Building Energy Mapping and Analytics

Concept Development Study Report

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Chapter 1. Subject

This report details the results of the OGC Building Energy Mapping and Analysis Concept Development Study (BEMA CDS). Sponsored by NRCan and drawing on numerous previous studies, the CDS released a Request for Information on building energy data and applications. The responses were presented and validated in 3 public workshops and form the basis for an Energy SDI notional architecture.

Chapter 2. Executive Summary

Mapping and analysis of the energy consumption of buildings is currently undertaken in Canada by local municipalities, energy utilities, and federal agencies independently and for various purposes and across different scales. These groups derive energy usage using many different sources and methods, yet fundamentally the data are the same: understanding of the building stock–the numbers, floor areas, and other characteristics of various building archetypes and how they impact energy usage. Despite this commonality, there is little to no coordination between these groups, resulting in differing methodologies, duplication of effort, lost energy savings, and lost opportunities for decarbonization, climate change mitigation, and climate resilience.

Purpose of the study

The Building Energy Mapping and Analytics Concept Development Study (BEMA CDS) is addressing the challenge posed by this situation through undertaking to:

- Characterize the state of development of energy mapping and analytics for building stock broadly; and
- Inform and propose IT architectural practices and standards to enable mapping and analytics specifically of residential energy use and efficiency.

Study premise:

Building energy mapping and analytics are critical for geo-targeting energy policies, programs, codes, incentives, and technology integration to accelerate the transition to a low-carbon built environment and economy.

Study Methods

The CDS drew from a number of information sources, including previous and related building energy work. It then developed and publicly released in February 2020 a Request for Information (RFI) soliciting responses from a wide audience of stakeholders and organizations to specific questions in eight subject categories concerning the building energy mapping and analytics domain.

It targeted three principal scenarios for development and application of building energy analysis and mapping:

1. Community Energy and Emissions Planning
2. Utility Conservation Potential Review & Demand Side Management Program Planning
3. Federal/Provincial/Territorial Building Energy - Policies, Programs, Standards, Building Code

The RFI responses were compiled and further validated in a series of 3 workshops in June 2020, which summarized the RFI responses, invited more detailed presentations from some of the respondents, presented preliminary results of the CDS, and engaged workshop participants in both validating and extending those results.

Study Outcomes

This report presents both the activities of the BEMA CDS and its outcomes. These outcomes include challenges that building energy data and applications face, as well as opportunities to address those challenges with improved technologies, data sharing practices, and improved understanding of the benefits that could result, such as identification and reduction of energy poverty.

Challenges in carrying out this study and in advancing building energy analysisinclude the following.

- Utility perspective on conservation, demand side management, regulation is underrepresented in the responses.
- Lack of awareness among stakeholders and building professionals of the potential for mapping and spatial data analytics to facilitate the transition to a low-carbon built environment.
- Data access and sharing issues include availability, privacy, confidentiality, propriety.
- Repetitive non-standardized methods are applied to collection, exchange, integration of datasets.
- Data source methods and confidence are wide ranging and poorly documented, variously measured, modeled, inferred, estimated, assumed, etc.
- Lack of access to retrofit cost estimates presents a barrier to deriving benefits from energy mapping and modeling data.
- Lack of an overall data framework prevents connecting the scale and resolution of spatial data to particular use scenarios
- It remains a challenge to connect archetyping methods (clustering / classification) with different use case scenarios

Identified opportunities include:

- Data access technologies that account for privacy, confidentiality, anonymity, e.g. enclave processing, anonymization by aggregation + noise injection (differential privacy)
- Adaptive classification and archetyping based on sample modeling
- National systems for consistent energy data at multiple scales
- Data sharing policies and standards organized to support critical use cases and stakeholders, e.g. federation contracts, mandated reporting.
- National building data layer for comprehensive analysis of building types, energy performance, retrofit / upgrade technologies, costs, and benefits.
- Community-utility cooperation facilitated by regional/national authority to understand opportunities /costs / benefits of new technologies and energy sources, e.g. renewables

Building energy and spatial data infrastructure

A critical challenge identified in this study has been the availability of the right spatial information elements to perform building energy analysis at the various levels of generalization and specificity where it can be useful in improving lives and advancing community goals. The idea of supporting the reusability and wide sharing of spatial data by providing information as infrastructure has been around for a while and is particularly highly developed in Canada. More recently, the concept, capabilities, and design of such infrastructure have been expanding in the age of cloud computing. It makes sense in this context to consider what spatial data infrastructure might look like that can support the diverse building energy needs, opportunities, stakeholders, and goals identified in this report. A notional architecture is presented in the report for such a future Energy Spatial Data Infrastructure (E-SDI).

Benefits of the BEMA CDS for sponsors and stakeholders

While there are many studies of practices relating to building energy, this study as a product of the Open Geospatial Consortium, represents a particularly valuable perspective by focusing on issues of data sharing and spatial data interoperability that stand in the way of more fully achieving the goals and value of building energy analysis. This perspective provides benefits to a number of stakeholders and programs.

1. Building energy scientists
    - Suggests paths to improved data interoperability, better models, increased coordination
    - Identifies potential approaches for reducing duplication, time and cost savings across organizations
    - supports better quality control, comparable data for planning and program evaluation
2. Government policy / regulation / building codes / standards creators
    - Identifies new approaches to inform national and provincial housing retrofit incentive programs
    - Anticipates data interoperability challenges and opportunities around the Alterations Codes for existing buildings
3. Community energy planners / organizers
    - Municipal energy planning, including design and delivery of housing efficiency programs
    - A geospatial view offers the possibility of improved coordination with utilities through a common operating picture
4. Utility planners / coordinators
    - Anticipates need for more geospatial analysis as more renewables come online; capital cost offsetting
    - Points to “behind the meter” methods that could improve uptake for conservation and demand management (energy efficiency) programs
5. Energy and Utilities Domain Working Group (DWG)
    - Supports identification of potential further R&D and standards development activities, beyond the timeframe of the BEMA-CDS study, for example that address evaluation of decarbonization strategies.

Future work recommendations

Among the many outstanding issues the BEMA CDS has raised, a few particular learning opportunities stand out.

- Design of an extensible and standardized national building dataset "layer", leading to both national application and improved comparability of promising building energy analysis methods.
- Sandbox activities such as interoperability pilots, modeling the mutual benefits of information

sharing and data interoperability

- Prototypes for an Energy SDI, demonstrating common availability of such technologies as cloud-based energy modeling, model-driven building archetypes, and enclave protocols for addressing data privacy and propriety constraints.
- Development of energy poverty indices that take into account fine-scale socio-economic, climate, and geographic factors in assessing the impacts and mitigation of building energy costs.

2.1. Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

Table 1. Contributors

Name	Organization	Role
Josh Lieberman	Open Geospatial Consortium	Editor
Eddie Oldfield	QUEST	Contributor
Jessica Webster	NRCan	Contributor
Ryan Ahola	NRCan	Contributor

2.2. Foreword

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Chapter 3. References

The following normative documents are referenced in this document.

- OGC® Web Services Common Standard, OGC 06-121r9, , 2006 [https://portal.opengeospatial.org/files/?artifact_id=38867&version=2]
- OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 2: SQL option, 2010 [https://portal.ogc.org/files/?artifact_id=25354]
- OGC® Land and Infrastructure Conceptual Model Standard (LandInfra), 2015 [http://docs.opengeospatial.org/is/15-111r1/15-111r1.html]
- OGC City Geography Markup Language (CityGML) Encoding Standard, 2012 [https://portal.ogc.org/files/?artifact_id=47842]
- ISO 42010 standard: Systems and software engineering — Architecture description, 2011 [https://www.iso.org/obp/ui/#iso:std:iso-iec-ieee:42010:ed-1:v1:en]

Chapter 4. Terms and definitions

For the purposes of this report, the definitions specified in Clause 4 of the OWS Common Implementation Standard OGC 06-121r9 [https://portal.opengeospatial.org/files/?artifact_id=38867&version=2] shall apply. In addition, the following terms and definitions apply.

- **Big Data**

  Refers to datasets that are too large or complex to be dealt with by traditional data-processing application software, according to any or all of volume, velocity, variety, or veracity.

- **BTAP: Building Technology Assessment Platform**

  BTAP is a framework being developed by NRCan to assist in the analysis of the energy performance of technologies used in commercial buildings.

- **CDM: Conservation and Demand Management**

  Energy conservation and demand management consists of measures for conserving or otherwise reducing the amount of energy consumed and for managing consumer demand for energy, including a forecast of the expected results of current and proposed measures. (cf.f. O. Reg. 397/11, s. 4 (2).).

- **CDS: Concept Development Study**

  Early stage in the OGC process for developing new standards and interoperability practices.

- **DSM: Demand Side Management**

  The modification of consumer demand for energy through various methods such as financial incentives and behavioral change through education (Wikipedia).

- **HTAP: Housing Technology Assessment Platform**

  HTAP [https://github.com/NRCan-IETS-CE-O-HBC/HTAP] is a collection of data and tools that automate and extend the HOT2000 residential energy simulation tool. The HOT2000 software suite can be obtained from Natural Resources Canada [https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-homes/professional-opportunities/tools-industry-professionals/20596].

- **NBL: National Building Layer**

  National scale database of building attributes for Canada for which planning is underway at the time of writing. See also Statistics Canada’s Open Database of Buildings [https://www.statcan.gc.ca/eng/lode/databases/odb].

- **OCAP®: Indigenous Ownership, Control, Access and Possession**

  https://fnigc.ca/ocap.

- **RFI: Request for Information**

  A CDS stage of widely gathering information from knowledgeable stakeholders on geospatial interoperability and data sharing challenges in a new domain.

- **SCEC3 Model**

  The Spatial Community Energy Carbon and Cost Characterization (SCEC3) model was developed by NRCan's CanmetENERGY-Ottawa for the City of Prince George, BC between 2008 and 2012. It used housing and building simulation on an archetype basis to create a baseline and future scenario projections for the City's housing stock in support of GHG-related targets, policies and actions in the Official Community Plan [http://www.toolkit.bc.ca/Resource/Evaluating-Residential-Energy-Emissions-and-Cost-Scenarios-Prince-George%E2%80%99s-Official-Community-Plan].

- **TaNDM**

  The Tract and Neighbourhood Data Modelling (TaNDM) project was led by the province of BC and sponsored by NRCan in 2010-12 to improve the structure and level of geography of energy and emissions inventory data. It developed a new bottom-up method for aggregating buildings energy and emissions data by building type to a privacy-compliance threshold.

4.1. Abbreviated terms

- COTS Commercial Off The Shelf
- IT Information Technology

Chapter 5. Overview

- **Section 6** covers the background of the BEMA CDS, as well as previous and related work on Building energy
- **Section 7** details the goals, use cases, questions, and logistics of the BEMA RFI
- **Section 8** compiles and analyzes the RFI responses.
- **Section 9** presents the structure, discussions, and outcomes of public validation workshops building on what was learned from the RFI responses.
- **Section 10** discusses the challenges and opportunities gleaned from the RFI and workshop outcomes
- **Section 11** outlines what an energy spatial data infrastructure might look like that is able to support multi-scale building energy mapping and analysis
- **Annex A** contains details of the RFI response

Chapter 6. Background

6.1. Goals and scope of the BEMA CDS

Mapping and analysis of the energy consumption of buildings is currently undertaken in Canada by local municipalities, energy utilities, and federal agencies independently and for various purposes and across different scales. These groups derive energy usage using many different sources and methods, yet fundamentally the data are the same: understanding of the building stock–the numbers, floor areas, and other characteristics of various building archetypes and how they impact energy usage. Despite this commonality, there is little to no coordination between these groups, resulting in differing methodologies, duplication of effort, lost energy savings, and lost opportunities for climate change mitigation and resilience.

The Building Energy Mapping and Analytics CDS is addressing this challenge by undertaking to:

- Characterize the state of development of energy mapping and analytics for building stock broadly; and
- Inform and propose IT architectural practices and standards to enable mapping and analytics specifically of residential energy use and efficiency.

6.2. CDS Stakeholders

A wide range of stakeholder individuals and organizations are concerned with and/or affected by building energy issues. They include:

- Municipalities
- Provinces/states (or equivalent sub-national entities)
- Federal/National governments
- Regulatory bodies
- University labs
- Consultants including geomatics, engineering, planning and design firms
- Academic Institutions including labs
- Utilities
- Federal or Territorial / Provincial / State Policy Organizations
- Non-governmental or charitable organization
- Enabling organizations supporting energy mapping and smart energy communities more broadly (one Canadian example is the Federation of Canadian Municipalities)
- Advocacy groups

6.3. Broader study relevance

Natural Resources Canada-CanmetENERGY-Ottawa (NRCan-CE-O) is leading a research activity called the Canadian Energy End-use Mapping (CEE Map) project. Funded by the Program of Energy Research and Development (PERD), NRCan's Innovation Fund and the GeoConnections Program, the CEE Map project plans to develop an online interactive mapping solution that will expose housing energy use and efficiency opportunities data to non-building science professionals, in a usable map format. Priority policy and program applications include municipal housing energy retrofit strategies and utility Demand Side Management (DSM) along transmission and distribution (T&D) lines. It also seeks to deploy authoritative buildings and energy data, standards and technical guidance to enable building energy mapping by other organizations.

The project will scope the current state of development of energy mapping and analytics in the building stock as a whole for both end-use and renewables as they apply directly to buildings; the focus for the development of the architecture will focus on the residential housing stock specifically.

The CEE Map project builds upon and advances past NRCan-CE-O research on energy mapping and building-archetype applications. Experience gained, partnerships developed, and IP generated in other projects (eg. Integrated Community Energy Mapping (ICEM), which includes the Spatial Community Energy, Carbon and. Cost Characterization Model (SCEC3) model and Tract and Neighbourhood Data Modelling (TaNDM) methodology) can inform both the CEE Map project and OGC CDS.

Additionally, NRCan-CE-O is developing housing and building reference archetypes using the Housing and Building Technology Assessment Platforms (HTAP and BTAP). These platforms generate housing and building modelled energy data, for new and vintage archetypes, for all weather regions across Canada for baseline and future scenarios. Work is at present being done with HTAP and BTAP to support the National Building Code of Canada. HTAP and BTAP archetypes and associated datasets will be deployed over the next few years. They are also being leveraged for research purposes in the CEE Map Project. In future, work to combine results from HTAP and BTAP into mapping platforms may also inform the development of alteration / retrofit codes applying to the existing building stock.

Other projects presently underway at NRCan-CE-O include the Low Carbon Community Energy Systems (LCCES) project, which is receptor-driven and focused on R&D for existing communities to support stakeholder needs. It consists of three components: 1. Advanced Technology Development 2. Stakeholder engagement 3. LCCES process development. Ultimately the LCCES project and low carbon community energy technology deployment will benefit from a baseline understanding of building energy use and efficiency opportunities to facilitate strategic technology integration.

NRCan-CE-O is also undertaking renewables resource assessment mapping in the areas of wind, solar, the arctic and hydrokinetic. NRCan CanmetENERGY-Varennes (NRCan-CE-V) is undertaking mapping research to characterize the potential for Building Integrated Photovoltaics (BIPV) and Building Integrated Photovoltaics and Thermal (BIPV-T).

6.4. Previous Work

Various Government of Canada priorities, initiatives and reports to which the CEE Map Project and the BEMA-CDS respond include:

- Community Energy Planning in Canada the Value of Energy Mapping Symposium

[https://www.nrcan.gc.ca/energy/efficiency/data-research-and-insights-energy-efficiency/housing-innovation/applied-technology-research-communities-and-infrastructure/community-energy-planning-canada-value-energy-mapping/4381]

- Combining Our Energies [http://publications.gc.ca/collections/collection_2009/parl/XC49-402-1-1-01E.pdf]
- Pan-Canadian Framework on Climate Change [https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html]
- A Data Strategy Roadmap for the Federal Public Service [https://www.canada.ca/en/privy-council/corporate/clerk/publications/data-strategy.html]
- Rethinking Canada’s energy information system: collaborative models in a data-driven economy [http://publications.gc.ca/collections/collection_2018/sen/yc26-0/YC26-0-421-16-eng.pdf]
- Reducing greenhouse gas emissions from Canada’s built environment [http://publications.gc.ca/collections/collection_2018/sen/yc26-0/YC26-0-421-16-eng.pdf]
- Building Canada’s Energy Future Together [https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/2018/en/BuildingCanadas_EnergyFutureTogether_en.pdf]
- Generation Energy Council Report [https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/CoucilReport_july4_EN_Web.pdf]
- Federal Geospatial Platform/Open Maps [https://www.nrcan.gc.ca/science-data/science-research/earth-sciences/geomatics/canadas-spatial-data-infrastruct/geospatial-communities-canadian/federal-geospatial-platform/11031]
- Canadian Energy Information Portal [https://www.statcan.gc.ca/eng/topics-start/energy]

Related supporting non-governmental reports that provide background and justification for the BEMA-CDS include:

- Status Report on Community Energy Plan Implementation: A Follow up to the National Report on Community Energy Plan Implementation September 2017 [https://questcanada.org/wp-content/uploads/2018/08/CEP-Implementation-2017-Report-FINAL.pdf]
- The Atlantic Canada Energy Data Roadmap [https://questcanada.org/wp-content/uploads/2018/08/Atlantic-Canada-Energy-Data-Roadmap-Full_Report.pdf]

6.4.1. Energy Summits

NRCan partnered with QUEST to host the OGC Energy & Utilities Summits [https://external.ogc.org/twiki_public/pub/EnergyUtilitiesDwg/WebHome/OGC_Energy_Summit_Report_June_28_2017.pdf] that identified key drivers for energy data exchange, needs for energy data, and a range of scenarios for the application of energy data to serve both communities and utilities interests. See Annex B of this report for more detailed information. The Summits developed the concept of a Smart Energy Community that seamlessly integrates local, renewable, and conventional energy sources to efficiently, cleanly, and affordably meet its energy needs. They also identified current challenges to successful energy data applications, future standards work to address some of those challenges, and significant next steps that could be taken:

- Key drivers of energy data exchange
    - Solving pain-points
    - Energy cost reduction

    - Energy/peak demand reduction
    - Climate change and CO_2 (reduction/management)
    - Acceleration of clean energy deployment / cost reduction
    - Infrastructure Renewal / Cost Avoidance
- Energy information Needs
    - To Inform Policy
    - To Improve Customer Choice
    - To Improve Utility Planning / Programs
- Scenarios supporting Smart Energy Communities
    - Integration of building attribute and energy data at parcel level.
    - Community Energy Planning - baseline and forecast energy use and GHG emissions planning across a community.
    - Integration of Green Button energy use data and spatial representation of energy use data.
    - Renewable resource assessments (yield estimation) and integration with demand profiles
    - Modeling of what-if scenarios / impacts of technologies and policy decisions on the metered building stock.
    - Model accuracy improvement (historical and forecast scenarios).
    - Privacy protection - de-identification / aggregation of energy demand to appropriate scale and privacy thresholds.
    - Smart Cities - other emerging requirements
- Scenarios supporting Smart Energy Utilities
    - Distribution grid model data management: asset management, integration of distributed energy resources (DER), automation/automated demand response (ADR), outage management, etc.
    - Capacity constraint and network analysis, power generation capacity/resources assessment and pre-certification for Distributed Energy Resources (DER) analysis / site selection.
    - Probabilistic forecasting, outage preparation / response/recovery, peak demand reduction, voltage / volt-amps reactive (VAR) control, intermittent renewable resource integration, etc.
    - Outage management – data integration, distribution network awareness.
    - Improved customer information management for load balancing and power quality.
    - Charging network management
    - Augmented reality for inspection/surveying of utility infrastructure, community energy projects
    - Integration of all-fuels data for improved supply management and community energy demand profiles
    - Integration of underground utilities information
    - Oil & gas pipeline management

    - Oil spill response.
- Current challenges
    - Access to (non-standardized) energy end-use data.
    - Integrating modeled building energy performance with aggregated/normalized energy consumption (metered) data.
    - Privacy protection, legal framework, exchange protocols, data standards / inconsistencies, risk perception.
    - Energy Mapping for municipalities – on-demand provision of complete energy, GHG, and efficiency maps (historical, seasonal, and forecast /what if), below the municipal boundary scale.
    - Complete / connected distribution network models.
    - Utility lack of understanding of benefits and return on investment from leveraging standards.
    - Access to Best Practices (albeit growing)
- Actions
    - Select scenarios for further research.
    - Carry out **Concept Development Studies** (such as BEMA-CDS) to develop interoperable solutions for key pain points in the energy and utility domain
    - Execute **Interoperability Pilots** for specific scenarios listed above, or as part of a national SDI, in order to build trust and prove business case/value propositions:
        - Internal pilots to satisfy utilities and regulators.
        - External web map services / 3rd party applications.
    - Develop best practices and standards for energy use data exchange, integration, and visualization.

6.4.2. IEA EBC Annex 70 Survey on Energy and Building Stock Data, Uses and Needs

Annex 70 [https://energyepidemiology.org] is an international collaboration of researchers, industry and government working to develop methods for improving data on building energy demand. Subtask A of this collaboration included conducting and analyzing an international survey of stakeholder needs for energy and building stock data. Some of the respondents to the BEMA CDS RFI had previously responded to this survey as well.

6.5. Related Work

Concurrently, NRCan’s Canada Centre for Mapping and Earth Observation (CCMEO) is working with Statistics Canada to develop a National Building Layer (NBL). Requirements for building attributes related to energy mapping and modeling have been provided to develop the data model and potential attributes for the NBL, the development of which will be piloted in Kelowna. The intent is to deploy building energy mapping in Canada nationally when the NBL becomes available as a base data layer for buildings.

Building standards references

- National Building Standard — A Swedish Case Study [1]
- Simple feature access standard [2]
- OGC® Land and Infrastructure Conceptual Model Standard [3]
- OGC City Geography Markup Language [4]
- Industry Foundation Classes [5]
- LAS Specification 1.4 OGC Community Standard [6]
- Semantic Sensor Network Ontology [7]
- GS1 General Specifications [8]
- INSPIRE Data Specification on Cadastral Parcels [9]
- GS1 General Specifications [10]
- Framework Data Content Standard Part 1: Cadastral [11]
- Cadastral Data Content Standard [12]
- MassGIS standard for digital parcels [13]
- TNM National Structures Dataset Standard [14]
- National Map Corps Structure Definitions [15]
- Real Property Asset Data Standard [16]
- Spatial Data Standards for Facilities [17]
- INSPIRE Data Specification on Buildings [18]
- NSG Application Schema [19]
- National Park Service Building Spatial Data Standard [20]
- Brick v1.1 [21]
- Building Topology Ontology [22]

Chapter 7. Request for Information (RFI)

7.1. Introduction

OGC and NRCan issued a Request for Information (RFI) to support the BEMA-CDS. The information being sought included who undertakes this work, what data they use, what building archetypes they make use of, how they develop and/or operate their models, and how the resulting analyses, maps, and applications are presently being used or could in the future be used.

The RFI solicited responses from a wide audience to specific questions in eight subject categories concerning the building energy mapping and analytics domain. RFI responses formed the principal basis for subsequent activities, such as the validation workshops, results webinars, and this report.

An OGC Concept Development Study relies on RFI responses and other inputs to develop and communicate an understanding of the principal geospatial data sharing and interoperability challenges and opportunities in a particular domain. As the usage scenarios described below make clear, there are opportunities for realizing the benefits of enhanced data sharing for building energy mapping and analysis, enhanced roles for geographic factors in this work, improved comparability between different workflows based on common data and practices, and improved applicability to the evaluation of programs and policies for increasing efficiency, conservation and renewable energy technology integration.

7.2. RFI Goals and Audience

The goal of the BEMA-CDS RFI was to gather information and viewpoints from a wide array of respondents representing the stakeholders and stakeholder organizations identified for the building energy domain in order to identify and outline a standards-based approach to building energy end-use and efficiency opportunities mapping that can accelerate the transition to a low-carbon built environment and economy.

This included:

- Characterizing the state of development of energy mapping and analytics in the building stock broadly; and
- Informing IT architectural practices and standards in order to advance the mapping and analytics of residential energy use and efficiency.

7.3. RFI Use Case Scenarios

7.3.1. Community Energy and Emissions Planning

Community energy managers tasked with developing policies and programs to achieve improved energy performance in new and existing buildings have diverse backgrounds. Knowledge of building science and efficiency and renewable energy measures for buildings varies amongst practitioners. They require but may not have ready access to data on building archetypes, their energy-related attributes, and the distribution of those archetypes in the stock. They need baseline and future scenario analysis to support evaluation of various conservation and technology measures that can be incentivized for deployment in new construction and/or as retrofits to existing buildings. For measures that are to be prioritized in the context of integrated resource planning, community energy managers need to know where to deploy them and how much they will cost , as well as a general projection of the estimated energy, GHG emissions and operating energy cost savings at local and community scales.

7.3.2. Utility Conservation Potential Review & Demand Side Management Program Planning

Program managers in utilities seek to understand the contribution of conservation and efficiency measures to utility demand and load requirements over time and across their service areas. This supports generation capacity planning, the planning and evaluation of Demand Side Management (DSM) programs and infrastructure renewal. Traditional DSM programs have focused on mass-market technology-specific measures such as changing light bulbs, removing old fridges or installing higher-efficiency furnaces. These individual measures are achieving fewer savings over time and miss the more significant energy savings that could be realized, for example, through combining multiple conservation measures into building retrofits. Another consideration is that the migration from large centralized fossil fuel and nuclear power generation to distributed and/or community scale low carbon energy generation may also significantly impact utility transmission and distribution infrastructure.

Utilities use geospatial analysis to inform asset management and right of way planning; however, it is thought that utilities often do not have the practice of using geospatial analytics to inform DSM program planning. With access to geospatially enabled, archetype-specific modelled energy data for baselines and scenarios, it is possible that additional value can be derived from DSM programs in offsetting capital costs for new transmission infrastructure through load reductions realized from conservation and efficiency measures.

7.3.3. Federal/Provincial/Territorial Building Energy - Policies, Programs, Standards, Building Codes

Government officials involved in policy, program, standards and construction code development relating to buildings require information on distinct housing or building types, also known as archetypes, to evaluate energy performance for a specific technology or assembly measure. This information informs the development of new or improved programs and policies, and establishes improved performance measures for inclusion in equipment standards or building codes. Data for these stakeholders is currently drawn from surveys, and housing and building simulations. Non-spatial stock analysis is performed by extrapolating results to larger geographies based on total number of dwellings thought to correspond to a given archetype. Limitations of these methods include limited survey sample sizes, and restricted applicability of both surveys and archetypes in smaller geographic areas. It may be challenging to derive meaningful results for emerging bottom-up use cases given these limitations.

7.4. RFI Questions

Questions posed by the RFI were grouped into 8 categories:

Stakeholder information

These questions included primary organizational affiliation, organizational role (such as data provider or decision maker), stakeholder category as described above, and key collaborations.

Applications and IT Architecture

Questions centered around building energy applications, their capabilities, targeted users, and application business models.

Data and Data Governance

Questions focused on significant datasets used for building energy applications, how they are obtained, what governance arrangements apply, and what standards they may conform to. Suggested data types were themselves grouped into four categories:

Table 2. Suggested types of building energy-related data

Physical Systems	**Energy Data**	**Environmental Data & Land Use**	**Other**
Building form typology	Energy use, all fuels	Weather data (e.g. temperature, relative humidity, wind speed)	Occupant socio-demographics
Building age	Energy use demand and peak	Renewable energy resource data (e.g. solar radiation and insolation etc..)	Occupancy
Floor area	Building energy performance rating	Location data (e.g. X,Y, postal code, city, state or province)	Ownership
Envelope materials	Billing data	Indoor environmental data (e.g. temp, relative humidity, $C0_2$)	Occupant comfort
Heating, cooling, ventilation, storage systems	Price or tariff	Spatial plan, zoning and density	Construction costs
Renewable technologies	Carbon intensity of fuel, including electricity	Planning legislation and building codes	System upgrade/ refurbishment costs

Physical Systems	Energy Data	Environmental Data & Land Use	Other
Utility infrastructure (e.g. transmission and distribution lines)	Modelled energy data (e.g. energy conservation measures)		Operation and maintenance costs

Requirements

This set of questions concerned the rights, policies, and constraints that may apply to employed datasets

Usage scenarios

Respondents here were asked to evaluate the three provided use case scenarios and suggest any others that may be applicable.

Operation and Organization

These questions concerned the organizational and commercial ecosystems in which building energy applications operate, such as geographic scales of aggregation and access to utility data.

Technology and Techniques

The category sought information both on technologies such as solar examined by building energy applications and technologies such as machine learning used by those applications.

Other Factors

Various other questions were included in this category, primarily around the role of standard data models and standard data interchange protocols.

7.5. RFI Process

Outreach to solicit responses to the RFI included, public release on the OGC website, communications on social media, and also targeted outreach to both OGC members and known building energy stakeholders. Responses were accepted in electronic form to the OGC TechDesk. A small number of telephone interviews were also conducted with key respondents to collect their responses to RFI questions. Compiled and analyzed responses are presented in the next section of the report.

Chapter 8. RFI Responses

This section includes summary narratives and statistics for responses to each of the nine RFI question categories. A detailed matrix of responses is included in Annex A

8.1. Responses Summary

A total of 33 responses were received, with the following geographic distribution:

Table 3. Responses by region

Canada	27
Europe	4
USA	2

8.2. Stakeholders

Stakeholders identified themselves as filling a variety of roles in a variety of types of organizations:

Table 4. Response by stakeholder organization and role

Consulting / commercial	10
Federal/national	9
Academic	7
NGO	4
Municipal	2
Utility	1
Researcher	12
Manager	7
Policy maker	7
End user	5
Developer	2

The most common respondent was a researcher. The most common responding organizations were consulting / commercial and federal / national. Respondents were also asked who were their own key stakeholders. The responses included utilities, municipalities, urban planners, city energy managers, building owners and residents, homebuilders, energy consultants, community program participants, engineering firms, and researchers.

8.3. Applications and IT Architecture

Respondents reported developing, using, and/or leveraging in their organizations a wide variety of applications, as well as IT technologies, approaches, and architectures, from desktop programs and python scripts to supercomputer systems. Examples are shown in the table below. In many cases, applications either make use of or feed into other applications, resulting in a somewhat informal but distinctive energy application ecosystem.

Table 5. Applications and analytical platforms

OpenStudio [https://www.openstudio.net]	US open-source tool for creation, modification, web-based simulation, and analysis of building energy.
EnergyPlus [https://energyplus.net]	Open-source tool for simulation of building energy.
AutoSIM	Automatic Simulator, world's fastest buildings simulator for scalably distributing EnergyPlus files on High Performance Computing devices, simulating on virtual disk, and returning results for storage and analysis. C, Python, MPI, OpenMP, tested on Argonne's Theta and ORNL's world-fastest supercomputer Jaguar and Titan (U.S. Copyright TXu 2-141-960).
SimStadt	Simulates heating and cooling energy demand of buildings and photovoltaic potential on city scale. Based on the heating demand, a district heating network layout can be generated. The entire simulation is based on 3D City Models using the OGC standard CityGML and the Energy application domain extension
City Building Energy Saver (CityBES)	focuses on energy modeling and analysis of a city's building stock to support district or city-scale efficiency programs. CityBES employs EnergyPlus to simulate building energy use and savings from energy efficient retrofits.
Stepwin	Uses InsightEngine, RBest, and Bridges to look at all possible ways of building a house, perform energy and costing calculations, then find which design performs best.
Building Energy Ratings (BER) Data Warehouse	Delivers the current state as well as time-based trends of BER across the country and enables analysis based on geography, building age, etc. to the national regulatory body.
Community Energy	Large model that pulls data and runs projections based on population growth, committed regulations, local government actions, and climate change including changes over time at the local level. It provides baseline, business as usual, and projections based on actions the local government chooses. Energy is modeled by fuel by sector by year for 2020 to 2050

SG2B python scripts	Simulate the energy consumption of building depending on the temperature, also different equipment impacts on the consumption (space heating, heat pump, solar rooftop, battery, electric thermal storage …), also simulate renewable electricity generation and integration into the existing grid.
CityInsight	Tools to evaluate retrofit pathways and district energy viability- see: https://cityinsight-interface.ssg.coop/halifax-emissions or https://plan4de.ssg.coop.
LightSpark	Analyses data from over 25 sources to provide one of the most detailed community and city energy intensity analysis to date with the goal of helping cities, municipalities and utilities more accurately target energy savings at the building and homeowner level.
ReCREAT (Remote Community Renewable Energy Analysis Tool)	Platform for renewable energy potential specific to Canadian northern and remote communities.
SCENARIO	Residential building load model at urban scale level for distribution networks planning with scenarios of technology penetration such as electric vehicle, solar production, electric heat storage, battery, DR technology, incentive tariff and building mapping to predict solar production potential on roof.

8.4. Data and Data Governance

Respondents indicated that many types of data are necessary or useful for building energy applications, but some were more frequently cited than others, as shown in the table below.

Table 6. Response rates for building energy related data types (>12, >9, >6)

Physical Systems	Energy Data	Environmental Data & Land Use	Other
Building form typology	Energy use, all fuels	Weather data (e.g. temperature, relative humidity, wind speed)	Occupant socio-demographics
Building age	Energy use demand and peak	Renewable energy resource data (e.g. solar radiation and insolation etc..)	Occupancy
Floor area	Building energy performance rating	Location data (e.g. X,Y, postal code, city, state or province)	Ownership

Physical Systems	Energy Data	Environmental Data & Land Use	Other
Envelope materials	Billing data	Indoor environmental data (e.g. temp, relative humidity, $C0_2$)	Occupant comfort
Heating, cooling, ventilation, storage systems	Price or tariff	Spatial plan, zoning and density	Construction costs
Renewable technologies	Carbon intensity of fuel, including electricity	Planning legislation and building codes	System upgrade/ refurbishment costs
Utility infrastructure (e.g. transmission and distribution lines)	Modelled energy data (e.g. energy conservation measures)		Operation and maintenance costs

Specific interest was expressed in national maps and the data that they represent, for example:

- **Building data** such as footprint, height, type, construction year, window-to-wall ratio, HVAC type, heating and cooling loads, floor area, envelope materials, cost, location, & other fields
- **Energy end-use data** (all fuels), demand and peak data (where available), & carbon intensity
- **Supply-demand data** on propane and heating oil at the community level
- **Photovoltaic** generation capacity
- **Renewable Energy Resource data** (e.g. solar irradiance, etc)
- **Modelled energy** consumption and EnerGuide audits by building archetypes, age, size,
- **Billing / Metered data**, when applicable
- **Weather data** (temperature, humidity, wind speed)
- **Occupant** socio-demographics
- **Building Codes**
- **Regulatory** / incentives regimes

Another question concerned useful data standards or standard models, rather than individual or proprietary models and formats. The small list included:

- EnerGuide Rating System
- Partners for Climate Protection (PCP) protocol for CEEP
- CityGML +/- Energy ADE
- IndoorGML
- buildingSMART Information Delivery Manual
- GeoSPARQL / PROV-O / ifcOWL
- gbXML (Green Building XML)

8.5. Requirements

Responses to questions in this category centered on privacy and data rights concerns as well as data preparation and protection issues that these concerns raise. The concerns were often expressed as microdata sensitivities related to fine-grained spatial and/or temporal resolution, not just inclusion of PII (Personally Identifiable Information). Example responses include:

Table 7. Response privacy concerns

Electrical use data	Whole-building electrical use data (esp. building specific, 15-minute) is protected, exempt, and highly sensitive. Published building-specific data is no finer than annual resolution. Higher-resolution temporal data is only made available by entire utility territory, building type, vintage, or other (usu. large) cluster of buildings.
Building data	Only collect the builder contact info and the job site address, also collect costing and material properties from manufacturers, the privacy and commercial confidentiality requirements for those are variable.
Utility data	When utility billing data is imported, there's no location or address. Although this is considered sometimes confidential by utilities.
Energuide	Energuide Audit data if revealed to consumer must have consent from the homeowner.
TaNDM aggregate utility data	An approach for getting utilities to integrate building types with their customer accounts and aggregating measured utility data by building type to level of geography to privacy thresholds.

8.6. Usage scenarios

Table 8. Response usage scenarios

1	Energy rating reports (building labelling), digital audits and labels, assessing energy ratings averages and trends at different levels (nation, region, location, building)
2	Grid integration of renewable energy
3	Building energy mapping tool and analytics for building capacity in research areas to support innovation
4	Municipalities, utilities and building owners collaborate to model all energy consumption in municipalities.
5	Identification of district energy potential, retrofit hot spots, validation of city-wide energy and GHG emissions.
6	Individual building owner energy cost management
7	Demographic energy analysis

8	Sensor-based analysis - how can these technologies can be supported in the context of building energy.
9	Cross-Domain Analysis – additional value when integrated with other domains (e.g. climate change, local development, population health, etc.)
10	Building energy analytics compliance within design applications.
11	Integrating supply and demand side mapping to identify regions that might be net-electricity producers (higher potential supply than demand) and therefore help to map flows of electricity in a given area
12	Renewable energy system design and operation, design of storage systems, transportation energy use mapping
13	Market Opportunity Assessment
14	Enabling communities with an additional tool to understand their energy resources and make investment decisions in renewable energy projects.

8.7. Operation and Organization

This category of responses included policy challenges, regional data challenges, and especially needs with regards to temporal and spatial resolution. Representative responses included:

Policy Challenges

- "Building energy modeling professionals are recalcitrant toward automatically-created, urban-scale energy models due to the high levels of building-specific property uncertainty and the lack of empirical validation against urban-scale measured data."
- "Every stakeholder needs to be more pro-active in sharing data. Statistics Canada, NRCan and OEE should make aggregated data available for each municipality to help them prepare Community Energy and Emission Plans. Policies or legislation should apply to all electricity or natural gas utilities in Canada. Crown corporations, especially, hold a lot of information. Only a law can help them disclose the information, as they don't know what to do and what not to do. CO_2 emissions by industries should be made public."
- "Primarily, policy that addresses a need for unified and structured data. Specifically around property assessment data and disaggregated energy data from utilities."
- "Significant restrictions regarding policy and commercial sensitivity of data makes it difficult to gain access to this data. In larger organizations, there are various different groups that need to be consulted in order to get the necessary information. "

Temporal resolutions cited ranged from 5 minutes to 1 year.

- "hourly would be a good industry-standard goal for data granularity."
- "Sensor data is logged as small as 6-minute increments but sometimes 15-minutes of 30 minutes, but a simulation typically runs on an hourly timestep. The daily/weekly/monthly/annual data is important, but the granular data is necessary to properly calibrate and identify hidden errors"

Spatial resolutions ranged from building to national and international scales.

- "Unified open-data platforms which provide information not only about residential buildings but also about their surrounding. For example, shading and trees around houses are significant for solar gain."

- "Aggregation of data is important. Different levels of jurisdiction are looking for different levels of aggregation."

8.8. Technology and Techniques

This category included a number of questions about specific technologies. In general, respondents indicated, for example, that they already use, or are planning to use machine learning techniques, but not blockchain or distributed ledger technology.

8.9. Other Factors

The principle questions in this category concerned building type classification, building energy "success factors", OGC standards, and energy data model types.

The responses to the first question generally revolved around the use and diversity of building "archetypes". Various methods are used to classify building archetypes as part of building energy mapping and analytics. There remains a need to standardize or promote best practices including for archetype-based analysis, as modeling each building individually in 4D is now feasible with enough data and computing power, but modeling all buildings is not yet practical, and classification by building type for analysis will always be important. Some of the archetype classification approaches cited by respondents included:

- No archetypes - model each individual house
- 3 archetypes: residential, commercial, industrial + energy usage
- 30 residential + 50 non-residential
- Many different housing typologies referred to in Official/Community Plan policies and zoning by-laws, as well as building codes
- 97 building type and vintage combinations modelled in OpenStudio
- FSA (geographic unit) aggregates
- 4-10 archetypes clusters defined by an unsupervised machine learning algorithm that clusters dwellings by age, floor area, location, energy and carbon footprint, ranging from
- 5 building types subdivided in 10 age classes in German archetype library
- 16 Building Types for 16 Climate Regions for three construction periods (768) in CBECS data
- ~6500 existing housing archetypes across Canada modeled in Housing Technology Assessment Platform (HTAP)

Success factors focused on better data, better support for goals of building energy analysis, and some technical advances. For example:

- "With more information on each building such as building type, building material or number of floors, we can make a better model for predicting energy usage. "
- "Realistic cost information for refurbishment scenarios are important for implementation

actions. The same for energy systems. A country wide shared library concept for such information would be extremely useful."

- "Having a single point of reference (e.g. a web portal) to access those mapping and analytics capabilities, drawn from a consolidated single-source-of-truth data layer (e.g. a data warehouse with data cataloguing capabilities)."
- "…market research needs to be done to identify the market size of the opportunity to warrant the up-front capital investments."
- "importance of the National Building Layer as being the foundation building geometry definition model for the application of a national program that would address a myriad of analytics, energy being just one"
- "Killer-app use cases with success stories that drive value and adoption"
- "Standard mechanisms for handling privacy concerns (move algorithm to data rather than vice versa)"
- "Having presentations of use case of how building energy mapping and analytics is used by by different organizations could be interesting. Sharing the experience and expose potential of the techniques."

Finally, responses concerning OGC standards showed some awareness of CityGML as a useful standard and limited visibility into the OGC API set of standards. Clearly there is work for OGC and its members to do in terms of both relevance and visibility.

8.10. Response Gaps

The major gap in responses received to the RFI was lack of participation by energy utilities. The one nominal response from a utility was in fact from an associated research lab. Importance was placed by other respondents on both utility data access and utility participation in community program, so they would be interested in responses from energy utilities to the RFI questions as well.

Chapter 9. Validation Workshops

Three validation workshops were held virtually in order to review, validate, backfill, and extend the RFI responses.

9.1. Workshop Process

The goal of these workshops was to both validate and follow up on the responses received from the BEMA RFI. Outreach focused on those who responded to the RFI itself, some of whom were also willing to present their work and perspective during the first workshop. Invitations to register for the workshops also went out to the broader OGC membership, other identified stakeholders, and the public at large. Overall, there were around 100 registrants for one or more of the workshops

9.2. Workshop 1: Presentation

The first workshop was held on June 16, 2020 as part of the Energy & Utilities Domain Working Group (E&U DWG) session at the OGC June Members Meeting. This workshop first provided background such as results of Energy Summits held in 2017 and 2018 by the DWG, including initial notions of an E-SDI. The workshop then proceeded to introduce the BEMA CDS and summarize the responses to the BEMA RFI. The workshop finished by previewing key findings, including gaps and opportunities identified in or by the responses.

Workshop 1 key findings: gaps and opportunities

- Limited response from utilities
- Significant activities that involve collection, exchange, integration of datasets with very little use of standards
- Lack of overall framework that connects scale and resolution of required spatial data to particular use scenarios
- Opportunity to connect archetype delineation (e.g., clustering) with application usage (whether computational, comparability, policy)
- Data access issues: availability, privacy, confidentiality, propriety
- Access to retrofit cost estimates identified as a particular barrier to benefiting from energy mapping and modeling data.
- Lack of attention to issue of energy poverty in programs that target energy conservation and carbon reduction.

9.3. Workshop 2: Contribution

The second workshop, held the following week on June 25, delved more deeply into findings from the RFI responses. For example, issues were raised in terms of building energy data use case.

1. Workshop 2 use case issues
    - Cited use cases significantly overlap all three (community, commercial, and governmental) scenarios

    - Use cases often involve the same stakeholders, but different objectives or priorities, e.g., individual energy decisions vs governmental policies and initiatives
    - Clearly there are many different ways to use building energy data
        - Livable buildings are essential to personal, family, community welfare
        - Livable buildings depend on energy and energy affordability
        - Buildings are a substantial component of energy demand and mix
        - Energy demand and mix affect the environment and economy, are affected by policy, regulation, and markets at regional, subnational, national, and international levels.

In addition to presentations by the study authors, five of the respondents agreed to give lightning talks on their own building energy work, illuminating and expanding on their RFI responses:

Workshop 2 lightning talks

- Rapid Building Energy Simulation with StepWin — Arman Mottaghi (Lambda Science)
- Photovoltaic Potential in Canadian Municipalities Using LiDAR and Other Building Data — Sophie Pelland (Natural Resources Canada)
- Prediction of the heating energy demand and related CO2 emissions using CityGML — Volker Coors (HFT Stuttgart)
- Automatic Building Energy Modeling (AutoBEM) — Joshua New (ORNL)
- Canadian Geospatial Data Infrastructure & Building Energy — Ryan Ahola (Natural Resources Canada)

Workshop 2 Feedback

Between the online chat box activity and a period of discussion at the end of the workshop, a number of issues were highlighted by attendees, who often added links to their work and others':

- "Energy mapping [should] also include not just energy use but also energy efficiency retrofits/builds and looking at the results and costs of retrofit or higher energy efficiency builds and the associated pay back? because the lack of confidence in results and pay back is one of the factors that limits implementation."
    - "Research in UK on domestic energy mapping and targeting retrofits - https://www.sciencedirect.com/science/article/abs/pii/S0959652617325660?via%3Dihub "
    - "CanmetENERGY is developing costing data in our HTAP and BTAP platforms, associated with archetypes."
- "The lack of interest in indoor environmental data indicates a gap in understanding the non-energy benefits high performance residences can provide, such as improved health and comfort, which are stories that are much more salable when bringing public onboard."
- "We did solar rooftop model for Halifax Nova Scotia based on lidar back in 2014: https://www.arcgis.com/apps/webappviewer/index.html?id=8c1749bb427f4bcca26e3b4318d9201c "
    - "About building footprints consistent with LiDAR, this product is also available : https://open.canada.ca/data/en/dataset/7a5cda52-c7df-427f-9ced-26f19a8a64d6 "

    - "Chris Krasowksi, now at the climate action secretariat in BC worked with city of Victoria ... on doing this precise project as part of his Masters of Science. He has a detailed methodology for using LiDAR and calculating solar irradiance and then we created a service for easy user interface and costing to help contractors and homeowners see their solar potential, recommended size and placement of system and cost of capital and energy costs/savings https://www.linkedin.com/in/ckrasowski/ "
- " HTAP's Github: https://github.com/NRCan-IETS-CE-O-HBC/HTAP "

Allison Ashcroft of Canadian Urban Sustainability Practitioners (CUSP) contributed both comments and a short talk on the theme of energy poverty:

- (Re: dataset priorities) "CUSP tool has multiple building age ranges and a ton of sociodemographic data. all of this is down to census tract/nhood level, but is for census year 2016"
- "Canadian urban sustainability practitioners [is] a municipal member-led peer network of 17 large cities across Canada. Core members are the sustainabilty (climate and equity) leaders in each city but we also connect finance depts and transportation, housing and social planning folks on climate/energy and climate risk and equity. Link is http://www.cuspnetwork.ca and our mapping tool for energy poverty and socio demographics is at http://www.energypoverty.ca . If anyone on this call is interested in transportation, you can also choose the transportation commute map from the dropdown too which we also cross-tabulate with households in energy poverty to identify households with high fuel cost burdens and home energy cost burdens."
- "Re energy poverty, the data is now available and now we just need to design programs that are not carve out low income programs, but universal/more integrated programs that target households with high energy cost burdens/energy poverty and measures to address the specific root cause - sometimes purely income, but quite often also high energy costs for core housing need, households in need of major repair, fuel type and access to clean affordable energy in certain geo areas or age of homes"
- "Our work is a proxy for energy poverty, it measures high energy cost burden as energy expenditures divide by after tax income. it is a quantitative proxy and does not reveal hidden energy poverty i.e. people in gig economy who have fluctuating income, those who keep their homes uncomfortable to save on energy bills, etc. and there can also be the anomalies of really wealthy seniors in West Vancouver who have a 20K ft^2 home and an outdoor pool heated to 80 degrees year round. You have to do some local ground-truthing and connect with community"
- "The other interoperability issue not mentioned is if you want to centre equity in programs and thus use socio-demographic data. We had to create household constructs because many of the demographics for newcomer, racialized, Indigenous language spoken at home, seniors, etc. is at individual not household level in the census. CUSP ordered custom datasets to create these household constructs"
- " For CUSP's energy poverty and equity work at http://www.energypoverty.ca, the map there which allows users to drill down to neighborhood scale and crosstabulate energy poverty across about 25 housing and household demographics, is really about 5% of what we can do with our data. Much more richness to be revealed which we would like to do with Tableau given it can crosstab down to 3, 4, even 5 levels of detail so practitioners can get very targeted in their policy and program design and be more intentional around centering equity"

9.4. Workshop 3: Synthesis

Workshop 3 was held on June 26 and organized around a set of 2-part discussion threads:

Discussion parts

1. Clarification of Issues
2. Identification of opportunities and solutions

Discussion topics

1. Data - access, quality, privacy, governance
2. Spatio-temporal analysis - granularity, archetypes, aggregation, computation, modeling
3. Interoperability - workflows, standards, technologies
4. Architecture - SDI, national datasets, services

9.4.1. Data

Issues

- Disparate original space and time scales
- Privacy, confidentiality, propriety, and accessibility
  - Legal culpability (varies by country) by combining data sets (i.e., for privacy or commercial/propriety reasons)
- Significant analysis / mapping activities that involve repeated collection, exchange, integration of datasets with very little use of standards
- Commercial vs personal vs governmental data
- Diverse data source methods and confidence, e.g., measured, modelled, inferred, estimated, assumed
- Access to relevant data on cost, effectiveness of retrofits and upgrades
- Access to relevant data on availability and potential of various energy types
- Access to building assessment data for energy modeling

Opportunities

- Organization of data sharing policies and standards to support critical use cases and stakeholders, e.g., federation contracts, NDAs, open government policies
  - Reduce repeated collection, exchange, integration of datasets, through the use of standards
- Data access that accounts for privacy, confidentiality, anonymity, e.g., enclave processing, anonymization by aggregation + noise injection
- National systems for consistent energy data at multiple scales
- National-level building dataset for comprehensive analysis of building types, energy performance, retrofit / upgrade technologies, costs, and benefits.
- Better community-utility level understanding of opportunities /costs / benefits of new technologies and energy sources, e.g., renewables

- As yet unrealized opportunity for use of sensor data to characterize building performance.

9.4.2. Spatio-temporal analysis

Issues

- Archetyping
  - Wide range of numbers reported from 3 to 6500 to modelling dwellings/buildings individually
  - Expected attributes were indicated as “popular”
  - Building energy rating or lable was viewed as of lesser importance
  - Challenge to connect archetypes to use cases for comparability, policy-making etc.
  - Significant analysis / mapping activities that involve repeated collection, exchange, integration of datasets with very little use of standards
- Granularity/Aggregation
  - Use cases for building energy data cover scales from individual buildings to national and international aggregations
  - Disparate area +/- time interval units for different datasets limit granularity of aggregation
  - Aggregations are more accurate for noisy data, less accurate for biased data
  - Unclear what scale is appropriate for a given public dataset or policy
  - Lack of overall framework that connects scale and resolution of required spatial data to particular use scenarios
  - Wide range in temporal resolutions or time-steps, from five minutes to a year
  - Disparate original space and time scales

Opportunities

- NRCan CANMetEnergy Varennes: grid integration of time is required for grid-integration of renewables.
- Spatial: depends on who the energy map is for. If trying to target an area for retrofits and improvement of wall insulation, postal codes and then going down to individual dwelling level are needed. Challenge in reporting data at individual dwelling level related to privacy and other things. In UK, gap is found between archetype calculations and true performance.
- Temporal: smart meters in the UK provide 30 minute for gas and electricity use. Six seconds resolution is not very useful to map.
- Future may be more complicated. High resolution Department of Energy Grid interactive efficiency buildings (GEB), with intelligent devices from the factory floor, voltage regulation, more insulation.
- Averaging or statistical distribution of known properties of buildings one way to get to an archetype. An interesting thing will be comparing the archetypes and prototypes to EIA [https://www.eia.gov/electricity/data/eia861/] data
- Using archetypes and adding data that is found from additional sources, modeling of a certain region, imagery (close or wide-range), actual archetypes that are useful but very different. Not

standardized, very difficult to implement them. IWU archetypes are only for residential buildings. Others for non-residential.

- TaNDM project [https://emi-ime.ca/inventory-model/tandm] involved exploring the collection of data at a parcel scale, enabling data aggregation and analysis at multiple neighborhood and community scales while not reporting the actual parcel scale data.
- Need for portfolio level data for policy design and to facilitate identification of leads for outreach, will also help industry identify new opportunities that need service (and justify potential market size to whoever needs to invest for these sectors to grow)
- Detailed building level or minute level data, … is the most accurate way to aggregate up data to meet the top-level policy needs of community profile, market assessment and potential. etc.

9.4.3. Interoperability

Issues

- Models for energy-relevant building data
- Exchange models / formats for energy usage / demand / cost data
- Exchange model / format for building retrofit design and cost data
- Alignment of building archetypes and classifications with datasets and each other.
- Alignment of geographic (climate, policy, regulatory, administrative, market area, generation, demand) units
- Common protocol for data disclosure and anonymity
- Metadata for data definition, quality, provenance, currency
- Use of “no standards” most common finding

Opportunities

- RETScreen [https://www.nrcan.gc.ca/maps-tools-publications/tools/data-analysis-sofware-modelling/retscreen/7465] renewable technologies screening tool has significant amount of utility information but needs to be tied to other information.
- Episcope [https://episcope.eu/welcome/] general agreement on building archetypes and modular approach to tools, work over different spatial and temporal scales.
- Green Building Studio [https://gbs.autodesk.com/GBS/] can be used to understand building energy profile but question whether interoperability exists to benchmark against other tools.
- Community level assessment for policy decisions provides an interoperability requirement to support integrating diverse building level data sources and tools (containers).
- GreenButton [http://www.greenbuttondata.org] has promise for standardizing building level data access but needs to be fully funded / implemented at fine scale, and provide privacy / propriety protections with regard to integration.
- Role of national building layer to provide consistent reference for building level data and integration pathways (region, archetype, etc.)
- Role of BIM / CityGML / Energy ADE to support building specific and city model levels of energy information.

- SHIFT tool [https://shift.opentech.eco/?2020=year&2025=year&richmond=municipality] is one instance of rolling up data into stories and visualizations for community impact.

9.4.4. Architecture

Issues

- National Layers of Interest
  - Building data such as footprint, height, type, construction year, window-to-wall ratio, HVAC type, and other fields
  - Energy end-use data; heating and cooling loads
  - Modelled energy use and EnerGuide audits by building archetype, age, size,
  - Real data on propane and heating oil at the community level
  - Photovoltaic electricity generation
- Architecture
  - Energy usage, demand
  - Geography and policy
  - Conservation, construction and renovation costs and benefits
  - Climate and decarbonization
  - Investment, economy, and poverty

Opportunities

- Architectural "dialectic" of multiple organizations able to perform analysis at building / parcel level in order to report and act at a larger policy-related aggregation level (region / category).
- Integration architecture that can combine building information with people information so that system processes can target improvement of peoples' lives and communities.

Chapter 10. Challenges and Opportunities

The RFI responses and workshop outcomes emphasized a number of gaps, challenges, and also opportunities related to progress in building energy mapping and analysis.

Summary of major gaps and challenges:

- Utility perspective on conservation, demand side management, regulation is underrepresented in the responses.
- Data access and sharing issues: availability, privacy, confidentiality, propriety
- Repetitive non-standardized collection, exchange, integration of datasets.
- Diverse data source methods and confidence, e.g., measured, modelled, inferred, estimated, assumed.
- Lack of access to retrofit cost estimates are a barrier to deriving benefits from energy mapping and modeling data.
- Lack of overall framework that connects scale and resolution of spatial data to particular use scenarios
- Challenge to connect archetyping methods (clustering / classification) with different use case scenarios

Use case issues

- Use cases (i.e. specific applications) cited by respondents significantly overlap all three (community, commercial, and governmental) scenarios
- Use cases often involve the same stakeholders, but different objectives or priorities, e.g., individual energy decisions vs governmental policies and initiatives
- Many different roles for building energy data:
- Livable buildings (inhabitable, affordable, sustainable, protective) are essential to personal, family, community welfare. Livable buildings depend on energy and energy affordability
- Buildings are also a substantial component of energy demand and mix (and increasingly — infrastructure). Energy demand and mix affect the environment and economy, are affected by policy, regulation, and markets at regional, subnational, national, and international levels.
- Building energy decarbonization is significant in climate response, needs to balance livability and resource availability

10.1. Use Case Scenario Gaps

10.1.1. Community energy and emissions planning

Table 9. Community Planning As Is / To Be

As Is	To Be
Utilities follow regulations, owners follow codes, municipalities variably coordinate conservation, decarbonization programs	Municipalities, utilities and building owners collaborate to model all energy consumption in municipalities.
Spotty public programs and commercial services	Identification of district energy potential, retrofit hot spots, validation of city-wide energy and GHG emissions.
Some understanding of energy poverty / justice but not comprehensive	Demographic energy analysis
Commercial opportunities but not yet clear incentives for community uptake	Enabling communities with an additional tool to understand their energy resources and make investment decisions in renewable energy projects.
Local realization	Renewable energy system design and operation, design of storage systems
Early days and the world has changed	Transportation energy use mapping

10.1.2. Utility conservation potential review & demand side management program planning

Table 10. Utility conservation As Is / To Be

As Is	To Be
May affect design, but investments depend on regulatory environment and capital costs	Grid integration of renewable energy
See above	Municipalities, utilities and building owners collaborate to model all energy consumption in municipalities
Limited by response options, e.g., retrofit costs	Individual building owner energy cost management
Prototype / pilot phase	Sensor-based analysis - how can these technologies can be supported in the context of building energy
Unclear from response.	Integrating supply and demand side mapping to identify regions that might be net-electricity producers (higher potential supply than demand) and therefore help to map flows of electricity in a given area
Patchy recognition of the opportunity for opportunities.	Market opportunity assessment

10.1.3. Federal/Provincial/Territorial building energy - policy programs, standards, building codes

Table 11. Federal/Provincial/Territorial conservation As Is / To Be

As Is	To Be
Pilot programs	Energy rating reports (building labelling), digital audits/labels based on spatial building stock models, assessing energy ratings averages and trends at different levels (nation, region, location, building)
See above.	Demographic energy analysis
Issues of privacy, costs vs benefits.	Sensor-based analysis - how can these technologies can be supported in the context of building energy
Impressive modeling capabilities, but hard to scale, needs scaling formalism.	Building energy mapping tool and analytics for building capacity in research areas to support innovation
Some examples, but prime role for infrastructure.	Cross-Domain Analysis – additional value when integrated with other domains (e.g. climate change, local development, population health, etc.).
Isolated examples.	Building energy analytics compliance within design applications/

10.2. Spatial and Temporal Issues

- Use cases for building energy data cover scales from individual buildings to national and international aggregations
- Disparate area +/- time interval units for different datasets limit opportunities for aggregation
- Aggregations are more accurate for noisy data, less accurate for biased data
- Unclear what scale is appropriate for a given public dataset or policy
- Sharing of non-aggregated microdata may be limited by privacy and/or propriety concerns, complicating production of aggregate measures.

10.3. Interoperability Issues

- Model comparability / interchangeability for energy-relevant building data
- Data exchange models / formats for energy usage / demand / supply / cost
- Data exchange model / format for building retrofit design and cost
- Alignment of building archetypes and classifications with datasets and each other.
- Alignment of geographic (climate, policy, regulatory, administrative, market area, generation,

demand) units with integration goals.

- Common protocol for data disclosure and anonymity
- Metadata for data definition, quality, provenance, currency

10.4. Value of Building Energy Analytics: Opportunities

- Data access that accounts for privacy, confidentiality, anonymity, e.g., enclave processing, anonymization by aggregation + noise injection
- Adaptive classification and archetyping based on sample modeling
- National systems for consistent energy data at multiple scales
- Data sharing policies and standards organized to support critical use cases and stakeholders, e.g., federation contracts, mandated reporting.
- National building data layer for comprehensive analysis of building types, energy performance, retrofit / upgrade technologies, costs, and benefits.
- Municipality-utility cooperation facilitated by regional/national authority to understand opportunities /costs / benefits of new technologies and energy sources, e.g., renewables

Chapter 11. Notional Architecture of an Energy Spatial Data Infrastructure (E-SDI)

A critical challenge identified in this study has been the availability of the right information elements to perform building energy analysis at the various levels of generalization and specificity where it can be useful in improving lives and advancing community goals. The need to provide national scales of support for data-driven decisions down to regional, local, and building scale is precisely the sort of requirement that standards and practices for sharing and reusing geospatial data are intended to address

The idea of supporting the reusability and wide sharing of spatial data by providing information as infrastructure has been around for a while and particularly highly developed in Canada as the Canadian Geospatial Data Infrastructure [https://www.nrcan.gc.ca/science-data/science-research/earth-sciences/geomatics/canadas-spatial-data-infrastructure/10783]. Increasingly, the concept, capabilities, and design of such infrastructure have been expanding to include specific regions (e.g. the Arctic [https://arctic-sdi.org]), and specific domains such as remote sensing [https://www.nrcan.gc.ca/science-data/research-centres-labs/satellite-receiving-stations/satellite-facilities/10816]. Another aspect of evolving SDI conceptions is the addition of shared computing and user application [https://www.nrcan.gc.ca/science-data/science-research/earth-sciences/geomatics/canadas-spatial-data-infrastruct/geospatial-communities-canada-ce/federal-geospatial-platform/11031] support. It makes sense in this context to consider what spatial data infrastructure might look like that can support the building energy needs and opportunities identified in this report.

This section of the report presents a notional architecture, or collection of ideas on how such an E-SDI might be designed. There are many methodologies for expressing such design ideas. An approach described by the ISO 42010 standard [https://www.iso.org/obp/ui/#iso:std:iso-iec-ieee:42010:ed-1:v1:en] recommends the description of information systems through multiple viewpoints relevant to specific stakeholders in its implementation, such as leaders, planners, engineers, and users. Although there are many realizations of this approach that specify a variety of standard viewpoints, recent work on smart city reference architecture [https://www.ogc.org/projects/initiatives/scira] has simplified this to a version with 3 principal viewpoints:

- **Enterprise -** stakeholders, scenarios, business cases, benefits and drivers, risks
- **Conceptual** - information models and computational designs
- **Implementation** - engineering solutions, platform and technology choices, deployment, lifecycle, human - system interactions

Each of these viewpoints look at issues of reusability, interoperability, and standardization in the resulting system or systems, but from the perspective of different roles in the process. This a valuable, but involved methodology for specifying complex architectural designs. While many element of these perspectives have been developed in this study, a full multi-viewpoint design but is not usually the best approach for working with design ideas at a notional level of detail.

An alternative (but complementary) approach adopts what is a typical design pattern for separating concerns and maximizing reusability of supporting infrastructure across multiple applications, namely a system of computing layers or tiers connected by uniform data exchange interfaces, protocols, and formats. In simpler systems, only data, processing, and user layers are required. A representation of a slightly more complex notional tiered design for an Energy SDI is shown in the figure below. The intent of this approach is to delineate distinct concerns and information flows that could then be further explored and specified using a viewpoint-based methodology.

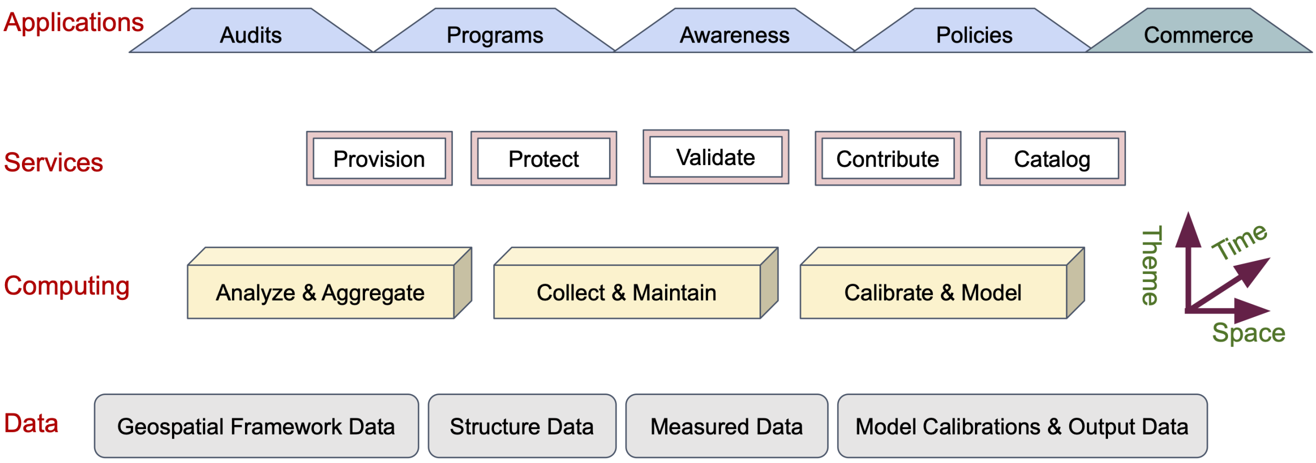

Figure 1. Notional E-SDI architecture

11.1. Notional E-SDI Tiers

11.1.1. Data Layer

The core of an SDI remains the collection, curation, governance, publication, and discovery of datasets considered to have value to a broad spectrum of applications and stakeholders, as well as validity across a broad spatial extent and stability over a significant interval of time. These rather strict criteria for infrastructure data support are increasingly being relaxed, however, as the value of uniform data processing support for more diverse data is being recognized.

In the case of building energy applications, there is still an important role for more traditional framework datasets, particularly spatial regions defined on administrative, environmental, or climate related bases. Three additional classes of data will be equally important:

1. Structure datasets provide the point of reference to which building energy information can be connected, as well as (likely multiple levels of) energy related building characteristics ranging from usage type and floor area to detailed building models. Building datasets are likely also to support multiple groupings, such as parcels, heating / cooling methods, zoning classifications, and building archetype schemes.
2. Measured / observed data may include all sorts of sensor outputs. Energy related data may include energy usage, cost, occupant activity, equipment status, ambient weather. This sort of data may not only be extremely varied in type and scale, as well as very transient, but may also be sensitive in terms of occupant privacy and utility operations propriety.
3. Model data that infer, simulate, or predict what can't be directly observed or measured, are increasingly recognized as having comparable infrastructure value to more traditional framework datasets. They also introduce new challenges as model documentation and even model computation join model inputs and outputs as infrastructure concerns. In many cases, the large number of possible model permutations introduces an additional dynamic dimension

where model results can only be provided "on demand" as needed by client applications.

The data layer in an SDI architecture has additional significance, because it often marks the point at which data standardization may be most conveniently applied, termed a Pivotal Point of Interoperability (PPI). While it would be ideal for all data to be created in a maximally common and reusable form, that is generally not the reality into which a new system is introduced. The point at which data first comes together from diverse sources into a common computing environment (e.g. a data lake) may where standardization into a common model, spatial scale, etc. is most easily accomplished. Increasing data diversity and scale, as well as the need to reprocess submitted data tend to lead to a requirement for an additional system tier, one that supports dataset processing capabilities.

11.1.2. Computing Layer

Traditionally, infrastructure datasets were created, compiled, and maintained "out of band", then provided in some limited form when ready for publication and cataloguing. In early versions of the U.S. National Spatial Data Infrastructure (NSDI), only dataset metadata were provided as "infrastructure", typically including a phone number by which an interested party could reach the data provider to negotiate some form of online, offline, or even hardcopy dataset transfer. With the increasing value of dynamic types of sensor and model data, as well as interest in more scalable, transparent, and standardized means of preparation, dataset processing capabilities have added an important new system tier. Another aspect is a developing preference for moving computations such as model runs closer to the multiple large datasets needed as inputs and outputs, while leveraging common cloud computing environments for computing efficiency.

Computing tasks for which this layer is responsible may include collection, derivation, modeling, and preparation that generate usable datasets, as well as standard or repeated analysis, aggregation, and evaluation tasks that support dataset use. Increasingly entire computing workflows are being implemented in system computing tiers. A sample workflow might include

- Collection and standardization of energy usage and occupancy data from Internet of Things (IoT) devices in selected buildings
- Simulation of energy usage from building models
- Optimization of new building archetypes from observed and predicted energy usage.
- Prediction of energy usage across new archetypes based on standard common characteristics

A dataset may be involved as an input or output in multiple computing tasks, which may in turn be involved in multiple computing workflows.

11.1.3. Services Layer

In a computing infrastructure system based on services, this layer is typically seen as providing data access and common application components to the users of the applications tier. Things are a bit more complicated when that infrastructure creates, modifies, analyzes, and/or derives the "source" datasets themselves. In this case, elements of the service layer also need to support interactions between users involved in data processing activities such as model generation or workflow orchestration. The service layer is also, increasingly, where distinctions are made between different application and user roles with entitlement to different access and processing privileges. A sample capability of this type which was raised repeatedly in the study might involves privileged access to microdata for individual buildings, properties, or occupants, in order to perform aggregate analysis and modeling that generates anonymized data suitable for use by a wider audience.

The services layer is commonly also a PPI where standardized service interfaces and API's can result in large improvements in reusability of services (as well as of the layers below it) across multiple applications.

11.1.4. Applications Layer

The applications layer in a modern SDI is assuming an increasing important as the range of user tasks that can be performed by web applications continues to widen. Where once it may have been necessary to ship a magnetic tape to a lab where a handful of people could work with its data on a minicomputer, it is now increasingly feasible and even preferable to work with such data by orchestrating its analysis and visualization through a browser based analysis notebook (e.g. Jupyter notebook) while all of the heavy, yet interactive computation takes place (or has already taken place) in scalable cloud computing resources on the same platform that stores and manages the datasets being provisioned. Given standardized data models / formats, and standard service API's, it becomes possible in the notebook model, for example, for virtually every user to have their own characteristic or task-specific application.

This is also important since the model of data providers "below" the data layers and data consumers above is more and more obsolete. Instead, a range of roles end up being supported by the application layer and the system layers that support it, from data provider, maintainer, modeler, auditor, broker, analyst, decision maker, and end user (whatever that is). Each role may share or use role-specific applications, workflows, computing capabilities, and service privileges. Even when desktop applications are involved, they are increasingly configured not as stand-alone devices, but essentially as extensions of the system applications layer.

11.2. E-SDI Issues

Clearly as an E-SDI may be supporting so many aspects of the full data provision - analysis - consumption lifecycle for such diverse and dynamic data, it will likely require increased resources relative to a traditional SDI, and also increased governance to ensure that standards are met, documentation is provided, and privileges are appropriately apportioned. A range of user roles also means that there are likely many more "contracts" to govern the federation of stakeholders. It may also meant that relationships between stakeholders which may have previously been out of band or non-existent become visible and formal in the context of the E-SDI. For example, provision of utility micro-data interacting with provision of socio-economic microdata, and aggregation of energy usage by service area and income level. Infrastructure can mediate such relationships, but it doesn't make their establishment any easier. It may, however, make such relationships as can be established more reusable as a common basis for resulting transactions and shared interests.

11.2.1. Access and Enclaves

An important challenge considered in the study is the tension between privacy or propriety of small-scale (parcel or building level) data and the utility of analysis and mapping based on it. There are two technologies being developed which an E-SDI may be able to take advantage of. First is "differential privacy" which provides a mathematical basis for determining the likelihood of re-identifying individual data in an aggregate analysis to which a measured degree of data "noise" has been added.

Second is the development of "enclave" computing, which provides for a workflow to span multiple privilege zones of a computing system, from a secure enclave where sensitive microdata is processed, to a more open zone where aggregated and anonymized products derived from the microdata can be made available for use by a wider audience. While these capabilities and system patterns have been implemented in localized systems, their incorporation into national-scale interactive infrastructure would be a new development. It should be noted, however, that many national census organizations have now turned to use (or at least consideration) of differential privacy as a more trustworthy form of anonymization, and of course have always employed some form of enclave computing to work with their microdata directly.

Extension of SDI to cover different roles and data sensitivities introduces the need to cover, consider, manage, and authenticate personal identities. This is clearly no small task, although many governments are considering this a form of infrastructure to be reused across a range of digital services, and so worthy of the scale of effort needed to do this securely and fairly.

11.2.2. Models and Model Artifacts

For a number of reasons, the use of model-derived data is increasing rapidly. This is due both to the increasing success of models, especially machine learning models, and to growing size and diversity of available data, which make many direct forms of analysis and visualization impractical. None of us are very good at visualizing 50 dimensions of data, but a good model may be able to reduce that to 3 meaningful ones. It is possible to treat model output as just another dataset. This can be dangerous since model results may be much less reliable or have different constraints than observed or consensus datasets.

This leads to a need for additional aspects of models to be made available along with their outputs. It includes metadata, but also extends to provenance - how was the model used and from what input data. It also includes the concept of "explainability" which covers a number of other typical modeling measures such as validity, sensitivity, stability, etc. A further challenge in an E-SDI is not only to provide access to this model documentation, but to educate at least some of its users on how to make use of models and their associated information to make good decisions. This certainly gets even farther afield from traditional SDI concepts, but is consistent with a general theme of serving more users more usefully.

11.2.3. E-SDI Points of Interoperability and Collaboration

As noted above, there are many ways in which an E-SDI can benefit from adherence to data standards and standard practices. There are at least two "points" in the layer design structure which are particularly important in this regard. They are the data layer (c.f. data lake concept) where existing datasets and datastreams can be re-processed for compatibility, and the serivces layer, where standard application capabilities can be packaged for reuse by targeted applications.

E-SDI interoperability in turn supports collaboration by providing commonality of terminology and behavior. This is helpful but not sufficient to support the wider range of collaborations that the diverse user roles in an E-SDI would need to carry out. Of course such collaborations have always existed, but they haven't always needed to occur within the domain and scope of the infrastructure itself. There is somewhat of a recursive aspect to supporting these collaborations, and the collaborations that in turn support them within the infrastructure (e.g., identity management). Any implementing organization or consortium will need to consider for themselves whether the cost of doing so will be worth the benefits of a functional E-SDI.

11.2.4. E-SDI Costs and Benefits

While these considerations are largely outside the scope of a notional architecture, it is worth noting that is a significant calculation given the increased scope of an E-SDI and its potential to replace or augment existing out-of-band capabilities and workflows. Of course, many of these may not have been successful in the past, so the functionality that an E-SDI provides may need to be weighed against intended activity which was not tracked and was often not successfully carried out in the past. This would clearly be an important component of a more detailed E-SDI solution architectural work.

Chapter 12. Conclusions and Recommendations

12.1. Summary of Outcomes

This report presents both the activities of the BEMA CDS and its outcomes. These outcomes include challenges that building energy data and applications face, as well as opportunities to address those challenges with improved technologies, data sharing practices, and improved understanding of the benefits that could result, such as identification and reduction of energy poverty.

Challenges in carrying out this study and in advancing building energy analysis include:

- Utility perspective on conservation, demand side management, regulation is underrepresented in the responses.
- Data access and sharing issues include availability, privacy, confidentiality, propriety
- Repetitive non-standardized methods are applied to collection, exchange, integration of datasets.
- Data source methods and confidence are wide ranging and poorly documented, variously measured, modeled, inferred, estimated, assumed, etc.
- Lack of access to retrofit cost estimates presents a barrier to deriving benefits from energy mapping and modeling data.
- Lack of an overall data framework prevents connecting the scale and resolution of spatial data to particular use scenarios
- It remains a challenge to connect archetyping methods (clustering / classification) with different use case scenarios

Identified opportunities include:

- Data access technologies that account for privacy, confidentiality, anonymity, e.g., enclave processing, anonymization by aggregation + noise injection (differential privacy)
- Adaptive classification and archetyping based on sample modeling
- National systems for consistent energy data at multiple scales
- Data sharing policies and standards organized to support critical use cases and stakeholders, e.g., federation contracts, mandated reporting.
- National building data layer for comprehensive analysis of building types, energy performance, retrofit / upgrade technologies, costs, and benefits.
- Community-utility cooperation facilitated by regional/national authority to understand opportunities /costs / benefits of new technologies and energy sources, e.g., renewables

Building energy and spatial data infrastructure

A critical challenge identified in this study has been the availability of the right spatial information elements to perform building energy analysis at the various levels of generalization and specificity where it can be useful in improving lives and advancing community goals. The idea of supporting the reusability and wide sharing of spatial data by providing information as infrastructure has been around for a while and is particularly highly developed in Canada. More recently, the concept, capabilities, and design of such infrastructure have been expanding and it makes sense in this context to consider what spatial data infrastructure might look like that can support the building energy needs and opportunities identified in this report. A notional notional architecture is presented in the report for such a future Energy Spatial Data Infrastructure (E-SDI).

12.2. Recommendations for Future Work

Among the many outstanding issues the BEMA CDS has raised, a few particular learning opportunities stand out:

- Design of an extensible and standardized national building layer, leading to both national application and improved comparability of promising building energy analysis methods.
- Sandbox activities such as interoperability pilots, modeling the mutual benefits of information sharing and data interoperability
- Prototypes for an E-SDI, demonstrating common availability of such technologies as cloud-based energy modeling, model-driven building archetypes, and enclave protocols for addressing data privacy and propriety constraints.
- Development of energy poverty indices that take into account fine-scale socio-economic, climate, and geographic factors in assessing impacts and mitigation of building energy cost.

Future energy analysis R&D

1. Develop authoritative data and make accessible on an open or licensed basis
    - Could be achieved through improved access to and interoperability between applications
2. Leverage existing and develop new technical guidance on highest and best use of data from different sources and types (e.g., measured, modeled, inferred, estimated, assumed)
    - E.g. Canadian Standards Association Quality Assurance and Quality Control of Building Energy Modelling for Program Administrators [https://www.csagroup.org/wp-content/uploads/CSA-Group-Research-Building-Energy-Modelling.pdf]
3. Create overall framework that connects use scenarios to spatial and temporal scale and resolution
4. Classify archetyping methods (clustering / classification) for different use case scenarios and stakeholder capacity
5. Conduct further research to understand utility perspectives, information systems, challenges and opportunities e.g., utility focus groups and national survey of utility information systems

Future standards R&D:

1. Better integrate energy, building, and spatial data for demand profiles, for example through creating an E-SDI data model that can underpin building energy mapping and analytics using OGC standards-based applications. This would ensure the ability to match building archetypes and utility customer classes, as well as aggregate data to different scales appropriately.
2. An important requirement for a useful E-SDI data model will be to match terminology, feature

types, phenomena, and event definitions across disparate data sources using semantic mediation, based on ontological mapping across the terms, concepts, and practices presently in use.

3. Develop Profiles of Implementation using OGC standards, e.g., OGC Application Programming Interfaces (API's), which support modeled energy data exchange for building level and wide area mapping and analytics, including backcasting and forecast scenarios (i.e., high-efficiency vs business as usual), while protecting privacy.
4. Improve accuracy of models (historical and forecast scenarios), using OGC standards and statistical methods comparing modeled vs measured data.
5. Demonstrate handling of building attributes for energy modeling by CityGML and/or IndoorGML. Advance CityGML demonstrations to integrate metered utility data.
6. Demonstrate de-identification, processing, normalization, aggregation, and visualization of measured energy demand (across all fuel/building types) to an appropriate scale and privacy threshold, with OGC standards, e.g. Web Processing Service (WPS).
7. Demonstrate how to integrate renewable resource information, for example as OGC WCS (coverages) with CityGML (Utility ADE) capabilities for yield estimation and modeling.
8. Demonstrate how to create high quality models of energy networks for applications across a utility enterprise, using OGC standards, including for capacity constraint analysis, probabilistic forecasting, outage management, load balancing, power quality, EV network management, surveying/inspection, Distributed Energy Resource Management Systems (DERMS), etc.
9. Develop specific profiles of WPS for handling workflows, parameters (user defined parameters etc) and for time-series representation.

Future E&U DWG activities:

1. Develop Concept of E-SDI - What gaps and opportunities exist to improve interoperability and architecture?
2. Test/demonstrate E-SDI, practices, use cases, to address concerns, challenges and opportunities with energy data modeling
   - Data collection and exchange standards
   - Enclave computing, aggregation
   - Model calibrations
   - National Building Layer/Spatializing national data sets
   - National CEE Map / Application
   - Services in the CGDI, using OGC standards
3. Augment Communications & Outreach
   - For better energy performance…

Appendix A: Annex A: RFI Respondents

Table 12. Respondent names and organizations

Name	Organization
Ryan Ahola	Canadian Geospatial Data Infrastructure
Allison Ashcroft	CUSP Network
Janet Ashworth	City of Ottawa
Kirby Calvert	University of Guelph
Jean Carrière	Trailloop
Christian Chan	C2 Planning
Sarah Cole, Ricardo Santos	Envitia
Volker Coors	Hochschule für Technik Stuttgart Institut für Angewandte Forschung
Véronique Delisle	CanmetENERGY Research Lab Varennes
Nina Dmytrenko	CMHC
Ursula Eicker	Concordia University
Alain Grignon	Climate Change Geospatial Action Learning Team
Yuill Herbert	SSG
Tianzhen Hong	Lawrence Berkeley National Lab (LBNL)
Caroline Jackson	City of North Vancouver
Murray Journeay, Nicky Hastings	Natural Resources Canada, Geological Survey of Canada, Pacific Division, Vancouver subdivision
Ryan Kilpatrick	CanmetENERGY Buildings & Renewables
Mitchell Krafczek	University of New Brunswick
Dale Littlejohn	Community Energy
Fabien Maistre	SG2B Inc.
Gordon McElravy	buildingSmart Canada
Kris McGlinn	ADAPT
Bill Meehan	ESRI Canada
Winston Morton	EfficiencyOne
Arman Mottaghi	Lambda Science
Joshua New	Oak Ridge National Laboratory (ORNL)
Jean-Samuel Proulx-Bourge	Canadian National Building Layer
James Riley	Lightspark

Name	Organization
Simon Sansregret	HydroQuébec
Aaron Taylor	CLEAN Foundation
Dave Turcotte	CanmetENERGY Research Lab Varennes
Jessica Webster	CanmetENERGY Ottawa

Appendix B: Annex B: QUEST CanmetENERGY Summary Report

QUEST

Final Summary Report

Building Energy Mapping Analytics and Working Group

September 28, 2020

To: Jessica Webster

Energy Planning Analyst

1 Hannel Drive

Ottawa ON K1A 1M1

QUEST is pleased to provide this final report to CanmetENERGY, Natural Resources Canada, in support of the Building Energy and Mapping Analytics Concept Development Study.

1.0 Introduction

The CanmetENERGY-Ottawa division of Natural Resources Canada (NRCan) is undertaking the

Canadian Energy End-use Mapping project (CEE Map). This project aims to develop an online map of building energy end-use and efficiency opportunities and associated data, best practices and standards to accelerate the uptake of building energy retrofits and the transition to a low carbon economy.
This project involves developing two prototypes of a residential energy use and efficiency opportunities map for the City of Kelowna, BC on parallel paths:

1. ESRI-based dashboard showing baseline energy, greenhouse gas and operating energy cost data in housing in collaboration with the Federal Geospatial Platform; and,
2. Engaging a third party service provider to develop an advanced ML based platform showing baseline and future scenario summaries for municipal and utility decision makers as well as customized upgrade recommendations to individual homeowners and occupants for their own homes, based on available data. NRCan's CanmetENERGY-Ottawa and GeoAnalytics divisions will create the CEE Map prototypes by adding outputs from the HTAP platform to characterize the residential use and efficiency opportunities in Kelowna's housing stock. These prototypes will serve as a basis for experimentation and evaluation of methods to best achieve the CEE Map project's long-term vision: **to create an authoritative online mapping platform(s) that will support housing energy end-use characterization and efficiency opportunity identification by non-building science professionals, and associated data, best practices and standards**.
   To help inform the CEE Map, CanmetENERGY-Ottawa also launched a study called "Building Energy Mapping and Analytics Concept Development Study" (BEMA-CDS) which was carried out by the Open Geospatial Consortium (OGC). The study included a Request For Information (RFI), a survey of international state of the art in building energy mapping, as well as stakeholder engagement through several webinars, towards identifying open standards and opportunities to advance interoperability for mapping of building energy end-use, efficiency opportunities, and opportunities to integrate renewable energy technologies into the building stock. The goals of the study are to:
   - Characterize the state of development of energy mapping and analytics for building stock broadly; and
   - Inform and propose IT architectural practices and standards to enable mapping and analytics specifically of residential energy use and efficiency. A key motivation for this study is that building energy mapping and analytics are critical for geo-targeting energy policies, programs, codes, incentives, and technology integration to accelerate the transition to a low-carbon built environment and economy. Municipal energy planning and utility demand side management (DSM) program efforts could also be enhanced with building energy mapping and analytics. However, access to and use of consistent, authoritative geospatial data on the building stock and its energy performance is a systemic challenge that no one organization can fix alone.
     The lack of geospatial data coordination results in duplication of effort, lost energy savings, and lost opportunities for climate change mitigation and resilience. _"The cross-section of measured, modelled, and simulated data could significantly improve energy performance of municipal- and utility-owned public buildings and infrastructure in Canada and the United States." _source: Mapped Out [https://www.renewcanada.net/feature/mapped-out/], Renew Magazine, E. Oldfield and D. MacPherson, July 2014 QUEST provided support to CanmetENERGY to help inform and advance the BEMA-CDS. This report covers what was done by QUEST in support of this project, including a summary of the OGC Energy & Utilities

DWG session and key findings from Energy Summits held in 2017 and 2018, a brief overview of initial findings collected by OGC, and a summary of recommendations.

2.1 Summary of Activities

QUEST, with the technical expertise of Spatial Quest Solutions, provided support to Natural Resources Canada, CanmetENERGY-Ottawa, for the Building Energy Mapping and Analytics Concept Development Study, through the provision of:

- Review of Materials supplied by CanmetENERGY-Ottawa – including background documents on CEE Map, IEA Annex 70, and draft Request for Information (RFI).
- Preparation of questions and question categories for the RFI
- Identification of potential respondents
- Outreach to potential respondents, and larger QUEST network
- Assistance with preparation, promotion, facilitation for the OGC Energy and Utilities Working Group sessions and two Validation Webinars
- Review of early results with project team
- Project team meetings throughout
- Interim Report [https://drive.google.com/file/d/1EoAO-dTnl3bZ1Bm3FvHE29ijlDnpQrB2/view?usp=sharing], and this Final Summary Report.

2.2 Types of RFI Questions submitted

QUEST reviewed all sections of the draft RFI and prepared a series of suggestions and additional questions which are contained in this document [https://docs.google.com/document/d/1G1TVAx92Drmdf4_tgjXAOk9IetmiqEup_lh8wp1WMIM/edit?usp=sharing] submitted to CanmetENERGY and OGC. The suggestions were discussed with CanmetENERGY and OGC, and the RFI was refined accordingly then launched by OGC and NRCan. The RFI focused on three principal usage scenarios for building energy mapping and analytics:
1. Community Energy and Emissions Planning
2. Utility Conservation Potential Review & Demand Side Management Program Planning
3. Federal/Provincial/Territorial Building Energy - Policy Programs, standards, building codes
The RFI questions were grouped into 7 categories including:

- Stakeholders
- Applications and IT architecture
- Data and governance
- Requirements
- Usage scenarios/use cases
- Technology and techniques
- Other factors

2.3 Types of Respondents identified

QUEST identified 30+ direct contacts in the contact list [https://docs.google.com/spreadsheets/d/

1icTGqe0dzlaNykBw182VwKCrq4zzqzuW0zYkMFkwB7g/edit?usp=sharing] (created by OGC), including for:

- Energy Utilities
- Energy Efficiency Agencies
- Municipalities and Municipal Agencies (e.g. FCM)
- Technical Institutes and Universities
- Non-profit organizations
- Software Providers
- Government Agencies

2.4 Outreach Channels used

QUEST supported the launch and promotion of the RFI, through:

- Direct Email to Respondents identified (reach: 30)
- OGC Energy & Utilities DWG list-serve (reach: 90+)
- QUEST Newsletters (Atlantic, Central, Western. Reach: 5000+)
- QUEST Social Media (on Twitter and LinkedIn)

3.0 Summary of OGC E&U DWG and key findings from Energy Summits

QUEST helped to prepare and co-facilitate the OGC Energy & Utilities Domain Working Group (OGC E&U DWG) sessions and Validation Webinars as part of this project, in June 2020. These sessions were held after OGC had collected responses to the RFI, and they engaged multiple participants / stakeholders to discuss the initial RFI findings.
The OGC E&U DWG brings together market participants and geospatial solution providers to identify marketplace requirements, present research, and inform potential updates to OGC standards in support of the energy & utilities domain. The BEMA-CDS project is an important contribution to the standards work of OGC, in the energy & utilities domain – it addresses several of the marketplace needs identified by the working group, and lays a foundation for future work.
In June, the OGC E&U DWG session included:

- A brief introduction to OGC (www.opengeospatial.org [http://www.opengeospatial.org])
- A recap of key findings from two Energy Summits (*summarized below in Section 3.1*)
- Introduction to CanmetENERGY, CEEMap, energy mapping in Canada, and BEMA-CDS
- Overview of Initial Findings from the RFI (presented by OGC, and *summarized in Section 3.2)*
- Lightning Talks:
    - Rapid Building Energy Simulation with StepWin *(Lambda Science)*
    - Municipal PV potential in the built environment in Canada *(CanmetENERGY-Varennes)*
    - Prediction of the heating energy demand and related CO2 emissions using OGC CityGML *(HFT Stuttgart)*
    - Automatic Building Energy Modeling (AutoBEM) *(ORNL)*
    - Canadian Geospatial Data Infrastructure & Building Energy *(Natural Resources Canada)*__

3.1 Key Findings of Energy Summits

"Harnessing the Power of Geospatial Information for Smart Energy Communities and Utilities" - Energy Summits [http://external.opengeospatial.org/twiki_public/pub/EnergyUtilitiesDwg/WebHome/OGC_Energy_Summit_Report_June_28_2017.pdf] highlighted world class research, and identified key trends and marketplace requirements that may be solved with advancement and implementation of OGC standards. A Smart Energy Community seamlessly integrates local, renewable, and conventional energy sources to efficiently, cleanly, and affordably meet its energy needs.

Speakers included: QUEST; Electric Power Research Institute (EPRI); US Department of Commerce; California State University; Center Observation, Impacts Energy MINES ParisTech; Natural Resources Canada; IRENA; Oakridge National Laboratory; Ordnance Survey; Agile Inclusion; University of Guelph; Technical University of Munich, OGC Standards Working Group Chairs; and others.

Next, we present some of the findings from the Energy Summits:

3.1.1 Key Drivers Identified

During the OGC Energy & Utilities Summit [http://external.opengeospatial.org/twiki_public/pub/EnergyUtilitiesDwg/WebHome/OGC_Energy_Summit_Report_June_28_2017.pdf], **key drivers** for energy data exchange were identified, including:

- Solving pain-points
- Energy cost reduction
- Energy/peak demand reduction
- Climate change and CO^2 (reduction/management)
- Acceleration of clean energy deployment / cost reduction
- Infrastructure Renewal / Cost Avoidance

3.1.2 Need for energy information

Broadly speaking, improved access to energy data can help:

- To Inform Policy
- To Improve Customer Choice
- To Improve Utility Planning / Programs

3.1.3 Scenarios identified in support of Smart Energy Communities

The scenarios identified in support of Smart Energy Communities below, can also serve as a future goal post for CEE Map and supporting national spatial data infrastructure:

- **Integration of building attribute and energy data** (estimated, modeled, or measured) at parcel level, to support ***building energy modeling*** and ***wide area analysis***.
- **Community Energy Planning**– Calculate and visualize baseline and forecast energy use and GHG emissions across a community, to target investments in efficiency and clean energy integration, and to provide users (e.g. a utility, community stakeholders) a tool for measuring impact of investment decisions.
- **Integration of Green Button energy use data** and spatial representation of energy use data, to

create more accurate models of consumption to help determine what efficiency improvements and demand response (DR) programs are suitable/available to a geographic location and energy consumption profile.

- **Renewable resource assessments** (yield estimation) and integration with demand profiles
- **Model what-if scenarios**/ impacts of technologies and policy decisions on the metered building stock
- **Improve accuracy of models** (historical and forecast scenarios), using OGC standards and statistical methods to compare modeled vs measured data
- **Privacy protection:** de-identification, processing, normalization, aggregation, and visualization of energy demand (across all fuel/building types) to an appropriate scale and privacy threshold.
- **Smart Cities / Smart Energy Communities**– emerging requirements

3.1.4 Scenarios identified in support of Smart Energy Utilities

Additional scenarios were identified during the Energy Summits, which are relevant to advancing Smart Energy Utilities:

- **Distribution grid model data management**: for example, OGC standards could be used to create a high quality Geographic Information System (GIS) model of an energy network for applications across a utility enterprise (e.g. for asset management; integration of DER; automation/ADR; outage management etc).
- **Capacity constraint and network analysis, power generation capacity/resources assessment and pre-certification** (demonstrated with OGC CityGML Utility ADE) to enable Distributed Energy Resources (DER) analysis / site selection.
- *Probabilistic forecasting *using weather data elements provided through The Weather Information Exchange Model - WXXM and using IEC CIM – for probabilistic forecasting, outage preparation & response/recovery, peak demand reduction, Volt/Var control, intermittent renewable resource integration, etc.
- **Outage Management** – Data Integration, Distribution Network awareness, and Exchange.
- **Improve Customer Information Management (CIM)**/Distributed Energy Resources (DER) for load balancing and power quality. Focus: how OGC standards can improve interoperability of distributed energy resource management system (DERMS) and GIS.
- **EV Charging Network Management** – has been demonstrated with WFS-T
- **Augmented Reality for Inspection/Surveying** for utility infrastructure, community energy projects
- **Integration of all fuels data** for improved supply management and community energy demand profiles
- Develop standards for **integrating underground utilities** e.g. OGC landInfra/InfraML or PipelineML
- **Oil & Gas pipeline**– some unique and common requirements with electric distribution networks
- **Oil Spill Response** (already demonstrated, OGC)

3.1.5 Areas of Future Standards Work

Some of the scenarios described above require integration of geospatial data using **new combinations** of standards. OGC Standards: WMS, WFS, WCS, SOS/SWE, SensorThings API, WPS, CSW, CityGML Utility ADE, LandInfra, IndoorGML, and PipelineML are all relevant to the scenarios identified*. *Other Standards: IEC CIM/DERMS; other IEC standards; Multispeak, Green Button, BuildingSMART, IFCs, are also relevant standards to the scenarios identified, however *work is needed *on exchange standards – for example, Green Button to Geographic Information Systems (GIS) / OGC standards-based applications. As another example, work is being done by OGC and BuildingSMART on BIM-GIS interoperability. Other areas of standards work includes to:

- Demonstrate how OGC standards (e.g. WMS, WFS, WPS, OGC APIs) can support energy data exchange for building level and wide area mapping and analytics, including backcasting and forecast scenarios (i.e. high-efficiency vs business as usual), while protecting privacy.
- Improve accuracy of models (historical and forecast scenarios), using OGC standards (WMS, WFS, WPS, etc) and statistical methods – by comparing modelled vs measured data.
- Better integrate energy and building data for demand profiles, for example through creating an Energy XML Schema, or Relational Schema, Hierarchical Schema, Semantic network requirements, that can underpin building energy mapping and analytics using OGC standards-based applications. This would ensure the ability to match building archetypes and utility customer classes, as well as aggregate data to different scales appropriately.
- Demonstrate how CityGML or IndoorGML standards can handle necessary energy related attributes for building modelling, such as space type, mechanical systems, insulation levels. Also, advance CityGML demonstrations to integrate metered utility data.
- Demonstrate how OGC standards (e.g. OGC WPS) are used for de-identification, processing, normalization, aggregation, and visualization of energy demand (across all fuel/building types) to an appropriate scale and privacy threshold.
- Demonstrate how to integrate renewable resource information, for example as OGC WCS (coverages) with CityGML (Utility ADE) capabilities for yield estimation and modeling.
- Demonstrate how OGC standards can be used to create high quality GIS model of energy network for applications across a utility enterprise, including for capacity constraint analysis, probabilistic forecasting, outage management, load balancing, power quality, EV network management, surveying/inspection, etc.
- For implementation of OGC WPS, there's a need for specific profiles and improved ability for handling parameters (user defined parameters etc) and for time-series representation.

3.1.6 Current Challenges

Energy Summit participants also identified several challenges:

- Access to Data – non standardized energy end-use data.
- Integrating modeled building energy performance with aggregated/normalized energy consumption (metered) data.
- Privacy protection, legal framework, exchange protocols, data standards / inconsistencies, risk perception.
- Energy Mapping for municipalities – on-demand provision of complete energy, GHG, and

efficiency maps (historical, seasonal, and forecast /what if), below the municipal boundary scale.

- Distribution Network Model – developing a complete / connected model, integrating location-based elements to improve forecasts and 'smart DER/DR assets', leveraging the model for OT and IT applications
- Lack of understanding of ROI, utilities not fully leveraging standards.
- Access to Best Practices (albeit growing)

3.1.7 Actions Arising from the Energy Summits

- **Select scenarios for further research**, which focus on achieving key requirements / providing the greatest impact across value streams.
- To advance solutions, OGC Members can contribute **Concept Development Studies** (such as BEMA-CDS), Profiles of Implementation, develop Engineering Reports, and collaborate to demonstrate interoperable solutions for key pain points in the energy and utility domain. Members could consider collaborating on interoperability pilots involving: OGC standards, with IEC CIM, DERMS, BIM, Green Button etc., for specific scenarios listed above, or as part of national SDI. The OGC E&U DWG can enable coordination between relevant Standards Working Groups, to facilitate development of interoperability pilots / projects, where new combination of standards are needed to solve pain-points in Energy & Utilities Domain
- **Build trust and prove business case/value proposition**:
  - Internal interop pilot to satisfy utilities and regulators.
  - External web map services / 3rd party applications.
- **Develop best practices** or standards for energy use data exchange, integration, and visualization. Publish outcomes.

3.2 Initial findings from RFI (presented at E&U DWG and Validation Webinars)

BEMA-CDS RFI findings were shared by OGC during the OGC E&U DWG and Validation Webinars (June 16, 25, and 26, 2020), where they were further discussed by multiple participants. The RFI findings and feedback collected during the validation webinars, are being further analysed by OGC to inform their report for CanmetENERGY-Ottawa. Here is a summary of the initial findings shared in June:

3.2.1 Usage Scenarios identified by RFI respondents

A general observation on usage scenarios is that use cases for building energy data cover scales from individual buildings to national and international aggregations. The use cases identified by respondents are listed below:

Community Energy and Emissions Planning

- Municipalities, utilities and building owners collaborate to model all energy consumption in municipalities.
- Identification of district energy potential, retrofit hot spots, validation of city-wide energy and GHG emissions.

- Demographic energy analysis e.g. energy poverty
- Enabling communities with an additional tool to understand their energy resources and make investment decisions in renewable energy projects.
- Renewable energy system design and operation, design of storage systems, transportation energy use mapping

Utility Conservation Potential Review & Demand Side Management Program Planning

- Grid integration of renewable energy
- Municipalities, utilities and building owners collaborate to model all energy consumption in municipalities.
- Individual building owner energy cost management
- Sensor-based analysis - how can these technologies can be supported in the context of building energy.
- Integrating supply and demand side mapping to identify regions that might be net-electricity producers (higher potential supply than demand) and therefore help to map flows of electricity in a given area.
- Market Opportunity Assessment (for specific technologies, programs, services)

Federal/Provincial/Territorial Building Energy - Policy Programs, standards, building codes

- Energy rating reports (building labelling), digital audits and labels, assessing energy ratings averages and trends at different levels (nation, region, location, building)
- Demographic energy analysis
- Sensor-based analysis - how can these technologies can be supported in the context of building energy.
- Building energy mapping tool and analytics for building capacity in research areas to support innovation
- Cross-Domain Analysis – additional value when integrated with other domains (e.g. climate change, local development, population health, etc.)
- Building energy modelling compliance within design applications.

   i. **Standards Used by RFI respondents** Several RFI respondents indicated they rely on no specific standards, while others indicated they use the following standards:

- EnerGuide Rating System (An EnerGuide rating is a standard measure of a home's energy performance)
- Partners for Climate Protection (PCP) protocol [https://data.fcm.ca/Documents/reports/PCP/PCP_Protocol_Canadian_Supplement_EN.pdf]for Greenhouse Gas Inventories
- OGC CityGML +/- Energy ADE (CityGML is an open data model and XML-based format for the storage and exchange of virtual 3D city models. The CityGML Energy ADE extends the CityGML Standard by features and properties, which are necessary to perform an energy simulation and to store the corresponding results.)
- OGC IndoorGML (specifies an open data model and XML schema for indoor spatial

information).

- buidingSMART Information Delivery Manual (The Information Delivery Manual (IDM) aims to provide the integrated reference for process and data required by BIM by identifying the discrete processes undertaken within building construction, the information required for their execution and the results of that activity)
- OGC GeoSPARQL (The OGC GeoSPARQL standard supports representing and querying geospatial data on the Semantic Web)
- PROV-O (PROV-O is a lightweight ontology that can be adopted in a wide range of applications)
- ifcOWL (ifcOWL provides a Web Ontology Language (OWL) representation of the Industry Foundation Classes (IFC) schema. IFC is the open standard for representing building and construction data)
- gbXML (An industry supported standard for storing and sharing building properties between 3D Architectural and Engineering Analysis Software.)

3.2.3 Time resolution for end-use cases

- Varies from 5 minutes to 1 year

3.2.4 OGC Familiarity

- Yes – 14, No – 6, No response – 13

3.2.5 National data and maps usage / interest

Respondents identified several types of data that could be provided as national data/maps. While not all suggested data types might be feasible to provide on a national basis, they are relevant to the scenarios described above:

- Building data such as footprint, height, type, construction year, window-to-wall ratio, HVAC type, heating and cooling loads, floor area, envelope materials, cost, location, & other fields
- Energy end-use data (all fuels), demand and peak data (where available), & carbon intensity
- Supply/Demand data on propane and heating oil at the community level
- Photovoltaic electricity generation
- Renewable Energy Resource data (e.g. solar irradiance, etc)
- Modelled energy consumption and EnerGuide audits by building archetypes, age, size,
- Billing or Metered data, when applicable
- Weather data (temperature, humidity, wind speed)
- Occupant socio-demographics
- Building Codes
- Other

3.2.6 Building archetypes number and approach:

Based on responses to the RFI, it was clear that various methods are used to classify building archetypes as part of building energy mapping and analytics. While this may be the case currently, there remains a need to standardize and promote best practices for building energy mapping and analytics – including archetype-based analysis. A CEE Map should allow for multiple types of analysis / different granularities. Some examples provided by respondents include:

- No archetypes - model each individual house
- 3 archetypes: residential, commercial, industrial + energy usage
- 4-10 archetypes clusters defined by an unsupervised machine learning algorithm that clusters dwellings by age, floor area, location, energy and carbon footprint, ranging from
- 30 residential + 50 non-residential
- 5 building types subdivided in 10 age classes in German IWU archetype library
- Many different housing typologies referred to in Official/Community Plan policies and zoning by-laws, as well as building codes
- 97 building type and vintage combinations modelled in OpenStudio
- FSA (geographic unit) aggregates
- 768 comprised of 16 Building Types for 16 Climate Regions for three construction periods found in Commercial Buildings Energy Consumption Survey (CBECS)
- ~6500 existing housing archetypes across Canada modelled in Housing Technology Assessment Platform (HTAP)

3.2.7 Gaps and Opportunities

Based on responses from RFI respondents, OGC also identified possible gaps and opportunities, with respect to building energy mapping and analytics. These gaps and opportunities are also reflected in the recommendations in Sections 4 and 5:

Gaps or Challenges included:

- Use cases often involve the same stakeholders, but with different objectives or priorities, e.g. individual energy decisions vs governmental policies and initiatives. It will be important to understand their particular requirements for energy data exchange and BEMA.
- Limited response from utilities, so utility perspective on conservation, demand side management, regulation is underrepresented. This requires further study (*see section 4.0*)
- Significant activities that involve repeated collection, exchange, integration of datasets with very little use of standards. A national CEE Map and/or energy SDI could reduce duplication.
- Diverse data source methods and confidence, e.g. measured, modelled, inferred, estimated, assumed. A national CEE Map and/or energy SDI could improve confidence.
- Energy data for inventories and models are derived from different sources and methods including:
    - Measured energy demand data
        - Municipalities and their consultants place more emphasis here
        - Limitations around aggregation, not being linked to building type, historical values only
    - Modelled building simulation data

    - Less readily accessible/usable by municipalities

- Disparate area +/- time interval units for different datasets limit granularity of aggregation. Aggregations are more accurate for noisy data, less accurate for biased data. Unclear what scale is appropriate for a given public dataset or policy. Lack of overall framework that connects scale and resolution of required spatial data to particular use scenarios. Solutions should enable scaling of data beyond a privacy threshold, for various use cases.
- Various techniques are applied inconsistently by different organizations to estimate current and projected end-use and efficiency opportunities. Best Practices or Standards could address this gap.
- Downscaling of national/provincial values using spreadsheets is not uncommon
- Data access issues: availability, privacy, confidentiality, propriety. Need Common protocol for data disclosure and anonymity. Sharing of non-aggregated microdata may be limited by privacy and/or proprietary concerns, complicating production of aggregate measures.
- Lack of access to relevant data on estimated cost and effectiveness of retrofits identified as a particular barrier to benefiting from energy mapping and modeling data.
- Lack of access to relevant data on availability and potential of various energy types
- Lack of attention to issues of energy poverty in programs that target energy conservation and carbon reduction.
- The strategic advantages of geospatial analysis are not broadly understood by many actors

Opportunities included:

- To harmonize observed overlap between scenarios (community, commercial, and governmental). This would mean services in CEE Map or Energy Spatial Data Infrastructure may serve multiple value streams / provide co-benefits at reduced cost.
- Opportunity to connect archetype delineation (e.g. clustering / classification) with application usage (whether computational, comparability, policy)
- Alignment of building archetypes and classifications with energy datasets and each other
- Alignment of geographic (climate, policy, regulatory, administrative, market area, generation, demand) units
- Metadata for data definition, quality, provenance, currency
- Exchange models / formats for energy usage / demand / cost data
- Exchange model / format for building retrofit design and cost data
- Commercial vs personal vs governmental data

4.0 Summary of September Energy & Utilities Working Group Session

QUEST helped to prepare and co-facilitate the OGC Energy & Utilities Domain Working Group (OGC E&U DWG) as part of this project, in September 2020. This session was held after OGC had collected and analysed responses to the RFI. There was over 50 participants in the session, who were engaged in discussing the findings and contributing input on notions of Architecture.

In September, the OGC E&U DWG session included:

- Introduction to CanmetENERGY, CEEMap, and BEMA-CDS (presented by NRCan)
- Overview of Findings and Analysis (presented by OGC)
- Q&A and Discussion

Following the Overview of Findings (already covered in Section 3), OGC provided an overview of further opportunities based on analysis of RFI findings. This includes opportunities for:

- Data access that accounts for privacy, confidentiality, anonymity, e.g. enclave processing, anonymization by aggregation + noise injection. Could also be achieved through private Spatial Data Infrastructure (SDI).
- Adaptive classification and archetyping based on sample modeling
- National systems for consistent energy data at multiple scales
- Data sharing policies and standards organized to support critical use cases and stakeholders, e.g. federation contracts, mandated reporting.
- National building data layer for comprehensive analysis of building types, energy performance, retrofit / upgrade technologies, costs, and benefits.
- Community-utility cooperation facilitated by regional/national authority to understand opportunities /costs / benefits of new technologies and energy sources, e.g. renewables

OGC also shared elements of a notional Energy Spatial Data Infrastructure (E-SDI) to support applications that focus on building energy opportunities. An E-SDI could include services based on OGC Standards, for example:

- Register & Catalog (CSW, API Records)
- Search (CSW, OGC API xxx)
- Access (WFS, WCS, STAPI, API Features, etc.)
- Process (WPS, API Processes)
- Sample (API EDR - DAPA)
- Transact (WFS, API xxx transactions)
- Authenticate - Authorize (OpenID, HTTP Auth, Federated DCS, etc.)
- Link - Relate (KB, GeoSPARQL, GQL, JSON-LD)

An E-SDI could also include access to data “layers”: framework, structure, observation, modeled data. For example:

- Building layers:
    - Vintage, characteristics and classifications
    - Energy usage
    - Activity
- Local
    - Weather

- Socio-economic demographic data
- Local / Regional
  - Regulatory rules
  - Construction and retrofit costs
  - Climate
  - Energy costs / availability / mix / potential
- National
  - Building archetype parameter ranges
  - Archetypal model calibrations
- Multi-scale
  - Building and archetype model outputs
  - District policy / DSM scenario model outputs

Depending on the use case, data may need to be offered at different Spatial scales: individual, municipal, regional, to national and global, and/or Temporal scales: minutes to decades.

OGC also discussed some of the challenges and issues:

- Technical Challenges:
  - Enclave computation for re-identifiable data (building, local)
  - Sampling interfaces to expose anonymized aggregates and model outputs
  - Tracking and provenance for different data velocities
- Data Issues
  - Is privacy / propriety the principal barrier to data sharing?
  - Should an Energy SDI include models outputs?
  - Should building owners / occupants have access to data for their building, or just the data providers and privileged analysts / modelers?
  - Can some computations be done in a public-private partnership (e.g. by utilities themselves).

The session concluded with a brief discussion about national architecture that could support building energy mapping and analytics. Some questions and comments pertained to availability of data, privacy protection, model outputs, SDI (examples in other countries), etc. There were no additional gaps identified. Participants were invited to identify interest to collaborate toward addressing the challenges and opportunities discussed above. Some of the pathways forward identified include:

- Public-private partnership (for data collection, integration, aggregation etc)
- Interoperability pilot / project, standards work
- Phased development of eSDI - private vs public services
- Modernization of decision support systems

Recommendations that were included in the main presentation, have been integrated with Section 6 - proposed Next Steps for Natural Resources Canada.

5.0 Next Steps for Utilities

To advance energy data exchange standards for building energy mapping and analytics, it will be necessary to engage energy utilities and regulators to understand their current challenges and develop best practices for energy data exchange, mapping, and analytics. This could include conducting a national survey or new study to identify common challenges, systems in place, new workflows, and benefits of analytics and spatialized data. In addition, the study could identify gaps and opportunities for improving regulation, or opportunities to demonstrate scenarios with real systems/data to prove value to ratepayers.

6.1 Current State

At present, the CanmetENERGY-Ottawa division of Natural Resources Canada is undertaking the Canadian Energy End-use Mapping project, which aims to provide an online building energy end-use and efficiency opportunities map and associated data, best practices and standards to accelerate the uptake of building energy retrofits and the transition to a low carbon economy. The initial CEE Map prototype is being developed in collaboration with the City of Kelowna, BC, built on the ESRI-based Model City developed by city staff. NRCan's CanmetENERGY-Ottawa and GeoAnalytics divisions will create the CEE Map prototype by adding outputs from the HTAP platform to characterize the residential use and efficiency opportunities in Kelowna's housing stock. This prototype will serve as a basis for experimentation and evaluation of methods to best achieve the CEE Map project's long-term vision: to create an authoritative online mapping platform that will support housing energy end-use characterization and efficiency opportunity identification by non-building science professionals. In addition, the Canadian Geospatial Data Infrastructure (CGDI) and GeoConnections, hosted by Natural Resources Canada, supports discovery and publishing of geospatial data, geoscience data products and web services. The CGDI leverages OGC interoperability standards to support discovery and publishing of geospatial data, encompassing reference (geographic) and business information for the benefit of all Canadians. This includes Open Maps (https://open.canada.ca/en/open-maps), Canada's Federal Government node of CGDI. GeoConnections also publishes a list of available web services in the .ca domain. This is a partial representation of what comprises CGDI. There is no single entry point to CGDI as it is a distributed SDI model.

6.2 Building an Energy SDI

To unlock the value of energy data for the benefit of all Canadians, Natural Resources Canada could expand the CGDI to include an energy Spatial Data Infrastructure (eSDI), improving access and availability of energy data across jurisdictions. This would not only support CEE Map and building energy mapping and analytics, it can help to address national and inter-provincial goals – e.g. a recent EMMC (Energy Ministers meeting) released a Ministerial Statement identifying one of their objectives is to: Improve access and availability of energy data across jurisdictions. Standards-based architecture for eSDI would support linkages with other SDIs where necessary - e.g. FGP, NFIS (https://ca.nfis.org/index_eng.html). Examples of other relevant SDIs are included in the Appendix. Energy SDI would be an OGC standards-based approach to enable the exchange, integration and visualization of previously disparate energy data, while respecting privacy regulation and energy policy contexts across provincial jurisdictions. An Energy SDI could enable private and/or public access to data on: administrative and legal boundaries, energy supply, renewable energy resource profiles, energy use / demand profiles, earth observation data, building information, utility network model data, or population demographics. An Energy SDI could support CEE Map, access to national data layers such as National Building Layer, services for archetype analysis, and other services. Over time, CEE Map and an Energy SDI could grow to include modelled and measured energy data, analysis features, consumable web services for GIS users, etc. Services in an energy SDI could provide capabilities for integrating data for backcasting and forecasting scenarios at different spatial and temporal scales. In so doing, an energy SDI can support Smart Energy Communities and Smart Energy Utilities. An Energy SDI would solve the need for improved access to data, in a standard and privacy compliant way, in order to facilitate decision-making (e.g. for targeting energy efficiency, integrating renewable resources, determining policies) in making the transition to a low carbon economy.

The potential economic, environmental, and health benefits of improved decision-making with location-based energy data, far outweigh the cost to implement energy SDI.

6.3 Notional Architecture:

Based on the discussion above, Figure 1 below is a notional architecture which includes CEEMap, Energy SDI, distributed data sources and web services, underlying IT infrastructure, and potential links to building energy modeling and rating systems.

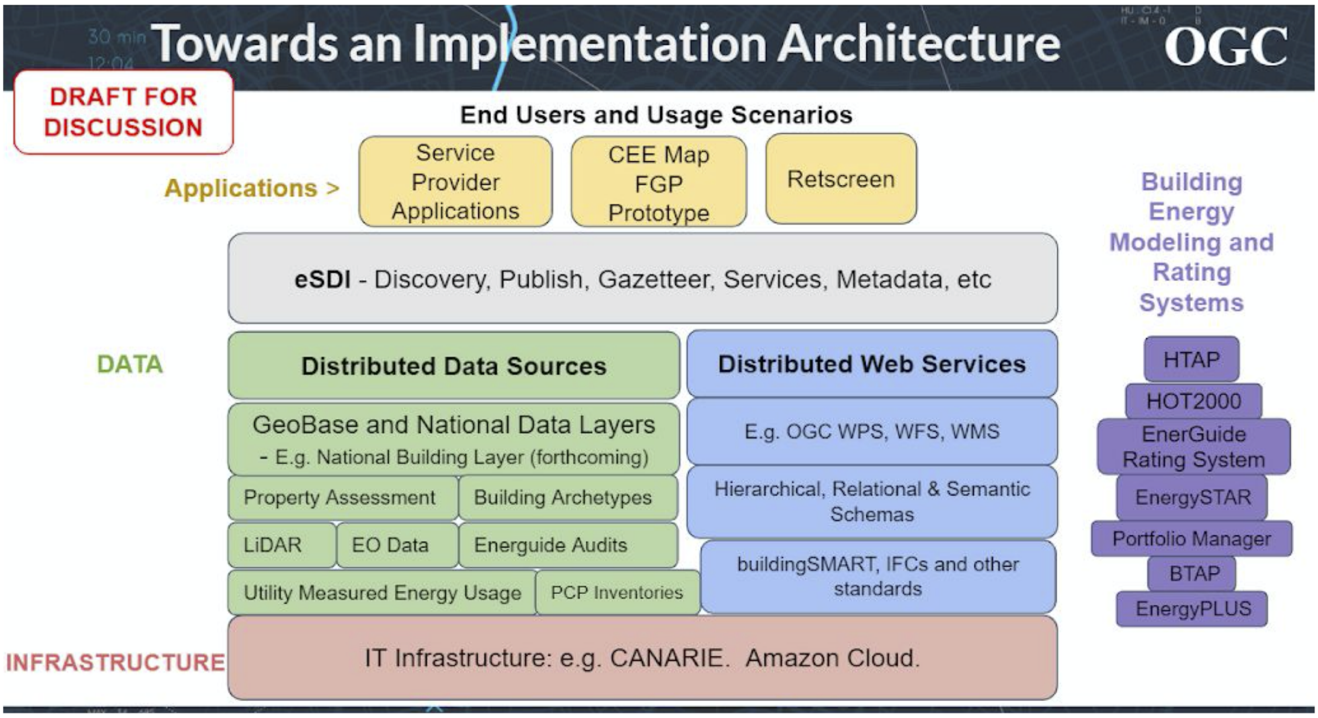

Figure 2. Notional Architecture

6.4 Additional Recommendations:

Based on the Gaps, Challenges and Opportunities identified in the above report, Natural Resources Canada could also consider:**

- Providing **input to the Canadian Centre for Energy Information** consultations
- Conducting **a utility focused study or national survey** **(as outlined in section 5) - to understand utility perspectives, information systems, challenges and opportunities
- Creating the **National Building Layer** to enable comprehensive analysis of building types,

energy performance, retrofit / upgrade technologies, costs, and benefits.

- Developing *authoritative data *and making it accessible on an open or licensed basis - Could be achieved through improved access to and interoperability between applications, as well as *data sharing policies and standards *organized to support critical use cases and stakeholders, e.g. federation contracts, mandated reporting.
- Leveraging existing and developing new* technical guidance *on highest and best use of data from different sources and types (e.g. measured, modelled, inferred, estimated, assumed), E.g. Canadian Standards Association Quality Assurance and Quality Control of Building Energy Modelling for Program Administrators [https://www.csagroup.org/wp-content/uploads/CSA-Group-Research-Building-Energy-Modelling.pdf]
- Providing guidance for and **adopting standards** (including OGC standards) for energy data exchange and mapping, while addressing data access issues: availability, privacy, confidentiality, propriety._ This should include guidance on how to use specific OGC standards in relation to specific use cases, and_ **common protocol** for data disclosure and anonymity.
- Establishing* best practices **for building energy mapping and analytics, building archetype classification/analysis, and wide area representation, of measured (e.g. metered consumption data, building type), modelled (e.g. HTAP/BTAP), inferred (e.g. GHG emissions) and estimated data types. Furthermore, *defining archetyping methods (clustering / classification) for different use case scenarios** and stakeholder type/capacity. A CEE Map should allow for multiple types of archetype analysis / different granularities, facilitate alignment of building archetypes and classifications with energy datasets and each other.
- Creating a *multi-disciplinary team *for advancing CEE Map and/or establishing and Energy SDI capable of reducing duplication of collection, exchange, integration, and visualization of datasets, using OGC Standards, for various use cases, scales, time scales, etc, while respecting privacy and confidentiality. Create an overall framework which connects use case scenarios, to spatial and temporal scale and resolution of data.
- CEE Map or energy SDI could provide access to* various national data layers* (e.g. NBL) as well as energy data (modelled, measured, etc), as well as data necessary for supporting use cases. While not all suggested data types might be feasible to provide on a national basis, they are relevant to the scenarios described above:
  - Building data such as footprint, height, type, construction year, window-to-wall ratio, HVAC type, heating and cooling loads, floor area, envelope materials, cost, location, retrofit costs and impacts, & other fields
  - Energy end-use data (all fuels), demand and peak data (where available), & carbon intensity, aggregated as needed.
  - Real data on propane and heating oil at the community level
  - Photovoltaic electricity generation (kW / MW)
  - Renewable Energy Resource data (e.g. solar irradiance, etc)
  - Modelled energy consumption and EnerGuide audits by building archetypes, age, size, etc
  - Billing or Metered data, when applicable
  - Weather data (temperature, humidity, wind speed)
  - Occupant socio-demographics

- Building Codes by Province
- Administrative Boundaries SEE APPENDIX FOR FULL LIST OF DATA TYPES TO CONSIDER.

- Establishing a system for **enclave processing**, anonymization by aggregation + noise injection. Could also be achieved through private Spatial Data Infrastructure (SDI).
- In order to create an energy SDI and fully interoperable CEE Map, there is need for undertaking *Interoperability Demonstration **of OGC standards *to meet the requirements of CEE Map, integration with HTAP/BTAP, CGDI, and Distributed Data Sources. This can also help inform OGC Standards Development, for example:
  - Demonstrate how OGC standards (e.g. WMS, WFS, WPS, OGC APIs) can support energy data exchange for building level and wide area mapping and analytics, including backcasting and forecast scenarios (i.e. high-efficiency vs business as usual), while protecting privacy. This could be for individual use cases, or as part of a national CEE Map or energy SDI.
  - Improve accuracy of models (historical and forecast scenarios), using OGC standards (WMS, WFS, WPS, etc) and statistical methods – by comparing modelled vs measured data.
  - Better integrate energy and building data for demand profiles, for example through creating an Energy XML Schema, or Relational Schema, Hierarchical Schema, Semantic network requirements, that can underpin building energy mapping and analytics using OGC standards-based applications. This would ensure the ability to match building archetypes and utility customer classes, as well as aggregate data to different scales appropriately.
  - Demonstrate how OGC standards (e.g. OGC WPS) are used for de-identification, processing, normalization, aggregation, and visualization of energy demand (across all fuel/building types) to an appropriate scale and privacy threshold.
  - Demonstrate how to integrate renewable resource information, for example as OGC WCS (coverages) with CityGML (Utility ADE) capabilities for yield estimation and modeling.
  - Demonstrate handling of building attributes for energy modelling by CityGML and/or IndoorGML. Advance CityGML demonstrations to integrate metered utility data.
  - Demonstrate how OGC standards and non-OGC standards can exchange data for the purpose of building energy mapping and analytics.
  - Develop specific profiles of WPS for handling workflows, parameters (user defined parameters etc) and for time-series representation of energy data.
  - And others.
- **Engaging post-secondary education** and private firms, in developing Energy SDI, as needed.
- Developing* public education or communication strategy* to promote the benefit of spatial data infrastructure and energy data to all Canadians.
- Ensuring **Metadata** for data definition, quality, provenance, currency
- **Update graphic templates** (see Figures 1 and 2 in the Appendix) to include newer standards and APIs. Update Figure 3 to capture the specific use cases that CEE Map or an Energy SDI may support, and align with OGC and other standards.

7.0 Conclusion

In conclusion, QUEST would like to thank CanmetENERGY-Ottawa, Natural Resources Canada, for the opportunity to support the BEMA-CDS project, as outlined above. We look forward to exploring how to help CanmetENERGY-Ottawa, Natural Resources Canada, advance the CEE Map beyond the prototype phase and consider the recommendations provided above.

8.1 SDI Examples

Here are some relevant examples of SDIs, based on OGC standards:

GeoVENER

https://www.earthobservations.org/activity.php?id=121 [https://www.earthobservations.org/activity.php?id=121] GEO Vision for Energy (GEO-VENER) focuses on Renewable Energy. Its goals is the availability and long-term acquisition of data from satellite and *in-situ* instruments and models to make possible the effective deployment, operation and maintenance of RE systems and their integration in the grid. One of many deliverables, it compiles resources related to energy within the catalogue of the community portal : http://www.webservice-energy.org/ [http://www.webservice-energy.org/] *The webservice-energy platform *hosts a collection of Web Services [http://geocatalog.webservice-energy.org/] offering data and applications in Renewable Energy and Environment.

IRENA Global Atlas

https://irena.masdar.ac.ae/gallery/#gallery

Canadian Geospatial Data Infrastructure (CGDI)

http://geodiscover.cgdi.ca/ [http://geodiscover.cgdi.ca/]. The GeoConnections Discovery Portal leverages Tier 1, Tier 2 and Tier 3 standards to support discovery and publishing of geospatial data and Web services.

New Zealand SDI

http://www.linz.govt.nz/ and www.geodata.govt.nz [http://www.geodata.govt.nz]

SDI of France

www.geoportail.gouv.fr [http://www.geoportail.gouv.fr] - The French geoportal allows viewing not only maps and aerial photographs, but also many other geo data related to the environment, development, public service. This ability to display geographical information allows creating maps to discover, understand and analyze territory.

8.2 Data Types

Good quality data is required to support SDI. Different scenarios may be supported by an energy SDI – each scenario requires different combinations of data that may be available in an SDI. Scenarios may involve geospatial data and web services as may be provided by both public and private entities, including government, utilities, service providers, and energy consumers themselves. The data types required in the scenarios listed above, include:

8.2.1 Reference data - Geographic

1. Land Use, coverage, topography
2. Administrative Boundaries, Parcel area boundaries
3. Municipal Zoning

4. Buildings Archetypes
5. Utility Networks (topology)
6. Transportation Networks
7. Location of residential densities, employment centres, location of waste and recycling centres, developable land, protected land.

8.2.2 Application data – Business Information

1. Building location and attributes
2. Energy use / demand (all fuel types) – including estimated, modeled, and measured/metered, at various scales or aggregations (depending on use-case)
3. Earth Observation data e.g. solar irradiance, wind regime, biomass potential yield / renewable resource intensity - LIDAR (NASA, MSC, or UNEP, or algorithm) data for Wind, Solar, Tidal, Vegetation cover (and clearing), and Biomass Capacity Resource Assessment. Resource Capacity assessments should include geospatial data for: supply mix (% / type), earth energy (mines, drilled boreholes, lakes/ponds, geothermal), wind energy (speed in km/hr; power in kW or MW), tidal energy (length, width in kms; depth in m; power in MW), solar energy and thermal energy (kWh/m^2/d), bioenergy (heating, CHP / Anaerobic digestion, power conversion), biomass (wide area analysis and site specific sources/applications), coal bed methane (billion cubic feet / BCF = GJ of energy), hydro potential (kW), industrial waste heat.
4. Geology data, e.g. for geothermal yield potential
5. Distance / proximity to grid (distribution and transmission) - Location of Generation, Transmission, and Distribution Assets (especially for strategic siting of renewable energy systems), and development of new loads.
6. Distribution Network Model: Utility assets, their connectivity, their uses for utility focused cases (e.g. outage management, capacity constraint analysis, etc)
7. Population demographics
8. Population density
9. Protected areas

*Some Key Related Units:**

- **Energy consumption figures in Therms, KWh, Megawatts, GJs, or BTUs,** can be used to describe, compile/add, compare the total consumption for an area (e.g. kWh by parcel, hectare/ha, kilometre/km^2), developable land (e.g. GJ/ha), building type and archetype (e.g. GJ by footage - metre/m^2), total floor space of a project or job (e.g. m^2/job), customer class (e.g. low-rise residential, commercial, general service <50kW or >50kW) or end-use type, and assess potential alternatives. This can include measured electricity and gas consumption baseline data (archival, published), modeled usage / forecast loads / per-capita consumption, real-time (every 15 minutes, hour, day, month) as well as forecast values (seasonal / annual / long-term), usually averaged by building archetype (and matched to parcels) or summed by zone, neighborhood / district, community or region). Anomalies from standard archetype energy consumption profiles can help users compare their usage (whether higher or lower) to average rates. Estimates based on building archetypes, aggregation by geography, normalization by population, and comparison to actual data (heat maps depicting deviations/anomalies from statistical average), are methods to avoid personal identification / problems related to privacy of data and re-identification.

- **Current monetary value of fuels** ($ per unit consumed) is important in assessing total funds expended per-capita, as well as Internal Rate of Return (IRR) and total potential savings / Return on Investment from investments in efficiency, or adoption of alternative supply options to meet space heating and power requirements. What-if scenarios (e.g. switching fuel type) can be evaluated through comparison of monetary values and units consumed
- For renewable energy technologies, the **installation cost** per unit energy generated ($/GJ), the operating cost per unit energy generated ($/GJ/yr), the CO2 emissions per unit energy generated (kg/GJ), **Maximum applicability** to the built form (%), Maximum applicability to displace conventional building energy generation (%), revenues from sale of energy including feed in tariffs (where applicable) – ($/yr).
- **Current monetary value of alternatives (by unit generated / offset)**, to help determine resource capacity, as well as Internal Rate of Return (IRR) and Return on Investment (ROI) of developing renewables (wind, solar, tidal, biomass), and participating in programs (e.g. DSM/Efficiency, Demand Response, net-metering, embedded generation, combined heat and power, district energy/heating). What-if scenarios (e.g. supply type selection) can be evaluated through comparison of monetary values and units generated / offset from traditional sources.
- **Emissions co-efficients** (CO~2 ~/ kWh for electricity, m^3 for gas, litre for gasoline) are used to convert energy consumption data into CO~2 ~emissions per lowest unit of comparison, based on the supply mix in each Province/Territory, and to model emissions from various energy supply types, baseline and future community energy scenarios. This can be used to compare the resulting emissions from selection of community energy options (such as district heating, CHP, and community energy systems).

8.2.3 Future SDI / Real Time Information

1. Green Button – energy use data
2. Orange Button – solar resource availability
3. CIM / DERMS – data on distributed energy resources
4. B2G / BIM – building and sensor data
5. V2G – vehicle data / transport data
6. IoT, SensorThings
7. VGI – e.g. volunteered data on energy efficiency upgrades / renewable energy plans and projects.

8.2.4 Derived data: associated costs/$, GHGs/$CO_2$, kWh/GJ.

These indicators can be processed on the fly, using standard coefficients / transformations. OGC WPS (web processing services) + algorithms can be used to provide geostatistical processing capability on distributed data, where new data values are created on-the-fly (or for queries that are pre-computed).

8.2.5 Relational schema

- Linking building types, categories, attribute codes, customer classes, energy types, common IDs.

- Building Types, Archetypes, Customer Class Relations
- Mapping energy intensities comparably across geometric areas requires matching of building typologies with building archetypes with utility customer classes, along with identification of common data links (e.g. name, type, class, ID), Building Type / Class and Archetype Attributes (e.g. stock age/vintage, size, height, orientation, footage, and other energy profile attributes). For example, Building Archetypes are ‘mapped’ to electricity and gas customer classes.

8.2.6 Hierarchical schema

From building/parcel (meter), to neighborhood scales, to geopolitical boundary (e.g. municipal/regional), to distribution network extent - to which energy data (business information) can be attached, aggregated or disaggregated. This can be used as part of an OGC WFS service, to provide boundary data for mapping energy values.

8.2.7 Other Non-Essential Data:

- Other data sources for spatial analysis can include vacant land-use inventory, present and proposed zoning, annexation plans, census data projections, regional planning studies, utility customer-usage information, and load research. These disparate data sources can translate future population densities into load projections and give greater insight into customer behaviour. With this data, utilities can organize sections of projected load growth into polygons as separate layers within their enterprise GIS (Connors, 2011).
- Occupant Characteristics / Consumer Profiles: though useful, this may not always be available, and is not collected in a standardized way. Surveys and targeted interviews can identify energy consumer characteristics, but must be constructed in a non-intrusive manner and with regard to privacy protocols.
- Efficiency Program Participants: identification of existing efficiency program participants, successful retrofits, and conservation subdivision designs, may be useful for knowledge exchange for before and after retrofit comparison. If compared with average consumption rates, baseline and forecast scenarios may be adjusted to reflect local circumstances and to compare efficiency retrofits impact (on costs, emissions).

8.2.8 Privacy Protected Data / Not Shared - Personally Identifiable Information:

Any information about an individual maintained by an agency, including (1) any information that can be used to distinguish or trace an individual‘s identity, such as name, social security number, date and place of birth, mother‘s maiden name, or biometric records; and (2) any other information that is linked or linkable to an individual, such as medical, educational, financial, and employment information. Other types of privacy protected data include:

- Actual Electricity / Gas Consumption / Billing Data for individual consumers (unless volunteered / consent obtained)
- Personal Data (e.g. name, occupation, gender, age, etc)
- Specific End User Profiles and Project Deployments (unless volunteered / consent obtained)

8.3 Data sources:

Data Sources identified that support the use cases described above, may include:

- Federal/Provincial/State Governments – Open Data / Geospatial Portals
- Utilities (public/Crowne, or private)
- Green Button
- Statistics Agencies
- Tax Authorities
- Building Owners
- Municipalities
- Planning Commissions
- IoT / Sensors
- EO data providers
- Data warehouses
- Global Atlas (e.g. IRENA), Web Service providers, or Brokerages

An energy SDI (including services provided by private and public entities) is best governed through a framework of policy, law, and the application of best practices including: Non-Disclosure Agreements, Service Level Agreements, Privacy Policy/Protocols for geospatial data exchange and privacy protection. This may be supplemented through digital authentication / identity management, IT and network security standards.

Table 13. Types of Decisions and Level of Aggregation for Energy Usage Data

Scale	Type of Decision	Data	Level of Aggregation for energy usage data
Building Scale (home/business)	• Compare building performance (historical, current) • Monitor / Manage Energy usage • Determine possible efficiency improvements • Determine suitability of e.g. solar, wind, geothermal, biomass, district heat, storage	• Energy usage/billing data (historical and instantaneous/interval data) • Building location and attributes • Renewable Resource availability (on site / adjacent to site)	individual building/meter(s)

Scale	Type of Decision	Data	Level of Aggregation for energy usage data
Building (industrial/ commercial)	• Compare building performance (historical, current) • Monitor & Manage Energy Use / process-related energy peak use • Determine possible efficiency improvements • Determine suitability of e.g. solar, wind, geothermal, biomass, district heat, storage • Curtail Peak Demand • HVAC System Planning and Optimization • Determine utility programs in your area (e.g. efficiency, demand response, net-metering etc).	• energy usage+demand, billing data (historical and instantaneous/interval data) • Sensor readings (e.g. building controls) • Building location and attributes • Renewable resource availability • utility program availability (by zone?)	individual building/meter(s)

Scale	Type of Decision	Data	Level of Aggregation for energy usage data
Municipal Government (corporate)	• Compare building performance (historical, current) • Monitor / Manage Energy usage (buildings, pumps, lights, vehicles, etc) • Determine possible efficiency improvements • Determine suitability of e.g. solar, wind, geothermal, biomass, district heat, storage • Siting of new renewable installations, EV / energy efficient facilities • Compare fleet performance, routing options • Plan alternate transportation routes / electrification • Determine GHG emissions from corporate energy usage (baseline and follow-up inventories / benchmarking progress) • Make investment decisions • Communicate efforts and Engage the public	• Location of all municipally owned facilities • energy usage+demand, billing data (historical and instantaneous/interval data) • Building locations and attributes • renewable resource availability • proximity to lines/substation (+ availability of net metering, embedded generation, or power purchase agreement from the utility.) • fuel billing data, vehicle performance data, vehicle age and maintenance • land use, commuter patterns • GHG coefficients for each Province • Cost\Saving attributes • Public input / volunteered geographic information • Open Data (e.g. municipal utility, transit, and road networks) Land Use/Basemap Data, Zoning	individual buildings / pumps / lights, meter(s)

Scale	Type of Decision	Data	Level of Aggregation for energy usage data
Community Scale	• Compare neighborhood energy demand • Determine GHG emissions from energy usage • Compare to other communities • target actions for improving efficiency, harnessing waste energy, renewable energy resources, etc. • Determine suitability of e.g. solar, wind, geothermal, biomass, district heat, storage • Provide input toward a Community Energy Plan	• Aggregated energy usage (historical, by sector, all fuels) • Land Use / Zoning • Building or parcel footprints, attributes • Public input / volunteered geographic information • Open Data (e.g. municipal utility, transit, and road networks) • Green Button data • Aggregated total consumption from utilities (by sector) • Renewable Resource availability • Cost\Saving attributes	aggregated monthly, seasonal, and yearly total energy consumption (all fuels) by residential, commercial, industrial, institutional sectors, normalized to building age/stock, and rolled up from a parcel level to a zone/neighborhood level, merging zones where there are low counts until a minimum privacy threshold has been reached (e.g. starting with minimum 25 clients, with none representing more than 50% of total consumption)

Scale	Type of Decision	Data	Level of Aggregation for energy usage data
Energy Utilities	• Monitor and forecast demand • Match Supply to Load (instantaneous) • Determine potential for new renewable sources (small/large scale) • Identify and target older/low-efficiency neighborhoods • Determine capacity constraints / investments in distribution grid • Determine impact of DER, ADR • Determine impact of Community Energy Plans • Activate controllable loads/ADR, to curtail peak demand • Predict and respond to outages	• energy usage/demand, billing data (historical and instantaneous/interval data) • renewable resource availability • Distribution Network Topology • Substation/Feeder Readings • Emissions Sensor readings • Volt/Var readings (power quality control) • Availability of DER/DR assets • Data from CEPs • Vegetation cover • Weather models/data	• energy usage (historical, current, forecast) all meters, represented at various scales as needed • quantification of electrical load, thermal load, and opportunities for demand curtailment (electrical load and thermal shifting) – this would include exact figures for available kWh/MW reductions from DER/DR assets.

Scale	Type of Decision	Data	Level of Aggregation for energy usage data
Provincial Government (their buildings)	• Measure seasonal/annual energy and GHGs • Monitor / Manage energy usage • Determine possible efficiency improvements • Determine suitability of e.g. solar, wind, geothermal, biomass, district heat, storage • Siting of new installations/facilities	• energy usage/demand, billing data (historical and instantaneous/interval data) • Provincial GHG coefficient • Cost/Saving attributes	individual buildings / lights, meter(s) (electricity, all fuels)
Provincial Government (e.g. GHG reporting)	Measure seasonal/annual energy and GHGs (all sectors) Policy-making	• Aggregated energy usage (by sector, for each fuel type) • Provincial GHG coefficient	Total consumption aggregated by season/year, by sector, for each fuel type, for an entire Province.
Energy Service Providers	• Determine possible efficiency improvements (of client) • Monitor / Manage energy usage • Determine suitability of e.g. solar, wind, geothermal, biomass, district heat, storage • Siting of new installations / facilities	• Aggregated Energy usage (historical for a zone) • Green Button Data (client's billing data, with consent – this could include historical and instantaneous energy usage/demand) • Renewable resource availability • Proximity to Utilities	• Total consumption (electricity/all fuels) aggregated by season/year, by sector, for a community • Individual buildings / lights, meters (e.g. from Green Button)

8.4 Illustration of how OGC Standards can support use cases

The following two figures illustrate one of the ways OGC standards can support energy use mapping and analytics scenarios while protecting privacy – This high-level profile of implementation shows how services can be configured to perform computation on the fly (WPS), attach resulting values to geographic boundaries (at different scales, with WFS), and produce a map image (WMS) for consumption. These are older graphics which do not reference newer APIs.

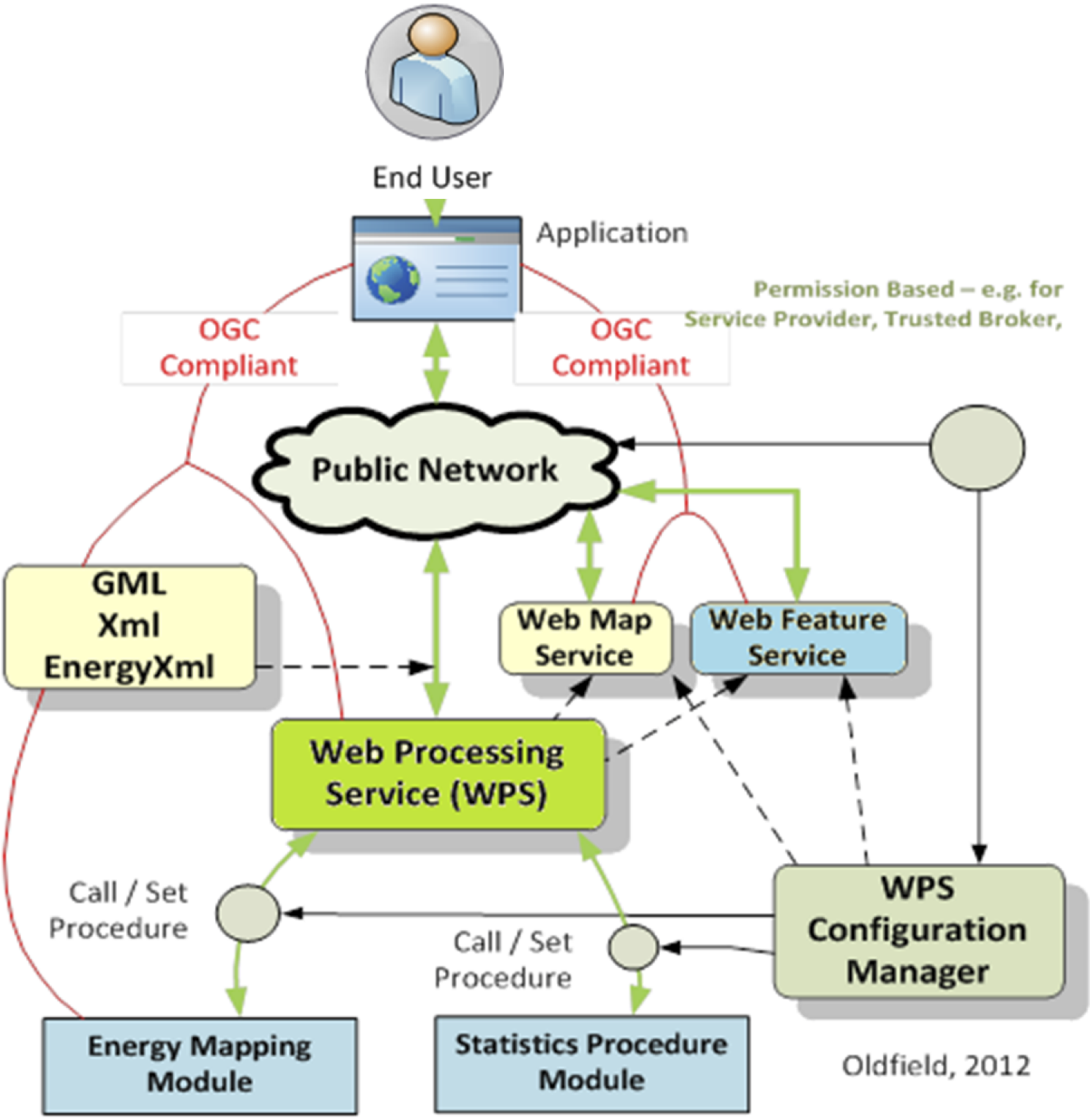

Figure 3. Notional E-SDI components

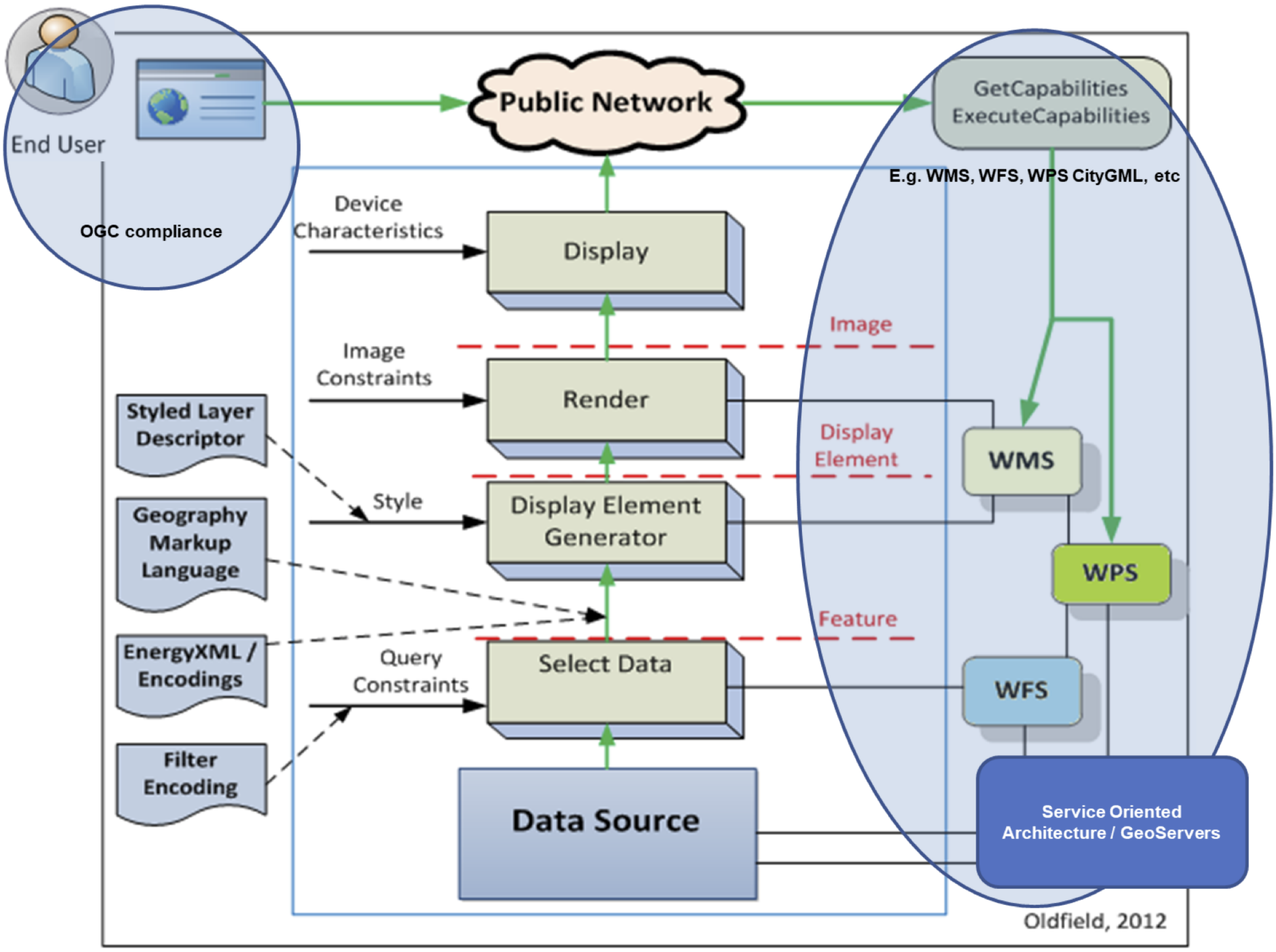

Figure 4. Notional data flow

The following figure was done as part of previous work for CanmetENERGY-Ottawa, but is a good example of how to align use cases with OGC Standards stack, which can help inform future work. It may be useful to develop a new version of this figure to capture the specific use cases that CEE Map or an Energy SDI may support.

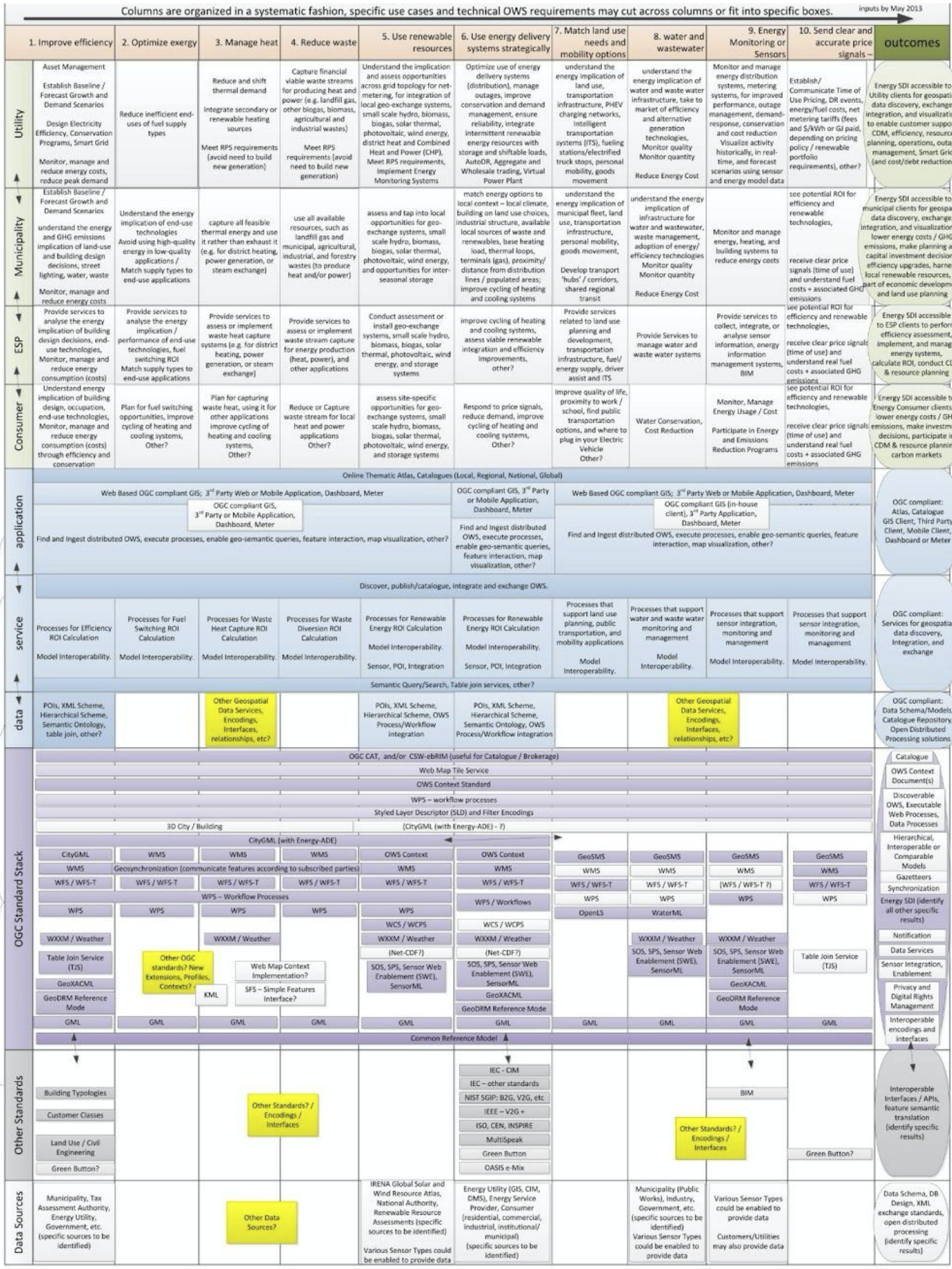

Figure 5. Usage scenarios and standards

Appendix C: Revision History

Table 14. Revision History

Date	Editor	Release	Primary clauses modified	Descriptions
September 15	J. Lieberman	.1	all	initial version
September 30	J. Lieberman	.6	all	draft version
December 15	J. Lieberman	.9	all	complete version
February 15	J. Lieberman	1.0	all	final review and revision

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