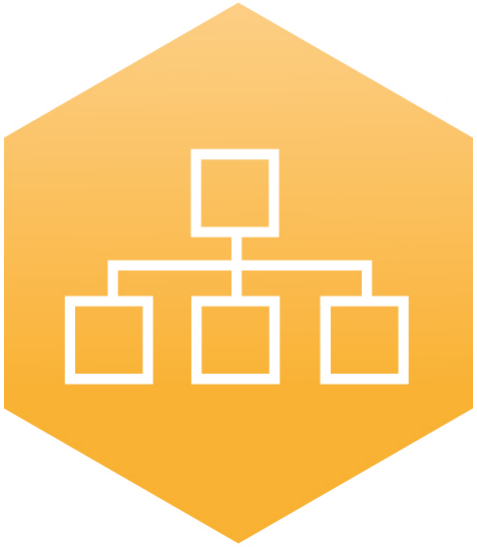
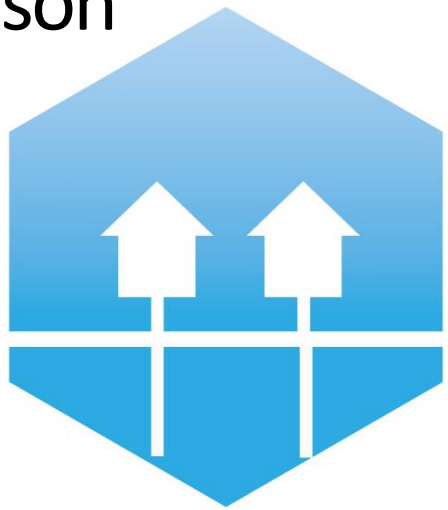
4th International Conference on Smart Energy Systems and 4th Generation District Heating
Aalborg, 13-14 November 2018

On integrating electric vehicles into Smart Energy Systems: Italy and Germany in comparison





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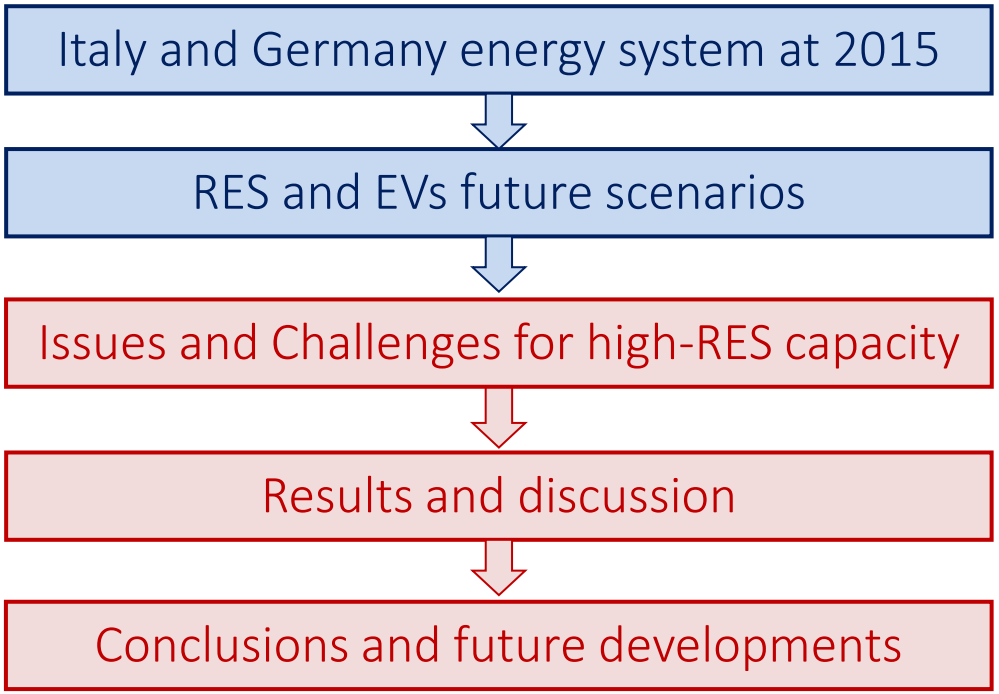
Outline



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Total Primary Energy Supply (TPES) at 2015

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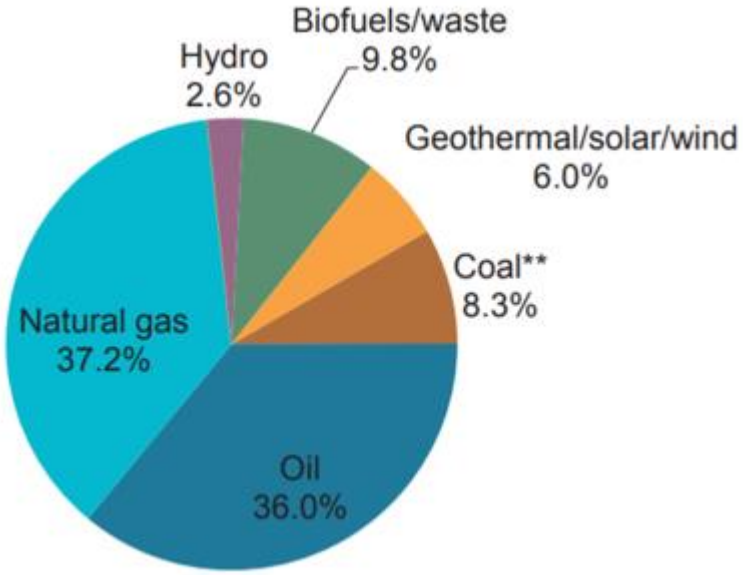
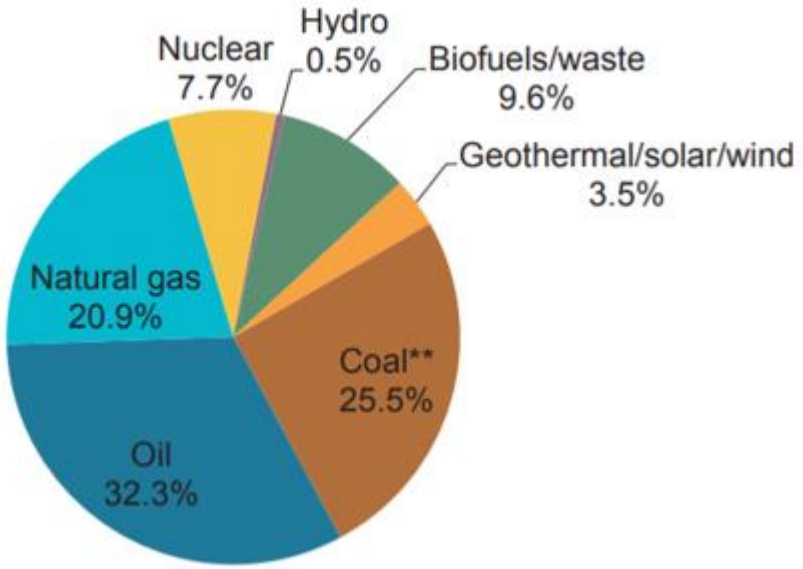
TPSE – Italy



153 Mtoe

TPSE – Germany



308 Mtoe

* Share of TPES excludes electricity trade. ** In this graph, peat and oil shale are aggregated with coal, when relevant.

Note: For presentational purposes, shares of under 0.1% are not included and consequently the total may not add up to 100%.

For more detailed data, please consult our on-line data service at http://data.iea.org.

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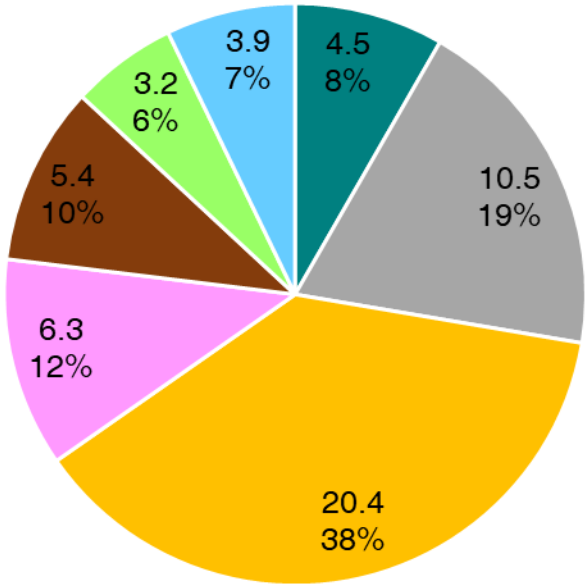
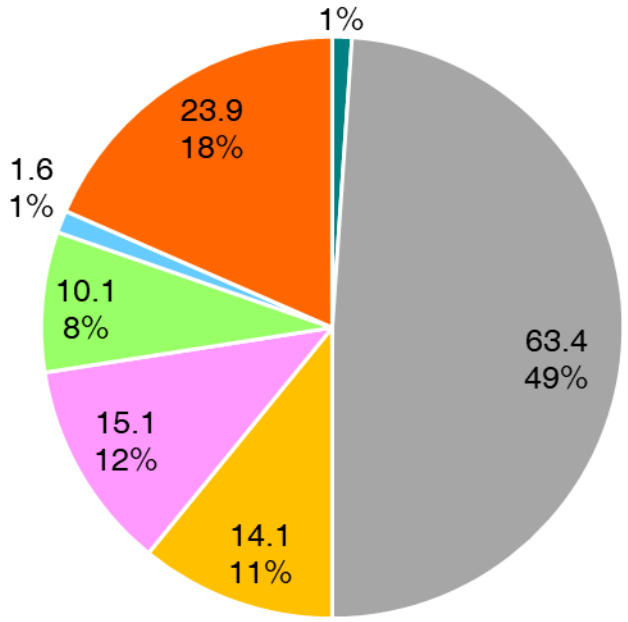
Primary energy supply: electricity generation at 2015*

*Source: IEA «Energy balaces for 2015»

PES for electricity generation – Italy (54.2 Mtoe)



PES for electricity generation – Germany (129.7 Mtoe)



Oil Coal Natural gas Biofuel and waste
Geothermal Solar and wind Hydro Nuclear

Emission factors:

Natural gas = 57 $kg_{CO2}/GJ_{Natural\ gas}$, Oil = 74 kg_{CO2}/GJ_{Oil}, Coal = 95 kg_{CO2}/GJ_{Coal}

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RES integration scenarios

	Intermittent RES capacity [GW]					
	Italy			Germany		
	RES2015	RES2030[1]	RES2050[1]	RES2015	RES2030[2]	RES2050[2]
Onshore wind	6.29	15.80	15.80	37.76	48.00	198.00
Offshore wind	-	1.15	1.15	0.99	11.00	54.00
PV	10.94	32.63	97.89	37.45	62.45	275.00
CSP	-	2.00	6.00	-	-	-
Total	**17.23**	**51.58**	**120.84**	**76.2**	**121.45**	**527.00**

[1]Derived from 2030 RES energy target as reported in "Strategia Energetica Nazionale 2017" and from current power hourly distribution. For 2050 wind capacity remains unchanged according to "Anev 2017 annual report" and capacity for solar increased until covering potential 93% of electricity generation as targeted by SEN2017.

[2]Derived from 2030 RES target as reported in "REmap, Renewable Energy Prospects: Germany" based on reference case 2030 and from "Auftraggeber und Unterstützer der Studie ENERGIEWIRTSCHAFTLICHE BEDEUTUNG DER OFFSHORE-WINDENERGIE FÜR DIE ENERGIEWENDE" using current power hourly distribution.

Other assumptions

Italy[1]:

- 10 GW decrease in conventional power plants by 2030;

Germany[2]:

- nuclear power plants completely dismissed by 2030;
- decline in coal and natural gas (-14 % and -29 % respectively);
- doubling biomass consumption for electricity generation.

[1]Source: “Strategia Energetica Nazionale 2017”

[2]Source: “REmap, Renewable Energy Prospects: Germany”

EV integration scenarios

Petrol private vehicles (e.g. @ Italy -30% conventional fleet replacement)

Size	Share by size	Initial vehicles (Mln)	Remaining vehicles (Mln)	Fuel Economy (l/100 km)	Consumption[1] (TWh)
Small (<1400 cm^3)	45%	7.30	5.11	5.10	23.82
Medium (1400÷2000 cm^3)	53%	8.57	6.00	6.00	32.92
Large (>2000 cm^3)	2%	0.30	0.21	7.70	1.46
Total		**16.17**	**11.32**		**58.20**

Diesel private vehicles (e.g. @ Italy -30% conventional fleet replacement)

Size	Share by size	Initial vehicles (Mln)	Remaining vehicles (Mln)	Fuel Economy (l/100 km)	Consumption[2] (TWh)
Small (<1400 cm^3)	1%	0.15	0.10	4.20	0.06
Medium (1400÷2000 cm^3)	85%	12.33	8.63	4.90	6.25
Large (>2000 cm^3)	14%	2.01	1.41	6.40	1.33
Total		**14.49**	**10.14**		**7.64**

9.2 million vehicles to be replaced by EV

[1]based on 10120 km/year

[2]based on 16505 km/year

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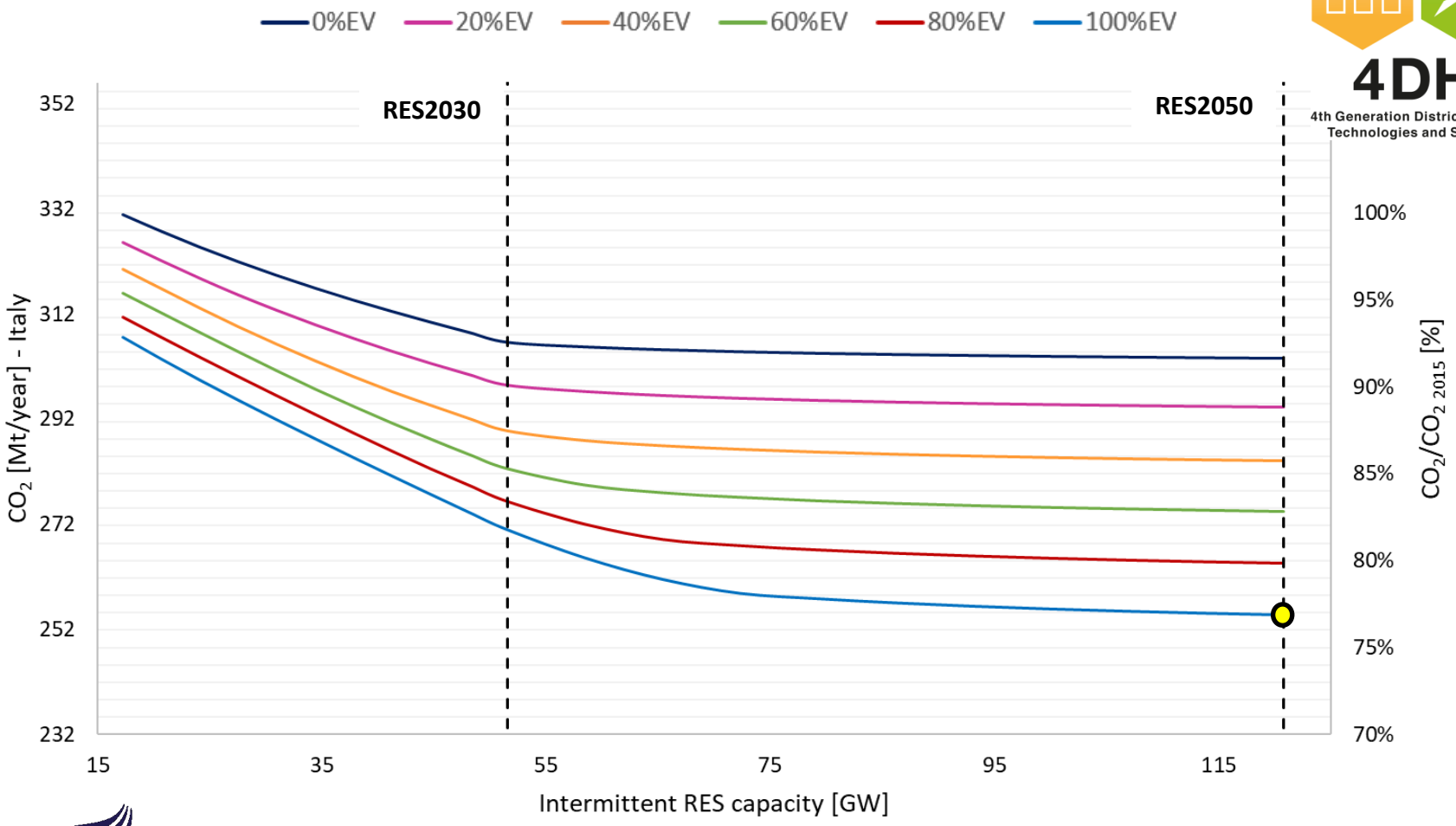
CO_2 emissions: Italy



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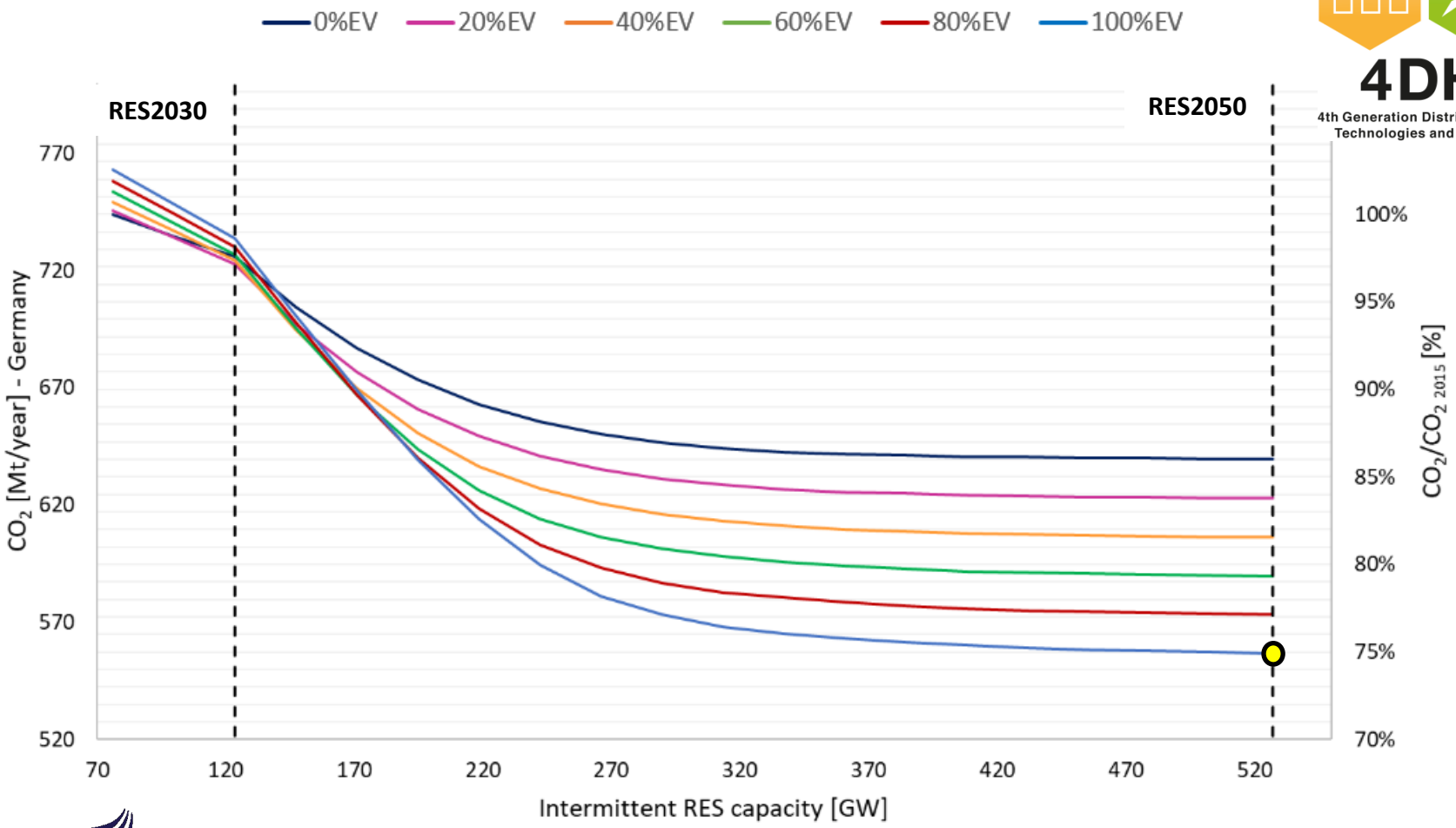
CO_2 emissions: Germany



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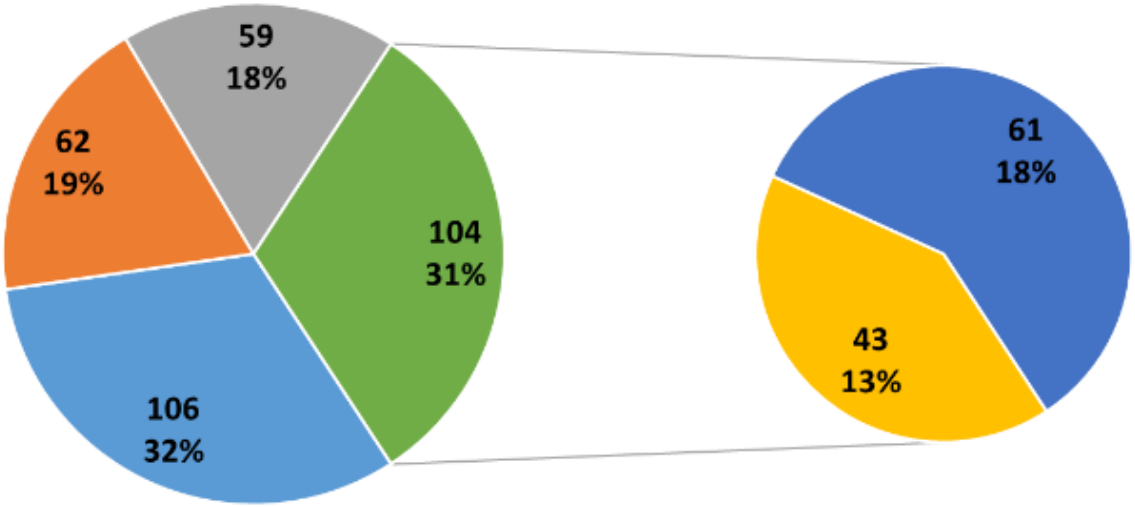
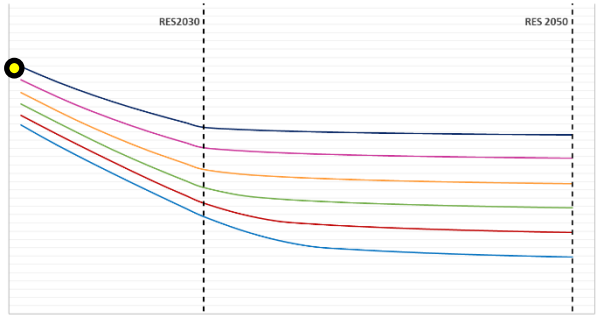
CO_2 emissions by sector: Italy

Base case 2015 - 331 Mt CO_2 - Italy





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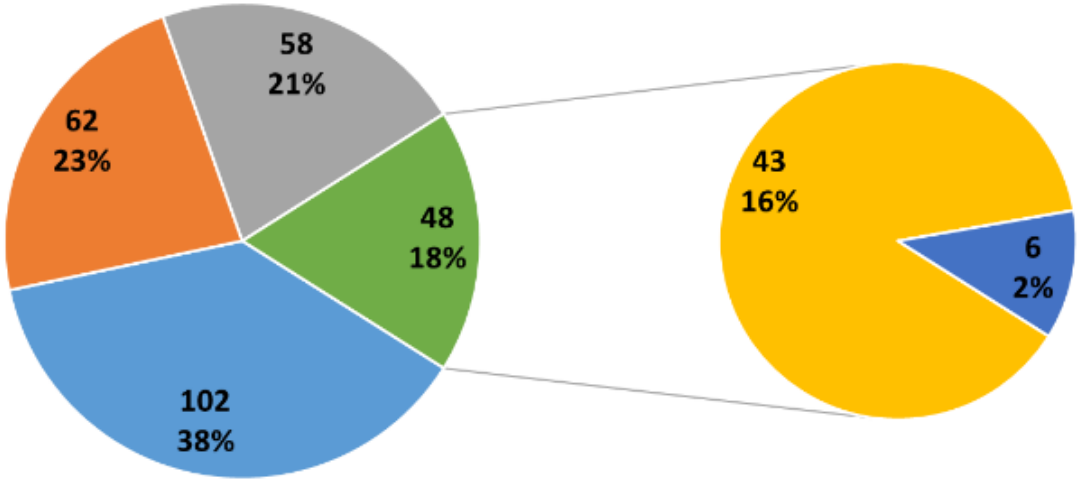
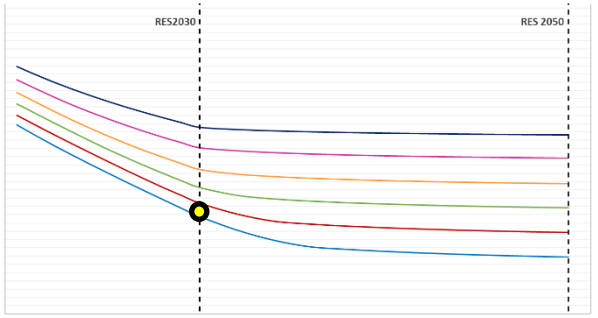
CO_2 emissions by sector: Italy

RES2030 + 100%EV - 270 Mt CO_2 - Italy (-18%)





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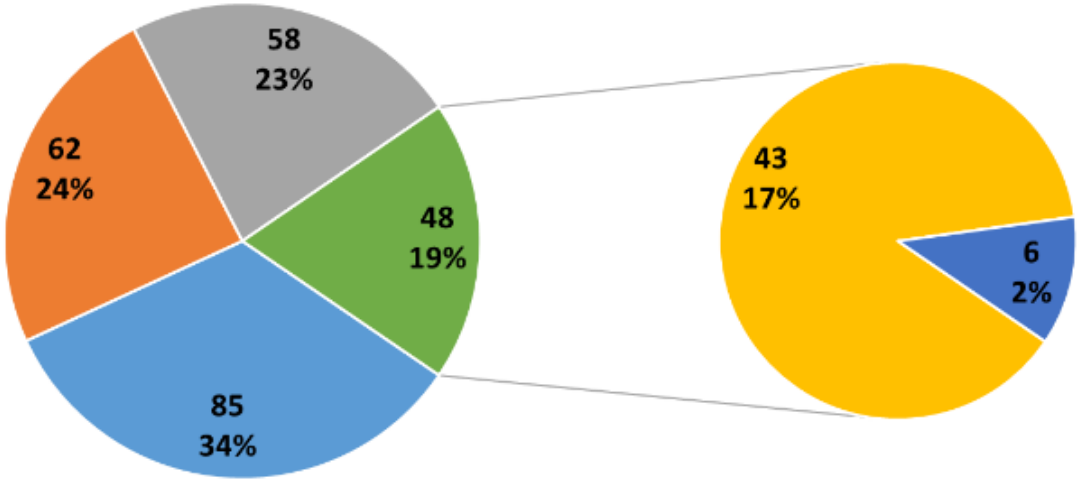
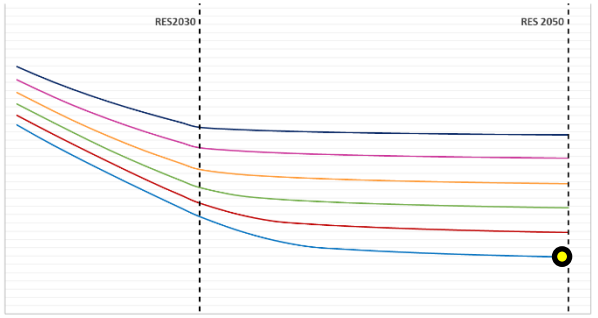
CO_2 emissions by sector: Italy

RES2050 + 100%EV - 254 Mt CO_2 - Italy (-23%)





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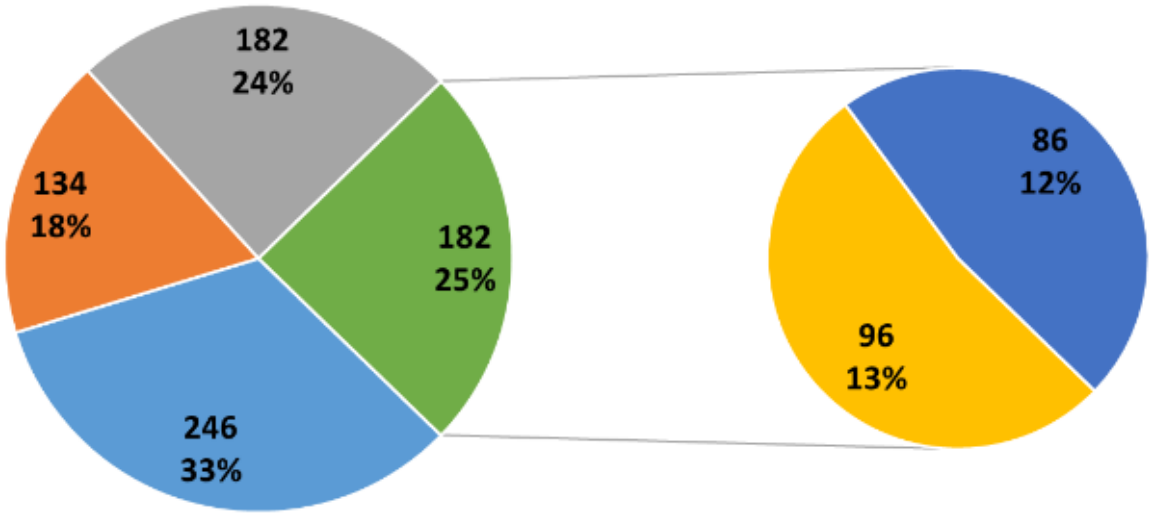
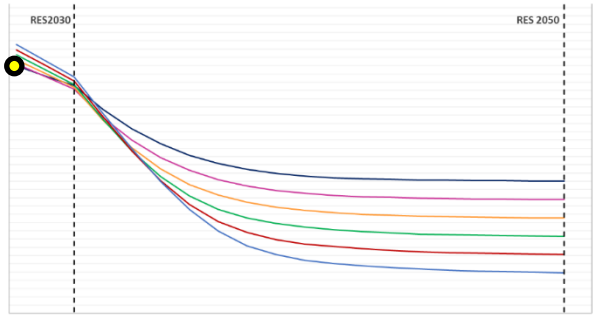
CO_2 emissions by sector: Germany

Base case 2015 - 744 Mt CO_2 - Germany





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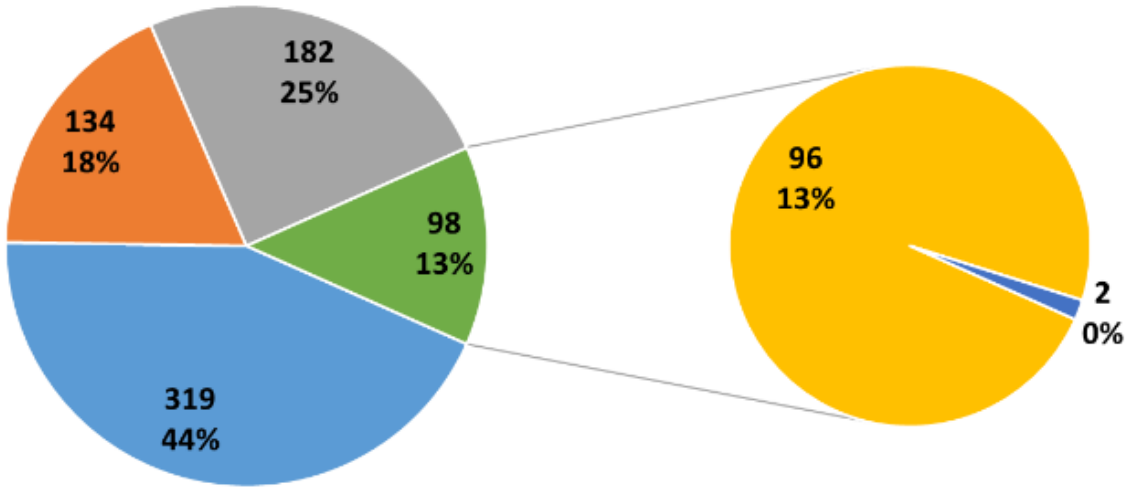
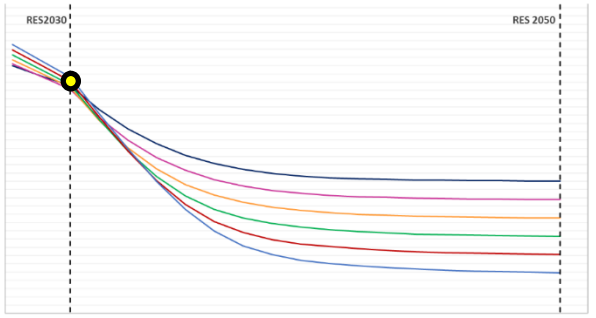
CO_2 emissions by sector: Germany

RES2030 + 100%EV - 733 Mt CO_2 - Germany (-2%)





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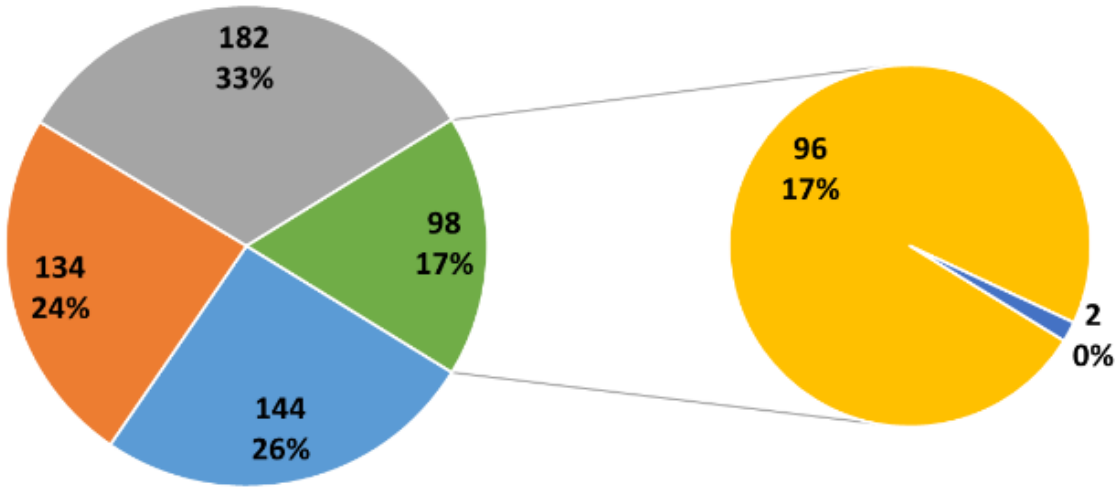
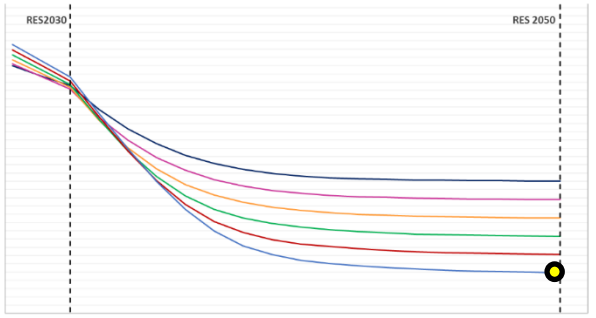
CO_2 emissions by sector: Germany

RES2030 + 100%EV - 733 Mt CO_2 - Germany (-25%)





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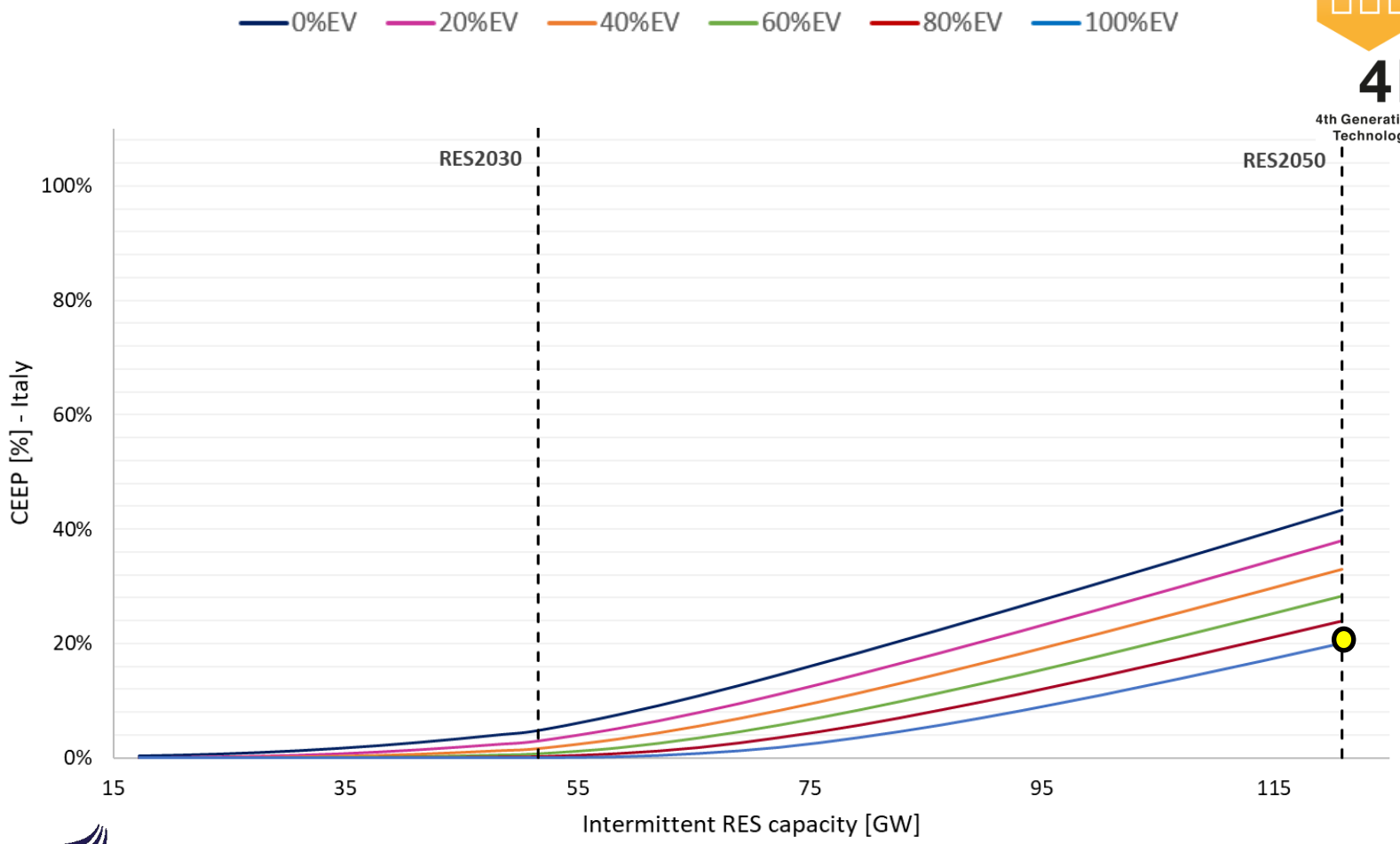
Critical Excess of Electricity Production (CEEP): Italy



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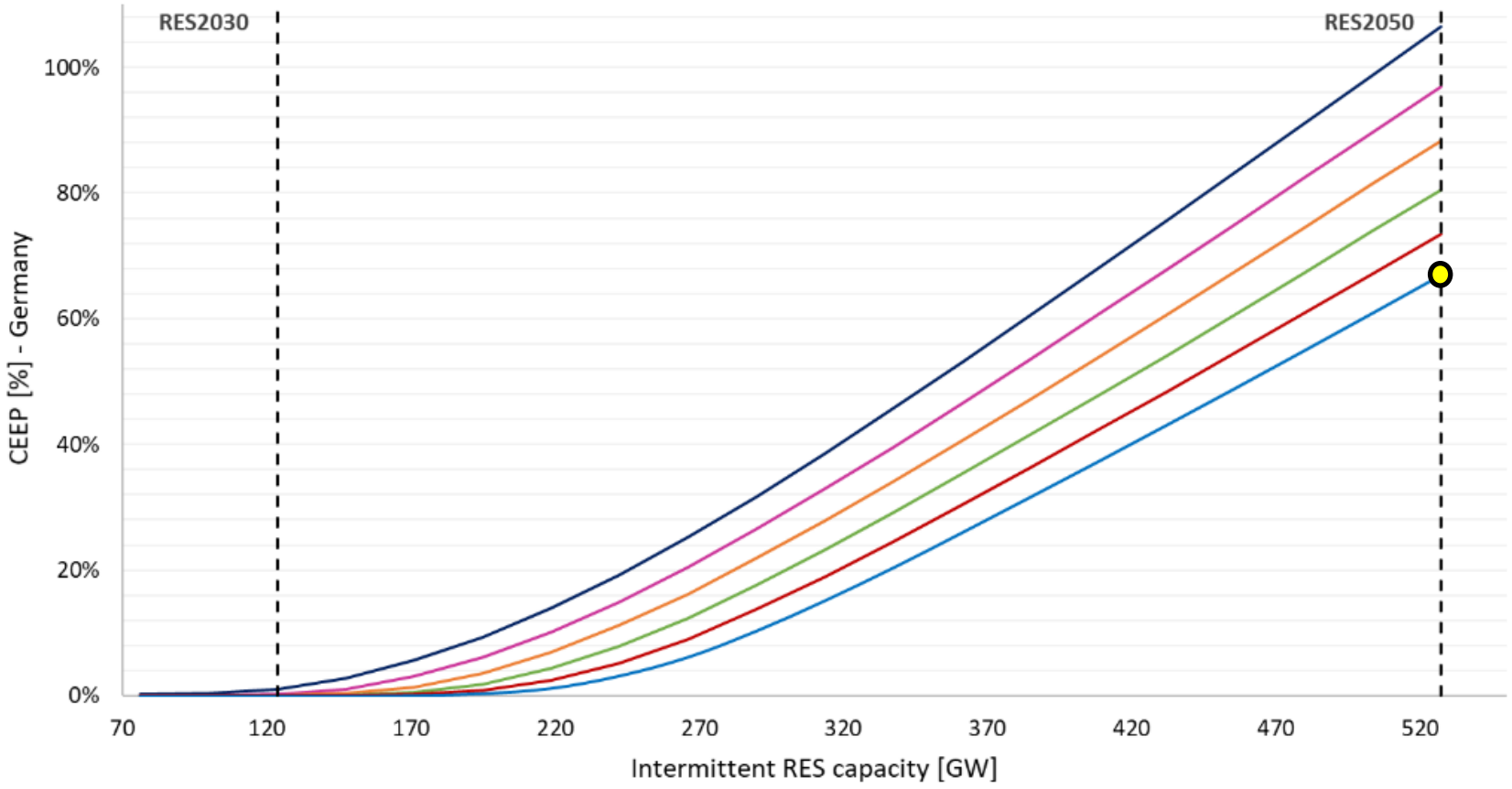
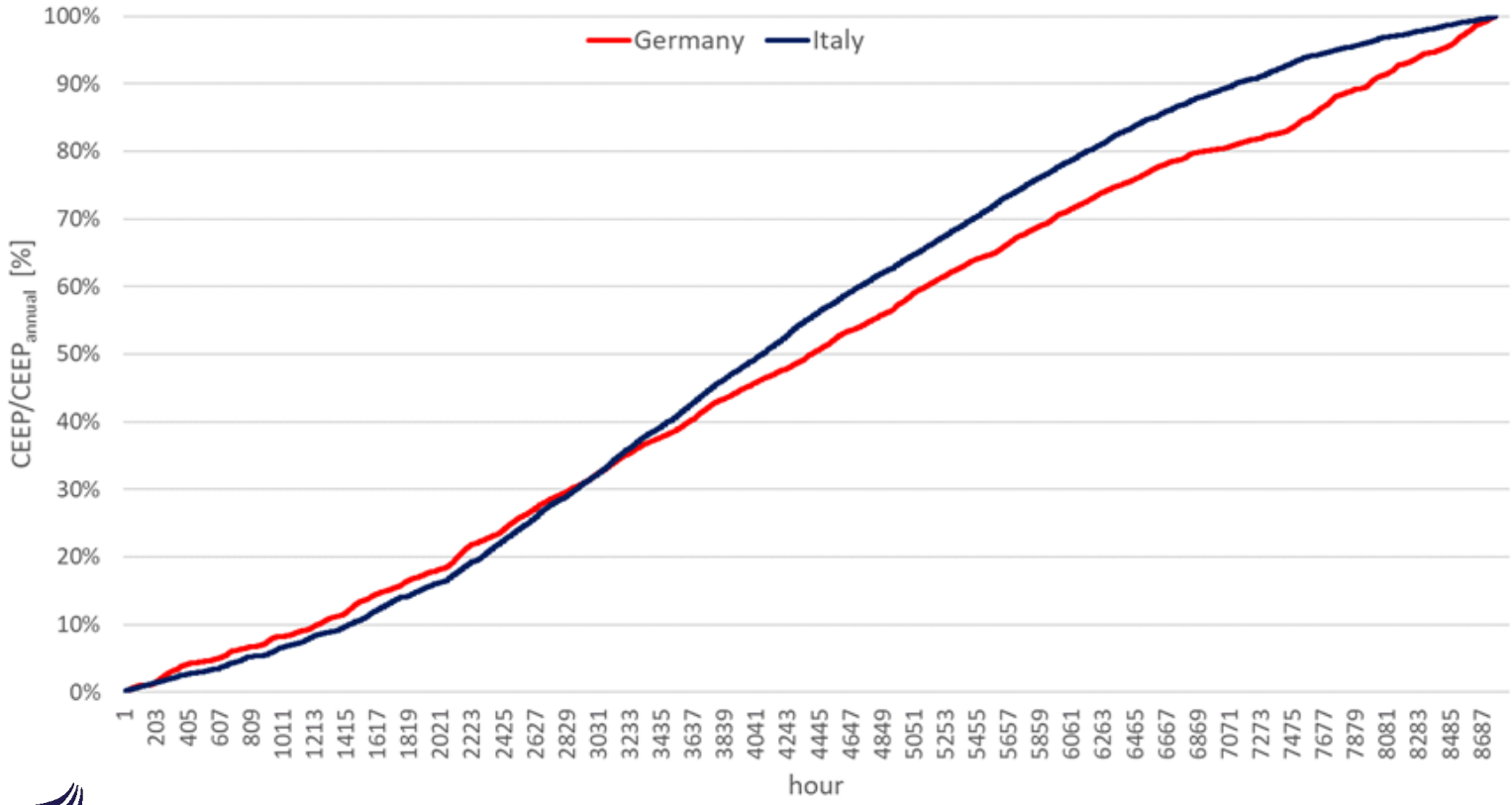
Critical Excess of Electricity Production (CEEP): Germany



Critical Excess of Electricity Production (CEEP): Annual cumulative percentage curve - RES2050 + 0%EV



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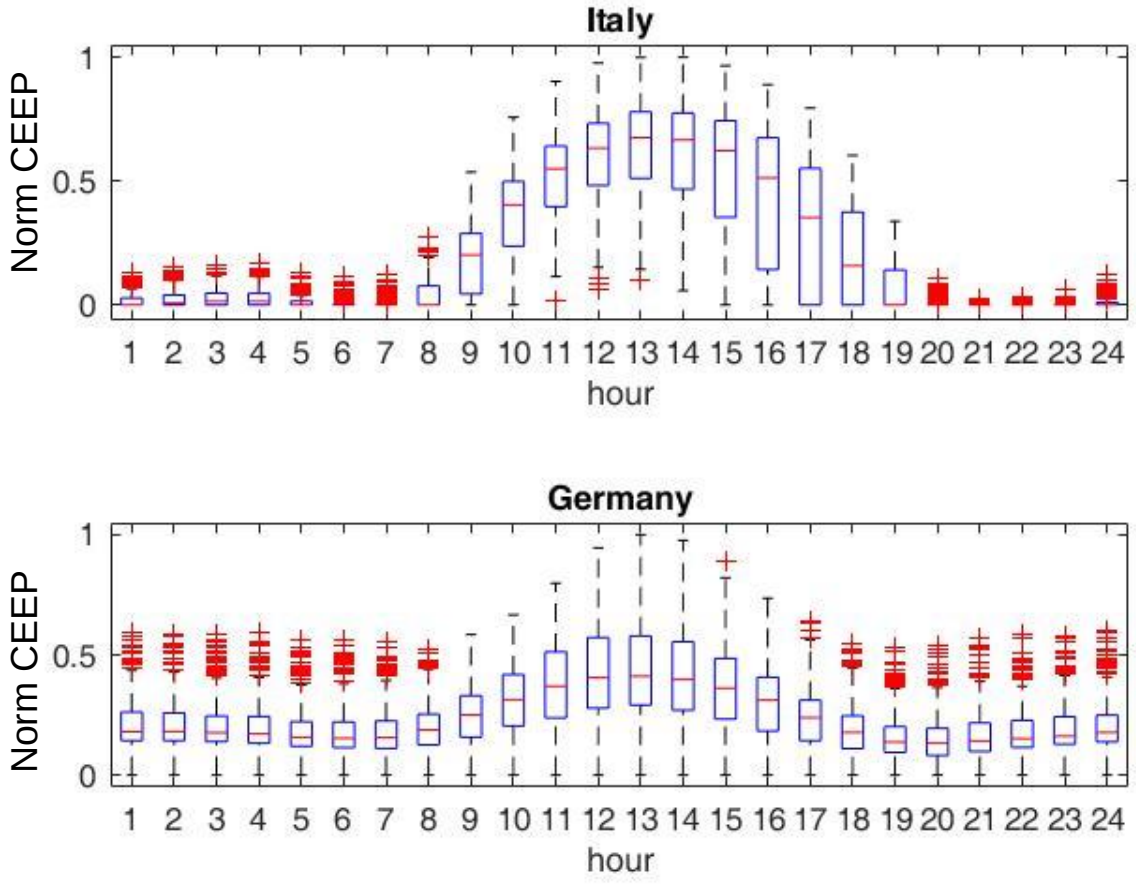
Critical Excess of Electricity Production (CEEP): Daily distribution - RES2050 + 0%EV



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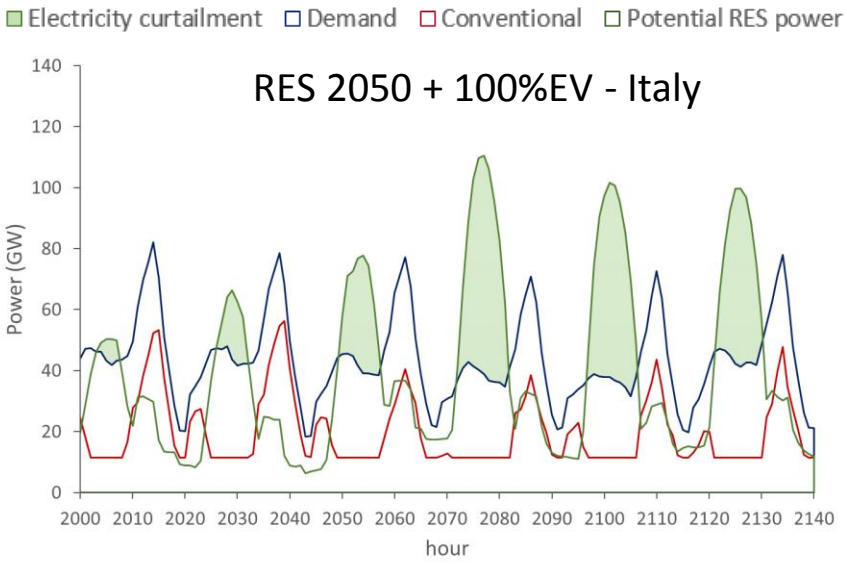
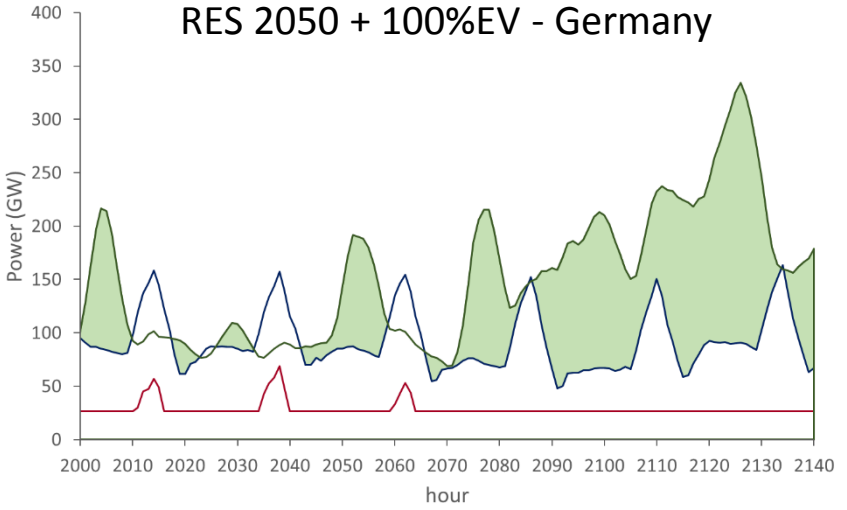
Supply and demand: Dump charge

Dump charge:
EV are charged according to driver's needs/habits





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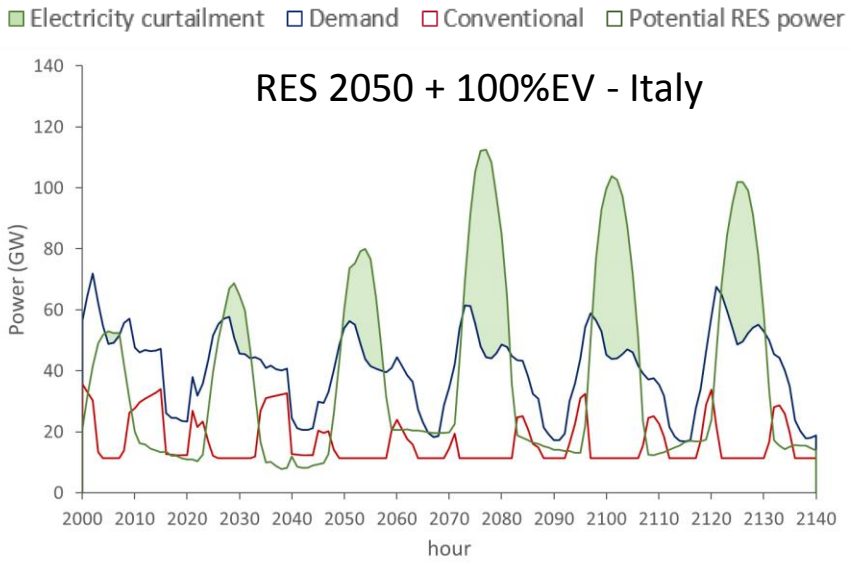
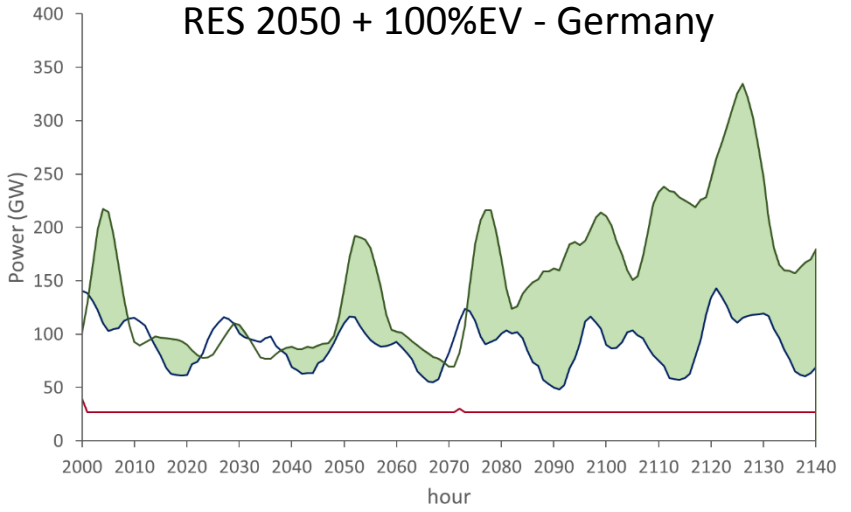
Supply and demand: Smart charge

Smart charge:
EV are charged with the aim to absorb potential RES surplus thus minimizing grid overloading





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CO_2 emissions variation: Italy vs Germany

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RES2050 - Italy

	0%EV	20%EV	40%EV	60%EV	80%EV	100%EV
CO_2 variation [%]						
Dump	-8.2%	-10.6%	-12.4%	-13.8%	-15.0%	-17.2%
Smart	-8.2%	-11.0%	-14.1%	-17.0%	-19.9%	-22.9%

RES2050 - Germany

	0%EV	20%EV	40%EV	60%EV	80%EV	100%EV
CO_2 variation [%]						
Dump	-14.0%	-16.2%	-18.4%	-20.3%	-21.9%	-23.0%
Smart	-14.0%	-16.3%	-18.5%	-20.7%	-23.0%	-25.2%

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Costs variation

RES2050 - Italy

		0%EV	20%EV	40%EV	60%EV	80%EV	100%EV
Variable costs [%]	Dump	-8.77%	-11.70%	-14.58%	-17.07%	-19.43%	-22.61%
	Smart	-8.77%	-12.28%	-16.16%	-19.84%	-23.55%	-27.25%
Investment costs [%]	Dump/Smart	16.22%	31.52%	46.81%	62.11%	77.41%	92.71%
Total costs [%]	Dump	7.85%	16.86%	26.07%	35.41%	44.79%	53.90%
	Smart	7.85%	16.85%	25.72%	34.66%	43.59%	52.53%

RES2050 - Germany

		0%EV	20%EV	40%EV	60%EV	80%EV	100%EV
Variable costs [%]	Dump	-11.0%	-14.0%	-16.9%	-19.7%	-22.2%	-24.5%
	Smart	-11.0%	-14.0%	-17.0%	-20.0%	-23.0%	-25.9%
Investment costs [%]	Dump/Smart	32.9%	43.2%	52.4%	61.6%	70.8%	80.0%
Total costs [%]	Dump	15.9%	21.0%	25.5%	30.1%	34.7%	39.5%
	Smart	15.9%	21.0%	25.5%	30.0%	34.4%	38.9%

Conclusions (1)

- The impact of EV on energy systems characterised by a different supply mix for the electricity generation sector has been assessed;
- Projections for 2030 and 2050 renewable energy capacities have been implemented along with progressively increasing shares of EV up to a total replacement of conventional vehicle fleet;
- EV penetration in the energy system worsen CO_2 emissions for the German case unless renewable installed capacity is increased up to approximately double the base case scenario, while electric private mobility proves to be sustainable in the Italian system even at the current RES capacity;

Conclusions (2)

- Smart charge positively contributes to emissions reduction, more significantly for the Italian case due to the particularly uneven distribution of excess of production throughout the day and the year with respect to Germany;

- To sum up, at the highest RES capacity, assuming a complete replacement of conventional cars by EV:
  - CO_2 emissions can be reduced by 25% and 23% for Germany and Italy respectively at the price of a significant amount of curtailments (respectively 68% and 22% of the total production);
  - The higher installed capacity and EV penetration in the energy system result in higher investment costs, however mitigated by a variable costs reduction (lower fuel consumption), thus leading to a total cost increase up to around 50%.

Future developments

- Optimum scenarios should be identified aiming at the best environmental and economic solutions;

- Possible synergies with other energy sectors (e.g. heating, heavy transport sector) should be investigated under a Smart Energy System perspective identifying the optimum sector-coupling strategy.

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Thanks for your attention

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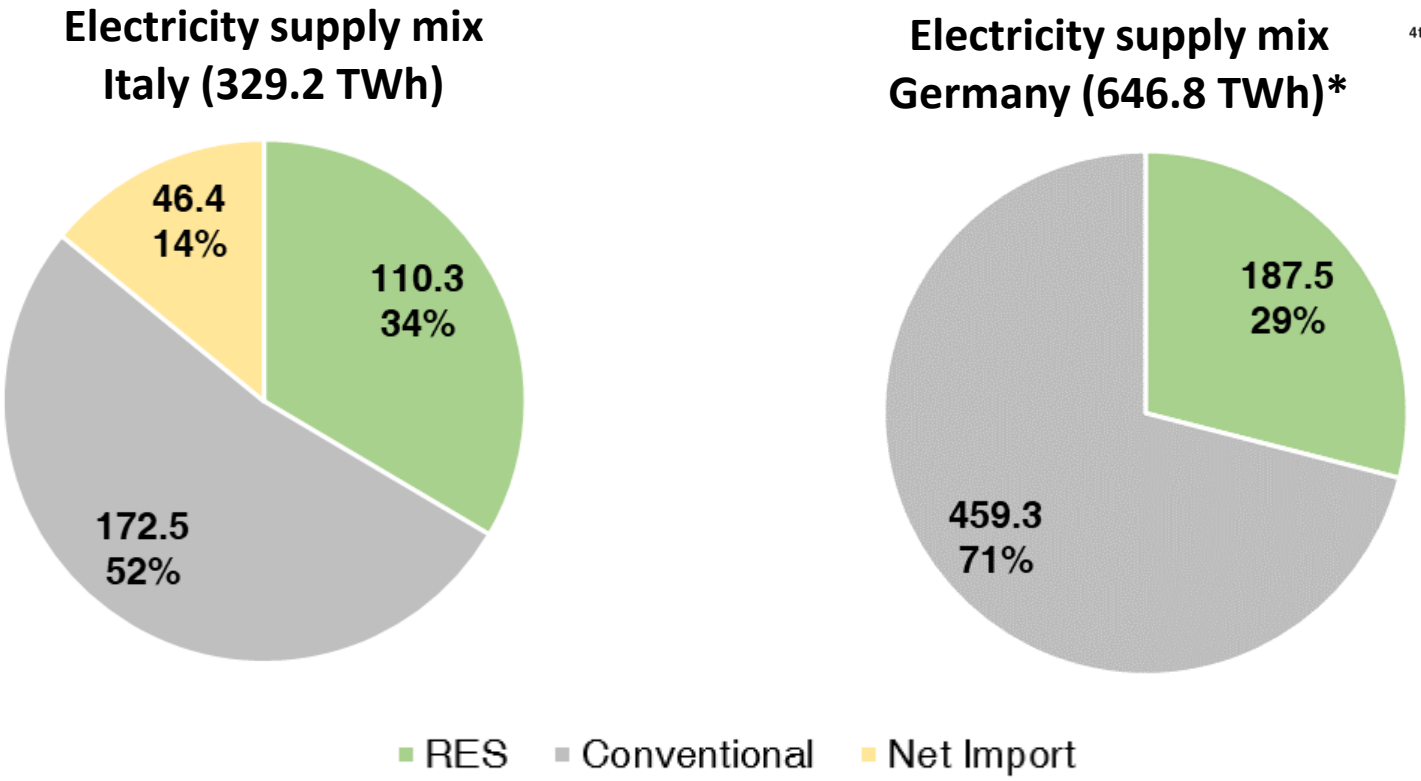
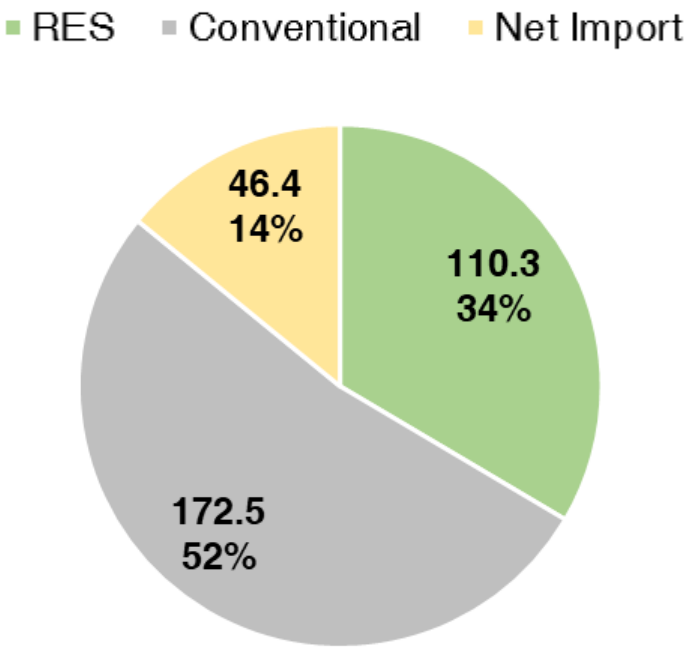
Electricity supply by source at 2015: Italy



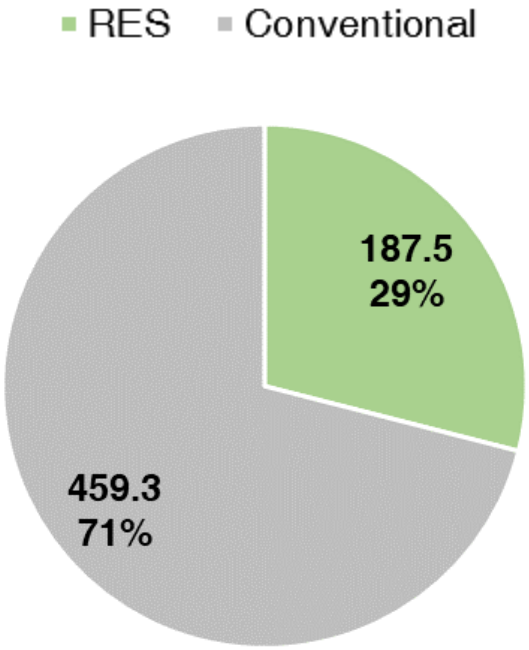
*Net *export* is 7% of electricity production

Energy supply by source at 2015: Italy



	TWh	% of total
RES	**110.3**	**34%**
Hydro	*47.0*	*14%*
Geothermal	*6.2*	*2%*
Wind	*14.8*	*4%*
PV	*22.9*	*7%*
Bioenergies	*19.4*	*6%*
Conventional	**172.5**	**52%**
Solid	*43.2*	*13%*
Natural gas	*110.7*	*34%*
Oil	*5.6*	*2%*
Other fuels	*13.0*	*4%*
Gross production	**282.8**	
Net Import	**46.4**	
Total gross demand	**329.2**	

Energy supply by source at 2015: Germany



	TWh	% of total
RES	**187.5**	**29%**
Hydro	*24.9*	*4%*
Geothermal	*0.1*	*0%*
Wind	*79.2*	*12%*
PV	*38.7*	*6%*
Bioenergies	*44.6*	*7%*
Conventional	**459.3**	**71%**
Solid	*283.7*	*44%*
Natural gas	*63.0*	*10%*
Oil	*6.2*	*1%*
Nuclear	*91.8*	*14%*
Other fuels	*14.6*	*2%*
Gross production	**646.8**	
Net Export	**48.3**	

*Net *export* is 7% of electricity production

Electricity production and excess @ RES2050 + 0% EV

Electricity national production (excluding CEEP)
Italy[1]: 323 TWh
Germany[2]: 644 TWh
Germany/Italy: 2

Excess of production
Italy: 140 TWh
Germany: 686 TWh
Germany/Italy: 5

$CEEP\%_{Germany} \approx 2.5\ CEEP\%_{Italy}$

[1]Import is still needed to cover fully electricity demand
[2]Differences with respect to 2015 demand due to model approximation

EV electricity consumption and potential excess

Excess of production @RES2050 + 0%EV
Italy: 140 TWh

EV electricity demand @100%EV
Italy: 84 TWh

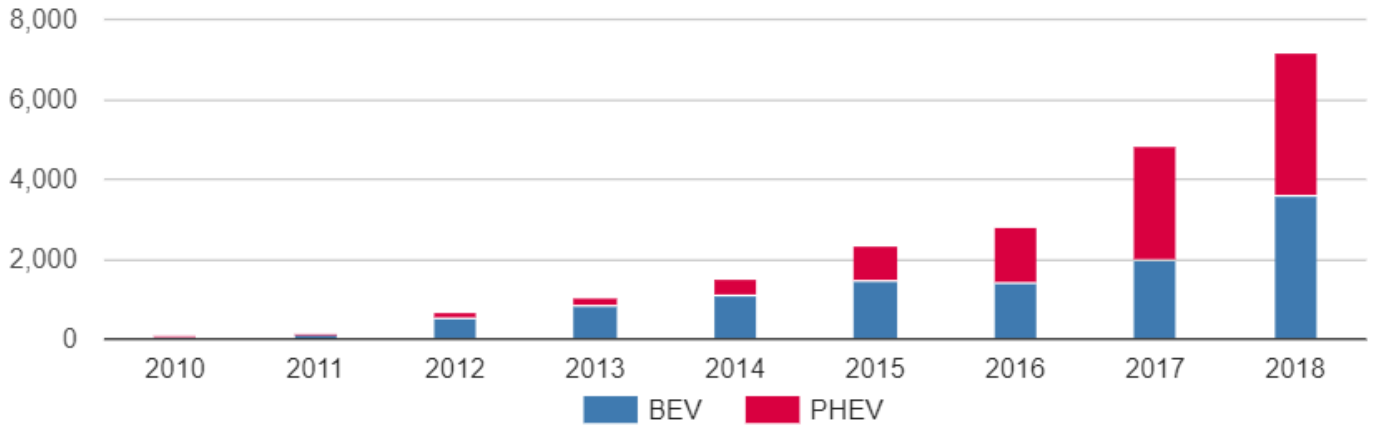
Number of EV @100%EV
Italy: 33.7 *10^6

56 TWh excess remaining to be exploited in other sector

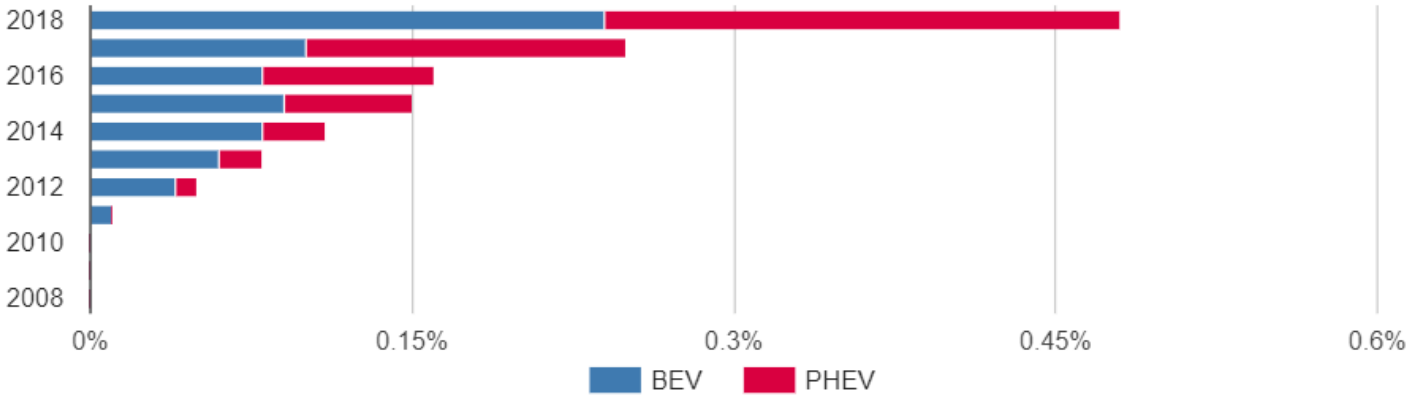
[1]Import is still needed to cover fully electricity demand
[2]Differences with respect to 2015 demand due to model approximation

EV market share - Italy

EV sales (absolute value)



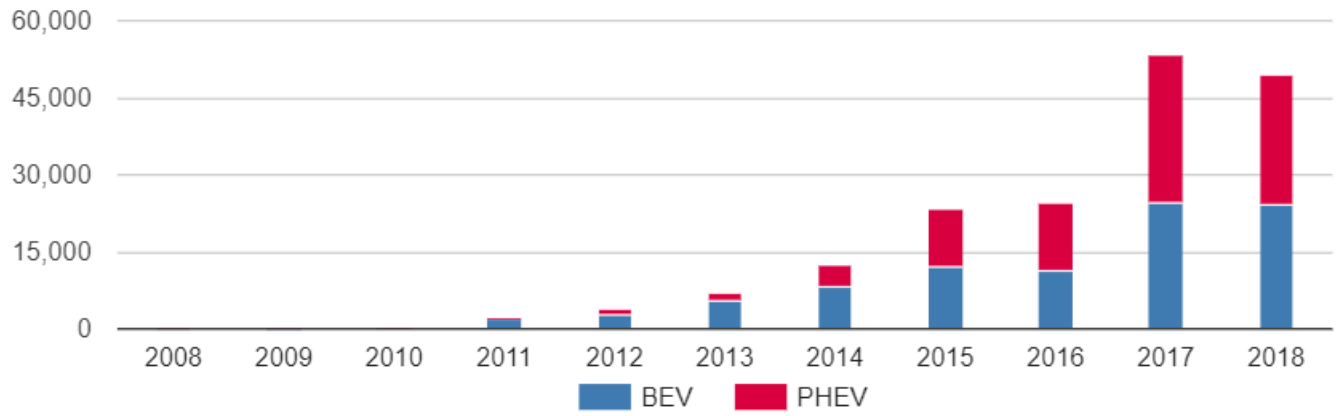
EV sales (% of total sales)



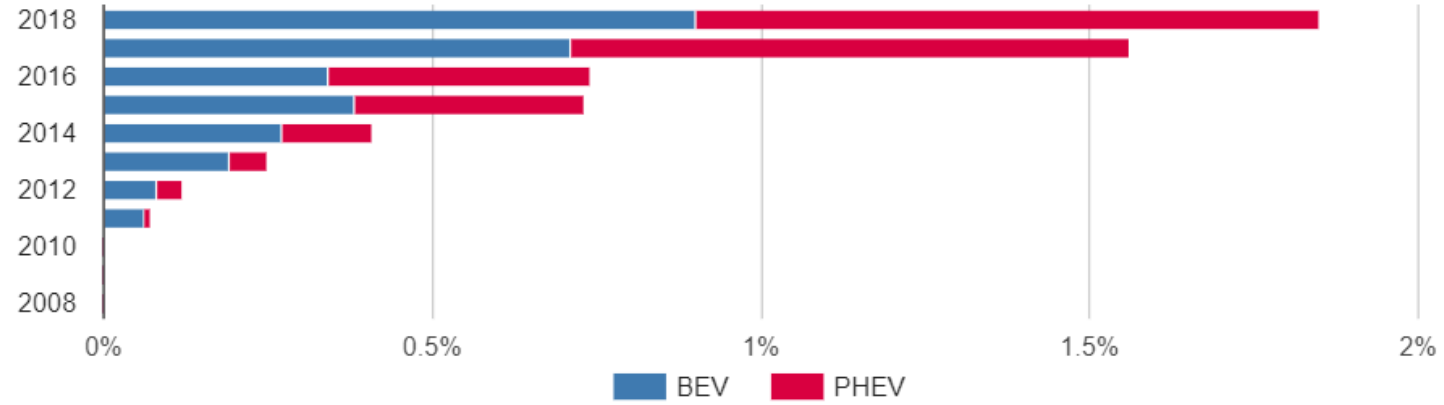
Source: EAFO, Italy

EV market share - Germanay

EV sales (absolute value)



EV sales (% of total sales)



Source: EAFO, Italy

EV market share: Italy - BEV

Vehicle model	2010	2011	2012	2013	2014	2015	2016	Tot 2015	Tot 2016	Capacity [kWh]	Range [km]
Fiat Panda	31	9	0	0	0	0	0	40	40	19.2	120
Fiat 500e	22	7	4	0	0	0	0	33	33	24	160
Renault Fluence	0	0	38	38	30	0	0	106	106	22	185
Nissan Leaf	0	5	146	323	336	390	473	1200	1673	24	199
Renault Zoe	0	0	0	204	156	328	210	688	898	22	210
Mercedes B 250e	0	0	0	0	0	80	90	80	170	28	200
Th!nk city	0	0	0	3	0	0	0	3	3	24	160
KIA soul	0	0	0	0	0	0	15	0	15	27	210
Bmw i3	0	0	0	34	124	111	91	269	360	22	190
Tesla Roadster	4	0	7	0	0	0	0	11	11	53	393
Tesla model X	0	0	0	0	0	0	23	0	23	90	414
Tesla Model S	0	0	0	19	55	134	218	208	426	60	390
Citroen C-Zero	0	87	146	55	15	164	145	467	612	14.5	150
Mitsubishi iMiev	3	36	14	0	0	0	0	53	53	16	160
Smart fortwo e-drive	33	80	37	155	252	115	0	672	672	16.5	135
Vw e-Up!	0	0	0	0	52	54	56	106	162	18	160
Peugeot iOn	0	59	116	17	25	0	26	217	243	14.5	150
Renault Kangoo	0	0	78	25	23	23	0	149	149	33	200
Fiat Doblò	12	6	0	0	0	0	0	18	18	43	150
Fiat (QUBO) Fiorino	10	4	0	0	0	0	0	14	14	23	200
Piaggio Porter	1	0	0	0	0	0	0	1	1	17	80
Total BEV Sales	**116**	**293**	**586**	**873**	**1068**	**1399**	**1347**	**4335**	**5682**		

EV market share: Italy - PHEV

Vehicle model	2010	2011	2012	2013	2014	2015	2016	Tot 2015	Tot 2016	Capacity [kWh]	Range [km]
Opel Ampera	0	3	62	19	0	0	0	84	84	16	56
Toyota Prius	0	0	39	8	87	0	0	134	134	4.4	23
Chevrolet Volt	0	0	38	38	0	0	0	76	76	16	56
Fisker Karma	0	0	6	0	0	0	0	6	6	20.1	51
Volvo V60 PHEV	0	0	0	135	59	0	0	194	194	11.2	43.5
Porsche Panamera	0	0	0	23	0	0	0	23	23	9.4	32
Mitsubishi outlander	0	0	0	0	85	133	0	218	218	9.8	52.8
Bmw i8	0	0	0	0	34	99	0	133	133	7.1	37
Vw Golf GTE	0	0	0	0	0	180	158	180	338	8.7	50
Audi A3 e-tron	0	0	0	0	0	86	0	86	86	8.8	50
Bmw 225xe	0	0	0	0	0	0	308	0	308	7.6	41
Bmw330e	0	0	0	0	0	0	107	0	107	7.6	25
Volvo XC90 PHEV	0	0	0	0	0	0	90	0	90	9	40
Others	0	0	0	9	76	242	654	327	981	4.4	23
Tot PHEV Sales	**0**	**3**	**145**	**232**	**341**	**740**	**1317**	**1461**	**2778**		

EV weighted-average technical specifications

Type	Category	N.	Share	Avg capacity [kWh]	Avg range [km]	Annual cons. [GWh]
BEV	Small	1515	35%	15.68	144.40	2.44
	Medium	2419	56%	23.17	198.66	4.18
	Large	219	5%	59.65	390.15	0.50
	Van	182	4%	33.13	194.40	0.46
Tot. BEV		**4335**				**7.57**
PHEV		**1461**		**8.56**	**40.23**	**4.60**
Tot. EV		**5796**				**12.17**

Cost analysis: RES

	Investment [M€/MW-e]	Period [Years]	O. and M. [% of Inv.]
Onshore wind	1.3	20	3.1
Offshore wind	2.4	20	3.0
Photovoltaic	1.3	30	2.1
Concentrating solar	6.0	25	8.2

Source: "(Heat Roadmap Europe 3 and STRATEGO WP2 Main Report) Enhanced Heating and Cooling Plans to Quantify the Impact of Increased Energy Efficiency in EU Member States: Translating the Heat Roadmap Europe Methodology to Member State Level.," 2015.

Cost analysis: EV

Conventional and EV purchase costs (k€) - Italy

	Petrol	*Diesel*	*EV*
Small	12.39	13.45	29.81
Medium	23.40	21.00	37.03
Large	62.65	58.17	88.33

Conventional and EV purchase costs (k€)- Germany

	Petrol	*Diesel*	*EV*
Small	13.60	16.20	24.96
Medium	23.40	26.40	36.43
Large	62.65	60.43	87.68