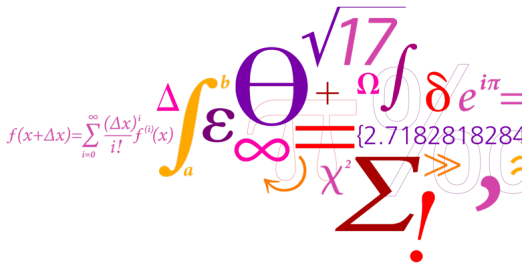


CAES – Compressed Air Electricity storage

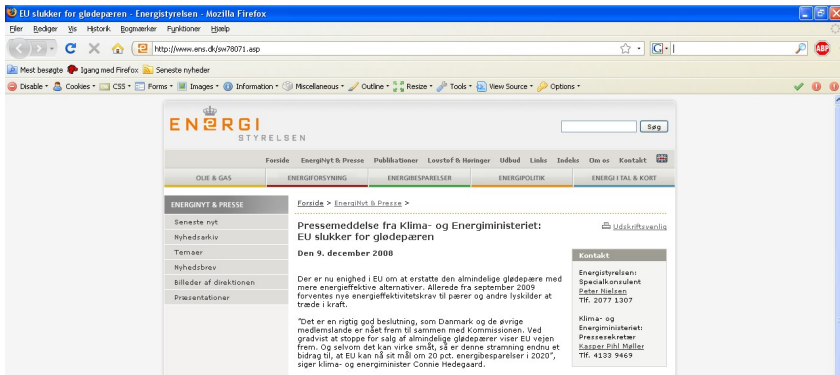
Brian Elmegaard

14 January 2009

DTU – Technical University of Denmark
Department of Mechanical Engineering

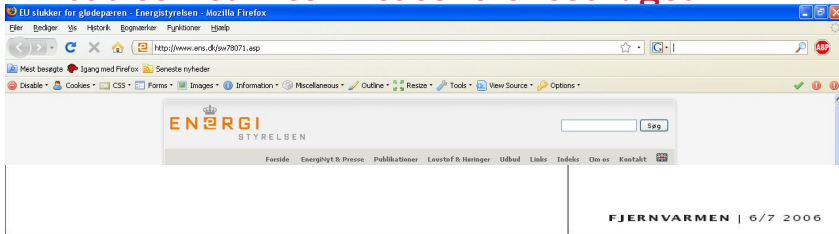


Electricity is a resource



The screenshot shows a Mozilla Firefox browser window displaying the Energinet website. The browser's address bar shows the URL <http://www.ens.dk/jw78071.asp>. The website header features the Energinet logo and a search bar. A navigation menu includes links for 'Forside', 'Energinet & Presse', 'Publikationer', 'Lovstof & Høring', 'Udbud', 'Links', 'Indeks', 'Om os', and 'Kontakt'. Below this, a secondary menu highlights 'ENERGIFORSYNING'. The main content area is titled 'Pressemeddelelse fra Klima- og Energiministeriet: EU slukker for glødepæren' and is dated 'Den 9. december 2008'. The text discusses EU's decision to phase out incandescent light bulbs in favor of more energy-efficient alternatives. A 'Kontakt' sidebar on the right provides contact information for Energinet's Special Consultant, Peter Nielsen, and the Ministry of Climate and Energy's Press Secretary, Poul Møller.

Electricity is a resource – but sometimes misuse is encouraged



Fjernvarmeværker forventer fremtid med elpatroner

Nu kommer den helt forureningsfri fjernvarme - men er elpatroner vejen til verdens reneste og mest effektive energisystem?

Electricity is a resource

– but sometimes misuse is encouraged

EU støtter for glødepæren - Energistyrelsen - Mozilla Firefox

• Energy always ends up as heat

• Heat production is not electricity storage

Fjernvarmen | 6/7 2006

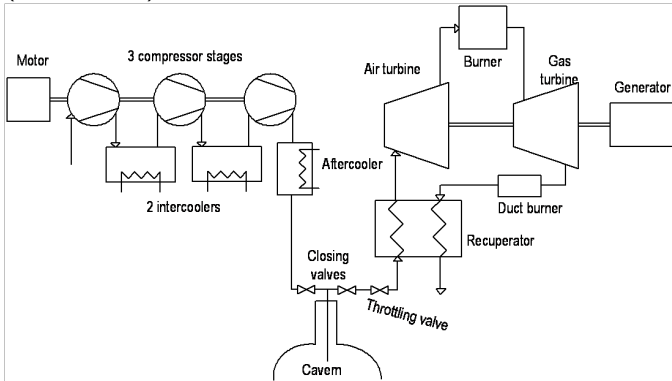
Fjernvarmeværker for fremtid med elpatroner

- Electricity is exergy
- Exergy is a resource to be handled with care

Nu kommer den helt forureningsfri fjernvarme - men er elpatroner vejen til verdens reneste og mest effektive energisystem?

Compressed Air Electricity Storage Technology

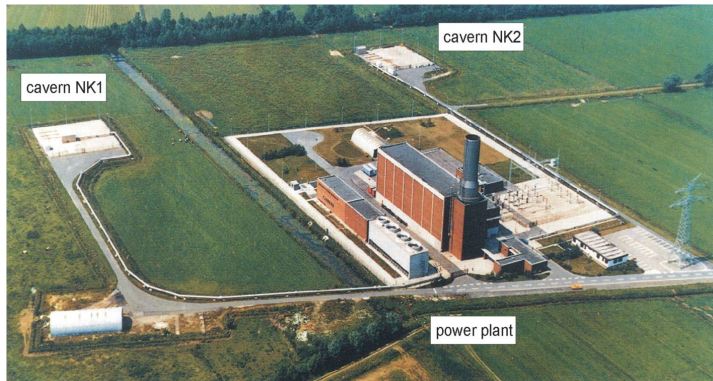
- Gas turbine divided into compression (electricity consumption) and expansion (production) Electricity stored as compressed air (60-100 bar) underground



CAES plants in operation

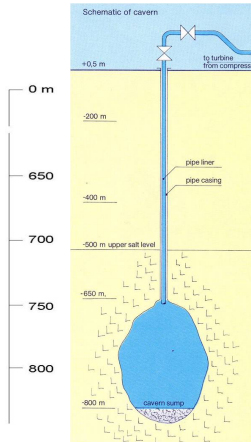
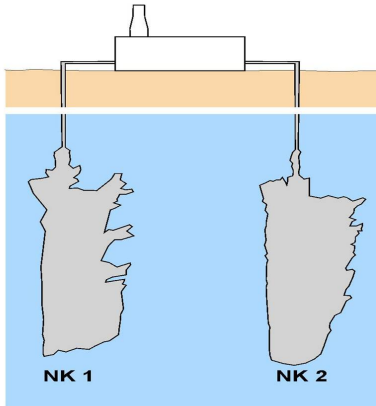
McIntosh Alabama 110 MW/26 h – 60 MW – 540000 m³

Huntorf Germany 60 MW/8 h – 290 MW/2 h – 300000 m³



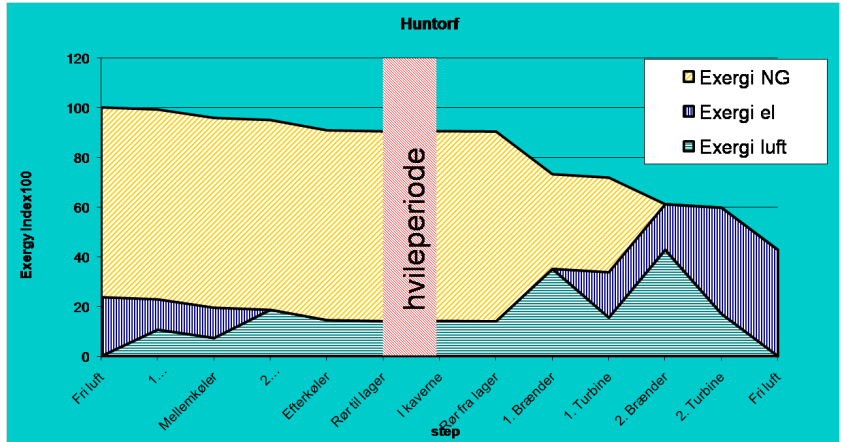
Ref: Huntorf CAES: More than 20 Years of Successful Operation (Crotagino, Mohmeyer, Scharf) 2001

Underground Caverns

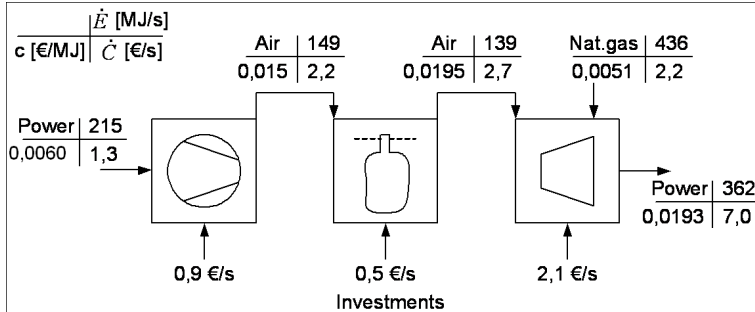


Ref: The Huntorf 290 MW CAES Power Plant, E.ON Kraftwerke, Farge

Energy flows



Energy and cost flow



Important losses Compressor cooling, irreversibility losses

Important costs Natural gas, storage

Future research Heat storage

Efficiency of CAES

Plant

Exergy in el	220 MW		34%
Exergy in NG	<u>435 MW</u>		66%
Exergy out total	655 MW		
Exergy out el	362 MW	$\eta_{x,CAES} =$	55%

Store

Exergy in el	220 MW		
Exergy to store	150 MW	$\eta_{x,storage} =$	69%

Production

Exergy from store	150 MW		26%
Exergy in NG	<u>435 MW</u>		74%
Exergy in total	586 MW		
Exergy out el	362 MW	$\eta_{x,production} =$	62%

El → store → El

$$\eta_{x,storage} = 69\% \cdot 62\% = 43\%$$

Bulk Electricity Storage Technologies

	Efficiency (el-store-el)
In operation	
Compressed Air (CAES)	45-60% (70%?)
Pumped Hydro	60-85%
Future	
Batteries	60-90%
Flow Batteries	55-65%
Hydrogen	20-35%
Conversion to heat	
<i>Degree of Utilization of exergy resource</i>	
Heat pumps	20-30%
Electric boilers	10%

Summary

- Electricity is an important resource, misuse should not be favoured
- Implementation of wind power is currently not a problem, but it requires the central plants to operate flexibly
- CAES and Electricity storage in general require:
 - Large investments
 - Significant losses of electric energy due to irreversibility in conversions
 - Large volume and/or area
 - Big price fluctuations or high consumer prices to be feasible
- CAES is competitive with other storage technologies
- CAES need further development, primarily heat storage

Huntorf operation

Wind Power and Electricity Surplus

Denmark West 2000-2008 Wind production: 39 TWh – Export to Germany: 30 TWh \Rightarrow 77% not implemented

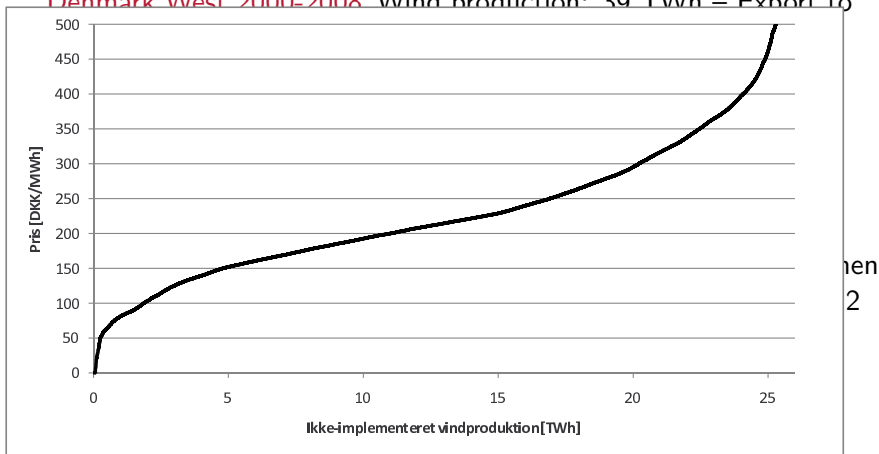
Denmark East and West 2000-2008 Wind production: 51 TWh – Export 18 TWh \Rightarrow 35% not implemented

Hour by hour Wind production: 51 TWh – Export when wind exceeds Danish consumption: 26 TWh \Rightarrow 51% not implemented

Hour by hour at low cost Wind production: 51 TWh – Export when wind exceeds Danish consumption and price is low: 2 TWh \Rightarrow 3% not implemented

Wind Power and Electricity Surplus

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Wind Power and Electricity Surplus

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Hour by hour Wind production: 51 TWh – Export when wind exceeds Danish consumption: 26 TWh \Rightarrow 51% not implemented

Hour by hour at low cost Wind production: 51 TWh – Export when wind exceeds Danish consumption and price is low: 2 TWh \Rightarrow 3% not implemented

Is electricity surplus a problem? That depends – it may be in the future