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Urban Energy Masterplanning—Approaches, Strategies, and Methods for the Energy Transition in Cities

Andy van den Dobbelsteen[*], *Rob Roggema*[†], *Nico Tillie*[*],
Siebe Broersma[*], *Michiel Fremouw*[*], *Craig Lee Martin*[*]
[*]Delft University of Technology, Faculty of Architecture (Netherlands)
[†]University of Technology Sydney, Faculty of Design, Architecture and Building (Australia)

INTRODUCTION

Many cities across the world have the ambition of becoming carbon neutral, but exact figures of progress toward that goal are limited. Regarding Europe's not overly ambitious 2020 carbon emission targets, many countries still have a long way to go (see Fig. 1), with cities as the prime objects for improvement.

It is fair to say that the energy transition is lagging behind, for which several reasons can be given. One assumption, based on experience with projects with various European cities, is that cities—their administrations and other stakeholders—generally have insufficient understanding of how to gain and maintain control over the complex process of the energy transition with its multiple actors and diverse objectives and responsibilities. Another suggested reason is the lack of appropriate approaches, strategies, and methods to guide the energy transition in formulating clear targets and intermediate steps of mainly technical and spatial interventions. These, however are currently under development, and are being tested in cities across the continent—such as in Gothenburg, London, Rotterdam, Cologne, and Genova within the EU project Celsius (www.celsiuscity.eu), and in Amsterdam and Grenoble, for the EU project City-zen (www.cityzen-smartcity.eu)—with promising results so far.

The main research question underlying this chapter is:

How can cities be supported in their energy transition toward carbon neutrality?

We will describe the development of approaches, strategies, and methods for the urban energy transition, their background and theoretical basis, and present urban case studies where they were applied. Finally, an outlook will be given for methodological developments in the near future.

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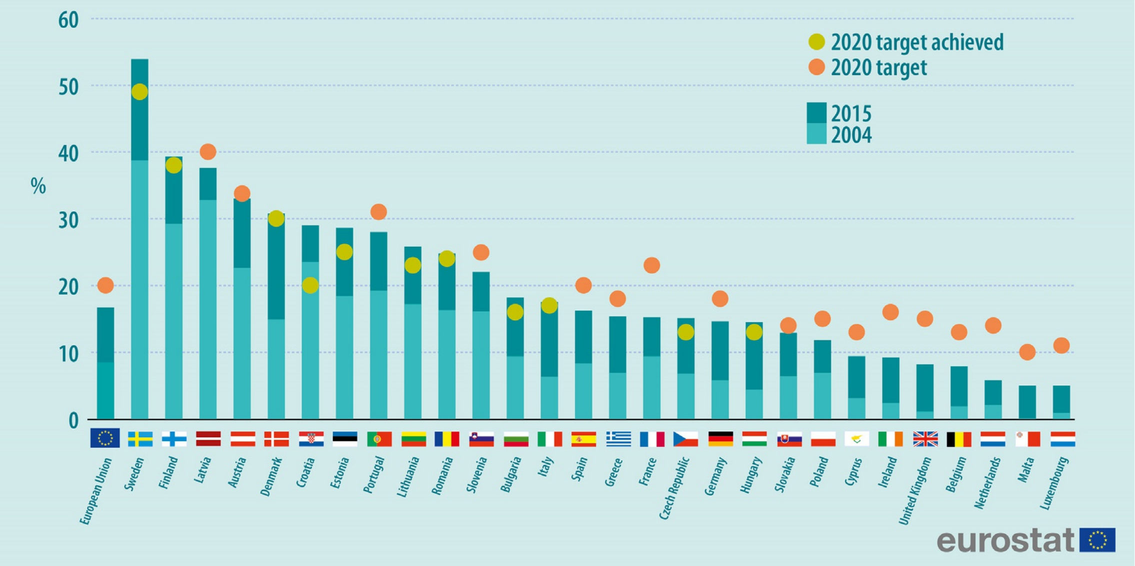

FIG. 1 Share of energy from renewable sources (in % of gross final energy consumption) and distance to 2020, CO$_2$ targets for EU member states (Eurostat, 2017).

HISTORICAL BACKGROUND

Government Incentives

After the UN Commission on Environment and Development (Brundtland et al., 1987) the Netherlands was the first country to introduce a national environmental policy plan ("Nationaal Milieubeleidsplan": NMP, NMP+, and NMP2) (Ministerie van VROM, 1989, 1990, 1994) that included a strategy for sustainable building (improving energy efficiency, closed cycles, quality improvement), in which the energy part was promoted through a three-stepped approach, the Trias Energetica (Duijvestein, 1997; Lysen, 1996): (1) Reduce the demand, (2) Use renewable sources, (3) Use finite sources cleanly and efficiently. Following the strong government-induced incentive for sustainable development, the energy performance code ("Energieprestatienormering," NEN, 1998) was introduced for buildings and so-called national packages with environmental measures were developed for various scales, such as the national package for sustainable urbanism ("Nationaal Pakket Duurzame Stedenbouw"). For several years, these packages were used by municipalities with the redevelopment of built areas until around 2000, when the Dutch government let go of their steering role in sustainability. It was only 6 years later—late, considering ICLEI's 1993 Cities for Climate Protection program—that cities started to express their ambition to become carbon neutral within due time, following Al Gore's book and film called "An Inconvenient Truth" (Gore, 2006), the slow acceptance of the "Cradle to Cradle" (McDonough and Braungart, 2002) concept, and the Clinton

Climate Initiative for carbon-neutral cities, boosted by the alarming reports of the International Panel on Climate Change (IPCC, 2007, 2014).

Many Cities United

In 2006, a city network on greenhouse gas reduction, initiated 1 year earlier by London's Mayor Ken Livingstone, partnered with the Clinton Climate initiative. With 40 cities in the initial network, the C40 was born. Nowadays, there are close to 90 cities active in this group. The C40's mission is taking action to address climate change by developing and implementing policies and programs that generate measurable reductions in both greenhouse gas emissions and climate risks.

Strangely enough, only few cities had and still have an accurate annual account of their CO_2 emissions, making pledges on carbon reductions meaningless. It is thanks to the Paris Treaty of 2015 (COP21) that countries, and with them the cities within, have been put under pressure to translate the ambitions expressed into pragmatic action agendas. Recent figures of the lagging national performances on carbon emissions, presented by the EU (as presented in Fig. 1), put extra force on the necessity to speed up the sustainable energy transition. Nonetheless, few cities have written action agendas that can guide such a process.

Energetic Explorations

Interestingly, the first concrete signs of plans toward a future of renewable energy were given on a larger than city scale. In the year 2005, when the northern provinces of the Netherlands asked to explore the opportunities for a shift from fossil resources to renewables, a regional plan was drawn up largely based on renewables. "Pallet of Possibilities" (Roggema et al., 2006) showed the energy richness of a region otherwise just blessed with a huge gas resource. The method of Energy Potential Mapping (EPM) was born in a first crude version during that project, research-by-design before known as such. The year after EPM was given a real methodological basis in the provincial spatial-environmental plan for Groningen (van den Dobbelsteen et al., 2007).

EPM charts the various energy potentials of a certain area at different layers of the earth's surface: from deep underground geothermal heat to solar energy and wind at high altitudes. It makes visible what otherwise is poorly understood: that each place has a richness in natural and anthropogenic energy sources. In the years 2008–2011, EPM was applied to many places in the Netherlands, among which, the city of Almere (van den Dobbelsteen et al., 2008) and town extension of Hoogezand-Sappemeer (Broersma et al., 2009). A special step was taken with the Heat Mapping study of the Netherlands, involving 3D maps of heat demands and potentials in cities such as Rotterdam (Broersma et al., 2010) (Fig. 2).

Climate Adaptation

In the same period, the province of Groningen explored the relationship between energy potentials and climate adaptation through a layered way of mapping causes and impacts of climate change for a climate-proof Groningen (Roggema, 2009a). Eventually, this mapping technique led to the development of the Swarm Planning methodology, which aims to plan for a resilient, climate-proof future. The layers in this methodology (Fig. 3) represent the paces of change of the underlying urban systems, such as the energy system, but also the transport network, the water network, natural resources, core nodes, and the so-called unplanned space, which aims to create space for unprecedented events (Roggema, 2012).

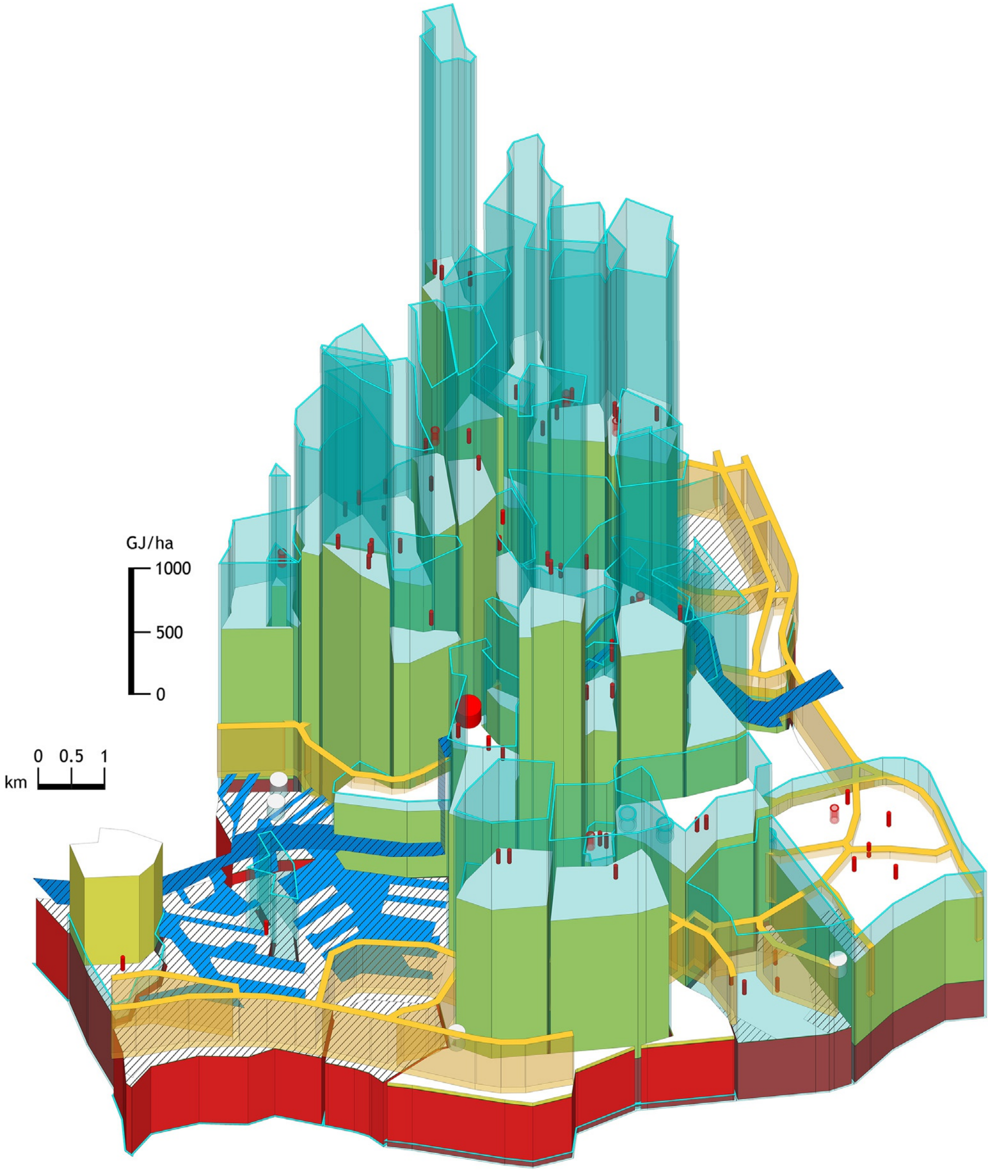

FIG. 2 3D presentation of heat demands and heat potentials in the city of Rotterdam (Broersma and Fremouw, 2011).

URBAN ENERGY APPROACHES, STRATEGIES, AND METHODS

Since the year 2008 in the Netherlands, several urban energy approaches have been developed to support the transition to more resilient cities, cities run on renewables. Based on the New Stepped Strategy, the Rotterdam Energy Approach & Planning (REAP) was introduced in 2009, and this set the standard for other methods, such as the Amsterdam Guide to Energetic Urbanism (LES in Dutch). More recently,

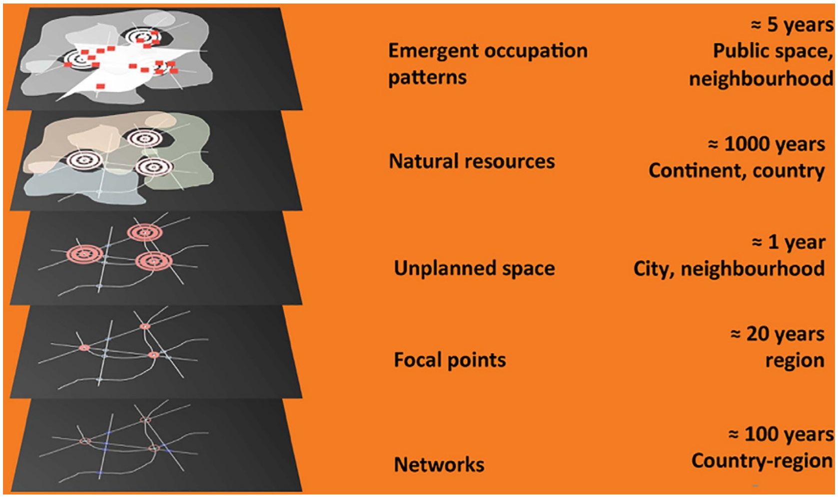

FIG. 3 The layers of Swarm Planning (Roggema, 2012).

on a European scale, urban Energy Master Planning was introduced, supporting roadmaps toward a sustainable future for cities.

The New Stepped Strategy

After almost 20 years of the original three-stepped strategy introduced by Duijvestein (1993) and Lysen (1996), statistical records still showed a slow transition to renewable energy and a lagging uptake of sustainable technology. In practice, the second step of renewables was often skipped as a result of the relatively high investment costs when the energy demand had not been sufficiently reduced, which was often the case. Hence, designers, consultants, and builders mostly put in their effort for efficient technology, the third step, which remained linked to fossil energy. Efficiency rarely achieves higher improvement factors than 15%. Therefore, partly related to the urgency for 100% independency from fossil fuels and inspired by Cradle to Cradle, the New Stepped Strategy was introduced (van den Dobbelsteen, 2008): (1) Reduce the demand, (2) Reuse waste flows, (3) Produce from renewable sources and let waste be food. As can be seen, fossil fuels have been ruled out completely. One should add an initiating step (0) regarding research of energy demands, supplies, and potentials. That way, the New Stepped Strategy can be summarized as: Research, Reduce, Reuse, Produce.

The Rotterdam Energy Approach & Planning

Specifically for the urban scale, the New Stepped Strategy was a crucial step in linking urban planning to CO_2 reduction and energy goals as it provided an incremental approach. This was done in the Rotterdam Energy Approach and Planning (REAP) (Tillie et al., 2009).

First, the energy consumption of buildings must become much more efficient to meet carbon reduction targets (step 1). After that, it is useful to determine whether waste flows from buildings can be reused (step 2). Recycling heat from ventilated air and waste water from showers, for example, is doing this. However, instead of moving forward to step 3 with individual buildings, cities can be seen as a system with different functions that can be linked, it is more interesting to scale up from the building level to the level of the neighborhood, district, or city before solving the remaining demand by renewables (Fig. 4).

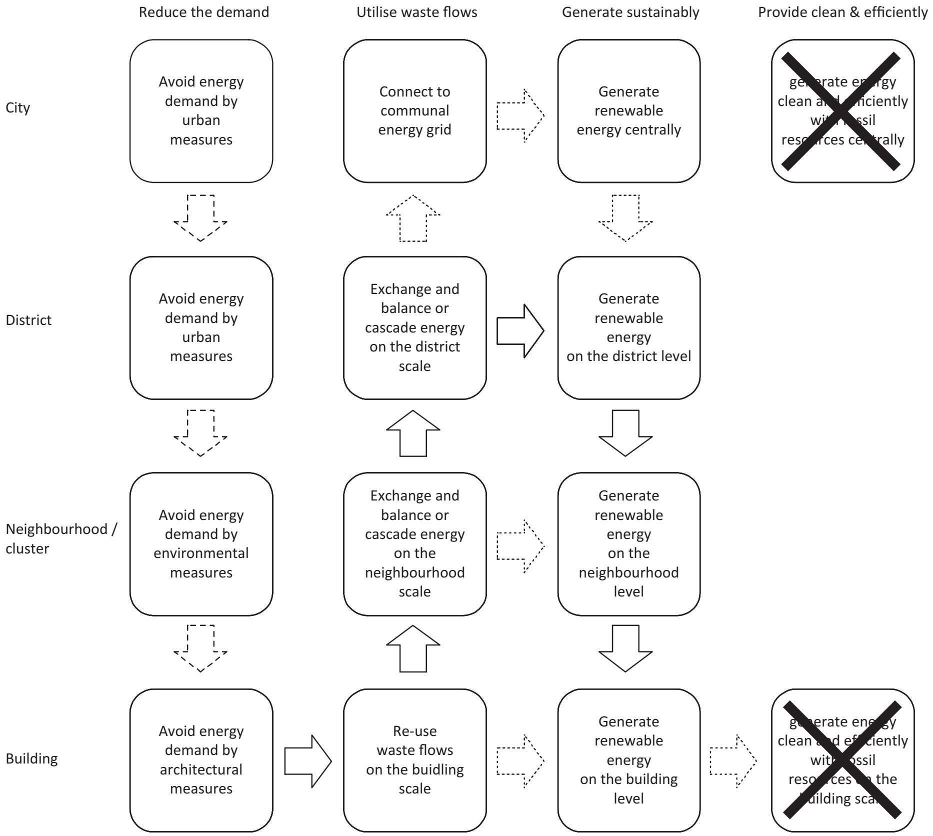

FIG. 4 The REAP methodology (Tillie et al., 2009).

Reuse From Building to Neighborhood

Urban functions have different patterns for heating, cooling, and the use of electricity. In Northwestern Europe, modern offices have to start cooling as soon as outdoor temperatures exceed 12°C. Under these conditions, residences still require to be heated. This provides opportunities for heat exchange between buildings, particularly during spring and autumn. A particular opportunity exists for the combination of supermarkets (which require permanent cooling for fresh products) with residences (which predominantly demand heating), 1 m^2 of supermarket can heat 7 m^2 of dwelling.

If not all waste energy flows can be solved at cluster or neighborhood level, REAP suggests to scale up.

Reuse From Neighborhood to District

Discrepancies in the energy balance at the neighborhood level (e.g., excess demand for waste heat or cold) may be solved at the level of the urban district. At the district level, it is likely that there will be a wider mix of functions available with different energy patterns. Larger amenities, such as shopping centers and concert halls, have a very specific energy pattern. Combining a number of these different amenities through energy exchange, heat cascading, and storage might achieve a higher level of energy efficiency and waste reduction.

Another option is possible. Useful functions might be added to complete missing links in the energy balance in an area. For instance, an amenity that requires extra heat on a yearly basis is a swimming pool, and one that requires cold is an ice skating rink.

Reuse From District to Entire City and Beyond

Many Northern European Cities have centrally regulated utilities, among which heat grids (fed with waste heat from conventional power plants, cogeneration plants, waste incineration plants, or industries). These heat grids, often falsely called district heating, provide temperatures between 90°C and 130°C. This temperature level is necessary for buildings that are poorly insulated and that have central heating systems based on higher temperatures. New housing projects are more effectively served with lower temperatures. Once connected to the high-caloric heat grid exchanging, cascading, and storing heat at the neighborhood and district level is no longer logical. This has two negative effects: the demand for energy is higher than necessary and energy is lost and the city heated up, which in summer can aggravate the urban heat island effect, which statistically leads to higher mortality rates (Huynen et al., 2001). Therefore, the city heat grid may better play a useful role for functions that do require higher temperatures, or as backup system that enables loading and unloading of excessive heat from districts, neighborhoods, and buildings.

Produce Renewable Energy

After these steps of waste energy reuse, the remaining energy demand needs to come from renewable sources. Some of the technologies for these are feasible at the individual scale, (e.g., PV panels and solar collectors); other forms of generation are potentially more feasible at the neighborhood, district, or city scale (e.g., ground-source heat pumps, bio-fermentation, geothermal heat, and wind turbines).

REAP Case Study

By using the steps indicated, REAP can help make an existing neighborhood low carbon, without requiring drastic urban planning measures. This was tested with Rotterdam neighborhoods, such as the Hart van Zuid shopping mall, where energy savings, new urban functions, exchange of heat, energetic balance, addition of roof greenhouses (that capture passive solar heat and sequester CO_2 from the building underneath), and use of PVT-panels made the area carbon and energy neutral.

REAP2

To make REAP ready for practical application, REAP2 was a follow-up study on smart grid opportunities for heating and cooling of the Merwe-Vierhavens, an inner-city port area confronted with a transition toward net zero energy. In REAP2 (Dobbelsteen et al., 2012), the REAP approach was extended and tested, which led to new technical concepts for energy exchange. The area contains warehouses, industrial buildings, offices, and a small power plant, some of which to be demolished, creating space for new, sustainable developments. This means that the energy demand and supply, heat in particular, will be varied. The technology and infrastructure therefore needs to be multifunctional and serve variable demands.

Principles and Strategies

From the project four principles of balancing heat and cold came forth:

- matching supply and demand directly,
- (inter-)exchanging residual heat and cold,
- cascading waste heat, and
- storing temporal differences in supply and demand.

Applying these principles at the scale of separate buildings, the quays, the entire area and the scale of Rotterdam, five strategies emerged (Fig. 5): two based on connection to the central high-temperature heat grid: A. heat cascading grid, and AB. cascading machine; one introducing a neighborhood facility: B. exchanging machine; and two disconnected from centralized energy infrastructure: BC. inter-exchange within a cluster, and C. individual self-provision.

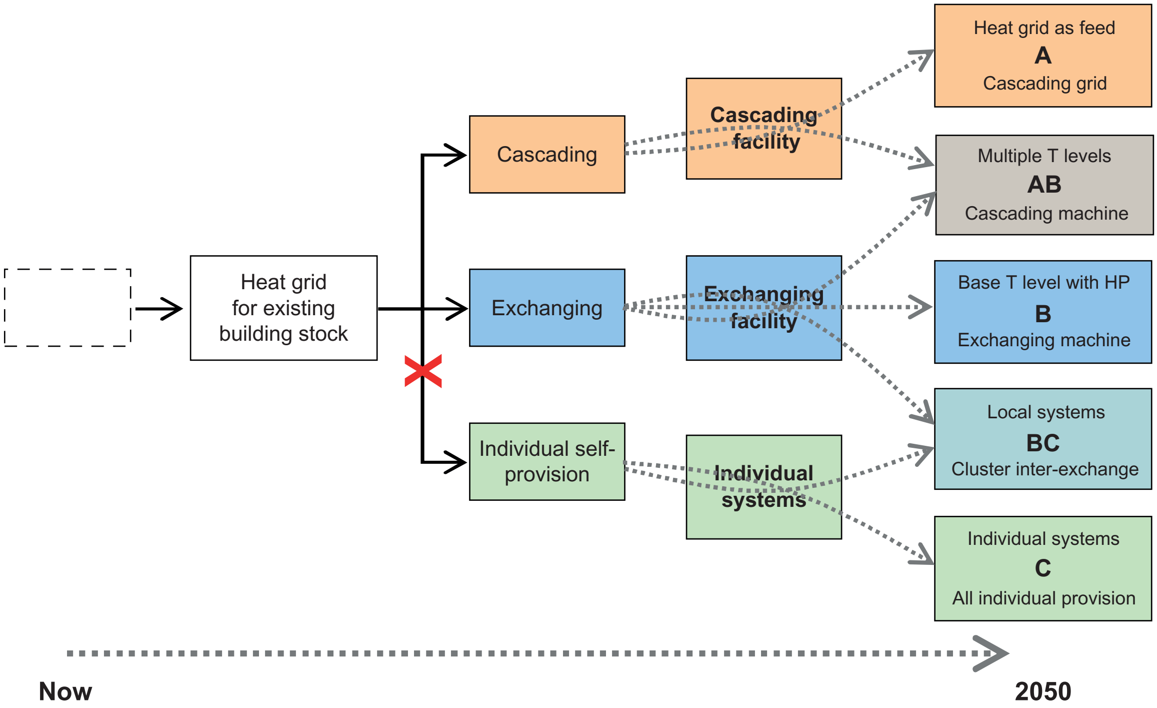

FIG. 5 The five strategies from REAP2 (Dobbelsteen et al., 2012).

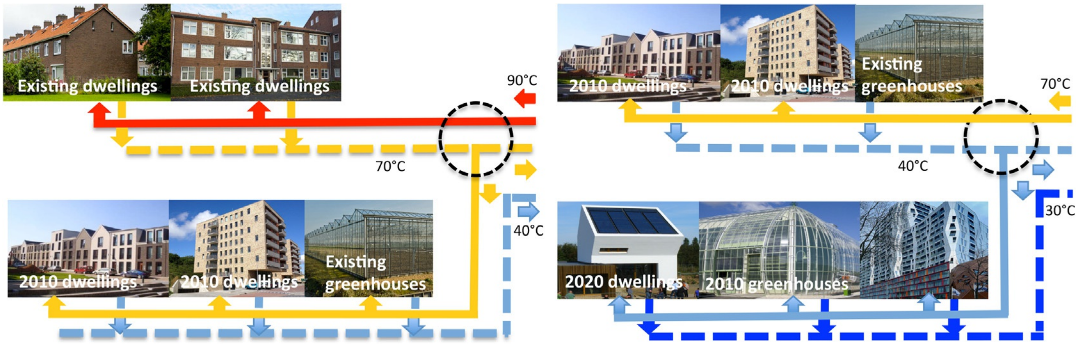

FIG. 6 Heat-cascading grid, connecting an old neighborhood with a newer one (*left*) and connecting a newer neighborhood with a very well-insulated one (*right*); the latter grid can be an extension of the first (van den Dobbelsteen et al., 2011; image by DWA).

The five strategies can be translated into technical solutions using available utilities but combining and connecting these in a novel way. Fig. 6 shows the principle of a heat-cascading grid, using the return flow of one neighborhood as the main supply for the other.

Cascading can also be established by a "cascading machine" connected to the central utility of high-caloric heat. This concept could provide water at different temperatures for buildings with different demands—depending on their heat system and thermal insulation—based on

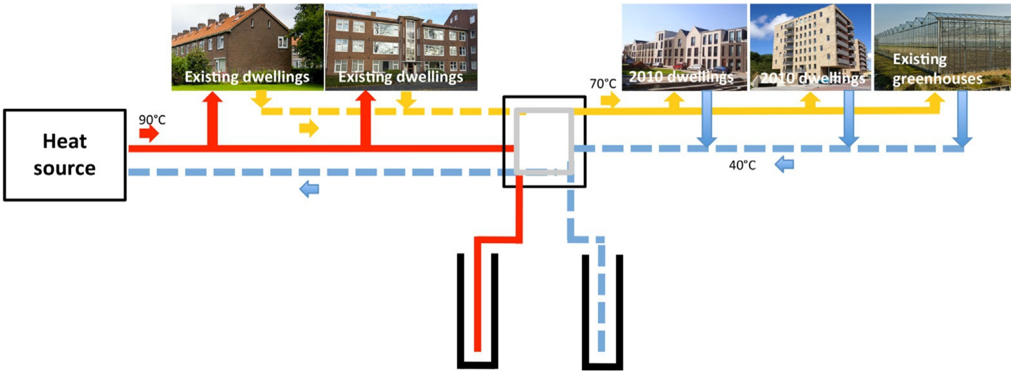

FIG. 7 Heat cascading via heat and cold storage facility: excess heat in summer can be stored in the underground for use in winter, when excessive cold can be stored for use in summer (van den Dobbelsteen et al., 2011; image by DWA).

the temperature difference between the feed water and the return water. An inter-seasonal heat and cold storage (e.g., underground aquifer storage systems and boiler systems) can shave off peaks in supplies and demands. See Fig. 7.

Technology and Space

The five strategies have specific spatial, social, legal, and institutional implications. Some of these implications became apparent when they were clarified by sketches of the technical principle and their respective spatial influence (Fig. 8).

The heat exchanging machine is a theoretical concept based on heat pumps that could be ground-breaking for the exchange of heat and cold in cities. The exchanging machine provides water at a low-caloric level (e.g., 40°C), which can be upgraded or downgraded—depending on the demand of a building—by an individual heat pump. The return temperature depends on the heat demand of the building. Excess heat can be stored, (i.e., in hot wells of underground aquifers, and excess cold in cold wells).

Urban Planning and Thermodynamics

As described by Stremke et al. (2011), the question of exchanging heat and cold in cities integrates thermodynamics into urban planning, and takes patterns of energy demand and supply in cities as the basis for novel utilities and infrastructure. Heat and cold storage will prove to be a valuable asset to a sustainable energy system, because the availability of renewable energy will fluctuate partly due to demand changes through the seasons. A multi-temperature storage system does not exist yet, but is already technically possible with the help of heat pumps.

Energy Potential Mapping

For the transition of our fossil fuel society to one based on renewables, good understanding is required of the energy potentials of an area under scrutiny. Next to the physical availability of renewable and residual resources, the vicinity of these resources, their compliance with demand patterns, and the exergetic quality of this energy are characteristics often overlooked in the past.

The method of Energy Potential Mapping (EPM) was introduced to fill this knowledge gap (Fig. 9), to help public institutions in their process of energy transition. It has become an essential part of sustainable energy plans on various scales and forms the basis for urban energy atlases and even national energy transition studies.

Energy and Space

At the basis of most EPM calculations lies the relation between energy and space. For

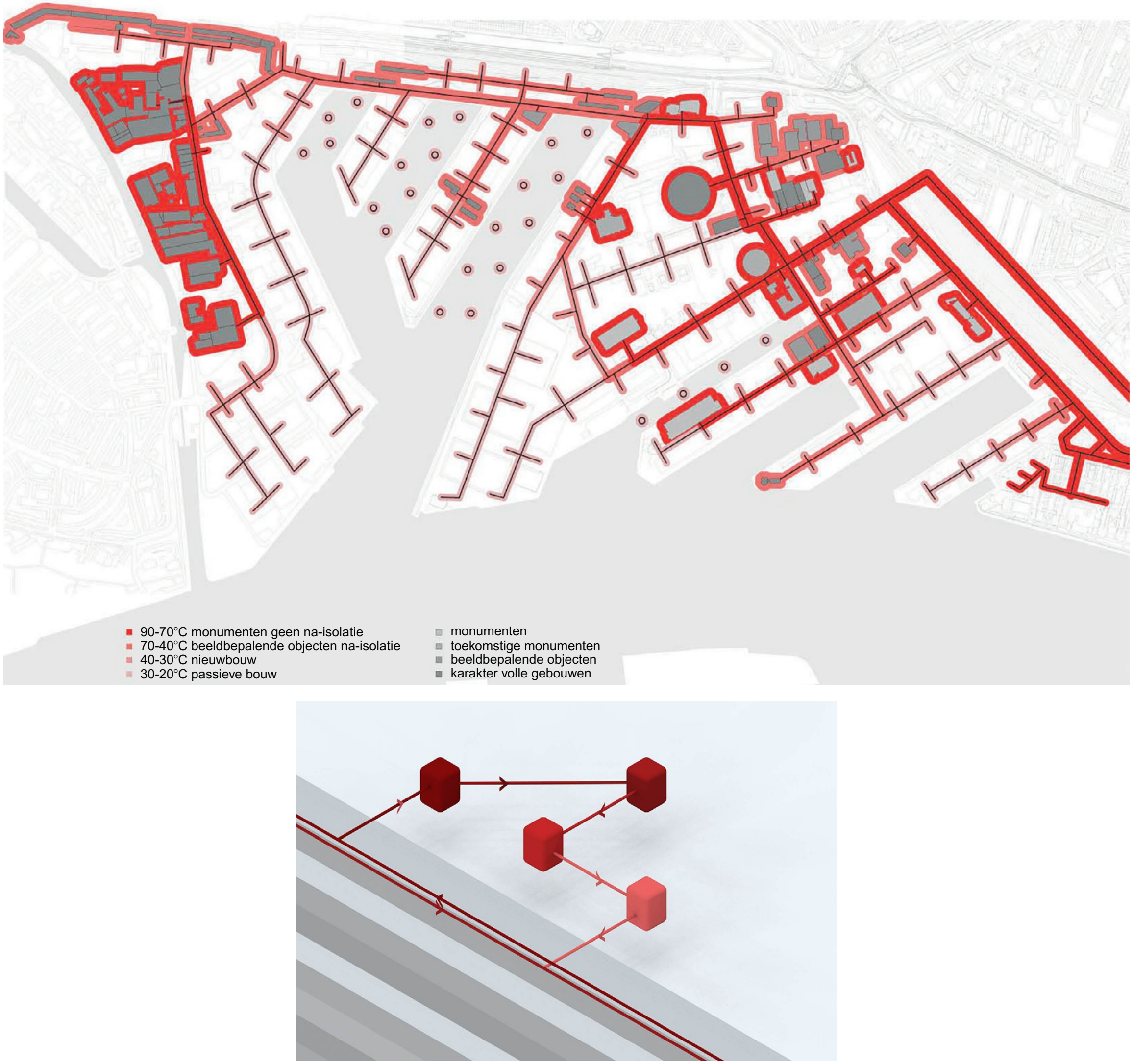

FIG. 8 Technical concepts and spatial implications to the Merwe-Vierhavens of the heat exchange strategies of A (heat-cascading grid), AB (cascading machine), B (heat exchanging machine), and C (individual self-provision). BC is a smaller combination of C and B (van den Dobbelsteen et al., 2011; images by Doepel Strijkers Architects).

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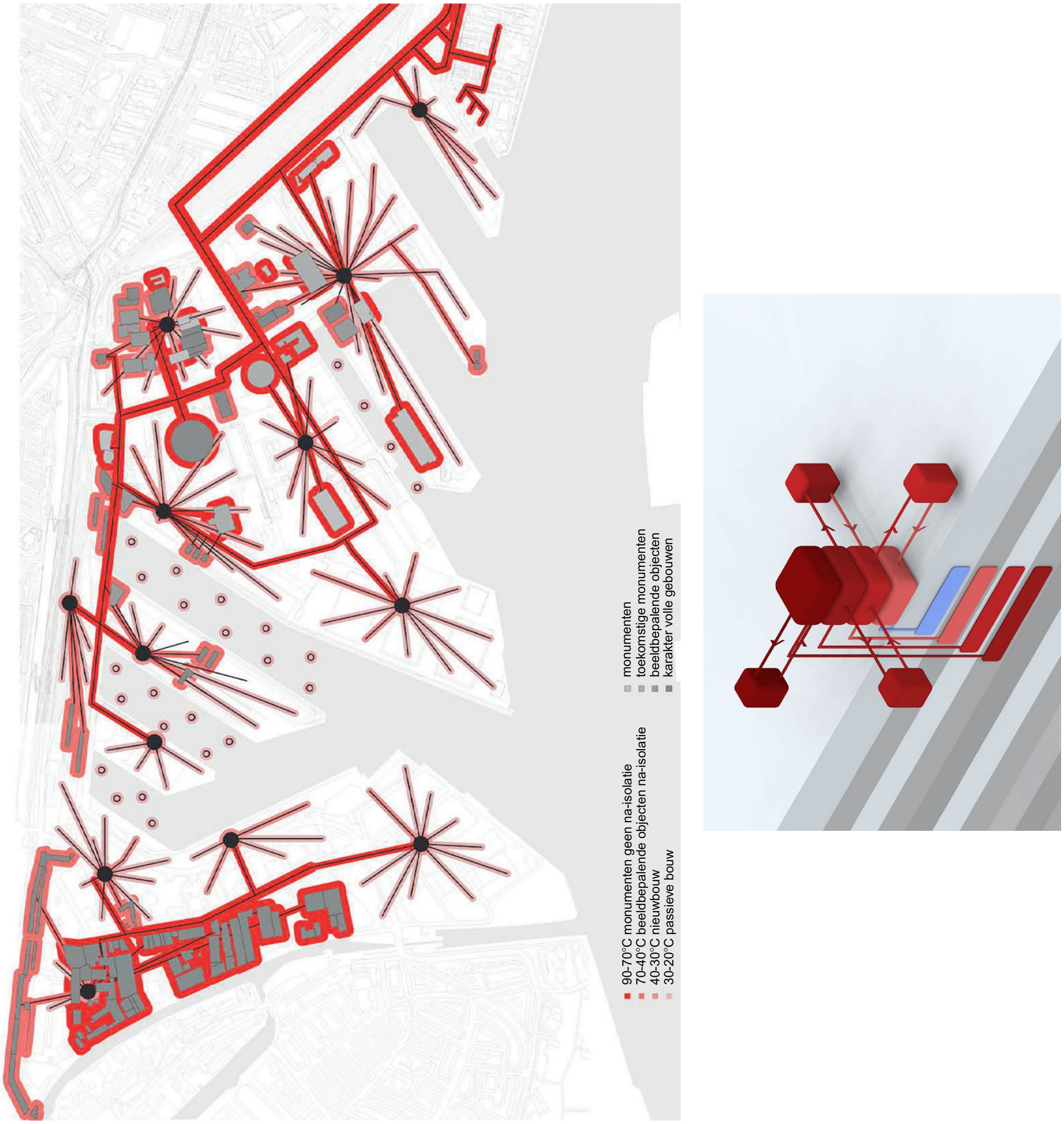
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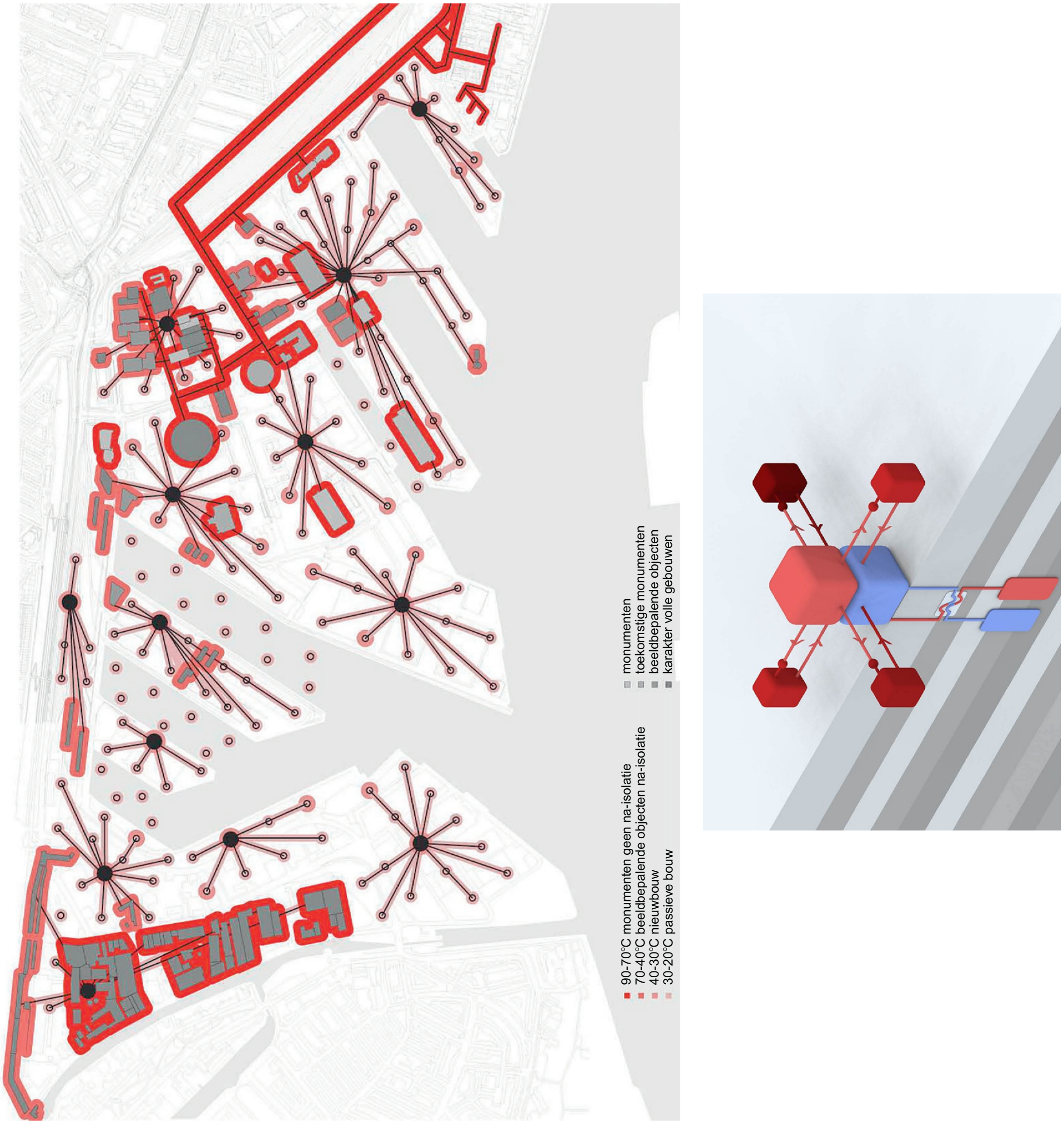
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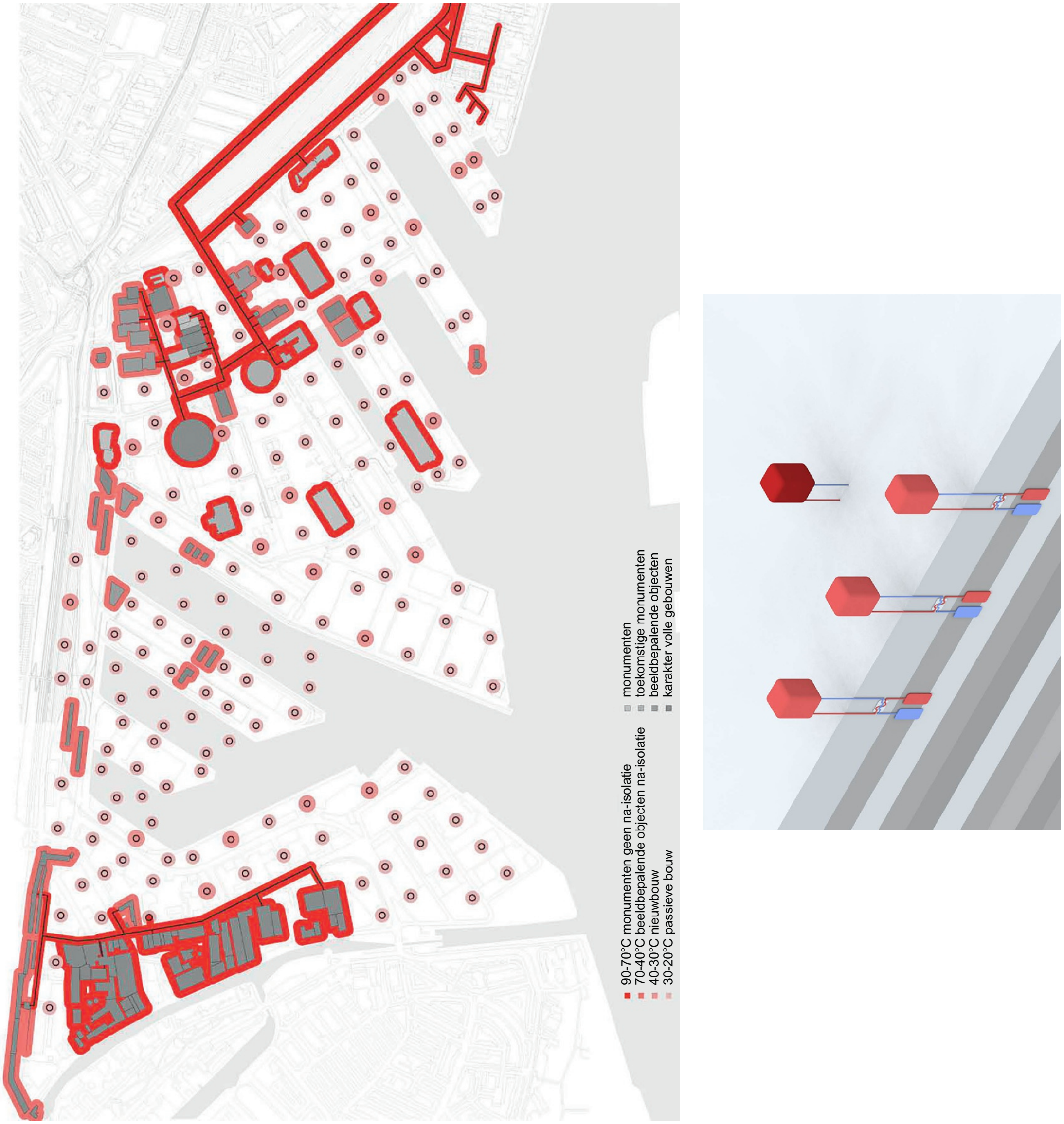
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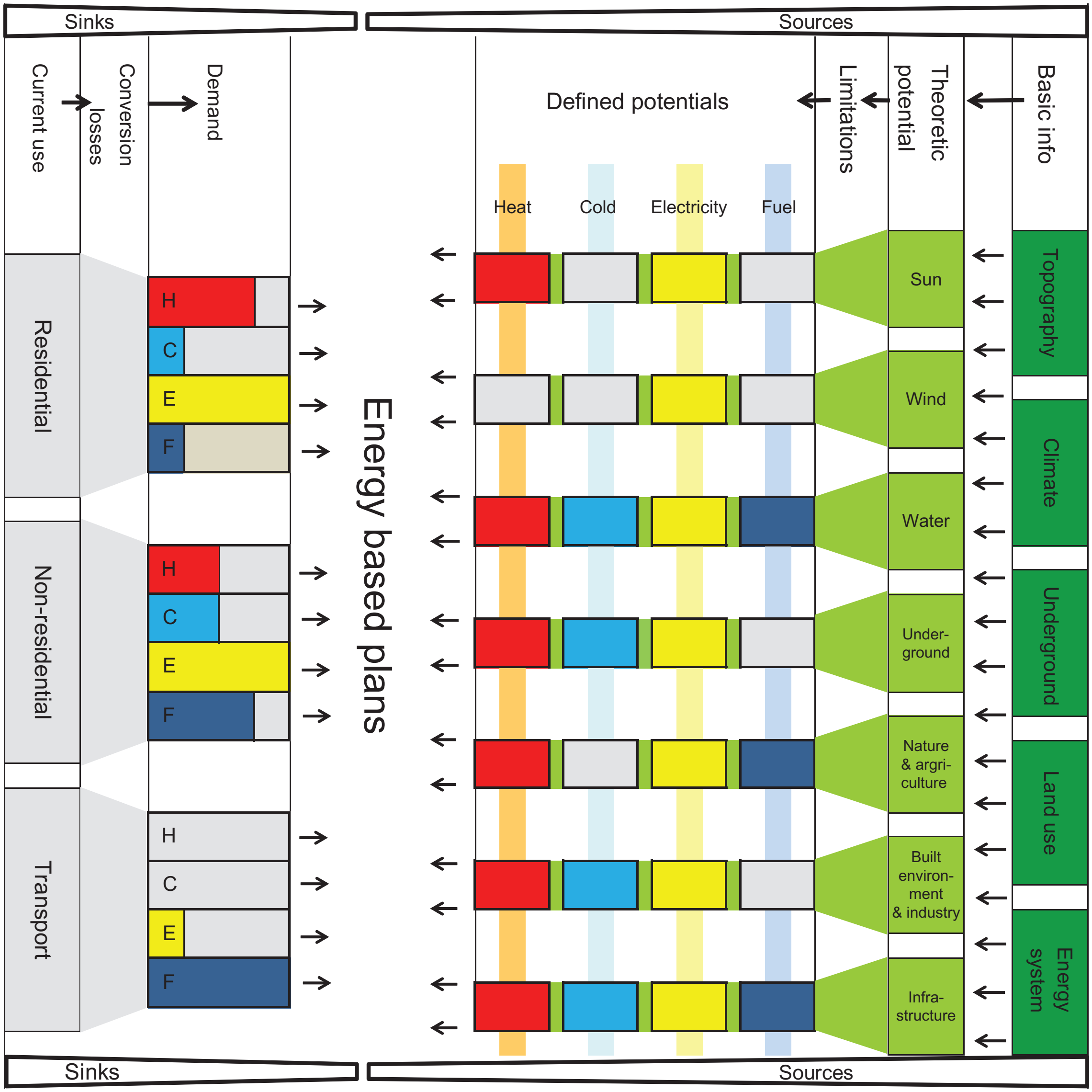


FIG. 9 Scheme of the Energy Potential Mapping method, with sources at the *right* and sinks at the *left* (Broersma et al., 2013a, b).

example, when considering the yearly photovoltaic yield of an area, the amount of suitable space (e.g., roofs) can be multiplied with the amount of solar radiation and the intended PV panel efficiency percentage.

This general principle can however be applied to many more renewable sources and some storage technologies (e.g., aquifer thermal storage and pumped hydroelectric storage). In the case of aquifer-based deep geothermal heat, the permeability and minimum interference distance to other doublets need to be considered, and for wind energy, the distance between both individual turbines and peripheral risk objects (e.g., houses, offices, roads, and refineries) determines the combined spatial yield (Fremouw and Broersma, 2016). The latter example illustrates the complexities arising from integrating renewable energy in urbanized areas, underlining the need for proper quantification. Opportunities however also arise in the form of multiple land use (e.g., solar PV on roofs) and reuse opportunities (e.g., residual heat from data centers and industry).

In recent years, existing calculation methods have been regularly refined and new tools developed to both present and combine the energy potential layers in a meaningful way. Solar photovoltaic potential yield can for example be calculated with much greater accuracy by using a high resolution Digital Elevation Model (DEM) and GIS-based topography. However, as both availability and accuracy of the required data vary wildly between regions, simpler methods are sometimes preferable.

Thermal energy forms a special case within EPM studies (Broersma and Fremouw, 2011). Contrary to electricity and fuels, transporting heat and cold over large distances is very expensive, the low energy density in most cases making this uneconomical beyond the regional scale. Therefore, as most renewable thermal sources will provide a low temperature, local planning is required. To dimension networks and short- and long-term thermal storage facilities, considering not just the available quantity, but also the exergetic quality (e.g., temperature levels) and the distance between sources and sinks are important (Broersma et al., 2013a, b). Recent European developments in thermal planning include the STRATEGO (http://stratego-project.eu/) and PLANHEAT (http://planheat.eu/) projects, the former providing a kilometer scale Pan-European thermal atlas, and the latter developing a high-resolution toolset for Heat and Cold (HC) planning at the urban level.

Urban Energy Atlas

As demand and renewable supply may not always match, fully renewables-based energy systems will in many places utilize multiple sources. Combining different energy demand, network, and potential layers in a uniform shape is therefore required. The resulting Urban Energy Atlas makes it possible to consider the quantitative, spatial, and temporal contributions of each source in such a system, as well as plan the transition toward this system.

One of the strengths of the EPM method is that it aims to present the acquired data in a way that is not exclusively focused on an audience with a highly technical background. Instead, the visualizations are designed to allow all stakeholders in the transition to renewable energy, to both understand and apply this information in their local plans.

For the region of Oostland in the Netherlands, an energy study (Broersma et al., 2013a, b) was done to define several sustainable urban energy interventions, for which EPM delivered a local energy atlas as a first analytical step (Fig. 10). Several maps give insight in quantities and locations of local demand and renewable supply (amongst others: electricity and heat demand for households and for non-residential functions; rooftop solar potentials for electricity and heat production, deep, mid- and low-geothermal potentials, and wind energy potentials).

Energy Master Planning

For cities that have ambitious goals for their energy transition, a sound plan is indispensable, giving directions, guidelines, proposals of energy interventions, and horizons to its goals. Energy Master Planning (van den Dobbelsteen et al., 2014) provides an approach in which the previously described principles from the New Stepped Strategy, the Rotterdam Energy Approach & Planning, and the method of Energy Potential Mapping are combined and structured in incremental steps of transition.

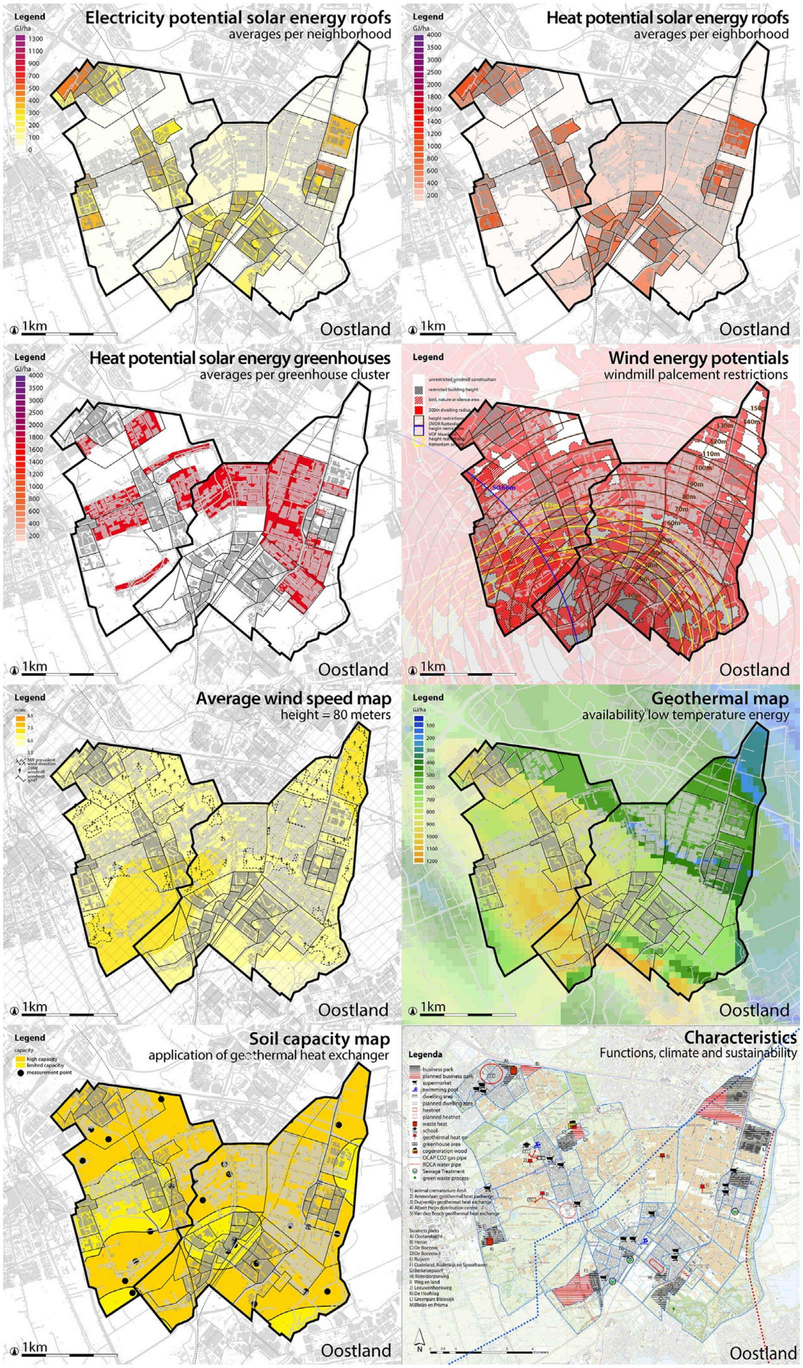


FIG. 10 Example of some of the energy potential maps as made for the Oostland region (Broersma et al., 2013a, b).

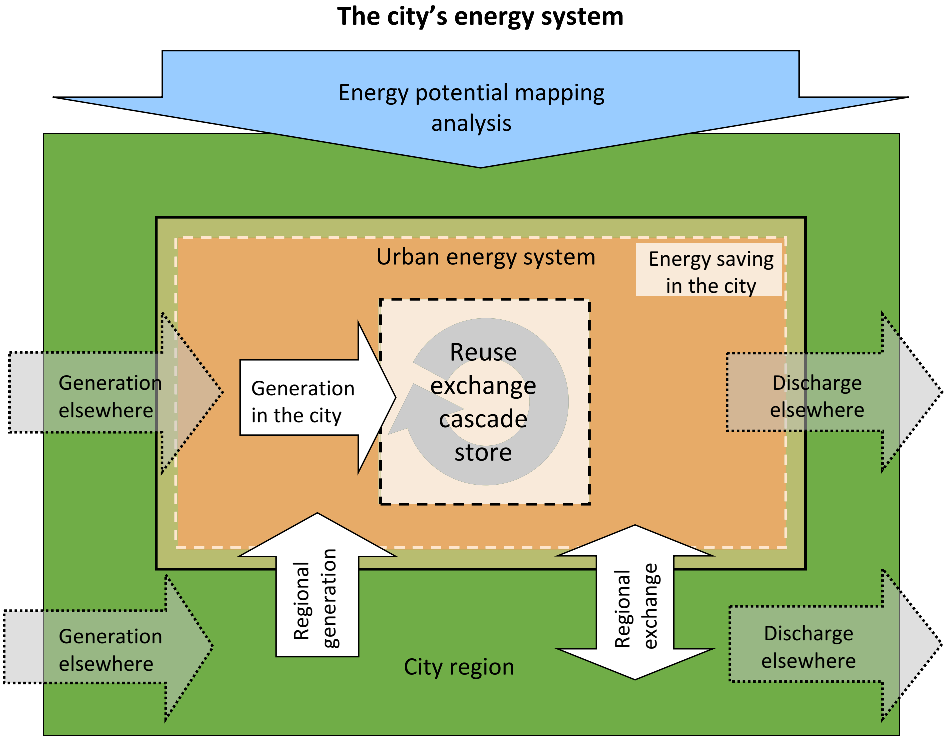


FIG. 11 Schematic framework of the Energy Master Plan for self-sufficient cities (van den Dobbelsteen et al., 2014).

Understanding the current urban energy system (Fig. 11), with its patterns of demand and supply, is the basic knowledge needed for an Energy Master Plan, and Energy Potential Mapping (EPM) can provide in this.

Steps

The first step toward energy self-sufficiency and for an Energy Master Plan is that of energy reduction. Energy retrofit measures not only can fill the gap between current demand and renewable available potentials, but also allow for renewable low-temperature sources to be used to meet the final lowered demand (after retrofit).

The second step is finding and creating energetic synergies. Supply and demand will not always be at the same time, place, and of equal quality (exergetic value). Means to deal with these discrepancies are exchanging heat and cold, cascading of (waste) heat, and intermediate storing of energy. Heat and cold networks at different temperature levels need to provide the necessary connections.

Finally, the remaining demand needs to be generated by renewable sources. Local production within the city deserves preference, especially for heat (and cold) to prevent unnecessary large heat and cold infrastructures. Because renewable energy production requires much more space than energy from fossil fuels and urbanized areas also have a concentrated energy demand and little space available, cities will often have to rely on their surroundings to become self-sufficient. Regional exchange and production must fulfil the final gap.

City-Zen

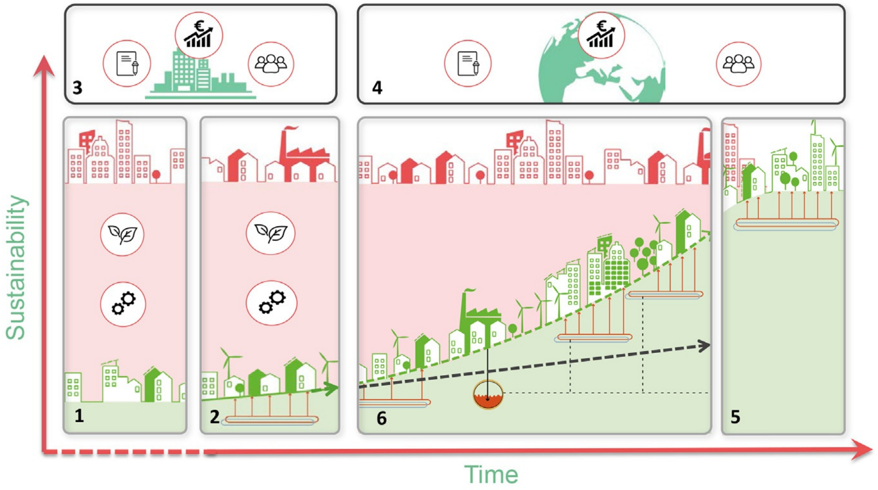
Energy Master Planning is currently further developed within the European FP7 project of City-zen (http://www.cityzen-smartcity.eu).

Next to the already described principles and steps of the Energy Master Plan, in this approach, the importance of non-technical factors is also addressed. Mapping the political, legal, social, and economic climate (step 3), next to the technical geographical of Energy Potential Mapping (step 1), delivers insight in barriers and opportunities for implementing energy measures and systems (as well as step 4). This allows for better framing energy measures on a time line and to think of (non-technical) actions that must remove these barriers upfront. The scheme of Fig. 12 visualizes the successive steps of the City-zen approach, of which the last two define the energy roadmap or EMP.

The distinction between steps 5 and 6 also stresses the importance of approaching the city at different scale levels. In step 5, not only the goals and the guiding principles for a final vision are set (e.g., 90% CO_2 reduction in 2050 by 40% energy reduction in the built environment, extension of the district heat network to 100,000 dwellings, 200 GWh of wind energy, etc.), also the share and main locations of these measures must be allocated to the city's districts. This allows in step 6 to be more specific in defining energy measures for the neighborhoods.

INTERACTIVE WORKSHOPS

So far, we have discussed different technical-spatial approaches, strategies, and methods. They have no value without proper action by people. As technocratic as the approaches discussed so far may seem, they have always been incorporated in processes with local stakeholders and connected to other factors of planning. The scholars involved with the development of the technical-spatial approaches, methods, and tools were similarly challenged



- **Step 1: Energy Analysis** (Mapping the technical geographical present)
- **Step 2: Present planning and trend** (Mapping the near future for energy plans)
- **Step 3: Society & stakeholder analysis** (Mapping the political-legal-social-economic climate)
- **Step 4: Scenario for the future** (Mapping external influencing variables)
- **Step 5: Energy vision with targets and guiding principles**
- **Step 6: Roadmap with energy interventions and actions**

FIG. 12 Scheme of the six steps of the City-zen approach for urban energy transitions.

to integrate them into creative sessions and workshops with cities. This section will discuss some of the workshops that have been developed since 2005.

Design Charrettes

The first energy workshops, held in Groningen and Jinze (China), followed the methodology of the design charrette (Roggema, 2013a). The NCI defines the charrette as: "a collaborative design and planning workshop that occurs over four to seven consecutive days, is held on-site and includes all affected stakeholders at critical decision-making points" (Lennertz and Lutzenhiser, 2006). Building on this, Condon (2008) formulates it as: "a time-limited, multiparty design event organized to generate a collaborative produced plan for a sustainable community." A typical charrette is seen as part of a dynamic planning process, which starts with the preparation phase, followed by the charrette, and finishes with the implementation phase (Roggema et al., 2011).

Preparation Phase

In this first phase, everything that is required to hold a successful design charrette is considered. Besides the obvious material required and bookings of the venue, the main issues in the preparation phase are the design brief and the selection of participants. In the design brief, the assignment is clearly defined. The goals and objectives, the design principles, if possible quantitative information, and the performance targets are described. The design brief is written in collaboration with several of the local stakeholders. The selection of participants is critical. People need to be interested in the charrette process. As it comes to the selection of participants, the right "mix" of people is essential. A combination of scientists, local experts, and stakeholders, decision makers and knowledge brokers, designers and technical experts, all contribute to the dynamic of the event.

The Charrette Phase

The second phase when participants first come together consists of the visioning charrette. During this charrette, the main goal is to envision the desired future. A typical visioning charrette includes the following parts: an opening event, a site tour, the design stages, during which iterative phases of conceptualization, drawing alternatives, and refinement of the vision take place (or in the words of Condon: talk-doodle-draw), the public meetings, and finally the after-party. In general, this type of charrette involves (mainly) designers for a full week. The purpose is to shift from nice sounding prospects to real solutions, which, in this phase, are represented in designs. During the charrette, a common language for solutions is developed and, because no implementation questions will be raised at this stage, the risk ideas that will be rejected is minimal. However, it may be expected that, in the openness of the process policy, contradictions will be revealed.

Implementation Phase

The implementation charrette phase typically lasts for four days and involves (mainly) design facilitators and stakeholders. Its aim is to develop a shared understanding of the desired future and what is needed to realize this future. In many governmental organizations, the so-called window of no is in operation. This prevents change from happening and is often well established through unwritten codes and invisible agreements. The implementation charrette is a powerful tool to go past this window of no.

The fast and efficient charrette process involves stakeholders in a powerful integrative way. Because the participants are connected and the solutions cannot be seen as separate, the charrette process helps to outpace approval processes, which can take years.

Report Phase

In the report, the results of the charrette are integrally presented in a visual and clear way.

The report functions as the "contract" for the participants and may be used in formal decision making processes.

Since the first design charrettes were executed, many charrettes have taken place in several different formats, and with a suite of subjects (Roggema, 2013b), such as on energy in China (Roggema, 2009b).

Roadshows

The Roadshow was specially developed for City-zen, discussed earlier, to bring findings of the EU research project to cities not directly involved. The Roadshow travels with a team of internationally recognized experts in the field of energy planning and design to help develop a sustainable agenda for cities and their neighborhoods. It has successfully visited Belfast, Izmir, Dubrovnik, and Menorca in the last 2 years, and is planning trips to six further cities by 2019.

The overall aim of the Roadshow is to work closely with people from the hosting city, whether they be city leaders, neighborhood associations, energy planners, architects, academics, students, and, of course, citizens. Roadshow outcomes allow the cities resources, their people, knowledge, and renewable energy potential to be directed effectively by first highlighting the neighborhood's lifestyle and energy challenges. Finally, on the last day of the 5-day event a definitive sustainable "City Vision" or "Island Vision" is presented to the city and its decision makers.

Method

The Roadshow method is simple but highly impactful and effective. It begins with "first contact," primarily an educational workshop studio, known as the SWAT Studio, which occurs in the months leading up to the Roadshow. This student-focused workshop facilitates an extended and detail discussion with city stakeholders.

Secondly, during the "five-day" Roadshow event itself, structured on a day-to-day "themed" basis that guides the evolution of the vision, expert input is delivered at key points throughout the week. The Roadshow is not intended to be a one-way stream of information and ideas, instead the aims are to activate, convince, openly invite, and encourage "the City" to be part of the process at any level that they feel comfortable with. Activities include going out of the studio and into the community to engage with various initiatives and urban circumstances using a precedent-based peripatetic walk-and-talk strategy.

The final outcomes of the Roadshow are coherently and succinctly communicated design proposals at all scales of city life and design ranging from room, façade, building, street, neighborhood, district, city, and island. The vision resembles the two integrated parallel workshops that run throughout the 5-days in that the final content is qualitatively spatial and quantitatively energy focused.

The key to Roadshow success has been to identify, reach, and gain the trust of city inhabitants and "decision makers." To achieve this, an exchange of knowledge, experience, and commitment continues to be crucial.

Roadshow Dubrovnik

During the Dubrovnik Roadshow in the fall of 2016, Gruž, a district adjacent to the cruise-ship harbor, was primarily taken as the focus area. The district suffers from poor quality housing and unhealthy effects of the diesel-run cruise ships, often the size of a city in their own. Normally dumping their waste water into open sea, the idea was to have (organic) waste taken on shore and processed via algae arrays, to nutrients, food, and bio-diesel, which could be sold to the cruise ships again. Next to this, a plan was made to energetically renovate buildings in the Gruž area, mostly through passive cooling strategies, façade refurbishment, and local production of solar energy. Wind turbines were proposed to be integrated onto the planned new golf course. Finally, and not least, a plan was drawn for public transport and human-powered transport between the harbor and historic city center.

Part of the Roadshow is the assessment of the initial energy and carbon performance (Fig. 13), whilst at the end of the week, the outcome of all proposed measures is again calculated. For Gruž, it turned out that from the initially required carbon offset of 1109 hectares of forest, only 36 remained.

Roadshow Menorca

The most recent Roadshow took place in the Balearic Island of Menorca in April of 2017. Menorca is a unique destination in that the energy inputs and outputs can and have been precisely determined due to its definite geographical borders. On the surface, the island appears in tune with its natural environment and resources, however the reality is that it is highly dependent on the Spanish mainland for 96% of its electricity via an undersea pipeline and on sea imported fuel-oil for its power station. Calculations by the Roadshow carbon accounting experts demonstrated how the island could be carbon neutral in a year's time through the implementation of various wind and solar measures including a 30-km PV canopy array entitled "La Spina Energética" that shaded the main road from Mahón to Ciutadella. Other proposals included modular plug-and-play systems at the building and street scale.

In addition to designs, the Roadshow offers contextual guidelines. For Menorca an example of these were:

- Create and protect green corridors,
- Remove cars from city center,
- Create green and shaded routes inside the city for bicycles and pedestrians,

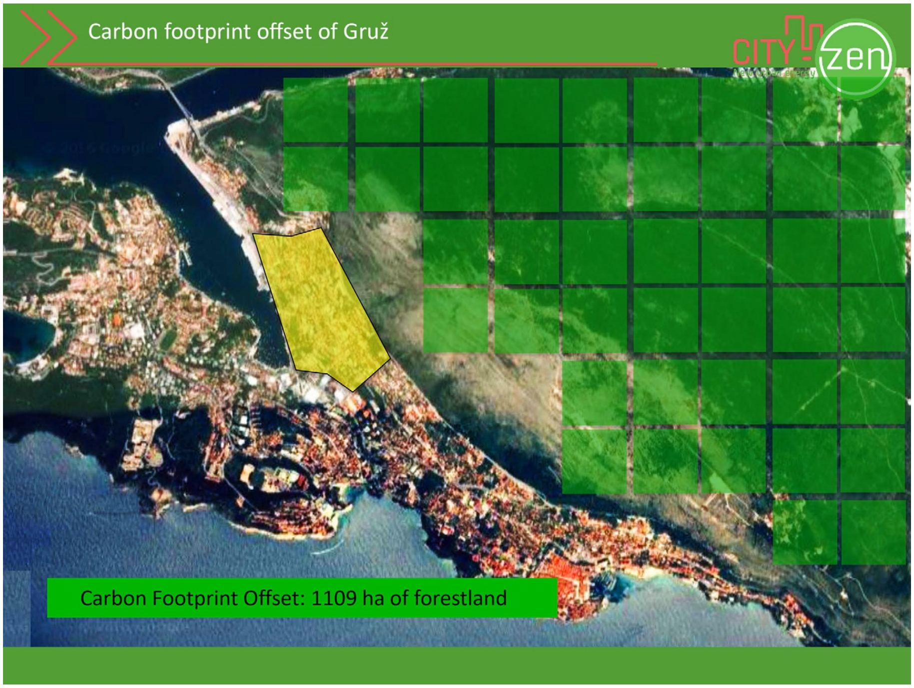


FIG. 13 The carbon footprint of Dubrovnik's Gruž and the carbon offset required to compensate for it.

- De-engineer the ring road,
- Allow city to grow in a structured way, and
- New public spaces created with car parking underneath.

GRAND SCHEMES TOWARD SUSTAINABLE CITIES

Amsterdam

The city of Amsterdam has considerable goals for their energy transition: 40 and 75% less CO_2 emissions by 2025 and 2040 respectively, compared to 1990 (Sustainable Amsterdam 2015) and for the short term in 2020, 20% more renewable energy production and 20% less energy use per capita compared to 2013. The short-term goals will mainly be met by wind and solar power and renewable heat and energy retrofitting of the existing housing stock.

A newly adopted strategy to reduce the carbon emissions toward 2040 is to phase out Amsterdam's natural gas use largely toward 2035 (Programma warmte en koude MRA, 2016), ambitious for a city that largely depends on natural gas to heat the building stock. Amsterdam already has two independent large district heat networks, one based on heat from waste incineration and the other on relative low-carbon waste heat from a power plant (on natural gas).

Amsterdam currently works together with 31 other public and private parties on a grand design for a super heat grid for the Metropolitan Region of Amsterdam (MRA) (Fig. 14) to meet the heat demand with sustainable sources. Both existing networks will be connected and expended to locations in the region with large amounts of industrial waste heat and deep geothermal potentials. Ultimately, this robust, efficient, smart, and open regional heat network will provide a baseload of 700 MW, providing heat for 500,000 equivalents of residential units.

Pijnacker

A concept of an energy master plan was proposed within the the Oostland energy study for the town of Pijnacker, in which an organically expanding low-temperature heat infrastructure provides on renewable heat fully in the demand (Fig. 15).

The concept is based on the idea that the area has many potentials for small-scale heat networks, in which heat is provided by exchange, cascading, or small-scale sustainable production. Already, few small-scale heat networks on geothermal energy exist and there are projects planned to extend these networks to nearby neighborhoods.

When a certain amount of smaller networks exists, a larger central grid will connect these, making the network more robust and allowing for more sources and sinks to be connected. The main grid must be slightly over-dimensioned to allow for a temperature decrease in time, when more low-temperature sources will be utilized and the demand for higher temperatures drops because of energy retrofit measures.

Rotterdam

In 2007, the Rotterdam Climate initiative was initiated. The Port of Rotterdam Authority, Deltalinqs (companies), DCMR Environmental Protection Agency Rijnmond, and the City of Rotterdam work as partners to enhance the sustainability of the city, the port, and the industrial complex. Their goal is a climate-proof Rotterdam and a 50% CO_2 reduction compared to 1990 levels by 2025 for all sectors. In the urban areas, good progress has been made due to energy efficiency agreements with housing associations. Also in 2010, Rotterdam invested €38 million to establish a district heating company. The goal is to transport residual heat from the port to residential areas. In 2020, an additional number of 50,000 households should be connected to the network, saving 25.2 million m^3 of gas and 80 kton of CO_2 annually. REAP and the GRIP energy scenario

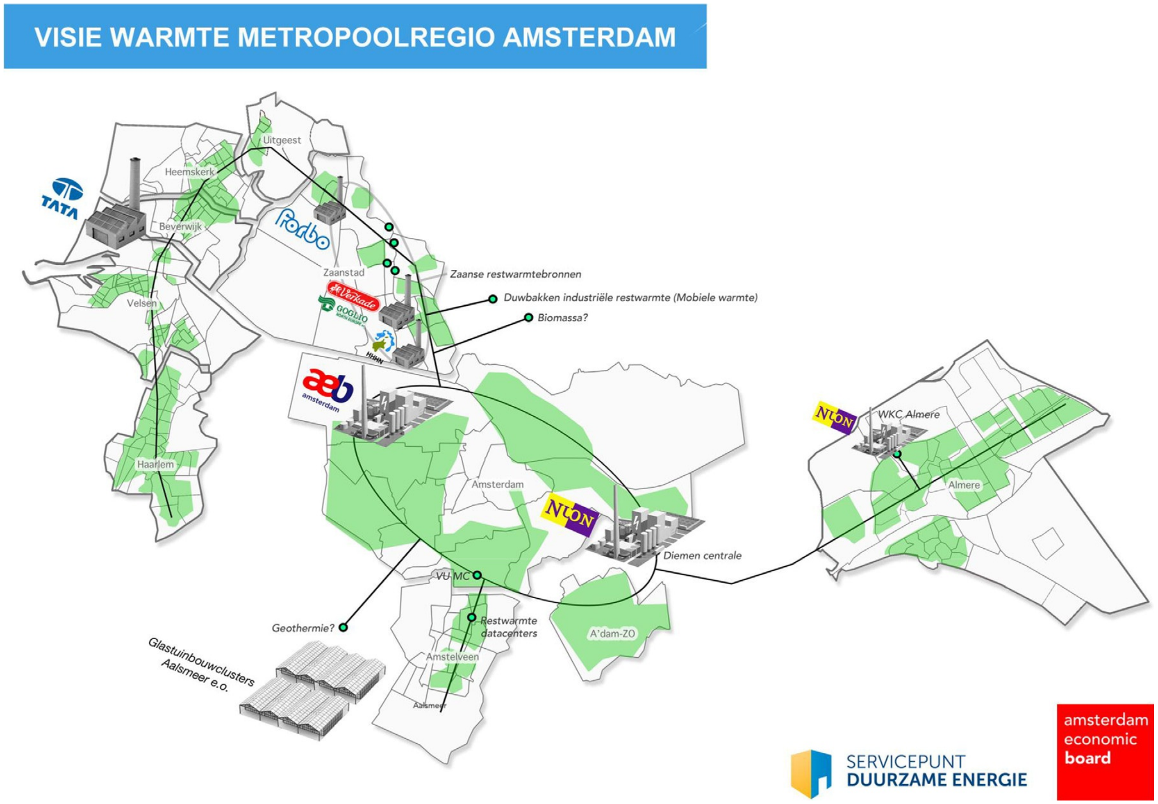


FIG. 14 Schematic design of a regional heat network for Amsterdam Metropole Region (Amsterdam Economic Board, 2015).

planning tool helped to build a stakeholder-based energy vision for the city.

Also, when it comes down to mobility, the city has the following strategy in the Rotterdam Vision on Sustainable Mobility (2008):

1. Clean use of the mobility system; the model shift from 12% to 22% in the past 10 years for biking as well as the growth of the use of public transport are examples of this.
2. Clean, silent, and fuel-efficient vehicles, technology-driven.
3. Clean fuels: using renewable resources.

Sydney

The city of Sydney has a long tradition in striving to become a zero-carbon city, basing its urban development on renewable resources (City of Sydney, 2013). The current policies comprehend a strong focus on resilience (Resilient Sydney, 2016a, b). Within this broader aim, the Greater Sydney Commission identified three main goals: Sydney becoming productive, livable, and sustainable (Greater Sydney Commission, 2016). As one of the examples to implement these broader visions, the NSW Office of the Government Architect developed a green grid strategy (GAO, 2016), which connects the green spaces of Sydney, and provides the framework for hundreds of projects of green infrastructure. Within this framework, green infrastructure is seen as a broad ambition, including the grey infrastructure of the energy grid, the sewage system, and accessibility.

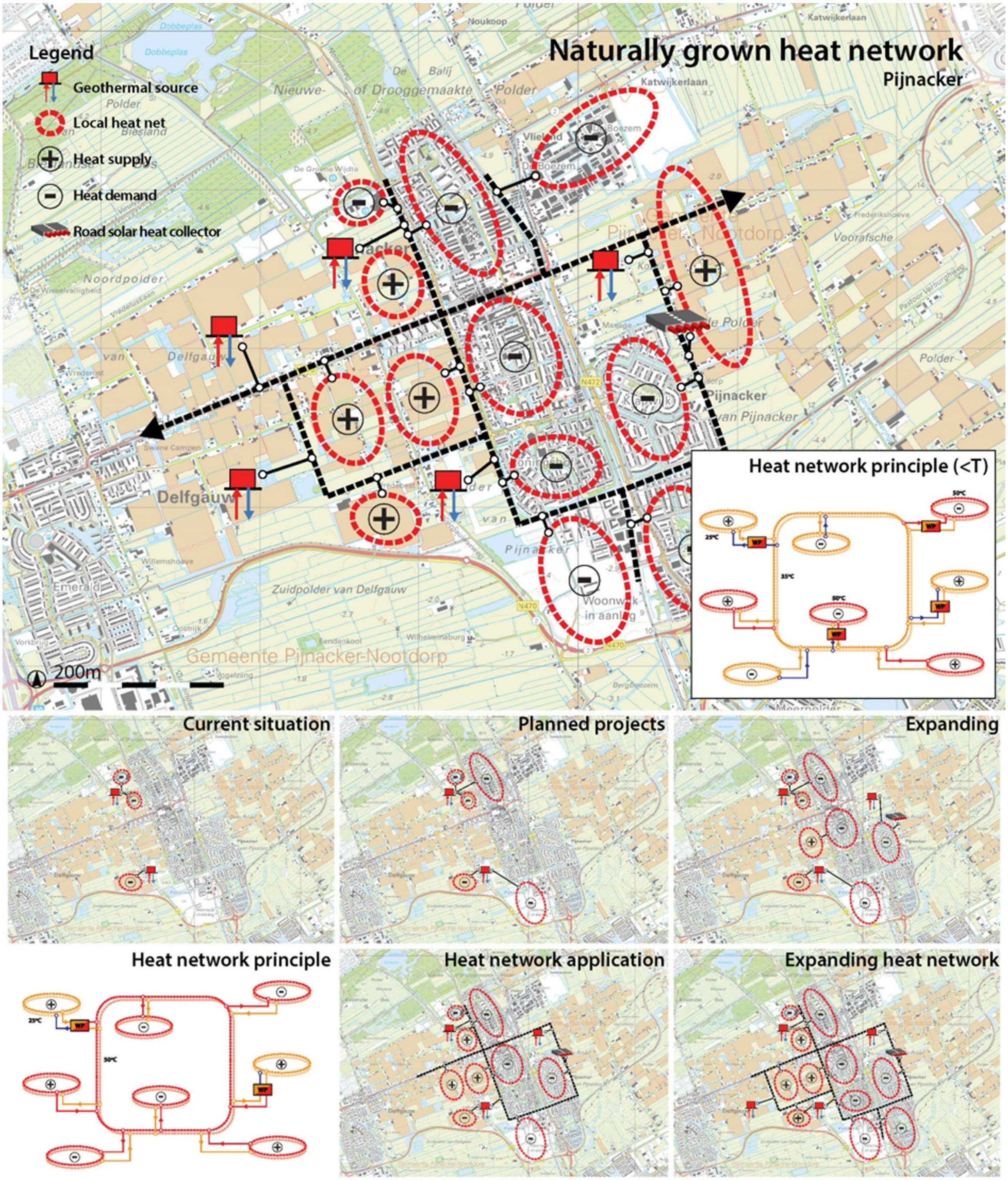


FIG. 15 Concept of an organically expanding low-temperature district heating infrastructure for Pijnacker (Broersma, 2014).

CONCLUSION

The climate crisis, fossil energy depletion, and scarcity of certain resources require a radical change in society, especially in cities, where more than half the population is living. The energy transition is the most urgent change to be accomplished, because without energy, nothing works properly in modern-day society and cities are dependent by more than 90% on energy supplies from outside. Therefore, a great sustainable city revolution is needed, and this requires effective means to make it happen.

This chapter has discussed various approaches, methods, and tools that have been developed during the last decade and that have helped cities to more clearly define their goals under different scenarios, to understand the current situation, and—most importantly—to propose solutions and strategies that help them to go forward.

We are not there yet; a long road lies ahead. Written by technical people, designers, and planners, this chapter has emphasized technical-spatial approaches and solutions the most, but they understand that political, economic, and social-cultural aspects are equally as important. Therefore, technical models need to be linked to governance, economic, and social models to become fully successful. The workshops discussed in section 5 gave a hint of the possibilities to involve experts and stakeholders with various backgrounds, with promising results. And that is what cities need.

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