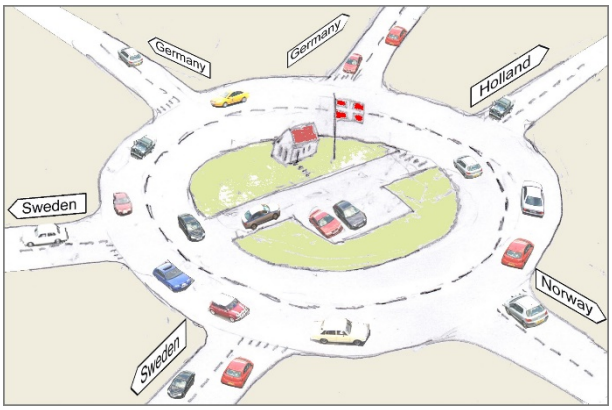
Denmark is a Roundabout in the European Grid

The Danish net import of electricity is about 23% of the consumption (2019). Imported electricity is not included in the *emission inventories*. Thus, import of electricity is a simple way to reduce the formal emission of GHG (greenhouse gases).

Nevertheless, some people have asked me if the imported electricity is black or green.

It is difficult to assess the origin of imported electricity, consumed in Denmark. It is necessary to make some assumptions. Based on meter values from six interconnections, there are numerous possible combinations and just as many possible results.



By counting the number of cars for each branch of a roundabout, it is possible to quantify total traffic flows, but the cars are mixed in the roundabout and we cannot follow each car from the entry to the exit of the roundabout.

Net import: 69% of the hours in 2019

Hourly metering values are used for analysing electricity flows in 2019. Denmark had a net import for 6032 of the year's 8760 hours. For each of these hours, the incoming traffic exceeds the outgoing traffic. It is possible to specify total incoming traffic for the hour by interconnector. The Danish net import is consumed locally. The rest is transit.

By assuming that import and transit have the same composition of origin, it is possible to specify the origin by branch. Export data can be used directly (table 1).

	DK import	6.032	hours
	Total	Total	Adjusted
	Import	Export	Import
	GWh	GWh	GWh
DKW-NO	3196	1076	2226
DKW-SE	1620	627	1057
DKW-DE	2611	1244	1474
DKE-SE	2976	535	1928
DKE-DE	1536	836	947
DKW- NL	613	207	396
	12552	4524	8027

Table 1 – DK exchanges during import hours in 2019

'Adjusted import' can be seen as a fair estimate of the origins of locally consumed Danish electricity import. The amount was 8 TWh in 2019 or 23% of the Danish electricity consumption.

The distribution of locally consumed import by nationality is shown in table 2 together with a specification of transit.

The supplying countries were Sweden (3.0 TWh), Germany (2.4 TWh), Norway (2.2 TWh) and Holland (0.4). The Cobra interconnector to Holland was commissioned in September 2019.

We do not know if the imported electricity was black or green.

Total	import	15837	GWh
	of which		
2019	to DK	Transit	Transit
		Origin	Destinat.
Country	GWh	GWh	GWh
NO	2226	1264	2251
SE	2984	1889	2799
DE	2421	4414	2291
NL	396	243	469
	8027	7810	7810

Table 2 - Import and transit by country in 2019

Table 2 shows that the transit traffic had the same magnitude as locally consumed import in 2019. While the import is for only the 6032 hours with net import, the transit is for all 8760 hours of the year. Transit via Denmark from Sweden to Sweden and from Germany to Germany may be included.

Verification

The total electricity import to Denmark was 15837 GWh in 2019 (table 3). This figure can be divided into 8027 GWh 'adjusted' import and 7810 GWh transit (table 2).

This import is valid for the 6032 hours with net import to Denmark.

DK	2019		
	Total	Total	Net
	Import	Export	Import
	GWh	GWh	GWh
DKW-NO	3384	3300	84
DKW-SE	1837	1436	401
DKW-DE	4136	1689	2446
DKE-SE	3487	1696	1791
DKE-DE	2346	1297	1049
DKW- NL	649	620	28
	15837	10038	5799

Table 3 - Total import and export in 2019

	DK export	2728	hours
	Total	Total	Adjusted
	Import	Export	Export
	GWh	GWh	GWh
DKW-NO	188	2224	943
DKW-SE	217	809	328
DKW-DE	1525	446	157
DKE-SE	510	1161	455
DKE-DE	810	461	185
DKW- NL	36	414	161
	3286	5514	2228

Table 4 - DK exchanges during export hours in 2019

To get the full picture, even an 'adjusted' export for the remaining 2728 hours is needed (table 4). The sum of the adjusted export (2228) and the transit (7810) equals the total export (10038, table 3).

The difference between adjusted import (8027) and adjusted export (2228) is the net import (5799, table 3). All figures seem to be consistent.

Danish wind power gaps and overflows covered by other countries

The increasing share of wind power in Denmark changes the shape and the amount of residual load, which is the electricity demand less wind and solar power. The residual load is the domestic market of the thermal power plants. It reflects the variations of the wind power.

2019	Load	Residual
	MW	MW
Max	5841	5569
Min	2330	-1604
Range	3511	7173
Load fac.	67%	43%

Table 5 – The fluctuating residual load

The variation range of the residual load is twice the load variation (table 5), and the load factor is only 43% (3767 duration hours). Base load units are unsuitable for this market. The result is that the wind power gaps are covered by electricity import.

When the high Danish share of wind power is mentioned as a model for other countries, it should also be explained that it is a crucial condition that other countries are ready to cover the gaps and to purchase the overflow. Danish grids and interconnections serve the Danish need for exchange of electricity plus a similar amount of other countries' need for electricity transit. The international electricity markets have made the Danish strategy possible.

Imaginative domestic solutions have been proposed, but realistic concepts are still missing. The Danish tradition for strong interconnections is the most efficient measure until now, but the market for balancing services may be more strained when the wind power penetration in the neighbouring countries reach the present Danish level.