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Exploring the Evolution of Decarbonisation Scenarios with Gridded-glyphmaps Visualisations

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Abstract

Local Area Energy Plans (LAEPs) are designed to provide holistic, coherent paths towards achieving net-zero emissions for local areas in the United Kingdom. They are meant to integrate a broad range of technical, social, and economic interventions (e.g., deployment of renewable technologies, reduction of fuel poverty, upgrades in the infrastructure of energy transport) over an extended time frame. Such plans are complex and understanding how they unfold across space and over time is difficult. Traditional geo-spatial visualisation methods, such as layered choropleth maps, face limitations in effectively conveying multifaceted data, especially when it varies over time. We instead explore gridded-glyphmaps to understand the effective ways of visualising multivariate spatio-temporal data in the context of understanding energy decarbonisation planning. We show how we can depict decarbonisation outcomes and costs for different types of interventions across different areas as small time-series glyphs. We designed and validated our approaches through iterative contextual interviews with stakeholders in the energy domain.

CCS Concepts

• ***Human-centered computing*** → ***Visualization techniques; Geographic visualization;***

1. Introduction

Local Area Energy Plans (LAEPs) are crucial for achieving net-zero targets in UK local authorities. They involve collaboration between stakeholders like Distribution Network Operators and local authorities, often facilitated by green energy consultants [CW23]. LAEPs aim to implement decarbonisation strategies at the local level, considering factors such as building characteristics and community behaviours [BNWF21, GOC*21]. LAEPs typically represent decarbonisation plans as spatio-temporal data at various resolutions, including interventions like renewable technology installation and building insulation improvements [DBB22, ABCS23]. Existing decarbonisation decision-making platform help stakeholders visualise and optimise these plans, but current visualisation methods have limitations, especially when they need to plan for multi-year decarbonisation policy over the many variables. To address these limitations, we explore gridded-glyphmaps [SRH23] to better visualise multivariate spatio-temporal decarbonisation data. This approach aims to enhance stakeholders' ability to interpret spatio-temporal decarbonisation data, such as comparing renewable energy installation cost and their potential over time.

2. Related Work

Decarbonisation planning is a complex process involving multiple variables across different geographical scopes and stakeholders, often represented as spatio-temporal datasets [PBR14, CW23]. Understanding these datasets typically requires sophisticated multi-criteria decision modelling or GIS analysis. To address this challenge, information visualisation is emerging as a key tool in the energy domain [CC21, LWT*22, CCS23, SM23, LSJ24], offering insights into temporal [AMST11] and spatio-temporal data [AAD*10, AAG03]. Our study employs gridded-glyphmaps [Sli18], a geospatial visualisation approach that facilitates interactive exploration of multivariate geospatial data using small visual glyphs distributed uniformly over geographic space. This method can reveal patterns within a common spatio-temporal context that might be missed in traditional univariate maps [SRH23, BDHL21]. In the context of decarbonisation, gridded-glyphmaps has been used to help understand the distribution and interdependencies of socio-, techno-, and economic variables in regions requiring intervention [LSJ24]. We extend this application by examining how such data is projected to evolve over time, providing a novel perspective on envisioned decarbonisation plans and their potential outcomes.

3. Methodology

Our visualisation focused on three key technological interventions based on a real-world decarbonisation scenario model in Cambridge, UK, over a 20-year time frame: *heat pump*, *Electric Vehicle (EV)*, and *Photovoltaic (PV) solar panel* installations. The model also considered financial constraints for installation based on three budget scenarios: *capped at £500k*, *capped at £15m*, or *uncapped*. Each technological intervention included installation costs, comprising estimated material and labour expenses, which determined how the budget would be allocated each year. We aggregated unit- and building-level information into postcode areas within Cambridge. For each renewable technology within each budget scenario, we calculated the estimated *carbon savings* based on the model developed by Advanced Infrastructure, Ltd. (AITL), a green energy consultant and our industry partner.

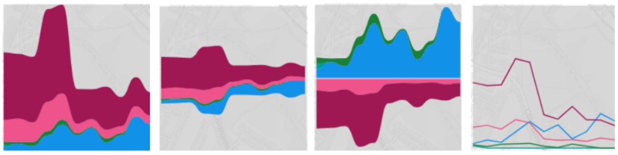

Figure 1: *Glyph designs to visualise timeseries decarbonisation data, from left to right: Stacked-Area, StreamGraphs, Mirrored Streamgraph, Line Chart. Blue and green hues show carbon saved over time as different low-carbon technologies are deployed, while pink and red hues capture the costs of those deployments.*

We developed multiple glyph designs (Figure 1) to represent the spatio-temporal data, including line charts, stacked area charts, stream graphs, and mirrored stream graphs. We gridded the area corresponding to the Cambridge local authority and placed the glyphs in each grid-cell. Thus, each glyph represents the aggregated outcomes (green-blue hues) and costs (pink-red hues) of deploying low-carbon technologies within the area encompassed by the grid-cell. To further enhance user interaction, we enabled settings that allowed users to change the glyph types and sizes, making it easier to analyse and compare different budget scenarios and their impact on carbon savings and installation costs across the area.

4. Discussion

Using gridded-glyphmaps (Figure 2), we were able to encode multivariate spatio-temporal data with various glyph designs, adding more nuance and detail with visualisation compared to traditional choropleth approaches. Specifically, showing temporal data using choropleth approaches typically relies on scrolling through time, one timestep at a time (either manually or via animation). This makes it difficult to build a mental model of how values change over time and even more difficult to compare such evolutions across different regions. Instead, this is captured explicitly in our glyphs as the depict the full progression of all variables at once. The gridded-glyphmaps thus enable rapid comparison of costs and carbon savings across different areas in Cambridge. Moreover, by changing the glyph size, users are able to switch between visualising finer details with smaller grid sizes and observing overall spatio-temporal trends with larger grid sizes.

This comprehensive view allowed decision-makers to quickly identify, e.g., which areas received the most budget allocations based on costs and which areas had the highest potential for carbon savings. In Figure 2, the green circle indicates areas with lower initial budget allocations than carbon savings over time, while the red circle shows areas with higher budget allocations than carbon savings. This also affects decisions on which renewable technology to prioritise, as the higher material costs for solar panels may lead to reallocating the budget to more cost-effective solutions. The ability to compare these variables within each grid cell, facilitated by the different glyph designs, further enhanced the decision-making process.

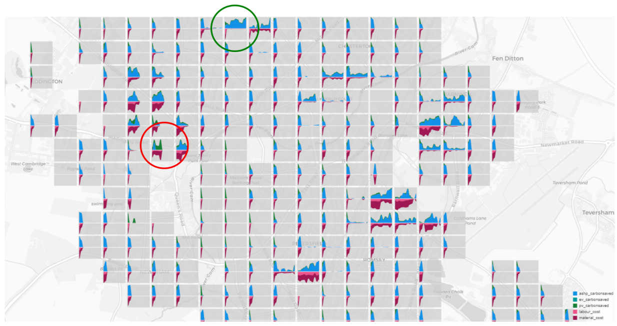

Figure 2: *Our gridded-glyphmaps prototype, visualising multivariate time series data in Cambridge, UK, as mirrored glyphs. The green and red circles indicate areas where budgets might need to be reallocated based on the progression of return of investment over time. The prototype can be accessed here:* `https://observablehq.com/@danylaksono/timeseries-scenario`

Contextual interviews with stakeholders provided feedback on our prototype. Despite initial unfamiliarity, stakeholders found the glyphmap metaphor effective, particularly the mirrored glyph design for comparing budgets and carbon savings. They appreciated the ability to identify spatial patterns by adjusting glyph sizes. However, we noted some drawbacks. The Modifiable Areal Unit Problem (MAUP) affected glyph behaviour [Won04, GMM*06, Man21]. Changing grid sizes revealed spatial nuances but made glyphs harder to discern at smaller sizes. Larger grids improved glyph visibility but sacrificed detail. Stakeholders suggested exploring different discretisation methods, such as using Lower Super Output Areas (LSOA) or Wards as the aggregation unit to facilitate collaborative decision-making based on each administrative area.

5. Conclusion

We demonstrate the effectiveness of gridded-glyphmaps for visualising multivariate spatio-temporal data in Cambridge's Local Area Energy Plan (LAEP). Using various glyph designs, we provided detailed insights into budget allocations and carbon savings each year, enhancing the decision-making process. Stakeholders found the visualisation useful for quickly identifying areas with significant budget allocations and carbon-saving potential, and appreciated the ability to compare budgets and carbon savings over time.

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References

[AAD*10] Andrienko G., Andrienko N., Demsar U., Dransch D., Dykes J., Fabrikant S. I., Jern M., Kraak M.-J., Schumann H., Tominski C.: Space, time and visual analytics. *International journal of geographical information science 24*, 10 (2010), 1577–1600. 1

[AAG03] Andrienko N., Andrienko G., Gatalsky P.: Exploratory spatio-temporal visualization: an analytical review. *Journal of Visual Languages & Computing 14*, 6 (2003), 503–541. 1

[ABCS23] Ampatzidis P., Bowyer E., Coley D., Stephenson V.: Decarbonising at scale: Extracting strategic thinking from epc and deprivation data. *Building Services Engineering Research & Technology 44*, 6 (2023), 625–639. 1

[AMST11] Aigner W., Miksch S., Schumann H., Tominski C.: *Visualization of time-oriented data*, vol. 4. Springer, 2011. 1

[BDHL21] Beecham R., Dykes J., Hama L., Lomax N.: On the use of 'glyphmaps' for analysing the scale and temporal spread of covid-19 reported cases. *ISPRS International Journal of Geo-Information 10*, 4 (2021), 213. 1

[BNWF21] Bouw K., Noorman K. J., Wiekens C. J., Faaij A.: Local energy planning in the built environment: An analysis of model characteristics. *Renewable and Sustainable Energy Reviews 144* (July 2021), 111030. URL: http://dx.doi.org/10.1016/j.rser.2021.111030, doi:10.1016/j.rser.2021.111030. 1

[CC21] Chen X., Chen X.: Data visualization in smart grid and low-carbon energy systems: A review. *International Transactions on Electrical Energy Systems 31*, 7 (2021), e12889. 1

[CCS23] Cheng K.-W., Chen Y., Shi Y.: Gridviz: a toolkit for interactive and multi-modal power grid data visualization. In *2023 IEEE Power & Energy Society General Meeting (PESGM)* (2023), IEEE, pp. 1–5. 1

[CW23] Collins A., Walker A.: Local area energy planning: achieving net zero locally. https://researchbriefings.files.parliament.uk/documents/POST-PN-0703/POST-PN-0703.pdf, 2023. Accessed: 2024-06-09. 1

[DBB22] Dixon J., Bell K., Brush S.: Which way to net zero? a comparative analysis of seven uk 2050 decarbonisation pathways. *Renewable and Sustainable Energy Transition 2* (2022), 100016. 1

[GMM*06] Grasland C., Madelin M., Mathian H., Sanders L., Lambert N., et al.: *The Modifiable Areas Unit Problem: ESPON 3.4.3 Final Report*. Research report, ESPON | Inspire Policy Making with Territorial Evidence, 2006. URL: https://hal.science/hal-03596052/file/2006_MAUP.pdf. 2

[GOC*21] Gudde P., Oakes J., Cochrane P., Caldwell N., Bury N.: The role of uk local government in delivering on net zero carbon commitments: You've declared a climate emergency, so what's the plan? *Energy Policy 154* (July 2021), 112245. URL: http://dx.doi.org/10.1016/j.enpol.2021.112245, doi:10.1016/j.enpol.2021.112245. 1

[LSJ24] Laksono D., Slingsby A., Jianu R.: Gridded-glyphmaps for supporting geographic multicriteria decision analysis. 1

[LWT*22] Liu S., Weng D., Tian Y., Deng Z., Xu H., Zhu X., Yin H., Zhan X., Wu Y.: Ecoalvis: visual analysis of control strategies in coal-fired power plants. *IEEE transactions on visualization and computer graphics 29*, 1 (2022), 1091–1101. 1

[Man21] Manley D.: Scale, aggregation, and the modifiable areal unit problem. In *Handbook of regional science*. Springer, 2021, p. 1157–1171. 2

[PBR14] Prasad R. D., Bansal R., Raturi A.: Multi-faceted energy planning: A review. *Renewable and sustainable energy reviews 38* (2014), 686–699. 1

[Sli18] Slingsby A.: Tilemaps for summarising multivariate geographical variation. *Workshop on Visual Summarization and Report Generation at VIS 2018* (2018). URL: https://openaccess.city.ac.uk/id/eprint/20884/. 1

[SM23] Stecyk A., Miciuła I.: Empowering sustainable energy solutions through real-time data, visualization, and fuzzy logic. *Energies 16*, 21 (2023), 7451. 1

[SRH23] Slingsby A., Reeve R., Harris C.: Gridded glyphmaps for supporting spatial covid-19 modelling. *2023 IEEE Visualization and Visual Analytics (VIS)* (2023). 1

[Won04] Wong D. W.: The modifiable areal unit problem (maup). In *WorldMinds: geographical perspectives on 100 problems: commemorating the 100th anniversary of the association of American geographers 1904–2004*. Springer, 2004, pp. 571–575. 2