EVALUATION OF EMISSION REDUCTION PERFORMANCE OF ELECTRIC VEHICLES UNDER VARIOUS CLIMATIC AND DRIVING CONDITIONS

Esin Tetik Kollugil, Kemal Sarıca, Y. Ilker Topcu

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– a multi-scalar perspective and transformation **–**
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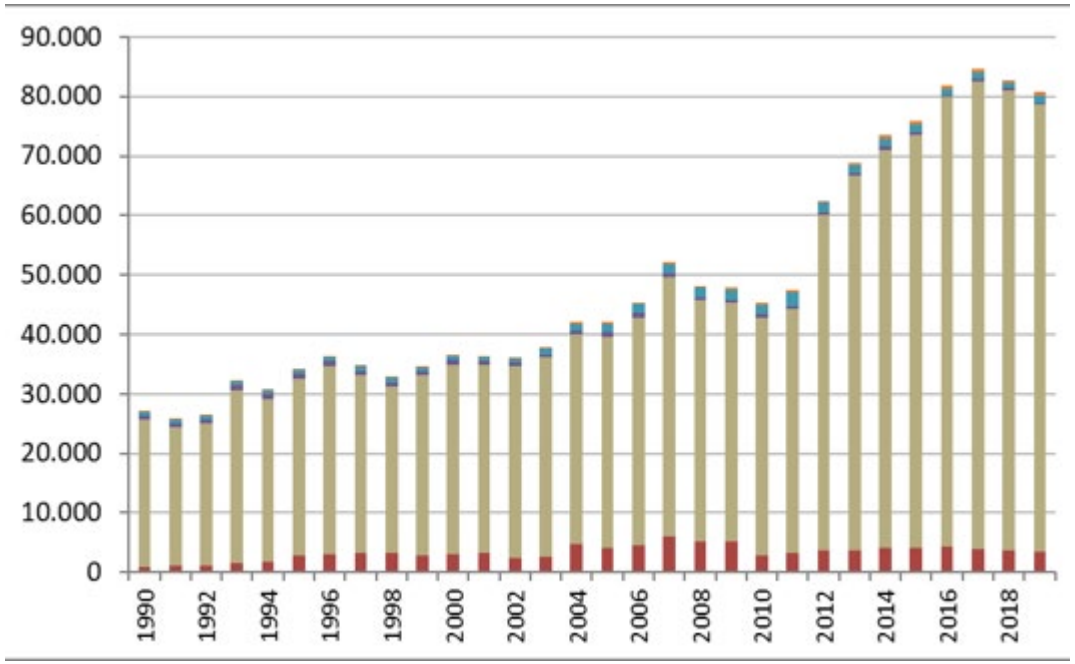
AGENDA

- Motivation
- Methodology
- Results
- Conclusions

INTRODUCTION

- In 2019, transport sector emissions of Türkiye
  - 16.3% of the total GHG, 22.6% of energy emissions
- 2050 Net Zero Emission Target
- Emission reduction strategies of transport sector
  - Reducing the share of fossil fuels
  - Electrification of the sector
    - Number of EVs is already doubled in 2023 (14,552 vehicles in 2022, 0.1%)
- Emissions reduction potential of EV electricity generation mix

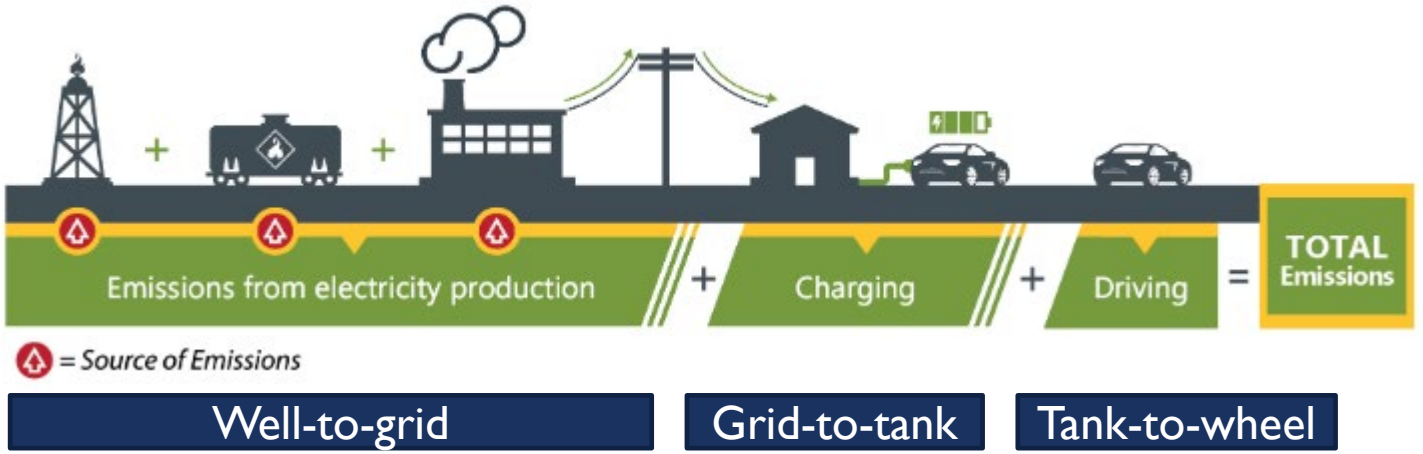


Transport sector emissions of Türkiye (CO_2-e)

INTRODUCTION

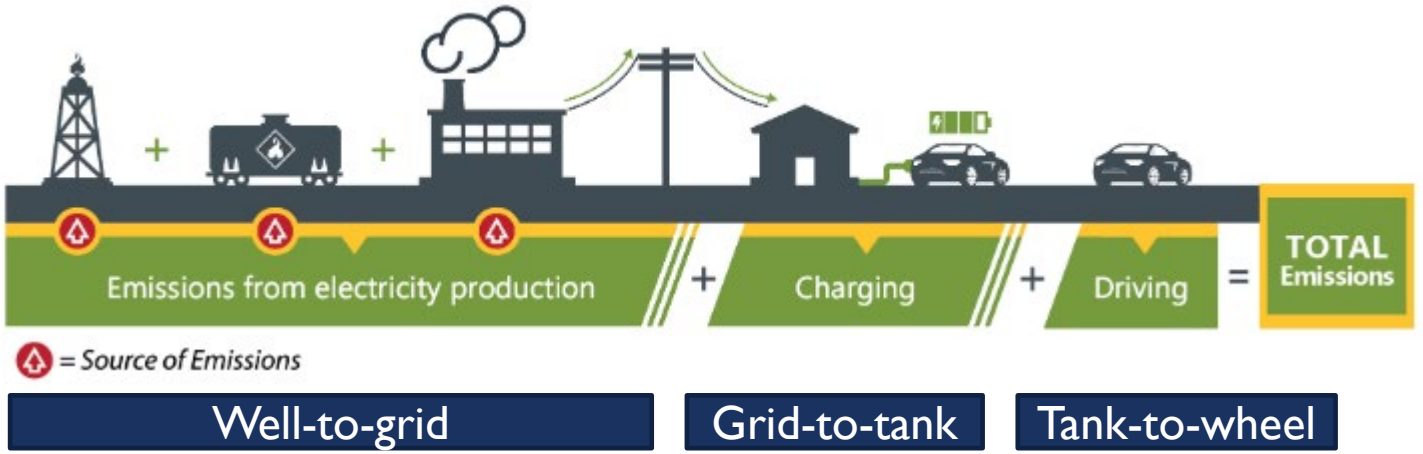
Total GHG Emissions

- Electricity Production
  fuel extraction, transportation, combustion
- Charging
  transmission and charging inefficiencies
- Driving conditions > > Range
  - Vehicle speed
  - Driving style
  - Additional weight
  - Terrain
  - Cabin energy consumption (cabin heating, cooling, air conditioning)
  - Climate conditions



INTRODUCTION

- Evaluation of the emission reduction performance of battery electric vehicles (BEVs or Evs)
  - Electricity Emissions (temporal)
  - Temperature (temporal and spatial)
  - Average speed, driving profile
- Comparison with diesel and gasoline fuelled conventional vehicles (ICE)
- 2015-2020



METHODOLOGY

TIME SLICE BASED AVERAGE ELECTRICITY EMISSION FACTOR

- **Fuel Combustion Emissions**
  - Hourly electricity generation by fuel type
  - IPCC fuel combustion CO_2 emission factors

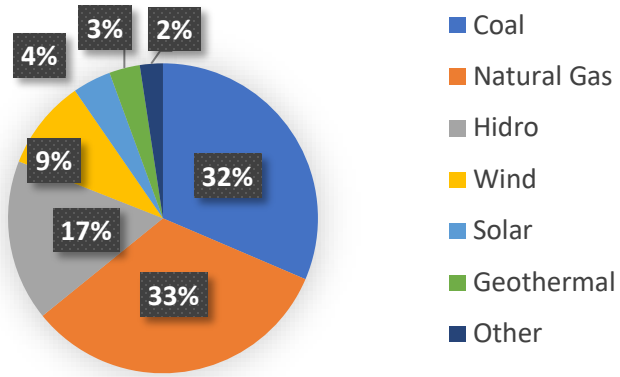
Additionally, non-combustion emissions included

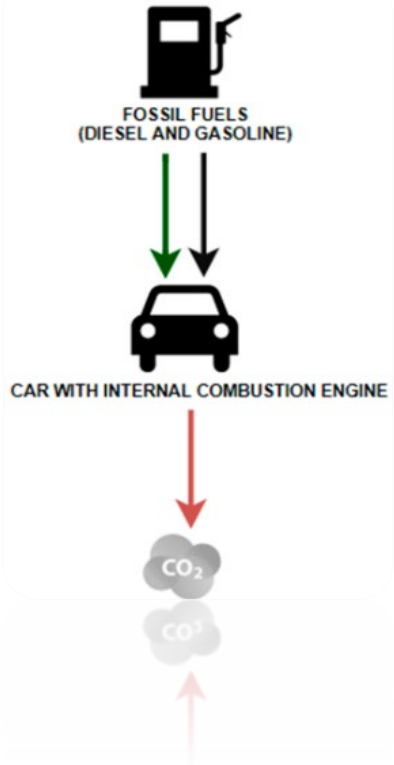
- **Fuel Provision Emissions**
  - Derived from a life-cycle-aseessment study (Turconi, 2013) for fossil fuels
- **Plant and Infrastructure Emissions**
  - Renewable resources

Charging

- Grid to motor inefficiencies for charger and battery
- Distribution losses

Electicity Generation Fuel Shares 2021

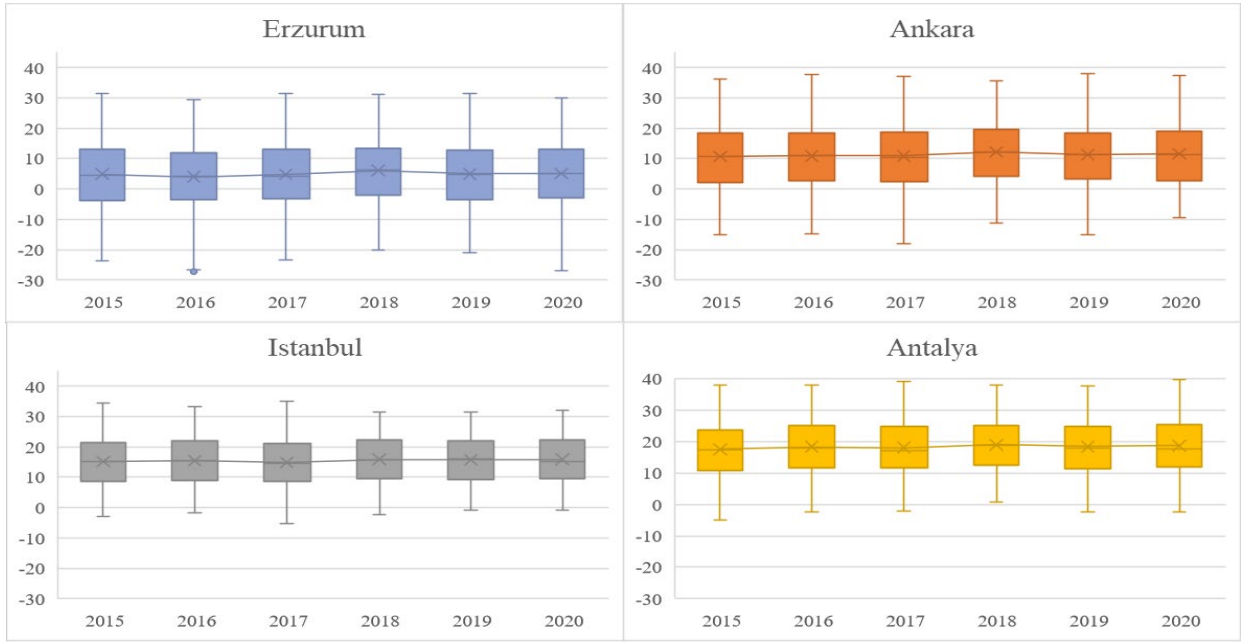




DATA

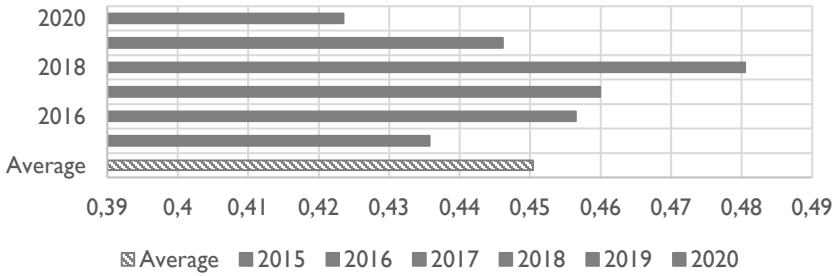
AMBIENT TEMPERATURE

- Hourly temperature values of 4 selected cities

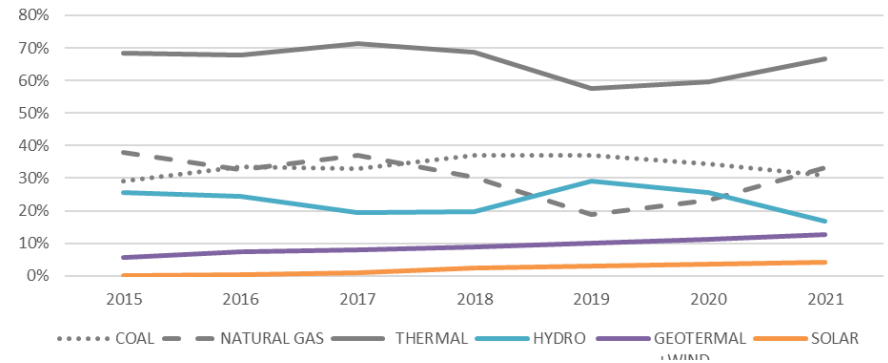


Annual temperature values of the cities (°C)

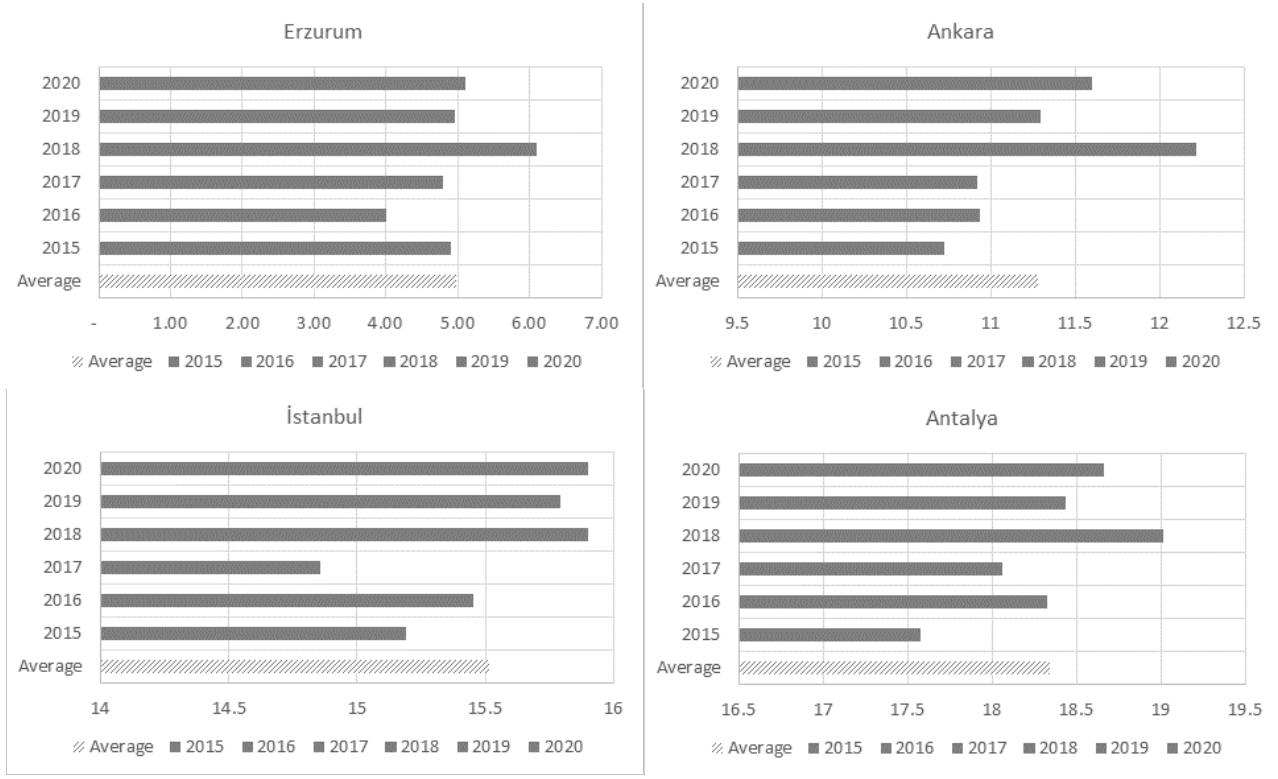
DATA



Annual average electricity emission factors (CO_2/MWh)

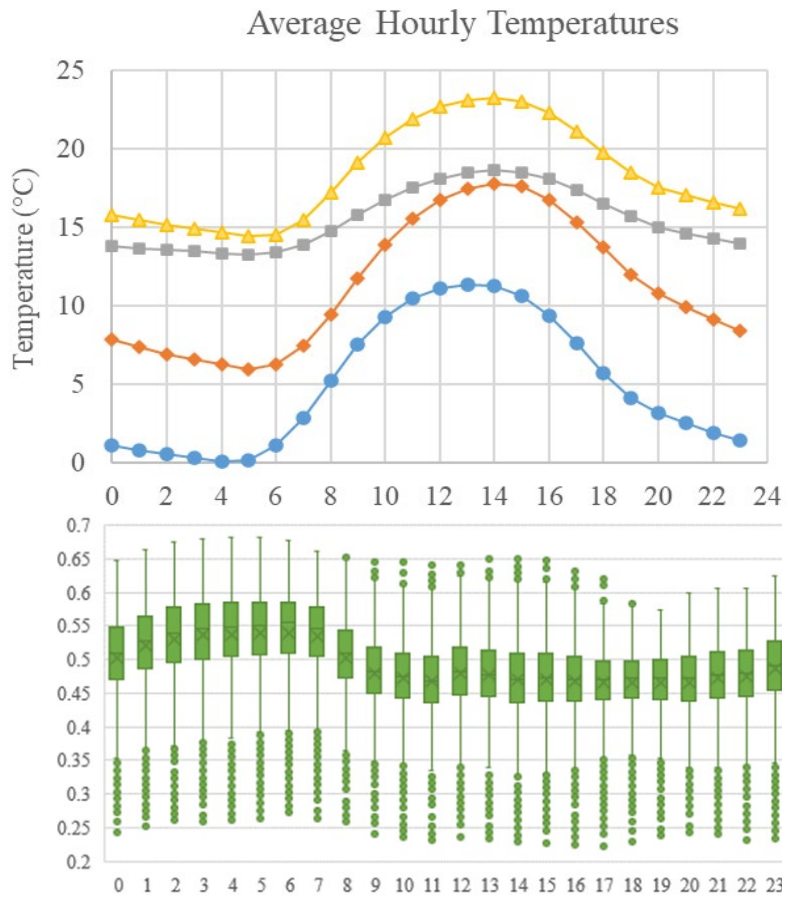


Electricity generation fuel mix

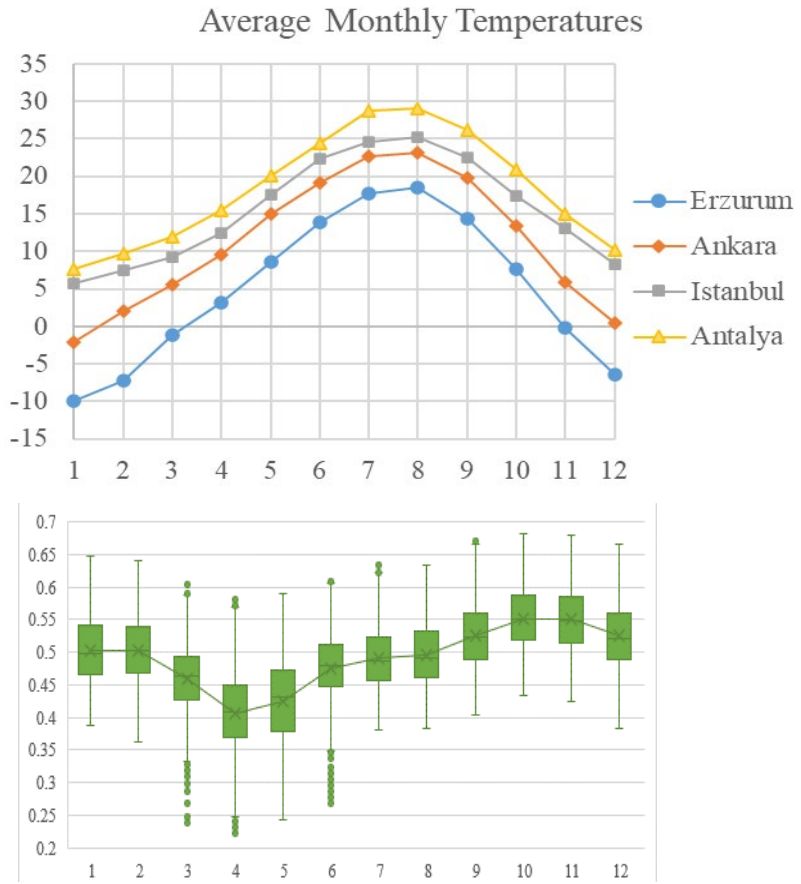


Annual average temperatures of the cities (°C)

DATA



Average hourly electricity emission factors (ton CO_2/MWh)



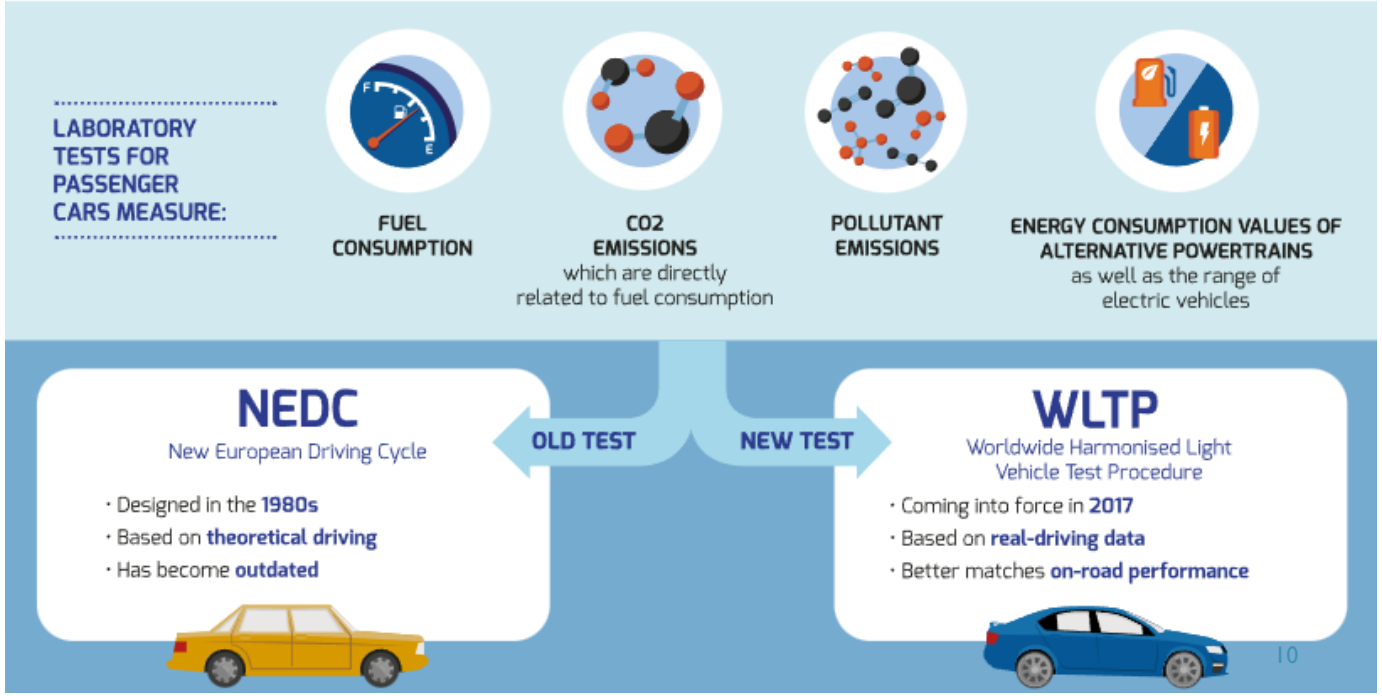
Average monthly electricity emission factors (ton CO_2/MWh)

METHODOLOGY

- **AVERAGE SPEED PROFILE**
- **WLTP** (Worldwide Harmonized Test Procedure for Light Vehicles) driving cycles

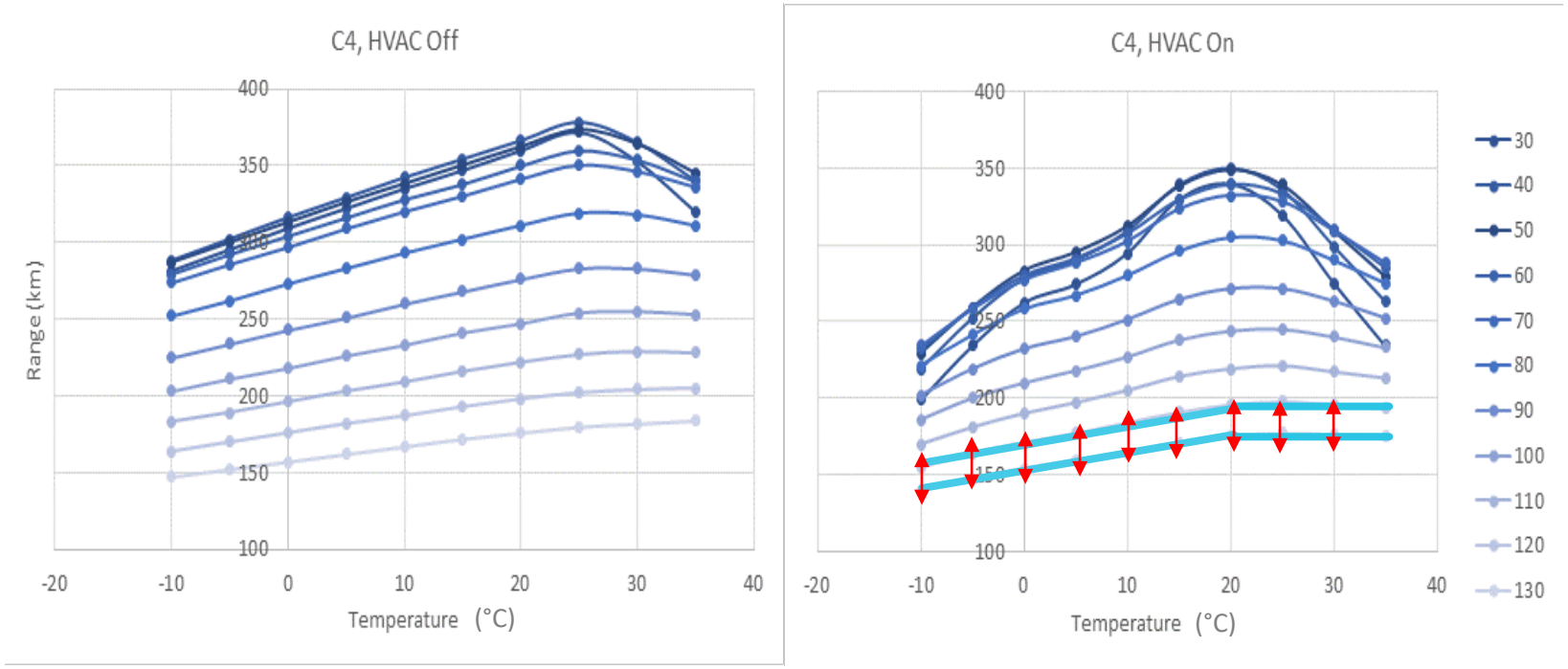
  Average speed with stops

  - Low city centre (18.9 km/h)
  - Medium town or suburban (39.3 km/h)
  - High rural (56.4 km/h)
  - Extra High motorway (92.0 km/h)
- WLTP test temperature 23°C
- Steady-state consumption (no cold start)



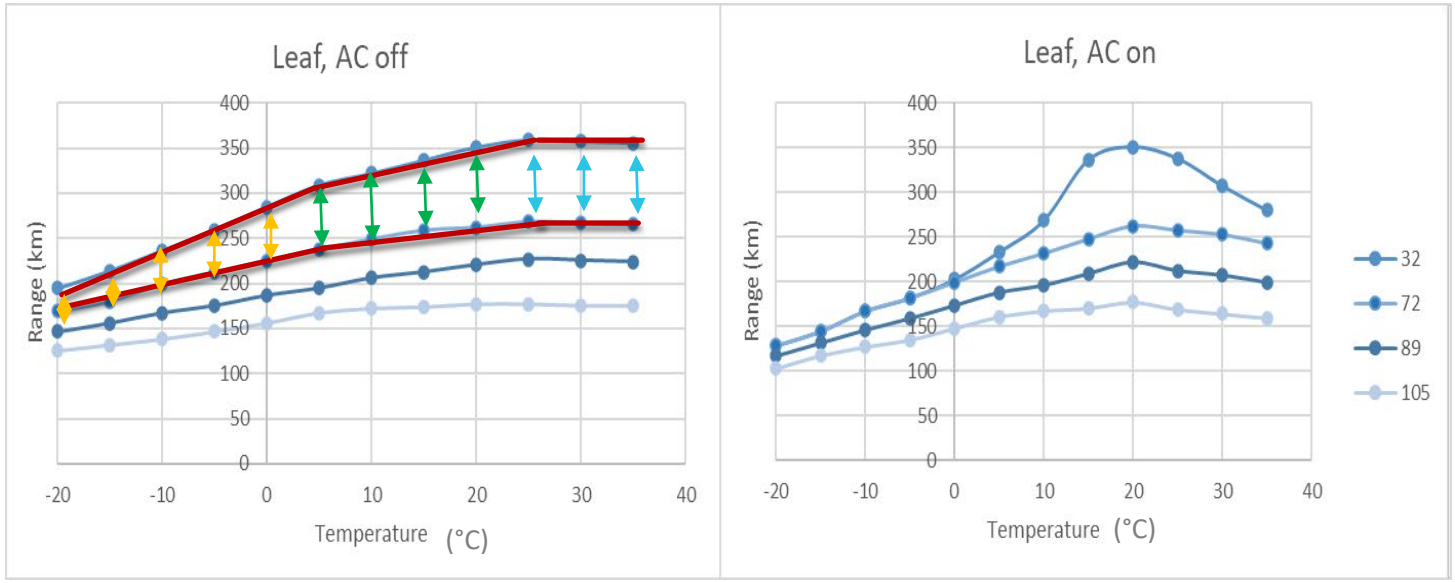
METHODOLOGY

- Citroen ë-C4 with 50 kWh battery



METHODOLOGY

- Nissan Leaf 40kWh battery



METHODOLOGY

- Citroen C4 Gasoline (96 kW engine power)
- Citroen C4 Diesel (97 kW engine power)
  - WLTP fuel consumption
  - A/C load for 23+ °C
    increased specific energy consumption is adopted from (Weilenmann et. al., 2005)

$$(\ln AC\ load)_i = -3.2632 - * 0.01848\ V_i + 0.059149 * T_i$$

significance value of 4.02 e-05 and an adjusted R-square of 95.4%.

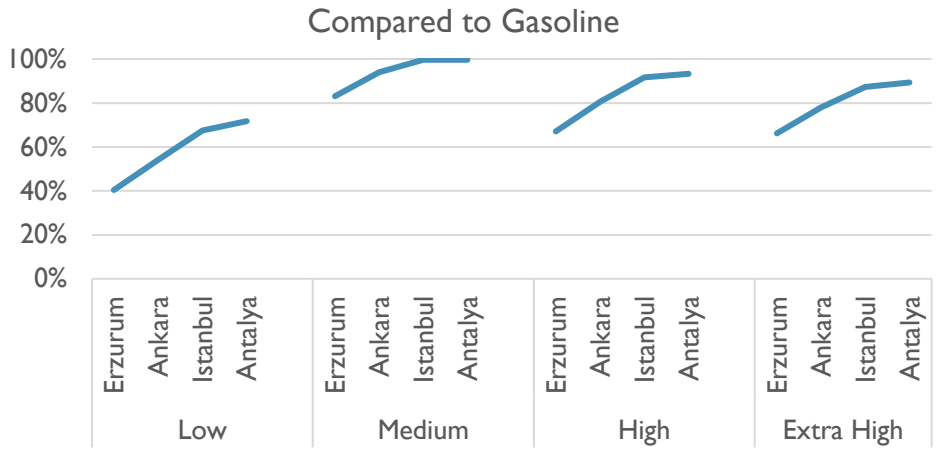
- **Assumptions for EV use**
  - Charge-and-drive assumption with DC fast charging
  - EV use is uniformly distributed in a year rather than following a charging/driving pattern

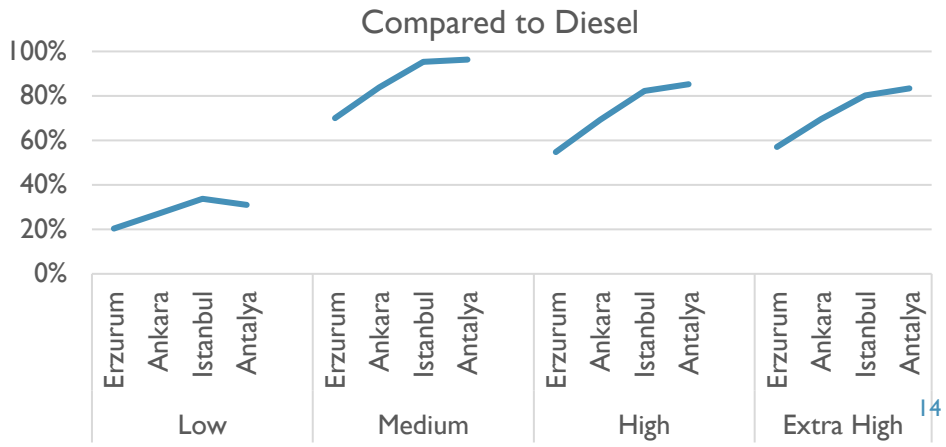
RESULTS

Driving Condition Impact

With HVAC system use

- Electric vehicles are invincible at **medium** speed driving profile
  - *Istanbul and Antalya*
    EV emissions always lower than gas-C4
    EV emissions lower than die-C4 at 95% of time
  - *Ankara and Erzurum*
    EV emissions lower than gas-C4 at 83-95% of time
    EV emissions lower than die-C4 at 70-84% of time
- e-C4 does not perform well in **low** speed driving profile
  - EV emissions higher than gas-C4 at 30-60% of the time
    EV emissions higher than die-C4 at 70-80% of the time
- **High & extra high** speed driving profile
  - EV emissions lower than gasoline at 65-93% of the time
    EV emissions lower than diesel at 55-85% of the time



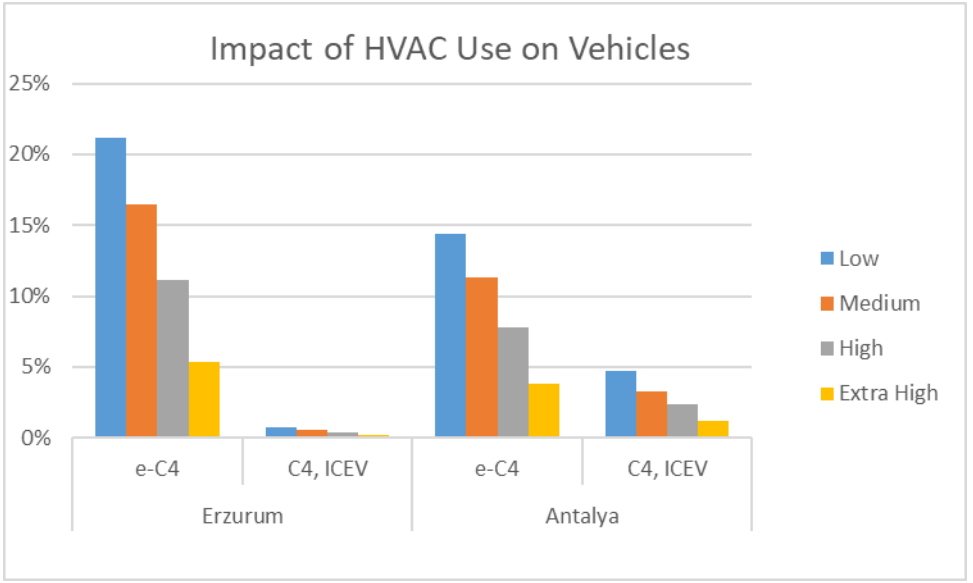


Ratio of the instances that EV emissions are **less** than ICEV emissions

RESULTS

HVAC effect

- HVAC use increase energy consumptions in both cold and warm weather in EVs
- But only at high temperatures in ICEVs
- Therefore, HVAC system effects the EVs more than ICEVs
- As the speed level increases, HVAC's impact on emissions decreases
- HVAC effects the EVs mostly at cold climate, and ICEVs at the mild climate

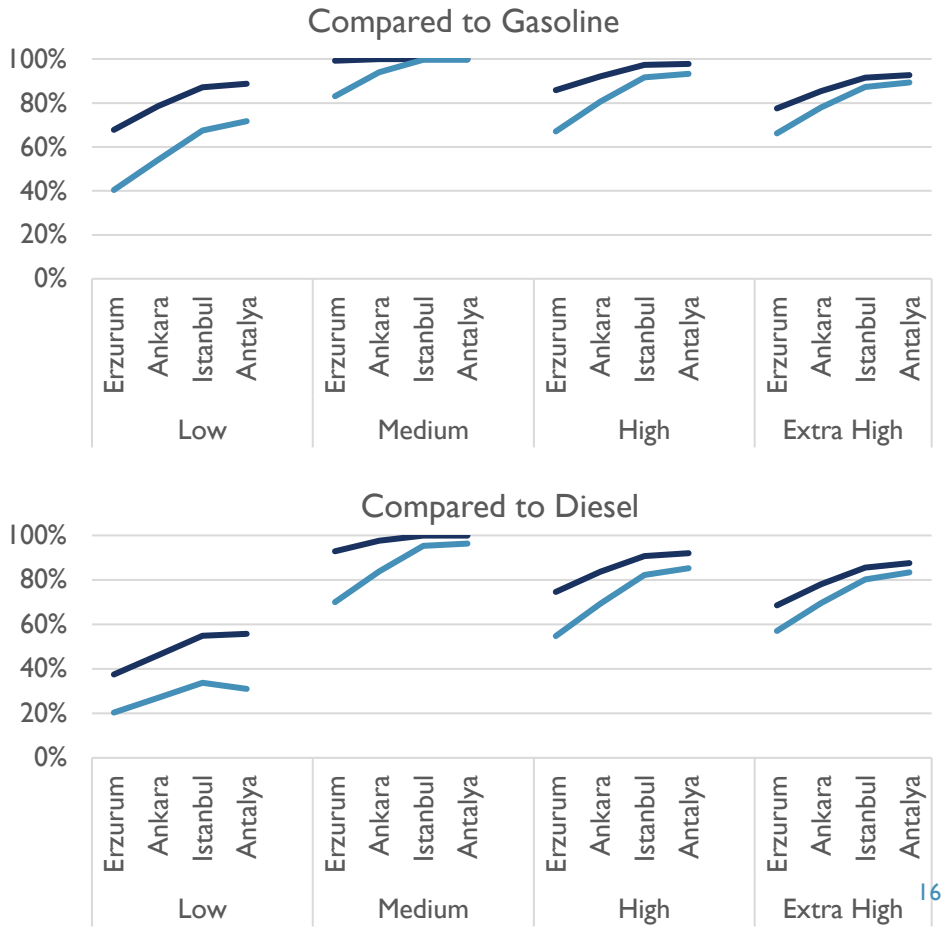


Based on average emissions released in the study period

RESULTS

HVAC effect

- If HVAC system is not used in both vehicles
  - In medium speed profile
    - EV *never* emits more emissions than gas-C4, in all cities (6-19% inc. in cold cities)
    - EV emissions are higher than die-C4, only 7% at Erzurum (33% increase)
  - Effect of HVAC system is high in the low speed profile
    - In cold cities, share of instances of lower-EV-emissions than gas-C4 increases to 70-80% (corresponds to 45-68% increase)
    - In mild cities, the share increases to 90% (corresponds to 24-29% increase)
    - For diesel comparison, the lower EV emission ratios are almost doubled but still remain below the 50%, in cold cities (corresponds to 71-85% increase)
    - In mild cities, 60-80% increase, moves these ratios to above 50%
  - In high and extra high speed profile, the increase rates are between 4-10% for mild cities and 9-36% for cold cities



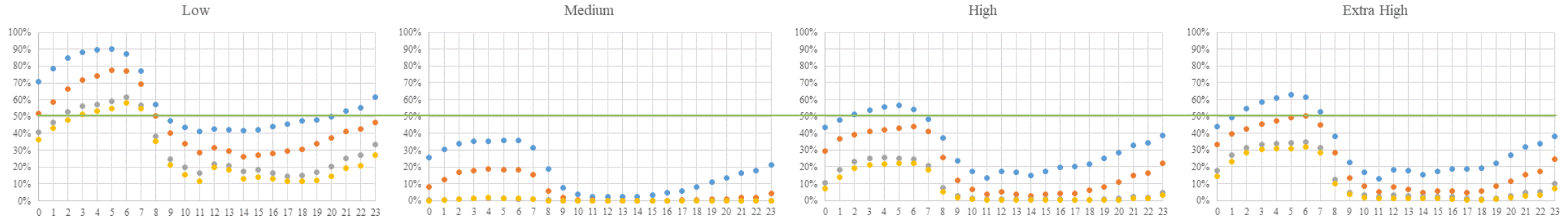
Ratio of the instances that EV emissions are less than ICEV emissions

RESULTS

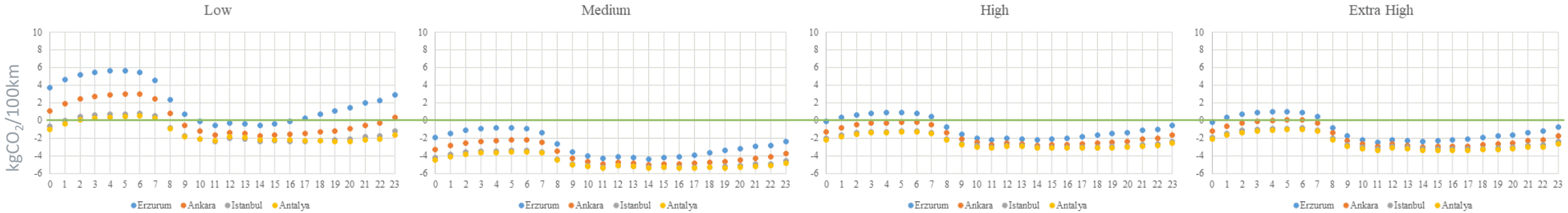
Hourly Variations

- Compared to Gasoline

Ratio of the instances that EV emissions are higher than ICEV emissions



Mean differences between the EV emissions and ICEV emissions (negative values declare the average reduction with EV)

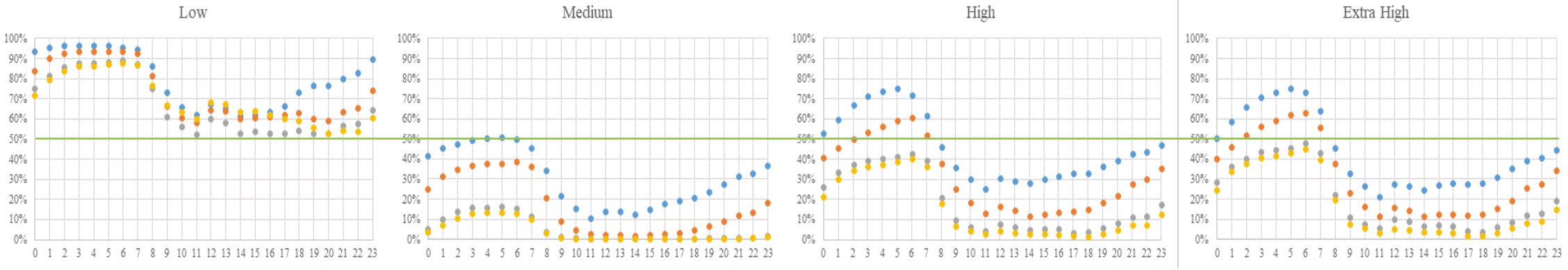


RESULTS

Hourly Variations

- Compared to Diesel

Ratio of the instances that EV emissions are higher than ICEV emissions



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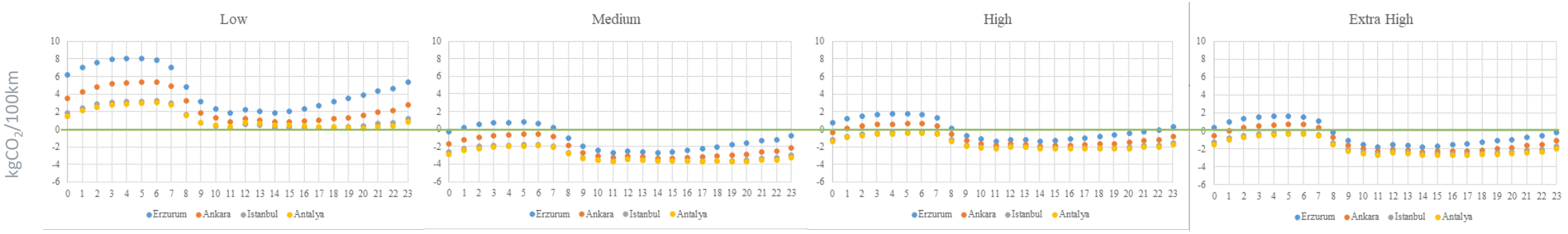
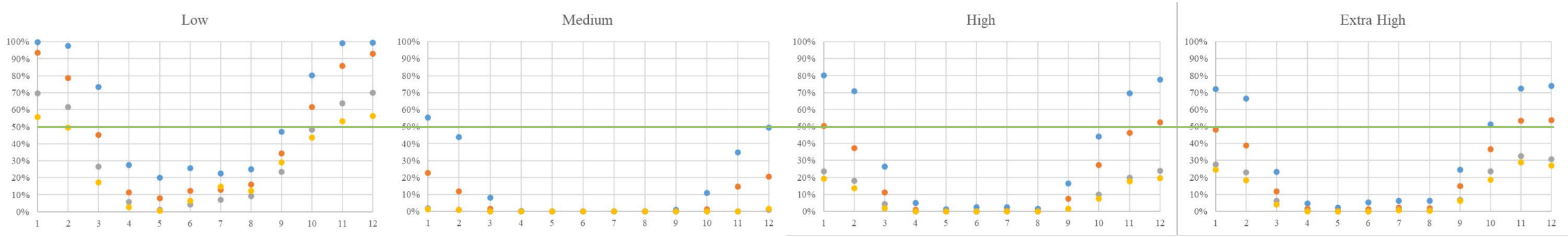


RESULTS

Monthly Variations

- Compared to Gasoline

Ratio of the instances that EV emissions are higher than ICEV emissions



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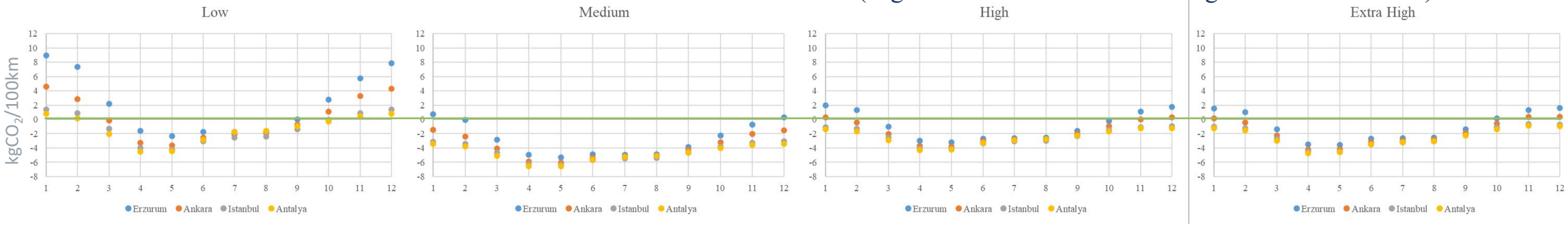

RESULTS

Monthly Variations

- Compared to Diesel

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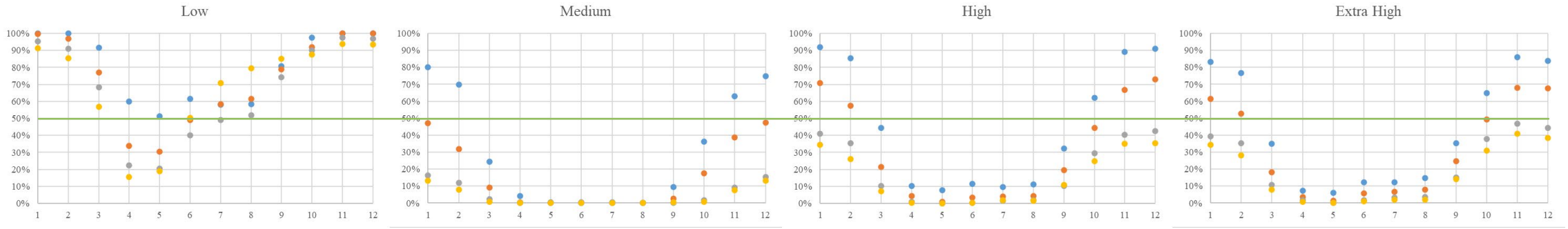

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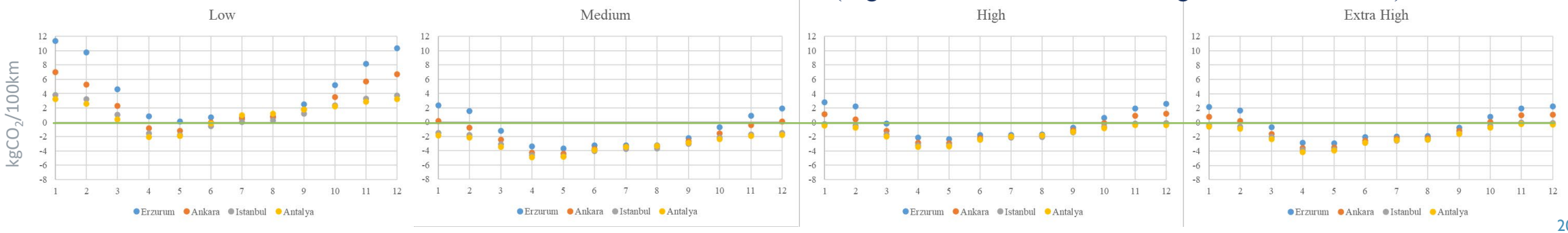


RESULTS

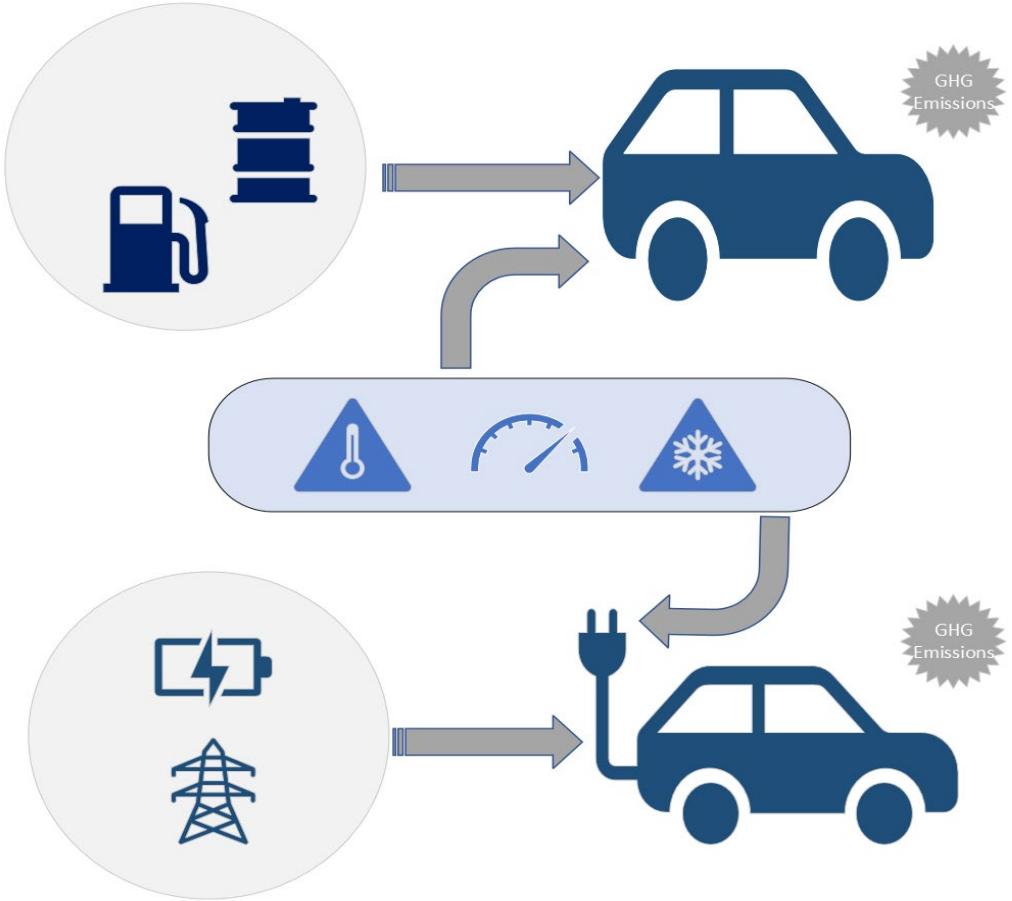
Vehicle effect

- Diesel vehicles perform better than gasoline vehicles in terms of CO_2 emissions
- EV models may react differently to the speed and temperature changes
- The analysis should be expanded with other EV models

CONCLUSIONS

- Recommendations for electrification of passenger cars towards decarbonisation
  - Driving conditions: Town or suburban drive (average 40 km/h with stops)
  - Lower electricity generation emissions, increase in renewables share required
  - Charging period: timing matters, daytime charging
  - Climate effect: EV use in mild-temperature cities should be prioritized, charging stations
  - Transmission and distribution efficiency is a critical factor
  - HVAC system use is a significant emission source for especially EVs, but also an important comfort parameter to abandon

THANK YOU!



For questions and recommendations
Contact information:
esintetikkollugil@gmail.com