Potential benefits of planned & coordinated charging of EVs under high penetration in South Africa

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Background to the Study

- Electric vehicles (EVs) are set to change how energy is consumed and supplied.

- Possibility 1: with plenty of EVs and minimal coordination and planning - limits the possible benefits through the electrification of mobility and creates challenges for the grid.

- Possibility 2: With proper planning and coordination – maximise the benefits from the EV technology
  - Increased revenue from electricity sales
  - Modernizing of the energy sector
  - EV considered as grid assets to provide energy storage
  - Critical for more renewable energy deployment

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Motivation and Research objectives

- Utilities will welcome the new load from EVs, but are unprepared to supply the energy needed to charge batteries when demand is highest
- High penetration of electric vehicles in a distribution system may potentially have negative impacts on the system's operation
- There is need to accurately understand the impact of EV charging on the demand profile using more accurate data.
- The main objective of the study is to analyse the impact of uncontrolled EV charging load on the electricity distribution network.

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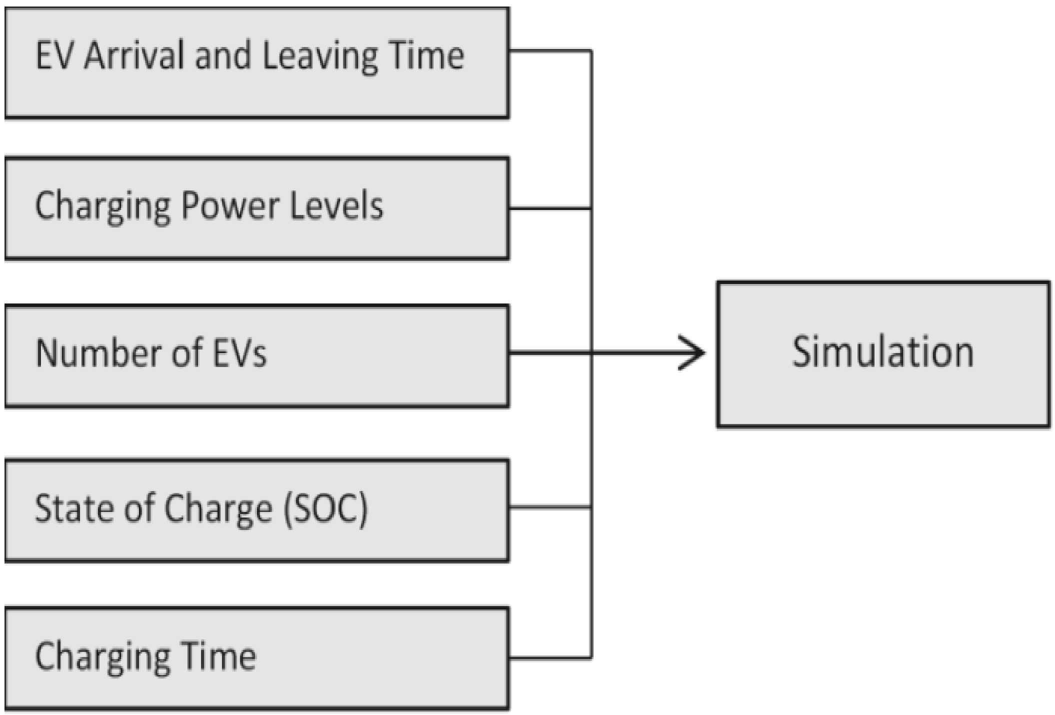
Research Methodology

- Using the 2013 NHTS – use the travelling patterns of commuters in private vehicles
- Assess the existing demand profile of the city of Ekurhuleni based on actual demand data.
- Probabilistic model to establish the EVs charging load to forecast expected load demand.
- Use Nissan Leaf Lithium-Ion battery properties to accurately estimate the State-Of-Charge of the battery.



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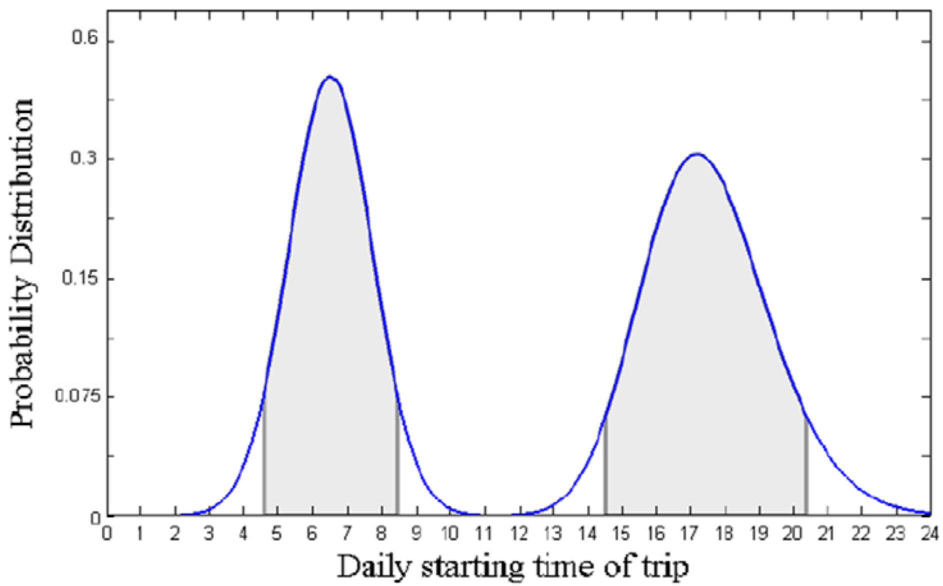
City of Ekurhuleni traveling patterns

- Majority of commuters drive to work between 5:00 - 8:30 and from work between 14:30 - 20:30.
- The average driving duration is about 49 min. This time was used for State-of-Charge (SOC) Estimate.
- It is assumed that the commuters will charge their vehicles immediately after they finish their trip.



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Charging Station Infrastructure

- Vehicles can be charged in a number of ways; characterized by the speed of charging.

- In this study, Level-2 charging is assumed

Type	Level-1	Level-2	Level-3
Power Level	220V: 1.2 – 2.0 kW	**(Low) 220V – 240 V: 2.8 kW – 3.8 kW** **(High) 220V – 240 V: 6 kW–15 kW**	220V – 240V: >15 kW – 96 kW
Charge Time	> 10 hrs	**Low: 8 hrs – 10 hrs** **High: 5 hrs – 8 hrs**	2- 5 hrs

Cost and complexity tend to increase with the increase in the charging speed.

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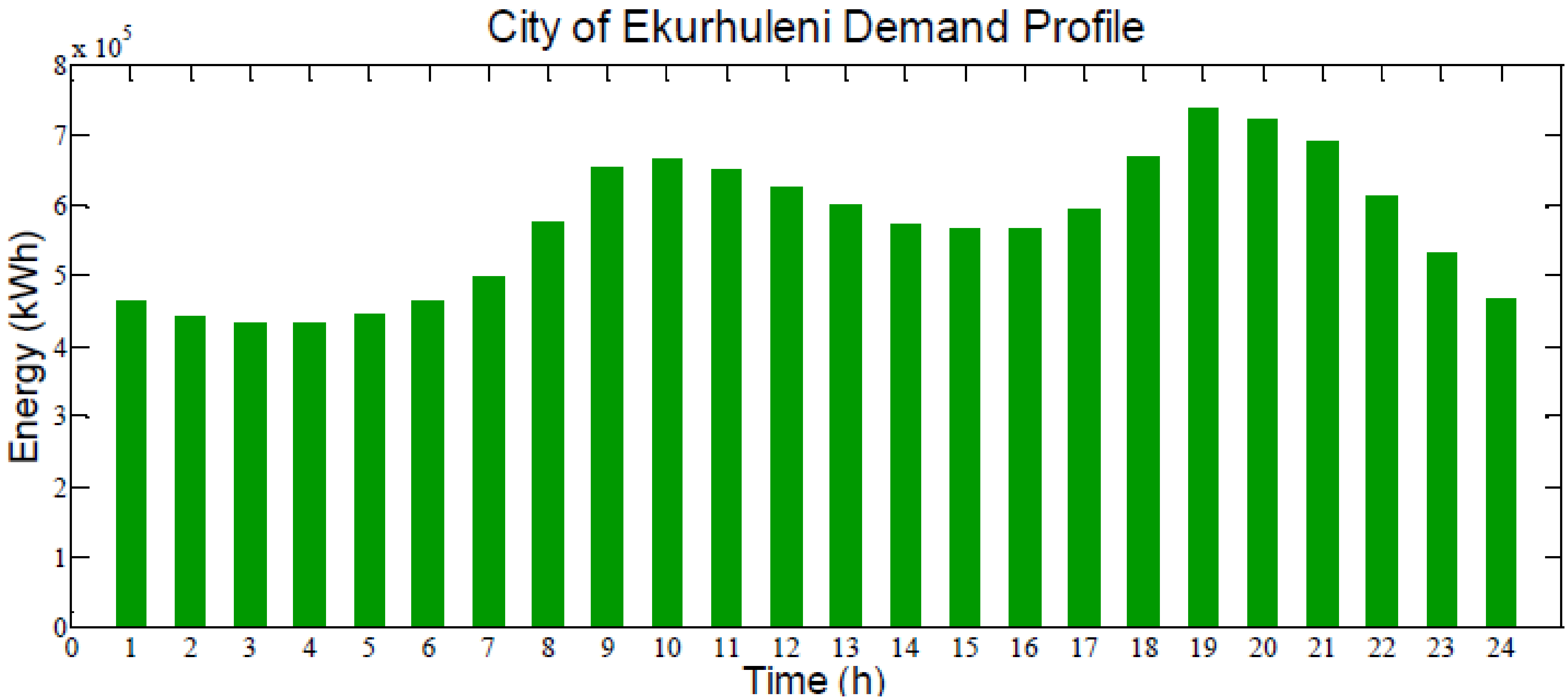
City of Ekurhuleni load profile during winter



Morning peak

Evening peak

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Number of electric vehicles and Battery Capacity

- According to the 2013 National Household Travel Survey, about 355 000 commuters use private vehicles to work in the City of Ekurhuleni

- The number of electric vehicles used in this study is 88750, which is 25% of the total registered private vehicles as predicted by the government.

- Lithium-ion batteries have attracted special attention for EV application because of the high power density, high energy density and long lifespan.

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Electric vehicle charging demand profile
Mathematical model

- **State of Charge**

$$SOC^i_{arrive} = SOC^i_{depart} - D_i \cdot C_i \cdot \frac{100}{BC_i}$$

  - SOC^i_{arrive} and SOC^i_{depart} are the state of charge of the i^{th} EV battery (in %) at the arrival and departure of the trip.
  - D_i is the distance covered by the i^{th} EV in the specific trip (in km).
  - C_i is the average consumption of the EV (in kWh/km)
  - BC_i is the total battery capacity of the i^{th} EV (in kWh).

- **Time to Charge**

$$T_i = \frac{\left(SOC^i_{depart} - SOC^i_{arrive}\right) \times BC_i}{\eta \times P_c} \times 60$$

- T_i is the charging duration,
- P_c is the charging level (in kW)
- η is the charging efficiency.

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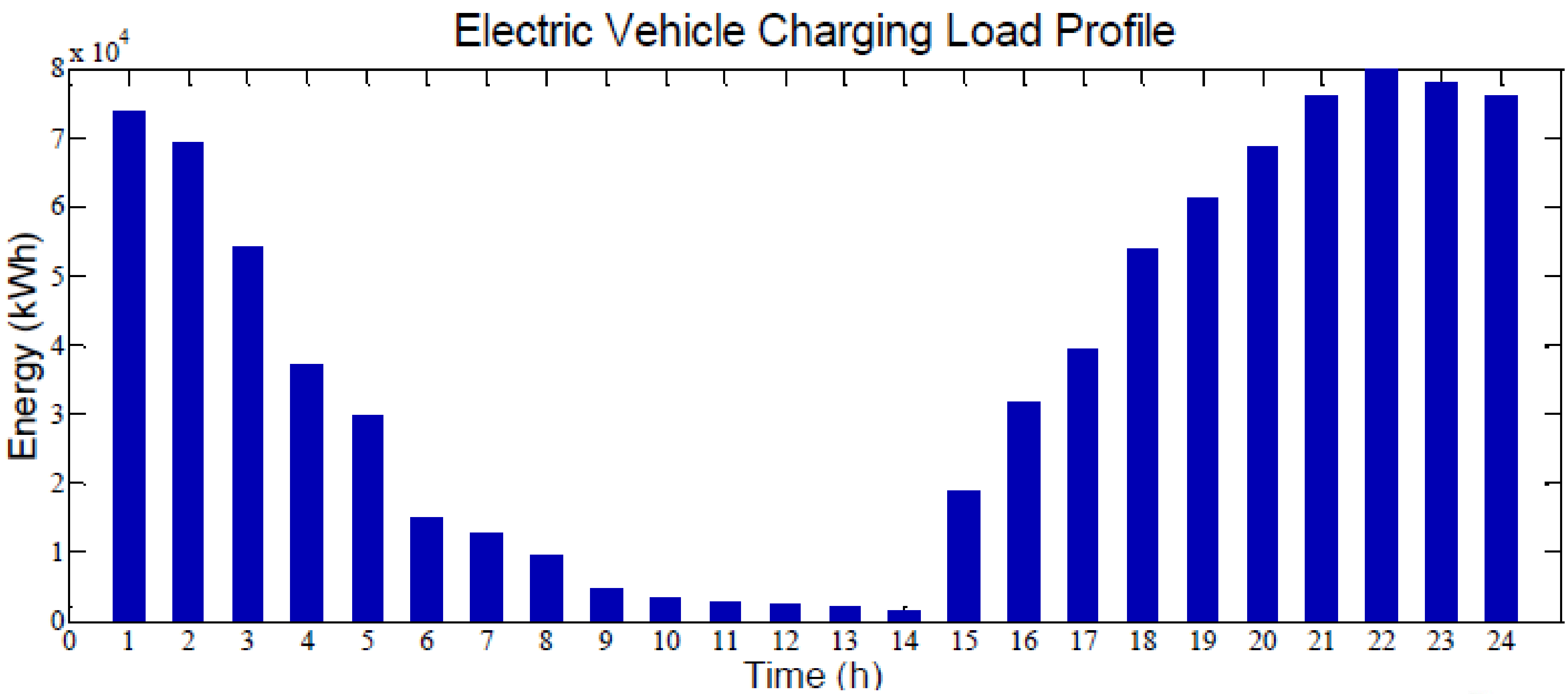
Electric Vehicle charging load profile



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Effect of uncontrolled EV charging on Demand Profile

- The EV peak charging coincides with the City of Ekurhuleni peak which occurs around 6-8pm. This could cause problems in the distribution system.

- The charging times of uncontrolled charging falls within all the TOU tariff windows, i.e. on-peak, standard and off-peak.

- Using the Miniflex tariffs, it could cost R1 164 293 to charge 355 000 vehicles in a day in winter.

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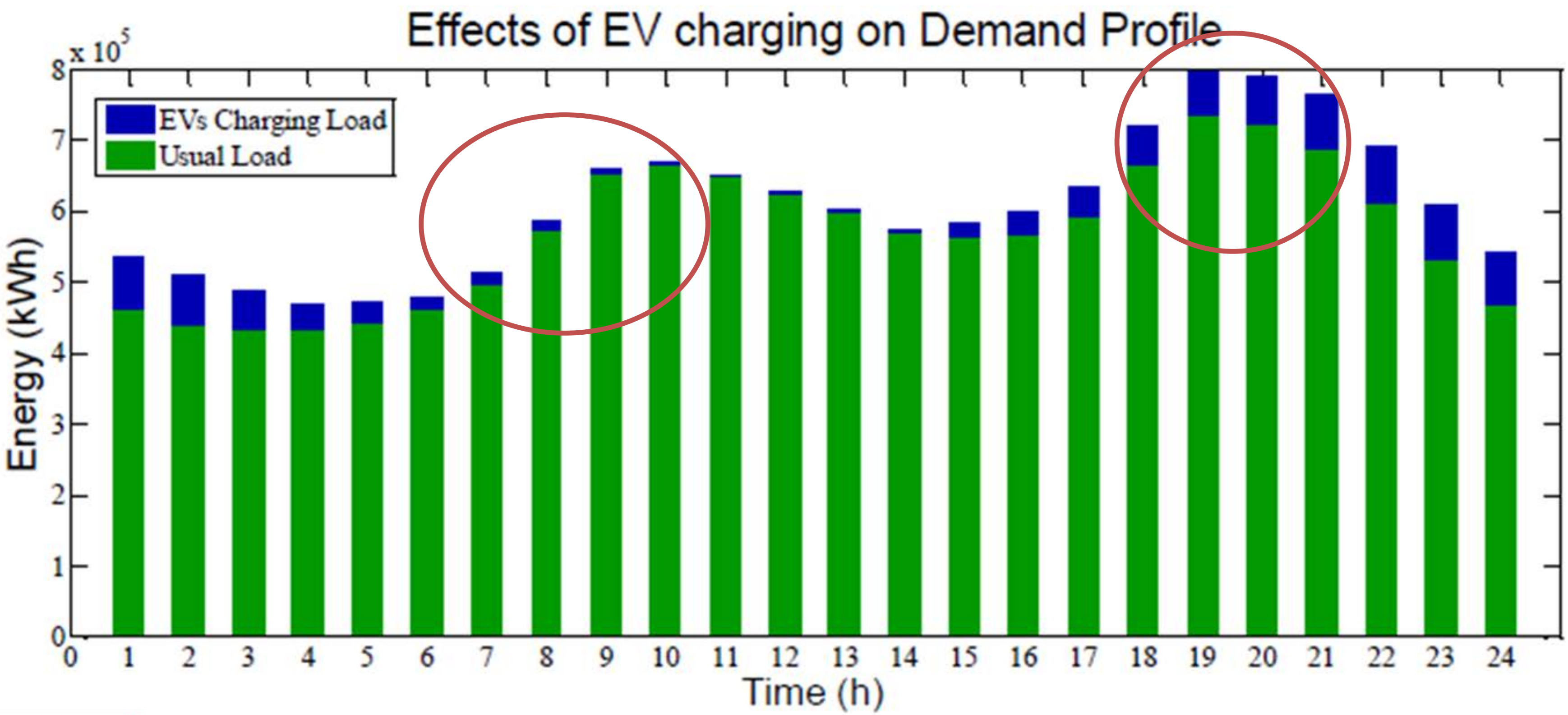
Effects of uncontrolled electric vehicle charging on Demand Profile



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The impact of Price-based DR on the demand profile under high penetration of EV

- Price-based DR has been proven as an effective motivation for shifting flexible loads such as EVs to off-peak hours.

- Peak demand due to the TOU tariff can be reduced by about 20% of charging EVs during the morning and evening peak times.

- Using the Miniflex tariffs, it could cost about R619 487 to charge 355 000
- vehicles in a day in winter under controlled charging.

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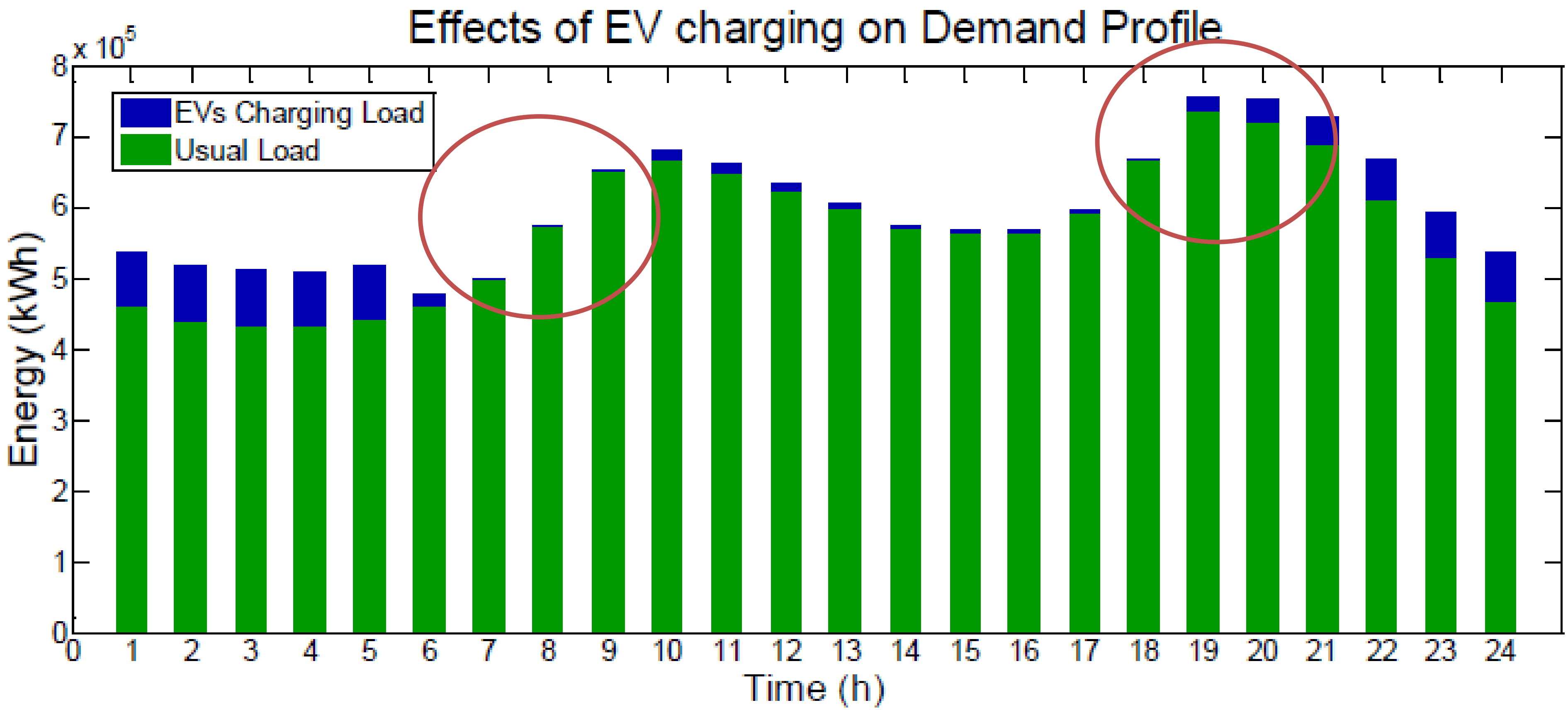
The impact of Price-based DR on the demand profile under high penetration of EV



Discussion and conclusion remarks

- The impact of priced-based demand response for the charging of the EVs has shown great reduction in peak demand.
- It was found that priced-based demand response can reduce peak demand by about 20% and reduce the price of charging 355 000 EVs on a winter day by 47%.
- The TOU tariff structure can motivate EV owners to shift the load from peak times to off-peak times.
- Charging in the off-peak hours would improve the load factor of the grid and lower overall electricity costs.

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Recommendations

- Controlled charging strategies are needed in order to restrict charging during peak hours.
- The high Level 2 charging is ideal for the stability of the power grid.
- Increasing the number of charging stations infrastructure, at work and public places, can also be another possibly load-shifting strategy.
- People can charge during the day at work and charge after peak hours at home.

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Thank you

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