TECHNOLOGY FACTSHEET



POWER TRANSFORM	1ER OFFSHORE HV													
Date of factsheet	21-1-2021													
Author Sector	Ricardo Hernandez Serna													
Sector	Infrastructure													
TS / Non-ETS	Non-ETS													
Type of Technology Description	Network This factsheet describes the use of HVDC power converters for alternate current/direct current (AC/DC) conversion. HVDC converters are mainly divided between current source													
	converters (CSC) and voltage source of CSC have been commercially in use side between asynchronous grids. Due to on the quality of the electrical power correct operation. DC current flows up voltages and power levels [4]. DC cab could result in rapid failure under cer VSC technology is based on the use of voltage and a more controllable. An a The VSC HVDC systems in service so f	ince the 50s, m its conversion Therefore, re- inidirectionally les power capa tain conditions f Insulated Gat advantage over far have been li	haking it a wel technique, th active compe to reverse it abilities are lin s of operation the Bipolar Tran r CSC is that it imited to low	II-establ nese cor nsation in a CS mited du [8]. nsistors does no er volta	iverters a and harn C connect ue to elec (IGBT). V ot require ges and p	absorb reactive nonic filters are tion, the DC cor ctrothermal hea /SC devices are a e reactive powe power ratings th	power from the required. As atrol system re- ating and prob- self-commuta er compensation nan CSC system	he adjacer a result, th everses th olems arisi ting, maki on and les ms due to	nt AC gri ne conve e polarit ng out o ng the o s AC har its low o	d, generating rter depends y of the DC vo f possible ele- peration of co monic filterin verload capal	harmonic curre on the AC syste oltage. DC cable ctrothermal ins onverter indepe	ents having a em's voltage es are still lin tability of th endent of th ess ancillary	a negati e to ensu mited to ne insula e AC sys r equipm	ve impa ire the lower tion tha tem's ent.
TRL level 2020	devices. Nevertheless, new projects s													
	CSC technology has followed many ye thyristor-based technology is its shor technology with a TRL 9. Compared to the CSC technology, VS still low (limited by the IGBT devices) The operating losses of VSC technolo Future development in VSC is the 'ful	t time overload C is a less matu , despite the ris gy have decrea	d capability ar ure technolog se on the pow ased dramatic	nd its hi y and st ver and ally in re	gh efficie ill in deve voltage r ecent yea	elopment, using ratings. ars to reach abo	I operating po IGBT devices out 1% per cor	ower loss i rated up t nverter sta	n a conv to 6.5kV tion (ha	erter station and 2000A.	of typically 0.7 The overload ca	– 0.8%. It is	conside his tech	red a nology i
ECHNICAL DIMENSIONS														
	Functional Unit							Value and	d Range					
Capacity	MW				Min Irrent			203	30			Max 2050		
Potential		%	Min		-	Max	Min	-		Мах	Min	-		Max
Market share		,,,	Min		-	Max	Min	-		Мах	Min			Мах
				_					I		1.00			
apacity utlization factor		I									1.00			
											1.00			
Capacity utlization factor Full-load running hours per year Unit of Activity Fechnical lifetime (years)											1.00			
Full-load running hours per year Unit of Activity Fechnical lifetime (years) Progress ratio Hourly profile Explanation	An ENTSO-e study estimates a need f investment in the European transmis investment. DC technologies will pla of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa	040, 43 additi role in the effe [9]. tion capacity, ated by 2050.	onal GV orts to r Europe This me	V of cross neet this has 22.1 eans that	s border capacit reinforcements GW of offshore the need for o	y on top of th s goals [5]. By wind capacit	e needs fo 2018, 10%	or 2030 i 6 of the ording to	s required. Th cross border l o European Co	be cost-efficier his increase woo lines were DC, v ommission's roo	uld represen while there a admap on o	nt about are arou ffshore i	28 bn € nd 30 G enewat
Full-load running hours per year Unit of Activity Fechnical lifetime (years) Progress ratio Hourly profile Explanation	investment in the European transmis investment. DC technologies will pla of cross border DC projects in the pip Added to the demand for cross borde	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa	040, 43 additi role in the effe [9]. tion capacity, ated by 2050.	onal GV orts to r Europe This me	V of cross neet this has 22.1 eans that	s border capacit reinforcements GW of offshore the need for o	y on top of th s goals [5]. By wind capacit	e needs fo 2018, 10%	or 2030 i 6 of the ording to	s required. Th cross border l o European Co	be cost-efficier his increase woo lines were DC, v ommission's roo	uld represen while there a admap on o	nt about are arou ffshore i	28 bn € nd 30 G enewat
full-load running hours per year Unit of Activity Fechnical lifetime (years) Progress ratio Hourly profile Explanation	investment in the European transmis investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa	040, 43 additi role in the effe [9]. tion capacity, ated by 2050.	onal GV orts to r Europe This me	V of cross neet this has 22.1 eans that	s border capacit reinforcements GW of offshore the need for o	y on top of th s goals [5]. By wind capacit	e needs fo 2018, 10%	or 2030 i 6 of the ording to	s required. Th cross border l o European Co	be cost-efficier his increase woo lines were DC, v ommission's roo	uld represen while there a admap on o	nt about are arou ffshore i	28 bn € nd 30 G enewal
ull-load running hours per year Init of Activity Technical lifetime (years) Trogress ratio Iourly profile xplanation	investment in the European transmiss investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate	040, 43 additi role in the effe [9]. tion capacity, ated by 2050.	onal GV orts to r Europe This me id powe	V of cross neet this has 22.1 eans that	s border capacit reinforcements GW of offshore the need for o	y on top of th s goals [5]. By wind capacit	e needs fo 2018, 10%	or 2030 i 6 of the ording to overter s	s required. Th cross border l o European Co	be cost-efficier his increase woo lines were DC, v ommission's roo	uld represen while there a admap on o	nt about are arou ffshore i	28 bn € nd 30 G enewal
ull-load running hours per year Init of Activity echnical lifetime (years) rogress ratio lourly profile xplanation OSTS ear of Euro	investment in the European transmis investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate	040, 43 additi role in the effe [9]. tion capacity, ated by 2050.	onal GV orts to r Europe This me id powe	V of cross neet this has 22.1 eans that r plants [s border capacit reinforcements GW of offshore the need for o	y on top of th s goals [5]. By e wind capacit nshore and of	e needs fo 2018, 10% y, and acc fshore cor 203	or 2030 i 6 of the ording to overter s	s required. Th cross border l o European Co	be cost-efficier his increase woo lines were DC, v ommission's roo	uld represen while there a admap on o oport the ins	nt about are arou ffshore i	28 bn € nd 30 G enewal
ull-load running hours per year Init of Activity echnical lifetime (years) rogress ratio lourly profile xplanation OSTS ear of Euro	investment in the European transmiss investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 <u>Euro per Functional Un</u> mln. € / MW	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate	040, 43 additi role in the effe [9]. tion capacity, ated by 2050.	onal GV orts to r Europe This me id powe	V of cross neet this has 22.1 eans that r plants [urrent	s border capacit reinforcements GW of offshore the need for o	y on top of th s goals [5]. By wind capacit	e needs fo 2018, 10% y, and acc fshore cor 203	or 2030 i 6 of the ording to overter s 30	s required. Th cross border l o European Co	be cost-efficier his increase woo lines were DC, v ommission's roo	uld represen while there a admap on o oport the ins 2050	nt about are arou ffshore i	28 bn € nd 30 G enewal
ull-load running hours per year Init of Activity echnical lifetime (years) rogress ratio lourly profile xplanation OSTS ear of Euro hvestment costs	investment in the European transmiss investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win	onal GV orts to r Europe This me id powe	V of cross neet this has 22.1 eans that r plants [urrent 0.09 - - -	s border capacit reinforcements GW of offshore the need for or [6].	y on top of th s goals [5]. By e wind capacit nshore and of	2018, 109 2018, 109 ay, and acc fshore cor 203 0. 0. - - - -	or 2030 i 6 of the ording to overter s 30 .09	s required. Th cross border l o European Co tations will be	be cost-efficier his increase wor ines were DC, w ommission's ros e needed to sup	uld represent while there a admap on o oport the inst 2050 0.09 – – –	nt about are arou ffshore i	28 bn € nd 30 G enewal n of HVI
ull-load running hours per year Init of Activity echnical lifetime (years) rogress ratio lourly profile xplanation OSTS ear of Euro hvestment costs Other costs per year ixed operational costs per year	investment in the European transmiss investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 <u>Euro per Functional Un</u> mln. € / MW	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win 0.08 Min	onal GV orts to r Europe This me id powe	V of cross neet this has 22.1 eans that r plants [urrent 0.09 - -	s border capacit reinforcements GW of offshore the need for or [6]. 0.10 <i>Max</i>	y on top of the s goals [5]. By e wind capacitenshore and of 0.08	2018, 109 2018, 109 ay, and acc fshore cor 203 0. 0. - - - -	or 2030 i 6 of the ording to nverter s 30 .09	s required. Th cross border l o European Co tations will be 0.10 Max	be cost-efficier his increase wor ines were DC, v ommission's ros e needed to sup 0.08 0.08	uld represer while there a admap on o oport the ins 2050 0.09 - -	nt about are arou ffshore i	28 bn € nd 30 G renewa n of HVI 0.10 Max
full-load running hours per year Unit of Activity Fechnical lifetime (years) Progress ratio Hourly profile Explanation ECOSTS Fear of Euro Investment costs Other costs per year Exercised operational costs per year excl. fuel costs)	investment in the European transmiss investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win 0.08	onal GV orts to r Europe This me id powe	V of cross neet this has 22.1 eans that r plants [urrent 0.09 - - - 0.00	s border capacit reinforcements GW of offshore the need for or [6]. 0.10	y on top of th s goals [5]. By e wind capacit nshore and of 0.08	2018, 109 2018, 109 ay, and acc fshore cor 203 0. 0. - - - -	or 2030 i 6 of the ording to overter s 30 .09	s required. Th cross border l o European Co tations will be 0.10	be cost-efficier his increase wor ines were DC, v ommission's ros e needed to sup 0.08	uld represent while there a admap on o oport the inst 2050 0.09 - - - - 0.00	nt about are arou ffshore i	28 bn € nd 30 G renewal n of HVI 0.10
Full-load running hours per year Unit of Activity Fechnical lifetime (years) Progress ratio Hourly profile Explanation COSTS Fear of Euro Investment costs Other costs per year Fixed operational costs per year Excl. fuel costs) Fear of Euro Fear of Euro Fixed operational costs per year Fixed opera	investment in the European transmiss investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 Euro per Functional Un mln. € / MW mln. € / MW	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate it it both rating (N c of VSC and CS shown due to th	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win 0.08 Min 0.00 Min MVA) and the C in the 1-4 c	onal GV orts to r Europe This me id powe Cu	V of cross neet this has 22.1 eans that r plants [s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category.	e wind capacit nshore and of 0.08 <u>Min</u> 0.00 <u>Min</u> etion. There w	are needs for 2018, 10% ay, and accord fshore cord 203 are a for a are a for a a a for a a a a a a a a a a a a a a a a a a a	or 2030 i 6 of the ording to overter s 30 .09 .09 .00	s required. The cross border I o European Co tations will be 0.10 0.10 Max 0.00 Max 5: 1-4 convert ost per MVA t	be cost-efficier his increase wor ines were DC, v ommission's rot e needed to sup 0.08 Min 0.00 Min er transformer han CSC within	uld represent while there a admap on o oport the inst 2050 0.09 - - - - 0.00 - - - - - - - - - - - - -	and 6-8 verters of	28 bn € nd 30 G renewal n of HVI 0.10 Max 0.00 Max convert category
ull-load running hours per year Init of Activity echnical lifetime (years) rogress ratio lourly profile xplanation OSTS ear of Euro hvestment costs ether costs per year excl. fuel costs) rariable costs per year osts explanation	investment in the European transmiss investment. DC technologies will play of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW mln. € / MW mln. € / MW Correlations were identified betweer transformers. There was an even mix although this breakdown cannot be s going back no more than 10 years [2]	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate it it of VSC and CS shown due to th l.	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win 0.08 Min 0.00 Min MVA) and the C in the 1-4 c	onal GV orts to r Europe This me id powe Cu Cu Cu I I I I I I I I I I I I I I I	V of cross neet this has 22.1 eans that r plants [s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category.	e wind capacit nshore and of 0.08 <u>Min</u> 0.00 <u>Min</u> etion. There w	2018, 109 and accord and acc	or 2030 i 6 of the ording to overter s 30 .09 	s required. The cross border I o European Co tations will be 0.10 0.10 Max 0.00 Max 5: 1-4 convert ost per MVA t	be cost-efficier his increase wor ines were DC, v ommission's rot e needed to sup 0.08 Min 0.00 Min er transformer han CSC within	uld represent vhile there a admap on o oport the instruction 2050 0.09 - - 0.00 - - 0.00 - - 0.00 - </td <td>and 6-8 verters of</td> <td>28 bn € nd 30 G renewa n of HVI 0.10 Max 0.00 Max convert categor</td>	and 6-8 verters of	28 bn € nd 30 G renewa n of HVI 0.10 Max 0.00 Max convert categor
ull-load running hours per year nit of Activity echnical lifetime (years) rogress ratio ourly profile xplanation OSTS ear of Euro ear of Euro ear of Euro ear of Euro ear of Euro exestment costs ther costs per year excl. fuel costs) ariable costs per year osts explanation	investment in the European transmiss investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW Energy carrier Energy carrier	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate it it both rating (N c of VSC and CS shown due to th	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win 0.08 Min 0.00 Min MVA) and the C in the 1-4 c	onal GV orts to r Europe This me id powe Cu Cu Cu I I I I I I I I I I I I I I I	V of cross neet this has 22.1 eans that r plants [urrent 0.09 - - - 0.00 - - - r of trans r transfor s. The sar	s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category.	e wind capacit nshore and of 0.08 <u>Min</u> 0.00 <u>Min</u> etion. There w	2018, 10% 2018, 10% ay, and acc fshore cor fshore cor 203 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	or 2030 i 6 of the ording to overter s 30 .09 .09 .00 .00 .00 .00 .00 .00 .00 .0	s required. The cross border I o European Co tations will be 0.10 0.10 Max 0.00 Max 5: 1-4 convert ost per MVA t	be cost-efficier his increase wor ines were DC, v ommission's rot e needed to sup 0.08 Min 0.00 Min er transformer han CSC within	uld represent while there a admap on or opport the inst 2050 0.09 - - - 0.00 - - per station the 1-4 content ent newly content 2050	and 6-8 verters of	28 bn 4 nd 30 G renewa n of HV 0.10 Max 0.00 Max conver categor
ull-load running hours per year nit of Activity echnical lifetime (years) rogress ratio ourly profile xplanation OSTS ear of Euro ear of Euro ear of Euro ear of Euro ear of Euro exetment costs ther costs per year excl. fuel costs) ariable costs per year	investment in the European transmiss investment. DC technologies will play of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW mln. € / MW mln. € / MW Correlations were identified betweer transformers. There was an even mix although this breakdown cannot be s going back no more than 10 years [2]	sion grid. By 20 y a significant r peline for 2030 er interconnect shore is anticipa nd to integrate it it of VSC and CS shown due to th l.	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win 0.08 Min 0.00 Min MVA) and the C in the 1-4 c	onal GV orts to r Europe This me id powe Cu Cu Cu I I I I I I I I I I I I I I I	V of cross neet this has 22.1 eans that r plants [s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category.	e wind capacit nshore and of 0.08 <u>Min</u> 0.00 <u>Min</u> etion. There w	2018, 10% 2018, 10% ay, and acc fshore cor fshore cor 203 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.	or 2030 i 6 of the ording to overter s 30 .09 .09 .00 .00 .00 .00 .00 .00 .00 .0	s required. The cross border I o European Co tations will be 0.10 0.10 Max 0.00 Max 5: 1-4 convert ost per MVA t	be cost-efficier his increase wor ines were DC, v ommission's rot e needed to sup 0.08 Min 0.00 Min er transformer han CSC within	uld represent vhile there a admap on o oport the instruction 2050 0.09 - - 0.00 - - 0.00 - - 0.00 - </td <td>and 6-8 verters of</td> <td>28 bn 4 nd 30 G renewa n of HV 0.10 Max 0.00 Max conver categor ed asse</td>	and 6-8 verters of	28 bn 4 nd 30 G renewa n of HV 0.10 Max 0.00 Max conver categor ed asse
ull-load running hours per year nit of Activity echnical lifetime (years) rogress ratio ourly profile xplanation OSTS ear of Euro westment costs ther costs per year excl. fuel costs) ariable costs per year excl. fuel costs) ariable costs per year	investment in the European transmiss investment. DC technologies will play of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW mln. € / MW mln. € / MW mln. € / MW Correlations were identified betweer transformers. There was an even mix although this breakdown cannot be s going back no more than 10 years [2] Energy carrier Main output:	sion grid. By 20 y a significant r beline for 2030 er interconnect shore is anticipa nd to integrate it it both rating (N c of VSC and CS shown due to th l. Unit	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win 0.08 0.08 Min 0.00 Min VVA) and the C in the 1-4 co he size of the -0.99	onal GV orts to r Europe This me id powe Cu Cu Cu I I I I I I I I I I I I I I I	V of cross neet this has 22.1 eans that r plants [s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category. mple size was de -0.99	e wind capacit nshore and of 0.08 0.00 <i>Min</i> etion. There w VSC tended t etermined by -0.99	2018, 10% 2018, 10% ay, and acc fshore cor 203 a a cor 203 0. - - - - - - - - - - - - - - - - - -	or 2030 i 6 of the ording to overter s 30 .09 .09 .00 .00 .00 .00 .00 .00 .00 .0	s required. The cross border I to European Contactions will be contact at the contact of the con	be cost-efficier his increase wor ines were DC, w ommission's rose e needed to sup 0.08 0.08 0.00 Min er transformer han CSC within I their most rec	uld represent vhile there a admap on or oport the instruction 2050 0.09 - - 0.00 - - 0.00 - - 0.00 -<	and 6-8 verters of	28 bn 4 nd 30 G renewa n of HV 0.10 Max 0.00 Max conver categor ed asse
ull-load running hours per year nit of Activity echnical lifetime (years) rogress ratio ourly profile xplanation OSTS ear of Euro westment costs ther costs per year excl. fuel costs) ariable costs per year excl. fuel costs) ariable costs per year	investment in the European transmiss investment. DC technologies will play of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW mln. € / MW mln. € / MW mln. € / MW Correlations were identified between transformers. There was an even mix although this breakdown cannot be s going back no more than 10 years [2] Electricity Electricity Electricity	sion grid. By 20 y a significant r beline for 2030 er interconnect shore is anticipa nd to integrate it it it uboth rating (N c of VSC and CS shown due to th l. Unit PJ	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win 0.08 0.08 Min 0.00 Min NVA) and the C in the 1-4 co he size of the	onal GV orts to r Europe This me id powe Cu Cu Cu I I I I I I I I I I I I I I I	V of cross neet this has 22.1 eans that r plants [urrent 0.09 - - 0.00 - - - 0.00 - - - r of trans r transfor s. The sar urrent -0.99 - -	s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category. mple size was d	e wind capacit nshore and of 0.08 <u>Min</u> 0.00 <u>Min</u> ation. There w VSC tended t etermined by	2018, 10% 2018, 10% ay, and acc fshore cor 203 a a cor 203 0. - - - - - - - - - - - - - - - - - -	or 2030 i 6 of the o ording to overter s 30 .09 .09 .00 .00 .00 .00 .00 .00 .00 .0	s required. The cross border I to European Contactions will be contact at the contact of the con	be cost-efficier his increase wor ines were DC, v ommission's ros e needed to sup 0.08 0.08 Min er transformer han CSC within their most rec	uld represent while there a admap on or oport the inst 2050 0.09 - - - 0.00 - - per station the 1-4 content newly content ent newly content 2050 -0.99 - - - - - - - - -	and 6-8 verters of	28 bn 4 nd 30 G renewa n of HV 0.10 Max 0.00 Max conver categor ed asse
ull-load running hours per year Init of Activity echnical lifetime (years) rogress ratio lourly profile xplanation COSTS ear of Euro hvestment costs ear of Euro hvestment costs Other costs per year excl. fuel costs) data per year excl. fuel costs) data per year excl. fuel costs per year	investment in the European transmiss investment. DC technologies will play of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW mln. € / MW mln. € / MW mln. € / MW correlations were identified betweer transformers. There was an even mix although this breakdown cannot be s going back no more than 10 years [2] Energy carrier Main output: Electricity	sion grid. By 20 y a significant r beline for 2030 er interconnect shore is anticipa nd to integrate it it it uboth rating (N c of VSC and CS shown due to th shown due	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore win 0.08 0.08 Min 0.00 Min VVA) and the C in the 1-4 co he size of the -0.99	onal GV orts to r Europe This me id powe Cu Cu Cu I I I I I I I I I I I I I I I	V of cross neet this has 22.1 eans that r plants [s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category. mple size was de -0.99	e wind capacit nshore and of 0.08 0.00 <i>Min</i> etion. There w VSC tended t etermined by -0.99	2018, 10% 2018, 10% ay, and acc fshore cor 203 a a cor 203 0. - - - - - - - - - - - - - - - - - -	or 2030 i 6 of the ording to overter s 30 .09 .00 .00 .00 .00 .00 .00 .99 .00	s required. The cross border I to European Contactions will be contact at the contact of the con	be cost-efficier his increase wor ines were DC, w ommission's rose e needed to sup 0.08 0.08 0.00 Min er transformer han CSC within I their most rec	uld represent while there a admap on or oport the inst 2050 0.09 - - - 0.00 - - per station the 1-4 content newly content ent newly content 2050 -0.99 - - - - - - - - -	and 6-8 verters of	28 bn € nd 30 G renewa n of HVI 0.10 Max 0.00 Max convert categor ed asse
full-load running hours per year Unit of Activity Fechnical lifetime (years) Progress ratio Hourly profile Explanation COSTS Fear of Euro Investment costs Other costs per year Exect operational costs per year excl. fuel costs) Variable costs per year Costs explanation Costs explanation	investment in the European transmis investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW mln. € / MW mln. € / MW Correlations were identified betweer transformers. There was an even mix although this breakdown cannot be s going back no more than 10 years [2] Electricity Electricity Electricity Propane	sion grid. By 20 y a significant r beline for 2030 er interconnect shore is anticipa nd to integrate it it uboth rating (N c of VSC and CS shown due to th c. Unit PJ PJ PJ PJ	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore wine 0.08 0.08 0.00 Min 0.00 Min MVA) and the C in the 1-4 co he size of the che size of the 1.00 0.09	onal GW orts to r Europe This me id powe Cu Cu onverte sample: Cu	V of cross neet this has 22.1 eans that r plants [0.09 - - - 0.00 - - - - 0.00 - - - - r of trans r transfor s. The sar urrent - - - - - - - - - - - - - - - - - - -	s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category. mple size was de -0.99 1.00 Max	e wind capacit nshore and of 0.08 0.00 Min 0.00 Min 0.00 Min otion. There w VSC tended t etermined by 0.99 1.00 Min 1.00	e needs for 2018, 109 2018, 109 ey, and acc ifshore cor 203 0.	ategories an TSOs w 30 .99 .99 .00	s required. The cross border I to European Contractions will be contracted attemption of the contractions will be contracted attemption of the contract of the	be cost-efficier his increase wou ines were DC, w ommission's rote e needed to sup needed to sup 0.08 <i>Min</i> er transformer han CSC within their most rec <i>Min</i> er transformer han CSC within their most rec <i>Min</i> <i>Min</i>	uld represent while there a admap on or oport the inst 2050 0.09 - - - - - - - - - - - - - - - - -	are arou ffshore i stallation and 6-8 verters o onstruct	28 bn € nd 30 G renewa n of HV 0.10 Max 0.00 Max conver categor ed asse = -0.99 1.00
ull-load running hours per year Init of Activity echnical lifetime (years) rogress ratio lourly profile xplanation COSTS ear of Euro hvestment costs ear of Euro hvestment costs Other costs per year excl. fuel costs) datable costs per year excl. fuel costs) datable costs per year excl. fuel costs) mergy IN- AND OUTPUTS NERGY IN- AND OUTPUTS	investment in the European transmiss investment. DC technologies will play of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW mln. € / MW mln. € / MW mln. € / MW Correlations were identified between transformers. There was an even mix although this breakdown cannot be s going back no more than 10 years [2] Electricity Electricity Electricity	sion grid. By 20 y a significant r beline for 2030 er interconnect shore is anticipa nd to integrate it it uboth rating (N c of VSC and CS shown due to th c. Unit PJ PJ PJ PJ	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore wine 0.08 0.08 0.00 Min 0.00 Min MVA) and the C in the 1-4 co he size of the che size of the 1.00 0.09	onal GW orts to r Europe This me id powe Cu Cu onverte sample: Cu	V of cross neet this has 22.1 eans that r plants [0.09 - - - 0.00 - - - - 0.00 - - - - r of trans r transfor s. The sar urrent - - - - - - - - - - - - - - - - - - -	s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category. mple size was de -0.99 1.00 Max	e wind capacit nshore and of 0.08 0.00 Min 0.00 Min 0.00 Min otion. There w VSC tended t etermined by 0.99 1.00 Min 1.00	e needs for 2018, 109 2018, 109 ey, and acc ifshore cor 203 0.	ategories an TSOs w 30 .99 .99 .00	s required. The cross border I to European Contractions will be contracted attemption of the contractions will be contracted attemption of the contract of the	be cost-efficier his increase wou ines were DC, w ommission's rote e needed to sup needed to sup 0.08 <i>Min</i> er transformer han CSC within their most rec <i>Min</i> er transformer han CSC within their most rec <i>Min</i> <i>Min</i>	uld represent while there a admap on or oport the inst 2050 0.09 - - - - - - - - - - - - - - - - -	are arou ffshore i stallation and 6-8 verters o onstruct	28 bn 4 nd 30 C renewa n of HV 0.10 Max 0.00 Max conver categor ed asse ed asse -0.99 1.00 Max
ull-load running hours per year Init of Activity echnical lifetime (years) rogress ratio lourly profile xplanation OSTS ear of Euro hvestment costs Other costs per year excl. fuel costs) data costs per year excl. fuel costs) data costs per year fosts explanation NERGY IN- AND OUTPUTS nergy carriers (per unit of main utput)	investment in the European transmis investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW mln. € / MW mln. € / MW Correlations were identified betweer transformers. There was an even mix although this breakdown cannot be s going back no more than 10 years [2] Electricity Electricity Electricity Propane	sion grid. By 20 y a significant r beline for 2030 er interconnect shore is anticipa nd to integrate it it uboth rating (N c of VSC and CS shown due to th c. Unit PJ PJ PJ PJ	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore wine 0.08 0.08 0.00 Min 0.00 Min MVA) and the C in the 1-4 co he size of the che size of the 1.00 0.09	onal GW orts to r Europe This me id powe Cu Cu onverte sample: Cu	V of cross neet this has 22.1 eans that r plants [0.09 - - - 0.00 - - - - 0.00 - - - - r of trans r transfor s. The sar urrent - - - - - - - - - - - - - - - - - - -	s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category. mple size was de -0.99 1.00 Max	e wind capacit nshore and of 0.08 0.00 Min 0.00 Min 0.00 Min otion. There w VSC tended t etermined by 0.99 1.00 Min 1.00	e needs for 2018, 109 2018, 109 ey, and acc ifshore cor 203 0.	ategories an TSOs w 30 .99 .99 .00	s required. The cross border I to European Contractions will be contracted attemption of the contractions will be contracted attemption of the contract of the	be cost-efficier his increase wou ines were DC, w ommission's rote e needed to sup needed to sup 0.08 <i>Min</i> er transformer han CSC within their most rec <i>Min</i> er transformer han CSC within their most rec <i>Min</i> <i>Min</i>	uld represent while there a admap on or oport the inst 2050 0.09 - - - - - - - - - - - - - - - - -	are arou ffshore i stallation and 6-8 verters o onstruct	28 bn 4 nd 30 C renewa n of HV 0.10 Max 0.00 Max conver categor ed asse ed asse -0.99 1.00 Max
ull-load running hours per year Init of Activity echnical lifetime (years) rogress ratio lourly profile xplanation OSTS ear of Euro hvestment costs Other costs per year excl. fuel costs) data costs per year excl. fuel costs) data costs per year fosts explanation NERGY IN- AND OUTPUTS nergy carriers (per unit of main utput)	investment in the European transmis investment. DC technologies will plat of cross border DC projects in the pip Added to the demand for cross border energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 Euro per Functional Un mln. € / MW mln. € / MW mln. € / MW mln. € / MW Correlations were identified betweer transformers. There was an even mix although this breakdown cannot be s going back no more than 10 years [2] Electricity Electricity Electricity Propane	sion grid. By 20 y a significant r beline for 2030 er interconnect shore is anticipa nd to integrate it it uboth rating (N c of VSC and CS shown due to th c. Unit PJ PJ PJ PJ	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore wine 0.08 0.08 0.00 Min 0.00 Min MVA) and the C in the 1-4 co he size of the che size of the 1.00 0.09	onal GW orts to r Europe This me id powe Cu Cu Cu Samples Cu Samples	V of cross neet this has 22.1 eans that r plants [0.09 - - - 0.00 - - - - 0.00 - - - - r of trans r transfor s. The sar urrent - - - - - - - - - - - - - - - - - - -	s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category. mple size was de -0.99 1.00 Max	e wind capacit nshore and of 0.08 0.00 Min 0.00 Min 0.00 Min otion. There w VSC tended t etermined by 0.99 1.00 Min 1.00	e needs for 2018, 109 2018, 109 ey, and acc ifshore cor 203 0.	or 2030 i 6 of the ording to overter s 30 .09 .00 .00 .00 .00 .00 .00 .0	s required. The cross border I to European Contractions will be contracted attemption of the contractions will be contracted attemption of the contract of the	be cost-efficier his increase wou ines were DC, w ommission's rote e needed to sup needed to sup 0.08 <i>Min</i> er transformer han CSC within their most rec <i>Min</i> er transformer han CSC within their most rec <i>Min</i> <i>Min</i>	uld represent while there a admap on or oport the inst 2050 0.09 - - - - - - - - - - - - - - - - -	are arou ffshore i stallation and 6-8 verters o onstruct	28 bn = nd 30 (renewa n of HV 0.10 Max 0.00 Max conver categor ed asse ed asse 1.00 Max
iull-load running hours per year Juit of Activity iechnical lifetime (years) Progress ratio Acurly profile ixplanation ixplanation ixer of Euro nvestment costs Other costs per year ixed operational costs per year excl. fuel costs) Variable costs per year Costs explanation inergy carriers (per unit of main putput) inergy in- and Outputs ixplanation MATERIAL FLOWS (OPTIONAL)	investment in the European transmiss investment. DC technologies will pla of cross border DC projects in the pip Added to the demand for cross borde energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 2015 2015 2015 2015 2015 2015	sion grid. By 20 y a significant r beline for 2030 er interconnect shore is anticipa nd to integrate it it uboth rating (N c of VSC and CS shown due to th c shown due to th c f PJ PJ PJ PJ s in a converter	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore wine 0.08 Min 0.00 Min MVA) and the C in the 1-4 cm he size of the he size of the -0.99 1.00 Min r station of ty	onal GW orts to r Europe This me id powe Cu Cu Cu Samples Cu Samples	V of cross neet this has 22.1 eans that r plants [0.09 - - 0.00 - - - 0.00 - - - - - - - - - -	s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category. mple size was do -0.99 1.00 Max 6. Whereas the	e wind capacit nshore and of 0.08 0.08 0.00 0.00 0.00 0.00 0.00 0.0	e needs for 2018, 109 y, and acc fshore cor fshore cor 203	or 2030 i 6 of the ording to overter s 30 .09 .00 .00 .00 .00 .00 .00 .00 .00 .0	s required. The cross border I to European Contactions will be contact at the second s	be cost-efficier his increase wor ines were DC, v ommission's rote e needed to sup needed to sup 0.08 <u>Min</u> er transformer han CSC within t their most rec <u>Min</u> t 1% per conver	uld represent while there a admap on or oport the inst 2050 0.09 	are arou ffshore i stallation and 6-8 verters o onstruct	28 bn 4 nd 30 G renewa n of HV 0.10 Max 0.00 Max conver categor ed asse d asse 1.00 Max Max
Full-load running hours per year Unit of Activity Fechnical lifetime (years) Progress ratio Hourly profile Explanation	investment in the European transmiss investment. DC technologies will pla of cross border DC projects in the pip Added to the demand for cross borde energy, over 250 GW of installed offs interconnectors between countries a 2015 2015 2015 2015 2015 2015 2015 2015	sion grid. By 20 y a significant r beline for 2030 er interconnect shore is anticipa nd to integrate it it uboth rating (N c of VSC and CS shown due to th c shown due to th c f PJ PJ PJ PJ s in a converter	040, 43 additi role in the effe [9]. tion capacity, ated by 2050. e offshore wine 0.08 0.08 0.00 Min 0.00 Min MVA) and the C in the 1-4 co he size of the che size of the 1.00 0.09	onal GW orts to r Europe This me id powe Cu Cu Cu Samples Cu Samples	V of cross neet this has 22.1 eans that r plants [0.09 - - - 0.00 - - - - - - - - - - - - - -	s border capacit reinforcements GW of offshore the need for or [6]. 0.10 Max 0.00 Max formers in a sta rmers category. mple size was de -0.99 1.00 Max	e wind capacit nshore and of 0.08 0.00 Min 0.00 Min 0.00 Min otion. There w VSC tended t etermined by 0.99 1.00 Min 1.00	e needs for 2018, 109 ey, and accord fshore conditions fshore conditions 0.	ategories and the solution of	s required. The cross border I to European Contractions will be contracted attemption of the contractions will be contracted attemption of the contract of the	be cost-efficier nis increase wou ines were DC, w ommission's rote e needed to sup needed to sup 0.08 <i>Min</i> er transformer han CSC within their most rec <i>Min</i> -0.99 1.00 <i>Min</i> <i>Min</i>	Id represent vhile there a admap on o oport the instruction 0.09 - - 0.00 - - 0.00 - - 0.00 - - - 0.00 - <td>are arou ffshore i stallation and 6-8 verters o onstruct</td> <td>28 bn 4 nd 30 G renewa n of HV 0.10 Max 0.00 Max conver categor ed asse ed asse -0.99 1.00 Max</td>	are arou ffshore i stallation and 6-8 verters o onstruct	28 bn 4 nd 30 G renewa n of HV 0.10 Max 0.00 Max conver categor ed asse ed asse -0.99 1.00 Max

EMISSIONS (Non-fuel/energy-relate	ed emissions or emissions reduct	tions (e.g. CCS)										
	Substance	Unit		Current			2030			2050		
			-			-			-			
			Min	-	Max	Min	-	Max	Min	-	Max	
				-			-			-		
missions			Min	-	Max	Min	-	Max	Min	-	Max	
				-			-	-		-		
			Min	-	Max	Min	-	Max	Min	-	Max	
				-			-			-		
			Min	-	Мах	Min	-	Max	Min	-	Max	
Emissions explanation												
OTHER												
Parameter	Unit	Unit		Current			2030			2050		
				-			-			-	-	
			Min	-	Max	Min	-	Max	Min	-	Max	
				-			-			-		
			Min	-	Max	Min	-	Max	Min	-	Max	
				-			-			-		
			Min	-	Max	Min	-	Max	Min	-	Max	
				-			-			-		
			Min	-	Max	Min	-	Max	Min	-	Мах	
xplanation												
REFERENCES AND SOURCES												
	e Electricity Grid Implementation											
	nvestment cost indicators and co			-	-	re.						
	for Transmission System. Technic			ultation and AC	ER opinion.							
	tage Direct Current Electricity – to		on.									
	ne map, power system needs in 20	030 and 2040.										
	Transmission and Distribution.											
	investment model cost paramete			frastructure.								
	al Maximum Limits on Power-Har	ndling Capacity of	HVDC Cables									
ENTSOE (2019). Statistical Fac	tsheet 2018.											