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Welfare Distribution Effects of Introducing a Multi-country Carbon Price Floor

Assessment of the 2030 EU Power System

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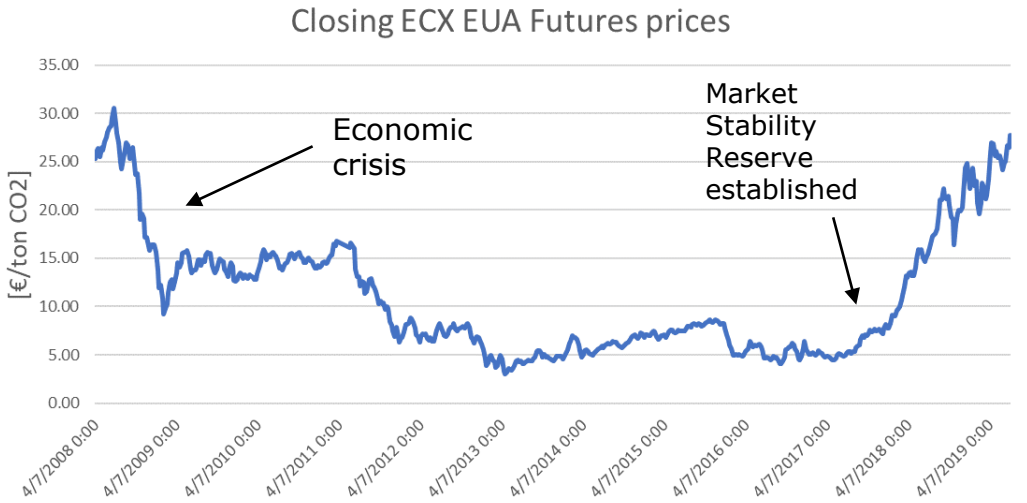
Content

- Problem statement & analysis:
  - Main drivers and thresholds regarding CPF debates in EU
  - Research questions & methodology
  - Welfare distribution analysis
- Concluding remarks & discussion

(Main) drivers for CPF discussions

- EU aims at reducing emissions by 80-95% in 2050 w.r.t. 1990 levels, and 40% by 2030
  - Power sector plays important role
- Main purpose EU ETS: stimulate low carbon investments ('polluter pays' principle)
- Main concerns effectiveness EU ETS:
  - Too low EU ETS price (low incentive)
  - high volatility (increased risk perception)
  - EU ETS Reforms (i.a. MSR) increased price but still not ensures stable and sufficiently high CO2 price
- Setting a minimum price for CO2 could help overcome these concerns



Source: Sandbag (2019), Carbon price viewer

(Main) thresholds for introduction of CPF

- UK first country to introduce a CPF, though price is capped and continuation after 2021 is uncertain
- In dec 2018, 9 EU countries signed a declaration for strengthening CO_2 pricing in EU where they commit to cooperate
  - DE, did not sign declaration i.a. because it is expected that CPF would mostly benefit FR NUC
- As pointed out by Matthes et al., 2017: "..*dealing with political narratives around winners and losers of a floor price is a key prerequisite for its successful implementation..*"
- Also: concerns for carbon leakage in case of non-unilateral implementation

Addressed research questions

1) *what is the impact on social welfare and CO_2 emissions when a regional CPF is introduced, and the impact of Germany deciding to cooperate or not?*
2) *what is the impact on social welfare and CO_2 emissions in case the EU ETS price is considered sufficiently high?*

Analysis year: 2030

Methodology – Analysis tool

EU Electricity market model COMPETES:

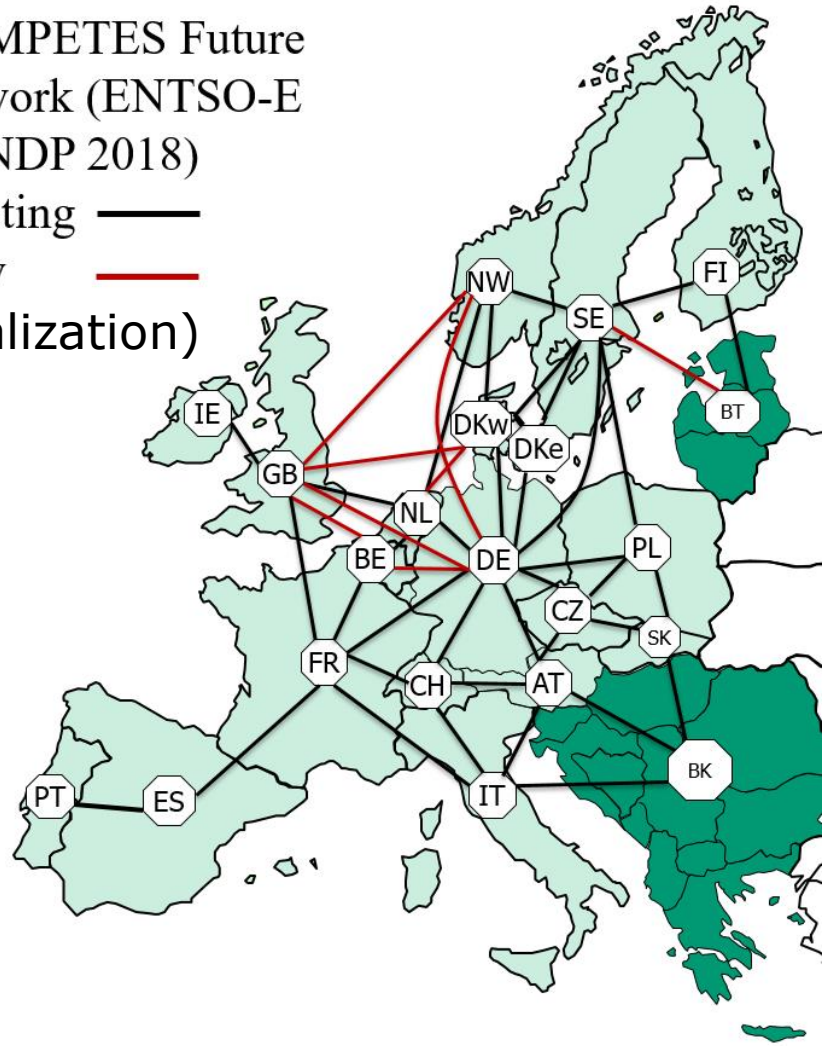
- Network constrained (NTC) optimization model (cost minimalization)
- Wide range of RES and conventional technologies
- Hourly resolution: demand, wind, solar, and hydro profiles

General scenario assumptions:

- ENTSO-E sustainable transition scenario
- Transmission: ENTSO-E TYNDP2018
- Fuel prices: WEO 2016
- Climate year: 2015

Two-stage modelling (unit commitment):

1. (Dis)investments (sample)
2. Day-ahead market (all hours)

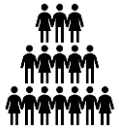


Methodology – scenarios and calculations

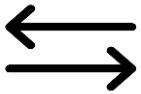
2030 Scenario	EU ETS price	CPF	Countries introducing a CPF
Reference	15 €/tonne	-	-
Alternative 1	15 €/tonne	30 €/tonne	NL, UK, IT, FR, IE, SE, FI, DK, PT
Alternative 2	15 €/tonne	30 €/tonne	NL, UK, IT, FR, IE, SE, FI, DK, PT & DE
Alternative 3	30 €/tonne	-	-

Indicators welfare assessment of main stakeholders:

Producers' surplus (PS): short-run producers' profits (gen. rev. – var. gen. costs) - (annualized) investments in new thermal capacity - fixed O&M costs for installed capacity



Consumers' payments (CP): (hourly sum of) product of demand and e-prices (wholesale)



(theoretical) congestion rents (CR): (hourly sum of) product of hourly price differences between two connected nodes and power flows

Carbon emission income government (CEI): Product of nodal CO2 emissions and EU ETS price + top-up tax CPF (if any)

ΔSocial welfare ALT: (PS ALT – PS REF) + (CP REF – CP ALT) + (CR ALT – CR REF) + (CEI ALT – CEI REF)

Avg. Yearly E-prices (€/MWh)

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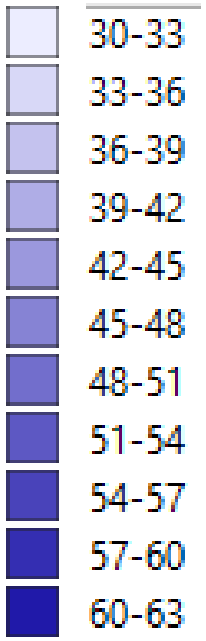
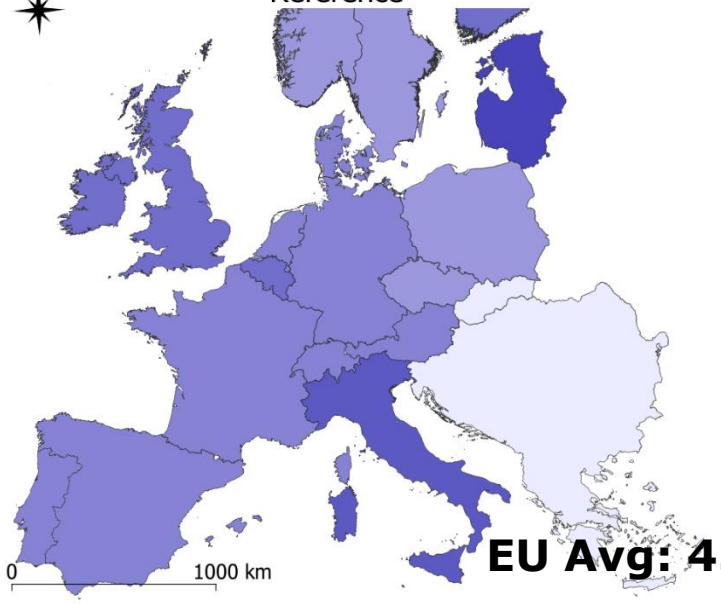
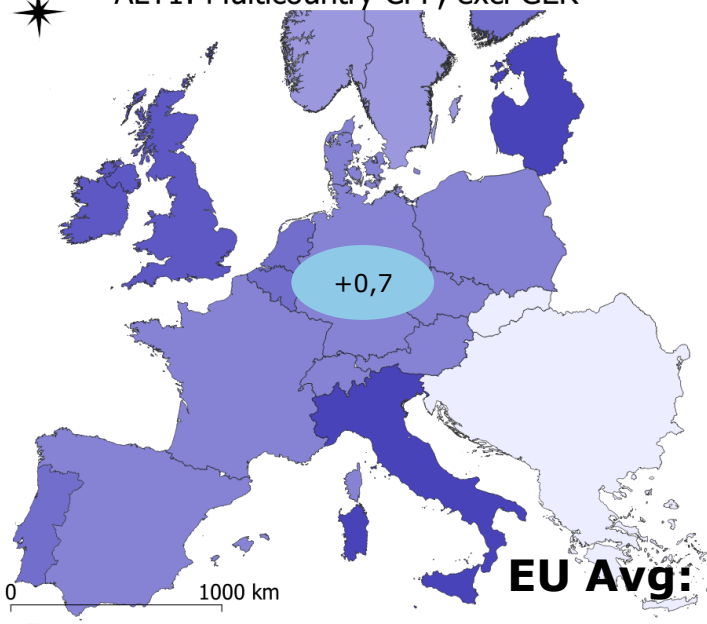


Reference



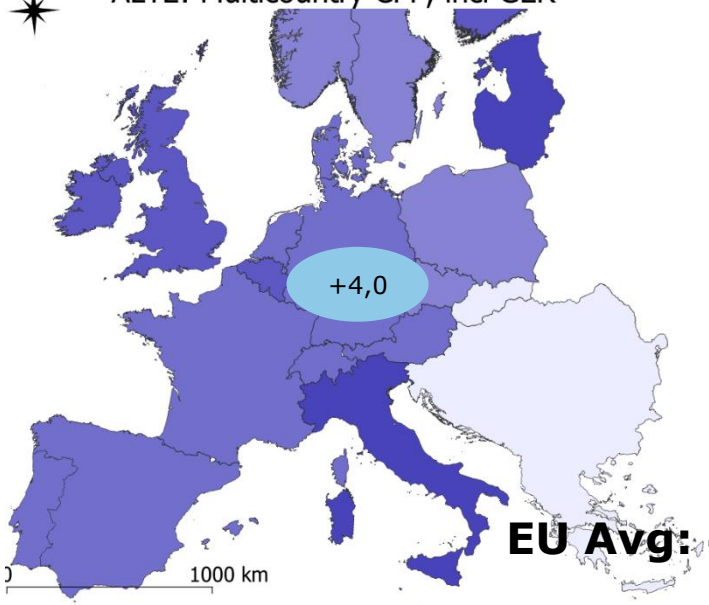
EU Avg: 45,6

ALT1: Multicountry CPF, excl GER



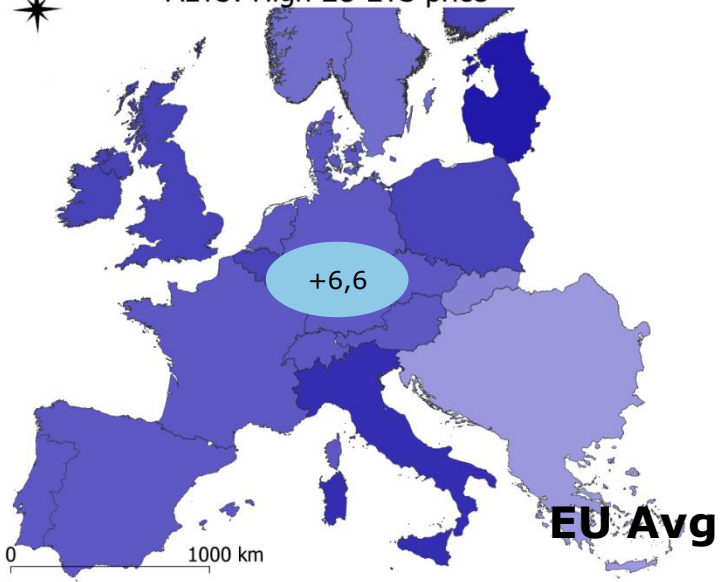
EU Avg: 47,2

ALT2: Multicountry CPF, incl GER



EU Avg: 48,9

ALT3: High EU ETS price



EU Avg: 52,6

Consumers' surplus (€Mln)

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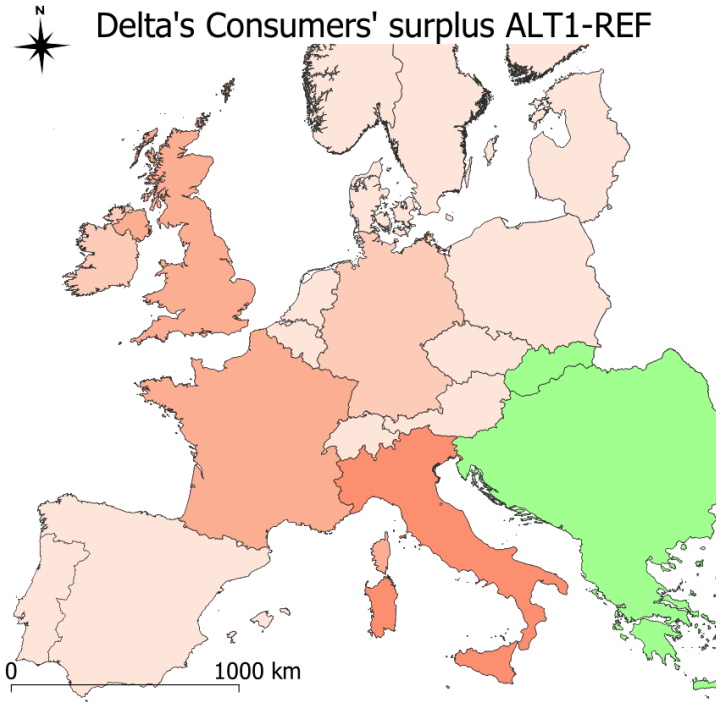

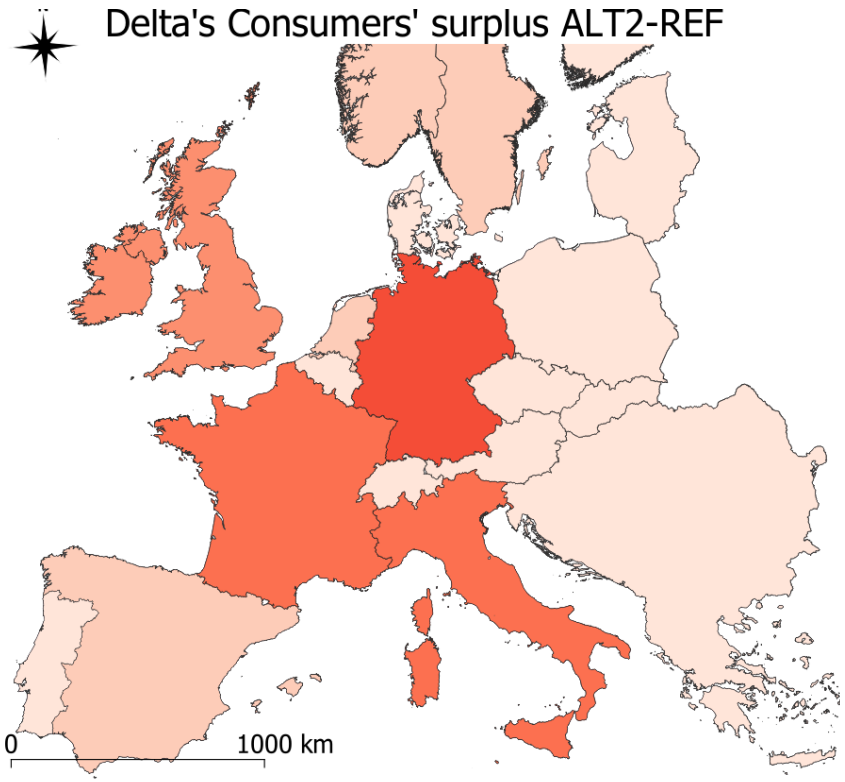

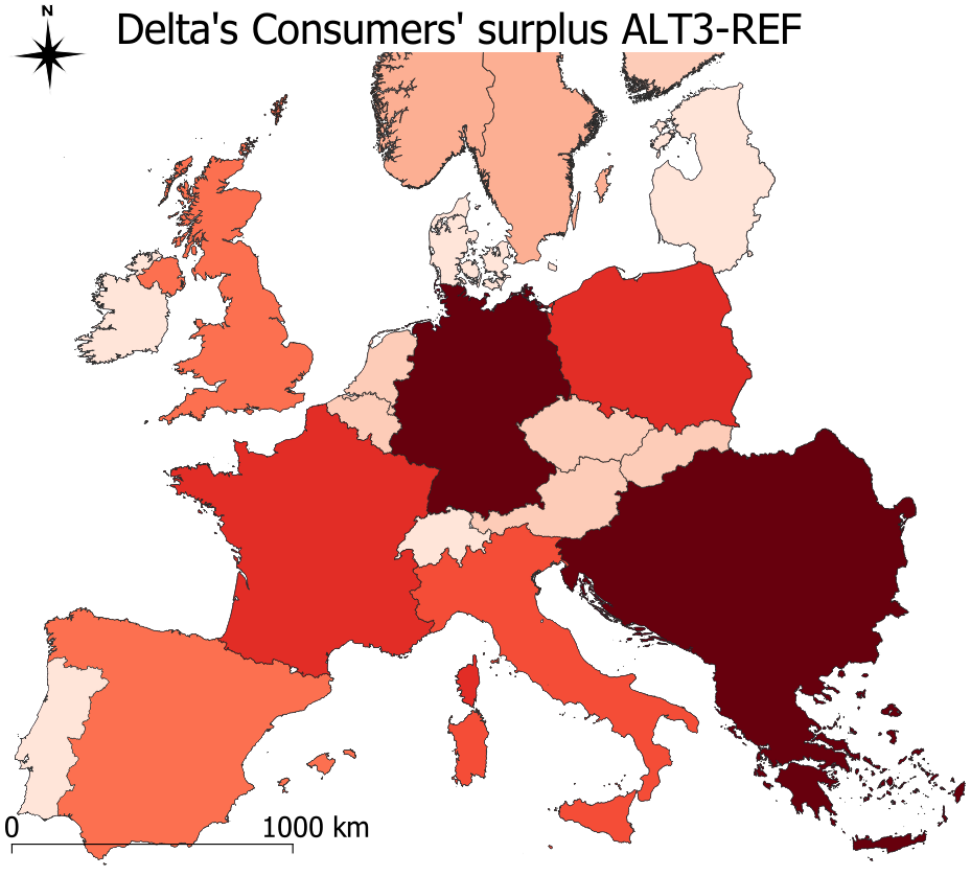

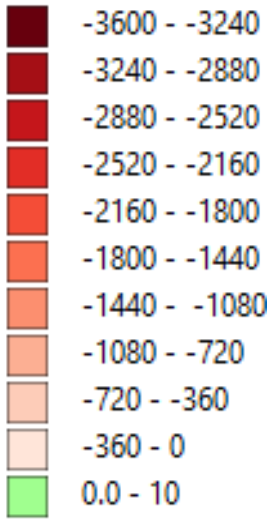

ΔProducers' surplus (€Mln)

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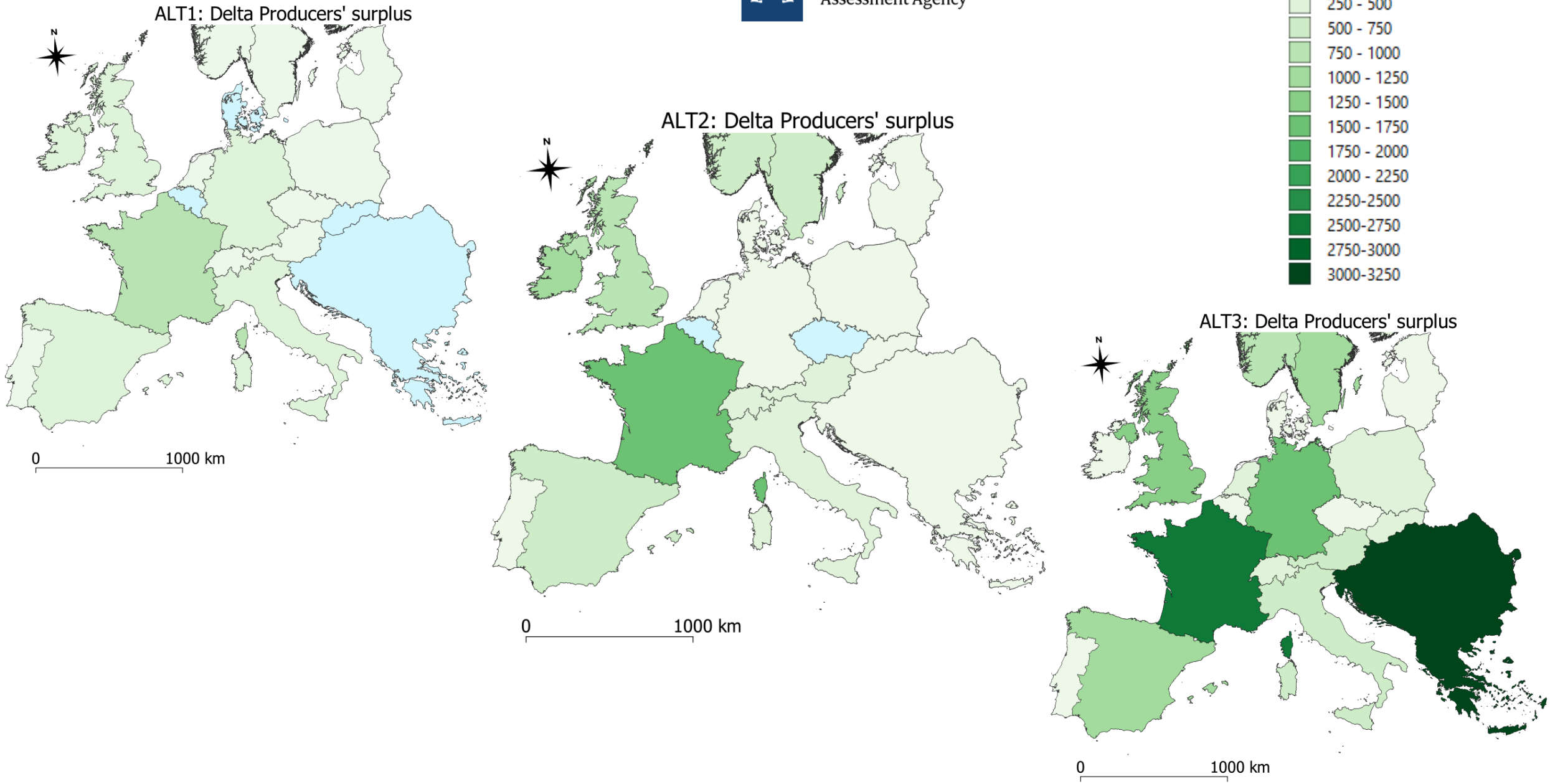

ΔCongestion rents (€Mln)

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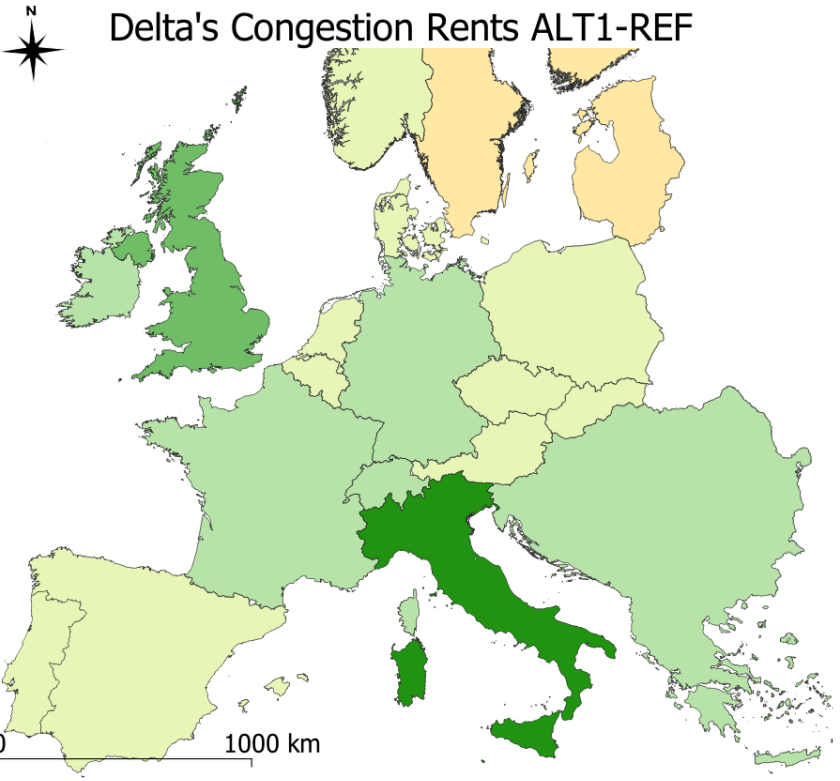

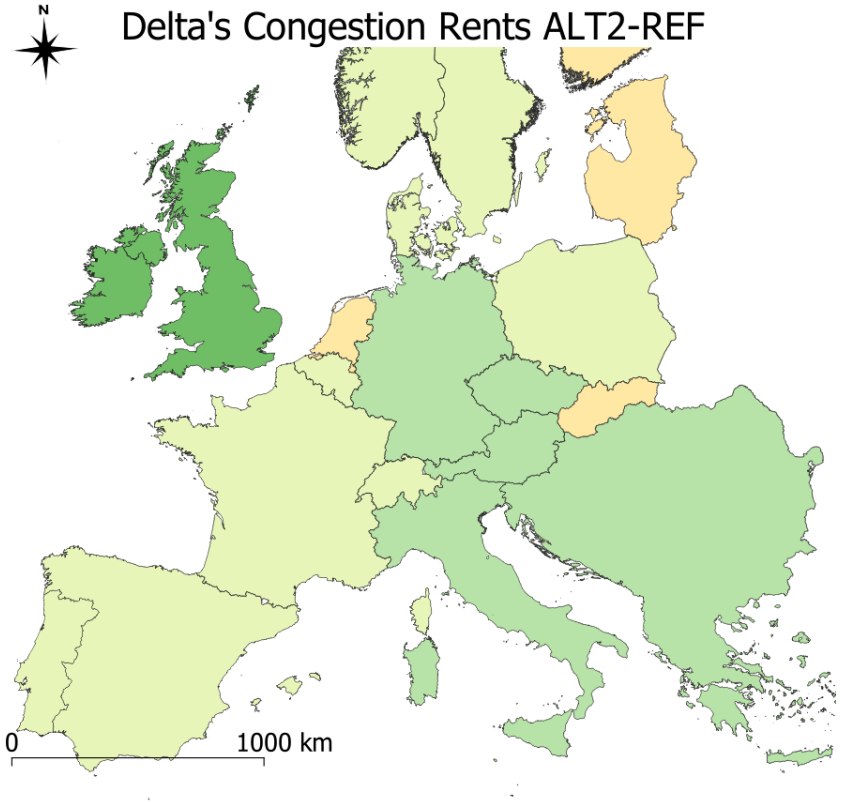

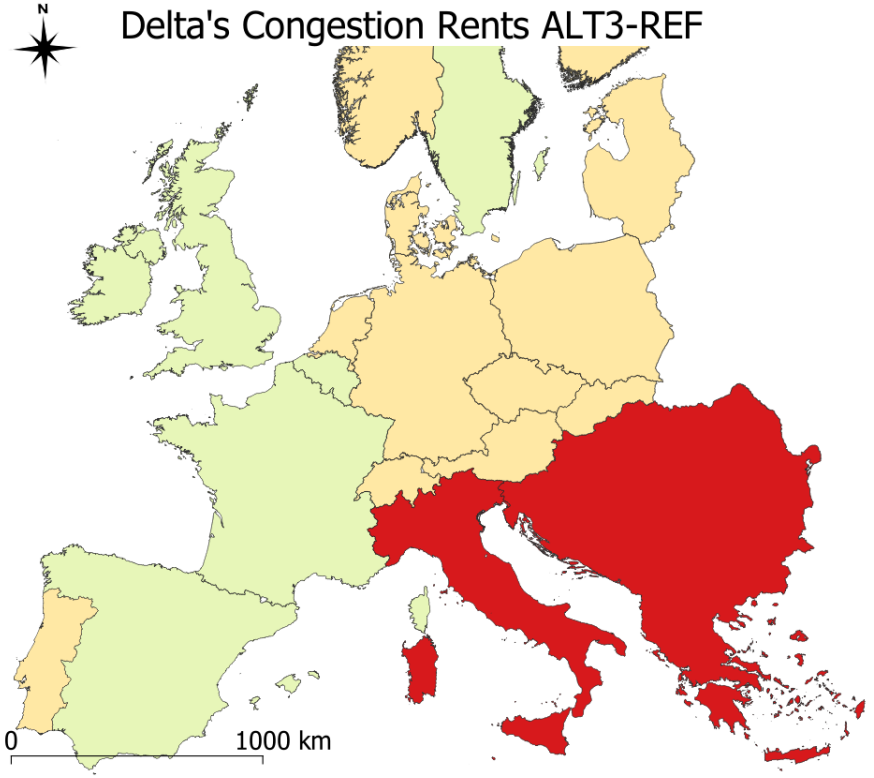

-200 - -150
-150 - -100
-100 - -50
-50 - 0
0 - 50
50 - 100
100 - 150
150 - 200

Additional income government carbon payments (€Mln)

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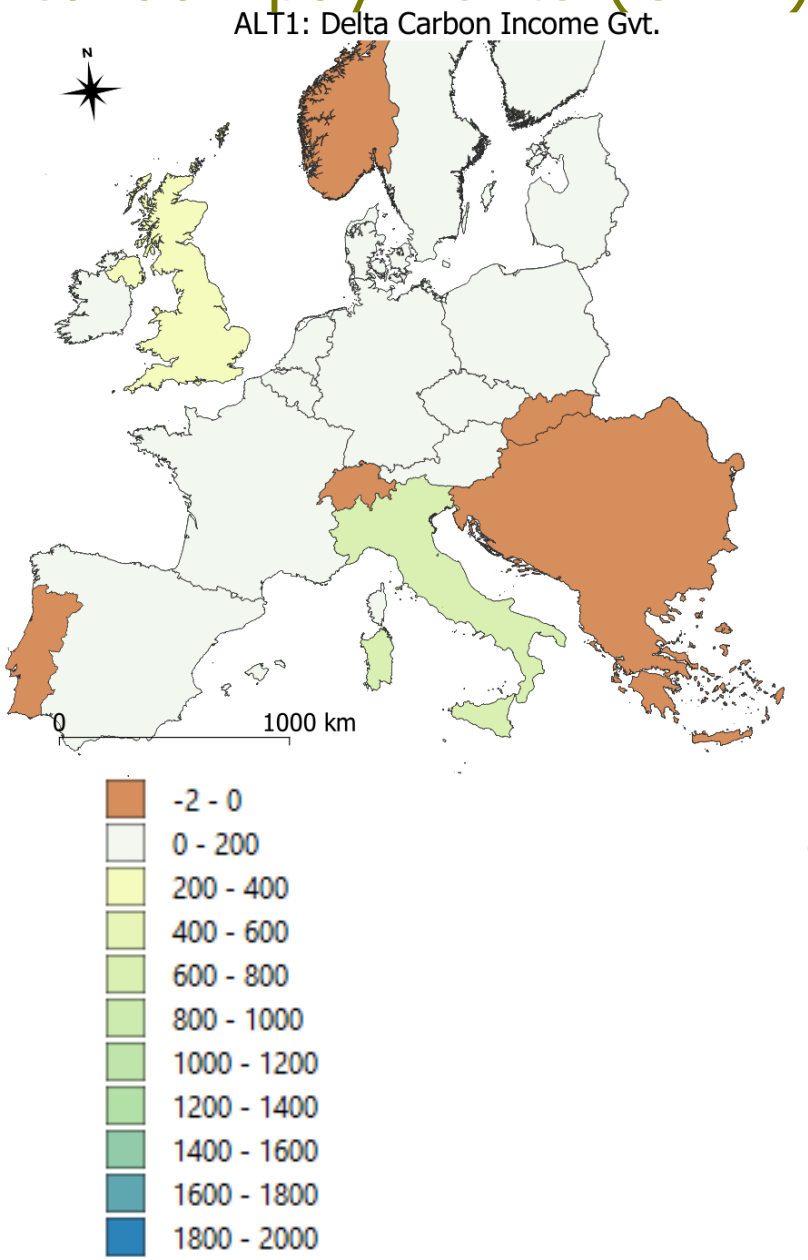

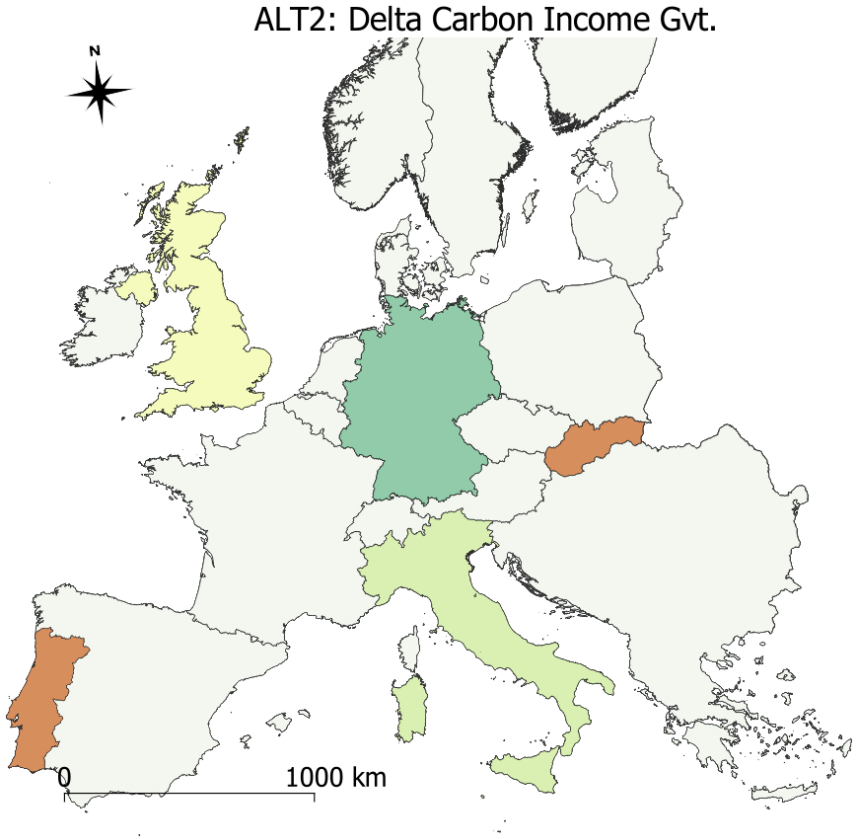

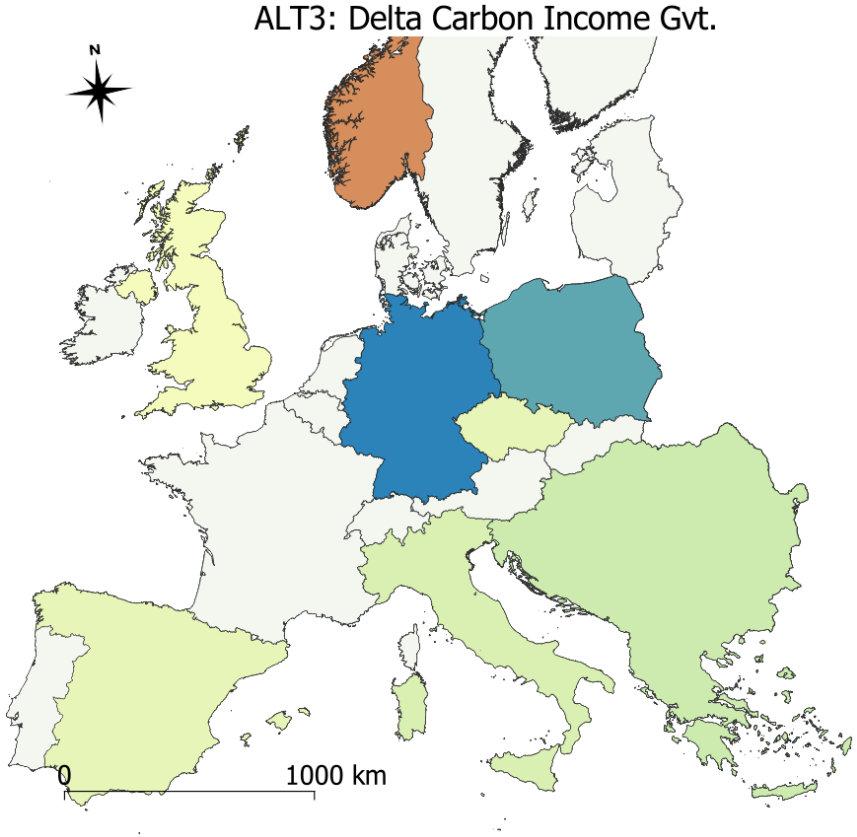

ΔSocial welfare (€Mln)

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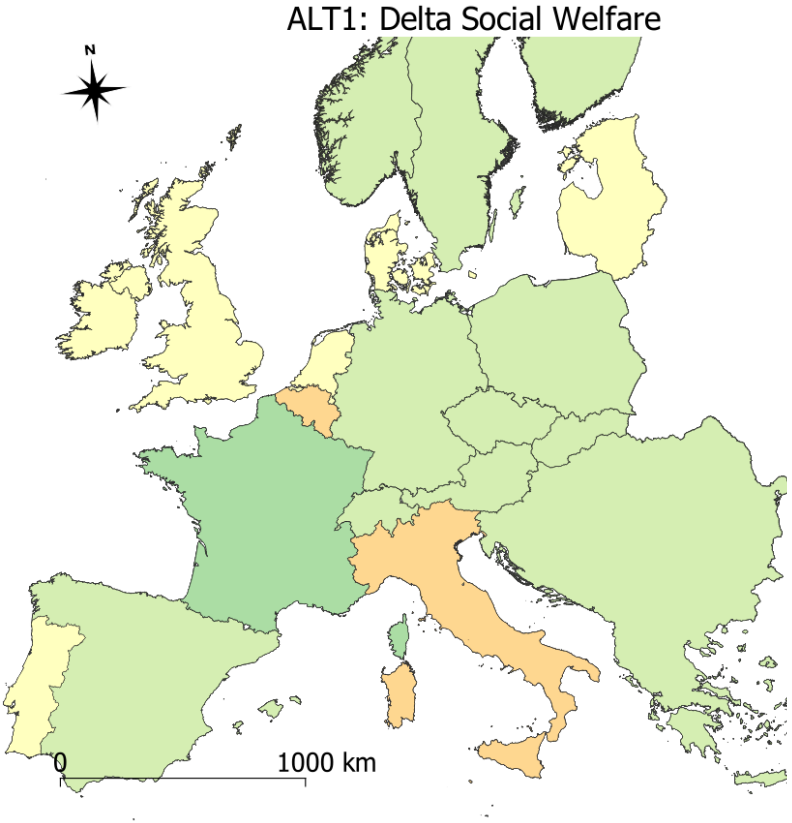
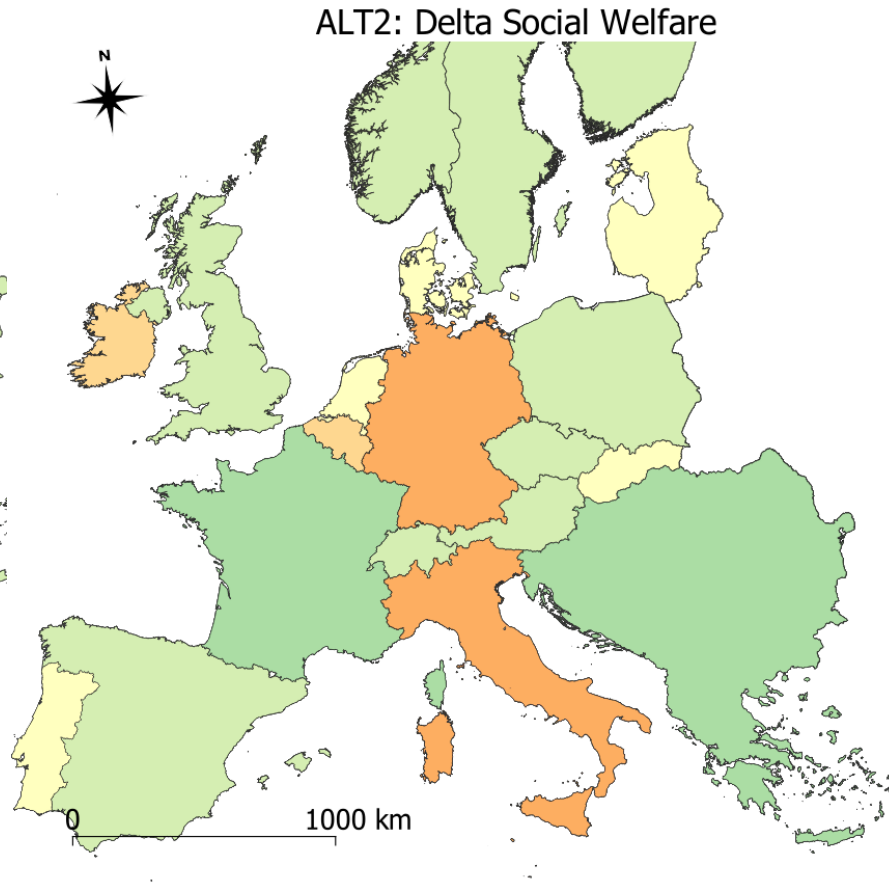
ΔSocial welfare ALT: (PS ALT – PS REF) + (CP REF – CP ALT) + (CR ALT – CR REF) + (CEI ALT – CEI REF)





-750 - -600
-600 - -450
-450 - -300
-300 - -150
-150 - 0
0 - 150
150 - 300
300 - 450

ΔCO2 emissions (Mton)

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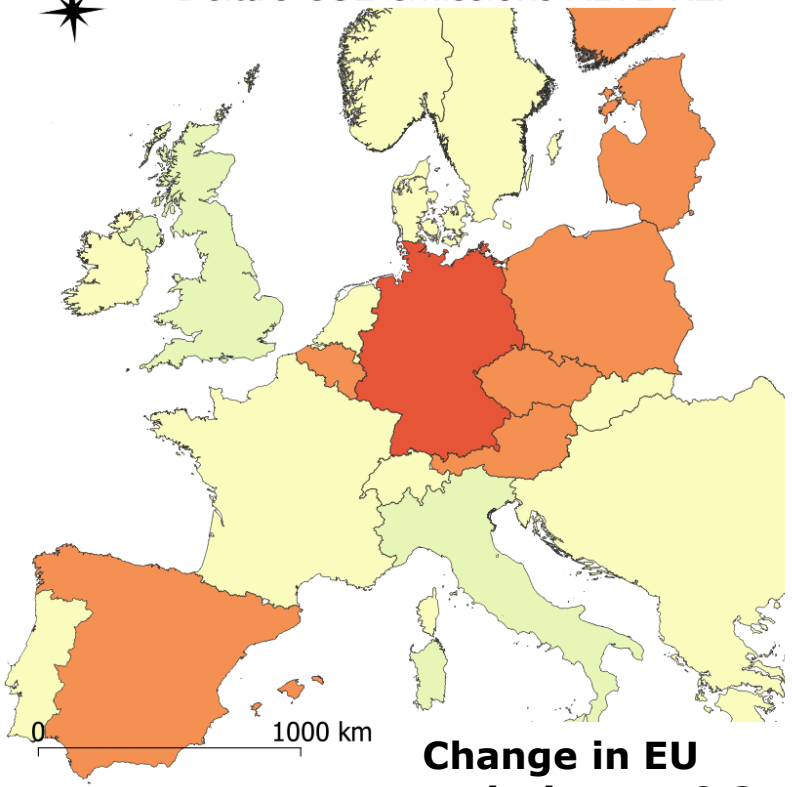
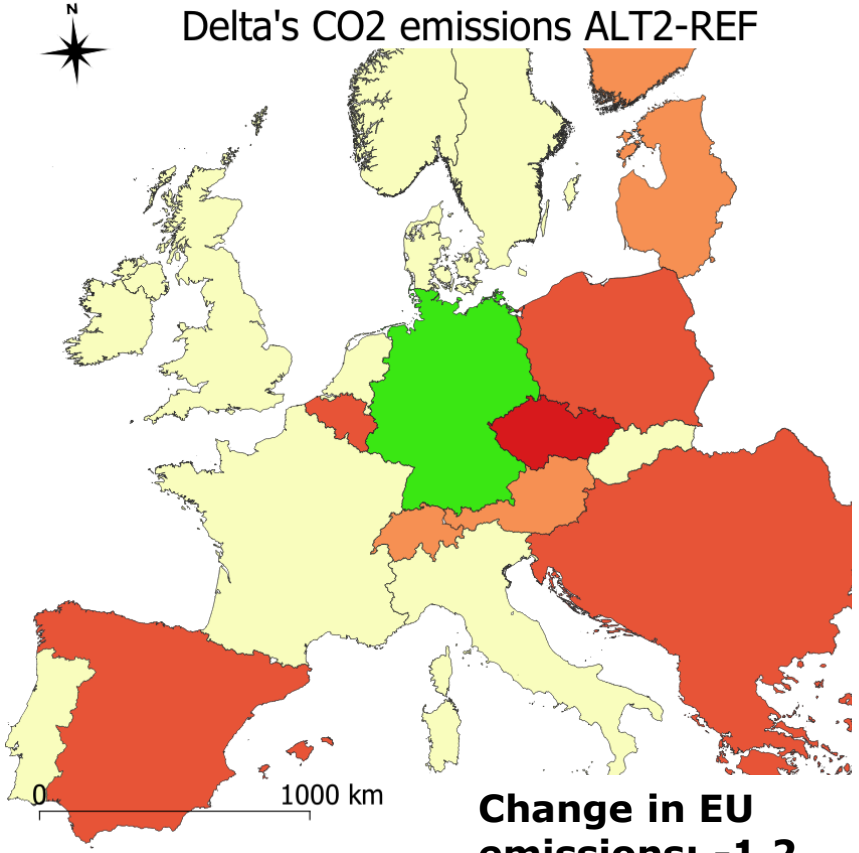
-20,00 - -17,50
-17,50 - -15,00
-15,00 - -12,50
-12,50 - -10,00
-10,00 - -7,50
-7,50 - -5,00
-5,00 - -2,50
-2,50 - 0,00
0,00 - 2,50
2,50 - 5,00
5,00 - 7,50

Delta's CO2 emissions ALT1-REF



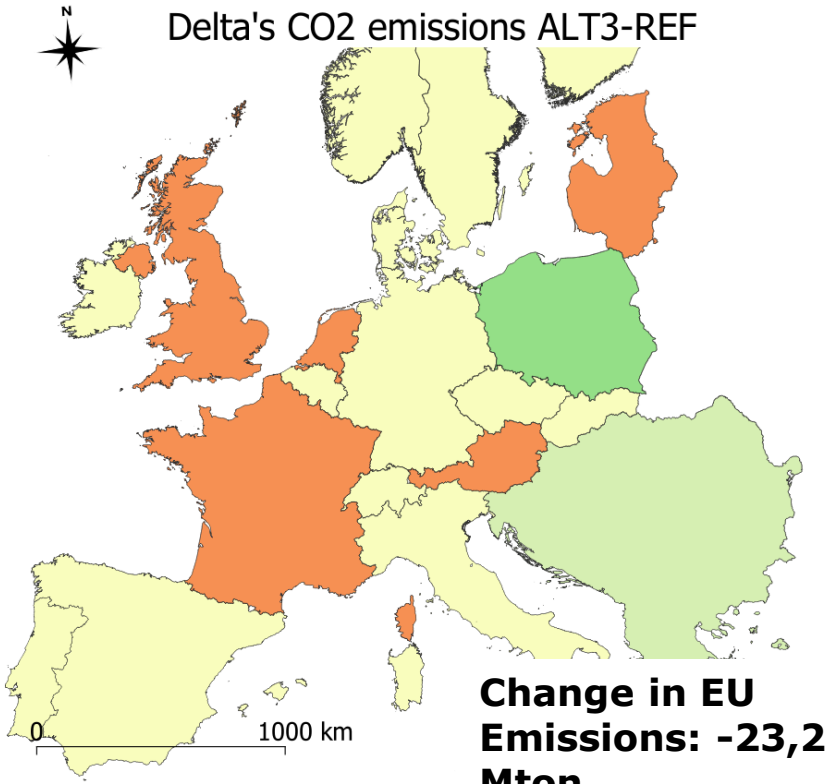
Change in EU emissions: +0,2 Mton

Delta's CO2 emissions ALT2-REF



Change in EU emissions: -1,2 Mton

Delta's CO2 emissions ALT3-REF



Change in EU Emissions: -23,2 Mton

Conclusions & discussion (1/2)

- Insights from analysis underline concerns by various stakeholders and countries
- A nonunilateral implementation of carbon floorprice will lead to carbon leakage (under model assumption of fixed EU ETS price)
- If the 9 countries that signed the declaration introduce a sufficiently high CPF, mostly gas units will be replaced by other (less efficient) gas units to meet demand (even slightly positive impact on CO2 emissions)
  - Hence, regarding emissions in the power sector only, introducing a CPF in mostly gas-based countries would be counterbeneficial
- Consumers' can generally be considered as 'losers' but might change in case governments decide to relocate (part of) additional tax income for compensation
- In case DE cooperates, there is a total CO2 reduction, but it is relatively small and DE can be considered a 'loser'
  - Considering this assessment, it would be highly unlikely that DE would sign the declaration as well

Conclusions & discussion (2/2)

- Social welfare of countries with a high share of low-carbon technologies (FR, NO etc) are benefitting from strengthened CO2 pricing
- Germany is highly important in reducing EU CO2 emissions, but only when emissions in other countries with high coal share are not increasing (e.g. PL)
  - Unilateral implementation of CPF would account for this; however PL probably not eager to cooperate since social welfare is expected to reduce
  - Further reforming the EU ETS to make sure that released EU ETS allowances will not surpress prices, might also account for this (potential impact on country's willingness to cooperate in introducing CPF)

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Thanks for your attention, any questions?

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Appendices

ENTSO-E Fuel & CO2 prices

		Fuel & CO_2 prices								
	Year	2020	2025	2025	2030	2030	2030	2040	2040	2040
	Scenario	Expected Progress	Coal Before Gas	Gas Before Coal	Sustainable Transition	EUCO	Distributed Generation	Sustainable Transition	Global Climate Action	Distributed Generation
€/net GJ	Nuclear	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
	Lignite	1.1	1.1	1.1	1.1	2.3	1.1	1.1	1.1	1.1
	Hard coal	2.3	2.5	2.1	2.7	4.3	2.7	2.5	1.8	2.8
	Gas	6.1	7.4	7	8.8	6.9	8.8	5.5	8.4	9.8
	Light oil	15.5	18.7	15.5	21.8	20.5	21.8	17.1	15.3	24.4
	Heavy oil	12.7	15.3	12.7	17.9	14.6	17.9	14	12.6	20
	Oil shale	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
€/ton	CO_2 price	18	25.7	54	84.3	27	50	45	126	80
	Main Fuel Price	*WEO 2016*	*WEO2016*	*WEO 2016*	*WEO 2016*		*WEO 2016*	*WEO 2016*	*WEO 2016*	*WEO 2016*
	Source	*New Policies*	*New Policies*	*450*	*New Policies with Higher Carbon Price*	Fuel Prices Provided by DG Energy	*New Policies with higher CO2*	*New Policies*	*450*	*New Policies with higher CO2*
	(Rows shaded Grey)							*Fuel Prices adjusted to create a "Low Oil Price Scenario"*		

Unit commitment model (MIP)

Minimize total operating costs+ Minimum Load costs+ Startup costs :

$$\min \sum_{\forall t} \sum_{\forall g} \left(c_g \left(p_{g,t} - u_{g,t} P_g^{\min} \right) + c_g^{\mathrm{SU}} v_{g,t} + c_g^{\mathrm{NL}} u_{g,t} \right) + \sum_{\forall i} VOLL \, l_{i,t}$$

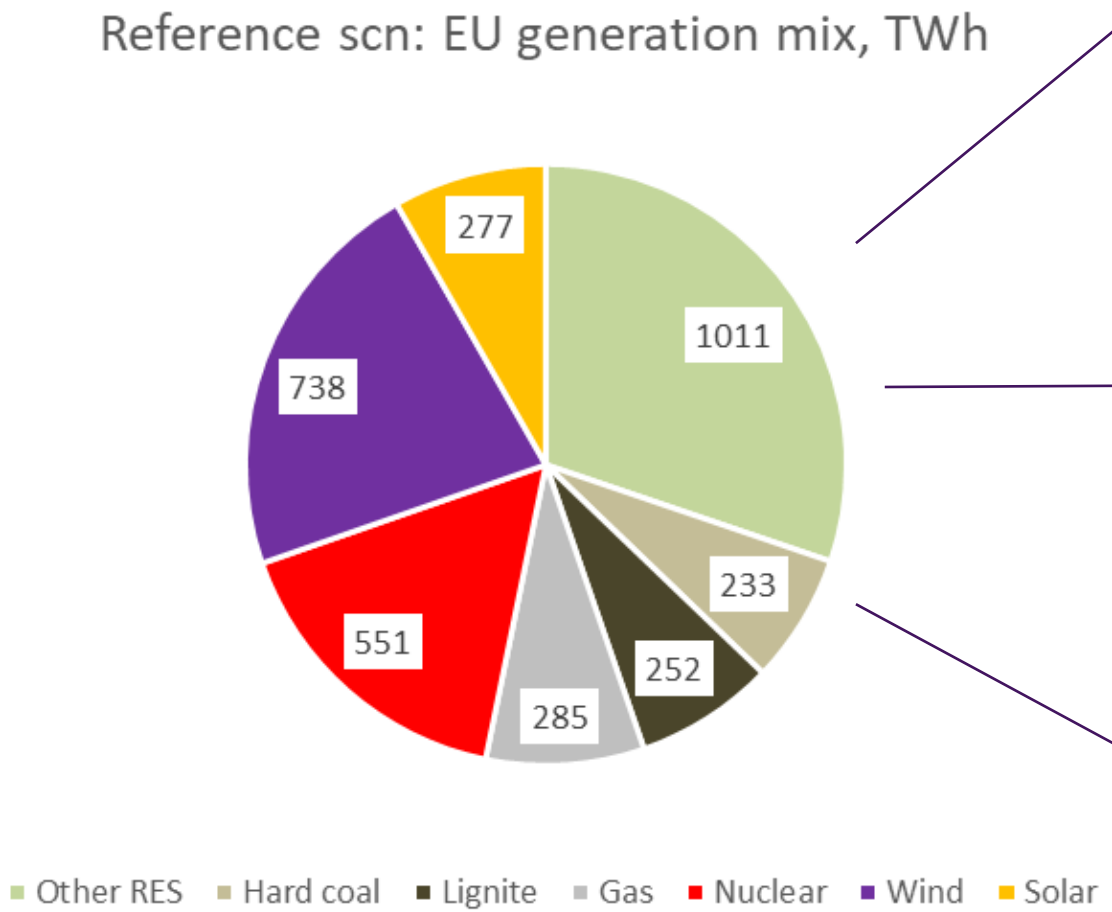
s.t. **Market clearing + Transmission + Storage+VRE + Load Shedding +Load shifting + Nonnegativity**

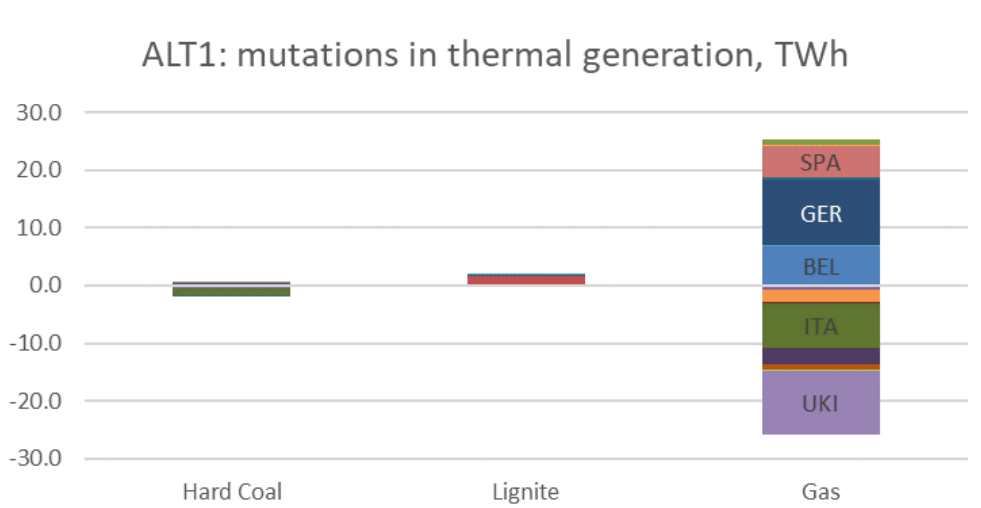
Generators:

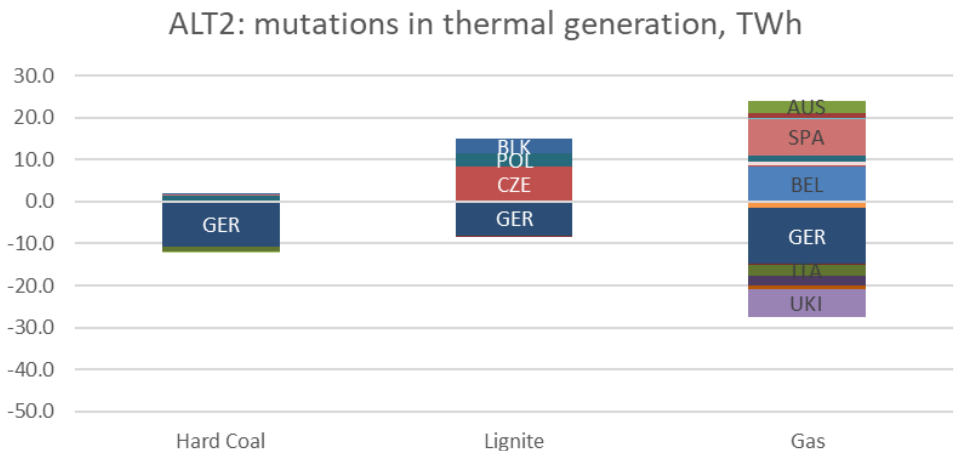
Power Capacity and reserves:	$p_{g,t} + r_{g,t}^{\mathrm{SP}} \leq u_{g,t} P_g^{\max} \qquad \forall g,t$
Minimum Load:	$u_{g,t} P_g^{\min} \leq p_{g,t}$
Ramping up:	$p_{g,t} - p_{g,t-1} \leq R_g u_{g,t-1} + R_g^{SU} v_{g,t} \qquad \forall\, g,t$
Ramping down :	$p_{g,t-1} - p_{g,t} \leq R_g u_{g,t} + R_g^{SD} \left(1 - u_{g,t}\right),\ \forall\, g,t$
Start-up/Shutdown:	$v_{g,t} - \omega_{g,t} = u_{g,t} - u_{g,t-1},\ \forall\, g,t$
Minimum up time:	$\sum_{r=t-\tau_g^{UT}+1}^{t} v_{g,t} \leq u_{g,t},\ \forall\, g,t \in \left\{\tau_g^{UT}, .., T\right\}$
Minimum down time:	$\sum_{r=t-\tau_g^{DT}+1}^{t} v_{g,t} \leq 1 - u_{g,(t-\tau_g^{DT})},\ \forall\, g,t \in \{\tau_g^{DT}, .., T\}, \forall g,t$
Reserve requirement:	$\sum_{\forall g(i)} r_{g,t}^{\mathrm{SP}} + \sum_{\forall v(i)} r_{v,t}^{\mathrm{storage}} \geq \alpha \sum_{\forall i} d_{i,t}^{peak} + \beta \sum_{\forall i} W_{i,t}^{peak},\ \ \forall i,t$
Integer variables:	$u_{g,t}, v_{g,t}, w_{g,t} \in \{0,1\}$

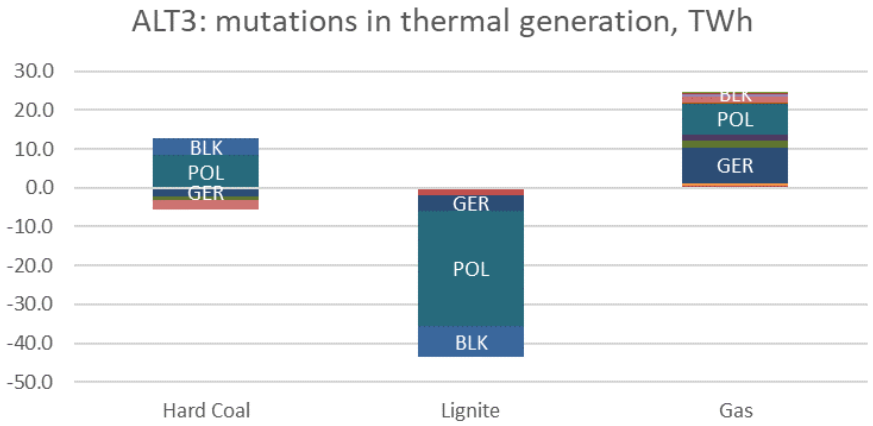
- Large-scale MIP: The integer variables for countries except NL are relaxed

Generation Mix 2030









Trade flows (TWh)

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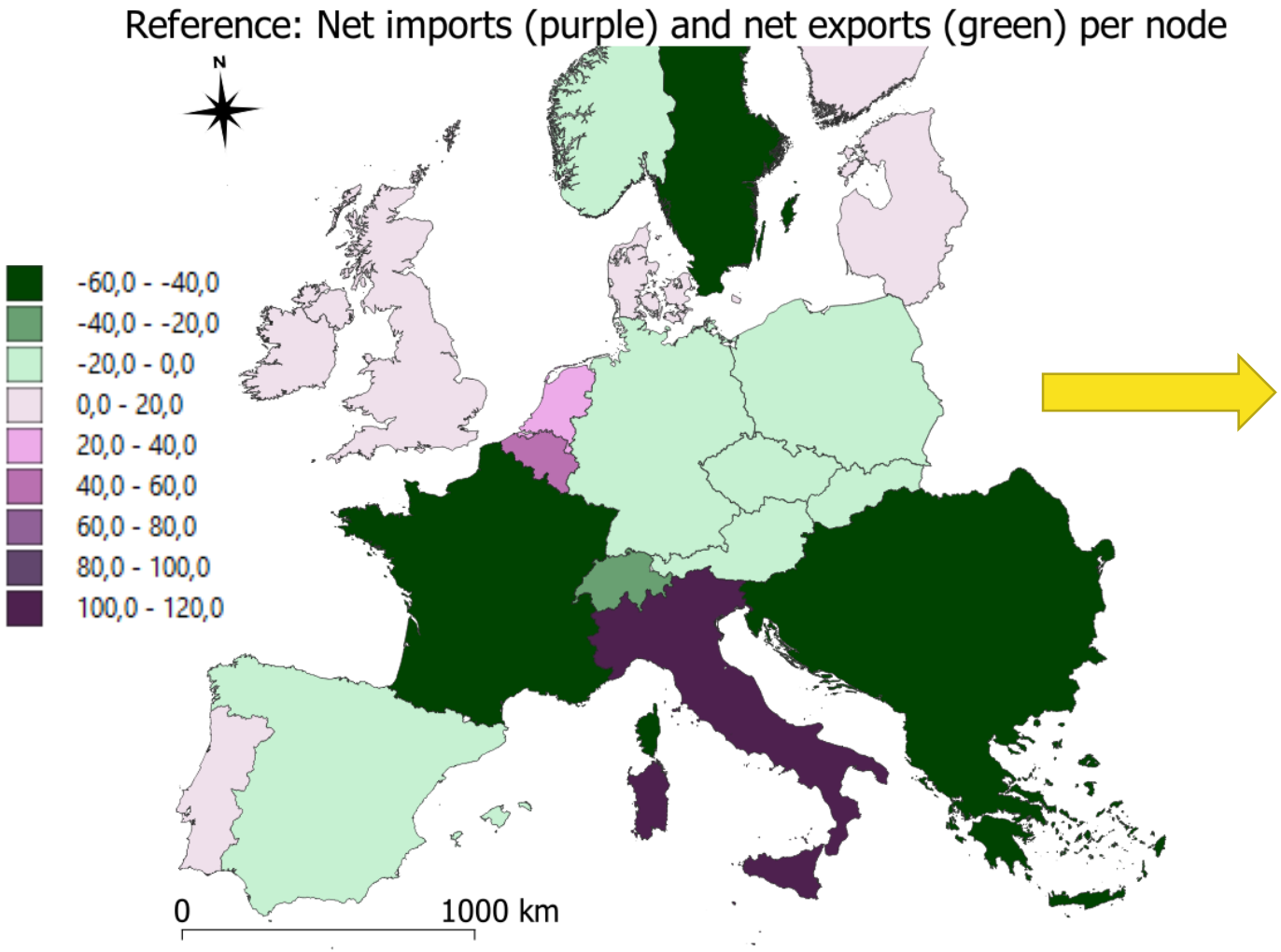
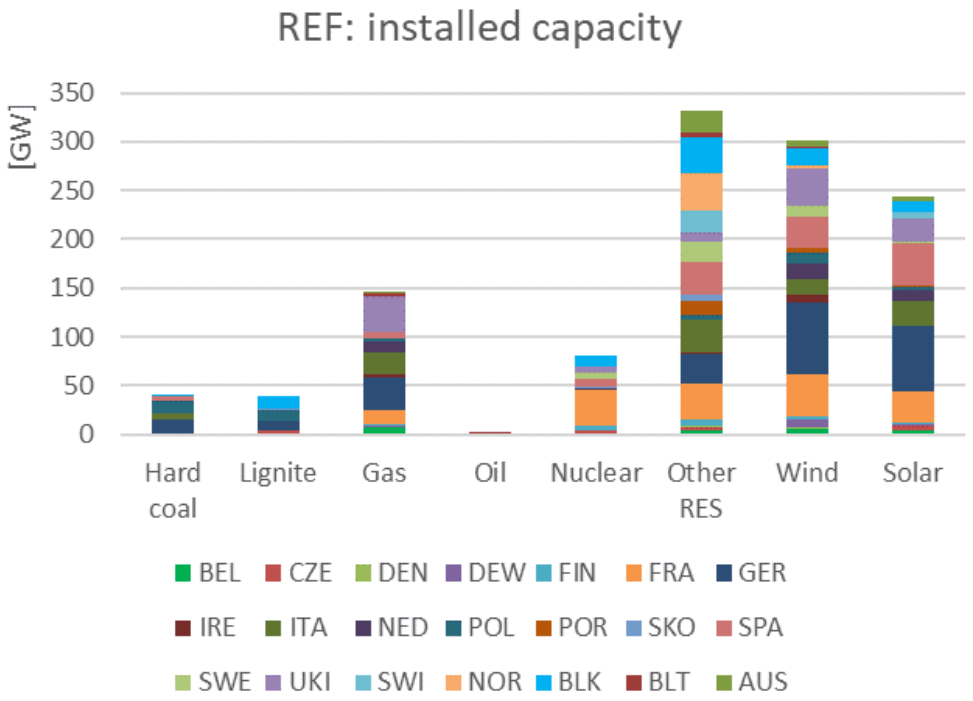
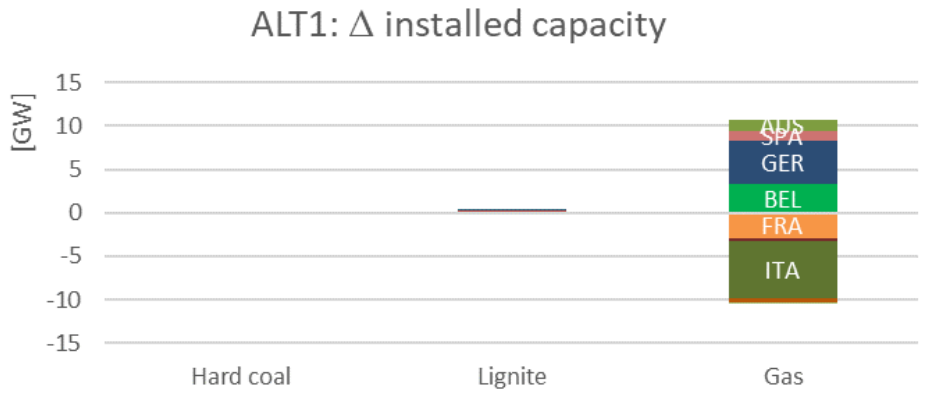
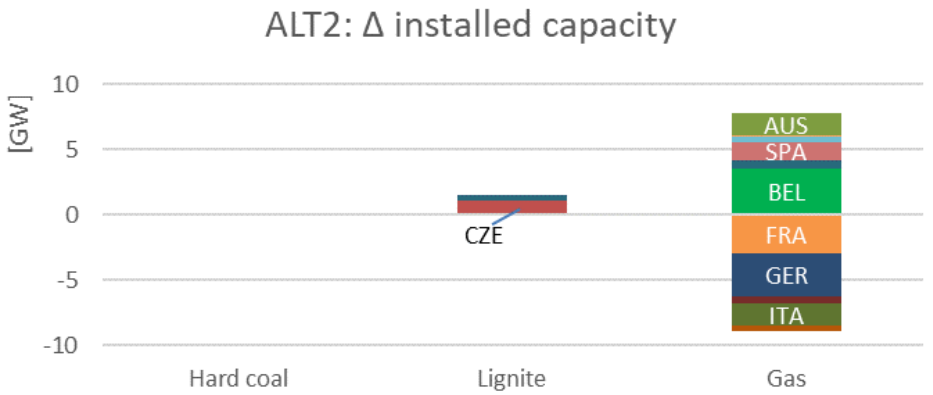


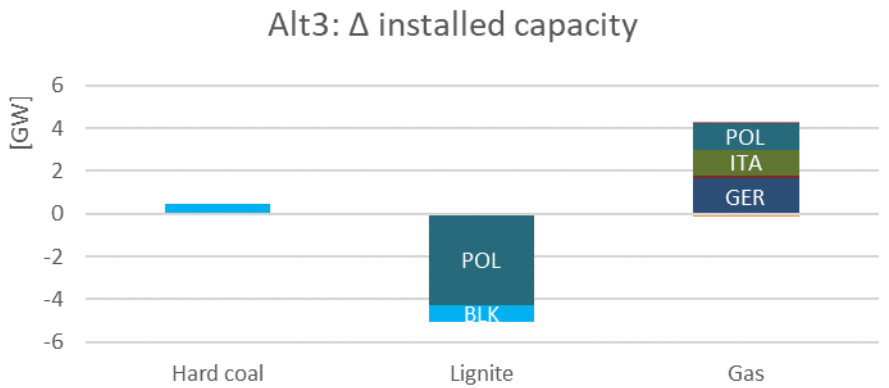
Total net imports (+) and net exports (-)	REF	ALT1	ALT2	ALT3
BEL	44	38	36	44
CZE	-9	-11	-18	-7
DK-east	5	5	5	5
DK-west	-2	-1	-1	-2
FIN	3	3	1	2
FRA	-42	-39	-41	-43
GER	-17	-29	13	-23
IRE	3	3	3	3
ITA	104	113	108	103
NED	23	26	25	22
POL	-3	-4	-9	10
POR	15	16	16	14
SKO	-2	-2	-2	-2
SPA	-2	-8	-11	-1
SWE	-41	-41	-42	-43
UKI	8	19	14	6
SWI	-23	-23	-24	-23
NOR	-8	-8	-8	-8
BLK	-53	-53	-57	-51
BLT	11	10	9	10
AUS	-13	-14	-16	-14

Installed Capacities

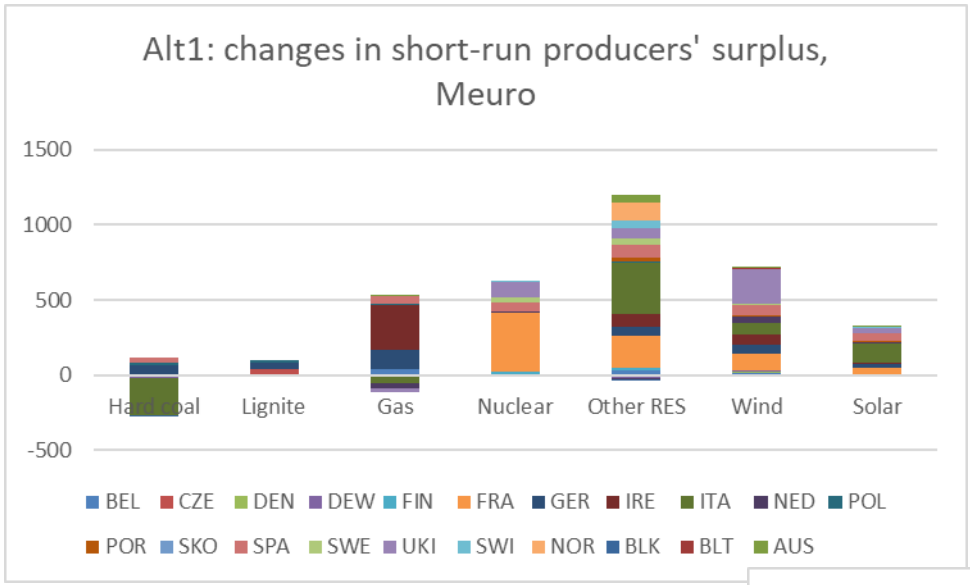


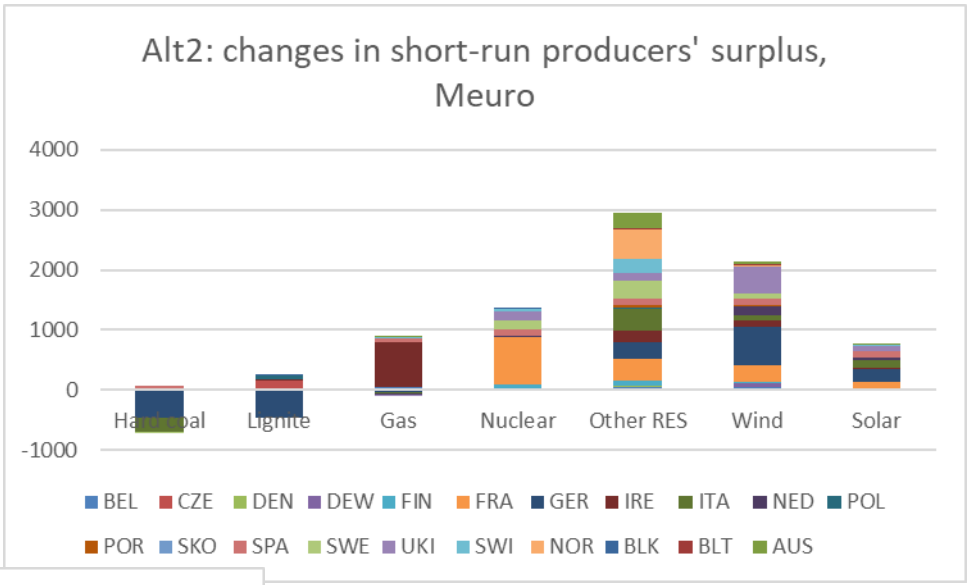


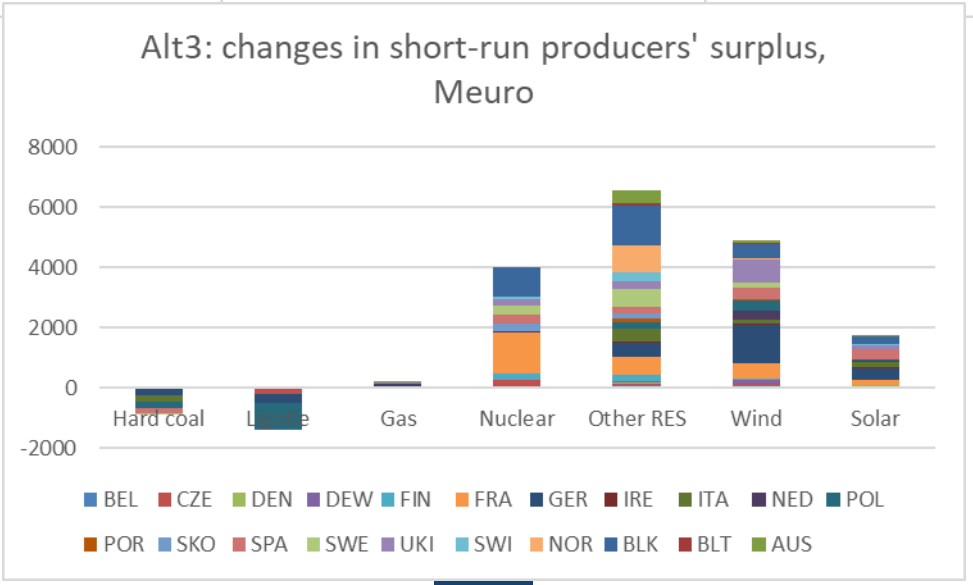




Short-run producers' surplus per technology







(short-run) producers' profits, Meuro

Short run producers profits, Meuro	Reference	Alt1	Alt2	Alt3	Alt1	Alt2	Alt3
BEL	1303	1389	1463	1500	86	160	196
CZE	2182	2230	2342	2363	48	160	181
DEN	314	309	345	378	-4	31	65
DEW	920	895	978	1058	-26	58	138
FIN	2923	2965	3149	3414	42	226	491
FRA	18341	19088	19869	21009	747	1528	2668
GER	15436	15819	15621	17099	382	185	1663
IRE	992	1448	2039	1066	456	1047	74
ITA	7689	7950	8013	8244	261	324	555
NED	2464	2481	2644	2872	17	179	408
POL	3909	3946	4025	3457	37	116	-452
POR	1529	1573	1595	1731	43	66	202
SKO	744	742	749	1182	-2	5	437
SPA	10062	10418	10605	11115	356	542	1053
SWE	6622	6710	7162	7750	88	540	1128
UKI	9296	9694	10086	10607	398	791	1311
SWI	3326	3398	3635	3763	72	309	437
NOR	6324	6448	6829	7250	124	505	926
BLK	6173	6160	6201	9192	-13	28	3019
BLT	766	774	811	867	8	45	101
AUS	3758	3823	4100	4328	66	342	571

Consumers' **Payments**, Meuro

					Delta		
Consumer Payments, Meuro	**Reference**	**Alt1**	**Alt2**	**Alt3**	**Alt1**	**Alt2**	**Alt3**
BEL	4124	4264	4405	4635	140	281	512
CZE	3082	3098	3099	3660	16	17	578
DEN	734	745	796	839	11	62	105
DEW	1144	1162	1243	1309	18	99	165
FIN	4130	4173	4352	4690	43	223	560
FRA	20379	21147	21844	22878	768	1465	2500
GER	24568	24930	26713	28137	362	2145	3569
IRE	1843	2487	3239	1980	644	1396	137
ITA	18235	19654	19744	20060	1419	1509	1826
NED	5481	5662	5872	6188	181	391	707
POL	9049	9080	9106	11263	31	58	2214
POR	2458	2524	2558	2743	67	100	286
SKO	1018	1015	1022	1446	-2	5	428
SPA	13041	13391	13568	14569	350	527	1528
SWE	6035	6137	6481	6925	103	447	890
UKI	14679	15487	15871	16367	808	1192	1688
SWI	2493	2546	2705	2847	53	212	354
NOR	6131	6245	6607	7007	115	477	876
BLK	7767	7756	7786	11181	-10	19	3415
BLT	1721	1731	1779	1916	10	58	195
AUS	3322	3374	3599	3812	52	277	490

Totals Congestion Rents, Meuro

					Delta		
Congestion Rent, Meuro	**Reference**	**Alt1**	**Alt2**	**Alt3**	**Alt1**	**Alt2**	**Alt3**
BEL		82	94	84	86	11	1	3
CZE		96	104	154	69	8	58	-26
DEN		13	13	16	14	0	3	1
DEW		54	68	59	53	14	4	-1
FIN		67	64	58	66	-3	-8	-1
FRA		418	483	447	438	66	30	21
GER		235	292	307	212	57	72	-23
IRE		51	102	171	52	51	120	1
ITA		645	843	743	479	198	98	-166
NED		89	121	78	77	32	-11	-12
POL		128	135	162	111	7	34	-16
POR		5	6	6	5	0	0	0
SKO		125	127	124	93	2	0	-32
SPA		142	146	142	146	4	0	4
SWE		124	123	130	125	-1	6	0
UKI		220	327	362	223	107	142	3
SWI		222	312	240	195	90	18	-27
NOR		120	144	136	116	24	16	-4
BLK		443	509	533	282	67	90	-161
BLT		53	51	46	50	-2	-7	-3
AUS		165	189	216	121	24	51	-44