Re-evaluating the Aaltos' Pre-war Housing:

a field study of the home environment in a case study

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Abstract

This paper explores the comfort of apartments designed by Aino and Alvar Aalto in the late 1930s in Finland. The focus is on one housing case study: *Terassitalo* (the terraced house) in Kauttua, (1937-38), which is related to three other housing projects in Sunila, Kotka (1937).

This research forms part of a larger body of field studies exploring the potential of historic examples to offer lessons for the design of high quality domestic environments in the present, with improved levels of comfort in the context of our changing climate.

The documented studies are conducted through mixed methods, which involves quantitative research (e.g., daylight and temperature monitoring and in-situ observations in relation to the climate inside and outside) and qualitative field research (e.g., resident interviews, drawing analysis and archival studies concerning the historical and environmental context).

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Findings highlight how this housing case study demonstrate the Aaltos' concern for the provision of comfort, from the design of the apartments and their orientation, responding to seasonal and diurnal changes in sunlight, and for establishing a relationship with nature, including solar gains and shade from surrounding trees. The architecture allows the residents to control their comfort by adapting to their environment, through passive strategies as well as active heating from radiators. These apartments make it possible for the residents to take advantage of an ever-changing environment. Lessons learned for current and future housing includes designing with *orientation, vegetation, empowerment, passive strategies* and *thermal enjoyment*.

Keywords: Aino and Alvar Aalto, Environment, Housing, Modern Architecture, Field Studies

Light and sun are such crucial prerequisites of living comfort that we must replace the current situation based on chance, by standards requiring not only that sunlight must enter every apartment, but that its orientation must be determined, let us say, with the accuracy of one degree. (Aalto 1930a, 81)

Introduction

In the the late 1930s Aino and Alvar Aalto realised housing projects in Kauttua and Sunila in Finland (Aalto 1938, 145-160; Aalto 1939, 161-165; Korvenmaa 2004b, 14-17; Mumford 2014, 286-289; Schildt 2007, 407-410). The architecture appears as white rendered blocks with flat roofs to express ideas of rational and modern international architecture. At the same time, this architecture was – according to the architects and others – conceived as a strong relationship to the specific site of its construction and consideration of the local climate (Fleig 1963, 96-107; Jetsonen and Jetsonen 2004, 42-51; McCarter 2014, 107-108).

In comparison to the Aaltos' private house in Munkkiniemi, Helsinki (1934-1936) and Villa Mairea (1938-1939), designed in the late 1930s (Hawkes 2020, 86-94; Lund 1991, 132-136; McCarter 2014, 80-86, 95-105; Pallasmaa 2003, 79-80), the housing projects in Kauttua and Sunila may be identified as more elemental, with simple design solutions repeated multiple times. The inclusion of nature and provision of a high quality environment is also evident in these projects however (Jetsonen 2004, 17-20), demonstrating the Aaltos' vision for the improvement of housing conditions for ordinary people.

The Aaltos had developed housing before their projects in Kauttua and Sunila, in the Aira building for Railway Workers in Jyväskylä (1924-1926), for example, and in the Agricultural Cooperative Building in Turku (1926-1928), which contained several different programmes including housing. Also in Turku, they designed the Tapani Standard Apartment House (1927-1929) as a multistorey building of standard elements (Weston 1995, 47). These housing projects were all situated in an urban context. In their groundbreaking design for the Paimio Sanatorium (1929-1933) the architecture would instead arise in a forest, and the Aaltos also developed housing for employees in a natural setting surrounding the sanatorium (Malmberg 2018, 5). The Aaltos were to continue this practice of including housing in the countryside, with visions of "forest cities" in both Kauttua and Sunila (Schildt 2007, 407-410; Weston 1995, 76-78). The idea of settlement in the forest relates to the predominant role of the forest within the Finnish cultural imagination (Norberg-Schulz 1993, 43-45; Treib 1998, 48-49). The forest is also an essential source of production in Finland, and it was the evolving wood pulp processing industry which the Aaltos were designing for in both Kauttua and Sunila. Here the creation of healthy modern housing facilities for the employees was a vision the Aaltos shared with Harry Gullichsen, the manager of the Ahlström Company, the main company responsible for pulp production in Kauttua and Sunila (Korvenmaa 2004b, 12-17).[2]

[2] Other outcomes of a fruitful partnership between the Aaltos and Harry Gullichsen and his partner Maire Gullichsen are Villa Mairea (1938-1939) and the Artek company (1935).

Figure 1. View of *Terassitalo* from the south. Looking up the steep slope that the house occupies surrounded by both evergreen pines and deciduous trees. Photographed March 21, 2022, 13:41 by Troels Rugbjerg.

It is important to contextualise the Aaltos' work within the broader architectural tradition of the Nordic countries (Weston 1995, 20). Here they were especially influenced by developments in Sweden and the architecture of Gunnar Asplund (Pallasmaa 1998, 25). Asplund's work evolved from a neo-classical vocabulary to Functionalism, a modern language of architecture which was introduced to the Nordic countries, beginning with the Stockholm Exhibition in 1930 (Aalto 1930b, 71-76). However, Asplund's architecture was not stylistically dogmatic; according to Alvar Aalto: *"everything started with people and all the innumerable strands of their emotional life, and with nature:"* (Aalto 1940, 243).

Similarly to Alvar Aalto's interpretation of the architecture of Asplund, the Aaltos sought to develop their architecture in relation to a specific context (Pallasmaa 1998, 32). In Alvar Aalto's 1926 article "From Doorstep to Living Room" (49-55), Alvar Aalto reflects upon the importance of relating the exterior to the interior of a home, and vice versa, by learning from the concepts of a garden and a courtyard in Italy and relating this to Finnish conditions: *"We might say: the Finnish home should have two faces. One is the aesthetically direct contact with the world outside; the other, its winter face, turns inward and is seen in the interior design, which emphasizes the warmth of our inner rooms."* (Ibid. 51-52).

Alvar Aalto was introduced to the modern movement in architecture and the Congress Internationaux d'Architecture Modern (CIAM) by the Swedish architect Sven Markelius, and he was able to join the second CIAM congress in Frankfurt in 1929 under the theme of: "Die Wohnung für das Existenzminimum" (the dwelling for minimal existence) (Mumford 2002, 27-42). This influence may be identified in the Aaltos design for "the Minimum Apartment Exhibition" in Helsinki in 1930 (Fleig 1963, 28-29). In the 1930 article: "The Housing Problem", Alvar Aalto reflects on human needs for modern living. He stressed the importance of sun, light, and air to the modern movement of architecture at the time and reflected upon how the layout of an apartment could be optimized when space was limited (ibid. 76-84). He referred to: *"the* tupa*, the living room-cum-kitchen of traditional Finnish farmhouse"* as a useful reference, as opposed to *"the concept of 'room'"*, which he criticised for being *"a relic of palace architecture"* and inadequate for modern family life (Ibid. 77). In the *tupa* of traditional Finnish dwellings, different activities occur alongside each other, taking advantage of one larger fireplace to keep warm, make food and provide light through darker periods (Weston 1995, 72, 97; Pelkonen 2009, 100).

The industrialisation of European society was characterised by increasing numbers of people living in cities under poor conditions. Modern architecture aimed to provide better living conditions by seeking to improve the relationship with the environment (Banham 1969, 29-44). The garden city movement in England proposed new ideas for settlements in the countryside, and their visions were adopted and developed by CIAM (Domhardt 2012, 174-178). The masterplan for Weissenhof Siedlung in Stuttgart, Germany (1927), designed by the German architect Mies van der Rohe, was an example of a modern settlement following a landscape as opposed to a formal order (Joedicke 1990, 13). The Aaltos would have been familiar with the Weissenhof Siedlung from Markelius, and it could be identified as a reference for their housing settlements in Kauttua and Sunila for the relation to the landscape (Schildt 2007, 271).

Poor urban living conditions, however, were not a problem in Finland before World War two (WW2), with limited industrial development mostly happening outside urban areas and in relation to the forest (Miller 2016, 68). This meant that the Aaltos' housing projects in the countryside of Kauttua and Sunila were able to continue a traditional way of settling in Finland (Norberg-Schulz 1993, 64), and at the same time appear visionary to the international modern movement. The quality of the Aaltos' housing is highlighted by the seminal work by Swiss architect and historian Sigfried Giedion: "Space, Time and Architecture" where the Aaltos' housing project *Terassitalo* is related to ideals of the modern movement with basic conditions for living in relation to nature: *"The flat roof-terrace of one house forms the large veranda of the next."…"As on the Greek island of Santorin, the houses of Kauttua use the natural slope to avoid the expense of staircases. In their form and shape they express man's relation to the soil from which he springs."* (Giedion 1959, 598).

Designed before WW2, the housing projects in Kauttua and Sunila were exceptional in Finland, however another significant Finnish housing project to be developed shortly afterwards is Olympiabyn (1939-1940), designed by the architects Hilding Ekelund and Martti Välikangas. Similar to Kauttua and Sunila, this scheme prioritised the orientation of the houses towards the sun, both from the overall planning of the settlement and in the layout of the apartments, and was also constructed with central heating (Wickberg 1965, 220-222). While the project is located in the suburbs of Helsinki, it still establishes a relationship with the surrounding trees (Lehtovuori 2008, 58-60; Mikkola 1980, 68).

The importance of the environment to modern architecture was arguably a rediscovery rather than a departure, featuring in architectural theory as far back as Vitruvius (Morgan 1914, 171). The development of modern architecture driven by industrialisation and new technology would however also mean new possibilities for managing the environment (Banham 1969, 26-28). This involved passive strategies and new active strategies of heating, cooling, and ventilating buildings, leading to a great increase in the use of energy for the running of buildings (Calder 2021, 344-352).

The implications and possibilities of exploring the environment in relation to specific historical cases of architecture have been thoroughly researched by

Hawkes and Lawrence in their studies of Hardwick Hall, England (1591-1598) (2021a, 861-892; 2021b, 293-316). Other examples of research concerning environmental aspects of historic buildings include Bone (2014, 11-215), Hyde, Upadhyay and Treviño (2016, 91-101) and Porteous (2002, 4-118). This research of the Aaltos' housing case study is part of a larger research project and aims to expand this field of research. This research sets out to re-evaluate and develop the history of housing design in the late 1930s by the Aaltos by aiming to understand – and learn from for housing today – the importance of environmental considerations in their work, some 90 years later. This involves understanding how passive strategies for achieving appropriate levels of comfort were fused with the visions of the modern movement to bring light and air inside, and improve the spatial layouts of apartments to accommodate the daily life of residents.

Figure 2. The living room of *Terassitalo*. From the third-floor apartment looking out the south-facing window to the private terrace. Photographed June 12, 2022, 15:28 by Troels Rugbjerg.

Housing in Kauttua and Sunila, Finland

Our research includes four housing case studies. The main case study is *Terassitalo* (the terraced house) (1937-1938), which is located in the settlement of Kauttua near the city of Eura, 210 km northwest of Helsinki. The three other housing case studies are *Mäntylä/Honkala*, *Mäkelä,* and *Rantala* (1937), which are part of the housing settlement of Sunila, near the city of Kotka, 134 km east of Helsinki.

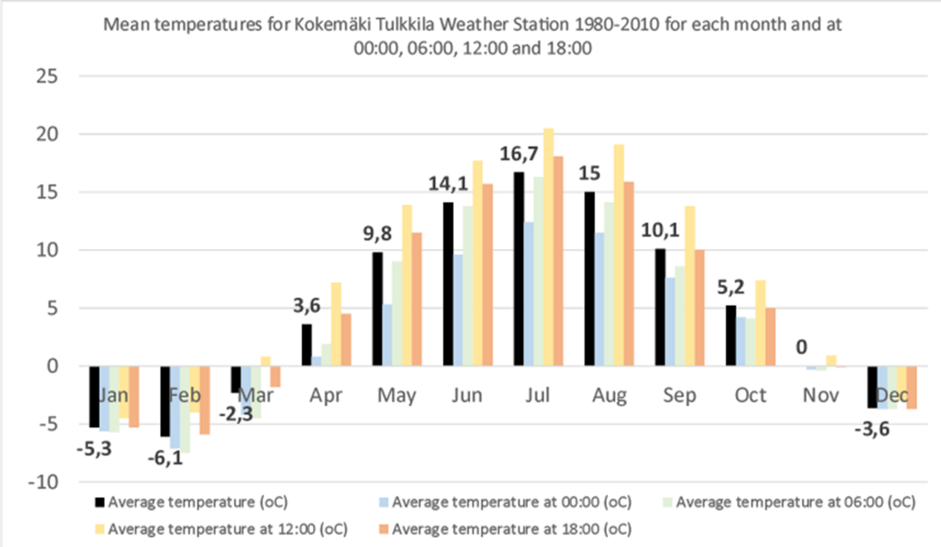
Terassitalo consists of one type of housing not far from a pulp factory (Korvenmaa 1989, 89-93; 2004a, 154-157). This housing project was a pilot for a type of housing that was supposed to be repeated several times to form a series, a project discontinued due to WW2. *Terassitalo* is identified as the most radical proposal in which the Aaltos relate apartments to the environment, as recognised by Giedion, including a heavily sloping landscape, which is the reason for the primary focus on this project in this paper (Giedion 1959, 598-599).

The three other housing case studies in Sunila, *Mäntylä/Honkala*, *Mäkelä,* and *Rantala* are all designed by the Aaltos and, constructed near to a new pulp factory (Korvenmaa 2004a, 104, 115, 118-119, 121-122; Mustonen and Wasastjerna 2010, 116-118, 123-124, 128-130). These three housing projects were the first part of the settlement to be constructed. While different in size, they share similarities in organisation e.g. all include a larger living room. General descriptive data of the four housing case studies are listed in Table 1.

Table 1: The four housing case studies.

House/s	Location	Year of construction	Nr. of apartments	Size of apartments	Floors in housing block	Floors of apartments
Terassi-talo	Kauttua, FI	1937-1938	6	38-100 m^2	4	1
Mäntylä/ Honkala	Sunila, FI	1937	60	29 and 46 m^2	2	1
Mäkelä	Sunila, FI	1937	14	85 m^2	2	2
Rantala	Sunila, FI	1937	5	180-280 m^2	2	2

The climate of the housing projects



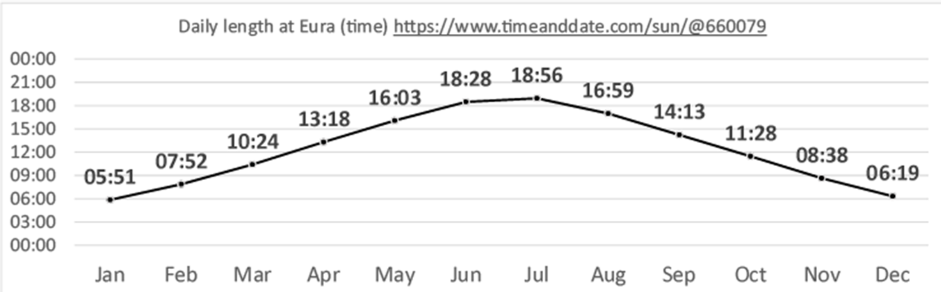


Figure 3a. Average monthly temperatures 1981-2010 at Kokemäki Tulkkila 61,15° North (19,5 km from Kauttua). In total and at 00:00, 06:00, 12:00, and 18:00.
Figure 3b: Daily length at Eura 61,07° North (3 km from Kauttua). Calculated from the use of: https://www.timeanddate.com/sun/@660079 [accessed: December 17, 2022].

As the environmental response is key to understanding the design of these case studies, it is important to consider the climatic conditions of their locations. Average temperatures of Kokemäki Tulkkila Weather station (from 1981-2010), located 19,5 km away from Kauttua, indicate how temperatures will often be below 0°C during the winter season, and that there will be a short, but warm summer season (Figure 3a) (Pirinen et al. 2012, 26). From this data, one can also find average temperatures for each month at four specific times of the day (00:00, 06:00, 12:00, and 18:00), to provide an indication of how the daily temperatures vary little during winter-time and substantially during spring-time. These differences relate to the strength of the sun that varies dramatically according to the varying length of the day across the year at the latitudes of these sites (Kauttua: 61,07° North, and Sunila: 60,49° North). Winter nights are long, with days of less than six hours, and summer days last up to 19 hours (Figure 3b). The importance of the changing environment to life at such high latitudes is emphasized by Norwegian architect Christian Norberg-Schulz: *"If we maintain* *that light defines the Nordic character, it is to imply that we understand 'climate' qualitatively. Light is conjunctive with weather, and in the north, weather plays a more important role than in the South's more stable world"* (1993, 6).

Annual mean temperatures in Finland have risen significantly due to climate change, by approximately 2°C since the nineteenth century, with change accelerating in recent years (Finnish Meteorological Institute 2019). The largest increase in temperature is occurring during winter-time, which means annual temperature ranges are decreasing.

Research method: recording the environment and evaluating indoor comfort

Figure 4: *Terassitalo* at three different times of the year. a. March 21, 2022, 15:22, b. June 13, 2022, 18:39 and c. October 17, 2022, 16:52. Photographed by Troels Rugbjerg.

A range of methods were employed to record the environment in the case studies, including temperature monitoring over an extended period; field studies on-site, and archival studies exploring their design and construction. The research methods used and their purpose are summarised in Table 2.

Four sensors were employed to monitor temperatures (°C), and relative humidity (RH, %) in one apartment in *Terassitalo* from March 21 to October 17, 2022 (sensor accuracy ± 0,4°C, 5% RH). One of these four sensors also monitored light levels (Lux), capturing daylight, sunlight, and artificial light. Data was collected at intervals of 10 minutes except for one sensor which collected data every 30 minutes due to the difficulty of securing sufficient power for the sensor. Sensors were positioned away from windows to prevent them from being affected by solar radiation, and they were positioned approximately 1,5 m above the floor level with variations between 90 cm and 2 m. One sensor monitored temperatures and relative humidity outside *Terassitalo* from June 13 to October 17, 2022. This outside sensor was positioned approximately 1 m above the ground and north of the building to minimise direct sunlight. For analysis, a minimum of three hours of data was removed at the beginning and end of the recording period to ensure that the data was not affected by the process of positioning or removing the sensors.

Field study visits to the selected housing projects *Terassitalo, Mäntylä/Honkala*, *Mäkelä,* and *Rantala* were undertaken in March, June, and October 2022 (Figure 4). These studies included walk-throughs to experience the apartments, supported with notes and photography, and interviews were conducted with residents to learn from residents' experience of comfort and the home environment more generally. To comply with ethical research guidelines the residents of the apartments provided their voluntary consent to participate in the study anonymously and where needed, pseudonymisation was used to maintain anonymity.

Drawings from the Alvar Aalto Archive (AAA) in Jyväskylä, Finland were studied, and they are referred to through the catalogue system of the archive xx/xxx.

Determining the cardinal orientation of the selected housing projects involved studying aerial photos and drawings.

Table 2: Different types of research used in this mixed method study and their purposes.

Methods of research	Type	Period of research	Outcome	Purpose
Sensors monitoring temperature, humidity, and light inside and outside.	Quantitative study of measurable data.	4-7 months.	Data is organised, visualised, and communicated in graphs.	To study and document differences in temperature, humidity, and light for a longer period.
On-site studies from walk-throughs including notes and photographing.	Qualitative experience of space documented through notes and images.	30 minutes to several hours.	Notes in sketchbooks, reports of experiences and images.	To record the environmental experience of the apartments.
Archival studies of drawings, images, documents, and literature.	Quantitative study of the spatial design. Qualitative study of sketches leading to the final design.	-	Notes and drawings.	To study spatial organisation, construction methods, and aid interpretation.

We relate the measured observations to the more qualitative considerations of the environment which were important to the Aaltos as presented in the introduction. This research enables us to reflect on past practices and learn for future housing, but it may also be of relevance to the conservation and management of historic examples of housing from this period, designed before contemporary ideas of sustainable architecture were fully developed or articulated (Gauzin-Müller 2012, 10; Pisani 2006, 83-96; Steele 2005, 6-9).

Construction and amenities

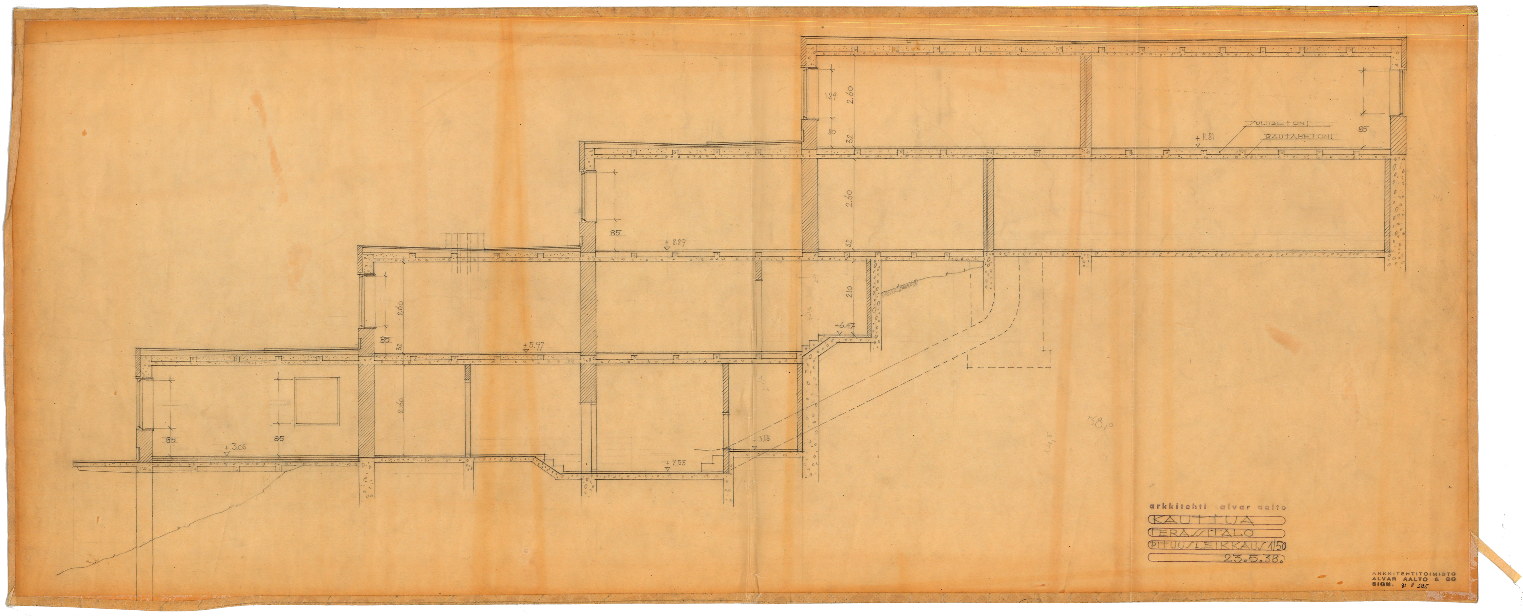


Figure 5. Longitudinal Section 1:50 of *Terassitalo.* Drawing of the Alvar Aalto Archive concerning the housing project: *Kauttua, Terassitalo, Pituusleikkaus 1/50* (AAA 81/505). © Alvar Aalto Foundation.

The housing cases were constructed from a combination of materials, but predominantly brick and concrete (Korvenmaa 2004a, 118-119, 121-122, 156-157), demonstrated in the longitudinal section of *Terassitalo,* where the drawing annotation indicates heavy brickwork for the loadbearing walls and the use of concrete for the floor slabs (Figure 5). This section also documents little use of insulation in the building envelope, resulting in thermal bridges.

No major alterations or developments of the building envelope of *Terassitalo* were detected, however, the roofs of both *Mäntylä* (Mustonen and Wasastjerna 2010, 130), *Mäkelä* (Ibid., 124) and *Rantala* (Ibid., 116, 118) have all been renovated with additional insulation.

The facades of the buildings are rendered continuously white to give a homogeneous expression. This was achieved by applying plaster to either conceal the materiality of the walls as in *Terassitalo* (Korvenmaa 2004a, 156), or to allow it to be partly visible as in *Mäkelä*, where the brickwork can still be detected (Ibid., 121), and in *Mäntylä/Honkala,* where the structure of the Siborex blocks can be seen on the outer walls (Ibid., 122).

All of these housing cases, except *Mäkelä*, have complementary woodwork on the exterior, forming railings and trellises for vegetation, and at *Mäntylä/Honkala* woodwork is included on the façade in relation to the rendered facade.

The houses feature smaller single windows, also combined to form longer horizontal openings in the living rooms of the apartments. These openings rarely span the entire width of the walls however, leaving an area free of windows, often on both sides (Figure 2 and 17).

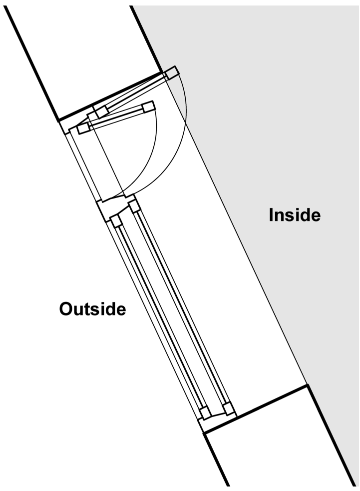


Figure 6. Plan diagram of the double-framed windows of *Terassitalo.*

The original double-framed windows can still be found in *Terrassitalo* (Figure 6). A replacement of the original double-framed windows in *Mäntyla/Honkala* was conducted in 2005 with new double-framed and triple-glazed windows carefully developed by measurement of the original windows (Mustonen and Wasastjerna 2010, 44, 47-48, 130). In *Mäkelä* the original double-framed windows were replaced with new doubled framed windows of wood-aluminum in 1998 (Ibid., 44, 124). At *Rantala* the original double-framed windows have been maintained and improved (Ibid., 44, 116).

Today, district heating provides hot water for the radiators, which are the primary heat emitters for the case studies, which are all equipped with thermostats. At the time of construction however heating came from a local source. Originally hot water for the radiators of *Terassitalo* came from a boiler inside the housing block. In Sunila heating was provided from a common building for both *Mäntylä/Honkala, Mäkelä,* and *Rantala* according to Alvar Aalto (1938, 145-160).[3]

The apartments were often constructed with a passive stack ventilation system, a common feature at the time as described by Neuvonen, Mäkiö and Malinen (2002, 131-135). This system includes an air inlet underneath the windows and above the radiators, where the radiators help pre-heat the fresh air from the outside. These air inlets can be found in all the case studies except *Mäntylä/Honkala*. There are usually outlets in kitchens, bathrooms, and/or toilets beneath the ceiling. The passive system of ventilation was found to be still in use today.

All the studied apartments were constructed with running water (Mustonen and Wasastjerna 2010, 11). A private bath was only provided in larger residences, and did not feature in the apartments of *Mäntylä/Honkala* or *Mäkelä*. These residences were provided with shared bathing and sauna facilities in a common building also designed by the Aaltos as part of the new settlement at Sunila (Ibid., 11). Today there are bathrooms in *Mäkelä* and in 2002-2004, a HVAC renovation was carried out in *Mäntylä/Honkala* to include an additional small shower (Ibid., 130).

[3] The apartments of *Rantala* also include a fireplace.

Detailed descriptions of the housing cases

All four housing case studies are organised in blocks of approximately the same width, between 9-10,6 m (Figure 7, 11, 12 and 13). The entrance to the apartments is from the north-east, and the larger living rooms of the apartments are oriented to the south-west.

Terassitalo, Kauttua

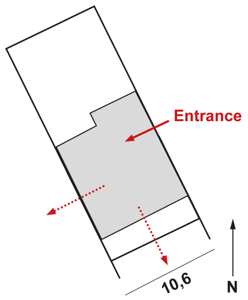


Figure 7: Plan diagram of apartments of *Terassitalo*. Shows the width of the building, the position of the main entrance and the orientation of the living room.

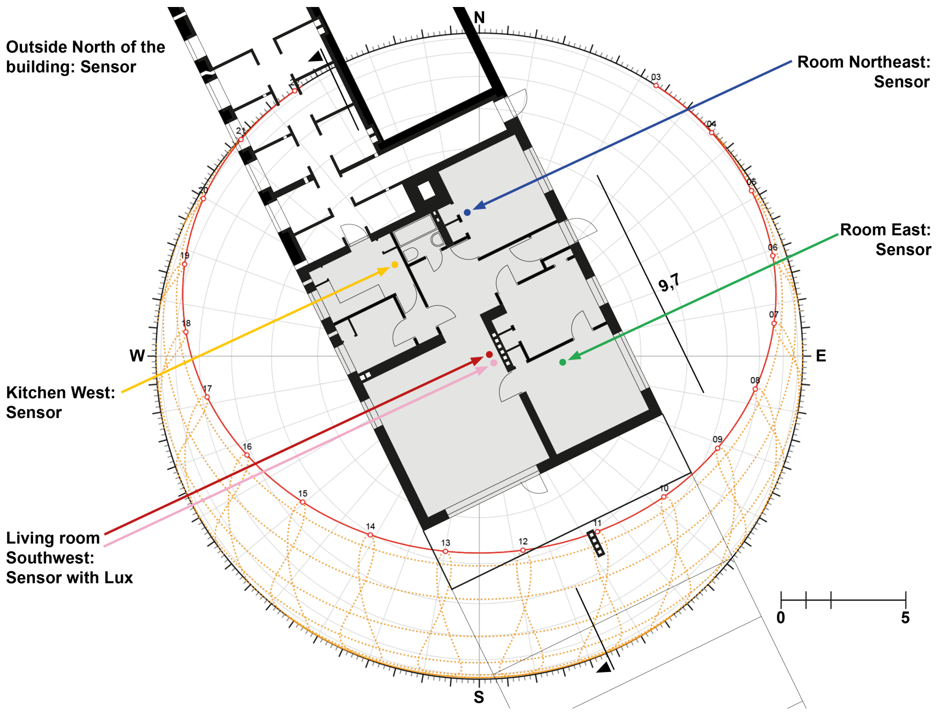


Figure 8: Plan of the third floor of *Terassitalo* with sun path diagram and position of sensors indicated on this plan. The building is rotated 25° from the cardinal points. Sun path diagram is constructed with the use of: http://andrewmarsh.com/apps/releases/sunpath2d.html [accessed: February 3, 2022].

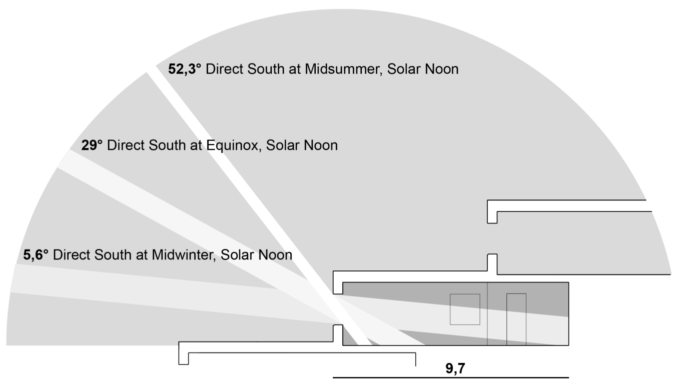


Figure 9: Section of *Terassitalo* with sun height at midwinter, equinox, and midsummer from direct south 0°.

Terassitalo, with apartments designed for engineers and their families from the pulp factory nearby, is oriented approximately east-west; however, the four floors of the building are staggered in relation to the steep slope of the landscape, to

allow four larger apartments on the four different floors oriented towards the south with a private terrace (Figure 1 and 8).[4]
The overall shape of the building makes it appear as giant steps that paradoxically do not contain any stairs, which was stressed in the publication of the housing project in 1939 with an economic explanation: *"The increase in the building costs brought about by the terrace-system, is compensated thereby that no stairs are required, so the rents will be about the same as for ordinary houses in stories."* (Aalto 1939, 165).

The four larger apartments are all slightly different but with a similar layout. Coming from a steep road on the slope, one enters from the east through a small vestibule to prevent heat loss. Small windows in the doors allow some light to enter. When inside the apartment one is led through a hallway to make a turn to the left, where the space opens up into a living room providing access to the terrace (Figure 2 and 17). Today there is both an inner and an outer door between the living room and the terrace, with a narrow area in-between to prevent heat loss. The drawings of the Aaltos only show one door, which indicates that a second door was added later (AAA 81/487-493).

Today, the woodwork on the south-facing terrace is covered with sheets of translucent trapezoidal plastic above (Figure 1), however, the Aaltos envisioned this woodwork to be covered by vegetation according to drawings (AAA 81/508-81/509, AAA 81/511-81/515). The annual development of vegetation growing on the woodwork would have contributed to the experience of the environment inside as the surrounding trees do today.

A horizontal window spans the wall in the living room alongside the doors to the terrace, but 60 cm of wall is left beside the window to permit furnishing. The western wall in the living room is unobstructed except for a smaller window facing west, found in three of the four larger apartments (Figure 8 and 18a). Awnings have been added over the south-facing windows of the living rooms, however they were not part of the original design according to a photograph (Aalto 1939, 161).

When studying plans for furnishing the living room, the Aaltos consistently present two groups of chairs positioned around a table to indicate how the space has the potential to be shared with two or more activities happening at once (Aalto 1939, 163). This vision of several parallel activities resembles the idea of the "tupa", the living-room-cum-kitchen of traditional Finnish farmhouses (Aalto 1930a, 77).

Along the eastern side of the apartment with the entrance, one finds private rooms of different sizes positioned either in "the front" of the apartment or further back towards the slope to the north. The kitchen is located in the northwestern corner opposite the entrance and the bathroom is oriented towards the north without any walls to the outside.

Three historic photographs from the 1950s show family life taking place around *Terassitalo* in response to the variations of the seasons (Figure 10). From playing in the snow in the low light during winter on the eastern side of the building, to jumping to keep warm in spring or autumn. A third photograph documents how a group of children are enjoying the warmth of the high sun on the terrace in summer, with hats worn for protection. These images document a rich social life with residents enjoying seasonal changes in the environment around the building.

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[4] Apart from these four larger apartments, there are also two smaller apartments on the fourth floor without an orientation to the south.

Figure 10: Historic photos from *Terassitalo* from the 1950's, presenting possibilities for play and social life in different seasons of the year. © Archive of the Eura Municipality.

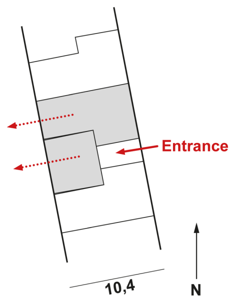

Figure 11. Plan diagram of apartments of *Mäntylä/Honkala.*

Mäntylä/Honkala, Sunila

The two similar buildings *Mäntylä* and *Honkala* in Sunila have several smaller apartments designed for workers of the pulp factory (Mustonen and Wasastjerna 2010, 128-130). These buildings form continuous blocks where the apartments are oriented approximately east-west, which one enters through a public area to a common stairway leading to six apartments on two floors (Figure 11). A smaller studio apartment in front of the stairway is oriented only towards the west. The two-room apartments have a smaller room oriented towards the east in relation to a kitchen and a larger living room facing west. There are wide horizontal windows on both the eastern and western sides, where a 60 cm wall is left on each side of the windows.

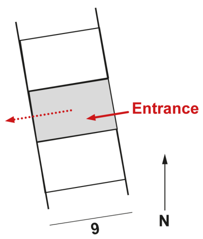

Figure 12. Plan diagram of apartments of *Mäkelä.*

Mäkelä, Sunila

The one building block of *Mäkelä* in Sunila has apartments oriented approximately east-west and divided on two floors, intended for supervisors of the pulp factory (Mustonen and Wasastjerna 2010, 123-124). One enters through a private garden from the east (Figure 12). Beside the entrance is a kitchen and towards the west is a living room from where an elaborated stairway leads a few stairs up to provide access to a common area outside of the apartments. Here there are also two doors as in the apartments of *Terassitalo*, opening both inwards and outwards. Drawings indicate this was part of the original design (AAA 81/124). The stairway continues to the second floor with two bedrooms, where one is oriented to the east and the other to the west. There are wide horizontal windows in the rooms of both floors, but as in the apartments of *Mäntylä/Honkala* they do not span the entire width of the walls.

Rantala, Sunila

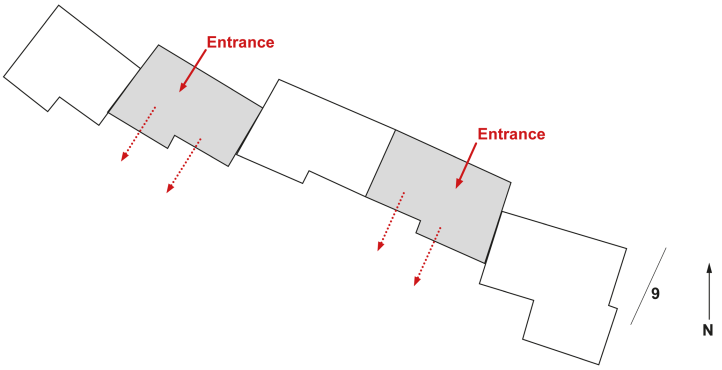

Figure 13. Plan diagram of apartments of *Rantala.*

As opposed to *Mäntylä/Honkala* and *Mäkelä* the apartments, or rowhouses, of *Rantala* are oriented mainly north-south with a slight fan-shape plan, opening up more towards the south (Figure 13). These five larger apartments of uneven sizes on two floors were intended for engineers of the pulp factory, similar to the apartments of *Terassitalo* (Mustonen and Wasastjerna 2010, 116-118). One enters the apartments from the north through a common area with a kitchen beside the entrance. A larger living room opens up towards the south and allows access to a private garden. The second floor also has a smaller living room with a northern orientation and private rooms mostly facing south. Horizontal windows span the walls but leave free areas toward the load-bearing transversal walls.[5] The windows in the living room on the first floor have extra height and start only approximately 30 cm above the floor to blur limits to the private garden. The northern side, on the contrary, has fewer and smaller windows. Awnings have been added to some of the windows of the south-facing living room.

Studies of the internal environment of the apartments

The in-situ studies include evaluation and discussion of light and temperature, presenting results from the thermal monitoring and field studies.

Light

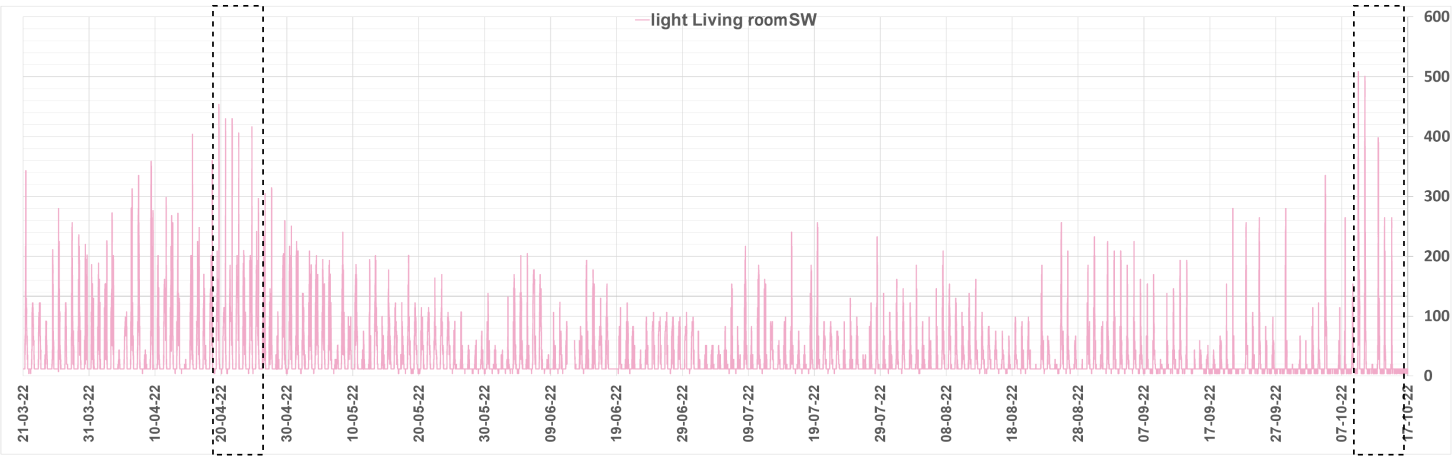

Figure 14: Monitored Lux level in the living room of *Terassitalo* from March 21 to October 17, 2022.

[5] An exception is however one larger window in the living room of one of the apartments of the housing block *Rantala* even spanning around a corner.

The graph (Figure 14) presents Lux levels monitored in *Terassitalo* for 211 days from a sensor positioned in the living room of a lower apartment.[6] After a gap in monitoring from June 11 to 12, 2022, the monitoring was reduced from intervals of 10 to 30 minutes due to battery power challenges. Lux levels can change rapidly depending on the outside conditions, which may not be reflected by the data.

The graph presents how the light level rises each day ranging from hardly any fluctuation to high peaks. One finds the highest Lux levels at the beginning of the monitored period in spring at 453,3 Lux on April 19, 16:40 and in autumn, as well as for the entire period, at 508,5 Lux on October 9, 12:00. Examining these two days and the following six days in more detail reveals the daily development of the light.

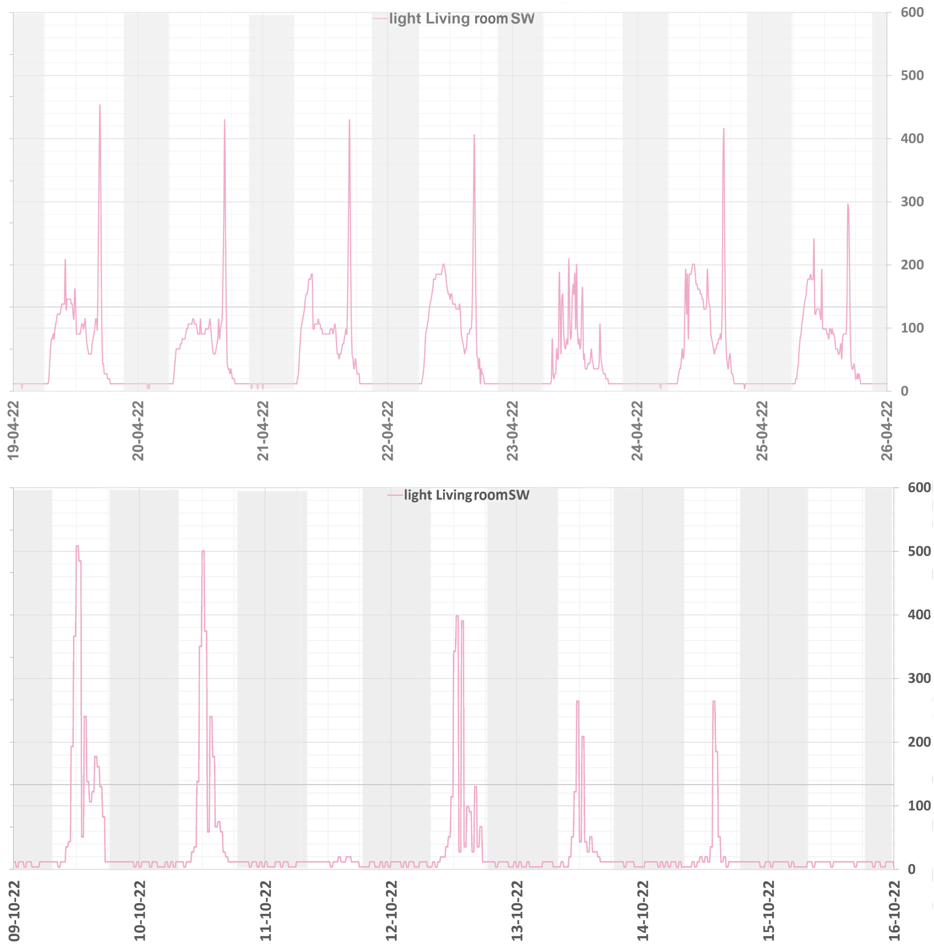

Figure 15. Monitored Lux-level in the living room of *Terassitalo.* a. April 19-26, 2022 and b. October 9-16, 2022.

The period in spring: April 19-26 shows two daily peaks of light: a lower, longer peak early and in the middle of the day and a sharper, short peak in the late afternoon (Figure 15a). Comparing these graphs with the plan of *Terassitalo* and the sun-path diagram and section of the apartment, the two different peaks can

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[6] When assessing the measured Lux levels and analysing the results one needs to consider the position of the sensor that was positioned 2 m above the floor and approximately 5 m from both the larger window towards the south and the smaller window towards the west to measure light from both windows equally. This withdrawn position means "conservative" results with relatively low light. If the sensor were positioned closer to a window and/or not so high the results could have been different.

be related to the two windows of the living room (Figure 8 and 9). The first subtle curve is due to light from the wider southern window where sunlight enters from a higher angle. The second sharper peak is caused by light from the western window where sunlight enters at a lower angle for a short intensive period.

For the period in autumn: October 9-16 this pattern is different (Figure 15b). There are high intense peaks of Lux earlier and in the middle of the day, which will be due to light coming from the wide southern window (Figure 8 and 9). This higher Lux level from the southern window will be caused by the lower angle of the sun in October compared to April, allowing more sunlight deeper into the living room. With no high peaks of Lux in the afternoon, one may deduce this is caused by the relative low angle of the sun compared to the period in April. Differences in the monitored Lux level between spring and autumn may however also be affected by the changing period of the data collection: every 10 minutes in April and every 30 minutes in October.

The time span between the early and later peak of registered Lux levels in April documents how the corner in the living room towards the southwest and the wall towards the west remain in shadow in the early afternoon. This area, with opportunities for furnishing, creates a darker zone in contrast to the light areas by the windows towards the south or west, and especially compared with outside on the private terrace (Figure 8). This demonstrates how the living room adapts to the shifting conditions of light over time, creating ‘niches’ within the room with different atmospheres, providing different opportunities for inhabitation and adding to the possibilities of sharing the space as with the “tupa” of the traditional Finnish farmhouse (Aalto 1930a, 77).

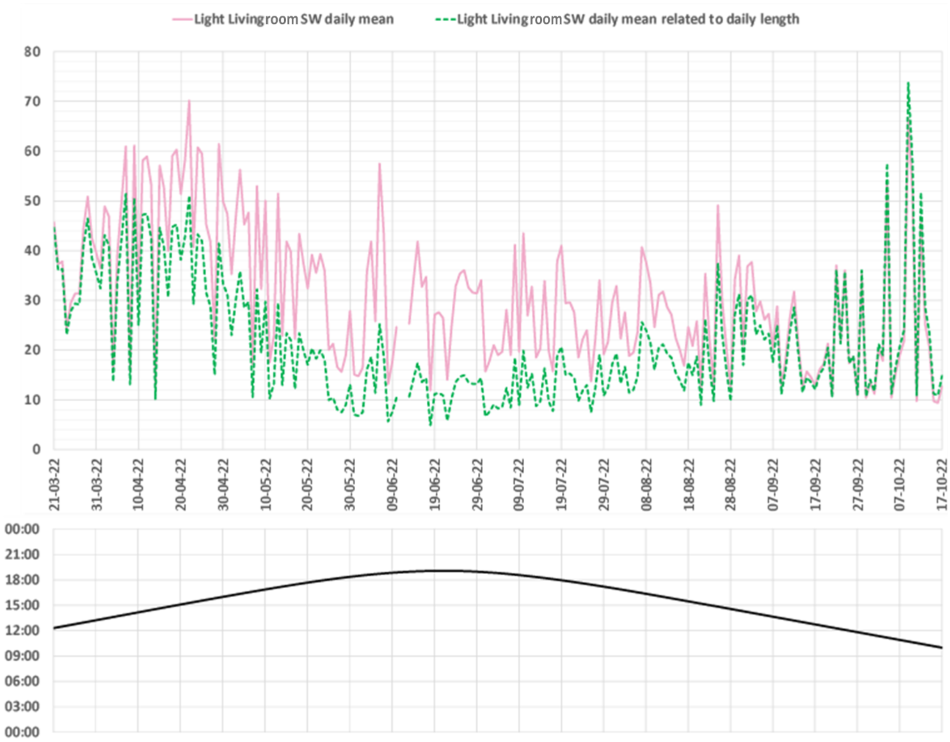

Figure 16a. Mean daily Lux levels in the living room of *Terassitalo* from March 21 to October 17, 2022 and calculated in relation to daily length.
Figure 16b. Daily length over the same period from March 21 to October 17, 2022 at Eura 61,07° North (3 km from Kauttua). Calculated from the use of: https://www.timeanddate.com/sun/@660079 [accessed: December 17, 2022].

To study general Lux levels regardless of daily variations, a mean Lux level was calculated for each day, presented in graph form (Figure 16a). These mean Lux levels were related to the variations of daily length at this latitude (Figure 16b) from a factor indicated as a green dotted line (Figure 16a).[7] Longer summer days with more daylight outdoors do not result in higher Lux levels measured by the sensor inside. Instead, there is a decrease in light, which decreases more when related to length of day. These lower Lux levels may be caused by the higher position of the sun during summer, resulting in less light reaching far into the living room during the middle of the day through the south facing window (Figure 9). The lower Lux level in summer will also be affected by the life of the trees that are growing around the building. During this period the leaves of the deciduous trees create a green filter and obstruct sunlight entering the apartments (Figure 2 and 4b). On the contrary, there are no leaves on the deciduous trees at the first peak of Lux level in April as the bud burst had not yet occurred (Figure 4a) (Linkosalo et. al. 2009, 456), and by October most leaves have already fallen as documented from on-site studies in October 2022 (Figure 4c). While measurements undertaken during winter are not included, it would also be interesting to study the impact of snow cover on the reflectance of light inside.

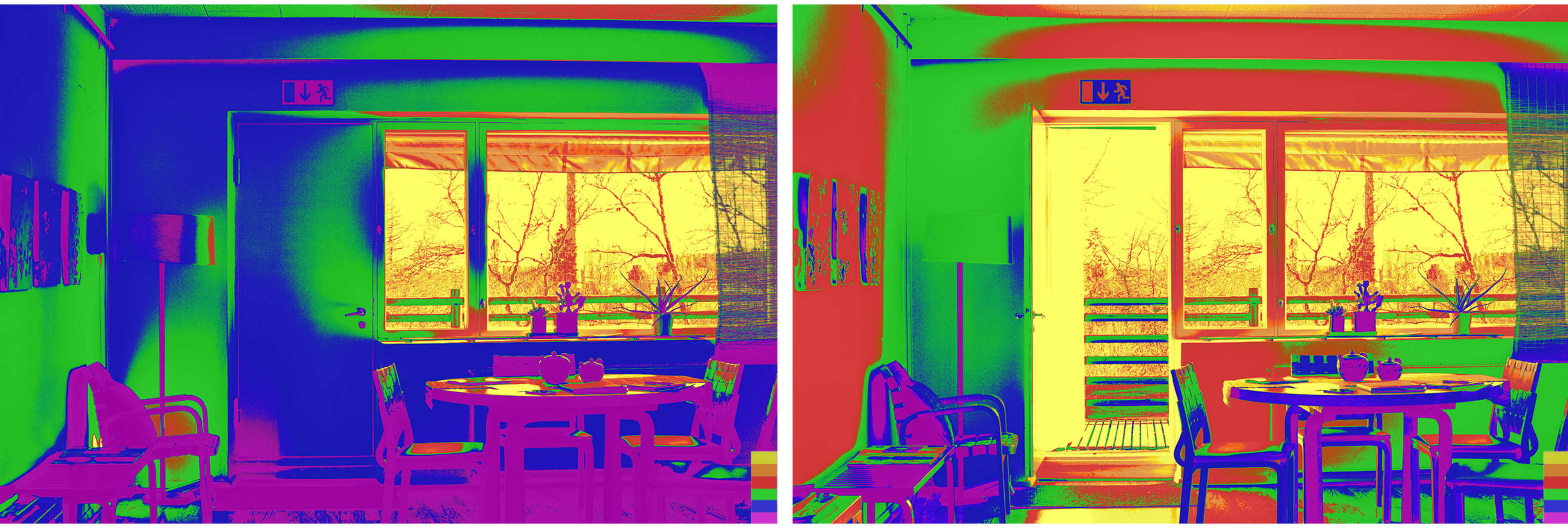

Figure 17. Simulation of measured luminance with false colors in the living room of *Terassitalo*. a. From the third floor apartment of the south facing window to the private terrace on March 20, 2022, 15:08 and b. with open doors to the private terrace on the same day at 15:09. Photographs by Troels Rugbjerg.

From photographs processed with false colors to simulate measured luminance (Figure 17a), one can study how daylight floods from the wide southern window into the living room of *Terassitalo*, and how even more daylight enters when opening the doors to the terrace (Figure 17b). Looking through the window one sees how the deciduous trees carry no leaves on these images photographed in March, allowing more light to enter, as opposed to summer (Figure 2).

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[7] Lux values measured every 10 minutes from March 21 to June 11, 2022. and every 30 minutes from June 12 to October 17, 2022, have been calculated to a mean for each day in the pink continuous line and related to a factor for daily length at Eura in the green dotted line.

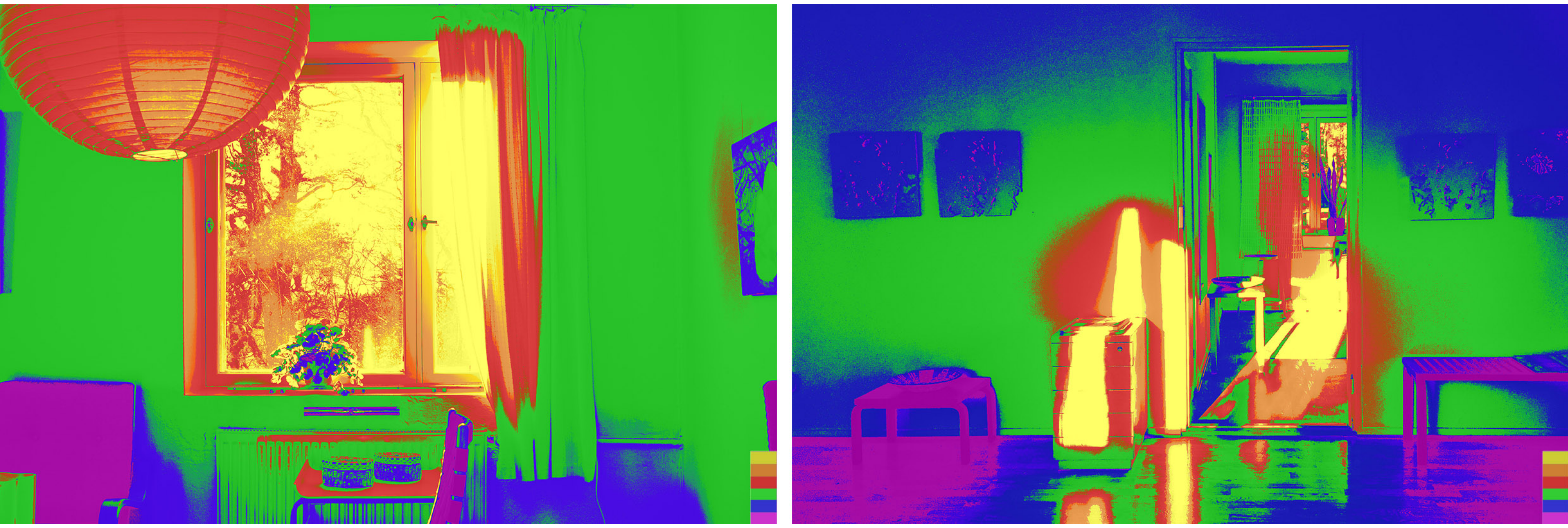

Figure 18: Simulation of measured luminance with false colors in the living room of *Terassitalo*. a. From the third floor apartment of the west facing window on March 20, 2022, 16:29 and b. from the opposite direction of the light entering into the apartment from this window on the same day at 17:28. Photographs by Troels Rugbjerg.

From a photograph of the smaller western window in the living room of *Terassitalo* also processed with false colors, one can identify a sharper lower light that enters in the afternoon (Figure 18a). A second image, photographed from a position close beside this window, documents how this creates a beam of light through the apartment and into the adjacent room (Figure 18b), which can be related to the short sharp peak of Lux level monitored in April (Figure 15a). Outside the western window, there are leafless trees close by that still cause some obstruction to the influx of light at the time of the photograph in March, however, the obstruction is greater in summer as documented from on-site measurements.

For the apartments of the housing cases in Sunila, there is also variation in daylight caused by the vegetation. For the many identical and smaller apartments of *Mäntylä/Honkala* qualitative variation is provided from the trees outside, mostly evergreen pines on the western side of these buildings. In apartments with larger trees nearby, this causes a substantial obstruction of light throughout the year as opposed to apartments where the trees are deciduous and/or further away.

Temperature

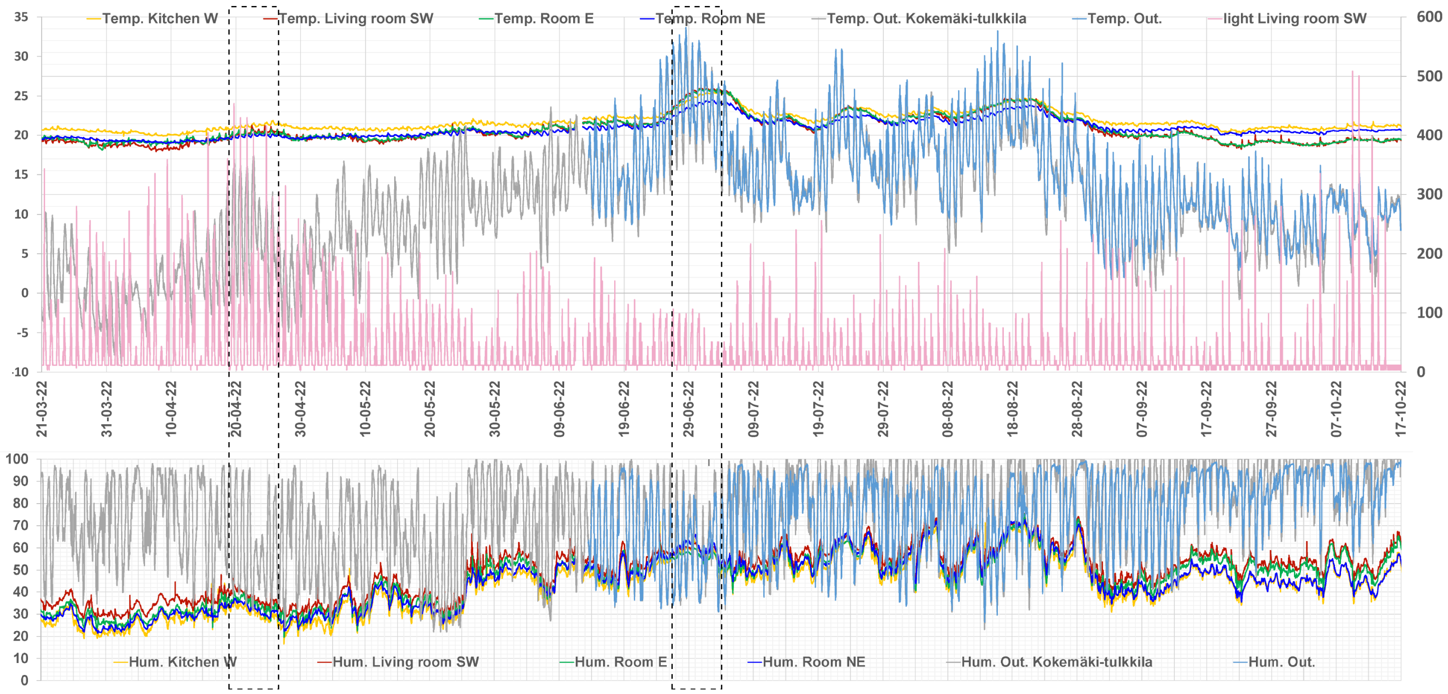

Figure 19a. Monitored temperatures and Lux levels at *Terassitalo* from March 21 to October 17, 2022. Temperatures on the Y-axis to the left and Lux levels on the Y-axis to the right.
Figure 19b. Monitored relative humidity over the same period.

These graphs (Figure 19a and 19b) present measurements of temperature (°C) and humidity (RH, %) for 211 days from four sensors positioned in a lower apartment of *Terassitalo,* and from one sensor positioned outside for a shorter period from the end of June 13, 2022. The plan (Figure 8) indicates the position of the sensors in relation to the exhibition apartment on the third floor, for the sake of pseudonymization. The graphs also present data from the weather station at Kokemäki Tulkkila, 19,5 km from Kauttua, and the top graph (Figure 19a) includes the Lux level of the living area as presented in the previous section.

This part of the study was conducted to understand the thermal environment inside the apartment in relation to the environment outside. Here the daily peaks of Lux level and fluctuations of the outside temperature and relative humidity confirm the general variations of the outside environment at this location (Figure 3). This contrasts with the measured temperatures from the four sensors inside, which record stable temperatures around 20°C for most of the period, due to active heating systems de-coupling the indoor from the outdoor environment.

The thermostats that are attached to the radiators affect the temperature monitored inside, however it is still possible to deduce subtle properties of the apartments in terms of heat through the measurements. The warmest periods during summer are particularly interesting as temperatures outside exceed the monitored temperatures indoors; this omits the effect of the thermostats as no heat is required. This period reveals variations of temperature without any active heating and thereby presents the building in a free-running state. In these warmer periods, temperatures measured inside rise with the higher temperatures outside to reach a level that is a mean of the varied daily temperatures. The temperatures rise with a slow response to the outside temperature, so that temperatures stay relatively high when the outside temperatures drop again.

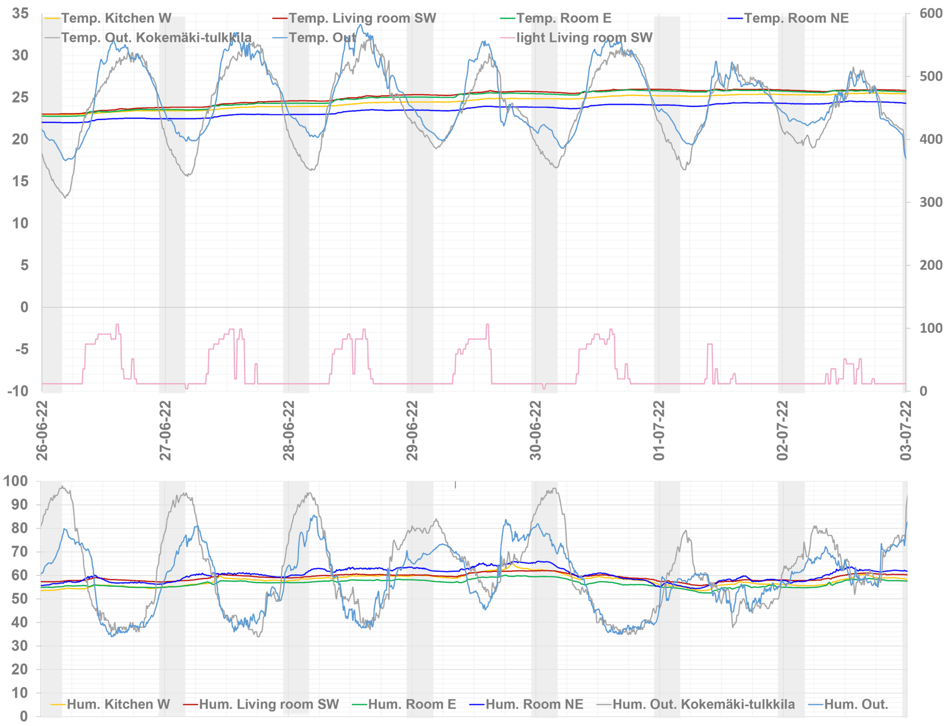

Figure 20a. Monitored temperatures and Lux levels at *Terassitalo* from June 26 to July 3, 2022. Temperatures on the Y-axis to the left and Lux levels on the Y-axis to the right.
Figure 20b. Monitored relative humidity over the same period.

The graphs (Figure 20a and 20b) focus on a seven-day period in June and July, including June 28, 2022, where the highest temperature was measured outside (32,3°C at the weather station and 33,7°C at the sensor positioned outside *Terassitalo*). During this period internal temperatures averaged 24,6°C, with a maximum of 25,9°C measured in relation to the outside temperatures. The thermal lag, as temperatures inside are slow to respond to high temperatures outside, demonstrates how indoor conditions remain pleasant even as it becomes hot outside. Temperatures indoors remained high as the temperatures dropped outside due to the apartment's thermal properties (i.e., mainly designed to retain heat inside during cold periods). This may present a potential problem in the future as temperatures rise due to climate change.

This monitored period also presents small but informative differences between the measured temperatures from the four sensors. The room towards the northeast, and the kitchen at the rear end of the apartment facing towards the slope, stayed cooler than the rooms at "the front" of the apartment facing south. With low Lux levels measured during this period, one may conclude that these temperature differences were caused by the properties of the combined thermal mass of the building and the slope, rather than by solar radiation.

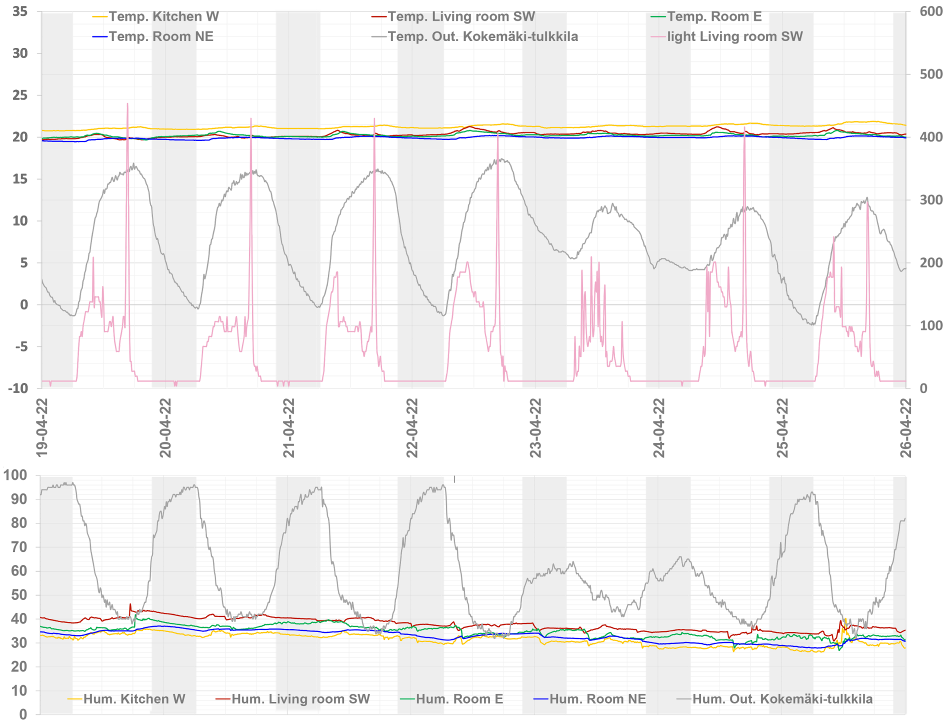

Figure 21a. Monitored temperatures and Lux levels at *Terassitalo* from April 19 to 26, 2022. Temperatures on the Y-axis to the left and Lux levels on the Y-axis to the right.
Figure 21b. Monitored relative humidity over the same period.

The graphs (Figure 21a and 21b) focus on the seven-day period following the highest measured Lux levels in spring on April 19. During this period the temperatures measured inside were constantly higher than outside, as a result of heat from the radiators. It is however possible to observe small variations of the temperatures inside related to the dramatically changing Lux levels, indicating changes in solar radiation. The subtle peaks of Lux levels early and in the middle of the day can be identified through temperatures rising in the room to the east and in the living room at “the front” of the apartment, exposed to sunlight from the south. The kitchen, oriented towards the west, sees higher temperatures of approximately 1°C at the rear of the building, and a slight fluctuation in the temperatures can be identified later in the day, possibly caused by sunlight heating up the western side of the apartment.

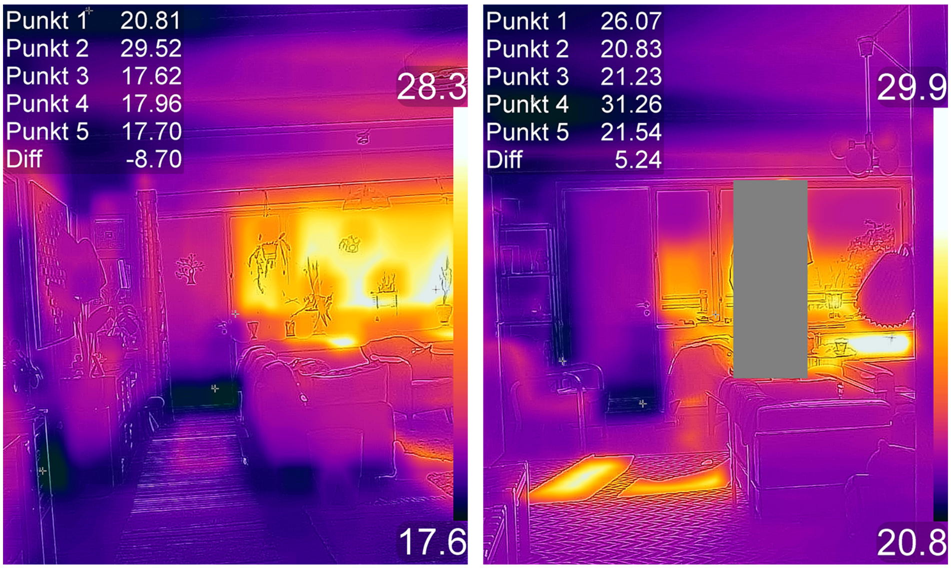

Figure 22: Infrared images from *Terassitalo*. a. the living room of the first floor apartment, March 20, 2022, 11:15 and b. the living room of the fourth floor apartment, March 19, 2022, 12:29. Developed with FLIR technology. Photographs by Troels Rugbjerg.

Comparing Infrared images of the living rooms of the apartments on the first and the fourth floor of *Terassitalo* demonstrates how the building is colder on the first floor as the floor is part of the building envelope, in comparison to the floor of the apartment on the fourth floor with an apartment below, resulting in a warmer surface (Figure 22a and 22b). There is however little difference between the ceilings of these two different apartments as they are both part of the building envelope due to the stepped design of the building.

The awnings of the south-facing windows in the living rooms of the apartments of *Terassitalo* block sunlight from entering, preventing possible overheating. This is also a possibility in *Rantala* where some of the south-facing windows have awnings to prevent sunlight, however, it is not possible in *Mäkelä* or *Mäntylä/Honkala*, where there are no awnings over the windows of the living room. As the main orientation of these apartments is towards the west, the sunlight will also be less strong. The specific trees growing outside the smaller apartments of *Mäntylä/Honkala* will affect the daylight entering as mentioned previously, however, they will also affect the temperatures inside and ensure comfortable humidity. Apartments with no mature trees close by may be affected by overheating in summertime.

Conclusion

The objective of this paper was to study the indoor environment of housing projects designed by Aino and Alvar Aalto in the late 1930s to understand aspects of their actual performance and to learn for future housing design. The primary case study was *Terrassitalo* (the Terraced house) in Kauttua, Finland (1937-1938), and three other housing case studies in Sunila, Finland (1937). A mixed research methodology was applied to the case studies, including thermal monitoring from sensors measuring temperature, relative humidity, and light, together with in-situ observations and resident interviews. These on-site studies were supplemented with archival studies.

Findings document how the apartments are well *oriented* towards the positions of the sun that vary substantially with the cycles of the year and the day at this relatively high latitude of approximately 61° North.

Stable and even temperatures were monitored in an apartment of *Terassitalo* despite substantial differences in the temperatures outside. This is due to thermostatic control of the radiators, however, during warmer periods in summer when the building is in a free-running state, the data reveals a tendency for temperatures to remain constant. These constant temperatures are maintained during warmer periods due to the thermal properties of the building and reduced solar radiation as the higher angle of the sun does not penetrate as far into the apartments.

The trees growing close to the buildings also contribute to the environment inside. The leaves of the deciduous trees filter the strong warm light of the sun during summer, however, during winter, when the deciduous trees carry no leaves, they let in the light. This leads to significant differences between the apartments at both *Terassitalo* and the three different housing case studies in Sunila, depending on tree locations. For the apartments in *Terassitalo* positioned on four different floors, there are differences in sunlight and temperature from the first to the fourth floor, caused by relatively little use of insulation in the building envelope. The forest as a natural setting of the studied housing case studies relates to visions of the modern movement in architecture to improve living conditions by involving nature developed from ideas of a garden city.

The studied apartments facilitate many possibilities for the residents to affect their thermal comfort and to engage with the environment. The active system of the radiators as heat-emitters is supplemented by a passive system of stack ventilation, which allows residents the possibility to adjust vents for airflow located between radiators and windows. These possibilities for a precise adjustment of one's thermal comfort, which the architecture offers, provide good opportunities to potentially conserve energy resources.

Another interesting feature of the apartments of *Terassitalo* is the comparison between the privacy of rooms receiving morning light and the shared space of the living room which receives daylight during the afternoon with possibilities for residents to get together later during the day. The larger living room provides possibilities for several parallel activities, and in this way, resembles the shared "tupa" space found in traditional Finnish farmhouses, although the traditional "tupa" includes the kitchen or cooking facilities, separated in this case. A further refinement that is evident from this study is how an area southwest of the living room is shaded during the early afternoon to provide a darker niche.

Organising rhythms of life in the apartment according to seasonal and diurnal rhythms (e.g. bedrooms on east, living spaces used in the afternoon on the west, in the northern hemisphere) can result in reduced energy use, as the layout takes advantage of light and solar radiation where and when it is needed, restricting it where it should be avoided.

Despite the climate warming due to climate change since the construction of these housing projects more than 80 years ago, and the different lifestyles of the occupants, these apartments still present qualities that are beneficial to the current residents. These apartments have enduring qualities as a result of a design that can adapt to the dynamic variations of an ever-changing environment.

The qualities identified in these case studies may be ascribed to current notions of sustainable architecture, and are relevant as we strive to learn lessons for housing design today and in the future. The following characteristics summarise the lessons of this study for current and future housing design:

Orientation: A thoughtful and precise consideration of the orientation of the architecture and the potential use of spaces at different times of day, responds to the shifting positions of the sun during both an annual and diurnal cycle.

Vegetation: Develop a relationship with vegetation outside to provide shade during warmer periods, and to let in sunlight during colder periods (if these are deciduous trees), and to provide a healthy microclimate with comfortable humidity.

Empowerment: Provide residents with opportunities to adapt to their thermal situation inside by adjusting light, heat, and also a passive system of ventilation. Allow these possibilities to be as straightforward and obvious to control as possible.

Passive strategies: Let strategies for affecting the indoor environment be as passive as possible, avoiding the use of energy. Strategies that need to be active, such as heating in a colder climate, should be minimised, and passive and active strategies should work together, as with the natural ventilation in these examples aided by the radiators.

Thermal enjoyment: Housing not only provides protection from the environment, but also allows one to experience the variations of the environment as a way of connecting with nature for a richer and more meaningful daily life.

Further research

Research identified in the future includes studying the technical aspects of the housing case studies, for example, modelled and actual energy use of the dwellings, including impact of the building geometry (e.g. the staggered effect), solar radiation, effectiveness of solar shading, HVAC system performance, in-situ U-value monitoring of the construction and resident satisfaction. Future studies should also include understanding the effect of historic alterations of the buildings (e.g. heating systems, additional insulation) and implications of changed expectations of comfort. These studies would benefit from identifying and learning from the engineers involved in these buildings, both concerning construction as well as HVAC. Finally, the housing case studies should also be compared (technically, environmentally, resident satisfaction etc.) with other relevant housing case studies from a similar period, but also compared to current housing projects to fully understand the successful, and transferable sustainable housing design principles to the present day.

Acknowledgements

We wish to express our sincere gratitude to the residents of the studied apartments for allowing us to conduct these field studies. We also wish to thank Raúl Castaño-Rosa and Mohammed Elsayed of the *Sustainable Housing research group* ASUTUT of Tampere University for valuable help and advice.

References

AAA = The Alvar Aalto Archive, Jyväskylä.

Aalto, A., 1926. From Doorstep to Living Room. In: G. Schildt, ed. 1998. *Alvar Aalto in his own words.* Translated from Finnish by T. Binham. New York: Rizzoli. pp. 49-55.

Aalto, A., 1930a. The Housing Problem. In: G. Schildt, ed. 1998. *Alvar Aalto in his own words.* Translated from Finnish by T. Binham. New York: Rizzoli. pp. 76-84.

Aalto, A., 1930b. The Stockholm Exhibition 1930. In: G. Schildt, ed. 1998. *Alvar Aalto in his own words.* Translated from Finnish by T. Binham. New York: Rizzoli. pp. 71-76.

Aalto, A., 1938. Sunilan sulfaattiselluloosatehdas. *Arkkitehti*, 1938, 10, pp. 145-160.

Aalto, A., 1939. Portaaton kerrostalo. *Arkkitehti,* 1939, 11/12*,* pp. 161-165.

Aalto, A., 1940. Erik Gunnar Asplund. In: G. Schildt, ed. 1998. *Alvar Aalto in his own words.* Translated from Finnish by T. Binham. New York: Rizzoli. pp. 242-243.

Banham, R., 1969. *The Architecture of the Well-Tempered Environment.* London: Architectural Press.

Bone, K. ed., 2014. *Lessons from Modernism, Environmental Design Strategies in Architecture 1925-1970*. New York: Monacelli Press.

Calder, B., 2021. *Architecture: From Prehistory to Climate Emergency*. United Kingdom: Pelican.

Domhardt, K. S., 2012. The garden city idea in the CIAM discourse on urbanism: a path to comprehensive planning. *Planning Perspectives,* 27:2, 173-197. https://dx.doi.org/10.1080/02665433.2012.646768.

Finnish Meteorological Institute. 2019. *Climate in Finland has become warmer.* Available at: Climate Guide website https://www.climateguide.fi/articles/en-suomen-ilmasto-on-lammennyt#moreelsewhere [Accessed 12 January 2023].

Fleig, K. ed., 1963. *Alvar Aalto - Das Gesamtwerk / L'oeuvre complète / The Complete Work. Bind 1.* Zürich: Verlag für Architektur (Artemis).

Gauzin-Müller, D., 2012. A Short History of Sustainable Architecture. in: H. Drexler and S. El Khouli, ed. 2012. *Holistic Housing, Concepts, design strategies and processes*. Munich: Detail Business Information GmbH. pp. 10-19.

Giedion, S., 1959. *Space, Time and Architecture: The Growth of a New Tradition.* 3rd edition. Cambridge Massachusetts: Harvard University Press.

Hawkes, D., 2020. *The Environmental Imagination.* 2nd ed. London and New York: Routledge.

Hawkes, D. and Lawrence, R., 2021a. Climate, comfort, and architecture in Elizabethan England: an environmental study of Hardwick Hall. *The Journal of Architecture,* 26:6, pp. 861-892. https://dx.doi.org/10.1080/13602365.2021.1962389.

Hawkes, D. and Lawrence, R., 2021b. Describing the historic indoor climate: thermal monitoring at Hardwick Hall. *Architectural Science Review,* 64:3, pp. 293-316. https://dx.doi.org/10.1080/00038628.2020.1856032.

Hyde, R., Upadhyay, A. K. and Treviño, A., 2016. Bioclimatic responsiveness of La Casa de Luis Barragán, Mexico City, Mexico. *Architectural Science Review,* 59:2, pp. 91-101. https://dx.doi.org/10.1080/00038628.2015.1094389.

Jetsonen, J. and Jetsonen, S., 2004. *Alvar Aalto Apartments.* Hameenlinna: Rakennustieto Publishing.

Jetsonen, S., 2004. The Core of Culture, Themes in Alvar Aalto's Residential Architecture. In: J. Jetsonen and S. Jetsonen. 2004. *Alvar Aalto Apartments.* Hameenlinna: Rakennustieto Publishing. pp. 17-20.

Joedicke, J., 1990. *Weissenhof Siedlung Stuttgart.* 2nd ed. Stuttgart: Karl Krämer Verlag.

Lehtovuori, O., 2008. *Suomalaisen asuntarkkitehtuurin tarina / The Story of Finnish Housing Architecture.* Helsinki: Rakennustieto Publishing.

Linkosalo, T., Häkkinen, R., Terhivuo, J., Tuomenvirta, H. and Hari, P., 2009, The time series of flowering and leaf bud burst of boreal trees (1846-2005) support the direct temperature observations of climatic warming. *Agricultural and Forest Meteorology,* Vol. 149, Issues 3–4, pp. 453-461.

Lund, N.-O., 1991. *Nordisk Arkitektur.* København: Arkitektens Forlag.

Korvenmaa, P., 1989. *Kauttua. Tuotanto ja ympäristö 1689-1989*. Finland: Ahlström.

Korvenmaa, P. ed., 2004a. *Alvar Aalto Architect. Vol. 7: Sunila 1936-54*. Helsinki: Alvar Aalto Foundation / Alvar Aalto Academy.

Korvenmaa, P., 2004b. Modern Architecture Serving Modern Production. In P. Korvenmaa. ed. 2004. *Alvar Aalto Architect. Vol. 7: Sunila 1936-54*. Helsinki: Alvar Aalto Foundation / Alvar Aalto Academy. pp. 9-22.

Malmberg, J., 2018. Preface. in: M. Hipeli, ed. 2018. *Alvar Aalto, Kauttua, teollisuus- ja asuinalue, Industiral and Residential Area, Kauttua, Eura.* Jyväskylä: Alvar Aalto Museum. pp. 3-5.

McCarter, R., 2014. *Aalto*. London and New York: Phaidon

Miller, W. C., 2016*. Nordic Modernism, Scandinavian Architecture 1890-2015.* Wiltshire, UK: The Crowood Press.

Mikkola, K., 1980. Finland: På spaning efter nutiden. in: G. Lundahl, ed. 1980. *Nordisk Funktionalism.* Stockholm: Arkitektur Förlag. pp. 56-75.

Morgan, M. H., 1914. *Vitruvius.* Cambridge: Harvard University Press.

Mumford, E., 2002. *The CIAM Discourse on Urbanism, 1928-1960.* Cambridge Mass. and London, England: the MIT Press.

Mumford, E., 2014. Alvar Aalto's Urban Planning and CIAM urbanism. In: M. Kries and J. Eisenbrand, ed. 2014. *Alvar Aalto, second nature.* Germany: Vitra Design Museum. pp. 278-309.

Mustonen, T and Wasastjerna, R., 2010. *Sunilan asuinalueen korjausohjeisto.* Available at: https://www.alvaraaltosunila.fi/fi/ohjeet [Accessed 13 January 2023].

Neuvonen, P., Mäkiö, E., and Malinen, M., 2002. *Kerrostalot 1880-1940.* Helsinki: Rakennustieto.

Norberg-Schulz, C., 1993. *Nightlands: Nordic Building*. Translated from Norwegian by T. McQuillan, 1996. Cambridge, Massachusetts and London, England: The MIT Press.

Pallasmaa, J., Toward a Synthetic Functionalism. In: P. Reed, ed. 1998. *Alvar Aalto, Between Humanism and Materialism.* New York: The Museum of Modern Art, New York. pp. 20-45.

Pallasmaa, J., Rationality and Domesticity. In: J. Pallasmaa, ed. 2003. *Alvar Aalto Architect. Vol. 6: The Aalto House 1935-36.* Helsinki: Alvar Aalto Foundation / Alvar Aalto Academy. pp. 56-81.

Pelkonen, E.-L., 2009. *Alvar Aalto, Architecture, Modernity, and Geopolitics.* New Haven and London: Yale University Press.

Pirinen, P., Simola, H., Aalto, J., Kaukoranta, J.-P., Karlsson, P. and Reija, R., 2012. *Tilastoja Suomen ilmastosta 1981–2010/Climatological statistics of Finland 1981–2010.* Helsinki: Finnish Meteorological Institute. Available at: https://helda.helsinki.fi/bitstream/handle/10138/35880/Tilastoja_Suomen_ilmastosta_1981_2010.pdf?sequence=4&isAllowed=y [Accessed 27 August 2023].

Pisani, J. A. D., 2006. Sustainable development – historical roots of the concept. *Environmental Sciences,* 3:2, 2006. pp. 83-96. https://dx.doi.org/10.1080/15693430600688831.

Porteous, C., 2002. *The New Eco-Architecture.* London and New York: Spon Press.

Schildt, J., 2007. *Alvar Aalto: his life.* Jyväskylä: Alvar Aalto Museum.

Steele, J., 2005. *Ecological Architecture, A Critical History.* United Kingdom: Thames & Hudson.

Treib, M., Aalto's Nature. In: P. Reed, ed. 1998. *Alvar Aalto, Between Humanism and Materialism.* New York: The Museum of Modern Art, New York. pp. 46-69.

Weston, R., 1995. *Alvar Aalto.* Hong Kong: Phaidon.

Wickberg, N. E., 1965. *Finnish Architecture*. Helsinki: The Otava Publishing co.