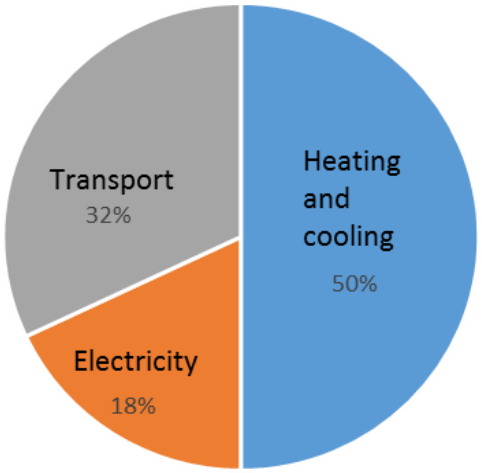
The benefits and effects of cross-border transmissions

Torjus Folsland Bolkesjø
Yi-kuang Chen
Jon Gustav Kirkerud

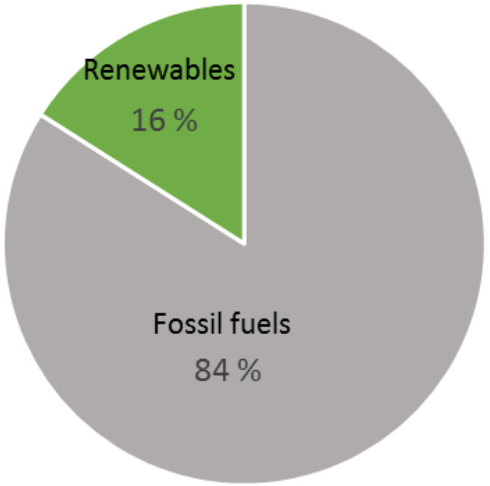
NorENS prosjektmøte
Ås, 28/05/2019

Utfordrende områder i dekarboniseringen av Europa: Varme, transport og fleksible energisystemer

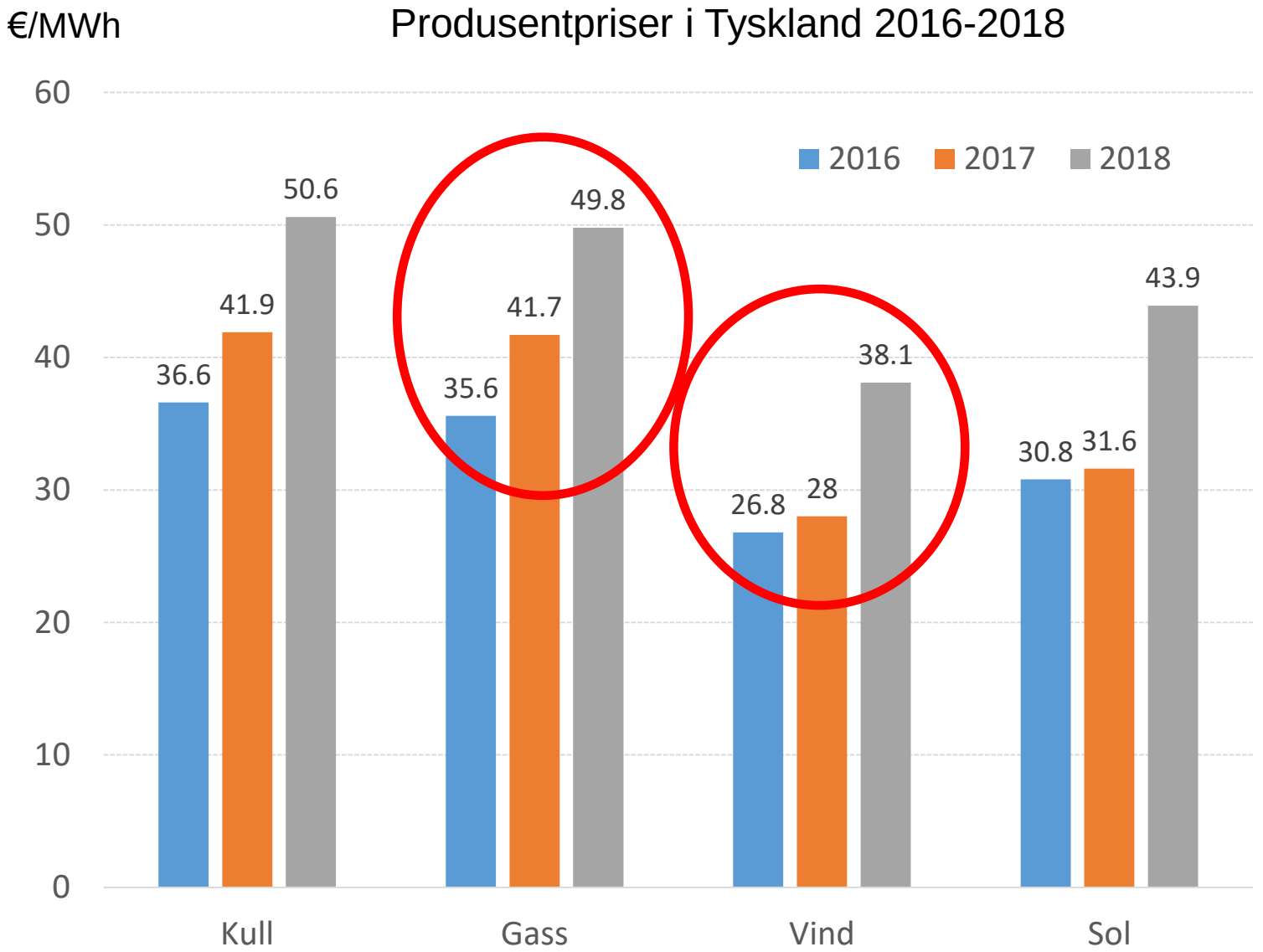
Fordeling av EUs energiforbruk



Andeler fossilt og fornybart i varme-sektoren



Kilde: EU Heating and Cooling strategy



Kilde: Fraunhofer

Lokalisering av fornybarproduksjonen blir viktigere

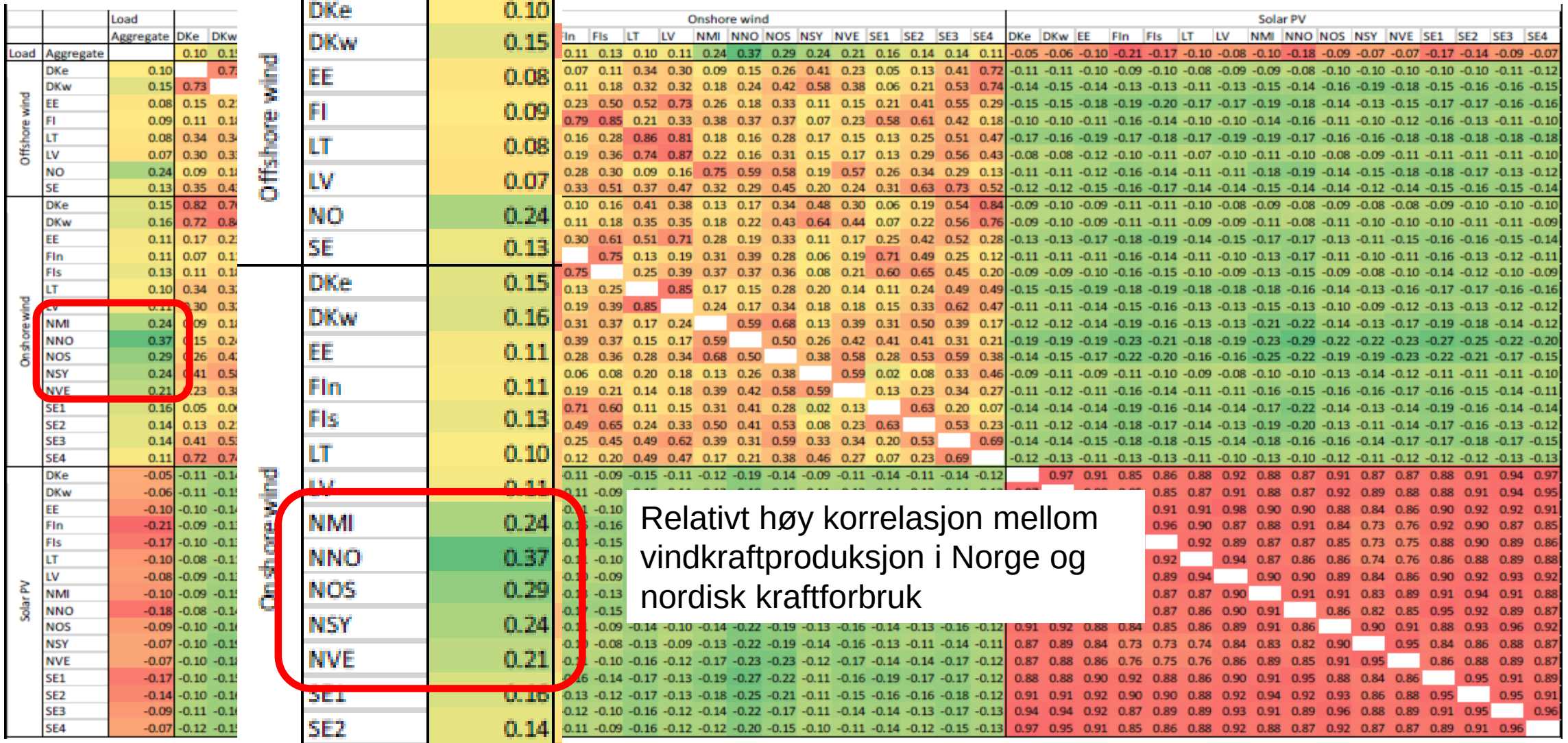
Korrelatsjoner mellom vind-og sol produksjon og samlet forbruk i Norden (Koivisto et al., 2016)

		Load	Offshore wind								Onshore wind															Solar PV														
		Aggregate	DKe	DKw	EE	FI	LT	LV	NO	SE	DKe	DKw	EE	FIn	FIs	LT	LV	NMI	NNO	NOS	NSY	NVE	SE1	SE2	SE3	SE4	DKe	DKw	EE	FIn	FIs	LT	LV	NMI	NNO	NOS	NSY	NVE	SE1	SE2	SE3	SE4
Load	Aggregate		0.10	0.15	0.08	0.09	0.08	0.07	0.24	0.13	0.15	0.16	0.11	0.11	0.13	0.10	0.11	0.24	0.37	0.29	0.24	0.21	0.16	0.14	0.14	0.11	-0.05	-0.06	-0.10	-0.21	-0.17	-0.10	-0.08	-0.10	-0.18	-0.09	-0.07	-0.07	-0.17	-0.14	-0.09	-0.07
Offshore wind	DKe	0.10		0.73	0.15	0.11	0.34	0.30	0.09	0.35	0.82	0.72	0.17	0.07	0.11	0.34	0.30	0.09	0.15	0.26	0.41	0.23	0.05	0.13	0.41	0.72	-0.11	-0.11	-0.10	-0.09	-0.10	-0.08	-0.09	-0.09	-0.08	-0.10	-0.10	-0.10	-0.10	-0.10	-0.11	-0.12
	DKw	0.15	0.73		0.21	0.18	0.34	0.33	0.18	0.43	0.76	0.84	0.23	0.11	0.18	0.32	0.32	0.18	0.24	0.42	0.58	0.38	0.06	0.21	0.53	0.74	-0.14	-0.15	-0.14	-0.13	-0.13	-0.11	-0.13	-0.15	-0.14	-0.16	-0.19	-0.18	-0.15	-0.16	-0.16	-0.15
	EE	0.08	0.15	0.21		0.42	0.53	0.64	0.18	0.46	0.21	0.22	0.82	0.23	0.50	0.52	0.73	0.26	0.18	0.33	0.11	0.15	0.21	0.41	0.55	0.29	-0.15	-0.15	-0.18	-0.19	-0.20	-0.17	-0.17	-0.19	-0.18	-0.14	-0.13	-0.15	-0.17	-0.17	-0.16	-0.16
	FI	0.09	0.11	0.18	0.42		0.26	0.35	0.33	0.50	0.14	0.17	0.50	0.79	0.85	0.21	0.33	0.38	0.37	0.37	0.07	0.23	0.58	0.61	0.42	0.18	-0.10	-0.10	-0.11	-0.16	-0.14	-0.10	-0.10	-0.14	-0.16	-0.11	-0.10	-0.12	-0.16	-0.13	-0.11	-0.10
	LT	0.08	0.34	0.34	0.53	0.26		0.80	0.12	0.41	0.38	0.33	0.52	0.16	0.28	0.86	0.81	0.18	0.16	0.28	0.17	0.15	0.13	0.25	0.51	0.47	-0.17	-0.16	-0.19	-0.17	-0.18	-0.17	-0.19	-0.19	-0.17	-0.16	-0.16	-0.18	-0.18	-0.18	-0.18	-0.18
	LV	0.07	0.30	0.33	0.64	0.35	0.80		0.17	0.44	0.36	0.33	0.63	0.19	0.36	0.74	0.87	0.22	0.16	0.31	0.15	0.17	0.13	0.29	0.56	0.43	-0.08	-0.08	-0.12	-0.10	-0.11	-0.07	-0.10	-0.11	-0.10	-0.08	-0.09	-0.11	-0.11	-0.11	-0.11	-0.10
	NO	0.24	0.09	0.18	0.18	0.33	0.12	0.17		0.22	0.12	0.18	0.20	0.28	0.30	0.09	0.16	0.75	0.59	0.58	0.19	0.57	0.26	0.34	0.29	0.13	-0.11	-0.11	-0.12	-0.16	-0.14	-0.11	-0.11	-0.18	-0.19	-0.14	-0.15	-0.18	-0.18	-0.17	-0.13	-0.12
	SE	0.13	0.35	0.43	0.46	0.50	0.41	0.44	0.22		0.45	0.43	0.46	0.33	0.51	0.37	0.47	0.32	0.29	0.45	0.20	0.24	0.31	0.63	0.73	0.52	-0.12	-0.12	-0.15	-0.16	-0.17	-0.14	-0.14	-0.15	-0.14	-0.14	-0.12	-0.14	-0.15	-0.16	-0.15	-0.14
Onshore wind	DKe	0.15	0.82	0.76	0.21	0.14	0.38	0.36	0.12	0.45		0.87	0.23	0.10	0.16	0.41	0.38	0.13	0.17	0.34	0.48	0.30	0.06	0.19	0.54	0.84	-0.09	-0.10	-0.09	-0.11	-0.11	-0.10	-0.08	-0.09	-0.08	-0.09	-0.08	-0.08	-0.09	-0.10	-0.10	-0.10
	DKw	0.16	0.72	0.84	0.22	0.17	0.33	0.33	0.18	0.43	0.87		0.24	0.11	0.18	0.35	0.35	0.18	0.22	0.43	0.64	0.44	0.07	0.22	0.56	0.76	-0.09	-0.10	-0.09	-0.11	-0.11	-0.09	-0.09	-0.11	-0.08	-0.11	-0.10	-0.10	-0.10	-0.11	-0.11	-0.09
	EE	0.11	0.17	0.23	0.82	0.50	0.52	0.63	0.20	0.46	0.23	0.24		0.30	0.61	0.51	0.71	0.28	0.19	0.33	0.11	0.17	0.25	0.42	0.52	0.28	-0.13	-0.13	-0.17	-0.18	-0.19	-0.14	-0.15	-0.17	-0.17	-0.13	-0.11	-0.15	-0.16	-0.16	-0.15	-0.14
	FIn	0.11	0.07	0.11	0.23	0.79	0.16	0.19	0.28	0.33	0.10	0.11	0.30		0.75	0.13	0.19	0.31	0.39	0.28	0.06	0.19	0.71	0.49	0.25	0.12	-0.11	-0.11	-0.11	-0.16	-0.14	-0.11	-0.10	-0.13	-0.17	-0.11	-0.10	-0.11	-0.16	-0.13	-0.12	-0.11
	FIs	0.13	0.11	0.18	0.50	0.85	0.28	0.36	0.30	0.51	0.16	0.18	0.61	0.75		0.25	0.39	0.37	0.37	0.36	0.08	0.21	0.60	0.65	0.45	0.20	-0.09	-0.09	-0.10	-0.16	-0.15	-0.10	-0.09	-0.13	-0.15	-0.09	-0.08	-0.10	-0.14	-0.12	-0.10	-0.09
	LT	0.10	0.34	0.32	0.52	0.21	0.86	0.74	0.09	0.37	0.41	0.35	0.51	0.13	0.25		0.85	0.17	0.15	0.28	0.20	0.14	0.11	0.24	0.49	0.49	-0.15	-0.15	-0.19	-0.18	-0.19	-0.18	-0.18	-0.18	-0.16	-0.14	-0.13	-0.16	-0.17	-0.17	-0.16	-0.16
	LV	0.11	0.30	0.32	0.73	0.33	0.81	0.87	0.16	0.47	0.38	0.35	0.71	0.19	0.39	0.85		0.24	0.17	0.34	0.18	0.18	0.15	0.33	0.62	0.47	-0.11	-0.11	-0.14	-0.15	-0.16	-0.13	-0.13	-0.15	-0.13	-0.10	-0.09	-0.12	-0.13	-0.13	-0.12	-0.12
	NMI	0.24	0.09	0.18	0.26	0.38	0.18	0.22	0.75	0.32	0.13	0.18	0.28	0.31	0.37	0.17	0.24		0.59	0.68	0.13	0.39	0.31	0.50	0.39	0.17	-0.12	-0.12	-0.14	-0.19	-0.16	-0.13	-0.13	-0.21	-0.22	-0.14	-0.13	-0.17	-0.19	-0.18	-0.14	-0.12
	NNO	0.37	0.15	0.24	0.18	0.37	0.16	0.16	0.59	0.29	0.17	0.22	0.19	0.39	0.37	0.15	0.17	0.59		0.50	0.26	0.42	0.41	0.41	0.31	0.21	-0.19	-0.19	-0.19	-0.23	-0.21	-0.18	-0.19	-0.23	-0.29	-0.22	-0.22	-0.23	-0.27	-0.25	-0.22	-0.20
	NOS	0.29	0.26	0.42	0.33	0.37	0.28	0.31	0.58	0.45	0.34	0.43	0.33	0.28	0.36	0.28	0.34	0.68	0.50		0.38	0.58	0.28	0.53	0.59	0.38	-0.14	-0.15	-0.17	-0.22	-0.20	-0.16	-0.16	-0.25	-0.22	-0.19	-0.19	-0.23	-0.22	-0.21	-0.17	-0.15
	NSY	0.24	0.41	0.58	0.11	0.07	0.17	0.15	0.19	0.20	0.48	0.64	0.11	0.06	0.08	0.20	0.18	0.13	0.26	0.38		0.59	0.02	0.08	0.33	0.46	-0.09	-0.11	-0.09	-0.11	-0.10	-0.09	-0.08	-0.10	-0.10	-0.13	-0.14	-0.12	-0.11	-0.11	-0.11	-0.10
	NVE	0.21	0.23	0.38	0.15	0.23	0.15	0.17	0.57	0.24	0.30	0.44	0.17	0.19	0.21	0.14	0.18	0.39	0.42	0.58	0.59		0.13	0.23	0.34	0.27	-0.11	-0.12	-0.11	-0.16	-0.14	-0.11	-0.11	-0.16	-0.15	-0.16	-0.16	-0.17	-0.16	-0.15	-0.14	-0.11
	SE1	0.16	0.05	0.06	0.21	0.58	0.13	0.13	0.26	0.31	0.06	0.07	0.25	0.71	0.60	0.11	0.15	0.31	0.41	0.28	0.02	0.13		0.63	0.20	0.07	-0.14	-0.14	-0.14	-0.19	-0.16	-0.14	-0.14	-0.17	-0.22	-0.14	-0.13	-0.14	-0.19	-0.16	-0.14	-0.14
	SE2	0.14	0.13	0.21	0.41	0.61	0.25	0.29	0.34	0.63	0.19	0.22	0.42	0.49	0.65	0.24	0.33	0.50	0.41	0.53	0.08	0.23	0.63		0.53	0.23	-0.11	-0.12	-0.14	-0.18	-0.17	-0.14	-0.13	-0.19	-0.20	-0.13	-0.11	-0.14	-0.17	-0.16	-0.13	-0.12
	SE3	0.14	0.41	0.53	0.55	0.42	0.51	0.56	0.29	0.73	0.54	0.56	0.52	0.25	0.45	0.49	0.62	0.39	0.31	0.59	0.33	0.34	0.20	0.53		0.69	-0.14	-0.14	-0.15	-0.18	-0.18	-0.15	-0.14	-0.18	-0.16	-0.16	-0.14	-0.17	-0.17	-0.18	-0.17	-0.15
	SE4	0.11	0.72	0.74	0.29	0.18	0.47	0.43	0.13	0.52	0.84	0.76	0.28	0.12	0.20	0.49	0.47	0.17	0.21	0.38	0.46	0.27	0.07	0.23	0.69		-0.12	-0.13	-0.11	-0.13	-0.13	-0.11	-0.10	-0.13	-0.10	-0.12	-0.11	-0.12	-0.12	-0.12	-0.13	-0.13
Solar PV	DKe	-0.05	-0.11	-0.14	-0.15	-0.10	-0.17	-0.08	-0.11	-0.12	-0.09	-0.09	-0.13	-0.11	-0.09	-0.15	-0.11	-0.12	-0.19	-0.14	-0.09	-0.11	-0.14	-0.11	-0.14	-0.12		0.97	0.91	0.85	0.86	0.88	0.92	0.88	0.87	0.91	0.87	0.87	0.88	0.91	0.94	0.97
	DKw	-0.06	-0.11	-0.15	-0.15	-0.10	-0.16	-0.08	-0.11	-0.12	-0.10	-0.10	-0.13	-0.11	-0.09	-0.15	-0.11	-0.12	-0.19	-0.15	-0.11	-0.12	-0.14	-0.12	-0.14	-0.13	0.97		0.90	0.85	0.85	0.87	0.91	0.88	0.87	0.92	0.89	0.88	0.88	0.91	0.94	0.95
	EE	-0.10	-0.10	-0.14	-0.18	-0.11	-0.19	-0.12	-0.12	-0.15	-0.09	-0.09	-0.17	-0.11	-0.10	-0.19	-0.14	-0.14	-0.19	-0.17	-0.09	-0.11	-0.14	-0.14	-0.15	-0.11	0.91	0.90		0.88	0.91	0.91	0.98	0.90	0.90	0.88	0.84	0.86	0.90	0.92	0.92	0.91
	FIn	-0.21	-0.09	-0.13	-0.19	-0.16	-0.17	-0.10	-0.16	-0.16	-0.11	-0.11	-0.18	-0.16	-0.16	-0.18	-0.15	-0.19	-0.23	-0.22	-0.11	-0.16	-0.19	-0.18	-0.18	-0.13	0.85	0.85	0.88		0.96	0.90	0.87	0.88	0.91	0.84	0.73	0.76	0.92	0.90	0.87	0.85
	FIs	-0.17	-0.10	-0.13	-0.20	-0.14	-0.18	-0.11	-0.14	-0.17	-0.11	-0.11	-0.19	-0.14	-0.15	-0.19	-0.16	-0.16	-0.21	-0.20	-0.10	-0.14	-0.16	-0.17	-0.18	-0.13	0.86	0.85	0.91	0.96		0.92	0.89	0.87	0.87	0.85	0.73	0.75	0.88	0.90	0.89	0.86
	LT	-0.10	-0.08	-0.11	-0.17	-0.10	-0.17	-0.07	-0.11	-0.14	-0.10	-0.09	-0.14	-0.11	-0.10	-0.18	-0.13	-0.13	-0.18	-0.16	-0.09	-0.11	-0.14	-0.14	-0.15	-0.11	0.88	0.87	0.91	0.90	0.92		0.94	0.87	0.86	0.86	0.74	0.76	0.86	0.88	0.89	0.88
	LV	-0.08	-0.09	-0.13	-0.17	-0.10	-0.19	-0.10	-0.11	-0.14	-0.08	-0.09	-0.15	-0.10	-0.09	-0.18	-0.13	-0.13	-0.19	-0.16	-0.08	-0.11	-0.14	-0.13	-0.14	-0.10	0.92	0.91	0.98	0.87	0.89	0.94		0.90	0.90	0.89	0.84	0.86	0.90	0.92	0.93	0.92
	NMI	-0.10	-0.09	-0.15	-0.19	-0.14	-0.19	-0.11	-0.18	-0.15	-0.09	-0.11	-0.17	-0.13	-0.13	-0.18	-0.15	-0.21	-0.23	-0.25	-0.10	-0.16	-0.17	-0.19	-0.18	-0.13	0.88	0.88	0.90	0.88	0.87	0.87	0.90		0.91	0.91	0.83	0.89	0.91	0.94	0.91	0.88
	NNO	-0.18	-0.08	-0.14	-0.18	-0.16	-0.17	-0.10	-0.19	-0.14	-0.08	-0.08	-0.17	-0.17	-0.15	-0.16	-0.13	-0.22	-0.29	-0.22	-0.10	-0.15	-0.22	-0.20	-0.16	-0.10	0.87	0.87	0.90	0.91	0.87	0.86	0.90	0.91		0.86	0.82	0.85	0.95	0.92	0.89	0.87
	NOS	-0.09	-0.10	-0.16	-0.14	-0.11	-0.16	-0.08	-0.14	-0.14	-0.09	-0.11	-0.13	-0.11	-0.09	-0.14	-0.10	-0.14	-0.22	-0.19	-0.13	-0.16	-0.14	-0.13	-0.16	-0.12	0.91	0.92	0.88	0.84	0.85	0.86	0.89	0.91	0.86		0.90	0.91	0.88	0.93	0.96	0.92
	NSY	-0.07	-0.10	-0.19	-0.13	-0.10	-0.16	-0.09	-0.15	-0.12	-0.08	-0.10	-0.11	-0.10	-0.08	-0.13	-0.09	-0.13	-0.22	-0.19	-0.14	-0.16	-0.13	-0.11	-0.14	-0.11	0.87	0.89	0.84	0.73	0.73	0.74	0.84	0.83	0.82	0.90		0.95	0.84	0.86	0.88	0.87
	NVE	-0.07	-0.10	-0.18	-0.15	-0.12	-0.18	-0.11	-0.18	-0.14	-0.08	-0.10	-0.15	-0.11	-0.10	-0.16	-0.12	-0.17	-0.23	-0.23	-0.12	-0.17	-0.14	-0.14	-0.17	-0.12	0.87	0.88	0.86	0.76	0.75	0.76	0.86	0.89	0.85	0.91	0.95		0.86	0.88	0.89	0.87
	SE1	-0.17	-0.10	-0.15	-0.17	-0.16	-0.18	-0.11	-0.18	-0.15	-0.09	-0.10	-0.16	-0.16	-0.14	-0.17	-0.13	-0.19	-0.27	-0.22	-0.11	-0.16	-0.19	-0.17	-0.17	-0.12	0.88	0.88	0.90	0.92	0.88	0.86	0.90	0.91	0.95	0.88	0.84	0.86		0.95	0.91	0.89
	SE2	-0.14	-0.10	-0.16	-0.17	-0.13	-0.18	-0.11	-0.17	-0.16	-0.10	-0.11	-0.16	-0.13	-0.12	-0.17	-0.13	-0.18	-0.25	-0.21	-0.11	-0.15	-0.16	-0.16	-0.18	-0.12	0.91	0.91	0.92	0.90	0.90	0.88	0.92	0.94	0.92	0.93	0.86	0.88	0.95		0.95	0.91
	SE3	-0.09	-0.11	-0.16	-0.16	-0.11	-0.18	-0.11	-0.13	-0.15	-0.10	-0.11	-0.15	-0.12	-0.10	-0.16	-0.12	-0.14	-0.22	-0.17	-0.11	-0.14	-0.14	-0.13	-0.17	-0.13	0.94	0.94	0.92	0.87	0.89	0.89	0.93	0.91	0.89	0.96	0.88	0.89	0.91	0.95		0.96
	SE4	-0.07	-0.12	-0.15	-0.16	-0.10	-0.18	-0.10	-0.12	-0.14	-0.10	-0.09	-0.14	-0.11	-0.09	-0.16	-0.12	-0.12	-0.20	-0.15	-0.10	-0.11	-0.14	-0.12	-0.15	-0.13	0.97	0.95	0.91	0.85	0.86	0.88	0.92	0.88	0.87	0.92	0.87	0.87	0.89	0.91	0.96	

Colouring is based on how benficial the correlations are for achieving a lower residual load variance

Lokaliser[illegible]barproduksjonen blir viktigere

Korrelatsjoner mellor[illegible]samlet forbruk i Norden (Koivisto et al., 2016)



Colouring is base[illegible]tions are for achieving a lower residual load variance

Lokalisering av fornybarproduksjonen blir viktigere

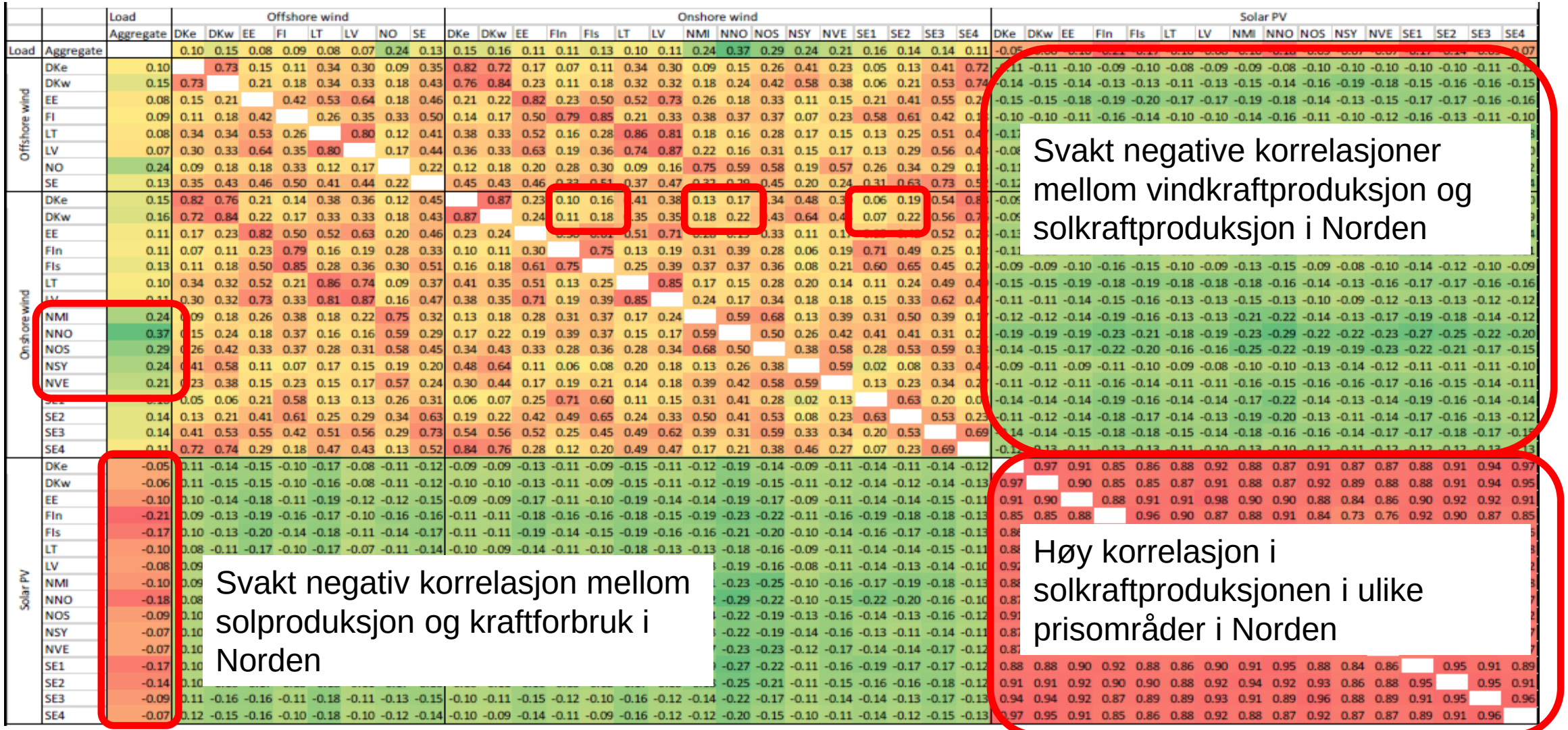
Korrelatsjoner mellom vind-og sol produksjon og samlet forbruk i Norden (Koivisto et al., 2016)

		Load	Offshore wind								Onshore wind															Solar PV															
		Aggregate	DKe	DKw	EE	FI	LT	LV	NO	SE	DKe	DKw	EE	FIn	FIs	LT	LV	NMI	NNO	NOS	NSY	NVE	SE1	SE2	SE3	SE4	DKe	DKw	EE	FIn	FIs	LT	LV	NMI	NNO	NOS	NSY	NVE	SE1	SE2	SE3	SE4
Load	Aggregate		0.10	0.15	0.08	0.09	0.08	0.07	0.24	0.13	0.15	0.16	0.11	0.11	0.13	0.10	0.11	0.24	0.37	0.29	0.24	0.21	0.16	0.14	0.14	0.11	-0.05	-0.06	-0.10	-0.21	-0.17	-0.10	-0.08	-0.10	-0.18	-0.09	-0.07	-0.07	-0.17	-0.14	-0.09	-0.07
Offshore wind	DKe	0.10		0.73	0.15	0.11	0.34	0.30	0.09	0.35	0.82	0.72	0.17	0.07	0.11	0.34	0.30	0.09	0.15	0.26	0.41	0.23	0.05	0.13	0.41	0.72	-0.11	-0.11	-0.10	-0.09	-0.10	-0.08	-0.09	-0.09	-0.08	-0.10	-0.10	-0.10	-0.10	-0.10	-0.11	-0.12
	DKw	0.15	0.73		0.21	0.18	0.34	0.33	0.18	0.43	0.76	0.84	0.23	0.11	0.18	0.32	0.32	0.18	0.24	0.42	0.58	0.38	0.06	0.21	0.53	0.74	-0.14	-0.15	-0.14	-0.13	-0.13	-0.11	-0.13	-0.15	-0.14	-0.16	-0.19	-0.18	-0.15	-0.16	-0.16	-0.15
	EE	0.08	0.15	0.21		0.42	0.53	0.64	0.18	0.46	0.21	0.22	0.82	0.23	0.50	0.52	0.73	0.26	0.18	0.33	0.11	0.15	0.21	0.41	0.55	0.29	-0.15	-0.15	-0.18	-0.19	-0.20	-0.17	-0.17	-0.19	-0.18	-0.14	-0.13	-0.15	-0.17	-0.17	-0.16	-0.16
	FI	0.09	0.11	0.18	0.42		0.26	0.35	0.33	0.50	0.14	0.17	0.50	0.79	0.85	0.21	0.33	0.38	0.37	0.37	0.07	0.23	0.58	0.61	0.42	0.18	-0.10	-0.10	-0.11	-0.16	-0.14	-0.10	-0.10	-0.14	-0.16	-0.11	-0.10	-0.12	-0.16	-0.13	-0.11	-0.10
	LT	0.08	0.34	0.34	0.53	0.26		0.80	0.12	0.41	0.38	0.33	0.52	0.16	0.28	0.86	0.81	0.18	0.16	0.28	0.17	0.15	0.13	0.25	0.51	0.47	-0.17	-0.16	-0.19	-0.17	-0.18	-0.17	-0.19	-0.19	-0.17	-0.16	-0.16	-0.18	-0.18	-0.18	-0.18	-0.18
	LV	0.07	0.30	0.33	0.64	0.35	0.80		0.17	0.44	0.36	0.33	0.63	0.19	0.36	0.74	0.87	0.22	0.16	0.31	0.15	0.17	0.13	0.29	0.56	0.43																	
	NO	0.24	0.09	0.18	0.18	0.33	0.12	0.17		0.22	0.12	0.18	0.20	0.28	0.30	0.09	0.16	0.75	0.59	0.58	0.19	0.57	0.26	0.34	0.29	0.13																	
	SE	0.13	0.35	0.43	0.46	0.50	0.41	0.44	0.22		0.45	0.43	0.46	0.33	0.51	0.37	0.47	0.32	0.29	0.45	0.20	0.24	0.31	0.63	0.73	0.52																	
Onshore wind	DKe	0.15	0.82	0.76	0.21	0.14	0.38	0.36	0.12	0.45		0.87	0.23	0.10	0.16	0.41	0.38	0.13	0.17	0.34	0.48	0.30	0.06	0.19	0.54	0.84																	
	DKw	0.16	0.72	0.84	0.22	0.17	0.33	0.33	0.18	0.43	0.87		0.24	0.11	0.18	0.35	0.35	0.18	0.22	0.43	0.64	0.44	0.07	0.22	0.56	0.76																	
	EE	0.11	0.17	0.23	0.82	0.50	0.52	0.63	0.20	0.46	0.23	0.24		0.30	0.61	0.51	0.71	0.28	0.19	0.33	0.11	0.17	0.25	0.42	0.52	0.28																	
	FIn	0.11	0.07	0.11	0.23	0.79	0.16	0.19	0.28	0.33	0.10	0.11											0.19	0.71	0.49	0.25	0.12																	
	FIs	0.13	0.11	0.18	0.50	0.85	0.28	0.36	0.30	0.51	0.16	0.18											0.21	0.60	0.65	0.45	0.20																	
	LT	0.10	0.34	0.32	0.52	0.21	0.86	0.74	0.09	0.37	0.41	0.35											0.14	0.11	0.24	0.49	0.49																	
	LV	0.11	0.30	0.32	0.73	0.33	0.81	0.87	0.16	0.47	0.38	0.35											0.18	0.15	0.33	0.62	0.47																	
	NMI	0.24	0.09	0.18	0.26	0.38	0.18	0.22	0.75	0.32	0.13	0.18											0.39	0.31	0.50	0.39	0.17																	
	NNO	0.37	0.15	0.24	0.18	0.37	0.16	0.16	0.59	0.29	0.17	0.22											0.42	0.41	0.41	0.31	0.21																	
	NOS	0.29	0.26	0.42	0.33	0.37	0.28	0.31	0.58	0.45	0.34	0.43	0.33	0.28	0.36	0.28	0.34	0.68	0.50		0.38	0.58	0.28	0.53	0.59	0.38																	
	NSY	0.24	0.41	0.58	0.11	0.07	0.17	0.15	0.19	0.20	0.48	0.64	0.11	0.06	0.08	0.20	0.18	0.13	0.26	0.38		0.59	0.02	0.08	0.33	0.46																	
	NVE	0.21	0.23	0.38	0.15	0.23	0.15	0.17	0.57	0.24	0.30	0.44	0.17	0.19	0.21	0.14	0.18	0.39	0.42	0.58	0.59		0.13	0.23	0.34	0.27																	

Relativt lav korrelasjon mellom vindkraftproduksjon nord i Skandinavia og i Danmark (og Tyskland)

Lokalisering av fornybarproduksjonen blir viktigere

Korrelatsjoner mellom vind-og sol produksjon og samlet forbruk i Norden (Koivisto et al., 2016)



Colouring is based on how benficial the correlations are for achieving a lower residual load variance

Europeiske energisystemstudier venter store bidrag fra Norge

Energy 134 (2017) 469–481

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

The benefits of cooperation in a highly renewable European electricity network

D.P. Schlachtberger [a, *], T. Brown [a], S. Schramm [a], M. Greiner [b]

[a] Frankfurt Institute for Advanced Studies, 60438 Frankfurt am Main, Germany
[b] Department of Engineering, Aarhus University, 8000 Aarhus C, Denmark

Krafteksport fra Norge i 2050 er **300%** av norsk forbruk
Det aller meste av eksportoverskuddet fra landbasert vindkraft…

Renewable Energy 139 (2019) 80–101

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

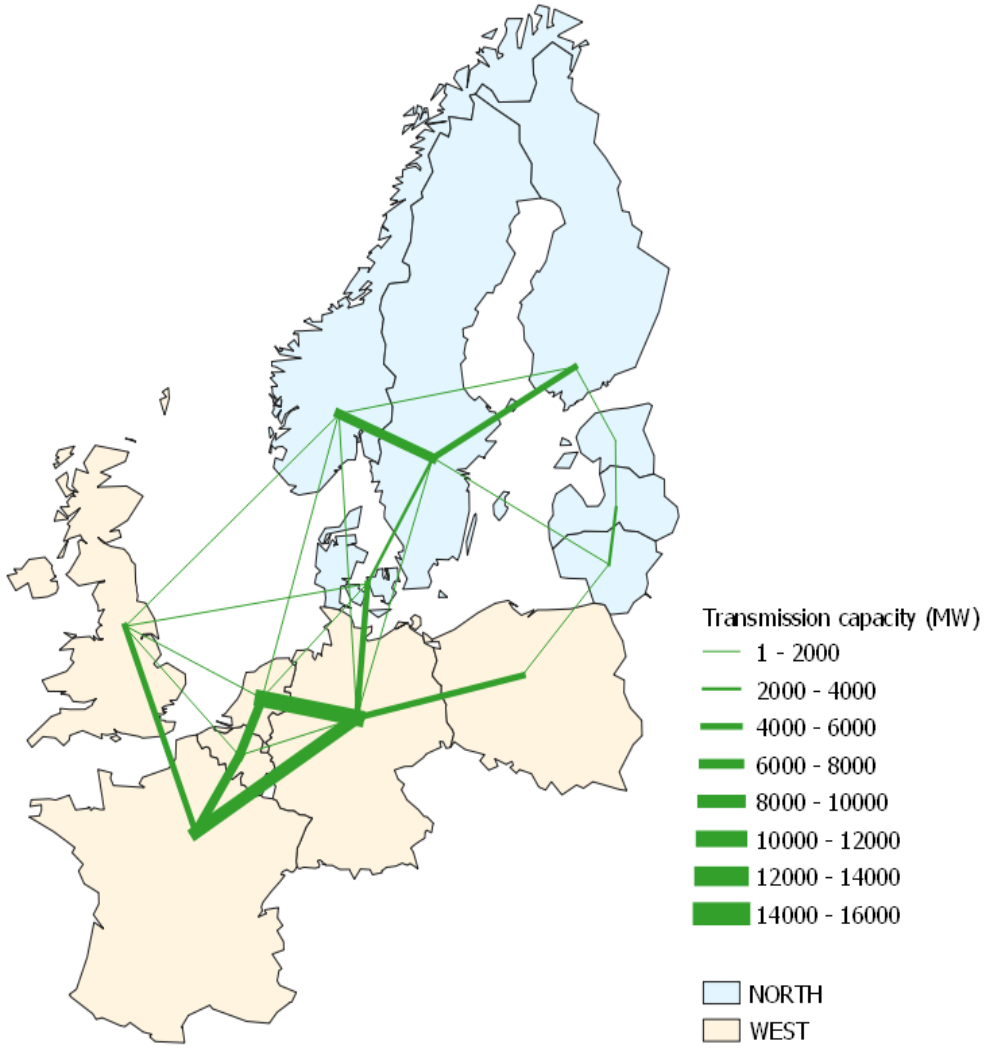
Flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe

Michael Child [a, *], Claudia Kemfert [b], Dmitrii Bogdanov [a], Christian Breyer [a]

[a] Lappeenranta University of Technology, Skinnarilankatu 34, 53850 Lappeenranta, Finland
[b] German Institute for Economic Research (DIW) and Hertie School of Governance, Mohrenstrasse 58, 10117 Berlin, Germany

Årlig krafteksport fra Norge på **119 TWh.** Det vesentlige fra landbasert vindkraft…

NorENS modellresultater



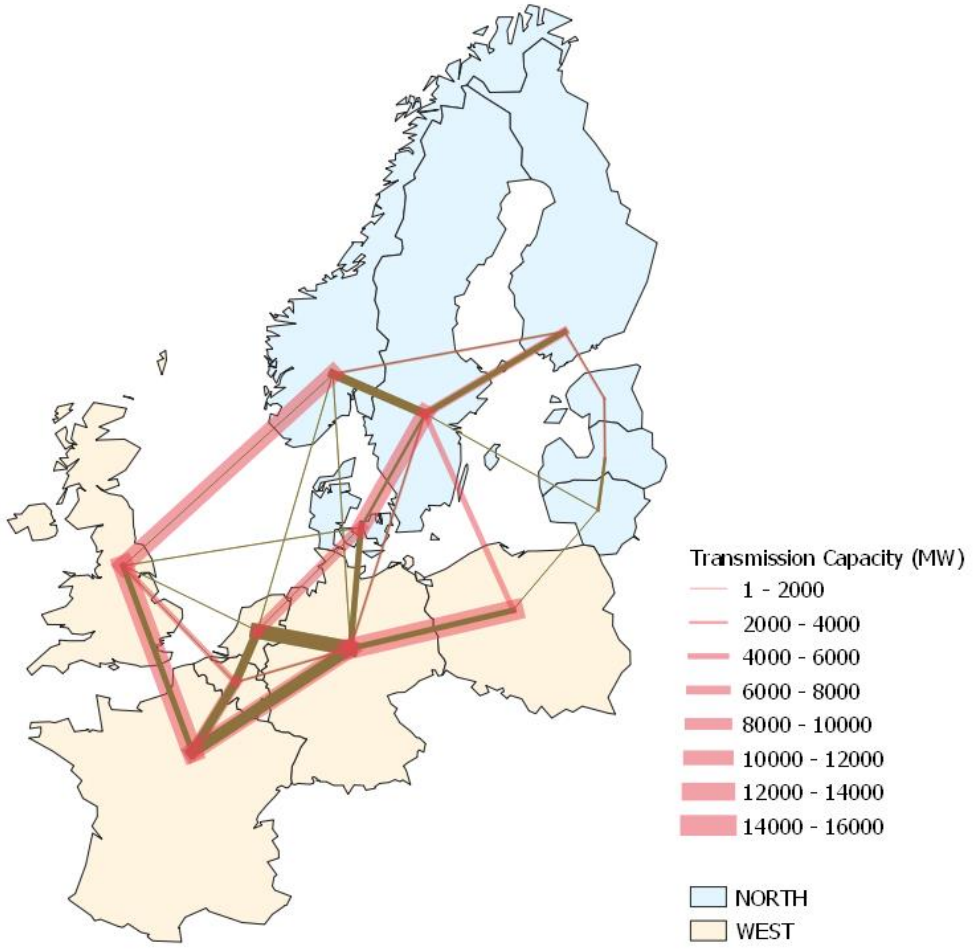
Forutsatte brensels og utslippskostnader

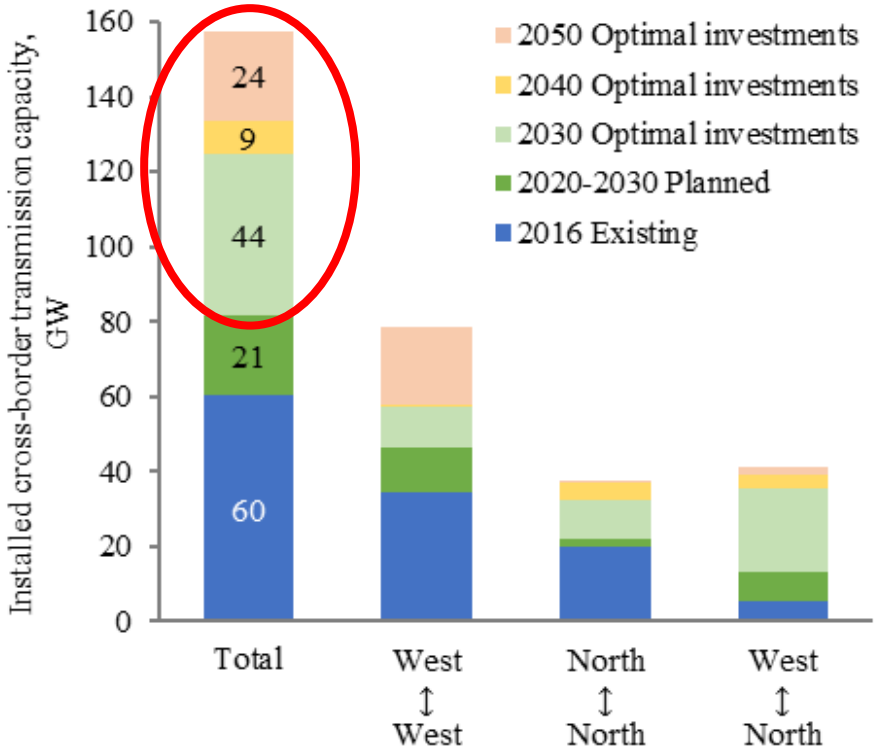
	Fuel				Emission
Unit	**€/ MWh**				**€/ t CO_2**
Year	**Coal**	**Lignite**	**NG**	**Biomass**	
2016	7.6	4.5	15	22– 31	5
2020	8.3	2.7	20	22– 31	17
2030	9.6	3.7	30	30– 38	26
2040	9.9	3.6	33	37– 45	40
2050	10.1	3.5	37	39– 47	54

Two scenarios of transmission capacities

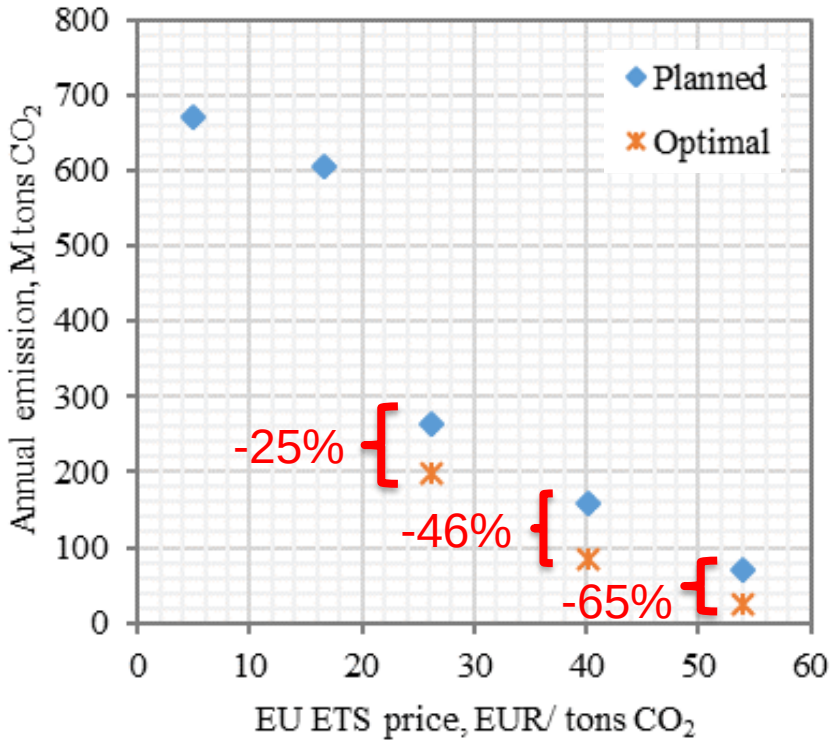
- Planned: exogenously given as of 2030
- Optimal: model-determined reaching least cost

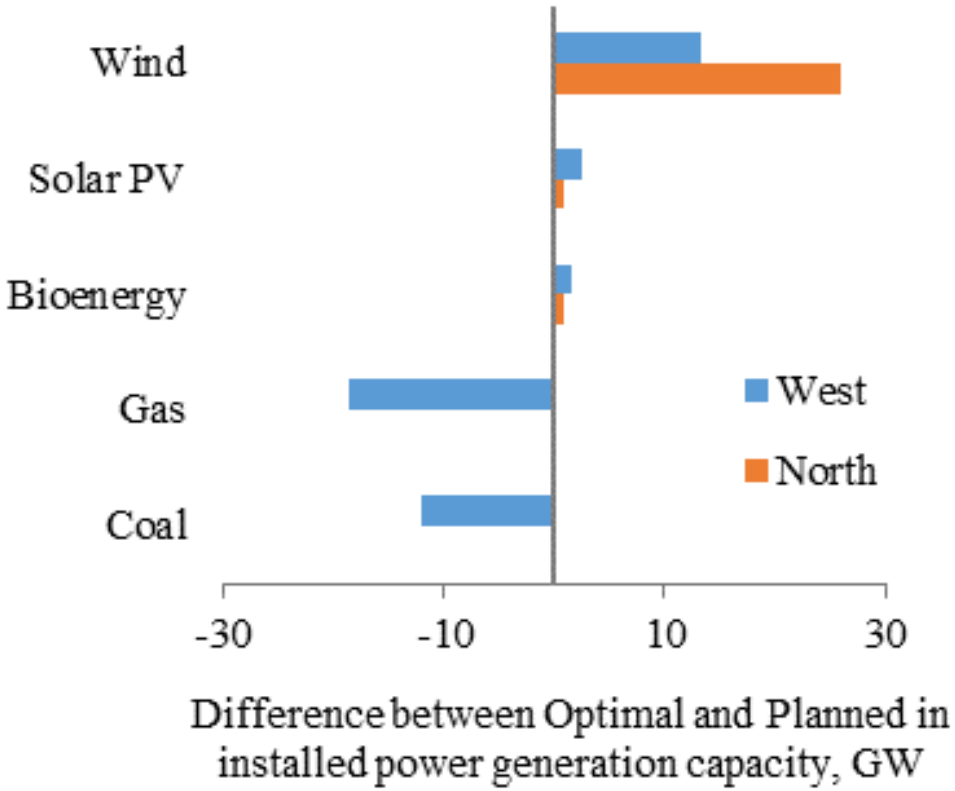
Når vi tillater investeringer i utenlandskabler i modellen:
Dobling i totalt import/eksportkapasitet fra forventet 2030 nivå





Flere kabler gir store endringer i produksjonsmiksen og reduserte utslipp



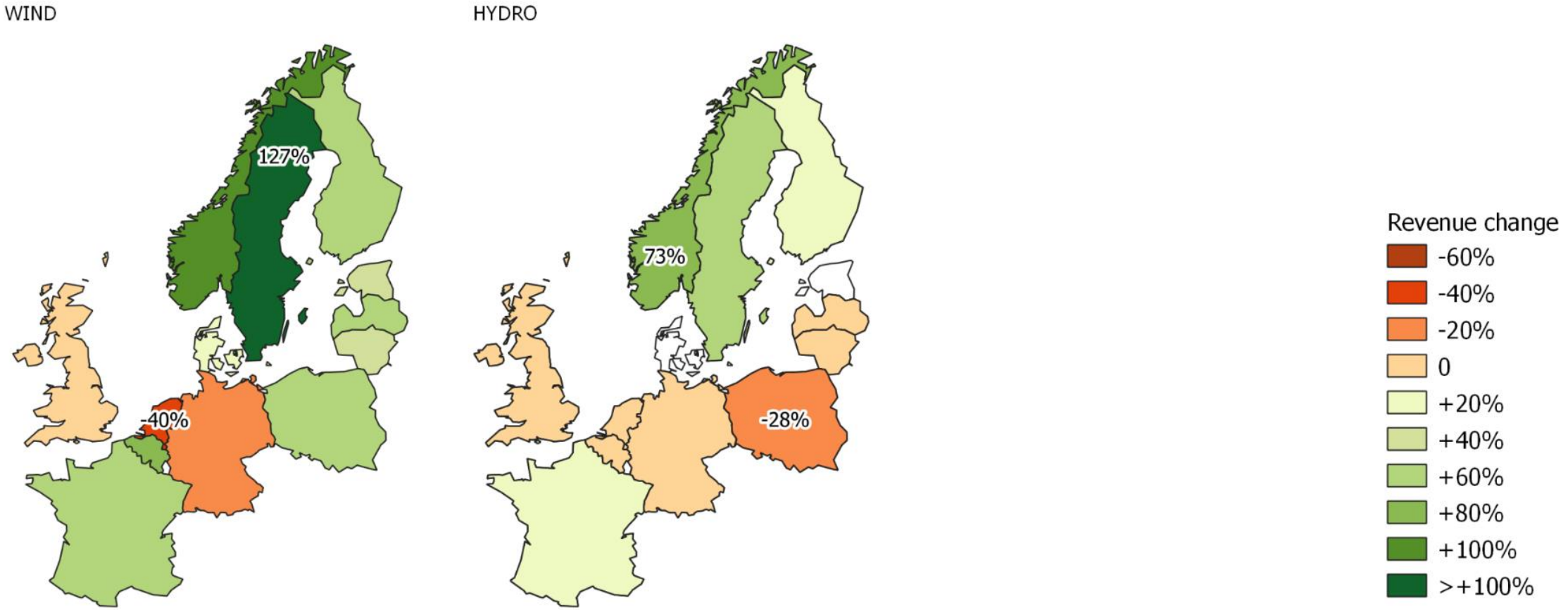


De lønnsomme utenlandsforbindelsene gir:
Økte inntekter for vindkraftprodusenter i nord…



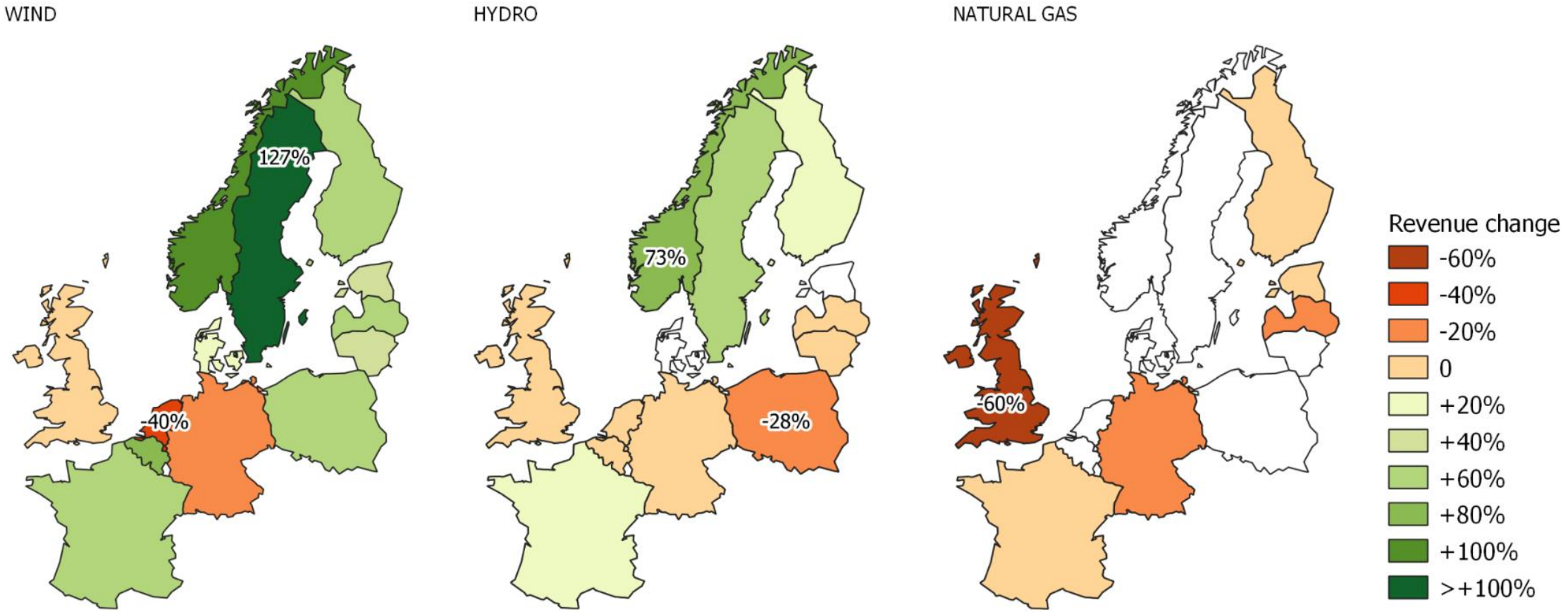
Modellresultater

De lønnsomme utenlandsforbindelsene gir: Økte inntekter for vannkraftprodusenter i nord…



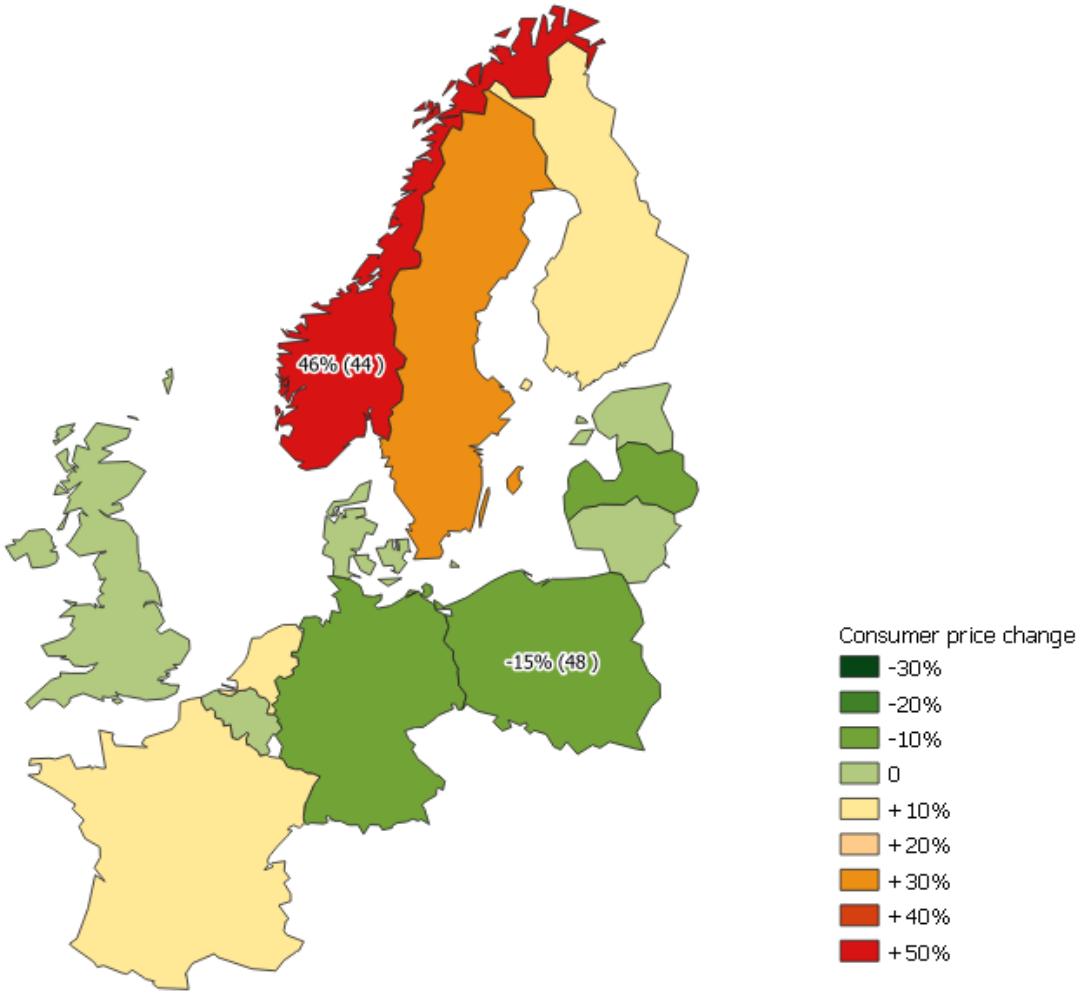
Modellresultater

De lønnsomme utenlandsforbindelsene gir: Reduserte inntekter for gasskraftprodusenter

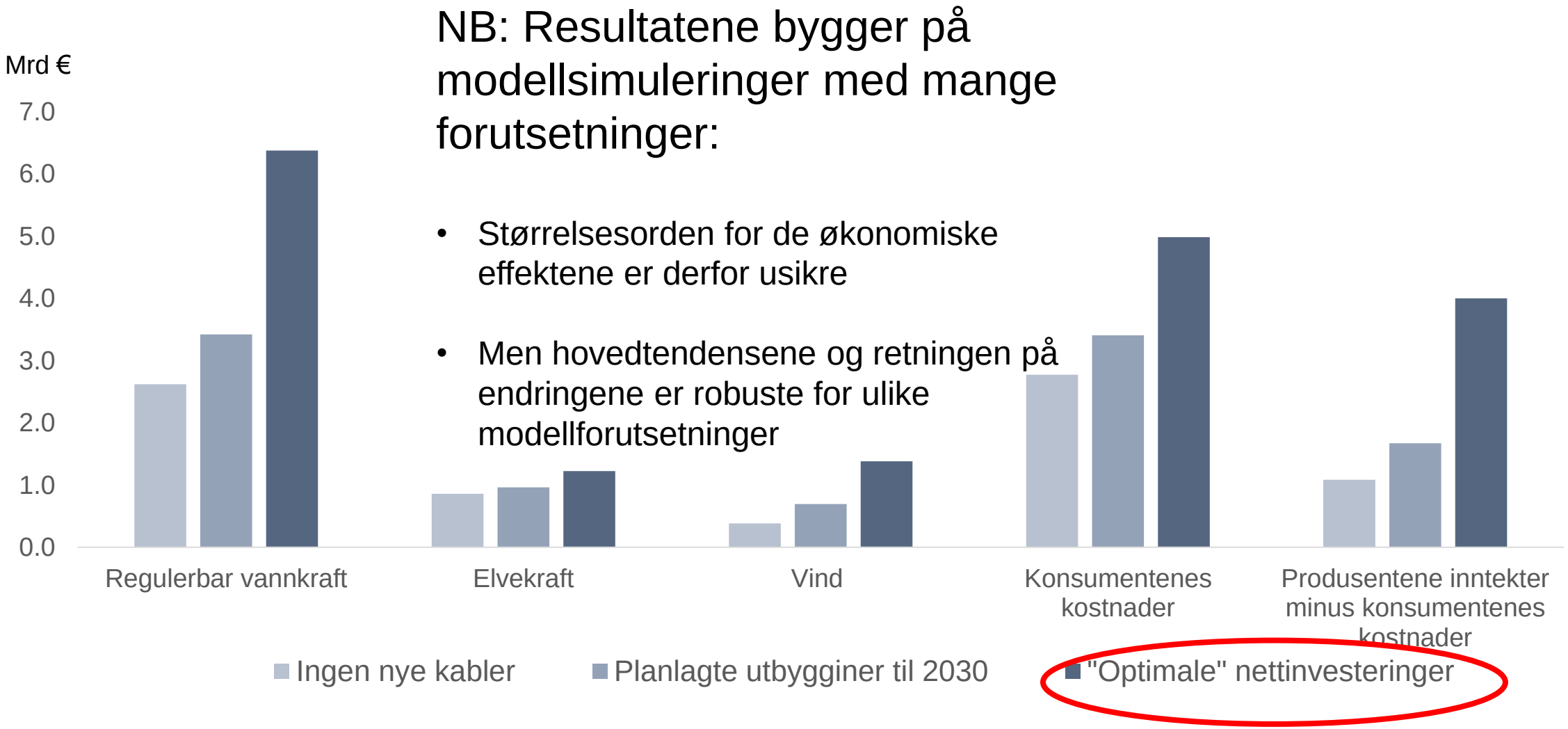


Modellresultater

Men, forbrukernes kostander i nord stiger…



Modellerte endringer i inntekter for produsenter og kostnader for forbrukere i Norge (modellår: 2040)



NB: Resultatene bygger på modellsimuleringer med mange forutsetninger:

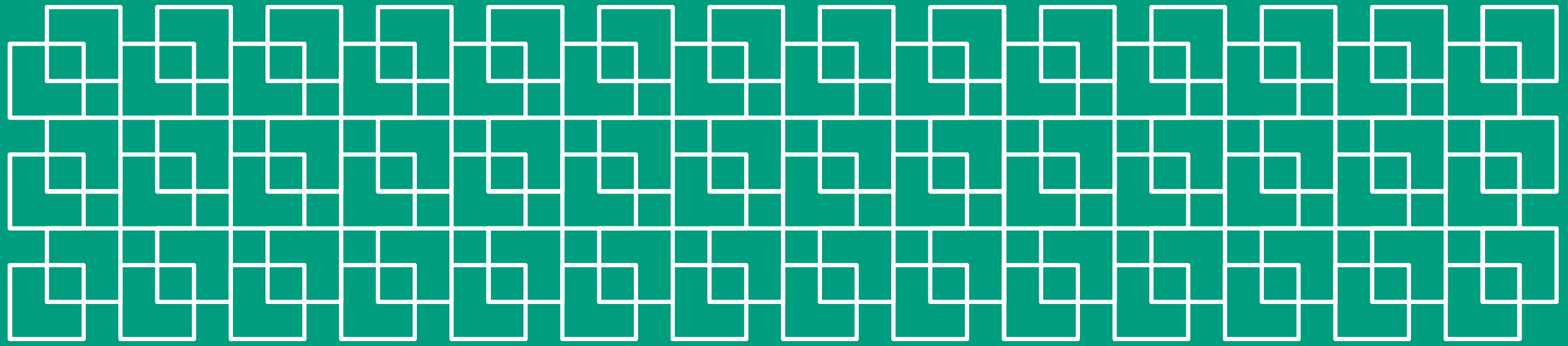
- Størrelsesorden for de økonomiske effektene er derfor usikre
- Men hovedtendensene og retningen på endringene er robuste for ulike modellforutsetninger

Conclusions

- The optimal scenario suggests additional 76 GW of cross-border transmission capacity expansion from 2030 to 2050
- More wind power substitutes fossil fuel based energy
  - Further emission reduction
  - Lower system costs
- Benefits asymmetrically distributed
  - ☺: Northern wind power producers, Northern hydro power producers, Western consumers
  - ☹: Fossil-fuel-based power producers, Northern consumers

➢Barrier and/or opportunity?

Takk for oppmerksomheten!



Ekstra

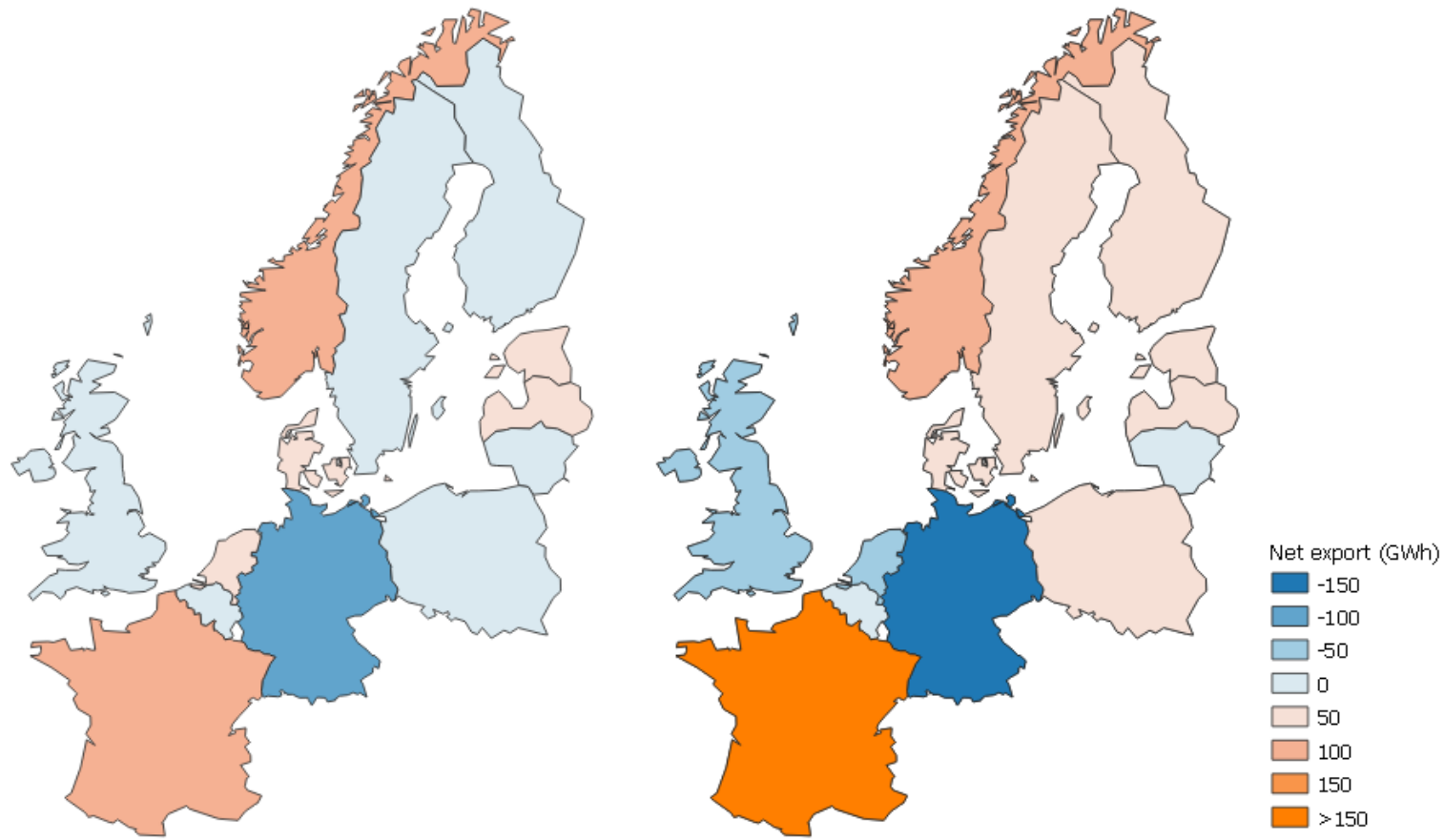
Transmission assumptions

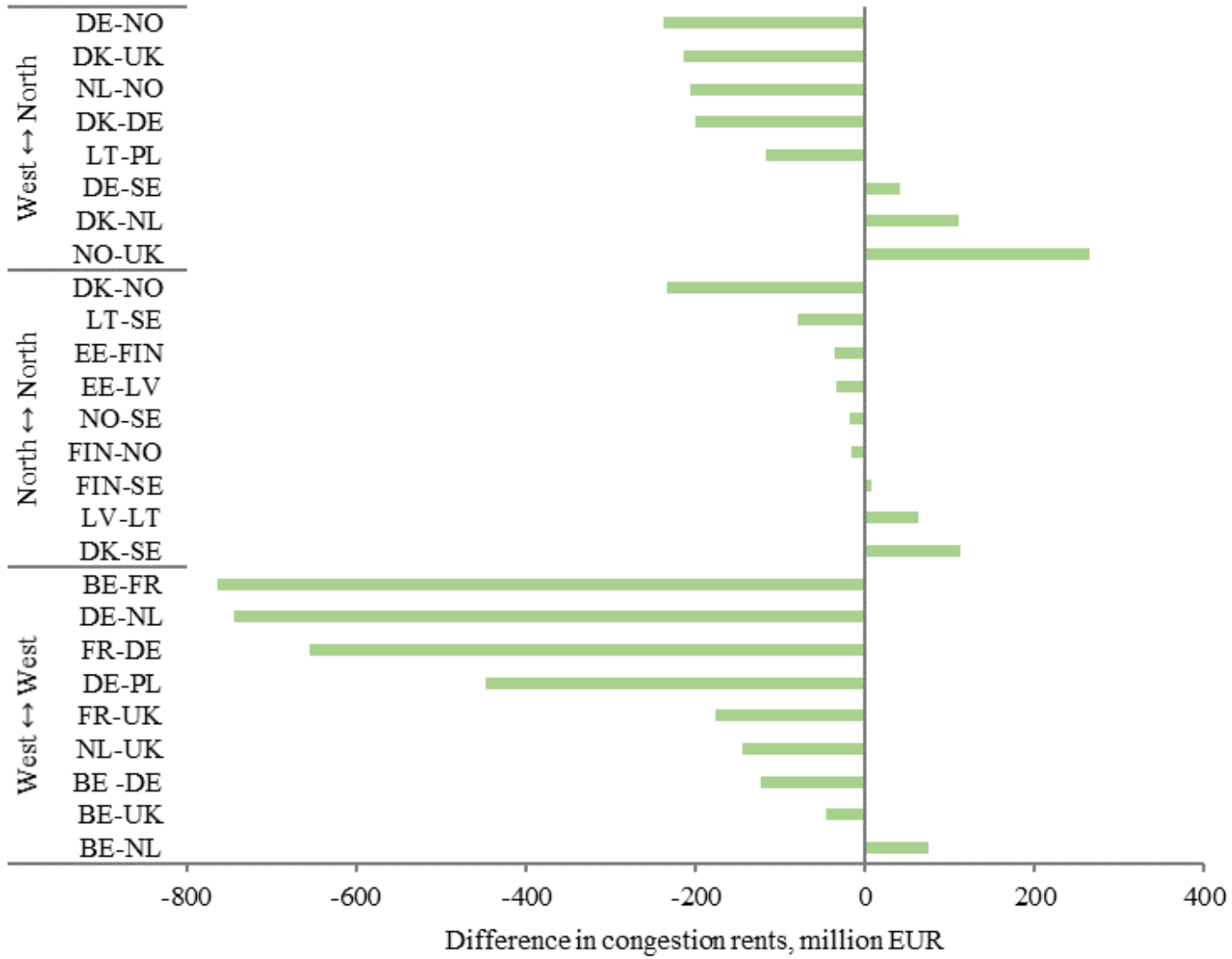
- Investment cost data derived from or estimated by established projects
  - a pay-back period of 40 years with 3.25% discount factor
- O&M cost: 0.1 EUR/MWh
- Efficiency: 95.8%
- Capacity rating: 90%

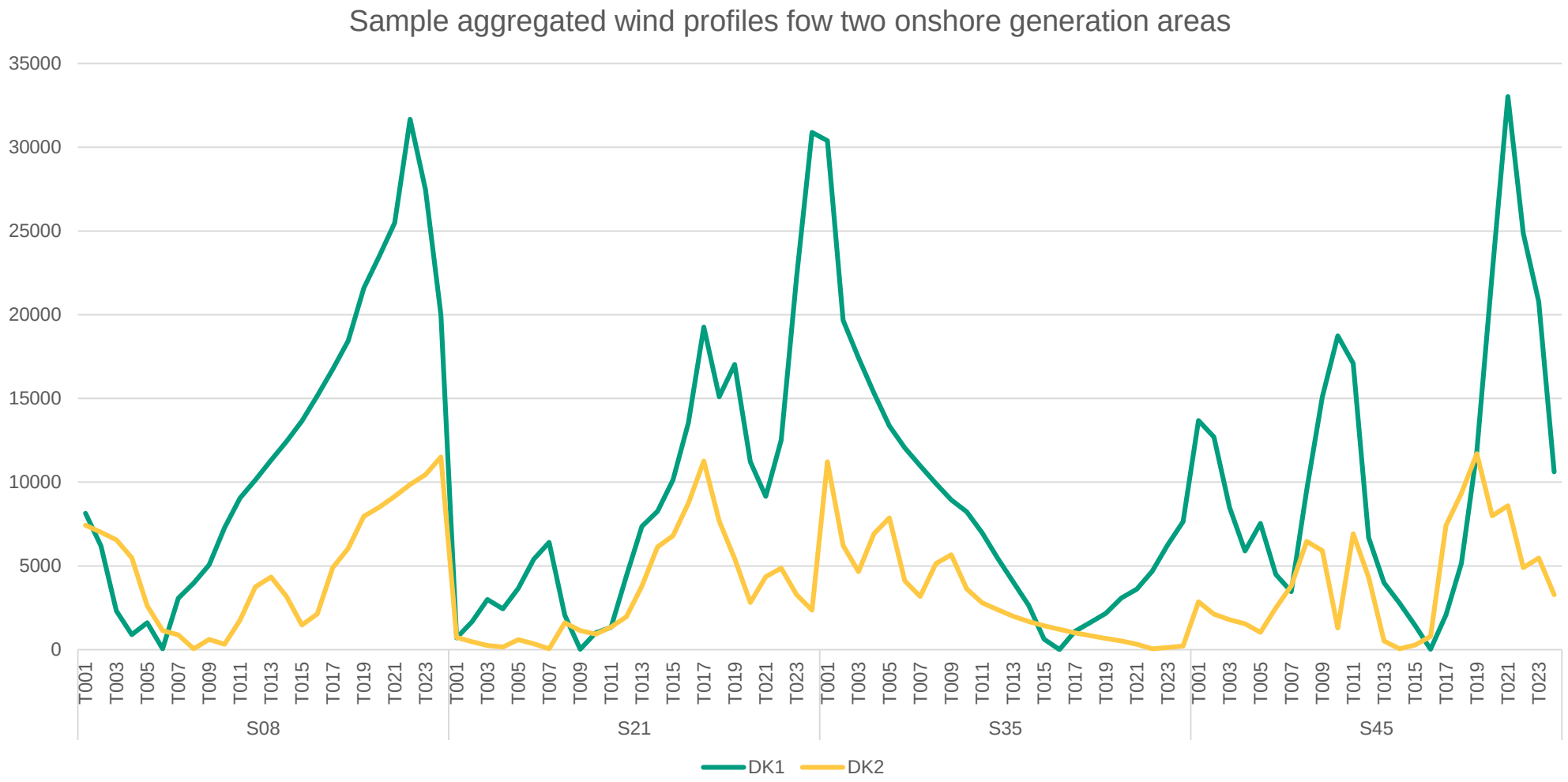
TABLE XINVCOST(YYY,IRRRE,IRRRI) 'Investment cost in new transmission capacity (Money/MW)'

	DK2	DK1	SE1	SE2	SE3	SE4	NO4	NO3	NO5	NO1	NO2	FIN	DE4-S	DE4-E	DE4-N	DE4-W	UK	EE	LV	LT	PL	NL	FR	BE
2016.DK2		509 574				421 379									568 371									
2016.DK1	509 574				774 161						695 800				568 371		1 195 600					842 800		
2016.SE1				568 371			489 975					568 371												
2016.SE2			568 371		568 371		538 973	568 371																
2016.SE3		774 161		568 371		568 371				568 371		793 760						999 600	999 600					
2016.SE4	421 379				568 371										725 163					989 800	862 400			
2016.NO4			489 975	538 973				568 371				568 371												
2016.NO3				568 371			568 371		509 574	568 371														
2016.NO5								509 574		519 374	489 975													
2016.NO1					568 371			568 371	519 374		509 574													
2016.NO2		695 800							489 975	509 574					1 185 800		1 215 200							
2016.FIN			568 371		793 760		568 371											676 200						
2016.DE4-S														568 371		568 371						568 371	568 400	539 000
2016.DE4-E													568 371		568 371	568 371					568 371			
2016.DE4-N	568 371	568 371				725 163					1 185 800			568 371		568 371								
2016.DE4-W													568 371	568 371	568 371									
2016.UK		1 195 600									1 215 200											872 200	735 000	401 800
2016.EE					999 600							676 200							450 800					
2016.LV					999 600													450 800		450 800				
2016.LT						989 800													450 800		568 371			
2016.PL						862 400								568 371						568 371				
2016.NL		842 800											568 371				872 200							450 800
2016.FR													568 400				735 000							568 400
2016.BE													539 000				401 800					450 800	568 400	

Country	Export_P	Import_P	NetE_P	Export_O	Import_O	NetE_O
BELGIUM	29 860	45 017	- 15 157	43 234	56 000	- 12 767
DENMARK	39 457	34 421	5 036	66 265	57 130	9 135
ESTONIA	7 859	5 145	2 714	12 070	7 960	4 110
FINLAND	14 887	16 326	- 1 438	26 579	16 568	10 011
FRANCE	103 727	11 512	92 214	166 450	4 840	161 610
GERMANY	155 686	259 035	- 103 348	183 005	336 647	- 153 642
LATVIA	7 871	7 104	766	12 885	8 506	4 379
LITHUANIA	6 125	13 564	- 7 439	6 266	17 329	- 11 063
NETHERLANDS	60 058	43 489	16 569	30 060	85 467	- 55 407
NORWAY	113 355	62 916	50 439	157 398	96 089	61 309
POLAND	16 865	23 285	- 6 420	52 377	40 101	12 276
SWEDEN	102 217	118 651	- 16 434	191 242	161 541	29 701
UNITED_KINGDOM	20 431	37 933	- 17 502	35 170	94 823	- 59 653




West ↔ North
DE-NO
DK-UK
NL-NO
DK-DE
LT-PL
DE-SE
DK-NL
NO-UK
North ↔ North
DK-NO
LT-SE
EE-FIN
EE-LV
NO-SE
FIN-NO
FIN-SE
LV-LT
DK-SE
West ↔ West
BE-FR
DE-NL
FR-DE
DE-PL
FR-UK
NL-UK
BE -DE
BE-UK
BE-NL
-800
-600
-400
-200
0
200
400
Difference in congestion rents, million EUR


Sample aggregated wind profiles fow two onshore generation areas
35000
30000
25000
20000
15000
10000
5000
0
T001 T003 T005 T007 T009 T011 T013 T015 T017 T019 T021 T023
S08
S21
S35
S45
DK1
DK2