Regional Energy Demand Analysis Portal (REDAP)
Digitalisation: enabling better government decision-making in the building & transport sectors

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Abstract. Worldwide, there is an increasing awareness and sense of urgency about the need to transition towards efficient, sustainable and low-carbon energy systems. This process, however, involves the complex task of performing integrated energy-demand analysis which helps to formulate the necessary clean and optimised energy supply strategies. For this reason, today’s governments are supporting collaborative research initiatives that will enable better-informed government decision-making on the rollout of smart energy systems. This ERA-Net-backed Regional Energy Demand Analysis Portal (REDAP) project [1] is one such initiative. REDAP aspires to become a globally-recognised digital methodology for estimating regional energy demand within the built environment. Informed by the recommendations of the UN’s Initiative on Global Geospatial Information Management (UN-GGIM), the REDAP consortium will improve, automate, standardise and replicate an existing and proven building sector energy demand analysis technique and incorporate into it a new methodology for analysing transport energy demand. The resulting ‘spatio-temporal’ model will provide governments with regional-specific insights into the integrated and ever-changing socio-economic and technological drivers behind this demand. By enabling governments to monitor and report on regional energy performance, REDAP is expected to address the targets of multiple Sustainable Development Goals, including: 7. Affordable and Clean Energy, 11. Sustainable Cities and Communities, and 12. Responsible Consumption and Production. Keywords: Built Environment, Transport, Buildings, Energy Efficiency, Data Analytics, Sustainability, Regional Development, Geographic Information Systems, 'digitalisation'.

1. Introduction

“Cities consume more than two-thirds of the world’s energy, and account for more than 70% of global carbon dioxide emissions. The choices that will be made on urban infrastructure in the coming decades – on urban planning, energy efficiency, power generation and transport – will have a decisive influence on the emissions curve. Indeed, cities are where the climate battle will largely be won or lost” [2].

Although urban areas represent the best indicators of societal sustainability, Europe has no harmonised and authoritative approaches to address regional energy demand. As a consequence, key-energy decision-makers, such as planners, policy-makers, and investment decision-makers, often
lack the type of decision-making certainty required in an increasingly data-driven and digital age. This also runs contrary to the core concept of integrated energy systems analysis, which emphasises the need for optimized energy strategies considering both energy demand and supply determinants and constraints (i.e. socio-economic, technological, regulatory, resource and environmental factors).

Considering the commonly held belief that “policy cannot keep up with technology”, this paper underlines the value and importance of digital ‘GovTech’ solutions. In particular, it argues that energy demand-supply strategies can only be sustainable if they are informed by thorough, robust, and replicable systems for monitoring and reporting on energy consumption patterns and supply choices. The paper also contends that by harnessing the information-management and communication benefits behind digitalisation approaches, governments could achieve greater transnational collaboration around energy systems, as well as more meaningful climate mitigation and adaptation strategies. This helps cities and communities develop their future energy visions and prepare related energy and climate action plans for future development which is both sustainable and resilient.

This paper elaborates on the adapted approach of REDAP in responding to the above-mentioned research need. After addressing the key drivers behind the need for energy demand assessment, energy monitoring and reporting, it demonstrates best practice on current energy demand analysis. The research objectives behind the REDAP project are then described and justified, followed by a discussion on the potential for exploiting the platform in order to support the decision-making process, including in preparing sustainable energy and climate action plans aligned to the SDGs goals 7, 11 and 12.

2. Energy demand drivers and the digitalisation need

The objective of the REDAP research is to provide an extra layer of decision-making certainty to the process of preparing sustainable energy and climate action plans at a range of geographic scales. As part of an integrated energy approach, the analysis process relies on adequate tools that enable an understanding of the key determinants which both drive future energy demand and limit or constraint energy supply alternatives. These determinants, which are mainly controlled by the socio-economic and technological attributes of the considered system are becoming increasingly understandable thanks to the ongoing ‘digitalisation’ of all domains of society.

Digitalisation enables the provision of consistent and adequate data which enables data-driven decision-making - a point reflected in the IEA statement: “Good data is an essential component of effective policy making on energy efficiency” [3]. The process enables a quantified description of the mentioned drivers for a better projection of energy consumption patterns across a range of sectors, such as building and mobility. This includes social determinants (e.g. demographic growth, family size, social behaviour, habit and attitudes); economic determinants (e.g. GDP per capita, investment and maintenance costs of technologies, price of energy provision), as well as technology determinants (e.g. energy efficiency and intensity of energy services, and smart digital solutions for optimised system performance).

Today, digitalisation lies at the heart of the energy system transformation, in particular as a response to the decentralisation and decarbonisation imperatives of urbanised regions. Within this context REDAP aims to demonstrate how often unpredictable socio-economic factors behind change can be, through clear, consistent and comparable data insights, better understood and, as a result, better managed. This includes, for example, providing clarity and transparency to the smart energy systems investment, value selection and appraisal process.

The following sections provide an elaboration on the various additional factors driving the process of digitalisation.
Environmental: Increasing awareness around human’s negative impact on the environment is necessitating governments to develop clear and credible sectoral decarbonisation strategies. Today’s scientific evidence overwhelmingly links carbon emissions to increased global temperatures, rising sea-levels, more extreme weather, as well as human health issues, settlement displacement, and food supply disruptions. Against the backdrop of an ever-increasing global urban population (expected to grow by approx. 1.65% per year between 2020 and 2025 [4]), cities are, therefore, the key battleground for decarbonisation. In particular, this battle will focus on the building sectors which accounts for 39% of global carbon emissions [5] and the road transport sector which, in 2014 accounted for more than 70% of all transport GHG emissions [6]. The dual-focus of this battle is especially important if nations are to meet the Intergovernmental Panel on Climate Change (IPCC) targets to keep GHG emissions from all sectors to well below 2°C [7].

Governance: Today’s governments face the significant task of balancing the obligations of emission reduction; economic protection, and national energy security with market and regulatory integration and compliance responsibilities. If governments are to incentivise and encourage the rollout of more sustainable energy supply and efficiency options (e.g. district heating and transport electrification infrastructure) then decisions need to be based on authoritative information. Accordingly, a digitalization approach will enable governments to improve their monitoring and reporting obligations. This includes helping to establish national frameworks to achieve the UN’s SDGs, to complete comprehensive emissions-focused Nationally Determined Contributions [8] (in accordance with the Paris Agreement), and for EU governments to finalise National Energy and Climate Plans (NECP) [9]. Digitalisation will also enable local governments who are committed, as signatories to the Global Covenant of Mayors alliance, to report on baseline emissions, progress, and actions. The importance of this digitalisation approach to solving urban issues is already emphasised by the UN’s Initiative on Global Geospatial Information Management (UN-GGIM), whose 2015 report underlines the need to develop an understanding of the potential of such data among “policy- and decision-makers, planners and delivery agents” [10]. This approach is well demonstrated by the “digital-twinning” initiatives of the UK’s recently-established Geospatial Commission, whose Gemini Principles [11] guide the development of value-creating GovTech systems that are authoritative, secure, robust, interoperable, and adaptable.

Socio-economic: Governments are adopting radically different approaches to understanding citizens and the impact of government decisions. In a world where data is considered the ‘new gold’, analytics enables governments to, within limitations, understand the profile, requirements, and expectations of the modern urban energy consumer or ‘prosumer’. These are globally-engaged citizens who are more mobile, more connected, and more accustomed to convenience in their lifestyles than any previous generation. As governments aim to take meaningful action regarding decarbonisation, the value of digital ‘behavioural-analysis’ techniques - techniques that underpin modern industry market-analysis practice - is therefore extremely important.

Technological: Today, the distinction between energy and computing systems is starting to blur, with terms such as ‘interoperability’, ‘capacity’, ‘decentralised’, and ‘on-demand’ dominating operations and strategy in both fields. This is becoming increasingly evident as the energy system transforms from a fuel-based to a more flexible infrastructure-based system, characterised by decentralised and intermittent renewable energy supply options (e.g. power and heat storage, EV-charging, demand response and demand-side management, smart grid and smart meters). For this reason, digitalisation technology is central to the process of the energy system modernisation - an augmented understanding of the distribution and profile of energy demand will enable the design of resilient and reliable infrastructure and systems that can both withstand and adapt to extreme human and natural events.
3. Contemporary energy demand modelling approaches

Digitalisation: ‘the process of converting something to digital form’ [12].

Perhaps reflecting the emergence of terms such as ‘distributed generation’, ‘flexibilisation need’, ‘electrified mobility’, and ‘prosumers’, location is now a critical attribute of digitalised energy systems. As a result, digital mapping or ‘geospatial’ technology has become an obvious means of making sense of complex energy systems - including the relationship between people, spaces and connections in urban regions. There are numerous examples in recent years which demonstrate how mapping technology (and in particular Geographic Information Systems (GIS)) can be used to interpret and understand energy system components. The Mayor of London Energy Map [13], for example, was used to develop the London Energy Plan and, in particular, to scope the future of energy use and systems in the city to 2030 and 2050. The mapping system supports policy within the London Development Plan, which requires each major development proposal to submit a detailed energy assessment (including evidence around chosen decentralised energy plans), and the digital outputs are used to create Supplementary Planning Guidance on Sustainable Design and Construction. Other notable examples of energy-mapping include: the Amsterdam Energy Masterplan (City-zen Project) [14], which is used by municipalities to target areas for Energy Saving Projects; the EU-funded Heat Roadmap Europe 4 (HRE4) project [15], which informs decarbonization heating and cooling sector strategies for 14 EU Member States; and the Los Angeles County Energy Atlas [16], which helps target areas for energy efficiency projects, answer energy-related planning queries and assess individual developments’ energy plans.

Today, map-based energy analytics is even being performed by major tech companies, whose vast computing and analytical capabilities are being deployed for the benefit of the urban environment. The online Environmental Insights Explorer (EIE) [17], which has been developed by Google in collaboration with the Global Covenant of Mayors for Climate & Energy, is perhaps the most notable example in this regard. Using a range of building stock, transport, emissions, and climatic datasets, EIE delivers data insights and predictions to municipalities who can use them to tailor and adjust relevant local policy and planning strategies. This centres around actions for carbon footprint reduction, such as urban renewable, energy offset potential, traffic optimisation, and holistic cross-sectoral climate mitigation and adaptation strategies.

4. Energy system digitalization: REGIONAL ENERGY DEMAND ANALYSIS PORTAL (REDAP)

Within the context of the above activity, REDAP represents a new approach to energy demand analysis. Its uniqueness is the fact that it involves attempts by three countries (i.e. Austria, Sweden, and Ireland) to develop a standardised and replicable methodology for energy demand analysis in both the building and transport sectors. As such, the research brings together available digital resources, computing infrastructure, and know-how in order to help decision-makers keep pace with rapidly changing energy demand patterns (including to understand the profile of modern energy consumers, and their general whereabouts and movements). In accordance with EU efforts to encourage smart solutions for energy consumers, REDAP, aims to become a system for responsive urbanisation - one which recognises that cities are complex, ever-evolving and unpredictable ecosystems.

While the project is informed by external innovation, the primary starting point for REDAP is an established and proven building stock energy demand analysis process that has previously been developed by the REDAP consortium partner, Codema, Dublin’s Energy Agency. Spatial Energy Demand Analysis (SEDA) [18] refers to a methodology that combines socio-economic, planning and building energy performance datasets with GIS technology for the purpose of analysing the characteristics and spatial distribution of this demand. Since 2014, a SEDA report has been developed for each of the four local government authorities across the greater Dublin region, with its purpose being as follows: 1. To analyse local level energy demand and production within a spatial
context; 2. To bridge the gap between and integrate spatial and energy planning at the local level; 3. To enable planners to better answer energy related queries; 4. To enable planners to create evidence-based energy policy. Today, SEDA informs a range of energy-related activities such as: developing community energy projects, CO2 emission baselines for Dublin’s Climate Change and Sustainable Energy Action Plans (SEAP) [19], as well as helping local authorities to fulfil their Covenant of Mayor reporting requirements.

In addition to SEDA, the REDAP research is informed by previous building stock modelling research by the Swedish partner, Chalmers University of Technology, which, according to Wallbaum et al [20], has been enabled by the increased availability of data from smart meters, cheaper meters, and wireless technologies, as well as from “more measurements, more powerful calculation tools, and more modelling research”. This includes research on topics such as ‘embodied energy’ [21], multi-scale spatial representation of urban building-stocks [22] (whose results were used to generate real-world transition strategies, masterplans and decision-making processes) and ‘synthetic building stocks’ [23]. The building stock research is also informed by the Swedish National Board of Housing, Building, and Planning (Boverket) surveys (BETSI) [24] on energy usage in the building stock (including houses, apartment buildings, and non-residential premises).

The state of the art component behind the proposed REDAP project is that it will incorporate a methodology to analyse energy demand in the mobility sector also - enabling a more holistic understanding of the complex relationship and interactions between buildings and transport energy demand. In order to do so, the research has adopted a unique conceptual framework called ‘energy demand landscapes’, wherein buildings (municipal, commercial, residential) are treated as static energy demand ‘spaces’ and transportation networks are considered as dynamic energy demand ‘connections’ between these ‘spaces’. By standardising the representation of the socio-economic characteristics of these spaces, across largely distinct regions, this framework is expected to enable effective energy planning and successful cross-boundary, cross-sectoral comparison between regions.

As European policy increasingly emphasises the importance of heating and transport electrification,
and as the distinction between these two sources of energy starts to blur, it makes sense (from a time, cost and grid-stability perspective) to examine the two sectors in a consistent and integrated manner. This includes identifying approaches for saving electricity for EVs in buildings, for optimising the location of required terrestrial-based road and building recharging infrastructure, for decisions around public sector fleet management and fuel efficiency (e.g. mixing conventional and battery-powered vehicles), and for developing improved strategies to accommodate ‘shared transport’ options. At the building level, REDAP could help inform incentivisation and subsidization strategies for renovation, retrofitting and upgrade schemes (such as the SEAI’s Near Zero Energy Building regulations [25] on energy efficiency in Ireland and the Swedish government’s Halvera Mera initiative [26] for energy efficiency in apartment buildings). At the strategic planning level, meanwhile, REDAP will help drive the agenda of the European Strategic Energy Technology Plan (SET-Plan) [27], including regional projects such as HeatNet NWE [28], which is currently informed by SEDA process (i.e. for identifying urban buildings which could benefit from district heating strategies).

5. Project methodology and scientific approach

“Regular, robust, inclusive, country-led reviews will be fundamental to achieving the SDGs, given their complexity and breadth.” [29].

United Nations Development Group (UNDG)

The scientific approach of REDAP addresses the absence of an authoritative and replicable methodology for analysing urban energy demand in the building and transport sectors. The partners will, therefore, test the hypothesis that this shared ‘information gap’ could be overcome if an existing process is standardized, automated, and tailored to each partner country’s energy governing structures. Accordingly, the project deliverable aims to be an effective, transparent and robust process for energy demand estimation and potentially a process for cross-comparison between and within distinct European regions. In terms of development, the REDAP proof of concept system is being developed within a 12-month timeframe, to allow for the performance of testing and improvement iterations during the final 12 months of the project. To do so, the technical partners are utilising Open Geospatial Consortium (OGC) [30] compliant open-source Geographic Information Systems (GIS) software and interoperability standards, as well as high-end computing systems for data management, visualisation and analysis (incl. relational database and Application Programming Interface (API) tools). REDAP project aims to achieve six key objectives as follow as shown in Figure 2.

Six key objectives of the REDAP project:
1. Automate the building-stock-focused Spatial Energy Demand Analysis (SEDA) process.
2. Incorporate into REDAP a transport energy demand analysis methodology.
3. Develop an improved reporting methodology for delivering energy demand insights to end-users.
4. Develop REDAP as a secure, online, database-driven, standardised, extendable, accessible system.
5. Encourage knowledge transfer between the partners and ERA-Net Knowledge Community.
6. Explore potential government replication, market, and partnership opportunities for REDAP.

In terms of sampling and setting, the consortium is focused on two urban municipality regions - Dublin (pop. 1.5 million) and Gothenburg (pop. 580,000) - which both, as signatories to the Global Covenant of Mayors convention [31], share the same emissions monitoring and reporting responsibilities. The Austrian partners will, meanwhile, focus on the rural Waidhofen an der Thaya municipality in the north of the country - thereby, demonstrating the interdependence of urban and rural regions in the regional analysis process. In order to frame the above analysis, the partners have adopted the definition of regions [32] as “area[s] having definable characteristics but not always
fixed boundaries.” Within each of these ‘test-bed’ regions, the partners are working with front-line energy planning experts who are expected to become end-users of the REDAP system. The non-profit and local government-focused test-bed ‘Need-Owners’ which represent these particular regions are defined by ERA-Net [33] as a party[s] which “seeks a solution to a specified need (problem) within its area of operation...[and that have]...practical insights into what the actual need is and an interest in being involved in the development of a solution.” In order to develop a relevant data modelling and data analysis system, the REDAP research will be guided by ERA-Net’s Three Dimensions of Integration, which requires a focus on smart energy system integration, innovation ecosystem integration systems (incl. commercialisation), and Cross Sectoral Integration (incl. synergies with existing technologies). It will also be guided by the Three Layers Research Model, which requires consideration of technological, market and real-world adoption and application matters.

In terms of data collection, the partners will collate (primarily from government sources) a range of regionally equivalent information on energy demand in the building and transportation sectors. For the transportation sector, this will include data relating to mobility and road patterns - including road network datasets, OpenStreetMap geospatial data [34], and travel survey results. For the static building stock dimension, REDAP will incorporate datasets which are currently used in the SEDA methodology, including building valuation, demographic, urban planning, administrative, energy datasets and, in particular, the EU mandated Energy Performance of Buildings Directive (EPBD) data (e.g. SEAI’s Building Energy Rating (BER) [35].

6. Expected Results
Regarding the building stock energy analysis process, the methodology is expected to deliver insights on the energy demand of urban ‘spaces’ and the profile of the market. This includes information on the intensity of energy use, the general type of fuel consumed, heat demand densities, average demand and expenditure per building type, and areas at risk of energy poverty. The results from the building stock energy demand analysis will help inform synergies between new and old developments (e.g. for utilizing waste heat with district heating systems, for renewable energy generation, energy retrofitting), it will inform medium-large scale plans and energy master plans, and it will potentially enable integration with real energy data for municipal sector buildings. The transport energy demand analysis methodology will, meanwhile, estimate the urban transport energy density by modelling this demand based on the spatio-temporal distribution considerations such as the chosen transport modes and routes. This combined building and transport energy demand analysis process is expected to lead to a better understanding of the relationship between transport and building sectors as well as the region’s future infrastructural requirements.

7. Discussion
Drawing on the core economic principles of supply and demand, REDAP is essentially about understanding the market for energy within regions, the characteristics of the market, and the potential for supplying this market demand in a sustainable, efficient, and low-risk manner. This paper argues that, as our work and lifestyles evolve rapidly, it is imperative that decarbonisation-focused governments utilise the digital resources and skills at their disposal in order to understand energy consumer profiles and the spatio-temporal patterns of energy demand. This is increasingly important as many governments
are failing to fulfil their monitor and reporting commitments on their respective energy and climate performances. According to Google [36] of the more than 9,000 cities that have committed to comply with the Paris Agreement, “less than 20% have been able to complete, submit or monitor greenhouse gas inventories”.

Although still at a relatively early stage, what the REDAP research has so far achieved is a consensus that the challenges around modern energy demand, including the planning for and management of supply, are not unique to different regions. Rather, they represent shared challenges which, in an age of market and regulatory integration, require collaborative solution development. This is especially important as the effects of climate change are felt on a global basis, and where the value of siloed national mitigation or adaptation efforts become both futile on the local level and irrelevant at the broader level.

Today, therefore, the means by which we understand energy demand in the built environment needs to be as advanced as the means by which we supply this demand, with government processes being smart and efficient - data-driven, automated, extendable and replicable. Curiously, this digital approach to energy demand analysis starts with recognising the relevance of wider digital trends themselves - such as the impacts of 'online' on retail zoning and 'on-demand' on transport strategies, the emergence of 24-hour cities and remote yet connected digital communities, and how data-driven lifestyles lead to more data centres, and increased pressure on often-near-capacity energy grids.

It is also worth noting that energy demand analytics may achieve more than just fulfilling governments’ monitoring and reporting obligations. In accordance with the SDG8 Decent Work and Economic Growth, digitalisation may, for example, open up new opportunities for innovation - such as data-driven business-models which focus on regional, sectoral, and cross-sectoral energy efficiency, and, assuming effective knowledge and skills transfer, future regional ‘data custodian’ roles. As a more detailed example, a demand analysis system could be adopted by regions in need of a process for matching sources of energy demand with sources of sustainable energy supply. This could include urban regions such as Dublin, where energy demand is expected to double over the next decade, and proponents of data centre developments, whose energy demand is expected to account for 31% of the total Irish energy consumption by 2027 [37]. According to Codema, a significant proportion of the required energy could be sourced from the approx. 2,400 MW of zero-carbon waste heat which goes unused in the Dublin region every year and distributed to consumers via the region’s expanding district heating infrastructure network. In terms of its economic value, this waste heat could have an annual market value of the approx. €1.2bn [38], of which a significant portion could profit the suppliers of this underutilised energy source. In addition to the individual-region approach, energy demand analysis could be performed at the broader level also - for example, to understand the changing patterns and trends of energy demand across European urban regions - home to three-quarters of EU citizens. It could also be used to understand the influence of national development strategies on energy consumption, such as the connectivity, broadband, and rural economic development proposals contained in Ireland’s National Development Plan (2018-27) [39]. In a similar manner, REDAP could inform the regional transportation strategy considerations of Gothenburg [40] and Greater Dublin Area [41] (both up to 2035).

At this early stage of the project implementation and in parallel to the running development and adaptations of the REDAP platform, contributing regions represented by the need owners are working alongside the research teams to collect, process and harmonise their GIS-building data in order to provide consistent and relevant results. The focus is on providing a simplified and systematic process of data provision that can be used by other regions once REDAP is successfully tested by and established within the participating regions. Currently, however, the key challenge remains in the fact that European regions apply different schemas to their data repositories for building and
mobility. The REDAP approach, therefore, will harmonise the different formats of GIS-based energy data and provide recommendations for further development. This will help improve the potential transferability and adoption of the system, including among municipalities and communities which are developing decision-informed mitigation and adaptation targets for existing energy and climate action plans.

8. Conclusion
The REDAP research represents a coordinated effort to develop a decision-support tool for improved spatio-temporal energy demand analysis of regional building and mobility sectors. The consulted project methodology seeks to treat buildings and transport networks as related rather than separate components of a wider ‘energy demand landscape’. Accordingly, the research offers governments an opportunity to rethink the concept of ‘regions’, to better understand the key socio-economic drivers behind this demand, and to approach shared challenges and opportunities on a coordinated and collaborative basis. To these ends, the ‘Govtech’ project is focused on the principles of standardisation, interoperability and replicability, as per the digitalisation recommendations of the UN’s geospatial focused-division.

As the project progresses beyond initial research stages, the partners intend on developing an authoritative and quantitative analysis methodology that will inform timely and constructive dialogue between all regional energy system stakeholders. In particular, this will involve aligning reporting and monitoring techniques to UN SDGs best-practice and representing regional energy demand scenarios in a less generic, more ‘tailored-to-intended-audience’ manner. In doing so, it is envisaged that this digitalisation system, which is focused on enabling the communication of comprehensive and pertinent information about key energy demand drivers, will help promote the decarbonisation of regional energy systems and help municipalities to develop better energy strategies and climate action plans. Moreover, the project partners will seek to demonstrate, through the REDAP project, how the energy digitalisation paradigm offers genuine potential for future innovation, cross-sectoral synergies, and cross-boundary collaboration.

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