METEOROLOGICAL TYPOLOGIES: *PHILIPPE RAHM*

In a letter to Pope Leo X in 1519, the painter Raphael distinguishes the architect's representational techniques from those of the painter: "perspective drawing may belong to the painter, but not to the architect, who is unable to obtain any correct measurement from a diminished line and who needs measurements that are all perfect in reality and not, misleadingly, perfect in appearance... first is the plan."[1] Raphael adopts Leon Battista Alberti's distinction between architecture and painting, which claimed the plan as the exclusive territory of the architect and reserved perspective drawing solely for the painter. We propose returning to this fundamental distinction, and to the plan as the essential starting point of our work, preceding all other types of representation.

While our representational tools may be traditional, however, the elements with which we compose are not. They shift from the visible to the invisible, from the solid to the climatic. Our plans are becoming meteorological.

Historically, typological classifications of architecture, from Vitruvius to J.N.L. Durand to Julien Guadet, rely on two basic types of categories: elements and compositional strategies. Elements of architecture are, for example, walls, vaults, roofs, columns, and windows, while examples of compositional strategies include symmetry, addition, inclusion, superposition, and juxtaposition. We propose maintaining these traditional architectural classifications, but replacing the standard elements with ones taken from the field of climatology and meteorology. In lieu of walls, ceilings, floors, doors, or windows, our essential elements are heat, moisture, light, inertia, and albedo. Instead of the compositional techniques of asymmetry, division, or subtraction we propose to use convection, conduction, radiation, and pressure to design a meteorological architecture.

Buildings produce nearly 50% of the world's greenhouse gas emissions due to the burning of fossil fuels to heat and cool them. While the building industry has belatedly begun to address some of these problems through remediative tactics—insulation, life cycle analysis, the use of renewable energies, and compact building design among them—what else might be done beyond socially responsible and ecological objectives to reduce CO_2 emissions? Might we be able to think of climate as a new architectural language, a language with meteorology in mind? Might it be possible to imagine climatic phenomena such as convection, conduction, or evaporation, as tools for architectural composition? Could vapor, heat, or light become the new bricks of contemporary construction? As the addressing of climate change becomes a mandate for the architect, could climate become one of his or her tools?

The vocabulary used to describe atmospheric phenomena (convection, pressure, depressions, temperature, heat, relative humidity, and reverberation, for example) thus becomes an architectural language. We seek to integrate the climatic mission of architecture not only as purpose but also as process. Architecture as meteorology opens other spatial dimensions and definitions. A meteorological architecture affords us the opportunity to shift from a purely visual and functional approach towards one that is more sensitive and more attentive to the invisible, climate-related aspects of space. Moving from solid to void, from visible to invisible, from metric composition to thermal composition, architecture as meteorology opens sensual, variable dimensions in which limits fade away and solids evaporate. The architect's task is no longer to build images and functions but to orchestrate climates and interpretations. At the large scale, meteorological architecture explores the atmospheric and poetic potential of new construction techniques for ventilation, heating, dual-flow air renewal, and insulation. At the microscopic level, it plumbs novel domains of perception through skin contact, smell, and hormones. Between the infinitely small of the physiological and the infinitely vast of the meteorological, architecture must build sensual exchanges between body and space and invent new aesthetic and philosophical approaches capable of making long-term changes to the both the form of tomorrow's buildings and the way we will inhabit them.

Following Alberti's claim for the measured plan, section and elevation as the proper tools of the architect, the encyclopedia of Meteorological Architecture embraces the orthographic drawing as a means to classify meteorological phenomena: conduction, convection, radiation, and pressure.

1. Raphael (Sanzio), Letter to Pope Leo X, 1519, as published in Liane Lefaivre and Alexander Tzonis, *The Emergence of Modern Architecture: A Documentary History from 1000 to 1810* (London and New York: Routledge, 2004), 94.

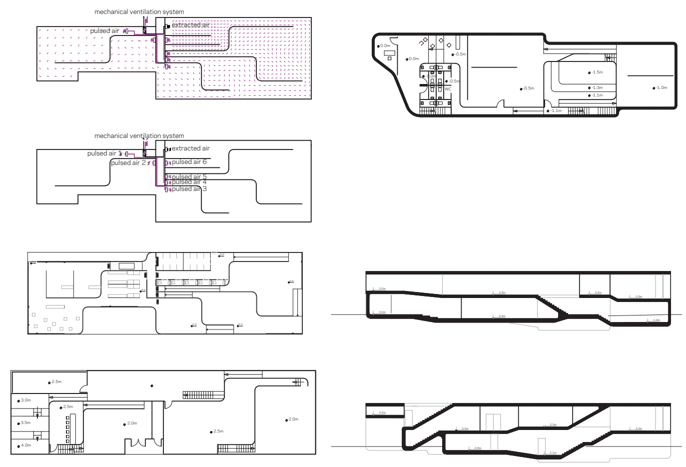
PRESSURE

These projects are organized according to the requirements of managing airflow so as to reduce the energy consumed by the building. The designs prioritize the building's air supply, thus transforming the technical issue of the ventilation duct and its distribution of air into one that is architectonic, spatial, and poetic. The diameter of the duct is increased until it becomes itself an inhabitable space that slides, bends, contracts, and expands along the entire length of the building.

PUBLIC AIR. This project reintroduces physiological needs into city planning. Air quality is defined as public space; it is heated in the winter or cooled in summer in relation to the climate, albedo, and vegetation, creating a public de-pollution process. Air organizes the form, shape, and materials of public space. The urban agenda of the project is to build two spaces, one cold, one warm, at the ends of the site and to weave buildings between them. The circulation corridors of the buildings become inhabitable,

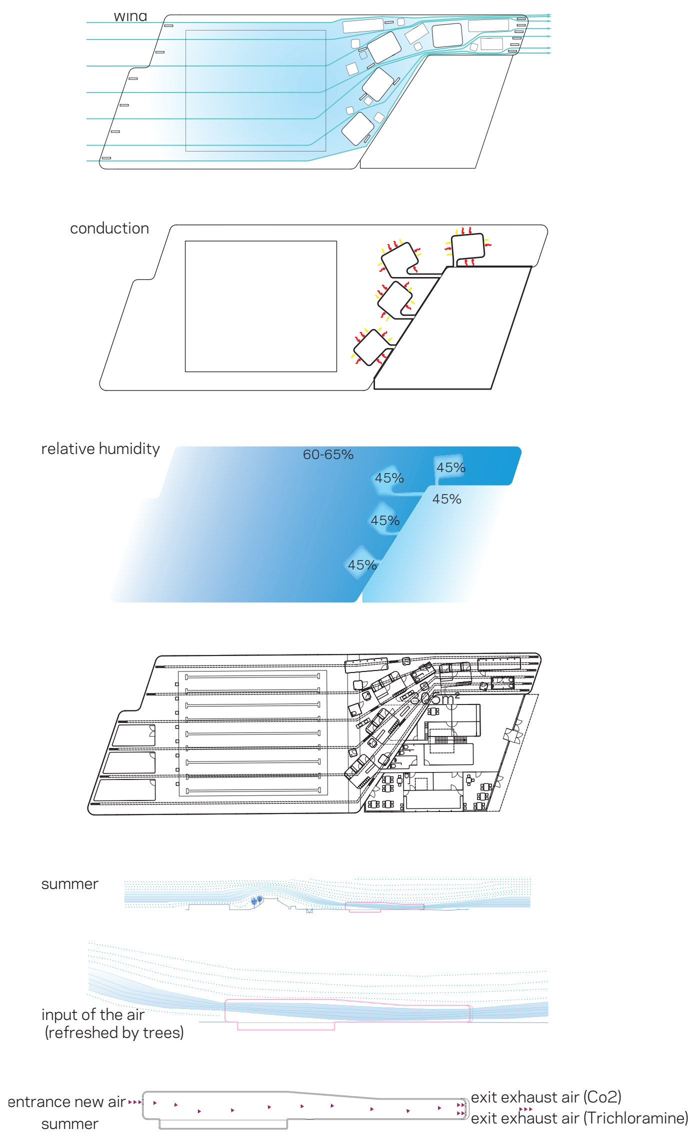
human-scaled ventilation ducts. The ends of these ducts are connected to the two public spaces, drawing on their ambient air.

AIRSCAPE. This project articulates the movement of air as an inhabitable airflow: an architecture as a drawing of wind, where its qualities express themselves in terms of velocity, volume, movement, propulsion, and extraction. The plan is composed in order to regulate and manage airflow, prioritizing the hourly rate of air renewal, reducing by a factor of eight the building's energy consumption. The recirculation rate is determined by factors of use: the number of occupants, the duration of occupation, and the level of physical activity. Spaces with fewer and more sedentary occupants require a lower rate of air



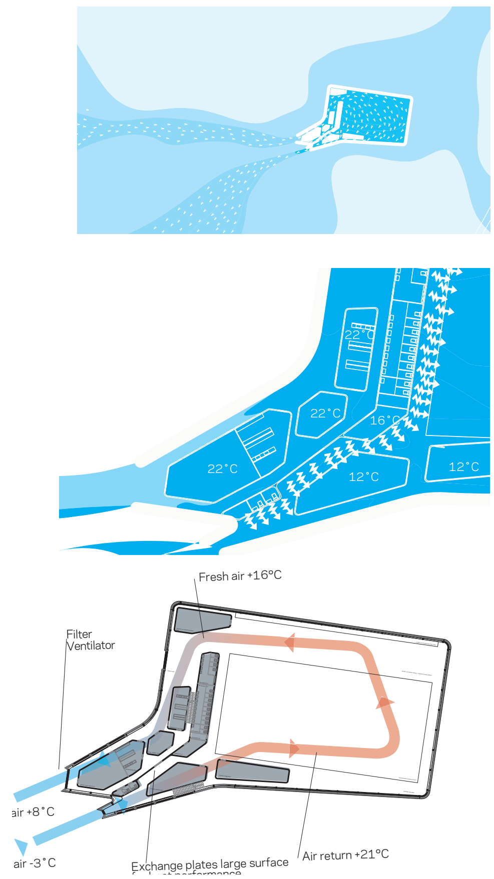
renewal than those that are more densely occupied with vigorously active people. The ventilation output rate increases from 7.5 liters during times of rest to over 120 liters per minute during physical activity. This increase occurs along with an increase in breathing rate, which necessitates a more rapid fresh air exchange rate. Therefore, we can design a precise relationship between the geometry of the space and the amount of air to be recycled and renewed, reinitiating the building's ventilation as a decisive factor in its architectural form.

INDOOR WIND. The shape of the building and its supporting structure are defined in relation to the prevailing winds: accompanying them, deflecting them slightly, leading them through the building uninterrupted. The roof is constructed of long glue laminated timber beams that deflect wind from the South-West to the North-East, gradually collapsing toward the locker room in order to exhaust stale air in summer and increase temperature in winter. In summer, the building opens to the wind along its entire length, while in winter, a mechanical ventilation system with a dual-flow heat exchanger follows the same path as the wind. The roof form directs fresh air between the beams and through the pool to the locker room, providing ground heat from the air that accumulates above the pool. We "chemically" separate the dressing rooms from the pool area and avoid bringing moisture into them by connecting their air supply with the lobby. The dressing rooms are heated using highly conductive aluminum walls;



the warm pool increases their temperature, while heat from the stale air is removed by a dual flow heat exchanger before being discharged.

WINDTRAP. A project for an athletic complex in Slovenia considers architecture as weather, oriented on the site in accordance with the prevailing wind. The building captures the warm breeze from the south and after capturing its heat, discharges the stale air to the north. The complex becomes a slight inflection from the natural movement of wind. The building uses a double flow ventilation system, which warms the incoming air with the exhaust air through an exchange between large conductive metal surfaces. The project spatially expands the double flow heat exchange air renewal system, which is normally the size of a machine, to the size of a building. Each space in the building participates in the exchange of heat, depending on its function: from the hottest at

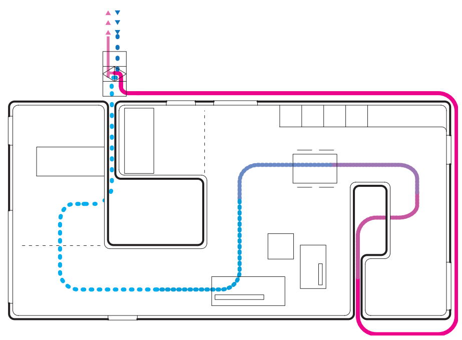


22° C (showers and changing rooms) to the coldest at 12° C (storage room.)

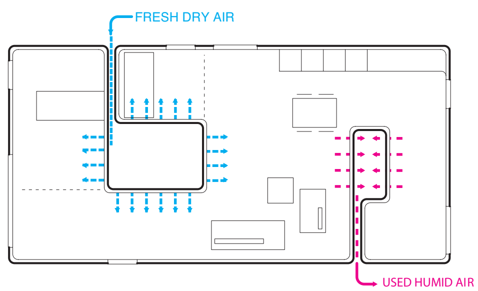
EVAPORATION

Building occupants produce water vapor in a quantity that varies according to the program of a space. The presence of water vapor in the air originates naturally from respiration and hot water usage, leading to risks of condensation and damage to the construction. Metal must be preserved in a very low-humidity air environment, between 15% and 30%, to prevent rusting by oxidation. Organic materials, on the contrary, need a higher rate of relative humidity for their preservation, up to 60%, in order to prevent their dehydration. To avoid the mold, however, this rate must not surpass 75%.

VAPOR APARTMENTS. The design of this building is based on the route vapor travels through the house. The new double-flux system of air renewal ventilation (one of the most efficient ecological solutions today for decreasing the energy consumed in the building) requires a precise one-way route of air in the house. The air renewal in this project starts in the driest part of the house (the bedroom) and finishes in the most humid (the bathroom), becoming more humid as it travels through the house. There is a slow stream of air running through the entire building, determined by the use of the space and the vapor produced by the body in relation to the physical activity performed there.



floor plan_apartment
air-flow related to the double flux air-renewal with heat-exchanger



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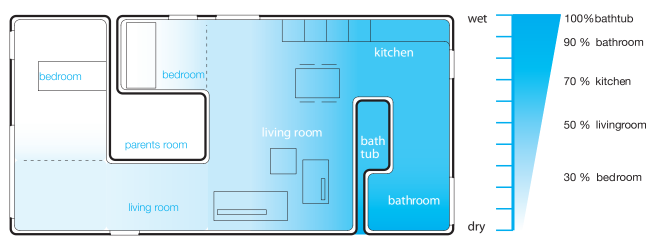
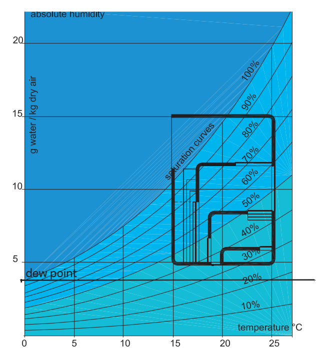


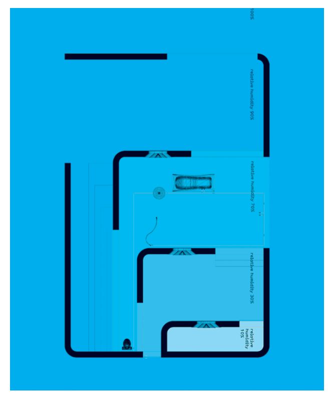
floor plan_apartment
functions related to humidity
horizontal stratification of humidity

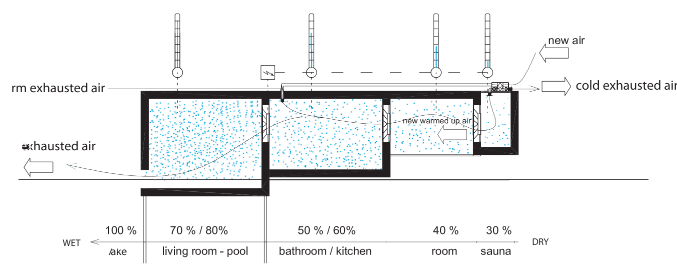
An adult produces 40 grams of vapor per hour when asleep, 150 grams when awake, 1500 grams when cooking, and 2400 grams when showering. The aim of this project is to compose a plan around the cartography of indoor humidity in order to create a more sensual relationship to the space. This spatial solution will reintroduce a diversity of climatic zones in the modern apartment, because it will be drier in one area or more humid in another. Instead of just providing a technical solution to the problem of air humidity, we want to transform this problem in a poetic way into a sensual landscape. The apartment will become closer to a natural landscape, with a variation in latitudes of relative humidity. The spaces become an interior geography, stretched between a miniature desert and an indoor tropical jungle, between a dry area at 30% of relative humidity and a wet region at 90% between which inhabitants can freely wander.

MOLLIER HOUSE. Our project establishes a stratification of the levels of humidity within a space. Living areas are arranged according to the route of fresh air through the house, from the driest and freshest to the most humid, from the bedroom to the bathroom, while refusing a deterministic relationship between form or space and function or program. Spaces become more or less dry, more or less humid, and are to be occupied freely, appropriated according to occupant's comfort, the weather, and the seasons. The plan of the house is a spatial representation of the Mollier diagram, creating new programmatic correspondences, in which one space can receive several functions that are assumed to be separated.



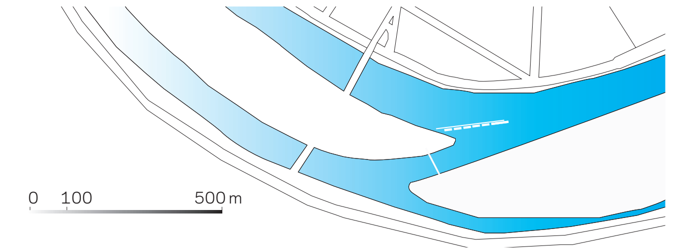
Mollier's graph

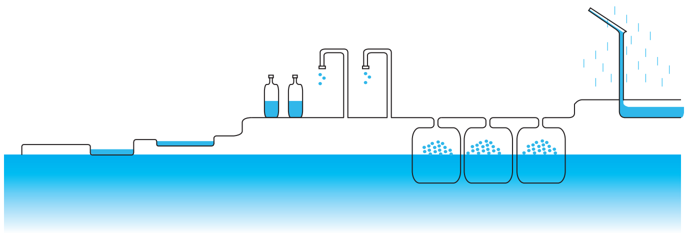




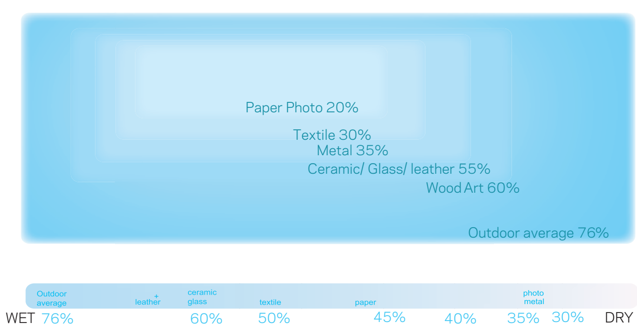
ambient hygrometries

DIFFERENT STATES OF WATER. This infrastructure project for the île Seguin Archipelago addresses the chemical and physical transformation of water. We recreated a ecological water cycle model beginning with rainwater collection, then consumption, waste, treatment, and ultimately its clean return, to the river. A pontoon three meters wide by 200 meters long expands or contracts to collect water. We use different states of water to support a bar, tanks, solar panels, and for a network of bathrooms, laundry, and a mini purification facility.

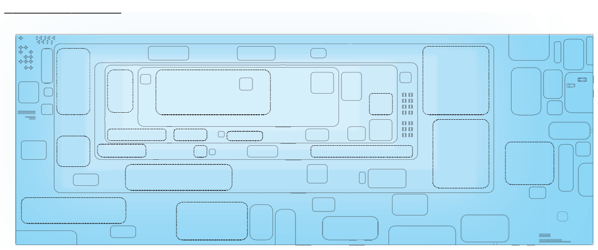




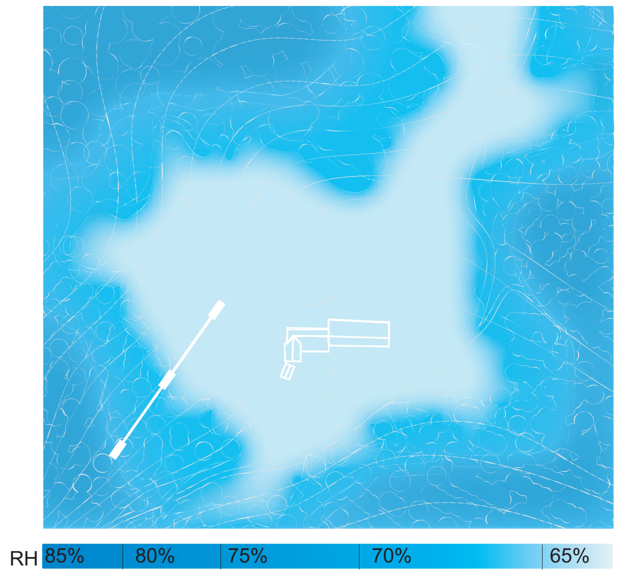
DILATED HOUSE. This project disperses the program of a house to the whole of the site in order to match specific spaces with their appropriate climates. The house is no longer a compact and closed object but extends across the landscape, multiplying views, situations, climates, and atmospheres. Rooms can be occupied in various places according to the hour of the day, the environment, or the season. The threshold between two rooms, normally a few centimeters deep, dilates to hundreds of meters. The

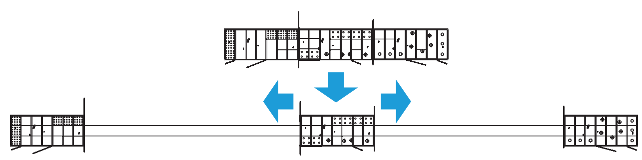


Recommended relative humidity for various material conservation



house now occupies one square kilometer, rather than 50 square meters, so the inhabitant lives at the scale of the landscape. Three sites—the meadow, the boundary of field and forest, and the forest itself—are each determined by climatic qualities: light, temperature, and humidity created by the trees. The interior quality of the rooms will vary according to the hour of day and season of year. Activity in each dilation will relate to the particular and required climate: the heat of the night forest, the warmth of the



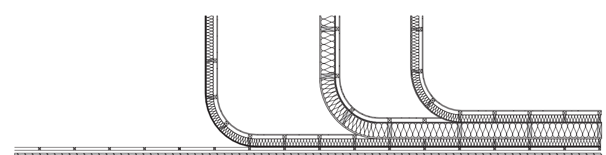


field on a winter's day, the freshness of the forest edge in the spring.

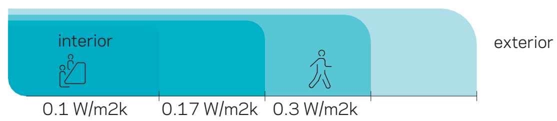
CONDUCTION

In physics, thermal conductivity, K, indicates a material's ability to conduct heat. It appears primarily in Fourier's Law of heat conduction, the transfer of thermal energy between neighboring molecules in a substance due to a temperature gradient. Thermal conductance is the quantity of heat that passes in unit time through a plate of a particular area and thickness when its opposite faces differ in temperature by one Kelvin.

THREE THERMAL BUBBLES. "Bubbles" that join thermal and programmatic conflicts are nested within each other, overlapping the most thermally sensible in the interior, and the most thermally resistant in the outside. Every bubble consists of a bearing wall, each one 16 cm thick. As we move from the



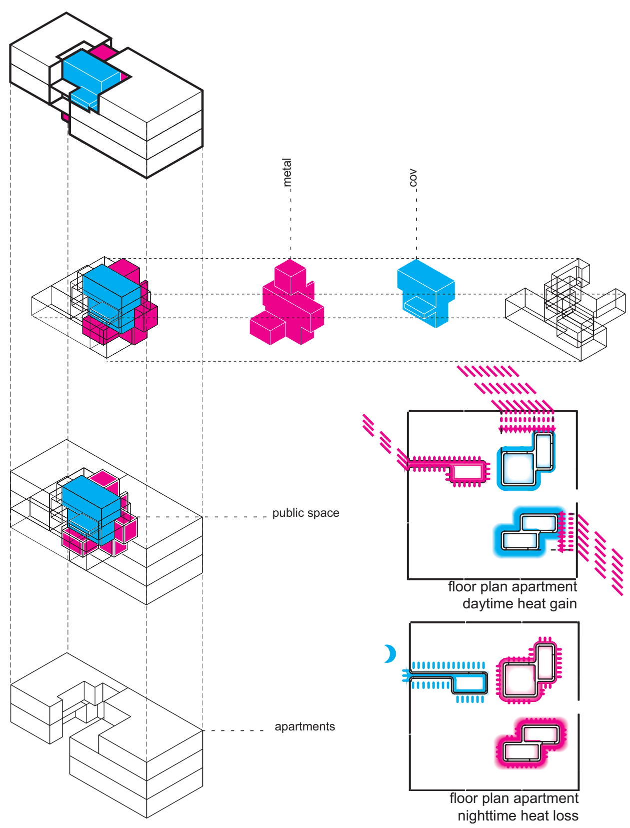
programmatic stratification related to the thermal transmission coefficient outside to the inside of the building, from one bubble to the other, we add more and more layers of isola-



principle of successive interlocking of the different thermal layers

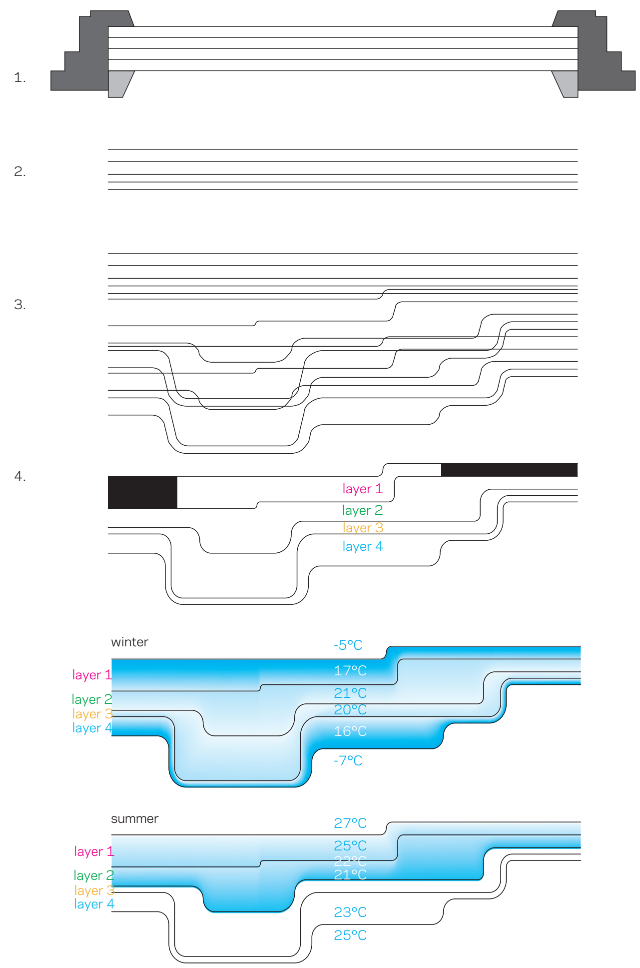
tion; in the first bubble we have just 16 cm of thickness, in the second bubble, 32 cm, and in the third, 48 cm.

CONDUCTIVE BUILDING. The design of this building is based on thermal conductivity. Its primary materials—wood and hollow fill fibre insulation—have a very low thermal conductivity coefficient (under 1 W/(m.k)). These two different materials will



bring either heat or cold through the insulated glass of the facade, either through the sun's radiation or the naturally lower temperatures at night.

TADEUSZ KANTOR MUSEUM. This project for a museum in Poland is literally a thickening of the space between the panes of glass in double or triple glazed windows until it becomes a livable space of several meters. Just as contemporary windows are constructed with several panes of glass (single, double, and triple pane) to improve insulation by decreasing the coefficient of thermal transmission (single pane: K =5,6, double: K = 3, triple: K = 2), our project adds layers to improve the thermal coefficient gradually, one layer after another, offering a variety of temperatures and luminosities. Against the homo-

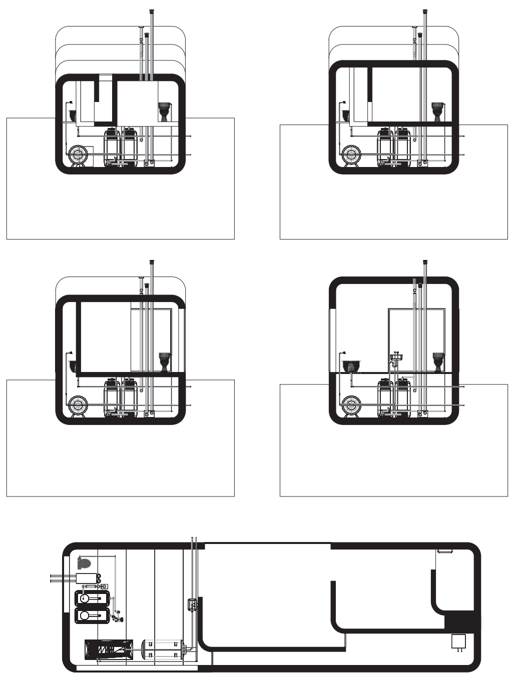


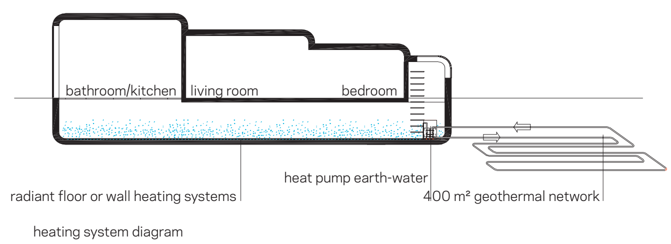
variation of temperature of the layers depending on the season

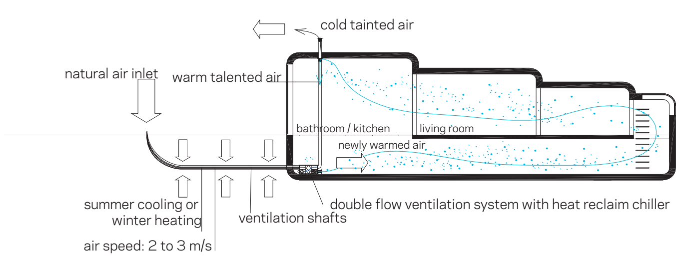
geneity modern climatization, we propose a diversity of atmospheres, temperature, and light. According to the type of activity and the season, we will choose which layer to inhabit. Here architecture allows the production of interpretable spaces open to future behaviors and functions.

UNDERGROUND HOUSES. The aim of this project is to construct an architectural climate that is closely related to the earth and soil beneath its surface. Both heating and cooling are generated underground using the unique properties of the Vassivière soil—baked with geothermal heat and air-cooled by the cold darkness of the ground; quality of air is sought above all else. Extracted from the soil, the air gives the interiors of these houses an earthy taste, a slightly brownish tone, and a geothermal quality of heat.

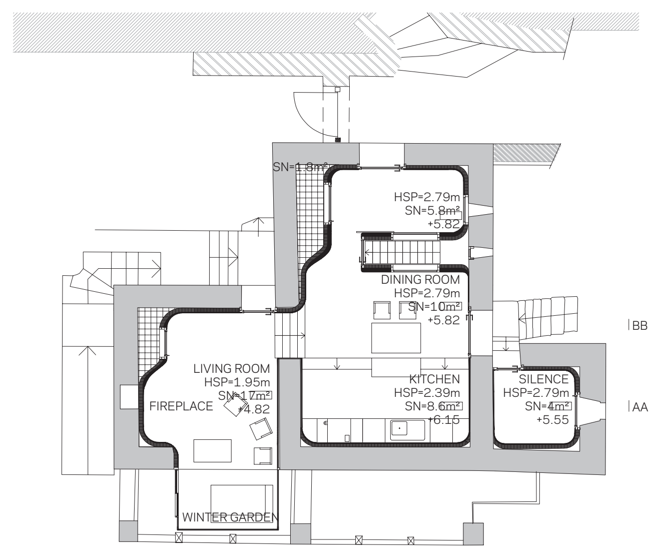
The project is developed as a succession of air movements, from the deepest to the most elevated, from darkness to light, from fresh to stale air. The house is sited on reserve of clean, new air, contained in the depths of the ground below so the underground landscape also becomes a useful climate. Like a reservoir, this volume is fed by clean air that has passed underground to be tempered. Several meters below its surface, the earth has an almost constant temperature of 8°C. This warmth is sought out and collected in a system of air wells, designed to cool in the summer or provide warm air in the winter. The basement, buried underground and well-insulated, is the only heated area in the house, its temperature moderated to a constant 21°C through a heating system installed in the flooring. Fed by a heat pump, this system diffuses the warmth produced in the earth. In winter, the airspace of the basement will be warmer than it is outside, while in summer it will be cooler. The basement air, tempered, fresh, and clean, is then pumped into the living areas in a system of controlled air renewal that is organized as a cascade. The clean air passes into the bedroom, through the living room, kitchen, bathroom, and finally the toilets, before flowing back out of the house, contaminated. The typology of the home becomes a function of the distribution of air in the house, from the cleanest to the most polluted spaces. The architecture thus maintains both physiological and sensual links with the terrain and with the soil; an architecture that is inscribed into the site and its geology, it becomes an architecture to be breathed.





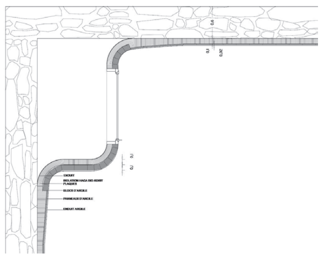


MERGOSCIA HOUSE. This project questions the coefficient of thermal ductibility, U, of a facade achieved with a certain depth of thermal insulation. Instead, a new layer of thermal insulation is offset from the existing stone façade in order to define intermediary spaces with a slightly lower thermal coefficient that are more sensitive to the exterior climate. The renovated architecture, now more variable, engages in a sensual dialogue with weather, seasons, sunlight, and soil. A chimney of sorts extends from basement to attic as a secret and irrational passage. Less controlled, but still thermally tempered, it transforms the house, making a set of open climate situations, with the coldest and wettest at the bottom and warmest and driest at the top. These spaces store the garden produce, as well as clothes and other objects, according to their moisture and temperature requirements. Mint leaves dry at



FLOOR PLAN 2

the top, while canned vegetables are stored away from the daylight, and syrup, broth, and apples at the bottom. We circulate in the intermediary space more sensitive to the variations in weather and geology. It becomes a new landscape, neither inside nor outside, more natural yet totally artificial, which opens itself to the perfectly isolated interior spaces. They are like new windows added to the existing ones, creating a temperate climate landscape through which one passes to move between floors.

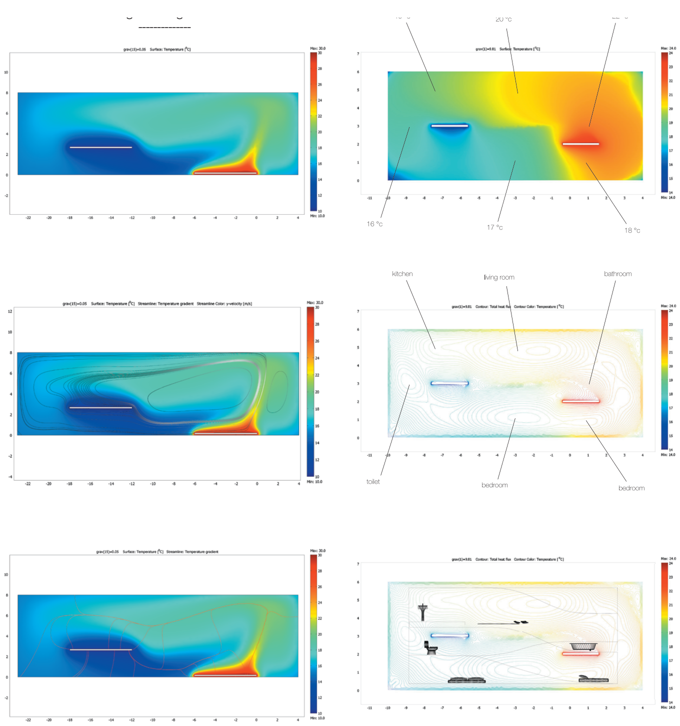


CONVECTION

In thermodynamics, heat energy transfer can occur between objects through radiation, conduction, and convection. Convection is the dominant form of heat transfer in gases and characterizes the combined effects of conduction and fluid flow. In convection, enthalpy transfer occurs by the movement of hot or cold portions of a fluid together with heat transfer by conduction. An increase in temperature produces a reduction in density. Hence, when air is heated, it rises, displacing the colder denser air, which falls. In this free convection, gravity and buoyancy forces drive fluid movement.

DIGESTIBLE GULF STREAM. This architectural prototype works between the neurologic and the atmospheric to produce a landscape that is simultaneously gastronomic and thermal. Rather than building spaces, this architecture creates temperatures and atmospheres. We placed two horizontal metal planes at different heights. The lower plane is heated to 28°C, the upper one is cooled to 12°C. Their spatial offset and temperature difference create a convection current, like a miniature Gulf Stream The rising hot air cools on contact with the upper sheet and then falls, where it is reheated on contact with the hot sheet, thus creating a constant thermal flow, an invisible landscape of heat. This architecture is literally structured on a current of air. The inhabitant may move around in this invisible landscape between 12°C and 28°C, temperatures at the two extremities of the concept of comfort, and freely choose a climate according to his or her activity, clothing, or social desires.

CLIMATIC TYPOLOGIES. Each apartment has a unique spatial quality achieved through varying heights and depths. The apartments are laid out according to calculations of temperature change dependent upon the intake of fresh air in the apartment at the lower levels. In a thermographic physical study, various functions are arranged in relation to the movement of interior temperatures and linked to

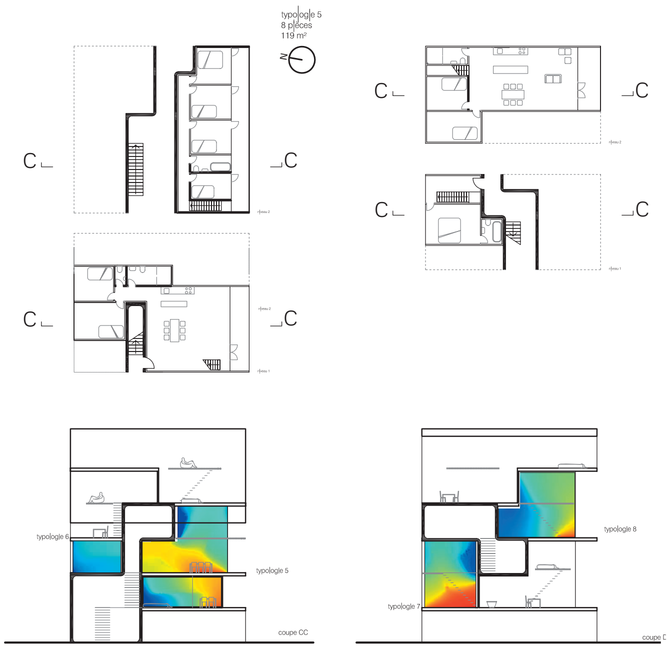


Section A-A

Section B-B

the temperature recommendations of the standard Swiss building code. Functions that require cooler temperatures are placed near the bottom (bedroom, kitchen) while those that require warmer temperatures (bathroom, living room) are higher.

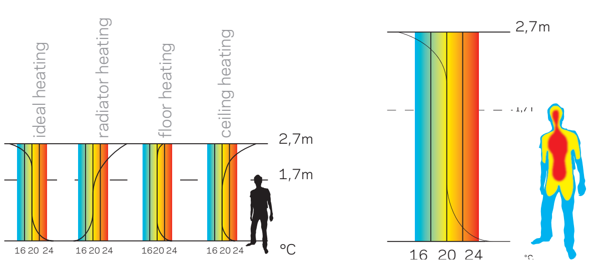
CONVECTIVE APARTMENTS. The design of this condominium building is based on Archimedes



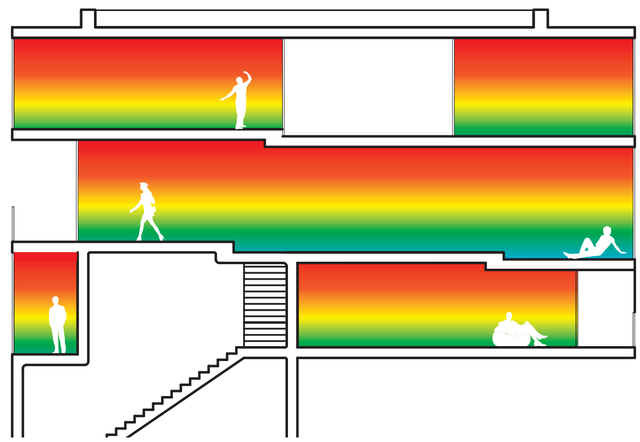
Section C-C

Section D-D

principle that warm air rises and cold air sinks creating as much as a 10°C temperature differential between the floor and the ceiling of an apartment. Depending on our level of physical activity and the clothes we wear, the temperature can vary in different spaces rather than being constant throughout an apartment. If we are under a blanket in bed, the bedroom temperature could be as low as 16° C. In the kitchen, if we are dressed and physically active, the temperature could be 18°C. The living room is often



20°C because we are motionless on the sofa, while the bathroom is the warmest space because we are naked. Maintaining a precise temperature in these specific areas could save energy by maintaining only the temperature we need. Taking these physical and behavioral thermal conditions as design tools, we create different depths and heights in the apartment: the bedroom will be lower and bathroom will be



higher. The apartment becomes a variable temperature thermal landscape, where the occupant wanders around as in a natural landscape, seeking thermal qualities related to the season or time of day. By deforming the horizontal floor slabs, Different heights with different temperatures also informing the external appearance of the building.