm, a group of climate activists and data experts that tracks almost every coal power project worldwide. China accounted for nearly three-fourths of the canceled capacity, scrapping 114 gigawatts in pre-construction projects over the seven-month period, CoalSwarm reported on Sept. 7, [2016].”


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Coal-fired power plant in Germany.

Image: PATRIK STOLLARZ/AFP/Getty Images
Four lessons from Europe’s climate leaders

“What do Europe’s leading cities have in common when it comes to cutting greenhouse-gas emissions? ..

1. Look for partnerships. Local authorities can’t do it alone. That’s evident in the way Amsterdam is working to achieve its sustainability plans. The city is systematically seeking agreements to reduce carbon emissions with industries, supply-chain managers and real estate developers, as well as bus and taxi companies. …

2. Make it convenient to go green. Making climate-friendly choices shouldn’t have to be an alternative lifestyle. Smart cities are making it easy for residents to do the right thing. That’s the philosophy in Rotterdam, where a programme called Power Surge strongly encourages residents to switch to electric cars. Rotterdam already provides 2,000 charging stations for electric vehicles, and is adding 2,000 more. As one added inducement, the city offered free parking permits for the first 1,000 vehicles to register for the programme. As another, electric car owners get a free charging point from the city.

3. Reuse energy and natural resources. Waste nothing. That’s an attitude some European cities have adopted to reduce the energy used in heating buildings — especially in cities fortunate enough to have district heating systems that deliver heat to buildings through networks of pipes. (Some cities also offer district cooling.)

Stockholm has a vast district heating system with nearly 3,000 kilometres of underground heat pipes that supply four-fifths of the city’s heating needs. The system captures waste heat from power plants and industries and shares it with homes and more than 10,000 large buildings. … District heating is integral to Rotterdam’s plan to eventually phase out natural gas and reduce carbon emissions. The city is committed to getting 40 percent of its residents on district heat by 2020 and aspires to have 50 percent connected to district heating by 2035.

4. Stress economic payoffs and quality-of-life benefits. While it’s easy to dwell on the calamitous impacts of climate change in terms of rising seas and severe weather, smart city leaders stress the positives. There are economic and other opportunities in pursuing these kinds of local climate solutions. Since 2009, Copenhagen has not just been narrowly focused on cutting carbon dioxide emissions. It has instead been determined to show the world that it is possible to combine growth, development, and quality-of-life improvements with radical reductions in emissions. Thus the city’s plan is to become greener, more efficient, more liveable, more competitive, and more prosperous. A drive to make the city carbon neutral by 2025 is framed as an effort to create new jobs, innovation, investment in green technologies.”

Enhancing the European energy sector goals. In light of the slack performance of some of the EU countries, the EU Parliament wants to accelerate the energy reform process: “The European Parliament wants production of energy from renewable sources between 2020 and 2030 to meet more ambitious goals than those suggested by the executive in Brussels. Renewable-energy production will be key to ensuring that the European Union itself complies with the UN-sponsored Paris Agreement, the first universal and legally binding global climate deal. While the European Commission wants production of at least 27% of energy in 2030 to come from renewable sources, a final report by the MEP in charge of this matter, Spaniard

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José Blanco, raises this figure to 35%, and asks to restore binding national targets. In what direction does a Europe that proclaims itself a world leader against climate change want to head? Does it want to drift along on the issue of renewable-energy production, or does it want to set itself ambitious goals that will entail greater effort? This, in a nutshell, is what the EU must now decide. … The union is now working on the regulations that will set clean-energy goals for 2030, since the 2020 targets – reaching 20% of energy from renewables – are already in place. The final document is expected to be ready and approved by the summer of 2018. Negotiations are three-way, between the EU Commission, the Parliament and the governments of the various member states. After signing the Paris Agreement in 2015, Europe already knows where it needs to be by 2030: it must have achieved a 40% reduction in greenhouse gas emissions, which scientists agree are responsible for global warming, down from 1990 levels. The next step is to define the instruments to reach that goal. And the energy sector is key in this respect. Late [in 2016], the European Commission presented its so-called Winter Package, a proposal for an energy directive for the 2020-2030 period. This package of measures stated that production of at least 27% of energy should come from renewable sources by 2030. But environmental groups and the renewables sector complained that this goal lacked ambition. These critics said that the EU was just drifting along on clean-energy issues, and even stepping on the brakes when it comes to encouraging clean energy, which is becoming increasingly competitive as demonstrated by an electricity auction held in Spain this past Wednesday. Between 2004 and 2015 (the last year with final Eurostat figures), the percentage of renewable-energy consumption grew from 8.5% to 16.7%. An official report by the EU Commission admitted that, simply by maintaining the current situation without introducing any additional measures – business as usual – by 2030 Europe will have reached 24.3% of renewable energy over final consumption. And that is without taking into account technological advances that are considerably reducing the costs of wind and solar energy, year after year. The report … proposes raising the 2030 goal to 35%. The report will now require approval by the EU Parliament’s energy committee and by the plenary session. Parliament sources said that in any event, the final proposal will be more ambitious than the Commission’s original goal. A year ago already, the EU Parliament said that this goal should be at least 30%.”

The grand vision for cities. Obviously, the most logic conclusion is the emerging vision of a city that produces more energy than it uses.  


5. PERSPECTIVES FROM CHINA

5.1 Sector Context and Policy Analysis

In the fight to avert runaway climate change, no country is more important than China, and nowhere in China is more important than its booming cities. So it’s good news that some of China’s biggest cities have committed to peak their greenhouse gas (GHG) emissions before China’s national goal of 2030. In early 2017, it became known that “the Chinese government ordered 13 provinces to cancel 104 coal-fired projects in development, amounting to a whopping 120 gigawatts of capacity in all. To put that in perspective, the United States has about 305 gigawatts of coal capacity total” … Because China is such a behemoth, its energy decisions absolutely dwarf anything any other country is doing right now. Case in point: Over the weekend, the Chinese government ordered 13 provinces to cancel 104 coal fired projects in development, amounting to a whopping 120 gigawatts of capacity in all. This move also shouldn’t come as a big surprise. In recent years, China, the world’s largest emitter of carbon dioxide, has been making major to restrain its coal use and shift to cleaner sources of energy. When Donald Trump and other conservatives in the United States complain that China isn’t doing anything about climate change, they simply haven’t been paying attention. … Back in 2013, China was using as much coal as the rest of the world combined, and it looked like coal use would keep growing astronomically forever. Local officials were planning hundreds of new coal plants as demand looked like it would keep soaring for decades. Except then an odd thing happened. Since 2013, China’s coal consumption has actually fallen — due in part to a major economic slowdown but also in part to sluggish output in heavy industries like steel and cement that have traditionally accounted for half the country’s coal use. (The usual caveats about China’s murky energy statistics apply.)

![China's declining coal consumption](chart.png)


126 "To put that in perspective, the United States has about 305 gigawatts of coal capacity total. The projects that China just ordered halted are equal in size to one-third of the US coal fleet. If the provinces follow through, it’s a very, very big deal for efforts to fight climate change." Source: Plumer, B. 2017. China’s war on coal continues — the country just cancelled 104 new coal plants. 17 January 2017. Vox.com. [http://www.vox.com/energy-and-environment/2017/1/17/14294906/china-cancels-coal-plants](http://www.vox.com/energy-and-environment/2017/1/17/14294906/china-cancels-coal-plants)
Increasingly, many analysts suspect that this slowdown in coal consumption is a lasting shift — particularly as China transitions away from heavy industry and investment-driven growth and into a modern service-oriented economy that’s far less carbon-intensive. Going forward, China’s economy is expected to be focused more on retail shops and hospitals, less on steel and cement plants. Energy demand will slow.

On top of that, as China’s leaders start to take global warming seriously, the country has been making massive investments in clean energy. As part of the Paris climate deal, China has pledged to get 20 percent of its energy from low-carbon sources by 2030. The government is planning to install an addition 130 gigawatts of wind and solar by 2020 and making big bets on nuclear power. Some analysts suspect this growth in clean energy could be sufficient to satisfy much of the future growth in household electricity demand.  

China has become a global leader in renewable energy. The share of renewables in China’s final energy mix status was 13% in 2010, including an estimated 6% traditional use of biomass, and 7% modern renewables. Hydroelectricity (3.4%) and solar thermal (1.5%) accounted for most of China’s modern renewable energy. Since 2010, wind power capacity has grown extremely fast and its generation contributes approximately 1% to final energy. Solar power has remained behind. Only recently, utility scale solar parks have been multiplied and growth is fast, although from a very small base. Roof-top solar PV is not yet widespread, but government supports initiatives to tap this option as well.


Rooftop solar installation in Shanghai.

Photo by TheClimateGroup/Flickr

With respect to sectors, renewables are traditionally important for the building heating sector, for which IRENA estimates for 2010 a share of 16% specifically for heating and also 16% for all final energy in buildings in China, including electricity and district heating and the shares of renewables in their generation.\(^{129}\) This high share is due to the high utilization of biomass, traditional and modern, and also biogas in rural and peripheral urban residential buildings. The solar thermal installations, which are also very common on urban buildings, also contribute significantly. China has the largest solar thermal capacity in the world, accounting for two-thirds of the total global capacity.\(^{130}\) All of this capacity is located in the building sector.

The modern urban buildings in the cold regions of China were traditionally heated from coal fired boilers connected through district heating. This emission intensive technology was replaced in many cities and district heating was expanded and in connected and supplied from power plants with cogeneration (more than half) and in many cases fed from surplus heat from industry. This has led to a strong reduction of GHG emissions per capita in the respective cities.\(^{131}\) The reduction however is limited when the cogeneration plants are coal fired. Switch to natural gas or renewable energy or waste energy co-firing is yet not very significant. Some decentralized Combined Cooling and Heating Plants (CCHP) were installed.\(^{132}\)

According to the Asian Green Cities index study, energy consumption and CO\(_2\) emissions are still critically high in Chinese cities. The majority of Chinese cities have relatively high CO\(_2\)

\(^{129}\) IRENA, REmap China, tables in annex. op. cit.
\(^{130}\) REN 21 Global Status Report 2014.
\(^{131}\) See the analysis by Dhakal, S., Urban energy use and carbon emissions from cities in China and policy implications, in: Energy Policy, Volume 37, Issue 11, November 2009, Pages 4208–4219
\(^{132}\) Concentrated on large complex facilities such as universities, hospitals, commercial centers or data centers in Beijing, Shanghai, Nanjing and others, See the 2014 presentation by China, [Link](http://nautilus.org/wp-content/uploads/2011/12/AES_2005_China5e.pdf)
emissions per capita, and Beijing, Guangzhou, Nanjing, Shanghai and Wuhan are among the highest in terms of energy consumption per US$ of GDP.  

**Legal Basis.** Relevant legal documents for the sector are laws and guidelines of the Ministry of Housing, and Urban-Rural Development (MoHURD), particularly those pertaining to eco-city development:

- **Land Management Law. 1998.** And based on the law, the detailed Enforcement Regulation has been developed, and undergone revisions for several times. The latest is the 2014 version.
- **Environment Protection Law. 1990.** Latest revised in 2014 and applied since 2015.
- **MoHURD. March. 2013.** The 12th 5-Year Plan on the Green Building and Green Ecological Districts.
- **State Council. April, 2015.** Suggestions on Enhancing Eco-civilization.
- **CCPCC and State Council. 2016.** The thirteenth Five-Year Plan (2016-2020)

The relevant legal reference documents related to the energy sector are:

- **National Energy Administration. 2012.** Notice of 12th Five Year Plan on Development of Biomass Energy.

**Policy Direction from the 13th Five Year Plan.** The Government’s pronouncement of the Five Year Plan objectives has stated several key objectives for the energy sector:

- Increased efficiency of energy resources development and utilization; effective control total aggregate of energy and water consumption, construction land, and carbon emissions. The total emissions of major pollutants shall be reduced significantly.
- Pilot projects will be introduced to promote comprehensive use of combined heat and power, the wide-spread adoption of energy saving regulations in government agencies, and of municipal green lighting and other urban energy saving projects.
- Technical specifications for the safety of heat supply will be introduced, as well as strengthened regulatory frameworks supporting urban energy savings, environmental protection and improved sanitation.
- Related service quality standards and evaluation methodologies will be optimized.
- Consumption-based billing for residential households will be promoted nationally, and all newly built residential buildings will need to be equipped with meters for heating, while existing buildings will be gradually retrofitted to reach 100% metered heat provision.
- Support reduced emission standards, and implement demonstration projects of "near-zero" carbon emission.

The 13th Five-Year-Plan on energy development raises its low carbon ambitions with the most far-reaching aims yet.  

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133 Asian Green City Index, Assessing the environmental performance of Asia’s major cities; A research project conducted by the Economist Intelligence Unit, sponsored by Siemens; [http://www.siemens.com/entry/cc/features/greencityindex_international/all/en/pdf/report_asia.pdf](http://www.siemens.com/entry/cc/features/greencityindex_international/all/en/pdf/report_asia.pdf); Unfortunately, energy intensity is calculated per unit GDP in current prices which reduces comparability of cities from different countries.

Figure 5: Energy Sector Investment Demand Estimate in the 13th Five Year Plan (2016-2020)


China’s 13th Five-Year Plan for energy

The table below illustrates the numerous 2020 targets already declared by the Chinese government through its Strategic Energy Action Plan (2014-2020) and its national 13th Five Year Plan. They are set against actual levels at the end of 2015 as a benchmark. The comparison serves as a basis to gauge if the Energy 13FYP is sufficiently ambitious to meet China’s domestic and international commitments.

It should be noted that what is currently known about the targets in the Energy 13FYP is based on media reports and publicly available information. It is subject to change depending on ongoing internal consultation and negotiations among policy makers.

<table>
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<tr>
<th></th>
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<tbody>
<tr>
<td>Energy Consumption Cap</td>
<td>about 4.8Gtce</td>
<td>5Gtce</td>
<td>no more than 5Gtce</td>
<td>4.3Gtce</td>
</tr>
<tr>
<td>Coal Consumption Cap</td>
<td>4.2Gt</td>
<td>N/A</td>
<td>less than 4.1Gt</td>
<td>3.96Gt</td>
</tr>
<tr>
<td>Energy Consumption/GDP</td>
<td>N/A</td>
<td>-15% from 2015 level</td>
<td>N/A</td>
<td>-18.2% from 2010 level</td>
</tr>
<tr>
<td>CO2 Emissions/GDP</td>
<td>N/A</td>
<td>-18% from 2015 level</td>
<td>N/A</td>
<td>-20% from 2010 level</td>
</tr>
<tr>
<td>Coal in primary energy consumption</td>
<td>62%</td>
<td>N/A</td>
<td>58%</td>
<td>64%</td>
</tr>
<tr>
<td>Non-fossil fuel in primary energy consumption</td>
<td>15%</td>
<td>15%</td>
<td>more than 15%</td>
<td>12%</td>
</tr>
</tbody>
</table>

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<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>200GW</td>
<td>N/A</td>
<td>210-250GW</td>
<td>129GW</td>
</tr>
<tr>
<td>Solar</td>
<td>100GW</td>
<td>N/A</td>
<td>110-150GW</td>
<td>43GW</td>
</tr>
<tr>
<td>Hydro</td>
<td>350GW</td>
<td>N/A</td>
<td>340GW</td>
<td>320GW</td>
</tr>
<tr>
<td>Nuclear</td>
<td>58GW</td>
<td>N/A</td>
<td>58GW</td>
<td>26GW</td>
</tr>
</tbody>
</table>

[Link to CarbonN.org news article about 40 countries committing to 100% renewable energy production]  
From this comparison, it is clear that most of the targets in the Energy 13FYP will not be entirely “new”. Many of them are well in line with existing thinking embodied in previously announced policy items, in particular the Strategic Energy Action Plan (2014-2020), which, at the time of its publication, was already considered ambitious curbing coal consumption and CO2 emissions beyond international expectations. Yet it is still noteworthy that policy makers seem to be even more determined to squeeze coal’s share in the country’s energy mix, lowering its 2020 percentage in primary energy consumption from 62% to 58%, and capping its consumption at 4.1 Gt (which means roughly at 2014 levels).

The country is also aiming higher for its renewable energy sector, even though different information sources differ on the scale of upward adjustment... [W]ind and solar installed capacity should reach 210GW and 110 GW respectively by 2020, higher than what was declared at the end of 2014. Those numbers seem to have grown even further to 250GW and 150GW in the most recent information released by the Economic Reference.

**Between the lines.** Media reports about the Energy 13FYP also reveal deeply rooted concerns that have troubled Chinese policymakers:

1. **Overcapacity:** China’s power sector is faced with a severe overcapacity problem. Slowing demand for electricity due to the economic downturn and slashing of energy intensive industries has caused widespread under-utilisation of existing power generation capacities, which are seeing their lowest utilisation hours since 1978. Yet the country is still seeing fast build-up of coal fired power capacities as a result of inertia (many projects were approved in the heyday of the economic boom) and perverse incentives (dropping coal price and a government fixed electricity tariff is increasing the profit margin for coal power). The worsening overcapacity situation has prompted regulators to consider putting a two-year “freeze period” in the Energy 13FYP for the approval of any new coal-fired power projects.

2. **Curtailment:** The other side of the overcapacity coin is curtailment of renewable energy, particularly wind and solar energy in western parts of the country. A combination of transmission bottlenecks and market set-up has blocked large chunks of renewable electricity from reaching the grid. In 2015, 15% of China’s wind energy was wasted, a historical high. Based on what’s written about the Energy 13FYP, the problem seems to have pressed policy makers to put more emphasis on reining in curtailment, at least for the first half of the 13th Five Year cycle, as opposed to further expansion of installed capacity. Whether this will become a factor that contributes to lower-than-expected wind and solar targets remains to be seen.”


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**New Urbanization Policy 2016.** Following the Central Urban Work Conference (20-21 December 2015) - the second such meeting on the issue 37 years after the first meeting in 1978 - on 6 February 2016, the Communist Party of China Central Committee and the State Council issued a roadmap for city development, including energy conservation: 135

- **Promote the development of energy conservation in the city.** Promote the district combined heat and power (CHP), green lighting, energy conservation in government departments; improve heat production efficiency; newly built residential buildings must be equipped with individual measurement of household heating consumption, while that shall be gradually provided for existing residential buildings.

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135 Extracted and translated from: [http://www.gov.cn/zhengce/2016-02/21/content_5044367.htm](http://www.gov.cn/zhengce/2016-02/21/content_5044367.htm)
China Development Bank Capital (CDBC) Policy for Green Urban Development. The CDBC’s policy document for Green Urban Development states several principles for the energy sector:

- **Renewable and District Energy**: Every project should analyze the potential for district energy, such as combined heat and power (CHP), waste to energy, and waste heat reuse. There should be 5-15% local renewable energy generation for residential areas and 2-5% for commercial areas.\footnote{136 China Development Bank Capital (CBDC). 2015. 12 Green Guidelines. CDBC’s Green and Smart Urban Development Guidelines. Beijing (draft). \url{http://energyinnovation.org/wp-content/uploads/2015/12/12-Green-Guidelines.pdf}}

- **Smart Technologies**: Smart lighting Systems, and smart grid technologies which support higher energy performance targets:

**Table 1: Relationship between Smart and Green Guidelines**

<table>
<thead>
<tr>
<th>Smart Guidelines</th>
<th>Relevant Green Guidelines</th>
<th>Relationship</th>
<th>Relevant Smart Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Energy Management</td>
<td>Renewable and Distributed Energy</td>
<td>Smart energy management technologies help to improve decision-making and even automates many decisions, which improves energy efficiency. Smart grid technologies help integrate a diverse mix of renewable and distributed energy sources to the grid and gives grid operators the flexibility to use the most efficient sources as conditions change throughout the day.</td>
<td>Smart Lighting Systems; Smart Grid Technologies</td>
</tr>
<tr>
<td>Green Buildings</td>
<td>Even if a building is equipped with all the right energy efficient fixtures, building management systems can ensure that buildings actually capture these efficiencies. Otherwise, many green buildings end up operating at a much lower efficiency due to lack of robust management.</td>
<td>Building Management Systems</td>
<td></td>
</tr>
</tbody>
</table>


**Renewable energy prospects.** This leaves large potentials for RE in the building sector untapped. IRENA estimates in prospects, that by 2030 some 36% of final energy consumption in the building sector will be directly or indirectly sourced from RE, a share which could be pushed to 54% with appropriate policies.\footnote{137 IRENA, Remap China, op cit.} Traditional biomass would be replaced entirely, which would increase efficiency. Modern biomass technology would use forest and agricultural residues, making them available also for firing in CHP. Solar thermal installations could be doubled. Low temperature geothermal sources will be tapped increasingly for heating. At the same time, building energy efficiency will be raised. These changes, in particular attaining higher clean energy shares and efficiencies imply a huge effort within cities, where by far the most building energy services will be provided in 2030.

Industry and even energy intensive industrial production is frequently located within cities in China, which raises the relative carbon emission (measured per capita) intensity of Chinese cities compared to similar sized cities in other countries.\footnote{138 Industry and Power Dominate CO₂ Emissions per Capita in Chinese Cities, according to Wang X. et alii, Low-Carbon Cities in China: Characteristics, Roadmap, and Indicators, in: Baumeier, A., Ijjasz-Vasquez J., Mehdiratte, S. (Eds.). 2012. Sustainable Low-Carbon City Development in China, Directions in Development – Countries and Regions. World Bank Washington DC.} Relocating such industry would
reduce the carbon footprint of the city and reduce other emissions but would also entail losses of jobs and economic activity. However, relocation is not a solution for the carbon issue, since the accumulation in the atmosphere occurs independently from the site of the source.

IRENA estimates that in 2010, only 1% of industrial heat demand was covered by RE sources and approximately 5% of overall final industrial final energy consumption, profiting from the high share of hydropower in the delivered power. By 2030, IRENA expects shares of 2% and 11% respectively. When a strong extra effort is made and in particular biomass sources from residuals are used, the shares could be driven to 10% and 21% respectively. Industry is an important partner in supplying heat to urban district heating.

**Transport energy.** In the transport sector, RE fuels in China play currently a marginal role, IRENA estimates a 1% overall share in final transport energy consumption in 2012. Due to strong efforts to increase biofuels and electric mobility are made by the Chinese government, IRENA expects for 2030 a share of 5% of biofuels, and of 7% when the RE content in the transport electricity is accounted for. The latter would be increased somewhat with higher shares of electric vehicles cars and when taking into account the higher RE share in power generation.

As seen, RE is already very important in power generation, not because of so called new renewables (wind solar and others) but because of the conventional hydropower. This mix is currently and will be in the future changing dramatically, in particular since wind power generation is increasing rapidly and solar power is picking up. Thus, RE shares in power generation will according to IRENA attain 29% in the business as usual reference scenario, and may be as high as 40% in a vigorous policy scenario.

There are important regional differences. Wind generation is concentrated in the Northwest and Northeast. Utility-scale solar photovoltaic (PV) generation is concentrated in the Northern and Western parts of China. Distributed solar PV is picking up, with a shift that started in 2013 and is expected to continue, mainly in Eastern parts of China. Biomass power, depending on the type of feed-stock available, agricultural residues and waste, is concentrated in central and northern parts of the country and residual forested areas in various parts of China. Some Chinese cities start generating power from waste water. This is an option that will require much more work, to assess feasibility of this approach. RE shares in district heating are currently marginal, and would remain approximately 1% in the business as usual development. However, according to IRENA it could be increased very substantially to as much as 36% if consequent use of biomass bioenergy would be pursued.

A recent assessment of the Chinese residential energy demand till 2030 provides important scenarios perspectives which need to be referred to here: Since the 1980s building energy efficiency has been actively promoted. In order to reduce the pace of growth of energy consumption, China will need to strengthen codes and standards, and develop green building projects which deploy new technologies. The estimate is that in the North of China, some 400 million m² will require retrofitting, and all new buildings should have mandatory applications of renewable and new technologies. This will make it necessary that economic measures and market mechanism are in place to stimulate the right investments, and that the right information reaches builders and investors.

The different scenarios studied under the EU-sponsored Europe-China Clean Energy Centre (EC2) program, suggest that energy consumption in the residential sector - due to space

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heating, cooking and water heating - will not stop its growth rate. In 2030 it will reach 12,400 and 19,000 PJ (420-650 Mt coal equivalent), including rural biomass. With the implementation of appropriate energy policies and within a suitable institutional framework the energy consumption could be reduced in 2030 by 125-525 (20-28%). Since space heating has been identified as the most consuming end-use, the main savings potential in buildings can be achieved through improved thermal performance, increasing district heating efficiency and by tightening energy codes. In order to reduce electricity consumption, the promotion of more energy-efficient building technologies and appliances needs to be more rapid. It is important that the behavior of residents is very important. Many savings can be adopted through ‘strong policies plus green life-style’. Such improvements are associated with a large use of new and more efficient technologies, renewables and implementation of energy-efficiency policies. The role of technologies is very important. However, as long as renewable energies and advanced technologies remain too expensive to be rapidly adopted, and without the right economic incentives or fiscal policies, relevant changes cannot be expected. The EU study concludes that if a high population growth scenario is given, and if per capita floor space increases to 40 sqm/person, on a strong action plan, strong actions combined with a green lifestyle promotion will be able to overcome the criticalities of the energy sector.
5.2 Objectives, Programs, Institutions and Sector Organization

The current RE targets (see picture from below) are formulated in the 12th Five-Year Plan for Renewable Energy Development (2011-2015).\textsuperscript{141} Based on these theses and recent updates and other information, IRENA has compiled the following set of targets:

| Table 2: China’s Renewable Energy Targets Overview |
|-----------------|-----------------|----------------|
| **Power sector** | **Status** | **Targets** |
| Biomass power | 8 GW\textsubscript{e} | 13 GW\textsubscript{e} including 8GW\textsubscript{e} agricultural and forest residues 2GW\textsubscript{e} biogas and 3GW\textsubscript{e} urban waste |
| Hydroelectricity | 249 GW\textsubscript{e} | 260 GW\textsubscript{e} |
| Pumped hydro | 20 GW\textsubscript{e} | 30 GW\textsubscript{e} |
| Solar PV | 5.4 GW\textsubscript{e} | 50 GW\textsubscript{e} (70GW\textsubscript{e} by 2017) |
| CSP | 0.014 GW\textsubscript{e} | 3 GW\textsubscript{e} |
| On-grid wind power | 100GW\textsubscript{e} onshore 5GW\textsubscript{e} offshore | 200GW\textsubscript{e} onshore 30GW\textsubscript{e} offshore |
| **Thermal applications** | | |
| Biogas | 47 million households | 50 million households |
| Solar thermal | 258 million m\textsuperscript{2} | 400 million m\textsuperscript{2} |
| Solar cooker | 2 million sets | |
| Geothermal | 4.6Mtce | 15 Mtce 580 million m\textsuperscript{2} building Space (heating), 1.2 million households (hot water) |
| Bioethanol | 2 Mt | 4 Mt |
| Biodiesel | 0.5 Mt | 1 Mt |


**Renewable energy targets.** As can be seen, China does not yet have RE objectives similar to those in European countries. Instead, China’s objectives are rather specific technology targets. In the 12\textsuperscript{th} Five Year Plan for RE,\textsuperscript{142} two of the key indicators are particularly relevant for urban development:

\textbf{(i) Renewable energy will significantly replace fossil energy for heating and conventional fuels}. China will continue to enlarge the scales of solar heating utilization, promote the direct application of medium-low temperature geothermal energy and heat pump technology, promote biomass molding fuel and biomass cogeneration, and speed up the development of biogas. By 2015, around 100 million TCE of fossil energy will be replaced by renewable energies to satisfy heating and fuel demand.

\textbf{(ii) Applications of distributed renewable energy will be scaled-up}. Establishing grid supporting system and management system in favor of distributed electricity generation such as solar power; establishing 30 new energy micro-grid demonstration projects; integrating


\textsuperscript{142} cf. [http://en.cnrec.info/tools/](http://en.cnrec.info/tools/)
diversified renewable energy technologies, such as distributed electricity generation (solar power, etc.) and renewable energy for heating and fuel applications; Establishing 100 New-Energy City and 200 Green-Energy County for pilot."

These indicators were set for 2011 – 2015. In the meantime, the ambitions for solar PV have been increased, and provide better opportunities for the large Chinese PV industry and in view of the rapidly decreasing prices of PV modules and cost of solar power. The solar PV target has been adjusted ambitiously upward. In 2014 NDRC announced a target of 70 GW for 2017, and in 2015 high level officials mentioned the very ambitious 100 GW target for 2020\textsuperscript{143} in view that in 2014, already approximately 26 GW\textsubscript{peak} of solar capacity was achieved.

From these and from the scenarios, technology targets and options which are particularly important for cities: In the short term until 2015, solar thermal and geothermal technology stand out in the heating sector. The salient objective until 2020, however, is the solar PV expansion to 100 MW in 2020 from 5.4 GW in 2010.

In the longer term, the RE technologies which cities should consider promoting to increase clean energy more and which are already competitive include:

- for heating and cooling: Air-to-Air heat pumps in residential and commercial and light industry, pellet burners, biogas (replacing traditional biomass) and: Advanced solar thermal for water heating as well as solar cooling;
- for transport apart from massively changing city transport mode replacing passenger road vehicles: Battery-driven electric two-wheeler, battery-driven electric cars, and plug-in hybrid cars;
- For power and district heating: Landfill gas, and solid biomass for CCHP, co-firing with natural gas.

BROAD Exhaust and Hot Water Combined Cooling, Heat and Power (CCHP) System in Shanghai Hongqiao CBD


\textsuperscript{143} Reporting from Chinas Parliamentary Sessions 2015, South China Morning Post. \url{http://www.scmp.com/news/china/article/1729979/china-pledges-cut-coal-use-increase-amount-renewable-energy-help-tackle}
**Electricity sector.** Different from Europe, the electricity sector in China has been unbundled, however only partly. Generation is separated from the other functions, which are provided by two regional integrated state owned grid companies. For electricity generation, competition is organized between several companies, effective in regional markets, which are interconnected only by weak transmission. The grid companies in charge of transmission, distribution, supplying customers and related services are internally organized by areas, provinces and also cities. In these city level affiliates of the grid companies, the municipalities are included in the board of directors, together with the representatives from the higher level affiliates. Therefore, the municipalities do have a rather direct access and some influence on the electric utilities.

Further institutional changes are on the agenda. These will coincide with fundamental changes in the operation of the power sector system, caused by more distributed generation on the distribution system level and variable renewable energy on all levels, and not the least, by the smart grid technology. It is important to note, that installation of electricity smart meters has advanced more rapidly than in in any other parts of the world. China’s State Grid is also testing micro-grid in Yangzhou, Jiangsu Province.

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**How China Wastes Its Renewable Energy**

“China can produce but it can't always deliver renewable energy efficiently enough. Last year, China was one of the first countries to submit its detailed plan for bringing down carbon emissions as part of the United Nations’ process to address global climate change. China’s Nationally Determined Contribution (NDC), sets out some impressive goals: peaking carbon emissions by 2030 or sooner; lowering the overall carbon intensity of China’s GDP; and increasing low-carbon energy sources to about 20% of the total energy mix. ... Key to turning these commitments into reality is China’s plan to dramatically scale up renewable energy from wind, solar, geothermal and other low- or no-carbon sources. China is already the largest renewable-energy investor in the world, contributing about $102 billion, or 36% of total global investment, to these projects in 2015. (By comparison, the U.S. invested about $44 billion in the same period.) China is not just putting up the money, it’s putting up the projects, with over 45 gigawatts of new solar and wind capacity developed in 2015.

But there’s a cloud behind this silver lining: China may be the global leader in renewable energy investment, but it’s also the leader in the percentage of that energy that never reaches consumers. China’s wasted, or “curtailed,” wind energy averages about 21% nationally, reaching as high as 40% in some provinces. If these curtailment figures continue, China will have a hard time reaching its carbon-peak commitments, or for that matter, any of its international climate goals. So why is China wasting so much of its renewable energy? A few years ago, the answer may have focused on the development of “ghost projects” – big wind and solar farms with no physical connections to the power grid. Those connectivity problems still exist. But in fact a bigger problem today is renewable power that is physically connected to the grid, but not transmitted to meet actual energy demand. ... In particular, China faces issues in three important grid management areas: power sector planning, market design and energy pricing. As a result, although renewable power plants are built, the power they generate is often wasted because it cannot be transmitted to demand centers, cannot be used at the right time, or is perceived to be too expensive."

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**Wind turbines near the Great Wall of China**

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**Heating sector.** Since several years, China and Chinese cities are working institutional reform of the district heating sector, in particular pricing and billing of heat consumption. A recent MoHURD project on Heat Reform and Building Energy Efficiency (HRBEE) that included 7 Northern China cities co-funded by the World Bank and the Global Environment Fund (GEF) is targeting this issue and aiming at modernization of heating systems and energy efficiency in urban homes.\(^{145}\) The project will (i) improve enforcement of energy efficiency standards for buildings, as well as design and use of insulation and other energy-saving measures; (ii) implement heat metering, cost-based pricing and consumption-based billing; and (iii) modernize heat supply systems so that residents can control when the heat is on.\(^{146}\) China sees renewables as a source of energy security, not just of carbon emission reductions. Issued by China’s State Council in September 2013, China’s Action Plan for the Prevention and Control of Air Pollution\(^{147}\) illustrates government desire to increase the share of renewables in China’s energy mix.

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**Heating Reform – Relevance for Green Building**

Recently, Ministry of Finance, MoHURD, the Ministry of Environmental Protection, and the National Energy Adminstation jointly held Video Conference for the clean heating in winter for the northern part of the China., According to the pilot program, the local municipal finance will invest about 69.7 billion yuan in the next three years to ensure the smooth implementation of clean heating renovation, plans to attract financial institutions, enterprises and other social capital of more than 200 billion yuan. At the end of last year, the Central Financial Leading Group held its fourteenth meeting, the northern region of winter clean heating has the key importance. This year’s government work report also put forward specific requirements for the promotion of clean heating in 2017. In order to promote the local to speed up the winter clean heating transformation, four ministries in May this year to organize the central fiscal support to the northern region of winter clean heating pilots, the pilot demonstration period is lasting for 3 years, the central financial compensation fund standards will be catogorized according to the city scale. Each year to arrange 1 billion yuan to municipality directly under the central government, the provincial capital city arranged 700 million yuan each year, prefecture-level cities arranged 500 million yuan each year. According to the introduction, according to the pilot city reported the implementation of the program, the next three years the local government will invest about 69.7 billion yuan, and accelerate the improvement of...
diversified financing mechanism, plans to attract financial institutions, corporate investment and other social capital of more than 2000 Billion, for the smooth implementation of clean heating to provide a strong guarantee. At present, the National Energy Administration is in coordination with the MoF, Ministry of Environmental Protection and MoHURD to do the preparation of the "northern winter clean heating plan (2017-2021)", it will list the overall goal of the winter clean heating, and set the strategy from the heating source, heating network, and end users to prove the guidance.

Source: MoHURD. http://www.mohurd.gov.cn/zxydt/201709/t20170913_233276.html

**Photovoltaics.** The huge Chinese PV industry and value chain is another driving factor for increasing RE share, in particular in the power sector. As part of China’s 12th Five-Year Plan, the Ministry of Industry and Information Technology announced the goal of reducing the cost of solar power to 0.8 yuan (12 US cents) per kilowatt-hour (kWh) by 2015 and 0.6 yuan (9 cents) by 2020. The 12th Five-Year Plan called for Chinese manufacturers to significantly increase production of solar PV panels in order to reach 5 Gigawatts (5 GW) by 2015, while poly-silicon producers will increase their annual production capacity to 50,000 tons. Direct and indirect government support for China’s solar PV industry participants has been the central element enabling Chinese silicon and solar PV manufacturers to become the world’s leading providers. Rapid expansion of production has also led to oversupply and a precipitous decline in the price of solar cells and modules worldwide. Some 95% of Chinese silicon PV cell and panel production has been bound for overseas markets. That has prompted competitors in other WTO members, including the US and, more recently, the EU, to file WTO international trade petitions seeking redress from alleged illegal subsidies and dumping of product in their markets. A shift in government policy and support toward redirecting Chinese output of solar PV cells and modules to the domestic market alleviates global market oversupply, as well as help defuse trade and currency management tensions.

The National Government of China has during the last 5 years revised or issued a number of programmes and initiatives including financial incentives and tariffs, which support clean energy development in urban areas, including

- National New energy city program
- Micro smart grid Program
- Solar PV (including subsidies for distributed PV)
- Biomass
- Wind energy
- Green vehicle and green buildings.  

**The National New Energy City Program.** Among those, and particularly relevant is the National New Energy City Program set up in the 12th Five Year Plan for RE was conceived as key measure to encourage distributed energy applications in 100 demonstration cities, located in 32 provinces. It cooperates with programs such as new energy city program (NEA), low-carbon pilot cities and communities (NDRC-National Development and Reform Commission), carbon exchange pilot cities (NDRC), circular economy pilot program (NDRC), low carbon industrial parks (MIIT-Ministry of Industry and Information Technology), renewable building application pilot cities (MOHURD-Ministry of Housing and Urban-Rural Development), and new energy vehicle pilot cities (MOST-Ministry of

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Science and Technology) etc. As the authorized government agency for the National New Energy City Program, the NEA is responsible for evaluation and approval of the applicant cities.

5.3 Examples of interventions

Different from Europe, there is no decades-long tradition of integrated urban energy planning and development in China. Therefore, the examples and cases for clean energy are less comprehensive. They include also continuous efforts of municipalities without an overall plan as well as specific technology and individual projects. Some cases have had difficult phases, from which also important lessons can be drawn.

Case 30 Tianjin: An Emerging Eco-City

Tianjin, in the cold climate zone, is hosting the large Sino-Singapore Tianjin Eco-city project. The Eco-City’s vision is to be a thriving city which is socially harmonious, environmentally-friendly and resource-efficient. It is a flagship cooperation project between the governments of Singapore and China. It is planned for 350,000 residents, and focusses on decentralized urban land-use, Green Transport and Green Infrastructure. In terms of energy, Tianjin Eco City is focused on building energy with strong involvement of the supply side from district heating including CHP, and increasingly including geothermal energy and also solar PV on the electricity side.149

Actually, other Tianjin districts outside the Eco-City, in particular the TEDA industrial area are also and specifically involved in clean energy activities. A special feature is an energy consumption monitoring platform of MoHURD in cooperation with the Tianjin construction bureau and with the numerous heat companies. This information would in theory allow better efficiencies in the system, and better pricing. This would mean that local DRC and Heat Companies play the game, and this is not yet the case. Another approach piloted in Tianjin is Building Level Sub-Stations as a way to increase efficiencies in the systems.

Case 31 Anshan, Liaoning Province: Restructuring district heating with heat recovery

Anshan in Liaoning province, in the cold to severe cold climate zone of China. The inner city has 1.8 M residents and a large heating area of 53 million m². In the initial situation coal fired boilers of 2050 MWth supplied a separated and unbalanced network. In the future, a district heating transmission line utilizing heat from CHP and surplus heat from steel plant and the geothermal sources will supply yearlong district heating supply also for domestic hot water, in pooled balanced networks. This will stabilize heat supply, increase energy efficiency and reduce CO₂ emissions supplying energy to the city by simply recovering energy that is already available but wasted, clean the urban air and improve indoor climate. The programme is developed in close cooperation with Anshan City Government, Angang Steel and the District Heating Companies. The investment is expected to be amortized by reduced operating cost in a couple of years. The restructuring project started in September 2013. After the completion of phase I, 173 thousand ton coal consumption has been saved, CO₂ emission 239 thousand tons, annual saving of operation cost of 60 million CNY. The

Investment is between 0.2~0.25 billion CNY, while the payback period is estimated to be 3-4 years.\textsuperscript{151}

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**Restructuring district heating- Inauguration Ceremony**

![Restructuring district heating- Inauguration Ceremony](http://bao.hvacr.cn/201309_2039622.html)

Source: [http://bao.hvacr.cn/201309_2039622.html](http://bao.hvacr.cn/201309_2039622.html)

Case 32 Minhang District, Shanghai: Anting New Town with innovative energy and waste management.

Anting is a district of Shanghai (China), in the hot summer – cold winter climate zone, along automobile production facilities and has numerous new showcase areas. For the new district “Anting New Town” built for 28,000 inhabitants an integrated infrastructure masterplan was established and implemented. The concept included district heating and district cooling, encompassing an energy concept based on German standards, from generation through network distribution up to the recipient in each room, so permitting drastic energy savings over Chinese standards.

Anting new town has had a very difficult start, due to various factors it has been a slow development. Anting is an indicator of the changing attitude of Chinese officials and citizens to integrated new concepts.

Right photo: http://www.myliving.cn/tanpan/view/201109/200.htm

Case 33 Hohhot, Inner Mongolia: various initiatives

Hohhot, the capital city of Inner Mongolia, is situated in the semiarid, severe cold zone of China. The south and south western region around Hohhot has rich and exploited coal and natural gas reserves. North of Hohhot, wind parks have multiplied. Already around 2000 numerous heat only boilers were replaced by a district heating line from the coal power station, although still coal fired. A heating energy concept was developed for the city. In view of the high wind energy production and the need to balance temporary surplus, a ‘power to heat’ concept was developed and concretized. The ADB-financed project intended to demonstrate the efficiency and viability of large-scale natural gas and wind-based district heating. Combining these two energy sources improve the poor air quality in urban areas of the Inner Mongolia Autonomous Region during the winter and help reduce carbon dioxide emissions.

Hohhot has won State-level demonstration projects involving the application of renewable energy in buildings, including the integration of solar thermal technology with buildings, solar heating technology, and the integration of rooftop solar photovoltaic. Hohhot will be a pilot city for the introduction of the distributed solar photovoltaic system in households and working places, in view of the situation of solar PV industry in the city.

Building PV Power System


Case 34 Dunhuang, Gansu Province: solar power.

Dunhuang city in Gansu province on the edge of the desert is a pivotal place for solar power development in China. Dunhuang has implemented a series of regional solar micro-grid pilot projects supported by the Institute of Electrical Engineering (IEE) of Chinese Academy of Sciences (CAS). These projects include Concentrated Solar Power and Heat Cogeneration (CSP-CHP) project - involving natural gas in the CHP part, solar vehicle micro-grid project, urban building integrated photovoltaic (BIPV) project, rural solar comprehensive utilization pilot project. A 100MW tower power plant molten salt CSP station in Dunhuang was announced and a first stage of 10 MW CSP tower in 2015. There exists a 16-hour heat storage system configuration in these projects.

Rooftop PV Elements in Qilizhen town of Dunhuang city, Gansu Province.

Source: http://gansu.qscn.com.cn/system/2014/03/12/010623394.shtml


Case 35 Datong, Shanxi Province: Solar-PV, driven by manufacturer in a coal mining city

In Datong, a producer of poly-silicon wafer for the Solar PV modules gained approval from the National Energy Bureau to begin work on a 310-MW ground-mounted and a 30-MW rooftop solar power project in the prefectural city of Datong. In December 2013 the phase II of 60MW went into operation. In June 2015 another 3000-MW PV project was approved as the first concrete project of the new national project "PV leaders’ project" initiated by MIIT, NEA, CNCA (Certification and Accreditation Administration). Taken together, the Datong Shanxi solar power projects will be the largest solar farm in China, and one of the largest in the world. With this Datong Shanxi solar PV farms, a producer from the upstream value chain becomes directly involved, make direct investments and take ownership of large-scale solar power projects.


Case 36 Huainan, Anhui Province: The world’s largest floating solar power plant went online

“China has announced that the largest floating photovoltaic (PV) facility on earth has finally been completed and connected to the local power grid. Long reviled for its carbon emission record, this is the Chinese government's latest achievement in its ongoing effort to lead the world in renewable energy adoption. Located in the city of Huainan in the Anhui province, the 40-megawatt facility was created by PV inverter manufacturer Sungrow Power Supply Co. Ironically, the floating grid itself was constructed over a flooded former coal-mining
region. Floating solar farms are becoming increasingly popular around the world because their unique design addresses multiple efficiency and city planning issues. These floating apparatuses free up land in more populated areas and also reduce water evaporation. The cooler air at the surface also helps to minimize the risk of solar cell performance atrophy, which is often related to long-term exposure to warmer temperatures. This is just the first of many solar energy operations popping up around China. In 2016, the country unveiled a similar 20 MW floating facility in the same area. China is also home to the Longyangxia Dam Solar Park, a massive 10-square-mile, land-based facility touted as the largest solar power plant on earth. … By 2020, China could reduce prices offered to PV developers by more than a third with solar power plants projected to rival coal facilities within a decade. The nation has also announced plans to increase its use of non-fissile fuel energy sources by 20 percent.”


Case 37 Hami, Xinjiang Autonomous Region: Changing energy mix

Changing energy mix at a power transmission nodal and feed in point, Hami is a city of approximately 370,000 inhabitants in the coal producing area of Xinjiang. There are important coal power stations and a nodal point of high voltage interconnection. Wind energy has been also developed in the region. More recently, utility size solar PV power has been connected to the grid, and solar CSP plants are under development. 

Source: left photo: http://news.163.com/16/0317/02/BIB0D8N600014AED.html
Case 38 Rizhao, Shandong Province: Solar heat and PV Utilization

Solar heat and power Rizhao, an urban area with about 350,000 inhabitants in the cold climate zone, is using solar energy to provide water, heating, and lighting. Under a municipal government retrofit program starting in the 1990s, the city made it mandatory for all buildings to install solar water heaters. After fifteen years of efforts, 99% of households in the central district obtained solar water heaters. Solar water heating is now considered common sense. In the total, the city has over half a million m² of solar water heating panels, the equivalent of about 0.5 MW of electric water heaters. Most traffic signals and street and park lights are powered by solar cells, reducing the city’s carbon emissions and local pollution. The achievement was the result of three key factors: a regional government that promotes and financially support the research, development and deployment of solar water heating technologies; a new industry which took the opportunity to engage in the business of producing affordable panels; and a city leadership. The cost of solar water heaters was reduced to that of a conventional electric water heater, and households were assisted with installation of new panels on their houses. The city assisted with awareness raising and publicity on mass media. Since 2001, the city has been promoting the solar panels through building regulations, and public engagement and education. Building regulations require solar energy equipment to be designed, constructed, examined and approved during new-build construction, solving technical and policy problems. As a result, 99% of buildings in urban areas, and over 30% of houses in rural areas are installed with solar water heaters. On top of this, most of the city’s traffic signaling, street lighting, and park illumination are powered by photovoltaic panels.

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Solar water heaters in Rizhao


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Case 39 Dezhou, Shandong Province: Solar City

In response to the government’s policy to save energy and reduce consumption of resources, Dezhou’s party committee and municipal government decided to implement a solar city strategy. The main goal is to develop a solar economy, and foster a solar culture. The Solar City Strategy Promotion Committee was established with the mayor as its head. Today, the China Solar Valley project in Dezhou is promoted strongly by the solar water heater industry concentrated in Dezhou, with more than 100 enterprises developing solar products. Future plans for Dezhou include the creation of a renewable energy university, and the government has given preferential tax benefits to the companies engaged in solar production.  

Source: China Sun Valley in Dezhou.  
http://d.hiphotos.baidu.com/baike/c0%3Dbaike116%2C5%2C5%2C116%2C38/sign=ed6726b93a6d55fbd1cb7e740c4b242f/d8f9d72a6059252d1fda5763339b033b5ab5b98c.jpg

Case 40 Rongcheng, Shandong Province: Wind energy city

Rongcheng city in Shandong province has relatively rich wind resources. The city has invested under stage one of an urban project in three wind power plants with total capacity of 200 million KWH per year.  

Source:  
left photo http://www.sdrcdz.gov.cn/gd/zdcy.asp?id=27;  

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Case 41 Wuxi, Jiangsu Province: China’s First Zero Energy Building

This Suntech Photovoltaic (PV) Research and Development Center was the first Zero Energy Building in China which incorporates building integrated Photovoltaic (BIPV) solution, energy-saving radiant-type AC system, and intelligent lighting control. This is particularly interesting for the southern climate zones with high air conditioning requirements. Suntech is a world market leader in the industry of solar energy. The Suntech PV R&D Center has a total space area of 64,000sqm, including the R&D Center and Recreation Center buildings. The building features facades that incorporate 20,000sqm of photovoltaic materials, from which the collected solar energy will be transformed and added to the main energy supply for daily operation of the building. Plus, coupled with many other building energy-efficient technologies, the building succeeds in the autarkic operation of energy supply, becoming a trend setter as a “Zero Energy Building” in China.  

→ Tool CE 1

There are a number of other innovative projects and schemes in the energy sector:

Case 42 Shanxi Province: Special Compensation Fund for Eliminating Inefficient Capacity

In Shanxi Province, a special compensation fund has been used successfully to eliminate particularly wasteful capacity. Financing for the fund comes from the central government allocation, the province’s Coal Sustainable Development Fund (paid for by a resource tax on coal production), its Electricity Construction Fund, and the provincial government fiscal budget. The main uses of the fund include:

- Compensation to enterprises that close down and demolish their inefficient production equipment.
- Mandatory demolition of targeted equipment in those cases where enterprises have been shut down.
- Site clearance and restoration.

Source: Chinese Government.

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162 Source: www.suntech.com
Case 43 Shanghai: An innovative green pricing mechanisms-the Shanghai Green Electricity Scheme

In 2006 the World Bank supported the creation of an Energy Conservation Center in the city of Shanghai and looked at the possibility of developing a green electricity scheme there. The scheme was named Jade Electricity by the Shanghai municipal government and allowed consumers to purchase, on a voluntary basis, part or all of their electricity from renewable energy sources. Participating customers paid a premium on their electric bills to cover the incremental cost of the additional renewable energy thus contributing to making the city’s electricity portfolio more sustainable and to reducing local air pollution. The program initially supported only wind and photovoltaic energy as renewable-based sources. The pricing mechanism adopted for Jade Electricity is that of the existing tariff plus a changing premium that is calculated on an annual basis. The price of Jade Electricity is subject to approval by Shanghai Municipal Government pricing authorities.

Source: Frederic Asseline.

Case 44: Shenzhen: World's Largest Waste to Energy Power Plant

B&W Vølund has been awarded a $40 million contract, to design the boiler with a capacity of 168MW, for Shenzhen Energy Environmental Engineering Co. Ltd.

The landfills keep piling up all over the world. China has in recent years opened its eyes for the need of better waste management. In the province Guangdong, the local municipality and developer, Shenzhen Energy Group, has decided to build a magnificent 267,000 m² waste to energy plant. The plant will be surrounded by rich nature which also reminds of the environmental and economic benefits of waste combustion.

The scope. B&W Vølund will supply equipment for the facility, including the DynaGrate® combustion grate system, hydraulics, burners and other boiler components. It is the first time the DynaGrate® technology is deployed in China. B&W Vølund will also provide construction advisors for the combined heat and power project. The plant is scheduled to begin commercial operation in mid-2019 and will then be fuelled by up to 5,600 tons of municipal waste a day, generating 168 MW energy.

Multi-functions and purposes. The Shenzhen power plant is firstly built with sustainability in mind. The roof will be covered with 44,000 m² solar panels so that the plan will provide energy from two source, combustion and solar panels. Furthermore, it will include a visitor center, observation platform and a surrounding park. Education and transparency of waste management will lay the foundation for a more environmental aware generation in the industrialised China. Visitors at the plant will be able to experience the visitor center, go on
an elevated walkway tour, offering a sneak peek into the inner workings of the plant, and of
cause be able to enjoy the 1.5 km panoramic view from the rooftop.

**The benefits of waste combustion.** Modern waste combustion recovers close to 100 per
cent of energy, water and metals from waste. In a top modern WtE plant like in Shenzhen,
99 per cent of the energy will be utilised for electricity and heating, 95 per cent of the water
is recovered, and if the domestic waste contains, e.g. aluminium packaging, 90 per cent of
the metals will also be recovered. The slag is recycled as gravel, the flue gas is 95-99 per
cent clean, and unwanted substances are removed from circulation.

power-plant?utm_source=State+of+Green+Newsletter&utm_campaign=2152db4ac2-
State+of+Green+Newsletter_newsletter&utm_medium=email&utm_term=0_2978bea9b9-2152db4ac2-
273119813
5.4 Good Practices - Illustrations

<table>
<thead>
<tr>
<th>China’s Largest Solar Power Farm, Datong, Shanxi Province</th>
<th>China’s first Zero Energy Building - Suntech at Wuxi, Jiangsu Province</th>
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<tbody>
<tr>
<td><img src="image1" alt="China’s Largest Solar Power Farm, Datong, Shanxi Province" /></td>
<td><img src="image2" alt="China’s first Zero Energy Building - Suntech at Wuxi, Jiangsu Province" /></td>
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<tr>
<th>Wind Farm in Xinjiang province</th>
<th>Rooftop solar water heaters are ubiquitous in China</th>
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</thead>
<tbody>
<tr>
<td><img src="image3" alt="Wind Farm in Xinjiang province" /></td>
<td><img src="image4" alt="Rooftop solar water heaters are ubiquitous in China" /></td>
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<tr>
<th>A 24 MW power station in Yangbajain Geothermal Field</th>
<th>Solar PV power generation in Hong Kong</th>
</tr>
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<tbody>
<tr>
<td><img src="image5" alt="A 24 MW power station in Yangbajain Geothermal Field" /></td>
<td><img src="image6" alt="Solar PV power generation in Hong Kong" /></td>
</tr>
</tbody>
</table>
Solar Photovoltaic panels

Source: Bomin Solar technology Ltd. www.bomsolar.com

Solar Street Lights in Beijing

Source: Florian Steinberg

Solar Traffic lights in Beijing

Source: Florian Steinberg

Wind Energy in Tianjin Eco-City

Source: Florian Steinberg

Rooftop Water Heaters in Tianjin Eco-City

Source: Florian Steinberg

5.5 Technologies and Products, Standards

Cities such as Rizhao, Yantai in Shandong province, Nanjing in Jiangsu province, Wuhan in Hubei province, and Zingtai in Hebei province, have formulated regulations and provided fiscal incentives to enforce the integrated design, installation, and construction of solar energy facilities in new buildings and in renovated public buildings. 163

5.6 Indicators

MoHURD has set (national-level) indicators for eco-city development (and so has the MEP) but these indicators focus largely on buildings and green space, they are construction-oriented and they fall short of addressing broader parameters related to land use, clean energy supply, or GHG emissions monitoring. The specific set on clean energy - 20% Renewable Energy supply - is still vague. And it is unlikely that it will be reached: supply of heat and power is via CHP plants outside the eco-city, and all the Tianjin EC can generate in RE is street lighting via PV and some geothermal. For the urban energy sector, the key performance indicators of the Sino-Singapore Tianjin Eco-City (SSTEC) are interesting as reference:

- Carbon emissions per unit GDP: 150 tons per one million US$. 164
- Proportion of green buildings: 100%. The percent of green buildings in new construction was practically zero in Tianjin in 2008.
- Usage of renewable energy: share of renewable energy in energy supply shall be at least 20%, compared to the national target of 15% by 2020.
- Central heating coverage: 100% as compared to Tianjin’s target of 90% by 2015.

### Table 3: Energy Sector: Key Performance Indicators for Tianjin Eco City

<table>
<thead>
<tr>
<th>KPI Area and Details</th>
<th>Indicative Value</th>
<th>Timeframe</th>
<th>Domestic standards</th>
<th>Domestic Benchmarks</th>
<th>International Benchmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of green buildings</td>
<td>100%</td>
<td>Immediate</td>
<td>National standard for Green building GB50378-2006 Technical Manual for Green Building Evaluation Garden City standard: ≥ 50% energy-efficient buildings and green buildings</td>
<td>China: less than 1% (current); 100% for Olympics buildings Energy-efficient buildings: 16% of existing buildings in cities and towns (2008); 71% of newly built buildings (2007) BJ: energy efficient buildings: 49.93% of existing buildings</td>
<td>Singapore: building area exceeding 2,000 m² should be 100% green building</td>
</tr>
<tr>
<td>Services network coverage</td>
<td>100%</td>
<td>By 2013</td>
<td>Eco-City standard: 65% Gas Garden City Standard 80%</td>
<td>By 2013 Central Heating: TJ: 83.2% (2005); TJ Plan≥85% (by 2010); ≥90% (by 2015) BHNA: 75% (2005); ≥88% (by 2010)</td>
<td></td>
</tr>
</tbody>
</table>

164 However, it is being queried whether the carbon emission per GDP indicator is adequate in a small city, since such an indicator may represent many economic and energy characteristics of larger economic regions. And its assumed clean industry-orientation is supposed to result in lower carbon emissions than in other cities with high shares of heavy industries. Hence, it has been suggested that an additional indicator like carbon emission per capita may be added to capture the effects of population density.
5.7 Evaluation Methodology

These broad KPIs are useful and strategic for the eco-city’s economic and energy planning. It will be imperative to pursue a service-oriented, knowledge-based and clean growth strategy, and to strictly enforce green building standards, make extra efforts to promote renewable energy, and to rely on modern district heating systems. However, there are some points of caution in the World Bank’s review of SSTEC’s performance targets. It is being queried whether the carbon emission per GDP indicator is adequate in small city, since such an indicator may represent many economic and energy characteristics of larger economic regions. And its assumed clean industry-orientation is supposed to result in lower carbon emissions than in other cities with high shares of heavy industries. Hence, it has been suggested that an additional indicator like carbon emission per capita may be added to capture the effects of population density.

The central heating coverage indicator may be misleading, since it is used to measure availability of modern district heating in northern China. However, in Tianjin there should be significant potential to develop clean or cleaner heating options, such a geothermal or gas-fired tri-generation. The target of 100% coverage of centralized heating does not yet indicate innovation in terms of heat supply. An alternative indicator could cover the performance of space heating provided by non-coal-fired technologies (although the electricity used by geothermal and heat pump systems may still be derived from coal-powered electricity plants). SSTEC has developed other important quantitative energy sector targets in heating/cooling efficiency, renewable energy usage, solar energy use, and natural gas usage which should be pursued if they make economic sense:

### Table 4: Additional Quantitative Objectives of SSTEC’s Energy Sector Plan

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Indicative Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating energy saving of residential buildings</td>
<td>≥ 70% (compared the current Tianjin standard of 65%)</td>
</tr>
<tr>
<td>Heating/cooling energy saving of public buildings</td>
<td>≥ 55% (compared with the current Tianjin standard of 50%)</td>
</tr>
<tr>
<td>Renewable energy usage in heating/cooling system</td>
<td>≥ 40% of building floor area</td>
</tr>
<tr>
<td>Solar energy usage in hot water system</td>
<td>≥ 80% of building floor area</td>
</tr>
<tr>
<td>Solar energy usage in road/landscape lighting system</td>
<td>≥ 90%</td>
</tr>
<tr>
<td>Natural gas usage in residential and public buildings</td>
<td>100% of buildings</td>
</tr>
</tbody>
</table>


Since the discussion on indicators is entering a more mature stage, CSUS has drafted for MoHURD a set of key performance indicators (KPIs) for the energy sector have been drafted recently, which will be tested in the near future:
### Table 5: Proposed Clean Energy KPIs

<table>
<thead>
<tr>
<th>Indicator Category</th>
<th>Indicators: indicative values</th>
<th>Current achievements / Time frame for accomplishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Coal utilization rate of city [1]</td>
<td>__% of total energy consumption</td>
<td></td>
</tr>
<tr>
<td>2. Total residential energy input for heating and cooling within city boundaries.</td>
<td>__kWh/(m²a)</td>
<td></td>
</tr>
<tr>
<td>- Decentralised heat/cold generation (fossil energy sources, district heating and part electricity delivered to residential customers)</td>
<td>__kWh/(m²a)</td>
<td></td>
</tr>
<tr>
<td>- Delivery chain losses in district heating and electricity chain (distinguishing source of generation)</td>
<td>__kWh/(m²a)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥60% [6]</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥10% [4]</td>
<td></td>
</tr>
<tr>
<td>5. Emissions from district heating (based on renewable energy coefficient 0:8)</td>
<td>Reduced by 50% 105 kWh/(m²a) gross area</td>
<td></td>
</tr>
</tbody>
</table>

Sources:

165 These key performance indicators were prepared and compiled by the EC-Link Project. See: EC-Link. 2016. Sino-EU Key Performance Indicators for Eco-Cities. Beijing (unpublished draft)
5.8 Lessons Learnt from pilot projects

Moving beyond isolated technologies. While many renewable energy technologies are already in massive supply in China, there is need to roll these out on a larger scale. And related to this, there is need for a development of micro-grids ("smart grids") which can absorb and distribute decentralised energy sources developed from renewable energy technology. Tool CE 1, Tool CE 2

Towards carbon neutral cities. The larger challenge, though will be to develop carbon neutral cities, and to make this the substance of Sustainable Energy Action Plans (SEAPs) which will be developed under the new Covenant of Mayors..

Future applications of glass facades as solar panels. The major challenge remains to convert existing glass facades in modern cities into a source of energy. Technological development of solar panels as integral parts of glass facades are expected to reach a nexus that will revolutionize our cities, their energy consumption and ecological footprint. It is expected that glass facades of the future can become not only places of energy transmission, but also the sources of energy generation themselves. Once glass facades become solar panels that can convert solar rays into energy, it should become possible to create carbon neutral buildings that can generate not only their own energy, but eventually produce energy in excess of their own consumption. This excess energy will be fed into the network and support other energy requirements, such as public infrastructure services, street lighting, or vehicular movements. The expected technological innovation will revolutionize our perception of buildings with glass facades, which currently are seen as a major source of energy wastage in the urban landscape. Additional features like ray absorption of glass panes will help to lower reflection of sun rays and generation of avoidable heat. 166 Tool CE 2

100% Renewable Energy Is Possible, Here’s How

If our transition to renewable energy is successful, we will achieve savings in the ongoing energy expenditures needed for economic production. We will be rewarded with a quality of life that is acceptable—and, perhaps, preferable to our current one (even though, for most Americans, material consumption will be scaled back from its current unsustainable level). We will have a much more stable climate than would otherwise be the case. And we will see greatly reduced health and environmental impacts from energy production activities.

It will take at least three decades to completely leave behind fossil fuels. But we can do it. And the first step is to start with the easy stuff. But the transition will entail costs—not just money and regulation, but also changes in our behavior and expectations. It will probably take at least three or four decades and will fundamentally change the way we live…

Level One: The Easy Stuff. Nearly everyone agrees that the easiest way to kick-start the transition would be to replace coal with solar and wind power for electricity generation. That would require building lots of panels and turbines while regulating coal out of existence. Distributed generation and storage (rooftop solar panels with home- or business-scale battery packs) will help. Replacing natural gas will be harder, because gas-fired "peaking" plants are often used to buffer the intermittency of industrial-scale wind and solar inputs to the grid (see Level Two).

Electricity accounts for less than a quarter of all final energy used in the U.S. What about the rest of the energy we depend on? Since solar and wind produce electricity, it makes sense to electrify as much of our energy usage as we can. For example, we could heat and cool most buildings with electric air-source heat pumps, replacing natural gas- or oil-fueled furnaces. We could also begin switching out all our gas cooking stoves for electric stoves.

Transportation represents a large swath of energy consumption and personal automobiles account for most of that. We could reduce oil consumption substantially if we all drove electric cars (replacing 250 million gasoline-fueled automobiles will take time and money, but will eventually result in energy and financial savings). Promoting walking, bicycling and public transit will take much less time and investment.

Buildings will require substantial retrofitting for energy efficiency (this will again take time and investment, but will offer still more opportunities for savings). Building codes should be strengthened to require net-zero-energy or near-net-zero-energy performance for new construction. More energy-efficient appliances will also help.

The food system is a big energy consumer, with fossil fuels used in the manufacture of fertilizers, food processing and transportation. We could reduce a lot of that fuel consumption by increasing the market share of organic local foods. While we’re at it, we could begin sequestering enormous amounts of atmospheric carbon in topsoil by promoting farming practices that build soil rather than deplete it—as is being done, for example, in the Marin Carbon Project.

If we got a good start in all these areas, we could achieve at least a 40 percent reduction in carbon emissions in 10 to 20 years.

**Level Two: The Harder Stuff.** Solar and wind technologies have a drawback: They provide energy intermittently. When they become dominant in our overall energy mix, we will have to accommodate that intermittency in various ways. We'll need substantial amounts of grid-level energy storage as well as a major grid overhaul to get the electricity sector close to 100 percent renewables (replacing natural gas in electricity generation). We'll also need to start timing our energy usage to coincide with the availability of sunlight and wind energy. That in itself will present both technological and behavioral hurdles.

After we switch to electric cars, the rest of the transport sector will require longer-term and sometimes more expensive substitutions. We could reduce our need for cars (which require a lot of energy for their manufacture and decommissioning) by increasing the density of our cities and suburbs and reorienting them to public transit, bicycling and walking. We could electrify all motorized human transport by building more electrified public transit and intercity passenger rail lines. Heavy trucks could run on fuel cells, but it would be better to minimize trucking by expanding freight rail. Transport by ship could employ sails to increase fuel efficiency (this is already being done on a tiny scale by the MS Beluga Skysails, a commercial container cargo ship partially powered by a 1,700-square-foot, computer-controlled kite), but relocalization or deglobalization of manufacturing would be a necessary co-strategy to reduce the need for shipping.

Much of the manufacturing sector already runs on electricity, but there are exceptions—and some of these will offer significant challenges. Many raw materials for manufacturing processes either are fossil fuels (feedstocks for plastics and other petrochemical-based materials) or require fossil fuels for mining or transformation (e.g., most metals). Considerable effort will be needed to replace fossil-fuel-based industrial materials and to recycle non-renewable materials more completely, significantly reducing the need for mining.
If we did all these things, while also building far, far more solar panels and wind turbines, we could achieve roughly an 80 percent reduction in emissions compared to our current level.

**Level Three: The Really Hard Stuff.** Doing away with the last 20 percent of our current fossil-fuel consumption is going to take still more time, research and investment—as well as much more behavioral adaptation.

Just one example: We currently use enormous amounts of concrete for all kinds of construction. The crucial ingredient in concrete is cement. Cement-making requires high heat, which could theoretically be supplied by sunlight, electricity or hydrogen—but that will entail a nearly complete redesign of the process.

While with Level One we began a shift in food systems by promoting local organic food, driving carbon emissions down further will require finishing that job by making all food production organic and requiring all agriculture to build topsoil rather than deplete it. Eliminating all fossil fuels in food systems will also entail a substantial redesign of those systems to minimize processing, packaging and transport.

The communications sector—which uses mining and high-heat processes for the production of phones, computers, servers, wires, photo-optic cables, cell towers and more—presents some really knotty problems. The only good long-term solution in this sector is to make devices that are built to last a very long time and then to repair them and fully recycle and remanufacture them when absolutely needed. The Internet could be maintained via the kinds of low-tech, asynchronous networks now being pioneered in poor nations, using relatively little power...

Back in the transport sector: We’ve already made shipping more efficient with sails, but doing away with petroleum altogether will require costly substitutes (fuel cells or biofuels). One way or another, global trade will have to shrink.

Great attention will have to be given to the interdependent linkages and supply chains connecting various sectors (communications, mining and transport knit together most of what we do in industrial societies). Some links in supply chains will be hard to substitute and chains can be brittle: A problem with even one link can imperil the entire chain.

The good news is that if we do all these things, we can get beyond zero carbon emissions; that is, with sequestration of carbon in soils and forests, we could actually reduce atmospheric carbon with each passing year.

**Doing Our Level Best.** This plan features “levels;” the more obvious word choice would have been “stages.”... How much energy will be available to us at the end of the transition? It’s hard to say, as there are many variables, including rates of investment and the capabilities of renewable energy technology without fossil fuels to back them up and to power their manufacture, at least in the early stages. This “how much” question reflects the understandable concern to maintain current levels of comfort and convenience as we switch energy sources. But in this regard, it is good to keep ecological footprint analysis in mind.

One way or another, the energy transition will represent an enormous societal shift. During past shifts, there were winners and losers. In the current instance, if we don’t pay great attention to equity issues, it is entirely possible that only the rich will have access to renewable energy and therefore, ultimately, to any substantial amounts of energy at all.
The most important thing to understand about the energy transition is that it's not optional. Delay would be fatal. It's time to make a plan—however sketchy, however challenging—and run with it, revising it as we go.”

Urban Chinese willing to pay extra for green electricity

“Over 90% of people are willing to pay more for electricity from renewable sources to control air pollution but lack market muscle, a survey in 10 cities finds

New research finds that city residents in China are willing to incur significant extra costs for the sake of clean air. The vast majority of China’s urban consumers are willing to pay higher bills to buy “green electricity” from renewable sources like wind, solar or biomass, a recent survey commissioned by the China Renewable Energy Industries Association (CREIA) has found.

The survey, by the market research firm Ipsos, found that 97.6% of respondents favoured using green electricity to tackle air pollution, and that 44% of those surveyed were willing to accept a 10 yuan (US$1.50) increase in their monthly bills for a greater share of green energy. But energy sector experts warn that consumer power in China’s utilities sector is too weak to produce a decisive shift in China’s energy mix, despite plentiful sources of clean energy. China’s “green electricity” sector generating from wind, solar and biomass has grown fast, and China now has more combined wind and solar generation capacity than any other country in the world. Yet nearly three quarters of China’s electricity in 2015 came from thermal power stations burning coal, causing air pollution and carbon emissions.”


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5.9 Outlook

The recent publication of China’s Intended Nationally Determined Contributions (INDC)\(^\text{168}\) not only announces the national targets for enhanced action on climate change for 2030 but also spells out policies and measures to implement them. Among these, the urban arena is explicitly mentioned several times as area for actions, most prominently in the section on regional policies and on controlling emissions from buildings and transportation. The energy supply sector is addressed in a separate section.

China to spend $361 billion on green energy, predicts 13 million jobs

Haze in Beijing

Earlier this week, Lloyd posted disturbing footage of smog rolling into Beijing. It's real, tangible air quality and health issues like these that have made green energy and a shift away from fossil fuels a political imperative in China in a way they just don't seem to be here in the US right now. One more example of this: Reuters reports on new government plans to plough 2.5 trillion yuan ($362 billion) into green energy by 2020. Interestingly, the government seems to be stressing not just the health and environmental benefits of such a move, but jobs too. The plan should, they say, create 13 million jobs in the clean energy industries—a welcome boost at a time when China's move away from polluting, heavy industries may also cost jobs in favor of cleaning up air.

Given current question marks over US commitment to climate action, this is one more welcome sign that progress will continue. And as more renewable energy infrastructure gets built, technology costs fall everywhere—leading to considerable disruption, even in markets where leaders would seek to delay.

It should be noted, of course, that while huge, $361 billion is unlikely to be enough to shift the country to a firmly clean energy pathway. By 2020, the government still predicts that only 15% of the country's energy production will be, with coal still accounting for 58%.

\(^{168}\) Department of Climate Change, National Development and Reform Commission of China, Letter to the Executive Secretary of the UNFCCC Secretariat, Beijing 30 June 2015, Enhanced Actions on Climate Change – Intended Nationally Determined Contributions, unofficial translation.
Still, much like G7 commitments to complete decarbonization, moves like this are about more than just their specific goals and targets. They send a clear signal to markets about which way the wind is blowing, and once investment starts to shift, new and more ambitious pathways become possible.


Obviously this announcement is the result of a wide ranging coordination of government departments which indicates the broad understanding of the pervasiveness and the wide permeation of the policies. Following this announcement, the drive for clean energy and urban sustainable low-carbon agenda will become even stronger, and the respective sector policies may become even more ambitious in the medium term.169

The INDC is also a clear indication, that China is including systemic solutions in the policies in addition to the introduction of individual clean technologies. Technological solutions are undoubtedly very important, but should not obscure the need for awareness raising about environmental behavior among citizens, companies and institutions and respective action. The INDC mentioned several times the importance of pattern change.

2014 was a turning point for climate change. And it’s all thanks to China

“Coal is China. China is coal.” That was the summary given by the International Energy Agency in 2012 as it attempted to contextualize the global industry. At that time China was producing and consuming half of the world’s coal.

Across China, around 2,600 coal-fired power stations keep the world’s second-largest economy running. They also churn out billions of tonnes of greenhouse gases.

A global shift away from coal

But China’s relationship with coal appears to be changing. According to the Institute for Energy Economics and Financial Analysis, global consumption of coal peaked in 2013 and China’s reduced use was a big driver in the worldwide fall.

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According to a recent paper published in the *Nature Geoscience* journal, China burnt 4.2 billion tonnes of coal in 2013. But a year later, consumption was down by 2.9% and 2015 saw another decrease of 3.6%. The report’s authors are confident that China has passed its peak use of coal decades before many commentators had predicted.

**Slowing the rate of climate change.** Nicholas Stern, a climate economist at the London School of Economics who co-wrote the report with colleagues at Tsinghua University in Beijing, said China’s coal peak was a pivotal moment in the fight against climate change.

“I think historians really will see 2014 as a very important event in the history of the climate and economy of the world.” “Given the international political and economic structures we now have to manage climate change, I think it will be very influential on others.”

**Scaling back on coal power.** China’s investment in coal infrastructure also appears to be going into reverse. In April, the National Energy Administration announced plans to scale back on the construction of new coal-fired power plants across the country. The executive secretary of the UN’s Framework Convention on Climate Change, Patricia Espinosa, welcomed the signs that China is becoming less reliant on coal. “This assessment of the possible peaking of China’s coal use is a very positive development in international efforts to address climate change.” “It underlines how ambitious and deliberate policies to shift away from highly polluting fuels to cleaner energy sources can deliver global climate benefits and national improvements in health and indeed in people’s lives.” As the use of coal falls, the race for renewables is gathering pace. China’s Renewable Energy Industries Association says solar energy production was up 28% in the first half of 2016. Wind and hydro power production has also increased by 13%. This is in line with an existing trend that has seen China lead the way in renewable energy investment.


“On combating climate change, China has already made its plans known with its declared goal of peaking carbon dioxide emissions by 2030. It also aims to increase
its share of non-fossil sources in its primary energy consumption to 20 percent while reducing carbon intensity by 60 to 65 percent from 2005 levels.”

China preparing its decarbonisation:

Beijing Mayor announces “We’ll cut coal use 30% in 2017”

“As if the astoundingly rapid rise of electric buses in China wasn’t reason enough for hope. Business Green is reporting that Cai Qi, Beijing’s mayor, may be doubling down on already-ambitious targets to cut coal use in and around the city. Having already committed to reducing coal use to 10 million tons in the city—a figure which would already require closing some coal plants—the mayor’s statement suggested that “extraordinary measures” would now aim to bring that figure down to just 7 million tons. Compare that to the 22 million tons that were being burned in 2013, and you get the sense of how rapidly things are shifting. The Business Green report includes another encouraging sign too: City authorities plan to take 300,000 older vehicles off the road this year, and replace them with cleaner alternatives. Given previous concerns that electric vehicles in China are really just coal-powered vehicles in disguise. It’s very exciting to see the switch away from coal happening right alongside a transition away from diesel and gasoline too.”


As the Covenant of Mayors will be introduced to China from 2016 onwards, there is a good opportunity that Chinese cities will soon work on Sustainable Energy Action Plans (SEAPs). These SEAPs will be supplementary instruments to other eco-city planning documents.

City leaders must take control of own energy future - Cities have more power to secure their own cleaner energy supply than they realise

Growing cities, already accounting for over 50% of global energy consumption, can no longer afford to rely on a centralised energy supply and will need to take greater control to meet growing demand.


Although it appears that China’s environmental script is repeated year-after-year, some inherent narratives could be shifting.
Arup’s “Innovating Urban Energy” perspective paper provides insight for the World Energy Council Scenarios Report and shows that new technologies, innovative financing mechanisms and political changes are opening up opportunities for cities to secure their own energy. Technology drivers, such as advanced power electronics, smart metering and local generation, are allowing cities to diversify their energy portfolio.

Transactive energy is highlighted as an approach to change the way energy is bought and sold. This combines economic and control mechanisms to enable a dynamic balance of supply and demand using value created as a key operational parameter. It is allowing cities to develop lower cost, more stable networks capable of handling a much greater share of renewable sources. This particularly applies to electricity, but the report identifies that account needs to be taken of the other energy vectors. Many cities have existing energy and transport infrastructure that need integrated planning. Not all energy can sensibly arrive as electricity from renewable sources so other vectors such as district heating and hydrogen gas networks have a role to play in this integrated planning.

Crucially these technology developments are blurring the line between producers, distributors and consumers by allowing non-traditional energy players, such as technology companies, to enter the market. Corporates are increasingly looking for opportunities to become power producers in the new urban energy rush and could become significant contributors in the future.

At the same time the study points to the growing role of civic leaders in climate change action, indicating that cities are increasingly willing to enter a sphere traditionally reserved for national governments. The report shows that civic leaders can succeed without national policies in place, highlighting that many will have the mandate to act even when central government does not. A renewed interest in municipal energy companies in Germany, for example, is cited as evidence of the growing confidence of local authorities looking to secure their own cleaner energy supply. New financial products – such as green bonds and crowd funding – are also opening up new sources for cities to fund their own energy initiatives.

The report also highlights growing recognition of the relationship between urban planning and energy efficiency. Rapidly growing cities in Asia and Africa are urged to look to spatial planning to help reduce energy usage. “City leaders are increasingly understanding that if they are to continue to grow and to improve the lives of their citizens, they will need to play a more active role in securing their own stable and low emissions energy supply. It is an exciting time because there are big technological and political shifts that are giving cities the opportunity to take control. And, increasingly, for businesses there is an opportunity to become energy

prosumers; producing their own energy and even supplying cities. We are helping civic leaders and companies around the world to understand the opportunities and what will work both technically and pragmatically within their local contexts.”

The new city of Songdo, South Korea, has a comprehensive energy plan that is highlighted in a new report. (Vichy Deal/Shutterstock.com)

6. VALUE ADDED and CROSS CUTTING THEMES

<table>
<thead>
<tr>
<th>Value added</th>
<th>Cross-cutting themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficient energy production and cogeneration of heat and power</td>
<td>Climate change adaptation</td>
</tr>
<tr>
<td>Efficient distribution: Decentralized production, close alignment of demand</td>
<td>Resilience to impacts of climate change</td>
</tr>
<tr>
<td>supply, smart grids and metering</td>
<td>Sustainable land management</td>
</tr>
<tr>
<td>High percentage of renewable energy within the overall energy supply</td>
<td>Biodiversity</td>
</tr>
<tr>
<td>Alternative energy sources: solar, wind, biofuel</td>
<td>Livelihoods</td>
</tr>
<tr>
<td>Waste–to–energy</td>
<td>Agriculture and food (alternative energy)</td>
</tr>
<tr>
<td>Co-benefits – carbon trading</td>
<td>Livelihoods</td>
</tr>
<tr>
<td>Combined heat and power plants</td>
<td>Land use planning</td>
</tr>
<tr>
<td>Retrofitting of inefficient energy plants</td>
<td>Awareness creation and environmental consciousness</td>
</tr>
</tbody>
</table>
7. AVAILABLE RESOURCES AND TOOLS

- ARUP Decentralized Energy Networks Masterplanning Guidance (DENet), http://www.arup.com/Projects/DENet
- Association for Decentralised Energy (ADE), District Heating Installation Map, see http://www.theade.co.uk/district-heating-installation-map_790.html
- Carbonn Climate Registry website is http://carbonn.org/
- Concerto Library .. http://concerto.eu/concerto/images/library
- Economist Intelligence Unit, Asian Green City Index, Assessing the environmental performance of Asia’s major cities; sponsored by Siemens; http://www.siemens.com/entry/cc/features/greencityindex_international/all/en/pdf/report_asia.pdf
- EnEff:Stadt, New approaches to analysis and planning for an energy efficient city, see, http://www.eenef-stadt.info/en/design-tools/
- European Association of local authorities, website, www.energie-cites.eu
- ICLEI, UN Habitat, Solutions Gateway, Low-carbon Solutions for Urban Development Challenges, Developed in the Urban-LEDS project http://www.solutions-gateway.org/
  - Annex 51: Energy Efficient Communities Case Studies and Strategic Guidance for Urban Decision Makers (IEA _ ECBCS Annex 51) http://www.annex51.org/, including:
IEA ECBCS Annex 51 - Subtask D: District Energy Concept Advisor (a computer software tool); launched by the German Federal Ministry for Economy and Technology. EnEff: Stadt, Fraunhofer Institute for Building Physics (IBP). http://www.district-eca.com/index.php?lang=de

- World Resources Institute, CAIT Climate Data Explorer [http://cait.wri.org/](http://cait.wri.org/)
EU Directives and Programmes:

- The effort sharing decision [http://ec.europa.eu/clima/policies/effort/index_en.htm](http://ec.europa.eu/clima/policies/effort/index_en.htm)
8. RECOMMENDED READING


Dhakal, S., Urban energy use and carbon emissions from cities in China and policy implications, in Energy Policy, Volume 37, Issue 11, November 2009, Pages 4208–4219


Kiss, C., Update on cogeneration in Europe, A view from the COGEN Europe National Associations; http://www.endseurope.com/docs/130419a.pdf (original data source EEA discontinued)


Examples of urban comprehensive clean energy plans:


ANNEXES

Annex 1: Tool CE 1 - Technology options for decentralized new energy supply.

**Name:** TECHNOLOGY OPTIONS FOR DECENTRALIZED NEW ENERGY SUPPLY

Cities are in the frontline for cutting carbon emissions. Decarbonising urban buildings and transport is key to attain Paris climate goals, but slow progress will test governments’ commitment. Cities must take the lead in the transition to a low-carbon energy sector (IEA 2016). This is particularly so since urban areas account for up to two-thirds of the potential to cost-effectively reduce global carbon emissions. “Cities today are home to about half the global population but represent almost two-thirds of global energy demand and 70% of carbon emissions from the energy sector, so they must play a leading role if COP21 commitments are to be achieved,”… “Because cities are centres of economic growth and innovation, they are ideal test-beds for new technologies – from more sustainable transport systems to smart grids – that will help lead the transition to a low-carbon energy sector.” (http://www.iea.org/topics/cleanenergytechnologies/)

What this tool does: This tool tries to help local governments to select most relevant and energy-efficient technologies. There are four technology revolutions available today. In the last five years they have achieved dramatic reductions in cost and this has been accompanied by a surge in consumer, industrial and commercial deployment. Although these four technologies still represent a small percentage of their total market (e.g. electricity, cars and lighting), they are growing rapidly. The four key technologies this report focuses on are: (i) onshore wind power; (ii) polysilicon photovoltaic modules; (iii) LED lighting; and (iv) electric vehicles (see: US Department of Energy, 2013).

Applications:
- Urban buildings provide useful space to self-generate the electricity they consume: by 2050, rooftop solar could technically meet one-third of cities’ electricity demand. And those buildings offer significant demand potential for the roll-out of the most efficient technologies, like energy-efficient windows and appliances.
- Best electric vehicles and public transport can lead to a low-carbon mobility system while reducing investment needs compared with current development trends in cities.
- The total renewable energy capacity installed currently provides around 23% of global electricity generation, sustained by progress in solar PV and on-shore wind that pushed the growth of renewable energy capacity to a record high, exceeding 150 gigawatts in 2015. This is an encouraging trend in line with the 2°C goal of having in excess of two-thirds of electricity generated by renewables in 2050. China is the largest renewable energy market, accounting in 2015 for more than half of the world’s new global onshore wind capacity and one-third of the solar PV capacity installed. (see IEA: http://www.iea.org/topics/cleanenergytechnologies/)

How does it work: The tool proposes to screen new or newly emerging technology options for the most cost-effective technologies for low-carbon cities.

- Technology screening.
- Review of alternative technology options.
- Comparison of new energy solutions versus conventional technology.
- Calculation of cost-efficiency of new energy solutions, taking into account:
  - Capital costs.
  - Life span of technology.
  - Maintenance costs.
- CO₂ impacts.
  - Compare local with imported products.
  - Availability of products on national/local market.
  - Quality of maintenance services.

**Consider Smart Objectives**

**Energy performance standard**
- **S:** Focus on specific product or product group
- **M:** Performance characteristics aimed for/set baseline
- **A:** Performance standard links to best available product on the market and is regularly updated
- **R:** Best available product is accepted by the target group
- **T:** Set clear target period

**Subsidy scheme**
- **S:** Focus on specific target group and on specific technologies
- **M:** Quantified energy savings target/set baseline
- **A:** Minimize freeriders
- **R:** Link the savings target to the available budget
- **T:** Link the energy savings target to a target period

**(Voluntary) Energy audit**
- **S:** Focus on specific target group
- **M:** Quantify the target audit volume (m², number of companies, % of energy use, etc.)/set baseline
- **A:** Encourage to implement recommended measures, e.g. by offering financial incentives
- **R:** Ensure that sufficient qualified auditors have been assigned and financial incentives are in place to carry out audits
- **T:** Link the quantified target to a target period


**Literature / further information:**


**Name:** DECENTRALISED MICRO-GRIDS

**What this tool does:** This tool will enable local decision makers to initiate the creation of decentralised micro-grids. The renewable energy sector will require micro grids if it wants to grow. This tool explains the importance of micro-grids, and how these can be developed.

“China has become the world’s largest market for power transmission and distribution (T&D), and is poised to become a major consumer of smart grid technology. Commitments by China’s political leaders to reduce the carbon intensity of its GDP by 40 to 45 % by 2020 relative to 2005, and to increase the use of renewable power promise a massive transformation of the nation’s energy landscape... First, China’s commitment to green development will lead to a tremendous need for smart grid technologies. Second, China has a unique structural context that could enable it to leap ahead in the development of the smart grid.” (McKinsey 2010).

**What are MICROGRIDS?**

Interconnection of small, modular generation to low voltage distribution systems forms a new type of power system, the Microgrid. Microgrids can be connected to the main power network or be operated islanded, in a coordinated, controlled way.

*source: www.microgrids.eu*
How does it work:

SmartGrids: Enhancing grid flexibility & robustness

• Compile tools of **proven technical solutions** that can be deployed rapidly and cost-effectively, enabling existing grids to accept power injections from distributed energy resources without contravening critical operational limits (such as voltage control, switching equipment capability and power flow capacity);

• Establish **interfacing capabilities** that will allow new designs of grid equipment and new automation/control arrangements to be successfully interfaced with existing, traditional, grid equipment;

• Ensure **harmonisation of regulatory and commercial frameworks** in Europe to facilitate cross-border trading of both power and grid services (such as reserve power, for instance Nordic hydropower), ensuring that they will accommodate a wide range of operating situations without creating perverse incentives or other unintended consequences;

• Establish shared technical standards and protocols that will **ensure open access**, enabling the deployment of equipment from any chosen manufacturer without fear of lock-in to proprietary specifications. This applies to grid equipment, metering systems, and control/automation architectures;

• Develop **information, computing and telecommunication** systems that enable businesses to utilise innovative service arrangements to improve their efficiency and enhance their services to customers.

**Smart Grids**

![Smart Grids Diagram](image)

*Future: Operation of systems will be shared between central and distributed generators. Control of distributed generators could be aggregated to form microgrids or ‘virtual’ power plants to facilitate their integration both in the physical system and in the market.*

Source: European Commission. 2006. (see below)

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**Future Network Vision**

![Future Network Vision](image)

Literature / further information:

- http://www.smartgrids.eu/
Annex 3: Tool CE 3 - Sustainable energy action plans (SEAPs)

**Name:** SUSTAINABLE ENERGY ACTION PLANS (SEAPs)

**What this tool does:** This tool guides through the preparation of Sustainable Energy Action Plans (SEAPs), the tool which is key to the implementation of the Covenant of Mayors (CoM). The CoM is being promoted by the EU and ICLEI.

“The Sustainable Energy Action Plan (SEAP) is a key document that shows how the Covenant signatory will reach its commitment by 2020. It uses the results of the Baseline Emission Inventory to identify the best fields of action and opportunities for reaching the local authority’s CO₂ reduction target. It defines concrete reduction measures, together with time frames and assigned responsibilities, which translate the long-term strategy into action. Signatories commit themselves to submitting their SEAPs within the year following adhesion.”...

**Scope.** The Covenant of Mayors concerns action at local level within the competence of the local authority. The SEAP should concentrate on measures aimed at reducing the CO₂ emissions and final energy consumption by end users. The Covenant’s commitments cover the whole geographical area of the local authority (town, city, region). Therefore the SEAP should include actions concerning both the public and private sectors. However, the local authority is expected to play an exemplary role and therefore to take outstanding measures related to the local authority’s own buildings and facilities, vehicle fleet, etc. The local authority can decide to set the overall CO₂ emission reduction target either as ‘absolute reduction’ or ‘per capita reduction’.

The main target sectors are buildings, equipment/facilities and urban transport. The SEAP may also include actions related to local electricity production (development of PV, wind power, CHP, improvement of local power generation), and local heating/cooling generation. In addition, the SEAP should cover areas where local authorities can influence energy consumption on the long term (as land use planning), encourage markets for energy efficient products and services (public procurement), as well as changes in consumption patterns (working with stakeholders and citizens)(1). On the contrary, the industrial sector is not a key target of the Covenant of Mayors, so the local authority may choose to include actions in this sector or not. In any case, plants covered by the ETS (European CO₂ Emission Trading Scheme) should be excluded, unless they were included in previous plans of the local authority.

**How does it work:**

- Build support from stakeholders: if they support your SEAP, nothing should stop it!
- Conflicting stakeholders’ interests deserve special attention.
- Secure a long-term political commitment.
- Ensure adequate financial resources.
- Do a proper CO₂ emissions inventory as this is vital. What you do not measure you will not change.
• Integrate the SEAP into day-to-day life and management of the municipality: it should not be just another nice document, but part of the corporate culture!
• Ensure proper management during implementation.
• Make sure that your staff has adequate skills, and if necessary offer training.
• Learn to devise and implement projects over the long term.
• Actively search and take advantage of experiences and lessons learned from other cities that have developed a SEAP.

Suggested List of Content for SEAPs

1. SEAP Executive Summary
2. Overall strategy
   A. Objective(s) and Targets
   B. Current framework and vision for the future
   C. Organisational and financial aspects:
      • coordination and organisational structures created/assigned;
      • staff capacity allocated;
      • involvement of stakeholders and citizens;
      • budget;
      • foreseen financing sources for the investments within your action plan;
      • planned measures for monitoring and follow-up.
3. Baseline Emission Inventory and related information, including data interpretation
   (see Part II of this Guidebook, chapter 5 Reporting and documentation)
4. Planned actions and measures for the full duration of the plan (2020)
   • long-term strategy, goals and commitments till 2020;
   • short/medium term actions.

For each measure/action, please specify (whenever possible):
• description
• department responsible, person or company
• timing (end-start, major milestones)
• cost estimation
• estimated energy saving/increased renewable energy production
• estimated CO2 reduction


Process:
Ten key elements to keep in mind when preparing the SEAP:
1. SEAP approval by the municipal council (or equivalent decision-making body)
2. Commitment for a reduction of CO2 emissions by at least 20 % by 2020
3. CO2 baseline emission inventory (BEI)
4. Comprehensive measures that cover the key sectors of activity
5. Strategies and actions until 2020
6. Adaptation of city structures
7. Mobilisation of the civil society
8. Financing
9. Monitoring and reporting
10. SEAP submission and filling the template

(Source: EU [see below])
### Examples of Building Sector Interventions

<table>
<thead>
<tr>
<th>POLICY INSTRUMENTS AT DISPOSAL OF THE LOCAL AUTHORITY</th>
<th>PRIVATE BUILDINGS</th>
<th>PUBLIC BUILDINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New</td>
<td>Renovated</td>
</tr>
<tr>
<td>Energy performance regulations</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Financial incentives and loans</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Information and training</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Promote successes</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Demonstration buildings</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Promote energy audits</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Urban planning and regulations</td>
<td>X</td>
<td>+</td>
</tr>
<tr>
<td>Increase the rate of refurbishment</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Energy taxes</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Coordinate policies with other levels of authority</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

X = most relevant  
+ = somehow relevant  
- = low relevance


**Literature / further information:**


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173 In late 2016, the EU announced a new planning tool which will replace the SEAPs: Sustainable Energy and Climate Action Plans (SECAPs). A format for these is yet to be developed.
The Europe-China Eco Cities Link (EC-Link) Project is funded by the European Union in cooperation with the Ministry of Housing and Urban-Rural Development (MoHURD), implemented by the European Consortium led by GIZ.