CONNECTED SENSORS

WHITE PAPER

Measuring the Carbon Footprint of Water

TABLE OF CONTENTS

INTRODUCTION

This paper aims to address the challenges of implementing carbon legislature and sustainability measures in the context of water and energy consumption. Implementing carbon and sustainability strategies mainly depends on how carbon production is measured. The responsibility for estimating carbon production has fallen primarily to industry. Since the scientific methodology has yet to catch up with the legislature and sustainability programs, Connected Sensors aims to provide a structured and scientific basis to achieve more accurate estimates of carbon production in the water and energy sectors.

Connected Sensors has taken a “counting carbon” approach to understanding the carbon footprint associated with residential and commercial water usage. It is termed “counting carbon” as it evaluates energy intensity to determine the carbon production related to specific processes. Systems and sub-systems are broken down into their fundamental operating principles to assess the carbon production based on the energy intensity and unit of energy/water consumption. The same approach was taken in the specific use case of determining the amount of carbon produced by a given residential building based on water consumption.

The context of the most current legislature was considered to understand how to implement a carbon production estimate. To this end, the regulations, methodologies, implementation, and carbon offset mechanisms have been investigated in a North American context.

BACKGROUND AND MOTIVATION

In undertaking this understanding, extensive ongoing research is required to develop a solid scientific approach to estimating carbon production. Much of the research on this topic is experimental and qualitative, leaving many questions for environmental sustainability initiatives:

- How much carbon do we need to offset this year?
- How much carbon did we actually produce?

The following research, analysis and modelling represent the Connected Sensors scientific methodology used to answer these questions. To understand the imperative and urgency of carbon management, the relevant regulations, methodologies, and implementations by industry have been researched.

The landscape of measuring carbon production is multi-faceted. There is limited data on specific measurements of carbon production in water usage systems. Measuring the amount of carbon we produce daily requires understanding engineering and energy. The commercial, financial, and political need to determine an estimate of carbon production has somewhat surpassed the work that has been done by the scientific community, leaving sizeable uncertainty in the engineering assumptions.

Looming financial, social, and environmental pressures to determine how much carbon is produced has accelerated interest in this topic. This is bolstered by the growth in ESG and sustainability initiatives looking to quantify and offset carbon production.

Exploration of this topic is further encouraged by increasing government incentives, laws and regulations in the energy and environmental sectors. It is also important to note that environmental awareness and representation of such is becoming increasingly crucial to industries and companies. The research and modelling presented herein are designed to cater to the needs of the industry by meeting reporting requirements and providing credibility to carbon production and offset mechanisms.

PROBLEM DESCRIPTION

In 2024, the urgency for individuals and businesses to become more sustainable is imperative. Sustainability includes many environmental and social challenges, and many solution methodologies exist. As mentioned in the background, the perspective of stakeholders must be considered. The following perspectives and facets of carbon production estimation have been considered:

To illustrate the problem, consider a multi-national company, Company A, which produces and sells household detergents. This company has constantly run factories that produce goods that are shipped onto the shelves all over the world. When Company A decides to 'go green,' they first need to determine how much environmental impact their operation has. Therein lies Challenge No. 1, estimating the total carbon contribution of the factories that produce the detergents, international transport and shipping, the running of offices, and even the formulation and packaging of the products. Challenge No. 1 is a credible methodology that can be used to estimate Company A's environmental impact using a carbon production estimate.

Since Company A also operates in Europe, it is subject to IFRS S1 and S2 under GAAP, which requires disclosure of environmental and sustainability risks. The disclosure forms a part of the annual financial audit reports. It is up to Company A and other companies in the household cleaning industry to set the reporting standards within the regulations.

The interdependency of customers and companies in meeting sustainability requirements relies on the validation of data. This is why Connected Sensors has chosen to approach the problem in the property management industry. Further investigation into the challenge revealed no straightforward method to determine the carbon footprint of a residential building. In defining the problem scope, it was determined that an engineering analysis coupled with real-time data is necessary to adequately estimate the amount of carbon produced by a given building.

The problem statement was used to determine the following key objectives:

- Creation of a model to assess carbon composition measurement and offset index methodologies to be applied to water consumption in a building.
- Development of scientific processes that can be used to estimate carbon production for water usage systems within commercial and residential buildings.
- Development of a reporting structure that complies with and contributes to IFRS S1 and S2.

SOLUTION CRITERIA

IFRS S1 and S2 are the overall benchmarks used to determine the legal requirements of the solution. The International Financial Reporting Standards (IFRS) encompass two pivotal standards, namely IFRS S1 and S2, each playing a crucial role in enhancing transparency and accountability within financial reporting, particularly concerning sustainability-related disclosures.

IFRS S1, titled "General Requirements for Disclosure of Sustainability-related Financial Information," comes into effect for annual reporting periods commencing on or after January 1, 2024. Its primary objective is to mandate entities to divulge pertinent information regarding sustainability-related risks and opportunities. The underlying aim is to furnish users of general-purpose financial reports with the requisite insights to facilitate informed decision-making regarding resource allocation to the entity.

Under IFRS S1, entities must disclose sustainability-related risks and opportunities that could reasonably impact their cash flows, access to finance, or cost of capital across various time horizons. The standard provides comprehensive guidelines for preparing and presenting such disclosures, ensuring their relevance and utility to stakeholders. Essential disclosure requirements include delineating governance processes, controls, and procedures for monitoring sustainability risks, outlining the entity's strategy for managing these risks, illuminating processes for identification and assessment, and reporting on performance metrics related to sustainability goals and regulatory compliance.

Additionally, while not explicitly outlined in the provided text, IFRS S2, titled "Climate-related Disclosures," also assumes significance in sustainability reporting, augmenting the framework established by IFRS S1.

Moreover, incorporating sustainability metrics within financial reporting, as mandated by these IFRS standards, underscores the growing importance of carbon accounting. This integration accentuates the imperative for consumers and stakeholders to accord due diligence to carbon accounting as an essential criterion for evaluating an entity's financial credibility and performance [1] [2].

Adopting IFRS S1 and S2 underscores a concerted effort to foster transparency, accountability, and sustainability within financial reporting practices, thereby elevating the prominence of carbon accounting as an integral aspect of evaluating an entity's financial standing and operational resilience.

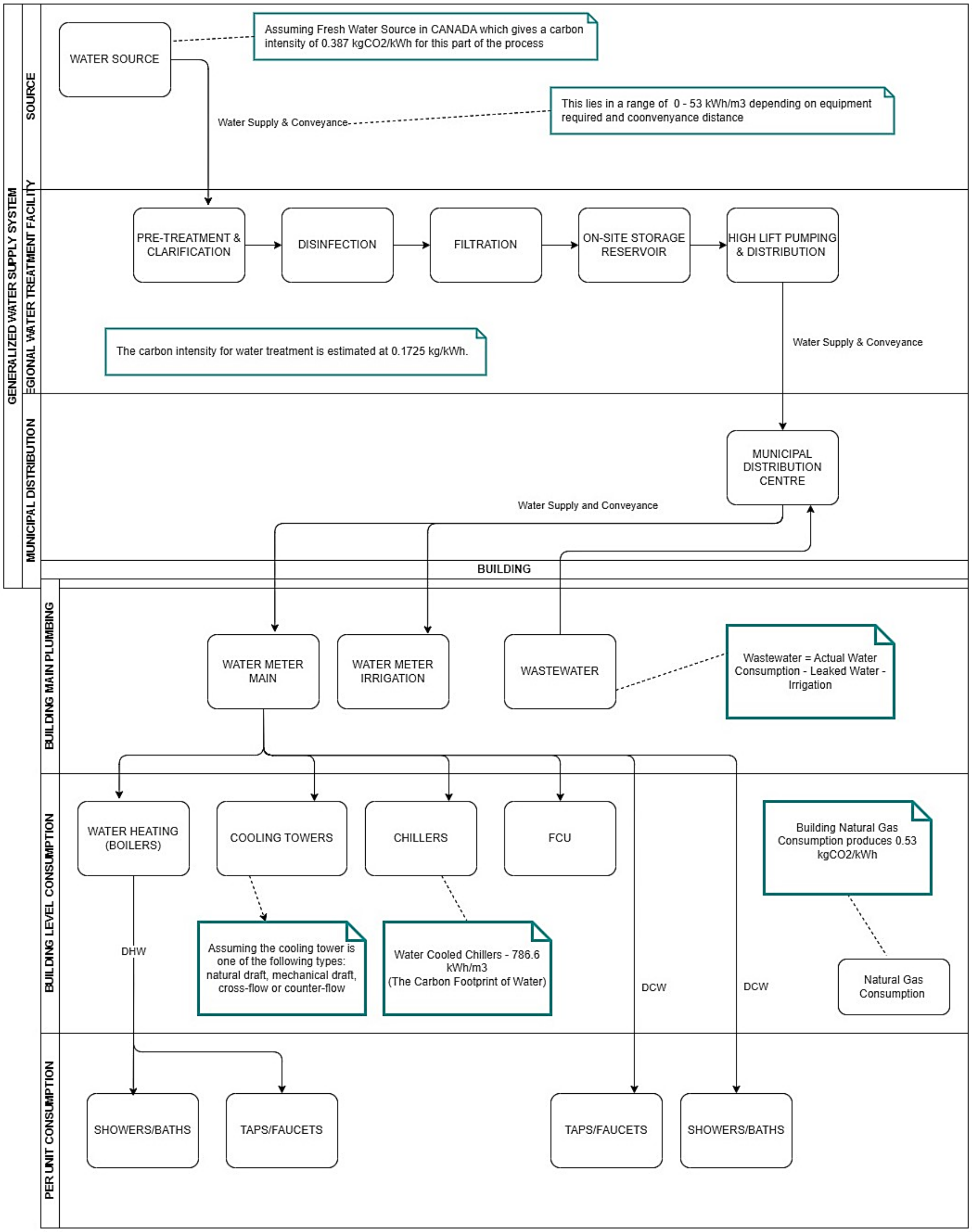
SOLUTION MODEL – CARBON ESTIMATION

The development of the carbon model is based on the preceding research. The model will be adapted to account for increasing detail as the accrued knowledge increases. It is understood that the initial implementation of this model is a first iteration and will be improved as we learn more from experts.

To determine the amount of carbon a building produces, an understanding of its usage of resources is required. To understand the process in simpler terms, we will look at the amount of energy (in a standardized kWh) associated with each process. We will consider three main resource/energy consumption forms: water, natural gas, and electricity.

Analysis of each system that uses these resources will result in a certain amount of carbon production based on the energy intensity of that process. For example, using any water pumping system to overcome pressure or height requires a significant amount of energy, thus producing a more considerable amount of carbon per cubic meter of water being pumped. For this reason, we have created a model that accounts for the carbon produced by both water supply and usage systems.

The model has been illustrated using a process map, which most closely represents the interactions between subsystems required to supply water to and within a building. Each subsystem has been simplified to contain key energy-intensive processes and the associated data for carbon estimates. Creating the model requires a long process of research where the accumulated learnings can be easily integrated into the model to improve the understanding and accuracy of carbon estimation.


GENERALIZED WATER SUPPLY SYSTEM
SOURCE
WATER SOURCE
Assuming Fresh Water Source in CANADA which gives a carbon intensity of 0.387 kgCO2/kWh for this part of the process
Water Supply & Conveyance
This lies in a range of 0 - 53 kWh/m3 depending on equipment required and coonvenyance distance
EGIONAL WATER TREATMENT FACILITY
PRE-TREATMENT & CLARIFICATION
DISINFECTION
FILTRATION
ON-SITE STORAGE RESERVOIR
HIGH LIFT PUMPING & DISTRIBUTION
The carbon intensity for water treatment is estimated at 0.1725 kg/kWh.
Water Supply & Conveyance
MUNICIPAL DISTRIBUTION
MUNICIPAL DISTRIBUTION CENTRE
Water Supply and Conveyance
BUILDING
BUILDING MAIN PLUMBING
WATER METER MAIN
WATER METER IRRIGATION
WASTEWATER
Wastewater = Actual Water Consumption - Leaked Water - Irrigation
BUILDING LEVEL CONSUMPTION
WATER HEATING (BOILERS)
COOLING TOWERS
CHILLERS
FCU
Building Natural Gas Consumption produces 0.53 kgCO2/kWh
DHW
Assuming the cooling tower is one of the following types: natural draft, mechanical draft, cross-flow or counter-flow
Water Cooled Chillers - 786.6 kWh/m3 (The Carbon Footprint of Water)
DCW
DCW
Natural Gas Consumption
PER UNIT CONSUMPTION
SHOWERS/BATHS
TAPS/FAUCETS
TAPS/FAUCETS
SHOWERS/BATHS

The calculations from the model are based on the fact that we can use the water consumption data from Water Monkey devices in a building to determine the volume of water supplied to a building. This will allow us to determine an estimated amount of carbon produced while providing that amount of water to the building and the wastewater treatment. All domestic water supplied must undergo a water treatment process that will include (with variations) disinfection, clarification, filtration, and other treatments.

The numerical estimates are based on freshwater sources, the norm in most Canadian municipalities. Freshwater as a source undergoes water treatment differently from other water sources, so we have based the calculations on that assumption.

Then, the carbon intensity for water treatment is estimated at 0.1725 kg/kWh.

To determine the amount of carbon produced in supplying water to the building, we are using:

Carbon Produced [kg/m3] = Energy Intensity [kWh/m3] * Carbon Intensity [kg/kWh]

Using the compiled research, the total estimated energy intensity for water supply to a building is 0,9463525 - 13,248935 kWh/m3 [3] [4] [5] [6].

The CPE (Carbon Production Estimate) is the proposed metric to show how much carbon a building produces in kg.

Basic CPE includes regional water processing and standardized water conveyance, which are required to supply water to a building. A further consideration is made for the appropriate percentage of wastewater. This is common to all buildings, and it is estimated that carbon production supplies water to the building.

Basic CPE is roughly 0.163293kg/m3 of water consumed.

Advanced CPE includes water usage within the building, where specific considerations are made for HVAC (Water Coolers, Chillers, Fan Coil Units), boilers, irrigation, and other water/energy-intensive processes. A list of applicable systems will be required to determine a more accurate estimate of carbon production to measure the advanced CPE.

The tiers of the CPE allow us to build onto the carbon model with increasing detail while allowing the flexibility to combine different system elements to represent the required system. A simplified example of Customer A is given as follows:

Most Canadian residences are served by a fresh water source.

The energy intensity of the equipment and processing at a fresh water source is estimated at 0.387 kgCO2/kWh.

Water Supply and Conveyance is required to deliver fresh water to the treatment facility.

The energy intensity of water supply and conveyance is estimated 0 – 53 kWh/m3 depending on the type of equipment and transport required at the location relative to the source.

The water treatment process is specific to each plant, but includes filtration, clarification, and disinfection.

The energy intensity of water treatment is estimated 0.173 kWh/m3 depending on the system.

Water distribution networks are complex systems that are designed to meet the municipal need.

The energy intensity of distribution is dependent on the transport distance, transport equipment and cost.

Municipal water supply feeds residential and commercial buildings via a metered system.

The internal usage of water and other utilities within the building will also have an effect on the carbon production estimate.

The CS carbon model is built on a systematic scientific methodology of associating carbon production with water supply and usage factors. The analysis is based on understanding the energy intensities required to supply and use water. Further to the scientific approach, extensive research into legislation and industry implementation of carbon estimations has been used to ensure customer credibility and relevance.

We have developed a basic carbon production estimate with plans to add further detail with ongoing research and development. We are looking to continue growing the model with the input of an industry-focused customer. Developing carbon and sustainability models requires a methodology and industry-relevant data. This allows CS and our customers to partake in leading industry standards on carbon regulations and data-driven sustainability actions.

With IFRS S1 and S2 currently taking effect in the European Union, the necessity for carbon reporting will reach North America at the beginning of 2025. The implications will apply to all North American companies using GAAP accounting systems as part of annual financial audits. IFRS S1 and S2 standards are based on a disclosure of environmental risk, meaning that the earliest and largest voices in each industry will dictate the extent and contents of these disclosures. This is mainly because the scientific process of calculating the exact carbon impact is playing catch-up with the legislation.

The CS model is designed to be part of the necessary carbon disclosures submitted by our customers for annual financial and sustainability reporting. Due to the developments in carbon legislation, the CS carbon analysis is among the first carbon production estimations in the industry. This allows us to bridge the legislature and carbon accounting gap to provide a data-driven carbon estimation based on water and energy consumption.

Here is where the mutual interest lies for ourselves and Customer A. Customer A will need to comply with IFRS standards in the coming years, and the advantage for them lies in leading the industry standard of disclosures while supporting current sustainability efforts.

CONCLUSION AND RECOMMENDATIONS

When considering the overall objectives laid out in Section 0, in the context of the research and investigations (described in Section 8), there is the possibility of multiple solutions to each interpretation of the problem. In the vast landscape of sustainability solutions, Connected Sensors has introduced a solution model that employs a systematic approach, leveraging insights into energy consumption and system design to estimate carbon footprint.

While investigating carbon markets, a search for a credible solution to determining an estimated carbon production showed differing perspectives and solutions that left scientific uncertainty. The simplified example of the Connected Sensors model (shown in Section 0) leverages the learnings from the different solutions researched. The ability to incorporate real-time analytics through our unique water monitoring products provided good insights into the impact of carbon production in residential buildings. This allows our customers to engage with sustainable solutions that directly and proactively reduce energy consumption.

Using a similar analogy to Company A (described in Section 0), we have Customer A, who manages a large group of residential buildings in North America. The buildings they manage serve vastly differing communities, each with energy consumption patterns. Additionally, the buildings vary in age, maintenance level, usage of large-scale HVAC systems, occupancy and amenities offered. Considering that Customer A will eventually be exposed to the regulations and standards described in Section 0, our proposed solution (detailed in Section 0) was applied to a standardized model to enrich Customer A's business insights.

Connected Sensor's position in the water monitoring and leak detection industry provides customers with the analytics and insight to determine areas of attention, particularly in their plumbing systems. The additional insight into the carbon impact of their consumption allows the customer to make sustainably driven decisions regarding water consumption.

REFERENCES

[1] IFRS (International Financial Reporting Standards), “IFRS S1 Sustainability Disclosure Standard,” ISSB, Delaware, 2023.

[2] IFRS (International Financial Reporting Standards) , “IFRS S2 Sustainability Disclosure Standard,” ISSB, Delaware, 2023.

[3] G. Finch, E. Burnett and W. Knowles, “Energy Consumption in Mid and High Rise Residential Buildings in British Columbia,” in *12th Canadian Conference on Building Science and Technology* , Montreal, Quebec, 2009.

[4] Natural Resources Canada, “Comprehensive Energy Use Database,” 2023. [Online]. Available: https://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/menus/trends/comprehensive_tables/list.cfm. [Accessed 25 October 2023].

[5] B. Griffiths-Sattenspiel and W. Wilson, The Carbon Footprint of Water, Portland: River Network, 2009.

[6] S. Pabi, A. Amarnath, R. Goldstein and L. Reekie, “Water and Wastewater Industries: Characteristics and Energy Management Opportunities: A Report That Describes How Electricity is Used and Can Be Managed Efficiently in Water and Wastewater Treatment,” Water Research Foundation & Electric Power Research Institute, Palo Alto, 2013.

[7] Sandbag (The Guardian) , “What is emissions trading?,” 05 July 2011. [Online]. Available: https://www.theguardian.com/environment/2011/jul/05/what-is-emissions-trading. [Accessed 05 December 2023].

APPENDIX

The research topics in this section include a collection of the resources used and their relevance. Since much of the research is being discussed, it is essential to understand the context and the learnings that can be used to develop the model.

While the objectives of this project include carbon estimations related to water consumption, the different uses of energy and water within a building should also be considered. This includes water supply and conveyance systems, HVAC systems, irrigation, and wastewater.

1.1. ENERGY CONSUMPTION IN MID- AND HIGH-RISE BUILDINGS IN BRITISH COLUMBIA

1.1.1. Contextual Background and Motivation for Reference

The study references data from the National Energy Use Database on the National Resources Canada government website. This research uses 'baseline consumption data from 39 multi-unit residential buildings (MURBs) in the Lower Mainland and Victoria, BC.' The baseline energy usage of data for residential buildings can be used as a point of reference since CS has several customers based in the North American region, especially Canada [3].

The study also aims to 'assess the actual energy consumption of in-service mid- and high-rise residential buildings,' which is an ideal case study for Connected Sensors. In addition to this, our Analytics Report for Client QuadReal gives us a quantitative comparison with the data provided in the study. Especially in the analysis of 'the contribution of gas and electricity to overall energy consumption and, specifically, space heat and ventilation... The disconnect between building energy consumption and billing to occupants for their share of total energy usage is highlighted.' Given the parallels in the analytical approach, validation will become increasingly crucial in verifying the carbon estimations [3].

1.1.2. Excerpts and Discussion of Relevant Data

The total energy intensity of household/building estimations given by Natural Resources Canada (NRCan) was used to highlight this study. We currently use NRCan's most recently available data to compile an overview of energy usage in specific parts of Canada [3] [4].

The study has also noted that energy consumption (which influences energy intensity) depends on who is responsible for the cost. Different energy consumption behaviours have been observed when the occupants/residents are responsible for paying for their energy supply compared to when the landlord is accountable for payment [3].

In addition, more specific energy uses in buildings have also been considered. The study includes the following schematic to describe HVAC systems in residential buildings [3].

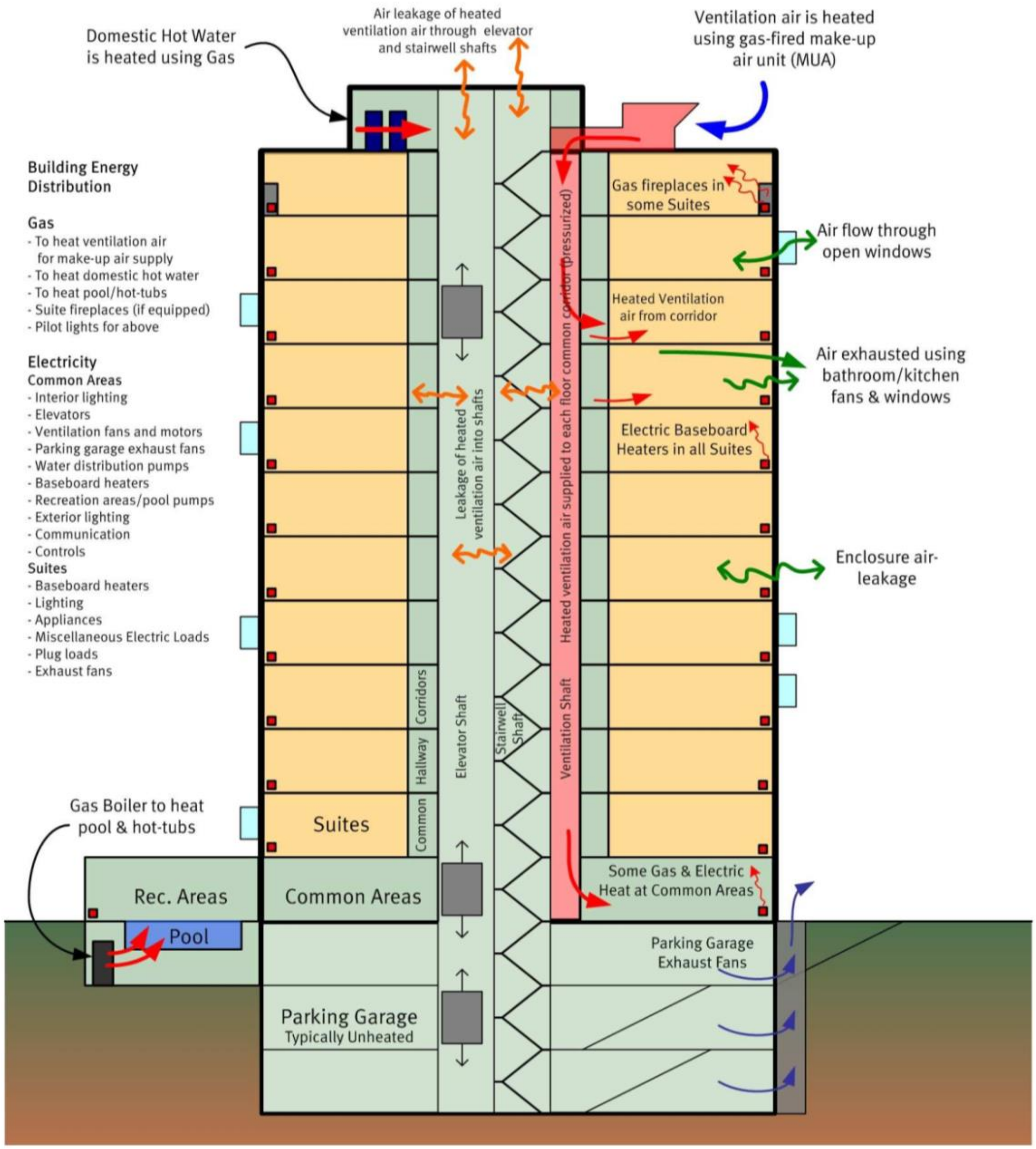


Figure 1: Schematic of a Typical High-Rise Residential Building - Heating and Ventilation Systems [3]

Further investigations into this study will be added during the further development of the carbon model. Current research is being undertaken to determine the energy intensity of the specific HVAC components.

1.2. THE CARBON FOOTPRINT OF WATER

1.2.1. Contextual Background and Motivation for Reference

This publication has been used extensively in the initial preparation of the CS carbon model as it provides a 'baseline estimate of water-related energy use in the United States.' It also provides a good framework for establishing the most important factors to consider when evaluating the total amount of carbon associated with water and energy consumption in a building.

The report aims to explore 'energy and carbon emissions embedded in the nation's water supplies.' The 'water-energy nexus' is defined as 'the set of interactions caused when humans develop and use water and energy.' This understanding of water consumption allows for systematically analyzing how water is used [5].

Due to the high density of water (8.34 lb/gal or 1000 kg/m^3), the energy required to move and treat water is significant. In most parts of North America, 'the energy required for supplying and treating water and wastewater constitutes the largest municipal energy cost.' This indicates the importance of considering the processes involved in water supply and treatment [5] [6].

It has also been noted that increasing water treatment standards at state and federal levels 'will increase the energy and carbon costs of treating our water and wastewater. [5].'

1.2.2. Excerpts and Discussion of Relevant Data

The following table summarizes some of the relevant metrics that have been used thus far:

Water Usage Metrics	Measurement	Reference(s)
Water Supply and Conveyance	0 – 3.6984 kWh/m^3	[5]
Water Treatment	0,0264 - 4,2268 kWh/m^3	[5]
Water Distribution	0.066 – 0.317 kWh/m^3	[5]
Wastewater Treatment and Collection	0.1849 – 1.2152 kWh/m^3	[5]
Wastewater Discharge	0 – 0.1057 kWh/m^3	[5]
Generic Energy Intensity of Groundwater	0.5285 kWh/m^3	[5]
Carbon Intensity of Freshwater	0.387 kgCO2/kWh	

1.3. CARBON MARKETS

Emissions trading, a market-based approach, aims to control pollution by introducing tradable pollution permits. This system adds a profit motive to encourage good performance, contrasting with traditional environmental regulation reliant solely on penalty threats [7].

Emissions trading became more prominent in the US in 1990 and has since become used to combat greenhouse gas emissions linked to climate change. The main form of emissions trading, known as "cap and trade," sets a cap on emissions and issues permits up to this cap level, with entities needing to hold permits corresponding to their emissions. This system puts a price on emissions and allows flexibility in reducing the impact, ideally at the lowest cost possible [7].

Despite its advantages, critics often highlight weaknesses such as lax caps, free permits to major polluters, and reliance on offsets purchased from carbon reduction projects outside the trading system, particularly in the developing world. Emissions trading, embodied in the Kyoto Protocol's Clean Development Mechanism (CDM) and the EU's Emissions Trading System (ETS), faces challenges due to the US's withdrawal from a proposed national policy. However, some regions and countries are exploring or implementing similar schemes, including China and South Korea [7].

The contemporary landscape of carbon credit solutions within the business sector often reveals a disjunction between prevailing market regulations and the requisite tools for precise carbon consumption assessment. While rules governing the carbon market strive for stringent control and accountability, the existing methodologies for determining carbon emissions often lack the sophistication necessary to provide detailed insights into actual consumption patterns. This disconnection underscores a fundamental challenge within the carbon market ecosystem, wherein regulatory frameworks outpace the development and implementation of robust measurement and reporting systems.

Furthermore, the inherent flexibility embedded within carbon credit transactions introduces complexities that can undermine the integrity of carbon valuation. Though designed to foster adaptability and incentivize emission reduction initiatives, the market's allowance for estimations and offsets may inadvertently dilute the actual value of carbon production. The reliance on estimative metrics, devoid of precise measurement mechanisms, poses inherent risks of overestimation or underestimation, compromising carbon trading mechanisms' efficacy.

In essence, while the carbon market represents a progressive paradigm in environmental governance, its efficacy hinges on the convergence of stringent regulatory oversight with the deployment of advanced measurement and verification tools. Bridging this gap is imperative to ensure the integrity, transparency, and viability of carbon credit solutions in fostering sustainable business practices and mitigating climate change impacts.