CABA™

# Improving Organizational Productivity with Building Automation Systems

## BOUTIQUE MULTI-CLIENT RESEARCH PROJECT

CABA AND THE FOLLOWING CABA MEMBERS FUNDED THIS RESEARCH:

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**Improving Organizational Productivity with Building Automation Systems: Phase 1**

*How better building strategies benefit organizational productivity metrics: a review and framework for evaluation*

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# EXECUTIVE SUMMARY



## ES.1 PROJECT BACKGROUND AND INTRODUCTION

This executive summary presents top-level trends and conclusions from the CABA Boutique Multi-Client Research Project "Improving Organizational Productivity with Building Automation Systems". CABA commissioned the National Research Council (NRC) to undertake this research project on behalf of the Intelligent Buildings Council (IBC), a working group of the Continental Automated Buildings Association (CABA).

The research and report has been created by the NRC, a primer research and development organization, for CABA. CABA is a leader in initiating and developing cross-industry collaborative research, under the CABA Research Program.

## ES.2 ABOUT THIS REPORT

This report is the primary deliverable for a CABA boutique multi-client research project. Numerous conversations between NRC and CABA, its members, and other participants in the commercial buildings value chain, indicated that quantifying and valuing the benefits of "better buildings" beyond energy would support industry growth and success in competitive real-estate environments. There is a renewed industry focus on how better buildings can support occupant health and well-being, and consequently enhance organizational productivity; this relationship thus elevates the ROI on building improvements. This research involved the review and synthesis of a vast body of published work in the fields of business, engineering, and psychology. The results enable organizations to evaluate multiple organizational productivity metrics against benchmarks, and to compare the demonstrated benefits of better buildings strategies to other corporate investments designed to improve these metrics. This project is the first phase of a multi-phase approach to identifying specific mechanisms by which building systems can improve workplace environments and organizational productivity. The final goal is to guide new product development, operational strategies, and to provide the industry with the means to monetize the value of their better buildings investments. The research was conducted from April 2016 to January 2017, with a final webinar presentation in March 2017.

## ES.3 ROLE OF THE STEERING COMMITTEE

The Steering Committee represented a cross-section of organizations in the building controls, materials, and IT marketplace. Representatives from each organization joined NRC and CABA on regular collaboration calls to guide the research scope and ensure it met project objectives. The organizations on the Steering Committee, joining NRC and CABA, were:

Figure ES.1 Project Steering Committe




## ES.4 ABOUT CABA

The Continental Automated Buildings Association (CABA) is an international not-for-profit industry association, founded in 1988, dedicated to the advancement of connected home and building technologies. The organization is supported by an international membership of over 350+ organizations involved in the design, manufacture, installation and retailing of products relating to home automation and building automation. Public organizations, including utilities and government, are also members. CABA's mandate includes providing its members with networking and market research opportunities. CABA also encourages the development of industry standards and protocols, and leads cross-industry initiatives.

## ES.5 ABOUT NRC

NRC is the Government of Canada's premier organization for research and development. NRC partners with industry to take research from the lab to the marketplace, where people can experience the benefits. Each year our scientists, engineers and business experts work closely with thousands of organizations, helping them bring new technologies to market, by leveraging our national facilities and global networks. NRC's Construction Portfolio is Canada's leading centre for research and regulatory support for building and infrastructure. NRC Construction is the custodian of the National Building Code, Energy Code and other construction codes and specifications, and conducts internationally-recognized research into: building envelopes and materials, indoor environments and system operations, fire protection, and civil engineering infrastructure.

## ES.6 PROJECT OVERVIEW

This report provides a framework by which vendors of "better buildings" technologies and their clients can value the effects of these technologies on organizational productivity metrics. In most cases, the better buildings approaches addressed are technologies facilitated by advanced building automation systems (BAS), or are whole-building strategies (e.g., green building certification) that typically include superior BAS features.

Despite widespread recognition that better building environments do improve employee well-being and other important organizational productivity metrics, such effects have been notoriously difficult to quantify convincingly. One consequence of this is that they have often been ignored by decision-makers, who have too frequently focused on space reduction strategies in office buildings, the real-estate cost savings of which are easy to measure.

In this report we leverage new, multi-metric approaches to defining organizational productivity, which have been peer-reviewed by international experts and published by respected industry organizations, to develop a framework for valuing building environments in comparison to other corporate strategies. The metrics used in this report are: absenteeism, employee turnover intent, self-assessed

performance, job satisfaction, health and well-being (symptoms and overall), and complaints to the facilities manager. Further, we took the novel approach of developing benchmarks for each of these metrics, and comparing the effects of better buildings strategies to other, commonly understood and practiced corporate strategies typically deployed to improve these same metrics. These strategies include: office type (private vs open-plan), workplace health programs, bonuses, and flexible work options.

Assigning a generic value to better buildings approaches is challenging because the value of each outcome metric varies greatly by country, industry, job type, organizational output, and many other factors that are very context specific. The approach taken in this report finds a way around this challenge. By comparing better buildings approaches to other corporate programs, which may have known costs and expected outcomes in a particular organization, the decision-maker is empowered to choose (or not) a better building approach relative to another approach.

As an example, let us say that both a new building technology and a workplace health program can be shown to reduce absenteeism by one day per person per year. The costs of these strategies will vary from place to place, but the local decision-maker knows the costs for their particular organization, and can compare them. In this (fictitious) example, one could say that installing this building technology was like giving everyone access to a workplace health program (with respect to absenteeism, at least!). In this respect, in an analogy to energy efficiency, it is like saying an energy-saving program is like taking so many cars off the road. The positioning of such information in different units (cars, not dollars, not kWh) can be more appealing to some decision-makers.

Our method in deriving this approach was a comprehensive search and synthesis of published information from several disciplines, from business, medicine, and psychology, to engineering and facilities management. The scope was limited to studies conducted in real organizations in large office (or "office-like") buildings, with outcome measures relevant to the goals of this report. The source material for the quantitative aspects was peer-reviewed material in the academic literature, although other credible material was used as supporting information. We had a geographic focus on studies from North America, Europe, and Australia/New Zealand, as these regions were relevant to the business interests of the project partners, and are also the regions in which appropriate studies are most likely to have been conducted, given historical trends. Nevertheless, accessible and relevant work from China, India or other important emerging markets was considered. In total, more than 4,000 abstracts, and 500 full publications were reviewed.

Table ES1. The Matrix showing the benchmarks associated with each metric, and the effects of various corporate programs. The benchmark has a purple background if it was derived from national/international statistical surveys, and no background if it was derived from targeted research studies or theory. The arrow in each cell indicates the direction of the effect. The number in a cell indicates the size of the effect (in the same units as the benchmark); this is often a range covering effects from multiple studies. An arrow without a number indicates that the direction of the effect is established, but a size was not derivable (in our preferred terms) from the published studies. The effects attributed to better buildings strategies are highlighted as they are the primary interest of the project.

| | Strategies (IV)→ | Better Buildings | Office Type | Workplace Health Programs | Bonuses | Fexible Work Options | |
|---|---|---|---|---|---|---|---|
| Benchmarks | Metrics or KPIs (CV) | | | | | | Unit |
| 2-15 | Absenteesim | ↓0.4-1.5 | ↓3.2 | ↓0-1.8 | ↓1.0 | | day/per/yr |
| 18-30 | Employee Turnover (int.) | ↓1.3 | ↓18 | 0 | ↓ | | 0-100 |
| 0 | Self-assessed Performance | ↑2-10 | ↑8-15 | ↑0-10 | ↑ | | % |
| 60-80 | Job Satisfaction | ↑4-9 | ↑5-10 | ↑0-12 | | ↑0-10 | 0-100 |
| 30-60 | Health & Well-being (symptoms) | ↓5-9 | ↓ | | | | 0-100 |
| 55-75 | Health & Well-being (overall) | ↑6-10 | ↑11-12 | 0 | | 6 | 0-100 |
| | Complaints to FM | | | | | | |

Table ES1, referred to as “the Matrix” in the main body of the report, summarizes the results of the synthesis. The results specific to each metric (or Key Performance Indicator, KPI) are summarized as follows:

- **Absenteeism:** Better buildings strategies reduce absenteeism by an amount that has tangible value to an organization. The size of this effect is similar to workplace health programs and bonuses, although substantially smaller than the benefit of private versus open-plan offices. Given that investments in better buildings are likely to persist with a relatively low on-going maintenance cost, such investments are worthy of consideration alongside other, common workplace strategies.
- **Employee Turnover:** Although retention of (high-performing) employees is often stated as a key HR goal for organizations, studies in the context of this report were sparse. With the exception of the benefit of private versus open-plan offices, effects were small or difficult to

quantify. There was a small effect of one better buildings strategy, and this study had a strong design and statistical analysis.

- **Self-assessed Performance:** Despite challenges in interpretation, self-assessed performance is a widely used and accepted metric, particularly in work contexts where direct task performance measures are unavailable. Again, better buildings strategies have a positive effect that is similar in size to workplace health programs, and the upper end of the range of effect sizes overlaps with the benefit of private versus open-plan offices. The effect of financial bonuses was also positive, but could not be quantified on our chosen scale.
- **Job Satisfaction:** Job satisfaction, derived by self-report survey, is a well-established and excellent KPI for the white-collar workplace; it is widely understood to be the antecedent to many other behaviours important to organizational success. Better buildings strategies have a positive effect that is similar in size to the benefit of private versus open-plan offices, workplace health programs, and flexible work options. As already described under absenteeism, given that investments in better buildings are likely to persist with a relatively low on-going maintenance cost, such investments are worthy of consideration alongside other, common workplace strategies.
- **Health and Well-being (symptoms):** Better buildings strategies reduce symptom prevalence through multiple mechanisms. Private versus open-plan offices also reduce symptoms, though the effect could not be quantified on our chosen scale. Perhaps surprisingly, evidence of the effects of other workplace programs was not identified.
- **Health and Well-being (overall):** Better buildings strategies have a positive effect, and the upper end of the range of effect sizes coincides with the benefit of private versus open-plan offices. Surprisingly, we found that workplace health programs had no effect on this metric, and one study showed that flexible work options were associated with a decline in overall health.

In short, better buildings strategies (e.g., improved ventilation, enhanced lighting conditions, green building certification measures) provide benefits to multiple organizational productivity metrics at levels similar to other corporate strategies. This supports the greater consideration and deployment of better buildings strategies as measures to improve organizational productivity beyond energy savings.

Despite the breadth of our search, the number of good-quality studies in this domain is relatively small, which is surprising given the importance of the office environment to so many people's lives. Therefore, our study highlights the need for more multi-disciplinary research in this domain, in general. Nevertheless, we identified several specific research gaps that are deserving of more attention:

- There are several outcome metrics that have a high emerging profile among white-collar organizations, but which have not yet been established (or even operationally-defined) as outcome measures in published research. These include: employee engagement, creativity, new employee attraction, internal communication effectiveness, and presenteeism. Given the frequency with which managers and HR professionals reference such concepts, we suggest that researchers devote time to developing ways to measure them.
- In the past productivity might have referred to the performance of employees on a given task. It is widely acknowledged that such a simple output measure is not relevant to knowledge workers, but what, if anything, should replace it? In this report we have focused on the widely-used measure of self-assessed performance, but the opportunity exists for researchers to develop new ways of measuring in a relevant way both the quantity and the quality of white-collar work. In particular, how could one measure these performance attributes in a universal sense that allows for comparison between studies and workplaces, rather than using a context-specific metric?

- Even when studies use commonly understood concepts and metrics, they may have used different ways of measuring them that are not necessarily seamlessly equated. For example, different researchers in different contexts might have measured job satisfaction using one or more survey questions, with different wordings and scales. We call on researchers to coalesce on common scales that have been previously validated, and ideally have already generated databases to facilitate comparisons.
- We also call on researchers to ensure that they report their studies in a way that facilitates comparison among themselves and across disciplines, and is attuned to what practitioners (and not just the researchers' academic peers) might need from their studies. This includes reporting basic descriptive statistics such as means and standard deviations for the different study groups (e.g., treatment versus control, pre-post intervention), and to be clear in describing the differences between study groups.
- There is also a strong need for longitudinal data and analysis. Many of the studies from real organizations that we refer to are cross-sectional, and they often illustrate correlations. In most cases, there are sensible hypotheses and mechanisms from which to imply causation, but these should be proven in future research. This involves tracking data over a lengthy period of time, ideally several years, and looking at the ordering of interventions and changes in variables of interest.
- Another important benefit of long-term data collection is to verify whether effects persist over time. To date it has been very difficult for researchers to have access to organizational data over a long-enough period to track the sequence of cause and effect, and to measure the persistence of any observed effects. One way to overcome this limitation could be to examine data that already exist as a means to track effects over longer periods. Although BAS data are often not archived, data from HR departments are typically kept for long periods and might reveal valuable effects when mapped to changes in the built environment that occurred in the past during normal business practice.
- One of the most surprising gaps in the literature was the lack of studies employing complaints to the facility manager as an outcome. This is surprising because the data are routinely collected and archived in electronic format in most large organizations, and it seems like such an obvious outcome for buildings researchers to pursue, with their historic focus on occupant comfort. This is also an area in which a business case could be made in a relatively straightforward manner. Even excluding the (potentially large) benefits that lowering occupant discomfort might have for a range of organizational productivity metrics, responding to a complaint has direct, tangible costs too, with both fixed ("truck roll") and variable (labour and parts to resolve the problem) components.
- The full potential for the Internet of Things (IoT), including wearable devices, to assist in the measurement of existing metrics, or to be a platform on which to develop new metrics, is still in its infancy.

This report represents the first phase of what we propose to be a three-phase project with CABA and its members to tackle the complex problem of valuing the effects of better building technologies and operations on organizational productivity.

The strategic goals of the phased project are to:

- Demonstrate that intelligent building technologies and operations (within the broader context of "better buildings") produce organizational productivity gains (expressed via multiple metrics), in addition to energy and other resource savings.
- Demonstrate that these gains are realized via specific improvements in indoor environment conditions.

- Identify the specific technologies and operational improvements that are most likely to deliver benefits.
- Provide results in a format that allows organizations to assign a value to the full benefits of better buildings.

Table ES2 shows the key elements related to each phase.

Table ES2. Key elements of the proposed phased research approach to valuing the effects of better building technologies and operations on organizational productivity.

| Phase | Elements |
|---|---|
| 1 | Synthesis of existing published information<br>Establish productivity metrics: benchmarks, effects of better building technologies, effects of other corporate programs |
| 2 | Demonstrate metrics with new analysis of existing, comprehensive, multiple metric data, all from a real organization(s) |
| 3 | Establish physical mechanisms via the BAS and other intelligent building features and operations for effects with on-site measurements |

In closing this Phase 1 of the project we will use the success and the enthusiasm of our existing CABA partners to build a consortium of interested parties and to launch Phase 2 in 2017.

# 1. LINKING BUILDING SYSTEMS TO ORGANIZATIONAL PRODUCTIVITY

## 1.1 INTRODUCTION

This report presents findings and conclusions from the CABA Boutique Multi-Client Research Project "Improving Organizational Productivity with Building Automation Systems". The executive summary of this report includes the following background on this research:

- Project Background and Introduction
- About this Report
- Role of the Steering Committee
- About CABA
- About NRC
- Project Overview

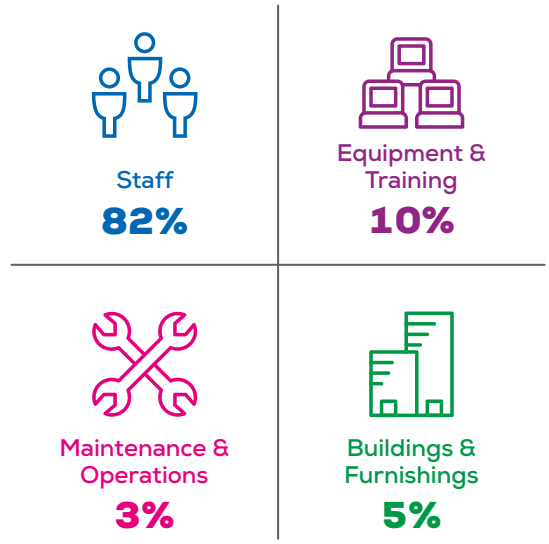
## 1.2 LINKING BUILDING SYSTEMS TO ORGANIZATIONAL PRODUCTIVITY

There is a long history of research establishing linkages between the physical office environment and the comfort of occupants (Brill, Margulis, Konar, & BOSTI Associates, 1984; Sundstrom, 1986). People in positions of influence who demand economic indicators to inform decisions on office accommodation and environmental control choices have often sought information on effects beyond indoor environment comfort; i.e., metrics perceived to have a more direct effect on employee health and well-being and organizational productivity. Such information is now growing in importance as enlightened employers seek sustainability options for their real-estate portfolio that go beyond energy efficiency. Established systems for certifying buildings according to their sustainability features have recognized the importance of indoor environment quality from the beginning, and its broad relationship to the well-being of occupants and the implications for their employers – a building cannot be sustainable if its occupants are dissatisfied; these systems include market leaders such as LEED (http://www.usgbc.org/leed) and BREEAM (http://www.breeam.com/). The WELL Building Standard is now starting to gain traction in practice, with its even stronger focus on healthful workplaces (https://www.wellcertified.com/).

The economic value of this line of enquiry has long-been understood. The largest expense of most (service economy) organizations is their staff (salaries, benefits, etc.), with technology (equipment and training) and buildings (leases, maintenance, operations, etc.) running close to equal second place. The cost of staff typically dwarfs the cost of buildings. Figure 1 illustrates a widely-cited breakdown of the costs associated with an office workplace over a 10-year period (Brill, Weidemann, & BOSTI Associates, 2001). Another common rule of thumb that is often quoted is that the annual operational costs of an office space are, on average $300/ft2 for staff payroll, $30/ft2 for space rent, and $3/ft2 for utilities (Best,

2014). Thus, one would not want cost savings in buildings to come at the expense of staff's ability to do their work. Ideally an organization would identify building strategies that support the productivity of the organization, and are cost-effective as a whole. In other words, a relatively small investment in building design and operation can have a relatively big benefit on organizational productivity through positive effects on staff (and energy use).

Figure 1. The costs associated with an office workplace over a 10-year period (Brill, Weidemann, & BOSTI Associates, 2001).



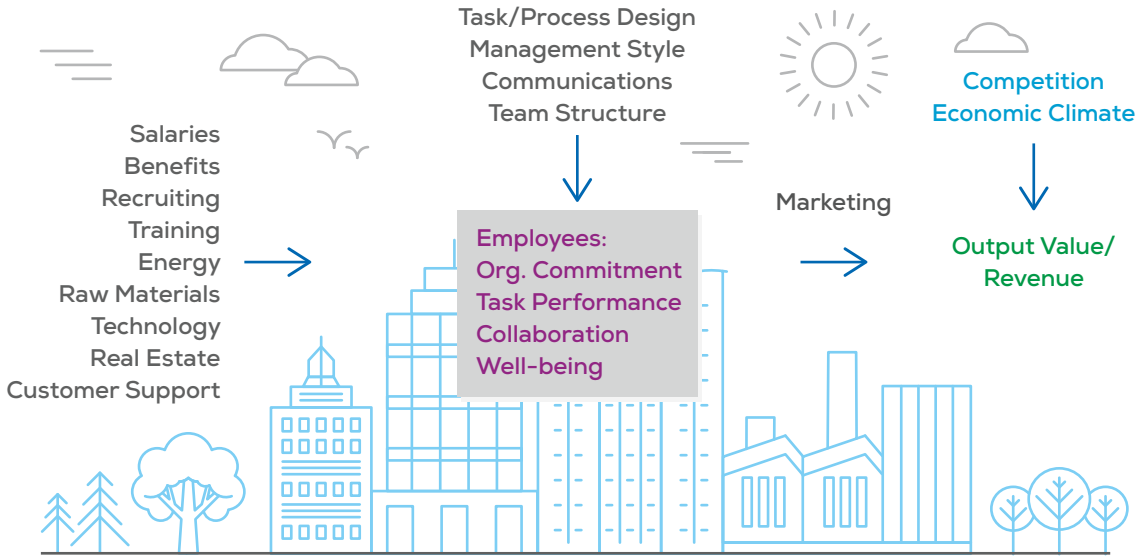

Good quality studies demonstrating such linkages are rare. This is partly because there has been no broadly accepted definition of what constitutes appropriate metrics, and thus suitable datasets have not been generated. At one time decision-makers sought very simple cause-and-effect relationships; i.e., "If I replace <BUILDING FEATURE X> with <BUILDING FEATURE Y> then productivity (simply thought of as the organization's bottom line, or the amount of work produced by an individual or business unit) will increase by Z percent". This is partly a hangover from an industrial production line model of productivity in terms of output of standard units. Few, if any, studies show direct causal effects that justify simple replacement of building features.

There is increasing acceptance that such a model is not applicable to most white-collar workplaces, where output is rarely measurable in such terms. Instead, productivity in white-collar workplaces is better represented by a basket of metrics, sometimes measured in different units, that all influence the overall balance of costs and revenues in an organization. This is the efficiency definition of organizational productivity (Pritchard, 1992). In an industrial model the value of outputs may be relatively easy to measure if one can count the number of units coming off a production line and the price of each unit in the marketplace is known; at the very least, one can calculate the total revenues for the organization. For organizations in a service economy, and certainly in the public sector, the value of outputs may be much more difficult to quantify. But what about the input cost side of the equation? Figure 2 illustrates just some of the factors that contribute to the productivity picture. Note that some of these can be influenced by building technology vendors, but many cannot.

Building features can affect both input costs and output values. Poor indoor air quality could result in increased illness absence (a cost). Employees who are not ill might have increased workloads to compensate for absent colleagues, and this could in turn result in lowered output quality (reduced output value). This is a more complex and nuanced approach than the simple industrial relationship, but offers a pathway to move forward in this domain that an overly simple metric does not offer. Furthermore,

organizations are now familiar with the use of multi-metric (or "balanced scorecard") approaches in other domains[1].

Figure 2. Schematic diagram illustrating some of the major contributors to the costs of running an organization, and their path via employee behaviour and well-being to the value of the organization's outputs.




Two important industry publications have appeared recently that map out an approach to valuing better buildings with respect to organizational productivity using multiple metrics. The CABA White Paper "Improving Organizational Productivity with Building Automation Systems" (Thompson, Veitch, & Newsham, 2014) proposed one such scorecard structure (Table 1). The focus of the white paper was on building automation systems (BAS), but the scorecard shown in Table 1 (and inspired by food nutrition labels) could be applied in whole or part to other building features or systems. Not all organizations would necessarily have access to all of these metrics, but consideration of many of them would advance this field.

Table 1. Proposed sample BAS-related organizational productivity label, showing example values, from the CABA White Paper (Thompson, et al., 2014).

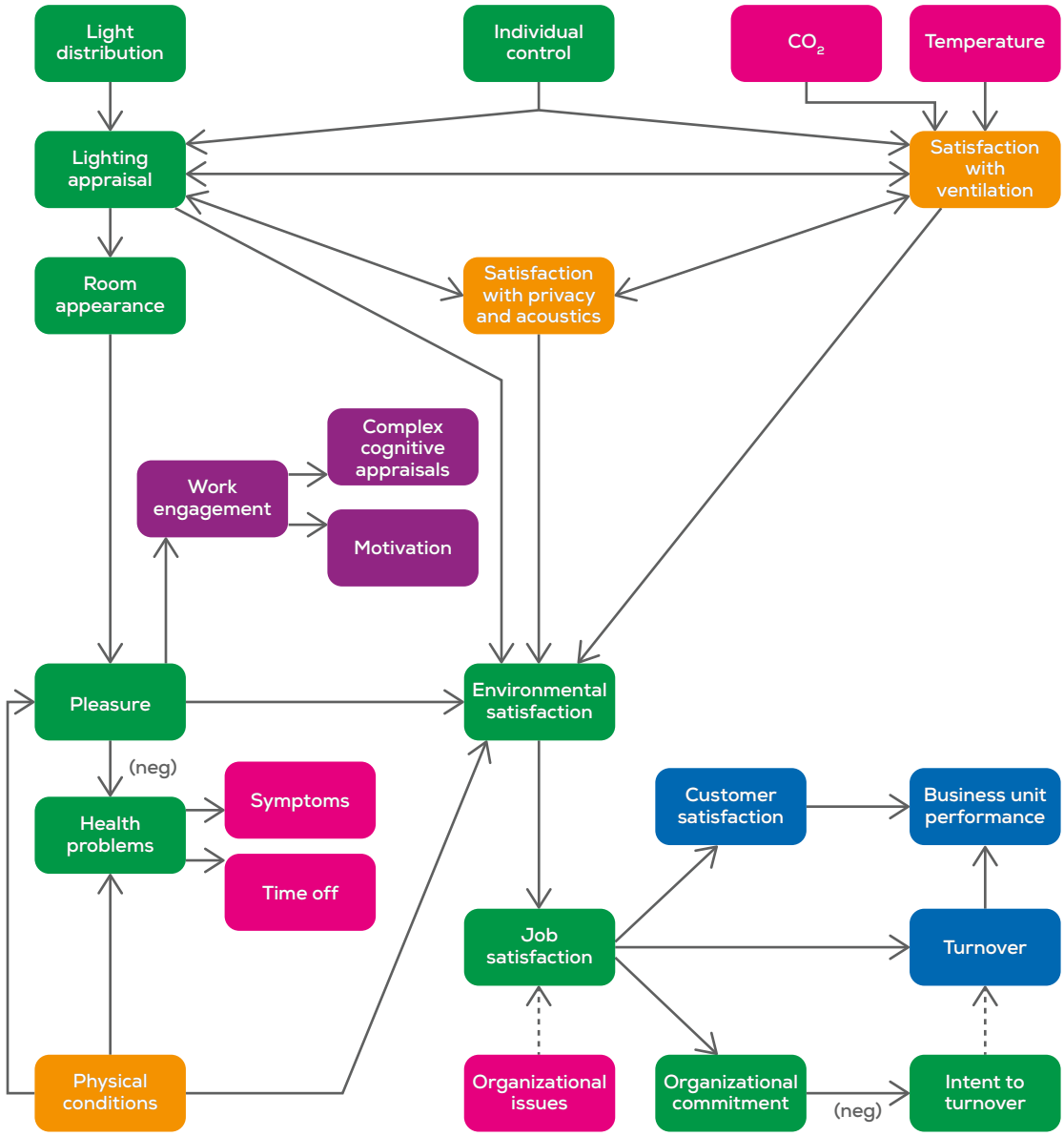
| **Building Organizational Productivity Label Per Building** | | | |
|---|---|---|---|
| Monthly Score | This Month | % of Our Target Value | Industry Norm |
| **Environmental Satisfaction** | **6** | **70%** | |
| Satisfaction with Lighting | 5 | | |
| Satisfaction with Ventilation & IAQ | 7 | | |
| | | | |
| **Job Satisfaction** | **3.5** | **50%** | |
| Linked to Organizational Issues | 3 | | |

| | | | |
|---|---|---|---|
| Linked to Environmental Satisfaction | 4 | | |
| | | | |
| **Health Ratings** | **7** | **55%** | |
| Health symptoms | 6 | | |
| Well-being | 7.5 | | |
| Mood | 6.5 | | |
| | | | |
| **Staff Commitment** | **4** | **50%** | |
| Organizational Commitment | 7 | | |
| Intent to Turnover | 1 | | |
| | | | |
| **Absenteeism (absence days per 100 employees)** | **10** | **10%** | |
| | | | |
| **Business Unit Performance** | **5** | **55%** | |
| Customer Satisfaction | 5 | | |
| Financial Outcomes | 5 | | |
| | | | |
| **Environmental Conditions** | **8** | **70%** | |
| Average particulate count (µg m-3) | 6 | | |
| Average ventilation rate (air changes per hour) | 6 | | |
| Light level range (lux) | 200-400 | | |
| Average articulation index | .5 | | |
| | | | |
| **Energy Use (kWhr/m2)** | **258** | **30%** | |
| Lighting | 65 | | |
| Heating, Cooling and Ventilation | 105 | | |
| Water | 15 | | |
| IT | 13 | | |
| Plug loads | 50 | | |
| Others | 10 | | |
| | | | |
| **Responsiveness** | **2.5** | **35%** | |
| Number of complaints (monthly) | 3 | | |
| Average response time (days) | 2 | | |

The choice of these metrics was not arbitrary. Those related to organizational productivity were derived from a conceptual model of the interplay of workplace environment elements, employee effects

and behaviours, and organizational outcomes established by a logical connecting of multiple studies addressing pieces of the model, as shown in Figure 3. No single study has ever measured this end-to-end network of variables and demonstrated their interaction, indeed, the CABA White Paper was a "call to action" and an enabler to this being done in future studies.

Figure 3. One possible detailed conceptual model showing how the physical environment created by a BAS system could affect job satisfaction and organizational productivity (Thompson et al., 2014).

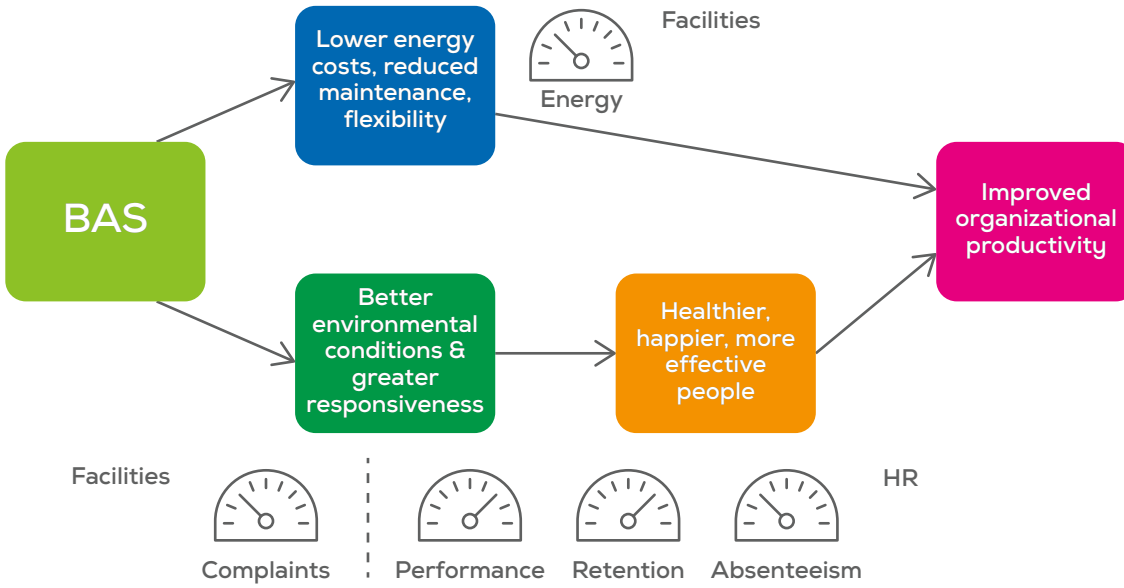



The World Green Building Council (WGBC), in their recent publication "Health, Wellbeing and Productivity in Offices: The Next Chapter for Green Building" (World Green Building Council (WGBC), 2014), provided an internationally-agreed framework for evaluating the effect of buildings on organizational productivity metrics. This report was developed by dozens of international experts and was motivated by a desire to support a business case for green building principles and certification beyond a simple payback on energy savings. The WGBC report also took a multi-metric approach in identifying

outcomes that could be positively affected by enhancements to the built environment, including: human resources (HR) outcomes, workplace perception, complaints to the facility manager (FM), and physical measures of the indoor environment[2].

Figure 4 illustrates the two main pathways by which a BAS can affect organizational productivity metrics. The upper pathway is via reducing energy costs; the lower pathway is the focus of this report, which is via improved workplace conditions that in turn support employee health, well-being, and ability to perform their tasks effectively[3]. A key insight from the WGBC report was the recognition that data on many of these important metrics already exist in an organization and are collected routinely (Figure 4). In other words, one does not necessarily have to engage in an expensive or invasive data collection campaign to explore the relationship between the built environment and organizational productivity in an organization. Rather, it may be a matter of securing permission to use existing data for this purpose, collating them, parsing them by building, and associating them with local building characteristics.

Figure 4. The two fundamental pathways by which BAS can improve organizational productivity, and the sources of data that might be used to demonstrate these pathways, and the holders of those data in typical organizations (Facilities or HR).




For example, HR databases might already hold data pertaining to staff retention/turnover, absenteeism, and other aspects of employee health and well-being. The HR departments in many organizations also conduct regular employee opinion surveys that contain data on job satisfaction and organizational commitment. The marketing departments in large organizations might conduct customer satisfaction surveys, and the finance department will likely have data on business unit performance. Many office building landlords regularly administer tenant satisfaction surveys that contain items related to environmental satisfaction. The facility management (FM) company (frequently a separate entity from the tenant and landlord) often maintains a database of complaints about the built environment registered by individuals, as well as the response time and cost. The FM might also keep historical records from the BAS, which will provide data on some physical indoor environment conditions, such as space temperature and RH, and zone-level $CO_2$ concentration.

Developing an appropriate method to valuing the effects of better building technologies and operations on organizational productivity clearly has great benefits in the marketplace, but is also a complex problem. NRC, with CABA, has proposed a phased approach to make meaningful progress, successively extracting greater value to CABA member organizations, while providing actionable outputs at each

phase. Three phases of increasing scope have been proposed, and this report represents the primary output from Phase 1. (See Table ES2)

The strategic goals of phased project are to:

- Demonstrate that intelligent building technologies and operations (within the broader context of "better buildings") produce organizational productivity gains (expressed via multiple metrics), in addition to energy savings.
- Demonstrate that these gains are realized via specific improvements in indoor environment conditions.
- Identify the specific technologies and operational improvements that are most likely to deliver benefits.
- Provide results in a format that allows organizations to assign a value to the full benefits of better buildings.

Table 2 shows the key elements related to each phase.

Table 2. Key elements of the proposed phased research approach to valuing the effects of better building technologies and operations on organizational productivity.

| Phase | Elements |
|---|---|
| 1 | Synthesis of existing published information<br>Establish productivity metrics: benchmarks, effects of better building technologies, effects of other corporate programs |
| 2 | Demonstrate metrics with new analysis of existing, comprehensive, multiple metric data, all from a real organization(s) |
| 3 | Establish physical mechanisms via the BAS and other intelligent building features and operations for effects with on-site measurements |

This Phase 1 report builds on well-established and published, peer-reviewed information from many disciplines characterizing work environments and quantifying organizational productivity metrics. In doing so, we demonstrate productivity gains via superior building technologies and practices (including via building automation systems (BAS)) through improvements in indoor environment and working conditions. Existing data and published information was gathered, synthesized, and used to develop outcomes on multiple organizational productivity metrics. We compared these gains to those demonstrated from other common corporate strategies (e.g., workplace health programs) because that will make clear their overall value to organizations.

The results provide an organizational productivity framework to enable decision-makers to benchmark their building on these metrics, and to value strategic investments in intelligent building technologies against other corporate strategies often deployed with the goal of positively affecting these same metrics. Demonstration of the net gains from investments in "better buildings" will enable organizations to include these in their return on investment (ROI) calculations, likely qualifying many more such investments than those that would occur from energy savings payback calculations alone. The stronger value proposition for "better buildings", including BAS, will assist technology vendors to innovate and grow and to better serve their clients among building operators/owners, and tenants.

The work described in this report was guided by a Steering Committee, formed by representatives of the project sponsors, CABA, and NRC. The role of this committee was to review and contribute to the project scope, to suggest content, and to ensure that the project outcomes would be valuable to their respective industries, and to building practitioners generally.

## Notes

1 See, for example, Kaplan and Norton (1992), who advocate for managers to focus on a handful of critical measures to improve business performance (which they likened to multiple dials in an aircraft cockpit), to avoid problems of sub-optimization based on a single measure. In a case study, they identified multiple metrics in four broad categories: How do customers see us? What must we excel at? Can we continue to improve and create value? How do we look to shareholders? These could be assessed in a variety of ways, including quantitative output or financial measures, or survey-based data, against context-specific goals.

2 Steelcase Applied Research & Consulting also used an explicit balanced scorecard approach specific to new work environments. This scorecard had four dimensions: financial measures, business processes, customer and stakeholder perceptions, and learning and sustainability issues. Some of these measures are reported in a case study at a large Peruvian bank: https://www.steelcase.com/insights/case-studies/banco-de-credito-del-peru-new-workplace-strategy.

3 A third pathway through real-estate costs is conceivable, but needs more evidence to establish. Analysis of data collected by the BAS, or more efficient space usage facilitated by enhanced BAS applications, might identify excess space inventory that could be reduced. It might also be possible to satisfactorily reduce space allocation per person if an advanced BAS delivered an environment that was superior in other and compensatory ways.

# 2. REVIEW AND ANALYSIS FRAMEWORK

## 2.1 ESTABLISHING VALUES

In this (Phase 1) study, in parallel with the multi-metric approach to measuring organizational productivity, we also take an alternative approach to valuing the effects of various strategies. Previous studies have often sought to evaluate the effects of better buildings (for example) with simple, universal monetary outcomes (dollars, euros, etc.), and have seen little uptake in the marketplace. We submit that (1) the multi-metric approach does not lend itself to a single monetary amount because not all metrics can be converted in a straightforward, meaningful or universal way into monetary units; and (2) the same metric, and increments of that metric, will have a different monetary value to different types of organizations at different places and times. Rather than providing simple monetary equivalents we propose to provide the information to organizations such that they can go through a monetization exercise themselves, should they wish to do so, using assumptions and multipliers that are unique to them and that would be unknown to NRC.

Another way to judge the utility of building investments to organizations is to compare their effects to other forms of investment that organizations might make. For that purpose, this project has also reviewed the literature on the effects of other corporate programs designed to deliver productivity effects. Again, the cost of implementing these other programs will vary from place to place, but the user of such information can weigh the cost of building technologies against these other programs, and judge their value given their likely relative benefits. We think that this approach will have more credibility and lead to more uptake.

As an example of point (2) above, consider a relatively straightforward metric of clear organizational value, absenteeism. Suppose we demonstrated that a particular building technology reduced absenteeism by one day per person per year. In a simplistic approach, this is often multiplied by a salary rate to provide an effect in dollars. But if we are referring to outgoing call centre workers, that lost day, at a relatively low salary, may be compounded by the business lost from successful sales calls. Alternatively, in an environment of highly-paid professionals, that lost day might be made up through additional, uncompensated work on an evening or weekend. Only a specific organization will know the salary rates and other contextual issues that attend to a day of absenteeism. This is entirely analogous to how energy savings of a particular technology are applied. We typically translate percent savings from one case study to another building, not dollar savings, because the cost of energy, and the base energy use, vary so much from place to place.

As a further way of quantifying value, one could look at other corporate programs to reduce absenteeism (for example). It may be true that a workplace health program can also be shown to reduce absenteeism by one day per person per year. The cost of implementing such a program, again, will vary from place to place, but the local decision-maker knows the costs for their particular organization, and can compare it to the cost of the building technology. In this (fictitious) example, one could say that installing this building technology was like giving everyone access to a workplace health program (with respect to absenteeism, at least!). In this respect, in the analogy to energy, it is like saying an energy program is like taking so many cars off the road. The positioning of such information in different units (cars, not

dollars, not kWh) can be more appealing to some decision-makers.

To extend the energy analogy further, we propose that the process should begin with benchmarking. If a building operator benchmarks their building's energy use against other similar buildings and observes underperformance, they obtain a signal that energy saving in their building is a reasonable priority, and is likely to be fruitful. Similarly, establishing suitable benchmarks for the proposed organizational productivity metrics will enable decision-makers to understand whether or not their own building's metrics are lower than desired. This might be expected to motivate them to look at options to improve these metrics, including better building options.

Tziner, Fein & Birati (2014) observed that well-being metrics[1] are – inappropriately – virtually absent from strategic decision making in organizations. They suggested that investments in programs designed to improve well-being should be weighed against other options for improving an organization's overall financial status, and provide a monetization framework for doing so. Although the framework is universal, the multiple inputs required are specific to each organization's unique evaluation of costs, benefits, and other financial multipliers. As such their approach may be a viable subsequent step to the approach we outline in this report.

## 2.2 SCOPE

We established the scope for this exercise in an iterative process, beginning with the CABA and WGBC reviews (Thompson, et al., 2014; World Green Building Council (WGBC), 2014), our knowledge of corporate strategies that might influence those KPIs, refinement through consultation with the Steering Committee, and subsequent shaping as the review progressed. The resulting scope is summarized in the table (referred to as the "Matrix" from now on), shown in Table 3. Rows in the table mark the chosen KPIs. For each metric (or key performance indicator (KPI)) of interest, a benchmark and normalized unit or scale of measurement has been established, where possible. Columns in the table show the corporate strategies selected for inclusion. The goal of this project was to derive estimates of the likely effects of each corporate strategy on each KPI, and to fill in the cells of the Matrix. The estimates were developed following an extensive literature review and qualitative analysis process, described below.

This approach, while conceptually appealing, has had some noteworthy challenges. First, the published studies that are required to fill out the Matrix are drawn from many different fields; this is a truly multidisciplinary problem, and one that has not been attempted before. The relevant publications come from the following fields: building science (engineering), psychology, business/management, public health, human factors and ergonomics. These are fields in which researchers do not often collaborate, and for which the methods and reporting formats can differ substantially. Thus, the net was cast very wide to capture as much relevant information as possible, and it was challenging to place heterogeneous studies on similar quantitative scales.

Further, even studies that ostensibly used the same metrics often measured them in different ways. For example, absenteeism differed in the types of absence included between studies; job satisfaction is typically measured using one or more survey items, and the wording of questions and reporting scales may differ between studies. We have made informed decisions and assumptions to evaluate and to rescale metrics into equivalent units.

Although the effects of different strategies may be presented in common units for a particular KPI, the mechanism by which that effect is manifest might be quite different. A private office might reduce absenteeism by limiting the airborne transport of pathogens from one employee to another, whereas a bonus might reduce absenteeism by eliciting greater enthusiasm for time on task, for example.

Table 3. The Matrix that provides a framework to compare multiple organizational productivity metrics across various corporate strategies. IV = independent variable; DV = dependent variable.

| | Strategies (IV) | Better Buildings | Office Type | Workplace Health Programs | Bonuses | Flexible Work Options |
|---|---|---|---|---|---|---|
| Benchmarks↓ | Metrics or KPIs (DV)↓ | | | | | |
| | Absenteeism | | | | | |
| | Employee Turnover (int.) | | | | | |
| | Self-assessed Performance | | | | | |
| | Job Satisfaction | | | | | |
| | Health & Well-being (symptoms) | | | | | |
| | Health & Well-being (overall) | | | | | |
| | Complaints to FM | | | | | |

To keep this potentially enormous task manageable given the time and resources available to us, we have made decisions to limit the scope of studies considered to be valid and relevant to our purpose. These decisions were made with some foreknowledge of what was likely to be available in the literature, and with the input of the Steering Committee:

- **Geographic**: focus on studies from North America, Europe, and Australia/New Zealand. These regions are relevant to the business interests of the project partners, and are also the regions in which appropriate studies are most likely to have been conducted, given historical trends. Publications are also available in English, facilitating accessibility by the research team. Nevertheless, relevant work from China, India or other important emerging markets was considered.
- **Building Types**: focus on large office, or "office-like" buildings. The primary interest of the research partners is in BAS, which are typically only applied in large commercial buildings. Further, the emphasis of prior relevant work has typically been in office buildings.
- **Study Types**: focus on studies conducted in real organizations. Although many lab studies have been conducted on various aspects of the built environment, the translation of the outcome measures used to real-world productivity effects, and the exposure times to conditions, mean that results have very limited applicability. Further, many of the measures we are interested in; e.g., absenteeism or job satisfaction, have no meaningful application in the artificial environment of a lab. In the hierarchy of studies designed to affect the real world, lab studies are very useful for identifying potential approaches which should then be proven in real-world settings.
- **Time**: focus on publications relevant to contemporary office design and work. This typically means publications reporting work conducted after the year 2000, but earlier work was considered if it was particularly germane, at least for context or supporting information.
- **Source Types**: focus on formal statistical databases for benchmarks, and peer-reviewed publications (journals, conferences) for estimating the size of effects. Nevertheless, studies from the so-called "grey" literature (e.g. industry reports, working papers) were considered

if the study quality was judged to be adequate. Popular media sources were not used in themselves (they were used as pointers to primary sources) as their findings are often abstracted out of context, or are based on anecdote rather than sound science.

- **Definitions of KPIs and corporate strategies**: Derive clear definitions for the rows and columns of the Matrix, to ensure comparability. These definitions are provided in the subsequent sections.

## 2.3 DEFINITION OF KPIS

Our choice of metrics was guided by those highlighted as important and potentially accessible by the CABA and WGBC reports, and was confirmed by the project Steering Committee. An overarching guide was to express benchmarks and effects in common units that are easily interpretable and comparable by practitioners. Furthermore, outcomes which might be derived using different scales, should be rescaled to a common scale to improve interpretation; following the suggestion in the CABA White Paper, we chose to normalize to a 0-100 scale.

### 2.3.1 Absenteeism

**Unit: Days/person/year**

This is the unit most frequently referred to in discussion of absenteeism (implicitly referenced to full-time employees), and is broadly understood and interpretable. It is also a unit of data collection common to both national databases and relevant research studies, and (from our experience) in HR databases. Sometimes the increment of measurement is the single day, and sometimes measurement is in categories (e.g., 1-3 days, 4-6 days, etc.). A challenge is understanding what types of absence are included in each data source. Ideally, we would have preferred to focus on short-term sick leave that an employee takes for their own illness, and following their own assessment of their health. This type of absence seems most likely to be attributable to the office environment[2].

### 2.3.2 Employee Turnover

**Unit: 0-100 scale (likelihood to look for another job)**

Our focus was on data assessing whether someone leaves their job voluntarily, again because the office environment might conceivably contribute to such a decision (American Society of Interior Designers (ASID), 1999). This is the inverse of employee retention, which organizations are commonly seeking to enhance. Management-initiated layoffs due to prevailing economic conditions would be unaffected by building quality or other strategies in the Matrix.

We considered two ways to measure employee turnover:

1. **Turnover rate**. This is the measure typically available in national statistical databases and industry surveys. This records how many people left their jobs in a given month or year and is often expressed as a percentage of total employment. Such "voluntary turnover" is also sometimes referred to as "quitting". However, few studies of the effects of strategies, particularly in the better buildings domain, have this as an outcome. This is partly because of the confidentiality of such data, and the fact that most studies do not encompass a timeframe over which meaningful levels of turnover occur at study sites.
2. **Turnover intent**. Intent to look for another job is more frequently used as a survey question in cross-sectional research studies and social surveys. Questions in different surveys are worded differently, as are the response scales. A typical question might read, "How likely is it that you will make a genuine effort to find a new job with another employer within the next year?" A typical response scale might have seven distinct categories (Likert scale), with end labels "Extremely Unlikely" to "Extremely Likely". The issues described above regarding

converting such data into a common 0-100 (implicitly rational) scale apply here. It is not typically known whether the desire to look for a new job is driven purely by the individual's preference or the foreknowledge of a need to look for a new job (e.g., layoffs are expected). Note that an organizational average of 25 on this scale would mean that, on average, employees say they are "somewhat unlikely" to be looking for another job, not that 25 percent of employees are actively looking for a new job.

Despite its limitations, the more common availability of turnover intent data over actual turnover in the relevant literature led us to choose it as our measure. We normalized reported values to a common 0-100 scale.

### 2.3.3 Self-assessed Performance

**Unit: 0-100 scale**

Of all the metrics, measures of the job performance are perhaps the most problematic. For many people, what immediately comes to mind is the task performance of individuals[3]. Measures of task performance are not often available in the public domain for studies of real workplaces. In our initial review of the literature we did look for possibilities, in cases where unit tasks were easily counted; e.g., call center metrics. We were also aware of at least one study that administered a battery of standard tasks over a short time period in employees' actual workplace. However, these studies were not usable in our context, and the generalizability of the results was questionable.

Nevertheless, we were aware of several studies, including our own work, in which employees of real organizations had been asked to self-assess their own productivity[4]. This approach has been used by several researchers in the better buildings field, but has also been used by other researchers. There is some debate as to its interpretation. A typical question phrasing by buildings researchers might be, "Please estimate how you think your personal productivity at work is increased or decreased by the physical environmental conditions", with a seven-point response scale from -30 percent to +30 percent. In NRC's interpretation, this is unlikely to be a reliable measure of an employee's actual material output in percentage terms, and is more a measure of environmental satisfaction in the sense of how the indoor environment supports the employee's ability to do their job. It does have the advantage of being broadly accepted and easily rescaled. Therefore, we used this as the metric of self-assessed performance in the present review, normalizing reported values to a common 0-100 scale.

### 2.3.4 Job Satisfaction

**Unit: 0-100 scale**

This concept has been addressed in many industry/social surveys and research studies via questionnaire. Indeed, job satisfaction has been posited as the antecedent to many other workplace behaviours that affect an organization's productivity. To quote Roznowski and Hulin (1992, p. 158): "... job satisfaction (scores) are the most useful information organizational psychologists or organizational managers could have . . . in predicting a variety of behaviours of organizational members." For example, people who are happier with their job are more likely to go out of their way to help colleagues and "talk up" the organization (e.g., Podsakoff, MacKenzie, Paine, & Bachrach, 2000), are less likely to want to leave the organization (e.g., Griffeth, Hom, & Gaertner, 2000), and are more likely to have positive outcomes with customers (e.g., Harter, Schmidt, & Hayes, 2002). Many different question wordings (and single items or averages of multiple items) and scales have used. An example single-item scale is, "Taking everything into consideration, what is your degree of satisfaction with your job as a whole?" rated on a seven-point scale from "Very Unsatisfactory" to "Very Satisfactory". We used judgement to interpret the equivalence of different question formats. Where we believed that equivalence existed, we normalized the data from each study to a common 0-100 scale.

### 2.3.5 Health and Well-being (symptoms)

**Unit: 0-100 scale**

In the buildings research domain, the prominence of Sick Building Syndrome (SBS) in the 1980s led to the relatively frequent use of surveys to assess associated symptoms. These symptoms included dry eyes, runny nose, back pain, etc., and surveys sought to isolate symptoms that occurred in the workplace, but receded when the employee went home. Survey methods included asking about frequency or intensity, or both, and these survey items prevailed in some studies after the SBS phenomenon subsided. Again, it was a challenge to interpret the equivalence of these different question formats and to re-scale the results from individual studies to a common scale.

### 2.3.6 Health and Well-being (overall)

**Unit: 0-100 scale**

Surveys are often used to determine an individual's general state of health or well-being. These have included both national and international social surveys, and individual research studies. In the context of our own work, to focus on the aspects more likely to be directly affected by the building, and to parallel the SBS symptom metric, we chose to focus more on general physical health rather than general mental health. These data were also normalized from the scales reported to a common 0-100 scale.

### 2.3.7 Complaints to Facility Manager

**Unit: complaints/person/year**

These data are routinely collected by the building managers in most large office buildings. Large building management companies (to which this function is often contracted out) typically have phone, web or other mechanisms to report complaints, which then are prioritized, and from which work orders are created. Complaints are typically related to unsatisfactory temperature, air quality issues, cleanliness, lamps burned out, etc. This is a ready source of data which could be used to evaluate the success of better buildings, if not other, strategies. Our intent was to calculate a rate of complaints that was normalized to the building population (complaints/person/year). However, we were unable to find any usable studies in the public domain that leveraged this metric. We will return to this topic in the research gaps discussion below.

## 2.4 DEFINITION OF CORPORATE STRATEGIES

The goal of the project was to compare the effects of building improvements ("better buildings") to the effects of other corporate strategies. Of the many options available, we chose to focus on strategies that we believed would be familiar to a building manager (e.g., bonuses) or strategies that might be implemented by, or with the participation of, the building manager themselves (e.g., office type, flexible work options).

The strategies shown in Table 3 are categorical and each could encompass numerous specific actions. For example "better buildings" might include: advanced BAS, enhanced ventilation, advanced lighting control and design, green building certification, alternative FM practices; "Workplace Health Programs" might include: general health check-ups and counselling, smoking cessation aid, diet and weight loss assistance, vaccination subsidies, mental health services, and so on. After searching more broadly, the resulting studies and available information provided guidance on how to narrow each of these strategies to actions that had meaningful data and would be relevant to a building practitioner.

### 2.4.1 Better Buildings

Although the focus of the project (in the title) is on BAS, studies that have looked at the BAS specifically; i.e., comparing outcomes from buildings with an advanced BAS versus buildings without one, proved to be non-existent. Thus, we broadened our outlook to studies that addressed elements associated with a typical BAS in the larger sense (e.g., ventilation enhancement, advanced lighting controls),

or whole-building approaches that would typically include a BAS upgrade or improvements to BAS elements (e.g., green buildings). For each study, the base building will have been different, and details will be provided in the narrative. Although the Matrix may aggregate these studies into an effect range, the associated narrative will give information about the specific measures, where available. This is the strategy that is of greatest interest to the project audience, and therefore the one that will receive a greater focus in this report.

### 2.4.2 Office Type

Although we had initially planned to examine various forms of ergonomic interventions (e.g., novel furniture types; chairs; equipment) and office layouts, this proved to be too heterogeneous for the purpose of this review. Instead, we chose to focus on a simple accommodation option: the comparison of private offices versus open-plan (and not the differences between different types of open-plan). This is a scenario that has been studied relatively frequently, as it is an office design option faced by a very large number of organizations over recent decades. The transition has typically been in one direction, with the fraction of private offices decreasing; by 2010, only around one-third of staff in commercial and institutional buildings in the US and Canada were still housed in private offices (International Facility Management Association (IFMA), 2010), and in a predominantly European sample of 100,000 office workers only eight percent had private offices (Leesman Ltd., 2016). The justification for this transition has typically been the expectation that it will bring increased flexibility, transparency, and enhanced communication between team members, although the underlying economic driver has been real estate-cost savings. It is a strategy that is very familiar to this report's audience, and thus serves as an excellent touchstone against which to compare other strategies.

### 2.4.3 Workplace Health Programs (WHP)

WHPs often form part of the benefits package in large organizations, with the general belief that this investment will support employee well-being, which in turn will benefit the organization's productivity[5]. WHPs tend to be offered as packages of measures designed to promote good health; e.g., health counselling, gym access, nutrition programs, stress management, physical tests (e.g., blood pressure), often in a menu from which the employee can choose as they see fit. Studies in this domain often do not track actual participation, or divide out the effect of a specific measure, but look at overall effects pre-post implementation; "Does the existence of the program itself have an effect?", rather than "Does participation benefit individuals?", or "Do the contents of a specific measure have an effect?" Each WHP studied had a different combination of measures, and we have aggregated the effects of these in the Matrix cell. Again, we provide summary details of the individual studies in the narrative.

### 2.4.4 Bonuses

It is a common belief that financial incentives offered to individuals will elicit employee behaviours and perceptions that will benefit organizational productivity. This belief is not always supported for more complex tasks[6], and even positive effects of financial bonuses are sometimes transitory and require continuous investment at the same level to maintain benefits, unlike effects associated with building improvements, which typically have a higher upfront cost with persistence based on lower-cost ongoing maintenance. In this report we focus on bonuses provided for general job performance, typically evaluated by a manager, rather than bonuses for a specific behaviour. For example, an attendance bonus might be expected to lower absenteeism, but have no broader effects.

### 2.4.5 Flexible Work Options

This category may contain a variety of options. Studies have typically looked at a package of options, and, as with WHP, results have often been referenced to the existence of the package, rather than actual participation. This category can include flexibility in scheduling working hours to be conducted in the organization's own building, the availability of multiple workplace locations within the building, or the

ability to telework (at least part-time, and from home or from other off-site locations). The latter option is particularly interesting, as it relates more to the physical accommodation choices that are highlighted in some of the other strategies, and is more relevant to the audience of this report.

## 2.5 LITERATURE SEARCH STRATEGY

The Matrix encompasses several disciplines and areas of inquiry, from business, medicine, and psychology, to engineering and facilities management, which necessitated including several databases in the literature search. Individual searches were conducted for each cell in the Matrix, although it became evident over time that many individual papers had information relevant to more than one cell. The databases searched for the main body of the Matrix were:

- Scopus
- PsycInfo
- Google Scholar
- APA Center for Organizational Excellence: Articles & Research Abstracts
- Conference Board of Canada

In addition, for the benchmarks, we also searched the following databases:

- General Social Survey, University of Chicago
- US Dept. of Labour, Labour Statistics
- Statistics Canada
- Nobscott Statistics
- National Institute for Occupational Safety and Health, Centre for Disease Control and Prevention
- Organization for Economic Co-operation and Development
- Gallup (Work and Workplace tables)
- General Social Survey, 2012, National Archive of Data on Art and Culture

Table 4 shows the list of search terms. Searches encompassed the title, keywords, and abstracts of database entries. In addition, the authors searched their personal databases for relevant articles, including NRC reports.

Table 4. List of search terms used for corporate strategies and KPIs. The terms are expressed in standard database search format. * = wildcard character, meaning it can be replaced by any character or string of characters (e.g., control* = control, controls, controller, controlling, etc). w/1 separating two words in the search term will find articles where these two words appear within one word of each other in a publication; w/2 within two words of each other, etc.

| Corporate Strategies | KPIs |
|---|---|
| **Better buildings**<br>• green buildings<br>• LEED<br>• healthy buildings<br>• building w/ automation<br>• thermal w/ comfort<br>• personal w/ control*<br>• individual w/ control*<br>• green w/ building*<br>• humidity*<br>• lighting<br>• IEQ / IAQ / ventilation/ HVAC<br>• indoor w/ air<br>• indoor w/ environmental<br>• daylight* | **Absenteeism**<br>• attendance<br>• "sick leave"<br>• leave<br>• absence*<br>• illness or sickness |
| **Ergonomic Improvements**<br>**ergonomic**<br>• standing desk*<br>• human W/1 factor* W/1 design*<br>• workstation* OR "work station*<br>• musculoskeletal W/1 prevention<br>• office w/ layout<br>• office w/ design*<br>• Bonuses | **Facility Complaints**<br>• complaints w/3 (building* or manager or operations or )<br>• building operations<br>• complaints or crowding or noise or discomfort or grievance |
| **bonus* / remuneration**<br>• economic w/2 incentive*<br>• monetary w/2 incentive*<br>• financial w/2 incentive*<br>  ◦ rewards<br>  ◦ merit<br>  ◦ contingent pay<br>• Flexible work options | **Employee Turnover**<br>• retention<br>• turnover<br>• voluntary<br>• retire<br>• resignation |
| **Work from home**<br>• flexible W/2 work<br>• flexible W/2 hours<br>• flexible W/2 schedule*<br>• flexible W/2 time / flexi-time / flextime<br>• telecommuting<br>• job sharing<br>• workplace Health Programs or Fitness Options | **Satisfaction**<br>• productivity or efficiency<br>• satisfaction<br>• fulfilment<br>• self-realize or self-actualize |

| Corporate Strategies | KPIs |
|---|---|
| **Workplace Health Programs**<br>• fitness<br>• stairway / steps / stairs / step challenge<br>• walkability or walks or pedometers or walking<br>• activity breaks or physical activity or physical fitness<br>• gyms / gymnasium / fitness facilities / onsite fitness<br>• transit options, bike-sharing<br>• yoga or sports or running or biking or skiing<br>• biking or cycling or transit options<br>• stretch breaks<br>• lockers, showers, bike racks<br>• reimbursement or incentives for gym membership<br>• discounted gym memberships<br>• health food / nutrition healthsmart, garden market<br>• diet, weight control / weight W/2 program*<br>• paramedical services – massage<br>• stress management<br>• workplace intervention<br>• mental fitness activities mental health<br>• programs – weight control / smoking / alcohol<br>• stress reduction<br>• lactation support program<br>• smoking cessation<br>• screening days – breast cancer, prostate, etc.<br>• The National Work Life Program – mental health support / screening<br>• UV prevention or UV screening | **Health**<br>• well-being<br>• health<br>• wellness<br>• symptoms<br>• sick building syndrome, SBS<br><br>**Individual Performance**<br>• productivity<br>• cognitive performance<br>• work/job/task performance |

Table 5 displays a rough estimate of the number of publications we reviewed in deriving our results. Our initial focus was on finding reviews, meta-analyses, or summaries that would be relevant in each cell in the Matrix. In other words, another respected researcher or team would have already found the relevant papers and reviewed them to deliver a reliable estimate of the overall effect derived from multiple studies. Such a literature review is the common starting point for research in any domain. This would have saved effort in tracking down and reviewing many more primary studies, but also would have added to the confidence in the result because it would have been based also on the work of others and the peer review of that work.

We chose the effect of Workplace Health Programs on Absenteeism as the first cell in the Matrix to explore, as we were confident of finding good, relevant studies, and were rewarded with several potential meta-analyses, one of which we used directly in the Matrix. However, our hope that this strategy would work for other cells in the Matrix was unfounded, and we resorted to reviewing many more primary studies.

Table 5. The number of publications considered as source material for the Matrix. The upper number in each cell is an estimate of the number of abstracts obtained from keyword searches. If the abstracts looked promising, we obtained the full publication and reviewed its entire contents for relevance. The lower number in each cell is an estimate of the number of full papers that were examined.

| | Better Buildings (BB) | Office Type (OL) | Workplace Health Programs (WHP) | Bonuses (Bon) | Flexible Work Options (FWO) |
|---|---|---|---|---|---|
| Absenteeism (Abs) | Title/abstract: ~250<br>Full/part text:~30 | ~200<br>~30 | ~70<br>~35 | 646<br>~20 | 145<br>~10 |
| Employee Turnover (Ret) | ~200<br>~15 | ~150<br>~20 | ~/190<br>~15 | ~10<br>~10 | ~50<br>~10 |
| Preceived Performance (PP) | ~200<br>~45 | ~150<br>~26 | ~140<br>~20 | ~120<br>~34 | ~100<br>~17 |
| Job Satisfaction (JS) | ~200<br>~25 | ~160<br>~32 | ~/70<br>~25 | ~490<br>~16 | ~50<br>~10 |
| Health | ~200<br>~35 | ~150<br>~22 | ~140<br>~30 | ~100<br>~10 | ~20<br>~10 |
| Facility Complaints (FC) | ~100<br>~20 | – | – | – | – |

## Notes

1 Here they mean concepts of the kind that feature in the multi-metric scorecard in Table 1, and an example they used in their paper is employee turnover.

2 Some studies do also suggest a relationship between an unfavourable physical workplace environment and some types of longer-term sick leave via fatigue and stress mechanisms e.g., (Bakker & Demerouti, 2007; Kant et al., 2003).

3 In fact, in less nuanced approaches, individual task performance has often been considered to be synonymous with productivity. We contend that this is incorrect, oversimplistic, and places too much emphasis on people as mechanistic elements in organizations. In very few modern, office-based organizations does the throughput of an individual scale directly and proportionally to the financial performance of their organization.

4 Another option might have been manager-assessed performance, but while this is commonly reported as part of employee performance reviews in organizations, it is rarely available in studies related to any of the strategies we examined.

5 This is skewed in some US workplaces. In the US, most employees receive health care coverage through their employer, and some organizations link employee premium contributions to participation in, or even demonstrated success from, WHPs. Thus, there may be a financial penalty to the employee of not participating, which changes the incentive structure associated with the program, and which could be expected to bias the demonstrated results.

6 See, http://www.ted.com/talks/dan_pink_on_motivation#t-704515

# 3. RESULTS AND DISCUSSION

Table 6 presents the Matrix summarizing the results of our review and synthesis of the literature. Numbers in the Matrix are supplemented below by a narrative section on each KPI, describing the benchmark and effects of various strategies, detailing the study or studies used to derive the number in each cell of the Matrix. The narrative also includes other reference material that supports the findings, but which was not used in the Matrix number for a variety of reasons including age, relevance, and reporting format.

The number in the cell represents the preponderance of available information, and is based on our judgement (i.e., it is not the result of a quantitative meta-analysis). We present a range if several studies contributed a variety of results. That range might start at zero if several studies found no effect and several found consistent effects. Generally, we present an arrow representing the direction of the effect. Where we are not able to derive a number (primarily because the results are not reported in a way compatible with the scale we have chosen) we present an arrow consistent with the direction of an effect. Empty cells denote combinations of corporate strategies and KPIs for which we found no relevant studies on which to base a conclusion. The discussion below is categorized by matrix row to highlight the comparison of the effects of the various corporate strategies.

The effects of strategies shown in the Matrix are simple main effects, based on a single factor. These are easy to interpret, but there are likely to be indirect effects as well. For example, if a strategy improves job satisfaction, there would likely be a consequent reduction in employee turnover, even if there are no studies for that strategy directly evaluating retention effects (see Figure 3, for example).

Table 6. The final Matrix showing the benchmarks associated with each metric, and the effects of various corporate programs. The benchmark has a purple background if it was derived from national/international statistical surveys, and no background if it was derived from targeted research studies or theory. The arrow in each cell indicates the direction of the effect. The number in cell indicates the size of the effect (in the same units as the benchmark); this is often a range covering effects from multiple studies. An arrow without a number indicates that the direction of the effect is established, but a size was not derivable (in our preferred terms) from the published studies. The better buildings strategies column label is highlighted as these effects are the primary interest of the project.

| | Strategies (IV)→ | Better Buildings | Office Type | Workplace Health Programs | Bonuses | Fexible Work Options | |
|---|---|---|---|---|---|---|---|
| Benchmarks | Metrics or KPIs (CV) | | | | | | Unit |
| 2-15 | Absenteesim | ↓0.4-1.5 | ↓3.2 | ↓0-1.8 | ↓1.0 | | day/per/yr |
| 18-30 | Employee Turnover (int.) | ↓1.3 | ↓18 | 0 | ↓ | | 0-100 |
| 0 | Self-assessed Performance | ↑2-10 | ↑8-15 | ↑0-10 | ↑ | | % |
| 60-80 | Job Satisfaction | ↑4-9 | ↑5-10 | ↑0-12 | | ↑0-10 | 0-100 |
| 30-60 | Health & Well-being (symptoms) | ↓5-9 | ↓ | | | | 0-100 |
| 55-75 | Health & Well-being (overall) | ↑6-10 | ↑11-12 | 0 | | 6 | 0-100 |
| | Complaints to FM | | | | | | |

Some of the individual studies described below appear in more than one section; that is they had outcomes relevant to more than one KPI. In these cases, and to avoid excessive repetition, we describe the study in more detail the first time it is cited, in subsequent citations we provide additional information related to the relevant KPI only.

## 3.1 ABSENTEEISM

**Absenteeism: Benchmarks**
**2 – 15 days/person/year**

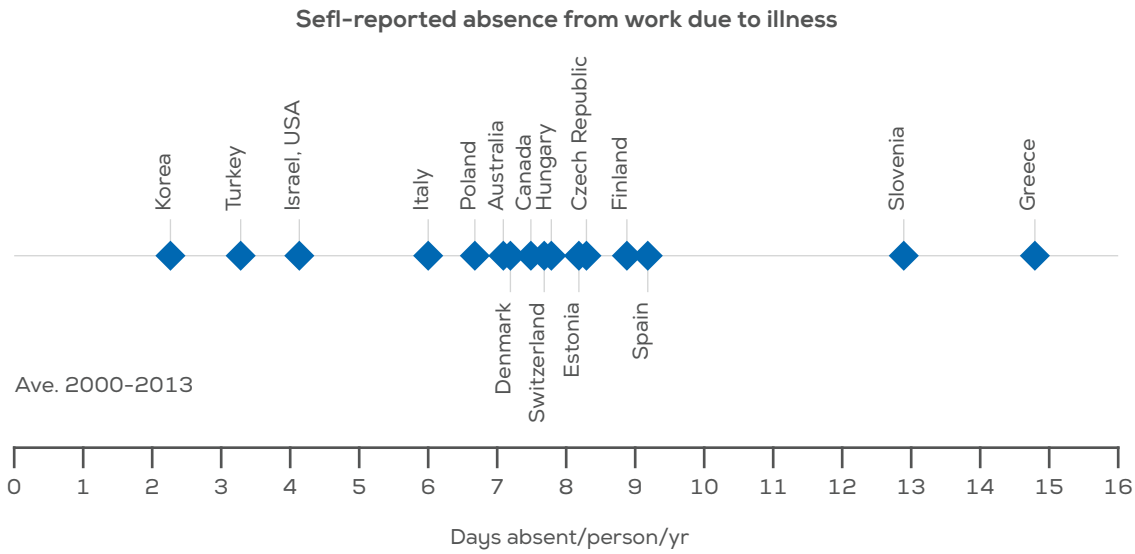
Abundant absenteeism data are available from national statistical databases. These data generally refer to sickness absence rates of employees, but there are differences in how each country's data are compiled. This can make comparisons between countries challenging. For some given countries, data are also available by industry, and over time. The Organization for Economic Co-operation and Development (OECD) notes that data from self-reports in household surveys and data from insurance sources

are not directly comparable, and reports them separately. We present self-report data here (where that option is available), as it is more directly comparable to the data from scientific studies of the effects of strategies, which also typically employ self-report via questionnaires. We provide salient examples of benchmark data in this section, with further examples in Appendix A.

For example the OECD (http://www.oecd.org/health/health-data.htm, click on "Definitions, Sources and Methods", "Self-reported absence from work due to illness") details some of the differences in collection methods between countries, which include: sampling frames, differences in the period of recall, and categories of response. These data typically include long- as well as short-term absence, and may capture long-term absence reports because such surveys are usually administered in the home. Research studies that are administered at work may miss those employees on long-term illness leave, and therefore may bias average absence downward.

Figure 5 shows OECD data, which is our best source of country-to-country comparison (http://stats.oecd.org/index.aspx?DataSetCode=HEALTH_STAT). The data show a wide range of values between countries, although there is a clustering between 6-9 days/person/year. Some of this variation may be due to methodology, as described above, though other differences due to culture, health care provision, employment contract norms (including provision for paid sick leave) may be expected. Also shown is the variation over time for a specific example country, the USA; the year-to-year variation was relatively small.

Figure 5. (upper) Absenteeism data from multiple OECD countries; if a country has data for more than one year the value shown is the mean over those years. (lower) Annual absenteeism data for the US.




| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USA | 5.0 | 4.6 | 4.4 | 4.1 | 3.9 | 4.3 | 4.1 | 4.0 | 4.4 | 3.6 | 3.8 | 3.7 | 3.7 | 3.8 | **4.1** |

For some countries, data are available by industry type; Figure 6 shows such data for one example country, Canada (http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=2790030&&pattern=&stByVal=1&p1=1&p2=38&tabMode=dataTable&csid=), derived from the Canadian Labour Force Survey. It is clear that there is a range of absenteeism by broad industry type. Public sector absences are higher, as is commonly observed, which may be due to better sick leave compensation, as well as more exposure to potential sources of illness (e.g., health care workers, teachers).

Figure 6. Absenteeism data for Canada, by major industry.

| Canada by Industry (2015) | Illness or disability (days/pers/yr) |
|---|---|
| Professional, scientific and tech services | 3.5 |
| Real estate and rental and leasing | 4.8 |
| Finance and insurance | 6.6 |
| Business, building and support services | 7.5 |
| Public administration | 10.7 |

NRC's own field studies related to office design and green building effects have asked office workers to self-report absences from work due to their own illness, and these may be extrapolated to annual values for comparison. NRC's Post-Occupancy Evaluation of Green Buildings (Green POE) project collected survey and physical data from 24 office buildings from across Canada and the Northern USA (Newsham et al., 2013). These were 12 "green" and 12 matched conventional buildings; most buildings were in the public sector, but four private sector buildings were also included. One module of this survey asked "During the past month, how many work days did you miss because you personally were ill?"; the mean response over all buildings was 0.59 (N=782). The extrapolated annual value is 7.1 days/pers/yr, which appears to be consistent with the national database information.

**Absenteeism: Effect of Better Buildings**
**0.4 – 1.5 days/person/year**

Milton, Glencross, and Walters (2000) examined the effect of outdoor air supply rate on the short-term sick leave of >600 clerical office workers in several buildings at a large manufacturer in the US. Absence was recorded in the corporate timecard system. A higher outdoor air supply rate (~50 cfm/person, 24 l/s/pers) was associated with 1.2-1.9 days/pers/yr lower sick leave, compared to a lower outdoor air rate (~25 cfm/p, 12 l/s/p). Note that the overall absenteeism rate was ~4 days/pers/yr, which is similar to the national average for the USA shown in Figure 5. Current ASHRAE minimum recommended outdoor air rate is 18 cfm/p, 8.5 l/s/pers. The authors note that this was an effect similar in size to giving a flu vaccination to the healthy working population.

Niemela, Seppanen, Korhonen, and Reijula (2006) reported an air quality intervention in an insurance company in Finland. The number of employees studied over a two-year period was 43-45, and absences were recorded by the host company's occupational health system. Specifically, the intervention was cleaning the ventilation system, replacement of duct lining, and air flow balancing. The authors report a reduction in short-term absenteeism equivalent to 0.65 days/pers/yr, associated with a reduction in reported health symptoms (although no statistical tests were reported). Note that the pre-intervention absenteeism rate was 2.4 days/pers/yr, which is very low compared to the national average for Finland shown in Figure 5 (although data in Appendix A suggests that the private-sector financial services industry tends to have lower absenteeism rates than national averages). The authors conducted a comprehensive literature review supporting the expected correlations between higher IAQ symptoms and increased absenteeism/reduced task performance.

Veitch, Newsham, Mancini and Arsenault (2010) studied a lighting and office furniture retrofit in large office buildings in Canada. One comparison in the study looked at new direct-indirect electric lighting with personal dimming control allied with new office furniture (lower, lighter-coloured panels defining cubicles) compared to the pre-existing electric lighting of direct parabolic luminaires with older office furniture (higher, darker-coloured panels). Overall, data were obtained from >1,000 occupants. The new lighting/furniture was associated with a reduction in self-reported absenteeism due to personal illness of 0.4 days/pers/yr. Note that the pre-intervention absenteeism rate was 3 days/pers/yr, which is very low compared to the national average for Canada shown in Figure 5.

Singh, Syal, Korkmaz, and Grady (2011) studied absenteeism effects associated with US office workers moving from conventional buildings to green (LEED certified) buildings in the US (N=56 and 207). Table 7 shows the LEED credits received in the two study buildings. Statistically-significant, though small improvements post-move were demonstrated, but they were specific to employees with specific medical conditions (e.g., asthma, respiratory allergies). Given that our Matrix is designed to address the general population, we do not reference this study's quantitative results here.

Table 7. LEED credits received by study buildings in Singh (Singh, et al., 2011) (reproduction of their Table 2).

| Credit number | Credit description | Building 1: pursued LEED-CI 2.0 and CS 2.0 (Platinum) | Building 2: pursued LEED-NC 2.1 (Gold) |
|---|---|---|---|
| Prereq. 1 | Minimum IEQ performance | Y | Y |
| Prereq. 2 | Environmental tobacco smoke (ETS) control | Y | Y |
| Credit 1 | Outdoor air delivery monitoring | Y | Y* |
| Credit 2 | Increased ventilation | Y | Y* |
| Credit 3.1 | Construction IAQ management plan; during construction | Y | Y |
| Credit 3.2 | Construction IAQ management plan; before occupancy | N | Y |
| Credit 4.1 | Low-emitting materials: Adhesives and sealants | Y | Y |
| Credit 4.2 | Low-emitting materials: Paints and coatings | Y | Y |
| Credit 4.3 | Low-emitting materials: Carpet systems | Y | Y |
| Credit 4.4 | Low-emitting materials: Composite wood and agrifiber products | Y | N |
| Credit 4.5 | Low emitting materials: Systems furniture and seating | Y | NA |
| Credit 5 | Indoor chemical and pollutant source control | Y | Y |
| Credit 6.1 | Controllability of systems: Lighting | Y | Y* |
| Credit 6.2 | Controllability of systems: Temperature and ventilation | Y | Y* |
| Credit 7.1 | Thermal comfort: Compliance | Y | N |
| Credit 7.2 | Thermal comfort: Monitoring | Y | N |
| Credit 8.1 | Daylight and views: Daylight 75% of spaces | Y | Y |
| Credit 8.2 | Daylight and views: Daylight 90% of spaces | Y | NA |
| Credit 8.3 | Daylight and views: Views for 90% of seated spaces | Y | N |

Y = credit attained; Y* = similar credit attained; N = not attained; NA = credit not available for LEED rating system pursued.

**Absenteeism: Effect of Office Type**
**↓3.2 days/person/year**

Pejtersen, Feveile, Christensen, and Burr (2011) analyzed survey data from 2,403 office employees in Denmark, including self-reported sick leave. After adjusting for potential confounding personal characteristics, they demonstrated that private offices were associated with 3.2 days/pers/yr lower sick leave compared to open-plan offices with more than six occupants (any office with more than one occupant was associated with higher sick leave). Note that the overall absenteeism rate was 7.1 days/pers/yr, which is very similar to the national average for Denmark shown in Figure 5. The authors discussed several possible mechanisms for the increased sick leave in shared offices, including: stress from greater exposure to unwanted noise, enhanced virus transmission, psycho-social factors and loss of privacy/autonomy. They also noted that occupants of private offices are more likely to have access to natural ventilation via a window, which, regardless of the resulting outdoor air rates and pollutant sources, is an extra factor of personal control, and personal control is generally desired by office workers.

Bodin Danielsson, Chungkham, Wulff, & Westerlund (2014) analyzed survey data from 1,852 office employees in Sweden, including self-reported sick leave. The format of data reported in the paper was not compatible with the standard format we are using in this report[1]. Nevertheless, the overall trend in results was for open-plan spaces to have higher (risk of) sick leave than private offices.

**Absenteeism: Effect of Workplace Health Programs**
**↓0 – 1.8 days/person/year**

Baicker, Cutler, and Song (2010) reviewed and statistically-combined (using meta-analysis) 32 high-quality studies on the effect of workplace health programs on organizational financial outcomes; of these, 22 addressed the effect on absenteeism over a period of, on average, two years. These studies were conducted in large organizations in multiple industries (with a variety of settings), and had a focus on US workplaces. The various WHPs typically had multiple components, which differed from study to study. Most programs included an initial health risk assessment, and had a focus on weight loss and fitness, smoking cessation, and multiple risk factors (including stress management, back care, nutrition, alcohol consumption, blood pressure, and preventive care). The (unweighted) mean effect across all studies was a reduction of 1.8 days/pers/yr, with all but one study showing some reduction. The overall (unweighted) mean absenteeism rate in the treatment groups was 8.7 days/pers/yr, which is quite high compared to the national average for the USA shown in Figure 5, but was skewed by two studies recording absenteeism of around or above 30 days/pers/yr. They concluded that absenteeism costs fall by about US$2.73 for every dollar spent on WHPs, although this was based on a simple multiplication of days saved by average hourly wage.

Kuoppala, Lamminpaa, and Husman (2008) reviewed 46 studies, seven of which were conducted in an office setting. Results were not expressed in units scalable to our needs, and were not isolated by office environments only. However, the authors concluded that "There is moderate evidence that work health promotion decreases sickness absences".

Marzec et al. (2011) studied California state public-sector workers in the US. The study period was two years, and included a basket of 13 health and well-being oriented interventions. The three-month average sick-time of April-June for 2005 and 2007 was used as the absenteeism measure pre- and post-intervention. Absenteeism showed no statistically-significant change over the study period, for the 404 people who participated at both the beginning and end points of the study. The absenteeism rate pre-intervention was equivalent to 6.7 days/pers/yr, higher than the US average benchmark, but this is common for the public sector.

**Absenteeism: Effect of Bonuses**
**↓1.0 days/person/year**

We identified only one good quality study that met our criteria, and it used data over six years from 177 managers in a single German employer. Pfeifer (2014) found that, while base salary was not significantly

correlated with managers' work absence, higher achievable bonus payments correlated with fewer absent working days due to sickness (as recorded in the company's personnel records); actual bonus payments averaged 16 percent of base salary. The mean absenteeism rate was 3.9 days/pers/yr. Translating the results format in the paper into the format we are using is not straightforward, as different analysis models were presented, and the results were scaled to the size of the bonus rather than simply to the presence/absence of the program itself. The most conservative estimate of the effect is a reduction of absenteeism of 29 percent for each log-point increase in the maximum achievable bonus. A one log-point increase in this sample, in the middle of the range, was equivalent to around €8,500, and a 29 percent reduction in the base absenteeism rate is equivalent to 1 day/pers/yr.

**Absenteeism: Effect of Flexible Work Options**
**↕ mixed effects**
Whyman and Petrescu (2015) examined the effects of a variety of workplace flexibility options on 135 private sector small and medium-sized enterprises (SMEs) in the UK. The average reported annual absence was 5.5 days per employee, in line with private sector benchmarks for the UK. Two flexible options were of particular relevance to our report: Home or mobile working was associated with higher absenteeism (by 2.5 days/pers/yr) (and lower financial turnover); and, family-friendly practices were significantly linked to lower absenteeism levels (by 2.8 days/pers/yr).

Dionne and Dostie (2007) used data from Statistics Canada's Workplace Employee Survey (1999–2002). Data came from non-agricultural workplace with more than 10 employees, but only for employees with less than fifty days absence in a year. Absences included: paid sick leave, other paid leave, and unpaid leave, but not vacations, paternity/maternity leave, or absence due to strikes or lock-out. A variety of work arrangements were considered, including working from home, and flexible hours. Many statistically-significant effects were found in both directions, but these effects were very small, and of little practical significance.

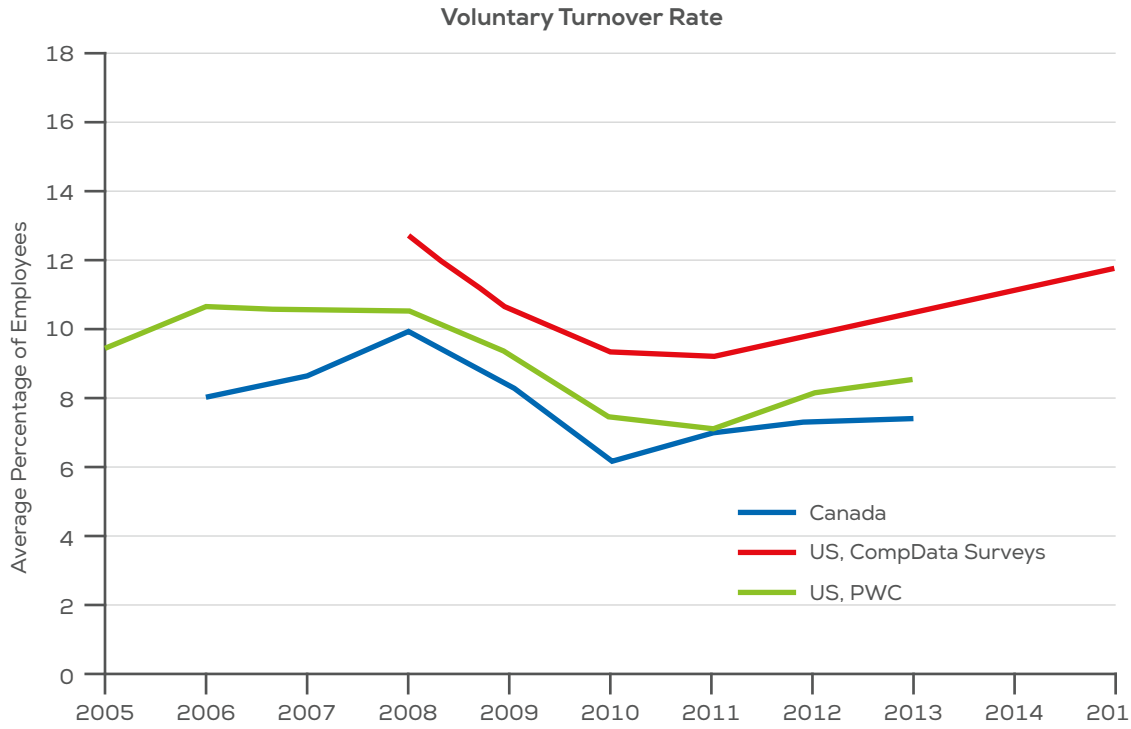
**Absenteeism: Summary**
Better buildings strategies reduce absenteeism by an amount that has tangible value to an organization. The size of this effect is similar to workplace health programs and bonuses, although substantially smaller than the benefit of private versus open-plan offices. Given that investments in better buildings are likely to persist with a relatively low on-going maintenance cost, such investments are worthy of consideration alongside other, common workplace strategies.

## 3.2 EMPLOYEE TURNOVER

**Employee Turnover: Benchmarks**
**18 – 30 (intent on a 100 point scale)**
Although the focus of our Matrix is on turnover intent, we begin by presenting data in actual voluntary turnover to provide some context. Again, data are available in many national statistical databases, using a variety of data collection methods. Differences may be observed between countries and regions, between industries, and over time. Figure 7 shows data illustrating differences between two countries on the same continent, changes over time, and differences between two different sources for the same country. The data shows that in North America, and averaged across all industries, the number of people who voluntarily left their job in any year was about 10 percent. The data also shows the drop in voluntary turnover occurring around the time of the financial crisis beginning in 2008. As expected, as general unemployment rose, people who already had a job were more reluctant to leave it, or were less likely to find more attractive employment elsewhere. This example illustrates one of the many important exogenous factors affecting organizational productivity metrics unrelated to building characteristics, and not under the control of the building manager or the organization. Source: http://www.conferenceboard.ca/e-library/abstract.aspx?did=5737; Source: http://www.compensationforce.

com/2016/04/2015-turnover-rates-by-industry.html; Source: http://www.pwc.com/us/en/hr-management/publications/human-capital-effectiveness-state-of-workforce-report.html. Further information on actual turnover rates is shown in Appendix B.

Figure 7. Actual voluntary turnover data over time, for Canada and the US.




The focus in this report is on turnover intent. National-level data of this kind are typically captured in social surveys directed at households. Here we describe the sources and the derived benchmark from each source on the normalized 0-100 scale. Details on how we converted the data from each source into this common scale are provided in Appendix C.

The University of Chicago General Social Survey is conducted regularly, and occasionally includes an item on turnover intent (http://gss.norc.org/; NIOSH supplement: http://www.cdc.gov/niosh/topics/stress/qwlquest.html). A derivative paper (http://static1.1.sqspcdn.com/static/f/1528810/23319899/1376576545493/Medina+Elizabeth.pdf) provides information that we can utilize from 2010. Data were collected from 4,618 respondents in the U.S. general population. Responses suggest an average likelihood of looking for a new job of 23 on a 0-100 scale.

Another US source is the University of Michigan Work, Family, and Health Study (http://www.researchconnections.org/icpsrweb/DSDR/studies/36158). This study aggregated data over 2009-2012 from two U.S. companies (IT and extended care). Data was collected from 9,148 respondents. Results suggest an average likelihood of looking for a new job of 30 on a 0-100 scale.

Equivalent Japanese data are also available from the Japanese General Social Survey (http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/34623). Data from 2010 were collected from 2,997 respondents in the Japan general population. Results suggest an average likelihood of quitting of 18 on a 0-100 scale.

NRC's Green POE study (Newsham, et al., 2013) included relevant data from occupants of 24 office buildings from across Canada and the northern US. Data was collected in 2010-2011 from 835 respondents. The overall results for all buildings suggest an average likelihood of quitting of 28 on a 0-100 scale.

**Employee Turnover: Effect of Better Buildings**
**↓1.3**
The previously described study by Veitch et al. (2010) also measured turnover intention using the same scale as Newsham (2013). We calculated the relevant value for the Matrix from the reported relationships. Direct-indirect electric lighting with personal dimming control allied with new office furniture was associated with a 1.3 point reduction in turnover intent compared to the pre-existing electric lighting of direct parabolic luminaires with older office furniture (Veitch, et al., 2010). The mean pre-intervention turnover intent score was 25.2, comparable to the range established by applicable benchmarks.

**Employee Turnover: Effect of Office Type**
**↓18**
The NRC Green POE study included among the physical data collected from the study buildings whether the office measured was private or open-plan (Newsham, et al., 2013). There was no systematic attempt to conduct physical measurements in the same workstations from which we received survey responses, but in a subset of cases this occurred by chance, and we were able to identify such cases reliably, and link the two sets of data in a total of 230 cases (Leder, Newsham, Veitch, Mancini, & Charles, 2016). However, the turnover intent question was only administered to about one-third (randomly sampled) of participants. Further, for the present purpose we constrained the analysis to conventional buildings in the sample, partly because this was more representative of the population of buildings as a whole, and partly because there were very few private offices in the remaining green building data. We conducted an analysis of variance (ANOVA) on these data (total N=48, across 11 buildings), with office type as the independent variable. The effect was statistically significant ($F_{1,46}=4.96$, $p=0.031$), with private offices (N=22, mean=22) associated with an 18-pt lower intent to turnover score compared to open-plan offices (N=26, mean=40); there were no statistically-significant main effects by job type or tenure. While the private office turnover intent score is comparable to applicable benchmarks, the open-plan office score is considerably higher.

Oldham and Fried (1987) studied the actual turnover rates of 109 clerical employees in 19 offices in a large university in the US. They found that 24 percent of the variance in turnover was attributable to four workplace characteristics: social density, number of enclosures, interpersonal distance, and (perceived) room darkness. The first three characteristics all relate to office type, and the maximum enclosure value would correspond to a private office. Unfortunately, the results were not presented in a format that was interpretable on the scale we have chosen, and so we use the information qualitatively. The authors conclude from their results that, "... Employees were most likely to withdraw from offices and to experience dissatisfaction with their work when the following conditions were present simultaneously: the office was rated as dark, few enclosures surrounded employees' work areas, employees were seated close to one another, and many employees occupied the office." This conclusion clearly supports the direction of the effect reported from Newsham et al. (2013) above.

**Employee Turnover: Effect of Workplace Health Programs**
**0, no effect**
Caillier (2016) conducted a study of 240 employees in 80 US federal agencies, using data collected 2011-2014. Because different employees responded in different years, the analysis was at the aggregated level of the agency, not at the individual. Turnover intent was measured with the following survey item: "Are you considering leaving your organization within the next year, and if so, why?" Response options were: "no", "yes, to take another federal government job", "yes, to take, a job outside of the federal government", "yes, other". Analysis focussed on those seeking another job outside government, on which there was no direct effect of health and wellness programs.

**Employee Turnover: Effect of Bonuses**
**↓, but effect size not determined**
We were unable to find any papers that expressed results and outcomes in a format consistent with the goals of this report. Nevertheless, we did review three high-quality studies whose results form a consistent trend in the expected direction: that bonuses (or other financial rewards for high job performance) are associated with lower turnover. However, this is an area rich in complex and subtle effects, and a close reading of the source papers is recommended for a full understanding beyond the gross effects we have extracted below.

Park and Sturman (2016) used two-year (2001-2002) longitudinal data from a large sample of US employees from a service-sector organization to study the effects of pay-for-performance (PFP) plans on employees' voluntary turnover; PFP included merit-based increases to base pay, bonuses, and long-term incentives (LTI) tied to the overall performance of the company (e.g., stock options). The study used data from a final sample of 720 white-collar employees in multiple locations. Voluntary turnover data were available from the organization's HR system, and amounted to 12 percent in 2002, similar to the US benchmarks for this type of work. The average rewards, as a percentage of baseline pay for merit, bonus, and LTI were 3.1%, 7.0%, and 1.2%, respectively. While each form of PFP was associated with lower turnover when considered independently, when applied collectively, as in this organization, merit pay had the strongest negative association with employee turnover, followed by LTI, whereas bonus pay actually increased employee turnover. Overall, effects were greatest for higher performing staff.

Salamin and Hom (2005) utilized data from 11,098 Swiss nationals who started work in a bank between October 1, 1994 and March 22, 1999. Voluntary turnover data were obtained from the HR department. By the end of the data period 35.7 percent of the total sample had voluntarily terminated. A simple annual rate cannot be divined given the different start dates of each employee, but this rate appears to be consistent with benchmark data. Both merit pay increases and bonuses were associated with sizable reductions in quit rates, and, overall, effects were greatest for higher performing staff.

Nyberg (2010) evaluated the behaviors and attitudes of 12,545 insurance employees over a three-year period (2004-2006) in multiple offices across the US. Actual turnover data were used. By the end of the data period 15 percent of the total sample had voluntarily terminated. As for Salamin and Hom (2005), a simple annual rate cannot be divined given the different start dates of each employee, but this rate appears to be consistent with benchmark data. Bonuses comprised a part of total compensation (~4%, on average), but were not evaluated separately. Both higher total compensation, and employee perception that higher performance was rewarded, were associated with lower turnover rates. Again, overall, effects were greatest for higher performing staff.

**Employee Turnover: Effect of Flexible Work Options**
No relevant studies were identified.

**Employee Turnover: Summary**
Although retention of (high-performing) employees is often stated as a key HR goal for organizations, studies in the context of this report were sparse. With the exception of the benefit of private versus open-plan offices, effects were small or difficult to quantify. There was a small effect of one better buildings strategy, but from a study with a strong design and statistical analysis.

## 3.3 SELF-ASSESSED PERFORMANCE

**Self-assessed Performance: Benchmarks**
**0% (relative effect of workplace strategies)**
We were unable to find any relevant national level databases, and would not expect that any exist. A typical format of such questions, with respect to the workplace environment, is "Please estimate how you think your personal productivity at work is increased or decreased by the physical environmental

conditions", with a seven-point response scale from -30 to +30 percent (Wilson & Hedge, 1987). In that sense, one would expect that an environment that is neutral with respect to self-assessed productivity in the experience of the respondent would yield a value of zero.

For example, NRC's Cost-effective Open-Plan Environments (COPE) project collected survey and physical data from nine office buildings from across Canada and the USA (Veitch, Charles, Farley, & Newsham, 2007); four of these buildings were occupied by a large private sector organization. The survey included self-assessed productivity using a scale like the one above, and responses were received from 747 occupants of open-plan offices; the mean response was -1.5 percent. The NRC Green POE study also included this scale, and responses were received from 2,523 occupants of open-plan offices; the mean response was 0.1 percent.

**Self-assessed Performance: Effect of Better Buildings**
**↑2 – 10%**

Singh et al. (2011) also surveyed their respondents on how the IEQ of their current work space affected their productivity. Data (N=86) revealed a two percent improvement in perceived productivity associated with the move to a green building.

Agha Hossein, El-Jouzi, Elmualim, Ellis, and Williams (2013) studied the staff of a private-sector company in the UK that moved from an older HQ building to a structurally similar, but newly refurbished, building located next-door. The refurbishment achieved BREEAM "Very Good" rating. Specific to building systems and controls, the main difference between the buildings was that the new building featured a functioning mechanical ventilation and air conditioning system with centralized building management system (BMS) control. The productivity question was not articulated as a percentage. Rather, employees were asked to what extent they agreed with the statement: "My current office environment already has a positive effect on my productivity". Respondents used a 5-point scale from "strongly disagree" to "strongly agree". If we assume this spans the same +30 to -30 percent scale as other, similar studies, then the observed statistically-significant difference of 0.33 scale points post-move (N=160 older building, N=183 refurbished building) equates to a five percent improvement in self-assessed performance associated with the better building.

Baird, Leaman, and Thompson (2012) compared data from a worldwide set of buildings with sustainable credentials (N=31) and conventional buildings (N=109), in which the same survey instrument had been used to evaluate a wide range of occupant satisfaction issues. A mean score on each factor was calculated for each building, and the authors conducted statistical tests on this set of mean values. They reported a statistically-significant difference in the effect of environmental conditions on perceived productivity of 7.8 percent favouring sustainable buildings (mean = +4.1 percent) over conventional buildings (mean = -3.7 percent), on average. The specific differences in building features and systems were not reported.

Thomas (2010) studied an office refurbishment in Australia, which was the first project in Australia to achieve the highest 6 Star (or World Leader) rating under the Green Star – Office Interiors system (http://new.gbca.org.au/green-star/). The researchers used a pre-post methodology, first surveying occupants at their previous (conventional) building (N=167), and then 15 months later at the new building (N=238). Key features of the new building included a more open layout designed to improve internal communication and daylight penetration[2], and an upgraded BMS. A floating temperature setpoint approach that referenced external conditions was implemented and the outdoor air supply rate, at 15 L/s/ person was 50 percent higher than the prevailing Australian standard. When asked to assess whether their productivity increased or decreased as a result of the environmental conditions of the building, the respondents returned an average perceived productivity rating of +7.2 percent for the new building on a nine-point scale of "–40 percent or less" to "+40 percent or more". This is a significant improvement from the mean rating of -2.4 percent rating for their previous accommodation (which was typical for a normative set of Australian buildings). Thus, the refurbished building was associated with an improvement of 9.6 percent.

Oseland and Burton (2012) reported a study done with 1,420 staff in 14 public-sector office buildings in the UK, using the same survey instrument as Baird (Baird, et al., 2012). Respondents in 1950s legacy buildings reported a mean perceived productivity rating 2.2 percent lower than in a more recently-built building, and 4.8 percent lower than in the newest building. Unfortunately, the specific building features were not reported.

MacNaughton et al. (2017) collected data from pairs of matched green and conventional buildings in five US cities (10 buildings in total). Data was collected from eight to 12 participants per building (N=109 in total). Participants completed a cognitive function test on the Tuesday and Thursday of a one-week assessment period. This was the strategic management simulation (SMS) software, a validated test of cognitive function which lasted 1.5 hrs, and required participants to respond to multiple plot lines. Participants in green buildings scored 26.4 percent higher than participants in similar conventional buildings. Although this standard task is not equivalent to self-assessed performance, and represents only one component of the work behaviours necessary for an employee to make a positive contribution to organizational productivity, the direction of the effect supports the other work in this section.

**Self-assessed Performance: Effect of Office Type**

**↑8 – 15%**

Using data from NRC's Green POE study (Newsham, et al., 2013), we ran a two-way ANOVA on the self-reported productivity measure with building type (green/conventional) and office type (private/open) as independent variables (N=228). We found a statistically significant main effect of office type, suggesting a 7.7 percent improvement associated with private offices[3] (private mean = +5.2%; open mean = -2.5 percent).

Bergstrom, Miller, and Horneij (2015) conducted a 12-month longitudinal study of Swedish office workers moving from private to open-plan offices; the study sample was small (N=21). Perceived productivity was assessed using 20 questions each with a 5-point response scale (developed by Brennan, Chugh, and Kline (2002), and thus the sum of these formed a 100-point scale. If we reverse code the responses so that higher is better, the mean response before the move (private offices) was 56.0, and after the move was 47.9, a difference that was statistically-significant. Given that these values were just above and below the mid-point of the scale, respectively, and given that the size of the effect is consistent with other studies, it seems reasonable for our purpose to interpret this as an 8.1 percent difference.

Brennan et al. (2002) conducted a six-month longitudinal study of Canadian private-sector office workers moving from (mostly, 76 percent) private offices in a downtown high-rise to (mostly, 81 percent) shared/open-plan offices in a business park; the study sample was small (N=21) within a much larger company. Perceived productivity was assessed as described above. Reverse coding and using the 100-pt scale as described above, the mean response before the move was 62.0, and after the move was 49.0, a difference that was statistically-significant. Again, it seems reasonable for our purpose to interpret this as a 13.0 percent difference.

Lee (2010) analyzed data from 15 LEED certified buildings in North America (N=3533). Participants were asked "Does the office layout enhance or interfere with your ability to get your job done?", with a 7-point response scale from enhances (+3) to interferes (-3); this seems directly scalable to our percentage scale, simply by multiplying by 10. Private offices had statistically-significantly higher scores than all types of shared or open offices. For example, the mean response from private offices was +14.0 percent, whereas the mean response from high-panel cubicle offices was -0.6 percent, or a difference of 14.6 percent.

**Self-assessed Performance: Effect of Workplace Health Programs**

**↑0 – 10%**

Coffeng et al. (2014) studied 412 employees of a European financial services company in a longitudinal study spanning 12 months. Work performance was assessed with the Individual Work Performance Questionnaire (IWPQ). The IWPQ consists of 16 questions in three subscales: task performance, contextual

performance, and counterproductive work behavior, using a 5-point scale. The mean self-rating of task performance increased from 3.3 (pre-, N=117) to 3.7 (post-WHP intervention, N=76) on a 1-5 scale (statistically significant). Specifically, the WHP was a social environmental intervention with the aim of stimulating physical activity and relaxation. Translating this effect size into the percentage scale we favour is not straightforward; we suggest a value of 5-10 percent is reasonable.

Rongen, Robroek, van Lenthe, and Burdorf (2013) conducted a meta-analysis of 18 studies, five of which were conducted in an office-like setting. Two of these included a measure of productivity, and one of which showed a significant positive effect of a WHP, and the other showed no effect.

Other studies have demonstrated no effect of WHPs on self-reported performance. Vuokko et al. (2015) conducted a study of asthma sufferers from non-industrial workplaces in Finland (N=43). Participants could only participate if they had taken at least 14 days of sick leave in the previous year due to air quality issues. The WHP included psychoeducation and promotion of health behaviour. There was no effect of the intervention on self-assessed work ability.

Blake, Zhou, and Batt (2013) assessed the effect of a WHP over a five-year period on National Health Service staff in a variety of categories (N=1,134) in the UK. While there were several benefits attributed to the program, there was no effect of the intervention on perceived work performance.

Pereira, Coombes, Comans, and Johnston (2015) reviewed eight studies on the effects of WHPs (focussed on physical activity) on productivity. Three of these studies were conducted in offices, and in all of these there was no demonstrated effect of the WHP on a measure of self-reported productivity.

**Self-assessed Performance: Effect of Bonuses**

**↑, but effect size not determined**

We were unable to find any studies that expressed their results in the format we have chosen for our report, or that could be converted into such a format. However, multiple studies did concur on the direction of this relationship: bonuses tend to improve productivity. These studies did not use employees' own self-assessments, but rather relied on an objective measure of task performance, or an assessment by a manager (or similar).

Lowery, Petty, and Thompson (1995) conducted a study at a large US utility. Employees could receive a bonus of up to 20 percent of base pay for superior performance, as rated by their manager. Surveys were completed (N~8,000) one month after bonus payments were disbursed, and evaluated employees' impressions of the bonus plan, there was no comparison group of employees not participating in the plan. Of all employee categories, 70 percent agreed that the bonus plan had a positive effect on their work habits and performance, but only 47 percent agreed that it had improved their personal productivity; nevertheless, 70 percent agreed that it had improved the company's performance.

Stajkovic and Luthans (2001) studied the effect on the objective performance of employees processing financial information (N=186). Simple bonuses for increased performance were associated with a statistically-significant improvement in performance over baseline of 11 percent; bonuses allied with a formal process to identify organizational deficiencies increased performance by 32 percent.

O'Neill (2014) studied the performance of employees in a call center in Mexico, owned by a US company. Staff (N=168) were provided with a small bonus for every sale of a specific type. Although there was an increase in mean sales per week after the bonus was applied, this difference was not statistically significant; notably, although the study was conducted over three months, bonuses were only in place for two weeks. However, when the bonus was subsequently removed, there was a statistically-significant decrease in sales of 22.4 percent.

Raj, Nelson, and Rao (2006) studied performance incentives in the IT department of a retail company in India; the study period spanned eight weeks. Employees (N=18) offered monetary rewards (15 percent discount on products sold by the company) and extra paid leave exhibited significantly higher performance assessed by management-appointed observers. Nevertheless, other non-monetary interventions (feedback, flexible dress code, flexible working hours) had similar or larger benefits.

Garbers and Konradt (2014) used meta-analysis to examine the effects of financial incentives on

peoples' performance (not self-reported). The overall effect of incentives for individuals (116 studies) was statistically significant, and positive. Data came from multiple settings, and the effects for office-like environments were not separated. Effects were larger for qualitative, rather than quantitative, performance measures, and for more complex tasks.

**Self-assessed Performance: Effect of Flexible Work Options**
No relevant studies were identified.

**Self-assessed Performance: Summary**
Despite challenges in interpretation, self-assessed performance is a widely used and accepted metric, particularly in work contexts where meaningful task performance measures are unavailable. Again, better buildings strategies have a positive effect that is similar in size to workplace health programs, and the upper end of the range of effect sizes overlaps with the benefit of private vs. open-plan offices. The effect of financial bonuses was also positive, but could not be quantified on our chosen scale.

## 3.4 JOB SATISFACTION

**Job Satisfaction: Benchmarks**
**60 – 80 (on a 100 point scale)**
Benchmarks for job satisfaction exist in national and international social surveys. Here we describe the sources and the derived benchmark from each source on the normalized 0-100 scale. Details on how we converted the data from each source into this common scale are provided in Appendix D.

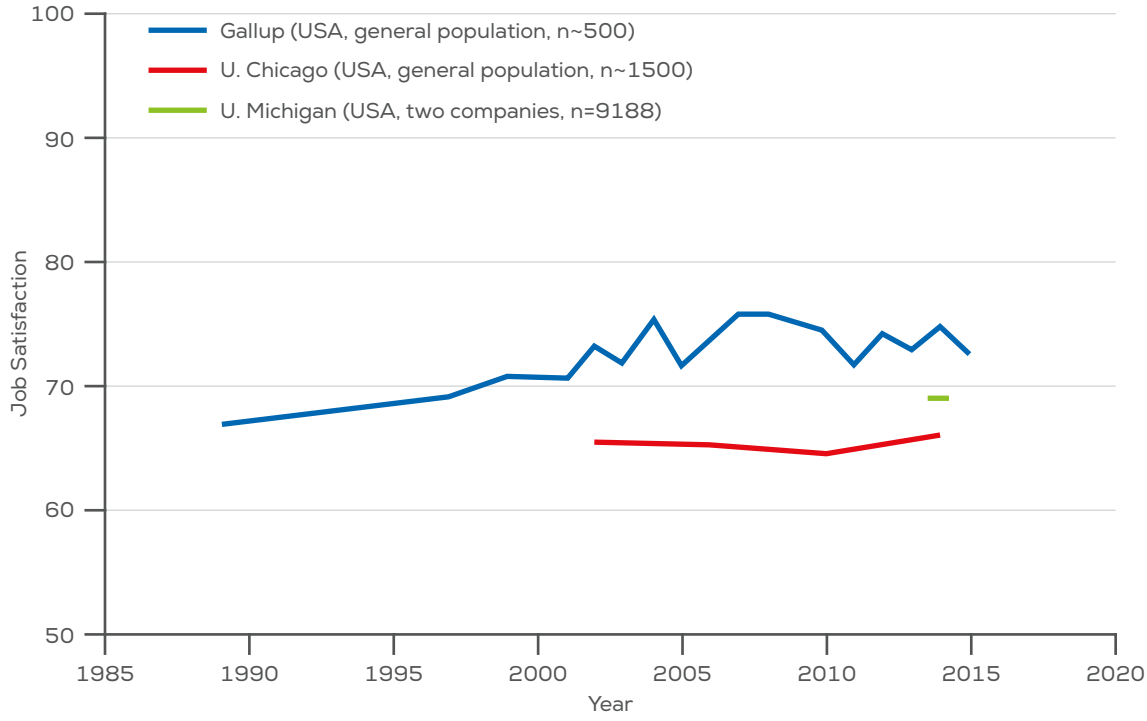
The University of Chicago General Social Survey is conducted regularly, and occasionally includes an item on job satisfaction (http://www.norc.org/Research/Projects/Pages/general-social-survey.aspx). Data are available from 2002-2014, based on ~2,000-4,500 (depending on the year) respondents in the U.S. general population. Responses suggest an average job satisfaction of 65-66 on a 0-100 scale.

Another US source is the University of Michigan Work, Family, and Health Study (http://www.researchconnections.org/icpsrweb/DSDR/studies/36158). The report we cite aggregated data over 2009-2012 from two U.S. companies (IT and extended care). Data was collected from 9,188 respondents. Responses suggest an average job satisfaction of 69 on a 0-100 scale.

A further source of U.S. data comes from Gallup, which has collected data on this topic from the general US population since 1989 (http://www.gallup.com/poll/1720/work-work-place.aspx). Data were gathered from ~500-1000 (depending on the year) respondents in the USA general population. Responses suggest an average job satisfaction of 67-76 on a 0-100 scale.

Figure 8 illustrates data from U.S. sources. The data, within a consistent source, are relatively stable over time, and differences between sources likely reflect differences in methodology and sampling techniques. Aggregation of these data suggests a job satisfaction score of around 70 for the US population.

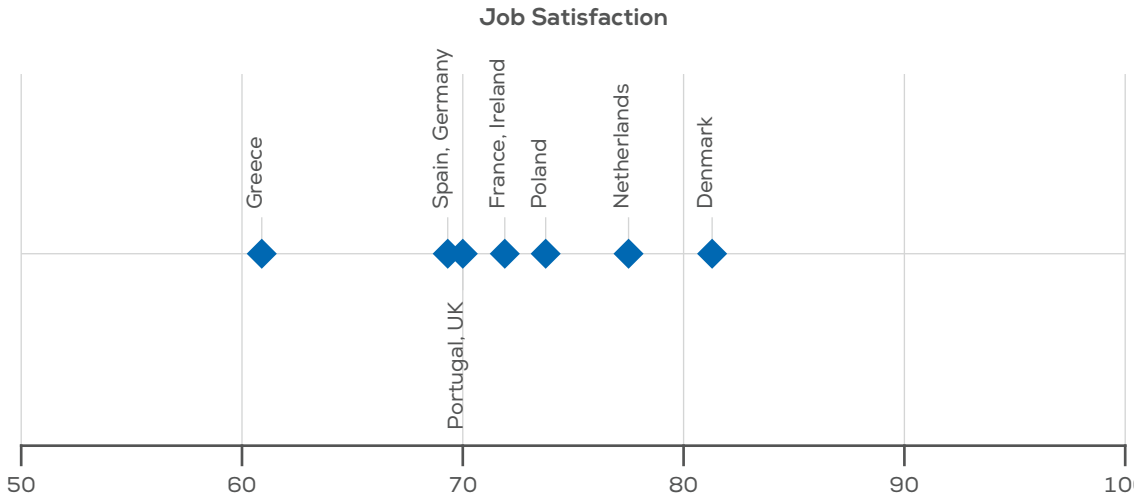
Figure 8. Job satisfaction data (rescaled to 0-100) over time, for three different US samples.




Equivalent Japanese data are available, from the Japanese General Social Survey (https://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/34623). Data from 2010 were collected from 3,072 respondents in the Japan general population. Aggregation of these data suggests a job satisfaction score of around 66 for the Japanese population.

Data are also available for many European countries (http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_pw01&lang=en; http://ec.europa.eu/eurostat/statistics-explained/index.php/Quality_of_life_in_Europe_-_facts_and_views_-_employment#Job_satisfaction). Data from 2013 were collected from 27,720 respondents in the general population. Figure 9 presents the mean responses from a sub-set of countries. Like the US data, these values are centered around a value of 70.

Figure 9. Job satisfaction data for a sample of European countries.




Note that these benchmarks were derived from the working population as a whole, and were not limited to office or service workers only.

NRC's Green POE study (Newsham, et al., 2013) also contained relevant data from occupants of 24 office buildings from across Canada and the northern US. Data were collected in 2010-2011 from 2,535 respondents, and responses suggest an average job satisfaction score of 77. Earlier NRC data from the COPE study from nine office buildings from across Canada and the USA (Veitch, et al., 2007) included responses from 770 occupants of open-plan offices; the mean response for job satisfaction was 68.

**Job Satisfaction: Effect of Better Buildings**

**↑4 – 9**

In Veitch et al. (2010), direct-indirect lighting with personal control (+new cubicles) was associated with an improvement in job satisfaction of six points when normalized to a 100-point scale, compared to direct parabolic lighting (+old cubicles). The normalized values pre- (JS=72.1) and post- (JS=78.4) the retrofit were consistent with the applicable benchmarks.

Hongisto, Haapakangas, Varjo, Helenius, and Koskela (2016) studied call center workers (N=40) in Finland. The work environment underwent a collection of improvements, including better environmental conditions (e.g., sound absorption, odour mitigation) and control (e.g., personal light switches), increased privacy, and more ergonomic furniture (including sit-stand desks). Job satisfaction was assessed via a single item on a pre-post (within subjects) questionnaire, "How satisfied are you with your work as a whole?", with a five-point response scale from "Very dissatisfied" to "Very satisfied", which we numerated 10-90. The refurbishment was associated with a statistically-significant increase of four points when normalized to a 100-point scale. Note that the normalized pre- (JS=62) and post- (JS=66) were somewhat lower than the benchmark for Finland (81) shown in Appendix D.

Agha Hossein et al. (2013) included a measure of "Enjoyment at work", which we can consider as a partial surrogate for overall job satisfaction. Employees were asked to what extent they agreed with the statement: "My current office environment already has a positive effect on my enjoyment at work". Respondents used a five-point scale from "strongly disagree" to "strongly agree", which we numerated from 10-90. The newly refurbished office was associated with a statistically-significant increase of 9 points when normalized to a 100-point scale. Note that the normalized pre- (48) and post- (57) ratings were somewhat lower than the job satisfaction benchmark for the UK, which might suggest that the equivalency of this survey item to job satisfaction is not completely valid, or that this workplace was not representative of the UK working population as a whole.

Although, on balance, studies suggest that "better buildings" are associated with higher overall job satisfaction, this relationship has not been demonstrated universally. For example, NRC's Green POE study found no statistically-significant difference in job satisfaction between green and conventional buildings (Newsham, et al., 2013).

**Job Satisfaction: Effect of Office Type**

**↑5 – 10**

Bergstrom et al. (2015) included a measure of "Internal work experience", which we can consider as a partial surrogate for overall job satisfaction (it does not perfectly map the same conceptual space). The score on this scale was the sum of responses to six separate items, each scored from 1-6, and thus the range of the outcome was 6-36, which we rescaled to 0-100. The prior, private offices were associated with a statistically-significant higher mean response of 10 points when normalized to a 100-point scale, compared to the new open offices. The normalized pre- (70) and post- (60) were somewhat lower than the job satisfaction benchmark for Sweden, which might suggest that the equivalency of this survey item to job satisfaction is not completely valid, or that this workplace was not representative of the Swedish working population as a whole.

Pejtersen et al. (2011) included a measure of job satisfaction; the score on this scale was the sum of responses to four separate items, and results were presented on a scale from 0-100. There was a systematic decline from single-person offices to offices shared with increasing numbers of people. The comparison of private offices to the largest shared spaces was associated with a higher mean response of 4.7 points. The mean scores for each type (private 52.6; large shared 47.9) were substantially lower than the job satisfaction benchmark for Denmark, which might suggest that the equivalency of these survey items to other measures of job satisfaction is not completely valid, or that this workplace was not representative of the Danish working population as a whole.

Danielsson and Bodin (2009) analyzed data from 469 office employees from 26 different companies/divisions in larger companies in Sweden. One item asked whether "the workspace design did not contribute to job satisfaction," and responses were dichotomized. There was a statistically-significant effect of office type, with 31 percent of occupants of private offices agreeing with this statement, compared to 64 percent of the occupants of large open-plan offices. Thus, although the data format did not lend itself to conversion to our 0-100 point scale, the trend in the data is consistent with the studies that could fit the Matrix.

De Croon Sluiter, Kuijer, and Frings-Dresen (2005) also provided support for the direction of this effect, although their data were not presented in a manner that allowed scaling to the format favoured in this report. After reviewing 49 studies they concluded that "... working in open workplaces reduces privacy and job satisfaction." The aforementioned study by Oldham and Fried (1987) was one of those included in De Croon et al.'s (2005) review. Oldham and Fried had found that 31 percent of the variance in "work satisfaction" (which was the mean score of nine items from the Job Diagnostic Survey) was attributable to four workplace characteristics: social density, number of enclosures, interpersonal distance, and room darkness; the first three characteristics all relate to office layout, and the maximum enclosure value would correspond to a private office. Workplace dissatisfaction was associated with more open offices.

**Job Satisfaction: Effect of Workplace Health Programs**

**↑0 – 12**

In Caillier (2016) job satisfaction of US public servants was measured with the two items: "Considering everything, how satisfied are you with your job?" and "Considering everything, how satisfied are you with your organization?" The scales for both items ranged from one (strongly disagree) through five (strongly agree). Mean scores for these survey items were obtained for each agency each year. If we numerate these labels as 10-90 on a 100-point scale, then the mean score across all agencies translates into 62 (min=45; max=73). These values are comparable to benchmarks for the US. Results indicated a

statistically-significant and positive association between health and wellness programs and job satisfaction; participation in a program increased job satisfaction by 12 points, all else being equal, when converted into a 100-point scale.

Conn, Hafdahl, Cooper, Brown, and Lusk (2009) conducted a meta-analysis on the benefits of programs promoting physical activity. The primary studies were conducted at a variety of workplaces, including education or health services, government, and manufacturing, and results were not reported for office-like work separately. A total of 17 studies included job satisfaction. An overall, statistically-significant and positive effect, in which physical activity programs improved job satisfaction, was reported for studies of one research design type (two-group pre-post) but not for two other research design types (two-group post-test, treatment pre-post).

Marzecet al. (2011) assessed job (dis)satisfaction as one of 15 factors on the University of Michigan Health Management Research Center's Health Risk Appraisal (HRA). Ratings of job dissatisfaction demonstrated no statistically-significant change over the study period (2005-2007). For the 404 people who participated at both the beginning and end points of the study, the percentage expressing dissatisfaction was 17.1 percent in 2005 and 17.6 percent in 2007.

Blake et al. (2013) studied National Health Service staff in the UK who experienced a wellness intervention. The results did show a statistically-significant improvement in job satisfaction associated with the wellness intervention, but the size of the effect was so small as to have no practical significance.

**Job Satisfaction: Effect of Bonuses**

Lowery et al. (1995) conducted a study at a large US utility. Of all employee categories, only 46 percent agreed that the bonus plan had a positive effect on their job satisfaction, although the figure was 61 percent for the sub-group of employees who were managers. Given the limited scope and vintage of this study, we do not think it is reasonable to draw a firm conclusion for this cell of the Matrix.

**Job Satisfaction: Effect of Flexible Work Options**

**↑0 – 10**

Fonner and Roloff (2010) compared teleworkers (N=89) who worked remotely at least three days per week, with office-based workers who were in an office environment at least three days per week (N=103). Job satisfaction was the mean of responses to five items, each scored on a seven-point scale. If we rescale this outcome (1=0 to 7=100), then the direct effect of telework was a statistically-significant improvement in job satisfaction of 10.3 points. Consideration of indirect effects, through benefits of telework on aspects including work-life balance, information exchanges, management of interruptions, elevated the improvement.

On the other hand, in Caillier (2016) there was no significant effect of flexible work options, neither telework nor flex-time, on job satisfaction.

Nijp, Beckers, van de Voorde, Geurts, and Kompier (2016) studied employees at a Dutch financial company. The company introduced a "new ways of working" (NWW) environment which provided for both temporal and spatial flexibility in work patterns. Data were collected one or two months before implementation, four months after, and 10 months after, and from 361 employees experiencing NWW and 80 from a control group. Following implementation, there was a large shift in work hours towards teleworking. Job satisfaction was measured using a single questionnaire item, "Indicate how satisfied you generally are with your work", with a 10-point response scale from "very dissatisfied" (0) to "very satisfied" (10). There was no statistically-significant effect of NWW on job satisfaction. Note that the baseline value of job satisfaction for the control group was 78 (when rescaled to a 0-100 point scale), which is consistent with prevailing benchmarks for the Netherlands.

**Job Satisfaction: Summary**

Job satisfaction, derived by self-report survey, is a well-established and excellent KPI for the white-collar workplace; it is widely understood to be the antecedent to many other behaviors important to

organizational success. Better buildings strategies have a positive effect that is similar in size to the benefit of private versus open-plan offices, workplace health programs, and flexible work options. As already described under absenteeism, given that investments in better buildings are likely to persist with a relatively low on-going maintenance cost, such investments are worthy of consideration alongside other, common workplace strategies.

## 3.5 HEALTH AND WELL-BEING (SYMPTOMS)

**Health and Well-being (symptoms): Benchmarks**
**30 – 60 (on a 100 point scale)**

We were unable to find any national statistical databases or social surveys that provided data on SBS-like symptoms in the general population. Therefore, our benchmarks are based on the limited data from studies of specific building populations in conventional buildings or prior to any intervention hypothesized to improve symptoms. Further data from these studies had to be in a format that could reasonably be translated into the 0-100 point scale on which we are standardizing.

Hongisto et al. (2016) studied call center workers (N=40) in Finland. Five specific symptoms (throat symptoms; eye symptoms; nasal symptoms; headache; stress) were each assessed for frequency on a five-point scale: “Never”, “Only rarely”, “Sometimes”, “Often”, “Very often”. If we numerate the extreme end-points of the scale at 0 and 90 respectively, then the scores for the symptoms prior to the intervention ranged from 45 (eye) to 56 (throat, stress).

NRC’s Green POE study also contains relevant data from occupants of 24 office buildings from across Canada and the northern US (Newsham, et al., 2013). Survey participants self-reported on eleven specific symptoms (smarting, itchy, or aching eyes; dry, irritated skin; teary eyes; dry eyes; sore back, wrists or arms; stuffy, congested, or runny nose; headache; sore, irritated throat; sensitivity to light; excessive fatigue; wheezing, chest tightness) were each assessed for frequency on a five-point scale: “Never”, “Very rarely”, “Monthly”, “Weekly”, “Daily”. Symptom scores were averaged into two symptom frequency categories: visual discomfort and physical discomfort. If we numerate the extreme end-points of the scale at 0 and 80 respectively, then the scores for the symptoms in the conventional building sample (N=480) ranged from 29 (visual) to 32 (physical). This lower range compared to Hongisto (Hongisto, et al., 2016) might represent methodological differences in scales or samples, or genuine differences between the study populations.

**Health and Well-being (symptoms): Effect of Better Buildings**
**↓5 – 9**

In Hongisto et al. (2016) the set of work environment improvements (including better environmental conditions and control, increased privacy, and more ergonomic furniture) were associated with a statistically-significant reduction in throat symptoms (p=0.031). Mean frequencies were reduced for all other symptoms, including a notable trend for reduced headache (p=0.051) suggesting a reliable reduction in symptoms overall. The size of the effects was equivalent to 4-9 points when rescaled to 0-100.

In Newsham et al. (2013), green buildings were associated with a statistically-significant reduction in both visual and physical symptom frequency, compared to conventional buildings. The size of the effects was equivalent to 7 (visual) and 5 (physical) points when rescaled to 0-100.

In MacNaughton et al. (2017), participants in green buildings reported 30 percent fewer sick building syndrome symptoms, compared to participants in similar conventional buildings, although data were not presented to allow conversion to a 100-point scale. Interestingly, participants in green buildings also reported better sleep quality, a finding that agrees with a similar beneficial association with green buildings reported by Newsham et al. (2013).

Marmot et al. (2006) studied the effect of the physical and psychosocial work environment on SBS symptoms and psychosocial work stress. Survey data were collected 4,052 UK civil servants in 44 buildings. A combined measure of workstation control (ability to adjust heat, artificial light, to open the

window, and fewer than 10 people in the room) was created. Greater workstation control was associated with a statistically-significant reduction in symptoms, although the format of symptom reporting precluded conversion to a 100-point scale.

**Health and Well-being (symptoms): Effect of Office Type**
**↓, but effect size not determined**

Pejtersen Allermann, Kristensen, and Poulsen (2006) studied indoor climate, the psychosocial work environment and occupants' symptoms in a cross-sectional survey in 11 naturally and 11 mechanically ventilated office buildings, with a variety of office types. The buildings were in Denmark, and included both public- and private-sector employers. Data were collected from 2,301 occupants. The format of symptom reporting precluded conversion to a 100-point scale; however, of 14 symptom types, all but two had a statistically-significant lower report frequency in cellular (private) offices compared to large, open offices.

Herbig, Schneider, and Nowak (2016) surveyed 207 office employees with similar jobs in two insurance company offices in Germany with different space occupation. A cumulative complaints measure combined four symptom categories (exhaustion, stomach, musculoskeletal, and heart complaints), each measured on a five-point Likert scales, ranging from 1 (none) to 5 (strong). The format of symptom reporting precluded conversion to the proposed 100-point scale, however, working in the open-plan office was associated with a statistically-significant increase in cumulative complaints (1.93 vs. 1.55).

**Health and Well-being (symptoms): Effect of Workplace Health Programs**
No relevant studies were identified.

**Health and Well-being (symptoms): Effect of Bonuses**
No relevant studies were identified.

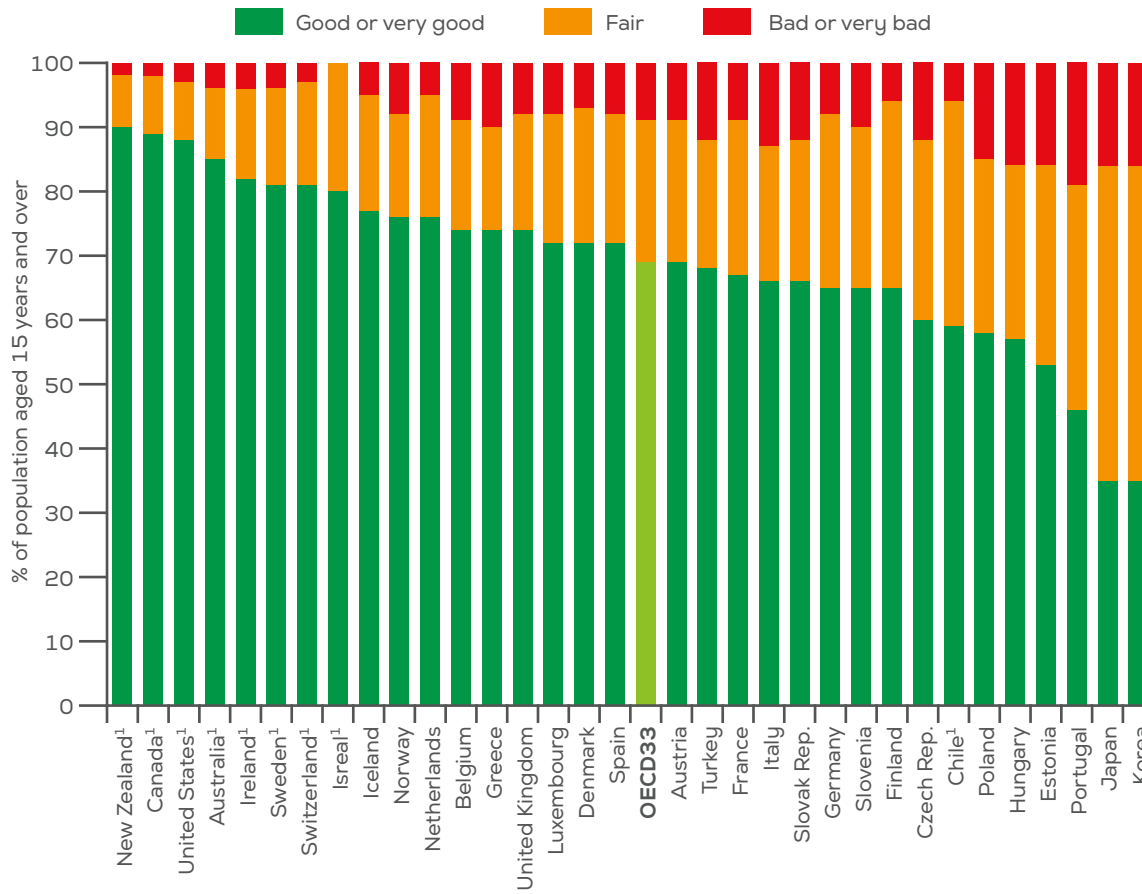
**Health and Well-being (symptoms): Effect of Flexible Work Options**
No relevant studies were identified.

**Health and Well-being (symptoms): Summary**
Better buildings strategies reduce symptom prevalence through multiple mechanisms. Private versus open-plan offices also reduce symptoms, though the effect could not be quantified on our chosen scale. Perhaps surprisingly, evidence of the effects of other workplace programs was not identified.

## 3.6 HEALTH AND WELL-BEING (OVERALL)

**Health and Well-being (overall): Benchmarks**
**55 – 75 (on a 100 point scale)**
The OECD publishes data on perceived health status for the most developed countries. Methodology varies by country, but it is generally based on a single item, such as asking respondents to rate their health as "excellent", "good", "fair", or "poor" (http://jech.bmj.com/content/59/5/342.full). The latest data, from 2013, is summarized in Figure 10 (http://www.oecd-ilibrary.org/sites/health_glance-2015-en/03/09/index.html?contentType=&itemId=%2fcontent%2fchapter%2fhealth_glance-2015-14-en&mimeType=text%2fhtml&containerItemId=%2fcontent%2fserial%2f19991312&accessItemIds=).

Figure 10. Overall health (self-rated) for OECD countries.




Results for these countries are not directly comparable with those fo other countries, due to methodological differences in the survey questionnaire resulting in an upward bias. In Isreal, there is no category related to fair health. Source: OECD Health Statistics 2015, http://dx.doi.org/10.1787/health-data-en (EU-SILC for European countries)

We used the following multipliers to convert this to a 0-100 scale: “Good or very good”=80; “fair”=50; “bad or very bad”=20. The result is shown in Table 8.

Table 8. Overall health (rescaled to 0-100) for OECD countries.

| | 0-100 Scale | | 0-100 Scale | | 0-100 Scale |
|---|---|---|---|---|---|
| New Zealand | 76.2 | United Kingdom | 69.6 | Slovak Rep. | 66.2 |
| Canada | 75.8 | Denmark | 69.3 | Slovenia | 66.2 |
| United States | 75.3 | Luxembourg | 69.1 | Italy | 66.1 |
| Australia | 74.5 | Greece | 69.0 | Chile | 65.8 |
| Ireland | 73.5 | Spain | 68.9 | Czech Rep. | 64.0 |
| Sweden | 73.1 | Israel | 68.0 | Poland | 63.2 |
| Switzerland | 73.1 | Austria | 67.9 | Hungary | 62.3 |
| Iceland | 71.2 | France | 67.6 | Estonia | 61.3 |
| Netherlands | 71.1 | Finland | 67.4 | Portugal | 58.3 |
| Norway | 70.4 | Germany | 67.0 | Japan | 55.8 |
| Belgium | 69.7 | Turkey | 66.8 | Korea | 55.7 |
| | | | | **OECD (33)** | **68.2** |

**Health and Well-being (overall): Effect of Better Buildings**

**↑6 – 10**

In this area of research, the typical format of questions on health invites a relative response based on the effect of the building in enhancing or degrading background health. In this respect, it is similar to the self-reported productivity-type questions.

Baird et al. (2012) also included a question on health in relation to building conditions: "Do you feel less or more healthy when you are in the building?" Responses were on a 7-point scale, with the mid-point (4) indicating neutrality. Conventional buildings had an overall rating of 3.29, whereas ratings of sustainable buildings were statistically-significantly higher at 4.25. If we apply the +/- 30 percent to numerate the endpoints of the scale, which is somewhat arbitrary and based on the self-reported productivity scale used in the same study, then this suggests an improvement of 10 points attributable to sustainable buildings.

In the study by Agha Hossein et al. (2013) employees were asked to what extent they agreed with the statement: "My current office environment already has a positive effect on my well-being" (physical and psychological health). Respondents used a 5-point scale from "strongly disagree" to "strongly agree", with the mid-point (0) indicating neutrality. The old office had a mean rating of -0.18, whereas the newly refurbished office had a statistically-significantly higher rating of 0.25. Again, if we assume this spans the same +30 to -30 percent scale, then this equates to a 6-point improvement in self-assessed health with the better building.

**Health and Well-being (overall): Effect of Office Type**

**↑11 – 12**

Bergstrom et al. (2015) used the Salutogenic Health Indicator Scale (SHIS) that included ratings of 12 health indicators during the past four weeks. The overall score on this scale was the sum of the responses to each item, each scored from 1-6, and thus the range of the outcome was 6-72. Prior to the move, occupants of private offices had an average rating of 49.6; 12 months after relocation to an open-plan office, the mean score had dropped to a statistically-significantly lower value of 41.5. Linearly rescaling these

values on a 100-point scale yields scores of 66 and 54, respectively, and an improvement associated with private offices of 12 points. However, the baseline value is a little low compared to the OECD benchmark for Sweden, which might signal methodological differences.

Herbig et al. (2016) surveyed 207 office employees with similar jobs in two insurance company offices in Germany with different space occupation. Mental well-being was measured with the World Health Organization Well-being Index (WHO-5), which includes five items to be answered on a six-point Likert scale, which range from 1 (at no time) to 6 (all of the time), assessed over the previous two weeks. Working in the open-plan office was associated with a statistically-significant decrease in mental well-being (3.69 vs. 4.27). Linearly rescaling these values on a 100-point scale yields scores of 54 and 65, respectively, and an improvement associated with private offices of 11 points. However, the baseline value is a little low compared to the OECD benchmark for Germany (but remarkably similar to the rescaled values from Bergstrom et al. (2015), which might signal methodological differences. One of these differences is that Herbig et al. (2016) addressed only the mental well-being component, whereas the benchmarks address physical as well as mental well-being.

Pejtersen et al. (2006) included single items on general health and mental health, each scored on a 0-100 scale. There was no statistically-significant difference between office sizes on either measure, and the mean score across the study population was 69 and 79, respectively. The general health score is very similar to the OECD benchmark for Denmark.

Seddigh, Berntson, Bodin Danielson, and Westerlund (2014) collected data from 1,241 employees from five organizations (both private- and public-sector) in Sweden. A single item measured general health: "How would you judge the state of your general health?" and the participants responded on a 5-point Likert scale (1 = very poor, 5 = very good). Cognitive stress was measured with the Copenhagen Psychosocial Questionnaire (COPSOQ); sample question: "How much of the time during the past 4 weeks have you found it difficult to think clearly?" scored on a 5-point rating scale (1= never, 5=always). There was no main effect of office type on general health, but private offices were associated with lower reported levels of cognitive stress (2.45 vs. 2.81). While this supports the general direction of the relationship from other studies, the cognitive stress question cannot be equated to even general mental health.

**Health and Well-being (overall): Effect of Workplace Health Programs**
**0, no effect**

Butterworth, Linden, McClay, and Leo (2006) collected data from 239 health care center workers in the US. One group self-selected into a program of health risk assessments, biometric screenings, support groups, health coaching, and other related offerings, focused on typical public health issues such as weight loss, fitness, stress, and nutrition. Two composite outcome scores were derived from responses to 12 survey questions: the Mental Composite Score (MCS), and the Physical Composite Score (PCS), each expressed on a 0-100 point scale. In an attempt to control for bias, 44 pairs of participants were matched. The effect of the treatment was not significant for the PCS, but there was a significant improvement of 3.5 points on the MCS. The baseline scores for the control group on these measures (PCS = 53.1, MCS=49.5) were low compared to the benchmark for the US, suggesting methodological differences in the scales.

Marzec et al. (2011) collected data from participants for 15 factors on a Health Risk Appraisal (HRA), one of which was perceived health. There was no statistically-significant change in this metric as a result of the wellness interventions. Neither was there an effect on self-reported stress; while there was a statistically-significant reduction on life dissatisfaction, there was also a statistically-significant increase in blood pressure.

Kuoppala et al. (2008) reviewed 46 studies, seven of which were conducted in an office setting. Results were not expressed in units scalable to our needs, and were not isolated by office environments only. The authors concluded that work health promotion had no effect on physical well-being.

Rongen et al. (2013) conducted a meta-analysis of 18 studies, five of which were conducted in an

office-like setting. Two of these included a measure of general health. One of these showed a significant positive effect of a WHP, whereas the other showed no effect.

Vuokko et al.'s (2015) study of asthma sufferers in Finland (N=43) included the RAND quality of life survey, scored on a 100-point scale, which comprised both physical and mental components. There was no effective improvement in these outcomes from the intervention. Pre-intervention, scores on these scales were in the range of 50-60. This is lower than the benchmark for Finland, but consistent with the fact that the participants had severe asthma.

Blake (2013) included a measure of general health and mood. Participants were asked to rate their general health on a six-point Likert scale (0 being very poor and 5 being excellent). The 12-item General Health Questionnaire (GHQ-12) was used to measure mood. There was no effect of the intervention on these measures.

**Health and Well-being (overall): Effect of Bonuses**

No relevant studies were identified.

**Health and Well-being (overall): Effect of Flexible Work Options**

**↓6**

Nijp et al. (2016) also included measures related to health. Fatigue was measured with three items: "I am bothered by fatigue", "I have enough energy for everyday life", and "Mentally, I feel exhausted", answered on a 4-point scale (1="almost never", 4="almost always"). Ten-point scales were also employed to assess to what extend they experienced stress (1="very little stress", 10="very much stress"), and health (1="very bad", 10="very good"). There was no statistically-significant effect of new ways of working (NWW) on fatigue. There were statistically-significant, but small effects on both fatigue and general health. Self-reported health actually got worse for the NWW group (pre-post: 7.47 vs. 7.04) compared to the control group (pre-post: 6.97 vs. 7.05). Linearly rescaling these values on a 100-point scale yields pre- scores of 72 and 66, respectively, very similar to the OECD benchmark for the Netherlands. Using a difference-in-differences method, the decrement associated with NWW was equivalent to six points.

**Health and Well-being (overall): Summary**

Better buildings strategies have a positive effect, and the upper end of the range of effect sizes coincides with the benefit of private versus open-plan offices. Surprisingly, we found that workplace health programs had no effect on this metric, and one study showing that flexible work options were associated with a decline in overall health.

## 3.7 COMPLAINTS TO THE FACILITIES MANAGER

No relevant studies pertaining to any organizational strategy were identified that could lead to suitable Matrix entries. For some KPIs, this is not surprising (there is no reason to expect that bonus pay would affect facilities complaints, for example). It is somewhat surprising not to find any studies addressing the effects of better buildings on facilities complaints.

Nonetheless, there exist a few reports that can provide some guidance for readers and further investigation. Federspiel (1998) analyzed complaint logs from more than 600 buildings in Texas and the midwest US. There were more than 4,000 complaints related to environmental conditions, and thermal sensation was the biggest single cause. Analysis suggested that most complaints were the result of poor control performance and heating, ventilation, and air-conditioning (HVAC) system faults, and that thermal sensation complaints took, on average, around two hours of technician time to resolve. In addition, they estimated that 71 percent of complaints could be eliminated via an upgrade to a modern Digital Data Control (DDC) system, with consequent savings in HVAC maintenance costs.

Further, Wang, Federspiel, and Arens (2005) established a statistically-significant correlation between dissatisfaction with the thermal environment and unsolicited complaints to the facility manager. They

collected summer and winter data from 45 US buildings. These data included occupant responses to a survey on thermal satisfaction administered by the researchers, and complaints (normalized by building size) registered in a maintenance call center. More complaints were registered in buildings with poorer thermal sensation scores.

**Notes**

1 We contacted the authors, but they were unable to provide the data in an appropriate format for our analysis.

2 Notably, the daylight harvesting system in office spaces was disabled after user complaints. A single sensor controlled multiple luminaires, which did not cater for very local variations in conditions (e.g., manual blind use).

3 The main effect of building type showed green buildings to be 4 percent higher on average. This effect was not statistically significant (p=0.09), but the magnitude is consistent with the effect sizes in the other "better buildings" studies in the previous sub-section.

# 4. DISCUSSION AND POSSIBLE NEXT STEPS

The Matrix is the main outcome of this project. The numbers in the Matrix represent our synthesis of available high-quality knowledge of the effects of various corporate programs on organizational productivity outcomes, and of available benchmark information. Our results are consistent in showing that, in general, "better buildings" approaches offer benefits across multiple metrics that are comparable in size to the benefits from other corporate programs. These better buildings approaches may be delivered via a BAS, or via a broader package of building enhancements that often included an enhanced BAS (e.g., green building certification). Whereas most of the other corporate strategies we studied have ongoing costs to the organization, most of the better building improvements would also lower building energy use, and some (e.g., lighting controls that reduce on-time; BAS systems that include fault detection and diagnostics) will reduce maintenance costs as well. Organizations that seek to improve their overall productivity would do well to consider these results in making strategic choices. The recently published Stoddart Review (The Stoddart Review, 2016) concurs that improvements to the physical environment in workplaces is an important, and under-recognized lever to increasing productivity. We propose that comparison to other corporate programs provides a more appealing and meaningful basis for many decision-makers to value "better buildings" approaches when making organizational investments.

The referenced studies support these findings for office workers in general, but the published data are not yet adequate to confidently differentiate effect sizes by industry type or employee demographics (e.g., age, generation, gender). The value of such effects will vary greatly by industry and employer, not just because of different potential effect sizes, but also due to differing employee compensation packages and output valuations.

Oseland and Burton (2012) noted that while most researchers acknowledge that there is a relationship between office design and environmental conditions and (organizational) productivity, the fact that it is difficult to quantify means that it is often simply ignored. Their approach was to conduct a meta-analysis of relevant studies, and to provide weighted-average "productivity" effects associated with several environmental factors, including: lighting, noise, temperature, ventilation, personal control, furniture, space, and combinations of multiple factors. They looked at 75 studies, and included studies in real workplaces as well as laboratories, and other reviews and surveys, but gave a greater weighting to studies from real offices. They also considered many productivity-related outcomes, including manual and cognitive tasks, self-assessed performance, absenteeism and retention, as well as real business outcomes, with a greater weighting given to outcomes considered to have a stronger relationship with real organizational output, and to the fraction of time actually spent on given tasks by office workers. Thus, they were more liberal in their inclusion criteria than we were, did not address the full range of KPIs that we addressed, and blended together several KPIs that we chose to keep separate. Nevertheless, their use of weightings did make a valuable attempt to temper some of the unrealistic productivity claims made by single studies that might have limited relevance to real-world settings. Their overall, single-factor effect was 1.7 percent (inter-quartile range 0.1-2.0).

Oseland and Burton (Oseland & Burton, 2012) also provided a case study in which they were able to use this meta-analysis to persuade decision-makers to value the effect of environmental improvements on organizational productivity in making an office retrofit decision. However, the decision-makers

in question were the employers of one of the authors of the meta-analysis and had sponsored the meta-analysis, and we have not seen evidence that this well-intentioned approach has been accepted more widely. We propose that our approach will be a more successful mechanism to engage decision-makers.

One striking difference in our results stands out: The data are very clear that cellular, private offices produce better outcomes than open-plan offices for most metrics, sometimes by a wide margin. Despite this evidence, it is clear from both anecdote and facilities usage data that open-plan offices dominate the market, and have done so for over thirty years (Brill, et al., 1984). Two explanations are often suggested as the reasons for the popularity of this office design: the increased occupant density reduces real-estate costs (for both renters and owners of their offices), and the belief (not supported by data (Brill et al., 2001; Veitch, 2012) that open offices will lead to desirable increases in collaboration and communication. Although the argument from real-estate costs seems like a rational one, the results for the other KPIs suggest that the overall organizational productivity consequence of abandoning private offices might not be what these organizations expect.

Perhaps the design choice has persisted because there have been few attempts to summarize the relevant KPIs and to relate them to benchmarks, as has been done here. The only metric typically used in relation to the workplace has been size, which has led to strategies that promote density, and thus a saving on the one metric used, rather than the well-being and performance of those inhabiting the space. Indeed, Oseland and Burton (2012) found that "... only one in eight organizations had productivity metrics in place and none monitored the relationship between the environmental conditions and business performance." Lacking metrics in this domain, organizations tend to focus on the real-estate costs of space, which are easily measured and monetized.

This is exacerbated by the classic split incentive problem, facilities management typically reports to the CFO/COO, with a motivation to cut costs, rather than to an executive with a responsibility for employee well-being or workflow optimization (The Stoddart Review, 2016). Indeed, the Stoddard Review goes as far as suggesting a new senior executive role of Chief Workplace Officer (CWO) to optimize the overlapping concerns of real estate and facilities, HR, and IT. The CWO would also be tasked with continuous workplace and work environment optimization, rather than this only being considered when a lease is renewed, which is currently typical.

The Leesman Index survey has now been administered to more than 100,000 employees in more than 1,000 workplaces in multiple countries, and aims to examine the fit between the work environment and the needs of the organization in terms of employee well-being and effectiveness (Leesman Ltd., 2016). Firstly, these data reinforce the enhanced performance of private offices compared to various forms of shared or open-plan settings. Secondly, the data identify physical features that carry high importance for office workers in creating an effective workplace, but generally have low levels of satisfaction, and which are related to other work cited in this report, these include: temperature control, air quality, access to natural light, and noise and visual distractions.

Our work has also highlighted some important research gaps, and supports a framework for future studies conducted with common methodology and reporting standards. The studies that underlie the Matrix come from different academic disciplines, used different methodologies and were reported in different ways. The goal of this work was to take a broad look at the available information across multiple metrics and domains, rather than a very deep look at a single element; the value of our work is in the comparisons it facilitates. Most Matrix numbers are based on a small number of studies that met our inclusion criteria, which facilitated comparison. As such, our work is not a formal meta-analysis, but is better considered as a more qualitative assessment with order-of-magnitude estimates of effects. To enable this broad look meant sacrificing some detailed statistical approaches to rescaling data from diverse studies, for example, in favour of expediency via straightforward (and sensible) assumptions; the project simply did not have the resources to take a more analytical approach. This is the first time such a broad look has been undertaken, and therefore our results should be seen as a starting point to support and inform future work to optimize the application of "better buildings" technologies.

It is noteworthy how few good studies there are conducted in real organizations and demonstrating effects that many in this field would have assumed were very well established. Although the directions of effects in the Matrix are almost always as hypothesized and in accordance with common sense[1], the size of the effects, and the range of workplaces in which they have been demonstrated, is limited. This is particularly the case if one looks only at very recent studies; many would argue that the pace of change in modern ways of working might render studies from more than a decade ago to be of lesser relevance. These few studies per cell in the Matrix tend to be consistent with one another; however, some cells are based on a single study, so new information could change the magnitude, and possibly the direction, of some effects.

The paucity of studies from real organizations likely reflects the challenge for researchers in conducting such work. Although, as the WGBC noted, much of the necessary data are already routinely collected, in some cases these data might be considered confidential by the host organization and thus not available for publication. It might also be the case that the longer timescales over which effects manifest themselves in such data is not compatible with the timescales that are meaningful to researchers. Studies in real organizations also present logistical challenges, although the recent explosion in means to handle data in electronic format can go some way to enabling researchers to study organizations housed in different cities. These observations may help to identify which researchers are more likely to be in a better position to pursue such work in the future.

There are several outcome metrics that have a high emerging profile among white-collar organizations, but which were not considered in this study because of the need to limit the scope to a manageable number of KPIs. One example of this is "employee engagement", which refers to an active state of enthusiasm for the job that includes behaviours that contribute to the organization's success. Some consider employee engagement to be more relevant to considerations of organizational productivity than the more generic concept of job satisfaction in that it represents a more active relationship between the employee and the employer[2]. There are industry surveys on engagement (e.g., Gallup; http://www.gallup.com/topic/employee_engagement.aspx), but this is a relatively new concept without a firmly established operational definition. One fruitful avenue for future work would be to establish a reliable and valid measure of employee engagement and to demonstrate its applicability to variations in building characteristics. Employee engagement could then be considered for inclusion as a standard element in post-occupancy evaluations of buildings and other workplace studies.

Another increasingly popular concept is creativity. We have heard several workplace designers speak of retrofitting office spaces to enhance creativity. There is a modest literature on this topic, which emphasizes the interplay of the physical and social environments to support creativity (Stokols, Clitheroe, & Zmuidzinas, 2002). Measuring creativity is a particular challenge, as it has different meanings and valuations in different industry sectors. Other concepts that managers and designers are often expecting to improve via workplace design are "communication" and "attraction" (of new employees). Again, an operation definition of communication is very context-specific, beyond the acoustic basics of speech intelligibility[3], the challenge is to define communication for what purpose? The purpose is likely the pre-cursor of other behavioural outcomes, which may differ substantially in relevance and importance between workplaces. How to measure the effect of workplace environmental conditions on attracting and recruiting new employees also remains to be defined, but has promise. The Stoddart Review (The Stoddart Review, 2016) reported that a survey of 520 HR professionals in the UK indicates that "... job candidates consider physical workplace a more important factor than leadership, CSR [corporate sustainability reports], technology and the diversity and inclusion agenda."

"Presenteeism" is yet another concept that is frequently discussed, its nomenclature contrasting with the largely well-understood concept of absenteeism, However, presenteeism is much more amorphous, relating in general to how effective, or "on task" someone is when physically at work. Its primary derivation relates to coming to work when sick (and when, perhaps, one should exhibit absenteeism) (Hemp, 2004), with potential causes including job insecurity, lack of paid leave, or excessive workload. However, in common parlance, the term has also become associated with other behaviours, such as

being at work and healthy but not actively engaged in activities of value to the organization, or spending more time at work than is needed for task completion or that is required by contract, to give the appearance of value to the organization. As this description suggests, it is still poorly defined, and is also difficult to measure. Its measurement relies on self-report by definition as it is not recorded by employees in HR records, and medical expenses are typically borne by the employees themselves, often via over-the-counter medications. It was not pursued as a KPI in this report as we know of no studies that have linked presenteeism to building characteristics or conditions. By some estimates, presenteeism is more costly to employers than absenteeism, and one can hypothesize relationships with building features; for example, ventilation systems might affect seasonal allergy symptoms (e.g., hay fever), space design might affect cold and flu transmission. Therefore, this represents another research gap worthy of exploration in future studies.

When the word "productivity" is mentioned in the context of the workplace the thoughts of many often turn immediately to the task performance of individuals. However, as we have explained above, this has become less relevant as the piece-work model has little applicability in the modern service-based economy, and when the broader interplay of a large array of input costs and output values are recognized. Hence our use of the term "organizational productivity" throughout the document to take the spotlight away from the performance of individuals and place it on the bigger picture. Nevertheless, the performance of individuals does have a role in the determination of organizational productivity. The challenge is how to measure both the quantity and the quality of this performance in the white-collar workplace? In particular, how could one measure these performance attributes in a universal sense that allows for comparison between studies and workplaces, rather than using a context-specific metric?

In this report, we have used self-reported productivity as a stand-in for individual performance because of its universality and accessibility, although we noted that it might be more representative of satisfaction with the environment in its ability to support work, rather than being a rational scale that correlates directly with the value of the individual's output. Given the diversity of tasks conducted by white-collar workers, another more universal measure is manager-assessed performance. This has the advantage of taking the subjectivity of the rating from the individual to a third-party observer well-placed to interpret the individual's performance in terms of its value to the employer. It is also a measure that is taken at least annually in most large organizations as part of broader employee evaluation and development exercises. One of the challenges for researchers is that such data are typically viewed as highly confidential, and therefore gaining access to these data, even on an anonymized basis, requires an unusual level of trust and a strong relationship between researcher and employer, as well as with the individual employees.

Comparing the effects of different corporate strategies on the same metrics required us to convert descriptive data from multiple studies onto a common scale. This necessitated numerous assumptions creating noise in the final outcomes. To take the example of job satisfaction, this is a widely accepted concept in workplace research and has been used in a very large number of studies for decades. Nevertheless, as a survey item, it has been measured in many different ways. In some cases the differences are subtle, but can still be expected to affect the results. Job satisfaction may be measured using a single question or derived from multiple questions; the wording of questions can differ or may have involved translation; respondents may be asked to consider different periods of time; or, there may be differences in the response scale (e.g., number of scale points, and label words on the scale). Comparisons across studies would be more reliable if the same measurement scales were used across the body of work.

In that vein, we encourage researchers concerned with understanding the effects of buildings on occupants to coalesce on a standard method of evaluating the metrics used in this report. One effective approach might be to use the question(s) used to derive applicable benchmarks. The advantage is that the benchmarks are likely to be maintained by national statistical organizations (or similar) over time as a point of reference, and themselves will undergo validity checks. If researchers have good reason to use another scale or to develop their own for a specialized purpose, we suggest they also use the more universal scale in parallel.

Another barrier to the effective comparison of studies was diverse standards of reporting. The studies we used were derived from the academic literature. As such, these studies are peer reviewed, and adhere to common basic principles of experimental design. Nevertheless, academic authors are not always attuned to what practitioners might need from their studies, focusing instead on an audience of their peers. This sometimes leads to reporting of results that leaves out some basic descriptive data, and in terms that are accessible only to academic experts. Several studies that met our other inclusion criteria fell short in this regard. For example, some studies did not report basic descriptive statistics such as means and standard deviations for their different study groups (e.g., treatment vs. control, pre-post intervention), and instead only provided effect sizes in various formats without enough information to derive means. This prevented us from deriving the straightforward main effects we were looking for (even prior to the rescaling issues above). We urge researchers to always include such descriptive information in their reporting. Very reasonably, some researchers are reluctant to report simple main effects as they might be misleading in deflecting attention from more valid interactions, moderating and mediating effects, etc. Nevertheless, if such work is to affect practice positively (which presumably is the ultimate purpose of research), results must be presented in a quantitative manner that is both meaningful and actionable by a practitioner. Recognition of main effects may be an appropriate stimulus to the exploration of more subtle interactions.

Although the Matrix presents a simple overview of main effects, the text of the report provides more details on the assumptions, limitations, and some examples of interactions and indirect effects. There is typically not enough information to untangle all of these effects, and no research team has looked at the full chain of relationships illustrated in Figure 3. Buildings researchers do not tend to look at HR outcomes (they focus on energy and comfort), and business or organizational psychology researchers do not look at effects of the built environment (they focus on pay and benefits, management style, workplace stressors, etc.). A study that addressed a broader set of outcomes and relationships simultaneously – covering the full chain from the built environment through to customer value – would make a landmark contribution to this field.

The effects listed in the Matrix should not be considered to be additive, that is, enacting two strategies cannot be expected to deliver the KPI benefits of the direct effects of the two strategies enacted separately. For clarity and simplicity, we have focussed on direct effects, but some cited studies did look at multiple effects and indirect effects. Nevertheless, we can expect a second positive strategy to have a positive effect, but that effect is likely not as great as if that strategy were applied first. There can be an expectation of "diminishing returns" (Oseland & Burton, 2012), if only because after one positive strategy has been applied successfully, there is then less room for improvement for a subsequent strategy.

There is also a strong need for longitudinal data and analysis. Many of the studies from real organizations that we can refer to are cross-sectional, and they often illustrate correlations. In most cases there are sensible hypotheses and mechanisms from which to imply causation, but these should be proven in future research[4]. This involves tracking data over a lengthy period of time, ideally several years, and looking at the ordering of interventions and changes in variables of interest.

Another important benefit of long-term data collection is to verify whether effects persist over time. To date it has been very difficult for researchers to have access to organizational data over a long-enough period to track the sequence of cause and effect, and to measure the persistence of any observed effects. This gap has been more prevalent on the buildings side than on the social science side. This inability to pursue long-term effects can be due to the host organization's commitment, or due to the researchers' own priorities and availability of support. One way to overcome this limitation could be to examine data that already exist for such work as a means to track effects over longer periods. Although BAS data are often not archived, data from HR departments are typically kept for long periods and might reveal valuable effects when mapped to changes in the built environment that occurred in the past during normal business practice (as opposed to research-driven interventions). It would be helpful to develop methods to efficiently and cost-effectively archive BAS data over the long term, so that it might be matched to parallel data streams from HR and other organizational data (e.g., customer satisfaction). This is

something we hope to be able to address in future phases of this CABA project. In fact, we have begun a relationship with a large multinational firm that gives us access to some of this kind of data, maybe we can leverage this, or something similar, in Phase 2.

One of the most surprising gaps in the literature was the lack of studies employing complaints to the facility manager as an outcome. Federspiel (Federspiel, 1998) noted at that time that he was "unable to find a single article published in the open literature that describes, documents, or analyzes unsolicited complaint data in buildings," and we were not able to find any new studies since. This is surprising because the data are routinely collected and archived in electronic format in most large organizations (or, more likely, by the third party that provides FM services), and it seems like such an obvious outcome for buildings researchers, with their historic focus on occupant comfort, to pursue. CABA and its members are very well positioned to unlock this data source at scale and make it available for research, and it would be particularly valuable if associated BAS data could also be provided. This is also an area in which a business case could be made in a relatively straightforward manner. Even excluding the (potentially large) benefits that lowering occupant discomfort might have for a range of organizational productivity metrics, responding to a complaint has tangible costs too, with both fixed ("truck roll") and variable (labour and parts to resolve the problem) components. Although these costs will also vary by context, they are likely easier to define, and may be accepted more broadly, than the financial counterparts of other outcomes. It is a straightforward hypothesis that better buildings (or changes to office type, or flexible work options) would lower complaints and thus direct FM costs.

A category of "better buildings" approaches that we were not able to include in this report might be most easily thought of as cell-phone enabled apps that integrate with various aspects of a BAS. These might include location-enabled lighting or HVAC, context-aware room booking and printer assignment, or streamlined parking and access systems. Many such systems are being trialled around the world[5], but a meaningful body of validated studies related to the KPIs in this report are not yet available to be cited. Given the expected influence of such systems in the future workplace, the lack of documented evidence of their effect may be considered an important research gap worth closing.

The growth of IT in the workplace also raises interesting opportunities for new ways of measuring the KPIs in this report, or developing new metrics of value to organizational productivity, but which were previously inaccessible. This might include data from fixed locations or on objects that form the "Internet of Things" (IoT), or from mobile devices carried by the occupants themselves. In the latter category are the almost ubiquitous smartphones, of course, but also the rapidly-growing category of wearables, which in the consumer market is being driven personal health tracking. In the past, researchers would have required funding to develop such sensors, and the co-operation of office workers to wear them for research purposes – now employees are putting them on themselves, and there is great potential to leverage such data for business and building operations purposes, with appropriate consent and privacy safeguards. For example, by one estimate, by 2018 at least 13 million wearable workplace devices will be integrated into wellness programs (The Stoddart Review, 2016). Such data might be used to monitor occupancy and to target and personalize building services, to develop spatial communication maps, to populate high-granularity charts of local environmental conditions, to relate workplace locations or events to stress reactions, to understand where people spend time in non-assigned workplaces; these are just examples, there are surely many more possibilities.

New LED lighting systems provide an intriguing potential future platform for added value in this domain. Office spaces have to have some form of electric lighting anyway, this will be based on LED technology in most new installations, and increasingly these LED luminaires are networked, may be powered over Ethernet, and carry integrated environmental sensors. Thus a high-resolution map of temperature, light and motion information can be developed using a building system that has to be there anyway; i.e., without adding another, dedicated system[6]. Nevertheless, the value of such data in improving organizational KPIs has yet to be proven. Another potential feature of some LEDs is the ability to dynamically change the spectral content of the light they deliver. The quantity and spectral content of light has been linked to human health. While there are several pathways, the one most

commonly referenced is through the regulation of circadian rhythms and related hormone expression (Commission Internationale de l'Eclairage (CIE), 2004/2009). It is hypothesized that modulating light level and spectrum during the day, to support circadian rhythm regularity, could deliver health benefits to the office worker population. However, such benefits have yet to be conclusively demonstrated in this context[7].

Although we used the substantial bibliographic resources and professional library staff available to us at NRC, in the time available we cannot guarantee to have found every relevant study. It is also important to recognize that just because specific technologies and operational practices exist in office buildings does not mean that there is a well-documented, objective study of the performance of that technology/practice, and with results in a format that we can use. Indeed, one outcome of this project is to identify topics where new research should be focused, as discussed above.

**Notes**

1 Although there are several examples where strategies expected to have a straightforward positive effect were shown to have no effect in a substantive number of studies; e.g., effect of WHP on overall Health & Well-being.
2 One could be satisfied with one's job while contributing little to the organization!
3 Presumably to optimize the audibility of sources of valuable speech communication, while reducing the impact of sources of distracting and unwanted speech – a challenge given that the same team member might represent both source types at different times, and that both types of source could be spatially co-mingled.
4 Some, but not many, studies have shown this, for example, bigger bonuses paid in one year are associated with improved job performance the following year, but the opposite relationship is not true.
5 The Edge building in Amsterdam is one such example, supported by Philips technology and with major tenant Deloitte: http://www.lighting.philips.com/main/cases/cases/office/edge.html
6 Again, The Edge building is an early example of this.
7 The suggested relationship was noted by MacNaughton et al. (2017): "Not surprisingly, our study suggests that previous night's sleep is a driver of cognitive function scores. More interesting is that better Sleep Scores were associated with better lighting conditions in the building."

# 5. CONCLUSIONS

In this report we have successfully demonstrated that better buildings strategies (e.g., improved ventilation, enhanced lighting conditions, green building certification measures) provide benefits to multiple organizational productivity metrics at levels similar to other corporate strategies. This supports the greater consideration and deployment of better buildings strategies as measures to improve organizational productivity beyond energy savings.

As such, this report provides a framework by which vendors of "better buildings" technologies and their clients can value the effects of these technologies on organizational productivity metrics. In most cases, the better buildings approaches addressed are facilitated by advanced building automation systems (BAS) and lighting control systems, or are whole-building strategies (e.g., green building certification) that typically include superior BAS features and lighting conditions.

We leveraged new, multi-metric approaches to defining organizational productivity that have been peer-reviewed by international experts, and published by respected industry organizations. The metrics used in this report are: absenteeism, employee turnover intent, self-assessed performance, job satisfaction, health and well-being (symptoms and overall), and complaints the facilities manager. We developed benchmarks for each of these metrics, and compared the effects of better buildings strategies to other, commonly understood and practiced corporate strategies typically deployed to improve these same metrics. These strategies include: office type (private versus open-plan), workplace health programs, bonuses, and flexible work options.

Our results were derived from an exhaustive review and synthesis of high-quality published information from several disciplines, based on research conducted in real organizations in large office, or "office-like" buildings. In total, more than 4,000 abstracts, and 500 full publications were reviewed.

Despite the breadth of our search, the number of good-quality studies in this domain is relatively small, which is surprising given the importance of the office environment to so many people's lives. Therefore, our study highlights the need for more multi-disciplinary research in this domain. We also identified several specific research gaps that are deserving of more attention:

- The need to develop reliable ways to measure concepts with a high emerging profile among white-collar organizations, including: employee engagement, creativity, new employee attraction, internal communication effectiveness, and presenteeism.
- The need to develop new ways of measuring in a relevant way both the quantity and the quality of white collar work. In particular, how could one measure these performance attributes in a universal sense that allows for comparison between studies and workplaces, rather than using a context-specific metric?
- The desirability for researchers to coalesce on common scales to measure key metrics.
- The desirability for researchers to report their studies in a way that facilitates comparison, and is attuned to what practitioners might need from their studies. This includes reporting basic descriptive statistics, and to be clear in describing the differences in study groups.
- There is also a strong need for longitudinal data and analysis, to inform both causality of relationships between strategies and outcomes, and to assess the persistence of effects.

- The potential to use archived data on complaints to the facility manager to develop business cases around better buildings strategies.
- The full potential for the Internet of Things (IoT), including wearable devices, to assist in the measurement of existing metrics, or to be a platform on which to develop new metrics, is still in its infancy.

This report represents the first phase of what we propose to be a three-phase project with CABA and its members to tackle the complex problem of valuing the effects of better building technologies and operations on organizational productivity.

The strategic goals of the phased project are to:

- Demonstrate that intelligent building technologies and operations (within the broader context of "better buildings") produce organizational productivity gains (expressed via multiple metrics), in addition to energy savings.
- Demonstrate that these gains are realized via specific improvements in indoor environment conditions.
- Identify the specific technologies and operational improvements that are most likely to deliver benefits.
- Provide results in a format that allows organizations to assign a value to the full benefits of better buildings.

In closing this Phase 1 of the project we will use the success and the enthusiasm of our existing CABA partners to build a consortium of interested parties and to launch Phase 2 in 2017.

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# APPENDIX B: SUPPLEMENTARY ABSENTEEISM DATA

Data on sickness absence by industry are available for several other countries, including Norway and Sweden, whose overall rates were not available in the OECD database. Data for 2013 was obtained from: http://norden.diva-portal.org/smash/get/diva2:811504/FULLTEXT06.pdf, and is shown in Table A.1.

Table B1. Absenteeism data for Scandinavian countries.

| Sector | Days/person/year | | |
|---|---|---|---|
| | Norway | Denmark | Sweden |
| *Private* | *12.8* | *7.3* | *5.5* |
| *Government* | *12.2* | *7.9* | *5.2* |
| *Municipality* | *17.0* | *12.8* | *9.1* |
| | | | |
| NACE sector | | | |
| Agriculture, forestry and fishing | 11.6 | 11.6 | 4.2 |
| Manufacturing, mining and quarrying services | 11.5 | 7.8 | 4.6 |
| Construction | 13.2 | 7 | 4.7 |
| Trade and transport, etc. | 14.2 | 7.5 | 5.1 |
| Information and communication | 9.3 | 5.7 | 3.2 |
| Financial and insurance | 9.1 | 7 | 4.2 |
| Real estate | 11.6 | 7.5 | 5.7 |
| Other business services | 11.0 | 7.2 | 5.5 |
| Public administration, education and health | 15.6 | 11.6 | 7.6 |
| Arts, entertainment and other services | 14.0 | 7.9 | 5.8 |
| (Activity not stated) | 12.6 | 9.6 | 9.7 |

Data from Switzerland for 2015 was obtained from: http://www.bfs.admin.ch/bfs/portal/en/index/themen/03/02/blank/key/arbeitszeit0/absenzen.html, and is shown in Table A.2. Note that the Swiss numbers may be inflated compared to other countries due to the inclusion in these absence data of the following categories, which are often excluded in other data: maternity leave, military or community

service, civil defence, reduction of working hours, labour dispute, personal or family reasons and bad weather.

Table B2. Absenteeism data by industry, for Switzerland.

| NOGA branch of economic activity | Days/person/year |
|---|---|
| Agriculture, forestry and fishing | 9.3 |
| Manufacturing, Mining and quarrying | 9.2 |
| Construction | 12.0 |
| Trade | 9.9 |
| Transportation and storage | 10.4 |
| Accommodation and food service activities | 7.5 |
| Information and communications | 6.8 |
| Financial and insurance activities | 9.1 |
| Real estate activities, admin. and support serv. activities | 11.3 |
| Prof., scientific and tech. activities | 10.1 |
| Public administration and defence | 8.4 |
| Education | |
| Human health and social work activities | 11.5 |
| Arts, other service activities | 9.9 |
| **Total** | **9.6** |

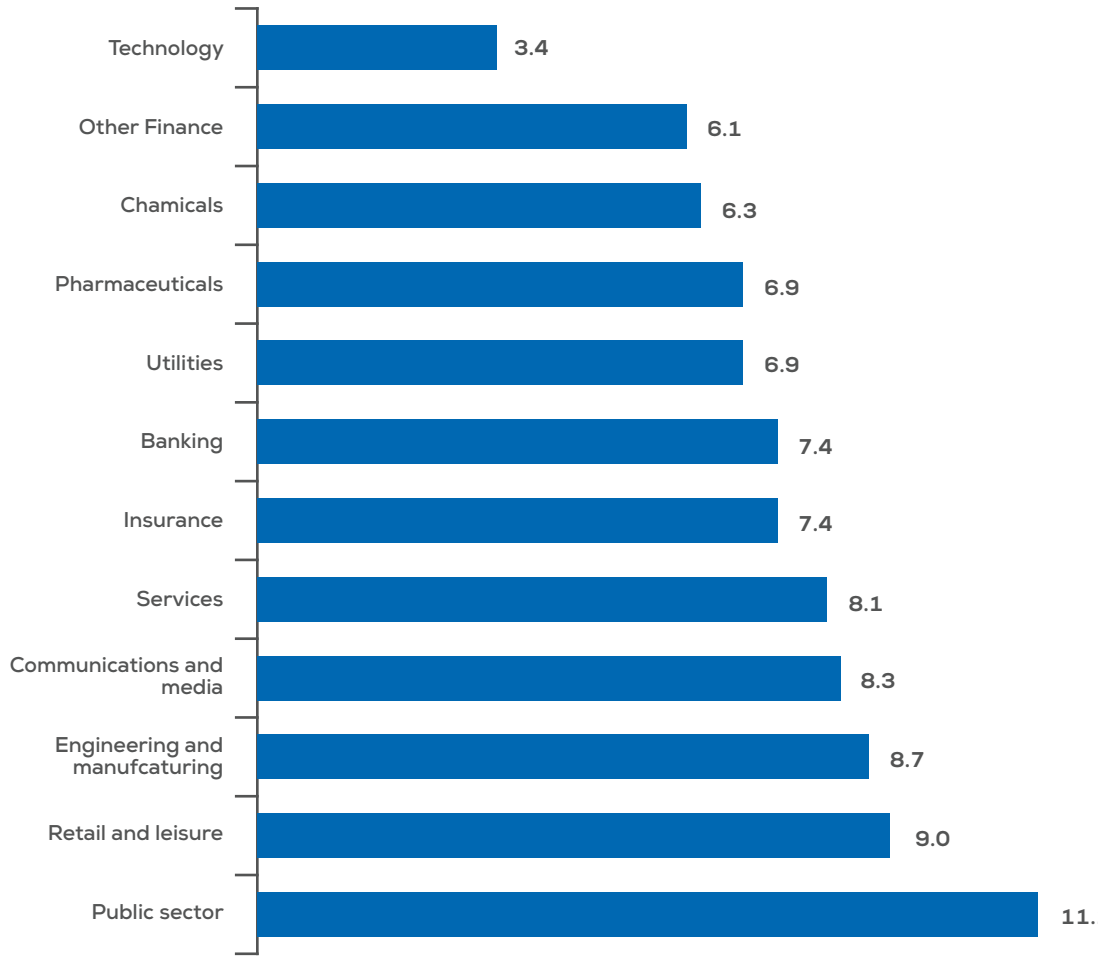
Calculated assuming 7.5 hr working day

We found two different sources for industry-specific data in the UK for 2013. The first came from a national statistical body (http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/dcp171776_353899.pdf), and the second from an industry survey (http://www.pwc.co.uk/services/human-resource-services/insights/the-rising-cost-of-absence-sick-bills-cost-uk-businesses-29bn-a-year.html), and is shown in Table A.3 and Figure A.1.

Table B3. Absenteeism data by industry, for the UK.

| Sector/Occupation Type | Days/person/year |
|---|---|
| Caring, Leisure and Other Service Occupations | 8.4 |
| Elementary Occupations | 6.6 |
| Process, Plant and Machine Operatives | 6.3 |
| Administrative and Secretarial Occupations | 5.6 |
| Sales and Customer Service Occupations | 5.5 |
| Professional Occupations | 4.7 |
| Associate Professional and Technical Occupations | 4.5 |
| Skilled Trades Occupations | 4.4 |
| Managers and Senior Officials | 3.4 |

Figure B1. Absenteeism data for various UK industries.



# APPENDIX C: SUPPLEMENTARY EMPLOYEE TURNOVER DATA

Actual voluntary turnover data by industry is readily available for Canada, the US, and the UK, from various sources, and we show examples in Tables B1-3. The sources for these data are: Canada ("Voluntary and Involuntary Turnover Rates, by Sector and Industry," Compensation Planning Outlook 2014, Conference Board of Canada, http://www.conferenceboard.ca/e-library/abstract.aspx?did=5737); US (Voluntary Turnover, Compensation Force 2015, http://www.humanresourcestoday.com/industry/survey/?openarticle-id=4885778&article-title=2015-turnover-rates-by-industry&blog-domain=compensationforce.com&blog-title=compensation-force); UK (CIPD 2013 Survey, https://www.cipd.co.uk/Images/resourcing-and-talent-planning_2013_tcm18-11302.PDF, Table 19). Where applicable, we have highlighted rows in the tables representing industries more likely to be relevant to the office building focus of this report.

Table C1. Actual turnover data by industry, for Canada (2013).

| Voluntary Turnover Rates, by Sector and Industry | |
|---|---|
| | % |
| Overall | 7.3 |
| **By sector** | |
| Private sector | 8.1 |
| Public sector | 5.1 |
| **By industry** | |
| Natural resources, excluding oil and gas | 6.8 |
| Oil and gas | 6.0 |
| Manufacturing | 5.0 |
| Food, beverage, and tobacco products | 6.5 |
| Chemical, pharmaceutical | 4.5 |
| Construction | 15.6 |
| High technology | 6.3 |
| Communications and telecommunications | 5.9 |
| Transportation | 4.5 |
| Finance, insurance, and real estate | 7.0 |
| Wholesale trade | 8.4 |

| Voluntary Turnover Rates, by Sector and Industry | |
|---|---|
| Retail trade | 20.6 |
| Education | 4.3 |
| Government | 4.9 |
| Not-for-profit | 8.3 |
| Services–accommodation, food, personal | 10.0 |
| Professional services | 14.6 |
| Utilities | 5.0 |
| Health | 6.8 |
| Scientific and technical services | 11.9 |

Table C2. Actual turnover data by industry, USA (2015)

| Voluntary Turnover Rates, by Sector and Industry | |
|---|---|
| | % |
| **All Industries** | **11.6** |
| Banking and Finance | 14.2 |
| Healthcare | 14.2 |
| Hospitality | 17.8 |
| Insurance | 8.8 |
| Manufacturing and Distribution | 9.1 |
| Not-for-Profit | 11.6 |
| Services | 9.0 |
| Utilities | 6.1 |

Table C3. Actual turnover data by industry, UK (2013)

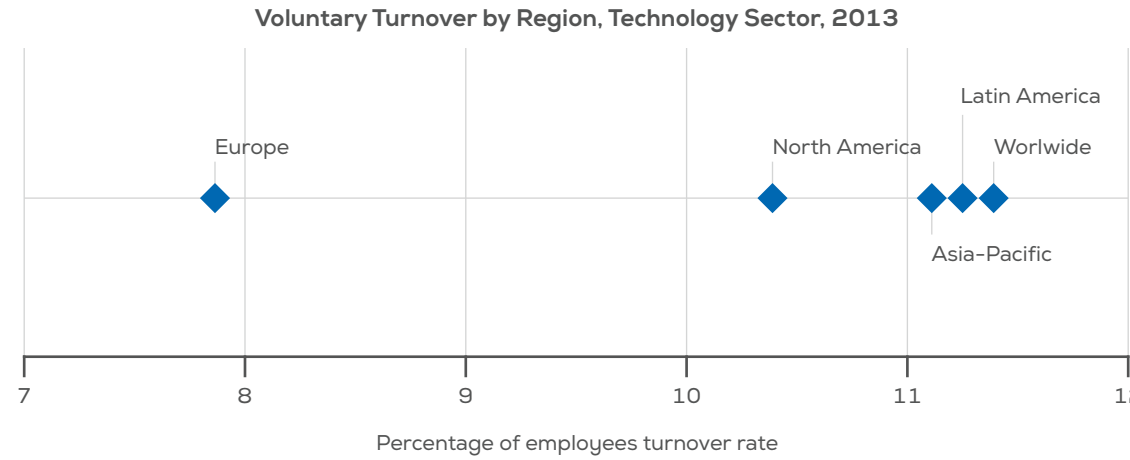
| | Voluntary Turnover Rates, by Sector and Industry, % | | | | |
|---|---|---|---|---|---|
| | 2009 | 2010 | 2011 | 2012 | 2013 |
| Manufacturing and Production | 7.7 | 2.7 | 3.7 | 4.5 | 3.1 |
| Private sector services | 10.4 | 7.4 | 8.7 | 8.9 | 11.8 |
| Public Sector | 7.6 | 5.8 | 3.4 | 1.9 | 4.2 |
| Not-for-Profit | 11.0 | 10.2 | 7.0 | 7.6 | 6.6 |

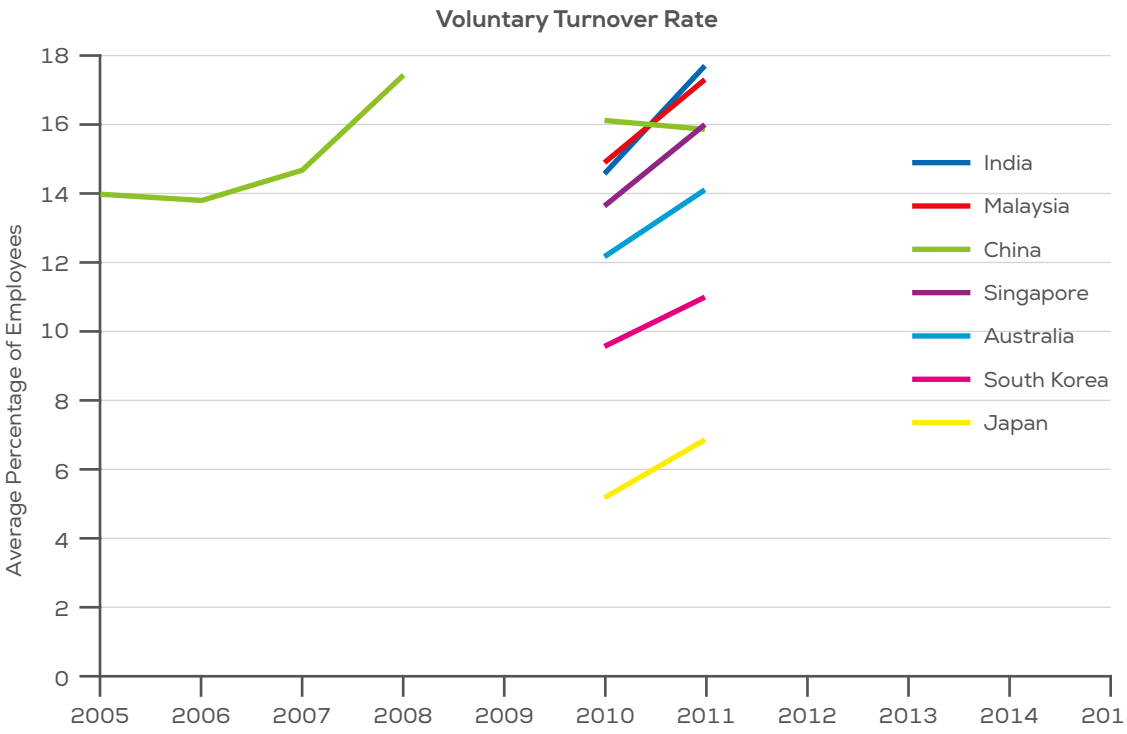
These rates are generally consistent with those shown in Figure 7. Additional "quit" data for the USA is available from the US Bureau of Labor Statistics (https://www.bls.gov/news.release/jolts.t04.htm); this source is highly detailed by industry and over time. However, the annual rates are substantially

and systematically higher than the rates quoted in other sources, and suggest a different definition or methodology.

Voluntary turnover data specific to the technology sector is available by region, and for a sample of countries worldwide, from: https://www.radford.com/home/insights/articles/2014/emea_tech_europe_leads_in_workforce_stability.asp; http://itactalent.ca/wp-content/uploads/hr-forum/2013-Oct-17-2013-2014-Compensation-Trends-Trista-Straver.pdf and illustrated in Figure B.1. These rates are generally consistent with those shown in Figure 7. These data suggest that turnover rates are typically, though not universally, higher in emerging economies.

Figure C1. Voluntary turnover rate for technology workers, for various regions and countries, and over time.



# APPENDIX D: TRANSLATING VARIOUS STUDY RESULTS FOR INTENT TO TURNOVER TO COMMON 0-100 SCALE

In the University of Chicago General Social Survey the question asked was: "Taking everything into consideration, how likely is it you will make a genuine effort to find a new job with another employer within the next year?" (http://www.cdc.gov/niosh/topics/stress/pdfs/qwl2010.pdf, Q 5.63), with a three-point response scale: "Not at all likely", "Somewhat likely", "Very likely". Shown below is the distribution of the responses across the three response scales, and our assignment of the response labels to the normalized 0-100 scale. The mean score is then = ((2818*0)+(969*40)+(831*80))/(2818+969+831) = 23.

| Scale | Not at all likely | | | | Somewhat likely | | | | Very likely | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0-100** | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| **Frequency** | 2,818 | | | | 969 | | | | 831 | | |
| **Mean Score** | 23 | | | | | | | | | | |

In the University of Michigan Work, Family, and Health Study two questions were relevant: "You are seriously considering quitting ^FCOMPANY for another employer" and "During the next 12 months, you will probably look for a new job outside ^FCOMPANY" (http://www.icpsr.umich.edu/cgi-bin/file?comp=none&study=36158&ds=0&file_id=1190655&path=DSDR), each with a five-point response scale: "Strongly Disagree", "Disagree", "Neither", "Agree", "Strongly Agree". We used the mean response to these two questions. Shown below is the distribution of the responses across the response scales (note that because we are averaging two responses, the responses from individuals may fall between the response categories from single questions), and our assignment of the response labels to the normalized 0-100 scale. The mean score is then = ((2439*0)+(744*13)+(2401*25)+(928*38)+(1184*50)+(572*63)+(469*75)+(170*88)+(241*100)/(2439+744+2401+928+1184+572+469+170+241 = 30.

| Scale | Strongly Disagree | | Disagree | | Neither | | Agree | | Strongly Agree |
|---|---|---|---|---|---|---|---|---|---|
| 0-100 | 0 | 13 | 25 | 38 | 50 | 63 | 75 | 88 | 100 |
| Frequency | 2,439 | 744 | 2,401 | 928 | 1,184 | 572 | 469 | 170 | 241 |
| Mean Score | 30 | | | | | | | | |

In the Japanese General Social Survey the question asked was: "Are you considering quitting your current job (your business)?" (http://www.icpsr.umich.edu/cgi-bin/file?comp=none&study=34623&ds=1&file_id=1182229&path=ICPSR; WLKEEPJA), with a three-point response scale: "I am not considering quitting at all", "I am not considering quitting (now)", I am considering quitting in the near future". Shown below is the distribution of the responses across the three response scales, and our assignment of the response labels to the normalized 0-100 scale. The mean score is then = ((1465*0)+(1319*30)+(213*70))/( 1465+1319+213) = 18.

| Scale | I am not considering quitting at all | | | I am not considering quitting (now) | | | | I am considering quitting in the near future | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-100 | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Frequency | 1,465 | | | 1,319 | | | | 213 | | | |
| Mean Score | 18 | | | | | | | | | | |

In NRC's Green POE study, three questions were asked: "I am planning to search for a new job outside of this organization during the next 12 months", "I often think about quitting this job", "If I have my own way, I will be working for this organization one year from now", each with a seven-point response scale: "Strongly Disagree", "Moderately Disagree", "Slightly Disagree", "Neither Agree nor Disagree", "Slightly Agree", "Moderately Agree", "Strongly Agree". We used the mean response to these three questions (final question reverse coded). We coded "Strongly Disagree"=0, and "Strongly Agree"=100. The mean value of the mean responses from all individuals was 2.69 on a 1-7 scale; the mean score on the 0-100 scale is then = 100*((2.69 - 1)/6) = 28.

# APPENDIX E: SUPPLEMENTARY JOB SATISFACTION DATA

Additional job satisfaction data are available from another Gallup survey, the Soul of the Community survey (http://www.icpsr.umich.edu/icpsrweb/NADAC/studies/35532). Data are available from 2008-2010, based on ~6,700-7,500 (depending on the year) respondents in specific US communities. Responses suggest an average job satisfaction of 80-81 on a 0-100 scale. This is considerably higher than other US sources, including Gallup itself, and might illustrate differences in methodology or sampling.

# APPENDIX F: TRANSLATING VARIOUS STUDY RESULTS FOR JOB SATISFACTION TO COMMON 0-100 SCALE

In the University of Chicago General Social Survey the question asked was: "All in all, how satisfied would you say you are with your job?", with a four-point response scale: "Not at all satisfied"; "Not too satisfied"; "Somewhat satisfied"; "Very satisfied". Shown below is the distribution of the responses across the four response scales, and our assignment of the response labels to the normalized 0-100 scale.

| Year | Mean score | Scale | Not at all satisfied | | | Not too satisfied | | | Somewhat satisfied | | Very satisfied | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0-100 | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 2002 | 66 | Freq. | 61 | | | 134 | | | 707 | | 872 | | |
| 2006 | 65 | Freq. | 55 | | | 110 | | | 770 | | 786 | | |
| 2010 | 65 | Freq. | 40 | | | 94 | | | 503 | | 524 | | |
| 2014 | 66 | Freq. | 36 | | | 87 | | | 505 | | 615 | | |

In the University of Michigan Work, Family, and Health Study three questions were relevant: "In general, you like working at your job", "In general, you are satisfied with your job", "You are generally satisfied with the kind of work you do in this job", each with a five-point response scale: "Strongly Disagree", "Disagree", "Neither", "Agree", "Strongly Agree". We used the mean response to these three questions. Shown below is the distribution of the responses across the response scales (note that because we are averaging three responses, the responses from individuals may fall between the response categories from single questions), and our assignment of the response labels to the normalized 0-100 scale.

| Scale | Strongly Disagree | | | Disagree | | | Neither | | | Agree | | | Strongly Agree |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-100 | 0 | 8 | 16 | 25 | 33 | 41 | 50 | 58 | 66 | 75 | 83 | 91 | 100 |
| Frequency | 20 | 18 | 25 | 108 | 98 | 201 | 313 | 639 | 799 | 3,213 | 979 | 798 | 1,977 |
| Mean Score | 69 | | | | | | | | | | | | |

In the Japanese General Social Survey the question asked was: "On the whole, how satisfied are you with the (main) job you have?", with a five-point response scale: "Dissatisfied"; "Somewhat dissatisfied"; "Neither satisfied nor dissatisfied"; "Somewhat satisfied"; "Satisfied". Shown below is the distribution of the responses across the five response scales, and our assignment of the response labels to the normalized 0-100 scale.

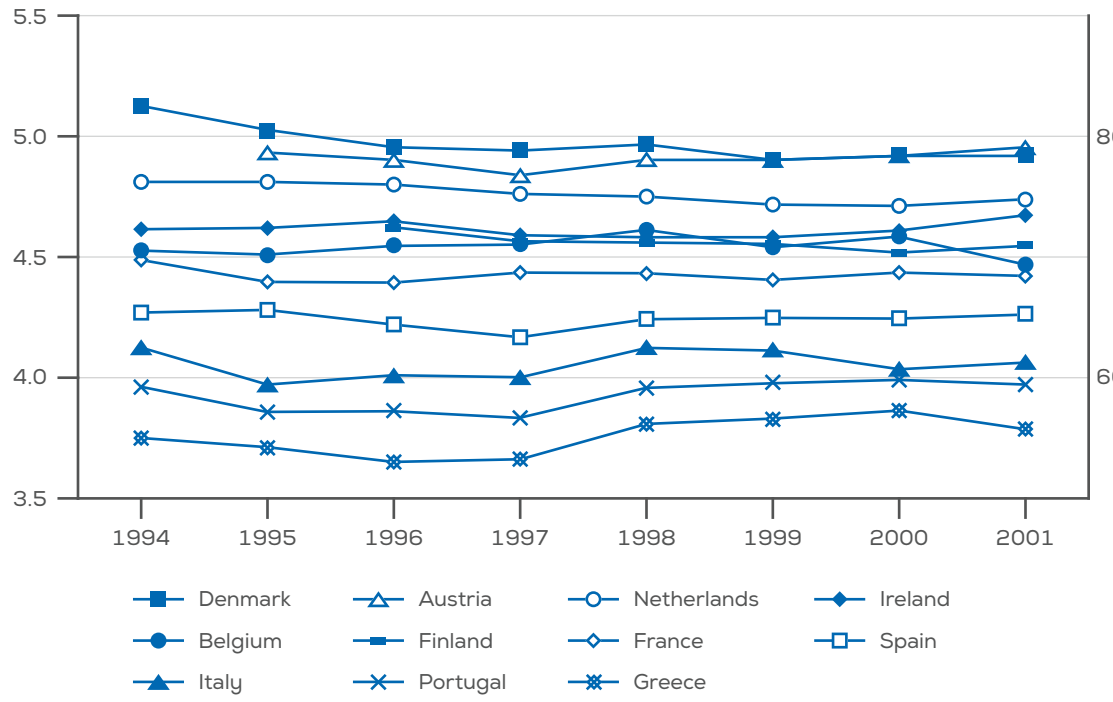
| Scale | Dissatisfied | | | Somewhat dissatisfied | | Neither satisfied nor dissatisfied | | Somewhat satisfied | | Satisfied | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-100 | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Frequency | 82 | | | 228 | | 719 | | 1,231 | | 812 | |
| Mean Score | 66 | | | | | | | | | | |

The data from Europe was a single question referring to the respondent's opinion/feeling about the degree of satisfaction with his/her job (http://ec.europa.eu/eurostat/documents/1012329/6071326/2013_Module_Well-being.pdf/93ac2517-f6ac-4ed5-8c42-ca89568ea5c9). Response was on an 11-point scale, from 0 (Not at all satisfied) to 10 (Completely satisfied). We simply multiplied the mean values from each country by 10 to scale responses to the normalized 0-100 scale. Shown below are the values for all countries in the study.

| | Job satisfaction (scale 0-10) |
|---|---|
| Bulgaria | 6.0 |
| Serbia | 6.0 |
| Greece | 6.1 |
| Germany | 6.9 |
| Spain | 6.9 |
| Croatia | 7.0 |
| Italy | 7.0 |
| Portugal | 7.0 |
| United Kingdom | 7.0 |
| **European Union (28 countries)** | 7.1 |
| Hungary | 7.1 |
| Romania | 7.1 |
| Ireland | 7.2 |
| France | 7.2 |
| Cyprus | 7.2 |
| Slovakia | 7.2 |
| Estonia | 7.3 |
| Latvia | 7.3 |
| Poland | 7.3 |
| Slovenia | 7.3 |
| Czech Republic | 7.4 |
| Belgium | 7.5 |
| Lithuania | 7.5 |
| Luxembourg | 7.5 |
| Malta | 7.5 |
| Netherlands | 7.7 |
| Sweden | 7.7 |
| Switzerland | 7.9 |
| Austria | 8.0 |
| Iceland | 8.0 |
| Norway | 8.0 |
| Denmark | 8.1 |
| Finland | 8.1 |

In an analysis entitled "Job Satisfaction in Europe" by Ahn & Garcia (https://web.ua.es/jelalicante/Ahn-Garcia.pdf), data from the European Community Household Panel (ECHP) Survey were examined over multiple years (1994-2001). The respondents in the ECHP were asked "How satisfied are you with your present situation in your work or main activity?" with 6 possible response categories ranging from "very dissatisfied" (=1) to "fully satisfied" (=6). The mean responses for various countries over time, on the original scale, and rescaled to 0-100 (very dissatisfied=0 to fully satisfied=100), are shown in Figure E.1. These values appear to be largely consistent with other data.

Figure F1. Job satisfaction data over time, for various European countries.




The European Social Survey (http://nesstar.ess.nsd.uib.no/webview/index.jsp?v=2&submode=abstract&study=http%3A%2F%2F129.177.90.83%3A80%2Fobj%2FfStudy%2FESS7e02.0&mode=documentation&top=yes; http://www.europeansocialsurvey.org/data/), included the single question "All things considered, how satisfied are you with your present job?". Response was on an 11-point scale, from 0 (Extremely dissatisfied) to 10 (Extremely satisfied). Responses were received from 23,109 respondents in the general population, and shown below is the distribution of these responses. We simply multiplied the mean values from each country by 10 to scale responses to the normalized 0-100 scale. The overall mean value was 71, which is consistent with other data.

| Scale | Extremely dissatisfied | | | | | | | | | | Extremely satisfied |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 0-100 | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Frequency | 263 | 219 | 452 | 773 | 813 | 2,283 | 2,219 | 4,157 | 5,898 | 3,413 | 2,619 |
| Mean Score | 71 | | | | | | | | | | |

In NRC's Green POE study a single question was asked: "Taking everything into consideration, what is your degree of satisfaction with your job as a whole?", with a seven-point response scale: "Very Unsatisfactory", "Unsatisfactory", "Somewhat Unsatisfactory", "Neutral", "Somewhat Satisfactory", "Satisfactory", "Very Satisfactory". We coded "Very Unsatisfactory"=0, and "Very Satisfactory"=100. The mean value of the mean responses from all individuals was 5.60 on a 1-7 scale; the mean score on the 0-100 scale is then = 100*((5.62 - 1)/6) = 77.

In NRC's COPE study a single question was asked: "Please indicate your degree of agreement or disagreement with the following statement ... I am satisfied with my job", with a seven-point response scale: "Very Strongly Disagree", "Strongly Disagree", "Disagree", "Neither Agree nor Disagree", "Agree", "Strongly Agree", "Very Strongly Agree". We coded "Very Strongly Disagree"=0, and "Very Strongly Agree"=100. The mean value of the mean responses from all individuals was 5.09 on a 1-7 scale; the mean score on the 0-100 scale is then = 100*((5.09 - 1)/6) = 68.

# APPENDIX G: ENGAGEMENT

Global data by region and by country is shown here:
http://www.gallup.com/poll/165269/worldwide-employees-engaged-work.aspx

Data for the US covering 2011-2015 is shown here:
http://www.gallup.com/poll/188144/employee-engagement-stagnant-2015.aspx

# APPENDIX H: GLOSSARY OF TERMS

| | |
|---|---|
| Abs | Absenteeism – time an employee is not present in the workplace, and not contributing to the organization, typically due to illness |
| ANOVA | Analysis of Variance – a statistical test of whether or not the means of several groups are equal |
| ASHRAE | American Society of Heating, Refrigerating and Air-Conditioning Engineers |
| BAS | Building Automation Systems |
| BB | Better Buildings – in this report refers to technologies facilitated by advanced building automation systems (e.g. enhanced ventilation, enhanced lighting control), or are whole-building strategies (e.g. green building certification) that typically include superior BAS features |
| BMS | Building Management System |
| BREEAM | Building Research Establishment Environmental Assessment Method – a method of assessing, rating, and certifying the sustainability of buildings |
| CWO | Chief Workplace Officer – proposed new senior executive role to optimize the overlapping concerns of real estate and facilities, HR, and IT, and to deliver continuous workplace and work environment optimization |
| DV | Dependent Variable – in statistical modelling dependent variables are the outputs whose variation is being studied |
| FC | Facility Complaints – complaints by occupants to facilities staff related to issues such as uncomfortable temperatures, indoor air quality etc. |
| FM | Facility Manager |
| FWO | Flexible Work Options – can include flexibility in scheduling working hours, the availability of multiple workplace locations within a building, or the ability to telework |
| HR | Human Resources |
| HRA | Health Risk Appraisal – assessment tool developed by the University of Michigan Health Management Research Center |
| IAQ | Indoor Air Quality |
| IEQ | Indoor Environment Quality – assessment of the total environment within a building, it includes IAQ, but also thermal comfort, acoustics, the lighted environment etc. |
| IV | Independent Variable – in statistical modelling independent variables are the causes of variations in the output |
| IWPQ | Individual Work Performance Questionnaire – a tool to assess the job performance of individual employees |
| JS | Job Satisfaction |
| KPI | Key Performance Indicator |
| LEED | Leadership in Energy and Environmental Design – a method of assessing, rating, and certifying the sustainability of buildings |
| LTI | Long-Term Incentives – employee bonus payments tied to the overall performance of the company |

| | |
|---|---|
| MCS | Mental Composite Score – an assessment of employee mental health |
| NIOSH | National Institute for Occupational Safety and Health |
| NWW | New Ways of Working – a specific instance of Flexible Work Options (FWO) |
| OECD | Organization for Economic Co-operation and Development |
| OL | Office Layout/Type – in this report, we focus on the private office vs. open-plan office contrast |
| PCS | Physical Composite Score – an assessment of employee physical health |
| PFP | Pay-for-Performance – a specific instance of an employee bonus system |
| POE | Post-Occupancy Evaluation – the process of evaluating the performance of buildings after they have been built and occupied for some time |
| PP | Perceived Performance – an employee's assessment of their own job performance |
| Ret | Retention/Employee Turnover – rate at which employees voluntarily leave an organization, or a measure of their intent to do so |
| RH | Relative Humidity – the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at a given temperature (%) |
| ROI | Return on Investment – an evaluation of benefits in relation to capital invested |
| SBS | Sick Building Syndrome – a phenomenon affecting building occupants who report acute negative health and comfort effects that appear to be linked to time spent in a building, but where no specific illness or cause can be identified |
| SME | Small and Medium-sized Enterprises – companies with relatively small numbers of employees |
| SMS | Strategic Management Simulation – a test of cognitive function |
| WGBC | World Green Building Council – a non-profit organization which is a coalition of national Green Building Councils |
| WHP | Workplace Health Programs – measures, which are often part of the benefits package in large organizations, designed to promote good health among employees |

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