TECHNOLOGY FACTSHEET



V.Z												
DIABATIC COMPRESSED	AIR ENERGY STORAGE	(CAES) F	OR LARG	-SCALE T	EMPORA	L ELECTRI	CITY STO	RAGE				
Date of factsheet	20-2-2020											
Author	Sam Lamboo											
Sector	Electricity generation											
ETS / Non-ETS	Non-FTS											
Type of Technology	Storage											
Description	Compressed air energy storage (CA	Compressed air energy storage (CAES) is based on storing electricity as compressed air. Compressed air is typically stored underground in suitable geological formations (salt, hard rock and										
	porous rock or aquiter). Abovegrou	nd CAES is also a	a possibility, nov	wever investme	nt costs in this o	case are higher.	· Diabatic CAF(Susse fuel (typi	colly natural gav	-) to heat the e	unanding air	
	(JRC ETRI, 2014). CAES is typically a large-scale, long-term storage option, and it is applied on the centralised grid.											
	2013; IRENA, 2017).											
TRL level 2020	TRL 9 The two large existing projects were already installed in 1978 (Germany) and in 1991 (Alabama) (DNV KEMA, 2013). More plants are being prepared, such as a plant in Larne, Ire											
	2018).			••				-		F		
TECHNICAL DIMENSIONS	T Sunctional Unit						(-lup and Pan)					
Capacity	kWh						3,000,000	je				
				580,000			-			3,000,000		
	NL	GWh		Current			2030			2050		
Potential			Min	550	Max	Min	- -	Мах	Min	-	Мах	
Market share	Global utility scale electricity storage	ge %	Min	0.30%	Max	Min	 I	Max	Min	- - T	Max	
Capacity utlization factor	<u> </u>		IVIIII	<u> </u>	IVIUA	IVIIII		1.00	IVIIII		IVIUA	
Full-load running hours per year												
Unit of Activity	PJ/year								21 4) Up to 20(······································	
Technical lifetime (years) Progress ratio	<u> </u>				30 years (IEA E	TSAP & IKEINA, 2	2012), 40-55 ye	ers (JRC ETRI, ∠	014). Up to 200	ייש) 000 cycles, N/A	NV KEIVIA, 2013) (IRC ETRI. 2014)	
Hourly profile	No											
Explanation	Project specifications determine ca	pacity and detai	iled project desi	gn. An example	from TNO (201	8): 100 MW/2,8	60 MWh (26h	discharge time)	with a cavern c	f 538.000 m3.	Assuming	
	charge time is similar to discharge t	ime (26h), then	the compressor	capacity requir	ed will be 350 n	n3/s. If taster cr	large times are	desired, a large	er compressor is	required.		
	The potential estimated by TNO is storage and may therefore not be o	50% of the theor completely avail	retical storage p able for CAES (T	otential in onsh NO, 2018).	ore salt caverns	s in the Netherla	ands. These sal ^a	t caverns can al	so be used for r	1atural gas or h	ydrogen	
	As of 2015, the global grid-connected CAES capacity is 440 MW (0.3%) and it is the largest installed utility scale storage after pumped hydro. Pumped hydro dominates the large-scale											
	electricity storage market with over	r 140 GW installe	ed capacity (99.	1% of installed o	apacity) (IRENA	A, 2015). More p	rojects are und	der developmen	ıt (TNO, 2018).			
	Reports on lifetime vary from 30 ye	ars (IEA-ETSAP {	& IRENA, 2012),	to 40-55 years	(JRC ETRI, 2014 [°]), and to 20-100	years (IRENA,	2017).				
COSTS												
Year of Euro	2015			Current			2020			2050		
Investment costs	€ / kWh	mit		35			31			2030		
			2	-	50	31	_	40	26		26	
Other costs per year	€/ KWh		I				-					
Other costs per year	€/ KWN €/ kWh		Min	-	Max	Min	-	Мах	Min	-	Мах	
Other costs per year Fixed operational costs per year (excl. fuel costs)	€ / kWh		0.46	- 0.46 -	Max 1.01	Min 0.40		0.80	Min 0.34		<i>Мах</i> 0.34	
Other costs per year Fixed operational costs per year (excl. fuel costs) Variable costs per year	€ / kWh € / kWh € / MWh		Min 0.46 1.21	- 0.46 - 1.21 -	Max 1.01 30.00	Min 0.40 1.21	- 0.40 - 1.21 -	Max 0.80 30.00	Min 0.34 1.21	- 0.34 - 1.21 -	0.34	
Other costs per year Fixed operational costs per year (excl. fuel costs) Variable costs per year	€ / kWh € / kWh € / MWh There are significant degrees of free	edom in designir	Min 0.46 1.21 ng (diabetic) CAl	- 0.46 - 1.21 - ES system, such	Max 1.01 30.00 as pump size al	Min 0.40 1.21 nd turbine size v	- 0.40 - 1.21 - vhich determir	Max 0.80 30.00 ie in combination	Min 0.34 1.21 on with the rese	- 0.34 - 1.21 - rvoir size the c	Max 0.34 1.21 harge and	
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			Current						2050			
	Euro per Functional Ur			Current			2030		2050			
Investment costs	€ / kWh			35	T		31	T		26	1	
			2	-	50	31	-	40	26	-	26	
Other costs per year	€ / kWh			-			-			-		
			Min	-	Max	Min	-	Max	Min	-	Max	
Fixed operational costs per year	€ / kWh			0.46			0.40			0.34		
(excl. fuel costs)			0.46	_	1.01	0.40	-	0.80	0.34	-	0.34	
Variable costs per year	€ / MWh			1.21			1.21			1.21		
variable costs per year			1.21	_	30.00	1.21	-	30.00	1.21	-	1.21	
	There are significant degrees of freed discharge times and the energy/pow The sources used have been chosen complete set of data, including CAPE investment costs from other sources JCH JU McKinsey (2015), and 2009 fc	dom in designin er ratio. Design because they ar X and FOM/VO vary from 2 €/I or Chen et al. (20	g (diabetic) CAE choices such as re recent public M estimates up kWh to 500 €/k 009).	S system, such these influenc ations and inclu to 2050. Detai Wh. Data point	as pump size and e system costs, ude projections is of the cost es s for the curren	nd turbine size which means t up to (at least) timates are not nt year (2020) d	which determin here are relative 2030. JRC ETRI , or only shortly iffer per source	e in combination ely large ranges (2014) is used a , elaborated in 2020 for JRC E	on with the rese in costs possib as primary source these reports, a TRI (2014), 201	ervoir size the c le. ce because it ha and estimation 6 for IRENA (20	harge and as the most s of 17), 2013 for	
Costs explanation	The main FOM costs calculated using 2030 and 2050. Other FOM costs are assuming a standard storage capacit VOM costs are only provided for 201 related O&M costs that vary with elements.	g the JRC ETRI (2 e from FCH JU N y of 15 hours (2 .3 by JRC ETRI (2 ectrical generation	2014) assumptic Ickinsey (2015) 200MW/3000M 2014) and it is as on. They exclud	on that they rep that states FON Wh system - JR ssumed the the e personnel, fu	oresent 1.3% of A costs as 15 €/ C ETRI, 2014). ay remain the sa el, and CO2 cos	investment cos /kW/year in 201 ame in 2020, 20 sts.	sts. It is assumed 3 and 12 €/kW 30 and 2050. V	d that FOM cost /year in 2030. T OM costs are de	ts remain 1.3% These have beer efined by JRC ET	of investment on calculated to FRI (2014) as pr	costs in 2020, M€/GWh/year oduction-	
ENERGY IN- AND OUTPUTS												
	Energy carrier	Unit	Current 2030 20					2050				
	Main output:		-1.00			-			-			
	Electricity	РJ	-1.00	_	-1.00	Min	_	Max	Min	_	Max	
		PJ		0.77			-			-		
Energy carriers (per unit of main output)	Electricity		0.77	-	0.77	Min	-	Max	Min	-	Мах	
				1.13			-			-		
	Natural gas		1.13	-	1.13	Min	-	Max	Min	-	Мах	
				-			-			-		
		PJ	Min	-	Max	Min	-	Max	Min	-	Мах	
Energy in- and Outputs explanation	The required amounts of electricity and natural gas are stated to obtain 1 PJ of electrical output - based on Huang et al (2017). Note that the output of electricity is higher than the input due to the addition of heat from the combustion of natural gas. Total efficiency is 53% in this configuration, which is at the high end of the 42-54% range reported by DNV KEMA (2013).											
EMISSIONS (Non-fuel/energy-related em	nissions or emissions reductions (e.g.	CCS)										
	Substance	Unit	Current			2030			2050			
				-			-			-		
			Min	-	Max	Min	-	Max	Min	-	Max	
				-	I		-	I		-	1	
Emissions			Min	-	Max	Min	-	Max	Min	-	Max	
				-	1		-	1		-	T	
		1	Min	-	Max	Min	-	Max	Min	-	Max	
				-			-			-		
			Min	-	Max	Min	-	Max	Min	-	Max	
Emissions explanation												

OTHER											
Parameter	Unit		Current			2030			2050		
Depth of discharge	%		N/A			-			-		
		-	-	-	Min	-	Max	Min	-	Max	
Charge time	Hours		26			-			-		
		26	-	26	Min	-	Max	Min	-	Мах	
Discharge time	Hours		15			-			-		
		2	-	26	Min	-	Max	Min	-	Мах	
Self discharge	% / month		-	1		-	-		-		
		-	-	-	Min	-	Max	Min	-	Max	
	The main discharge time is based on the size of typical system as reported by JRC ETRI (2014) - 200MW/3,000MWh. TNO (2018) compares three plants (Huntdorf (DE), McIntosh (US and Larne (IE)) with varying specifications (Huntdorf capacity is ca. 300 MW and 600 MWh and McIntosh capacity is ca. 110 MW and 2,860 MWh). Capacity, charge time, and discha time depend, amongst other things, on cavern size and the specifications of the turbine and compressor used for the project.										
REFERENCES AND SOURCES	nce Indicators (ETRI) projections for 2010-2050										
DNV-KEMA 2013 Systems Analysis B	Remarkators (ETRI) projections for 2010-2030										
IRENA 2017 Electricity Storage Costs											
Luo et al. (2015). Overview of curren	, t development in electrical energy storage technolo	gies and the applic	ation notential	in nower syste	moneration						
TNO 2018 Ondergrondse Onslag in I	Nederland: Technische Verkenning	gies and the applie		in power syste							
IRENA 2015. Renewables and Electric	city Storage: a technology roadmap for REmap 2030										
IEA-ETSAP & IRENA 2012. Electricity	storage technology brief										
FCH JU McKinsey (2015). Commercia	alisation of energy storage in Europe										
Chen et al (2009). Progress in electri	cal energy storage system: A critical review										
Huang et al (2017). Techno-economi	c modelling of large scale compressed air energy sto	orage systems									