



UiO : **Department of Technology Systems**
University of Oslo

TEK5370 - L9 Grid Conversion

L9 from Grid to Smart Grid

Josef Noll,

Professor, University of Oslo, Department of Technology Systems

Secretary General, Basic Internet Foundation

Kjeller, Norway, m: +47 9083 8066, e: josef@jnoll.net



Oblig 5: Energy consumption in the home

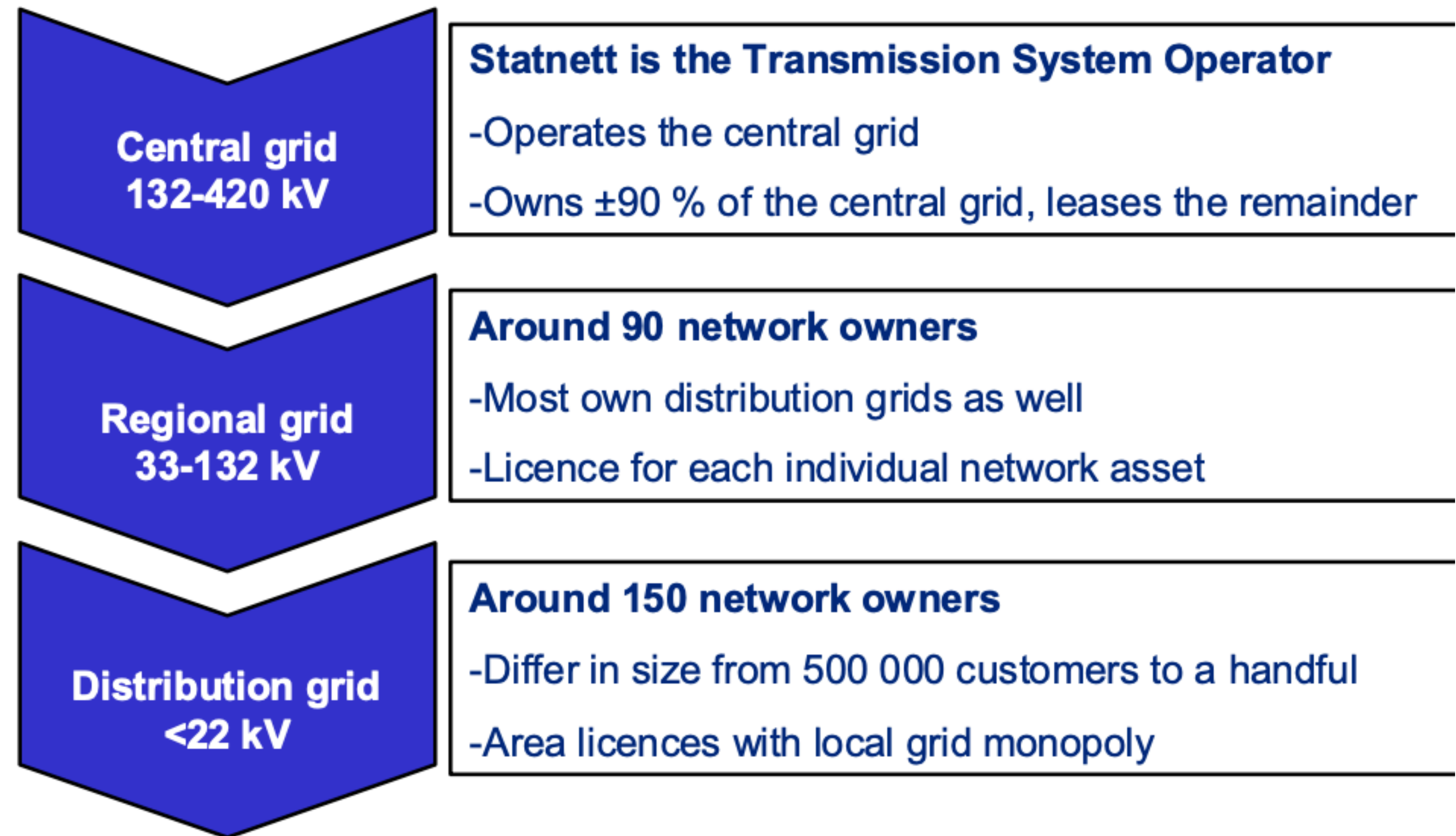
- ♦ 1) Home energy consumption
 - ➔ understanding of numbers
 - ➔ e.g. water heating
- ♦ 2) statistical analysis
 - ➔ “what can we read out from the data?”
- ♦ 3) Power provision and usage profiles
- ♦ 4) Electric cars and their influence on the grid

Month	Oslo (kWh)
Oktober 2018	1050
September 2018	1350
August 2018	1150
Juli 2018	500
Juni 2018	900
Mai 2018	1050
April 2018	1500
Mars 2018	2200
Februar 2018	2600
Januar 2018	2700
Desember 2017	2400
November 2017	2100



Goal - a stable grid at minimal costs

- ✦ TSO - Statnet
- ✦ Regional Grid (Hafslund, BKK)
- ✦ DSOs



Source: NVE



Energy usage Norway

♦ Energy production (2018)

- ➔ 95.8% water
- ➔ 2.3% burning
- ➔ 1.9% wind



	produced [TWh]	used [TWh]	Export/ Import [TWh]			
2018	145.7	135	10			
2017	149.3		21.3/6.1			
2016	149.6					
2014						



[1] <https://www.tu.no/artikler/norge-brukte-rekordmye-strom-i-fjor/430005>

[2] <https://enerwe.no/norges-stromforbruk-okte-til-1354-twh-mens-produksjonen-falt-til-1457-twh-i-2018/166697>

Long distance line: NorNed, 580 km HVDC, 700 MW

- ♦ Read and discuss
<https://owncloud.basicinternet.org/index.php/s/RnDuts87lhHmajn>
- ♦ NorNed, the 580 km HVDC (High Voltage Direct Current)
 - thermal, dielectric
 - marine environment (hydrographical, bathymetric, and geophysical conditions)
 - protection needs
 - permission requirements
 - installation spread and methods
 - operational requirements.

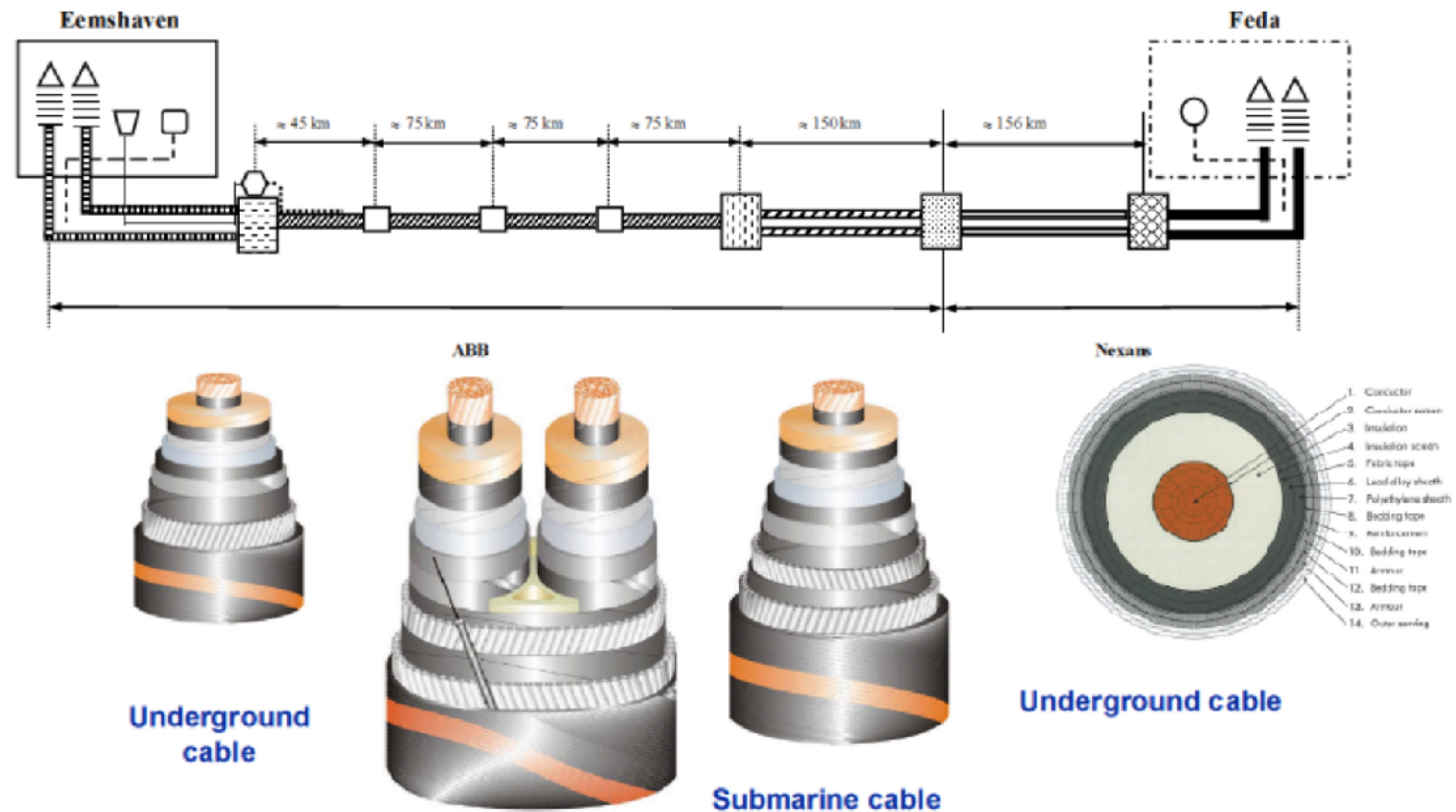


Figure 2 – Cable types

NorNed - Facts

	Dutch underground	Shallow waters 1	Shallow waters 2
Route length	1.4 km	270 km	150 km
Conductor size	790 mm ²	790 mm ²	790 mm ²
Insulation	20 mm	20 mm	20 mm
Armouring	Single layer	Double-layer	Double-layer
Configuration	2 x single-core	Two-core (FMI)	2 x single-core

Figure 3 - Shallow part cable system

- ♦ power to be transmitted: 700 MW continuous
 - measured at receiving end
- ♦ +/- 450 kV voltage level
 - transient voltage level: 900 kV
- ♦ maximum dimensioning current in this case: 824 A



Figure 6 – The deep part of the NorNed cable route



Energy balance Norway

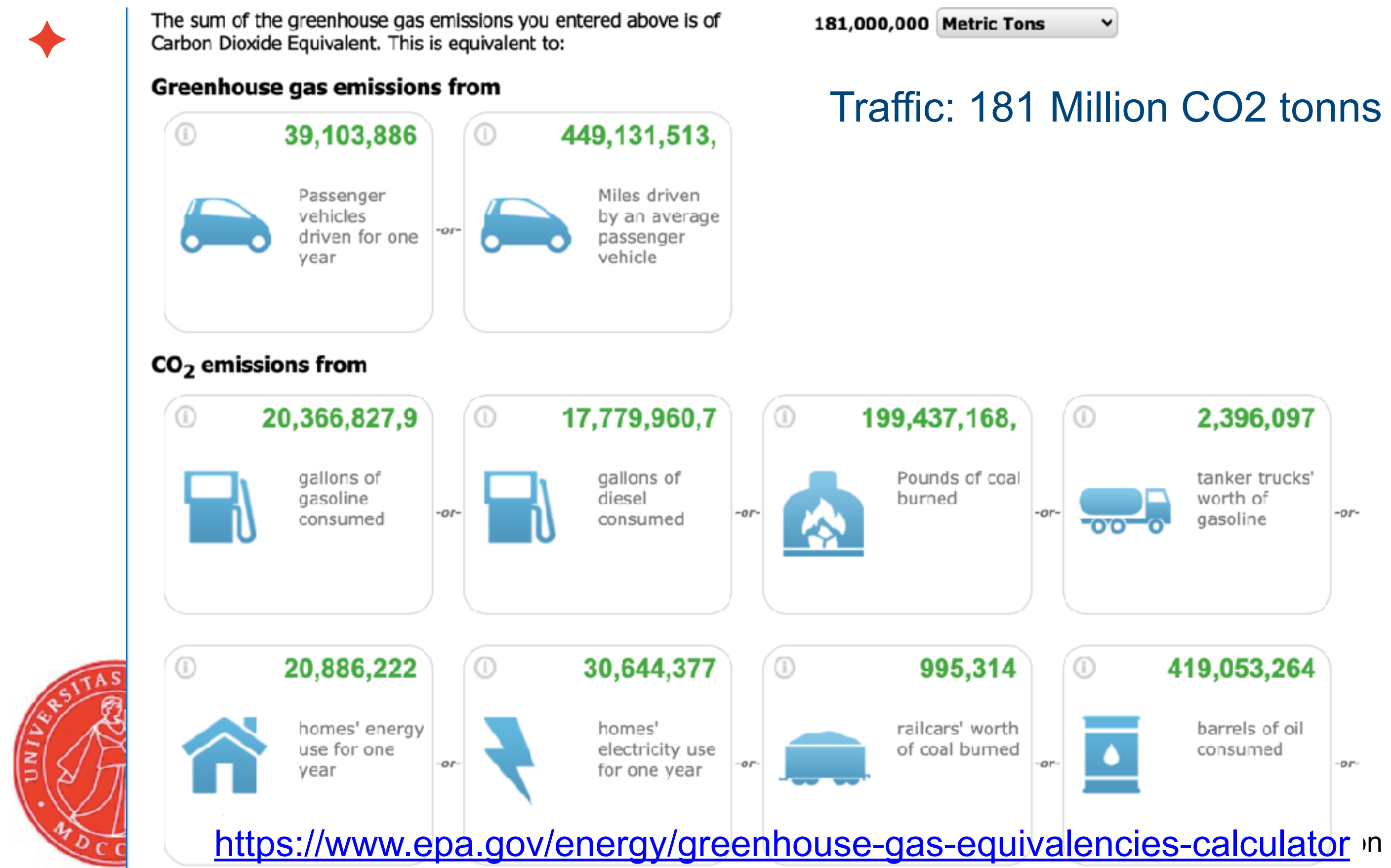
- ✦ Calculate in %
 - ➔ production
 - ➔ industry
 - ➔ transport
 - ➔ households (see next page)
 - ➔ warming/usage
 - ➔ transport household

Energybalance Norway [TWh]	2017	2018	Change [%]
Production of primary energy	2483	2394	-3,6
Import	114	129	13,7
Export	2271	2186	-3,8
International Storage	9	9	6,8
Change in availability	11	-10	-184,9
Netto inland resources (SUM above)	328	319	-2,8
transformation	6	1	-76,6
own energy in energyproducing	76	76	0
losses	9	10	16,4
Netto inland incl. resources	241	244	1,1
	28	28	2
	213	216	1
Industry	72	73	1,4
Transport	54	53	-0,8
Other sectors (incl. households)	88	89	1,8
Statistical errors	8	-10	-223,3

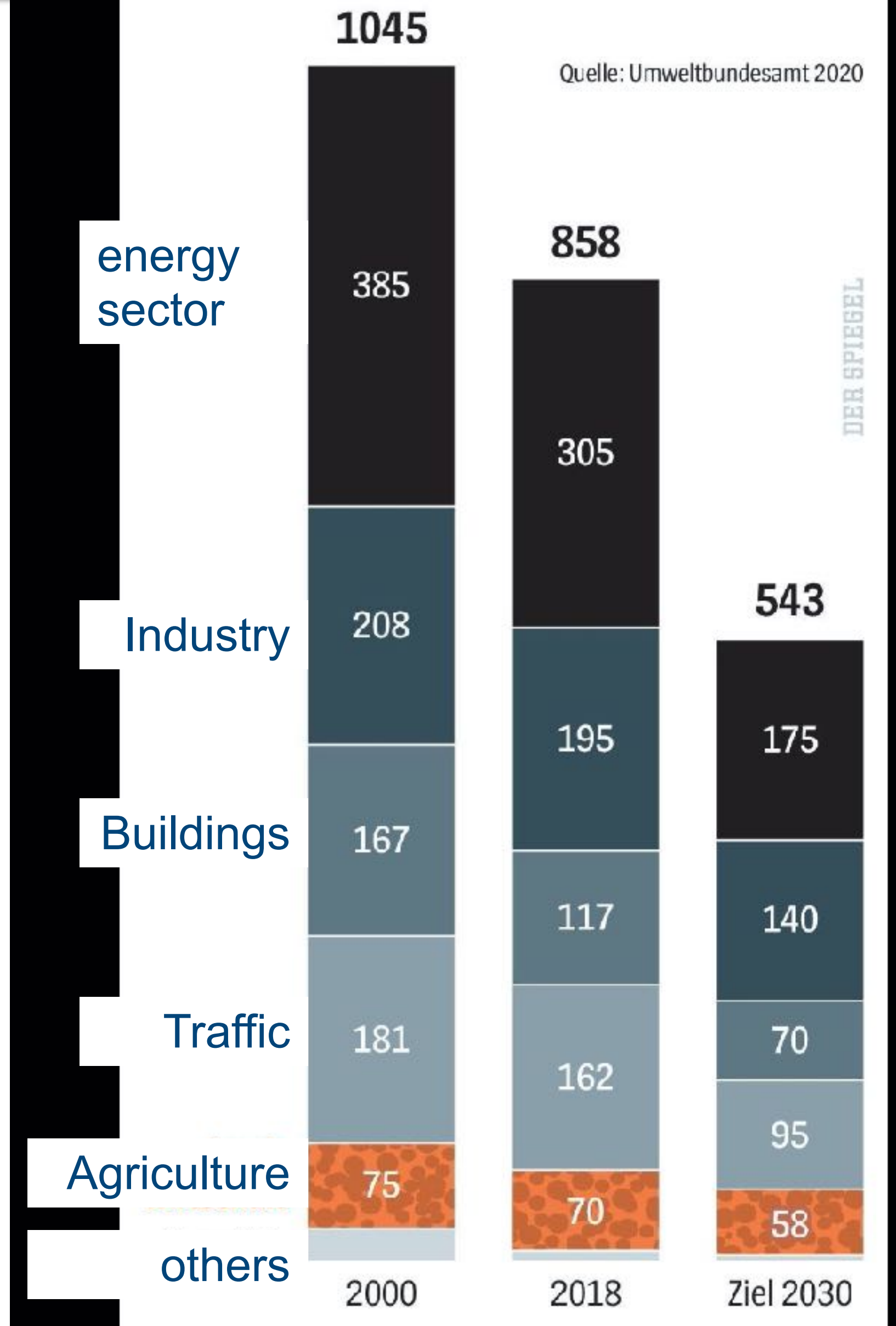


Energy conversion

✦ To what extent can Norway contribute to the energy conversion in Germany?



CO2 emissions in Germany by sector, in Million Tonns CO2 equivalent



Energy Consumption Households Norway

- ✦ Calculate the % of usage for
 - ➔ heating
 - ➔ Electricity based heating
 - ➔ Transport

Energy consumption households Norway	2014	2015	2016	2017	2018
Electricity	36918	38690	40045	40442	40537
Coal	-	-	-	-	0
Oil	777	725	807	656	421
Parafin	226	187	174	124	112
LPG	78	57	97	90	103
Wood	5268	5620	5411	4981	5637
Natural Gass	44	39	42	89	9
Remote varm water	1000	1037	1212	1271	1284
Car Petrol (benzin)	10150	9537	8899	8524	8096
construction diesel	730	742	755	768	781
Car Diesel	10152	10654	10582	9270	9567
Bio petrol	611	682	1582	2357	1783
Total incl petrol/diesel [GWh]	65953	67971	69606	68574	68331
Total exclusive petrol/diesel [GWh]	45040	47098	48543	48422	48884
Energy/household [kWh]	28656	29138	29458	28849	28362
Energy/person [kWh]	12838	13097	13293	12995	12903
El. energy/household [kWh]	16040	16586	16948	17014	16825
El. energy/person [kWh]	7186	7455	7648	7664	7655
#people	5137429	5189894	5236151	5276968	5295619
#household	2301546	2332722	2362884	2376971	2409257

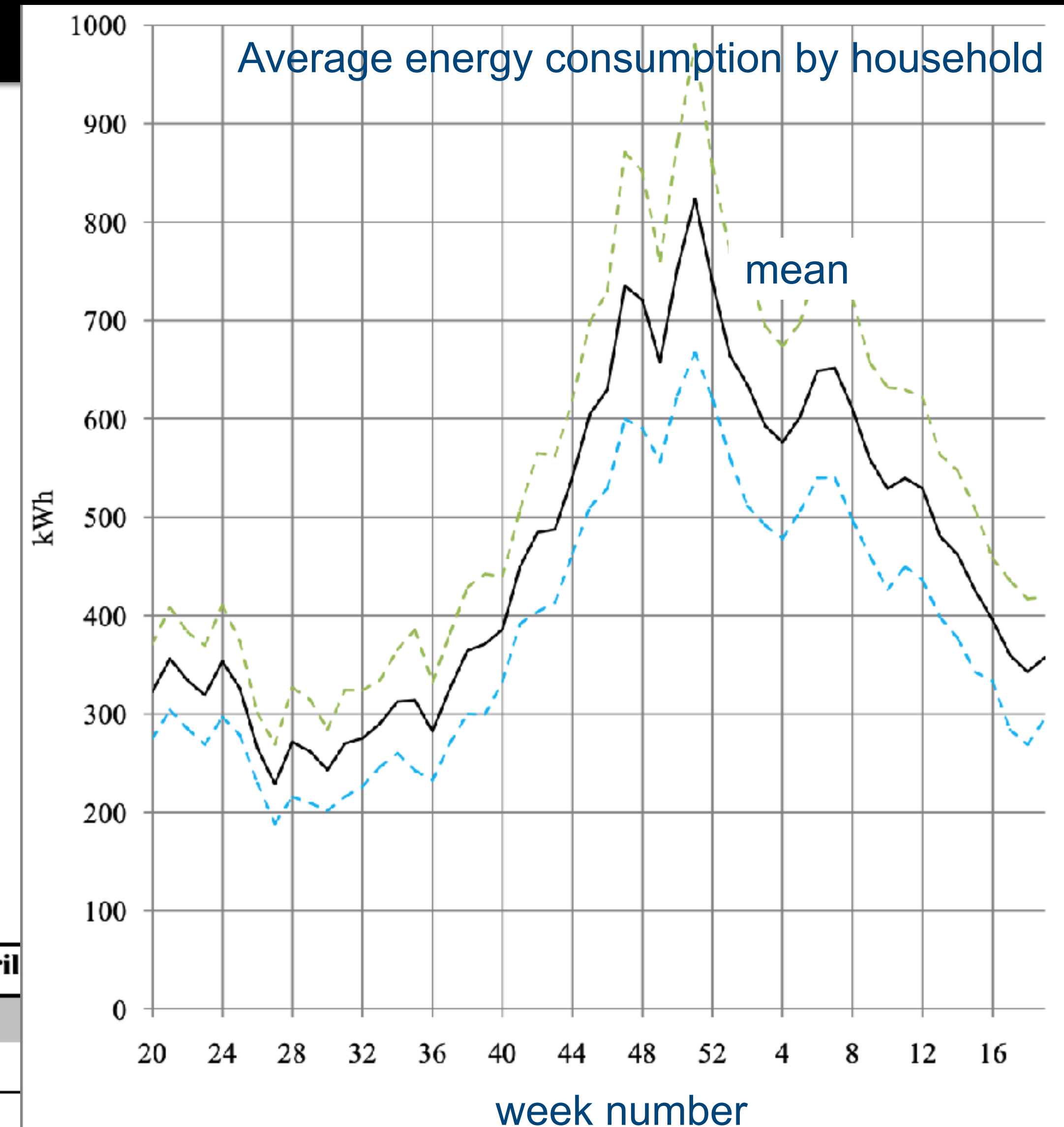


Electricity variability

- ♦ Strong variation during the year
→ heating with electricity

Monthly mean temperature Ørlandet

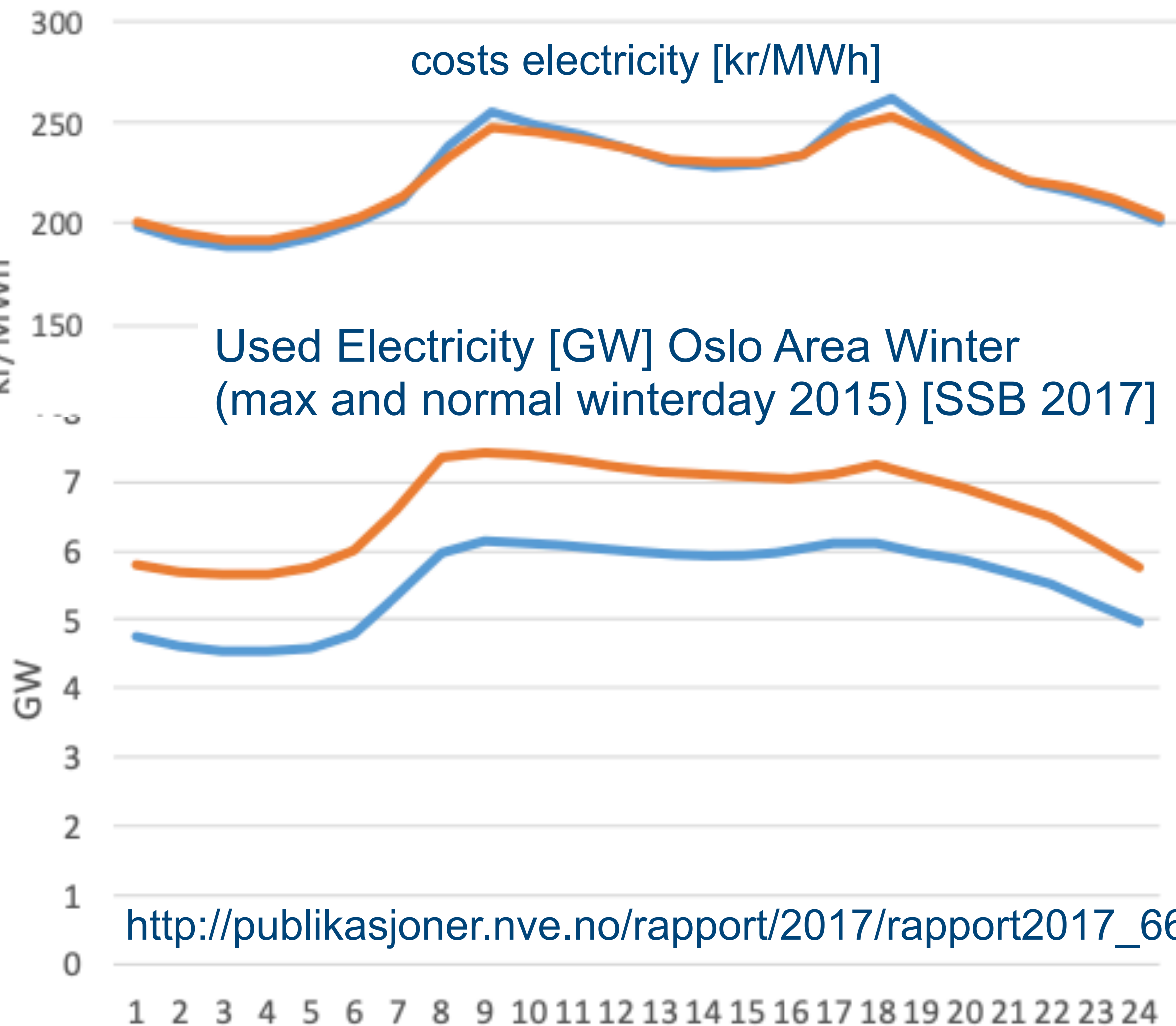
Måned	Mai	Juni	Juli	Aug	Sept	Okt	Nov	Des	Jan	Feb	Mars	April
Middel, °C	7,7	10,1	14,4	14,2	10,6	7,6	-1	-3,7	1,6	-0,5	2,1	7,2
Normalår, °C	8,7	11,4	12,7	12,9	9,9	6,9	2,6	0,5	-0,7	-0,3	1,4	4,1



<https://www.sintef.no/globalassets/project/eldek/publisering/stromforbruk-i-norske-husholdninger.pdf>

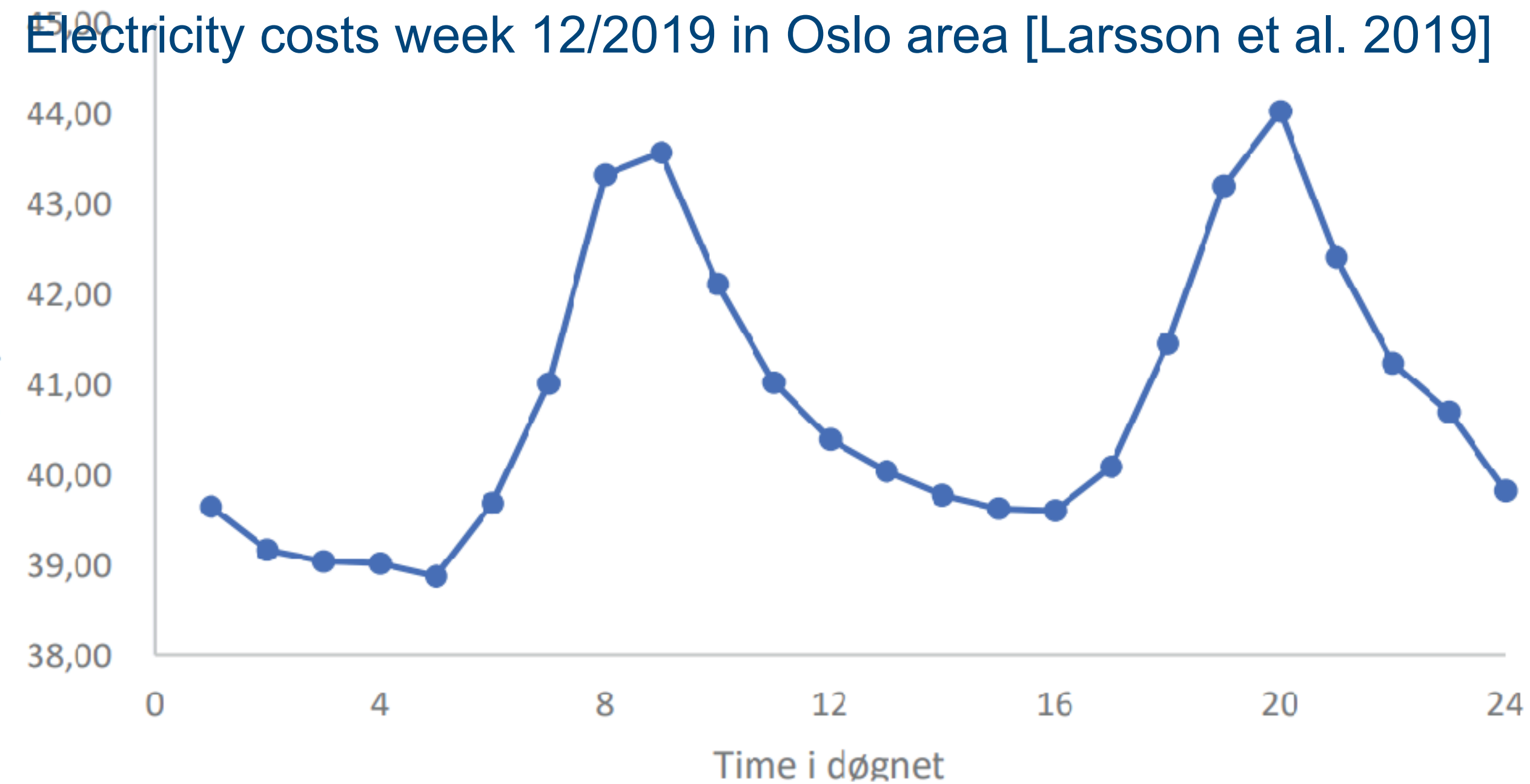


Electricity usage and costs (Oslo)



http://publikasjoner.nve.no/rapport/2017/rapport2017_66.pdf

Grid Conversion



Tools in house - 2011 (no electrical cars)

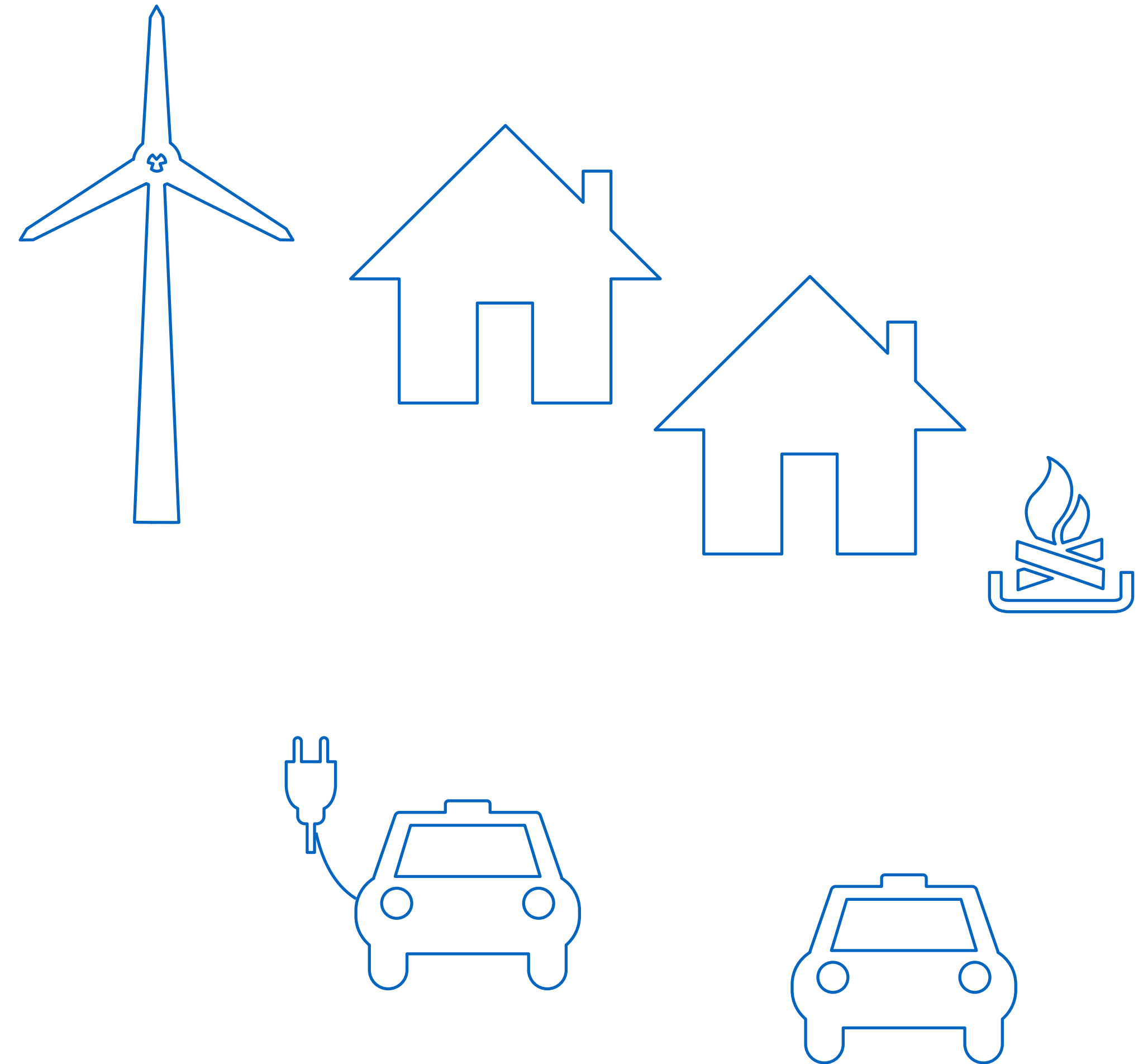
	Målt forbruk for 2 uker	Årlig gjennomsnittsförbruk	Eierskap	Korrigert årlig gjennomsnittsförbruk
	[kWh/apparat]	[kWh/apparat]	[%]	[kWh/enebolig]
Vaskemaskin	8,278	215,217	100 %	215,217
Tørketrommel	15,406	400,547	27 %	108,148
Kjøleskap	42,006	1092,156	82 %	895,568
Fryser	25,457	661,892	100 %	661,892
Oppvaskmaskin	10,482	272,522	82 %	223,468
Komfyr	8,610	223,864	36 %	80,591
TV	13,949	362,672	91 %	330,032
PC	5,954	154,794	54 %	83,589
Varmtvann	127,463	3314,042	73 %	2419,251
Belysning	2,058	53,513	63 %	33,713
Kjøkkenutstyr	31,444	817,551	18 %	147,159
Annet	38,915	1011,779	18 %	182,120
Sum målt	330,021	8580,548	-	5380,746

<https://www.sintef.no/globalassets/project/eldek/publisering/stromforbruk-i-norske-husholdninger.pdf>



Why measuring the load?

- ♦ Upgrade of lines
- ♦ Stability of grid
 - know the load
 - proactive maintenance
- ♦ Variability due to natural resources
- ♦ Increased demand
 - car charging
- ♦ Assume: All transport sector becomes electrical



<https://www.sintef.no/globalassets/project/eldek/publisering/stromforbruk-i-norske-husholdninger.pdf>



Energy prices - a European perspective

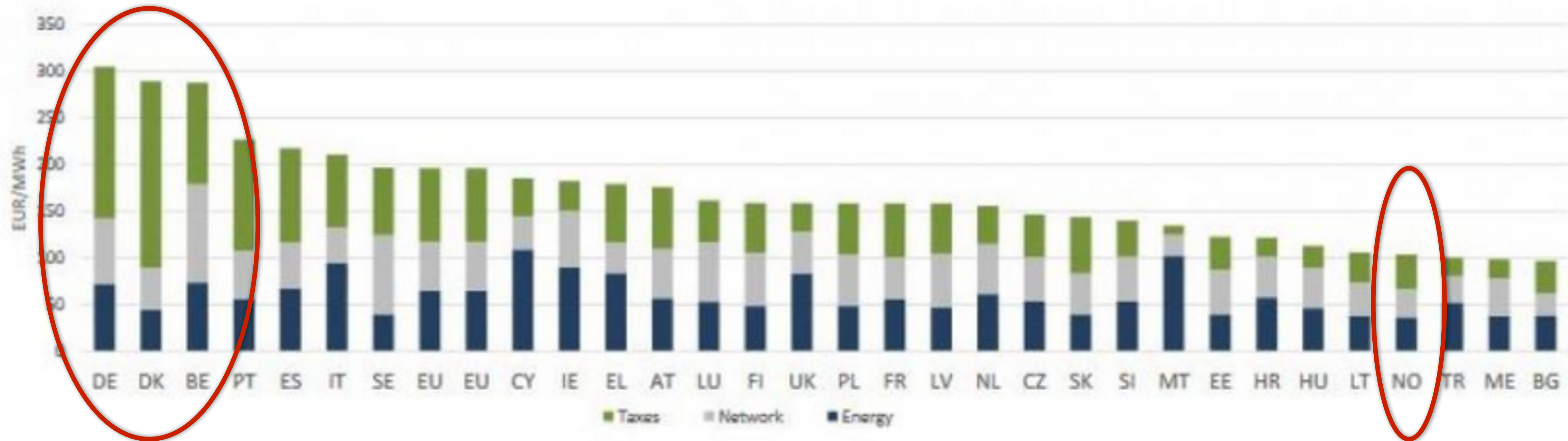


Figure 2 — Household electricity prices in 2017 (most representative consumption band) — Source: DG ENER in-house data collection³

[source: <https://www.cleanenergywire.org/factsheets/what-german-households-pay-power>]

- ♦ In 2014, an average German household used less than a third of the power of its US equivalent, and also less than an average household in other major industrialised countries in Europe, such as France, Britain, or Spain.



Discussion of “Upgrading Electricity Grid”

- ♦ Energy in the home will be almost doubled
 - ➔ Electric cars with charging at home
- ♦ Requires new infrastructure _OR_ Smart Grid
- ♦ Open issues?
 - ➔ Do we have enough energy to redistribute?
 - ➔ What are the implications on the user site?

