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Energy Master Planning for Resilient University Campuses—Best Practices from Austria

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ABSTRACT

The energy supply in Austria was first established in the 1880s with regenerative microgrids for industries and public buildings. These were unified and modernized step by step to form what is now one of the most reliable power supply systems in the world. A large share of more than half of the power production comes from hydro power stations, many of which also provide pump storage. Since the 1950s, previously wasted heat from fired power stations has been distributed to dense urban areas via district heating. Oil price crises, rising awareness for environmental issues, and increasing availability of incinerable waste have led to a diversification of fuel and inclusion of geothermal heat and waste heat from industrial processes.

Public buildings and communities were at the start of the Austrian modern energy supply system, and with growing demand for transformation of energy supply to meet net zero requirements, today they serve as models for the future. Thus, the efforts and methodology applied on Austrian university campuses are presented here as a result of the Austrian Research Promotion Agency (FFG) Project 864147, funded by the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, to contribute to the International Energy Agency Energy in Buildings and Communities Programme (IEA EBC) Annex 73, Towards Net Zero Energy Public Communities, which focuses on developing guidelines and tools that support the planning of net zero energy resilient public communities.

Two case studies illustrate the transition towards net zero resilient energy:

- *Case Study 1: The Campus Technik of University of Innsbruck, where building envelopes and building technology have been modernized to reach an energy consumption close to what is achieved in high-quality new construction, with inclusion of heat regeneration from ventilation and use of ambient cold for night ventilation.*
- *Case Study 2: The new campus of Wirtschaftsuniversität (WU) Wien, which uses groundwater heat in a cyclic way both for heating and cooling, where core activation allows for mostly direct use without the need for heat pumps to adapt temperature levels.*

This paper briefly describes the specific Austrian situation of legislation, tradition, and policy that creates the framework for changes towards net zero energy supply. The two case studies illustrate how this framework has been handled by the planning teams to meet the objectives in the most cost-effective way and how challenges have been dealt with and successfully overcome.

INTRODUCTION

In Austria, energy planning focuses on individual buildings or (maximally) on small clusters of buildings. On the other hand, district energy providers do master planning at the community level but consider the individual buildings to be the end consumers. Addressing building clusters or whole districts in an integral approach that includes energy suppliers encourages synergies to improve energy efficiency and sustainability. For example, if the same team assesses both the buildings and the supplying energy systems, they can develop an integral solution that combines building renovation with the use of renewable heat sources. Buildings can be renovated in a way that allows for a reduction of supply temperature in the district heating. In turn, renewable energy sources can be used

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in an efficient way to provide the low-temperature heat supply. The main barrier for integral solutions that involve building clusters or entire districts is the steep increase in complexity both of the technical systems and of multi-stakeholder processes.

For public buildings and communities like university campuses and hospitals, energy resilience is required. A resilient energy system is defined as one that can prepare for and adapt to changing conditions and that can recover rapidly from disruptions (WH 2015; HQDA 2015). Usually, energy resilience is realized in a separate process, e.g., by installing uninterruptible power supply units for critical infrastructure. System resilience can, however, be enabled by holistically designing energy systems that explicitly account for threats (Jeffers et al. 2020).

This paper reviews how integral planning has been used in two case studies in Austria, both public building processes that have realized high-quality solutions. We look at how this differs from standard building and planning processes and assess how resilience was considered in these processes.

The Methods section presents our methodology and briefly describes the two case studies. The Results section analyzes the framework, involved stakeholders, and applied planning methods used in both case studies. The Discussion section summarizes what can be learned from the cases and how resilience has been realized. The conclusions address the future of planning for public communities and how resilience is a part of that process.

METHODS

This analysis is based on two Austrian cases, both recent best-practice examples of university campuses. The two campuses are owned by the public building owner Bundesimmobiliengesellschaft (BIG). They have been chosen for this study because in both cases innovative methods have been applied to realize campuses that meet all requirements for sustainable, efficient, and successful education and research.

The first case study focuses on the Campus Technik of the University of Innsbruck. This ensemble of buildings from the 1960s with a total gross floor area of around 36,000 m^2 (387,360 ft^2) was renovated and modernized in the years 2013–2016.

The second case study investigates the creation of the new university campus of the University of Economics and Business of Vienna, WU Vienna. The WU campus, which contains seven buildings with a total of 100,000 m^2 (1,076,391 ft^2) gross floor area has been designed with a green building concept in mind and was opened for use in 2013. For local heat and cold supply an aquifer is used.

For these case studies, we cooperated with the projects' responsible parties at BIG and interviewed some of the stakeholders and project developers. We also studied publications on the planning processes as well as internal documents from their planning, construction, and monitoring phases for a quantitative and qualitative analysis.

We also include general information derived from a literature search and other current Austrian projects that pertain to building targets, master planning processes, and how resilience is addressed for energy supply.

RESULTS

In this section we start with a description of the public building owner Bundesimmobiliengesellschaft (BIG) that is in charge of the objects of interest. We then analyze national boundary conditions, regulations, and policies for buildings and give a short overview of energy supply systems. We then briefly present some general public building practices and touch on how resilience is usually addressed. Finally, we describe the two cases, including information on the sites, goals, procedures, and lessons learned.

The Building Owner

Bundesimmobiliengesellschaft (BIG) is one of the largest real estate owners in Austria (BIG 2020). Its portfolio holds around 2.012 real estate assets with a fair market value of around 12 billion € ($14 billion), consisting mainly of educational buildings like schools and universities. The major tenants are the federal ministries for education, science, and research; Austrian universities; and other federal ministries like justice, finance, and interior.

In cases of renovation and new construction, BIG cooperates with the tenants and their financing parties to provide an energy-efficient and sustainable solution. The user, e.g., a school, defines functional requirements, which are checked by the competent ministry. The building owner, BIG, calculates the costs that presumably arise from building or renovation. Generally, BIG competes within the market, and public tenants choose the best offer; they are not forced to rent a building owned by BIG. Contract periods for renting often last around 50 years or longer, which allows for long-term planning. For both BIG and the tenant, construction costs are important since they must be covered by rental payments. Thus, BIG must balance the costs against the European Union (EU) 2010 requirement for public buildings to incorporate best practices (EU 2010).

National Boundary Conditions, Regulations, and Policies

Energy Systems. Austria has a tradition of comparatively detailed regulation of the construction sector, security being one of the most important values. Public power infrastructure is being kept at a high level of quality and reliability, e.g., by using ring lines to create redundant supply systems and by using underground distribution systems (Reichl and Schmidthaler 2011). Power comes mainly from hydro power stations (60%) and thermal power stations (24%); the rest is provided by wind, biomass, and photovoltaic (PV) sources (E-Control 2020).

Heat supply depends on population density. In urban or densely populated areas, heat is usually delivered via district heating systems or from a central gas heating source in the cases of larger building complexes. Conversion of generation plants from coal and gas to biomass, biogas, refuse incineration, solar, and industrial waste heat is under way. In rural areas, most people rely on building-specific heat from gas, oil, and biomass. Like in district heating, there is a trend towards renewable sources, e.g., solar thermal and PV in combination with electrical heat pumps (Rohracher and Späth 2008; Heinz et al. 2007). These changes are motivated by a desire to lower greenhouse gas (GHG) emissions, reduce the dependency on foreign energy supply, and strengthen local forestry. Figure 1 shows statistical data on energy sources used for space heating in 2017 in Austria.

Recently, energy targets for district heating systems have been introduced. Subsidies are now only granted to systems with defined operating efficiencies of at least 85% (Public Consulting 2020).

Buildings. In Austria, energy targets originated from construction needs of industrialization after the two world wars. When apartments were needed, construction was—and still is—stimulated by financial support in the form of subsidized loans offered by public institutions. Large companies use this financial support to build projects with many residences (Stagel 2004). To guarantee that construction meets a certain standard, those subsidies have been tied to fulfillment of energy targets since the 1980s. These targets have evolved and are now applied also to nonsubsidized residential buildings and office buildings as well.

In 2008, energy targets for buildings that previously differed by region were unified. Now all regional building codes refer to the guidelines published by Austrian Institute for Building Technology (OIB 2019). When OIB guidelines are updated, it takes some time before each region begins to refer to the new guidelines in its building code.

The OIB guidelines define targets for heat demand, U-factors, and renewable energy sources and refer to Austrian Ö-Norm standards for calculation methods. The requirements are integrated into calculation software for energy performance certification, the use of which is mandatory for each new construction or larger renovation project. According to the 2019 version of the OIB guidelines, different metrics can be used to assess energy performance (OIB 2019). The most common metric used for declaring energy efficiency of residential and nonresidential buildings is the useful heating demand. The maximum allowed heating demand *HWBmax* depends on the surface-to-volume ratio of the building and for new buildings is calculated according to

$$HWBmax = f \times \left(1 + \frac{3.0}{\ell c}\right)$$

with ℓc as the volume-to-surface area ratio. The factor f is changing and different for new and renovated buildings, as listed in Table 1. Buildings labeled "cultural heritage" do not have to fulfill energy targets regarding heat demand.

In the 2019 version of the OIB guidelines, there are also rules for the use of renewable energy: if renewable energy is supplied to the building from an external source, a minimum 80% of the energy demand for heating and domestic hot water must be covered by this source. On the other hand, if a solar thermal installation produces hot water at the building, a minimum share of 20% of the final energy demand for domestic hot water must be covered (OIB 2019).

Energy Resilience. Austria has a secure and reliable power supply system that uses ring lines and hydro storage power stations and that is embedded in the European power system. The public Austrian E-Control is in charge of controlling energy security (E-Control 2020), and for 2018 reported an average interruption duration (SAIDI) of 25.21 min for unplanned interruptions and a total of not-delivered energy of 0.041%.

Public buildings are typically served by district heat and the public power system. In case of critical infrastructure like hospitals and data systems, uninterruptible power supply (UPS) units with kinetic storage and diesel tanks are standard. Design of backup supply is regulated by OEVE EN 1 part 4 53 (WKO 2007). In rural areas, agricultural tractors serve as mobile backup units.

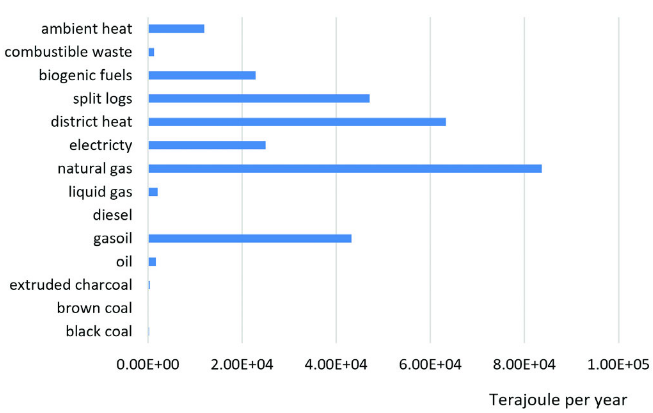

Figure 1 *Energy sources used for space heating in Austria in 2017. (Data source: Statistik Austria.)*

Table 1. Calculation Rules for Maximum Allowed Heat Demand for Nonresidential Buildings from OIB (2019, Translated and Simplified), where ℓc is the Reciprocal of Surface-to-Volume Ratio

		New Construction	Large Renovation
HWBmax, kWh/m²a	Current regulation	$12 \times (1 + 3.0 / \ell c)$	$19 \times (1 + 2.7 / \ell c)$
	From 01.01.2021 on	$10 \times (1 + 3.0 / \ell c)$	$17 \times (1 + 2.9 / \ell c)$

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General Planning and Construction Practices for Public Buildings

Design-Bid-Build. The standard construction method used in Austria is design-bid-build. Bid-build is often not considered, because it cannot be easily applied due to the EU act on procurement, as described in the following section. Comparisons of the two methods are available by Hale et al. (2009) and Ling et al. (2004).

In design-bid-build, work packages for procurement are defined at the end of the design phase.

Procurement. For state and public bodies at the central government level in Austria, the Federal Public Procurement Law 2018, BVergG (Bundesvergabegesetz 2018) applies (RIS 2020). The Act of 2018 reforming public procurement turned the connected package of EU directives 2014/24/EU of February 26, 2014, into Austrian law. The new procurement regime has introduced some fundamental changes affecting contracting authorities as much as contractors. The main limits for applying EU rules have been set to 144,000 € ($158,709) in the BVergG for most types of services and supplies purchased by central government authorities, while in the EU guideline §4, a value of 134,000 € ($147,688) had been proposed as a limit for service contracts. A lot of different limits are set for sub-central authorities and other sectors.

Although EU rules try to guarantee fair competition and low costs, they sometimes prevent specific and regional solutions. In fact, there are alternative ways for tendering, e.g., competitive dialogue. Directive 2004/18/EC defines competitive dialogue as follows in Article 1 clause 11C:

> 'Competitive dialogue' is a procedure in which any economic operator may request to participate and whereby the contracting authority conducts a dialogue with the candidates admitted to that procedure, with the aim of developing one or more suitable alternatives capable of meeting its requirements, and on the basis of which the candidates chosen are invited to tender. (EC 2004)

This means that it is possible to include producing companies in the planning process, which helps integral planning for innovative solutions.

Integral Planning. Integral planning denotes cooperation of planners from different fields such as energy, building physics, and building services in one team. This planning method certainly allows for more innovation, since interfaces between different teams are not fixed from the start. Integral planning implies the following:

- Involvement of stakeholders (future users, operators)
- Involvement of constructing parties
- Master planning considering the local supply situation
- Integration of energy topics into design work
- Consideration of procurement in the planning process (e.g., cost-efficiency by repetition, competition by limited size of work packages)

Organizational tools have been created to enhance integral planning, including software tools for project management and platforms for information exchange such as building information modeling (BIM), which is under development now in several projects (Barnes 2019).

Barriers to Integral Planning. There are inherent barriers to integral planning, e.g., growing complexity and incompatible software systems. Another issue is the predominant way of planning, where architects start with the design work and other experts are involved only in detailed planning phase. Much work is done to overcome these barriers, e.g., by unifying planning software in BIM and by applying management methods to integral planning teams.

Still, due to the above challenges, most buildings and campuses are created in conventional ways. Sometimes however, extraordinary framework conditions allow for a demonstration project in which new methods are applied.

Case Studies

The building projects analyzed for this paper have reached ambitious targets, including very low energy consumption and use of local renewable sources.

Campus Technik, University of Innsbruck, Austria. The object of interest is an ensemble of buildings from the 1960s, which has been retrofitted and modernized, with a total floor area after retrofit of 36,000 m^2 (387,360 ft^2). The main focus was on the building envelope, building services, and modernization of the heating and cooling systems for the buildings. Many buildings were renovated, and the modernization of the eight-story main building was accompanied by a research project so there is literature available (Jäger et al. 2013). Additional funding was available to account for extraordinary expenses due to the innovative process applied.

Urban Area of Interest. Innsbruck, which lies in a valley encircled by high mountains, has a humid continental climate with 3200 heating degree days. It is characterized by high temperatures and thunderstorms in the summer and heavy snows in the winter. Foehn storms (caused by warm southerly winds from the northern slopes of the Alps) are common. Around 130,000 people live in Innsbruck.

The Campus Technik of the University of Innsbruck was built in the 1960s at the west end of the town, outside of the built-up area. Innsbruck has grown since, so that the university now lies at the town border, with residential areas developing in the surrounding areas. A master plan for the years 2010 to 2020 had been created for Campus Technik (Klotz 2012) (Figure 2). The focus of the master plan was on spatial planning and not on energy issues. The 1960s buildings of Campus Technik were renovated in 2012–2015 after a planning phase starting in 2008.

Stakeholders and Needs. Reasons for the renovation were the age and functionality of the buildings as well as comfort and energy consumption. The buildings tended to overheat in summer and have high heat demand in winter. Some components for the building ensemble had reached an end-of-life status. On the other hand, the main concrete construction could be used for at least another life cycle. Thus, the decision

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Figure 2 *Master plan for Campus Technik. (Source: Architect Prof. ETH Dipl.-Ing. D. Eberle.)*

was taken to address these main challenges of bad comfort and high energy consumption by renovating the buildings.

The building owner, BIG, was in charge of the renovation project. Figure 3 shows the organizational structure used for integral planning for the main building. As the diagram shows, the university as a future user was not involved in the core research project team. However, students and employees were identified and involved as stakeholders because they are the users of the buildings. Moreover, since "buildings" is one of the research topics of Campus Technik, some of these users have expertise related to building processes, building technology, and indoor climate, which accentuates the value of their involvement.

Financing and Goal Definition. Due to public interest to make a sustainable investment, the goal was to reach sustainability goals such as low energy consumption but also to keep costs low. Without additional financing, this would have led to application of a standard procedure in which innovative solutions would not be easily attained. The standard renovation procedure in Austria consists of insulating the building envelope with expanded polystyrene or mineral rock wool and replacing windows with new triple-glazed units.

However, in this case, extra funding became available to make a test case for integral planning for one of the buildings.

An additional team of experts from external research institutes accompanied the standard planning procedures by offering innovative ideas and conducting system energy and life-cycle optimization. The tools used included simulation software to analyze indoor climate quality, energy flows, and life-cycle costs.

Energy and Resilience. The result of the project was an innovative combination of well-established elements, including building automation, a multifunctional façade with automated windows to regulate ventilation and indoor temperatures (see Figure 4), and a groundwater well for cooling and exhaust air heat recovery. This combination allows for further use of the existing distribution system for ventilation and heating/cooling. Renewable energy sources are heat recovered from exhaust air as well as cold from the groundwater well.

Remaining heat demand is covered by the university-owned gas plant, as it had been before renovation. Figure 5 shows the energy system architecture of Campus Technik; the schematic view follows the standard developed in International Energy Agency Energy in Buildings and Communities Programme (IEA EBC) Annex 73, Towards Net Zero Energy Public Communities (IEA 2020).

The buildings attained calculated heat demands of down to 15 kWh/m^{2}a (54 MJ/m^{2}a).

During the first two years after modernization, a reduction of up to 63% of the total energy consumption was measured, compared to the consumption before renovation.

The renovated campus buildings have increased resilience due to reduction of peak and total loads using efficient devices, automated natural ventilation at night to avoid overheating, and lower heat demand due to high-quality insulation. To further increase resilience, a UPS has been installed.

Planning/Tools. Integral planning was successful in creating an innovative solution setup with low life-cycle energy consumption and cost. The reduction in energy consumption results in an estimated 15-year amortization period. The resulting life-cycle costs calculated by the external group of scientists were lower than those for the business-as-usual solution, depending, however, on future energy prices and maintenance costs for automated windows.

Lessons Learned. The Campus Technik project was an extraordinary success. All buildings now require much less energy, with 63% reduction from 745 MJ/m^{2}a to 272 MJ/m^{2}a end energy for the best monitored building, and provide a high-quality work environment.

Experience from the Campus Technik project shows the importance of including expertise and practical knowledge

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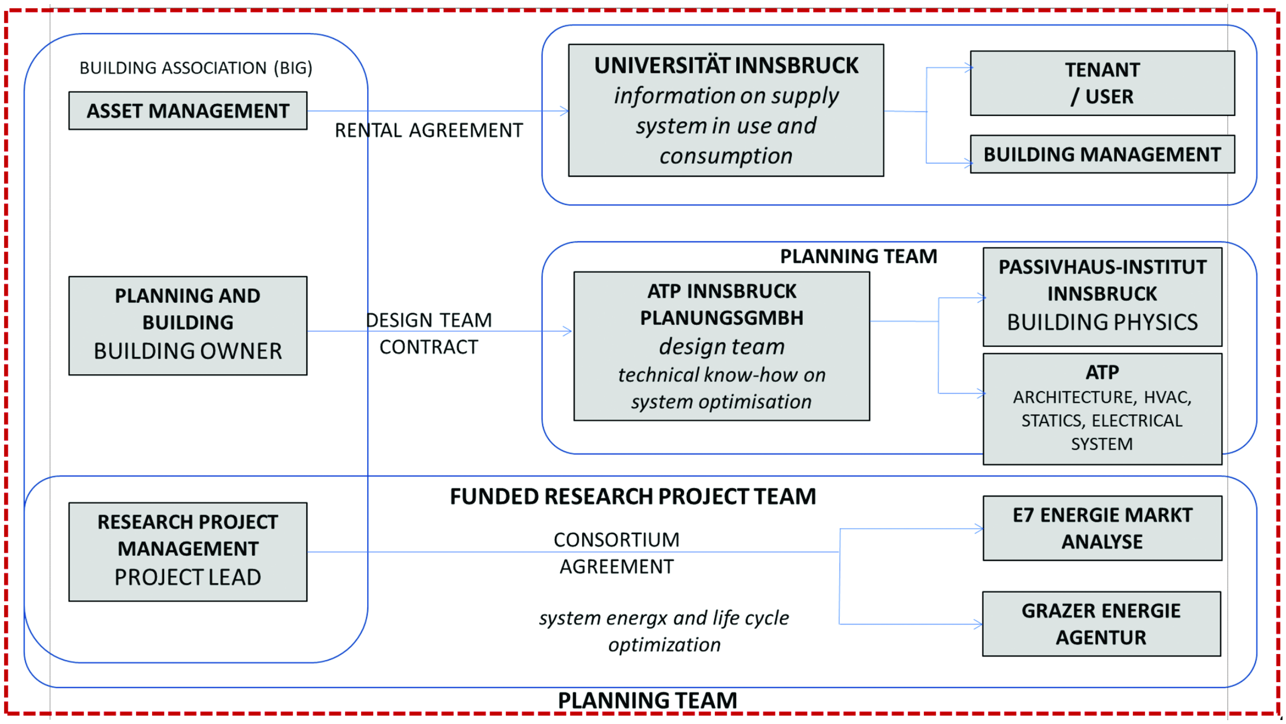

Figure 3 *Stakeholder structure during the planning process. Input necessary for whole-system resilience analysis is italicized. (Source: BIG 2020, translation and details added.)*

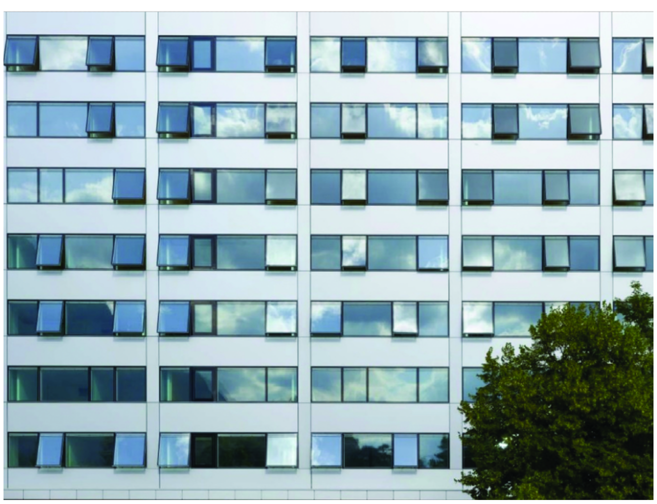

Figure 4 *New façade with automated window opening for ventilation on the main building at Campus Technik. (Source: ATP architekten ingenieure, Innsbruck architekten.)*

from many fields in the integral planning process: in the planning process, new façade elements were designed, but during the procurement phase it was revealed that the planned version could not be realized at a reasonable cost. In future projects, expertise from production companies will be included directly in the planning phase.

District heating owned by the university not only supplies Campus Technik but also neighboring residential buildings. Therefore, supply temperature in the district heating system could not be reduced.

University Campus, University of Economics and Business (WU) of Vienna. In 2006, Wirtschaftsuniversität (WU) Vienna was housed by many different buildings scattered around Vienna. In the main building, space was too short to cover the growing demand. There were two options: to renovate and enlarge the main building or to build a new campus, where all institutes would be gathered. When a fire destroyed the basement of the main building in 2006, it was decided to create a new centralized campus.

In 2013, the new campus of WU Vienna was inaugurated. The campus contains a total of seven green buildings with a 100,000 m^2 (1,076,391 ft^2) gross floor area. Figures 6 and 7 show an orthophoto and a map of the campus. Core activation and a well-insulated building envelope enable the use of an aquifer for local heat and cold supply. Groundwater is also used for irrigation of surrounding areas and toilet flushing. To lower the power demand, building automation and lighting are optimized. Calculated heating energy demand for different buildings varies between 15 and 42 kWh/m^2 (4758 and 13,322 Btu/ft^2); most buildings reach values around 16 kWh/m^2 (5075 Btu/ft^2). Two-thirds of the overall heating and cooling demand are covered by local renewable sources.

Urban area of Interest. Vienna is the capital of Austria. It has a rather mild oceanic climate with around 3400 heating degree days and is known for an almost constant wind. It is one

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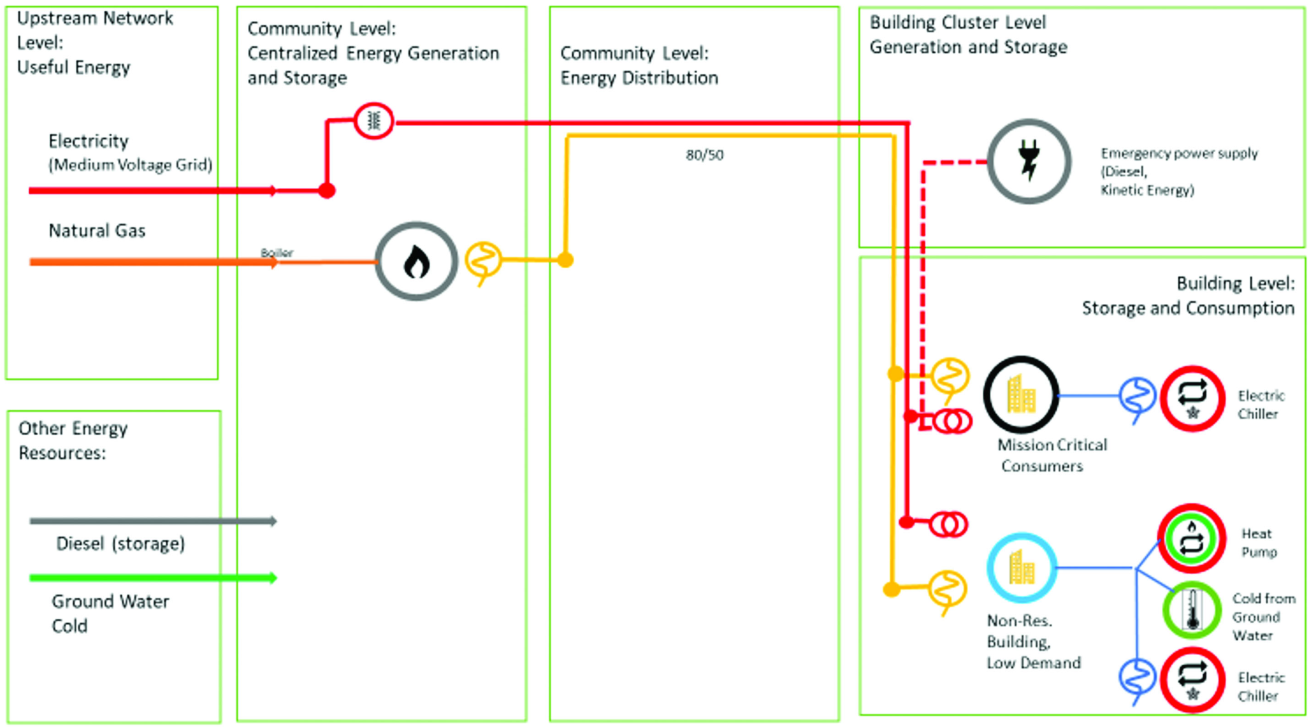

Figure 5 *Energy system architecture of Campus Technik in Innsbruck. Note that the university-owned district heating system also supplies nearby residential communities.*

of the towns with the highest quality of life in the world, due to its many cultural opportunities, excellent public transport, low crime rates, and good air quality. With 1.9 million inhabitants, it holds around a fifth of the Austrian population and is the fifth largest city in the EU. Around 200,000 students are enrolled at the city's nine public and five private universities or at its other colleges of higher education.

The WU campus was constructed on grounds of about 91,000 m^2 (979,160 ft^2), close to the green leisure area Prater, in an area well serviced by public transport. Recent construction of a river power station has created a groundwater sea below the lot that is used for energy supply.

Wind is certainly one of the specific challenges the planners had to face, since an unfavorable arrangement of buildings can lead to strong local drafts that can make outdoor areas uncomfortable.

Goals and Framework. At the start of the planning process, a group of experts agreed upon the green building goals to be reached, considering international certification systems such as the Leadership in Energy and Environmental Design® (LEED®) Green Building Rating System, the Building Research Establishment Environmental Assessment Method (BREAM), and German Sustainable Building Council (DGNB) certification, as well as results from the Austrian klimaaktiv program and new OIB guidelines. The focus was on the following:

- Minimization of life-cycle costs
- Use of long-life construction components and materials
- Energy efficiency of building envelope and services
- Use of regenerative sources for energy and materials
- Prioritization of the use of local sources
- Protection of local and global environments
- Low emissions from materials, energy production, and infrastructure

The WU campus was designed to surpass national requirements for building energy use and to integrate use of local energy. Because the campus is the home of the University of Economics and Business of Vienna, an important goal was to offer 25,000 students, 1500 employees, and visitors with high indoor and outdoor quality that would augment the international reputation of WU Vienna.

Moreover, it was decided that investment costs should not exceed the limit that was agreed on by university administration, responsible public entities, and the ministries of education and finance.

Organization and Stakeholder Involvement. University buildings and campuses are usually created either by the university itself or by the public building company BIG, which then leases the building to its users, as in the case of Campus Technik. For the new WU campus, the choice of the university was to cooperate with BIG by creating a joint venture. Together they founded a new company in which both parts could cooperatively plan, build, and later administer the new campus. The company belongs to BIG (51%) and WU (49%). Another important stakeholder is the public, as represented by the administration of Vienna. Vienna has a tradition of urban development for common interest.

Planning Process. The planning process for the WU campus was made up of the following steps:

- *Organizational Structure:* Define the organizational structure to be used to master the challenges. The outcome was a joint venture involving BIG and WU in providing design, construction, and later services to the WU campus.

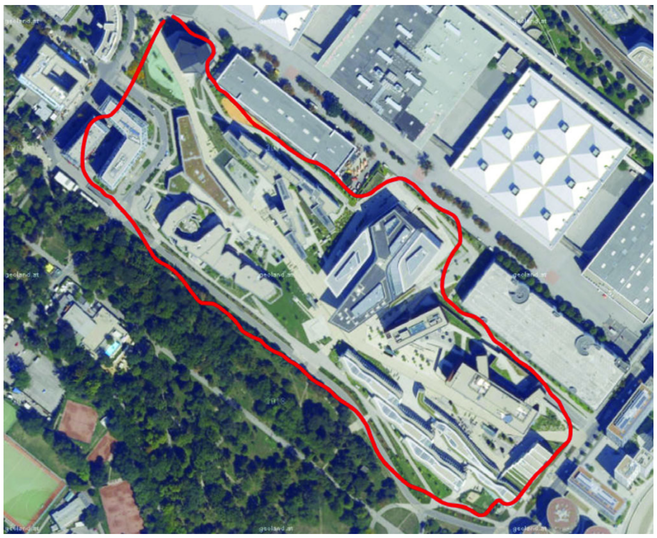

Figure 6 *Orthophoto of the University Campus of the Vienna University of Economics and Business. (Source ©basemap.at.)*

- Concept/Financial/Energy Goals
  - First, the functional and energy goals for the new campus were defined in the newly founded company.
  - The financial limit was fixed at 490 million € ($557 million) in a work group consisting of the financing parties, the ministry of finance, the ministry of science, BIG, and the university.
  - With these requirements in mind, an appropriate location was sought. There were not many spots available in Vienna that were large enough. The final area was chosen due to its accessibility to public transport (two metro lines, one of which lies along that other Viennese universities), the public green leisure area nearby (Prater), and the groundwater sea that could be used as an energy source (described later).
  - For this location, the architecture office BUSarchitektur was assigned with creation of a master plan (austria-architects.com 2020).
- *Architectural Competition:* The 2008 master plan established the framework for the public two-level architectural competitions for each of the five planned building groups. It included the idea of having a strong communication with public space, enabled by publicly accessible infrastructure in the ground floor of each building. Another request for the architectural design was to connect the campus to the public space around it.
  - The winners of the architectural competitions were entrusted with the planning procedure for their building and to submit construction plans to responsible authorities at the end of 2009.

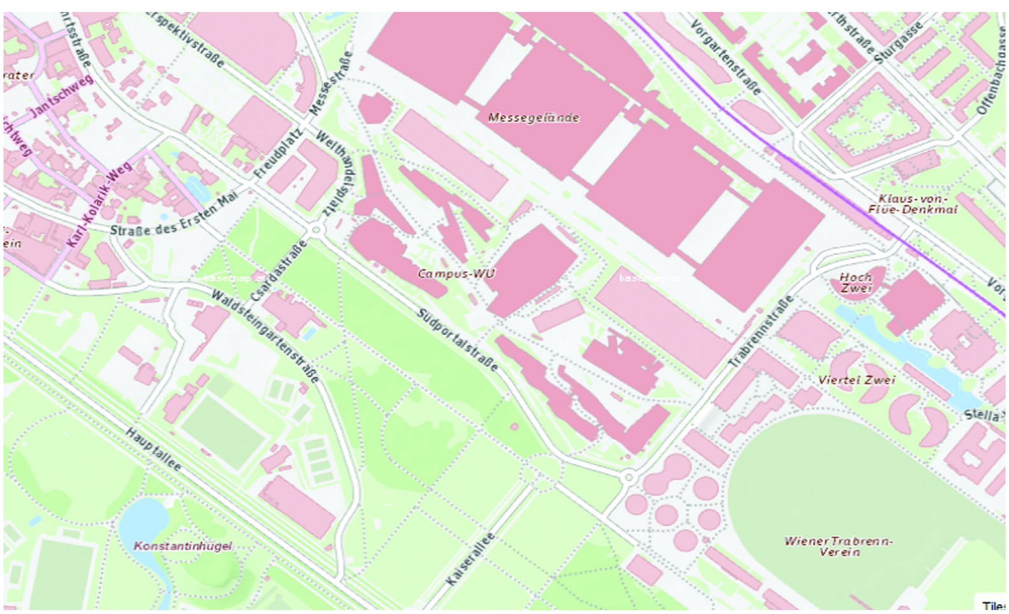

Figure 7 *Urban embedding of WU Vienna, between a fairground and the popular and well-known urban outdoor area "Wurstelprater," with excellent public transport. (Source: Openstreetmap, © Contributors to Openstreetmap.)*

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Energy and Resilience. The energy supply of WU Vienna is based on groundwater, for both heating and cooling. To increase efficiency and allow for direct use of groundwater, building cores have been activated (Rijksen et al. 2010). In winter, waste heat from the data center is used for space heating via a heat pump. Demand peaks are covered by Vienna district heating. The Tables 2 and 3 show the supply temperatures of the heating and cooling system, which allow for direct use of groundwater in many applications. The groundwater system is cyclic, in the sense that in the summer, waste heat from cooling is fed into the ground, to be used for heating in the winter.

To reduce power consumption, building services are optimized by monitoring and control. Lighting is optimized by light and motion sensors to reduce power consumption.

Power is delivered from the public 10 kV grid by a ring main, thus contributing to resiliency. Figure 8 shows a representation of the energy system architecture, which follows the standard developed in IEA EBC Annex 73, Towards Net Zero Energy Public Communities (IEA 2020). Dynamic diesel aggregates are used to guarantee uninterruptible power for the

Table 2. Design Temperatures of Heat Distribution Systems

	Supply Temperature, °C / °F	Return Temperature, °C / °F
Floor heating	40 / 104	30 / 86
Core activation	30 / 86	27 / 80.6
Low-temperature radiators	55 / 131	35 / 95
Heat to inlet air	45 / 113	30 / 86
Floor convectors	70 / 158	50 / 122
Portal air curtain	70 / 158	50 / 122

Source: 2010 building specification of the WU campus project.

Table 3. Design Temperatures of Cold Distribution Systems

	Supply Temperature, °C / °F	Return Temperature, °C / °F
Core activation	16 / 60.8	19 / 66.2
Precool register	14 / 57.2	19 / 66.2
LAN rooms (direct cooling)	14 / 57.2	19 / 66.2
LAN cabinet (redundant)	14 / 57.2	19 / 66.2
Cool register	7 / 44.6	13 / 55.4

Source: 2010 building specification of the WU campus project.

two data centers and also to provide safety illumination and emergency ventilation.

Telecommunication is provided to the provider rooms by two different "dark" fibers, which are connected to different sources in Vienna. Thus, the connection is redundant, increasing resilience.

To save drinking water, a separate water system was established for toilet flushing and watering of green areas; it is fed by groundwater.

Lessons Learned. The organizational measure to create a joint venture between expert building group BIG and expert user and financial expert WU Vienna was certainly one of the most important decisions in the planning and construction of WU Vienna. Another important choice was the construction lot. Characteristics of the location and available energy sources in fact have created a stable framework for further master planning. In the second step, framing of the goals and the master plan for the area provided essential input to the architectural competitions.

In this case of WU Vienna, a district cooling system was added to the usual district heating. The possibility to use groundwater and to regenerate heat sources by cooling made district cooling the most cost-effective solution.

In such a big project, procurement can be used systematically to keep construction costs low. Proper sizing of the work packages encourages a constructive level of competition, which promotes cost-efficiency. This strategy has been tested successfully at WU Vienna.

DISCUSSION

This section lists current challenges that affect public buildings, the importance of defining goals for integral planning, and the best practices used in the two described case studies to address energy and resilience issues. Presently, the most important challenges in public buildings are these:

- Difficulty and complexity of integral planning, which translates into extra planning costs for experts.
- Uncertainty of project costs due to large variations (~10%) of construction costs depending on the situation of the economy.
- The tendency for economic decisions to be made on the basis of construction costs rather than on life-cycle costs. (Note: In both case studies, life-cycle costs were considered.)
- Problems related to the differing interests of the owner (BIG) and the user (the university). Even though both parties in these cases were public entities, they were financed from different sources, which highlighted differences.
- Problems of information sharing. In large projects, knowledge/information is distributed and not localized. This could mean that everyone involved has the same information, but more often it means that some informa-

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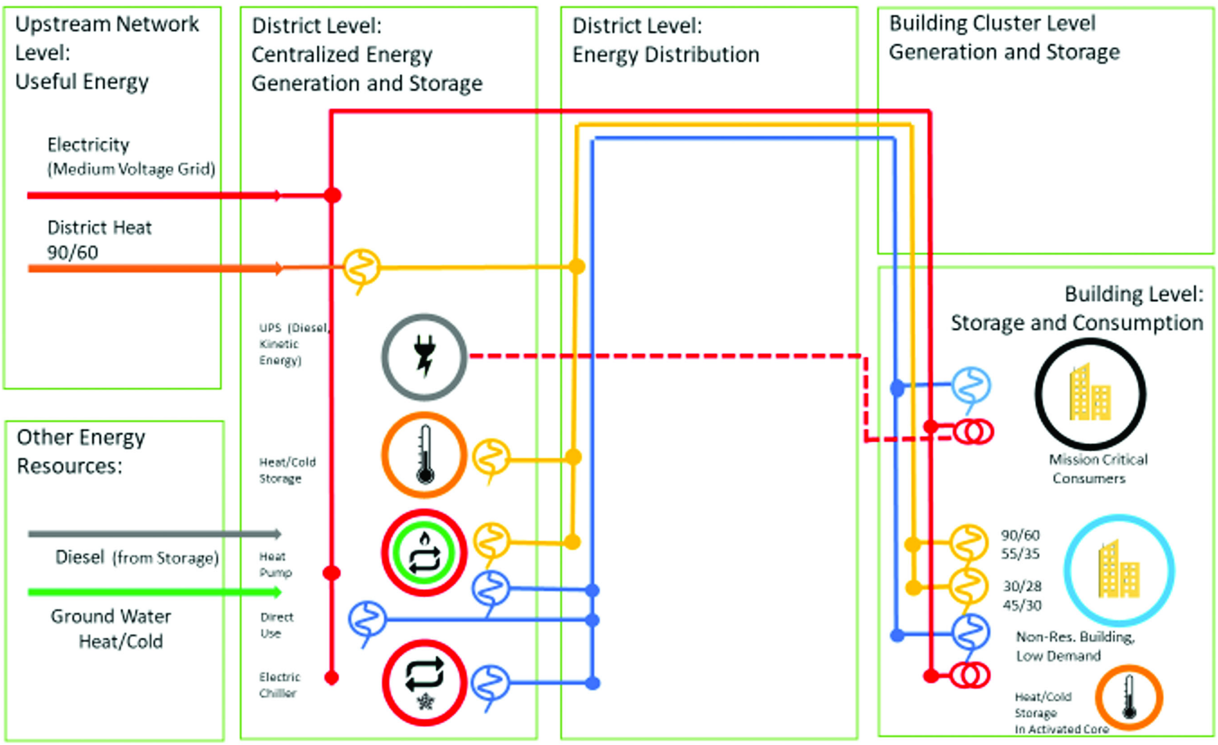

Figure 8 *Energy system architecture of WU Vienna. The campus is provided with heat and cold from a campus-wide district heating and cooling network. Both heating and cooling are generated from a ground source, with a heat pump raising the temperature when necessary.*

tion is restricted to some users. Effort has to be made in the planning stage to gather all relevant information.

Goal Definition and Integral Planning

In both cases, the definition of goals and financial limits was crucial. The goals and limits, together with regulation and on-site conditions, make up the framework for the integral planning process. In standard planning, interfaces and decision ranges are set by tradition, standard procedures and solutions, and a common mindset; however, in integral planning, these fixed structures must be replaced by a new framework consisting of goals and on-site conditions.

Energy

Energy was an important issue in both case studies, as it is in most other cases involving public buildings. In the renovation case, energy efficiency and recovery in operation were the main methods used to reduce the environmental footprint; the focus of life-cycle calculations was on financial cost.

In the case of the newly constructed WU Vienna, life-cycle calculations were made for energy, emissions, and costs. The planning process for the WU campus was multiphase and multilayer. This allowed for the combination of master planning in the first phase and individual architectural statements for single buildings in later phases. In a parallel process, energy planning started from the decision to use groundwater and core activation for both heating and cooling and was concluded when this concept was integrated into the design and planning process of single buildings.

The differences between new construction and renovation in these cases clearly show the following:

- In the case of renovation, many paths have already been fixed and not all options are available (e.g., choices for architecture, materials, and energy sources have already been made).
- For a renovation to achieve a building efficiency close to that of new construction, integral planning is essential, since renovation must consider many issues such as building envelope improvements, technology upgrades, and user expectations.
- If one is faced with the choice of new construction or renovation, an important consideration is that the process of new construction involves a much greater life cycle than renovation; thus, in many cases renovation is preferable.

Resilience

The two case studies addressed resilience differently, by renovation and new construction. In the case of renovation, UPS units were installed. In the case of new construction, resilience was integrated more at the core of master planning.

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The master plan level of the WU campus considered energy resilience and information sharing. At the campus level, local energy generation and high-efficiency building envelopes and technology reduce energy dependency, while district heat serves as backup and covers peak demand. For power supply, a ring line and UPS create redundancy and resilience. Groundwater is not only used for heating and cooling but also for many other campus needs. As required by regulation, many threats, including those from humans and the environment, were considered in the planning process.

In summary, these case studies clearly show the positive effect of integral planning and system integration, both for renovation and new construction projects.

SUMMARY AND OUTLOOK

This paper provides insight into the current planning procedure for buildings and communities in Austria by presenting best practices followed in two case studies of public building. It includes lessons learned from these cases and shows how energy and resilience were addressed.

To prevent climate change and mitigate its consequences, the construction sector has to transform. More attention on emissions and energy requirements is needed. On the other hand, the increasing frequency of disruptive events will challenge communities. Today's buildings must meet tomorrow's challenges.

Cooperative processes are required, involving experts from different fields to improve the infrastructure in existing communities. Especially for buildings with high requirements such as university campuses, standard processes need to be adapted to allow for integral planning.

Presently, energy-attentive master planning at the community level and also at the single-building level are objectives of research and development in Austria. Land use planning is being revised, because in the last decades in both urban and rural areas, undesired splinter development has occurred that has consequently increasing municipal costs for traffic and supply systems. At the community level, pilot projects consider how energy can best be included in the land use master planning process (Stöglehner et al. 2013; Edtmayer et al. 2019). Waste heat and solar heat are being considered and implemented as energy sources for district heating systems (JKU 2016). On the single-building level, building codes increasingly require the use of local and renewable sources (OIB 2019).

Buildings with improved envelopes and better insulation will require less heat in winter but will also have higher cooling needs in summer. District cooling (especially if it can be combined with heating for reciprocal gain) is increasingly becoming a preferred option, especially for office buildings and buildings with areas used by many people such as universities. This will almost certainly increase with rising global temperatures.

Several processes are currently helping the transformation towards energy-aware master planning in Austria:

- Development of procedures and goals to reduce uncertainties arising from the loss of previously fixed interfaces between different stockholder parties
- Digitalization to create and support organizational and functional tools for campus construction and operation, e.g., project management tools and BIM for integral planning
- Integration of site-specific information on local supply systems and renewable sources at the community and regional levels, e.g., into the regional geographical information system (GIS) platform, to offer information to planners (e.g., Hofer and Mörth 1998; Abart-Heriszt 1999)
- Monitoring and publication of data on pilot projects and plants
- Involvement of future users and building managers/ operators to guarantee system operability and to increase acceptance (e.g., projects in Seestadt Aspern [WoGen 2020])

Just like energy, resilience is receiving more attention. Up to now, the issue of resilience has mainly been considered for critical infrastructure; the standard measure to increase resilience has been the installation of UPS units. To increase the resilience of the overall power supply, the national policy is to use investments efficiently to maintain supply to all parts of the country, e.g., by closing power lines to rings to increase redundancy and by providing for flexibility with pump hydro power stations and for stability with river power stations.

In recent years, in response to volatile distributed energy generation from PV and wind, research and pilot projects have begun to investigate demand shifting as a way to increase flexibility on the distribution level (Weiß et al. 2019). Moreover, many municipalities have expressed a desire to promote local economic circuits to lessen their dependence on the national infrastructure. It is possible to achieve a local net zero balance by combining modern renewable generation methods such as PV and solar thermal with combined heat and power (CHP) by biomass. The project ANDRES Concepts from 2009 gives an overview of microgrid development in Austria (Einfalt et al. 2009).

In summary, there are two approaches to energy resilience. The first approach begins on the national or even European level and focuses on a stable overall supply. The other approach is mainly carried by municipalities that seek to promote local solutions and to secure their supply even if overall infrastructure fails. It involves low-consumption buildings and local energy generation and storage, and it sometimes strives toward creation of microgrids. This second approach could grow, since many municipalities have already attempted to reach a net zero balance by raising investments in distributed-generation infrastructures.

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