II

RESEARCH ARTICLES

EMERGING FORMS OF SUSTAINABLE URBANISM: CASE STUDIES OF VAUBAN FREIBURG AND SOLARCITY LINZ

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ABSTRACT

This study is an ongoing interdisciplinary collaboration, which discusses possible emerging forms of sustainable urbanism in the 21st century. The idea of sustainable urbanism is examined in this paper in more than environmental and ecological aspects, to highlight the emergent forms of urbanism based on new paradigms that inform on the shape of cities to come. The two case studies discussed embody complex topics of design, dwelling, community in space, building technologies, environmental strategies, as well as models of affordability. At the same time, new trajectories in the development of sustainable urban housing are explored. It is based on the following case studies:

Case Study 1: The new city district of Vauban Freiburg, in Germany, describes the guiding principles and their implementation in the planning and design of this new major development: Vauban comprises 2,000 homes to house 5,000 people, as well as business units to provide about 500 to 600 jobs.

Case Study 2: solarCity Linz, in Austria, currently comprises about 1,300 homes and 3,000 inhabitants. It was designed as a flagship development for renewable energies in urban design and includes projects by architects like Foster and Partners, Richard Rogers, and Thomas Herzog. Construction time of the nucleus of solarCity took place from 1995 to 2005.

KEY WORDS

sustainable cities; emergent forms of urbanism; renewable energy

INTRODUCTION

The idea of sustainable urbanism is examined in this paper in more than environmental and ecological aspects, to highlight the emergent forms of urbanism based on new paradigms that inform on the shape of cities to come. The built experiments discussed embody complex topics of design, dwelling, community in space, building technologies, environmental strategies, as well as models of affordability, but at the same time explore new trajectories in the development of sustainable urban housing. This study is an ongoing interdisciplinary collaboration, which discusses possible emerging forms of sustainable urbanism in the 21st century. (1) It is based on the following case studies:

Case Study 1: Vauban describes the guiding principles and their implementation in the planning and design of a new major development of a sustainable city district: a 38-hectare former barracks site near the town center of Freiburg, Germany that was purchased by the city in 1994 with the goal to convert it into a flagship environmental and social project. Vauban comprises 2,000 homes to house 5,000 people, as well as business units to provide about 500–600 jobs. The project is currently nearing completion and is widely seen as one of the most positive examples in Europe of environmental thinking in relation to urban design.

Case Study 2: solarCity Linz currently comprises about 1,300 homes and 3,000 inhabitants. It was designed as a flagship development for renewable energies in urban design and includes projects by architects like Foster and Partners, Richard Rogers, and Thomas Herzog. Construction time of the nucleus of solarCity took place from 1995 to 2005.

CASE STUDY 1: VAUBAN

Freiburg, a university town in the southwest of Germany with some twenty years of environmentally sensitive policies and practices, has often been called

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the European capital of environmentalism. (2) The purchase of Vauban, a 38-hectare former French barrack site near the historic town center presented the excellent opportunity for the city to build a flagship environmental city quarter. Three phases were planned for implementation between 1998 and 2006, and comprised 2,000 homes for a population of 5,000, plus small businesses to provide 500 to 600 jobs within the quarter. (3) In the following we will sum up the ideals and ideas for Vauban. (4)

Ideals and Ideas

Diversity in place—a community to be created in place by achieving a good mix of demographic groups, cutting through different generations, work, culture and abilities—the new, inclusive city quarter is envisioned to comprise privately-financed homes mixed with social housing, without any groups being singled-out.

Design by choice—allotment of small parcels to be developed by different architects working with different client groups allowed for a variety of design solutions based on simple guidelines set by the city authorities. This model enables multiple built solutions developed from the ground-up instead of the top-down planning model, encouraging a sense of ownership and shared responsibility in developing the form of the community.

Self-organizing communities—the integrative approach to shaping the form of the city quarter works through innovative processes and embody an interdisciplinary approach. By articulating their needs and expectations, the community is formed in space even before the first building is erected.

Open-ended development—new layouts that allow for openness for a multitude of uses through flexible planning and design make room for changes in family type, size and composition in the future. The design and layouts of public amenities and institutions are intended to accommodate changing social needs as the community matures.

Public space—good public spaces at different scales are created with a strong emphasis on public safety through the design and layouts of these spaces. These spaces form the backbone of the new city quarter.

Environmental urbanism—clear guidelines for the development of the new city quarter favor environmentally-friendly urbanism a new reality—car-reduced neighborhoods both through removing the need for automobiles as well as restrictions to car-parking. Tramlines form the backbone of public transportation linking the new city quarter with the rest of the city. For local travel, amenities and public institutions are located within walking distance.

Tools and Implementation

Building regulations—the Freiburg city authorities had been able to achieve their environmental and social aims through planning regulations and conditions for the sale of individual plots. These included increased building density, social and functional mixes, flat roof greening, and rainwater disposal within the building boundaries. The requirements for Vauban further some of these aims, some more stringent than national requirements.

Building co-operation—a large part of the success of the Vauban development could be attributed to the ground-up community planning process facilitated by the non-profit organization, Forum Vauban (now Stadtteilverein Vauban), founded in 1994 at the inception of the project as a forum to initiate public participation that went far beyond what was legally required. (5) The "Baugruppen" model (groups of future builders) proved to be crucial for Vauban. The extended citizen participation in Vauban led to a large number of workshops in that participants discussed topics like designing residential streets, green spaces and energy consumption that often led to suggestions, which were presented to the

FIGURE 1. Housing block, Vauban. (image source: authors' own)

official planners and often became part of the planning and design of the new district. (6)

Community building—the implementation of joint building projects and public participation through Forum Vauban helped to forge a mix of residential buildings and workplaces. Community relations were built even before physical building. (7) In an attempt to determine a heterogeneous community, a model called the "Blockprofil" was developed along categories of resident types in terms of martial status, number of children, occupation, etc, to ensure that the desired diversity was fulfilled. (8)

Programs—Vauban houses its population not only in new buildings, but also included the use of some renovated barrack buildings as student housing and functions to service the quarter, such as schools, shops and various offices related to the new city quarter.

Mobility concept—Vauban is designed to reduce the need for car-use and to cut overall journey distance. Tram and bus stops are placed not more than 500 m from buildings in the neighborhood. The car parking garages located at the edge of the development support the creation of car-reduced Vauban—car access is limited and restricted to the main access road. A city bus already runs through the district and in 1998, the city authorities approved the extension of the existing tramline to run the length of the main street in the development, with the plan to enable connection between tram and the rail network in the near future.

Traffic infrastructure and public space—in Vauban, the streets are taken over by a multitude of public functions besides being access roads. On the development's main tree-lined thoroughfare that links the quarter to the city, the street is bounded by a footpath-cum-cycle track, which buffers the housing developments and community gardens. There is a speed limit of 30 km/h on the main thoroughfare, while the side access roads have a limit of 10 km/h and are no-parking zones, aside for set-downs and deliveries. As such, they take on the function of "urban courtyards". Shops, offices, medical facilities, and cafes surround the main public square of the quarter. Other types of public spaces include the arcade spaces created by lifting apartments above ground floor businesses and retail units and are fronted by a short-term parking

FIGURE 2. Rolf Disch, Solarsiedlung, Vauban. (image source: authors' own)

area. The north- and south-end of the quarter have streets, which are entirely residential. (9)

Green spaces—Existing trees had to be included in the layout for Vauban. The vegetation of an existing creek was made a conservation area. The new district has a calculated mix of open public "green corridors" and private green spaces. Three green corridors connect the creek area with the new district in the North. In anticipation that at the completion of the development, the built-up areas would have taken up about half of the surface area of the ground area, provisions for rain water collection in the form of large one meter wide trenches along the streets to ensure that rainwater could be returned to the soil to maintain the natural water table.

Environmental measures—already the masterplan for Vauban took into consideration many environmental factors e.g. prevailing winds on the site. (10) In the quarter, all buildings must meet the low energy house requirements of an annual heating energy consumption 65kWh/m^2 or less. (11) With a few exceptions, buildings were restricted to a height of three to four floors to ensure good climatic performance in outdoor spaces a good quality of daylight. Many buildings are equipped with solar panels, others have green roofs. (12) Buildings consume about 30% of the energy that comparable but "unsustainable" buildings consume, and 65% of this energy comes from renewable sources. About two thirds of Vauban's houses are served by a combined heat and electricity plant that is powered by a mix of 80% wood-chips (which are considered a

renewable and carbon-neutral source of energy) and 20 % natural gas. (13) Also included in the development are buildings designed as passive houses that do not need conventional heating systems. The heat requirements are covered by so-called internal gains, passive solar gains and a technically simple heat recuperation system. The buildings are insulated with 35 to 40 centimeters of mineral wool or polyurethane and have triple-glazed windows that are coated with a heat reflective material. (14) The buildings are oriented north to south and unobstructed by adjacent plus-energy buildings and produce 15kW/m^2 per year. Vauban's environmental performance is monitored by the Öko-Institut (Institute for Applied Ecology) Freiburg. (15)

Critique

We would like to conclude this section by evaluating the Vauban project as it is built against the ideals and ideas embodied in its inception. For the sake of the discussion, we condense the ideas in four thematic areas that raise questions of idea versus actual form. We would like to point out that this discussion is still open-ended as many of our observations may have to be quantitatively verified to be used as actual data. (16)

Community—that Vauban was conceived on the site of former French Army barrack grounds allowed for an experimental community on a site that in parts offered almost a *tabula rasa* condition. Such a condition both afforded innovation, but to some degree, detachment from the surrounding environs of Freiburg. It is also unclear how well the work-live environment expressed in the brief for Vauban has come to fruition. The employment opportunities within the quarter are few, consisting mainly of operators of the small retail outlets, services providers such as cafes, schools, and a limited number of small offices. The adjacent communities may add to the conviviality of Vauban's center, but it remains to be seen if these communities form social networks. The pluralistic communities mentioned in the ideals translate in the actual quarter to a population that seemed composed of young married couples, middle-class white-collared workers, college students and those who share the similar progressive mindsets. About 17% of Vauban's current population is under the age of 17. Such a demographic also creates demands for amenities for children and teenager, which might become obsolete once this clustered demographic age group outgrows these facilities. It is a rare sight in Vauban to see older persons, or those from more diverse racial and occupational backgrounds.

Urban form—Vauban's main street corridor, Vauban Allee is about 35 meters wide, with a street-car track and stations situated in the median. If one were to consider the urban scale of the project by analyzing a section through its main street in relation to the buildings on both sides, one would expect such a scale to suggest an urban thoroughfare. Vauban's policy of limiting cars in the precinct seems in contradiction to such a scale. The main street also leads to a dead end on the West of the site, so that the street would not become a vehicular thoroughfare. Such a policy does keep traffic low, but also leads to a cut-off from surrounding neighborhoods. While the clear guidelines for sustainable building leads to interesting and diverse solutions for the house and apartment forms, it is not clear how the ideal of "growth" could be implemented, as Vauban has clear boundaries.

Environment—Vauban displays a complex network of environmentally friendly planning measures. The accumulation of those best practices has some negative effects on the urbanity and connectivity of the new city quarter. For example, the rather unattractive, one meter deep infiltration trench for storm water runs for the whole length of the boulevard and not only adds four meters to its dimensions, but also hinders the exchange between the two boulevard sides. There would have been opportunities to overlay some of these services and to make better use of the green spaces for rainwater retention. It appears that these eco-technologies and practices have to be further studied in their effects on urban space.

Public space—the most successful public spaces in Vauban are the small-scale residential streets, which are car-reduced zones, and function as children's play areas. These streets act like extended front porches, and are often meeting places of neighbors, and provide a good sense of public safety. However, as one moves towards the scale of the main street and the arcaded walkways, a real sense of urbanity is lacking in its public space. Whereas the abundant linear green parks are heavily populated by chil-

dren, the oversized main street that would have offered the opportunity of a vibrant street life is fairly vacant in the middle of the quarter. It also seems as though there is a lack of critical mass of population to make these areas lively.

CASE STUDY 2: SOLARCITY

The second case study, solarCity, was chosen because it shows many similarities to Vauban: it is a new city quarter in Linz, Austria that aims to have minimal environmental impact through its self-sufficient energy generation systems as well as processes to deal with waste and waste water on site, as well as retaining rainwater within the locale. The experimental community aims to be a model for ecological living at the beginning of the 21st century. Built on a site near the historical City of Linz, solarCity is a public housing initiative. The project aims to be on the cutting edge of architectural and landscape design, and is also an exemplar of public-private partnership in achieving the goals of sustainable planning, design and construction. (17)

The City of Linz and the Austrian planner Roland Rainer commissioned the new city quarter. The brief called for a model residential community with a potential settlement of between 5,000–6,000 homes, using the state-of-the-art eco-technologies. It was to serve also as a living laboratory for low energy consumption. In 1994, the city teamed up with four of the most important non-profit making residential construction organizations in Linz with an agreement to finance and plan the first phase of the model estate with an initial 630 low-energy homes. A further eight non-profit construction organizations joined in 1996 and the initiative was to include 1,317 homes. Based on Rainer's masterplan the first 630 homes were designed by well-known architects such as Norman Foster, Richard Rogers and Thomas

FIGURE 3. Aerial, solarCity. (image source: authors' own)

FIGURE 4. Auer + Weber, solarCity. (image source: authors' own)

Herzog, assisted by German engineer Norbert Kaiser, a specialist in environmental technologies. The sustainable city was to be a model future city to promote low cost building and low energy consumption methods on a worldwide basis. The city held an architectural competition in 1996 for the design of more homes. The winner was the Viennese architect Martin Treberspurg, a solar specialist with experience in public residential construction. (18)

Ideals, Ideas, and Implementation

Site layout and traffic—the sustainability ideals were to examine optimum density, flexibility of housing types and to promote pedestrian and cycle traffic—a car-free environment as far as possible. The network of road and paths would be planned so that cars would be parked in collective garages and the estate connected to the city center via trams, express buses and the Ebelsberg bypass. In the medium term, the aim would be to increase access via a rapid rail system. The natural topography was to be respected in laying out the homes, making most of building orientation and the local climatic conditions. An attractive town center with kindergartens, schools and a multi-function center are planned in the center of the new quarter, not only serving the new district, but also older communities nearby.

Building design and materials—the buildings would primary have a linear framework and have a height of two or three stories. The town center would be primarily north-south oriented, with passive environmental measures effected through atriums and compact layout; active measures include controlled building ventilation and hear recovery systems, underground air pre-heating or cooling depending on the seasons and PV collectors integrated with the roof or façade systems. (19) Excess heat in summer is lessened via covered passages and light deflecting mirrors. A catalogue of building materials based on eco-building principles and criteria is compiled by the builders, who would have to work on the basis of such agreements. (20)

Community—in 1996 the Wohnbund Salzburg was commissioned to develop an overall structural plan for a sustainable community for the new city quarter. A mix of housing types, owned as well as size of apartments to be built are determined to ensure a diversity of family types would be able to afford to live in the new quarter. Active participation from the future community was also encouraged, who will also eventually care for the areas in the vicinity of their homes as well as for some public spaces. Some of the ideas embodied in the implementation of solarCity include:

Environmental measures—energy would be not be supplied by the city grid but would come from the widespread use of solar panels and installations that would make the whole city self-sufficient and even return energy surplus to the city grid. A compact layout was favored with buildings largely oriented

FIGURE 5. Richard Rogers Partnership, solarCity. (image source: authors' own)

towards the south, with highly insulating facades, natural ventilation and lighting and optimum storage of heat. Hot water would be generated by solar collectors with a cover extent of at least 34%. (21)

Natural and open spaces—the city placed high importance on the environmental impact of the new development on the riverine ecology on the Traun River, but at the same time would like to introduce open and public spaces in the parkland. A landscape design competition was held in 1997 by the city for such development. (22) The Kleiner Weikersee, a natural lake in the region, would be expanded to create new bathing areas, and a bridge added for pedestrians and cyclists at the narrow crossing. The Traun-Danube riverside nature reserve would be preserved, but made accessible via timber gangways, information stations and a system of paths. Recreation space for the development would include an intensively designed park landscape between the residential and natural areas, with areas for relaxation and recreational activities. An existing stream, the Aumühlbach would be re-established through eco-engineering and would be integrated with the park landscape.

Water and waste disposal—within the framework of a pilot project for waste disposal is the "waste water-free estate." 106 homes and the school would be fitted with special toilets that would separate grey, yellow and black water. The yellow water would be enriched with nutrients and applied as agricultural fertilizer, while solid waste would be composted. Grey water would be cleaned in sand and reed bed filters and fed into the nearest stream. A rainwater reclamation system using hollows gullies and reservoirs would ensure that rain water is retained in local ground.

Urban morphology—the masterplan for solarCity in many ways are modeled after the Garden City model. Both are designed in a radial form with neighborhood wards in each quadrant. While the Garden City is linked to the Central City via train, solarCity is linked to Linz City via tram. (23) The town center and commercial facilities in both cases

FIGURE 6. Herzog + Partner, solarCity. (image source: authors' own)

are located in the center of the radiant, and the city surrounded by a green belt—in the case of the solarCity, the nature reserves helm in the development almost on three sides, while the existing districts of Ebelsberg and Pichling are on the west and southwest. The development of the solarCity is tightly bound by development regulations for sustainable development and building orientation, while the Garden City models are regulated to control form and spatial environment.

Like the Garden City, solarCity's form and density tend towards decentralization of the city in being a satellite city quarter. However, while the Garden City is developed as a co-op, solarCity is a project initiated by the municipal government as public housing. Nevertheless, the environmental "stakeholding" as well as the participation of the community in shaping the public spaces near their homes allows the community to determine some aspects of the development.

Critique

Like in our Vauban case study, we evaluate solarCity as it is built against the ideas embodied in its inception. These are condensed in three thematic areas. Like in the case of Vauban, the discussion is open-ended as our research is still ongoing.

Urban form—the layout of the city means that the buildings generally relate to the streets only on their short ends, so that the streets actually have little interaction with building—a situation where there is a lack of street-fronts. The overall spatial configuration as well as the low building density makes this development a suburban model rather than an urban model for a sustainable community. The site and morphology of the development, being hemmed in on all sides by nature reserve or the existing urban developments mean that there would be little scope for growth and expansion of the development. Its similarity to the Garden City brings forth the well-known critiques of such a model, whereby the move to decentralize from the central city makes these developments "bedroom communities" rather than real cities. The spatial environment of solarCity recalls a village rather than an urban setting. While the planning of a car-free community is laudable, the lack of a main street in the development, where the layering of functions often create vibrancy and animation on the streets, effectively takes away the possibility of the creation of true urban public space.

Planning paradigm—unlike Vauban, where the residents already form building development co-ops before construction, solarCity is commissioned by the municipal government, so that the future residents are not the "developers" of their own units. The result is less choice and diversity in architectural expression of the housing forms, and perhaps less sense of ownership. With its strict environmental and ecological regulations and control, it is envisaged that residents would have little scope for altering their dwellings in the long term, a critique also of the Garden City model, such as in Letchworth, UK. The result is more of a model community for learning about ecological construction and mode of living—an educational showpiece—rather than a development that would allow future choice and diversity of developments.

Community—the clear boundaries of the development allow little overlap with surrounding communities. It remains to be seen if the existing communities near the new city quarter would actually make use of facilities provided in solarCity or if the development would become a self-contained community of like-minded residents.

CONCLUSION

Measuring sustainable development—it would be immensely useful to be able to use measurable evidence to affect a comparison of the two developments as they are almost similar in size and scope. However, at the present, there are tools to measure individual building performance, such as Building Environmental Assessment (BEA) tools where performance of buildings are assessed against a standard, but ways of measuring sustainable urban development as a comprehensive framework are still in the process of development. Tools like Environmental Impact Assessment (EIA) are project specific and measure only the impact on ecological values of high or pristine ecological value. (24) Other tools such as ecological footprinting (EF) as developed by Wackernagel *et al* measure and evaluate ecological impact on a national level. (25) Its limitations are also that it takes into account a set of values concerning ecological systems but lack dimensions pertaining to social and

economic factors. As such, it is difficult to discuss the findings in measurable factors that are correlated, and their interactions taken into account. We believe that the developments as a whole, including the factors of architectural and urban design as well as social and community dimensions, exceed the sum of the environmental technologies, photovoltaic systems and waste disposal systems.

Lessons in creating new sustainable communities—the studies of Vauban and solarCity Linz suggest some important factors that are strongly correlated in creating sustainable developments:

- Design plays a role in creating integrated environmental technology systems so that they form part of the larger inhabitable environment rather than showcases of environmental science. Good architecture and urban design creates identifiable community spaces and sense of place that are the glue to tenable sustainable communities.
- Net densities of the developments are generally low, from about 0.65 plot ratio in solarCity Linz and 1.2 plot ratio in Vauban, with about 50 to 100 persons per hectare respectively. The question is if such developments can have increased capacities and still retain the high quality of environment. The generous space provisions in both studies enable the developments to provide the best solutions for the widest numbers of factors. The efficiencies of the development may become less ideal with increased densities and plot ratio. For example, increasing the numbers of floors and heights of the buildings may not result in increase in area suitable for the installation of photovoltaic panels, in addition to the fact that the resulting waste accumulation may be difficult to be dealt with on site.
- The scale of both development also suggests that a population of up to 5,000 (i.e. a traditional neighborhood size) may be an ideal size for population retention and "stakeholding" in building the community and subscribing to the particular lifestyles and beliefs that these developments embody, such as the progressive, "green" agenda central to Vauban. As such, these communities might be networked within regional developments as linked constellation, rather than as expanded developments.

It may be inferred that the idea that cities are more efficient with increasing densities should be replaced with the framework that integrated design solutions on an urban scale provide sustainable solutions that balance quality of life, diversity of population, public transport systems and community scale with the ecologies of site as well as the social and economic factors. Improved environmental technologies support and enhance, but not replace, the primacy of well-designed urban form in creating good, sustainable living environments and public spaces.

Vauban presents itself as a viable and real alternative to sub-urbanization of neighborhoods and the loss of the sense of urbanism and citizenship in residential developments. Without a preconceived model of architectural typology or urbanism, Vauban is a bold experiment in the planning and design of housing for the future, and bringing back the qualities of the city into neighborhood developments, yet at the same time seeking alternatives such as limiting but not prohibiting car-use by making such a need almost non-existent.

SolarCity on the other hand demonstrates the aestheticizing of sustainable urban design and architecture to reveal new possibilities in their expression. The development proves that sustainable development can at the same time be very attractive in both form and spatial aspects, and would surely be an inspiration to architects and urbanists. The compact urban form can be expandable via future developments of similar cities potentially forming a constellation of satellite cities linked to a central city.

Despite the open questions of connectivity with surrounding communities and the lack of urban quality compared with city core areas, the case studies of Vauban and solarCity allow us a glimpse of possible alternatives to urban neighborhood development, which allows flexibility for change, yet not depleting the resources for future generations to come.

NOTES

1. This paper is the result of the collaborative interdisciplinary research project titled TransUrban that is funded by the Harvard University Graduate School of Design.
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5. Schubert, M. (Stadtteilverein Vauban). Personal interview with the authors 6 July 2006.
6. Fabian, T. (Stadtplanungsamt Freiburg, Projektgruppe Vauban). Personal interview with the authors 5 July 2006.
7. Glatz, B. (Stadtteilverein Vauban). Personal interview with the authors 6 July 2006. There were three main project actors in the Vauban project: *Projektgruppe Vauban* (Project Group Vauban), responsible for the administrative coordination of all involved local authorities; *Gemeinderätliche AG*, a committee of the City Council; and *Forum Vauban,* a local citizen's association.
8. Fabian, T. (Stadtplanungsamt Freiburg, Projektgruppe Vauban). Personal interview with the authors 5 July 2006.
9. The building regulations of the federal state of Baden-Württemberg made it necessary to invent a legal framework to realize this concept. The *Verein für Autofreies Wohnen* (Association for Car-free Living) in Vauban was founded as a legal body for its implementation.With more than 140 households within the first developing section alone, Vauban is one of the biggest projects of this kind in Germany.
10. There is a stream of cold air coming from the declined slopes of open land uphill of Vauban. Barriers against this stream, which has a very good impact on the local climate conditions, were reduced to a minimum.
11. The average energy standard in Germany for buildings built between 1995 and 2000 is about 100 kWh/m^2 per year, the standard of older buildings is about 200 kWh/m^2 per year.
12. 50% of the electricity for Vauban is produced by the onsite co-generation plant, 10% by photovoltaic devices.
13. Solar PV and other renewable energies still only provide 2% of the power that Freiburg needs. The city currently generates 50% of its electricity from natural gas CHP plants. The rest is imported, including 30% from nuclear. Freiburg's goal is to decrease nuclear influence and increase the energy from renewable sources to 10 % by 2010.
14. Disch, R. (Architect of Solarsiedlung). Personal interview with the authors 5 July 2006.
15. According to the provisional figures of the institute, Vauban produces per year: 28 GJ energy savings, 2100 t CO_2-equivalent reduction, 4t SO_2-equivalent reduction, 1600 t mineral resources savings. This is the first time that a complete urban neighborhood is analyzed with respect to all its components.
16. Schroepfer T., Hee L., Werthmann C. (2007). transUrban: Vauban. Conference proceedings: *Sustainable Development III*. Wessex: WIT Press 2007.
17. City of Linz (2007) [Online]. Available: www.linz.at/solarcity
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19. Generally, the passive solar design includes strategies to maximize solar gains and minimize heat loss and overshadowing.
20. E.g. the Kindergarten is largely built out of timber. Façades in solarCity include passive solar energy recovery systems, decentralized wall-integrated ventilation devices, wood, aluminum or synthetic material high-quality windows.
21. It was planned that the development would not be supplied by the city's electricity grid but co-generate its own energy which would make the neighborhood completely independent and even allow it to return part of its energy surplus.
22. The project attempts to demonstrate how a city development and nature can be brought together and how its inhabitants can be offered a high standard of living without having the natural environment suffer a result. The project includes preservation of surrounding marshland in its entirety, avoidance of ecological barriers and divisions, preservation of valuable biotopes, re-admittance of flood-water to restore the natural ground water level of flooded marshland, natural forest cultivation, and reduction of noise and emission levels.
23. Like Vauban, solarCity is designed to reduce the need for car-use and to cut overall journey distance.
24. Hyde et al. argues for an environmental brief that could address the exiting limitations of measurement tools. See Hyde R. et al. *The Environmental Brief—Pathways for Green Design*, Oxon: Taylor and Francis, p. 28.
25. Mathis Wackernagel *et al* developed the measure of the ecological footprint (EF), defined as the land area necessary to provide for a given lifestyle of a population, and is measure in hectares. It includes the amount of arable land, grazing land, fishing grounds and built-up land to support that population and lifestyle. Added to this is the amount of forest that would have been required to absorb the carbon dioxide emitted by the fossil fuels used by the population. All types of land are then converted to land of average biological productivity (ability of the land to produce biomass), based on a scaling factor. See Wackernagel, M. *et al.*, 1999, "National Natural Capital Accounting with the Ecological Footprint Concept," *Ecological Economics 29*, pp. 375–390.