Method to
Analyse Cost Effectiveness
of
Different Charging Systems for Electric Buses

Nordic Electric Bus Initiatives
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Tool for
Holistic analysis
of
Charging infrastructure

ELECTRIC GRID

CHARGING INFRASTRUCTURE

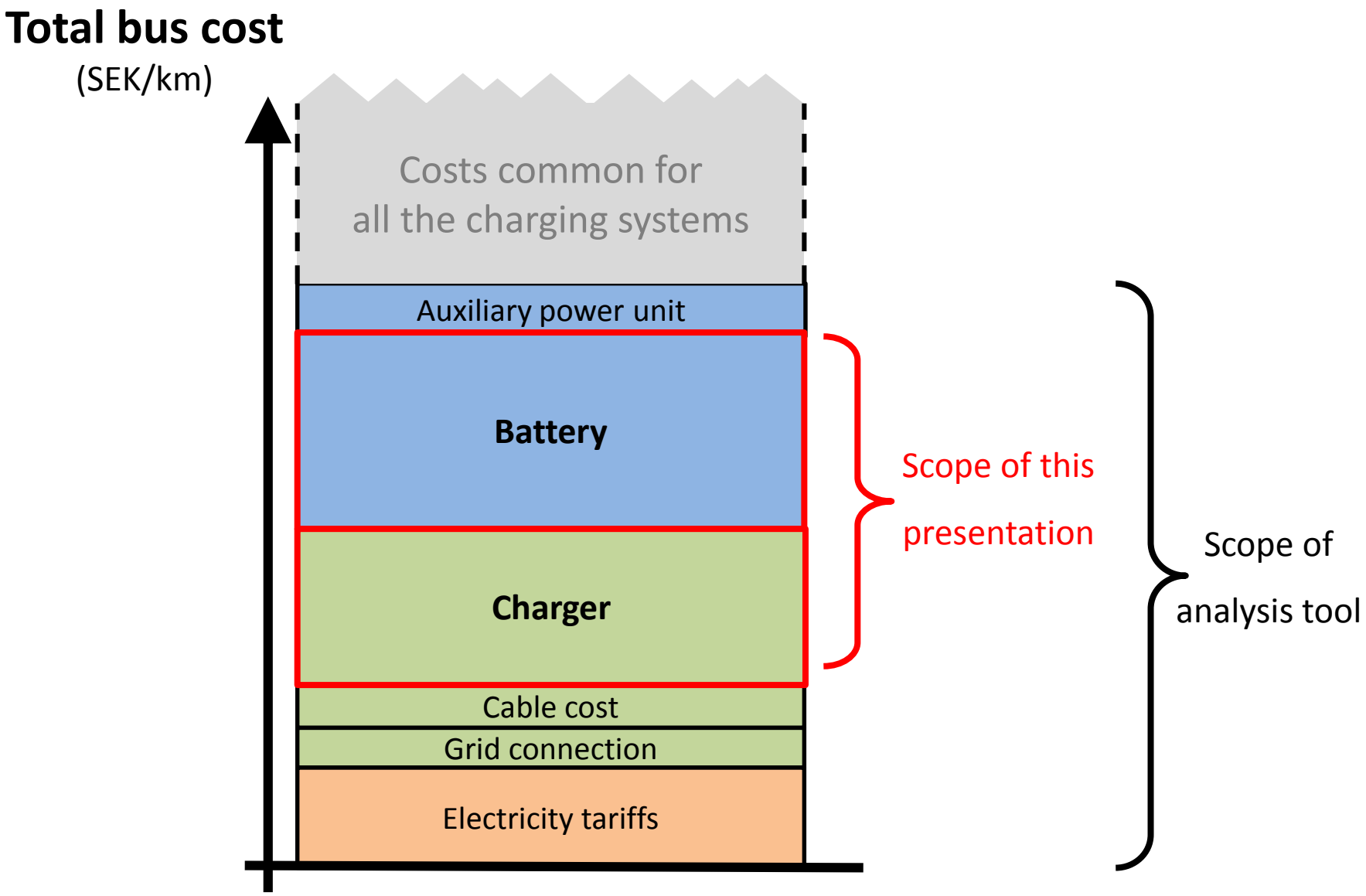
ENERGY STORAGE

BUS LINES

<u>Some results so far</u> - preliminary

- Infrastructure and buses must be analysed together.
- **End stop charging** cheaper than Night and Bus stop charging.

Analysed costs



Comparing three charging solutions

Bus line 19 in Gothenburg:

- 12 km - 22 stops
- 11 Articulated buses
- Service 19 h/day

Night charging	End stop charging	Bus stop charging
6 hour in bus depot	**5 minutes** at each end stop	**10 sec** at each bus stop

Assumptions: Life lengths 10 yr for bus / 20 yr for infrastr., Energy simplified to 1.5 kWh/km

Battery sizing for different charging

Find
cheapest battery

which

simultaneously meets
all requirements

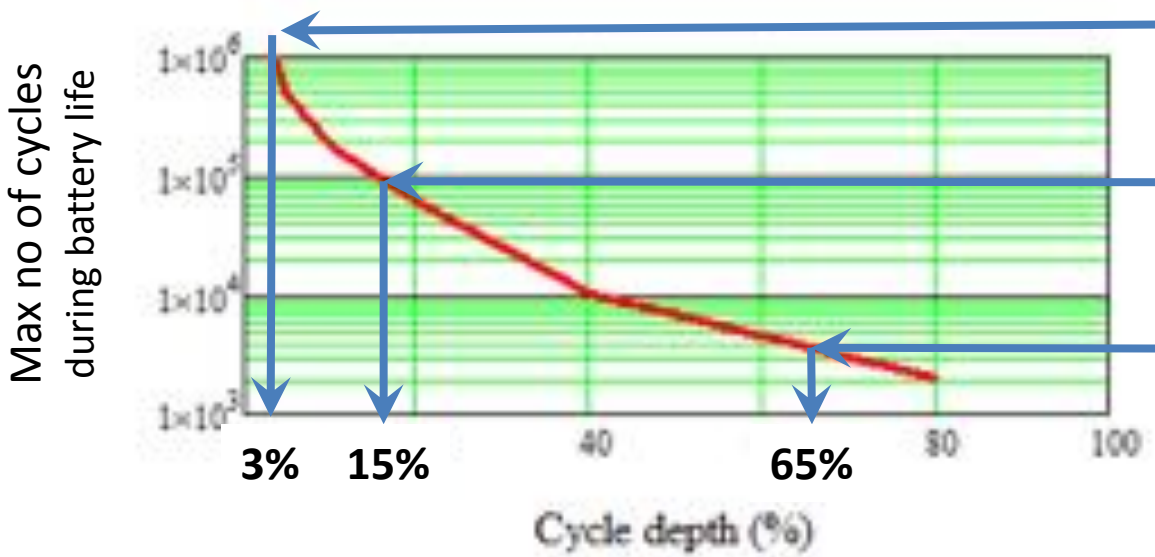
- Energy
- Cycle number
- Peak power
- …

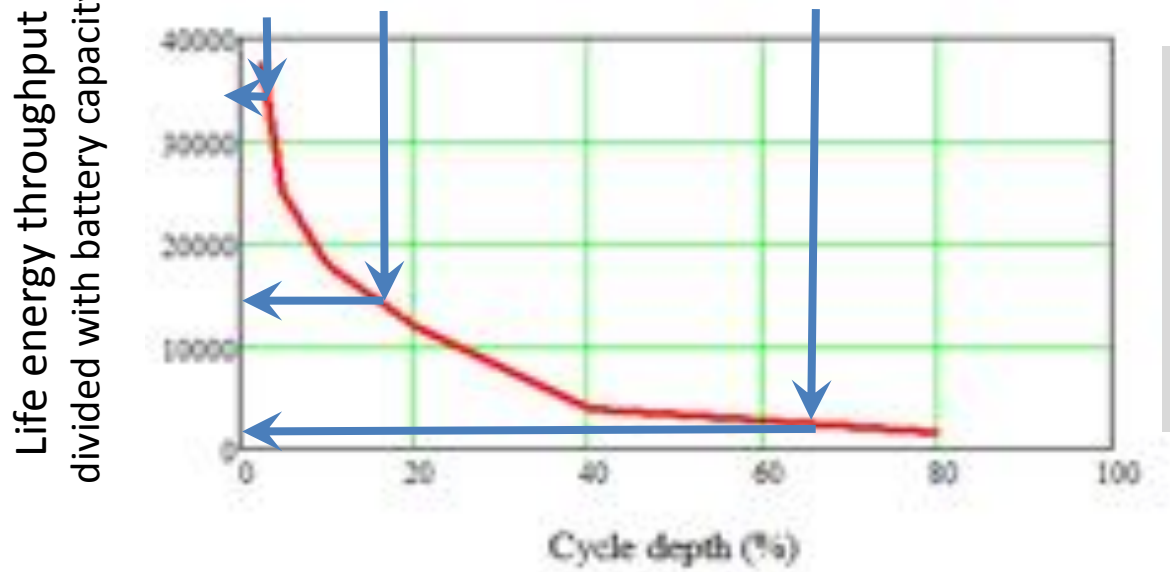
Energy required for normal charging cycle

	Night charging	End stop charging	Bus stop charging
Distance between normal charging	12 *24 km 288 km	1/2 * 24 km 12 km	1/44 * 24 km 0.55 km
Energy required	**432 kWh**	**18 kWh**	**0.82 kWh**
Number of normal charges during life	Once per night 3´650	Once per single trip 87´600	44 times per roundtrip 1´930´000

The tool also include sizing for special situations like missed charging. They do not influence results in this example.

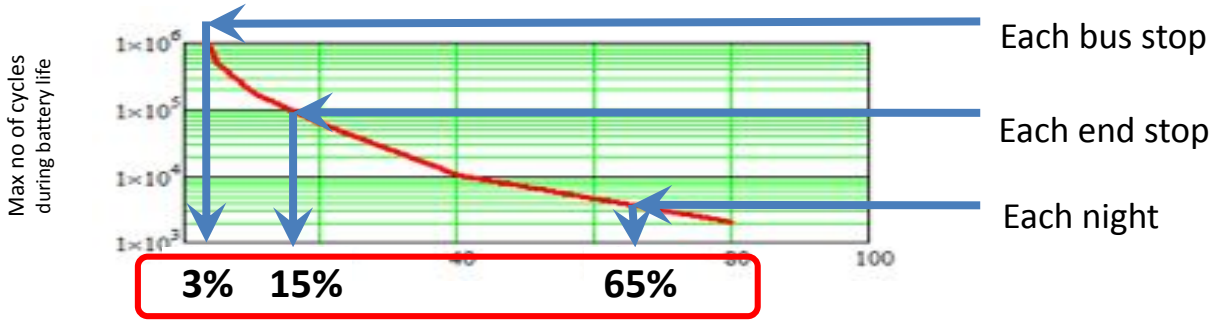
Many cycles require smaller cycle depths





Same battery allows more energy throughput at small cycles!

Required battery capacity for 10 year life



	Night charging	End stop charging	Bus stop charging
Distance between normal charging	288 km	12 km	0.55 km
Energy required	432 kWh	18 kWh	0.82 kWh
Number of normal charges during life	3´650	87´600	1´930´000
Required battery capacity	432 kWh/0.65 = **665 kWh**	18 kWh/0.15 = **120 kWh**	0.82 kWh/0.03 = **27 kWh**

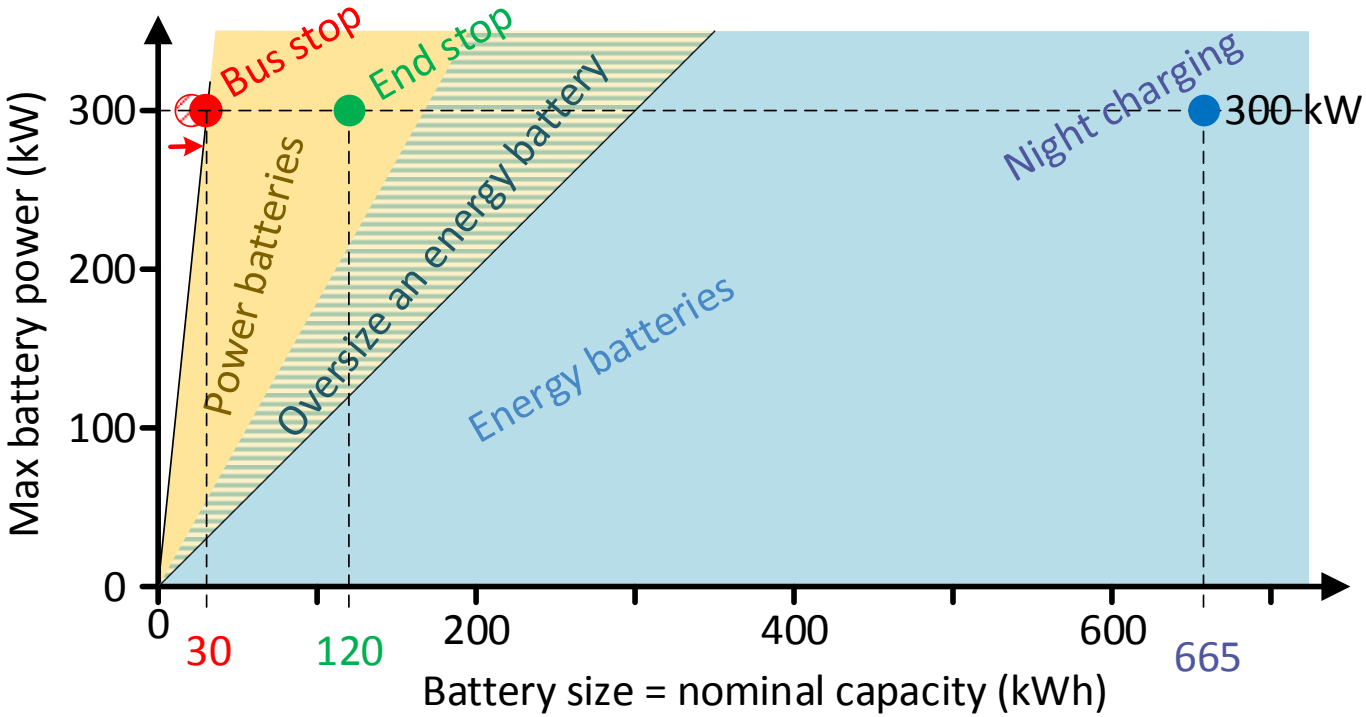
Required battery peak power: 300 kW (for propulsion)

(Note: final method will include power limits depending on duration of the power peak)

Battery type and size

Power optimized batteries, 14’000 SEK/kWh*

Energy optimized batteries, 7’000 SEK/kWh*



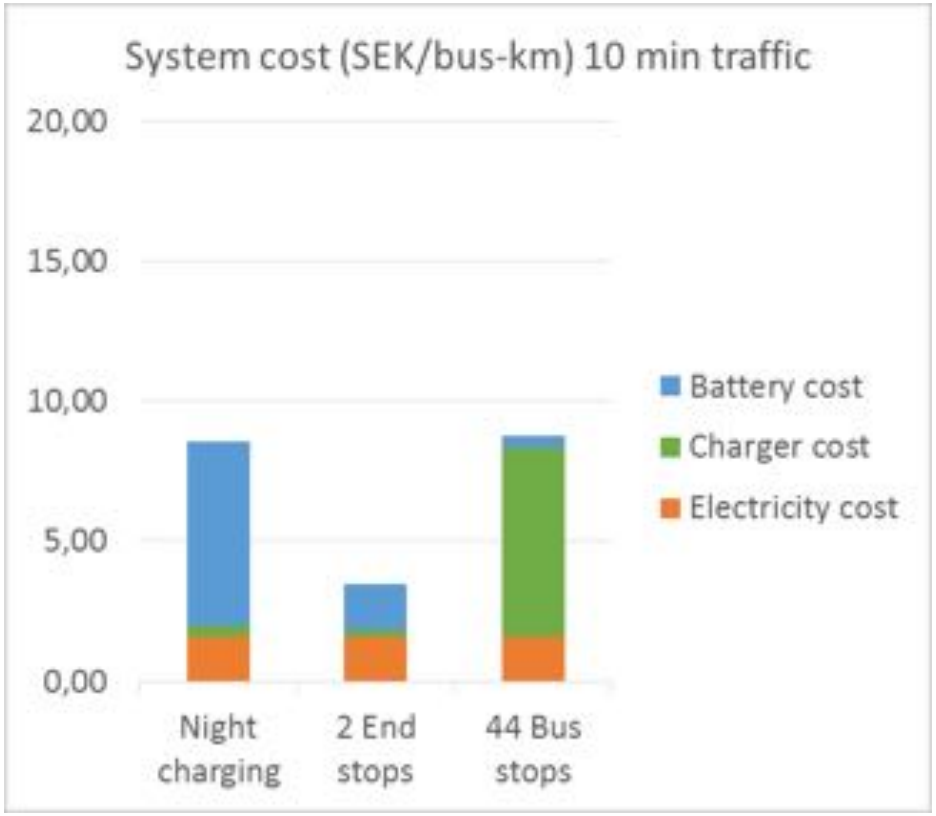
	Night charging	End stop charging	Bus stop charging
Battery size	665 kWh/Energy	120 kWh/Power	27⇒30 kWh/Power
Battery cost per bus	4.7 MSEK	1.7 MSEK	0.42 MSEK

Cost of chargers

Bus stop charger 295 kW	– 2.7 MSEK
End stop charger 216 kW	– 2.1 MSEK
Night charger 77 kW	– 0.77 MSEK

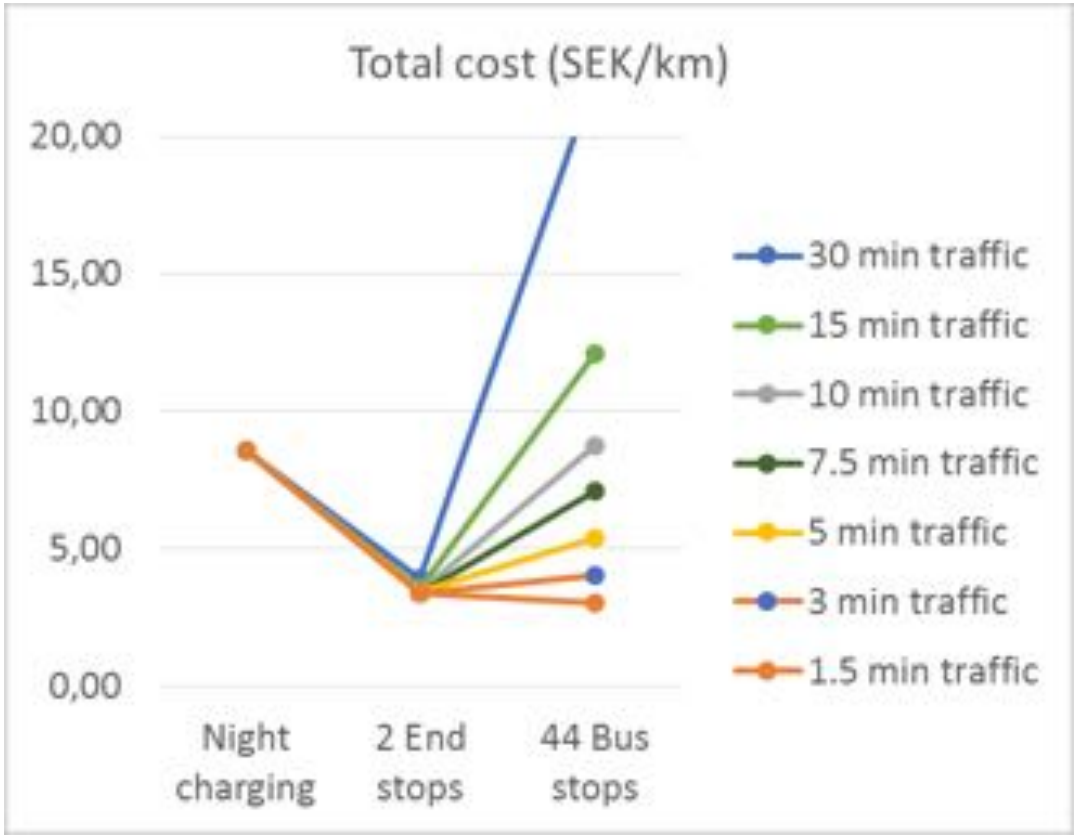
	Night charging	End stop charging	Bus stop charging
Total Charger power for bus line	11 * 77 kW = **847 kW**	2*216 kW = **432 kW**	44*295 kW = **13´000 kW**
Total charger cost for bus line	8.5 MSEK	4.2 MSEK	119 MSEK
Fraction of time utilized for charging	25 %	45%	1.6 %

Total cost for battery, charger and electricity



Night charging:	Expensive Battery
Bus stop charging:	Expensive Chargers
End stop charging:	Low cost for both battery and charger (requires standstill time)

Total cost for different bus frequency



End stop charging *seems cheaper than both Night charging and Bus stop charging*

Note: Preliminary results!

Thank you!

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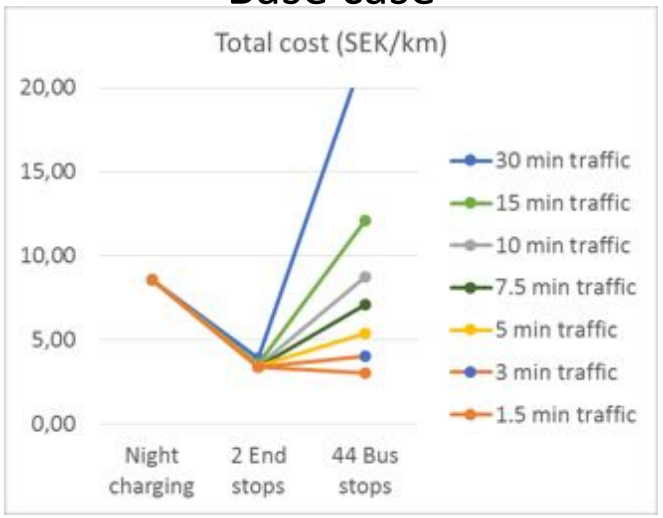
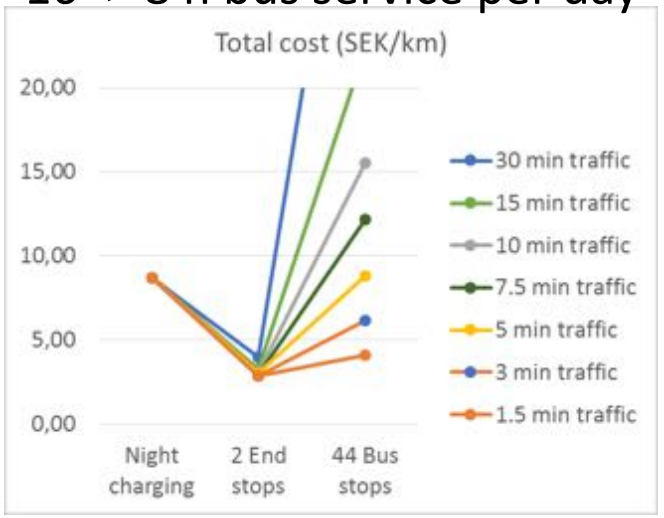
What could change these results?

Base case

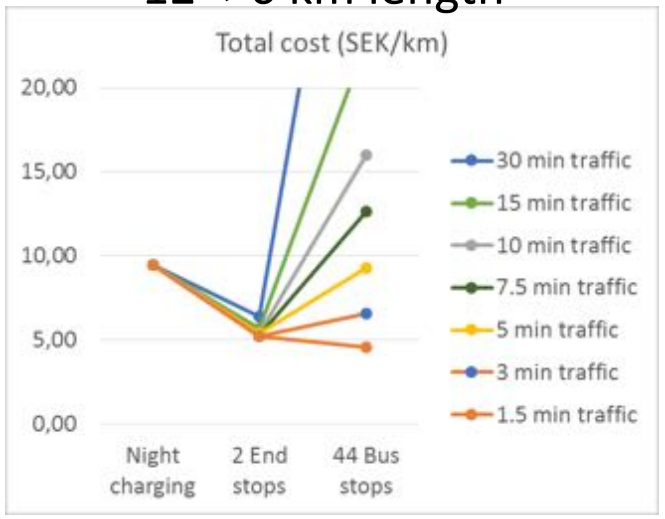


16=> 8 h bus service per day



50% battery price

12=>6 km length



Coming analysis

- Vary different parameters like
  - Component price
  - Length of bus line, …
  - Type of bus operation
  - zero emission zones
- Robustness to failures
  - Need for Extra buses, backup chargers or a diesel engine?
- Dual mode buses

Plan for follow up project with more complex systems.