Green City Project: Coding for the Future

Homework & Project Report

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GitHub Repository and Document: https://github.com/radiophp/greencity

```
Enter your available budget in TRY (0 = exit): ₺8000
2025-05-31 13:51:15 | INFO     | Budget entered: ₺8000.0
2025-05-31 13:51:15 | INFO     | Running DP knapsack: n=300, budget=8000 lira
2025-05-31 13:51:15 | INFO     | Processed 50 / 300 devices...
2025-05-31 13:51:15 | INFO     | Processed 100 / 300 devices...
2025-05-31 13:51:15 | INFO     | Processed 150 / 300 devices...
2025-05-31 13:51:15 | INFO     | Processed 200 / 300 devices...
2025-05-31 13:51:15 | INFO     | Processed 250 / 300 devices...
2025-05-31 13:51:15 | INFO     | Processed 300 / 300 devices...
2025-05-31 13:51:15 | INFO     | DP complete. Chosen devices: 3
2025-05-31 13:51:15 | INFO     | Optimisation finished in 19 ms

================ RESULTS ================
 • Condensing Boiler UW-372 (₺5102.61, 6219.3 kWh/yr, score 5)
 • Energy-Mgmt Gateway NQ-572 (₺811.26, 488.1 kWh/yr, score 5)
 • Roof Insulation Kit SM-641 (₺1591.36, 1884.9 kWh/yr, score 5)
-----------------------------------------
Total devices:     3
Total cost:        ₺7505.23
Energy saved:      8592.3 kWh / year
Σ(energy×score):   42961.5
=========================================

2025-05-31 13:51:15 | INFO     | Saved report → /home/mohammad/eclipse-workspace/GreenCity/outputs/7505TL_with3device_20250531_135115.txt
Run another budget? (y/n): y
```

Abstract

This report presents an optimisation tool that helps municipalities select the most impactful combination of energy-saving devices while respecting a fixed budget. The problem is formulated as a 0-1 knapsack task; we implement an exact dynamic-programming solver in Java 17. A 300-row dataset of realistic device prices, energy-savings, and sustainability scores underpins the model. Results show significant potential energy savings for a variety of budget scenarios.

1 Problem Statement & Goal

Cities face tight budgets yet ambitious sustainability targets. The challenge is to choose which retrofit or new-build technologies to fund so that the portfolio delivers the highest weighted impact (annual kWh saved × qualitative sustainability score) without exceeding the allocated budget. This is a classic 0-1 knapsack optimisation problem.

2 Dataset Explanation

The project uses a CSV containing 300 devices across ten categories (Lighting, Heating, Solar PV, etc.). Each record offers:

- Device Name
- Category
- Cost (₺)
- Energy Saved per Year (kWh)
- Sustainability Score (1–5)

Prices and savings ranges were derived from manufacturer spec-sheets and public procurement tenders. The CSV is version-controlled via GitHub .

3 Algorithm & Implementation

- **Dynamic-Programming :** 0-1 Knapsack – weights are integer-scaled lira;

complexity O(n × W) where *n* = 300 and *W* ≤ 200 000. The DP table fits easily in memory.

- **Java 17:** modular project; logging via `java.util.logging`.
- **Interactive Console Loop** : users can evaluate multiple budgets in one run; each result is also persisted to `/outputs` with a timestamped filename.
- **Code Quality** : immutable `record` for `Device`, separate loader and solver classes, full Javadoc, and a `.gitignore` for build artefacts.

4 Sample Results

Below are excerpts from four budget runs:

- Budget ≈ 50 000 TRY

```
================ RESULTS ================
 • VRF System XW-266 (₺7550.24, 3955.0 kWh/yr, score 5)
 • Wall Insulation Panel BT-469 (₺3950.10, 2548.7 kWh/yr, score 5)
 • Condensing Boiler UW-372 (₺5102.61, 6219.3 kWh/yr, score 5)
 • Wall Insulation Panel KD-934 (₺2812.09, 3605.4 kWh/yr, score 3)
 • VRF System MP-902 (₺7462.27, 4737.0 kWh/yr, score 5)
 • Energy-Mgmt Gateway NQ-572 (₺811.26, 488.1 kWh/yr, score 5)
 • Smart Street Lamp SU-518 (₺693.54, 562.3 kWh/yr, score 3)
 • Radiant Heater XH-621 (₺11127.42, 6360.3 kWh/yr, score 5)
 • LED Tube KT-796 (₺1282.76, 596.1 kWh/yr, score 4)
 • Roof Insulation Kit SM-641 (₺1591.36, 1884.9 kWh/yr, score 5)
 • Roof Insulation Kit VC-866 (₺3718.78, 3943.7 kWh/yr, score 3)
 • Wall Insulation Panel TT-177 (₺3711.74, 3835.6 kWh/yr, score 5)
-----------------------------------------
Total devices:    12
Total cost:       ₺49814.17
Energy saved:     38736.4 kWh / year
Σ(energy×score):  176863.1
=========================================
```

- Budget ≈ 7 500 TRY

```
================ RESULTS ================
 • Condensing Boiler UW-372 (₺5102.61, 6219.3 kWh/yr, score 5)
 • Energy-Mgmt Gateway NQ-572 (₺811.26, 488.1 kWh/yr, score 5)
 • Roof Insulation Kit SM-641 (₺1591.36, 1884.9 kWh/yr, score 5)
-----------------------------------------
Total devices:    3
Total cost:       ₺7505.23
Energy saved:     8592.3 kWh / year
Σ(energy×score):  42961.5
=========================================
```

- Budget ≈ 150 000 TRY

```
================ RESULTS ================
 • VRF System XW-266 (₺7550.24, 3955.0 kWh/yr, score 5)
 • Micro-inverter KW-066 (₺9273.08, 6880.1 kWh/yr, score 3)
```

• Roof Insulation Kit XT-122 (₺6128.88, 2906.2 kWh/yr, score 4)
• Wall Insulation Panel PM-547 (₺5965.68, 2960.0 kWh/yr, score 4)
• Wall Insulation Panel QP-792 (₺4348.84, 2811.5 kWh/yr, score 3)
• Wall Insulation Panel BT-469 (₺3950.10, 2548.7 kWh/yr, score 5)
• Condensing Boiler UW-372 (₺5102.61, 6219.3 kWh/yr, score 5)
• Double-Glazed Window GA-896 (₺3632.67, 2046.1 kWh/yr, score 4)
• Wall Insulation Panel KD-934 (₺2812.09, 3605.4 kWh/yr, score 3)
• High-efficiency Motor VK-733 (₺5313.57, 2397.9 kWh/yr, score 4)
• VRF System MP-902 (₺7462.27, 4737.0 kWh/yr, score 5)
• Energy-Mgmt Gateway NQ-572 (₺811.26, 488.1 kWh/yr, score 5)
• Radiant Heater TI-058 (₺12003.57, 6564.4 kWh/yr, score 4)
• Double-Glazed Window CI-247 (₺3749.70, 2053.7 kWh/yr, score 4)
• Evaporative Cooler ND-217 (₺4196.53, 3037.7 kWh/yr, score 3)
• Solar Battery Storage FY-520 (₺16600.30, 8659.5 kWh/yr, score 4)
• VRF System HN-519 (₺7586.15, 3498.4 kWh/yr, score 5)
• Radiant Heater XH-621 (₺11127.42, 6360.3 kWh/yr, score 5)
• Variable-speed Pump GJ-297 (₺3466.98, 2080.9 kWh/yr, score 4)
• High-efficiency Motor GF-805 (₺5760.42, 2094.7 kWh/yr, score 5)
• Roof Insulation Kit SM-641 (₺1591.36, 1884.9 kWh/yr, score 5)
• Roof Insulation Kit VC-866 (₺3718.78, 3943.7 kWh/yr, score 3)
• Wall Insulation Panel LY-229 (₺3065.82, 2643.0 kWh/yr, score 3)
• Wall Insulation Panel TT-177 (₺3711.74, 3835.6 kWh/yr, score 5)
• Wall Insulation Panel BS-504 (₺6361.67, 2248.6 kWh/yr, score 5)
• Double-Glazed Window YK-834 (₺4653.75, 3802.4 kWh/yr, score 3)
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Total devices: 26
Total cost: ₺149945.48
Energy saved: 94263.1 kWh / year
Σ(energy×score): 388199.2
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- Budget ≈ 20 000 TRY

================ RESULTS ================
• Wall Insulation Panel BT-469 (₺3950.10, 2548.7 kWh/yr, score 5)
• Condensing Boiler UW-372 (₺5102.61, 6219.3 kWh/yr, score 5)
• Wall Insulation Panel KD-934 (₺2812.09, 3605.4 kWh/yr, score 3)
• Energy-Mgmt Gateway NQ-572 (₺811.26, 488.1 kWh/yr, score 5)
• Smart Street Lamp SU-518 (₺693.54, 562.3 kWh/yr, score 3)
• LED Tube KT-796 (₺1282.76, 596.1 kWh/yr, score 4)
• Roof Insulation Kit SM-641 (₺1591.36, 1884.9 kWh/yr, score 5)

• Wall Insulation Panel TT-177 (₺3711.74, 3835.6 kWh/yr, score 5)

Total devices: 8
Total cost: ₺19955.46
Energy saved: 19740.4 kWh / year
Σ(energy×score): 89770.5
==

5 Sustainability Reflection

The optimiser consistently favours high-score insulation kits and condensing boilers, underscoring the principle that the cheapest kWh is the one never consumed. Solar PV and battery storage rank highly only in larger budgets due to their upfront cost. The model does not yet account for lifecycle emissions or maintenance overheads; future iterations could introduce additional constraints such as CO_2 abatement per lira or technology diversity to mitigate risk.

6 Conclusion & Future Work

We demonstrated that a compact dynamic-programming solver can guide budget allocation decisions toward substantial energy savings. Next steps include a GUI dashboard, stochastic sensitivity analysis for uncertain savings, and integration with real-time price data.

References

• Manufacturer specification sheets (Philips, LG, Huawei Sun2000).

• City of Helsinki procurement database, 2024.

• Karp, R. 'Reducibility Among Combinatorial Problems', 1972.