BIRKHÄUSER

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NET ZERO ENERGY BUILDINGS

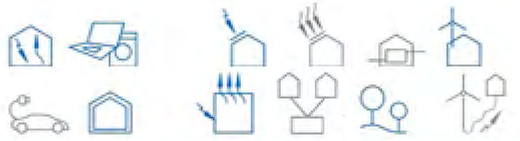
INTERNATIONAL PROJECTS OF CARBON NEUTRALITY IN BUILDINGS

EnOB
Forschung für
Energieoptimiertes Bauen

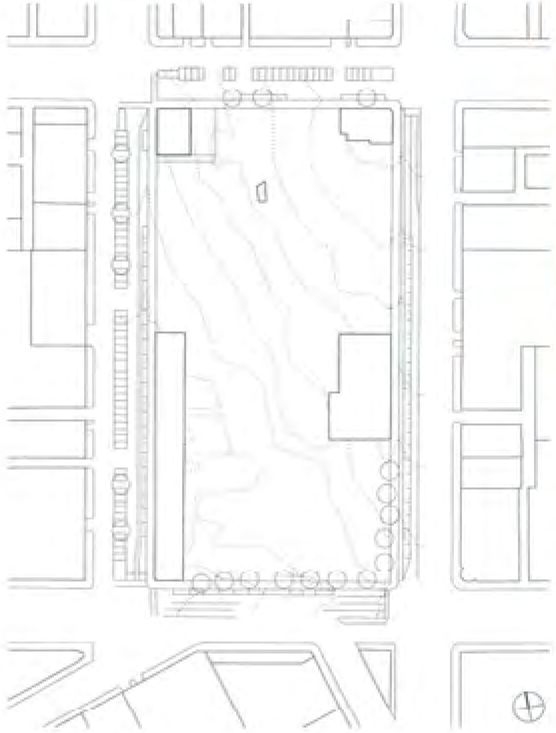
DETAIL Green Books

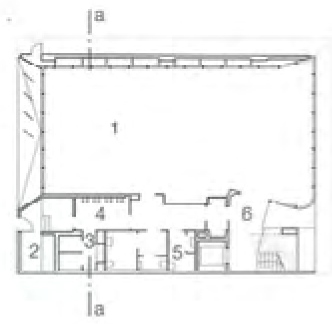
PIXEL BUILDING

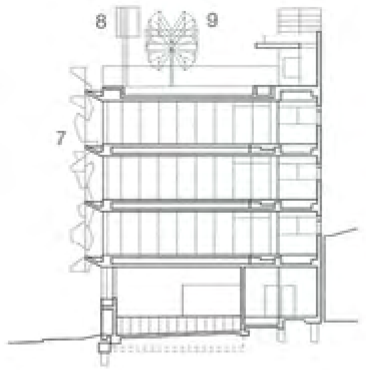
Melbourne, AUS 2010



Client: Grocon, Melbourne
Architect: Studio 505, Melbourne
Energy consultant: Umow Lai, Victoria
Building services: Umow Lai, Victoria
Monitoring: Grocon, Melbourne
Main stakeholder: client







B 16.01 Site plan, scale 1:4000
B 16.02 Ground floor plan, scale 1:600
B 16.03 Section, scale 1:600
B 16.04 View from north-west

1 Office
2 Entrance
3 IT/services
4 Corridor/photocopier
5 Storage
6 Staircase
7 Sunshade
8 Wind turbine
9 Solar trackers

B 16.01
B 16.02
B 16.03
B 16.04

On the site of a former brewery in Melbourne, Australia, an office building with the illustrative name Pixel was erected in 2010. It is used by the developers of the new urban district being created there as a planning and information location and through its special sustainability and positive CO_2 balance serves as a demonstration object for a number of new buildings. Passive strategies such as sunshade and daylight optimisation reduce the need for cooling and heating, while recyclable materials minimise the amount of CO_2 produced in making the building. The photovoltaic arrays and the micro wind turbine power generators on the roof are dimensioned to offset all climate gas emissions from the gas absorption heat pump and the other building service plants. It is planned to create a surplus to balance the emissions resulting from the building's construction.

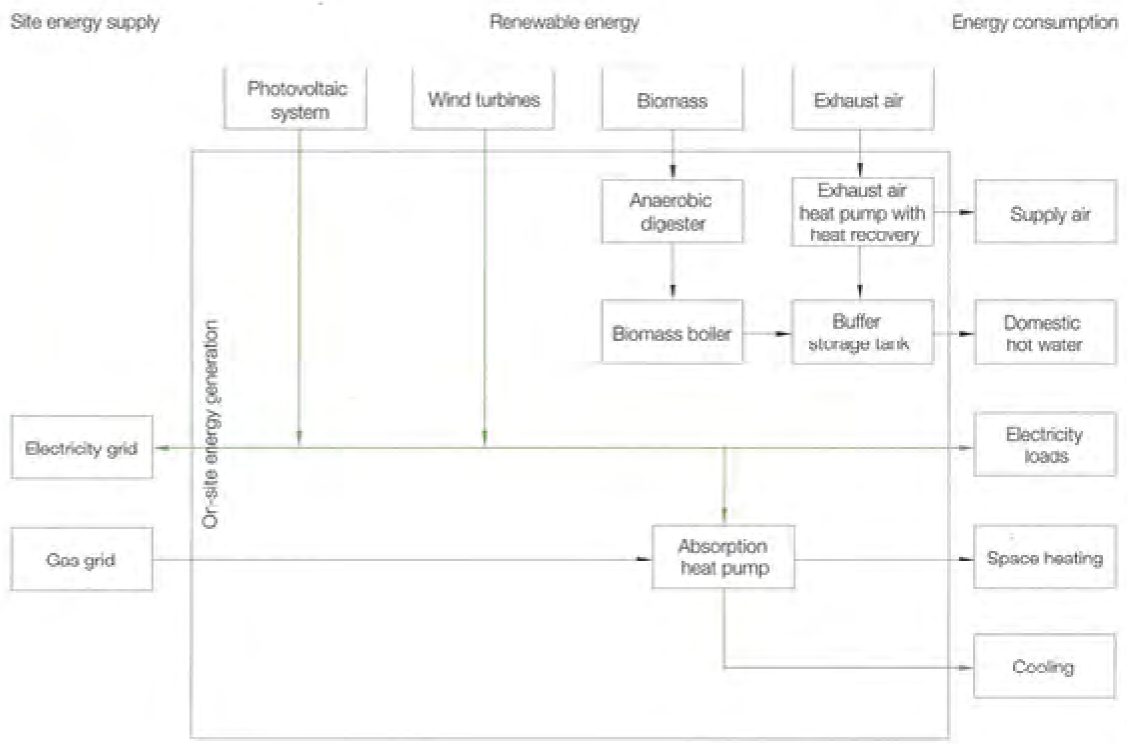
DEVELOPMENT, DESIGN, AND STAKEHOLDERS
The central location of this site offered immense development potential, turning the urban renewal project into one of the most ambitious construction projects in Australia and attracting great attention to the Pixel office building as a demonstration object (Fig. B 16.01). By using the building as an example to initiate sustainable concepts and energy-efficient new buildings locally, the planning team aims at implementing a variety of strategies to reduce CO_2, and increase energy efficiency and sustainability. Due to the lack of an assessment basis for climate neutral buildings in Australia, during the design phase theoretical concepts on balancing from the United States were used as a basis for the emissions balance. Upon completion in 2010 the building achieved the maximum number of points for "Green Star Office Design" from the "Green Building Council of Australia" (GBCA) and is regarded as Australia's "greenest" building. The project team also aims to achieve the highest ratings under the American LEED and the British BREEAM certification systems.

ARCHITECTURE The Pixel building features a total floor area of 840 m² distributed on four levels and stands on the north-western boundary of the site that covers nearly 20,000 m². The column-free ground floor offers space for a sales area, while the three upper floors contain office areas that can be used in a variety of ways (Figs. B 16.02 and 03). They are accessed from a staircase core bordering the east-facing firewall. The other three facades comprise large areas of glazing.

CONSTRUCTION AND INSULATION The reinforced concrete floor slabs rest on the walls of the solid staircase core and on three precast concrete piers outside the insulated building envelope of the western facade. The windows, which have thermal glazing (U_w-value 1.80 W/m²K), recede here by about a metre to provide architectural sun shade for the facade that receives a lot of sun during working hours. The massively built core contains all the utility spaces, an elevator, and the single escape staircase. Those interested in what is happening on the building site can visit a viewing area on the roof of the building. The staircase landings are generally separated from the office areas only by a glass wall, thus providing these spaces with a vivid impression and offering insights into the development of this new district. The solid eastern wall, interrupted in only a few places by single glazed windows, (U-value 5.8 W/m²K), is insulated internally with 5 cm of glass wool and has a U-value of 0.55 W/m²K. Beneath 30 cm of soil for the extensive planting, the top of the reinforced concrete roof slab is insulated with 10 cm of extruded polystyrene (U-value 0.31 W/m²K).
Most of the materials used for the building's structure and envelope can be reused after its demolition. An innovative type of concrete was developed for the concrete elements, and the "Centre for Design" of RMIT in Melbourne has certified that this mix offers an almost 50 % reduction in energy expenditure and CO_2 emissions compared to standard concrete, while still providing comparable compressive strength. It further contains a high proportion of recycled aggregates.

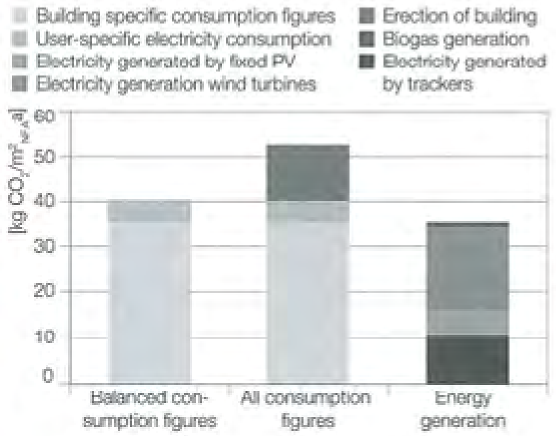
ENERGY EFFICIENCY The primary structure of concrete and the large window fronts form a simple building volume, the face of which is defined by the structure of the sun shade panels that gives this building its name (Fig. B 16.04). The numerous coloured four or five-sided composite aluminium panels are arranged in front of the facade at different angles so that the view outside is not obstructed. Sufficient daylight can enter through the full-height windows while preventing direct solar radiation from heating up the rooms excessively. The ways in which the individual plates are overlaid and tilted, and the angles at which they are fixed reflect their particular orientation (Fig. B 16.06, p. 136). The largest number of plates is in front of the very sunny western facade. Here, they are only slightly turned away from the building and form an almost closed surface. In front of the southern facade, which receives less sun, there are relatively few such panels to provide shade. On the northern side, the panels are fixed in an almost vertical position. In the southern hemisphere, this is where solar intake occurs due to the high sun position. The colourful metal plates also protect the staff from glare. The shade system was optimised with the help of daylight simulations. The few windows in the eastern facade feature an internal, centrally controlled glare protection system that closes automatically between 8 and 11 a.m. to exclude the intensive solar thermal load of up to 150 W/m². The windows in the loading area of the ground floor are shaded either by the tall surrounding buildings or internal blinds.
In addition to the intelligent exploitation of daylight, an energy-efficient lighting system (fluorescent tubes) in the office ensures low heat loads. They are dimmed in accordance with the amount of daylight and connected to presence sensors. In all other rooms apart from the offices LED lighting is used.
To passively cool the building during the night, the windows of the upper floors open automatically on cool nights, allowing cold air to flow across the solid ceiling slabs (there are no suspended ceilings) and withdraw the heat stored during the day.

ENERGY SUPPLY The wind turbines on the roof are also a unique feature that make the theme of renewable energy clearly visible. The vertical axis wind turbines developed specially for the inner city location and the local wind situation in Melbourne are not affected by the frequent change in wind direction and allow an even generation of



1.7 kW of electricity at a wind speed of 8 m/s. To exploit the high solar thermal load of almost 1600 kWh/m²a, a photovoltaic array measuring 38 m² produces electrical energy. 18 of a total of 30 photovoltaic modules, each with a performance of 211 W_p, are mount on three solar trackers (dual axis system that follows the sun). The other modules are positioned on the roof of the staircase tower that is inclined slightly towards the north.
The centralised ventilation system with heat recovery (75 %) by means of a plate heat exchanger is coupled with an air-air heat pump serving as air conditioning system. A network of ducts in the raised floors of the office areas and floor outlets equipped with diffusers introduce pre-conditioned air into the building. The four floors can be serviced separately with different air and temperature levels by means of a volume flow regulator. The supply air is introduced at a temperature of at least 18 °C (at full cooling capacity of 363 kW) and maximum 34 °C (at full heating capacity of 28 kW). The relative air humidity is supposed to not exceed 60 %.
In addition, a reversible absorption heat pump with a maximal thermal capacity of 68 kW cooling and 141 kW heat feeds the water coils located on the underside of the solid concrete ceilings with cold or warm water. This thermally activates the mass of the concrete slabs. The heat pump runs on natural gas (101 kW).
A burner uses biogas produced from faeces by an anaerobic digester to provide hot water in connection with a 300 l buffer tank. This enables water to be heated when there is sufficient biogas, and detaches production, which can't be precisely predicted on account of the irregular amount of biogas, from consumption (Fig. B 16.05).

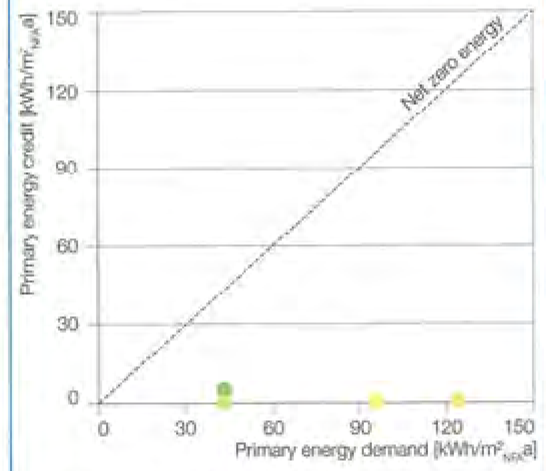
B 16.05
B 16.06
B 16.07



B 16.05 Technical schematic of energy provision
B 16.06 Shade provided by rigid sun shade elements on the north facade
B 16.07 Calculated annual energy consumption parameters including embodied energy and energy generation
B 16.08 Energy evaluation
B 16.09 Building and energy parameters (values refer to net floor area, NFA)

ENERGY BALANCE The dominant factor in the energy consumed at the Melbourne location is clearly the cooling system. The gas used to heat the building amounts to almost 6 $kWh/m^2_{NFA}a$ in comparison to 42 $kWh/m^2_{NFA}a$ required for cooling. The total power consumption for operating the building amounts to 22 $kWh/m^2_{NFA}a$. Due to the low emissions factor for natural gas (0.21 kg CO_2/kWh) in comparison to grid electricity (1.34 kg CO_2/kWh), the introduction of gas in the emission balance is advantageous, despite the low performance value of an absorption heat pump. The electricity comes, for the most part, from brown coal power stations. The entire CO_2 equivalent of the energy consumption amounts to roughly 26 kg $CO_2/m^2_{NFA}a$, whereby the function-related consumption for the offices, calculated at 12.5 kg $CO_2/m^2_{NFA}a$, is not included. This contrasts with a power generation figure of 12 $kWh/m^2_{NFA}a$ from the photovoltaic arrays and 14 $kWh/m^2_{NFA}a$ from the three wind turbines. The CO_2 emissions credit from the grid connected plant amounts to a total of approximately 36 kg $CO_2/m^2_{NFA}a$. The production of biogas contributes 2 $kWh/m^2_{NFA}a$.
The negative emissions balance does not allow the emissions generated in producing the building, which amount to 239 kg CO_2/m^2_{NFA} (Figs. B 16.07 and 08) to be offset. However, simulations reveal that the generation by means of wind and solar energy is well suited to the needs of Melbourne's electricity grid. The high cooling loads of the building mean that there are peak loads around midday on warm summer days.

LESSONS LEARNED The intensive search for suitable technologies to reduce the amount of energy needed to cool and heat the building, as well as the time required to develop the wind turbines meant that the planning and construction phases extended over a period of 29 months.
In the initial phase of operating the building the combination of the ventilation and cooling measures in the floor slabs and in the adjoining raised floors required a considerable amount of fine tuning. But this ultimately resulted in a pleasant internal climate. The individually controlled systems do not interfere with each other and it is possible to respond to the different spatial situations on the individual floors.
Uplights fitted later in the offices have provided an even distribution of light that was not achieved initially. However, directing light at the ceiling caused problems with the light sensors of the daylight control system. The uplights were therefore integrated in an adapted lighting control system. Initially the tracking system of the photovoltaic panels reacted solely to brightness, and at night rotated the panels to face the nearby lights of the city, thus using additional energy. Timers are to be added to the system so that the trackers move only during the daytime.



By including all calculated demand values an annual zero energy balance is not achieved:
- Measured annual total primary energy consumption including user electricity (123 kWh/m²a)
- Building-specific primary energy demand (94 kWh/m²a)
- Self-demand coverage by monthly calculable biogas, wind, and solar electricity yields (81 kWh/m²a)
- Annual balance by electricity surpluses not entered in the monthly primary energy balance (3 kWh/m²a)

Use of specific primary energy factors for the location Melbourne

SITE	Melbourne (AUS)
Annual global radiation at site	1600 kWh/m²a
Annual mean temperature at site	13.5 °C
Context	urban
BUILDING ENVELOPE PARAMETERS	W/m²K
U-value, exterior walls	0.55
U-value, windows (incl. frames)	1.80
U-value, roof	0.31
U-value, ground floor slab	0.13
Mean U-value, building envelope	1.06
BUILDING EQUIPMENT PARAMETERS	
Photovoltaic system area	38 m²
System area per m²	0.05 m²/m²
Photovoltaic capacity	6 kW_p
Capacity per m²	7.50 W_p/m^2
Wind capacity	5 kW_{el}
Capacity per m²	6.00 W_{el}/m^2
GRID INFRASTRUCTURE AND ENERGY SOURCES	
Supply infrastructure	electricity grid, gas grid
Energy source supply	natural gas, electricity
Feed-in infrastructure	electricity grid
Feed-in energy source	electricity

DESIGN STRATEGIES, CONCEPTUAL FOCUS
mechanical ventilation with heat recovery, external sunshade system as signature element, thermal activation of concrete core, gas-fired absorption heat pump, photovoltaic units, micro wind turbines, biogas production and use, reusable and recycled building materials

BUILDING CHARACTERISTICS	
Net floor area, NFA	837 m²
Gross floor area, GFA	1136 m²
Gross volume, V	3567 m³
Building envelope, A	1310 m²
Surface to volume ratio, A/V	0.37 m²/m³
Building costs (net, construction/technical systems) (2010)	5100 €/m²
Number of units	4
CONSUMPTION PARAMETERS (simulation)	kWh/m²a
Space heating demand	5
Water heating	1
Site energy consumption for heat (incl. hot water)	6
Final energy cooling	42
Electricity demand	22
Total primary energy demand	123
Total primary energy generation	84

B 16.08
B 16.09