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# GIS-Based Mapping of Slope-Dependent Energy Consumption and Recovery for Sustainable E-Bike Mobility

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## INTRODUCTION & AIM

**Background and problem**

• Post-COVID-19 urban mobility patterns increased the importance of short-distance and last-mile micromobility systems.
• E-bikes are useful for compact urban travel; however, their performance depends on battery range, rider effort, and topography.
• Road slope is a decisive spatial factor: uphill segments increase consumption, while downhill segments may create regenerative recovery potential.
• Network-level average energy values hide local differences; a short but steep connector may be more critical than a longer flat segment.

**Aim and contribution**

• To calculate energy consumed, energy regained, net energy, and Spatial Energy Index values at road-segment level.
• To map these indicators in GIS/Folium and identify energy-advantaged and energy-disadvantaged corridors.
• To provide a practical, place-sensitive decision-support layer for e-bike planning, service-area evaluation, and sustainable micromobility strategies.

## METHOD

| Parameter | Value |
|---|---|
| Total Mass (Bike + Rider) (m) | 100 kg |
| Gravitational Acceleration (g) | 9.81 $m/s^2$ |
| Rolling Resistance Coefficient | 0.005 |
| Aerodynamic Drag Coefficient (Cd) | 0.7 |
| Frontal Area (A) | 0.5 $m^2$ |
| Air Density (ρ) | 1.225 $kg/m^3$ |
| Regenerative Efficiency (η) | 0.7 |
| Motor Power (P_motor) | 250 W |

**Classification and visualization strategy**

• Four thematic layers were produced in Folium: Spatial Energy Index, net energy, energy consumed, and energy regained.
• Segment colors represent relative energy intensity, while point markers emphasize segment-level variation and hotspots.
• Values were interpreted as spatial decision-support indicators rather than as fully calibrated field measurements.

**GIS-based decision-support workflow**

Road network + DEM → endpoint elevation extraction → slope calculation → segment energy model → consumed/recovered/net energy indicators → SEI normalization → GIS/Folium thematic maps → corridor interpretation.

**Interpretation logic**

• High consumption: uphill or resistance-intensive segments.
• High recovery: downhill corridors with regenerative potential.
• Low/negative net energy: energy-advantaged movement direction.
• High SEI: short segments with disproportionate energy burden.

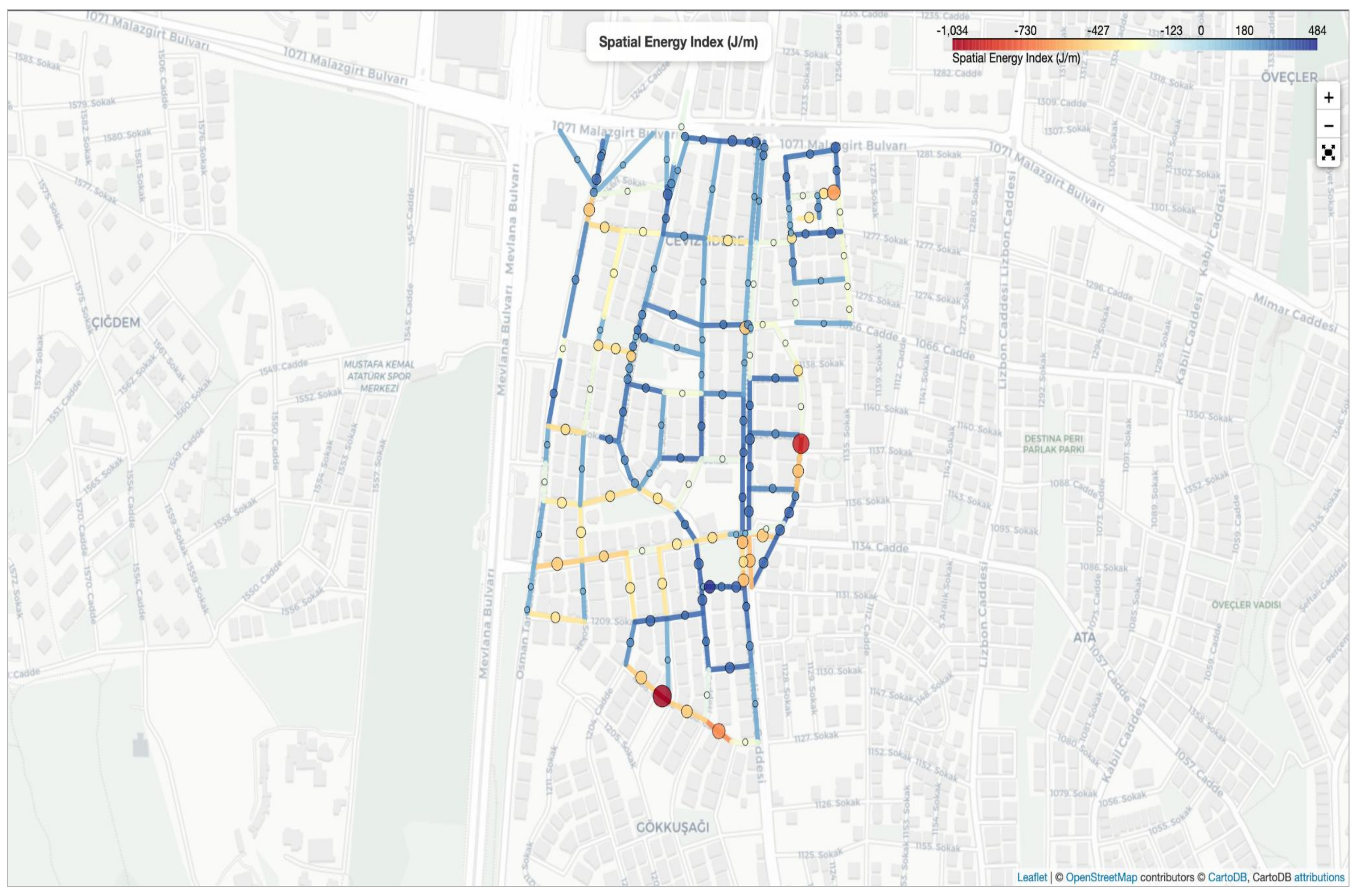
## RESULTS & DISCUSSION

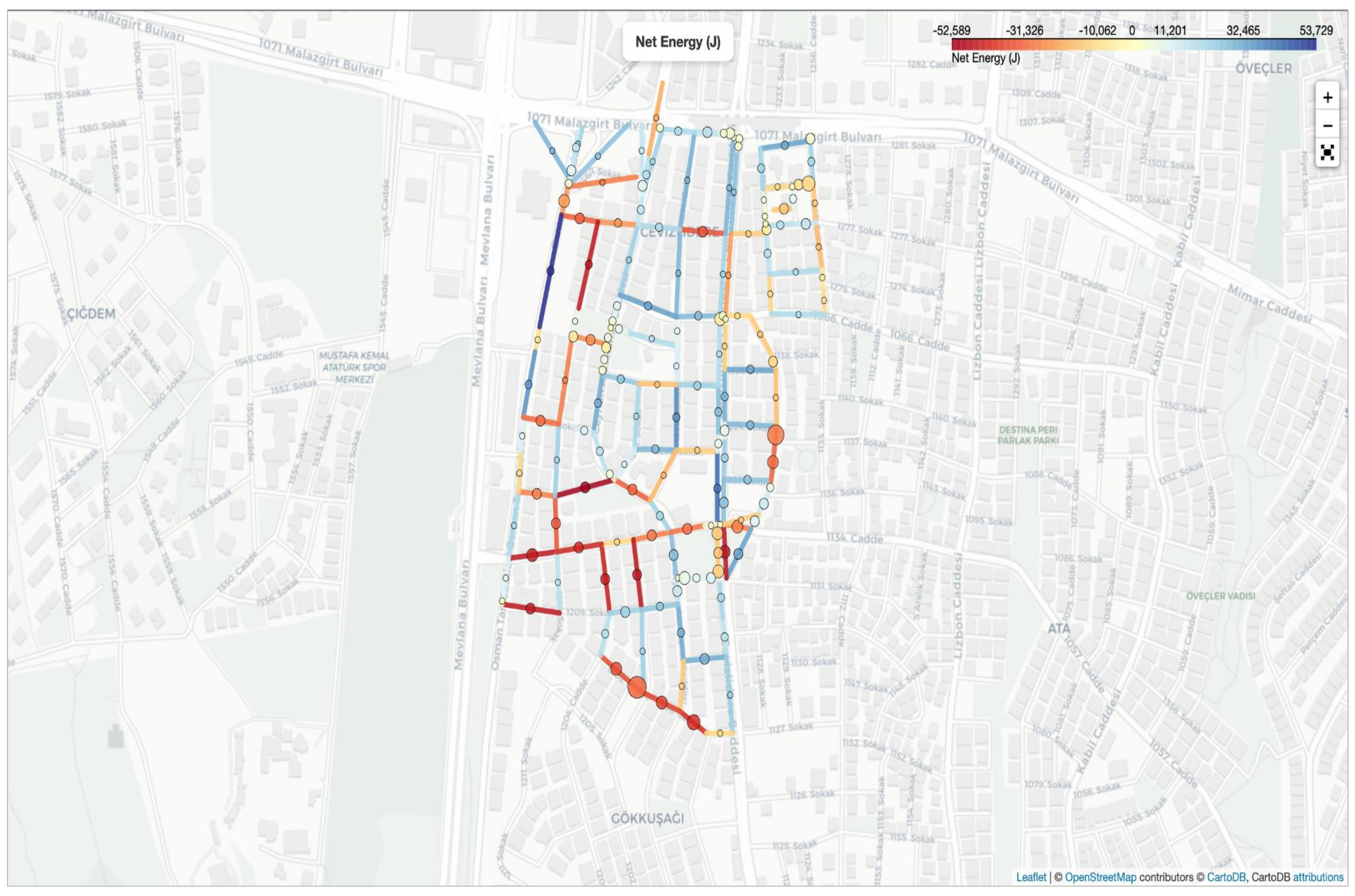
**Results**

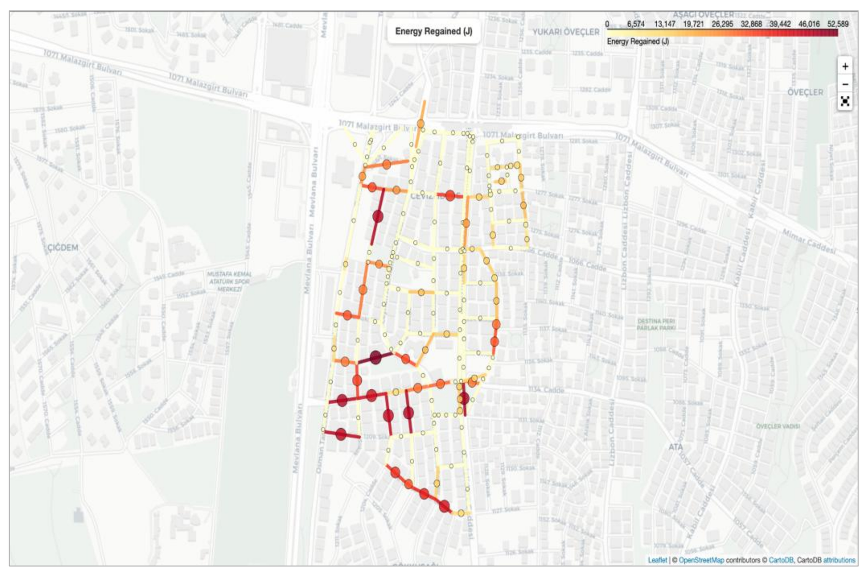
• The maps demonstrate that e-bike energy performance is spatially heterogeneous and highly sensitive to slope direction.
• Energy consumed values identify uphill or resistance-intensive parts of the network and mark critical energy-cost corridors.
• Energy regained values reveal downhill segments where regenerative braking can contribute to recovery, within assumed efficiency limits.
• Net energy integrates consumption and recovery, distinguishing energy-advantaged and energy-disadvantaged movement patterns.
• SEI normalizes net energy by segment length and reveals short but steep transitions that would be hidden in distance-only analysis.

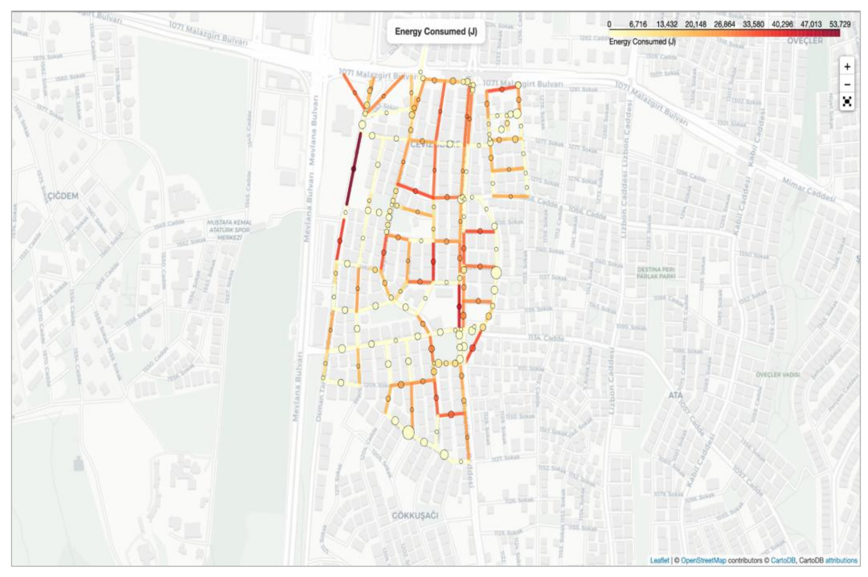
**Discussion**

• A single average energy value is not sufficient for micromobility planning. Segment-level GIS layers provide more actionable spatial evidence.
• The outputs can support municipalities, operators, and route-planning applications in evaluating topography-sensitive corridors.





## CONCLUSION

• Segment-based energy consumption, regenerative recovery, net energy, and SEI indicators were calculated for an urban e-bike network.
• The resulting thematic maps show that nearby roads can have very different energy profiles due to slope and directionality.
• The framework provides a practical basis for energy-aware micromobility planning and route evaluation.

## FUTURE WORK / REFERENCES

**Future work**

• Calibrate the model with real GPS, speed, elevation, and battery observations; include traffic, stop-and-go behaviour, road surface quality, weather, rider profile, and speed variability.
• Extend the framework to multi-criteria route optimization and real-time decision-support tools.

**Selected references**

• Erener & Şirin (2024), International Journal of Engineering and Geosciences, 9(1), 34–48.
• Liu et al. (2017); Fotouhi et al. (2019); Tal et al. (2016); Zhang et al. (2021); Sadeq et al. (2020).