Deloitte Qupermarket Hackathon Challenge

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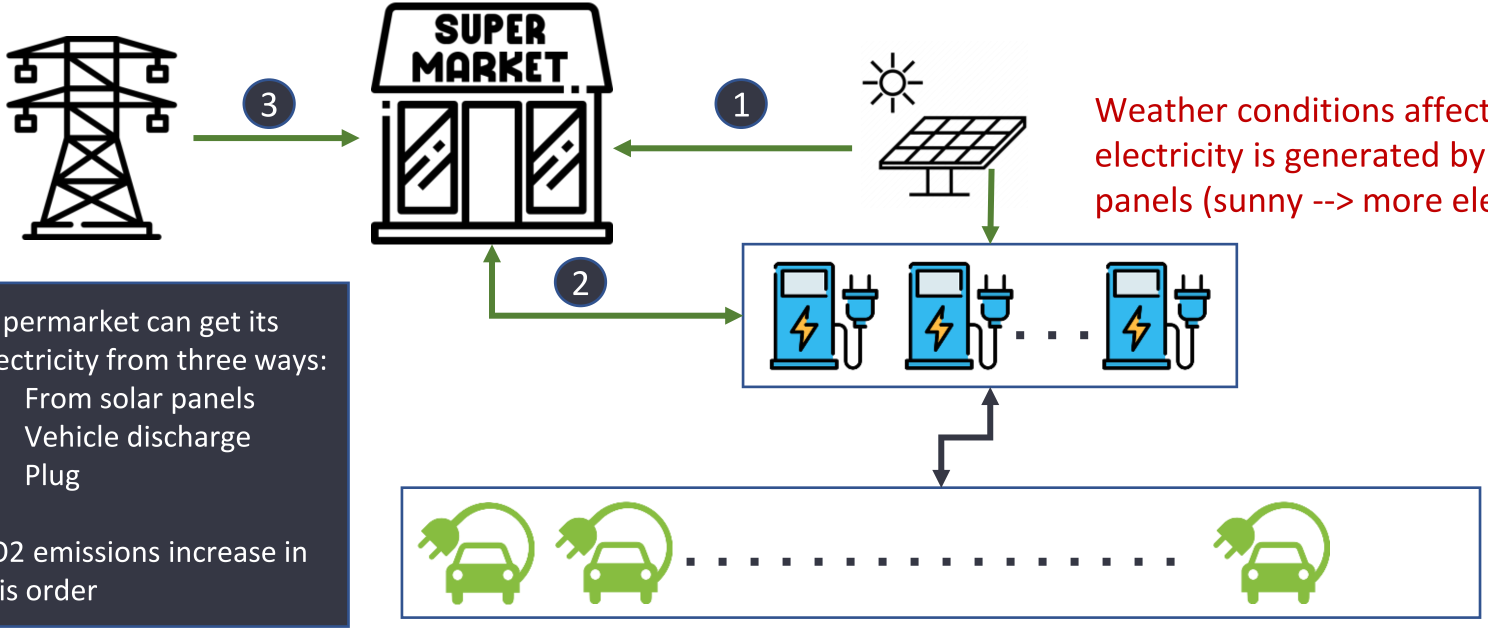
Problem Statement

Goal: Optimize the energy consumption of Qupermarket in regard to its CO_2.



Weather conditions affect how much electricity is generated by solar panels (sunny --> more electricity)

Supermarket can get its electricity from three ways:

1. From solar panels
2. Vehicle discharge
3. Plug

CO_2 emissions increase in this order

‘m’ electric vehicles visit the supermarket on a given day. They also have additional batteries that can be used as storage to ‘discharge’ electricity

Approaches

1. Quantum Inspired Approach (Simulated Annealing):

   The QUBO function accepts the factors like power availability from sources and consumption elements and also the vehicle data for discharging and charging and optimize the vehicles to be discharged and charged.

1. **Hybrid Approach (Quantum Inspired (Simulated Annealing) + Classical (Energy computation)):** ****our final approach**

   The consumption and energy availability is computed classically for each interval considering the mandatorily charging and route to optimization only if energy is not met by Solar power.

1. Classical Approach (Gurobi Optimization)

Approach 1 - Quantum Approach - QUBO Data

Step 1: Construct the objective function

{Existing mall battery value} + {Solar Power} + {Vehicle Discharging power} - {Vehicle Charging Power} - {Mall consumption} = {Mall battery Capacity}

Step 2: Constraint 1 to ensure the same vehicle is not simultaneously discharged and charged.

Step 3: Calculate the excess Plug power needed.

Approach 2 - Hybrid approach - QUBO Data

Step 1: Compute the remaining energy needed to charge the vehicles and restore in the mall battery. Assume the vehicle is mandatorily charged and is not a part of optimization.

{Energy needed} = {Mall battery Capacity} - {Existing mall battery value} + {Solar Power} - {Vehicle Charging Power} - {Mall consumption}

Step 2: If Energy needed is not enough to meet consumption and restore mall battery, then discharging power is looked upon. So, construct the QUBO to optimize the discharging vehicles to meet the energy needs

Step 3: If still Energy needs are not met, calculate the excess Plug power needed.

Key

Reduce Carbon cost at the expense of mandatorily charge back the vehicles when leaving the mall

Ensure none of the vehicles is missed to charge when leaving the mall.

This is a feasible assumption, as cars need enough electricity to depart.

Solution approach

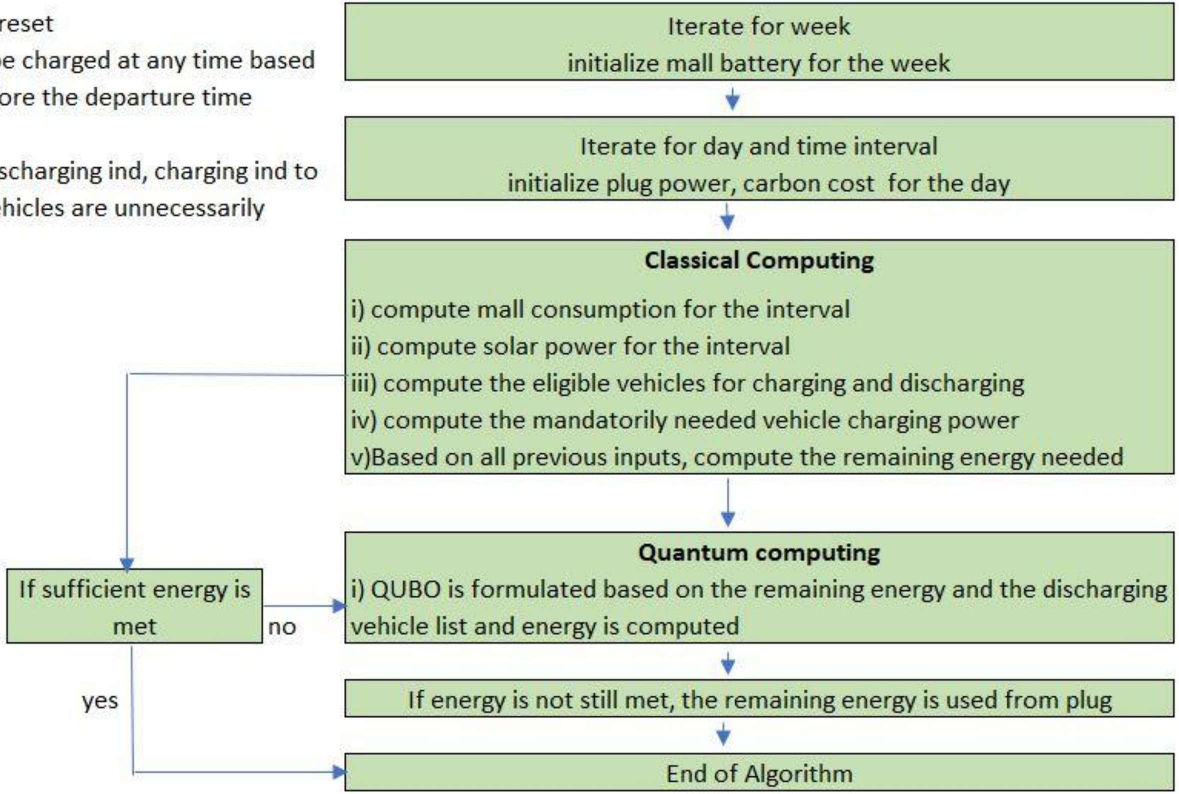
Assumptions:

i) mall battery is weekly reset

ii) car once arrived can be charged at any time based on the energy needs before the departure time

Simplification:

Introduced 2 columns discharging ind, charging ind to ensure no discharging vehicles are unnecessarily charged back.



Solutions and selling points

- The optimized charging/discharging schedules
  - **Lowest CO_2 emission**: **13.3%** lower than other teams, **12.5%** lower than quantum algorithm
  - **User-friendly**: directly tell users our suggestions
  - **More realistic**: consider charging, discharging, recharging and no charging

** Vehicles that was not discharged but got charged back during exit

Vehicle	Day	Discharging time	Battery power % discharged	Charging time	Battery power % Charged back
Mo16	Monday	8:30	77	9:00	79
Mo46	Monday	12:30	52	13:00	61

** Vehicles that were discharged and not charged back

Vehicle	Day	Discharging time	Battery power % discharged	Charging time	Battery power % Charged back
Mo2	Monday	8:00	73	8:30	42
Mo8	Monday	8:00	92	8:30	15

** Vehicles that were discharged and charged back during exit

Vehicle	Day	Discharging time	Battery power % discharged	Charging time	Battery power % Charged back
Mo3	Monday	8:00	73	9:00	67
Mo6	Monday	8:00	71	9:00	51

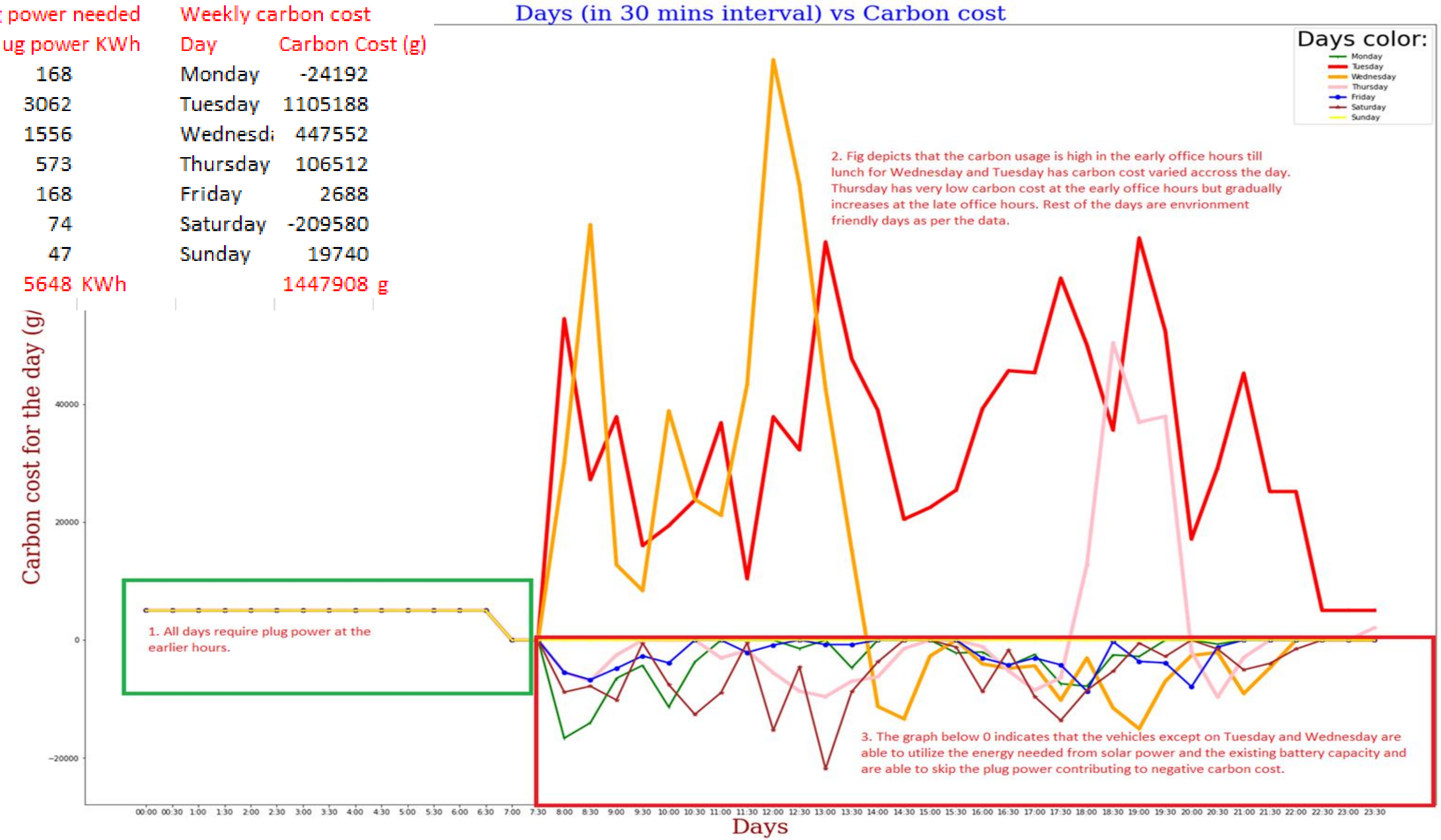
** Vehicles that were neither discharged nor charged

Vehicle	Day	Discharging time	Battery power % discharged	Charging time	Battery power % Charged back
Mo1	Monday	8:00	92	8:00	53
Mo4	Monday	8:00	85	8:00	14

Carbon Cost Analysis (Hybrid Approach)

Weekly plug power needed	
Day	Plug power KWh
Monday	168
Tuesday	3062
Wednesdi	1556
Thursday	573
Friday	168
Saturday	74
Sunday	47
	5648 KWh

Weekly carbon cost	
Day	Carbon Cost (g)
Monday	-24192
Tuesday	1105188
Wednesdi	447552
Thursday	106512
Friday	2688
Saturday	-209580
Sunday	19740
	1447908 g



Analysis - Hybrid vs Quantum Approach

Carbon cost is noticed in high range, as few optimizations consider few vehicles and plug power is used	**Carbon cost is noticed better compared to the former one** as the discharging vehicles are properly optimised and only if energy is needed, plug power is sought.
Vehicles are not fully utilised to the extent	Only Discharging vehicles are put in optimization process, so vehicles are effectively discharged.
Since **charging vehicles are also under optimization, there is a possibility of missing** the vehicle to be charged thus may put the customer in a situation to wait for the technical assistance	Since **charging vehicles are mandatorily charged based on the energy** needed in a classical way, there is no possibility of any customer being missed, ensuring customers safe exit from mall.
Every interval, there is a call to the optimization engine to predict the discharging and charging vehicles.	Every interval, energy is classically computed and **there is a optimization call only if energy shortage is there**, else Algorithm effectively uses solar power and existing mall battery energy.

Conclusion

- **Comprehensiveness**: complete all the tasks √
- **Innovation**: employ hybrid, quantum and classical algorithm √
- **Feasibility**: applicable and scalable for future tasks √
  - Simulator
  - Hardware (Dwave)
- **Quantum community impact**: √
  - Encourage customers to use Solar energy in the Qupermarket by providing coupons and free parking, etc.
  - Fits into hospitals**, parking, malls, offices etc, and can collaborate with electric grid companies
- **Lowest CO_2 emission** schedule for Qupermarket! √
- **Businesses**: √
  - since less qubits, can pay license easily for basic optimizers and every one can use.
  - Since hybrid approach, companies can use existing workforce and maintenance will be almost equal to existing projects.

**For Hospitals and critical installations, model may not fit if they follow irregular parkings.

Vehicle Charging/Discharging schedules

** Vehicles that were discharged and charged back during exit

Vehicle	Day	Discharging time	Battery power % discharged	Charging time	Battery power % Charged back
Mo3	Monday	8:00	73	9:00	67
Mo6	Monday	8:00	71	9:00	51
Mo12	Monday	8:30	89	9:30	36
Mo24	Monday	9:30	85	10:30	83
Mo25	Monday	10:00	98	11:00	32
Mo75	Monday	16:30	70	17:30	33
Mo87	Monday	17:30	55	18:30	86
Tu7	Tuesday	8:00	65	9:00	17
Tu10	Tuesday	8:30	38	9:30	89
Tu34	Tuesday	12:00	22	13:00	11
Tu40	Tuesday	12:30	43	13:30	93
Tu46	Tuesday	13:00	39	14:00	82
Tu49	Tuesday	13:00	63	14:00	32
Tu55	Tuesday	14:00	78	15:00	8
Tu64	Tuesday	15:30	52	16:30	37
Tu68	Tuesday	16:30	82	17:30	46
Tu70	Tuesday	16:30	79	17:30	10
Tu77	Tuesday	17:00	52	18:00	69
Tu80	Tuesday	17:30	85	18:30	95
Tu89	Tuesday	18:00	77	19:00	15
Tu90	Tuesday	18:30	41	19:30	91
Tu93	Tuesday	18:30	36	19:30	89
Tu94	Tuesday	18:30	41	19:30	27
Tu99	Tuesday	19:00	70	20:00	58
Tu104	Tuesday	19:30	38	20:30	32
Tu109	Tuesday	20:30	33	21:30	65
We1	Wednesd	8:00	90	9:00	75
We11	Wednesd	8:30	76	9:30	21
We19	Wednesd	10:00	34	11:00	34
We24	Wednesd	11:00	63	12:00	94
We26	Wednesd	11:30	25	12:30	27
We28	Wednesd	11:30	53	12:30	76
We31	Wednesd	12:00	68	13:00	42
We33	Wednesd	12:00	50	13:00	81
We36	Wednesd	12:00	91	13:00	89
We39	Wednesd	12:30	86	13:30	26
We45	Wednesd	13:00	96	14:00	58

** Vehicles that were discharged and not charged back

Vehicle	Day	Discharging time	Battery power % discharged	Charging time	Battery power % Charged back
Mo2	Monday	8:00	73	8:30	42
Mo8	Monday	8:00	92	8:30	15
Mo9	Monday	8:00	73	8:30	39
Mo10	Monday	8:00	79	8:30	39
Mo11	Monday	8:30	91	9:00	35
Mo18	Monday	8:30	74	9:00	66
Mo19	Monday	9:00	85	9:30	5
Mo21	Monday	9:00	86	9:30	75
Mo26	Monday	10:00	83	10:30	40
Mo29	Monday	10:30	71	11:00	32
Mo58	Monday	13:30	83	14:00	50
Mo61	Monday	13:30	90	14:00	64
Mo73	Monday	15:30	61	16:00	18
Mo88	Monday	17:30	78	18:00	37
Mo93	Monday	18:00	85	18:30	34
Mo105	Monday	18:30	92	19:00	43
Mo108	Monday	19:00	78	19:30	32
Tu1	Tuesday	8:00	68	8:30	18
Tu2	Tuesday	8:00	89	8:30	39
Tu5	Tuesday	8:00	96	8:30	78
Tu6	Tuesday	8:00	90	8:30	36
Tu9	Tuesday	8:00	87	8:30	75
Tu11	Tuesday	8:30	55	9:00	19
Tu18	Tuesday	9:30	53	10:00	47
Tu19	Tuesday	10:00	79	10:30	56
Tu21	Tuesday	10:30	87	11:00	77
Tu22	Tuesday	10:30	85	11:00	51
Tu25	Tuesday	11:00	55	11:30	21
Tu26	Tuesday	11:00	73	11:30	32
Tu29	Tuesday	11:30	85	12:00	76
Tu31	Tuesday	12:00	95	12:30	21
Tu32	Tuesday	12:00	98	12:30	95
Tu33	Tuesday	12:00	57	12:30	50
Tu39	Tuesday	12:30	67	13:00	27
Tu41	Tuesday	12:30	51	13:00	32
Tu43	Tuesday	12:30	85	13:00	82
Tu51	Tuesday	13:30	99	14:00	22

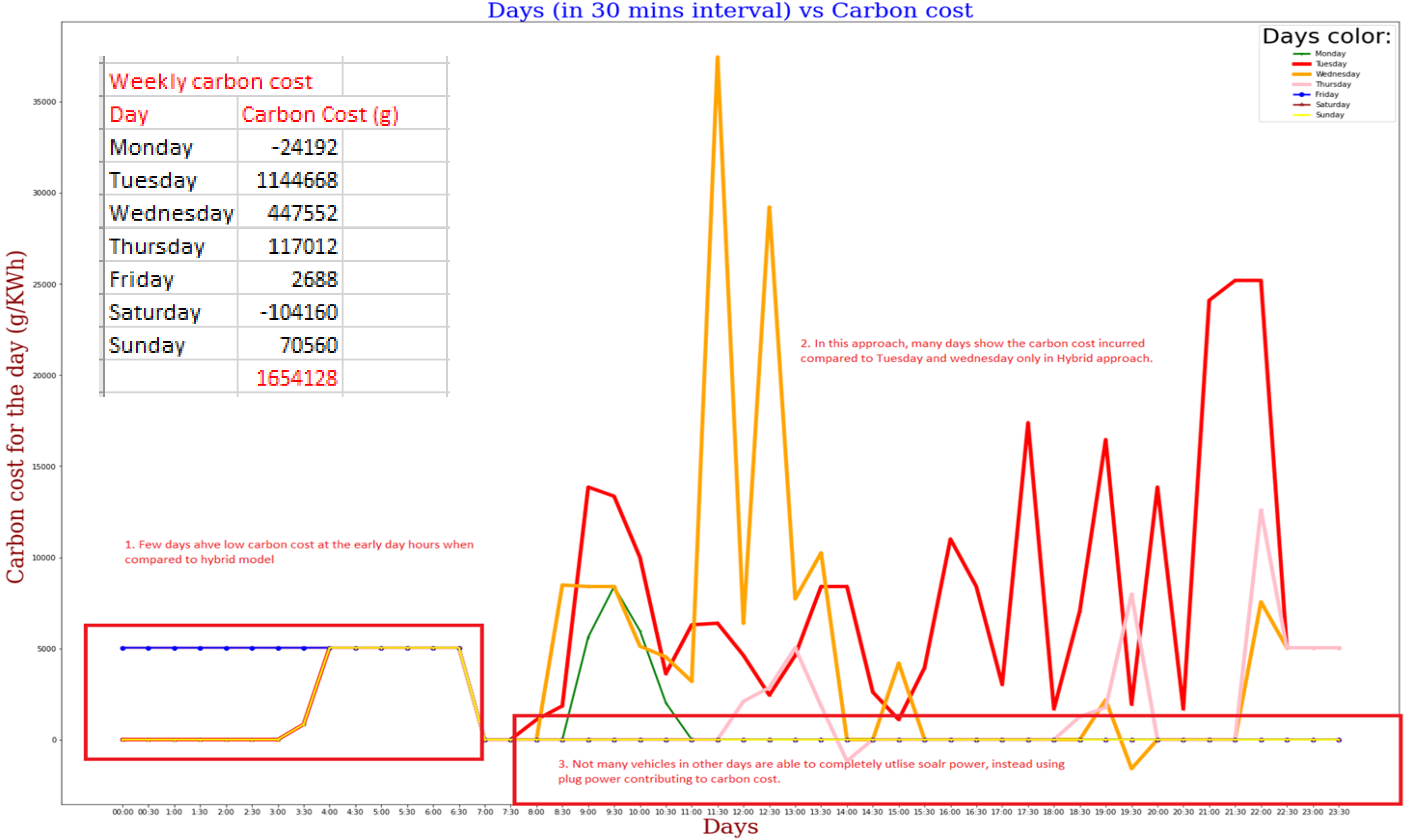
** Vehicles that was not discharged but got charged back during exit

Vehicle	Day	Discharging time	Battery power % discharged	Charging time	Battery power % Charged back
Mo16	Monday	8:30	77	9:00	79
Mo46	Monday	12:30	52	13:00	61
Mo49	Monday	12:30	76	13:00	94
Mo59	Monday	13:30	61	14:00	93
Mo74	Monday	16:00	54	16:30	94
Mo76	Monday	16:30	80	17:00	87
Mo78	Monday	16:30	87	17:00	94
Mo82	Monday	17:00	85	17:30	94
Mo84	Monday	17:00	71	17:30	75
Mo90	Monday	17:30	82	18:00	86
Mo91	Monday	17:30	55	18:00	86
Mo92	Monday	17:30	73	18:00	86
Mo100	Monday	18:00	63	18:30	79
Mo110	Monday	19:00	57	19:30	65
Mo121	Monday	20:30	63	21:00	76
Tu16	Tuesday	9:00	70	9:30	95
Tu28	Tuesday	11:00	37	11:30	70
Tu38	Tuesday	12:00	50	12:30	55
Tu47	Tuesday	13:00	33	13:30	71
Tu48	Tuesday	13:00	35	13:30	92
Tu61	Tuesday	15:00	35	15:30	91
Tu71	Tuesday	16:30	46	17:00	67
Tu75	Tuesday	17:00	77	17:30	94
Tu76	Tuesday	17:00	21	17:30	49
Tu78	Tuesday	17:30	47	18:00	78
Tu81	Tuesday	17:30	47	18:00	64
Tu100	Tuesday	19:30	39	20:00	93
Tu106	Tuesday	20:00	34	20:30	44
Tu108	Tuesday	20:30	21	21:00	58
We6	Wednesd	8:00	40	8:30	73
We13	Wednesd	8:30	28	9:00	65
We18	Wednesd	10:00	23	10:30	30
We20	Wednesd	10:00	45	10:30	88
We21	Wednesd	10:30	72	11:00	89
We22	Wednesd	10:30	58	11:00	80
We47	Wednesd	13:00	60	13:30	63
We50	Wednesd	13:00	48	13:30	87

** Vehicles that were neither discharged nor charged

Vehicle	Day	Discharging time	Battery power % discharged	Charging time	Battery pow Charged ba
Mo1	Monday	8:00	92	8:00	
Mo4	Monday	8:00	85	8:00	
Mo5	Monday	8:00	86	8:00	
Mo7	Monday	8:00	95	8:00	
Mo13	Monday	8:30	98	8:30	
Mo14	Monday	8:30	77	9:30	
Mo15	Monday	8:30	87	8:30	
Mo17	Monday	8:30	85	8:30	
Mo20	Monday	9:00	78	9:00	
Mo22	Monday	9:00	71	9:00	
Mo23	Monday	9:00	85	9:00	
Mo27	Monday	10:00	79	10:30	
Mo28	Monday	10:30	72	10:30	
Mo30	Monday	11:00	53	12:00	
Mo31	Monday	11:00	76	11:30	
Mo32	Monday	11:00	65	11:00	
Mo33	Monday	11:30	93	11:30	
Mo34	Monday	11:30	67	12:30	
Mo35	Monday	11:30	67	11:30	
Mo36	Monday	11:30	99	11:30	
Mo37	Monday	12:00	67	12:00	
Mo38	Monday	12:00	88	13:00	
Mo39	Monday	12:00	51	12:00	
Mo40	Monday	12:00	89	13:00	
Mo41	Monday	12:00	74	12:00	
Mo42	Monday	12:00	67	13:00	
Mo43	Monday	12:00	74	12:30	
Mo44	Monday	12:00	82	13:00	
Mo45	Monday	12:30	67	13:30	
Mo47	Monday	12:30	88	13:00	
Mo48	Monday	12:30	51	12:30	
Mo50	Monday	12:30	74	13:00	
Mo51	Monday	13:00	95	13:30	
Mo52	Monday	13:00	66	13:00	
Mo53	Monday	13:00	93	13:00	
Mo54	Monday	13:00	58	13:00	
Mo55	Monday	13:00	85	14:00	

Carbon Cost Analysis (Quantum Approach)



Weekly carbon cost	
Day	Carbon Cost (g)
Monday	-24192
Tuesday	1144668
Wednesday	447552
Thursday	117012
Friday	2688
Saturday	-104160
Sunday	70560
	1654128