RESEARCH THE LOCAL CIRCUMSTANCES

2

Library of the Voorlinden Museum, Wassenaar, the Netherlands
[photo: Andy van den Dobbelsteen]

This chapter will focus on step 0, preceding the actual redesign process: research. After all, you need to know within which context you are performing your work.

The previous chapter 1

The previous chapter provided the basics, by introducing zero-energy design, explaining why it is important, and providing an outline of the book.
By watching the short film ‘Energy Slaves’, about the energy use of a household, it became clear how much human power would be involved in generating this energy demand.
Energy and power were discussed, the differences between their units, as well as the meaning of quantities of energy.
Finally, the heat balance of a building was discussed, as well as how the incoming and outgoing flows of energy can be determined.

This chapter 2

To kickstart this chapter, it is recommended that you watch a mini-documentary of the Prêt-à-Loger house. The smart bioclimatic design interventions and technology of this case will be explained first.
The first section of this chapter will discuss the different climates around the world, how these have influenced vernacular architecture, and which different climate aspects determine the energy performance. It will clarify why using locality is an important means to create energy-efficient buildings.
The section thereafter will be a guide through the history of climate design, especially bioclimatic design, illuminating its principles and mechanisms.

Assignment

For those working on a zero-energy (re)design, the assignment related to this chapter would be two-fold.

1. Analyse your own local climate, or the climate of the site of your building. For this, the section about the climate will give you some sources. You can present these in graphs and tables. Do it in the fashion that helps your own decision and design process most.
2. Analyse the vernacular architecture of your region, meaning the region of your building. The easiest way is to have a look around: go hiking, cycling or – if necessary – driving around to see historic architecture, look it up in related literature or search for it on the web.
   Deduce the climatic and technical design principles used in these forms of architecture. Present these in notes, drawings, sketches, or schemes.

Case 1 Prêt-à-Loger

BY ANDY VAN DEN DOBBELSTEEN

Please first watch the **Zero Energy Design: Prêt-à-Loger** mini-documentary on the website.

This section will recapitulate how smart bioclimatic design was used in the Prêt-à-Loger house, the redesign of the terraced house.

Solar Decathlon

Prêt-à-Loger was the submission of a TU Delft student team to the Solar Decathlon competition of 2014 in Versailles. The competition between 20 university teams was held in part of the gardens of Louis Quatorze, the Sun King (figure C1.1).

Figure C1.1 The Solar Decathlon Europe venue in the gardens of the Versailles palace, France [image: SDE2014 Organisation]

In contrast with the other teams, the TU Delft students decided to come up with a plan to solve a much more urgent problem than designing a new house: refurbishing an old one that represents 1.4 million dwellings in the Netherlands, the typical terraced row house.

Temperature

For the design process the team started with an analysis of the local climate. Figure C1.2 depicts the temperature map of the Netherlands. The location of Honselersdijk, where the reference house was situated, is on the 10.6 line near the western coast.

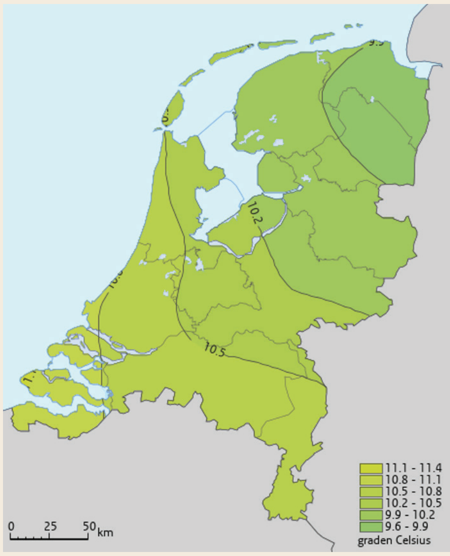

Figure C1.2 Temperature map of the Netherlands (average of 1991-2020), with the site of the original terraced dwelling that stood as a model for the Prêt-à-Loger house, next to monthly differences [KNMI 2020]

The annual mean temperature is around 10.5°C, increasing gradually due to climate change[1]. People typically want an indoor temperature of around 21°C, so at present, the climate is too cold by 11 degrees. Therefore, most of the year, even accounting for climate change, it is important to capture the sun and preserve the heat with thermal insulation.

It also means that the soil temperature will only fluctuate a small amount, around 11°C, and that you can use the soil for cooling in summertime and for pre-heating in winter. In chapter 05 we will see how that is done.

Precipitation

Figure C1.3 is the climate map for precipitation in the Netherlands, which has already changed a lot under the influence of climate change. The reference house, situated in the western part along the coast, receives 900 mm of precipitation, mostly rain. The house has a roof of 50 m^2. This means a total amount of 45 m^3 of rainwater will run off. This is approximately equal to what is currently used for the toilet and garden. Therefore, it seems obvious to use the rainwater,

1 Latest expectations are an increase by 2-3°C.

especially knowing that the Dutch now use high-quality drinking water for these purposes.

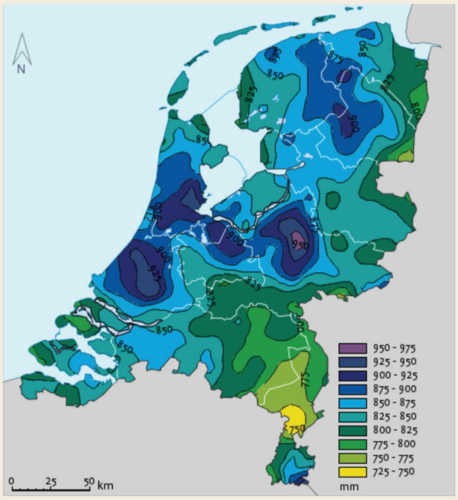

Figure C1.3 Precipitation map of the Netherlands (average of 1981-2010) [KNMI 2020]

Wind

Looking at the wind map and patterns at a height of 100 m (figure C.1.4), we see that the coastal region where the house is situated has very strong winds. On average, they are 7 m/s, which is 25.2 km/h, or 15.7 miles an hour. This seems like good business for wind turbines, which is true, but in this part of the country there is a lot of horticulture in greenhouses, among which no big turbines are allowed. Moreover, smaller urban turbines are relatively expensive for what they produce.

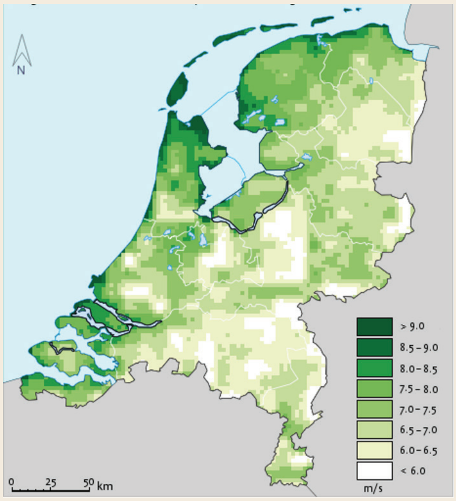

Figure C1.4 Wind velocity map of the Netherlands (average of 1981-2010) at a height of 100 metres [KNMI 2020]

Sun

The solar intensity on a horizontal plane in this part of the world is around 114 W/m^2, which in a year's time comes down to around 1000 kWh of solar energy. So, the total amount of passive solar energy – for instance through 1 m^2 of glass roof – is also 1000 kWh. If we produced hot water through a solar collector, the yield would be approximately 450 kWh of hot water, and if we used photovoltaics (PV), a net yield of around 150 kWh of electricity would be generated in a year's time.

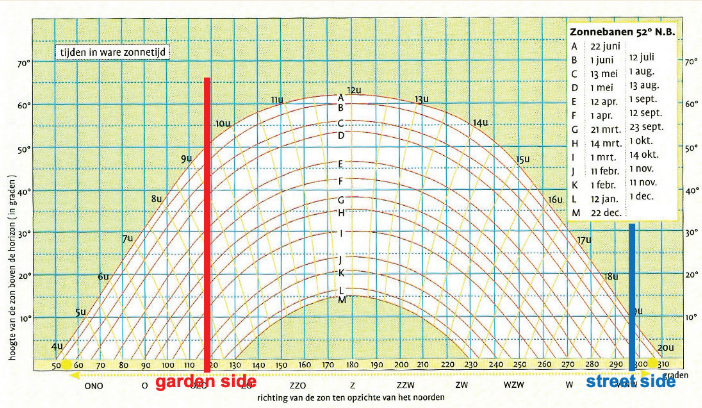

Figure C1.5 Sun chart for 52° northern latitude (the latitude of the original terraced house) with the orientation of the garden and street side of the house [adaptation of Bosatlas/Wolters Noordhoff 2005]

You are already familiar with the sun chart from section 1.2. Looking at the chart, you can find the reference house's orientation on the garden and street side. We can see that if we want to do something with solar heat, we should use the garden side.
We now know enough to start looking at the retrofit proposal.

The original house

Figure C1.6 presents a section of the original house from 1960. It has timber-framed floors and roof slabs, next to a non-insulated cavity wall of sand-lime-stone on the inside and masonry on the outside. The windows have single glazing.

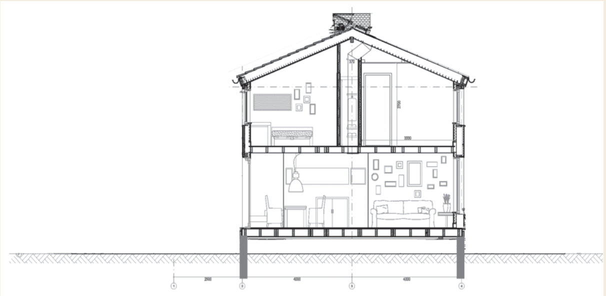

Figure C1.6 Section of the original terraced dwelling that stood as a model for the Prêt-à-Loger house [Prêt-à-Loger team]

Reduce: post-insulation

In the first step of the New Stepped Strategy – reduce – the team added post-insulation to the house. Internal roof insulation and ground floor insulation were the easiest parts. For a thickly insulated north-western façade, the outer brick gable was virtually knocked out, twenty centimetres of vapour-permeable insulation added, and the exterior covered with brick slips. On the south-eastern façade, the cavity of the wall was filled with vapour-permeable insulation. See figure C1.7.

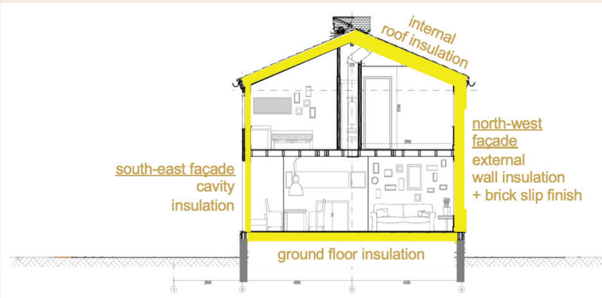

Figure C1.7 Section of the original terraced dwelling with post-insulation measures; thermal insulation supplied by Sto Isoned + TBI [image: adaptation of Prêt-à-Loger by Andy van den Dobbelsteen]

Reduce: replacing windows and glazing

As another measure of step 1, single glazing was replaced with the best-insulating double-glazed windows, and the team introduced daylight-catching solar tubes (figure C1.8).

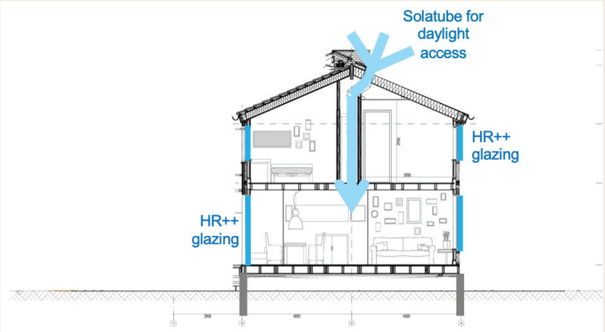

Figure C1.8 Section of the original terraced dwelling with window and daylight measures; windows supplied by Select Windows/Recystel; daylight catchers supplied by Solatube [image: adaptation of Prêt-à-Loger by Andy van den Dobbelsteen]

Reuse: Soil-based ventilation and heat recovery

Step 2 of the New Stepped Strategy was more complicated for the re-design. Figure C1.9 illustrates how fresh air is let in through pipes underground, taking on the stable temperature of the soil before it enters the house. A heat exchanger establishes a maximum heat recovery from exhaust air.

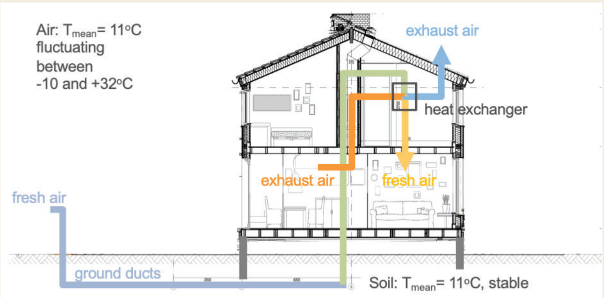

Figure C1.9 Section of the original terraced dwelling with proposed ventilation measures [image: adaptation of Prêt-à-Loger by Andy van den Dobbelsteen]

For the Solar Decathlon competition in Versailles however, it was forbidden to dig into the soil. That is why the team eventually came up with another solution: in the crawl space of the house, a battery of phase change material (PCM) was installed, pre-cooling or pre-heating the incoming air in a similar way to the physical mechanism of the soil (figure C1.10).

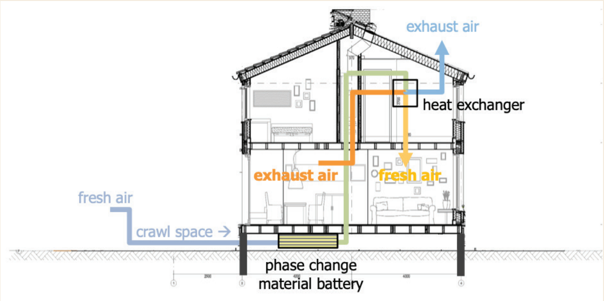

Figure C1.10 Section of the original terraced dwelling with eventual ventilation measures, using phase change materials (PCM) instead of the soil; PCM supplied by Van Dorp Installaties, heat exchanging unit by Putman, ducts by TBI [image: adaptation of Prêt-à-Loger by Andy van den Dobbelsteen]

Produce: Glass house for power & heat

Continuing with step 3 of the New Stepped Strategy, the generation of renewable energy can be divided into electricity and heat, both linked to the most radical intervention the team made: the greenhouse. The structure of this greenhouse contains solar cells in-between two glass panes. This is the power station of the house.

The greenhouse also captures solar heat, which rises and forms the source for an adiabatic heat collector between the original roof and greenhouse, which extracts the heat, hence cooling down the air and solar cells, and transports it to a heat pump, which boosts the temperature to 55°C and stores it in a hot water tank. This hot water can be used for the central radiator heating and for hot water purposes, such as the shower. See figure C1.11.

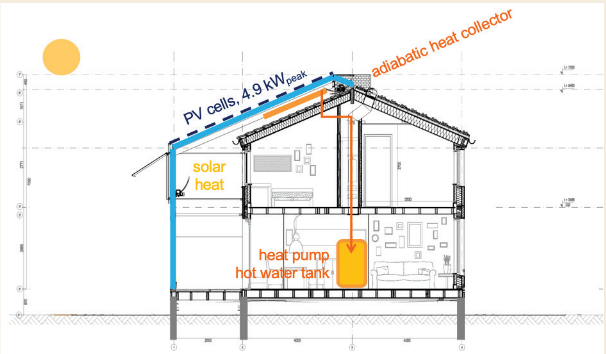

Figure C1.11 Section of the Prêt-à-Loger house with the added glasshouse, photovoltaics, and heat pump system; greenhouse engineering supplied by Nobutec, foldable doors by Solarlux, glass-integrated PV by DMEGC, heat collector and heat pump by SolarCompleet, shading screens by Serge Ferrari [image: adaptation of Prêt-à-Loger by Andy van den Dobbelsteen]

Rainwater collection and usage

The greenhouse and roof are also used for the collection of rainwater, which is stored in a tank under the extension (figure C1.12). This water is used for toilet flushing and watering the plants.

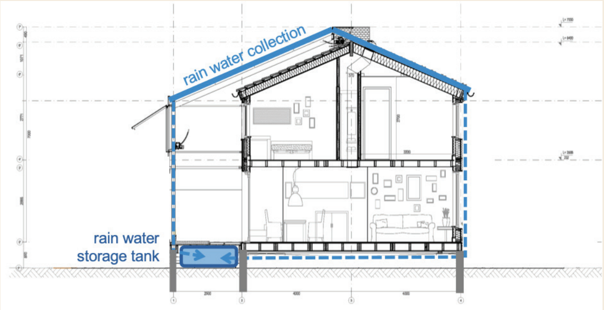

Figure C1.12 Section of the Prêt-à-Loger house with water collection measures; rainwater storage system supplied by Putman + Gardena [image: adaptation of Prêt-à-Loger by Andy van den Dobbelsteen]

Green around and in the house

Talking about plants: the team also wanted to demonstrate how a dwelling like this could contribute to biodiversity in the neighbourhood. This was done by adding a green roof to the north-west, introducing plant species suited for the local climate in the front and back garden, and by proposing the growth of herbs, fruit, and vegetables in the greenhouse (figure C1.13).

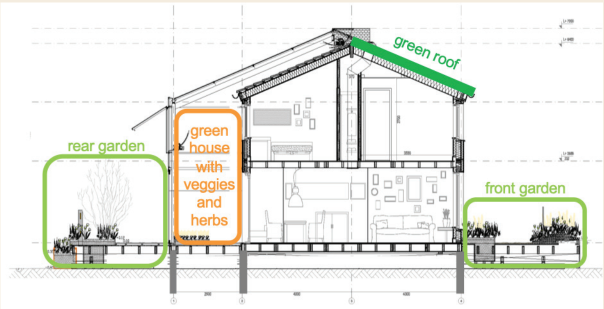

Figure C1.13 Section of the Prêt-à-Loger house with greenery measures; rainwater storage system plants supplied by NL Greenlabel, green roof by Derbigum [image: adaptation of Prêt-à-Loger by Andy van den Dobbelsteen]

Prêt-à-Loger at the Solar Decathlon Europe 2014

Figure C1.14 is a picture of the Prêt-à-Loger house during the Solar Decathlon competition in Versailles. On the sides, the team created cross-sections of the neighbours' houses, allowing visitors to see the differences between the original section and the retrofitted dwelling in the middle.

Figure C1.14 The Prêt-à-Loger house at the SDE 2014 competition in Versailles, France, June 2014 [photo: Andy van den Dobbelsteen]

Prêt-à-Loger won four competition awards (two 1st and two 2nd prizes) and finished 3rd overall. One of the first prizes was the sustainability competition, so the Prêt-à-Loger house could be called the most sustainable terraced dwelling in the world.

The Green Village

After the competition in Versailles the house was rebuilt on the TU Delft campus in August 2014, on a patch of land for experimental testing called the Green Village (C1.15), and at the moment of writing it still serves as a demonstration object and a literal living lab, because there is one student living in it.

Figure C1.15 The Prêt-à-Loger house on the experimental site of The Green Village at the TU Delft campus [photo: Tim Jonathan]

2.1 The Climate

BY ANDY VAN DEN DOBBELSTEEN

Since we now understand the difference between power and energy and how to determine the energy use of your building, we will now start to look at step 0 of the New Stepped Strategy: Research. This section will focus on the climate in which our building is situated and what that means for our building design.

2.1.1 Climates across the globe

Ocean currents and climate types

The universe, the sun, the moon, the greenhouse effect, oceans, land, ice caps: all are factors that have created a planet with different climate zones and ocean currents that transport heat and cold across the planet. Figure 2.1 shows ocean currents and the different climate zones across the world, as classified by Köppen-Geiger. Every colour depicts a different climate.

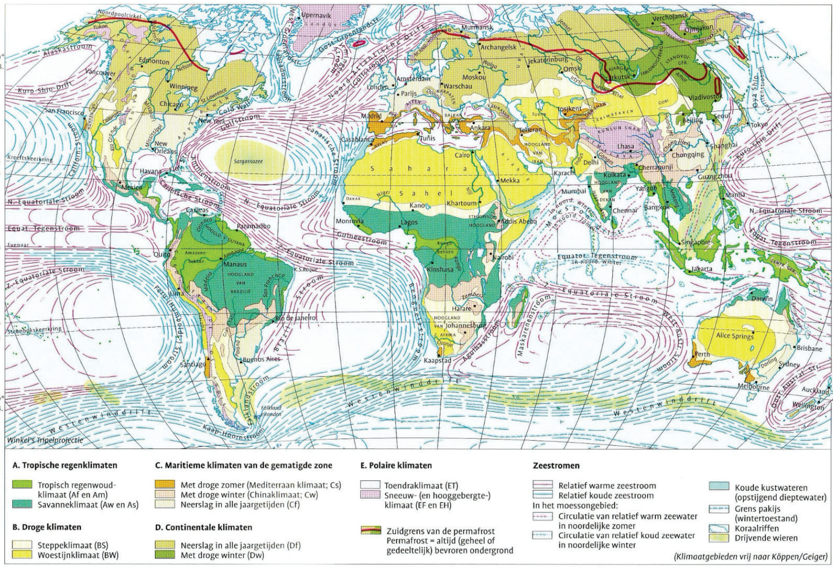

Figure 2.1 Map of climates across the world, based on Köppen-Geiger [Bosatlas/Wolters Noordhoff 2005]

Best known climate types

Let us have a look at the best-known climate types, shown by figure 2.2.

maand	gemiddelde temperatuur (°C)	neerslagsom (mm)	gem. minimum temperatuur (°C)	gem. maximum temperatuur (°C)	relatieve vochtigheid (%)	duur zonneschijn (uren)
jan.	26.4	51	21.0	31.0	86	158
feb.	26.1	71	22.0	31.0	88	165
mrt.	27.0	120	22.0	32.0	87	198
apr.	26.7	154	21.0	32.0	87	195
mei	26.1	442	20.0	31.0	88	155
jun.	25.0	958	21.0	30.0	89	105
jul.	24.4	797	20.0	29.0	87	84
aug.	24.7	354	21.0	29.0	87	81
sep.	24.7	720	21.0	29.0	90	96
okt.	25.3	598	21.0	30.0	88	121
nov.	26.1	237	21.0	31.0	87	147
dec.	26.4	122	21.0	31.0	87	155
jaar	**25.7**	**4624**	**21.0**	**30.5**	**88**	**1660**

maand	gemiddelde temperatuur (°C)	neerslagsom (mm)	gem. minimum temperatuur (°C)	gem. maximum temperatuur (°C)	relatieve vochtigheid (%)	duur zonneschijn (uren)
jan.	13.6	7	9.0	18.8	59	236
feb.	14.9	4	9.8	20.5	54	238
mrt.	16.9	4	11.7	23.4	53	291
apr.	21.2	2	14.7	28.4	47	318
mei	24.5	0	17.5	32.0	46	353
jun.	27.3	0	20.4	34.2	49	384
jul.	27.6	0	21.7	34.4	58	391
aug.	27.4	0	21.9	33.9	61	375
sep.	26.0	0	20.4	32.6	60	333
okt.	23.3	1	17.9	29.6	60	304
nov.	18.9	3	13.8	24.7	61	258
dec.	15.0	5	10.3	20.2	61	236
jaar	**21.4**	**26**	**15.8**	**27.7**	**56**	**3717**

maand	gemiddelde temperatuur (°C)	neerslagsom (mm)	gem. minimum temperatuur (°C)	gem. maximum temperatuur (°C)	relatieve vochtigheid (%)	duur zonneschijn (uren)
jan.	2.8	67	0.0	5.2	88	52
feb.	3.0	48	-0.1	6.1	85	79
mrt.	5.8	65	2.0	9.6	81	114
apr.	8.3	45	3.5	12.9	76	158
mei	12.7	62	7.5	17.6	74	204
jun.	15.2	72	10.2	19.8	77	187
jul.	17.4	70	12.5	22.1	77	196
aug.	17.2	58	12.0	22.3	78	192
sep.	14.2	72	9.6	18.7	84	133
okt.	10.3	77	6.5	14.2	86	106
nov.	6.2	81	3.2	9.1	88	60
dec.	4.0	77	1.3	6.4	89	44
jaar	**9.8**	**793**	**5.7**	**13.7**	**82**	**1524**

maand	gemiddelde temperatuur (°C)	neerslagsom (mm)	gem. minimum temperatuur (°C)	gem. maximum temperatuur (°C)	relatieve vochtigheid (%)	duur zonneschijn (uren)
jan.	-9.3	42	-14.2	-6.4	85	32
feb.	-7.7	36	-15.7	-3.7	82	71
mrt.	-2.2	34	-10.5	0.5	81	128
apr.	5.8	44	-1.4	8.7	68	170
mei	13.1	51	5.0	18.3	61	265
jun.	16.6	75	8.7	22.0	62	276
jul.	18.2	94	11.9	23.7	67	272
aug.	16.4	77	9.3	22.3	71	235
sep.	11.0	65	3.8	16.9	76	144
okt.	5.1	59	-1.8	10.0	82	77
nov.	-1.2	58	-6.0	1.3	84	32
dec.	-6.1	56	-11.5	-4.5	87	19
jaar	**5.0**	**691**	**-1.8**	**9.1**	**76**	**1721**

maand	gemiddelde temperatuur (°C)	neerslagsom (mm)	gem. minimum temperatuur (°C)	gem. maximum temperatuur (°C)	relatieve vochtigheid (%)	duur zonneschijn (uren)
jan.	-25.2	4	-28.5	-21.9	73	geen gegevens beschikbaar
feb.	-27.7	4	-30.9	-24.3	70	
mrt.	-26.2	4	-29.5	-22.8	71	
apr.	-19.0	5	-22.8	-15.2	77	
mei	-7.1	4	-9.8	-4.3	87	
jun.	1.1	7	-1.3	3.5	89	
jul.	4.1	24	0.9	7.2	88	
aug.	3.3	24	0.7	5.7	91	
sep.	-0.8	15	-2.8	1.0	91	
okt.	-10.3	11	-12.9	-7.7	86	
nov.	-18.7	6	-21.6	-15.8	79	
dec.	-24.0	4	-27.3	-20.7	74	
jaar	**-12.5**	**112**	**-15.5**	**-9.6**	**81**	

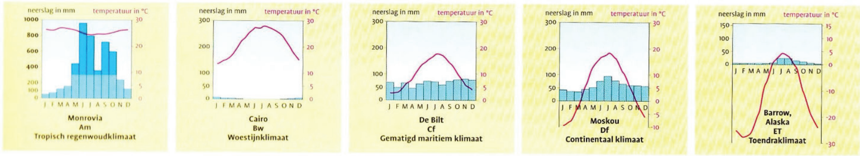

Figure 2.2 Best-know climate types [Bosatlas/Wolters Noordhoff 2005]

On the left you can find data relating to a tropical climate, such as in central Africa. If you look at the graph carefully, you will see that the temperature is always high, and that there is a wet and relatively dry season. What you cannot see is the high average humidity.

The next climate is that of a desert, such as in northern Africa. There is hardly any rain and little temperature difference between winter and summer. What you cannot see here is the diurnal differences, which in such a hot arid climate can differ a lot: it can be freezing at night and sizzling during the day.

In the middle we see the temperate climate, such as in north-western Europe, with relatively cool temperatures, not too much difference between summer and winter, and precipitation all year round. But not as much as in a tropical climate.

Fourth is the continental climate, as in Russia. It resembles the temperate climate, but is more extreme in summer and winter, and there is also a greater seasonal difference in precipitation.

Finally, on the right, we see the polar climate, with the lowest temperatures of course, but with an enormous difference between winter and summer. There is very little precipitation, mostly snow.

Climate charting your own region

If you want to know more of the climate in your own region, we can recommend these sources for you: your own national meteorological agency, an online programme called Climate Consultant, free to download, and sun charts provided for free by the University of Oregon.

2.1.2 Back to locality

The indifferent office

Now, if we see all these differences, it is strange that buildings look the same everywhere, especially when you consider offices. Looking at the pictures of figure 2.3, there are several features one cannot distinguish:

(1) the location of these offices

(2) the orientation of the building: the elevations of each building look the same.

Figure 2.3 Office buildings with indistinguishable locations; left to right: Melbourne, Amsterdam, Ho Chi Minh City [photos: Andy van den Dobbelsteen]

Understanding the climatic differences of the three buildings, maintaining a comfortable temperature withing them only seems possible thanks to the technical building services, which can correct the shortcomings of the architectural design. In one climate they can help to cool, in another to heat, and they can also change the humidity. However, this costs a lot of energy. So, if we want to save energy, the first thing we will have to do is design for local circumstances.

Locality

Locality means that a building fits the characteristics and climate of the site. Other terms that reflect this principle, are:

- Genius Loci, the spirit of the place.
- Bioclimatic design, buildings that are adapted to the local climate.
- Vernacular architecture, architecture that has historically evolved due to local availability or lack of resources, when people had to solve things effectively.

Vernacular architecture

Figure 2.4 depicts three examples of vernacular architecture.
In the tropics, where temperatures are always high, vernacular architecture makes optimal use of the cooling capacity of wind, by creating air-permeable facades and floors.
In contrast, roofs need to be suited to withstand heavy rainfall, and buildings should be put on stilts to keep animals out and to maximise air flow.

In desert areas, we see narrow streets for shading, houses with a lot of mass which tempers diurnal differences, white-plastered surfaces to reflect the sun, and flat roofs that can cool down under a clear night sky.

In colder climates, buildings need to be well-insulated to preserve the heat, and have steep pitched roofs to keep out rain and withstand snow.

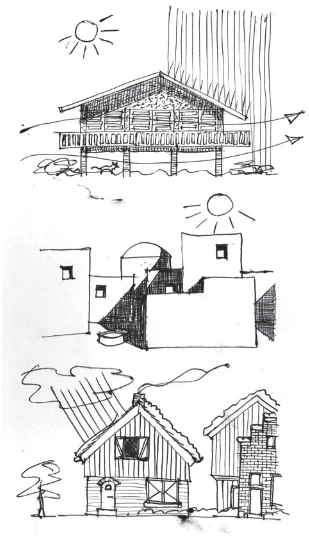

Figure 2.4 Vernacular buildings of three different climates: tropical climate, desert climate, cold climate [images: Andy van den Dobbelsteen]

Therefore, every building demands its own best local solution, but its design can be approached similarly, which is what this book will try to teach you.