The Windfall Protocol

Blockchain-Based Infrastructure to Accelerate Building Retrofits & Energy Efficiency Initiatives

BLOCK SCIENCE

Possibilian

A report produced for Natural Resources Canada,
by BlockScience, Windfall Ecology Centre, and Possibilian,
with community coordination by SuperBenefit.

Acknowledgements & Disclaimers

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1. Executive Summary

Canada needs systemic shifts in energy efficiency retrofit programs in order to accelerate the national transition towards our net-zero emission targets by 2050. Homes and buildings account for nearly one-fifth of Canada's carbon footprint[1], but at current retrofit rates it will take 142 years to transition residential buildings, and 71 years for commercial buildings.[2] Yet our transition to a zero carbon economy is needed within the next 26 years - preferably within the next decade, given the speed of the unfolding climate crisis.

The Windfall Protocol Research Group[3] has completed a five-month study with funding from Natural Resources Canada (NRCan)[4] to survey this landscape from a systems perspective and identify design considerations for a new layer of multi-stakeholder coordination and shared digital infrastructure. **Partners including Windfall Ecology Centre, Possibilian, BlockScience, and SuperBenefit are researching and developing an open-source blockchain-based protocol to facilitate energy efficiency labelling and data sharing for residential and commercial buildings to accelerate retrofit adoption dubbed the Windfall Protocol.** This paper outlines a high level conceptual architecture and technical considerations, as well as a planned pilot in Durham Region.

The Windfall Protocol aims to address many of the gaps that exist between stakeholder groups in current building energy efficiency subsidy programs. For participants, it can reduce complexity of accessing information and retrofits, and offers new incentive pathways. For regulators and incentive providers, the protocol offers opportunities for smart and targeted incentives, improved data flows, and actionable net-zero strategies. **This multi-stakeholder digital infrastructure could be leveraged for large-scale transformation of energy markets, open new avenues to finance energy efficiency retrofits, and supercharge the coordinative capacities and incentives needed to drive the volume of retrofits required for net-zero.**

In addition to digital, technical, and economic innovation, the protocol will also require multi-stakeholder governance and representation in design choices and trade off decisions with social, technical, economic, and environmental impacts. As part of these efforts, the Windfall Protocol Research Group is also convening a consortium of stakeholders[5] to solicit feedback and engage in discussions on further development of the program and the protocol it aims to produce.

This paper informs the next phase of research and development for the Windfall Protocol

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[1] Government of Canada, *"Annex: Homes and Buildings"*, 2021
[2] Haley, B. and Torrie, R. *"Canada's Climate Retrofit Mission: Why the climate emergency demands an innovation-oriented policy for building retrofits"* by Efficiency Canada, June 2021.
[3] The Windfall Protocol Research Group is a working group stewarding this initiative. At the time of writing, members include Durham Region, Windfall Ecology Centre, Possibilian, BlockScience, and SuperBenefit with initial funding from Natural Resources Canada.
[4] Natural Resources Canada website https://natural-resources.canada.ca/home
[5] Windfall Protocol Community outreach documentation https://wp.docs.superbenefit.org/

Research Group in defining the Windfall Protocol Program - including a pilot implementation in the Durham municipality of Ontario, Canada. The goal is to create an open-source energy efficiency retrofit protocol with the steering capacities required to guide our systems on a more resilient and regenerative environmental and economic trajectory.

2. Introduction

"We will not achieve the required greenhouse gas (GHG) and energy efficiency performance from our existing building stock by working within current market structures and policy approaches."

- Brendan Haley & Ralph Torrie,
Canada's Climate Retrofit Mission

Canada must achieve rapid, wide-scale retrofitting of residential and commercial buildings to reach net-zero emissions by 2050 (or 2035, under more ambitious time scales consistent with the climate emergency). Numerous barriers are contributing to inefficiencies and coordination challenges in energy efficiency retrofitting initiatives. Homeowners face high up-front capital costs, financing hurdles, and split incentives between owners and renters. Policy and program designers face the challenges of data silos, jurisdictional fragmentation, and open-loop subsidy programs that have no tie between retrofits and energy efficiency outcomes. Utilities often face technological debt and business models that can be counterproductive to efficiency outcomes.

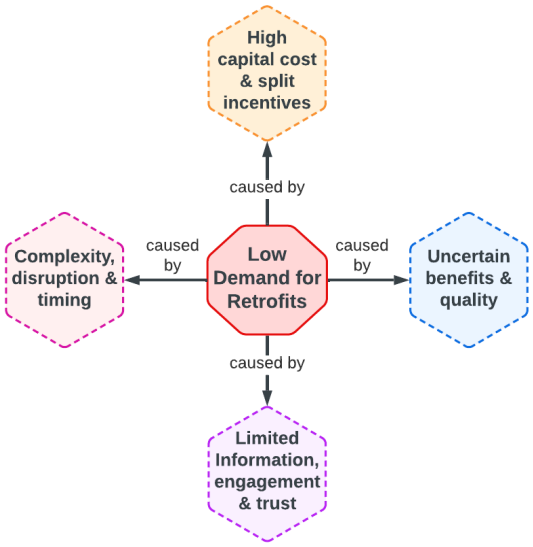

Figure 1. A diagram showing some of the reasons for low retrofit demand in Canada's residential net-zero programs.[6]

These barriers have contributed to low demand for residential retrofits, leading to a slow start in building retrofits towards Canada's net-zero targets. A slow transition is increasingly expensive,

[6] Centre on Innovation and Energy Demand, Warm Homes for All: A comprehensive policy approach for residential energy efficiency retrofit in the UK, 2018

requiring hundreds of billions of dollars in emergency funds globally by governments to support households and businesses with rising energy costs - funds on par with, and in some countries eclipsing, clean energy and transition investments.[7]

To address these challenges, reports from strategic policy advisors recommend digital innovation as one potential area for high-leverage interventions. Many of the barriers to current programs result from fractured data and information flows between relevant stakeholder groups. Coordinative infrastructures such as shared databases - with appropriate access control and permissioning for data privacy - could provide more comprehensive access to building data, retrofit information, and energy data feeds. These infrastructures could streamline retrofit programs, close the subsidy loop with measurable outcomes, suggest more targeted incentives and subsidies, and provide avenues for retrofit market transformation.

This report provides the initial results of research into the building decarbonization landscape for development of the Windfall Protocol, an open-source blockchain-based protocol to facilitate energy efficiency labelling and data sharing for residential and commercial buildings to accelerate retrofit adoption. This paper includes a high-level overview of a research and requirements-gathering exercise that includes stakeholder mapping, program motivations and requirements, a high-level exploration of conceptual architecture and technical considerations, as well as a subset of requirements for a minimum viable protocol for a deployed pilot. It also outlines how such a protocol could address key stakeholder challenges and points to areas for further research including how the system could scale and employ participatory protocol governance, alternative financing mechanisms, enhance coordination around retrofits, target more effective subsidies and incentives, and enable better coordination in progressing towards net-zero targets.

3. Program Motivations

> *"Now is not the time to pause on energy efficiency action but the time to further exploit efficiency's potential to address the multiple intersecting crises of energy, climate, and cost of living."*
>
> - International Energy Agency, Energy Efficiency 2023

The Windfall Protocol could be seen as the culmination of a program dedicated to building energy efficiency improvements using distributed ledger technologies (DLTs), in which the Windfall project with Durham Region serves as an initial pilot deployment of a minimum viable protocol with a more limited set of requirements. Any initiative that aims to address as large a goal as enabling Canada's net-zero targets must be approached in an iterative manner. It is common in large public infrastructure initiatives to structure workstreams towards specific outcomes into programs, which consist of multiple projects, pilots, and dependencies between them.

[7] International Energy Agency *"Energy Efficiency 2022"* and "Energy Efficiency 2023".

This program was initiated by the Windfall Protocol Research Group in response to a request for proposals from Natural Resources Canada that called for, *"Projects that use information technologies, such as the internet-of-things and non-fungible tokens, to monitor energy usage and GHG emissions of homes, establish a 'Live Labelling System', and disclose accurate information through a secure decentralised system."* While the use of novel technologies like non-fungible tokens (NFTs) and DLTs could be used where they offer functional improvements over existing data infrastructures, it is worth observing that many of these technologies are at a Technology Readiness Level[8] (TRL) of 2 or 3. The program would have the aim of taking the Windfall Protocol to TRL5 or 6, in a deployed minimum viable protocol.

4. Stakeholder Mapping

> *"We define stakeholders more broadly than traditional systems engineering, expanding the category to include all who are impacted by a given project, rather than just its sponsors or funders because we believe that our approach results in both increased accountability and superior design, operations, maintenance, and governance."*
>
> - BlockScience, Block by Block: Managing Complexity with Model-Based Systems Engineering[9]

To begin our analysis, we look at 'People', 'Purpose', and 'Environment' as the constitutive infrastructure[10], meaning the social, legal, technical, economic, and environmental considerations that comprise the boundaries of a system or organisation. Stakeholders map to the people in any given system. It is crucial to understand the groups and subjects affected by energy efficiency markets, building retrofit systems, and those who could be affected considering any new or integrated system(s).

In this section, we briefly summarise an analysis of stakeholders' rights and affordances, implicit and explicit motivations, incentives, and key challenges, as well as how information flows between them.

Building Owners & Occupants

Motivations, Rights & Affordances

This stakeholder group contains two distinct roles - owners and occupants - however, those roles may sometimes be held by the same individual or individuals. Home or building owners may seek retrofits for many reasons including adding to the value of the property or reducing their environmental footprint, while occupants may look to improve in-home comfort, saving on

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[8] Technology Readiness Levels are a framework developed at NASA to evaluate and understand novel technologies as they mature: https://www.nasa.gov/directorates/somd/space-communications-navigation-program/technology-readiness-levels/

[9] Zargham, M. and Ben-Meir, I. *Block by Block: Managing Complexity with Model-Based Systems Engineering,* 2023.

[10] Zargham, M. et al. *What Constitutes a Constitution?, 2023.*

energy bills, and increase resilience to potential outages or infrastructure changes.[11] They must facilitate and finance the retrofits and can access rebates and subsidy programs depending on the jurisdiction where they live. Building occupants could initiate or support the retrofit process, but are more likely subject to the decisions of the building owner, depending on the legal jurisdictional requirements around renter's rights and retrofits.

Data Access

This stakeholder group has limited access to their natural gas and electric energy usage data with jurisdictional variance. Only Nova Scotia[12] and Ontario,[13] have adopted the Green Button Standard[14] which enables utility customers access to their energy usage data. This group is key in granting permission to building data, contributing to data flows that can greatly accelerate retrofitting programs and help to improve granularity in information, supporting more targeted subsidies and rebates, and close the loop between retrofits and energy usage data.

Key Challenges

Under current models, retrofit projects are left to the building owners or occupants, who must navigate a tangled web of subsidy programs, with little or no coordination between suppliers. They also must front thousands of dollars and wait several months for rebates.[15] The owner may not live at the property, so they may not be motivated by reducing the monthly energy bills if they are not responsible for paying them. This scenario can lead to information asymmetry and what is known as "split incentives" between building owners and occupants (though many solutions have been studied).[16] While they may have some access to data, there is a lack of third-party organisations to support them in making use of this data. There may also be impacts on renters due to gentrification - retrofits can increase property values and building owners could choose to sell the property or raise the rent.

In First Nations communities, which often face issues with insufficient infrastructure in northern or rural off-grid or grid-distant communities, there are additional challenges to consider including high building costs, logistical challenges, and varying building contexts.[17] Low-income housing occupants or renters who cannot afford to buy a home are excluded from the benefits of government programs and are dependent on building owners to finance retrofits.[18]

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[11] Natural Resources Canada. Toward a Canada Green Buildings Strategy, 2023.
[12] Green Button Alliance. Canadian Initiatives: Green Button Mandates, Legislation, & Regulatory Inclusion.
[13] Province of Ontario. Ontario News Release: Helping Energy Customers Save Money with Green Button, 2021.
[14] U.S. Department of Energy. Green Button: Open Energy Data.
[15] Brown, Donal, Paula Kivimaa, and Steven Sorrell. An Energy Leap? Business Model Innovation and Intermediation in the 'Energiesprong'Retrofit Initiative. Energy Research & Social Science 58 (2019): 101253.
[16] European Commission, JRC Technical Reports. Overcoming the Split Incentive Barrier in the Building Sector: Unlocking the energy efficiency potential in the rental & multifamily sectors, 2017.
[17] Natural Resources Canada. Summary of Engagement with Indigenous Partners, 2023 for the Canada Green Buildings Strategy Consultation, Government of Canada.
[18] Gaede, J. et al Efficiency Canada and Carleton University. 2022 Canadian Energy Efficiency Scorecard: Provinces and Territories.

Local & Regional Governments

Motivations, Rights & Affordances

Municipal, regional, and provincial governments vary widely in retrofitting programs and partnerships.[19] They can apply for and support the administration of large subsidy programs,[20] support stakeholder coordination along with building owners and occupants, and/or develop partnerships with financing entities to orchestrate special interest rates for retrofit lending. There is a mix of municipal and private ownership of utilities and power sources.[21] Municipalities are key in promoting local generation and renewable energy through public outreach campaigns, guides, and enabling regulatory environments favorable for prosumers.[22] They are also key in developing partnerships and collaborations with utilities.[23] Municipalities and provincial governments also differ in the way they handle property assessments and collecting data, with some provinces like Ontario outsourcing data collection and database maintenance to entities like the Municipal Property Assessment Corporation (MPAC).[24]

Data Access

There is wide jurisdictional variance in what data streams government entities have access to and what data is publicly available regarding residential, public sector, and commercial buildings. Commonly, municipal and provincial governments can receive data from other government agencies and regulators, utilities, and other civil and municipal data. For example, in Durham Region, the municipality has a data-sharing agreement with NRCAN to access Energuide data. MPAC also shares tax roll data with Durham Region. In contrast, in the City of Saskatoon, all tax roll and energy data is publicly available.[25]

In Ontario, Broader Public Sector buildings (BPS), must report energy and emissions through Energy Star Portfolio Manager[26]. It is the Minister of Energy's prerogative to decide what level of detail is publicly disclosed; BPS buildings disclose fully. Private sector buildings over 50,000 square feet in Ontario must also report energy and emissions data to the province[27]. Currently, the province only publicly discloses energy and emissions from commercial buildings at the Canada Post Forward Sorting Area (FSA) level - an area larger than a full postal code.

Key Challenges

Municipalities are on the frontline of the increasing demands of growing populations and urban agglomeration, with high administrative costs, and resource limitations to meet the various

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[19] Delphi Group. Green Retrofit Economy Study: Summary Report, 2022.
[20] Green Municipal Fund. Funding Opportunities.
[21] Canada Energy Regulator. Provincial and Territorial Energy Profiles - Canada, 2023.
[22] Decentralized Energy Canada. 7 Drivers of Decentralised Energy Systems, 2023.
[23] Gass, P. et al. Int'l Institute for Sustainable Development. Cities and Smart Grids in Canada, 2017.
[24] Municipal Property Assessment Corporation website.
[25] City of Saskatoon. Home Energy Map.
[26] Ontario Regulation website. O. Reg. 25/23: BROADER PUBLIC SECTOR: ENERGY REPORTING AND CONSERVATION AND DEMAND MANAGEMENT PLANS, 2023.
[27] Ontario Regulation website. O. Reg. 506/18: REPORTING OF ENERGY CONSUMPTION AND WATER USE

demands of maintaining several avenues of local public infrastructure.[28] While outsourcing or having subsidiarity in some services such as property assessment can benefit governments, it can also create mixed incentives and more overhead in streamlining data flows and access.

Utility Companies

Motivations, Rights & Affordances

Utility ownership in Canada is predominantly public, private, or a mix of both, but can also be run as a cooperative. Utility companies are locally connected to municipalities, sometimes through direct administration. They offer a main line of communication to home and building owners through advertisements and often deploy financing, subsidies, and retrofit programs directly. Because of the large-scale service and infrastructure of utility companies, they have access to a diverse array of financing opportunities to invest in infrastructure. Many utilities operate under a Cost-of-Service Business Model, tying revenues to the amount of energy sold, and incentivizing infrastructure ownership including large capital expenditures which may not always be optimised for energy or capital efficiency.

Data Access

Utilities are a key data intermediary as they hold access to real-time energy consumption and building occupancy change data. They are administrators of the Green Button program in Ontario and Nova Scotia, and other billing data and API access initiatives across Canada. They could support improving data transparency for consumers and regulators, and incentivize homeowner permissioning of data with discounts on services. They also must balance data privacy and sharing concerns along with granularity questions around how detailed to be in the data provisioning process.

Key Challenges

There are 60 different local distribution companies (LDCs) across Ontario alone,[29] and across Canada, the range of technical infrastructure, capabilities, and administrative costs can be a hindrance in various aspects of infrastructure updates and integrations such as data availability and opportunities for on-bill incentives and financing. There is no data or tracking tie between retrofit programs and energy usage. There are mixed incentives currently for many utilities to reduce energy usage, and utility business models are threatened by massive changes to utility infrastructure.

There is a huge opportunity to transform business models, and even open new revenue streams with a shift to bidirectional and decentralised energy production.[30] This could help to balance homogeneity driven by economies of scale with heterogeneity driven by local and regional diversity however, path dependencies, cost to transition and competition are some factors slowing potential transitions.

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[28] Fed'n of Canadian Municipalities. Canada's housing challenge is also an infrastructure challenge, 2023.
[29] Electricity Distributors Association. Facts about Ontario's Local Hydro Utilities.
[30] He, E., Brown, D., Lovekin, D., Pembina Institute. Transforming the Utility Business Model, 2022.

National Government & Regulators

Motivations, Rights & Affordances

There is a mix of regulatory bodies associated with residential and commercial building retrofits. Federally, NRCAN oversees the setting, maintenance, and upgrades of energy certifications and regulatory standards, and licensing of service and training organisations[31]. Other boards like the Canadian Board for Harmonized Construction Codes (CBHCC) oversee building codes.[32] Provincial boards,[33] regional and municipal governments oversee utility and energy regulation, as well as building codes, permitting, and even noise by-laws that can affect or limit some retrofitting projects.[34]

Data Access

Regulators hold energy consumption, efficiency, emissions, and other aggregate analyses on retrofitting projects and initiatives as well as directive and policy guidelines on maintenance and access to data.[35] As mentioned previously in the tax roll data example, similarly, there is jurisdictional variance on the openness and access to data, though many stakeholder groups recognize the need for accessible and streamlined data.[36]

Key Challenges

While many reports cite the necessity of innovation, in fast-moving markets of energy efficiency and climate change mitigation it may be difficult for regulatory bodies to keep up with new technologies or construction techniques required for deep retrofits. Regulators must also balance data privacy considerations while also supporting calls for more transparency in data and processes. They must also keep up with the increased demands that will be required to certify more energy auditors and more frequent updates of energy standards (which may have the increased complexity of context dependencies or heterogeneity based on province or technology access).

Energy Auditors (Residential)

Motivations, Rights & Affordances

Energy auditors are licensed by NRCAN and use regulated protocol and Energuide[37] standards to audit and support the labelling of residential buildings. They get directly compensated by homeowners (who often receive rebates for some or all of the cost from government programs) to provide on-site audits and walk-throughs and can speak directly with building owners and tenants, offering education. Their assessments can verify or counter virtual audits or other data

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[31] Government of Canada Website. Natural Resources Canada Home Page.
[32] Lockhart, K. and Sharane, S. Efficiency Canada, Carleton University and Low Carbon Cities Canada. Regulating Energy and Emissions in Existing Buildings: A Primer for Canadian Municipalities, 2023.
[33] International Confederation of Energy Regulators. Canada's Energy and Utility Regulators (CAMPUT)
[34] Agar, B., Pembina Institute. Barriers to deep retrofits: Regulatory solutions from across Canada, 2020.
[35] Example database: NRCAN's National Energy Usage Database (NEUD). Example provincial data directive: Ontario Energy Board's Digital and Data Directive 2021.
[36] Natural Resources Canada. Toward a Canada Green Buildings Strategy, 2023.
[37] Government of Canada Website. EnerGuide in Canada.

projections with on-the-ground information. Increased efficiency of energy audits could lead to more retrofits.

Data Access
Auditors collect and store detailed on-site audit and building data, which could be cross-referenced with other data streams to improve granularity and update attestations to energy assessments. This group must also adhere to jurisdictional data privacy and security requirements.

Key Challenges
A shortage of certified energy auditors has been cited as a key bottleneck in the acceleration of energy efficiency and retrofitting initiatives across Canada,[38] and is particularly acute in the Northwestern Territories with some sources citing up to a two-year wait for a residential home audit.[39] There have also been reports of wide variance in audits[40] and studies on common problems in audits like overestimating savings, incomplete building descriptions, and missing opportunities.[41]

Retrofit Providers & Contractors

Motivations, Rights & Affordances
This group consists of private firms that provide retrofit services, equipment, and maintenance. They are incentivized to advertise subsidies to consumers in order to sell their products. They are a primary communication channel with homeowners to provide education around the various retrofit subsidy opportunities available. They often push sales for certain products based on available rebates to homeowners to maximise sales.

Data Access
They collect and store detailed data from manufacturers on the latest products like heat pumps, window upgrades, and solar technology to research and sell products. They also have detailed information on financing options, marketplace standards, and metrics, and record retrofit sales and service data.

Key Challenges
Retrofit providers must stay up to date and adhere to regulatory processes which can sometimes affect their business models, add administrative overhead and extra steps, or slow retrofits. As retrofits become more in demand, they may also face supply chain[42] constraints and waste management issues[43] as they try to keep up with demand. Due to the types of incentives

[38] Cummings, M., CBC News Article. Demand for energy auditors still high in Alberta months after federal grant launch, 2021.
[39] Cabin Radio Article. NWT still needs more home energy auditors to address growing backlog, 2023.
[40] Porter, C. Toronto Star News Article. Home Energy Audits Flawed, 2007.
[41] Shapiro, I., Ashrae Journal. 10 Commons Problems in Energy Audits, 2011.
[42] Greer, K. and Dr. Wade, J. Department for Business, Energy & Industrial Strategy, Government of the United Kingdom research paper. International Review of Domestic Retrofit Supply Chains, 2021.
[43] Tingley, D. Paper in Communications Engineering. Embed Circular Economy Thinking into Building Retrofit, 2022.

available, they may also have biases in selecting retrofits with the best payouts, influencing homeowners who may choose retrofits based on financing, not necessarily energy efficiency.

Finance & Incentive Providers

Motivations, Rights & Affordances

This stakeholder group includes banks, credit unions, federal, provincial, and municipal grant and loan programs, and utility-mediated retrofit rebate programs. Access to capital is crucial to encourage retrofits, as affordability has been identified in retrofit reports as a prominent issue for acceleration and conducting more extensive energy efficiency improvements.[44] Enhanced coordination of retrofit programs could lead to larger loan books and new lending and business model opportunities. Federal, provincial, and municipal governments have a wide range of tools to draw from: they can develop alternative retrofit repayment mechanisms, offer credit enhancements to incentivize finance, issue bonds, use carbon pricing revenues to support funding or loan programs, and/or establish funds, trusts, or Green specialized institutions, such as a Green Bank.[45]

Data Access

Access to data is limited for private groups looking to assess risk, benefits, and potential return on investment. More granular and accessible data could support targeted subsidies and improve financing opportunities by helping to reduce risk and the cost of underwriting.

Key Challenges

Efficiency Canada estimates the cost of the retrofit overhaul of Canada's buildings between $580 to $972 billion - $39 to $62 billion annually over 15 years or $20 to $32 billion annually over 30 years. For comparison, the estimate cites how much Canadians spend annually on home renovations - $80 billion - and what the country spends per year on fuel and electricity - $57 billion.[2]

Research suggests that innovative financing approaches such as on-bill financing or local improvement charge programs may help accelerate investments in efficiency upgrades, but they must be combined with other support mechanisms.[46] There is no incentive for cross-promotion of subsidy, loan, and rebate programs which are fragmented across public and private organisations and sometimes competitive politically or otherwise. Another challenge is the size of projects, which are often "too small" at the municipal level to gain competitive financing.[47] Loans are also dependent on market fluctuations. In addition to financing challenges, there can

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[44] Beer, M., The Energy Mix article. Low Funding, Fewer Deep Retrofits Limit Gains from Canada Greener Homes Program, 2024.
[45] Gaede, J. et al Efficiency Canada and Carleton University. 2022 Canadian Energy Efficiency Scorecard: Provinces and Territories.
[46] Energy and Mines Ministers' Conference Report. Financing Energy Efficiency Retrofits in the Built Environment, 2016.
[47] Information from a stakeholder interview with Durham Region officials in November, 2023: In its energy efficiency pilot program, the municipality is managing $7.5 million in loans and says it received rates for residential retrofits at prime interest plus two percent. To achieve sub-prime with a larger financing entity, Durham officials said they were told loans would need to total closer to $100 million.

be up to six months of delay in rebate programs, adding to the financial burden of the home or building owner. Finally, without public and community banking or platforms for participatory micro-lending programs, most financing and returns on investment are highly concentrated, benefitting large banks and private entities, with little or no returns for local communities.

Realtors & Real Estate Platform Operators

Motivations, Rights & Affordances

Realtors and real estate platforms are critical stakeholders in decarbonization, offering a powerful channel in scaling energy efficiency labelling and retrofit acceleration as intermediaries in commercial and residential building transactions and ownership transfer.[48] Energy efficiency initiatives and regulations can affect key aspects of real estate including investment and financing, government legislation, leasing and development, renovation and retrofitting, and construction.[49]

Data Access

Real estate platforms hold and have consolidated key building data that can support virtual audits to estimate energy usage via various machine learning algorithms that can extrapolate based on energy efficiency models. Platforms could leverage additional data if made available.

Key Challenges

Although energy audits could be a benefit for them (much like the introduction of “walk scores”), many realtor groups and platforms are resistant to add extra steps in their process and are worried that poor energy results for homes could hurt their business. They have pushed back against mandatory energy audit and labelling regulations[50] and must balance regulatory pressure with marketing, although investors may increasingly desire the inclusion of energy efficiency data in market valuations and risk valuation in analysing investments.

The Earth: Flora, Fauna & Funga

“I do not see a delegation for the Four Footed. I see no seat for the Eagles. We forget and we consider ourselves superior. But we are after all a mere part of Creation, and we must consider understanding where we are. We stand somewhere between the mountain and the ant. Somewhere and only there as part and parcel of the Creation.”

-Chief Oren Lyons, Onondaga Indian Nation Council of Chiefs of the Six Nations of the Haudenosaunee Confederacy [51]

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[48] McKinsey & Company article. Climate risk and the opportunity for real estate, 2022.
[49] Bennett Jones article. ESG and its Impact on Real Estate, 2023.
[50] Cummings, M., CBC News Article. Home energy labels would lower emissions, reduce mystery for buyers, says Edmonton mayor, 2021.

[51] A Seat at the Table: Huston Smith In Conversation with Native Americans on Religious Freedom, 2006.

Motivations, Rights & Affordances

Indigenous ways of knowing have long recognized the personhood of nature, nature as kin, and maintain world and mental models that acknowledge deeply and intricately connected ecologies. Only within the last 50 years have the rights of nature and earth rights been recognized in legal systems in nations states around the world. In February 2021, the Innu Council of Ekuanitshit and the Minganie Regional County Municipality (Minganie RCM) recognized the legal personality of the Mutehekau Shipu river in eastern Quebec.[52] The body of water was granted legal personhood, the first time a river received such recognition in Canada. The river was granted nine rights, including rights to flow, be safe from pollution, maintain its natural biodiversity, as well as to sue. The Mutehekau Shipu can be represented by Guardians appointed by both the municipality and the Innu Council to act on its behalf and protect its rights.

Data Access

The Earth is a rich source of data flows as all-natural ecologies and living systems exchange information whether expressed as energy, water, nutrients, or biomass. The majority of these flows are not accounted for, resulting in systemic environmental destruction. Any system aiming to accelerate decarbonization of buildings and ecological repair must consider and integrate key Earth data in developing measurement and verification to reach environmental targets. The flows of resources and associated processes affecting the carrying capacity, resilience and sustainability of the planet should be considered to the best extent possible in systems design and analysis.

Key Challenges

As many wisdom keepers and scholars have spoken and written about, humans' disconnection from, and relationship with, land must be repaired. The mutual reciprocity of nature and humanity's role in the great balance requires not only policy change but change in the heart.[53] The Windfall Protocol Research Group offers the inclusion of this primary stakeholder group as a step in this direction.

[52] Jang, M. J.D. Rights of Nature and Indigenous Peoples: Navigating a New Course, 2022.
[53] Kimmerer, R. Wall. Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants, 2013.

5. Program Requirements

"If we don't change directions, we're going to end up where we're headed."
-Reuben Snake, Winnebago Nation, 1943 –1993

We begin the design explorations of the Windfall Protocol Program by outlining requirements. As seen in Figure 2 below, low demand for retrofits has many causes. A protocol aiming to streamline retrofit demand will need to address each of these causes in turn.

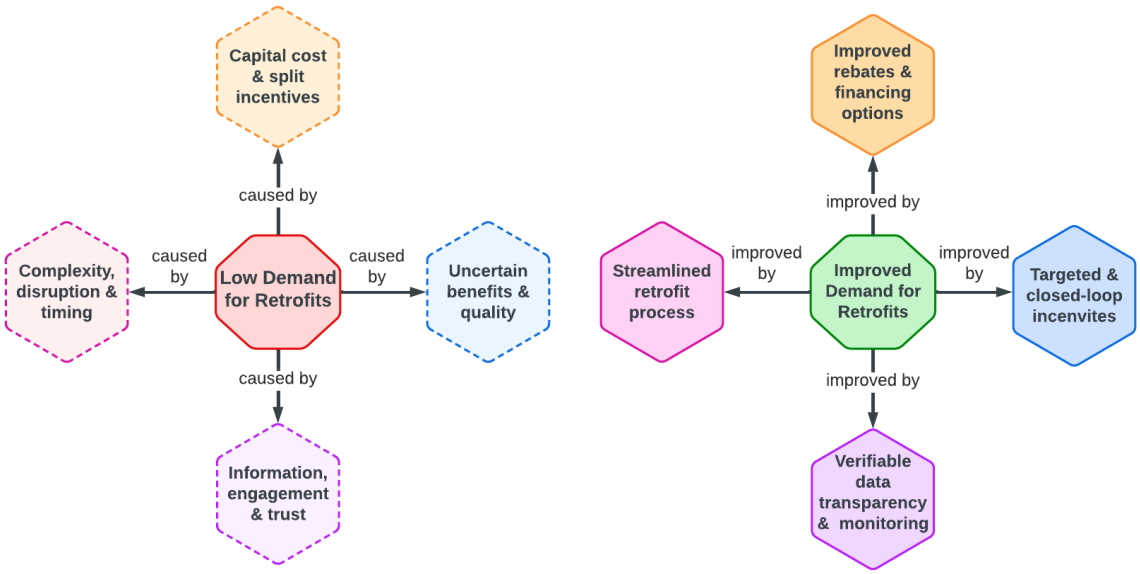

Figure 2. Identifying causes for historical low demand for retrofits and ways to improve them.

To address the causes of low retrofit demand, the goals of this program are to enable:

- Improved rebate programs and financing options
- A streamlined retrofit process
- Verifiable data transparency and monitoring, while respecting user and data privacy
- Enabling targeted closed-loop incentives from realised energy efficiency outcomes

To enable these improvements, we begin by exploring and analyzing initial requirements for the Windfall Protocol Program in relation to their functional domains and the stakeholders they impact.

Technological domain:

- A shared data infrastructure with permissionable access for all stakeholders that is able to index, filter, and aggregate building data across multiple parameters for various uses (e.g. surfacing high impact retrofit opportunities for cross-sectional groups)
- The capability for stakeholders to transact with that data infrastructure using various data sources within their permission set

- A method to register various data schemas to the data infrastructure, such as Green Button energy data, building data, or audit data and indicate privacy considerations
- A method to log attestations (verifications) to the data infrastructure and to append proofs of external data sources such as energy feeds or audit reports
- An open API instantiated from an open source code repository (with documentation) that enables observable application development and extension
- A method to analyze retrofit attestations against reported energy usage
- A method to address jurisdictional data residency requirements

Governance domain:

- A method to assign and revoke ledgers to building addresses to account for physical construction and demolition of buildings, respectively
- A method to assign and update various stakeholders credentials, permissions, and access control
- A method to govern updates or conflicts in data schemas and formats
- A method to govern updates to the underlying protocol

Economic domain:

- A method to create, update, and automate targeted incentive policies and performance-based contracts
- A method to support ongoing research and development of the protocol along with maintenance costs of infrastructure
- A method to align interests of participants with the success of the protocol and improved net-zero outcomes

These requirements will support in guiding initial discovery and design of a high-level architecture and identification of core protocol building blocks that will lay the groundwork for the pilot implementation. The initial pilot aims to implement a subset of the above requirements in a minimum viable protocol, aiming to establish a core infrastructure that can be developed in an iterative fashion. Additional funding will support a pilot implementation in Durham Region, as well as ongoing, modular upgrades to protocol functionality to enable its application in further use cases and additional jurisdictions.

6. Protocol Building Blocks

> *“Deploying retrofits at infrastructure scale requires a mission-oriented policy approach, which establishes ambitious goals and invites a bottom-up search for replicable emission reducing retrofit solutions. These solutions will require reshaping the structure of existing retrofit markets to create economies of scale and learning.”*
>
> \- Haley, B. & Torrie, R.
> Canada’s Climate Retrofit Mission

The Windfall Protocol Research Group has identified three primary building blocks for a protocol that meets the requirements discussed in Section 5:

- the **building ledger**, which holds records or proofs of any data relevant to the building
- an **attestation and credentialing service**, which assigns access permissions to control who has read or write access and verifies external data updates to the ledger
- a **targeted incentive policy designer** that will allow policymakers to set conditional rebates and subsidies to meet net-zero targets in ways that match energy policy incentives to local needs and context more efficiency and effectively.

These building blocks all exist within the shared governance of the Windfall Protocol, which would be minimally restrictive to suit different uses of the protocol in wide-ranging circumstances. This layer would support upholding data privacy requirements, oversee data standards updates, and provide input on the economics of the protocol such as fees to support ongoing research, development, and infrastructure operations and maintenance, along with other economic considerations.

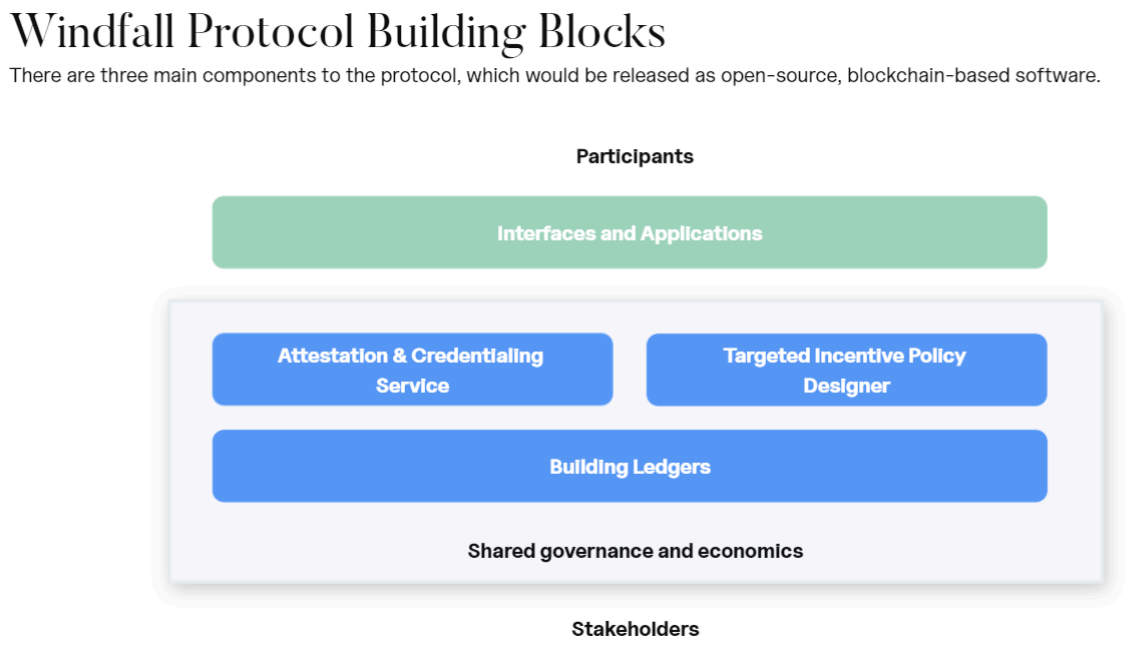

Figure 3. Participants would experience the Windfall Protocol through interfaces and third-party apps that would access the underlying data (depending on permissions) from the building ledger, attestation and credentialing service, and incentive policy designer.

Building Ledger

Windfall Protocol proposes to address the issue of fractured data by centering on the building itself, often an invisible entity in retrofit programs. By assigning each building a ledger of account, homeowners have one secure location where they can register building data, audit and

retrofit information, and the resulting changes to its energy footprint. By aggregating all information relevant to a building in one place, the building ledger acts like a permissioned databus that can be accessed by stakeholders with appropriate credentials. This also makes it possible to perform closed-loop analysis by connecting retrofits to actual energy efficiency outcomes, a benefit to regulators and policy-makers who seek to improve retrofit programs and more effectively target incentives.

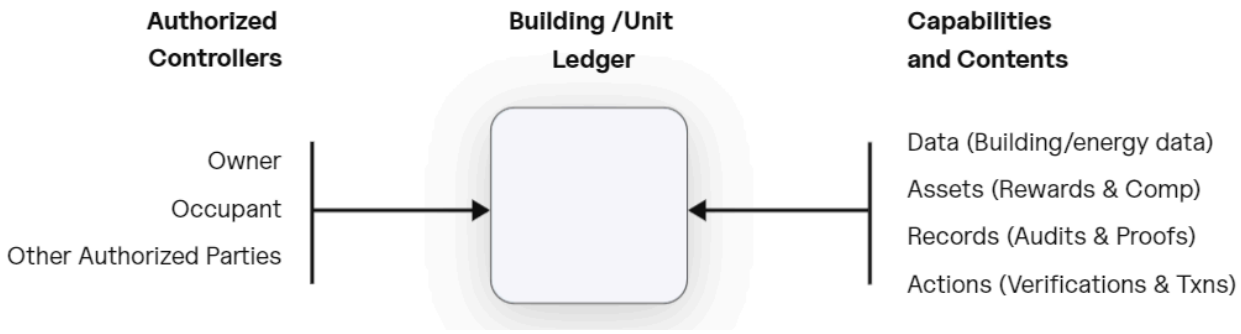

Figure 4. A simplified depiction of a building ledger including data feeds about building information, audit data, energy feeds, and retrofit attestations.

Attestation & Credentialing Service

The building ledger also must be able to register updates to building data through appended data, such as audit reports. This leads to the need for another core component - an **attestation and credentialing service** that can permission actors to reliably interact with these data feeds and append new data to the building ledger. The attestation service would enable the building ledger to store verifiable proofs of real-world data related to audits, equipment, energy usage, or any associated files or records that are relevant to the building and its energy efficiency.

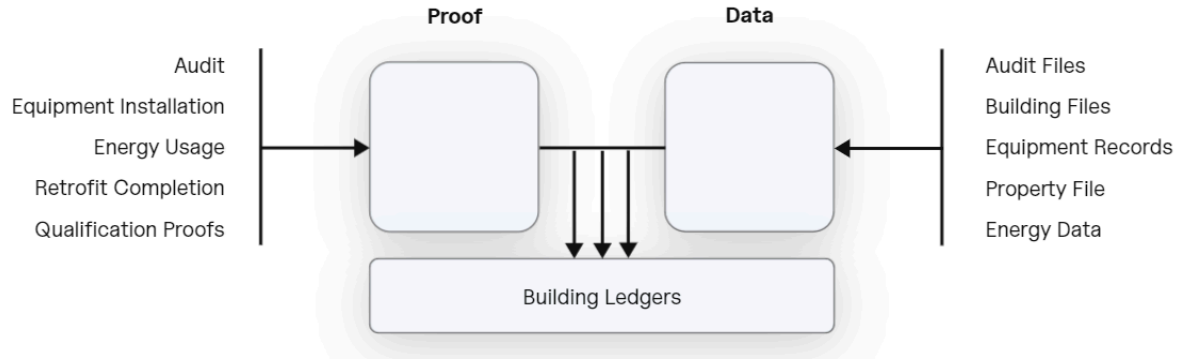

Figure 5. A depiction of on-chain attestation proofs and off-chain data being stored on building ledgers.

Some examples of attestations that could be tracked in the Windfall Protocol are the credentials that Natural Resources Canada provides to energy auditors, or an attestation by an auditor about a particular audit. They could also be used by utilities attesting to a building's energy

history, or by a contractor attesting to the type and model number of equipment being installed on location. The space of composability for these tools to interact with many existing data systems is vast.

Targeted Incentive Policy Designer

In addition to the building ledger and attestation service, another building block in the Windfall Protocol is a **targeted incentive policy designer** for municipalities, governments, or other entities to offer targeted incentives and financing options to accelerate retrofits. This could be done granularly based on various parameters like building size, a particular retrofit upgrade, or could filter to aggregate data and identify larger-scale retrofits by regional climate or other shared parameters, such as suggested in the Energiesprong model[54] developed in the Netherlands and researched for deployment in Canada.

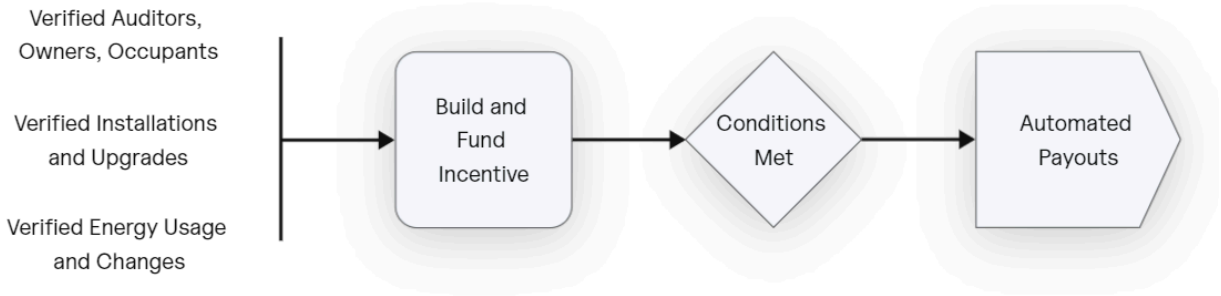

Figure 6. Targeted incentive policies can be programmed to transmit automated payouts on the satisfaction of subsidy conditions.

Some examples of targeted incentive policies could include:

- Energy efficiency/reduction contests based on measurable energy outcomes
    - E.g. The top households to reduce energy over a month in a given region win $100 off their home energy bill
- Improved automation and data analysis to identify high leverage retrofit engagement
    - E.g. Policymakers able to identify and prioritise building types or regions eligible for mass retrofits
- Conditional incentive policy design across multiple building attributes
    - E.g. In [municipalities / buildings / residential or commercial / etc.] that meet conditions of [-15C avg winter temperature / >50 year build / etc.], apply incentive towards [heat pump installation / new window & door quote / etc.] in the form of [direct rebate / 0% interest loan / etc.]

Interfaces & Applications

With protocol building blocks serving as infrastructure, municipalities, utility companies, and third-party service providers could build applications, interfaces and other protocols, such as data dashboards, or negotiating group financing offers, for example. These applications could

[54] Sustainable Buildings Canada Website. About the Energiesprong program.

also be open-sourced, modularized, and then customized to suit different jurisdictions and stakeholder needs.

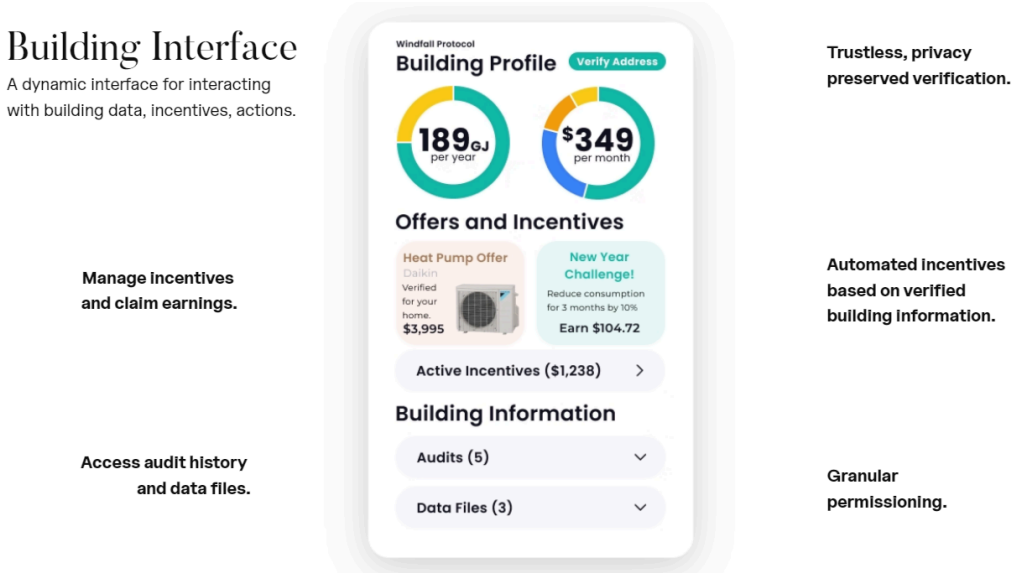

Figure 7. shows a mock-up of what a user interface with a building profile dashboard, incentive and product financing offerings, and other energy efficiency information might look like along with example actions and features.

7. Technical Considerations

"We need a shift in mindset from data protectionism to data stewardship. Data stewards are responsible both for protecting data and ensuring that the risks of privacy breach are low and ensuring access and use of data for the public good."

- Bubela, T., Simon Fraser University et al
Data-sharing lessons Canada can learn from the COVID-19 pandemic[55]

Prior to implementation of the Windfall Protocol building blocks, there are several technological domain considerations to be explored. In this section, we outline some of the relevant characteristics of distributed data architectures that could sidestep some of the challenges of centralized data and decision-making silos, to provide desired properties of extensibility and interoperability to the protocol. We will also explore the types of data that will be involved in the Windfall Protocol, as well as data access control considerations to ensure data privacy and integrity. We also examine the energy implications of the technical infrastructure itself, to ensure its integrity and alignment with the program's goals.

[55] Bubela, T. et al, *Globe & Mail OpEd. Data-sharing lessons Canada can learn from the COVID-19 pandemic, 2023.*

Data Architecture

Windfall Protocol proposes a data architecture that leverages blockchain technology for data security, routing, and availability as needed. Blockchains were built to facilitate decentralized networks, resources, and assets, and are increasingly being adopted at an institutional scale. Several features of blockchain technologies lend themselves to providing permissioned access to multiple stakeholder groups over intersecting data. Their benefits could be applied to the challenges faced in accelerating reductions in building energy consumption via the following key properties:

Decentralized Infrastructure

Part of the reason for the difficulty of data management in multi-stakeholder ecosystems is the centralization of data storage and access. These data silos lead to information asymmetries in energy retrofit ecosystems, limiting the coordinative capacity of involved stakeholders. Blockchains address this challenge by providing a shared data registry that can manage access for all stakeholders who hold adequate permissions. Shared infrastructure also implies reduced costs compared with redundant proprietary systems, and also guarantees modular composability, holding the potential to accelerate adoption and innovation.

Immutable Data Integrity

Another key requirement of the protocol architecture is data integrity and availability. The structure of blockchain architectures, a ‘chain’ of data ‘blocks’ all linked together through cryptographic hashing, and with data proofs available for linked data on low-cost storage, provides guarantees for the integrity and availability of data. In this way, blockchains can enable safe, low-cost sharing of data with varied privacy and permissions while guaranteeing data integrity.

Automated Smart Contracts

Certain blockchain architectures, like Ethereum[56], also offer smart contracts that could enable conditional processes and automated incentives in energy efficiency programs. This could allow incentives to be programmatically delivered, based on verified actions and outcomes, lowering costs of manual monitoring and improving retrofit ecosystem efficacy.

Data Privacy, Security & Sovereignty

Storing private data on public ledgers can often be a point of contention for institutional uses of blockchain infrastructure. However, private data need not be stored on-chain at all, since verifiable attestations act as reliable proof of their existence off-chain. Public and private blockchain ledgers offer various advantages, with some even specifically catered to energy markets like the Energy Web Alliance[57]. The choice of data storage architecture must keep data security, privacy, and sovereignty as key considerations, with configuration capacities that can uphold legal and jurisdictional requirements and respect the First Nations Principles of OCAP®

[56] Ethereum: https://ethereum.org/
[57] Energy Web Alliance: https://www.energyweb.org/

(ownership, control, access, and possession) of data management[58] as well as update data sharing parameters and permissions if necessary. The architecture and protocol economics should also enable data intermediaries to add value to data products and receive fair compensation rather than extracting value and creating asymmetries that counter the public good.[59]

Real-World Assets & Data Markets

Several applications of blockchain technology involve the stewardship of real-world assets and data markets relevant to our analysis of data storage infrastructure. One example, Ocean Protocol[60], is a blockchain-based data market platform, which facilitates the upload, storage, and exchange of large datasets, all secured via access permissions. The protocol's compute-to-data service even allows for computation and data analysis without revealing the underlying data.

Applications of blockchain technology for the stewardship of real-world assets and climate solutions have also gained rapid popularity in the last few years, with markets for carbon credits as a primary use case. Regen Network[61] has been a leader in bringing carbon credit offset markets on-chain, setting off a flurry of institutional exploration into the use of blockchains to manage tokenized "real-world" and ecological assets.

Energy Efficiency of Technological Infrastructure

Blockchain technologies, and Bitcoin in particular, have faced public scrutiny for their energy consumption levels.[62] This critique is primarily aimed at "Proof of Work" consensus mechanisms[63], which require large amounts of energy to provide computational power toward securing the Bitcoin network. However, many blockchains have since developed alternative consensus algorithms that use up to 99.95% less electricity, such as "Proof of Stake" systems like the Ethereum blockchain.[64] However, much like other electricity-powered technologies such as cloud computing, social networks, and artificial intelligence, developers of these technologies are working towards reducing unsustainable energy consumption by decarbonizing operations[65], bringing more transparency in renewable energy usage, and adapting mechanisms to facilitate sustainable industry growth.[66] Research suggests DLTs could even be an ally in reducing the energy consumption of existing systems (like replacing some energy-intensive payment systems

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[58] First Nation's Principles of Ownership, Control, Access, and Possession (OCAP®) of data: https://fnigc.ca/ocap-training/
[59] Data intermediaries paper citation forthcoming
[60] Ocean Protocol: https://oceanprotocol.com/
[61] Regen Network: https://www.regen.network/
[62] University College London, Centre for Blockchain Technologies. DLT Environmental Impact, 2023.
[63] Zhou, S. et al. MDPI Journal. A Systematic Review of Consensus Mechanisms in Blockchain, 2023.
[64] Shaping the future of Ethereum: Exploring Energy Consumption in Proof-of-Work and Proof-of-Stake Consensus
[65] World Economic Forum blog. Why the debate about crypto's energy consumption is flawed, 2022.
[66] EU Blockchain Observatory and Forum. Energy Efficiency of Blockchain Technologies, 2021.

with the latest digital currency technologies that consume less energy),[67] driving the decentralization of energy production,[68] and supporting energy load balancing with smart grids.[69]

The Windfall Protocol Research Group will consider the energy consumption of technologies employed, and design considerations could include carbon offsets or other energy credits to cover associated energy usage by the digital infrastructure itself.

Data Types

"*A functioning market requires the right information.*"

- Efficiency Canada
Canada's Climate Retrofit Mission

In looking at data architectures, it is important to understand what types of data will flow through the system. The two primary types of data that the building ledger will be tracking are **Building Data** and **Energy Data**. By appending timestamped updates of building and energy data to the building ledger, including audits and retrofits, the Windfall Protocol aims to address the core challenge of siloed data in the retrofit process.

Building Data

Building data includes information such as the building envelope to understand heat loss and gain, building equipment that delineates energy demand, and property information that can inform the building's capacity for renewable energy solutions. Data can be held by disparate authorities such as municipalities and real estate assessment corporations and may be accessible through sharing agreements with regional partnerships.

Audit & Retrofit Data

Building data can be updated through audits (virtual or manual), which take place both before and after retrofit installations are completed. Retrofit data is recorded in audits, and audit reports can be considered 'state updates' to existing Building Data. Audits form a pre- and post-snapshot of the energy profile of a building, establishing a baseline against which to measure efficiency improvements. Audit reports are usually prepared using HOT2000[70] energy modelling outputs.

Energy Data

Energy usage data for a building is now available for download and use by over 60 million North American consumers through the Green Button standard for energy data access.[71] The Green

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[67] International Monetary Fund blog. How Crypto and CBDCs Can Use Less Energy Than Existing Payment Systems, 2022.
[68] SAP Insights. Blockchain's Energy Crisis.
[69] Alladi, T. et al. Pubmed Central Journal, U.S. National Center for Biotechnology Information. Blockchain in Smart Grids: A Review on Different Use Cases, 2019.
[70] Government of Canada webpage. HOT2000 Software Suite, 2023.
[71] Green Button Standard: https://www.greenbuttonalliance.org/green-button

Button Alliance also has an API for third-party apps to connect with energy data streams, which could be stored or attested to on the building ledger.

Metadata

Metadata can be colloquially defined as “data about data”. In addition to data about the building itself, its energy footprint, and retrofit updates, building ledgers could also track metadata about the building, such as part numbers and certifications of the various hardware or equipment installed. Tracking the model version of installed smart metres, for example, could greatly improve data availability that could help to scale future retrofit opportunities by highlighting compatibility requirements ahead of recommended retrofits.

Additional Data Formats

Data incorporated by the Windfall Protocol could be extended to include additional data formats relevant to a building, such as geospatial data, water data, carbon flows, property tax data, or any other information about the building’s features. New data and file types could be included over time by including their schemas in the attestation service to enable structured data access and analysis. While data standardisation exists within each domain, such as Green Button standards for energy data or HOT2000 outputs for audit data, harmonization between these various standards will be necessary to unlock greater protocol functionality.

For implementation, consideration of varying data schemas will be detailed to enhance consistency and interoperability of data registered on the ledger. This work will occur in the implementation phase of the project, mentioned in the following section, outlining the minimum viable protocol for the Durham deployment.

Data Access Control

Data control and permissioning in the Windfall Protocol must prioritize the privacy of the homeowner, and the security and sovereignty of data for all participating stakeholder parties. Model-View-Controller[72] is a general software design pattern that is used to develop user interactions with digital systems by breaking them down into three parts: the **model**, which can be understood as the underlying datasets and associated schemas defining their structure, the **view**, which can be understood as the interface through which a user can interpret the underlying data, and the **controller**, which can be understood as the set of policies by which a stakeholder might update the underlying data.

[72] Model-View-Controller: https://en.wikipedia.org/wiki/Model%E2%80%93view%E2%80%93controller

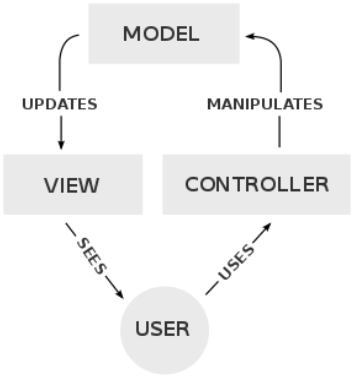

Figure 8. A diagram of the Model-View-Controller design pattern demonstrates a user's interaction with a software system via views (reads) and controllers (writes) to an underlying data model.

In using this design pattern for data access control in the Windfall Protocol, views might be understood as “read access”, and controllers might be seen as “write access” to the building ledger, which is the underlying data infrastructure or “data model” in the Windfall Protocol.

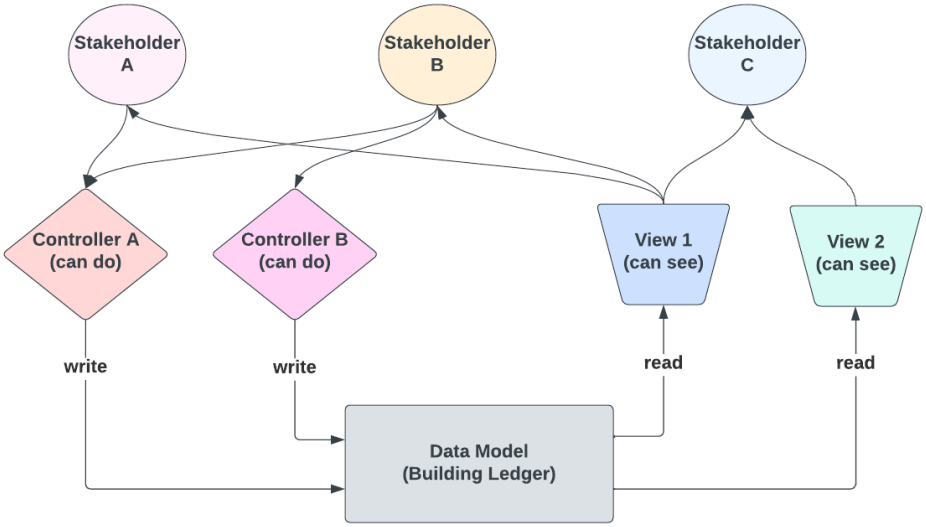

Figure 9. A representation of the data access control for Windfall Protocol, using the Model-View-Controller pattern to understand the read and write access for different stakeholder groups.

As a stakeholder, interacting with the Windfall Protocol takes place via a customizable permissioning layer facilitated by the attestation and credentialing system that only allows relevant stakeholders to interact with a given building ledger. Access for each data type and stakeholder group could be customized per deployment of the Windfall Protocol and can emulate access control and privacy policies in current data management systems for energy and building data.

8. Durham Region Pilot: Minimum Viable Protocol Implementation

"The challenge of decarbonizing Canada's buildings sector is complex and multi-faceted and brings with it strong climate and economic benefits for all Canadians. It will require innovation, collaboration, and investment to reach the goal of net-zero buildings by 2050."

- Natural Resources Canada, Toward a Canada Green Buildings Strategy[73]

The initial deployment in Durham Region will roll out a minimum viable protocol (MVP) of the Windfall Protocol program. The MVP will focus on a reduced set of requirements and the first two protocol building blocks - creating a building ledger and a basic version of the attestation and credentialing service that can layer on data and information to the ledger and provide permissioning for those data streams with varying access by stakeholder group.

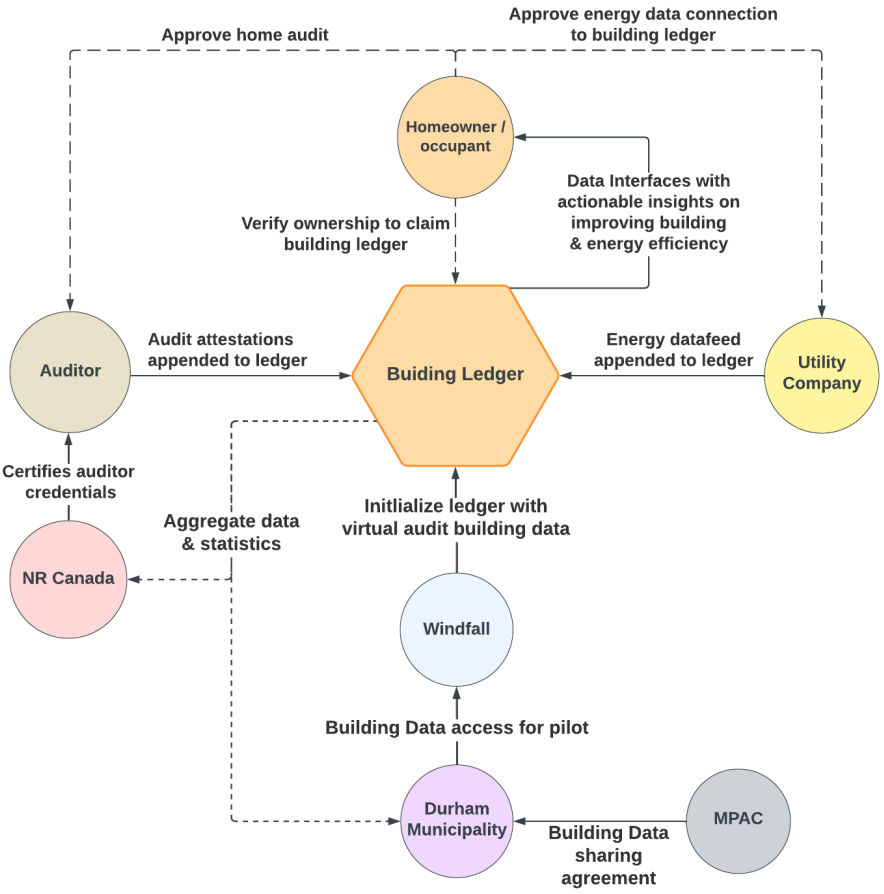

Figure 10. A system-level view of stakeholder interactions with the building ledger in the proposed Durham Region pilot deployment of the minimum viable protocol.

[73] Natural Resources Canada Report. Toward a Canada Green Buildings Strategy: WHAT WE HEARD FROM THE PUBLIC AND BUILDINGS SECTOR STAKEHOLDERS, 2023.

Minimum Viable Protocol Requirements

Technological domain:

- A shared data infrastructure with permissionable access for all stakeholders
- The capability for stakeholders to read and write to the ledger from various data sources within their permission set
- A method to register various data schemas to the data infrastructure, such as Green Button energy data, building data, or audit data and indicate privacy considerations
- A method to log attestations (verifications) to the data infrastructure, to append external data sources such as energy feeds or audit reports
- An open API for additional application development and extension

Governance domain:

- A method to assign and revoke ledgers to building addresses
- A method to assign and update various stakeholders credentials, permissions, and access control
- A method to govern updates or changes in data schemas and formats
- A method to govern updates to the underlying protocol

Economic domain:

- A method to support ongoing research and development of the protocol along with maintenance costs of infrastructure

Durham Greener Homes Program

Durham Region has been recognized as a leader in innovation for its efforts in digital transformation and energy planning, amongst other accolades of note.[74] In 2022, it launched the Durham Greener Homes project[75], in partnership with and administered by the Windfall Ecology Centre, as a solution to lower the overhead for homeowners and support them throughout the retrofitting journey. The program offers participants access to energy coaches who support them with completing in-home energy assessments, identifying eligible retrofits, helping to select qualified contractors, and navigating utility and government rebates. It also provides incentives and below-market rate financing[76] from local credit unions secured by a loan loss reserve fund.[77]

Virtual Audit and Labelling Initiative

In continuing work on its Durham Community Energy Plan - which calls for deep retrofits of the approximately 200,000 homes in the region by 2050 - Durham Region is accelerating the low carbon pathway with plans to launch a virtual audit and labelling program using the virtual Home Energy Assessment Tool (v-HEAT) in the second quarter of 2024. Building on the Greener Homes Project, Windfall Ecology Centre developed the v-HEAT virtual audit to support the

[74] Durham Region Website. Durham Region honoured as one of the top Intelligent Communities 2023.
[75] Durham Greener Homes Website. About Durham Greener Homes, 2022.
[76] Durham Greener Homes Website. Financial help for energy-saving green retrofits.
[77] Evaluation Services Corporate Review Branch Department of Canadian Heritage paper. Summative Evaluation of the Loan Loss Reserve Fund, 2005.

acceleration of residential retrofits. Lowering the energy assessment barrier even further, the virtual audit uses a machine learning algorithm to predict energy usage and utility costs of a building with approximately 91 percent accuracy, using only property and tax roll data. The model was designed using data from over 100,000 on-site EnerGuide energy audits[78] and can return a query in just half a second. No private data is revealed in Windfall's virtual audit, and only homeowners can access the information from the audit on a portal, where they must authenticate an account and provide their postal code and tax roll number. During the virtual audit, Windfall stores data locally on secure servers, and only holds data permissioned by agreements with Durham Region.

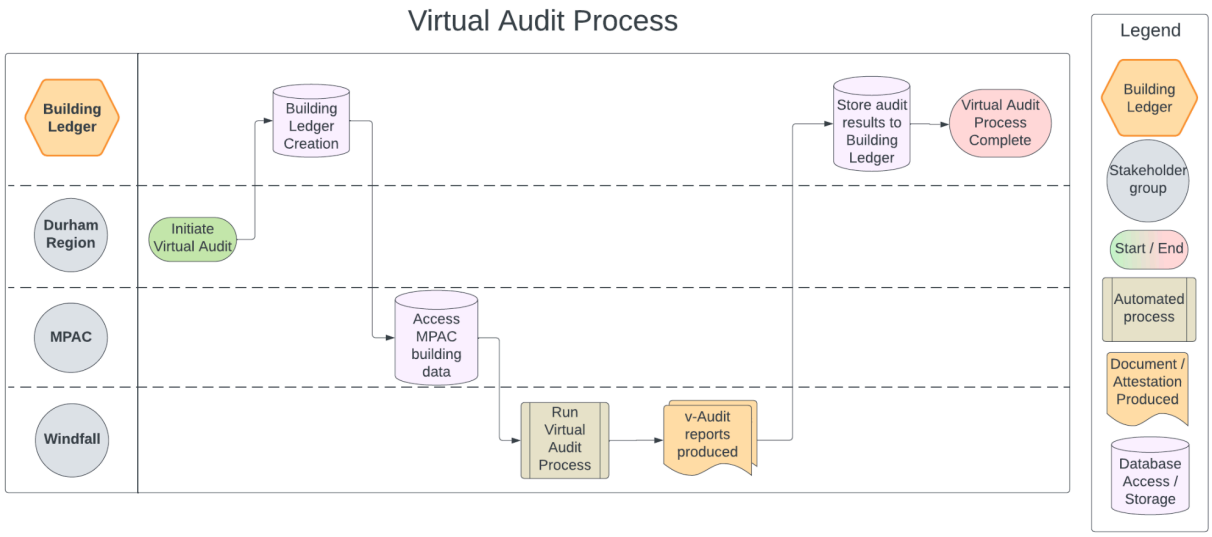

Figure 11. A process flow diagram of the Virtual Audit process and how it relates to the Building Ledger.

Windfall Ecology Centre will use the v-HEAT audits to create virtual labels for Durham's 200,000 residential homes. The municipality plans to send direct communications to homeowners and occupants, inviting them to collect their energy label by enrolling in the program. Once enrolled, they will be presented with options for retrofits. The virtual audits can also be used by the home energy coaches to support in assessing retrofit information for Greener Homes program participants.

Establishing a Building Ledger Energy Baseline

Virtual audit data offers a low-cost, scalable method to establish a baseline energy footprint for all buildings in the pilot region, creating an ideal use case for the implementation of building ledgers to register that data via Windfall's minimum viable protocol.

The energy label generated from the virtual audit will be the first information logged on all building ledgers in the region to pre-configure them with baseline data. Building owners and

[78] Government of Canada Website. EnerGuide energy efficiency home evaluations, 2023.

occupants can claim their building ledger by verifying their address on a web portal and gaining access to read and limited write privileges. From there, other data, attestations, and documents could be registered on the ledger including Green Button energy usage data permissioned by the homeowner or occupant through their local utility, in-home Energuide audits, and retrofit upgrade attestations from registered auditors. This information could generate additional energy labels and certifications for the building.

Establishing Attestation Capabilities on the Building Ledger Baseline

Once the virtual audit information is appended to the building ledger to serve as an estimated energy baseline for the building, additional data attestations can append new information on top. Connecting a building's energy data feed would be one such example of an attestation feed that could be facilitated through the GreenButton API. A process flow diagram for how a homeowner or occupant would initiate their home energy data connection can be seen in Figure 12 below.

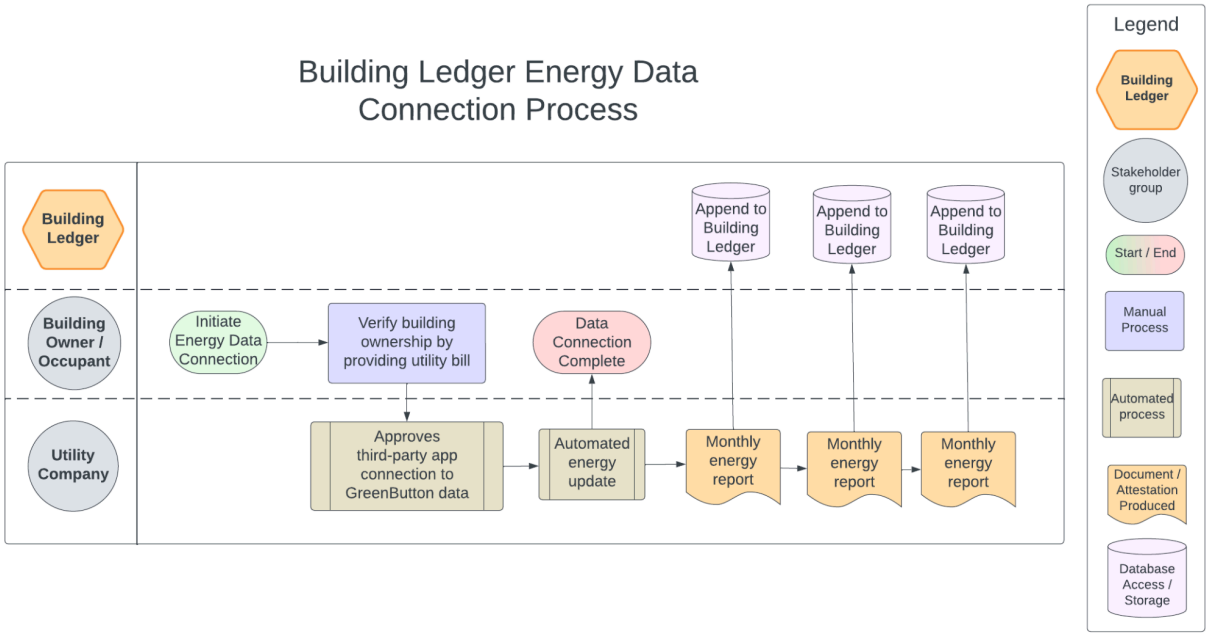

Figure 12. A diagram of the process a building owner could carry out to connect their building energy data to their building ledger.

Aside from energy data, other types of attestations relevant to the building ledger could include in-person audits, which are scheduled before and after any retrofit process to attest to the state of the building before and after an upgrade. Any relevant information could be appended to the building ledger, ranging from the model numbers of installed retrofit equipment to the audit reports themselves, which can be used as new baselines for future energy efficiency targets.

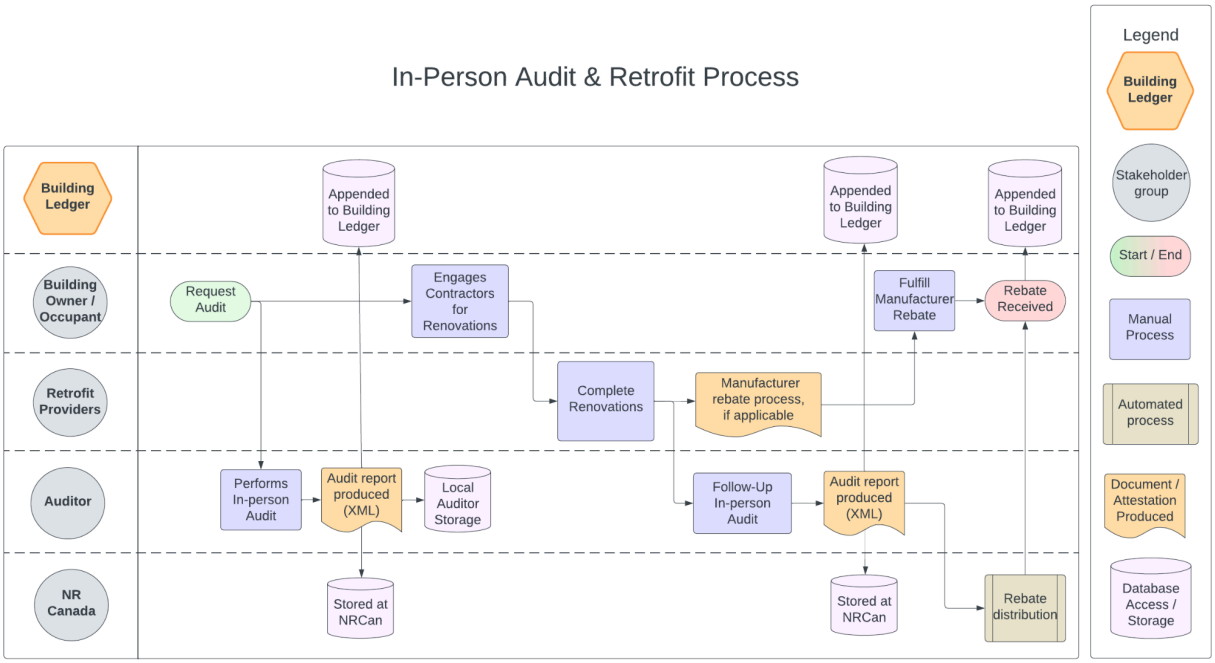

Figure 13. A diagram of the in-person audit process, demonstrating the audit before and after a retrofit upgrade is performed, as well as how their outputs can be appended to the building ledger.

Having the various data streams on one ledger could offer more visibility for building owners/occupants to see all information relevant to the building's carbon footprint and make it easier to grant more granular permissions for data usage that preserves privacy. The various data streams could also enable other functionalities for the system, such as improvements to the virtual audit algorithm or giving municipalities greater access to a variety of data streams for indexing and aggregation; this could also unlock greater retrofit financing opportunities through economies of scale.

Deploying the Protocol: Technology Options

While the Windfall Protocol Research Group is developing a pilot implementation with a subset of the requirements to address a specific instance for deployment, it will be important to build it in a modular way. This will allow for additional functionality and possible deployments in other jurisdictions. With this consideration in mind, we introduce some existing technologies that could fulfill this and other functional requirements needed to deploy the core building blocks. A comprehensive assessment including full analysis, trade-off and integration considerations, technical specifications, and recommendations will be conducted in the Development phase of work (see roadmap below). This section offers a high-level overview of some of the types of tooling under consideration for the Durham pilot and beyond.

Dynamic Non-Fungible Tokens

NFTs are unique digital objects that exist on a blockchain with a unique contract address, and metadata can be attached e.g. images, documents, or other data. That metadata is fixed in static NFTs, while dynamic NFTs (dNFTs) offer the ability to update the metadata - which is well-suited for the tokenization and representation of real-world assets. The data updates can be triggered by various conditions both on and off-chain. Inherently blockchains are unable to access off-chain data and computation however, several decentralized computing platforms enable the bridging of this data.

Figure 14. Dynamic NFTs representing a building could change to reflect addresses, maintenance history, or past sales - or in the case of the Windfall Protocol - building envelope data, virtual or Energuide audits, retrofit information, and more. Image by Chainlink.

Chainlink[79] is one such platform that provides off-chain data and computation services that can be used as inputs to trigger dNFT updates bridging the on and off-chain worlds. It also offers a service that can connect any API to an NFT contract.[80] dNFTs and on-chain-off-chain bridge services could be employed to fulfil the functionalities needed for the building blocks of the Windfall Protocol. Integration with other technologies such as Ethereum Improvement Proposal 6551 (EIP-6551[81]) will allow NFTs to own assets and interact with applications without requiring changes to existing smart contracts. This opens up further composability using these tools and would enable key functionality for dNFTs to operate as building ledgers in the pilot.

[79]Chainlink: https://chain.link/
[80] Chainlink Article. What is a Dynamic NFT? (dNFT), 2023.
[81] Ethereum Improvement Process 6551: https://eips.ethereum.org/EIPS/eip-6551

Ceramic Network

Ceramic Network[82] is a decentralized data storage and retrieval system for updateable data, as well as an attestation service that allows for credentials and claim verifications through Decentralised Identifiers (DIDs). Leveraging InterPlanetary File System (IPFS) for data storage and integrating blockchain for consensus mechanisms[83] (which ensure network security), Ceramic diverges from traditional blockchain frameworks that are predominantly transactional and immutable by nature. This infrastructure allows for the creation, hosting, and sharing of dynamic content without centralized oversight. However, the platform's reliance on IPFS and blockchain technologies must incorporate tradeoffs related to scalability and data retrieval speeds.

Hats Protocol: On-Chain Data Permissioning

The Windfall Protocol pilot will require credentialing and attestation services to assign permissions to various stakeholders for access to various data views, and the capability to write attestations to the building ledger regarding new audit, building, or energy data. Hats protocol is in use by Windfall Protocol to manage permissions for community communication channels and could be extended further for role-based data permissions among a growing community of energy efficiency infrastructure researchers and practitioners.

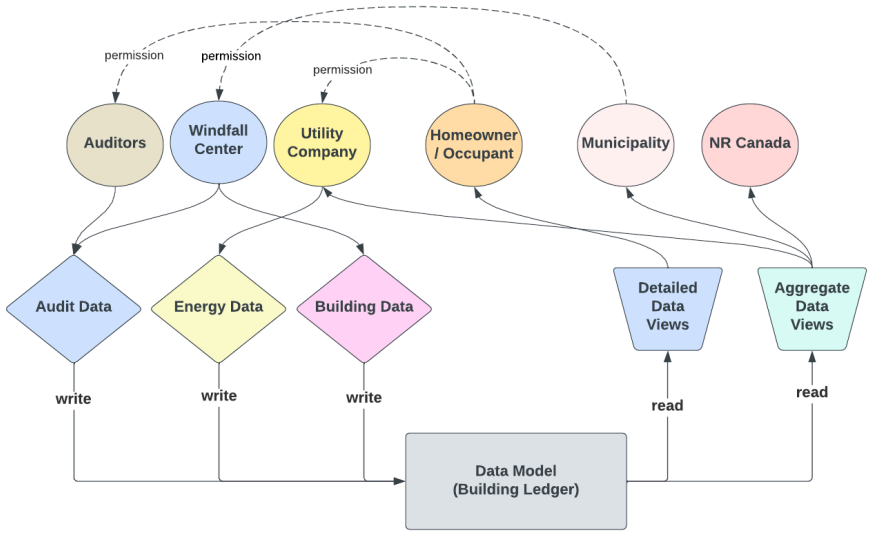

Figure 15. A diagram of the Model-View-Controller system for the Durham Region pilot deployment of the Windfall MVP, indicating access permissions for each stakeholder group involved.

Ethereum Attestation Service

The Ethereum Attestation Service[84] is an open-source attestation infrastructure that is compatible with several of the tools discussed above. This service allows for customized rules

[82] Ceramic Network: https://ceramic.network/
[83] John, F. et al. Consensus Mechanisms in Blockchain: A Deep Dive into the Different Types, 2023.
[84] Ethereum Attestation Service: https://docs.attest.sh/docs/core--concepts/attestations

for data attestations and permissions, which will be required for the jurisdictional variety in rulesets and permissioning in the Windfall Protocol, to be customizable to meet local needs and standards. The Ethereum Attestation Service has a strong focus on privacy considerations for data management.[85]

9. Stakeholder Challenges Addressed by the Windfall Protocol

> *"The establishment of shared digital infrastructure to facilitate energy efficiency improvements has the potential to mobilize tens of billions of dollars in investment in community infrastructure while expediting actions towards net-zero and providing much-needed local and national economic revitalization."*
>
> - Windfall Ecology Centre

The Windfall Protocol aims to address many of the gaps that exist between stakeholder groups in current building energy efficiency subsidy programs. For participants, it offers unified interfaces for building and energy data and incentive opportunities they could benefit from. For regulators and incentive providers, the protocol offers opportunities for smart and targeted incentives, improved data access, and actionable net-zero strategies, providing more effective transition pathways to an energy-efficient future.

Figure 16. A diagram illustrating the desired properties and value propositions of a new layer of shared digital infrastructure and their associated affordances.

A shared databus with a building ledger, attestation, and credentialing service, and in a future phase of development, a targeted incentive policy designer, could allow for more granular subsidies and the aggregation of retrofit demand, leading to greater economies of scale in energy efficiency retrofits. This multi-stakeholder digital infrastructure could even be leveraged for large-scale transformation of energy efficiency markets, open new avenues for financing, and supercharge the incentive and coordinative capacities for the depth and speed required to drive the volume of retrofits required for net-zero. Below, we look at how the Windfall Protocol could address the key challenges of stakeholders surfaced in the Stakeholder Mapping exercise.

[85] EAS Privacy: https://docs.attest.sh/docs/core--concepts/privacy

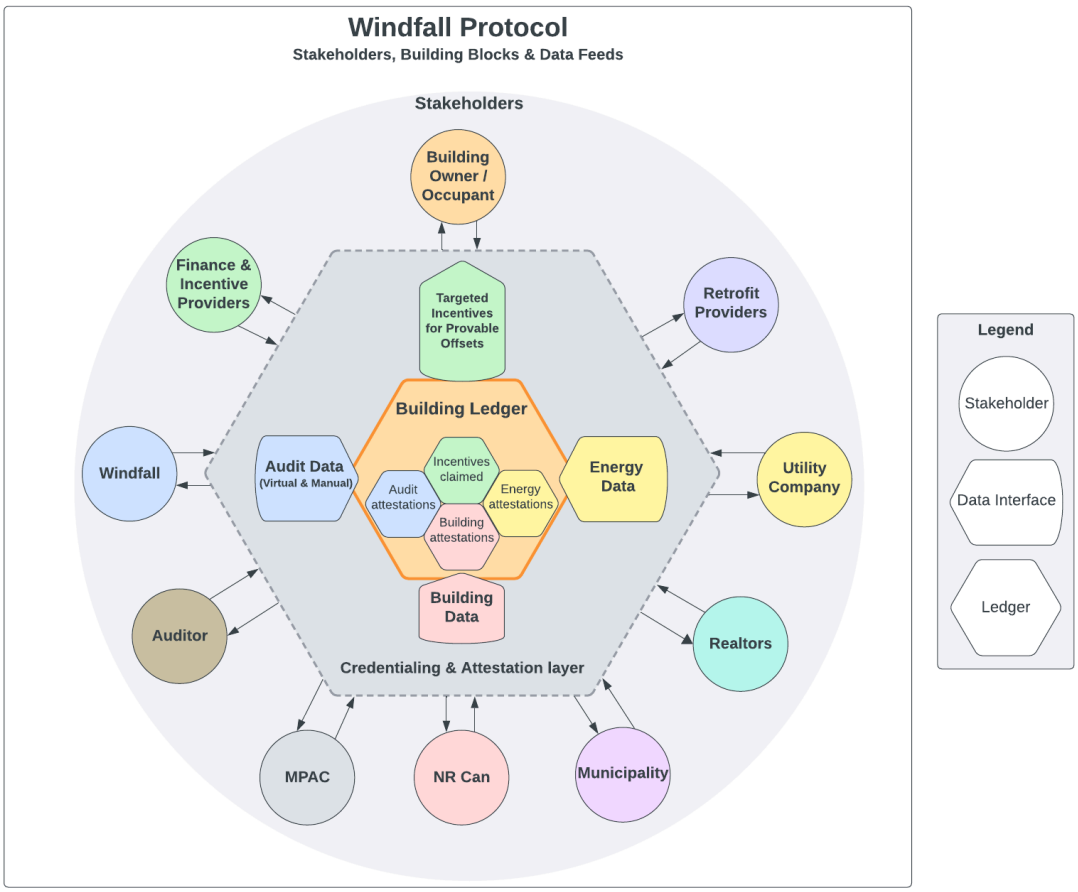

Figure 17. Representation of protocol building blocks, including building ledger, data feed attestations, and credentialing layer for conditional stakeholder access.

Building Owners & Occupants

One key challenge identified for this stakeholder group was split incentives. This could be addressed, granularly within the protocol via incentives offered within the interface, based on the account. For example, building owners could receive incentives for equipment, while occupants (renters or tenants) could receive targeted incentives for energy usage. Payouts could also go to an account for the building itself, allowing incentives to carry over beyond occupancy or ownership change, or be split amongst stakeholders. Up-front financing was also identified as a need; building owners could receive direct offers from finance and incentive providers via municipal or regional governments. These payouts could also be automated when certain conditions are met, e.g. energy usage targets or retrofit completion attestations. By having access to the building information and customized profiles based on their stakeholder role, the overhead for managing retrofits, financing, and incentives would be greatly reduced - another key challenge identified in this research.

In addition to these use cases and examples, tailored programs could be offered to fit the specific incentive, finance, building, and access challenges of First Nations, off-grid

communities, and low-income groups. This could enable more flexibility to cost-effectively implement bespoke cost and benefit-sharing schemes across a diverse set of stakeholders and ways of governing assets.

Local & Regional Government
For municipalities and regional governments, the protocol could reduce administrative costs in advertising, facilitating, and administering retrofit information and programs. The protocol would also ensure and support the government's prerogative of maintaining data privacy and security, while streamlining data flows and permissionable access. The enhanced data flows, granularity, and indexing of data could also support this stakeholder group in accessing better financing and funding opportunities, both for their citizen's retrofits and their own initiatives in accelerating retrofits. The protocol may also enable better coordination amongst municipalities in sharing successful pilots, patterns, and programs they are deploying.

Utilities
A key challenge for utility companies has been the expense and overhead of complying with open data regulation and updating technical infrastructure. The Windfall Protocol could support streamlining data via open APIs while enabling building owners and occupants to directly grant access to their data. Better data availability and integration on shared infrastructure will also make it easier for utilities to innovate and improve on-bill incentives and financing. The protocol could even facilitate a shift towards utilities as platforms for distributed energy production and financing, opening potential new streams of revenue and alternative business models.

National Government & Regulators
Similar to local and regional governments, the key challenge of balancing data privacy and security and streamlined flows of data with transparency would be addressed with Windfall Protocol and its permissioning capabilities. The decentralized infrastructure would also support helping this stakeholder group to keep up with fast-moving markets and retrofit products, as retrofit providers could enter data into the ledger, and metadata to track installs granularly, down to the serial or product number, or type of heat pump along with a photo for example. They could also create automated processes to accelerate the certification of energy auditors, done through an application built on top of the protocol.

Energy Auditors
A key challenge identified in this stakeholder group was that there is a shortage of certified energy auditors. In addition to the automation of certification, an educational application or portal could be built on top of the protocol that streamlines the training and certification of energy auditors. A machine learning tool could be built on top of the protocol to analyze and aggregate audit data to identify overestimates and flag incomplete building descriptions or missing opportunities - a key challenge surfaced in the research involving this stakeholder group. Incentives could also be offered to encourage data sharing between auditors, to improve overall audit efficacy.

Retrofit Providers & Contractors
With shared infrastructure, retrofit providers could have access to a tailored portal from governments, supporting them in staying up-to-date and adhering to regulatory requirements. They could also build their reputation with verified installs and offer incentives directly to priority buildings. As more energy-efficiency software and devices come online, the protocol and energy usage connection could also be used as a validation layer on the performance and claims of those devices and software. With ties between energy usage and retrofits, incentives can be geared toward the most energy-efficient retrofits, rather than retrofit bias in previously open-loop programs.

Finance & Incentive Providers
Finance and incentive programs could be streamlined with the Windfall Protocol, reducing fragmentation and competition. Government and other stakeholders could be permissioned to see what is already offered by other programs, layer on supplementary incentive offers to fill in gaps and focus on deep, rather than basic, retrofits. Building data could be aggregated so financiers could offer retrofit financing to groups sharing certain parameters. The release of funding could be automated by smart contracts when certain conditions are met - e.g. a private attestation of a credit check. A module could be built on top of the protocol that enables the creation of a Green Bank that can disperse funding to the building itself or the building owner or occupant. This could also support low-interest micro-lending or a community financing and investment platform backed by a government or loan loss fund, so citizens or a municipality could invest in their neighbor or community's retrofits, and receive a return.

Realtors & Real Estate Platform Operators
Realtors and Real Estate Platform Operators have an opportunity to be ahead of the curve in offering investors and buyers energy efficiency information about homes to improve their capability to make risk assessments and decisions regarding building purchases. With the Windfall Protocol, they could have additional information to offer buyers if the property they are looking to purchase is eligible for subsidies. This could increase the attractiveness of the home, knowing electricity costs could be lowered with retrofits. Incentive providers could also consider granting a commission to realtors for retrofits converted after the sale of a building.

The Earth: Flora, Fauna & Funga
This stakeholder group can benefit directly from any successes of the protocol in reducing harm to natural and living systems. Building ledgers are capable of including data representing any flow, including fresh or waste water, carbon generation, more granular energy flows, etc., and can be linked to geographic locations with geospatial representation. Building ledgers could also be extended to, and integrated with, other protocols and ledgers representing natural bodies (that have received personhood), to account for data and other interactions - giving "voice" to the flows of nature. Distributed ledgers could also support stakeholder participation in the governance and stewardship of the interactions with, or usages of, these bodies, ensuring their rights and benefits, and the ability to extend those to future generations (e.g. encoding

seven-generation sustainability[86] as expressed in Haudenosaunee Confederacy values[87]).

Representing these flows and ledgers in our systems holds the potential to embed ecological well-being and considerations into human-made systems and internalize “externalities”. Some various expressions of this idea can be seen in projects like ÆRTH[88], Regen Network, Earth Ledger[89], and ixo[90] among others.

10. Further Recommended Research

Inclusion of Retrofits & Stakeholder Research for Other Building Types

While the Windfall Protocol pilot focuses on single-family residential energy efficiency labelling due to the existing partnership with Durham region, energy efficiency priorities and strategy development also include multi-unit residential buildings, small, medium, and large commercial buildings, and institutional buildings and retrofits.[91] Existing energy reporting mandates across commercial buildings would vastly improve the data accessibility for more accurate incentive and retrofit targeting and would be a promising area of further research towards inclusion in subsequent iterations of the Windfall Protocol. The Protocol could be expanded to include other types of installations as well, such as community renewable energy assets like solar arrays, wind turbines, or geothermal projects, improving local energy resilience. These other building types and installations also include different processes and data flows for energy audits which would need to be analyzed for further development to include these sectors and stakeholder considerations in additional modules to the protocol.

Targeted Incentives & Protocol Economics

While the Durham region deployment of the Windfall Protocol will not be implementing smart incentives in its initial rollout, they are a primary area of interest for further development and subsequent deployment. Conditional subsidies and programmatic incentives could help to massively scale retrofit opportunities, by targeting them to the geographic localities or building demographics where they can have the most impact. Indigenous, minority, and low-income communities could be prioritized for subsidy support in ways that increase their sovereignty and continue down the path of reconciliation. Smart incentives could be conditioned on any aspect of building data, geographic location, or targeted energy reduction method. The customizability of these new tools, especially when tied to verifiable data, offers high leverage to energy efficiency efforts on a national scale.

Protocol economics is also an area where further research is necessary. Windfall Protocol aims to be an open and extensible protocol with broad participatory governance among users.

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[86] Seven-Generation Sustainability
[87] Haudenosaunee Confederacy: Values.
[88] https://www.aerth.live/
[89] https://earthledger.one/
[90] https://www.ixo.world/
[91] Integral et al. Toronto Environment & Energy Division. The City of Toronto’s Net-Zero Existing Building Strategy, 2021.

Operational costs of the protocol could be covered through nominal fees charged for incentive distributions via the protocol, possibly being distributed among users, or pooled into a treasury governed by stakeholders.

Zero-Knowledge Proofs & Fully Homomorphic Encryption

Zero-knowledge proofs[92] and fully homomorphic encryption[93] are state-of-the-art cryptographic technologies that hold promise to improve privacy and security for protected data, even while allowing it to interact with external data analysis and verification systems. These tools could allow a building ledger to hold or reference fully encrypted data, preserving its analytic capabilities while maintaining privacy over the details of the data itself. In other words, data could be analyzed against certain criteria to verify information to a third party without revealing the information itself. Zero-knowledge technology is already implemented in the Ethereum Attestation Service to ensure privacy-preserving attestations in the proposed pilot deployment. Further research into these technologies is warranted to stay on top of the latest developments in this tooling to maximise data security as the protocol progresses.

AI-integrated Data Aggregation & Analysis

Further data access efficiencies could be provided through AI-integrated data analysis of records appended to a building ledger. This could enable a more adaptive data ontology to account for data formats that could be onerous to integrate with the protocol manually and difficult to account for through more traditional automation techniques manually feasible to integrate. For the security of the homeowner, any use of artificial intelligence in the processing of protected data would require provable privacy-preserving guarantees, which could make use of zero-knowledge proofs (ZKPs) or fully homomorphic encryption (FHE). Ongoing research into knowledge networks and the safe use of artificial intelligence in data analysis without resorting to fragile unifying standards will inform further research in this direction.[94]

Emergent Collective Funding Mechanisms

To fully scale energy retrofit programs to the level they need to be to reach net-zero targets, alternative funding options will need to be developed for retrofit financing. Loan books are difficult to negotiate with credit unions and banks due to the competition of zero-interest loans from the federal government. For their part, federal loans are capped per applicant, and often not available until several months into the retrofit process, leaving a gap in capital funding for home retrofit projects, especially among lower-income and minority groups who often have the most to gain from retrofit opportunities. New methods of collective funding for retrofit improvements could be facilitated through the Windfall Protocol, for example, collective funding for community projects. Pooling local funds as investments into community renewable energy projects such as solar arrays or wind turbines that paid energy dividends back to the community, would be some examples of possibilities that collective funding mechanisms could enable in a

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[92] Protocol Labs report. The State of Zero-Knowledge Proofs: From Research to Serious Business, 2023.
[93] Institute of Electrical and Electronics Engineers article. The Future of Fully Homomorphic Encryption, 2023.
[94] BlockScience paper: Knowledge Networks and the Politics of Protocols, 2023.

future iteration of the Windfall Protocol. This could allow communities to earn renewable dividends through decarbonization, and improve their energy-resilience in the process.

Energy Market Transformation Opportunities

The Windfall Protocol aims to address several key gaps in energy efficiency programs, but other improvements could be considered through energy market transformation opportunities. Current net-zero targets could be impeded by existing 'cost of service' business models, where energy efficiency improvements result in the loss of additional revenue for the utility. Alternative business models for energy market transformation are common in many jurisdictions (e.g. in New York), such as revenue decoupling mechanisms, performance incentive mechanisms using efficiency KPIs, or even transforming utilities into energy platform services.[28] With these alternative models, utilities can act as hubs of energy infrastructure that support facilitating energy demand reduction and the purchasing and selling of energy from a range of third-party providers and prosumers. This model of emergent, localized production could facilitate faster adoption of energy efficiency targets. As these business models change, the flows of data they facilitate may also change. The design of the Windfall Protocol must be able to adapt to updates and changes in data schemas and processes.

Feature Extension & Protocol Governance

To meet the data interoperability needs of a cross-jurisdictional protocol, Windfall Protocol will be composable with new data plug-ins and feature extensions. This would require decision-making processes for updating data standards, and addressing the changing needs of the protocol over time. As a multi-stakeholder system, a consortium governance model could be taken into consideration, where a "governance surface"[95] is defined and a polycentric decision-making[96] structure formalized. For simplicity in initial deployment, governance of the protocol pilot is managed primarily by Windfall Ecology in partnership with Durham Region municipality, with support from Possibilian, SuperBenefit, and BlockScience.

11. Conclusion & Next Steps

"A very great vision is needed, and the man who has it must follow it as the eagle seeks the deepest blue of the sky."

-Crazy Horse, 19th Century Lakota
Leader of the Oglala Tribal Band, 1849 –1877

We are living in a time of unprecedented economic and environmental challenges. Having crossed six of nine planetary boundaries[97], we stand at the threshold of ecosystemic collapse and are already witnessing mass degradation of the natural environment and irreparable harm

[95] Zargham, M. and Nabben, K. BlockScience presentation recording. The Foundations of Decentralized Governance, 2021.
[96] McGinnis, M. Ostrom Workshop webpage and presentation recording. A Brief Intro to Polycentric Governance, 2021.
[97] Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009. Stockholm Resilience Centre. Planetary Boundaries, 2023.

to people and the planet. We must drastically and rapidly re-align our institutions, technologies, economies, and human-made systems to the regeneration of our communities and natural ecosystems.

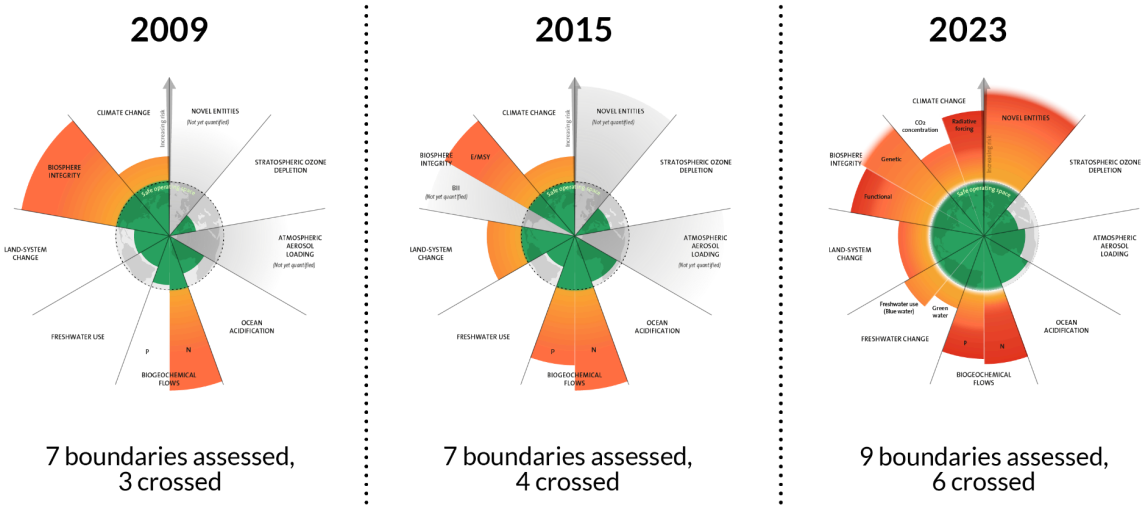

Figure 18. The evolution of the planetary boundaries framework.[98]

Unprecedented challenges require unprecedented systems innovation. This requires intervention at the highest leverage point in a complex system - which, according to renowned systems and environmental scientist Dr. Donella H. Meadows, is the mindset or paradigm in which the system itself was created, including its goals, power structure, rules, and culture.[99] This requires questioning assumptions, technological and cultural inertia, examining path dependencies, and approaching design from first principles to create a system that can enable different outcomes - one that is inclusive and considerate of all stakeholder needs and holds possibilities for collective flourishing.

The Windfall program focuses on a subset of challenges within the Climate Change Boundary - accelerating building retrofits to meet Canada's net-zero targets. A paradigm shift in this context requires a new layer of multi-stakeholder collaboration that can enable the systemic innovation required to decarbonize Canada's buildings.

This report has identified and outlined key starting points with the delineation of a larger program of digital innovation around building energy efficiency: developing a new layer of shared digital infrastructure, re-orienting towards a model of data stewardship rather than ownership, business model and incentive transformation that ensures consideration of stakeholder needs and challenges. It has also identified areas for further research and exploration in this larger program, as well as a subset of requirements for an initial pilot deployment.

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[98] Image licensed under CC BY-NC-ND 3.0 (Credit: Azote for Stockholm Resilience Centre, Stockholm University. Based on Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009)
[99] Meadows, D. The Donella Meadows Project Academy for Systems Change. Leverage Points: Places to Intervene in a System.

The Windfall Protocol Research Group and partners at Durham Region are working to secure funding for the next stages of work in the pilot roadmap, including the documentation of technical specifications to initiate the development of an MVP on a closed testnet before launching to a wider group of pilot stakeholders in the Durham Region. This multi-organizational research group is also continuing discussions with a stakeholder consortium to solicit feedback on further program development and protocol design, operations, maintenance, and participation.

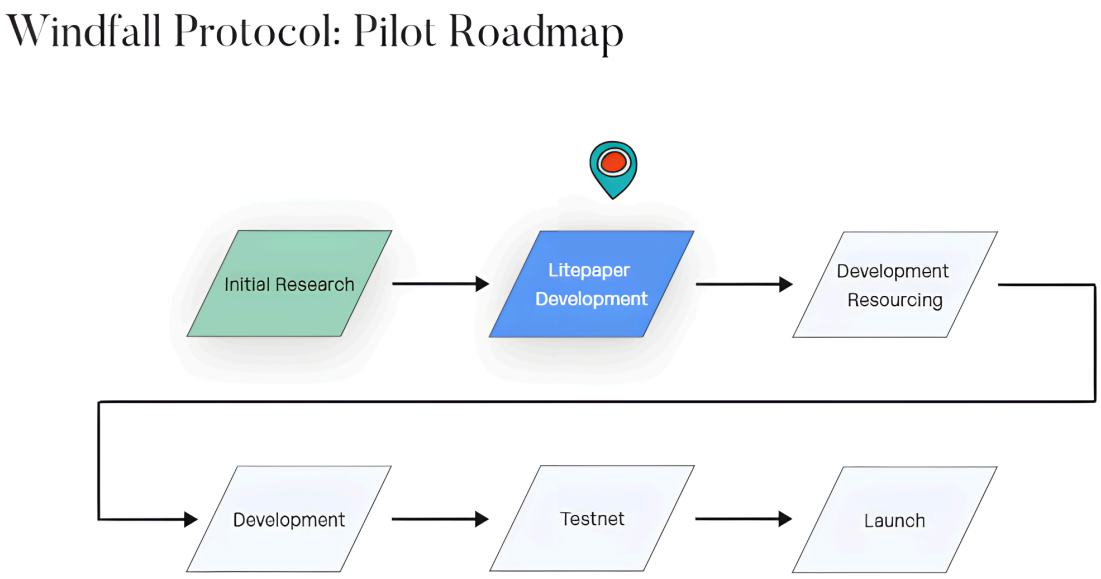

Figure 19. A high-level roadmap for the research and development of the Windfall Protocol Durham Region pilot implementation (minimum viable protocol).

The Durham pilot represents one instance of the larger Windfall Protocol implementation. The Windfall Protocol Research Group envisions evolving the architecture to serve other jurisdictions, as well as inviting the research, collaboration, and development of other modular applications and protocols on top that aim to accelerate building retrofits.

As noted in Canada's Climate Retrofit Mission: "Canada's policy system already has many of the building blocks to implement a mission-oriented approach. Missing elements include an independent and innovation-focused organisation to guide the mission, coupled with on-the-ground teams exploring ways to reshape how retrofit markets function." The Windfall Protocol Research Group and stakeholder consortium offer a schelling point for coordination and leadership in this crucial mission. The group welcomes participation and collaboration to resource and further develop ideas explored in this report, and work together towards not just net-zero goals but net-positive ones, with the capacity for regeneration to serve seven generations and beyond.