RECONFIGURING WORKSPACE CONFIGURATIONS FOR A SUSTAINABLE FUTURE

Understanding the links between new working trends and the sustainability of workspaces in a post pandemic reality

P5 REPORT

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Abstract:

Climate change is advancing at an unforeseen pace, with the built environment responsible for 40% of global emissions. With the acceptance of climate risk as a financial risk, market participants bear the responsibility of mitigating this problem. Office real estate plays a crucial role as a sustainable workspace is also crucial in its retention of talented workforce. With hybrid working expected to become a non-negotiable fixture of the workplace ecosystem, the office of the future is very different. The relationship between employees and the workspace continuously shifts due to changing occupancy patterns that stem from these evolving working processes, which in turn impacts the energy consumption of a building. This thesis attempts to understand the impact of hybrid working processes on the energy consumption of workspace environments using a quantitative research design to answer the following research question: ***How is the energy consumption of the workspace environment impacted by hybrid modes of working?*** The methodology includes data from a literature review, synthetic data simulations and occupancy and energy data from two case studies. The results demonstrate that there are benefits from employing a hybrid working model, provided offices are equipped or retrofitted to ensure their energy usage can respond to the dynamic occupancy levels. Furthermore, workspace design should reflect and cater to the diverse habits and preferences of the end user to ensure efficient use of space. However, these benefits are not equitably distributed as the energy saved is offset onto the end user thereby widening the existing inequalities in place. Future design and policy should consider user, building, campus and city scale solutions to create a balanced and sustainable outcome that benefits society as a whole. A system mapping identifying the different impact areas of hybrid working and their interdependencies has been formulated to support improved management of building assets for real estate professionals and business.

Keywords:

Corporate real estate, workspace, employee well-being, hybrid working, energy consumption, sustainability.

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List of abbreviations

BES – Building Energy Simulation

BMS – Building Management System

CRE- Corporate Real Estate

CREM – Corporate Real Estate Management

ETS- EU Emissions Trading System

FTE- Full Time Employee

KPI- Key performance Indicators

NeWSPs- New Working Spaces

NZE- Net Zero Emissions

PMS- Performance Management System

RE- Real Estate

TCO- Total Costs of Ownership

WFH- Hybrid working

WFO- Work from office

Chapter 01

Introduction

According to the International Panel on Climate Change report (2022), emissions have peaked and need to reduce by 43% by 2030 to remain below the 1.5°C rise threshold. The built environment is critical to this, with an added urgency in commercial real estate due to its complexity. While governments world over are setting plans in to motion to move to a net zero economy, real estate needs to make bolder and urgent moves.

1.1. Climate Change and the built environment:

90% of global GDP is now linked to a net zero carbon target of some kind. UNEP (2022) states that decarbonising the built environment is crucial since energy-related emissions from building operations and operational demand of buildings have increased by 2-5% compared to pre- pandemic levels.

1.2. Real estate and the sustainability:

Commercial and real estate sector contribute to almost 60% of global emissions with this percentage higher in some of the largest global business centres (Figure 1). While city governments worldwide are setting ambitious targets for a net zero economy, these remain aspirational unless proactive efforts are taken by multiple collaborators – including market actors (JLL, 2022).

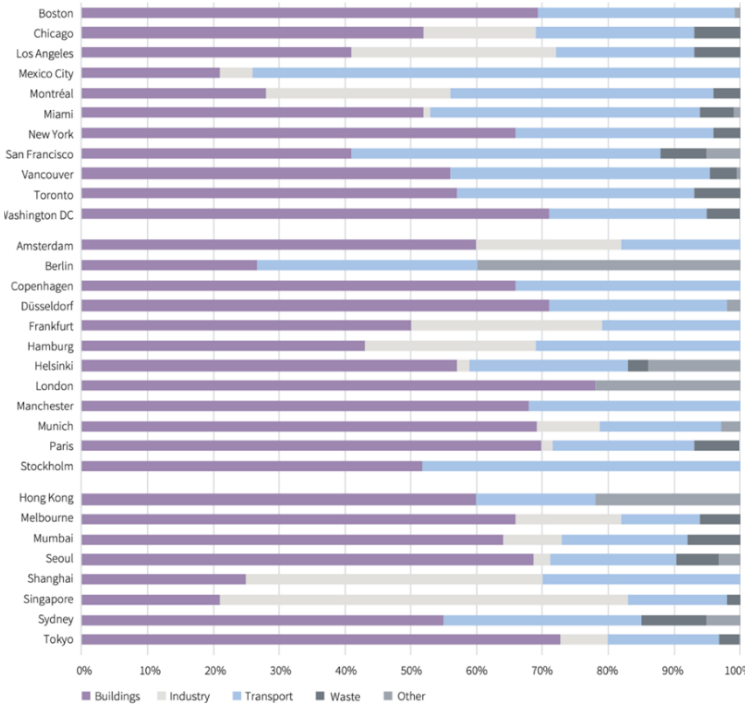


Figure 1 Share of Emissions by User Sector (JLL, 2022a)

1.3. Problem Statement

Office real estate is critical to a sustainable future (Zhang et al., 2022) as expanding office sizes and increased occupancy has resulted in substantial increases in energy use in office buildings. Decreasing CO_2 emissions is contingent on improved energy efficiency (Worrell et al., 2001), lowering office buildings' carbon footprint and, therefore, counteracting climate change. The sector can also positively impact the health and wellbeing of employees. Workers are motivated to work for organisations that provide a sustainable lifestyle for themselves but also make a positive impact on the community (JLL, 2022b). Corporates are hence necessitated to **anticipate change** and **future proof** their portfolios to mitigate the risk of asset stranding.

Historically, the office has been a congregation space where people gather to do one job primarily- work. This has changed drastically with the pandemic, as work has extended to the personal confines of one's home. While companies' world over are still in the process of adjusting work processes, it is quite clear that remote working with its many advantages will continue to be a be part of future working processes.

De Paoli & Ropo (2015) emphasise that offices remain central to workspace functions and will not disappear but must be re-configured for a healthy environment. Office use and performance is intrinsically linked to occupancy patterns and this newly emerging blended working strategy is bound to have impacts at a building and portfolio level (Mantesi et al., 2022). Recent studies on hybrid working have primarily focussed on employee performance and productivity, while side-lining its impacts on the energy performance of space.

This thesis attempts to study the link between hybrid working processes, its impact on the workspace environment and its role in the transition to a sustainable future with the following research question:

Main RQ: How is the energy consumption of the workspace environment impacted by hybrid modes of working?

1.4. Research sub questions:

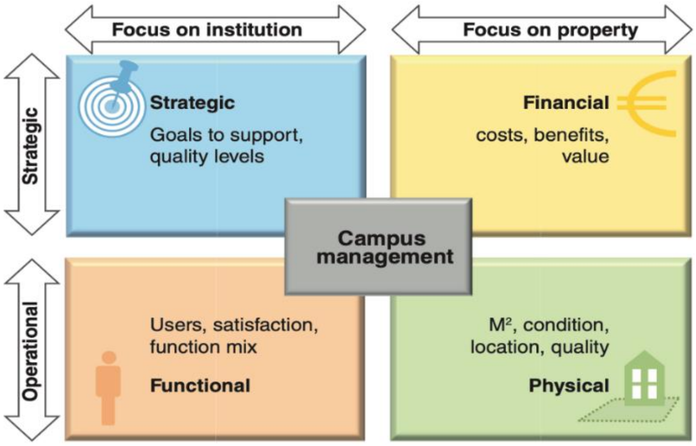


Figure 2 Four stakeholder perspective (A. C. Den Heijer, 2021)

Freeman & McVea (2001) mention that a successful strategy integrates the interests of all stakeholders rather than emphasizing one. The four-stakeholder perspective scheme (Strategic, Functional, Physical and Financial) as developed by Den Heijer, (2021) is referenced to address variables that might be overlooked. The research sub questions are thus formulated along these 'players'.

According to Gratton (2021) adjusting the workspace configuration for new working processes requires intentionality. Part of this intentionality involves identifying and accommodating the trade-offs of these emerging trends while also being willing to take risks. This will be explored using the following research question:

- SQ1: What is hybrid working?
- SQ2: How has the definition of a 'workspace' evolved due to hybrid working?

"Spatial hybridity changes the nature of work, organization and management in domestic space, cyberspace and organizational space" (Halford, 2005).

Due to the interconnection between office space performance, employee wellbeing and occupancy patterns, it is critical to understand the evolution of workspace environments resulting from hybrid working. This addresses a combination of functional and physical perspectives, explored using the following sub question:

- SQ3: How has hybrid working impacted the use office space?

One of the consequences of hybrid working is the dynamic demand that arises out of it. It is also important to account for rebound effects that impact energy performance of space when mediated by hybrid working. This is explored using the following sub question:

- SQ4: How is the energy footprint of a user impacted by the dynamic occupancy that results from hybrid working?

The impacts on the fourth stakeholder, the financial player will not separately be analysed due to the limitations of this thesis.

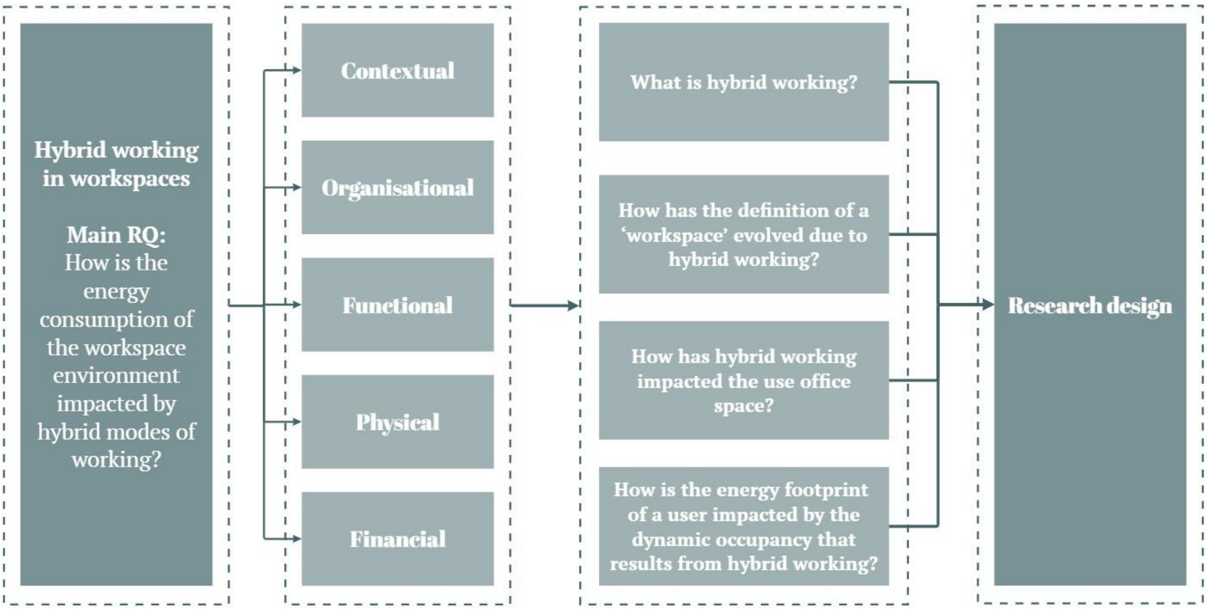


Figure 3 Research questions (Author)

1.5. Conceptual model

The research proposal is visualised using the conceptual model below, where the relationship between energy consumption and the workspace environment is to be determined, with hybrid working being the moderating variable between the two.

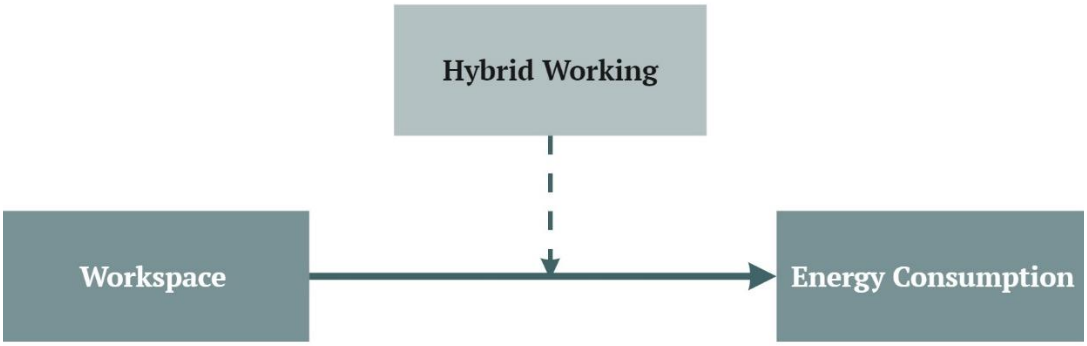


Figure 4 Conceptual model (Author)

Chapter 02

Theoretical background

This chapter is a summary of the literature review on hybrid working and its implications on workspaces, thus forming the theoretical foundation of this thesis. It concludes with a conceptual adapted from Den Heijer (2012), and identifies the Key Performance measures that will be studied and evaluated in the subsequent stages of the research.

Remote working, though prevalent now, is not a new phenomenon. Frequently referred to as teleworking, it originated in the early 1970's because of the energy crisis which impacted work travel and was facilitated by advancing digital technologies (Torten et al., 2016).

2.1. Teleworking or remote working:

The European Framework Agreement on Telework (2002) defines telework as "*a form of organising and/or performing work, using information technology, in the context of an employment contract/relationship, where work, which could also be performed at the employer's premises, is carried out away from those premises on a regular basis".*

It was never the primary choice prior to the pandemic with only 3% of the EU workforce opting for it in 2019, Eurostat (2021). The main reasons for this included underlying structures and features of certain jobs and tasks, limited infrastructure and technology available at the time, and market failures in work organisation. This was precipitated by the lack of trust by managers for employees who considered remote working to be a loss of control and reduced coordination (Grzegorczyk et al., 2021).

2.2. Hybrid Working:

While companies are now pushing for employees to return to offices, our understanding of work and workspace has been completely overhauled by the pandemic.

2.2.1. What is Hybrid Working?

Halford (2005) defines hybrid working as when individuals work both at home and in embodied organisational spaces; with working relationships being conducted both virtually and in proximity. Hybrid workspaces are not "*simply relocated or dislocated, but multiply locate"'* which results in synchronous and asynchronous phases of work.

The following sections summarise the effects of adopting remote working models in workspaces.

2.2.2. Impacts on Employee Relations:

The impacts of hybrid working on employees revealed mixed results.

Babapour Chafi et al. (2021) reported increased empowerment and work satisfaction resulting from enhanced individual productivity, flexibility, and autonomy in designing and adjusting work time and processes to meet individual needs. There was better cohesion amongst geographically distributed teams as remote working technologies increased interactions.

Conversely, Halford's (2005) study reports increased overworking, anxiety, and conflicts due to high levels of scrutiny and self-discipline that homeworkers subjected themselves to. This stress was compounded by socio-spatial isolation of working from home, affecting the informal networks that were central to work life.

Babapour Chafi et al (2021) also report strained social ties induced by remote working- including social and professional isolation resulting from limited spontaneity and informal social interaction. This also resulted in risks to career progression, lengthy workdays, exhaustion from nonstop online meetings, elevated emotional tiredness, inadequate line manager supervision, increased cognitive stress/overload, and musculoskeletal health issues. Another source of frustration was the lack of access to the required technical support and infrastructure. Monotony was another commonly reported symptom due to the lack of stimulation and input one received in office. However, it is important to note that these negative effects might have been magnified by the extreme measures in place due to the COVID-19 pandemic.

A study by L. Yang et al., (2021) shows that remote work can impede collaboration and innovation, *"as workers' networks become more static and siloed, with fewer bridges between disparate parts of an organisation"* (Babapour Chafi et al., 2021: 2). Employees found it harder to convey and agree on complex information and build relationships across online formats, resulting in limited group creativity. The decreased weak ties also led to reduced access to new information, and obstructed innovation.

However, Breideband et al., (2023) report that the 4 C's of a team: **communication, coordination, cohesion and climate** are unrelated to work location. Location played a role in team conflict; as participants who worked from a private room at home reported lower team conflict than those who worked in the office, due to a better control over disruptions and space.

2.2.3. Impacts on Employer- Manager relations:

Similar mixed results were found for the impact of remote working on employee- manager relations. Giovanis (2018) concludes that there is a direct relationship between workplace performance and the quality of managerial relations with employees. De Paoli & Ropo (2015) state that the challenges of leadership are magnified in virtual environments, resulting in reduced collaboration, socialization and overall team effectiveness.

According to Babapour Chafi et al. (2021) managers had more time for reflection and strategic work due to reduced commuting, as well as increased collaboration and knowledge exchange between geographically distributed managers. Halford (2005) however reports that managers were unable to rely on "*proximate, visual, or embodied relations with staff*", emphasising close link between space and management.

Intensified control mechanisms led to feelings of micromanagement which had to be consciously overcome through trust-based leadership styles and avoiding control and traditional oversight (Babapour Chafi et al., 2021). While establishing loyalty across distributed groups was difficult, managers also found it challenging to identify and address employees' issues in a remote work context and struggled to let go of control while also providing support and fulfilling their responsibilities. Professional, organisational, cultural, and linguistic barriers are accentuated by physical distance and virtual communication. Supervisors who did not interact often with subordinates were observed to exhibit formal and aloof leadership.

Physical presence and co-location in open-plan offices are critical to being a good leader and building trust for effective collaboration in remote teams (De Paoli & Ropo, 2015). They also stress the importance of workspaces that stimulate face-to-face teamwork and communication when organisations have many virtual teams, referred to by them as *'spatial leadership'.*

"Leadership, in a virtual team, does not rely on a designated leader's competencies but is constructed and maintained by the team members' experiences of workspaces" (De Paoli & Ropo, 2015).

2.2.4. Impacts on organisational culture:

Organizational culture comprises the shared beliefs, values, and interaction methods that shape an organization's social environment (Wong, 2023).

As per Edward T. Hall's cultural iceberg model, most corporate culture components such as unwritten norms, interpersonal interactions, and status in the workplace, are invisible below the surface. Babapour Chafi et al., (2021) reveal a weakened shared culture and a general disconnect from the organisation when working remotely as these culture components take a hit. According to Grzegorczyk et al. (2021), this can be overcome by making these values prominent in the hybrid environment and adopting a trust-based relationship. Organisations must collectively optimise the coordination of individual flexibility to ensure seamless operations in hybrid set ups. Flexibility should shift from being role-based to task-based, where individual flexibility doesn't compromise collective operations.

However, Aksamija & Milosevic (2023) reveal that 'flexibility' of post pandemic workspaces was not universally celebrated, as many feared it could lead to a diminished sense of belonging and a weakened work culture if everything became temporary and in constant flux.

2.2.5. Why is Hybrid Working here to stay?

Hybrid working was found to be qualitatively different from full time teleworking due to the spatial management of workloads and the option to engage in proximate interactions, with self-managed control resulting in fewer reported intrusions into domestic space (Halford, 2005). Hybrid work offers enhanced opportunities for both spontaneous and planned social interactions, which strengthen group cohesion, facilitate knowledge exchange, promote collective learning, and encourage creative collaboration. Additionally, when office spaces and integrated digital technologies are aligned with the evolving needs of employees, they can effectively balance the changing work culture and mitigate the negative effects of remote working (Babapour Chafi et al., 2021).

"Rather than thinking of the office as a place primarily for solitary activity, from which one occasionally breaks out in time and space to settings intended for social activity, the office might be designed primarily as a social setting, from which one occasionally seeks out more private places for contemplation, concentration, and confidentiality." (Becker, 2002: 147)

According to Appel-Meulenbroek et al. (2022), hybrid work also provides access to a wider pool of talent, reduced space needs and lower operation costs and other expenses connected with maintaining a physical office due to dynamic schedules and fewer personnel in the office. However, if office environments seem uninspiring, insufficient, or less comfortable than their remote workspaces, employees may become disinclined to use them. It is hence critical to evaluate the spaces available and consider the jobs that employees do, the degree of cooperation necessary between personnel, and the technology and types of spaces employees require to be successful (Babapour Chafi et al., 2021).

2.2.6. The influence on office space:

Halford's (2005) study on hybrid workspace suggests a reclassification of work tasks into the office stream and the home stream. The home stream, where isolation helped with fewer distractions, had less need for peer or managerial support because the tasks were frequently straightforward and followed bureaucratic or technical norms. In contrast, the office stream involved team and managerial support, assistance, or training for unfamiliar tasks. Organisational space was hence characterised by challenging forms of work which necessitated interaction with other employees.

Workers demonstrate improved engagement, performance, and co-ordination when they are physically collocated (Olson & Olson, 2014), due to the frequency of informal interactions that can lead to productive team outcomes (Kraut et al., 2002). The combination of workspaces (office and home) produced favourable outcomes since the maintenance of office space enabled staff and managers to meet various needs for face-to-face interactions.

Those who work solely at home had difficulties ending the day as time shifted from being clock-based to task-based (Steward, 2000). However, this was found to be different in Halford's (2005) study as clock-based time boundaries overrode the lack of spatial boundaries. These findings indicate that these workers—operating in hybrid workspace—maintain two distinctive sets of working practices both in terms of what they do in the different spaces of their working lives, and how they do it. Appel-Meulenbroek et al.'s (2022) study on the influence of noise perceptions, crowdedness, and furniture layouts on worker decisions, indicates that employees make conscious choices in relation to available office and home workspace designs.

Table 1 below summarises the advantages and disadvantages of hybrid working at different organisational levels, from the literature review so far.

Category	Employee	Employee- manager	Organisational
Advantages	Productivity Flexibility Autonomy on how and when to work Reduced commute Increased Empowerment Work satisfaction	More time for reflection More time for strategic work Reduced commute	Better cohesion among geographically distributed teams Increased collaboration Increased knowledge exchange Wider talent pool Reduced space needs Lower operational costs
Disadvantages	Overworking Anxiety Conflicts Isolation Strained social ties Inadequate supervision Increased monotony Risks to career progression	Micromanagement Inability to identify issues Struggle to let go of control	Weakened shared culture General disconnect from organisation Reduced collaboration Limited creativity
Recommendations	Physical presence and co-location with other team members	Spatial leadership	Trust based leadership Flexibility Adaptability User oriented evaluation of solutions

Table 1 Advantages and disadvantages of hybrid working (Author)

2.2.7. Implications for CREM:

Organizations are increasingly investing in innovative offices to support more nomadic, group-based, flexible, or remote working styles (Davis et al., 2011). However, solutions must be unique, customised (Van Koetsveld & Kamperman, 2011) and evaluated from a user perspective (Hansen et al., 2011, Lindahl et al., 2013).

Aksamija & Milosevic's (2023) studies evoke similar results and emphasise user inputs on work patterns and social structure as being central to proposed spatial reconfiguration and repurposing strategies. The traditional set-up office is undesirable for conducting work in a changing work culture. Offices are hence evolving into places for team collaboration client meetings, and occasional independent work, while individualized tasks are primarily conducted remotely or from home.

Mantesi et al. (2022) state that the future office will mainly function as a place for solidarity, community building, knowledge exchange, social interaction and to create a feeling that employees are part of something bigger. Offices are expected to become a social hub with changes in the ratio between collaborative and focused-work zones. Activity based working environments are expected to increase as they can support a more dynamic and flexible way of working that is anticipated in the future.

Flexibility – in many forms – is a highly regarded commodity and corporates should strive to incorporate them into hybrid working policies (Holberton & Fraser, 2023). In addition to a company's dedication to work-life balance, flexibility was cited as an important factor by 40% of respondents worldwide and in Europe for evaluating career prospects. Offering a suitable degree of flexibility in work schedules is essential to a business's Employee Value Proposition and capacity to draw in new employees.

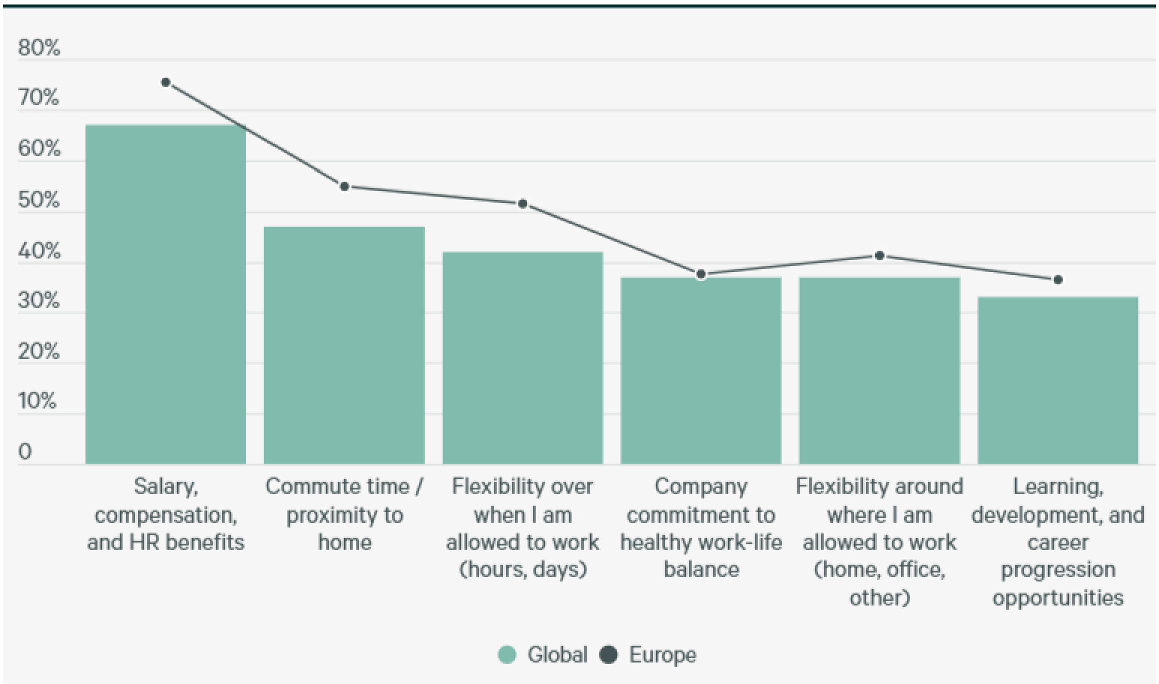


Figure 5 Primary factors in assessing future job opportunities (Holberton & Fraser, 2023)

2.2.8. The Future of the Workspace:

The above sections reinforce that offices remain central to workspace functions but need to be configured to ensure a healthy environment by catering to the specific requirements of the end user.

Due to the dynamic demand induced by the hybrid model, it is critical to incorporate flexibility within the ownership/ leasing model of office space as this protects companies from the risks associated with a distributed workforce. This flexibility will be key to most real estate strategies going forward with CBRE (2022) reporting that 82% of building occupiers surveyed prefer flexible office space options when they select buildings. The configuration and usage of space are also impacted by this new trend of hybrid working, which is expected to reverse the decades-long trend of densification (Mantesi et al., 2022).

While the literature review thus far has focussed on the functional aspects of hybrid working, very limited research has explored the consequence of hybrid working on the energy consumption of a building. The next section therefore attempts to see if any such link exists in scientific publications.

2.3. Office Workspace and Energy Consumption

Mantesi et al., (2022) claim that changing work processes have both technical and social dimensions. This is a hence a crucial time to redefine the office to support flexibility while also producing more energy efficient buildings.

2.3.1. Energy Performance of the built environment:

Over 1/3rd of worldwide energy consumption and emissions are attributed to buildings. Furthermore, the energy use in this sector increased by about 1% in 2022, with 35% of the energy due to electricity - a jump from 30% in 2010. Fossil fuel usage has also increased at an average annual growth rate of 0.5% since 2010 (IEA, 2023).

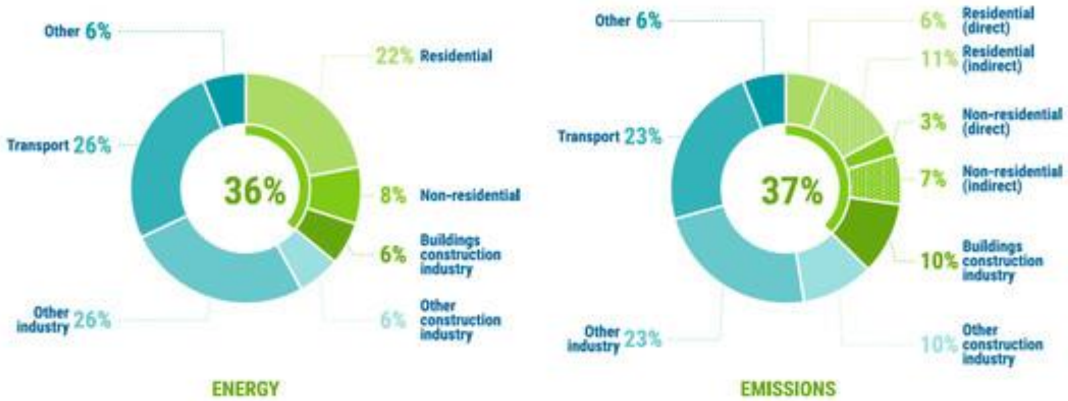


Figure 6 Construction Industry's Share of Global Final Energy and Energy-Related CO2 Emissions (UNEP, 2021)

To align with the Net Zero Energy (NZE) Scenario the building sector will need to reduce emissions five times faster in the upcoming decade compared to before. This means that the energy consumption per unit area in 2030 needs to reduce by approximately 35% (Santamouris & Vasilakopoulou, 2021). These numbers emphasise the importance of making the built environment as energy efficient as possible.

Global CO2 emissions saw the biggest fall till date of about 6% during the pandemic (UNEP, 2022). While direct emissions from the built environment saw a minor fall in 2022 compared to the previous year, the emissions related to the operational energy of a building increased by about 5% in 2021, amounting to a total of approximately 10Gt CO2 emissions, captured in figure 7.

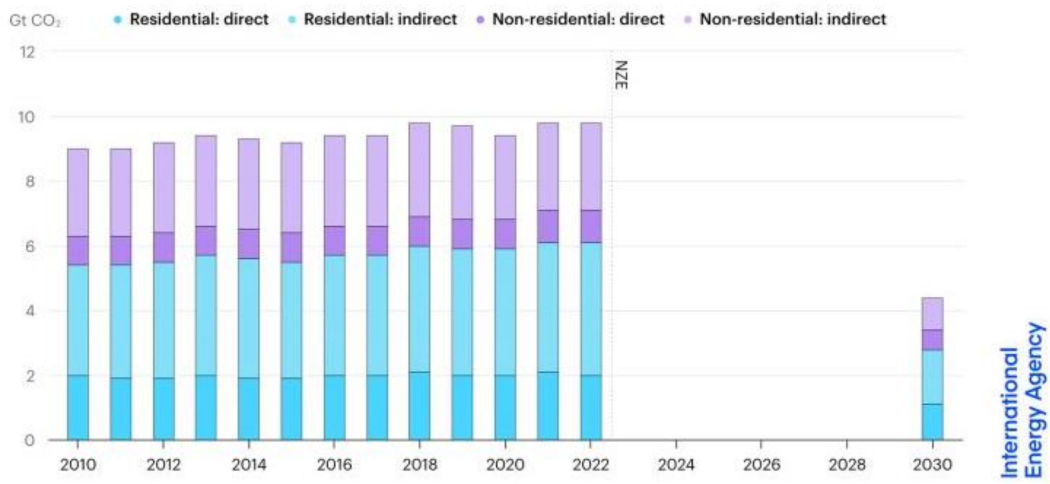


Figure 7 Global CO2 Emissions from Operation of Buildings (IEA, 2023)

Within the European Union, the EU Emissions Trading System (ETS) is a market instrument that is central to its climate change strategy, serving as its primary means of reducing greenhouse gas emissions in a cost-effective manner using a ‘cap and trade’ principle. The 2023 revisions of the ETS Directive introduced a new system called ETS2, distinct from the EU ETS which targets CO2 emissions from fuel combustion in buildings, road transport, and additional sectors, particularly small industries not covered by the existing EU ETS. This system aims to complement the European Green Deal's policies in these sectors and assist Member States in meeting their emission reduction goals outlined in the Effort Sharing Regulation (ESR).

Given the inadequacy of emission reductions in these sectors thus far, ETS2 will set a carbon price to incentivize investments in building renovations and low-emission transportation, contributing to the EU's objective of achieving climate neutrality by 2050. Furthermore, as part of the ETS2, all emission allowances will be auctioned, with a portion of the proceeds allocated to a Social Climate Fund (SCF) to assist vulnerable households and micro-enterprises. Member States must utilize the rest of the revenue from ETS2 auctions for climate action and social initiatives, and they are obligated to report on the allocation of these funds (European Commission, n.d.).

2.3.2. Why should offices be energy efficient?

Office buildings have some of the largest energy requirements, ranging from 100 to 1,000 kWh/m2 per year in Europe (Dubois & Blomsterberg, 2011), with energy use attributed to growth in information technology, air conditioning, or density of use (Schneider Electric, 2006).

It is imperative to study and understand occupancy patterns in offices since the performance of a building is significantly impacted by human behaviour. Reducing energy consumption in offices is advantageous for businesses, yielding cost savings, enhancing corporate reputation, and contributing to climate change mitigation. Office real estate, a major business expense, can be optimized to significantly improve employee satisfaction, thereby boosting performance and well-being (Mantesi et al., 2022). Despite these benefits, many companies have been hesitant to adopt energy effect measures in offices due to previously held misconceptions that this could affect the productivity, well-being, and overall comfort of the end user (Schneider Electric, 2006).

Kozusznik et al.'s (2019) results are a useful reference for stakeholders keen to implement green building solutions, adopt energy-saving measures in offices and improve employees' functioning. They provide evidence for the rationale of investing in energy saving and sustainable solutions in office buildings from a user centric approach – with results of increased productivity and, therefore, economic gains for businesses. Improving workers' comfort and productivity is contingent on increasing their awareness and developing devices that encourage energy-saving behaviours. The key factors that influence the relationship between sustainable buildings and employee outcomes include occupants' control, adaptive behaviour, facility management services, training in building features, and access to private workspaces. These elements play crucial roles in promoting energy efficiency and enhancing the well-being of occupants in sustainable buildings.

This proves that organisations can implement energy saving measures at different scales- locally at the employee level, apply sustainable solutions to several workstations at the office level or design and refurbish entire office buildings according to low-energy certification, thus minimising the financial risk for companies with limited budgets.

The current shifts in workplace culture provide a valuable opportunity to rethink workspace requirements while integrating energy reduction and climate change agendas into future operations and design. The COVID-19 pandemic has underscored the unpredictability of the future, prompting businesses to prioritize resilience and uncertainty planning in their real estate portfolios. Preliminary studies on teleworking suggest significant savings if a hybrid work structure is adopted. Crow & Millot (2020) report that 1% of global oil consumption can be reduced yearly by teleworking at least once per week with the resulting overall impact being a decline of 24 million tonnes of global CO_2 emissions annually.

2.3.3. Operational energy and the office:

WEF (2021) states that 75% of the existing building stock, which amounts to over 220 million structures, are energy inefficient in Europe alone, as many of them rely on fossil fuels for heating and cooling. The key to ensure a meaningful energy transition involves tackling the biggest carbon emission source - operational energy in buildings (WGBC, 2023).

Operational energy is the energy consumed throughout the occupancy phase of a building's life cycle, encompassing activities such as space and water heating, space cooling, lighting, and the operation of equipment and appliances (Azari, 2019). These emissions account for 28% of all global carbon emissions. Climate change is also contributing to higher utility costs due to more expensive energy production (CBRE, 2023).

Azari (2019) reports over 58% of the operational energy consumption of commercial buildings from activities like space heating (27%), water heating (7%), space cooling (10%), and lighting (14%). Space cooling rose more than 3% due to the rising temperatures, while contrastingly, energy for space heating declined by 4%, due to milder winter in several places, including Europe (IEA, 2023). These numbers also provide evidence for climate change and global warming.

Mantesi et al's (2022) study on the energy performance of a flexible building in UK found the total annual energy consumption was below the pre-COVID-19 standards, despite the many unknowns associated with hybrid working. Energy consumption of buildings can be significantly reduced if future offices combine more collaborative areas and less space for individual focused work, a hybrid model of work and building services that are flexibly tied to occupancy patterns. The key parameter in their study is the utilisation factor or the number of people occupying a space, which is often dynamic during hybrid working. They report that incorporating flexibility in the operation of building services can help reduce the energy consumption of the future office to half of pre-COVID-19 levels.

The improvement in comfort levels and the expansion of human activities have caused 11.18% increase in per capita energy consumption during the past ten years. Furthermore, the spatial layout of many offices nowadays is inefficient due to poor designs that do not incorporate occupant behaviour, resulting in significant energy wastage. Identifying such occupant behaviour can help eradicate such energy wastage and reduce the energy consumption by 26% (Chong et al., 2021).

2.4. Rebound effects:

The energy performance of workspace environment employing hybrid working is also a measure of other factors, referred to as **rebound effects**.

Guerin (2021) defines them as situations where people engage in inside activities (i.e. non work related, such as having the TV on) or additional non-work-related travel, that they would not have undertaken if they were not teleworking. Hook et al's (2020) review of 39 studies study on the effects of teleworking on climate and energy, identifies four areas of impact, i.e. energy used in: (a) commuting; (b) non-work travel; (c) the home; and (d) the office. Most studies indicated a net reduction in energy use and/or emissions with the most common metric being vehicle distance travelled as a proxy for energy consumed by motorised travel. However, studies that had a wider scope (with more impact categories) provided lower estimates of energy savings. Given that PV auto consumption could become bigger in the coming years, this might also have a positive impact, however this is to be explored in further research.

2.4.1. Impacts on distance travelled:

Few studies reported a reduction of about 0.01 to 14% in energy consumption, primarily from **decreased amount of commute** (upto 20%) (Hook et al., 2020). Corresponding benefits included reductions in the number of trips (30%), time savings from reduced congestion (28%) and associated reductions in carbon emissions. Other environmental benefits included reduced pressure on transport infrastructure, lowered pollution emissions, lessening work travel fuel consumption and improved air quality.

In contrast, de Vos et al's (2019) study in the Netherlands using longitudinal data between 2008- 2018 found an increased commute of 12% by teleworkers on average, mostly among moderately urban municipalities, situated between cities belonging to the urban core. This is likely due to their proximity to larger cities, and the presence of good quality infrastructure between large cities.

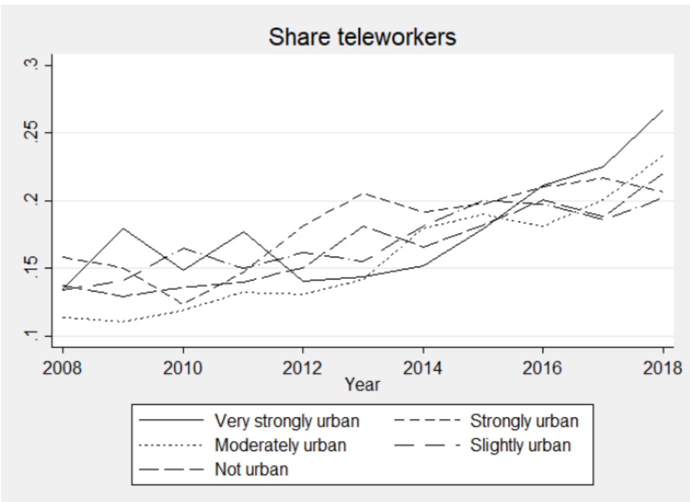


Figure 8 Share of teleworkers across urban levels over time (de Vos et al., 2019)

According to Balepur et al., (1998) and Chakrabarti (2018), gains from eliminating commutes on teleworking days were partly or wholly offset by longer commutes on non-teleworking days. Furthermore, evidence from both the US and Europe suggests that the adoption of teleworking may induce long-term changes in residential location that offset the environmental benefits. Lachapelle et al., (2018) report that the environmental benefits of teleworking will depend upon both the **frequency of teleworking** and **how far** teleworkers live.

Another potential effect of teleworking is the surge of non- work travel as a complementary effect, with Zhu (2012) reporting 10.8% more non-work trips per day for teleworkers over non teleworkers (4.18 versus 3.77) which were, on average, 15.7% longer (36 km versus 32 km). This mostly arises due to an inability to daisy chain or link together non-work trips efficiently. Other reasons include increase in leisure trips, with teleworkers taking advantage of their extra time (Rietveld, 2011). However, Hook et al., (2020) stress that there is no definitive evidence to support that non work travel has rebounded since most studies focus narrowly upon commuter travel while ignoring interactions between teleworking practices and non-work travel.

2.4.2. Impacts on Office Energy Consumption:

The common hypothesis related to teleworking is a reduction in employee's office capital and operational costs due to the shift from energy intensive commercial buildings to more energy efficient residential buildings. Pérez et al (2005) conclude that any energy saved from reduced office occupancy could in fact lead to increased operational energy use at home. If offices do not downscale their real estate portfolios and opt for smaller spaces with decreased energy footprint, the net result of increased teleworking could be increased building energy consumption (Kitou & Horvath, 2008).

In contrast, Hook et al.'s (2020) literature review had many studies that indicated overall energy savings by teleworking due to reductions in per capita office space (e.g. through hot desking) and decreased workspace thermal regulation requirements. Matthews & Williams (2005) estimate that the potential energy savings from reducing office space are comparable to those from reduced commuting. These gains are again dependent on a range of factors, including the extent to which firms downsize portfolios based on the number of teleworkers. Shimoda et al., (2007) stress that for part time teleworkers, companies may need to retain the same sized premises for the days with in-office work, leading to insignificant energy savings. Among the papers reviewed by Hook et al., (2020) the **frequency of teleworking over the course of the week** is crucial in determining impacts and they conclude that full-time (or near full time) telework has the greatest potential for energy savings.

	Nature of impact on energy use and emissions	
Type of effect	*Reduce*	*Increase*
Direct		• Energy consumed in manufacturing, using and disposing of ICT equipment
Higher-order	• Reduction in commuting travel and energy use • Reduction in office energy use	• Increase in weekly travel due to longer commute on non-teleworking days • Increase in non-work travel by teleworker • Increase in energy consumption at home for heating, cooling, lighting and other uses • Increase in travel by teleworking household due to increased availability of car

Table 2 Summary of the direct and indirect impacts of teleworking on energy consumption (Hook et al., 2020)

2.5. Office of the future

The office of the future will be more human-centric than before, combining the best of remote and in-situ work, and facilitated improved communication across the digital and physical work environments. Offices are expected to evolve into "workplace ecosystems" (Molla, 2022) which facilitate *"learning development, collaborating, mentoring, socialising",* thereby offsetting the gaps of remote working. Activity based workspaces which host a diversity of spaces and functions to meet needs of all users are expected to be the norm.

This literature review helped understand current advancements and research on hybrid working and answer the first two sub questions. i.e.:

- SQ1: What is hybrid working?
- SQ2: How has the definition of a 'workspace' evolved due to hybrid working?

A significant gap has been identified with respect to the impacts of hybrid working on the energy performance of the workspace environment. This is critical, given the increasing urgency of climate change. Furthermore, 80% of buildings in the global north that will be in use in 2050 already exist today (Grainger, 2022). With asset refurbishment and renovation expected to gain significant investment in the next few years, it is even more critical to understand the relationship between workspaces, the way they are used and their subsequent energy use, to make informed decisions.

This thesis attempts to aid in this transition by establishing clear evidence of the impacts of these new working processes on overall energy performance, thereby supporting the formulation of comprehensive real estate strategies for business owners and built environment professionals that meet their organizational, economic, and environmental targets.

2.6. System mapping (Conceptual framework):

In order to understand the impacts of hybrid working on the energy consumption of workspaces, the following objectives are identified:

- Identifying the impacts of dynamic occupancy on the energy performance of workspace environment
- Assessing the energy footprint of hybrid workers and hybrid workspaces.
- Assessing the effects of the rebound effects from teleworking
- Determining the hybrid working conditions that result in energy optimisation.

Concept mapping is a useful technique for specifying target measures in an inductive approach (Rosas & Camphausen, 2007) and for thematic analysis (Jonsen & Jehn, 2009).

Figure 9 is a mapping of the different impact areas of hybrid workspaces (conceptual framework) and has been adapted from Den Heijer's (2021) four-perspective scheme. The concepts mapped here are different Key performance Indicators (KPI's) of hybrid working. The subsequent measurement stage will focus on collecting data within the '*physical*' perspective to answer the main research question. These insights will then be integrated into the mapping to arrive at broader generalisations on the links between hybrid working, workspace environments and energy consumption.

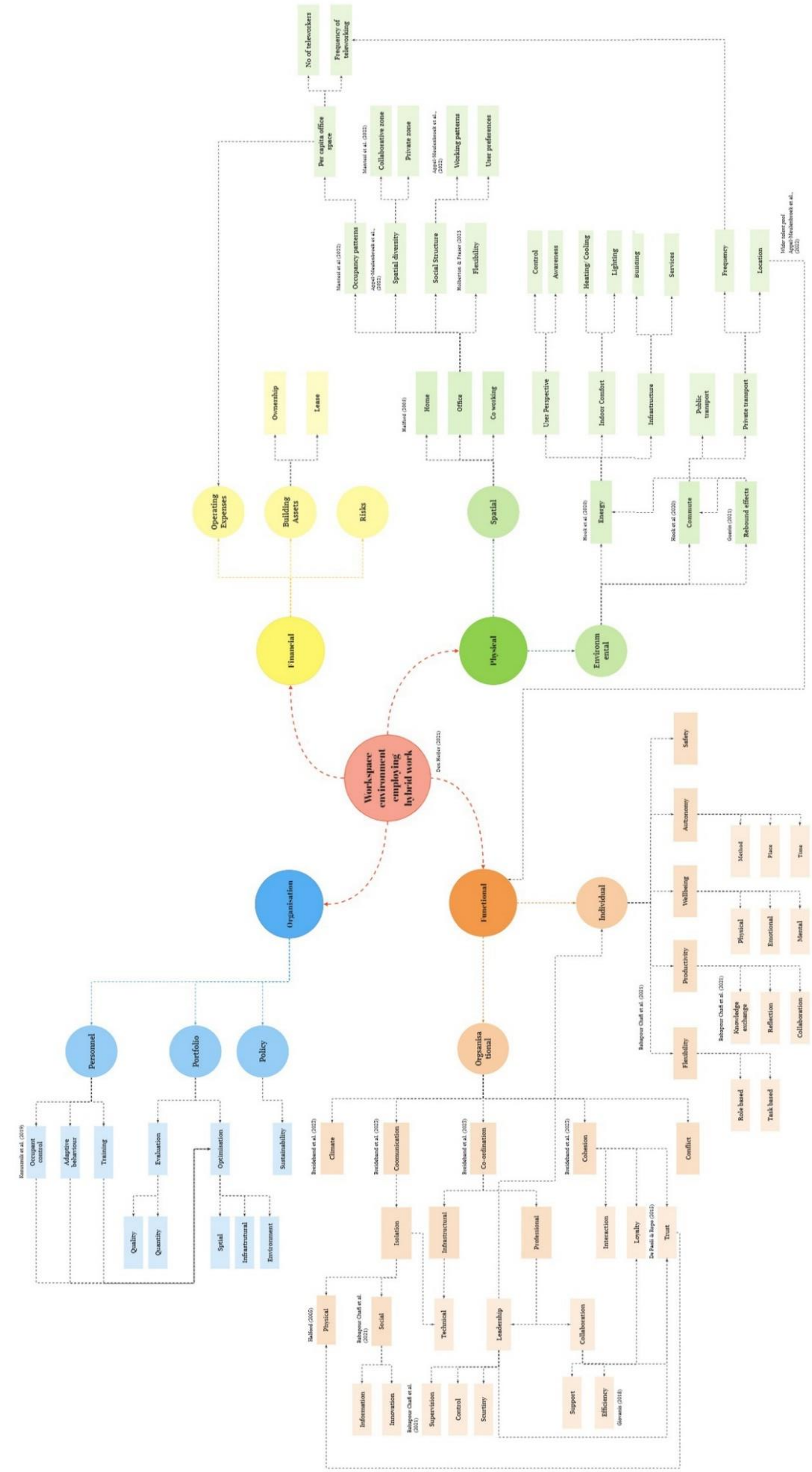


Figure 9 System mapping of workspace impact adapted from Den Heijer (2021), (Author, Attached separately for better legibility)

Chapter 03

Methodology and Research Design

The thesis follows an inductive line of research, using a quantitative research design to establish links between hybrid working, workspace environments and energy consumption.

3.1. Type of study and methods:

The study was organised into three phases as seen in figure 10 below:

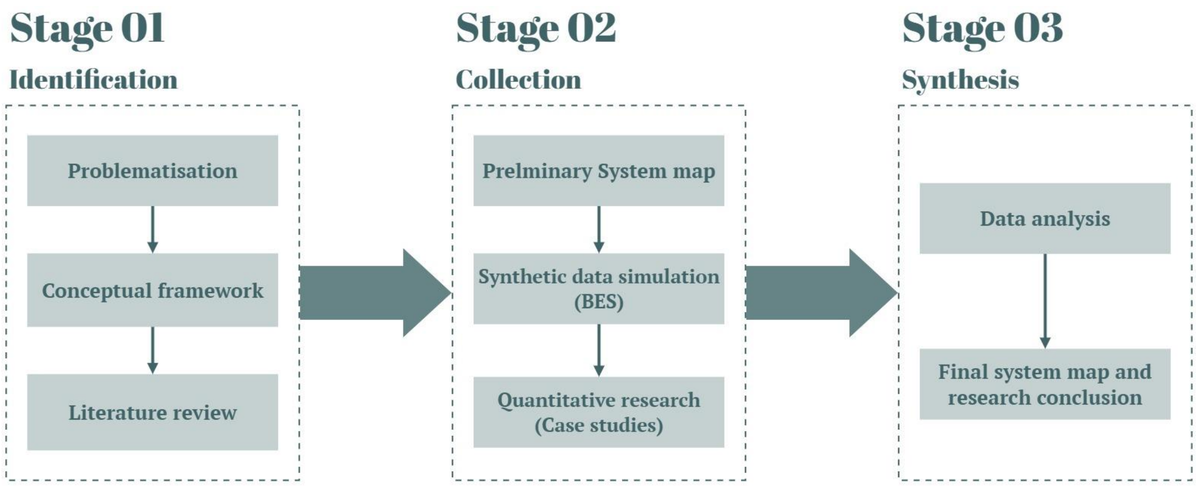


Figure 10 Research stages (Author)

The <u>first stage</u> of the data collection formed the theoretical basis of the study. During this stage an extensive in- depth literature review was conducted to understand the foundations of hybrid working and its implications on workspaces, therefore answering SQ1 and SQ2. This was also used to map out the different impact areas of hybrid working (refer section 2.6), establishing links and interdependencies between the main concepts. The parameters identified in this framework were used as the Key Performance Measures/ KPI's for the subsequent data collection and analysis.

The <u>second stage</u> of the research involved data collection from synthetic simulations and case studies to quantitatively measure and compare the energy footprint of workspaces and employees impacted by hybrid working and were used to answer SQ3 and SQ4. This stage also involved a study on mobility and hybrid working, curated using desk research and document study.

The <u>third stage</u> involved synthesis and conclusion of the findings. While the synthetic modelling provided some answers to the differences between hybrid working and full-time work, these were then compared and validated by the analysis of the two cases studied. The findings from every stage were fed back into the overall system mapping and parameters identified in this framework were used to answer the main research question and deliver two final outcomes: practical recommendations for RE professionals and business owners on the impacts of hybrid working, thereby facilitating improved decision-making and a broader expansion on macro lever societal and urban level impacts of the phenomenon.

3.1.1. Synthetic Study Design:

Synthetic data was derived from Building Energy Simulations (BES) performed on the simulating engine TRNSYS. This stage began by designing different workspace and working scenarios based on contextual parameters derived from the framework, such as occupancy patterns, working patterns, and spatial standards, leading to a total of six scenarios. Following this different occupancy, comfort and energy parameters were calibrated on the associated software interface, TRNBuild. The energy demand was simulated for each scenario on TRNSYS over a period at 1 year at 1-hour intervals and resulted in the first set of conclusions. This has been detailed in Chapter 04 and 05.

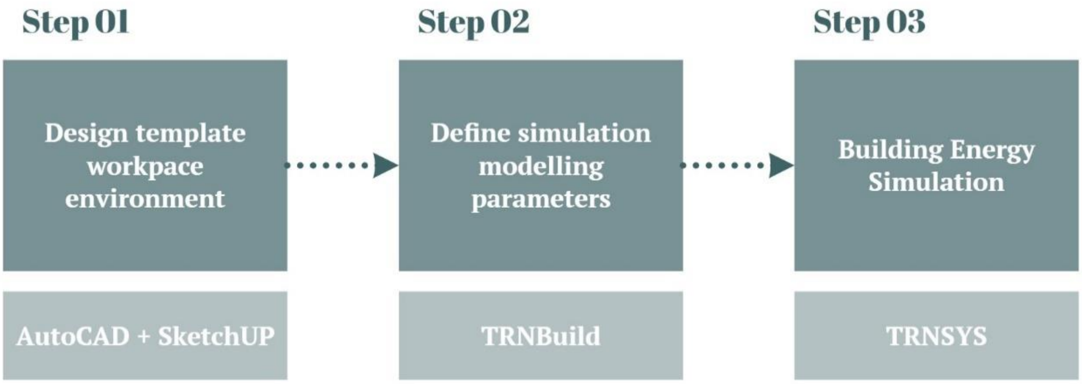


Figure 11 Synthetic study design (Author)

3.1.2. Case study Design

Case Selection

The theoretical framework, developed in section 2.6, was used to select the case studies. Data was gathered in terms of location, function, size, age and hybrid set up to select the most relevant cases that allowed a greater degree of generalisability of the findings. A maximum of three case studies were intended to be chosen based on these parameters. A multi-case study design, which includes more than one case study, is necessary since it is hard to generalise, and replicate results based on a single case (Sofaer, 1999).

Case studies introduction

Two office case study categories haven been selected- corporate finance and an academic research-based office. In this section a brief overview of the case studies is provided. However, a full case description can be found in the individual case analysis in chapter 6.

Case Study Set 01: ING Belgium
Function: Corporate Finance

ING MARNIX

LOCATION: BRUSSELS, BELGIUM
AREA: 54,058 M^2
YEAR OF CONSTRUCTION: 1960'S
OCCUPANT CAPACITY: 814 SEATS (746 being added by 2024 end)

ING LOUVAIN-LA-NEUVE (LLN)

LOCATION: LOUVAIN-LA-NEUVE, BELGIUM
AREA: 10,875 M^2
YEAR OF CONSTRUCTION: 2019-2021
OCCUPANT CAPACITY: 514 SEATS

ING GHENT

LOCATION: GHENT, BELGIUM
AREA: 16,000 M2
YEAR OF CONSTRUCTION: 2011-2018
OCCUPANT CAPACITY: 608 SEATS

ING COURS SAINT MICHEL (CSM)

LOCATION: BRUSSELS, BELGIUM
AREA: 60,000 M2
YEAR OF CONSTRUCTION: 1960'S

Case Study 02: TU Delft
Function: Research based office

Building 28, TU Delft

LOCATION: DELFT, THE NETHERLANDS,
GFA: 10,500M^2
YEAR OF CONSTRUCTION: 1960's

3.2. Data Collection Techniques:

Bryman (2016) categorises data from any study into primary and secondary. The data collection technique for this research was a combination of the two, with data derived from desk research and quantitative modelling.

Desk Research: The secondary data in this thesis is generated from previous publications and articles. This data collection technique was used to develop the theoretical foundation of this research with data from different academic and scientific papers, books and grey literature. The literature study helped define the conceptual framework (impact mapping of hybrid working) adapted from Den Heijer's (2012) four perspective frameworks on campus management and formed the base for the quantitative study by identifying the Key Performance measures that would be studied and evaluated in the subsequent stage of the research.

Synthetic Data: The primary data of this study was generated from synthetic simulations and case study analysis. Models of typical workspace and home environment were generated for different working scenarios and the energy performance of each were simulated using Building energy simulation (BES) on the simulation engine TRNSYS, to draw the first set of conclusions for the study.

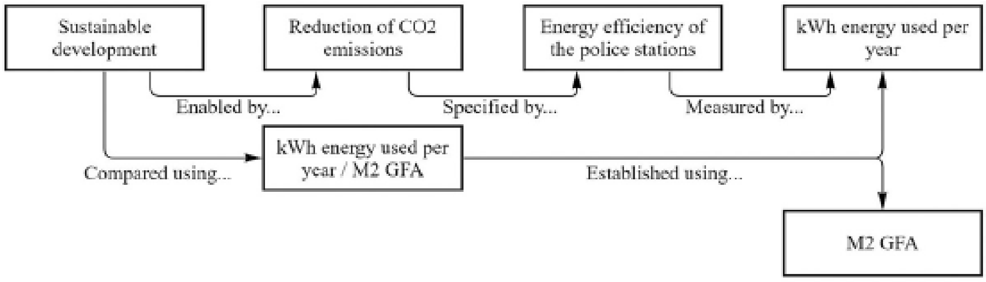


Figure 12 CREM Performance Management System (van Staveren et al., 2024)

The above performance measurement framework devised by van Staveren et al., (2024) formed the basis for the theoretical modelling. As such, the energy consumption of each scenario was a measured against the kWh/m^2 energy used per year.

Case Study: The results from the synthetic study were compared to the data obtained from the selected case studies that incorporated hybrid working to draw generalisations that answer the main research question. The framework used to perform the case study analysis was adapted from the performance measurement systems formulated by Ferreira & Otley (2009) and involved first understanding each workplace's *'vision and mission' before* proceeding to analyse and evaluate the KPI's of this thesis (occupancy and energy demand metrics). Apart from the data dashboards, supplementary documents from each case were examined to obtain a comprehensive understanding of the actions, policies, protocols and initiatives being implemented in these offices.

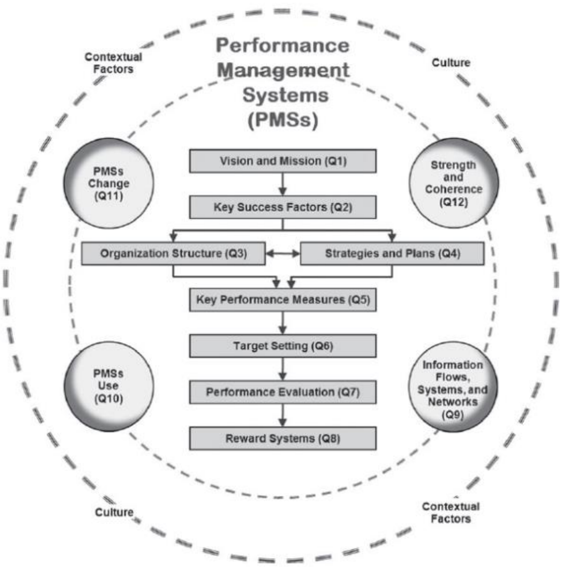


Figure 13 The performance management systems (PMSs) framework (Ferreira & Otley, 2009)

3.3. Data Analysis:

The findings from the literature study defined the conceptual framework of the study which was a preliminary system mapping of the different areas of impact of hybrid working along the four-stakeholder perspective of Den Heijer (2021).

The cross study involving synthetic simulations and case study analysis were used to measure the quantitative implications (energy footprint) of hybrid working. Each stage began with an individual analysis to draw a preliminary set of conclusions. This was followed by a cross analysis where data from the different techniques employed were compared to draw conclusions and generalisations that answer the main research question while also validating the study conducted.

The insights from the above were then used to update and refine the interdependencies in the systems map, establishing clear links between the performance of hybrid working, employee well-being, office spatial configuration and energy performance while also answering the main research question. The overall research design framework has been visualised in figure 14 below:

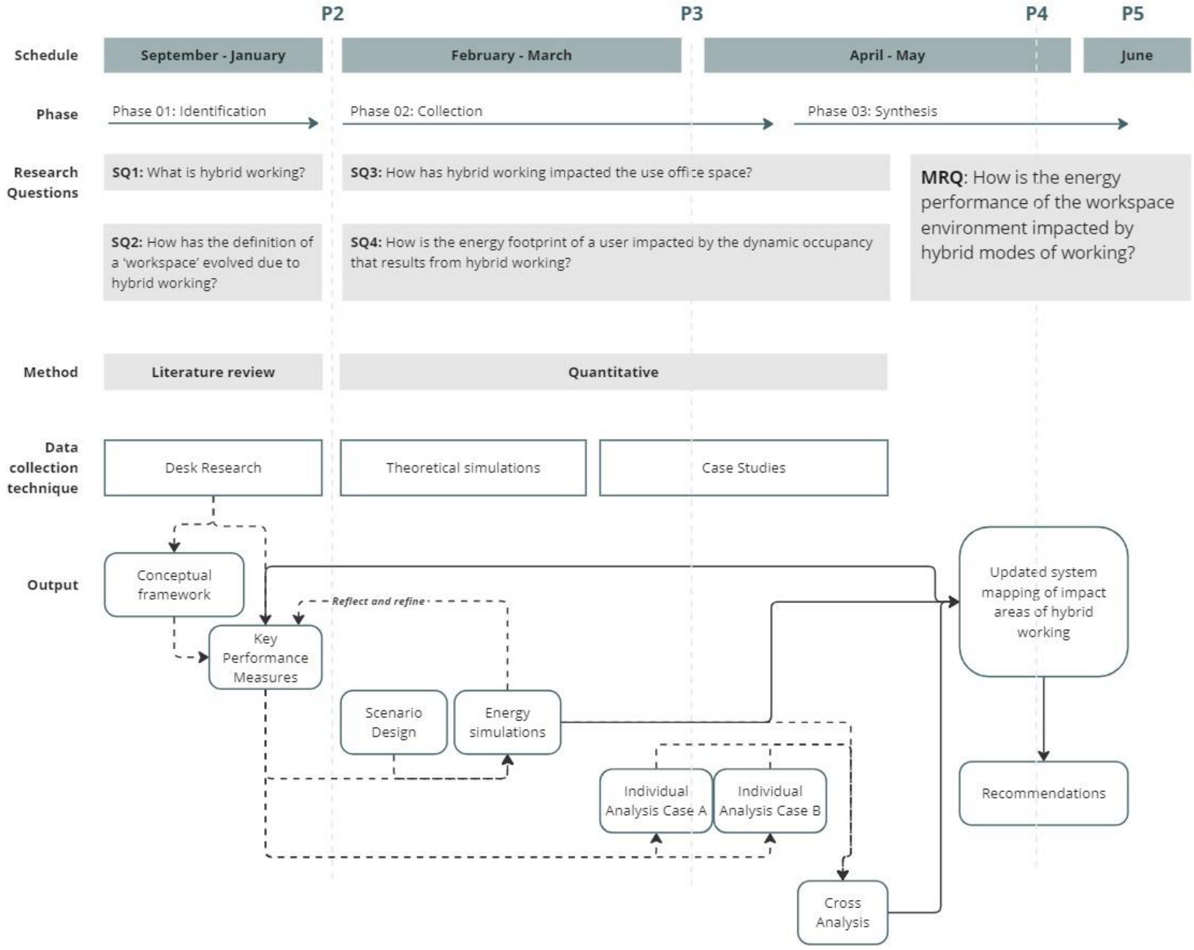


Figure 14 Research design framework (Author)

3.4. Data Plan:

To improve the legitimate reuse of knowledge, this thesis followed the FAIR principles (Wilkinson et al., 2016), meaning that data should be: Findable, Accessible, Interoperable and Reusable.

Findable (F): with appropriate titles and keywords and APA 7th style for referencing, making sources traceable and acknowledging the work of others that contributed to this research.

Accessible (A): The thesis will be uploaded to the TU Delft Education Repository and has open access through this repository.

Interoperable (I) using English as the main working language. Furthermore, the research instruments were kept simple to minimise risk of confusion.

Re-usable (R) by documenting all processes and data that is generated and reduced so that it can be easily built upon for future research purposes. Furthermore, this thesis is re-usable by means of a CC-

BY-NC license, implying that it can be shared and be used to produce derivative works if it is adequately attributed to the authors and used for non-commercial purposes. However, in compliance with ethical issues pertaining to safeguarding the participant parties' identities, raw data shall remain confidential.

3.5. Ethical considerations

There is minimal involvement of human participants in this research. Nevertheless, this thesis respected ethics of research by ensuring voluntary participation and informed consent of the participating entities. The data was safeguarded through adequate secure storage measures and ensuring accessibility only to the research team. Furthermore, other authors and publications that have contributed to this thesis have been duly acknowledged and all the works presented here are free of plagiarism or research misconduct.

3.6. Research Output

3.6.1. Goal

According to Beard (2012), learning environments and workplaces are dynamic containers which stimulate mobility, communication, cognition, social interaction, a sense of being and belonging- all of which are central to overall cognitive understanding and performance.

Business success lies in staying ahead of the curve and this is an opportunity for employers to recalibrate working processes to facilitate improved organizational, economic, and environmental targets. Office buildings are expensive business assets but are also resources that can provide genuine benefits to employees if employers proactively work towards it (JLL, 2022b).

The goal of this research is to contribute to the study of workplace management with valuable insights on the sustainability discourse based on current trends of socialisation, working processes and use of space.

3.6.2. Deliverables

This study aims to offer insights relating to the impacts of hybrid working on the use of space and thus the energy consumption of workspaces, through a thorough understanding of hybrid working over the last few years.

"Strategic management demands that the manager has a clear understanding of the owner's or occupier's objectives and the core activities that will take place in or on the property. It demands that the manager can understand the activities that the property supports and the competitive demands that it faces daily. The manager can then develop property action plans that are capable of balancing short- and long-term goals." (Edwards & Elison, 2009)

Whether a property is held for investment purposes or as an operational asset and whether for financial profit or for other objectives, Edwards & Elison (2009) state that strategic management of property is the only method of ensuring that it is managed for maximum value. It is hoped that this thesis can formulate a comprehensive understanding of current working processes for CRE professionals, business owners and end users to participate actively in the transition to a sustainable society.

3.6.3. Dissemination and audiences

This thesis is currently positioned in the Global North to establish common ground in terms of advancement of necessary technologies and the degree of flexibility and autonomy afforded to the end user of workspaces. The primary audience includes corporate businesses as it is intended to add value to work processes by identifying links between spatial configuration, employee well-being and energy performance. Real estate investors, managers and developers are also expected to benefit from the study since initial literature studies point to a shift in the perception of workspace requirements. Multinationals with a global portfolio may be interested in the implications of this research due to the wide prevalence of hybrid working across geographic teams.

3.7. Personal Study Targets

I was personally interested in the topic of hybrid working, having experienced it myself and was keen to study the implications of hybrid working for CREM. Secondly, climate change and global emissions has become urgent with its effects becoming more apparent and extreme. Hybrid work allows work to extend beyond the physical confines of an 'office' and one cannot ignore the energy spillover of this phenomenon. It is imperative to study and establish clear links between the interdependencies between the various parameters that define current workspace environments and we, as professionals in the built environment need to be proactive in this dialogue.

Additionally, to be critical of my own progress and work, the following study targets were set up as a personal guide:

- Ensure that research is cohesive, coherent, and feasible.
- Be organised, efficient and disciplined with the use of my time.
- Set realistic targets and be patient.
- Improve my writing and presentation skills.
- Use this thesis as an opportunity to explore my interests in research.

Chapter 04

Scenario Design

The chapter explains the design of different working and workspace scenarios, beginning with the different spatial protypes that function as template layouts, followed by the details of different occupancy and energy usage which will be used to generate synthetic data in Chapter 05.

4.1. Workspace environment design:

The first step in the scenario design was to create 'typical' workspace environments, which serve as the foundation for energy performance simulations. The workspace environments are divided into two categories: the office environment and the home environment. A third workspace environment, the co-working space, which has emerged due to teleworking trends, will not be included within the scope of this thesis.

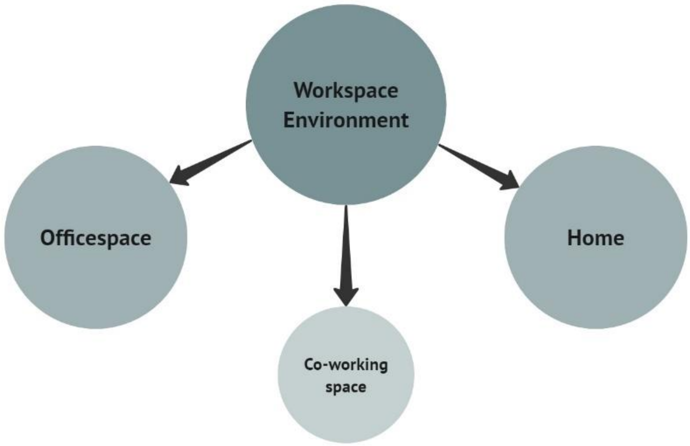


Figure 15 Workspace environments (Author)

4.1.1. Office Environment:

The activity-based workspace, a combination of different zones which cater to diverse activities, that is predicted to be the norm (Mantesi et al., 2022) is used as the template to design the typical office environment. Spacewell & Memoori, (n.d.) recommend that the future workplace be dynamic and adaptable to the changing needs of the business, with a mix of tailored spaces that *'seek to maximize engagement and collaboration and align with the activities of both individuals and teams'.* They also emphasise the importance of creating *'destination'* areas that inspire creativity, facilitate serendipitous interactions, or provide a relaxing oasis within the workplace.

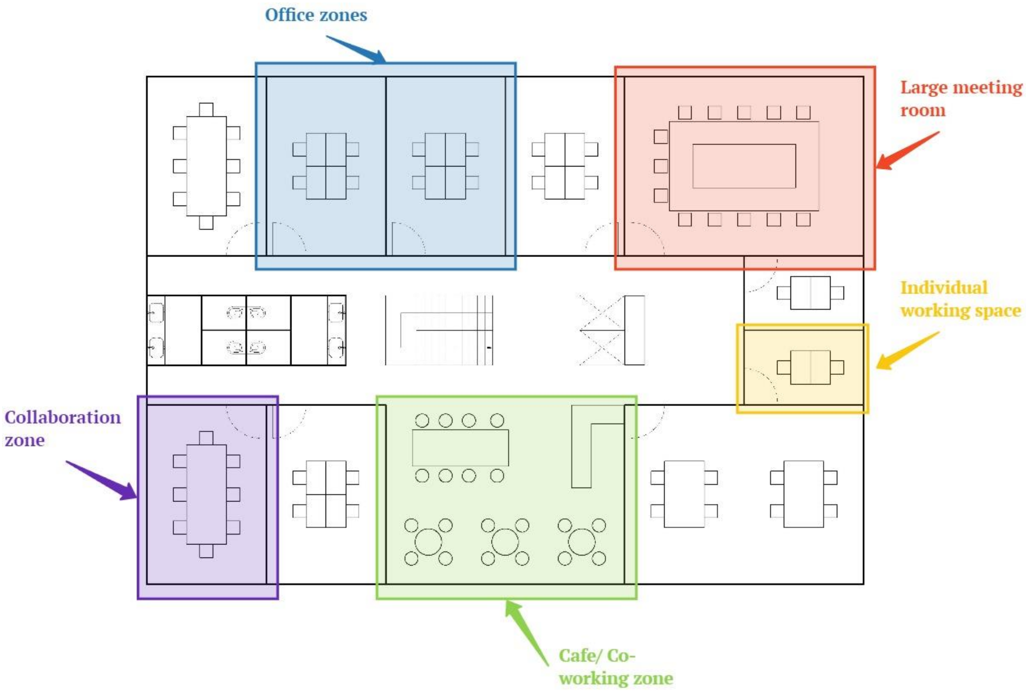


Figure 16 Typical office layout designed based to reflect Activity based working (Author)

The different zones defined in the typical workspace (figure 16) have been developed based on standards specified in the NEN 2580 which is a measurement method that determines the surface area of land and buildings by means of terms, definitions, and determination methods in the Netherlands. Based on these standards, the space required for a single person is a minimum of 7m^2 resulting in standard grids of 1.8m in length. A café work zone has been consciously added to mimic the extremely successful *Espresso Bar* that we have at our own Architecture faculty at TU Delft. These spaces, besides offering a break from the mundane landscape of typical office environments, also offer opportunities for "*workspace collisions*" between colleagues.

4.1.2. Home Environment:

As this research is set in the Northwest Europe, Dutch housing trends have been taken as the standard metric. According to CBS, there were 8.3 million private households in the Netherlands in 2023, 3.3 million of which were single-person households. The average Dutch household consists of 2.12 people (Fig 17) with a quarter of Dutch households living in a home smaller than 75m^2 and 17% living in a home with a living area larger than 150 m2.

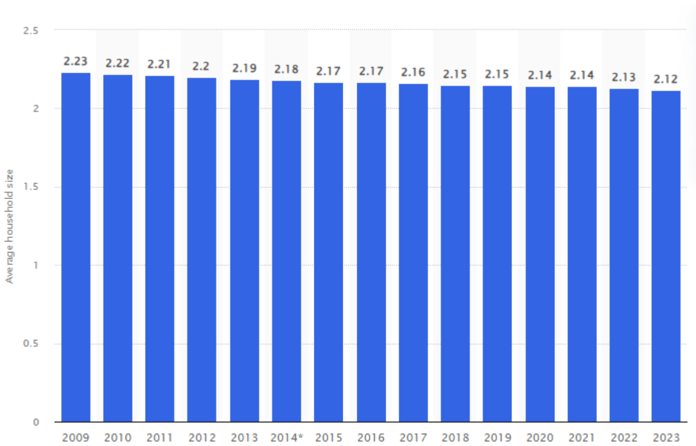
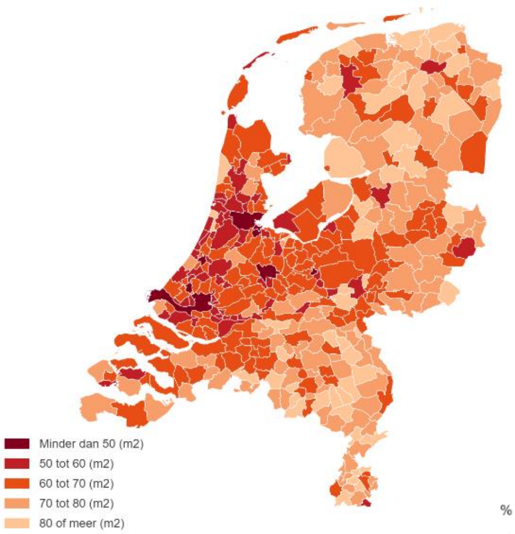


Figure 17 Average household size in the Netherlands from 2009 to 2023 (CBS, 2023)



Within the Randstad area, two-thirds of Amsterdam households have less than 75 m ^{2} of living space due to the high proportion of single-person households such as students and young people starting their working career. As seen in the figure 18, studios or single bedroom apartments between 50-60m^2 are quite commonplace, in response to the rising housing challenge.

Figure 18 Average living area per person for couples without children in the Netherlands (CBS, 2022)

Within multi person households (with or without children) there is a high percentage of houses between 100-150m^2 in size.

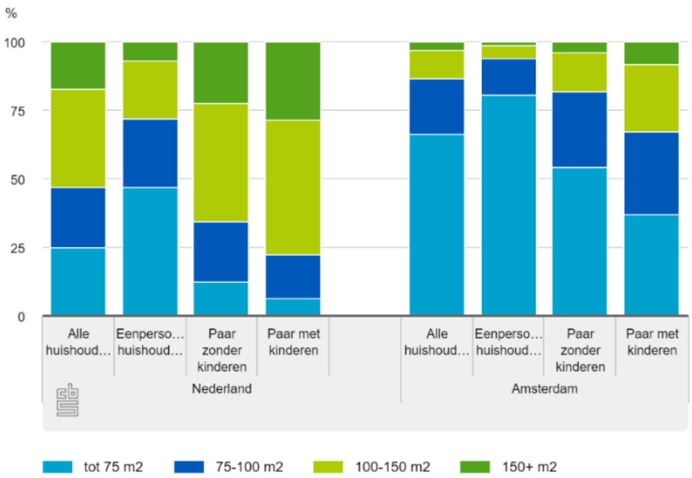


Figure 19 Living area by household type (CBS, 2022)

Two housing templates have thus been developed, a studio apartment of about 50m^2 for a single person household (Fig 20) and a larger apartment of around 140m^2 (Fig 21) for a multi person household.

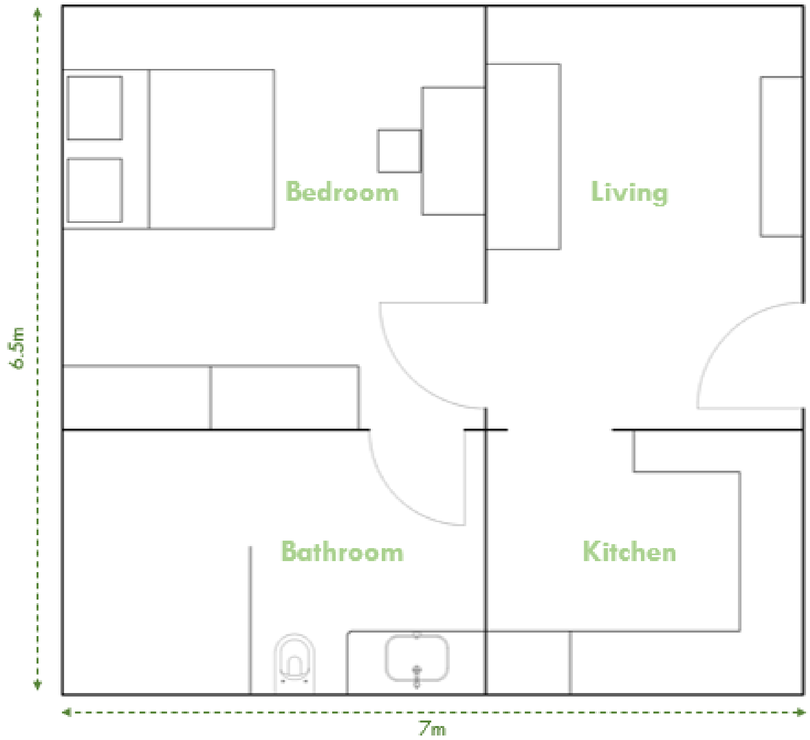


Figure 20 Single person household Layout (Author)

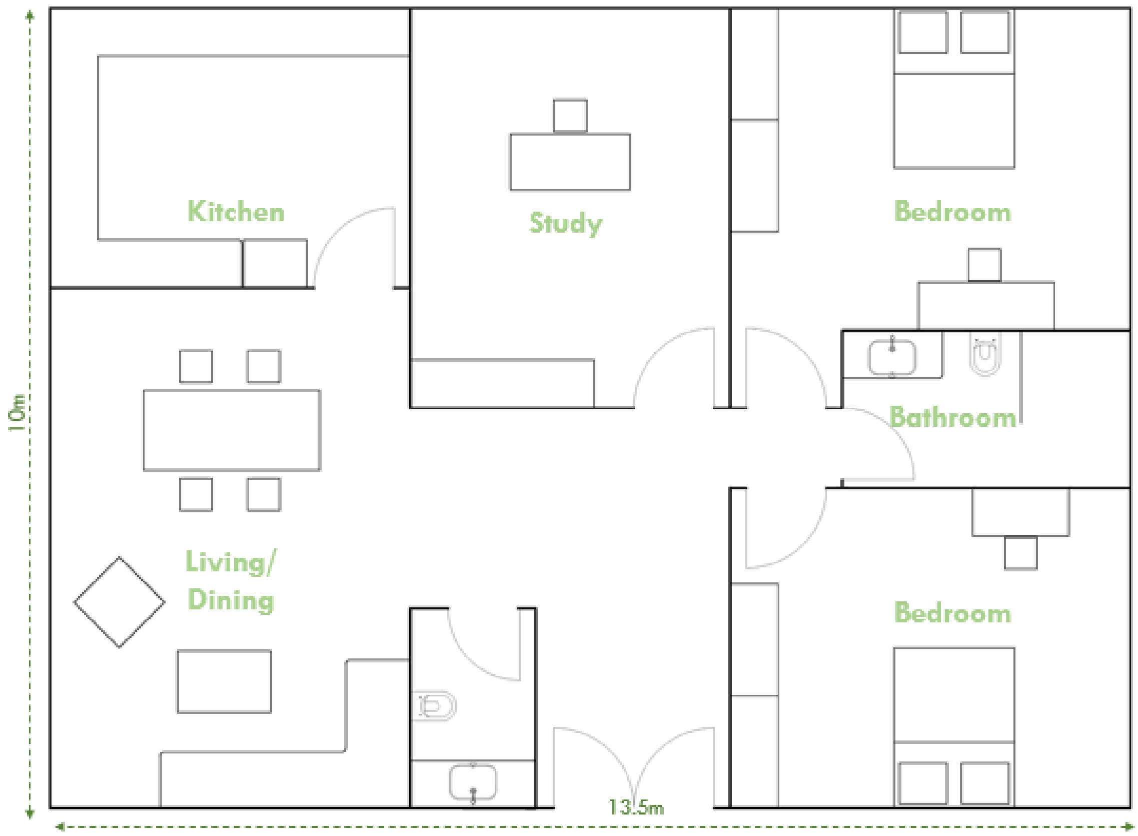


Figure 21 Multi person household Layout (Author)

This results in ***3 workspace environment*** templates which form the basis for the synthetic data modelling.

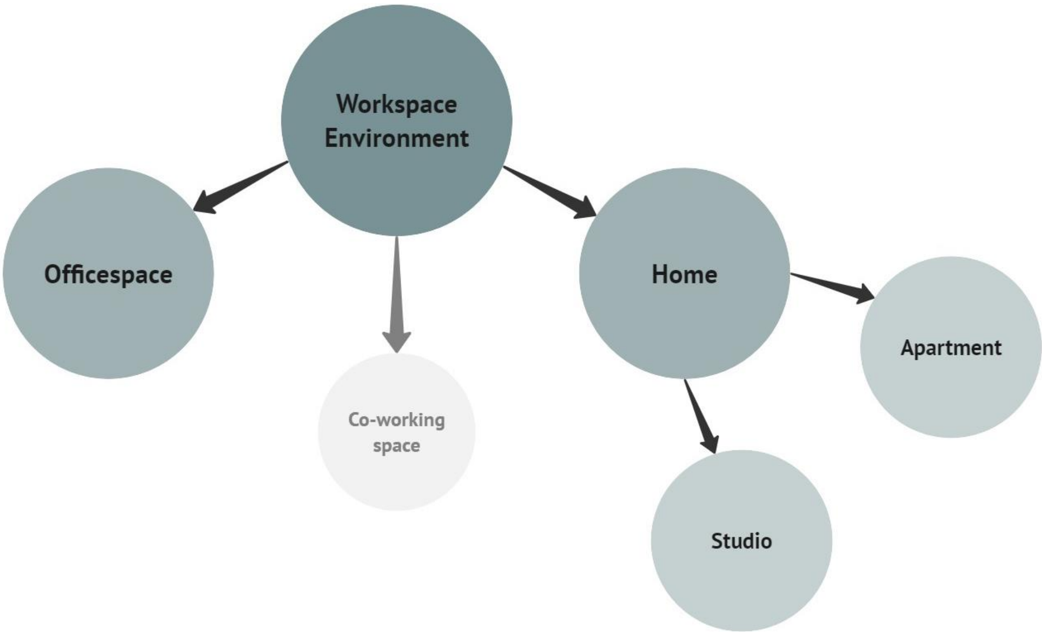


Figure 22 Workspace environments (Author)

The following section details out the difference between a **'hybrid working' (WFH)** scenario and a **'work from office'' (WFO)** working scenario.

4.2. General teleworking trends:

According to Robert Sadow, the CEO and co-founder of Scoop Technologies, work is moving towards "structured hybrid," in which there are a set number of days that people are required to come into the office. (Semuels, 2023). Research by Professor Prithwiraj Choudhury at Harvard University with Fast Company suggests that the ideal amount of time to spend in the office is between 23 and 40 % of your week (Roy, 2021). This is corroborated by research conducted by Savills between January and March 2023 which indicates that occupancy in offices is highest between Tuesday and Thursday, with Friday being the least visited day.

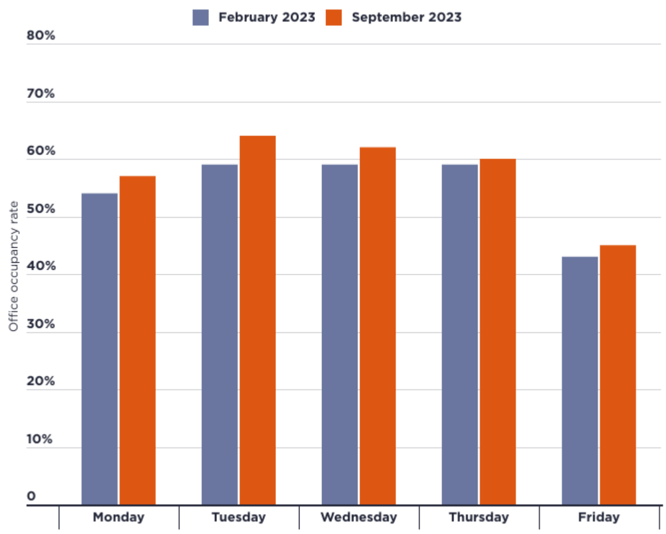


Figure 23 European average daily occupancy rates (Savills, 2023)

According to research by McKinsey mentorship, collaboration, trust between colleagues, retention and overall team performance is vastly improved when workers spent at least 50% of their time together in person, with Katy George, McKinsey's Chief People Officer and a Senior Partner, referring to it as "the '*hybrid sweet spot".* On the other end of the scale, reserving two to three days a week for remote work gave employees more time for focused work, and improved teams' feelings of psychological safety and belonging (Mischke et al., 2023).

4.2.1. Working trends in the Netherlands

Within the Netherlands, standard working time is between 36 – 40 hours with a typical working day lasting for about 7-8 hours from 9:00 am to 5:00 or 6:00 pm (Boundless, n.d.).

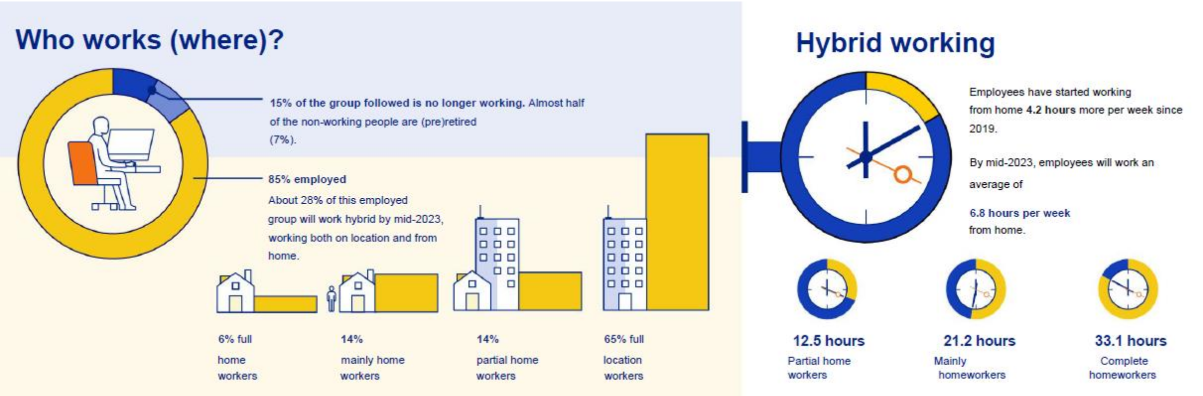


Figure 24 Working trends in the Netherlands (Oude et al., 2021)

A study conducted by TNO (Oude et al., 2021) among 6,323 participants who also completed the National Working Conditions Survey (NEA) 2019 revealed that employees worked remotely an average of 19% of their working time in mid-2023, compared to 9% in 2019. This amounted to employees spending about between zero and three days working from home.

Sectoral Differences: It is also important to note that differences are bound to occur depending on factors like the proportion of knowledge-economy workers, housing costs and the size of the firm.

TNO's study (Oude et al., 2021) reveals differences in hybrid working trends between as highly educated employees worked from home more often than average, working 10 hours per week. Employees in ICT (15.7 hours), financial services (18.5 hours), public administration (12.6 hours) and business services (9.8 hours) worked more hours at home than average. This is supported by Mischke et al.'s (2023) research using a regression analysis of US counties which reveals that the higher a county's ratio of knowledge-economy workers (professional services, information technology, and finance industries) to other workers, the lower its average office attendance. Similarly, the higher home prices are in an urban core relative to its suburbs, the lower the metro area's average office attendance is. Furthermore, employees at larger firms report significantly lower office attendance than do those at smaller firms since larger companies tend to have more resources and technology to facilitate working from home. Another is that the sense of community may be stronger at smaller companies, prompting more employees to visit the office (Mischke et al., 2023).

4.2.2. Typical Working Week Scenario Calibrations:

Hybrid Week: Keeping the above working trends and research results in mind, the hybrid working week was designed such that office occupancy was highest on Monday, Tuesday and Thursday. Office occupancy specific to NW Europe is typically low on Wednesdays to align with the operating hours of schools. The typical hybrid working week is thus designed to swing from a scale of 0-1, with 1 indicating full occupancy and 0 indicating none, between 7am and 5pm from midnight on Monday (0 hours) to Sunday (168 hours). This has also been calibrated for the accompanying housing environment (Studio or apartment) as seen in Figure 25.

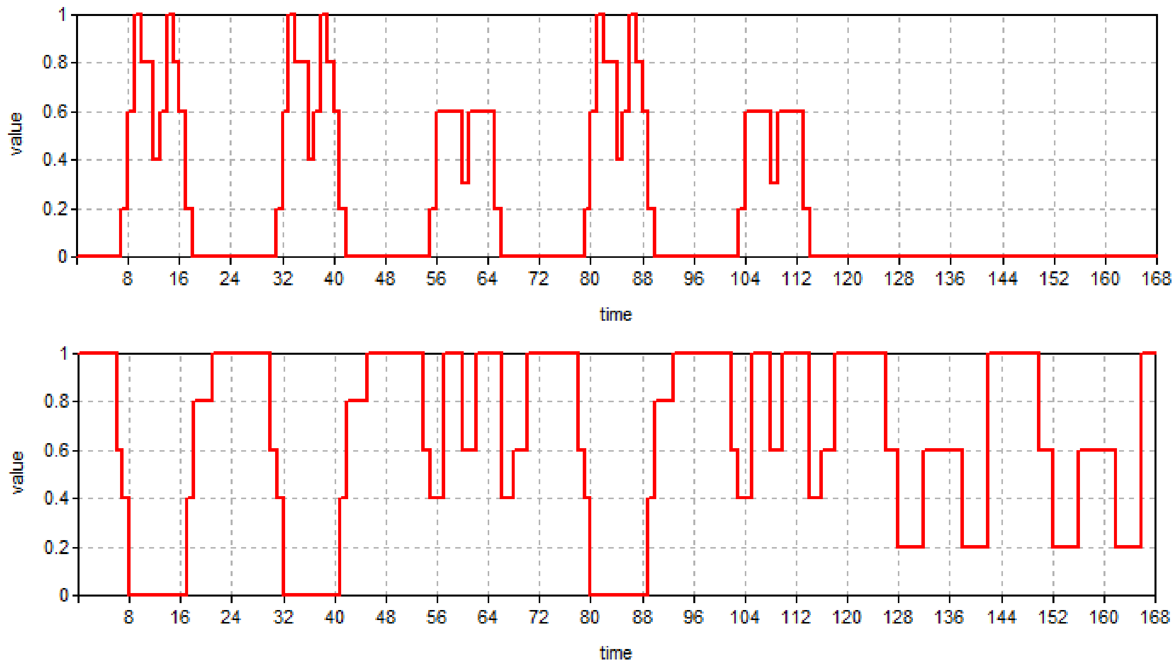


Figure 25 Weekly office (above) and housing unit (below) occupancy during a hybrid working week as calibrated on TRNSYS (Author)

Work from office (WFO) week: In order to draw conclusive results, the simulations from a hybrid working week are then compared to a full-time work from office (WFO) working week scenario, the occupancy of which is indicated in the figures below for both the office environment and the home environment. In this scenario, no days are reserved for teleworking and the occupancy at home between 8:00 and 17:00 each day is hence 0.

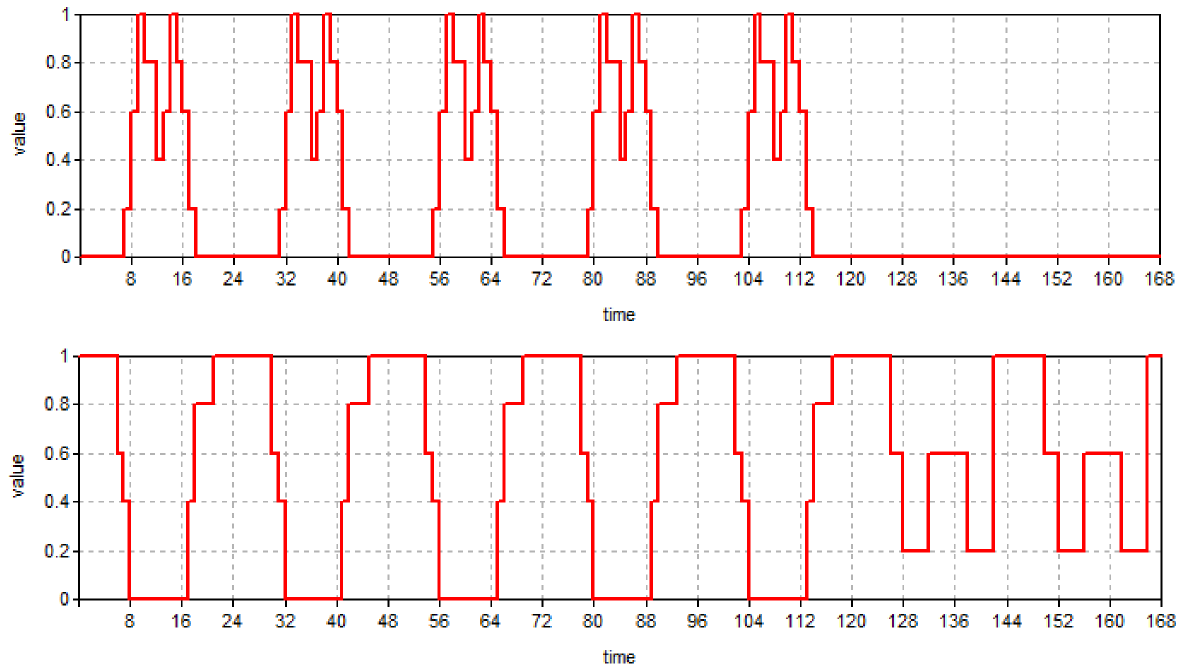


Figure 26 Weekly office (above) and housing (below) occupancy during full time work from as calibrated on Trnsys (Author)

It is important to note that since these are synthetic simulations, an idealistic scenario is considered with the peak occupancy for a designated WFO day considered to be 100%.

4.3. Final Scenarios

As a result of the working environments and working week schedules detailed above, a total of 6 different scenarios have been configured (Fig 27).

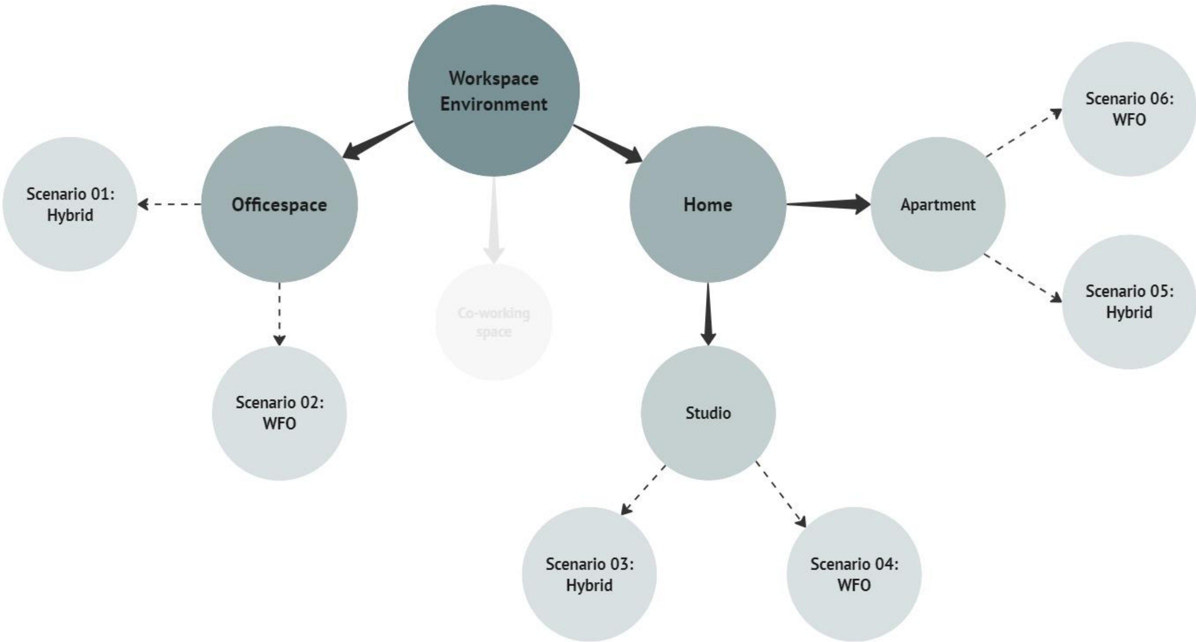


Figure 27 Final Working scenarios (Author)

The next stage involves detailing out the different operating parameters to be calibrated for performing energy simulations of each scenario.

4.4. Simulating Energy Performance of each scenario:

The energy performance of the different scenarios is measured against the operational energy consumed by the space, i.e. the energy used to heat, cool and light up the space. 3-dimensional models of the layouts depicted in section 4.1. are developed on SketchUp and imported into the energy simulation software (TRNSYS). The parameters that define the simulations are calibrated using the associated visual interface (TRNBuild) which reads and processes the file containing the building description.

4.4.1. Operating Schedules:

The operating schedules of the temperature conditioning systems are calibrated on TRNSYS using a scale of 0 to 1 across the week (Monday midnight 0 hours to Sunday at 168 hours) to reflect the different working scenarios that have been designed as seen in figure 28 below. The ***office*** operating schedule is set at 0.6 for the days that are designated as hybrid working days (Monday, Wednesday and Friday).

The operating schedule of the temperature conditioning systems at the ***home*** workspace are calibrated between 0-1 to reflect the level of activity at the house during the WFH days and weekends while it is set at 0 between normal working hours (8:00 to 17:00) on a WFO day (Monday, Thursday and Thursday).

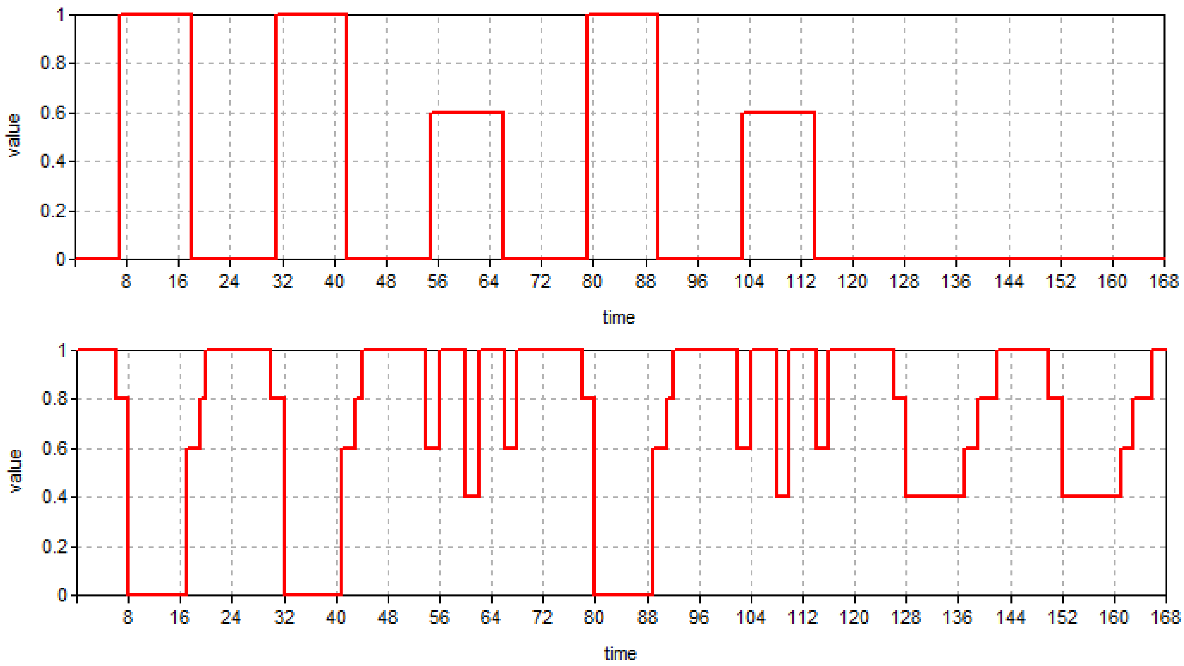


Figure 28 Weekly office (above) and housing unit (above) operating schedule for hybrid working week as calibrated on Trnsys (Author)

The same operating schedules are also calibrated for an ***office*** and ***home*** workspace for a full time 'work from office' week.

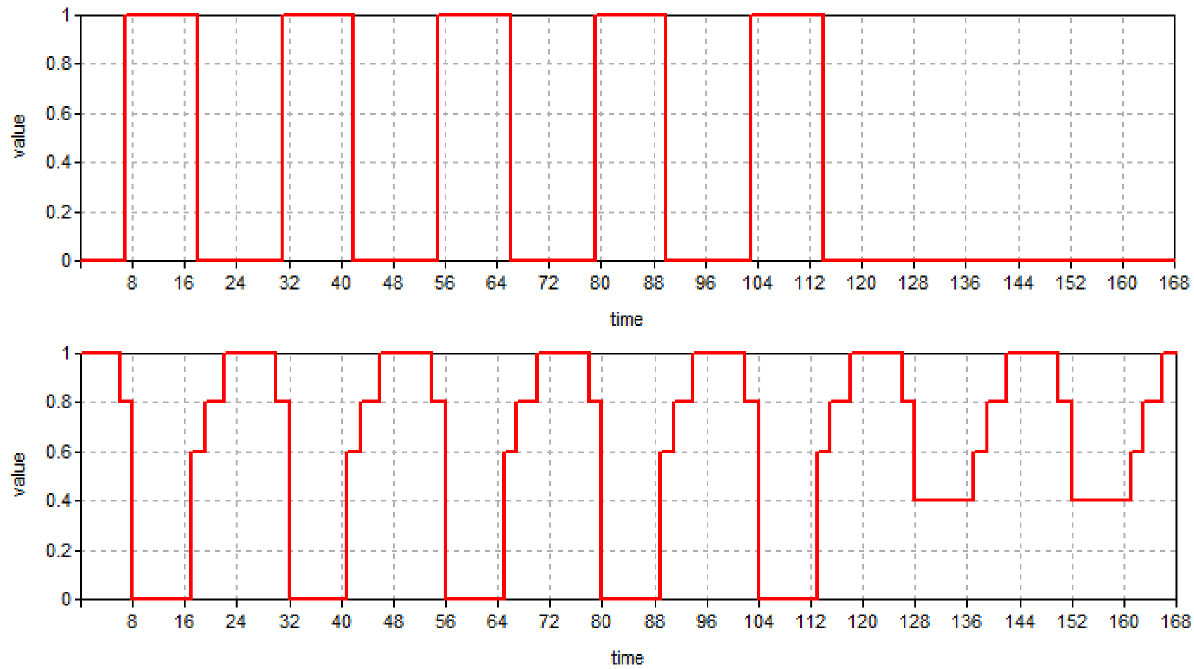


Figure 29 Weekly office (above) and housing (below) operating schedule during full time work working week as calibrated on Trnsys (Author)

The next section details the different 'regime' types calibrated on TRNBuild- infiltration, ventilation, heating, cooling, comfort, gain and daylight control types. REGIME represents the air within the airnode (zone) with the input data establishing initial conditions, gains, and conditioning.

4.4.2. Infiltration Type:

Infiltration rate, typically measured in air changes per hour (ACH), represents the number of times the air within a space is replaced by outdoor air in one hour due to infiltration. The infiltration rate can vary widely depending on the building's age, construction quality, and maintenance.

For modern, well-insulated office buildings in the Netherlands, the infiltration rate is relatively low, between 0.1 to 0.5 air changes per hour under normal conditions. The infiltration is specified by adding infiltration type on TRNBuild and is set at 0.5ACH for the office workspace environments. Studies by Asikainen et al., (2013) suggest that the mean ± SD air change rate per hour (ac/h) in residences varies from 0.6±0.4 in northern Europe with the average in Netherlands being 0.6. The infiltration rate of the home workspace environment is therefore set at 0.6 ACH. The values for each scenario are captured in Table 3 below.

Scenario Type	Space Type	Parameter	Value
Apartment	Multi Family house	Infiltration (ACH)	0.6
Studio	Single Family House		0.6
Office	Office (Small)		0.5
	Office (big)		0.5
	Meeting room (big)		0.5
	Reception/ Misc		0.5

Table 3 Infiltration factor for different workspace environments (As inputted on TRNBuild)

4.4.3. Ventilation Type Parameters:

An air flow e.g. from heating or cooling equipment into the airnode can be specified by a ventilation type. The ventilation parameters are set such that one ventilation type can be used for several airnodes by defining the supply area flow in relation to the reference floor area. Furthermore, the supply air conditioning is set such that it is computed externally by another component. The option OUTSIDE is set for the temperature and the humidity, resulting in the temperature and the humidity of the outside air being used. Figure 30 displays the base settings used to define the ventilation type (common to all scenarios).

Figure 30 Ventilation Type Settings as calibrated on TRNSYS (Exported from TRNBuild

The volume flow rate is set to operate according to the weekly occupancy schedule with different values being used based on the building and airnode type. These different values reflect the level of occupancy in the zone and are indicated in table 4.

Scenario Type	Space Type	Parameter	Value
Apartment	Multi Family house	Volume Flow Rate (x Weekly Occupancy Schedule)	1
Studio	Single Family House		0.6
Office	Office (Small)		2.6
	Office (big)		3.6
	Meeting room (big)		12
	Reception/ Misc		2.5

Table 4 Volume Floor rate factor for different workspace environments (As inputted on TRNBuild)

4.4.4. Heating and Cooling Type:

According to CNESST (2004), to ensure optimal working temperatures, at 50% relative humidity, 'operable' temperatures are between 23 and 26°C in the summer, and between 20 and 23.5°C in the winter. The heating and cooling requirement of each airnode (zone) is calibrated on TRNBuild by setting the room setpoint temperature, the heating power with its radiative part, and the humidification of the air within the airnode.

Scenario Type	Space Type	Parameter	Value
Apartment	Workspace	Heating Temperature in °C (Unlimited power at 50% relative humidity)	21°
	Miscellaneous Space		18-20°
Studio	Workspace		21°
	Miscellaneous Space		18-20°
Office	Office (Small)		21°
	Office (big)		21°
	Meeting room (big)		21°
	Reception/ Misc		21°
Apartment	Workspace	Cooling Temperature in °C (Limited power at 50% relative humidity)	24°
	Miscellaneous Space		25-26°
Studio	Workspace		24°
	Miscellaneous Space		25-26°
Office	Office (Small)		24°
	Office (big)		24°
	Meeting room (big)		24°
	Reception/ Misc		26°

Table 5 Heating and cooling values for different workspace environments (As inputted on TRNBuild)

Heating: For the energy simulations, the room temperature set point is set at 21°C for *workspaces* within each scenario while miscellaneous spaces (reception/ café/ living rooms/ kitchen, etc) are set to be heated to between 18-20°C. The heating power is set to 'unlimited' with 50% relative humidification.

Cooling: For the energy simulations, the room temperature set point is set at 24°C for *workspaces* within each scenario while miscellaneous spaces (reception/ café/ living rooms/ kitchen, etc) are set to be cooled between 25-26°C. The cooling power is set to 'limited' based on the weekly occupancy schedule, with 50% relative dehumidification.

4.4.5. Lighting Performance:

The European Union has set NEN lighting standards (NEN 12464-1) for lux values in various indoor lighting environments. The NEN-EN 12464-1:2011 standard specifies which lux values are used as standards for an indoor workplace. As per these standards, the minimum lighting level inside a workplace must be 500 lux.

Office buildings	Lux
Workplace	500
Conference room	500
Hallway	100
Front desk	300
Archive	200
Canteen	200

Table 6 Lighting levels as mandated by NEN standards (Lumeco, n.d.)

Daylight factors are also calibrated on TRNSYS based on standard regulations as described in section 3.11 of the Bouwbesluit (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2012). Distinction is made between daylight openings in facades and daylight openings in roofs. In the case of openings in the facade the illuminance during 50% of daylight hours should be 300 lux over 50% of the space and 100 lux over 95% of the space. This means that the daylight factor in the Netherlands should be at least 2.1% in 50% of the area and 0.7% in 95% of the area. In spaces with roof lights the illuminance over 95% of the space during 50% of daylight hours should be 300 lux. This results in a daylight factor of 2.5% for workspaces in the Netherlands and 10% for living spaces (Table 7). The lighting performance is set to function at the same operating schedules as described in section 4.4.1.

	Relative equivalent daylight area [%]	Absolute equivalent daylight area [m^2]
Living	10	0.5
Gathering		
a) childcare	5	0.5
b) others	-	-
Cell	3	0.15
Healthcare	5	0.5
Industry	-	-
Office	2.5	0.5
Lodging	-	-
Education	5	0.5
Sport	-	-
Shopping	-	-
Others	-	-

Table 7 Required equivalent daylight areas (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2012)

4.4.6. Energy Gains:

Another factor considered while simulating the energy are the internal energy gains and losses resulting from people, electrical equipment and lights. The energy gains are computed through a combination of the following convective and radiative powers for each scenario:

Gains		Office	Studio	Apartment
People	Radiative	2.5 to 10 W/m^2	0.8 W/m^2	1 W/m^2
	Convective	2.5 to 10 W/m^2	0.8 W/m^2	1 W/m^2
Electrical Equipment	Radiative	0.3 to 2 W/m^2	1 W/m^2	1 W/m^2
	Convective	1 to 5 W/m^2	5 W/m^2	5 W/m^2
Lights	Radiative	7 to 10 W/m^2	2 W/m^2	2 W/m^2
	Convective	2 to 4 W/m^2	0.5 W/m^2	0.8 W/m^2

Table 8 Parameters set for each gain type across different simulation scenarios (Author)

Chapter 05

Synthetic Modelling

This chapter describes the synthetic data of the thesis where Building energy simulation (BES) using TRNSYS as the simulation engine is used to generate the energy consumption of each ***workspace*** scenario.

5.1. Energy Simulations

TRNSYS, a simulation environment for the transient simulation of systems, is typically used by engineers and researchers to model energy concepts and has been used to simulate the energy performance of a multi-zone building in this research thesis. The energy performance of each scenario is simulated for a period of 1 year (8760 hours), from January 1st to December 31st, at 1-hour intervals.

Two sets of simulations are generated for each scenario: one that functions hybrid each week for a year while the other is generated considering a full time WFO for each week of the year. The parameters that define the energy simulations are calibrated based on the details in Chapter 04 to produce the following results related to operational energy. In this chapter, the simulation results for the aggregated energy use per year for heating and lighting are displayed. Other simulations performed have been included in Appendix I.

5.2. Simulation results

5.2.1. Office environment

A template office floor layout, modelled on Sketch Up, is imported into TRNSYS (Figure 31). To limit the computational time required for the simulations, the office building model is simplified to one floor section of it, situated in a middle floor. In this layout, multiple zones have been created to reflect the different areas of an activity-based office layout. Four sides of the layout are exposed to the outside while the two longer sides are equipped with windows.

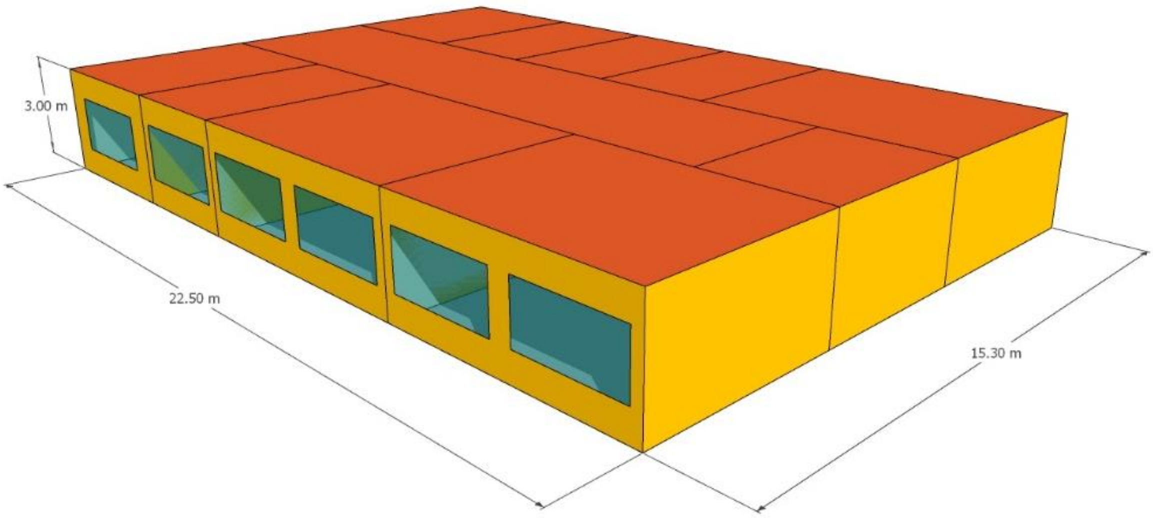


Figure 31 3-dimensional model of office environment (Author, exported from SketchUp)

The energy consumption of the office has been generated for two scenarios, one where employees work full time from office every week of the year and another which employs hybrid working 3 days of the week, each week in a year. This hybrid working scenario results in a maximum occupancy of only 60% on the two designated hybrid working days.

Figure 32 indicates the energy use for heating (and cooling) across the different zones during hybrid working and WFO, with the maximum simulated value being 75 (hybrid) and 77kWh/m^2 (WFO) for the large meeting room zone.

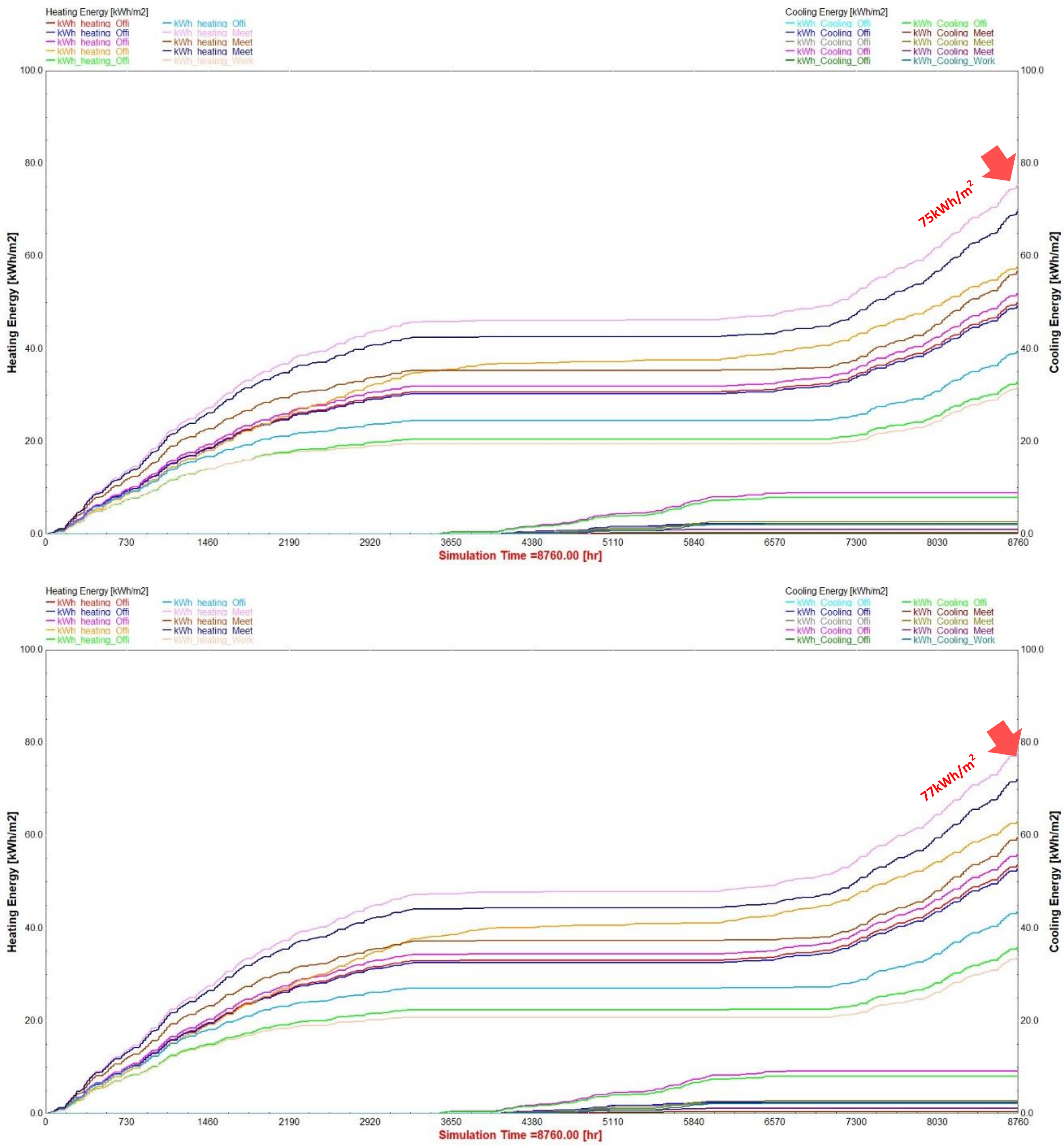


Figure 32 Office- Annua; Heating Cooling Energy use, Hybrid (above) and WFO (below) (Author, exported from TRNSYS)

A decreased energy use per m^2 is visible between the two sets of results, the initial indication of which is opportunity for building owners and operators to generate savings from hybrid working processes.

5.2.2. Housing Environment: Multi Person Household

The template multi person house floor layout, modelled on Sketch Up (Fig 33), is imported into TRNSYS to calibrate the different settings for the simulations.

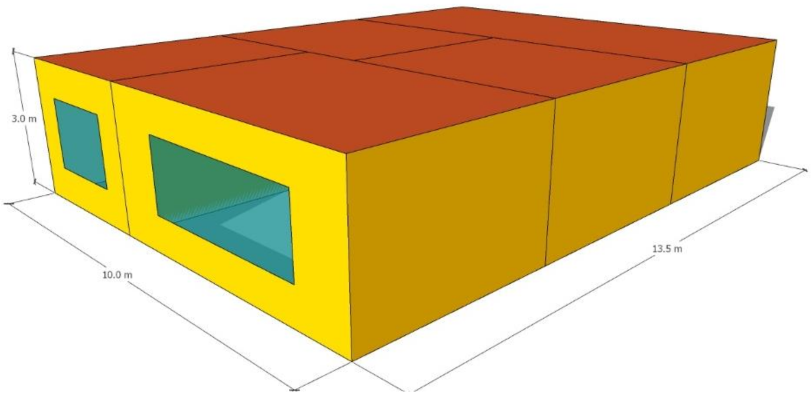


Figure 33 3-dimensional model of apartment (Author, exported from SketchUp)

The energy consumption of an apartment (multi-person household) and studio (single person household) where the occupants work from office full time (5 days a week) and Hybrid (3 days in office and 2 days at home) were then simulated on TRNSYS to yield the below results.

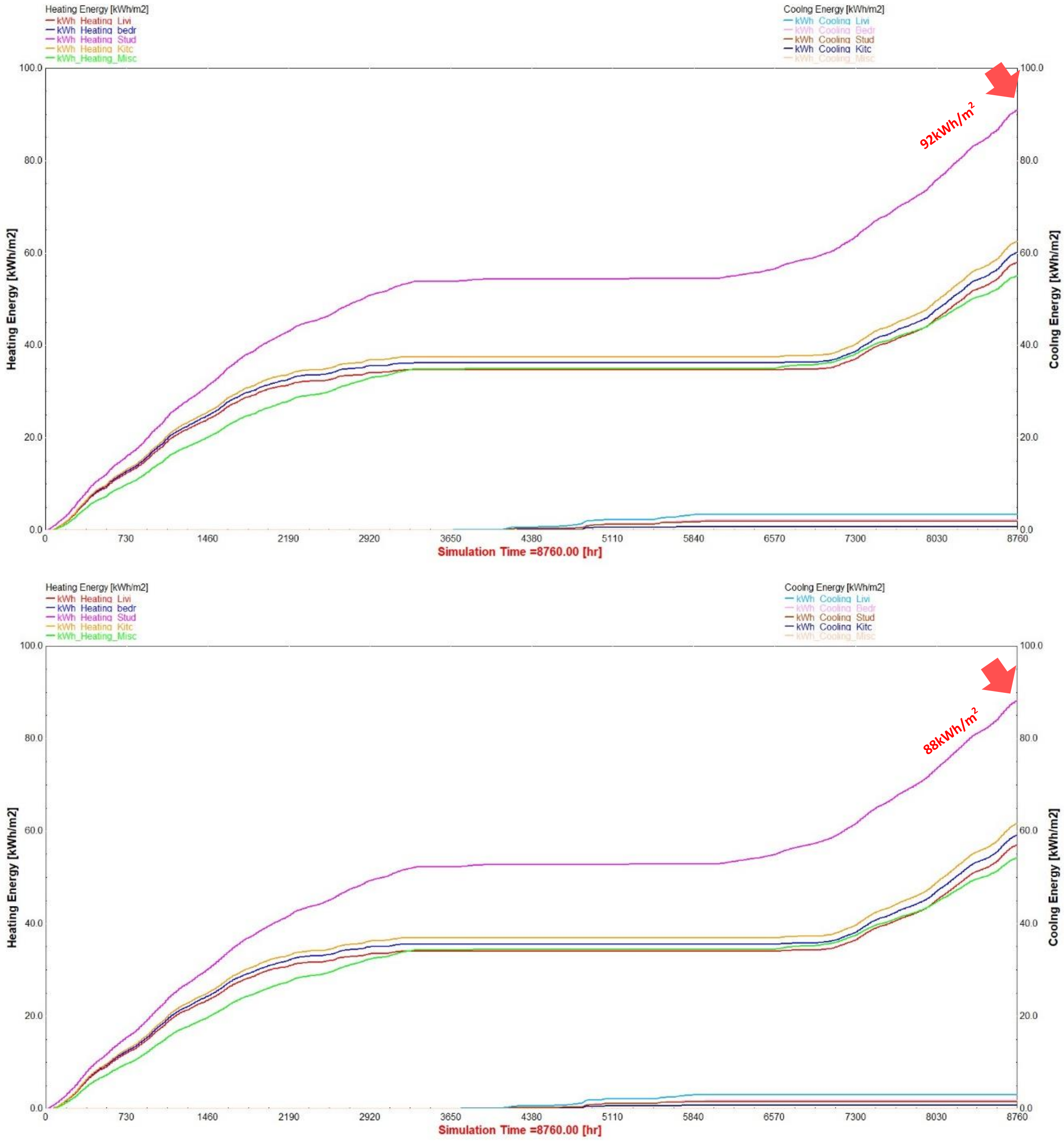
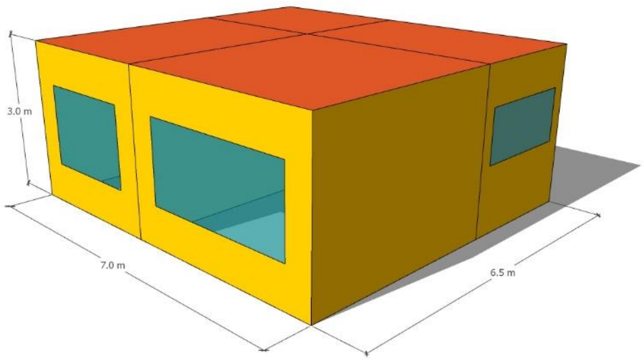


Figure 34 Apartment-: Annual Heating Cooling Energy use, Hybrid (above) and WFO (below) (Author, exported from TRNSYS)

The first implication of the simulated data is the increased energy use for both scenarios when compared to the office data sets. Secondly, as seen from Figure 34, a hybrid working scenario utilises approximately 4kWh/m^2 more than a WFO working scenario, implying that some of the energy savings of hybrid working at offices are shifted onto the individual remote workers.

5.2.3. Housing Environment: Single Person Household



The template Studio floor layout, modelled on Sketch Up (Fig 35), is then imported into TRNSYS to calibrate the different settings for the simulations and produce the following results.

Figure 35 3-dimensional model of studio environment (Author, exported from SketchUp)

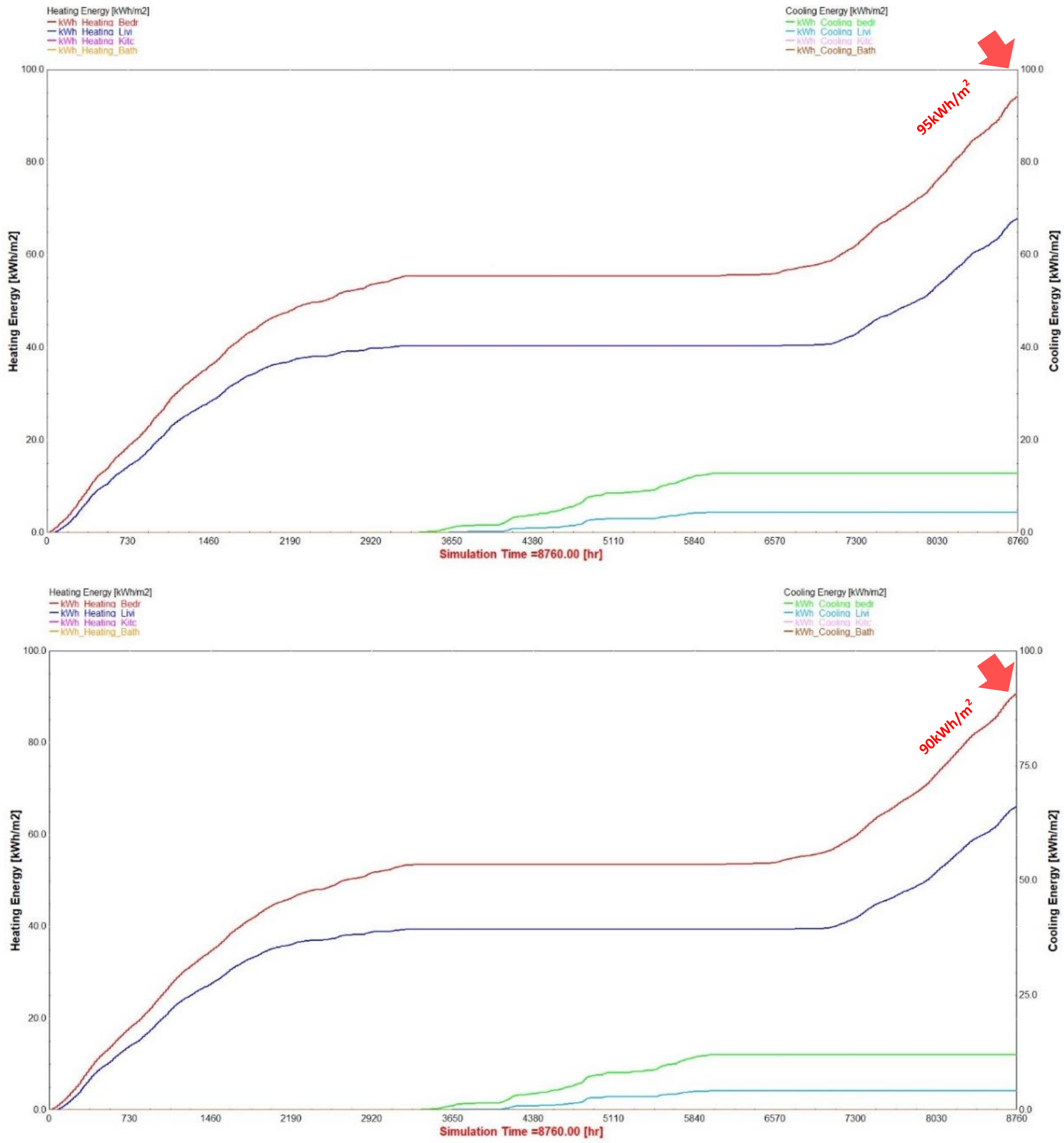


Figure 36 Studio- Annual Heating Cooling Energy, Hybrid work (above) and WFO (below) (Author, exported from TRNSYS)

The simulated datasets of the studio align with the previous graphs, producing an increased energy usage of around 5kWh/m^2 between hybrid working and a WFO scenario. This confirms the offset of office energy savings onto the employees. Secondly, the energy usage per m^2 is the highest in a single person household scenario when compared to the other two.

5.3. Results

To compare and analyse the data produced by the simulations, the maximum energy per m^2 for heating of each scenario has been tabulated below.

S.No	Workspace environment	Space	Working Type	Max Energy use (kWh/sq m)
1	Office	Office room	WFO	62
2			Hybrid	57
3		Meeting	WFO	77
4			Hybrid	75
5		Co-working/ Cafe	WFO	34
6			Hybrid	31
7	Apartment	Study	WFO	88
8			Hybrid	92
9		Living/ Bedroom	WFO	57
10			Hybrid	60
11	Studio/ Single Bedroom House	Study/ Bedroom	WFO	90
12			Hybrid	95
13		Living/ Misc	WFO	65
14			Hybrid	67

Table 9 Maximum annual heating energy usage for the different workspace environments (Author)

The initial analysis of the simulation results indicates the following:

- There is a uniform difference in energy demand of about 5kWh/m^2 between WFO and hybrid working across all three workspace environments without taking systems efficiency into account.
- Energy demand per m^2 is higher in residential workspaces than the office.
- Energy demand per m^2 is the most intensive in single person households.

5.3.1. SWOT Analysis:

The results of the simulation are positioned along the SWOT analysis to understand its implications on the management of the workspace environment.

These simulations indicate that there is a potential savings in energy consumption for an office that employs hybrid working (2 days of the week at minimum). However, it is important to note that the simulations have been generated considering that the consumption dynamically responds to occupancy.

Hence any savings in shifting to a hybrid mode of work is contingent on **coupling consumption to occupancy** or **reducing the space being occupied.**

Offices feature a large diversity of space and allow a more dispersed use of resources. Large scale corporates are also typically equipped with sophisticated control mechanisms that allow for a more efficient isolation of energy resources. Furthermore, when one accounts for the number of teleworkers per m^2, these results indicate a rather inefficient use of both space and energy resources between residential workspaces and the office.

The potential savings from employing a hybrid working week is however offset by increased energy consumption at houses. The simulation results reveal how energy intensive household workplaces can be, with single person household compositions particularly showing disproportionate usage. While an increase of 4-5kWh/m^2 per worker is not exorbitant at an individual level, when multiplied across the entire workspace that opts to work remotely, the cumulative results could be exorbitant. Lastly, even without accounting for hybrid working, the simulation data indicates that energy demand per m^2 is higher in residential than commercial places, and the most intensive in single person households.

Figure 37 SWOT analysis (Author)

Functionally, there is a certain degree of autonomy and flexibility that accompanies hybrid working. However, working from office allows a cleaner separation of work and personal lives, characterised by standard working hours. This blurring of boundaries is one of the common reported disadvantages of remote working, resulting in longer working hours and consequently increased energy use. Additionally, all the simulations have been performed with an optimistic expectation of 100% maximum occupancy during peak hours of a day (10-11:00 and 15-16:00) with gradual increases and decreases. However, achieving a 100% occupancy rate on any given day is quite hard in practice.

5.3.2. Implications along the Four Perspective Scheme:

The system mapping is therefore first updated to reflect that the spatial characteristics are a factor of the **context** and the **workspace environment**. Context is further defined by the occupancy pattern and social structures in the prevailing area. The workspace environment at home links back to the social structures in place while at office is defined by space type and its morphology.

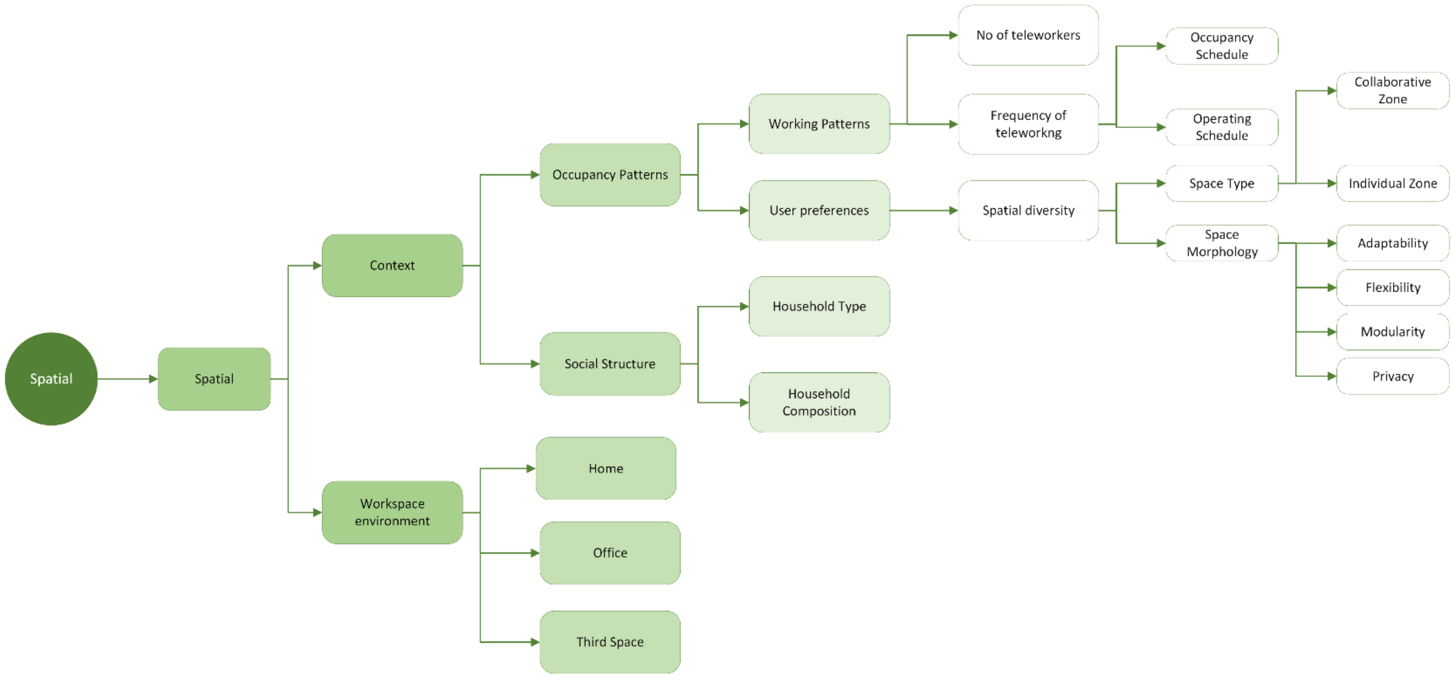


Figure 38 Updated system mapping of the spatial characteristics of the physical (Author)

5.3.3. Tipping point of hybrid work:

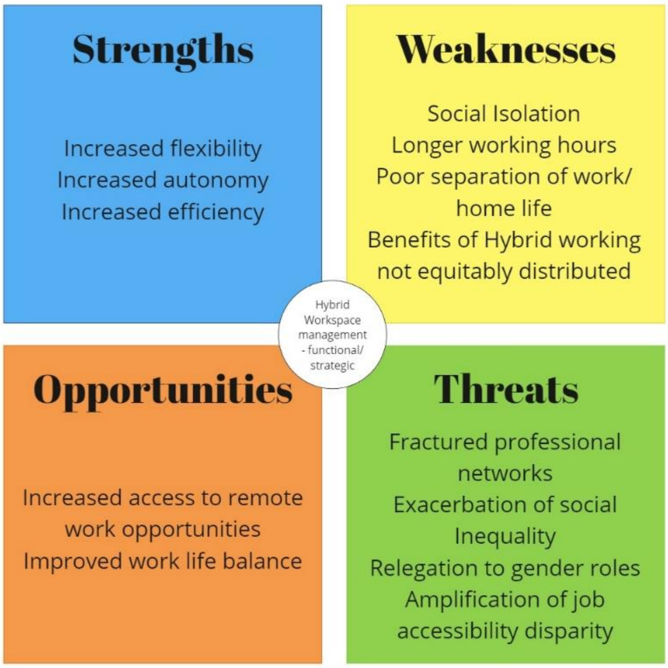


Figure 39 SWOT analysis (Author)

While the term "hybrid" generally refers to a combination of two or more distinct entities that is intended to produce a new and ***improved*** version of the original components, the simulations performed in this research lend to the hypothesis that the benefits of hybrid working are **not equitably distributed**. This inequality can occupy many dimensions:

Social Inequality: There is an **increased inequality** between teleworkers that is a function of household composition and household size with the largest burden falling on the smallest occupancy compositions. Spatial inequalities are a manifestation of economic inequalities and Reuschke & Felstead (2020) suggest that they have become even more pronounced during the pandemic. Additionally, figures from Statistics Netherlands (Figure 40) suggest a deterioration of financial situation in recent years. With the **additional burden of increased energy costs** from hybrid working, this points to a widening financial gap between teleworkers.

Consumer attitudes and expectations		
Financial situation last 12 months		
Total	%	100
Got much better	%	3
Got a little better	%	14
Has remained the same	%	32
Got a little worse	%	36
Got much worse	%	14
Do not know	%	1
Financial situation for the coming 12 months		
Total	%	100
Getting much better	%	3
Get a little better	%	17
Remain the same	%	52
Getting a little worse	%	21
Getting much worse	%	4
Do not know	%	3
Financial situation of own household		
Total	%	100
Make debts	%	3
Tapping into savings	%	14
Just getting by	%	23
Save some money	%	47
Save a lot of money	%	10
Do not know	%	4

Figure 40 Consumer confidence; household characteristics for the year 2023 (CBS, 2023)

Besides the financial burden on the user, studies also suggest that teleworking results in **skewed gendered roles.** Loezar-Hernández et al., (2023) report disproportionate effects of teleworking on women as they did not have separate areas at home that they could use exclusively for professional purposes and had to share their workstations with their families, which affected their concentration and prompted interruptions. Furthermore, they were more likely to be entangled in domestic labour (e.g., childcare, homeschooling, cleaning, and cooking) and as a result were at *"risks of detaching…from professional work, precarizing their labour, and consolidating their roles as traditional housewives"* (Çoban, 2022).

Spatial Inequality: From an egalitarian perspective, every individual should have equal access to job opportunities, regardless of their geographical location or underlying socio-demographic characteristics (Wee et al., 2011). The advantages of hybrid teleworking are not uniformly distributed due to pre-existing personal and work-related limitations. As hybrid teleworking becomes more common, it could worsen inequalities in job access, raising questions about how job opportunities will be distributed in hybrid work environment (Van Lent, 2023).

Chapter 06

Case Study Analysis

In this chapter, occupancy, and energy use data from two case studies – ING Belgium and Building 28 at TU Delft, are analysed. The datasets are individually analysed and compared to the results of the synthetic simulations, detailed in Chapter 05, to draw broader conclusions.

6.1. Case Selection Criteria

The system mapping has been established from literature, data, and simulations based in Europe and America due to similarities in working trends. To ensure an adequate degree of comparability, it was necessary that the company had offices operating in Northwestern Europe, specifically The Netherlands, Belgium and German. Based on details mentioned in previous chapters, it was also important to identify workplaces that followed a hybrid mode of working. Additionally, data availability, specifically an active tracing of the asset occupancy and/ or energy performance was an important factor to evaluate and compare with the conclusions drawn from the simulations. To increase the generalisability of the conclusions, data from contrasting workplace settings were collected.

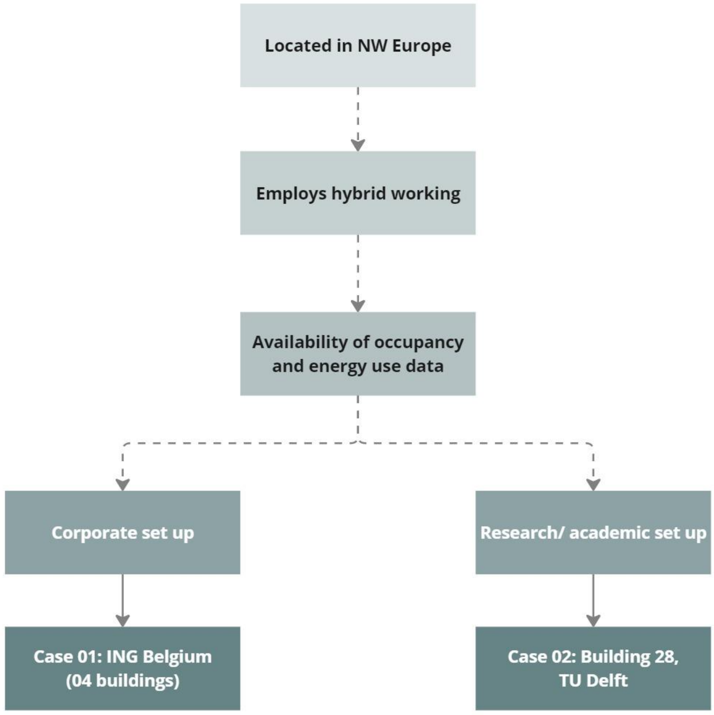


Figure 41 Case selection criteria (Author)

6.2. Performance Measurement:

"Performance measures used in CREM should be identified based on the company's core business goals instead of using traditional accounting measures focusing mainly on cost reductions or capital minimization." (Lindholm & Gibler, 2005)

The analysis of the chosen cases utilises an adapted form of Otley and Ferreira's (2009) Performance Management System (PMS) Framework. This involves first understanding the vision and mission of the selected cases as well as the strategies/ plans currently in place. Following this, the occupancy and energy performance metrics which serve as the Key Performance measures for this research are studied. The performance data is then evaluated within the conceptual framework of this study.

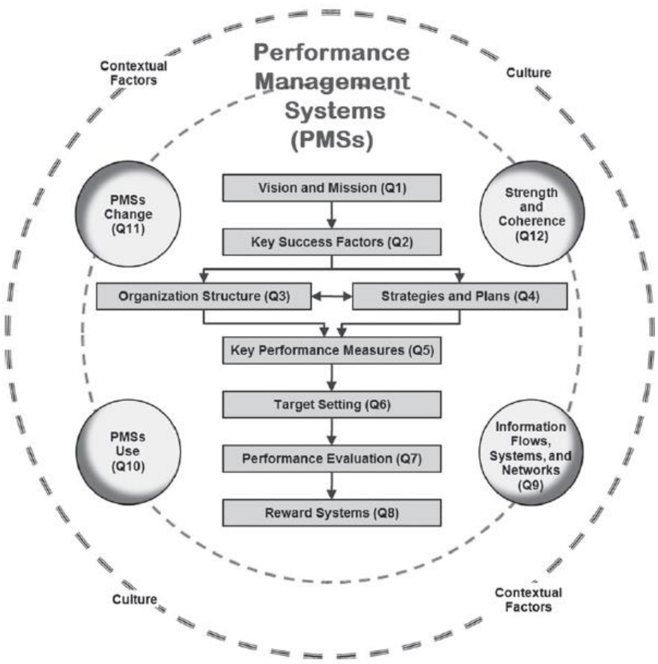


Figure 42 The performance management systems (PMSs) framework (Ferreira & Otley, 2009)

6.3. CASE STUDY 01: ING Belgium

The first case, ING (Belgium), is a multinational bank rooted in the Netherlands. For several decades, it has been a global changemaker in the banking industry. ING's main businesses include retail banking, direct banking, commercial banking, investment banking, wholesale banking, private banking, asset management, and insurance services.

6.3.1. Vision and mission:

ING considers itself a digital-first bank and places high value on a superior customer experience. As such, scalable technology and operations are an important element of their employee handling operations, enabling them to collaborate at a global level. They state in their 2023 report (ING, 2023) that one of the factors that contribute to their success is '*the ability to attract and retain highlight qualified personnel".*

Approach to sustainability: ING aims to be a pioneer in sustainability by integrating and aligning ESG governance within their overall operations. They strive for net-zero emissions across their buildings, data centres, and business travel, setting a goal to achieve net-zero for buildings by 2035 through improvements in energy efficiency, space efficiency, and low-carbon heating systems.

Their digitalization efforts are a key part of reducing their environmental footprint. This initiative also has a social dimension, empowering employees to actively participate in the sustainability strategy by increasing awareness of their own CO2 footprints. Policies promoting this include CO2 budgets to reduce business travel, the use of video-conferencing tools, and encouraging rail travel for distances under 500 km. Additionally, ING is developing a global sustainability learning program and upskilling initiatives to engage employees in sustainability-related topics (ING, 2023).

6.3.2. Hybrid working and ING:

Approximately 80% of the workface was forced to work from home during the pandemic. With the relaxation of social distancing measures, ING switched to a 50/50 policy in 2022 allowing employees to spend half their time working from home (Comfort, 2022). This flexibility is also extended to working hours, as employees can adjust their daily schedules to accommodate a host of other functions or the possible rebound effects of hybrid working.

Currently, over 77% of ING employees work hybrid spending one to four days in the office (ING, 2023). However, over the last two years, one of the biggest challenges faced by ING is bringing employees back to the office and ensuring an alignment between their real estate portfolio and demand, as reported by Peter Mostien (VergeSense, 2023).

For this research thesis, occupancy data from the four main office buildings of ING Belgium, the Belgian subsidiary of ING Group, were reviewed. The bank leases land and buildings for its headquarters and branches, with lease terms typically spanning 3-6 years. The current spatial planning includes a desk-sharing policy, providing approximately 70 seats for every 100 FTE's (Full time employees).

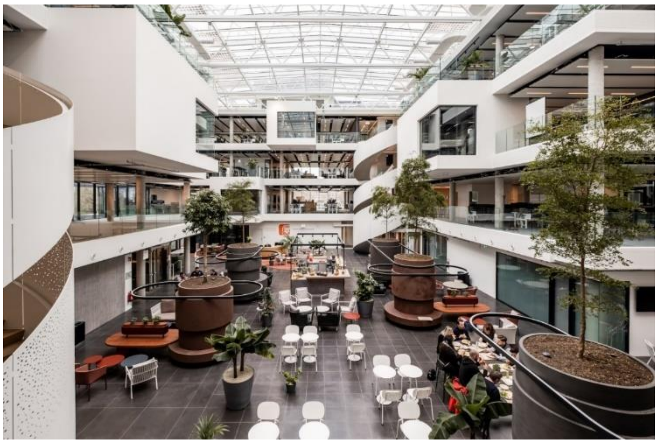
6.3.3. Building details

ING MARNIX

LOCATION: BRUSSELS, BELGIUM
AREA: 54,058 M^2
YEAR OF CONSTRUCTION: 1960'S

The office at Marnix, Brussels is the new headquarters for ING Belgium and was constructed in the early 1960's. The building underwent a retrofit recently to make it future poof with an emphasis on employee wellbeing, smart technology and environmental solutions. It now contains open workspaces that reflect ING's commitment to agile working and the New Way of Working, translating to a capacity of 814 desks for 1165 FTEs. An additional 746 seats are being added to Marnix at the end of 2024 to accommodate 4500 more people.

ING LOUVAIN-LA-NEUVE (LLN)



LOCATION: LOUVAIN-LA-NEUVE, BELGIUM
AREA: 10,875 M^2
YEAR OF CONSTRUCTION: 2019-2021

The ING office at Louvain La Neuve offers approximately 10.200m^2 of offices around a large atrium on 4 levels, and 320 parking spaces on 2 basement levels. A typical office floor configuration is organized around clusters of collaboration areas: meeting rooms, focus booths, informal pockets that act as buffers between different team zones. The building has been designed to accommodate sustainable mobility, with an infrastructure for bicycles and electric cars in the underground parking garage with 350 parking spaces. Given the desk sharing policy, ING LLN has a capacity of 514 seats for 495 FTE.

ING GHENT

LOCATION: GHENT, BELGIUM
AREA: 16,000 M2
YEAR OF CONSTRUCTION: 2011-2018

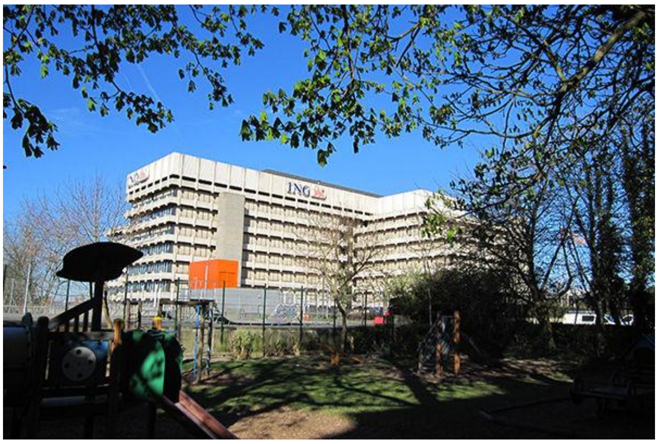
Diamond is a 7-story standalone office building located on the Koningin Fabiolalaan in Ghent, next to the main railway station of the city. This building accommodates the regional bank headquarters in the historical city of Ghent, Belgium and has a BREEAM certificate of 'very good'. It has a seating capacity of 608 seats for 623 FTEs.

ING Cours Saint Michel (CSM)

LOCATION: BRUSSELS, BELGIUM

AREA: 60,000 M2

YEAR OF CONSTRUCTION: 1960's



The ING office at Cours Saint Michel, has about 60,000m2 of office space and is located at Mérode station - close to the Mérode district between the European district and the eastern districts of Brussels. The office has a seating capacity of 1638 seats for 4134 FTE. CSM is in the process of being taken over by a new occupied and ING will hence move out of the premises by the end of the year.

6.3.4. Aggregated occupancy data overview

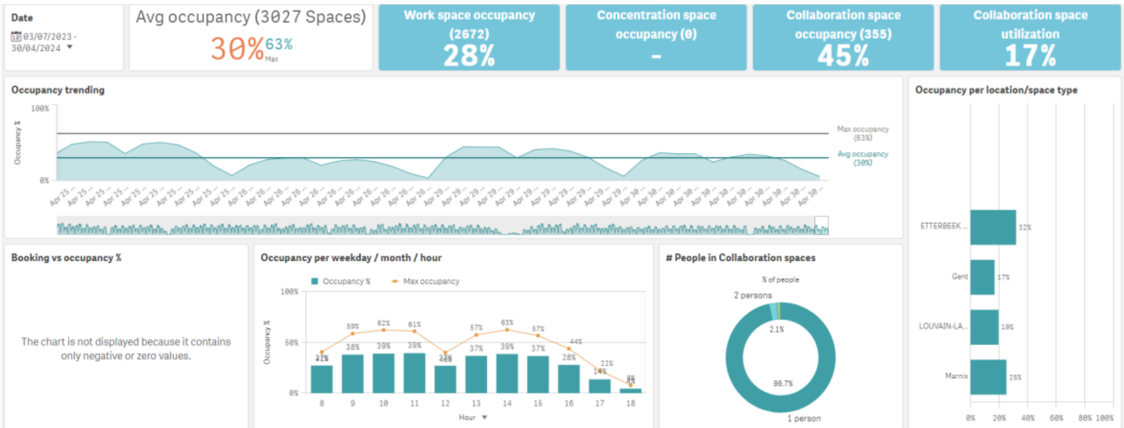


Figure 43 Aggregated occupancy details (Exported from Spacewell database)

Aggregated spatial usage (occupancy and utilisation) were exported from the Cobundu Smart building platform which provides real time usage about occupancy, utilisation, comfort and air quality metrics. Data from the above four buildings was analysed for a period of **ten months** (July 3rd 2023 to April 30th 2024) between 8:00 and 18:00, considering Monday to Friday as the typical working days in a week. A summary of the same (Figure 43) indicates an average occupancy of 30% (63% max) with collaborative spaces showing higher occupancy than workspaces. The maximum occupancy being 63% across these ten months indicates that over 1/3rd of the space remains consistently unoccupied.

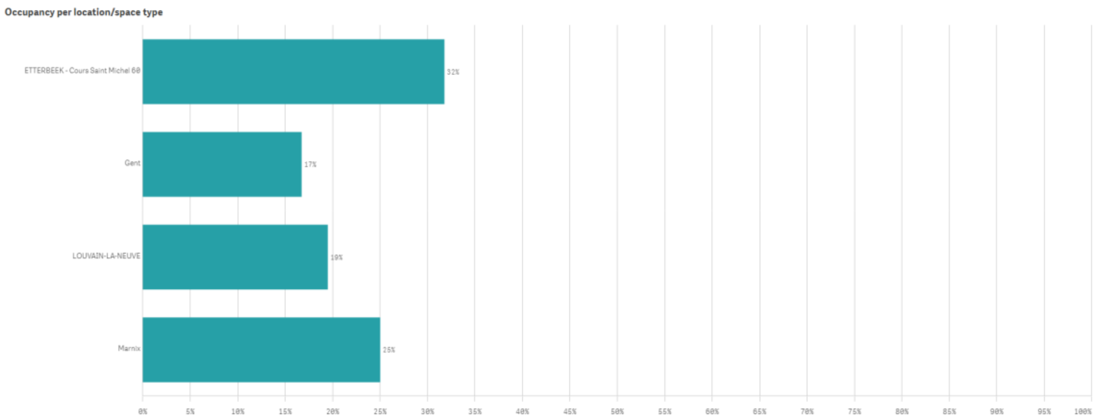


Figure 44 Average occupancy split between the four buildings (Exported from Spacewell database)

Occupancy Trends: Daily occupancy trends point to an almost uniform daily occupancy between 9:00 and 15:00, with maximum peaks being recorded at 10-11:00 and between 14-15:00.

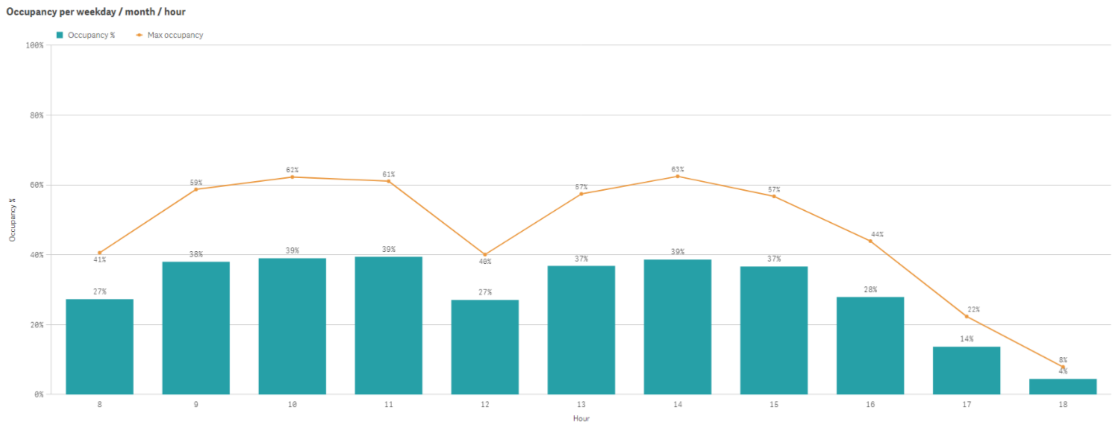


Figure 45 Cumulative occupancy trends on an hourly basis for the four buildings (Exported from Spacewell database)

Weekly occupancy details (Fig 46) of the four buildings point to usage peaks on Tuesdays and Thursday with Wednesday and Friday showing the least usage. ING Ghent is the outlier among these buildings, with Mondays showing the least occupancy in a week, followed by Friday and Tuesday. However, this still tracks with the general trends of occupancy in the NW Europe being low at the start/ end of the week.

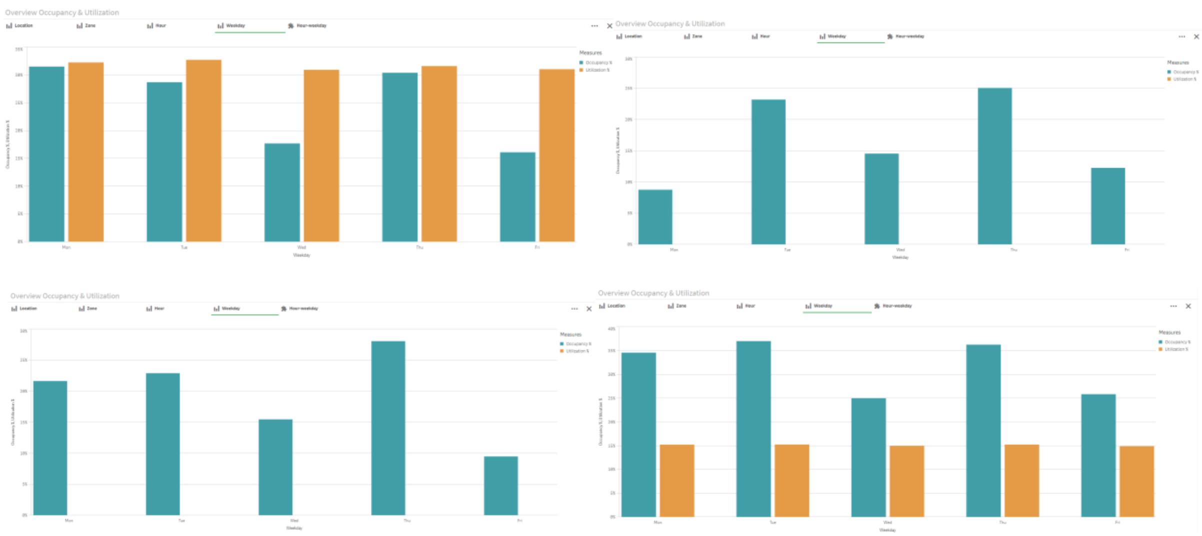


Figure 46 Weekly occupancy trends at ING Marnix, Gent, LLN and CSM respectively (clockwise) (Exported from Spacewell database)

An interesting result of this occupancy data aggregation is the prevalence of uniform working hours that align with typical working day despite the flexibility to adjust what a ‘typical’ working day looks like. Additionally, another clear output of this data is the synchronisation of weekly occupancy peaks.

Distribution of space: For the distribution of space, data was analysed for ING CSM and ING Marnix building for a period of the **three months** (February 1st 2024 to April 30th 2024) as not all the work desks in the other buildings are equipped with sensors. The figures below point to the distribution of space types and their usage in ING CSM and ING Marnix. The spatial capacity points a to higher provision of workspaces to collaborative and meeting spaces (Figure 47 and 48).

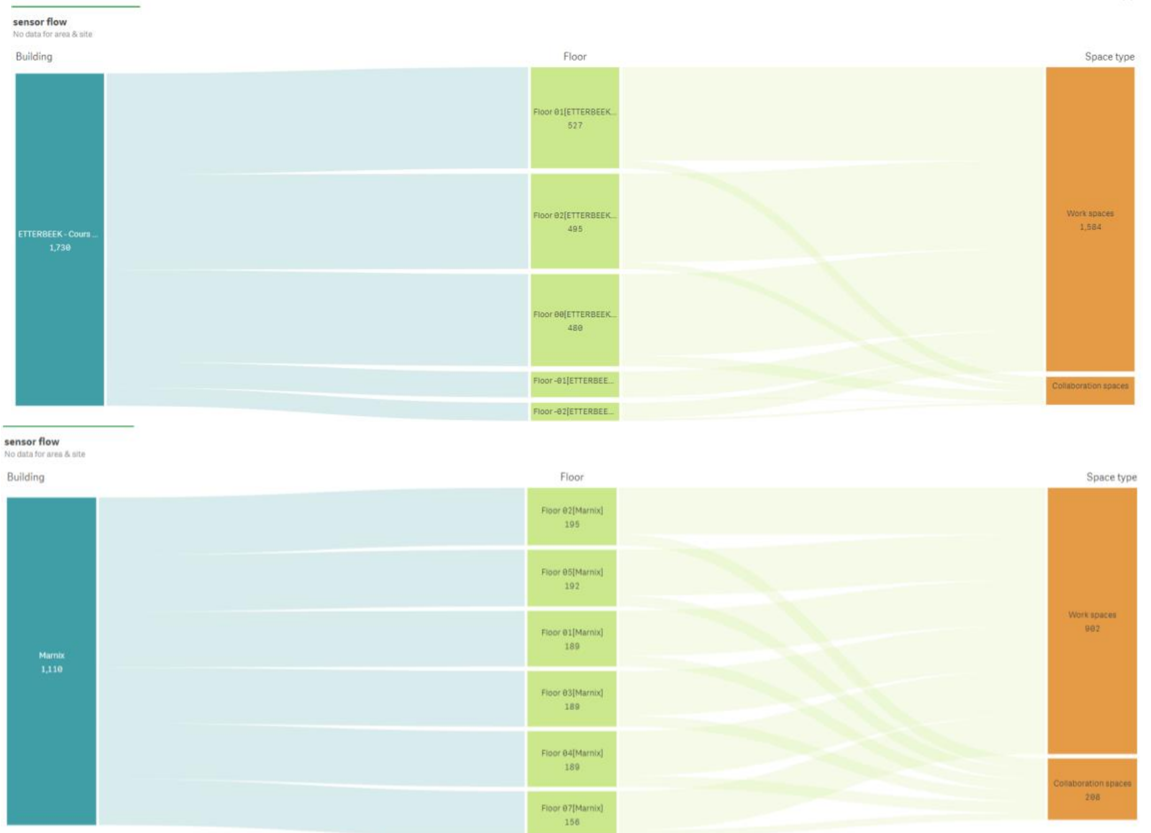


Figure 47 Distribution of space types in ING CSM (above) and Marnix (below) (Exported from Spacewell database)

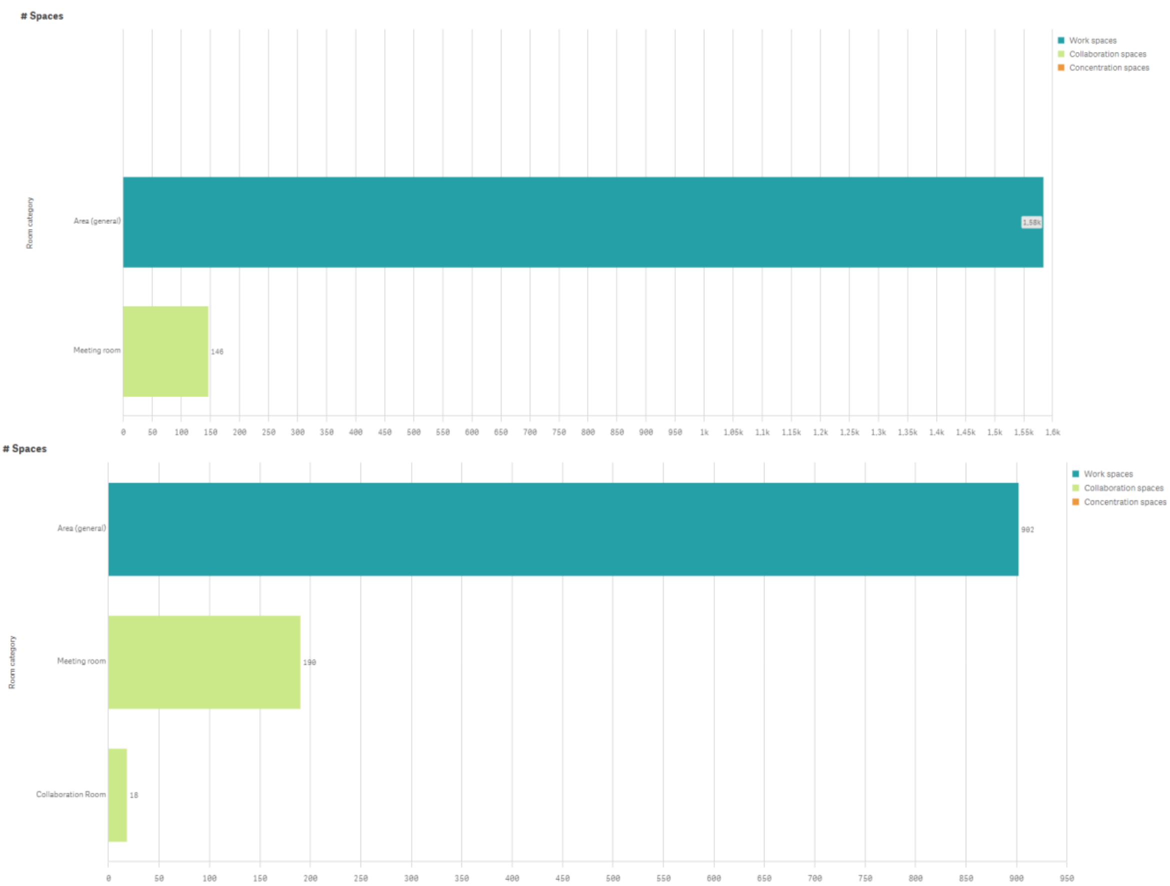


Figure 48 Split up of space types in terms of # of desks at ING CSM (above) and Marnix (below) (Exported from Spacewell database)

The usage data for this period produces some interesting results. While there are much fewer collaborative spaces in ING CSM, these are the spaces showing a high occupancy (55%). However, it is also important to note that there is a retrofit project underway at Marnix, resulting in employees having to work at CSM.

In contrast, ING Marnix has a higher number of desks designated as collaborative spaces, but these show a lower occupancy of only 14% when compared to the usage of the work desks which stands at 28% (Figure 49).

Avg occupancy

Country | Building | Floor — Space category | Zone | Room category | Values | Department

	Totalen		Collaboration spaces		Work spaces	
	Number of spaces	Avg occupancy	Number of spaces	Avg occupancy	Number of spaces	Avg occupancy
-	2840	30%	354	35%	2486	29%
ETTERBEEK - Cours Saint Michel 60	1730	32%	146	55%	1584	30%
Marnix	1110	26%	208	14%	902	28%

Figure 49 Average aggregated Occupancy across the four buildings (Exported from Spacewell database)

Similarly, the seating capacity provision between the two buildings differs significantly. ING CSM, being an older office, primarily offers spaces with 5-9 seats or more, with almost no individual workspaces. However, usage data reveals that these spaces are typically occupied by individual workers, with 97.1% of usage involving only one person as seen in figure 50.

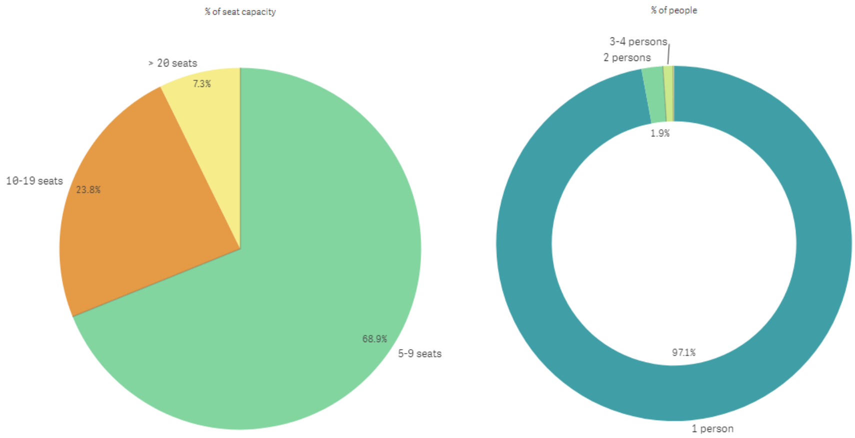


Figure 50 Seating capacity vs seating usage ING CSM (Exported from Sapcewell database)

In contrast, ING Marnix, a newer building, allocates 85% of its space for smaller groups with 2-4 seats. However, similar to ING CSM, more than 90% of the usage is by individual workers.

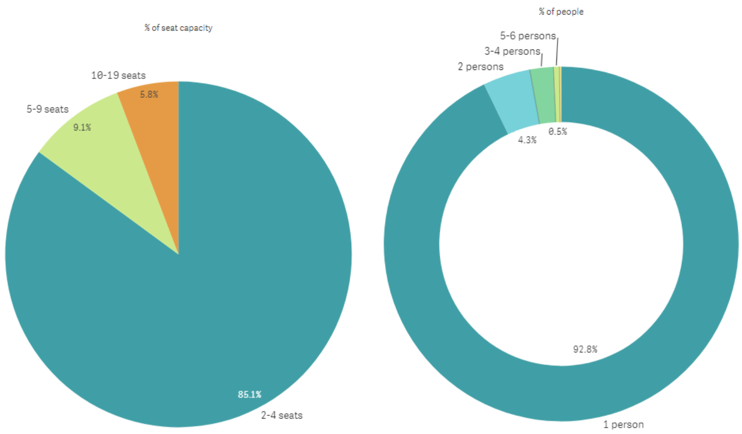


Figure 51 Seating capacity vs seating usage ING Marnix (Exported from Spacewell database)

At first glance, there appears to be a mismatch between spatial provision and employee usage behaviour, indicating a disparity between supply and demand. However, considering the high proportion of online work and virtual meetings, there might be a greater need for individual spaces that support undisturbed work. Additionally, as ING is a global financial corporation with a presence across the world, collaboration with teams from other branches and across various time zones is integral to their working processes. Marnix, which recently underwent a retrofit, seems to accommodate these new working trends better than CSM, offering a more diverse range of seating capacities. Despite this, there remains a misalignment between provision and actual usage, as indicated by the observed data.

6.3.5. Results

Figure 52 SWOT analysis (Author)

The aggregated data is analysed using a SWOT analysis to understand its implications, as depicted in Figure 52. The current usage patterns reveal a weakness in office occupancy, indicating an oversupply of office space. Over a 10-month period, the average occupancy is only 30%, with a maximum of 63%, leaving more than one-third of the space consistently unused.

Furthermore, the current spatial planning predominantly favours work desks over collaborative spaces, despite usage data showing that about 97% of the utilization is by individual workers. This discrepancy raises concerns about the alignment between ING's vision and mission of achieving net zero through space and energy efficiency, and its operational strategies. This misalignment exacerbates the mismatch between demand and supply, leading to increased energy consumption and costs.

If the energy usage is dynamically tied to occupancy, inflated energy costs could be avoided and accounted for. However, the layouts at ING Marnix (Fig 53) are largely organised into open floor configurations, segregated into zones through different seating arrangements. Typically, this would make it more complex to isolate energy usage (in terms of heating/ cooling) to one zone.

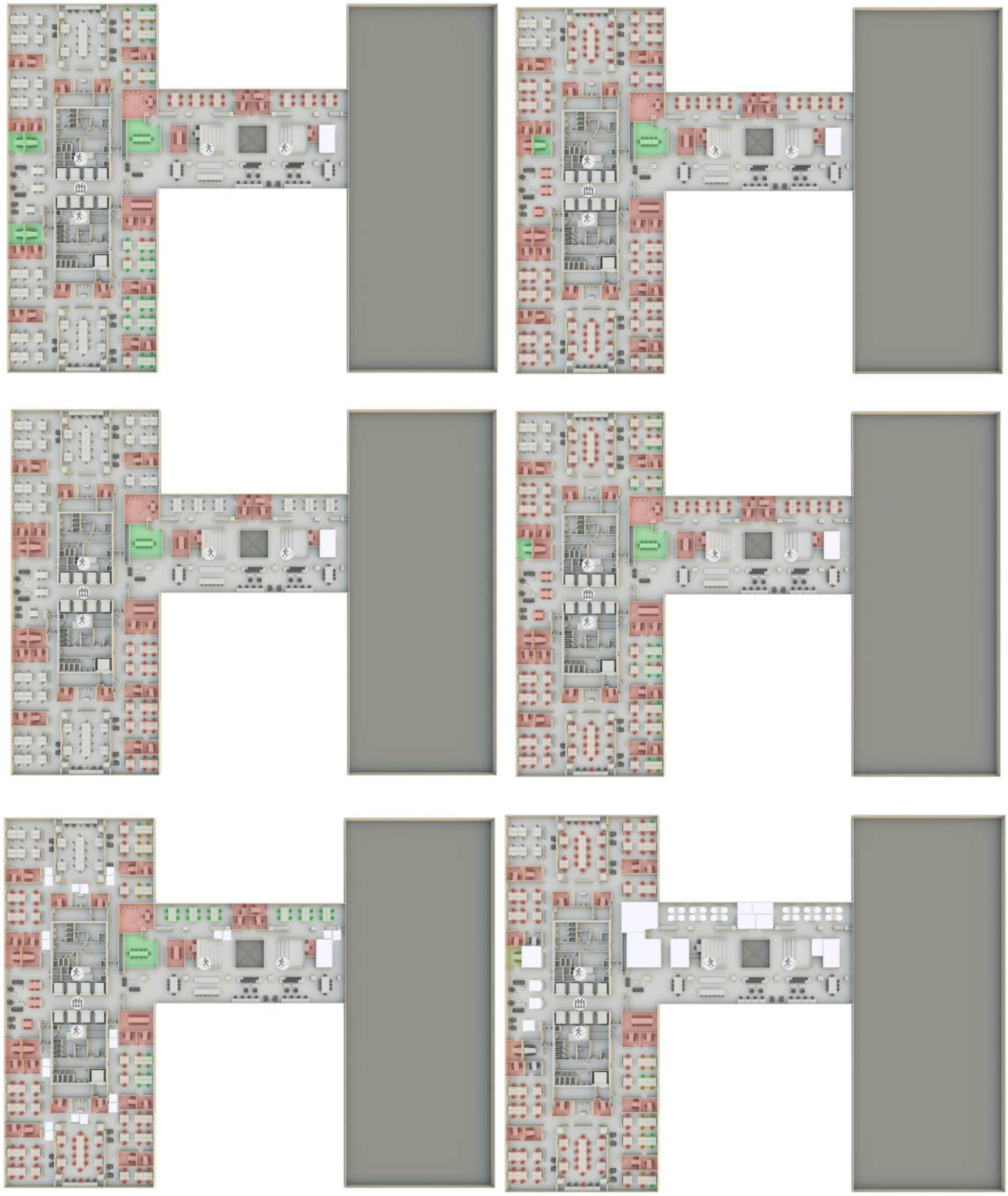


Figure 53 Floor layout occupancy ING Marnix (Exported from Spacewell database)

In the absence of energy usage data from ING, it is hard to definitely conclude that this works against them, but it is safe to assume that even with a dynamically operated energy system, there might still be energy wastage resulting from the large amounts of space that remain underoccupied on average.

Occupancy trends based on spatial type provide differing results. While CSM indicates an increased usage of collaborative spaces, this is not the same for Marnix. However, one aspect that is common to both is the high usage of spaces by individual workers. This is also compliant with Peter Mostien's assertion (VergeSense, 2023) that people are coming to office for individual work, **alongside** their teams.

Furthermore, as seen in Figure 53, Marnix hosts an open space working configuration. The assumptions behind this concept are that open spaces and flexible use of workstations benefit collaboration and performance through increased communication. While this is a simple causal relation, it is more complex, ***"since the physical work environment does not determine employee behaviour"*** (Gifford, 2014:p. 341; Vischer, 2008) and the high proportion of individual worker usage seems to confirm the same. With the recession of the pandemic, there is also increased mobility **within** the office building as employees seem to require more space than before. All of this points to **changing employee behaviour** with respect to the use of space due to hybrid working.

One of the strengths identified from the data presented is that despite the flexibility provided by hybrid workings, there are common occupancy trends being recorded for all the buildings with hourly peaks mostly occurring between 10-12:00 and 14-15:00, and weekly peaks mostly occurring on Tuesdays and Thursdays. Friday is consistently the least visited the day in the office. This standardised data set allows for employers and business owners to look at innovative or alternate ways to optimise space without risk of affecting working outputs.

6.3.6. Solutions:

With the modern workspace taking on the attributes of a campus in recent years, Den Heijer's (2012) recommendation to consider the different attributes of a city that can help in managing a campus become relevant here.

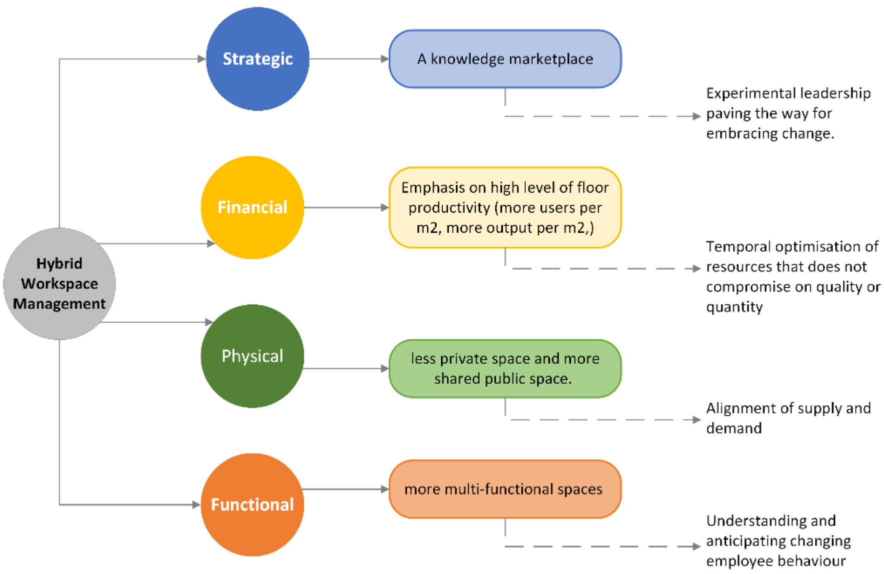


Figure 54 Manging a campus perspective (Author)

All of them have a combined effect on performance criteria, i.e. competitive advantage, profitability, productivity, and sustainable development. These can be further tailored to the specific needs of the organisation.

Physical Solutions:

<u>Rightsizing of portfolio:</u> As ING's positions itself as a digital first bank, these results offer an opportunity for the company to ***rightsize*** their real estate portfolio by aligning spatial and asset provision with this changing employee behaviour. This involves a conscious understanding about the data but also the details between the data, and more specifically the behaviour behind the data and the employees

behind the behaviour. Solutions need to be tailored to specific contextualities, resulting in a larger range of behavioural solutions than previously.

ING Belgium has already taken a few measures to account for this. ING CSM is expected to be emptied by the end of 2024 and the 4000 FTE currently housed there will be shifted to ING Marnix. ING Ghent and LLN are also in the process of freeing up one floor each, representing a reduction of +/- 150 desks, thereby maximising the spatial efficiency of their portfolio.

<u>Temporal Optimisation of Space:</u> The physical is also a manifestation of the temporal. The data above has only been collated for a typical working day (8 to 18:00, Monday to Friday). When we analyse the hourly occupancy trends for the four buildings across the same ten-month period, their premises are minimally occupied from 17:00 onwards. Furthermore, there is consistently 0% occupancy on the weekends for this period.

Figure 55 Aggregated daily (above) and weekly (below) Occupancy Trends (Exported from Spacewell database)

The uniform synchronisation of time-based occupancy statistics across the four buildings offers employers and building owners a reliable and fairly standardised data set to consider innovative ways to optimise portfolio performance on a temporal level, or a time-based optimisation of building assets which does not reduce their spatial footprint. One example of this would be to partner up with other institutions to occupy their premises when not in use (example: 17:00 onwards, or on weekends). While there is risk and security limitation to sharing resources (specifically IT) within financial corporations, there is scope for such innovative strategies to be incorporated for other industries that can integrate this (example: academic spaces).

Functional:

<u>Leadership and employee behaviour:</u> Solutions can extend to how employees operate within the organization. ING has already made efforts to align employee behaviour with sustainability goals, but further progress can be achieved by leadership paving the way for change. Anticipating employee needs and experimenting with space utilization are crucial steps in this process

To effectively promote positive change, it's important to implement multiple policies, often referred to as the carrot and stick method. This approach combines "punishments" and "rewards" to encourage desired behaviour. For instance, discouraging private automobile ownership can involve restricting parking spaces, lowering speed limits, and shifting urban development goals to prioritize active modes of transportation and public transit over private cars (Xanthopoulos et al., 2024).

<u>Employee Attrition:</u> ING places high value on being able to attract and retain a talented workforce. While the literature on hybrid working points to increased employee retention from flexible working patterns, reduced in-person interactions may weaken physical and social ties, potentially diminishing employee loyalty and leading to increased attrition. Employee attrition poses a financial burden, as acquiring and training replacements for high-performing employees consumes resources.

Maintaining a fine balance in flexible working arrangements is crucial. As Robin Erickson, Vice President for Human Capital at the Conference Board, suggests, strong mandates to return to on-site work may hinder retention efforts, especially among women (Mulholland, 2023).

Strategic:

As a global changemaker, ING strives to lead by example. In recent years, office spaces have evolved into destinations for both employees and clients, with workspace solutions gradually transitioning into branding strategies. In light of this trend, employers like ING can explore repurposing their existing assets to *"breathe new life into the old"* through retrofitting spaces. Den Heijer (2012), suggests that repurposing existing spaces instead of constructing new ones aligns with sustainability goals and reflects the trade-off between the quantity and quality of space.

Financial:

The unpredictability of hybrid working processes also puts pressure on funding structures. Rapid changes in space and employee demands makes long term investments risky and very rarely feasible. Short term funding structures, through temporary leases or shared resources, either with other companies or with local entrepreneurs would help cushion the risks of such unknowns while also serving to bolster neighbourhood economies through the ripple effects of such partnerships- representing a shift in approach from cost control to total costs of ownership (TCO).

6.3.7. Updating the framework:

The different parameters identified through the analysis of this case is incorporated into the physical dimensions of the system mapping to produce the following update.

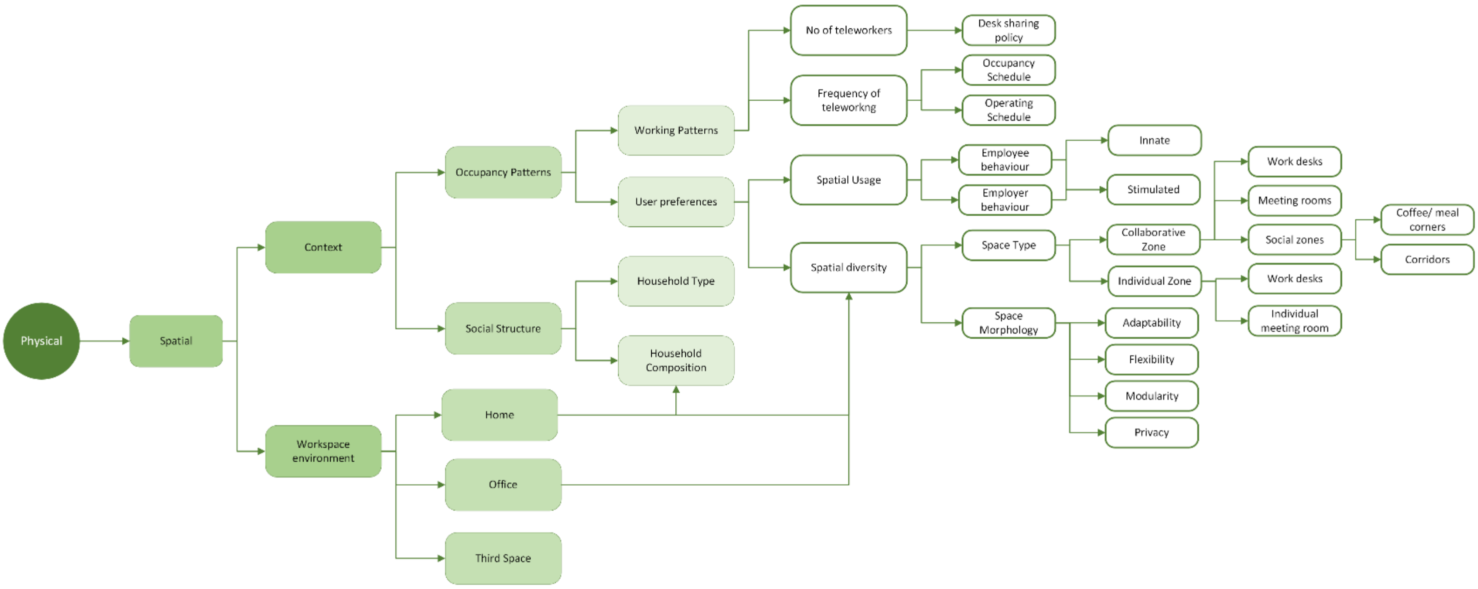


Figure 56 Updated mapping of physical components (Author)

6.4. CASE STUDY 02: Building 28, TU Delft

In this section, aggregated energy demand data from an office + educational building in TU Delft were collected to compare with the theoretical data produced from the simulations in Chapter 05.

6.4.1. Vision and mission:

The motto of TU Delft is 'Impact for a better society'. In line with their sustainability ambitions, the university aims to achieve carbon neutrality, climate adaptability, and circularity by 2030, encompassing considerations such as buildings, energy systems, waste management, and mobility.

Similar to ING, TU Delft positions itself as a front runner innovation and sustainability across various fields including science, engineering, design, planning, and governance, aspiring to set an example for others to follow. For the past three years, the university has implemented a hybrid working policy that allows employees to work from home up to two days a week.

6.4.2. Case details

LOCATION: DELFT, THE NETHERLANDS,
GFA: 10,500M^{2},
CONSTRUCTION: 2002
RENOVATION: 2018

Building 28 at TU Delft, situated on Van Mourik Broekmanweg 6 in Delft, underwent renovation in 2018 to accommodate the expanding Electrical Engineering, Mathematics & Computer Science faculty at the university's campus. Originally a TNO office building, it spans approximately 10,500m2 across seven floors. The redesign prioritized flexibility, featuring adaptable floor plans facilitated by dividers that can be installed, moved, or removed to meet evolving needs. The emphasis on flexibility aims to optimize space utilization efficiently. Notably, the redesign prioritized staff privacy and productivity, minimizing disruptions from meetings and fostering focused work environments. This approach encourages communication and collaboration among departments, research groups, and users while ensuring employees can concentrate on their tasks.

While designated as a 100% office function space, the breakdown of area allocation, depicted in Figure 56, reveals that 36% is dedicated to office space, with the remainder utilized for research and support facilities. Typically, the building operates from 7:00 am to 6:00 pm, Monday to Friday.

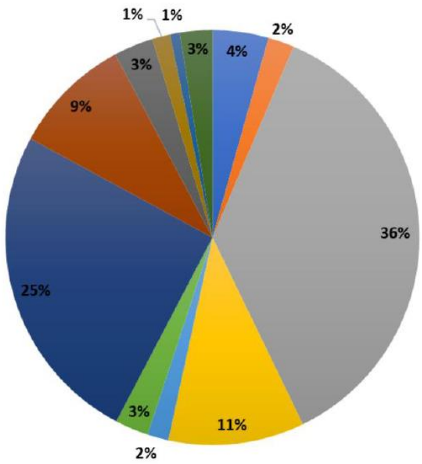


Figure 57 Building 28 functional split (Brains4Buildings

6.4.1. Occupancy Data:

Occupancy data for Building 28 was sourced from the Brains 4 Buildings project and analysed from February 19th, 2020, to December 31st, 2022. This data provides insights into occupancy levels, determined by monitoring CO_2 levels within the rooms using sensors at 10-minute intervals.

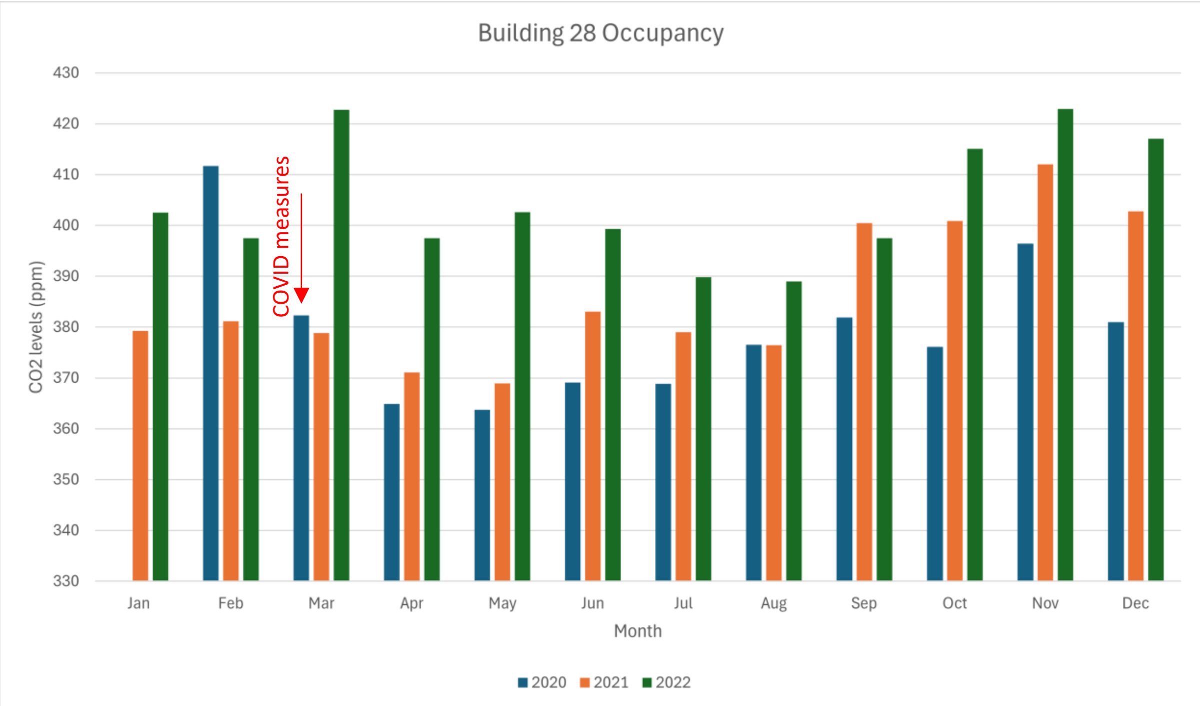


Figure 58 Aggregated occupancy as a measure of CO2 levels between 2020-2022 for Building 28, TU Delft (Own Computation based on data procured from Brains4Buildings)

As depicted in Figure 58, there is a noticeable contrast in occupancy levels between 2020 and 2022. The abrupt imposition of emergency pandemic measures on March 13th, 2020, prompted an immediate shift from predominantly on-campus activities to remote work. This shift is starkly evident in the sharp decline in occupancy levels observed between February and March 2020. As pandemic restrictions gradually eased towards the end of 2021, there was a corresponding uptick in occupancy levels over the following year.

To gain insights into weekly occupancy trends, November was selected as a representative month due to its consistently high occupancy levels across the three years. The occupancy data was then aggregated on a weekly basis to track trends, as illustrated in Figure 59.

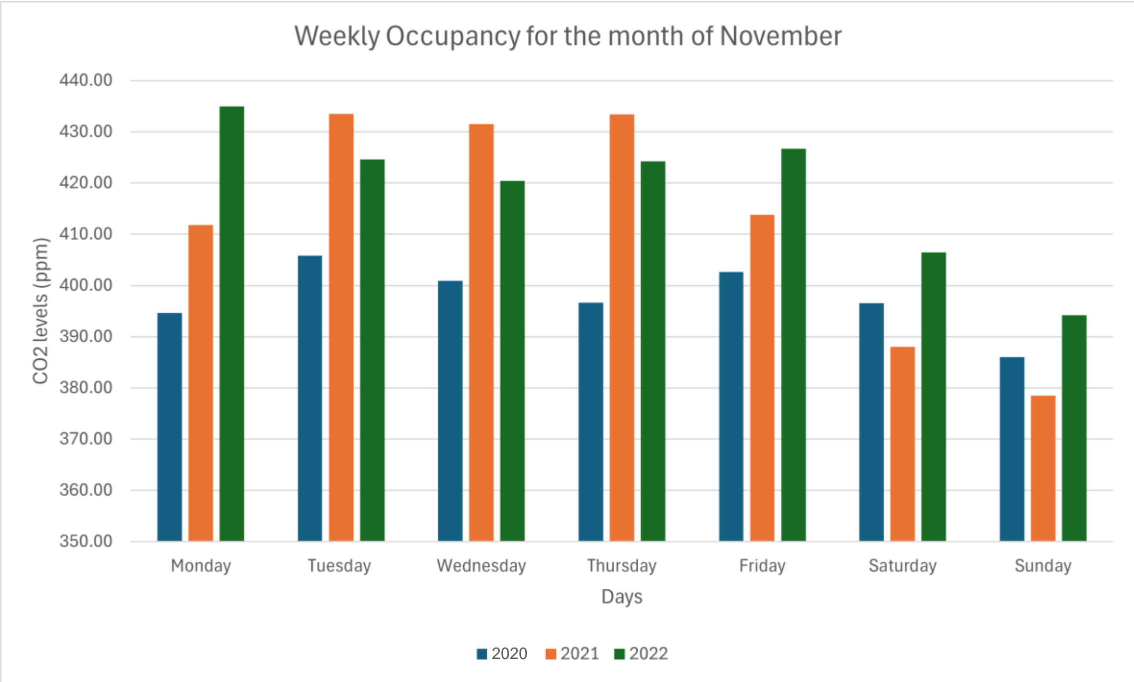


Figure 59 Aggregated weekly occupancy for November 2020-2022 for Building 28, TU Delft (Own Computation based on data procured from Brains4Buildings)

While the disparity in occupancy levels between 2020 and 2022 is striking, it is noteworthy that occupancy patterns in 2020 began to exhibit more structure, reflecting the increasing adoption of hybrid working practices. The peaks observed mid-week in 2022 align with national and international trends favouring hybrid work arrangements.

The data above indicates that despite the adoption of hybrid working measures over the last few years, occupancy has not drastically fallen. In the absence of occupancy data pre-COVID it is hard to ascertain that these match pre- pandemic levels, but the increase suggests that the physical office space is still a vital component of the functioning for Building 28.

To further understand the impacts of hybrid working, the energy consumption of the building is also analysed.

6.4.2. Operational Energy Usage:

The building has a building management system (BMS) that is connected to the mechanical installations. The BMS allows for reporting malfunctions, viewing the status of installations, centrally operating the system, and adjusting control settings. It is integrated with the heating, cooling, and air treatment systems. Additionally, the building features a sensor system that records energy usage (electricity and gas) every hour.

The aggregated electricity demand trends over six years (2018, pre-COVID, to 2024, post-COVID) are mapped below, clearly showing a reduction in energy usage due to the hybrid working policies that have become more common in recent years (Figure 60).

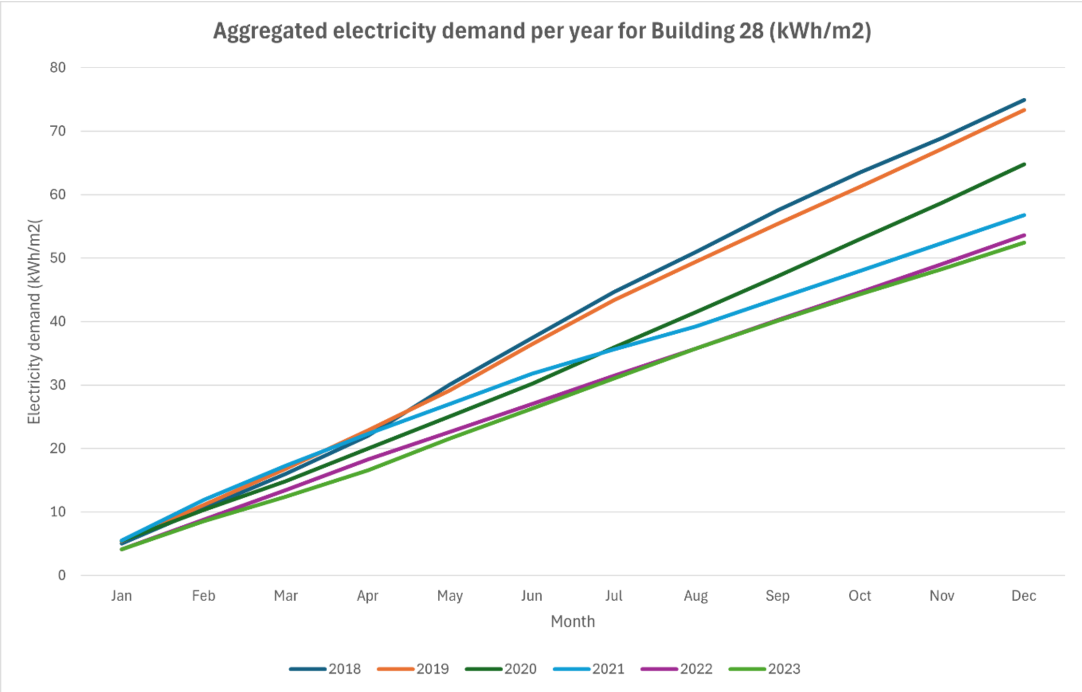


Figure 60 Aggregated electricity usage per year between 2018 and 2024 in Building 28, TU Delft (Own Computation based on data procured from TU Delft)

An analysis of the aggregated electricity demand per m^2 for 2018 shows a yearly demand of 73kWh/m2 (Figure 60). This was the period prior to the imposition of COVID restrictions where occupancy was uninhibited by lockdown restrictions and hybrid working was not commonplace. These pre-pandemic levels align with the results of the WFO energy simulations computed on TRNSYS detailed in Chapter 05. In recent years, the campus has adopted a hybrid working policy, which is reflected in the aggregated yearly energy usage shown in Figure 61. However, the exact recorded values differ from the theoretical results computed in Chapter 5. Specifically, the hybrid-friendly policy has resulted in a significant decrease of 23 kWh/m^2 in Building 28, compared to pre-pandemic levels.

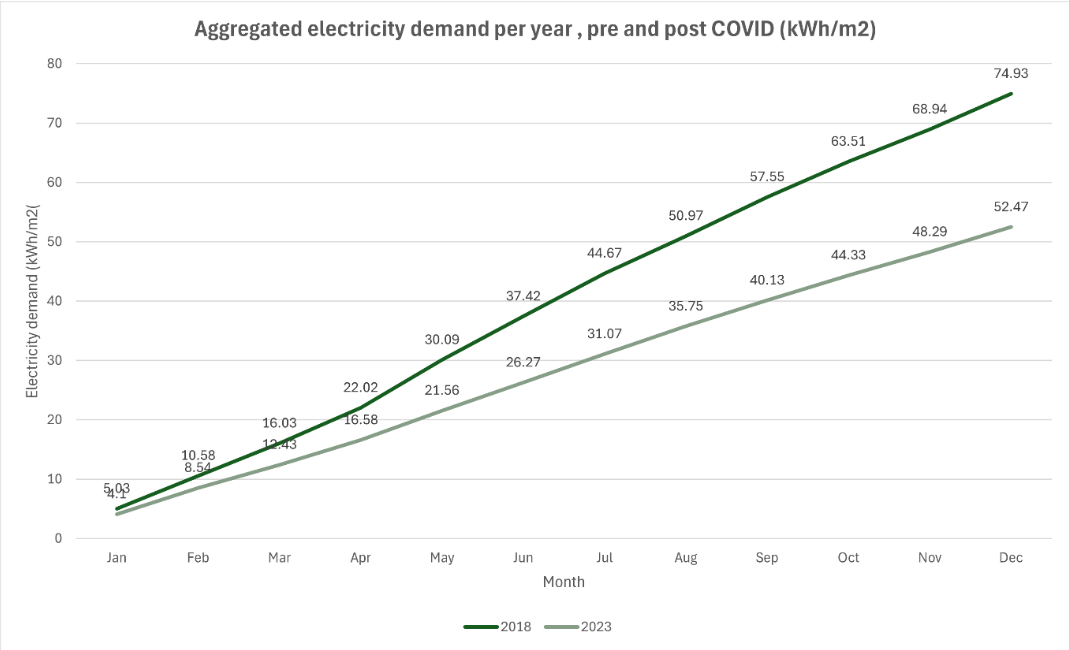


Figure 61 Aggregated electricity usage comparison pre and post Covid in Building 28, TU Delft (Own Computation based on data procured from TU Delft)

Despite the increase in occupancy levels from 2020 to 2022 (section 6.4.1), the energy usage data for the same period shows a decrease when mapped in aggregation annually (Figure 62) and monthly (Figure 63).

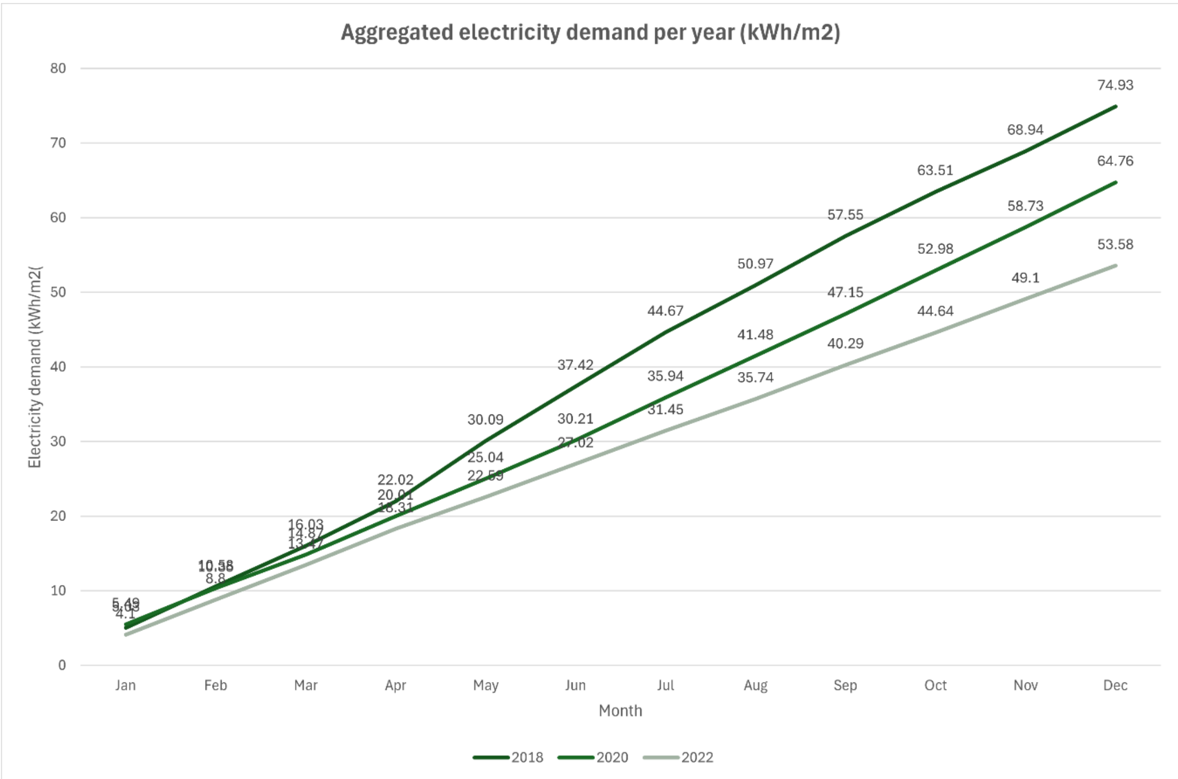


Figure 62 Aggregated electricity usage comparison pre and post Covid in Building 28, TU Delft (Own Computation based on data procured from TU Delft)

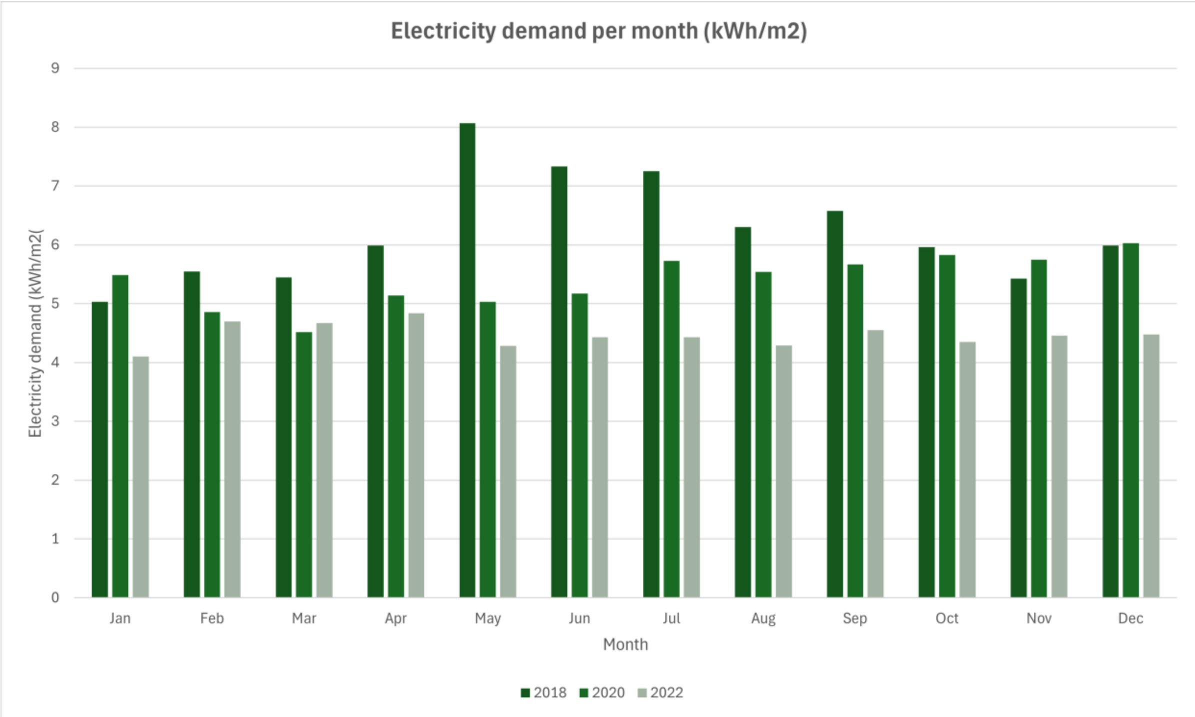


Figure 63 Monthly electricity usage comparison pre and post Covid in Building 28, TU Delft (Own Computation based on data procured from TU Delft)

There was no reduction in spatial area during this time. While the reduced energy consumption could be attributed to overall climate change leading to lower energy needs, the energy measured here pertains to electricity requirements—primarily for artificial lighting and equipment—this reduction is likely due to improved energy management systems that dynamically adjust to occupancy levels.

6.4.3. SWOT Analysis

Figure 64 SWOT Analysis of data collected (Author)

A SWOT analysis of the data collated above point to energy savings from adopting a hybrid mode of work. The use of a sophisticated building management system which is calibrated to respond to sensors in the room has helped optimise the energy consumption. These results suggest that when the operational energy usage is **dynamically tied** to occupancy patterns using sensors, as employed at Building 28, there can be potential savings from reduced energy usage.

At a spatial level, despite the prevalence of hybrid working practices, the use of the **physical office space continues to remain imperative**. While there are individual productivity benefits from adopting hybrid working, functionally these dispersed employee networks can lead to **fractured professional and social networks** and **impede innovation**. The data from Building 28 aligns with the hypothesis that academia and research benefit from **face-to-face interactions** in the workplace, which help foster the diffusion of knowledge and the generation of new ideas.

Furthermore, adopting a structured hybrid policy with specific days of the week reserved for working in the office, offers both employees and employers further opportunities to maximise the benefits of hybrid working.

According to (Elkington, 1997) sustainability has three main dimensions: social sustainability (people), ecological sustainability (planet) and economic sustainability (profit, altered to prosperity later). All three need to be addressed for a sustainable development. The overall sustainability of a workspace is also a function of the social element, and this is the biggest challenge that accompanies hybrid working policies.

6.4.4. Conclusions

The physical aspect of the mapping is updated based on the analysis and conclusions from the two case studies to produce the following updated mapping.

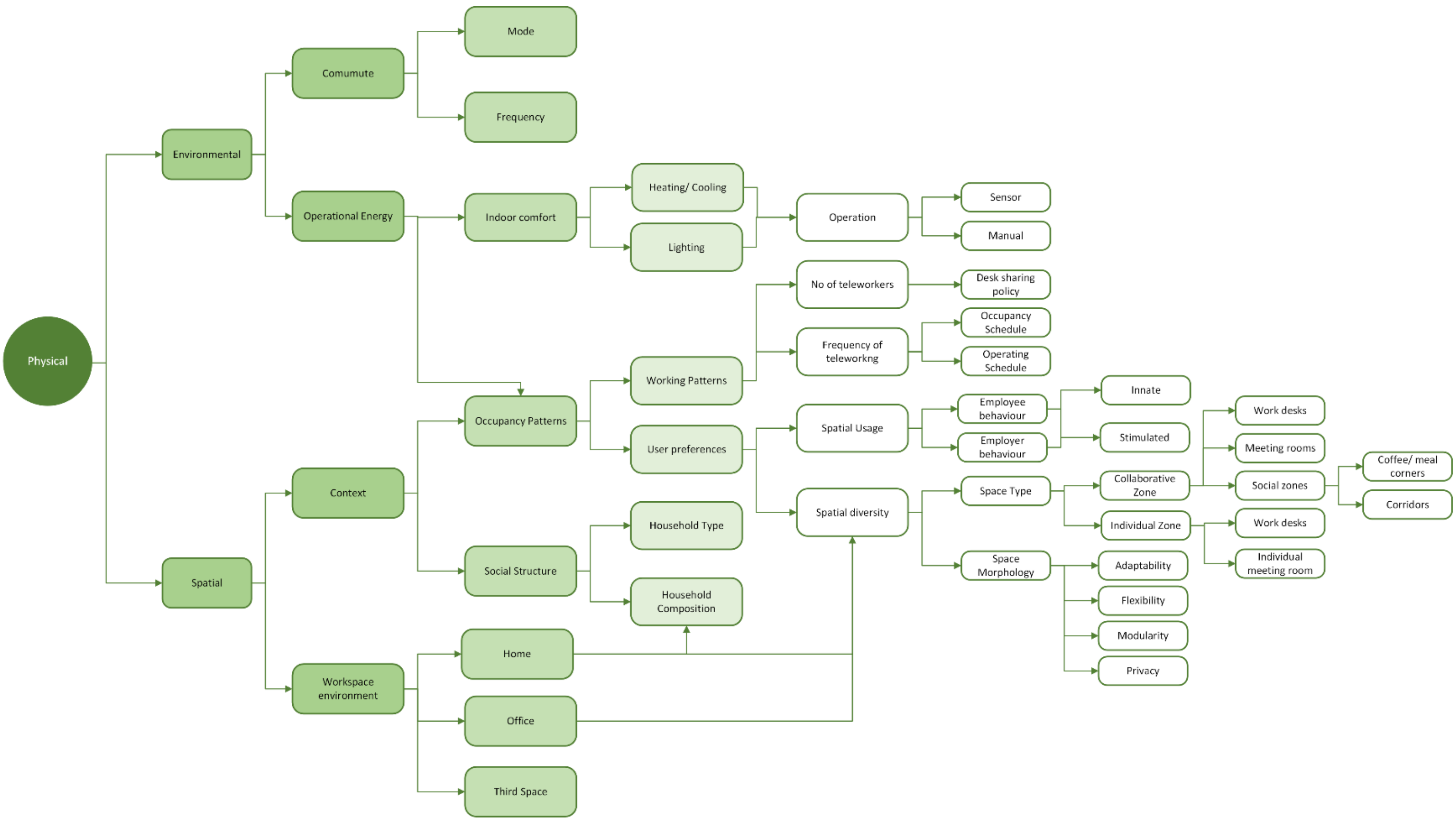


Figure 65 Updated Environmental Factors(above) and total Mapping (Author)

Chapter 07

Mobility and teleworking

Transportation serves as a vital link connecting people, cultures and economies globally, facilitating trade, travel and access to essential services like education and healthcare. However, the sector is closely linked to working trends due to the high proportion of emissions contributed by daily commute. The mobility aspect of the sustainability of hybrid working is analysed using desk research from Europe and The Netherlands.

7.1. Current state of mobility and emissions:

Transport is responsible for about a quarter of the EU's total greenhouse gas (GHG) emissions. In 2015, more than 70% of all emissions from transport was a result of road transport, standing at about 852.3million tons of CO_2 as reported by the European Commission (Labee et al., 2022), with the commute to work accounting for 27-47% of daily travel (EEA, 2024).

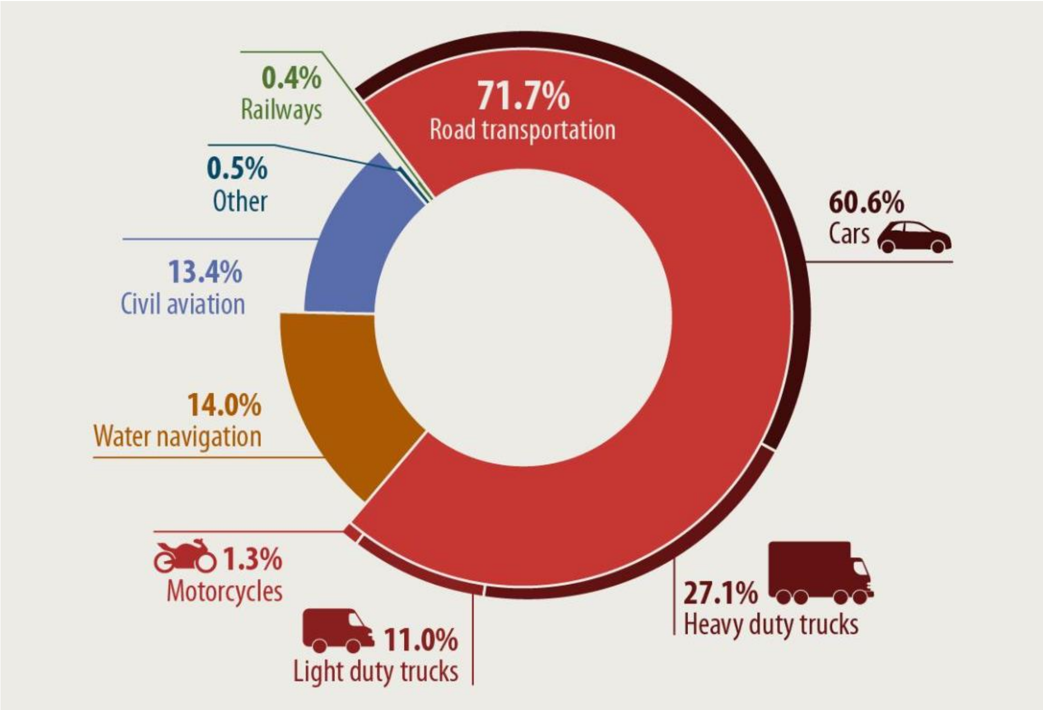


Figure 66 Transport emissions in the EU based on transport type in 2019 (EEA, 2022)

7.2. Hybrid working induced changes on work commute:

One of the biggest contributors to the self-assessed productivity benefits of WFH are the savings in commute time. According to Barrero et al., (2023), the average daily savings from commute and grooming due to WFH is approximately 68 minutes per week per worker, which accounts for 2.8% of a 40-hour workweek.

Within the Netherlands, most kilometres travelled pre-COVID-19 were by car (50%), with public transport accounting for only 11% (CBS, 2020a). Of this, commuting accounted for 27% of total kilometres travelled, with this share being larger for public transport kilometres (33%).

In 2020, the Knowledge Institute for Mobility Policy (KiM) carried out an initial measurement with the Mobility Panel Netherlands (MPN) to gain insight into the consequences of the COVID 19 and resulting teleworking trends on mobility patterns and expectations. The research was conducted among a sample of approximately 2,000 panel members of the Mobility Panel Netherlands (MPN) who had to complete a 'travel diary' for three consecutive days in the period from May 11 to May 22, 2022, supplemented with a personal questionnaire. The questionnaire was aimed at mapping current travel behaviour, related experience aspects and expectations for the future (if there are no new COVID measures).

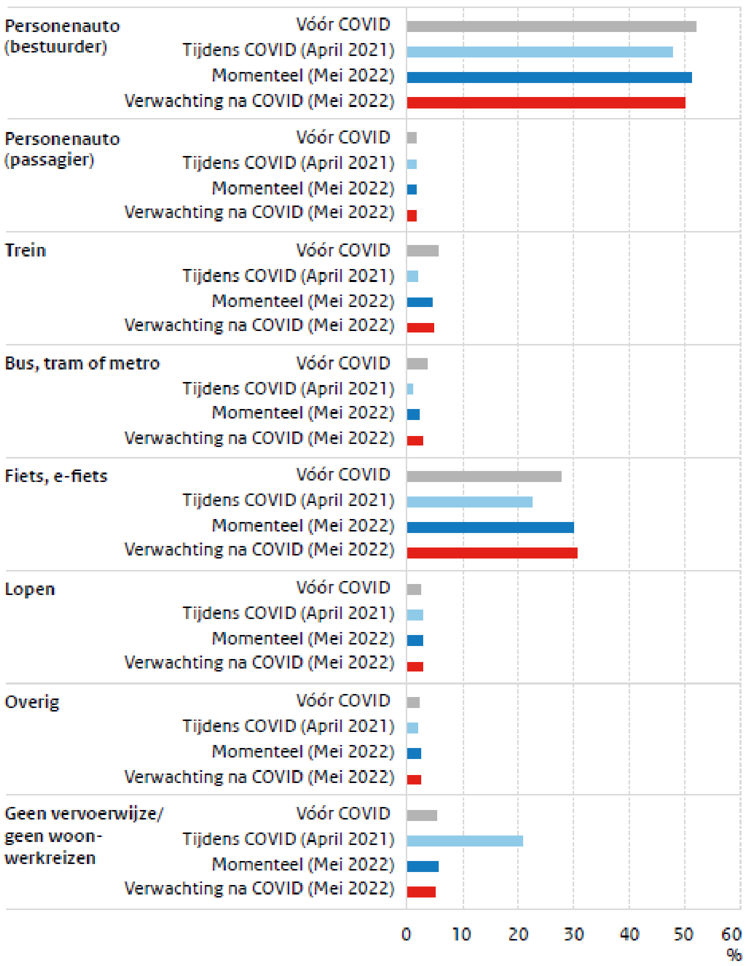


Figure 67 Choice of transport mode for commuting before, during and expectation for the longer term (without COVID measures) at two measurement moments (April 2021 and May 2022) (KiM Netherlands Institute for Transport Policy Analysis (KiM), 2023)

The results indicate that while the use of car and public transport showed a slight decrease, the car continues to remain the most important mode of transport for commuting even after the pandemic as seen in Figure 67. Workers travelled relatively frequently on Tuesdays and Thursdays for work-related trips prior to COVID. These remained the busiest days during the time of this survey as well as for future expectations.

Working people reported fewer business trips than before COVID (Figure 68). The group that travelled for business four or more days a week was slightly smaller in May 2022 than before COVID and is expected to remain so in the longer term. The share of workers who almost never travel for business was slightly higher than before COVID but will probably develop towards pre-COVID levels in the longer term.

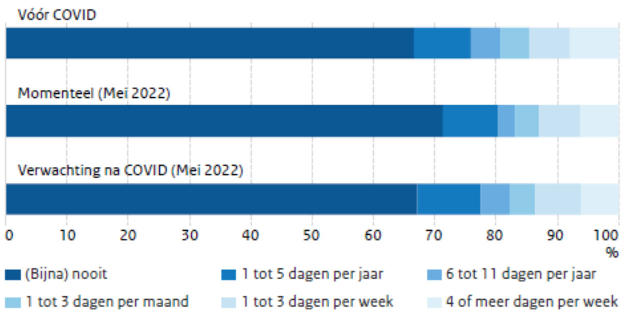


Figure 68 Number of business trips before COVID, currently (May 2022) and longer-term forecast (Netherlands Institute for Transport Policy Analysis (KiM), 2023)

Their research also reported that 2.5% of people had decided or considered taking a job further away due to flexibility afforded by hybrid working. This can also be attributed to the (potential) accessibility of jobs, education and shops and retail jobs that can be reached within acceptable travel time, which has increased on average for Dutch people in the period 2010-2022. The accessibility of jobs is relatively high on the Amsterdam-Eindhoven axis and the accessibility of jobs has improved particularly in the urban regions of Amsterdam (including Almere) and Rotterdam-The Hague.

Accessibility	Jobs within acceptable travel time	Education within acceptable travel time	Shops within acceptable travel time
	Number		
2022 compared to 2018 (%)	+3%	+5%	+2%
2022 compared to 2010 (%)	+18%	+26%	+14%

Figure 69 Changes in accessibility (KiM, 2023)

As road transport is responsible for more than 70% of all CO2-emissions in the EU (Alonso Raposo & Ciuffo, 2019), a reduction in car use resulting from increased telework would positively affect environment, liveability, and accessibility (Hamer et al., 1991). However, as the largest switch towards teleworking in this pandemic was observed among public transport (i.e., train) users, this potential change in habits is likely to affect public transport more than car use.

7.3. Hybrid working and train commute:

Hamersma et al., 2020 report that the largest shift was observed among the workers who were highly educated and/or those who commuted by public transport (Hamersma et al., 2020). The shift to teleworking coupled with governmental advice against travelling resulted in falling public transport use with train ridership falling to 7% of the normal ridership at its lowest (Ton et al., 2020).

Travel patterns in general changed drastically, with active and personal modes of mobility increasing at the expense of shared modes like the tram, bus and metro (Figure 70).

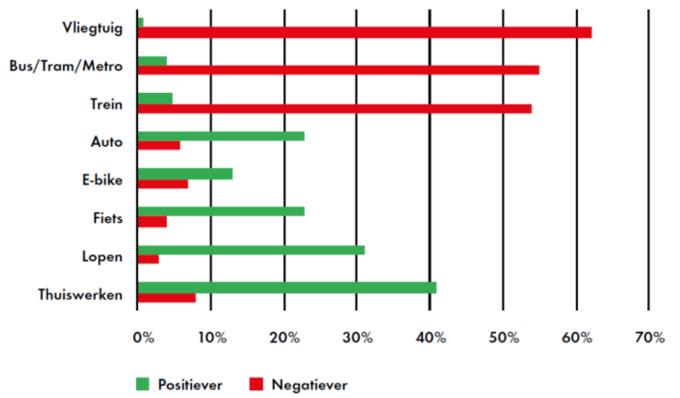


Figure 70 Change in attitude about means of transport induced by Covid (Ton et al., 2020)

Ton et al's (2022) study on the impacts of teleworking on public transport both during and after the pandemic highlights that groups accustomed to teleworking were least affected by the pandemic. Those with high willingness to telework are expected to decrease their use of public transport for commuting in the future, especially during peak hours. Their research also indicates that shared mobility services- such as OV-fiets, Felyx and Greenwheels- has the most negative expectations among users. Such reduced levels of trust in public transport services affects the efficiency of last mile connectivity with people shifting towards personal modes of travel for more convenient and efficient end to end travel.

There are also advantages to a reduced use of public transport systems as it could lead to improved efficiency if peak hours are reduced. Ton et al. (2022) stress the importance of knowing the public transport usage numbers, but also when and where they do so. Understanding the patterns of decreased ridership is crucial for planning and operating efficient public transport systems since capacity requirements are typically based on peak hours. A comprehensive understanding of ridership trends can help optimize infrastructure and vehicle capacity more effectively. Flexible working hours and spreading telework across days are suggested strategies to alleviate peak hour congestion, requiring synchronisation of policy and communication from both governments and employers.

On the other hand, groups with low willingness to telework are expected to return to their former behaviour post-pandemic, limiting their impact on public transport operations and planning. Efforts to welcome them back to public transport may be needed, along with improvements to support increased teleworking if necessary.

7.4. Teleworking and Job accessibility in the Netherlands:

A study by Van Lent (2023) on the effects of hybrid teleworking on socio-spatial job accessibility inequalities among groups in the Dutch workforce from an egalitarian perspective suggests that on a spatial level, hybrid teleworking enhances job accessibility in economically vibrant areas like the Randstad, further exacerbating spatial disparities.

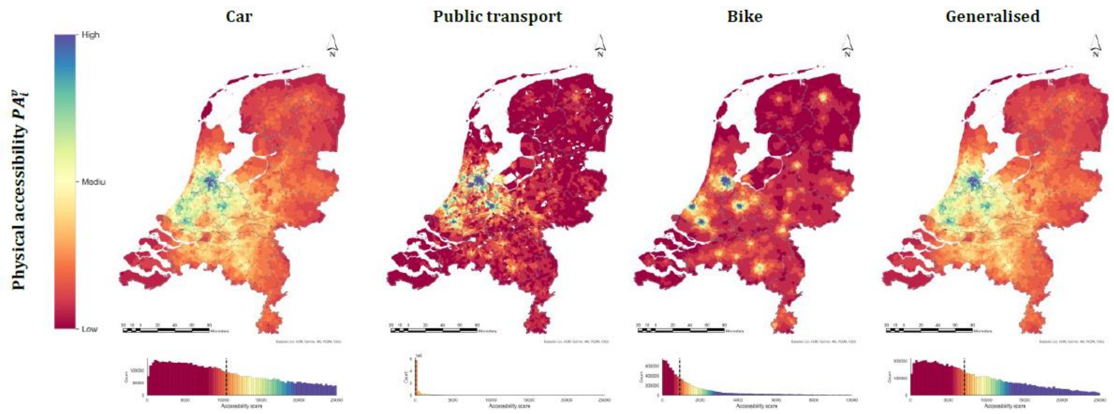
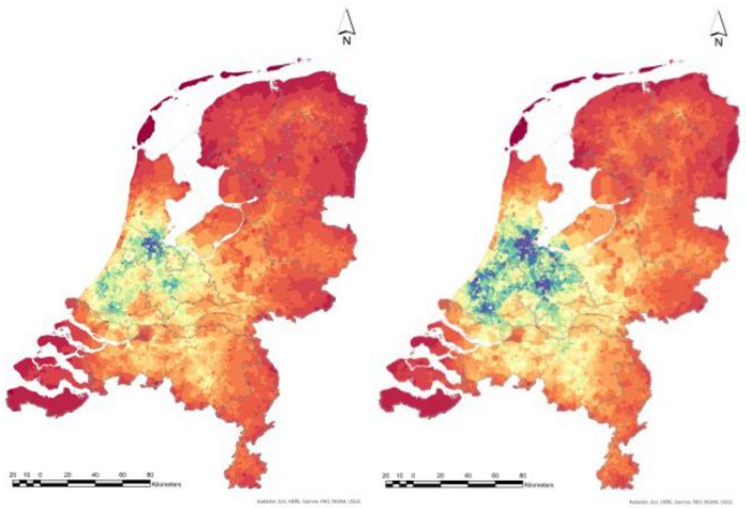


Figure 71 Spatial distribution of physical ($PAiv$) and hybrid ($HAiv$) job accessibility, without job competition (Hansen-based) (Van Lent, 2023)

Using a Hansen-based model, Van Lent's study suggests that urban agglomerations within the Randstad area in the west experience overall higher job accessibility levels than the outer peripheries of the Netherlands for every mode of transport and in the generalised model (Figure 71).



Car: When overlaying the dimension of hybrid teleworking, the median job accessibility levels of the population significantly increased across all modes of transport. Amongst car users, this increase is localised within the Randstad, however it is slightly less clustered as hybrid teleworking benefits many individuals commuting by car irrespective of their spatial location.

Figure 72 Job accessibility by car, physical vs hybrid

Public Transport: For urban cores like Amsterdam and Utrecht, public transport provides high physical accessibility to jobs. With hybrid teleworking, areas well-connected to public transport networks see improved job accessibility. The high accessibility tends to be concentrated around key nodes like train stations and bus stops, leading to a pattern of job accessibility that's dispersed spatially but locally clustered around these transportation hubs.

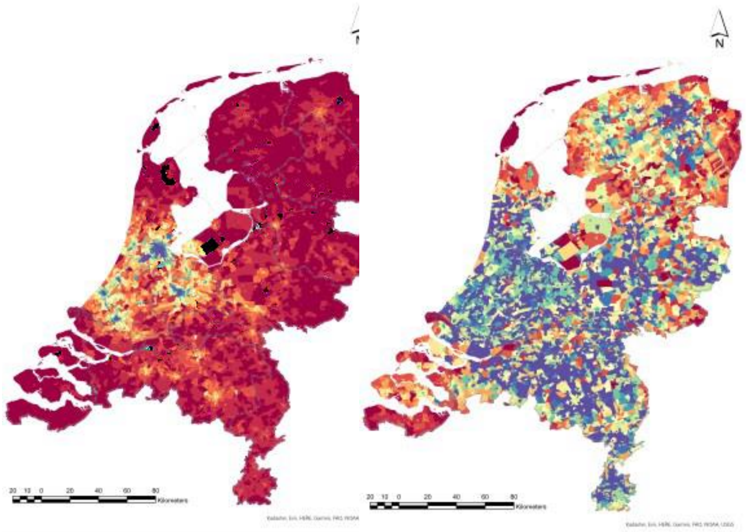
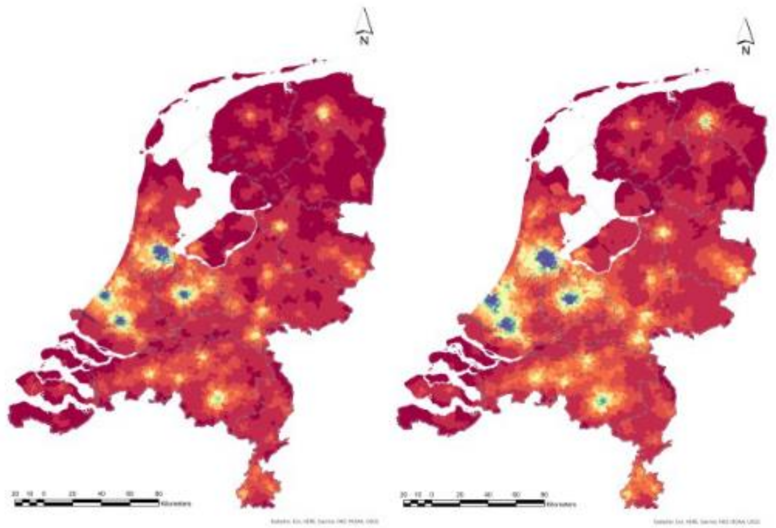


Figure 73 Job accessibility by public transport, physical vs hybrid



Bike: Physical accessibility by bike exhibits a localized distribution, limited to certain Dutch cities. The spatial distribution of accessibility by bike sees only marginal spatial increases with hybrid teleworking.

Figure 74 Job accessibility by bike, physical vs hybrid

Overall: Car-based job accessibility greatly influences the overall accessibility picture for Dutch workers, especially in dense urban areas. There's a notable increase in job accessibility in the western part of the country, mainly in urban zones, while non-urban areas show little change. Additionally, the introduction of hybrid teleworking accentuates the differences in job accessibility between urban and outer regions, particularly in the Randstad area.

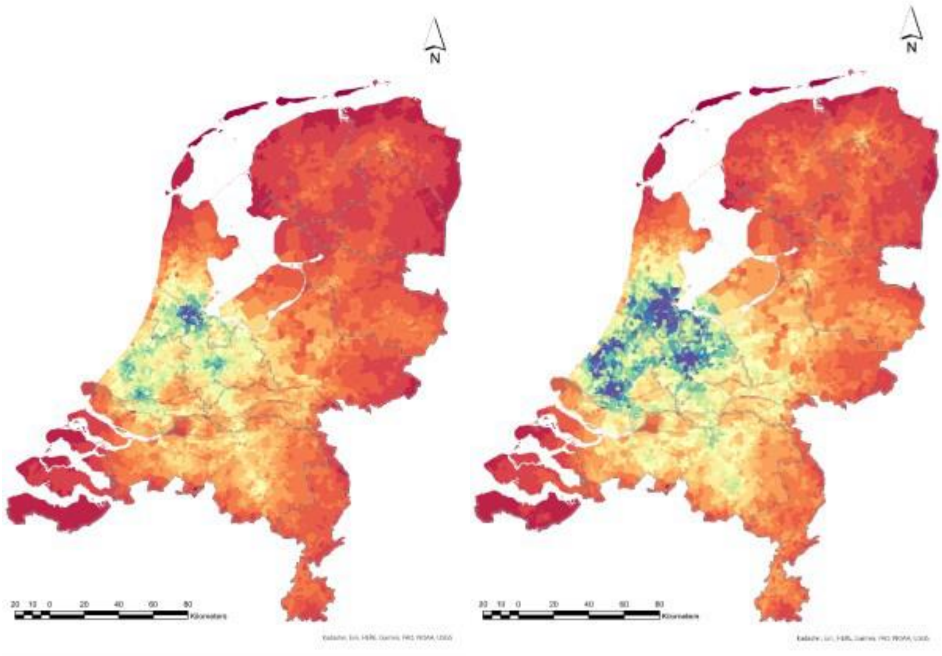


Figure 75 Generalized Job accessibility, physical vs hybrid

The extended willingness to commute of a hybrid teleworker expands the number of potential job opportunities, provided that these jobs are within reach and well-connected to the infrastructure network of the corresponding mode of transport. On a social level, her analysis shows that high-educated males in tele-workable occupations, like education and healthcare, experience greatest inherent accessibility benefits.

Her research provides evidence for the fact that there is improved access to job opportunities due to hybrid working but these benefits are disproportionately dispersed and typically benefit those who can telework and who already live in economically advantageous regions. Additionally, it also emphasises that digitalisation within the employment landscape reshapes inequalities within the Dutch workforce.

7.5. Analysis

The different impact areas of hybrid working on mobility are positioned using the SWOT analysis in figure 76. Distance, the foremost and most effective boundary between home and work, contributes to increased productivity by the separation of private and professional spheres (Jachimowicz et al., 2021).

Hybrid working can have environment impact through mobility, but this is largely reliant on a successful reduction of car use. The possibility of future outbreaks will likely increase people's aversion to risk when it comes to transportation and travel leading to changes in individual travel habits, including decreased frequency of commutes and a shift in preference towards different modes of transportation and shorter trip distances.

Figure 76 SWOT Analysis of hybrid working and mobility (Author)

Modal Shift:
According to Alonso Raposo & Ciuffo, (2019) public transport faces challenges from emerging mobility technologies and business models by offering more individualistic mobility options such as ride-hailing services, shared mobility apps, and micromobility solutions like electric bicycles and scooters. Post-pandemic shift in mobility trends coupled with the overwhelming prevalence of hybrid working may cause declining public transport usage due to concerns about disease transmission and efficient time management. This in turn increases demand for private cars, biking, micromobility, and walking as alternative modes of transportation (Christidis et al., 2021). However, these newer solutions don't necessarily lead to improved transport efficiency but instead draw commuters away from public transport, which is often seen as outdated, unsafe, and uncomfortable. Consequently, many cities, particularly in the USA, are witnessing a notable rise in road congestion because of this shift in transportation preferences (Alonso Raposo & Ciuffo, 2019). They also stress that flexible transportation options may not be accessible to price-sensitive segments of the population unless they are effectively integrated into the public transport system.

Strategy and Policy:
At a strategic level, employers can facilitate and incentivise sustainable alternatives through their mobility policy. Fuhr & Pociask (2011) suggest that an example of this would be by revising the parking policy to include facilities for cleaner mobility modes (e.g. secured bicycle parking spaces) within the parking rea. Public transport operators can also support this by providing passes that allow workers to visit multiple work locations while also taking into account occasional days where employees work at home. The location, accessibility and proximity of new head offices and satellite office by public transport is also crucial for their potential success (Nilles, 1988; Van Acker et al., 2007).

Macro level Governance:
At a macro level, Christidis et al., (2021) stress that EU policies have significant influence on transport, particularly in response to climate change and air quality concerns. The post-pandemic period presents an opportunity to reorient EU policy priorities towards promoting micromobility and clean transport

modes, thereby improving environmental quality and fostering innovation. The European Green Deal outlines priorities compatible with post-pandemic strategies for the transport sector. Supporting technologies and business models aligned with these priorities can yield long-term benefits. However, there's a risk of decreased investment in transport innovation amid competing health priorities and limited funds. To ensure a cleaner and more equitable future for transport, enhancing governance and involving citizens in the development of innovative mobility solutions will be crucial.

7.6. Updated System Mapping:

Estimating the effects of commute induced by hybrid working is not a linear task due to the many parameters influencing mobility which have been mentioned in the previous sections of this chapter. A visual representation of the different impact areas of mobility and hybrid working therefore results in the following network:

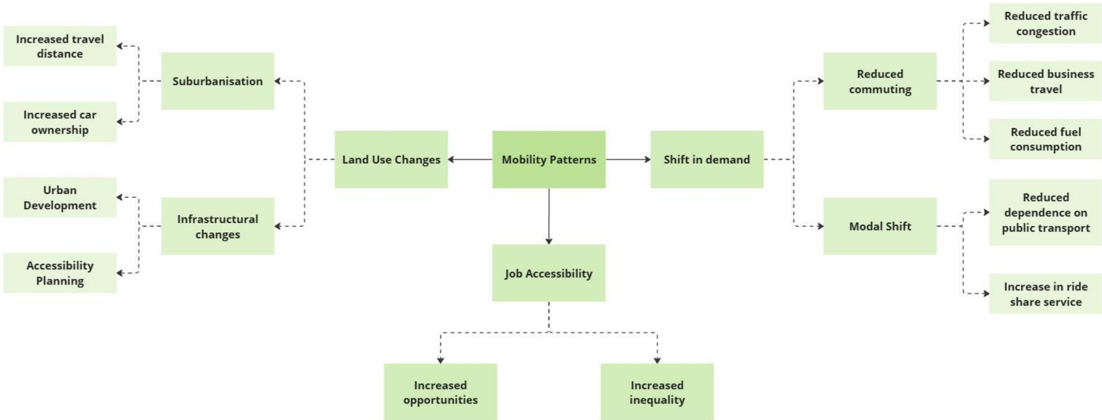


Figure 77 Impacts of teleworking on mobility (Author)

This is re-inserted into hybrid working network to produce the following mapping of the networks and interdependencies relating to commute.

Figure 78 Updated parameters relating to commute and hybrid working (Author)

This is inserted into hybrid working network to produce the following mapping:

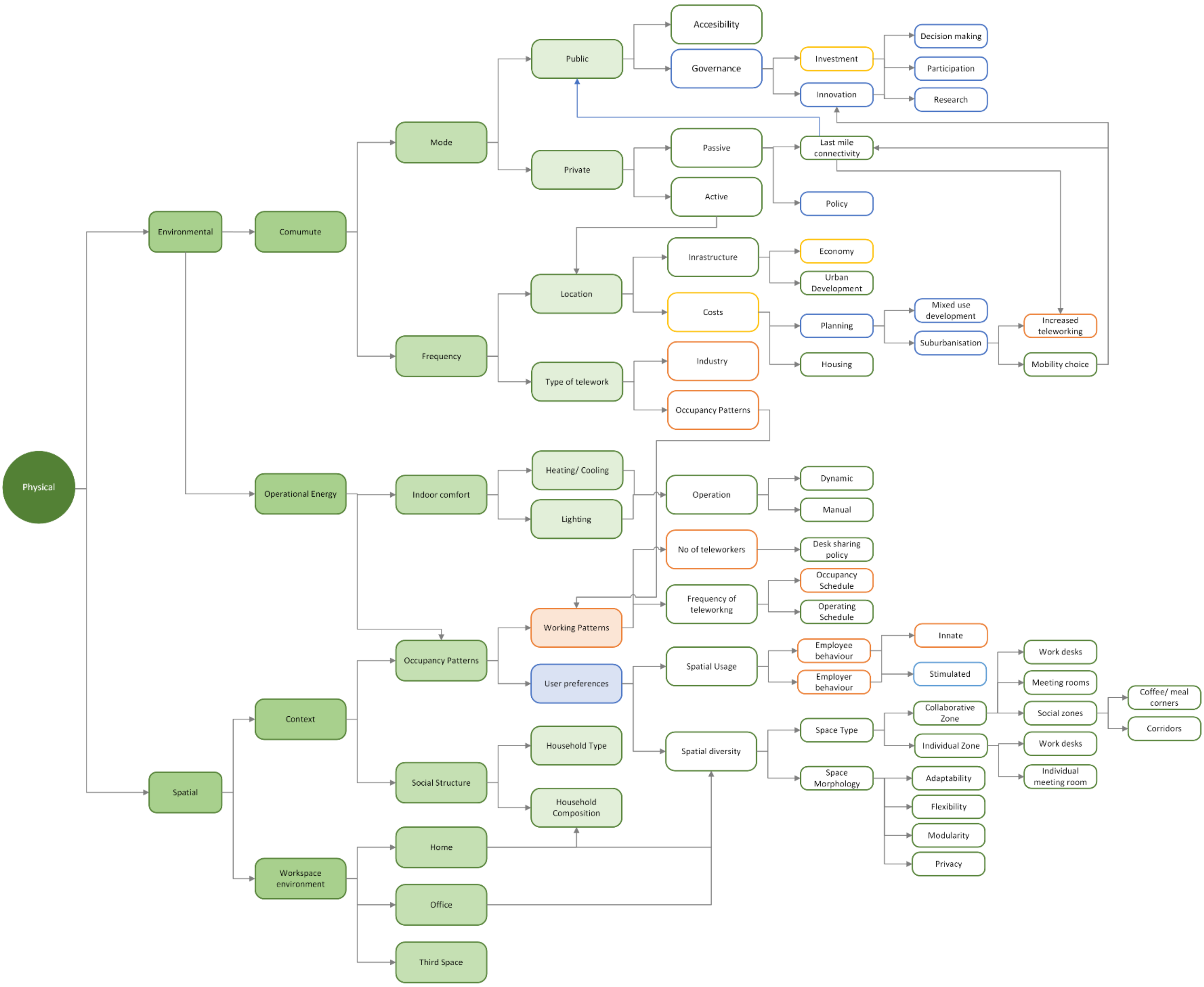


Figure 79 Updated physical parameter mapping of hybrid working (Author)

Chapter 08

Discussion

In this chapter, the interpretation of the findings from the empirical data analysis is examined in relation to the theoretical background. The section begins with a reflection of the methodology involved, followed by the generalization of the findings and concludes with an exploration and reflection of different themes explored in this research that will serve to answer the research questions and the practical implications of the same.

8.1. Reflection

This thesis aimed to understand the implications of new working trends, particularly hybrid working, on the sustainability of workspaces. To achieve this, Den Heijer's (2012) four-perspective framework was employed to position various parameters identified from an extensive literature review. The data collection focused on the physical aspects of hybrid working using a quantitative approach that combined synthetic modelling with case study data.

The research involved designing multiple scenarios based on current workplace, housing, and working trends, such as working hours, occupancy patterns throughout the week, and the spatial composition of home versus office environments. Six scenarios were developed for the study. Subsequently, a synthetic (lab) study simulated energy consumption across these scenarios. This stage presented challenges due to the numerous factors involved, which could progressively complicate the analysis. Thus, it was crucial to set clear boundaries for the study to obtain reliable results without excessive complexity.

In real estate management, focusing exclusively on one aspect of a phenomenon is nearly impossible. Therefore, throughout the data analysis, it was essential to integrate the physical findings into the overall framework continually, deriving functional, strategic, and financial implications from them.

van Staveren et al., (2024) assert that corporate real estate management (CREM) is complex due to the increasing number of real estate added values and the tensions between them. Real estate managers often face trade-offs, where enhancing one added value may come at the expense of another. A similar situation arose in this thesis regarding the research methodology, as a quantitative approach tends to focus less on understanding the context of the problem (Queirós et al., 2017). The study's results could have benefited from incorporating a qualitative dimension into the data collection and analysis. However, given the limitations of time and resources for this thesis, it was decided to enhance the study's quality by relying solely on a quantitative method.

8.2. Generalisability of findings:

Yin (2009) refers to analytical generalisability as being able to use the insights from findings to convey theory that could be applied to other similar cases. The analytical generalisability of this thesis was improved from two fronts: triangulation and cross case analysis.

Triangulation is a widely accepted way to improve the analysis and interpretation of findings from various types of studies. Norman Denzin (2015) identified four types of triangulations:

- Data triangulation: the use of multiple data sources in a single study.
- Investigator triangulation: the use of multiple investigators/researchers to study a particular phenomenon.
- Theory triangulation: the use of multiple perspectives to interpret the results of a study; and
- Methodological triangulation: the use of multiple methods to conduct a study.

This research employed the technique of methodological triangulation to decrease the deficiencies and biases that come from any single method. This was achieved by using a combination of desk studies, synthetic/ lab based modelling and empirical data from case studies to increase the validity and reliability of results.

Furthermore, to strengthen the reliability of generalizations a cross-case analysis having diverse circumstances, as recommended by Yin (2009) was employed by using data from offices operating in differing set ups and then comparing them with each other and the data from the synthetic modelling. Given the broad boundaries of this study, this contrast helped strengthen and complement the results.

8.3. Practical implications

Remote working is an umbrella term encompassing teleworking, agile working, smart working, and working from home. Within this context, hybrid work—where employees split their time between remote locations and official workspaces—has gained popularity. Most EU workers have expressed a preference for working from home several times a week in the long run (Eurofund, n.d.). This is accompanied by long term consequences for the organisation, functioning, management and design of workspaces. Cushman and Wakefield warn that a substantial portion (76%) of office stock across Europe face a risk of becoming obsolete by 2030 without intervention. With working trends continuously changing over the last few years, it is now an opportunity and necessity to reposition these assets (Spacewell, 2024).

However, as emphasised by Den Heijer (2012), every decision needs to address four stakeholder perspectives to ensure that all the '*players at the table'* are accommodated: organisational, financial, functional and physical. This also occurs at different scales of society.

8.3.1. Building Scale:

<u>Environmental Sustainability:</u> Teleworking offers opportunities to reduce or optimise the carbon footprint of companies through reduced energy usage and space requirements.

One way to optimise space requirements would be using flexible offices which facilitate a more efficient utilization of available space, rendering certain areas or entire floors unnecessary. These redundant spaces can then be repurposed for other functions and the concentrated use of workspace in flexible offices leads to savings in the usage of electric appliances.

Secondly, renovating and improving existing building services that enable a dynamic response of energy usage to occupancy levels is a way to future proof workspaces without any spatial reductions. These benefits can also be extended to the generation of waste. Microsoft's offices in Amsterdam have a system that optimises catering requirements based on occupancy levels, resulting in minimised food waste. Such examples showcase how technology can be optimised to support flexible working arrangements while also streamlining the energy efficiency of space.

<u>Financial Sustainability:</u> There are clear financial benefits for business owners who employ hybrid based working policies. Remote work can lower labour costs and the overhead costs that come with a reduced physical footprint. These cost savings must be considered along with the productivity consequences, now and in the future, when optimizing over working arrangements. Functionally, this would entail a shift in working arrangements with new skills and work habits, new managerial practices, and new organizational capabilities for it to be effective (Barrero et al., 2023).

At a spatial level these savings are contingent on ensuring that the office building can respond to these dynamic occupancy patterns through smart building systems. Given this situation, there is also room to optimise building portfolios through downsizing of space. However, as emphasised by Peter Mostien of ING (VergeSense, 2023), spatial requirements and the mobility of employees within office workspaces have increased. This presents an opportunity for employers to opt to **rightsize** their portfolio instead through two dimensions:

- A ***spatial rightsizing*** by an optimisation of space requirements based on specific user behaviour and requirements. Making trade-offs is regarded as a solution for situations with conflicting objectives with no alternatives that satisfy all stakeholders. This forces the decision maker to decide which goal to prioritise over the other (Da Silveira, 2005; Keeney, 2002) with the typical strategy in such cases being a trade-off between quantity and quality: less floor space, more intensively used and better quality.
- However, the standardised behaviour observed from dynamic occupancy trends suggest that there is also room for ***temporal rightsizing***, or a time-based optimisation of an asset. A temporal optimisation could be achieved using flexible leasing agreements where partners or other businesses could help maximise the use of space. In the long terms, this would mean that buildings need to be planned, designed, and reconfigured to allow for multifunctional spaces, resulting in ***hybrid buildings***.

With the enaction of the ETS2, fuel prices are expected to increase with these increases passed on to the customer. Business owners and operators are therefore incentivised to reduce emissions by investing in energy efficient measures now given that these measures will become stricter in the coming years. Furthermore, such working transitions mean that traditional long-term top-down funding systems will be replaced by more short-term bottom-up structures, where local community spaces and micro entrepreneurs are also integrated within the financing structures.

Social Sustainability: While there are clear environmental and financial benefits from employing hybrid working, the results of the data analysis suggest that they are largely skewed in favour of the employer by shifting operational costs from offices to homes (Green et al., 2020) and potentially creating a rebound effect when both office and homes are heated and cooled (and for a larger portion of the day).

Furthermore, the results from the synthetic simulations indicate that **size matters,** with a larger burden being placed on the economically and socially disadvantaged, thereby having implications for the social aspects of sustainability. This reinforces inequalities in terms of what kinds of jobs can be done from home or how suitable dwellings are for the set-up of home offices (Wethal et al., 2022). Barrero et al.'s (2023) studies on remote working in America support this hypothesis as they reveal a high propensity to work from home in the Information sector, Finance, and Insurance and Professional and Business Services that share certain characteristics which facilitate or incentivize work from home.

This inequality also occupies a gender dimension with gender inequality persisting in crisis situations, particularly in terms of telework conditions. Research suggests that men and women experience telework differently, with men facing less interference with their work and more opportunities to concentrate on their tasks (Sullivan & Lewis, 2001,Hartig et al., 2007, Araújo, 2008). Moreover, outside of crisis contexts, Ramos & Jordão (2014) report that the sources of work-related stress differ between men and women. For men, stress is often linked to job performance and career advancement, while for women, it's associated with managing double workloads.

Lastly, it is important to note the loyalty of an employee under hybrid working conditions. Distributed working networks result in reduced social and professional ties, making it a challenge to build loyalty within an organisation. The lack of social engagement reduces teleworkers' organizational identification, hindering their alignment with the organization's values and goals. This in turn could affect organisational turnover, with 'quiet quitting' and high organisational attrition becoming very real possibilities. However, according to Caillier (2013) being denied teleworking privileges has a greater impact on turnover intentions. A healthy balance between remote working privileges and in-person interactions must hence be maintained to ensure optimal functional and organisational performance.

8.3.2. Macro Scale:

At a macro scale (city or regional level) a large-scale adoption of hybrid working can result in shifting urban morphology.

Expanding knowledge networks: Looking beyond a single workplace, cities have long functioned as hubs for knowledge spillovers across workers, firms, and industries and as centres of invention, innovation, and entrepreneurship.

In this light, the big shift to work from home raises concerns about its potential to slow the pace of innovation and the growth rate of productivity (Barrero et al., 2023). Brainstorming activities benefit from in-person meetings, but some other aspects of the innovation process do not. Lin et al. (2023) develop evidence that collaboration at a distance is especially challenging in the early stages of research ***"when an idea is hard to articulate, and knowledge is tacit."*** Profit-oriented firms have strong incentives to recognize and respond to the internal costs and benefits of hybrid working arrangements. However, if those arrangements yield idea spillovers beyond the boundaries of the firm, outcomes might not be efficient or socially desirable. A shock-induced shift to work from home could slow the pace of innovation by undermining the idea-generating capabilities of workplaces (Barrero et al., 2023).

Increasing Suburbanisation: Since the 1960s, the significance of corporate offices has been a topic of ongoing discussion. Initially, advancements in technology were expected to transform work, enabling managers to oversee operations from any location. By the 1970s, flexible production methods led companies to reconsider their work environments. IBM, for example, adopted open-plan offices with shared desks. As technology became more affordable, work processes accelerated, and outsourcing reduced costs. Consequently, the focus shifted towards allowing employees the freedom to choose where to live, rather than relocating for work.

Studies have suggested that WFH could make people accept longer commutes (de Vos et al., 2019) and change where people live (Alizadeh, 2013). Wethal et al., (2022) reported that some households were willing to move out of cities due to the elimination of long commutes during WFH, which would mean more affordable housing, better access to nature, and support from extended family. Conversely, others discussed how their WFH experience made them appreciate the value of living centrally, as not having to commute had been highly beneficial.

According to Gato & Haubrich (2024) the advancement of digital technologies and telecommunication has facilitated globalized and digitized work, enabling professionals to work from decentralized locations. This trend has led to the emergence of new working spaces (NeWSps) outside major urban centres, offering opportunities for a broader range of professionals. Yet, this reverse migration, particularly for knowledge workers, faces challenges in infrastructure and accessibility in non-core areas, which remain a concern for public administration.

Emergence of New Working Spaces (NeWSPs): NeWSps have emerged in response to changes in work dynamics, driven by technology, preferences, policies, and specific local contexts. They offer numerous benefits beyond traditional offices and remote work, providing flexibility in working hours and locations. By fostering diverse interactions among professionals, such spaces facilitate interdisciplinary collaborations, knowledge exchange, and skill enhancement (Mariotti et al., 2024).

Furthermore, reduced commute to city centres offers the possibility to reinvigorate local and regional high streets and transport centres., with such community locations having the potential to host workplaces.

Within the academic sphere in metropolitan cities, traffic congestion, high commuting, meal costs, fatigue, and physical effort have been found to be detrimental to working on campus (Clark et al., 2016). Support spaces on campus (e.g., meeting rooms and break areas on campus) offer an intermediate space between home and the office, offering a good balance between individual activities at home and collaborative activities on campus (Gorgievski et al., 2010; Appel-Meulenbroek et al., 2022), leading to increasing demand for third and fourth places to work.

8.3.3. Implications for CREM:

"*Strategic management demands that the manager has a clear understanding of the owner's or occupier's objectives and the core activities that will take place in or on the property. It demands that the manager is able to understand the activities that the property supports and the competitive demands that it faces daily. The manager can then develop property action plans that are capable of balancing short- and long-term goals*." (Edwards & Ellison, 2004)

Hybrid working represents a seismic shift for corporate real estate managers, necessitating a re-evaluation of space utilization strategies and office design. The demand for physical office space can take on new spatial and temporal forms, prompting a reassessment of leasing agreements and property portfolios.

Flexibility becomes crucial, accommodating fluctuating occupancy levels and diverse work styles. There's an increased emphasis on creating collaborative, engaging environments for in-office days to foster connection and innovation. Integration of technology infrastructure is essential to support seamless hybrid collaboration, ensuring the office remains a compelling destination for teamwork.

The labour market is also undergoing significant changes, favouring flexible working arrangements like remote work and freelance gigs. This trend prompts organizations and CREM to rethink traditional office setups. Alternate hybrid work models gain popularity, allowing remote work part-time and expanding traditional office boundaries to support 'third spaces' fostering collaboration and innovation.

Den Heijer (2012) in her paper on campus management suggests that collective competitive advantage for attracting talented knowledge workers to Europe can be facilitated by knowledge exchange through a shared network of campus managers. Hybrid working is fast becoming a universally accepted reality for future working processes. This implies a shared level of problems at an international level, with sufficient grounds to enable and facilitate knowledge exchange through common regional or global networks. Such knowledge networks are beneficial not just to exchange management information but also to discuss a collective strategy which can then take on different localised and contextual solutions that position users at the centre.

Change is inevitable, and faster than before and this makes the role of the corporate real estate manager even more important. However, a successful switch will necessitate CREM managers to pivot towards innovative solutions that prioritize employee requirements and well-being, innovation, and collaboration over traditional notions of occupancy and space.

8.4. Scope for future research

While remote working was once considered a privilege limited to certain employees and industries, the pandemic necessitated its widespread adoption and spurred companies to digitize their services for operations to stay afloat. This shift underscores the importance of both digital infrastructure and functional space for successful remote work. Researchers now have an opportunity to delve deeper into this relationship between digital technology and workspace functionality.

This phenomenon highlights the emergence of ad-hoc or intermediate spaces between the home and traditional office, known as the *"third place"* by Ray Oldenburg: spaces that facilitate social interaction, community building, and support beyond the confines of home and work. Third places are characterized by their informal, voluntary, and enjoyable gatherings. Understanding the physical, social, organizational, and digital dimensions of third places can help researchers and practitioners create more effective strategies and solutions for flexible, adaptable, and collaborative work environments tailored to the needs of different types of workers.

Additionally, the rise of hybrid working offers a fertile ground for labour economics research. Investigating its effects on labour costs, wage structures, productivity, and employee satisfaction can provide valuable insights into the changing nature of work. Understanding how remote and on-site work interact may inform better compensation models and potentially redefine conventional employment concepts. This shift towards hybrid working presents a rich area for comprehensive study into its multifaceted impacts on labour economics.

Chapter 09

Conclusion

The hybrid working phenomenon is complex and underexplored due to its novelty and uniqueness. This thesis set out to understand the implications of adopting a hybrid mode of work on the sustainability of the workspaces using the following main research question: ***"How is the energy consumption of the workspace environment impacted by hybrid modes of working?"***

This involved mapping the different impact areas of hybrid working using the four-perspective framework for campus management (A. Den Heijer, 2012) to identify the links and dependencies between the different parameters influenced and influencing hybrid working. A quantitative study employing synthetic modelling and case study analysis was used to focus on occupancy and energy metrics and answer the different research sub questions. The subsequent sections provide the conclusion to each sub-question and culminate in a comprehensive response to the main research question.

9.1. Answering the sub questions

SQ1: What is hybrid working?

Hybrid work is a form of work where employees have the **flexibility to either work at home or in embodied organisational spaces**; resulting in wok being split across physical and virtual workspaces (Halford, 2005). It is expected to be a permanent feature of future working processes due to the empowerment and work satisfaction from improved individual productivity, flexibility, and the autonomy to design and adjust work time and processes to one's needs (Babapour Chafi et al., 2021).

However, the **socio-spatial isolation** of remote working affects the informal networks that are central to work life, resulting in increased overworking, anxiety, conflict, and stress (Halford, 2005). This isolation weakens social and professional networks due to limited spontaneity and informal interactions at the workspace (Babapour Chafi et al., 2021), thereby impeding collaboration and innovation (Yang et al., 2021).

Upper management levels report **more time** for reflection and strategic work, increased collaboration, and knowledge exchange due to reduced commute. However, hybrid working also magnifies the spatial embeddedness of traditional management practice and De Paoli & Ropo (2015) stress that physical presence and co-location in open-plan offices are essential for being a good leader and to build trust within teams. Soubelet-Fagoaga et al., (2021) emphasise that teleworking requires a climate of trust and flexibility, rather than control and presence.

At an organisational level, hybrid working typically results in **weakened shared culture** and a disconnect from the organisation (Babapour Chafi et al., 2021), the consequences of which include a high attrition rate. However, Appel-Meulenbroek et al., (2022) report that hybrid working provides access to a wider pool of talent, reduced space needs and lower operation costs and other expenses connected with maintaining a physical office due to dynamic schedules and fewer personnel in the office.

SQ2: How has the definition of a 'workspace' evolved due to hybrid working?

The separation of work between **two distinct physical spaces** leads to hybrid collaborations, with phases of synchronous and asynchronous work and tasks being divided into **office and home streams**. The home stream is characterized by routine tasks requiring high productivity that benefit from isolation, while the office stream is reserved for challenging work that necessitates peer and managerial support (Halford, 2005).

Offices have been reconfigured over the past few years, with **activity-based workspaces** reflecting more 'we' than 'me' becoming the norm. However, literature emphasizes the importance of understanding the activity patterns and preferences of employees before implementing such spatial changes.

This is evidenced by the case of ING Marnix and CSM, which exhibit a high degree of individual worker use despite the prevalence of many collaborative zones. It is crucial for organizations to calibrate unique and customised landscape solutions (Van Koetsveld & Kamperman, 2011) where projects are evaluated from a user perspective to optimise future/ subsequent interventions (Hansen et al., 2011, Lindahl et al., 2013).

This separation of home- office space also leads to the conception of alternate working spaces. Migliore et al's (2024) research on post covid working trends amongst academics reports that public **third spaces** such as coffee shops, libraries or coworking spaces were used for teamwork and collaborations. Additionally, in-transit spaces (e.g., cars or trains) and privately owned studios are accessed for individual and collaborative activities respectively. Furthermore, other organization premises are exploited for collaborative and individual activities for academics involved in joint research work.

Hybrid working has thus extended the boundaries of an office to include a much wider scale and diversity of spaces, across both the physical and virtual realm, resulting in the conception of **workspace environments**.

SQ3: How has hybrid working impacted the use of office space?

The separation of home and office spheres has **redefined the office** as a space for meetings, social interactions, and enhancing team cohesion, resulting in dynamic occupancy levels throughout the day and across the week.

In Northwestern Europe, the general trend shows higher office attendance on Tuesdays and Thursdays, with Wednesdays and Fridays being the least visited days. This pattern is confirmed by data from ING Belgium, where all four buildings typically exhibit weekly peaks on these same days. Occupancy data from Building 28 in 2022 suggests that as hybrid work becomes more structured, occupancy patterns tend to **standardize**. This standardization highlights the link between professional and private lives, as uniformly low levels on Wednesdays align with school hours. Such predictability in occupancy data reduces risk for employers looking to optimize their assets in response to newer working trends.

Regarding spatial distribution, ING Marnix, recently renovated to accommodate new ways of working, features a variety of spaces, including work desks, collaboration rooms, and meeting rooms of different sizes. However, usage data indicates that these spaces are largely used by individual workers rather than teams. This supports the hypothesis that **the physical work environment does not determine employee behaviour** and it is in fact the inverse, thereby emphasising the critical role of user participation and employee behaviour in the (re)design of workspace layouts. Furthermore, Peter Mostien's observation that there is **increased mobility within the office**, with employees requiring more space than before, reflects the changing behaviours induced by hybrid working.

However, the occupancy data from Building 28 reveals that despite the prevalence of hybrid working practices, the **role of the physical office space has not diminished** within the academic sphere. This reinforces the hypothesis that knowledge-sharing and innovation are stimulated by face-to-face interactions at the workplace.

Current spatial planning trends are already responding to these changes with offices designed to maximise creativity and the production and dissemination of knowledge (Kraut et al., 2002), and to encourage chance and social encounters. Tagliaro & Migliore (2022) suggest that workspace layouts could be improved with dedicated areas or facilities for collaboration (e.g. meeting rooms, small break areas, etc.). The dynamic demand resulting from a hybrid model has also increased the popularity of flexible office space and this flexibility will be key to most real estate strategies moving forward, as it allows companies to hedge against the risks associated with workforce dispersion (Grzegorczyk et al., 2021).

SQ4: How is the energy footprint of a user impacted by the dynamic occupancy that results from hybrid working?

The common hypothesis related to teleworking is that it reduces employees' office capital and operational costs by shifting from energy-intensive commercial buildings to more energy-efficient residential buildings.

This aligns with the results of the synthetic modelling (Chapter 05), where a template office space that employs a hybrid working policy—allowing employees to work from home two days a week—experiences a reduction of approximately 5 kWh/m² in energy demand. This finding is corroborated by real-time data from Building 28 at TU Delft. Their energy usage trends, tracked from pre-COVID times to the present, indicate a significant decrease in energy requirements compared to non-hybrid working processes, despite no reduction in their spatial footprint. It is important to mention that the impacts of climate change, i.e. increasing global temperatures and their effects on workspace energy requirements have not been considered for this study.

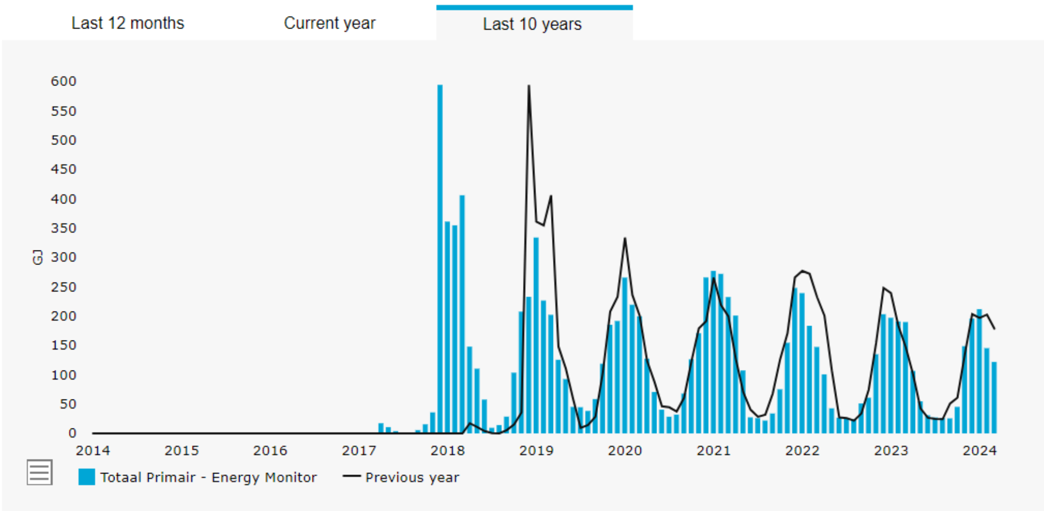


Figure 80 Primary Energy Usage Trends from 2017 to 2024 (Exported from TU Delft Energy Monitor)

Such savings are conditional on **energy usage being tied to occupancy levels**. ING Marnix, one of the buildings studied for this thesis was recently renovated to include a larger variety of spaces that cater to newer working trends. Despite these changes, the average occupancy levels over the last ten months stands at 30%, and a max of about 60%, leaving a significant amount of space unoccupied. While energy data for the same period is unavailable, it is reasonable to assume that if energy usage is not aligned with occupancy, 70% of the space may have been heated, cooled, and lit despite being unoccupied. Open plan configurations which have become the norm for workspace design over the last few decades, coupled with dynamic occupancy from hybrid working, make it technically complex to isolate operational energy demands to the occupied seats. Hence **the energy benefits of hybrid working could, be overstated unless there is a significant reduction in the physical space being occupied.**

Additionally, there is a rebound effect to consider. Pérez et al (2005) state that any energy saved from reduced office occupancy could lead to increased operational energy use at home. The synthetic simulations performed for the energy demand of homes that employ hybrid working confirms this with small household compositions shouldering the largest burden While the increase in energy use at an individual level is not exponential, when multiplied across the entire hybrid workforce, the impact could be substantial. This also highlights the **social dimension of sustainability** that needs to be addressed, as these rebound effects disproportionately affect the already economically and socially disadvantaged.

The energy footprint of a hybrid worker is also a function of mobility. Hybrid working can induce sizable environmental impacts, largely contingent on **reducing car use**. One consequence of hybrid working is an increased tendency among employees to live further from their office due to decreased commuting frequency. Studies suggest that this could result in modal shifts with people opting for private transport due to concerns about disease transmission and efficient time management, leading to increased demand for private cars, biking, micromobility, and walking as alternative modes of transportation (Christidis et al., 2021). These changes in mobility patterns also affect urban geographies, with increasing suburbanisation being a consequence of people opting to live further from their offices.

At a functional level, **hybrid working could enhance job accessibility** due to workforce dispersion. However, such benefits are more pronounced when combined with a robust public transport system. In the absence of adequate infrastructure, the energy savings from reduced commutes can be offset by increased car usage. Even within this dimension of hybrid working, benefits are unevenly distributed, typically favouring those who can telework and already live in economically advantageous regions.

9.2. Answering the main research question:

While prior research has expanded upon the productivity and functional level benefits of hybrid working, this thesis set out to study the energy level impacts of this phenomenon using the following main research question:

"How is the energy consumption of the workspace environment impacted by hybrid modes of working?"

From a **physical** perspective, hybrid working offers benefits to the business owner due to dynamic occupancy, which in turn leads to a reduced energy demand. These benefits are a function of occupancy patterns, workspace arrangements, energy consumption systems and commute. Additionally, studies have shown that remote working does not hinder productivity or work quality. This study also reinforces the crucial role of the availably of information and data in the transition to a sustainable future as it is only through awareness of our current practises, including its benefits and drawbacks, that we can take stock of how the future could be improved.

However, work is inherently a **social phenomenon**, and this is where hybrid working shows shortcomings.

The benefits afforded by hybrid working are disproportionately distributed with business owners and employers typically reaping the positive attributes of this. The synthetic modelling (Chapter 05) indicates that any savings in energy demand from the dynamic occupancy of hybrid working are often offset by increased energy use at employees' homes. Employees in smaller households and family configurations typically bear the largest burden, highlighting an **implicit inequality** in these working trends. This inequality has both financial and social dimensions, as marginalized groups are less likely to benefit from new working trends.

At a larger societal level, it is the previously marginalised who are once again unable to reap the benefits of newer working trends. These results are also visible in the study of the impacts of hybrid working on mobility, with people who live in economically advantageous areas with well-connected public transport infrastructure, able to maximise the benefits of hybrid working. While the quality of work does not diminish with hybrid working, the lack of social interactions can constrain essential functional elements such as trust, collaboration, and overall organizational cohesion.

According to Najjar (2022), sustainability is a dynamic, complex, and expansive notion that spans over many perspectives as depicted in Figure 80. Given this interconnectedness, it is impossible to isolate the environmental aspects of hybrid working and deem them beneficial, especially when these benefits are not equitably distributed across other dimensions.

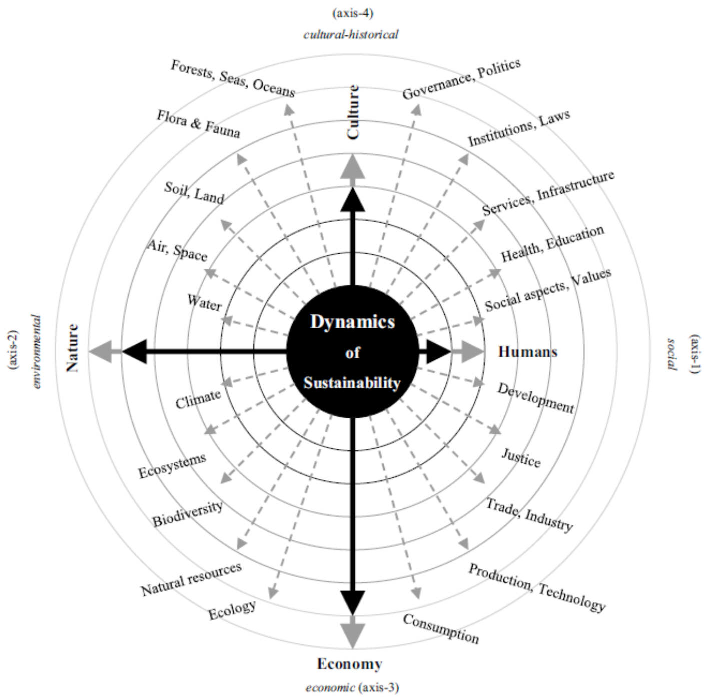


Figure 81 Dimensions of sustainability (Najjar, 2022)

Hybrid working is expected to be a permanent feature in future working processes. Therefore, it is crucial for building and business owners to understand its various dimensions to make informed decisions in planning, designing, operating, and maintaining their assets. The following section summarizes practical suggestions that built environment professionals can consider to enable an equitable distribution of the advantages of hybrid working at different scales.

9.2.1. Updated Framework:

The mapping is updated to reflect the different parameters identified across all four perspectives to produce the following:

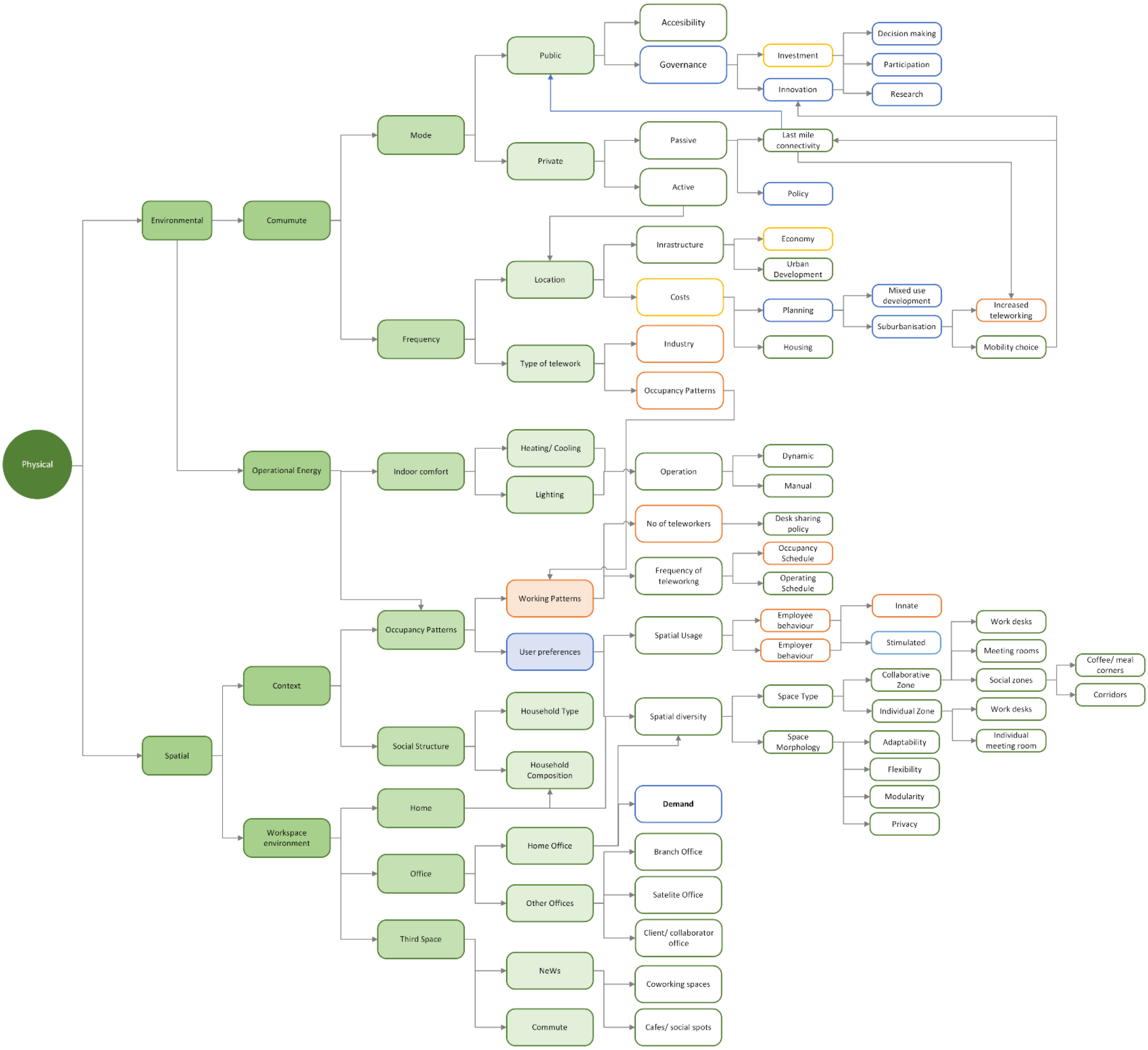


Figure 82 Updated physical aspects of hybrid working (author)

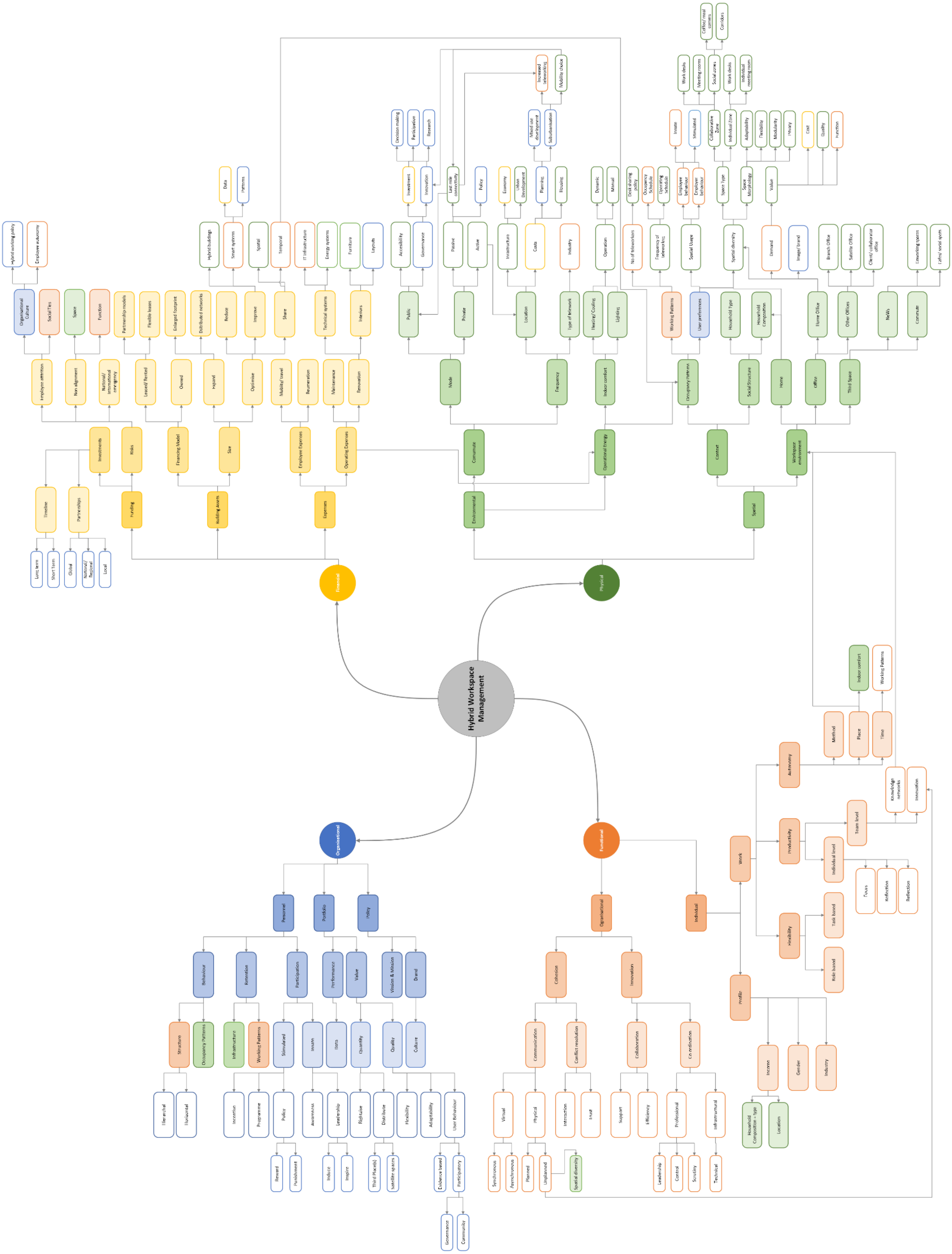


Figure 83 Updated system mapping (author, attached as separate document)

9.3. Recommendations for Practitioners:

Hybrid-working has pros and cons that should both be acknowledged in future real estate strategies. This involves questioning established work practices and workplace arrangements, and deeply investigating the diversity of workers' needs and preferences at different scales- the user, the building, the campus and the urban scale.

Figure 84 Solutions for CRE professionals (Author)

9.3.1. User Scale:

The efficacy of urban improvements relies on the understanding and participation of each user in the community. Tagliaro & Migliore (2022) recommend **evidence-based analysis** to profile workers' various requirements as their research points to differences detected across gender and age groups on the impacts of covid/ remote working.

Engaging employees and managers in **participatory design** can be an effective strategy to both inform the design process and foster a sense of belonging and ownership. Workplace changes **stimulate** workers to develop new organizational methods, which is crucial for supporting policymakers, founders, and other stakeholders. This involvement can guide decision making on policies and funding opportunities to bolster such initiatives, enhance local development, and **inspire** collaboration under favourable conditions.

9.3.2. Building Scale:

Due to the increased integration of technology and mobility within our working lives, the physical office needs to be re-imagined as a dynamic entity rather than a static space. This can take on different forms, as detailed below.

<u>Building Retrofit:</u> There are two advantages to employing a hybrid building strategy. It protects owners from unpredictable shifts in preferences. Secondly, with shorter leases becoming more prevalent in the office sector, the value of a space is increased when it becomes adaptable. This makes it important to retrofit or renovate older buildings to become more energy efficient. Industries should push to design systems and spaces, rather than optimising to produce new.

The ability to offer flexible working patterns as well as an infrastructure to facilitate them is becoming important for large companies hoping to attract and retain a talented workforce. Upgrading the operational energy system to dynamically respond to occupancy levels will safeguard the owner from the risks of unpredictable working processes. Smart buildings that use a dense network on sensors and actuators to collect occupancy and comfort data and translate it into user friendly dashboards will be critical in optimising office ecosystems. Such systems establish patterns and co-relations and enable a data driven approach to building operations that improves individual performances by facilitating overall operations.

"The future of work will rely on IoT and AI to create better buildings attract the best talents." Coen van Oostrum

Non-traditional space solutions like hybrid or "neutral-use" buildings whose design, infrastructure, and technology could be easily modified to serve different uses are possible solutions. Given the unpredictability of hybrid working, it is also worth exploring modular design solutions that can be adapted to changes in work patterns as required. Such strategies also percolate in the way the interiors and furniture are designed, paving the way for designers to be an active participant in this transition.

<u>Destination spaces:</u> Recent trends indicate weak office occupancy resulting from increased remote working. This offers the opportunity to shift the perception of an office towards being a destination space, offering more than just a place to work. Colenberg et al. (2020) stress that the office's social function as a meeting and community place requires appropriate and diverse spaces that offer a balance between virtual and physical interactions while also offering adequate spaces for rest and working individually. Their suggestions include introducing identity rich home zones for teams along with of mixing of departments and centralized facilities to support casual encounters.

The spontaneous interactions that occur in corridors are the crux of social and professional ties and this can be supported by providing a variety of spaces that facilitate this as well as well as possibilities for and marking of team and organizational identity. With activity-based workspace becoming the norm, Colenberg et al., (2020) emphasises the importance of balancing the visual and physical openness and standardization of the environment with the employee's need for privacy, identity marking and a sense of community.

As Despina Katsikasis states "*a building is there to enable people to perform and do their best work"*. Building retrofits should be accompanied by a conscious understanding of the role of each element within the overall office functioning. While historically the role of the office reflected the hierarchal power structures at work within the organisation, its focus today revolves around reflecting brand culture and value and generating trust and community.

Rightsizing of assets: There has been a shift in tenant's preferences for high quality space with many paying more per square foot to provide attractive space to their employees and to encourage increased office attendance. According to Dufner & Saven (2020) with offices shifting towards a collaborative, hospitality driven environment, buildings that facilitate human connection will have an edge. In recent years, the office has begun to resemble an urban landscape—permeable, diverse, and interconnected. To truly activate office spaces, we must emulate the vibrancy of great cities, fostering environments that encourage spontaneous interactions and unexpected encounters. Given the increasing function of office buildings as a company's signboard for both customers and potential employees, high-quality, future-proof and flexible office space become even more critical.

This is also an opportunity to rethink conventional leasing agreements. Private lobbies, or a "building within a building" or a temporal sharing of resources are examples that allows a level of flexibility otherwise unexplored. This also provides room for larger operators to investigate partnership models with local property developers, where underperforming assets are being replaced by community-oriented hubs with smaller footprints.

9.3.3. Campus Scale:

Distributed Campuses: Migliore et al., (2022) recommend that future academic campuses promote a distributed campus as a development strategy which incorporate private spaces (i.e., homes, organizations' premises, privately owned studios) and public spaces (i.e., coffee shops, libraries, parks) to be considered as university facilities which meet diverse academic work needs. They state that exploiting and converging off-campus spaces within a comprehensive campus strategy is a development opportunity from which all the stakeholders involved can benefit. The modern workspace, with its distributed employee networks, is a campus in its own right. Workspace environments could hence benefit from such distributed networks through the incorporation of satellite offices and co-working spaces. Such strategies minimise offsetting the energy excesses onto the end user, provide the option of relocating to affordable areas without increasing commute costs and could potentially support organisation culture and cohesion by being support workspaces for those who opt to work remotely.

Expanded Knowledge Networks: Working from home means a loss of serendipitous encounters in and around the workplace. While knowledge flows more readily among people who work in the same location, one must also consider the opportunity costs of such workplace trends. Remote collaboration technologies tremendously expand the opportunities to form teams that are optimized for specific research projects and questions (Barrero et al., 2023). Forman & van Zeebroeck (2019) find that the spread of internet connectivity increased knowledge flows across locations, as reflected in between-location patent citations within firms.

The Fourth Place: The fourth Place is relevant due to the significance of "*tacit knowledge, social interactions, networks, and the spatial dimension of innovations in the knowledge economy*" (Morisson, 2017: 6). It combines social connection and work, fostering teamwork and knowledge exchange while meeting the needs of the community for leisure and a sense of belonging.

In addition to access to physical and digital infrastructure and resources, they present similar dynamics of sharing and engagement between people from diverse professions, qualifications, and experiences, similarly to Oldenburg's (Oldenburg, 2002) "third place" concept. They can be seen as localized innovation and creativity environments that involve professionals, businesses, and communities of interest through formal and informal meetings for learning and collaboration.

9.3.4. Urban Scale:

Mixed Use Developments: Mixed use neighbourhoods that are not dominated by a single type of real estate are one way to adapt real estate at a macro scale. Mischke et al's (2023) research shows that such neighbourhoods suffered less than office dense neighbourhoods during the pandemic. That resilience gives investors, developers, and cities more reason to engage in placemaking.

Furthermore, increased teleworking points to greater propensity to live further away from workspaces due to the flexibility afforded by teleworking. Such teleworking-induced migration to suburbs could result in lower-density units that tend to be less energy- and transit-efficient. Transit oriented, walkable, multifamily, and mixed-use developments in suburbs could help offset these inefficiencies. The **distributed campus model** suggested in the previous section could also contribute to the planning of multi-functional districts which actively integrate multiple functions within residential, tertiary, and public activities (A. C. den Heijer & Curvelo Magdaniel, 2018); (Di Marino & Lapintie, 2020). Besides the shorter commutes, distributed workspaces also extend the economic ripple effect to local shops and businesses.

Such regional strategies could also alter the way residential stocks are designed. Brand owned co-living models which blur the boundaries of home and office have been designed by Japanese architect Go Hasegawa as a reaction to the limited housing, situated in the context of Japan's extreme work culture. While such models are not universally applicable, it provides room to explore such alternate living ideas.

Strong public infrastructure support: With remote working trends increasing the tendency to live further away, it is equally important to have strong public transport infrastructure in place, with adequate last mile connectivity. This ensures a minimal risk of rebounding to private modes of transport, which would simply offset any environmental savings from such shifts.

Such spaces have the potential to evolve into mobility hubs, seamlessly integrating workspaces and expanding existing transport nodes into micro-community centres that serve multiple functions. The success of these hubs depends on a deep understanding of local community needs, to enable the effective integration of various amenities while also catering to the target audience.

Participatory Design: To achieve a cleaner and more equitable future, improving governance and engaging citizens in developing innovative solutions, through research and experiments, is key. The suggestion of 'European living labs' networks, as suggested by Alonso Raposo & Ciuffo (2019) is an example where labs can serve as test environments for new solutions, with citizens actively participating in the process. While advancements in remote working trends offer promising benefits, decision-makers must acknowledge the complexity of various factors and involve citizens in evaluating future visions and needs through informed discussions.

Addressing the needs of current users is crucial, but it is equally important to anticipate future requirements and ensure the necessary flexibility for adaptation. Prioritizing communication and open-source information between parties is essential. Additionally, fostering social value by providing platforms for local entrepreneurs should be a key focus. Decentralizing interactions and promoting transparent governance can help create cities that prioritize the well-being of citizens over commercial interests.

9.4. The Future of Workspace Environments:

Hybrid environments are where the physical collides with the virtual, or as Den Heijer (2021:72) succinctly summarises it, where *"clicks were added to bricks".* Real estate leaders now have an opportunity to reconsider roles within organisations, operational structures, financial models, distributed solutions, and environments that host teams, given the significant shift in the working trends and workforce distribution. At the neighbourhood and building levels, and even in the design of the floors of buildings, choosing diversity, adaptability, and flexibility rather than uniformity can help cities thrive.

> *"Business performance is ultimately about people performance."* (Schump & McLaurin, 2023)

Spreading awareness about the functionality and intentions of sustainable urban systems and spaces is critical to get long-term thinking in motion. Creating an effective physical environment that offers a human-centric experience, considering employee and societal behaviour, will be paramount for attracting and retaining a talented and sustainable workforce. In other words, knowledge sharing is ultimately how design and the resilient city democratises.

Chapter 10

Limitations and Recommendations

- Model simulations are theoretical and based on simplified models of the home and workspace. They do not consider other factors that influence the energy performance of a space including the exact configuration of the house (row housing/ apartment/ independent house). Furthermore, the parameters used for the energy simulation are generalised. Different material palettes and layout configurations might therefore produce variations in the results.
- Another limitation of this research is its cross-sectional design. The data for the first case study is collected for a period of ten months, after COVID measures have elapsed, between July 2023 and April 2024. There is no data relating to occupancy and utilisation of the spaces prior to the Covid Pandemic or during. Thus, it was not possible to analyse the influence of pre-covid and covid scenarios on the contents analysed. The data for the second case study is collected over a span of 5 years (2018- 2023) and the change over time was easier to identify.
- Climate change and the impacts of rising global temperatures on the energy demands of workspaces have not been analysed in detail during this study and hence poses a limitation.
- Another potential limitation of this study is the impossibility of generalising these results universally due to contextual differences that also influence working patterns. While this could have been avoided by increasing the geographical boundaries of the study, that was beyond the scope of this thesis due to time and resource limitations.
- The results derive from a sample size of only two industry types. Therefore, future studies applying more robust methods that look at other working typologies are desirable to improve generalizability.
- The results of this study are shaped by synthetic modelling and data from corporate financial institutions and research-based offices. However, this phenomenon has implications across almost all industries and future research could explore the impacts of hybrid working on other industries and even more specifically on alternate working typologies, such as startups or SME's.
- In addition to adding to the body of knowledge on CRE, this thesis highlights the importance of current headquarters as hubs for socialization and collaboration and challenges businesses to reconsider their primary roles and layouts.
- This study identified the prevalence of co-working spaces as another workspace environment. Due to the limitations of this thesis, this could not be incorporated in the data collection and synthesis. This provides potential for further research to study the implications of co-working spaces on the future of workspace sustainability.

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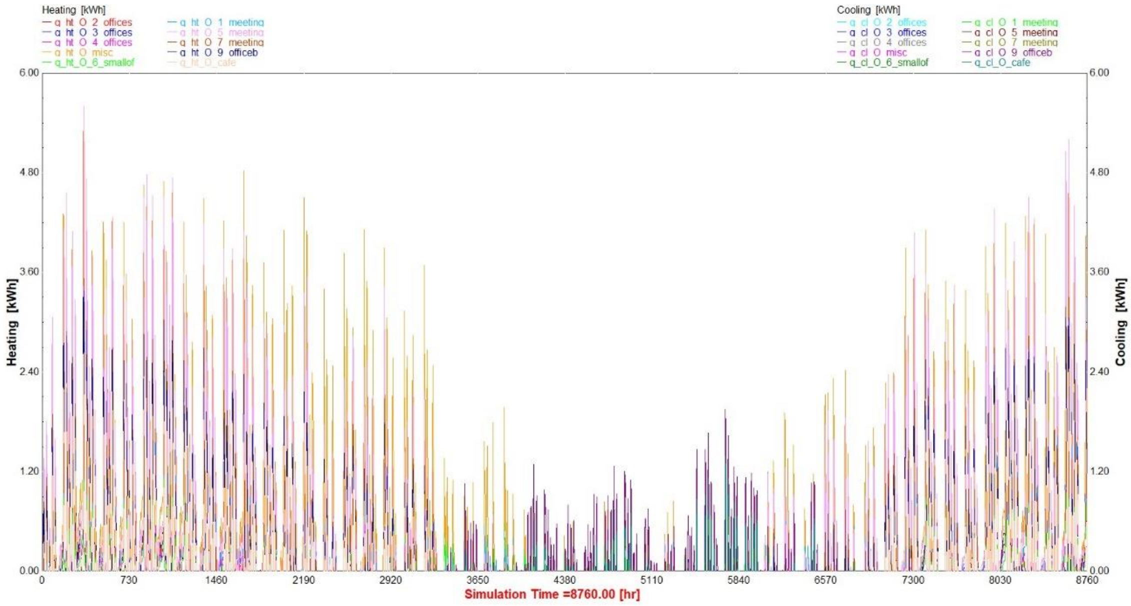
Appendices

Appendix I: Energy Simulation exports from TRNSYS

In this chapter, exports of the other simulations that were performed during the synthetic data modelling detailed in Chapter 05 have been included for reference.

11.1 Office Environment:

The following graphs depict the energy flux (in kWh) across one year for a hybrid and WFO scenario, simulated at intervals of one hour.



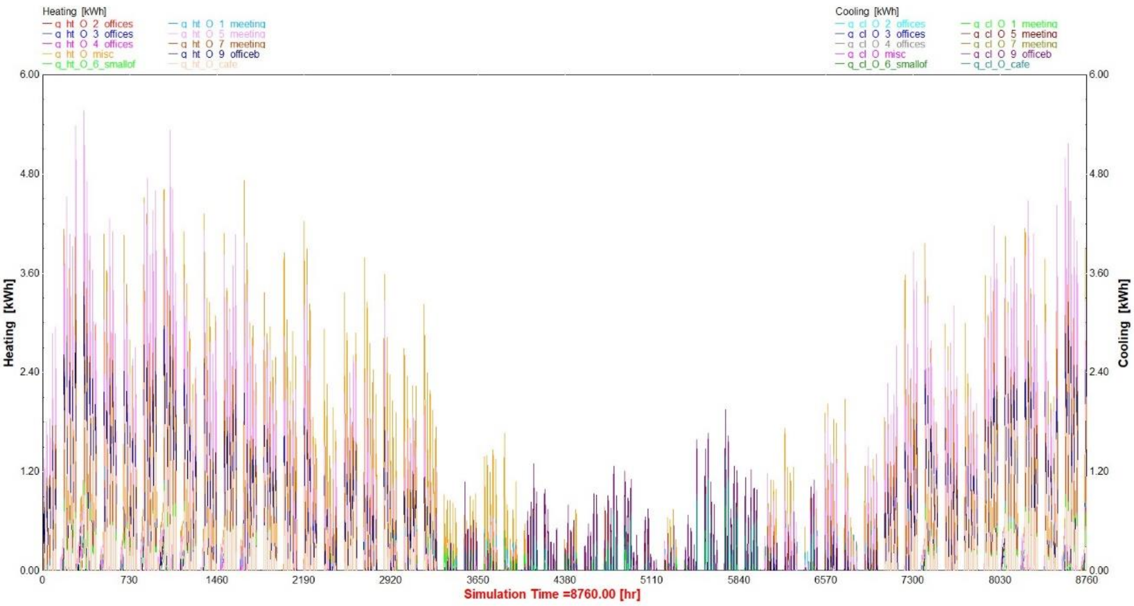


Figure 85 Heating Cooling Energy flux across the year in an Office, Hybrid. (above) and WFO (below) (Author, from TRNSYS)

The following graphs depict the energy required for artificial lighting (in kWh/m^2) across one year for a hybrid and WFO scenario, simulated at intervals of one hour.

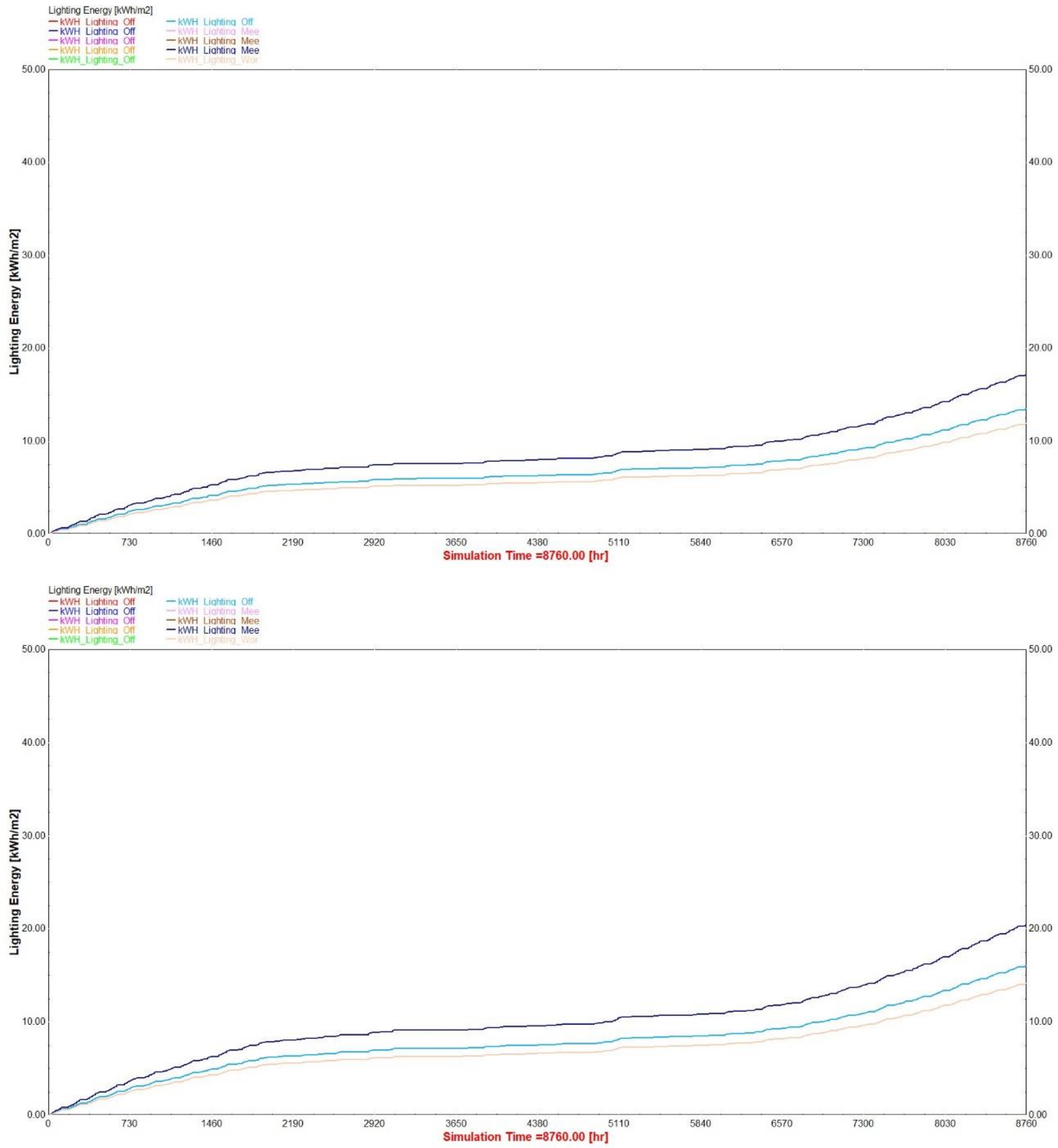
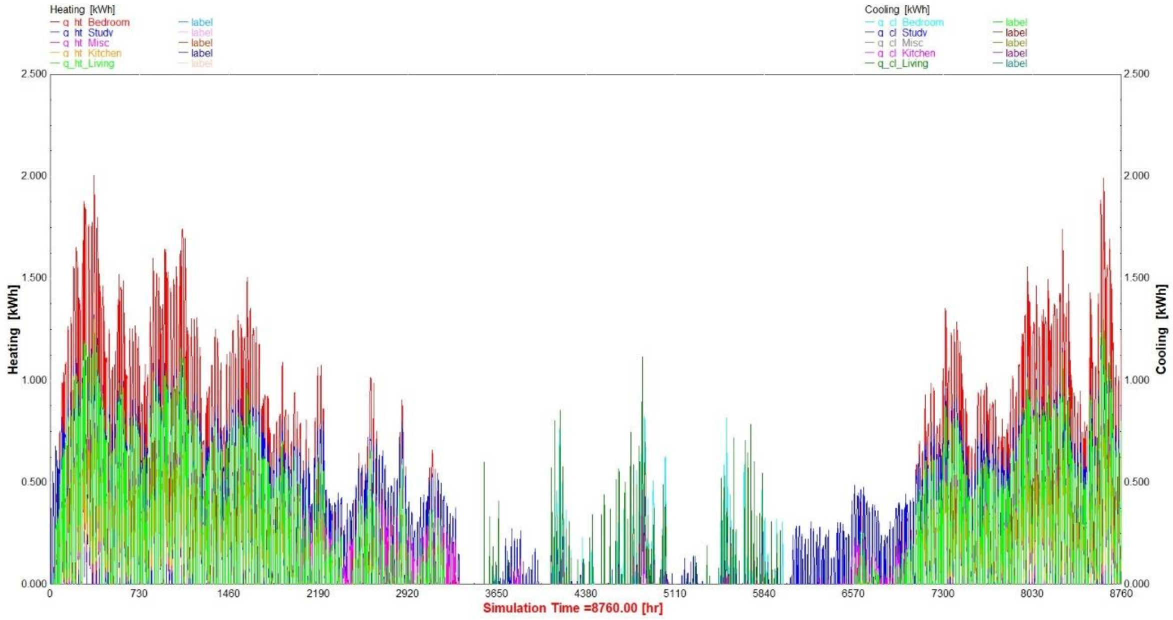


Figure 86 Artificial lighting Energy use in a year in an Office, Hybrid (above) and WFO (below) (Author, from TRNSYS)

11.2. Multi Person Household Composition:

The following graphs depict the energy flux (in kWh) across one year for a hybrid and WFO scenario, simulated at intervals of one hour.



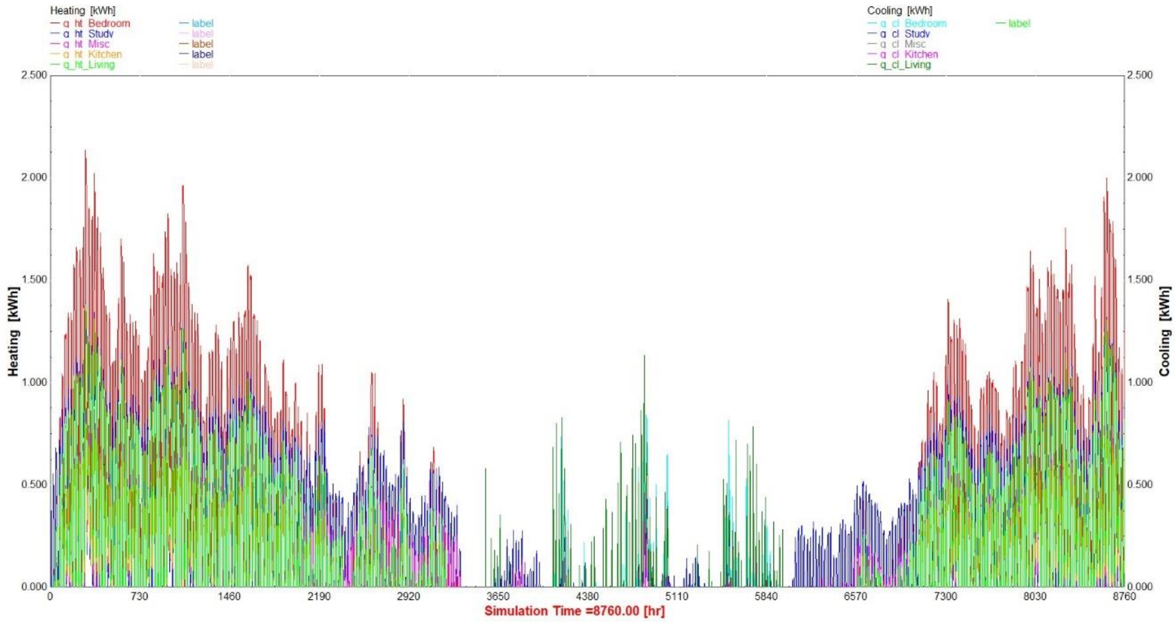
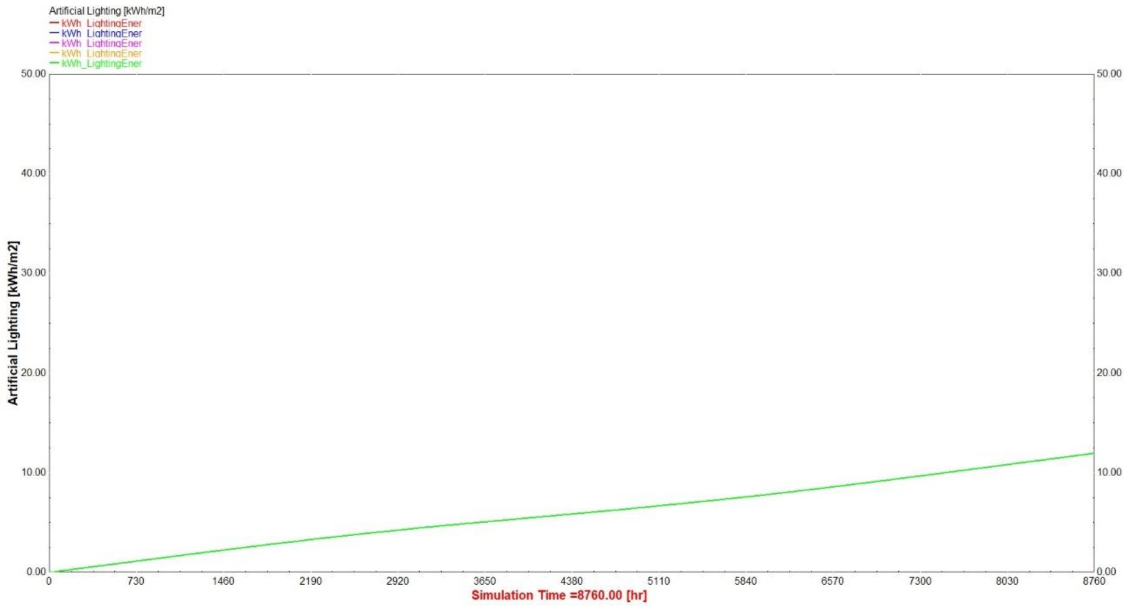


Figure 87 Apartment- Annual Heating Cooling Energy flux, Hybrid (above) and WFO (below) (Author, from TRNSYS)

The following graphs depict the energy required for artificial lighting (in kWh/m^2) across one year for a hybrid and WFO scenario, simulated at intervals of one hour.



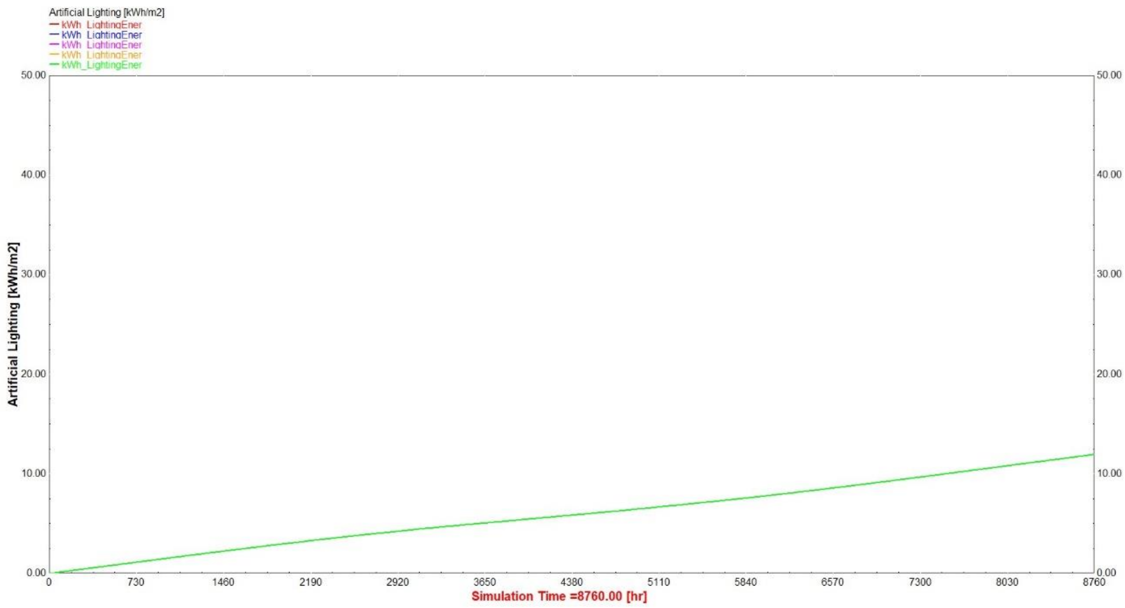


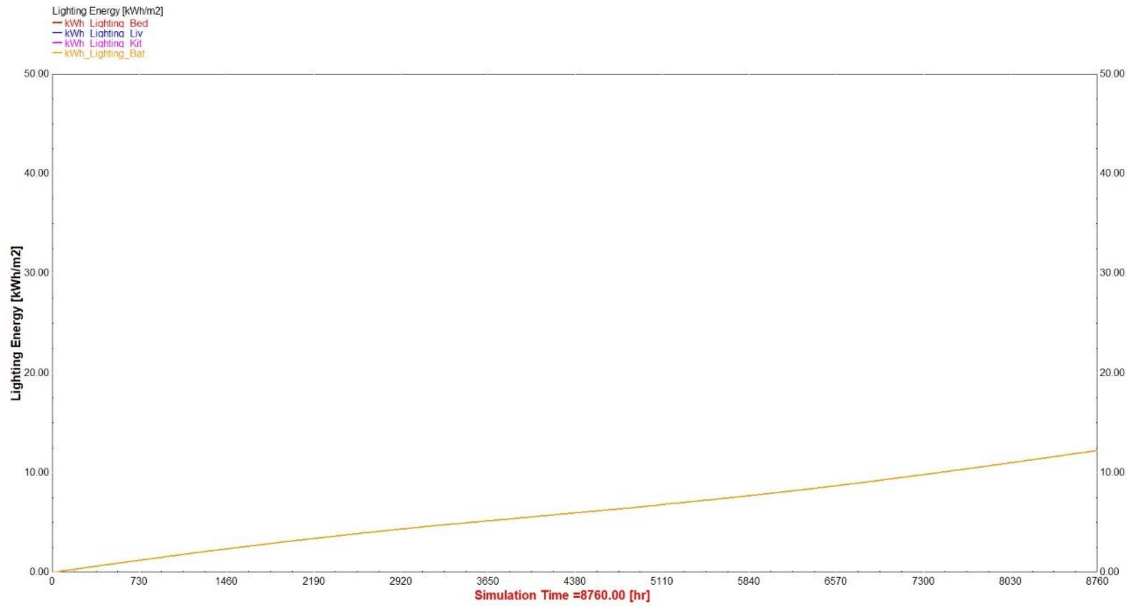
Figure 88 Apartment- Annual artificial lighting Energy use, Hybrid (above) and WFO (below) (Author, from TRNSYS)

11.3. Single Person Household Composition:

The following graphs depict the energy flux (in kWh) across one year for a hybrid and WFO scenario, simulated at intervals of one hour.

Figure 89 Studio- Annual Heating Cooling Energy flux, Hybrid (above) and WFO (below) (Author, from TRNSYS)

The following graphs depict the energy required for artificial lighting (in kWh/m^2) across one year for a hybrid and WFO scenario, simulated at intervals of one hour.



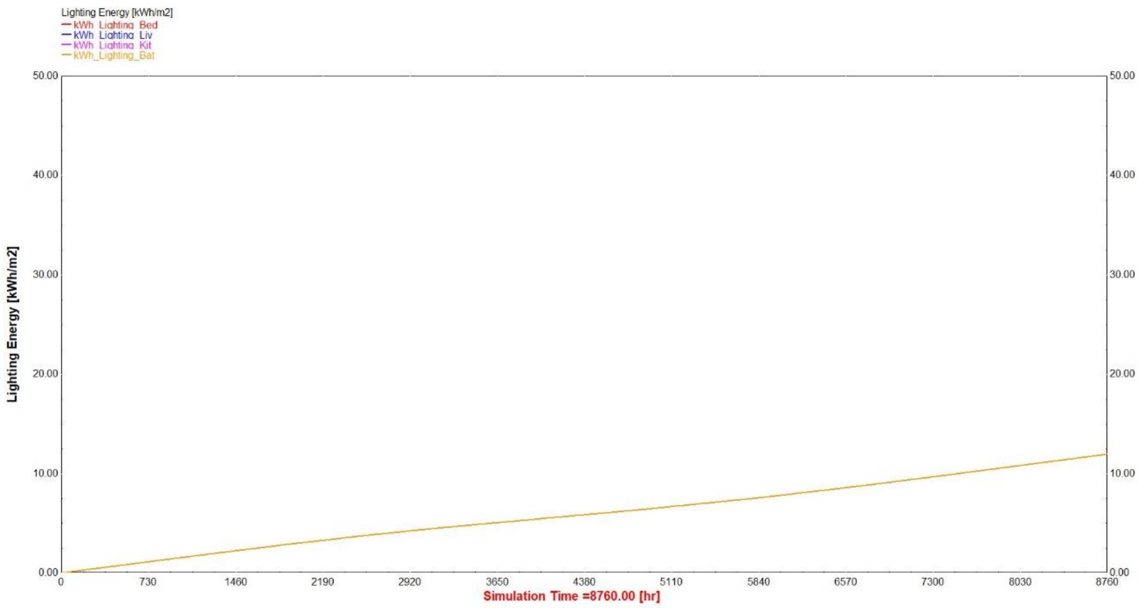


Figure 90 Studio- Annual artificial lighting Energy use, Hybrid (above) and WFO (below) (Author, from TRNSYS)

Appendix II: Data Management Plan

Plan Overview

A Data Management Plan created using DMPonline

Title: Reconfiguring workspace configurations for a sustainable future

Creator: Sanjana John

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2021)

Project abstract:

Climate change is advancing at an unforeseen pace with 40% of global emissions being attributed to the built environment. There is an onus on market players to mitigate this crisis since climate risk is now accepted as financial risk. Office real estate in particular plays a crucial role since its contribution towards a green future is also expected to help retain a talented workforce. However, the office of today is very different and hybrid working is soon to become a non-negotiable reality of the workspace ecosystem. The relationship between employees and the workspace is continuously shifting due to changing occupancy patterns that stem from these evolving working processes which impacts the energy performance of a building. This thesis thus attempts to understand the impact of hybrid working processes on the sustainability of workspaces by analysing the functional, strategic, functional and financial components of real estate management, with a specific focus on the environmental quotient using a quantitative research design. The thesis uses theoretical modelling, and data from two case studies to understand the impacts of hybrid working on the occupancy levels and energy demand of work spaces. Reflective interviews with research experts in the field of hybrid working will be conducted as a conclusion to the project. A system mapping identifying the different areas of impact of hybrid working and their interdependencies will be formulated based on the above methods to support the conclusion to the research question, thereby enabling improved management of building assets for real estate professionals and business owners that mutually benefits all actors involved.

ID: 148494

Start date: 03-09-2023

End date: 19-06-2024

Last modified: 03-05-2024

Reconfiguring workspace configurations for a sustainable future

0. Administrative questions

1. Name of data management support staff consulted during the preparation of this plan.

My faculty data steward, Janine Strandberg, has reviewed this DMP on 10/04/2024.

2. Date of consultation with support staff.

2024-03-30

I. Data description and collection or re-use of existing data

3. Provide a general description of the type of data you will be working with, including any re-used data:

Type of data	File format(s)	How will data be collected (for re-used data: source and terms of use)?	Purpose of processing	Storage location	Who will have access to the data
Audio-recordings of interviews with the expert professionals as a form of reflection.	.mp3	Interviews are conducted during using Microsoft teams software or on-site visits to the office of the expert professional. Audio recordings are made on an external device or the same device (if online, Teams), before being moved to OneDrive. Recordings are deleted after transcription.	Capturing the opinions on the impacts of hybrid working on the functional, physical, financial and environmental aspects of office management.	One Drive (primary) External recording device (temporary)	Sanjana John and graduation mentors, Alexandra Den Heijer and Michael Peeters
Transcriptions of recordings	.docx	Transcriptions created manually based on audio-recordings. Participants will be asked to review the transcriptions of their interview before the transcript is finalised.		One Drive	Sanjana John and graduation mentors, Alexandra Den Heijer and Michael Peeters
Personally Identifiable Information (PII) processed for administrative purposes (e.g., name, email, work address).	.pdf and .docx	Contact information for participants taking part in interviews, received [from participant sign-ups, professional network, etc.]. Informed consent forms are signed digitally and contain participants' name + email.	For administrative purposes: obtaining informed consent and communicating with participants	One Drive	Sanjana John and graduation mentors, Alexandra Den Heijer and Michael Peeters
Signed consent forms	.pdf	Will be shared with the participant by email prior to the interview	To record the consent of the participant to collect data and process the same	One Drive	Sanjana John and graduation mentors, Alexandra Den Heijer and Michael Peeters
Occupancy data of the selected case studies	.xls	Re-use of existing data from selected case studies (data available under a data processing agreement)	To understand the differences in occupancy of offices when hybrid working is followed	One Drive	Sanjana John and graduation mentors, Alexandra Den Heijer and Michael Peeters
Operational energy usage data of the selected case studies	.xls	Re-use of existing data from selected case studies (data available under a data processing agreement)	To understand the differences in energy demand of offices when hybrid working is followed	One Drive	Sanjana John and graduation mentors, Alexandra Den Heijer and Michael Peeters
Thesis report	.pdf and .docx	Documentation and record of the research.	Long term documentation	One Drive	Sanjana John and graduation mentors, Alexandra Den Heijer and Michael Peeters

4. How much data storage will you require during the project lifetime?

- < 250 GB

II. Documentation and data quality

5. What documentation will accompany data?

- Data will be deposited in a data repository at the end of the project (see section V) and data discoverability and re-usability will be ensured by adhering to the repository's metadata standards
- Other - explain below
- Methodology of data collection

I will adhere to disciplinary metadata standards - in accordance with the framework adopted by the European Commission using the principles of FAIR to ensure easy discoverability and reusability.
The final thesis report will be data will be uploaded to the Education repository.

III. Storage and backup during research process

6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

- Another storage system - please explain below, including provided security measures
- OneDrive

Signed informed consent forms as well as other contact information (PII) will be be stored in a separate folder from research data to minimise the risk of re-identification. Physically signed informed consent forms will be stored securely as well, for instance in a locked cupboard in a locked office.
External recording device: used as a temporary storage location for recording on-site interviews. Interviews will be deleted from device as soon as they are moved to OneDrive.

IV. Legal and ethical requirements, codes of conduct

7. Does your research involve human subjects or 3rd party datasets collected from human participants?

- Yes

8A. Will you work with personal data? (information about an identified or identifiable natural person)

If you are not sure which option to select, first ask your Faculty Data Steward for advice. You can also check with the privacy website . If you would like to contact the privacy team: privacy-tud@tudelft.nl, please bring your DMP.

- Yes

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- No, I will not work with any confidential or classified data/code

9. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question. If this is not the case, you can use the example below.

The datasets underlying this research will be only be released as part of the final thesis report and will be uploaded to the Education Repository at the conclusion of this thesis. This applies to the transcripts of the interview and the dataset provided by the commercial partners involved in the research.

During the active phase of research, the main researcher from TU Delft will oversee the access rights to data (and other outputs), as well as any requests for access from external parties.

10. Which personal data will you process? Tick all that apply

- Other types of personal data - please explain below
- Data collected in Informed Consent form (names and email addresses)
- Signed consent forms
- Gender, date of birth and/or age
- Access or identification details, such as personnel number, student number
- Email addresses and/or other addresses for digital communication
- Telephone numbers
- Names and addresses

Name of workspace
Job title
Audio recordings of interviews

11. Please list the categories of data subjects

Expert research professionals in the subject of hybrid working.

12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?

- No

15. What is the legal ground for personal data processing?

- Informed consent

16. Please describe the informed consent procedure you will follow:

Participants of the interview will be provided an opening statement with information about what participating in the research entails. All participants of the interview will be asked for their written consent for taking part in the study and for data processing before the start of the interview.

17. Where will you store the signed consent forms?

- Same storage solutions as explained in question 6

18. Does the processing of the personal data result in a high risk to the data subjects?

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply).

If two or more of the options listed below apply, you will have to complete the DPIA. Please get in touch with the

privacy team: privacy-tud@tudelft.nl to receive support with DPIA.
If only one of the options listed below applies, your project might need a DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to get advice as to whether DPIA is necessary.
If you have any additional comments, please add them in the box below.

- None of the above applies

19. Did the privacy team advise you to perform a DPIA?

- No

22. What will happen with personal research data after the end of the research project?

- Other - please explain below

The necessary personal data will be stored for the duration of your project and one month after following which it will be destroyed.

23. How long will (pseudonymised) personal data be stored for?

- Other - please state the duration and explain the rationale below

No pseudonymised personal data is stored.

24. What is the purpose of sharing personal data?

- For research purposes, which are in-line with the original research purpose for which data have been collected

25. Will your study participants be asked for their consent for data sharing?

- Yes, in consent form - please explain below what you will do with data from participants who did not consent to data sharing

Personal data will be deleted after processing,

V. Data sharing and long-term preservation

27. Apart from personal data mentioned in question 22, will any other data be publicly shared?

- All other non-personal data (and code) produced in the project

29. How will you share research data (and code), including the one mentioned in question 22?

- My data will be shared in a different way - please explain below

The data will be included in the report of my graduation thesis and will be uploaded to the TU Delft Educational Data Repository.

30. How much of your data will be shared in a research data repository?

- < 100 GB

31. When will the data (or code) be shared?

- At the end of the research project

32. Under what licence will be the data/code released?

- CC BY-NC

The thesis will be uploaded to the Education Repository and it can be used to produce derivative works if it adequately attributed to the author and used for non commercial purposes.

VI. Data management responsibilities and resources

33. Is TU Delft the lead institution for this project?

- Yes, the only institution involved

34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

My graduation supervisor, Alexandra Den Heijer, professor at Delft University of Technology, Faculty of Architecture, Department of Management in the Built Environment, Public Real Estate (a.c.denheijer@tudelft.nl)

35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?