The „City of Tomorrow“ - A response to climate change

While heating and hot-water supply for the buildings in a German city still accounted for close to half of carbon emissions in 2010, heating for the buildings in the ‘City of Tomorrow’ releases hardly any carbon dioxide at all, because it is independent of fossil fuels. Though climate change entails hotter summers, the climate adapted buildings of the City of Tomorrow are capable of absorbing the resulting higher demand for cooling without virtually any added emissions. The buildings from the previous decades are zero-energy buildings that require no more energy than they produce themselves. Most of these new one- or two-storey buildings actually produce even more energy than they consume, as they are equipped with solar cells or solar collector panels. Due to consistent local climate protection measures, the old buildings of the city have been completely modernised in terms of energy consumption. This has drastically reduced heat demand, even though only about one fifth of these houses have attained the level of a ‘passive house’. By successfully carrying out energy modernisation measures in public buildings such as schools, hospitals or kindergartens, the local authorities set the standards at an early stage and were a model to be followed, particularly as they skilfully communicated the savings thus achieved. External insulation materials for buildings have become so thin that they hardly affect the expression of forms in urban development and architecture. Thanks to the heat storage capacity of innovative external insulation, air-conditioning remains the exception. The requirements of the preservation of historic buildings and monuments even in historic city centres are largely met, particularly as the potentials for interior insulation have been developed further and earlier shortcomings have been greatly reduced.

Oil or gas heaters are rare now, and where they are still in use, they are powered by bio-oil or biogas. The people of the City of Tomorrow have long come to appreciate the efficiency of heat and power cogeneration (‘combined heat and power’ generation or ‘CHP’). Through a system of highly efficient close range and long-distance district heating mains, that has been steadily built up during the last two decades, the heat resulting from power generation is distributed to buildings in densely built-up areas. In less densely developed areas, people mainly use heat pumps and solar heating systems for heat supply. Some house owners prefer to use micro-cogeneration units that combine heat and power generation in their own cellar. Biomass – preferably from waste water and other waste – has become the main source of energy for thermal power stations. This energy can also be distributed through the existing natural gas infrastructure in the form of biogas. Biomass also plays an important role in small local CHP stations, which supply a street or a housing estate with locally generated heat and power.

In the long run, however, a carbon-neutral city requires utilities mainly based on electricity. In contrast to small municipalities, it is not possible for large cities to achieve self-sufficiency in terms of electricity in their own area. They continue to depend on electricity imports. This electricity is mainly generated from renewable sources and only a small portion comes from large-scale power stations. The carbon emissions from these large power stations can be separated and stored by using CCS technology (carbon dioxide capture and storage). Renewable energy sources such as solar energy systems and wind power plants are the main sources of power generation in Germany. Furthermore, solar energy from facilities in Southern Europe and wind power from off-shore plants on the coasts of Western and Northern Europe are transformed into electricity on a large scale. This is then transported via a stable and extensive

European interconnected power grid to where it is needed with only little loss in transit. Following the strategy of ‘generate first, then import’, local solar energy systems and wind energy plants within the city also generate clean electricity. This is complemented by small hydroelectric power stations that are installed along the waterways in the city. In this way, many residents of the City of Tomorrow have turned into ‘prosumers’, who not only generate electricity and feed surpluses into the grid, but also consume it themselves. The public utilities are therefore energy service providers rather than electricity producers. They act as an intermediary between supply and demand and ensure energy supply through load management between central and local grids. This also applies to the efficient public utilities of the City of Tomorrow, who were at the forefront in building up a smart electricity grid, further developing combined heat and power generation (CHP) and local heat supply, and finally in realising heat and electricity supply that is largely based on renewable energy sources.

The technological difficulty to store electricity surpluses efficiently has been overcome. In this way, it is possible to balance the highly fluctuating energy input from renewable sources. This considerably facilitates load management within the smart grid. In practice, electric cars play an important role as energy storage devices. During times of surplus feed current from renewable sources, they can be recharged at low cost, while during peak load times they can function as a load balance. Moreover, after having been used in the cars, the car batteries can still be used as stationary storage devices. However, thanks to substantial research investment, a strong competitor to electro-chemical current storage has arisen in the primary energy source of hydrogen. Signs of the emergence of a new hydrogen economy can already be seen: national electricity surpluses are used for the electrolytic production of hydrogen, which in turn can be utilised for energy production in fuel cells or turbines. Thanks to higher efficiency, the energy from fuel cell units is gradually replacing CHP power plants.

The well developed smart grid of the City of Tomorrow includes intelligent control systems in the field of building services engineering. Many people have equipped their flats with sensors ensuring that electricity for heating pumps or for illumination is only consumed when needed. These make use of the cheaper electricity tariffs during low-usage hours for running laundry machines or dishwashers. The public utilities of the City of Tomorrow successfully align peak demand with peak production, by making use of variable time based electricity tariffs. Electricity is cheapest when there is an oversupply and it is most expensive when a shortage is imminent. The prices for grid-connected energy such as heat and electricity, including hot water supply, therefore vary greatly during the day. In their capacity as energy managers of their flats, the inhabitants of the City of Tomorrow are fully aware of the fact that they can save in the long run. As far as property owners are concerned, using solar technology to generate electricity or heat has become a generally accepted standard. Hybrid collectors generate solar electricity and solar heat and in this way make very efficient use of the limited roof and façade surface area of the city. When signing their tenancy agreements, tenants at the same time acquire share certificates for the solar power unit on their roof. They can swap these for electricity bonuses to ‘refuel’ their electric cars.

Traffic volume in the City of Tomorrow is no less than it is today. On the contrary: overall volume has increased, because the number of single and two-person households has risen. Therefore, individual demand for mobility has also gone up. However, this is not noticeable, as traffic flows smoothly and congestions are rare. Smart traffic management systems enable vehicles to communicate with each other and with their infrastructure and control traffic subtly and smoothly. The traffic load from private transport has been eased by a massive increase in local public transport and by implementing new comprehensive mobility concepts. The concept of 'shared space' has become prevalent in residential areas. This concept implies that pedestrians, cyclists and cars share public roadway area on an equal basis and act considerately towards each other. Pavements, bicycle paths, railways and car traffic lanes remain separate on the connection roads and thoroughfares of the city. However, in principle, cars are still given priority. The pavements along these main roads are wide and have green spaces, and the network of bicycle paths is tightly knit, safe and with a clear layout.

Electric cars have become the predominant means of private transport within the city. In contrast to vehicles with combustion engines, they are exempted from paying parking fees and congestion charges for the central area. They have been made even more popular by implementing flexible and economic mobility service schemes, which include electric bicycles (pedelecs). When in a hurry, you are bound to find an available E-vehicle parked on public ground anywhere within the city area. Using your mobile phone, you can easily find one, enable it, use it and park it again anywhere in the city. Billing for using these vehicles is made with a mobility card that combines the flat rates for public transport with the fees for E-mobility services. Large building societies offer their tenants the mobility card as part of their renting services. Real-time information on connections, delays or interesting events is transmitted via mobile devices – a service that has become a part of everyday life for users of the public transport system. It is now even possible to organise spontaneous journeys just in time. Senior citizens, for whom the formerly complicated ticket machines and timetables of the public transport system were nearly impossible to comprehend, now praise the user friendliness of the new system. A system linking local public transport to long-distance traffic on the one hand, and to pedestrian and bicycle traffic on the other hand, is also quickly understood by visitors to the city. This high degree of electric mobility – whether on rails or on tyres – has considerably reduced exposure of the city's inhabitants to noise and exhaust fumes.

The general policy framework and technologies in freight traffic and trade also contribute to this positive development, although despite manifold efforts at traffic planning, the overall traffic volume has more than doubled since the turn of the century. Freight is reloaded at terminals on the outskirts for distribution in the city centre, for which purpose usually City-E transporters are used. As too many 'E' lorries would also congest the roads of the City of Tomorrow, some goods are reloaded onto 'load trams' and barges. In such a way, the terminals serve to integrate as many carriers as necessary (including road, railway, water and airborne transport). These are by no means tarred and built-up spaces from disused industrial areas, but rather commercial estates that fit in nicely into the green belts around the city. The 'cargo tubes' of the City of Tomorrow also start from there. These are oversized pneumatic tube conveyors that deliver freight up to a diameter of two metres within the city.

Because of the extensive mobility service schemes at their disposal, which include cross-country journeys, more and more people of the City of Tomorrow have stopped using a car of their own. By fully linking the spheres of residence, work and shopping with each other in multi-use residential areas or even within a single building, many distances in the City of Tomorrow can be covered on foot or by bicycle. This returns many spaces previously occupied by cars to the planners and residents of the city, that can now be re-designed without limitations. This had made many new benefits possible, such as wide bicycle paths lined with grass or trees and shady trees in the residential areas plus a lively and green city centre. These measures not only enhance the quality of life but also compensate for the remaining carbon emissions. Fresh air corridors that are necessary for maintaining a pleasant urban climate in the City of Tomorrow have not only been defended against new construction projects. New corridors have also been created by demolishing such residential areas, where buildings could not be modernised in terms of energy efficiency. Sustainable design of materials cycles has become an established planning criterion. Heat is recovered from waste water and the main sewage plant of the City of Tomorrow generates electricity from sewage gases. Systematic analysis and optimisation of the main material flows including energy, waste, water and wastewater has become a generally accepted standard. Water supply for the extensive communal gardens, for instance, that have emerged in the fresh air corridors between the residential quarters, comes from recycled grey water. Urban organic agriculture of this kind not only contributes to the city's general supply, but also makes residents more familiar with such topics as health and food.

The residential area has developed into the most important level of urban planning. Especially on the outskirts of the city the spheres of private life, work and production are more intertwined than they used to be. Here was the cradle of the city of short distances, where people from various social groups, cultures and generations learned to live together more easily than in other parts of the City of Tomorrow. Particularly such features as decentralised energy supply through shared solar panel roofs in a street, jointly used rooftop greenhouses and shared cars, contributed to forging a new community identity. This process was supported by active local management of residential areas and led to new forms of living together, such as in intelligently designed multi-generational houses. These residential areas combine greater individual flexibility and a greater sense of solidarity to a new form of collective and cooperative individuality. Here the re-urbanisation of the City of Tomorrow first took shape and subsequently served as an example to other parts of the city, suburbs and the city centre, which were of a more mono-cultural character. The city centre is now full of bustling life, a place where people socialise and stage numerous festivals and other events.

To many of the residents of the City of Tomorrow, the increasing complexity of their environment was initially difficult to comprehend. They didn't understand the available options for climate protection properly, particularly as far as the long-term cost-benefit ratio was concerned. In the beginning, even city planners had a hard time to find convincing solutions for the complex restructuring process of the City of Tomorrow to become a carbon neutral city. The local authorities wanted to be able to make sound decisions on climate policy and at the same time wanted to avoid that the introduction of new systems might end in failure due to complexity and lack of transparency. They were thus determined enough to cautiously ignite enthusiasm among their citizens for this project in order to become the No.1 in terms of climate protection on the national level. 'Reducing complexity' was the order of the day. The schools and adult evening classes of the city soon adopted practical issues relevant to the efficient use of energy and resources to their curricula. The University of the City of Tomorrow was the first nationwide to establish an interdisciplinary KEMO (abbr. for 'Climate/energy management and organisation') course of studies. This made the career profile of an energy consultant with a university education increasingly popular. The local authorities deserve credit for their pioneering role in carrying out detailed analyses of all kinds of potential, which allowed them to begin with those levers of climate protection policies that promised to yield the highest benefit. In the process, they also implemented some unpopular measures such as raising fees by means of the ‘climate protection cent’ for the benefit of scientific research. This continues to make sense, as scientific research in the relevant fields has remained as dynamic as ever. On the other hand, the local authorities keep people informed of all possible ways of saving money and successfully introduced considerably cheaper tariffs in public transport. All these measures led to a feeling of uncertainty among the city’s residents. However, they also created an atmosphere of increased curiosity, whereby people got accustomed to new patterns of behaviour. Ever more citizens of the City of Tomorrow take an active part in reshaping their city. This didn’t go without controversy, of course. Some residents, for instance, complained about uniform solar panel roofs spoiling the appearance of the old part of the city. Others asked, how they were supposed to pay for the increased rents in modernised old buildings. They vehemently raised the issue of true cost calculation in evaluating different transport systems. Protection of personal data from over-intelligent electricity suppliers was a long-running issue. But through continuous discussions, most residents of the City of Tomorrow came to understand and accept the new developments in their city. They now identify more with their city than did their ancestors – and now they can reap the rewards from their ancestors’ early efforts to turn their city into a carbon neutral city. The cost for energy is considerably lower than in other comparable German cities. This is also an important benefit when seen from the social perspective. Mobility services are now considerably more attractive and easier to use. Even though no oil and gas is burned any longer, the quality of life is higher than before. Moreover, energy supply has become much securer compared to many other regions in Europe. Above all, the general standard of living in the city has risen. By restructuring their city, the residents of the City of Tomorrow created many new jobs in future technologies and new companies from the energy sector have been attracted to the city. A large proportion of financial resources that used to drain off for energy purchases abroad, now remain in the city and the region.

Apart from the experts from the government departments involved in preparing the results presented above, the experts listed below were also invited to take part in this work by the Federal Minister of Education and Research, Annette Schavan, and by the Chairman of the Office ‘Partners for Innovation’ and President of the Fraunhofer Research Organisation, Hans-Jörg Bullinger:

Dr. Ing. Wulf-Holger Arndt	TU Berlin (Berlin Institute of Technology), Center for Technology and Society, Bereich ‘Mobility and Space’
Dr Richard Aumayer	Robert Bosch GmbH, C/AGR, External Affairs, Governmental and Political Relations
Dr Stefan Braun	Fraunhofer IAO Institute for Human Resources Management and Organisation
Barbara Dörsam	MVV Energie AG, New Technologies
Attila Dahmann	German Private Equity and Venture Capital Association
Klaus Illigmann	Federal State capital of Munich, Department of Urban Planning and Building Regulation / Urban Development Planning
Prof Matthias Koziol	University of Technology Cottbus, Institute for Urban and Regional Planning, Dept. Urban Technical Infrastructure
Dr Jörg Kruhl	E.ON Energie AG
Klaus Krumme	University of Duisburg-Essen, Centre for Logistics & Traffic (ZLV)
Mathias Maerten	Siemens AG, Energy Sector, Technology & Innovation
Inka Mörschel	Fraunhofer IAO, Office of the ‘Partners for Innovation’
Dr Uwe Pfenning	University of Stuttgart, Dept. for Sociology of Technology and Environment

Dr Jörg Pietsch	Potsdam Institute for Climate Impact Research
Sebastian Seelig	TU Berlin (Berlin Institute of Technology), Department of Urban and Regional Planning (ISR)
Gerhard Stryi-Hipp	Fraunhofer Institute for Solar Energy Systems
Dr Volker Stelzer	Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe
Dr Michael Weinhold	Siemens AG, Energy Sector
Sabine Wischermann	Ruhr-Universität Bochum, Dept. for Energy Systems and Energy Economics
Dr Andreas Witte	RWTH Aachen University, Chair and Institute of Urban and Transport Planning