NTNU – Trondheim
Norwegian University of Science and Technology

eSmart SYSTEMS

CHARGEFLEX

Management of charging of electric vehicles

EGRD Workshop, The Research Council of Norway, Oslo 4 June 2015

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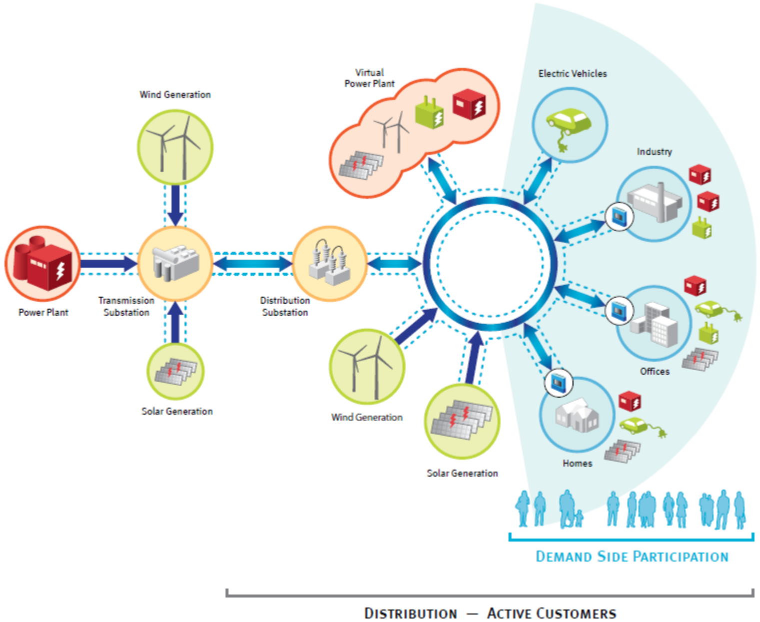
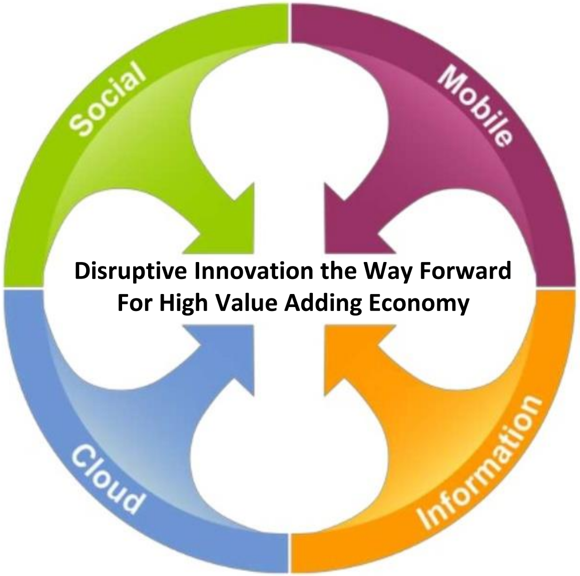
Presentation outline

- eSmart Systems
- Electric Vehicle (EV) situation in Norway
- Possible challenges with EV implementation
- The ChargeFlex project
  - Framework
  - Ongoing work
  - Some preliminary findings

eSmart Systems

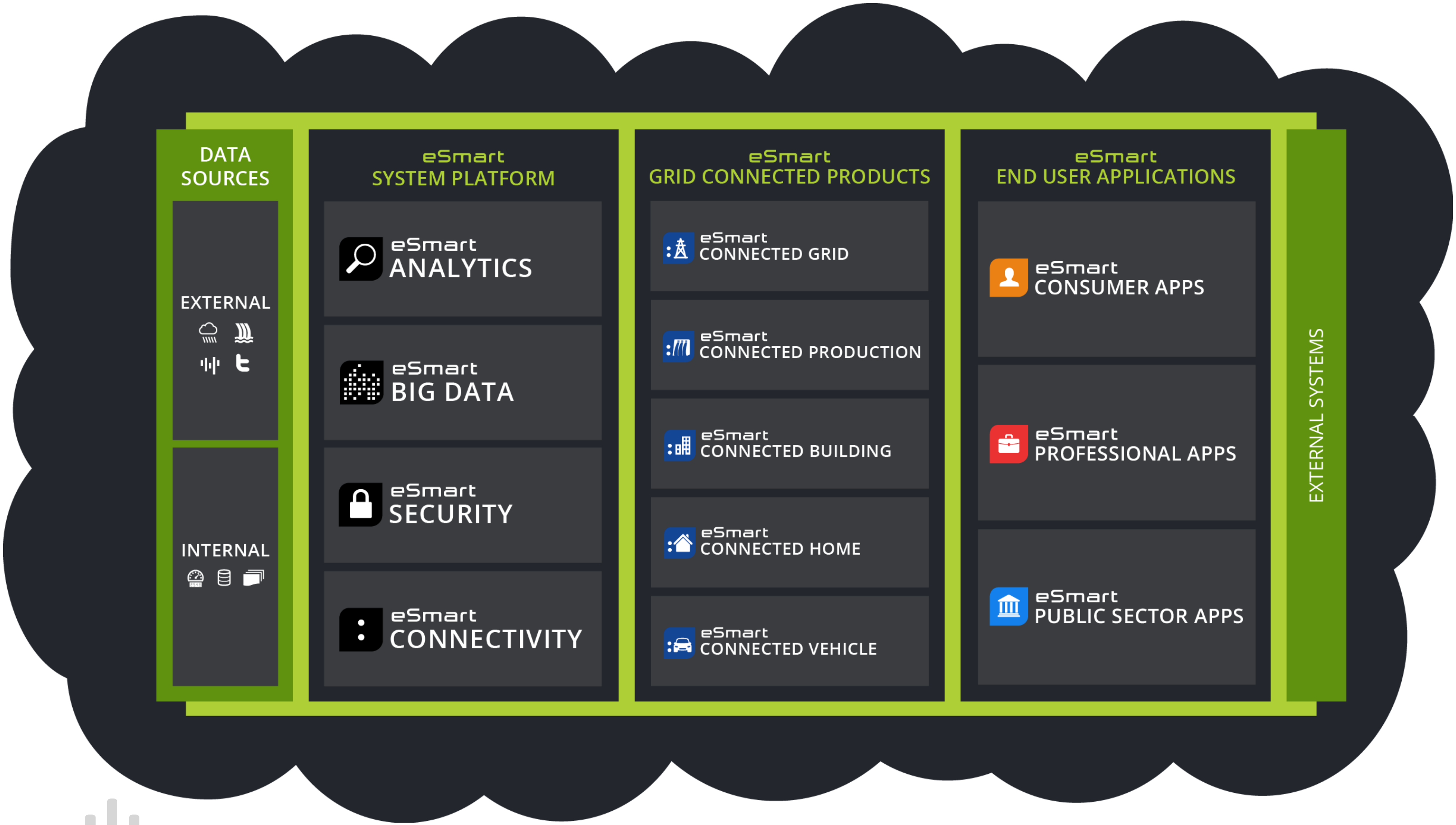
- Startup-company, established 2013
- «Child» of NCE Smart Energy Markets
- Located in Halden
- Funded partly through Innovation Norway, utilities and employees
- App. 30 employees, 3 full-time researchers
- Business idea based on 2 mega trends





The Nexus of Forces

Source: Gartner 2013



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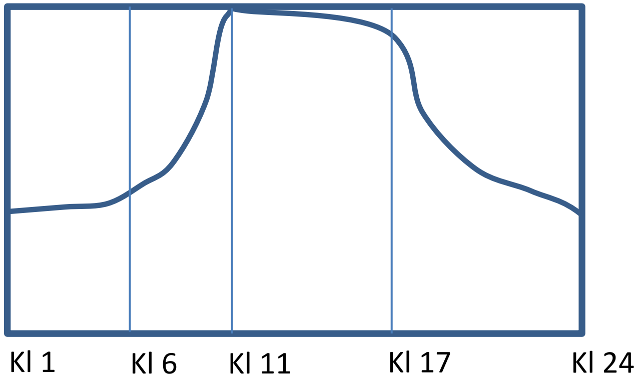
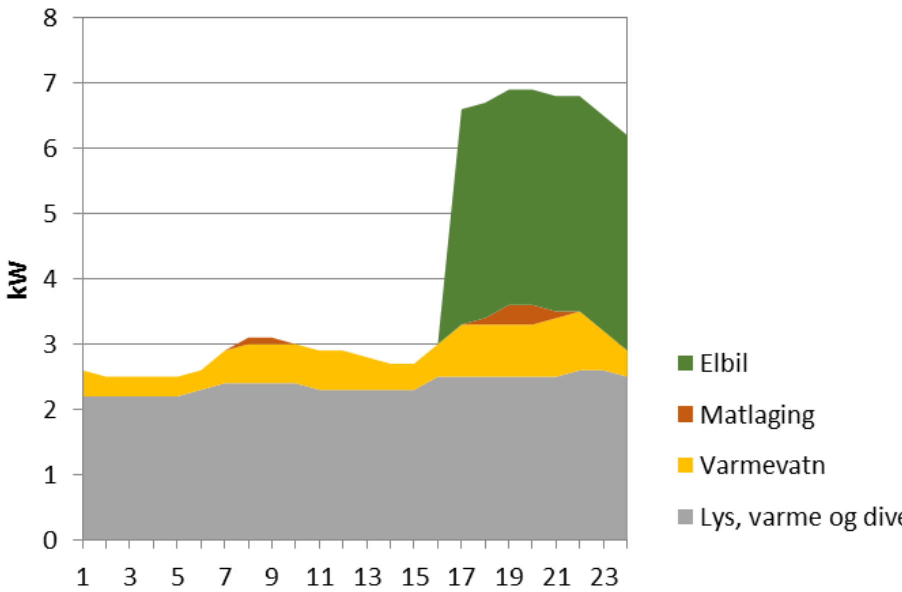
EVs in Norway

- Strong incentives:
  - No import tax
  - No VAT
  - Free toll roads
  - Free parking
  - Access to bus lanes
- Norway has the largest number of EVs per capita in the world. In April 2015 we passed 50.000 of a total 2.500.000
- In Q1 2015 23 % of all new cars sold in Norway were EVs (battery EVs and plug-in hybrid EVs)

Challenges with high penetration of EVs

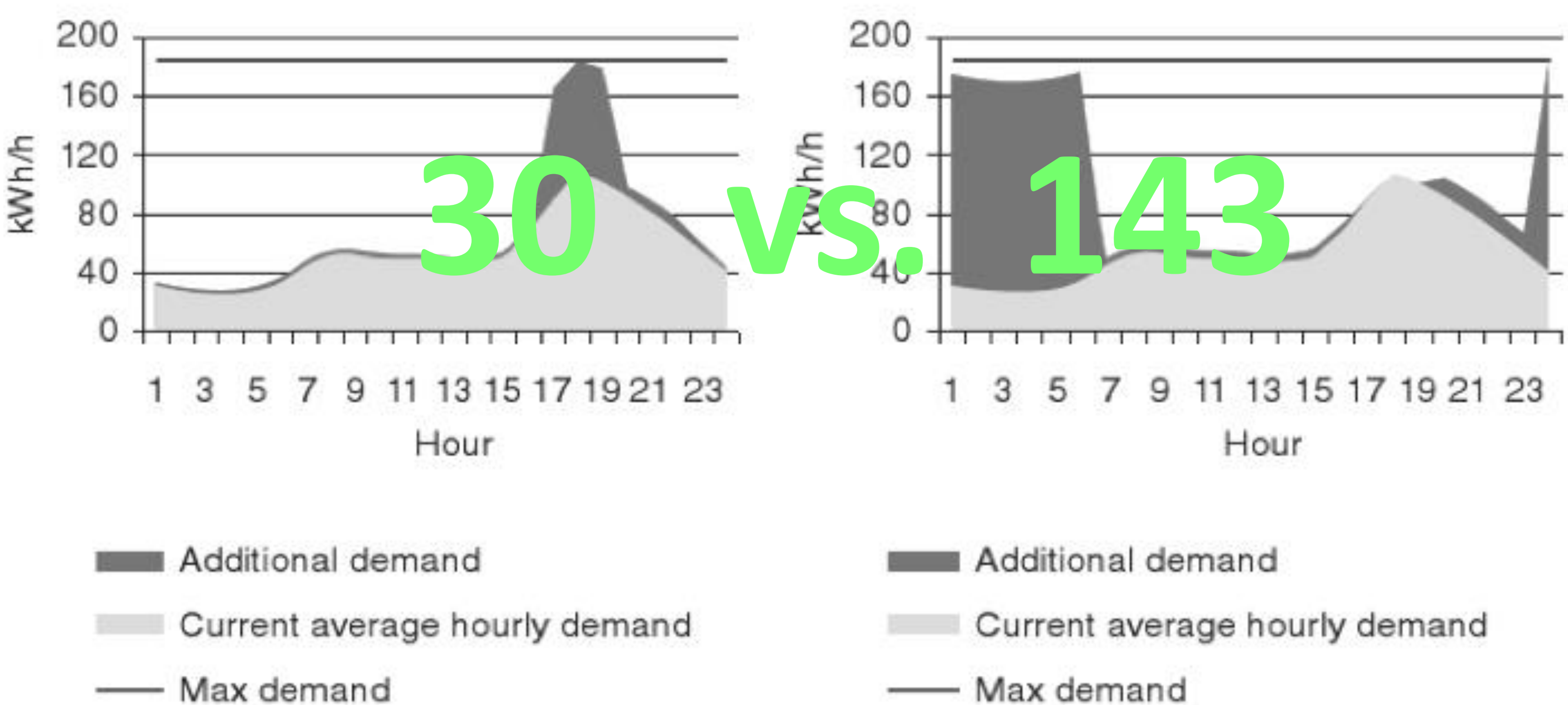
- No problem with energy
- Increased load peak in total electricity system, especially when charging at work (morning peak) and at home (afternoon peak).





Challenges with high penetration of EVs

- Uncoordinated simultaneous charging may lead to need capacity reinforcements in the local grid
- This is expensive, and will probably have small utilization time



Options to meet the peak challenge

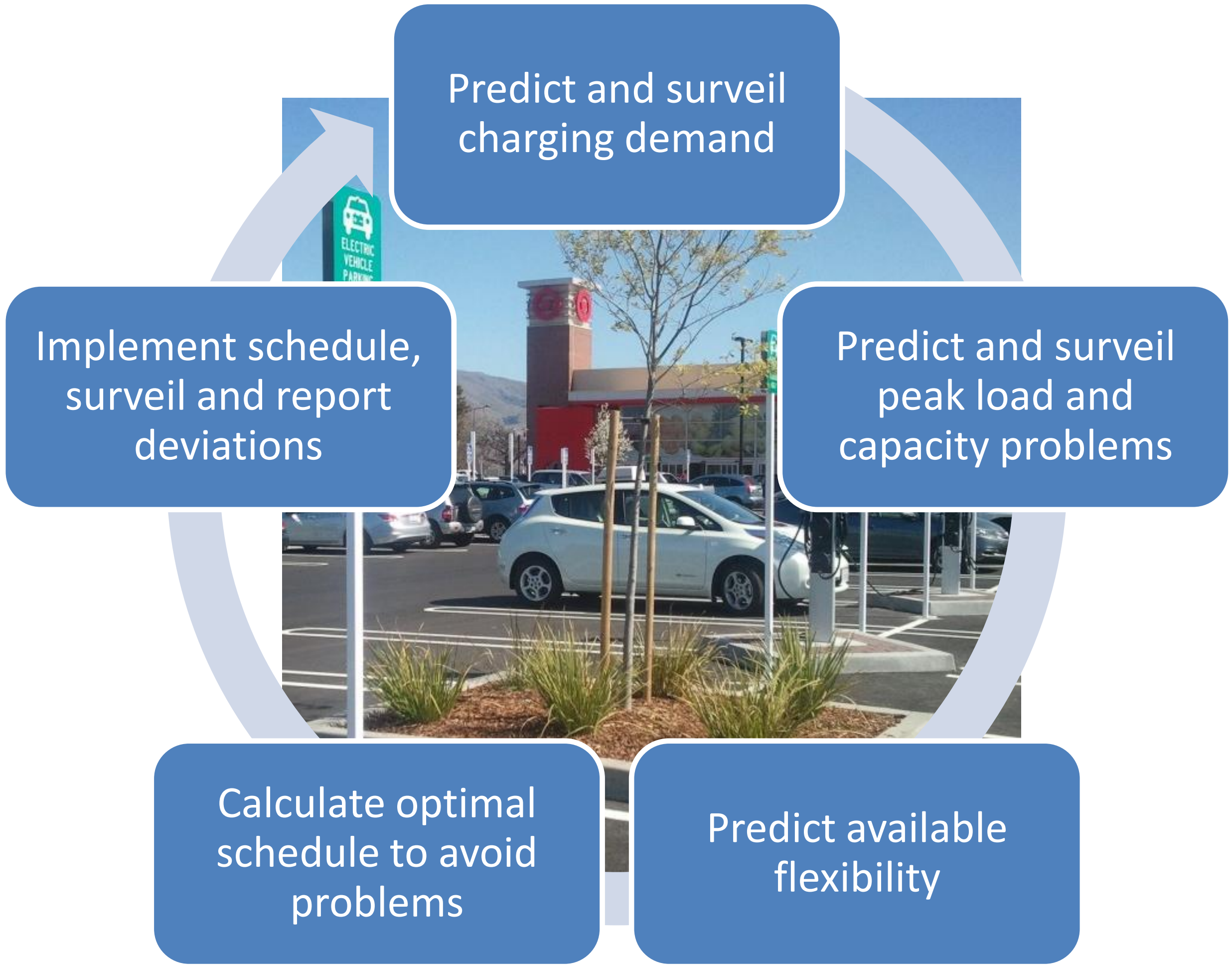
- Refuse installation of chargers
- Invest in new capacity at different levels
  - Heavy investments (who should pay?)
  - Low utilization rate
  - Environmental issues
- Utilize demand side flexibility
  - Demand response
  - Invest in storage technologies
- Control the EV charging process

ChargeFlex in brief

- 3 years, started 2015, app. 12 MNOK
- Funded by RCN Pioneering research and innovation
- «Increased grid capacity for EV charging through smart management of available flexibility»

Process and research need

- Big data
- Uncertainty
- Dynamics



Pilots

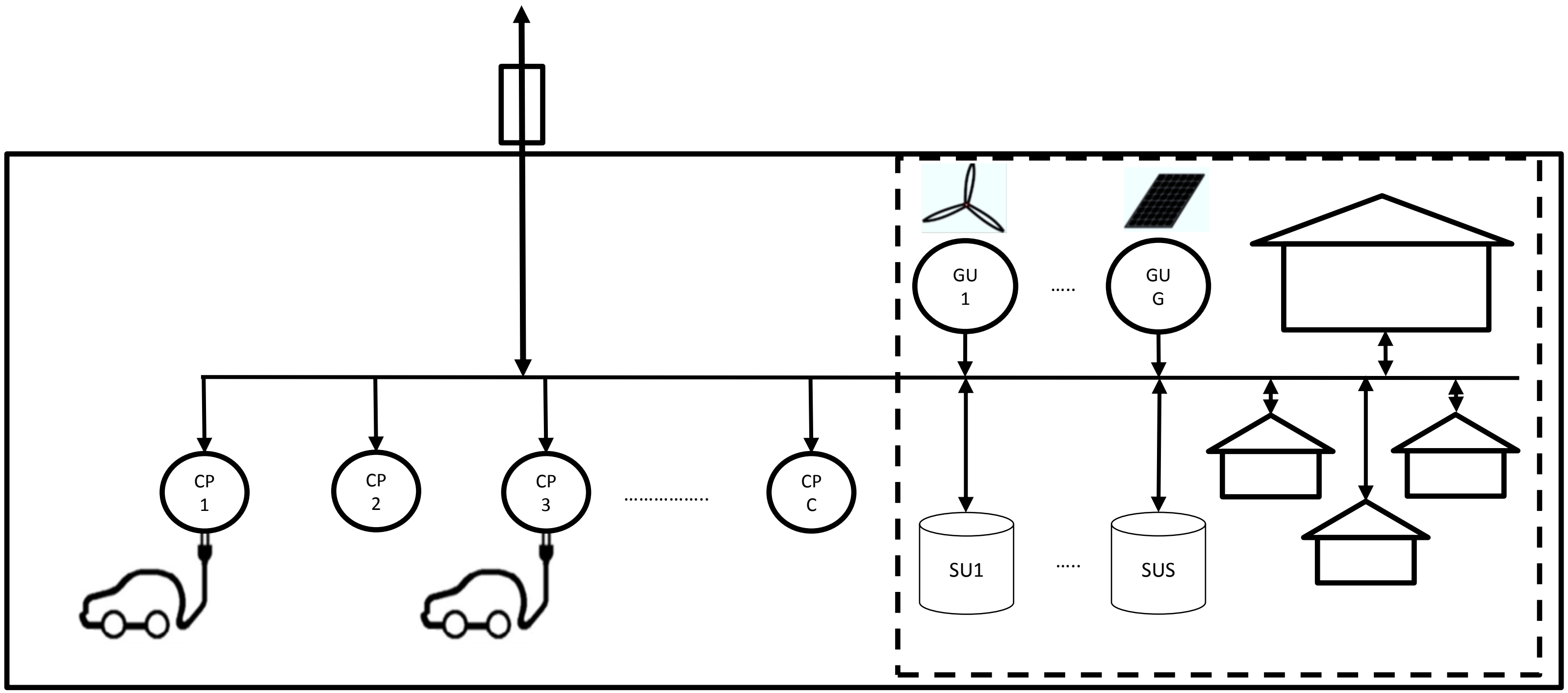
Ladetorget Moss

Remmen kunnskapspark

Ongoing work

- We want to develop decision support models for the operational phase that can work in real life
- How to keep load flow below a given limit?

Model and system boundaries



- Decisions:
  - Charging power to each charging point in each time slot
  - Utilization of storages and other flexible components

Possible management strategies

1. **Rule based strategy** — Simple, easy to implement
2. **Optimization based strategy** — More complex, requires more information

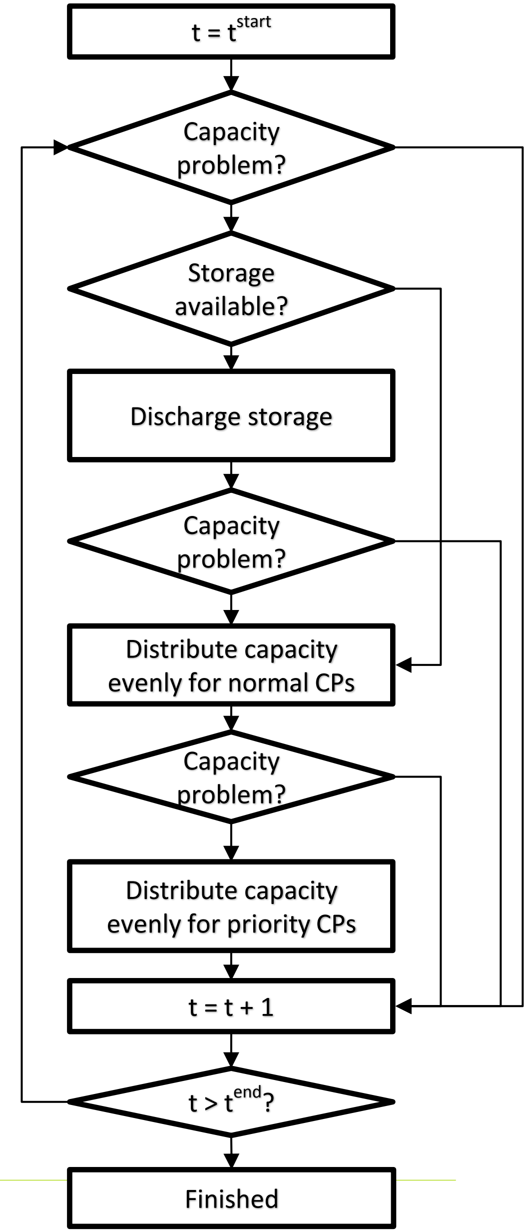
- For comparisons we also analyze
  - No control strategy (business as usual)
  - Full information strategy (Optimization based strategy with perfect foresight, used as a bench mark/upper bound)

- We introduce the concept of priority/normal charging
- Can not anticipate perfect foresight – decisions must be made on information available. We receive new information in each time slot or every time a new EV connects/disconnects

Rule based management strategy

- Simple algorithm
- Myopic/”here and now”
- Does not require extra information

Period	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
1								2,2	0,8	0,6	0,6	0,6	0,6			
2				2,5	2,2	2,6	2,5	2,2	0,8	0,6	0,6	0,6	0,6			
3										0,6	0,6	0,6	0,6			
4					2,2	2,6	2,5	2,2	0,8	0,6	0,6	0,6	0,6			
5							2,5	2,2	0,8	0,6	0,6	0,6	0,6			
6																
7																
8				5,0	4,4	5,1	5,0	4,4	1,7	1,2	1,2	1,2	1,2			
9				5,0	4,4	5,1	5,0	4,4	1,7	1,2	1,2	1,2	1,2			
10										1,2	1,2	1,2	1,2			
11		7,4	7,4	5,0	4,4	2,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0			
12														8,8	8,8	8,8
13									11,0	11,0	11,0	11,0	11,0	8,8	8,8	8,8
14																



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Optimization based management strategy

- Requires more information
  - Expected time to departure
  - Wanted charging volume (kWh)
- Linear program:

$$\min z = \alpha \sum_{c \in C} \sum_{y \in Y} \left(P^{pri} \Delta_{c,y}^{pri} + P^{norm} \Delta_{c,y}^{norm} \right) + \beta \sum_{t \in T} \chi_t^{purch} - \gamma \sum_{c \in C} \chi_{c,1}$$

- Minimize not delivered charging demand
- Minimize purchase/ maximize utilization of local generation

29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
0,0	0,0	0,0	0,0	0,0	0,0	3,7	0,0	3,7	3,7	3,7	3,7	0,0	3,7	3,7	3,7
0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,5	3,7	0,0	3,7	0,0	0,0	0,0	0,0	0,0
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,7	0,0
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	3,7	0,0	0,0	3,7	0,0	0,0	3,7
7,4	7,4	7,4	7,4	4,6	7,4	3,3	7,4	7,4	7,4	7,4	7,4	0,0	7,4	0,0	7,4
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0,0	0,0	0,0	0,0	0,0	7,4	7,4	7,4	7,4	7,4	7,4	0,0	7,4	7,4	7,4	7,4
7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	7,4	3,5	7,4	2,8
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
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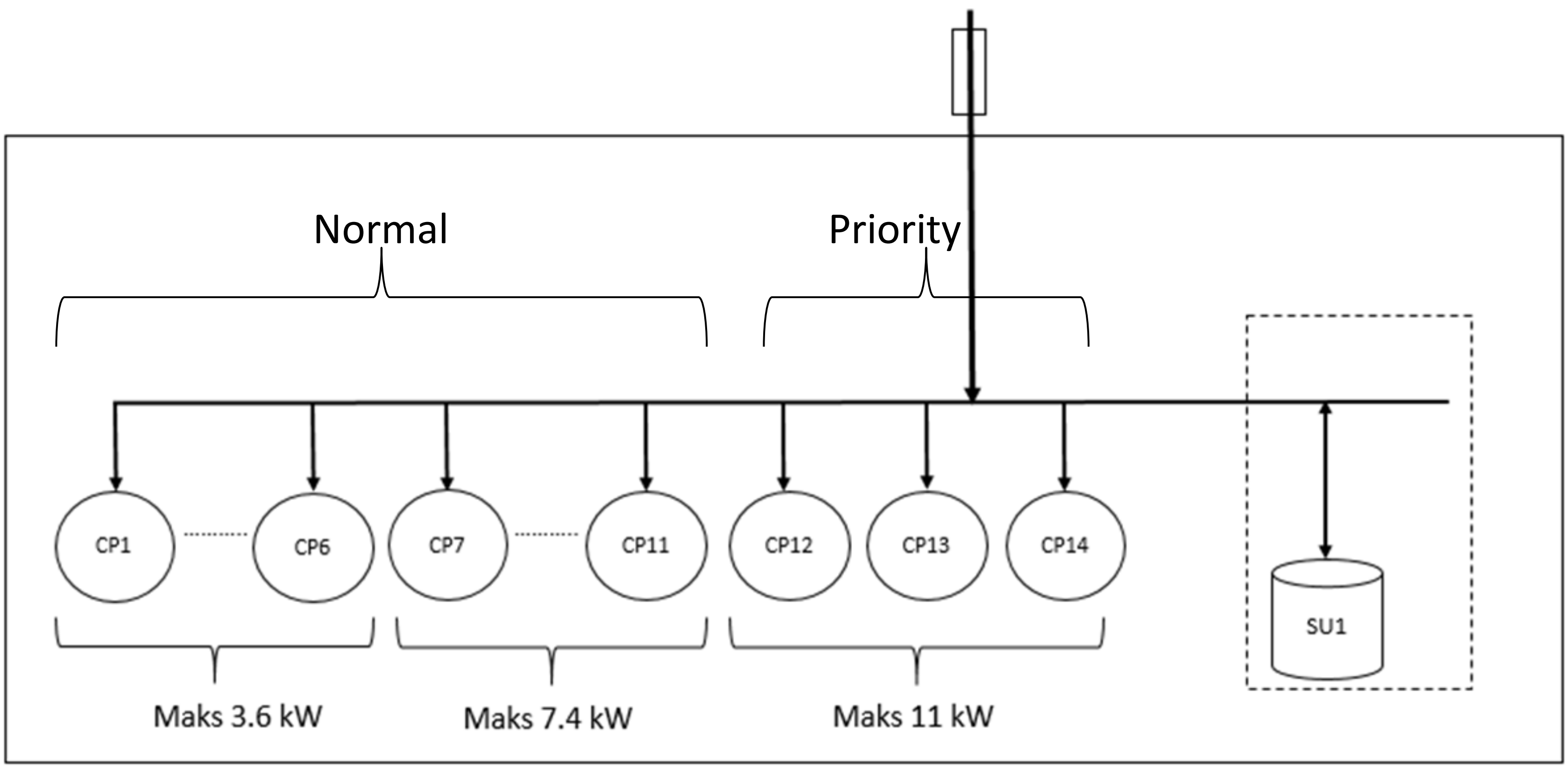
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Case study

- Based on a projected charging station in Halden
- 15 minutes' time slots

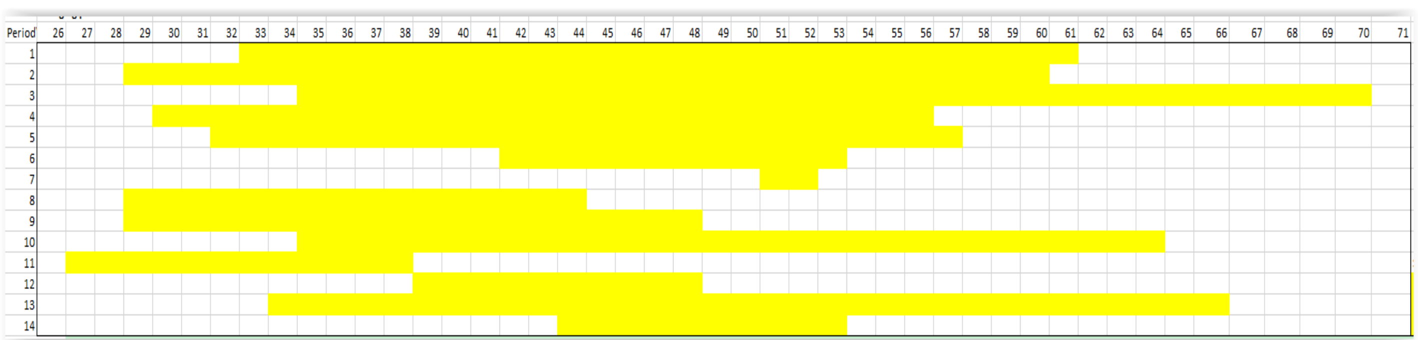


Input data on charging sequences from real life

	StartDateAndTime	Device	Resource	Time(min)	Volume	Unit
2	2014-12-01 08:44:59	Inspiria 1	DO1	418	36,02	kwh
3	2014-11-30 19:30:19	Inspiria 1	DO1	142	4,45	kwh
4	2014-11-30 15:42:13	Inspiria 1	DO1	7	0,49	kwh
5	2014-11-28 09:32:34	Inspiria 1	DO1	390	38,73	kwh
6	2014-11-26 07:59:29	Inspiria 1	DO1	395	32,06	kwh
7	2014-11-25 07:53:54	Inspiria 1	DO1	471	25,29	kwh
8	2014-11-24 08:08:48	Inspiria 1	DO1	507	43,52	kwh
9	2014-11-23 12:25:15	Inspiria 1	DO1	113	17,18	kwh
10	2014-11-21 08:04:00	Inspiria 1	DO1	405	57,36	kwh
11	2014-11-19 09:02:21	Inspiria 1	DO1	252	9,20	kwh
12	2014-11-18 08:04:59	Inspiria 1	DO1	478	49,69	kwh
13	2014-11-17 08:28:07	Inspiria 1	DO1	440	16,15	kwh
14	2014-11-14 23:12:05	Inspiria 1	DO1	45	11,38	kwh
15	2014-11-13 13:38:37	Inspiria 1	DO1	32	8,98	kwh
16	2014-11-12 08:06:17	Inspiria 1	DO1	172	37,13	kwh

Example dataset

Charging point	Start period	End period	Charging demand	Mode	Mean power demand
1	33	61	7,5	N	1,07
2	29	60	15,7	N	2,02
3	35	70	9,8	N	1,12
4	30	56	13,5	N	2,07
5	32	57	11,5	N	1,83
6	42	53	2,7	N	0,98
7	51	52	1,1	N	4,28
8	29	44	13,6	N	3,62
9	29	48	14,8	N	3,11
10	35	64	7,5	N	1,03
11	27	38	6,6	N	2,40
12	39	48	6,9	P	3,05
13	34	66	42,7	P	5,33
14	44	53	19,0	P	8,46
Sum			172,61		
Min	27	38	1,1		
Max	51	70	42,7		



Research questions

We want to analyse the management strategies in two directions:

1. Research question 1: How will the different management strategies perform given a specific setup?
2. Research question 2: How much grid capacity is needed for the different strategies to deliver all charging demand?

3. Research question 3: What is the value of the different management strategies?

Research question 1

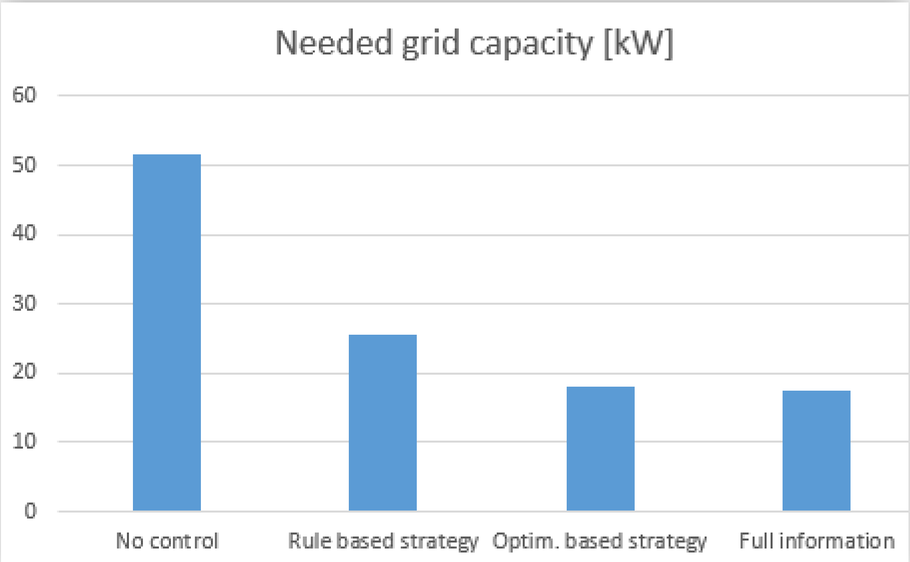
- How will the different management strategies perform?
- Example one specific case:

	Full info	Optimering		Regelbasert		Awik opt/regel.	
		kWh	%	kWh	%	kWh	%
Levert lading	172,6	169,8	98,4	140,8	81,6	29,0	16,8
Ikke-levert behov	0,0	2,8	1,6	31,8	18,4		
Målfunksjonsverd	683,0	690,0					
Sum kjøp	172,6	169,8		140,8		29,0	
Sum salg	0,0	0,0		0,0		0,0	

- Preliminary findings:
  - Optimization based results deviate little from full information
  - Rule based and optimization based deliver equal amounts of charging in cases with very small or large capacity
  - Optimization based outperform rule based in cases where full information meets the need
  - Optimization based uses local generation more efficiently

Research question 2

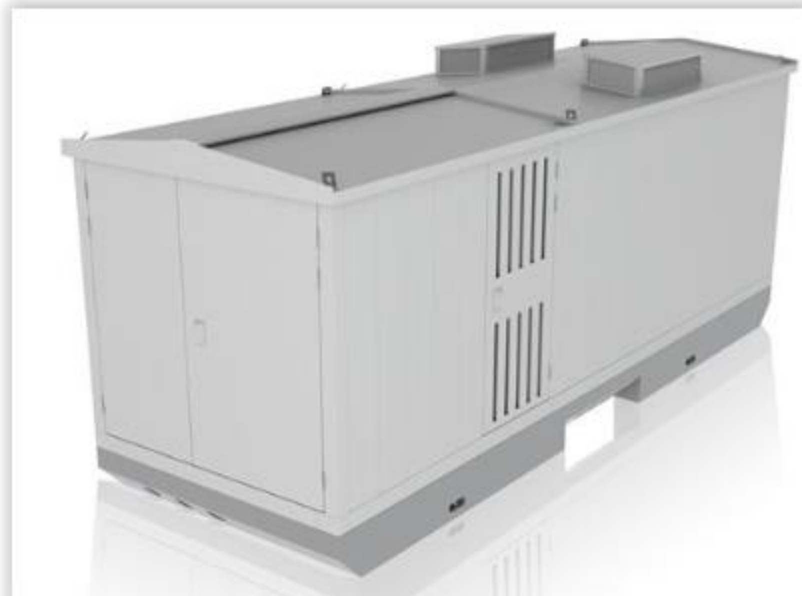
- How much grid capacity is needed for the different strategies to deliver all charging demand?
- Example:
  - No control: 51,7 kW
  - Rule based: 25,5 kW
  - Opti. based: 18,2 kW
  - Full information: 17,6 kW



- What can we learn?
  - The value of optimization based strategy is 33,5 kW (51,7 – 18,2) not needed capacity

Research question 3

- As an alternative: what storage size will deliver the same result?
  - 33,5 kW
  - 70 kWh
- Alternative valuation of optimization based management strategy: the cost of a storage with these parameters



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Summary and further work

- Data collection will start tomorrow ☺
- Work on management strategies will continue
- Results will be input to grid analysis
- Indirect control will be analysed
- Prediction work will start
- Business models work will start

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Thanks for your attention!

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