Program Temadag

Optimal udnyttelse af solcelle-el i énfamiliehus

21. juni 2016 kl. 13.00 – 16.00

13.00 – 13.15 v/Iben Østergaard

- Velkomst og indledning
- Kort beskrivelse af de to forsøgsopstillinger
- Og kort beskrivelse af status.

13.15 – 13.45 v/Ivan Katic

- Forsøgsresultater, cykluseffektivitet m.m.
    - Forsøg 1 og forsøg 2 –
- Status, problemer,
    - Forbrugsprofiler
    - Lav virkningsgrad på inverter

13.45 – 14.00 v/Claus Martin Hvenegård og Ivan Katic

- Præsentation af dimensioneringsprogram

14.00 – 14.45

Besøg i Energy Flex house og kaffepause

14.45 – 15.15 v/Lars Barkler

- Videre perspektiver med batterier til lagring af solcelle-el :
    - Erfaringer i Lithium Balance
    - Hvor tæt er vi på at kunne levere batterisystemer til husholdninger
    - Økonomi mm.

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- Varmepumper eller andre termiske lagre for solcelle-el

15.45

- Opsamling og afslutning

TEKNOLOGISK INSTITUT LiTHIUM BALANCE BATTERY MANAGEMENT SYSTEMS ELFORSK

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TEKNOLOGISK INSTITUT

LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

ELFORSK

TEKNOLOGISK
INSTITUT

Deltagerliste Udskrevet: 20/06/16

27347 - Temadag med fokus på udnyttelse af batterier og varmepumpe i forbindelse med solcelleanlæg i énfamiliehuse

21. juni 2016, 13:00 - 16:00 i Indgang 1

Foredragsholdere:
Lars Barkler, Lithium Balance
Rasmus Mosbæk, Lithium Balance
Ivan Katic, Teknologisk Institut
Claus M. Hvenegaard, Teknologisk Institut
Organisator: Iben Østergaard, Teknologisk Institut

Navn	Firma
Jim Holse	4700 ApS
Mikkel Fjeldsø Nielsen	4energi
Casper H. Nielsen	Andelsboligforeningen Steen
Rolf Pedersen	Bjelkebyg v/Katrine Riber Bjelke
Tine Sode	Bolius Boligejernes Videncenter A/S
Michael Simonsen	Brossi
Jakob Haraldsted	Både & ...
Ditte Mikkelsen	Dansk Energi
Jesper Tornbjerg	Dansk Energi
Jørn Borup Jensen	Dansk Energi
Dorte Lindholm	ELFORSK
Jens Meyerdierks	Energielektrikeren ApS
Steffen Damm Hansen	Energimidt Forsyning & Service A/S
Torsten Malmdorf	Energistyrelsen
Kim Jørgensen	Energitjenesten
Vagn Juulsen	Energitjenesten
Carsten sohl	Energitjenesten Vestjylland
Mikkel Eger Sommer	EUC Nordvestsjælland
Jesper Bille	Flemming Nielsen ApS
Martin Nordly	Green Tech FM ApS
Rene Pedersen	Gribskov Isolering ApS
Kristian Abkjær	J.K. El og Køl ApS
Jens Mouridsen	JL El-Teknik ApS
Jesper Lund	JL El-Teknik ApS
Morten Rønne	JL El-Teknik ApS
Kasper Hansen	Kasper Hansen
Anders Repsdorph Nielsen	Kemp & Lauritzen A/S
Jan Sandberg	Kildevangsgården v/Jan Sandberg
Sven Kristiansen	Landsforeningen af socelleejere
Per Stallknecht	Lejre Kommune
Bruno Bomholdt	Montagecenter Nordsjælland
Ib Brøndsted	Murermester Ib Brøndsted ApS
Lars Mønster	Mønster Byg Aps
Jesper Knudsen	NCC Construction Danmark A/S
Anders Jørgensen	Rex Naturvarme
Ib Rothman	SEM Byg ApS
Johnnie Aas	SIF Gruppen A/S
Jacob Mortensen	Solar A/S
Søren Rise	TEKNIQ
Kjeld Nørregaard	Teknologisk Institut
Søren Poulsen	Teknologisk Institut
Torben Thestrup	Thestrup Totalservice
Leif Pinholt	Thy Windpower ApS
Nils Henrik Christiansen	V.B. Byggeindustri A/S
Lars Christensen	Viasol A/S
Rasmus Christiansen	Viasol A/S

Videre perspektiver med batterier til lagring af solcelle-el

Temadag, Teknologisk Institut

Lars Barkler

21. juni 2016

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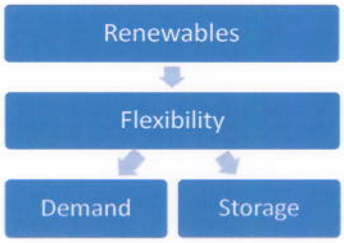
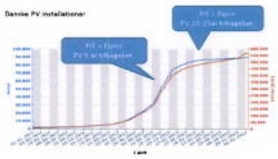
Hvorfor lagre energi?

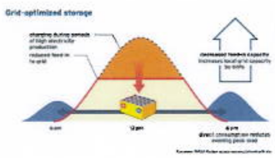


LiTHIUM BALANCE BATTERY MANAGEMENT SYSTEMS — ELFORSK — DANISH TECHNOLOGICAL INSTITUTE

Hvorfor batterier til Solcelleanlæg?

- Solceller producerer strøm, når du ikke har brug for det
  - Typisk husstand kun 25-30% egetforbrug
  - Resten sælges på elnettet, til faldende Feed-in-tariffer
- Egetforbruget kan øges med et batteri
  - Mest økonomisk at øge til 70-80% med et batteri





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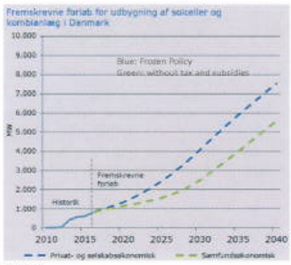
Forventet markedsudvikling

Danmark: 10-dobling i 2040



Reference: Energinet.dk, Solceller og batterier i Danmark, 1. feb. 2016, Dok. 15/0995-9

Globalt: 5-dobling i 2025

Reference: Frost & Sullivan, May 2016

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Batteriøkonomi - foranalyse

Batteri ved 8 kWh brugbar kapacitet	Bly syre (Dansk forhandler, i dag)	Lithium Ion (Dansk forhandler, i dag)	Lithium Ion (markedsforventning om 3-5 år)
Pris ca.	32.000 kr.	70.000 kr.	40.000 kr.
Cykler	1200	6000 - 7000	
Vægt	400 kg	115 kg	
Volumen	900 L	200 L	
Virkningsgrad	75 %	90 %	
Levetid	3 år	15 år	
Energiindhold i kWh	16 kWh	10 kWh	
Brugbar kapacitet	50 %	80 %	
Brugbar kapacitet i kWh	8 kWh	8 kWh	
Solcellecykler pr. år	200	200	
Antal kWh i levetiden ialt	200 x 3 år x 8 kWh = 4800 kWh	200 x 15 år x 8 kWh = 24000 kWh	
Pris pr. lagret kWh	6,66 kr./ kWh	2,92 kr kr./ kWh	1,67 kr kr./ kWh
Energitab per lagret kWh ved FIT på 0,60 kr/kWh	0,20 kr./ kWh	0,07 kr kr./ kWh	0,07 kr kr./ kWh

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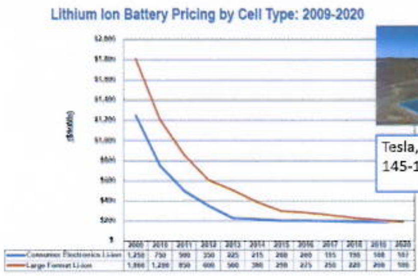
Den virkelige revolution er Tesla's prispres



Tesla, LG m.fl. lover nu 145-150 $/kWh

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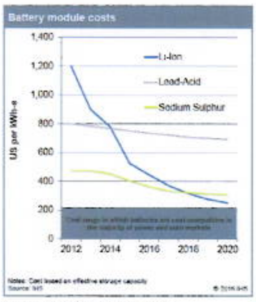
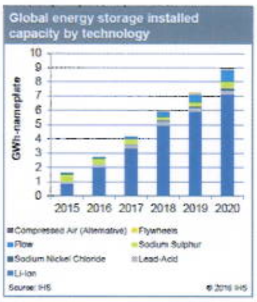
Lithium-ion slår de andre lagringsteknologier





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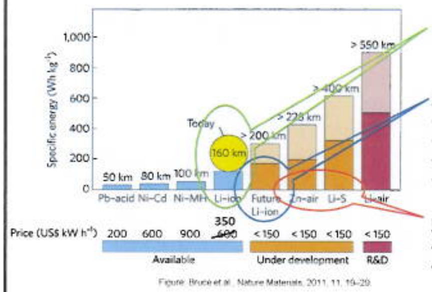
Er der noget endnu bedre på vej?



1-2 år
- Volumen
- Pris

3-5 år
- Cycles
- Levetid
- Densitet
- C-rates

5-15 år
- Nye kemier
- Pris?

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Resultater fra testen i EnergiFlexHouse

Lithium-ion solcellebatterier til husstande

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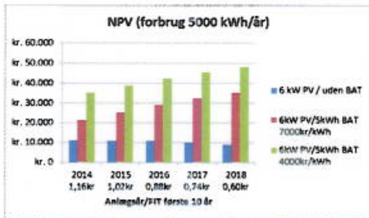
Økonomisk foranalyse

- Faldende FIT gør solcelleanlæg mindre rentable
- Det mere end opvejes MED et batteri
- De nye batteri-priser 5-dobler rentabiliteten af solcelleanlæg



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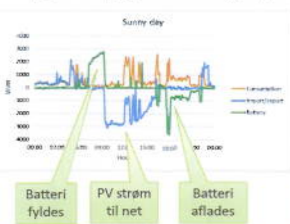
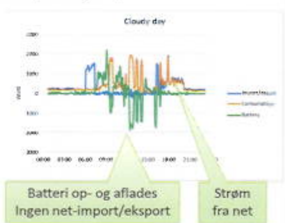
1 års test i TI's EnergyFlexHouse

- 15% bedre økonomi end foranalysen (timeværdier) pga. skyggefulde dage (flere cykler/år)





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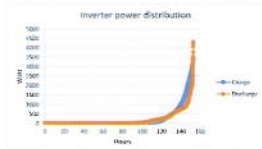
Prototype test i EnergyFlexhouse
Udfordringer for slutkunden

- Batteriet er mere effektivt end forventet
- Der er stort effekttab i invertere i standby mode
- De fleste invertere, der påstås Li-ion klar, er det reelt ikke.
  - De er reelt bly-batteri invertere og vil reducere Li-ion batteriernes levetid
- De færreste sol-batterier på markedet opfylder anbefalede eller gældende sikkerheds-standarder



	Battery	Converter	Total
March	96%	64%	61%
April	97%	77%	75%
May	98%	79%	77%
June	97%	60%	58%
July	89%	84%	75%
August	99%	75%	75%

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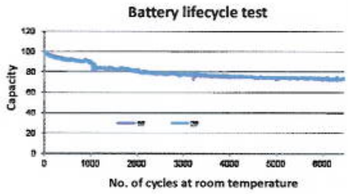
Yderligt potentiale ved fleksible elpriser

- Solcellebatterier kan ikke forbruge alle cykler i levetiden
- Gratis at bruge overskydende cykler til opladning fra elnettet
- Oplad batteriet om natten, hvis elprisen er lavere end om morgenen



Sol bruger 230 cykler/år
12-15 års bat-levetid = 2700-3500 cykler til sol
Minimum 3000 cykler til ladning fra elnettet
(afhænger dog af Li-ion kemi)
Ved 40 øre/kWh besparelse, betales 20-25% af batteriet af netopladning

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Hvad nu?

- Projektet viser behov for at arbejde med:
  - Inverter-effektivitet
  - Sikkerhedsstandarder for solcellebatterier
  - Solcelle-batterier på markedet, der opfylder sikkerhedsstandarderne
  - Praktiske vejledninger for installation og vedligehold af solcellebatterier

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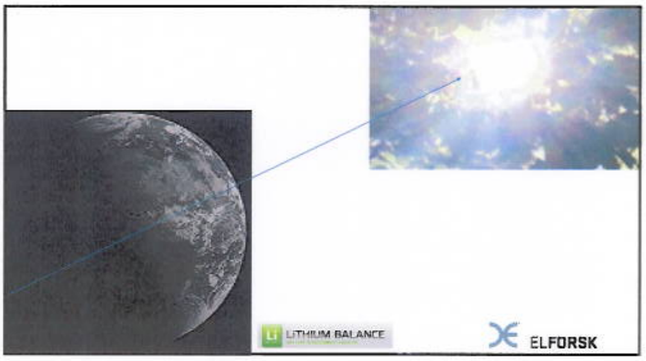

Velkommen til tema-møde om:
Optimal udnyttelse af solcelle-el i énfamiliehus

Et Elforsk projekt med deltagelse af:

Teknologisk Institut

Lithium Balance support fra

Gaia Solar

LITHIUM BALANCE ELFORSK

Optimal lagring af sol-celle-elektricitet i énfamiliehuse

- **Program**
- 13 – 13.15.
  Iben Østergaard
- Velkomst og indledning
- Projektindhold – og status
- 13.15 – 13.45
  Ivan Katic:
- Forsøgsresultater, cykluseffektivitet m.m.
  - Forsøg 1 og forsøg 2 –
  - Samlet og hver for sig
- Status, problemer

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- 13.45 – 14.00
  Claus Martin Hvenegård og Ivan Katic:
- Præsentation af dimensioneringsprogram
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Baggrund

- 4 - 6 kW anlæg producerer 20 – 30 kWh på sommerdag.
- Forbrug i husholdning 10 – 12 kWh.
- Formål: lagre så meget som muligt – inden resten sendes på nettet

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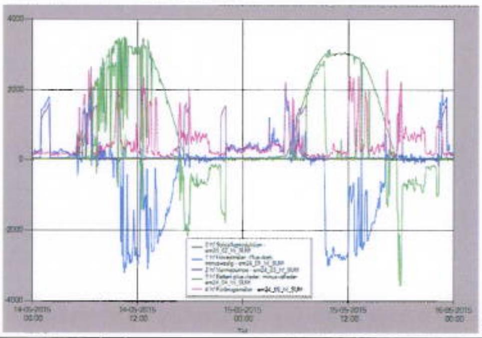

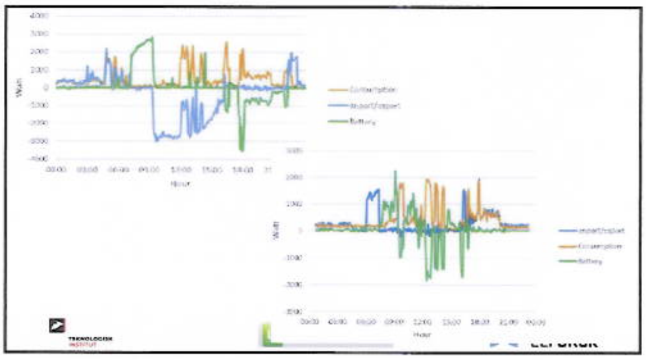

Priser for lagring på batteri, varmtvand (varmepumpe) og gulvvarme

Case:	[illegible]	[illegible]	[illegible]		[illegible]	
Teknologi	[illegible]	Li-ion batteri med inverter	Varmtvand+VP		Termisk lager med VP	
Nominel kapacitet	[illegible] kWh	[illegible] kWh	[illegible] kWh (dagligt energi til varmtvandsopvarmning)			
Reel kapacitet	[illegible] kWh	[illegible] kWh	[illegible] kWh [illegible]		[illegible] kWh [illegible]	
DOD	[illegible]	[illegible]				
Mer-investering ca.*)	[illegible] kr	[illegible] kr	[illegible] kr (kun ændring af styring)		[illegible] kr (kun ændring af styring)	
Anslået maksimal levetid	[illegible] år	15 år	15 år		30 år	
Antal cykler i levetid	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
Energiomsætning i levetid	[illegible] kWh	[illegible] kWh	[illegible] kWh		[illegible] kWh	
Cyklus effektivitet	[illegible]	[illegible]	[illegible]	Tab ved forøget temperatur	[illegible]	Tab ved forøget temperatur
Lagerpris	[illegible] kr/kWh	[illegible] kr/kWh	[illegible] kr/kWh		[illegible] kr/kWh	

Af de foreløbige beregninger fremgår det at der er meget store forskelle på prisen for energilagring.

Batteri 10 kWh	Bly syre	Lithium Ion
Pris ca.	10.000 kr.	70.000 kr.
Cykler	2000	6000 - 7000
Vægt	250 kg	115 kg
Virkningsgrad	75 %	90 %
Levetid	3 år	15 år
Brugbar kapacitet	50 %	90 %
Dvs. brugbar kapacitet i kWh	5 kWh	9 kWh
Solcellecykler pr. år	200	200
Antal kWh ialt	200x 3 x 0,75 x 5 kWh= 2250 kWh	200 x 15 år x 0,9 x 9 kWh = 24.300 kWh
Pris pr. kWh	4,44 kr./ kWh	2,88 kr kr./ kWh

Batteri-valg

- Og herudover har Lithium batteriet følgende fordele:
- Store optimeringsmuligheder
- Fylder og vejer mindre
- Ingen udvikling af farlige gasser

Konklusion på forundersøgelse

- Batterier er endnu for dyre, men er interessante i forhold samspil med elnettet. Alt efter kilde kan man finde pessimistiske eller optimistiske udsagn om potentialet for decentrale batterilagre
- De batteripakker som allerede er på markedet, kan hæve egetforbruget fra et typisk solcelleanlæg mærkbart, og flere kan desuden styre forbrugssiden
- Varmelagring kan etableres og drives langt billigere, men værdien af lagret overskudsstrøm skal her sammenlignes med produktionsprisen for varme.
- De to lagersystemer kan ikke sammenlignes direkte, p.g.a. deres forskelligartede natur, men er begge interessante i forhold til energisystemets fremtidige krav og behov.

Solcelleanlæg kombineret med batterilager samt varmepumpe

Et PSO-projekt støttet af Elforsk

Deltagere: Teknologisk Institut, Lithium Balance
Ivan Katic, Energi & Klima ik@teknologisk.dk

Hvorfor energilagring?

- Forbruget følger sjældent produktionen
- Nye afregningsformer (time eller øjebliks-)
- Nye tekniske muligheder med hybrid invertere
- "Gratis" energilagring i bygningsmasse og varmt vand

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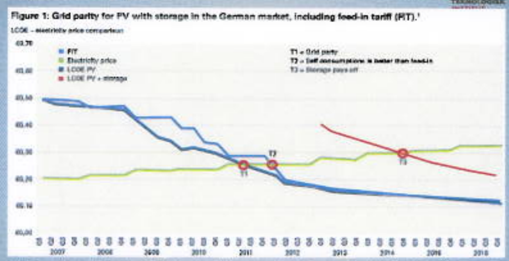
Batterilager?



- Stigende udbud af batteripakker med Li-Ion eller blybatterier

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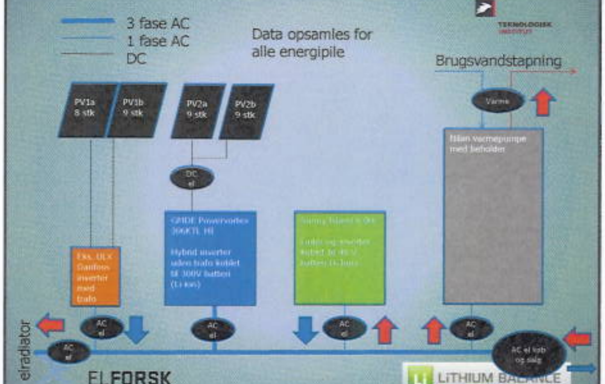

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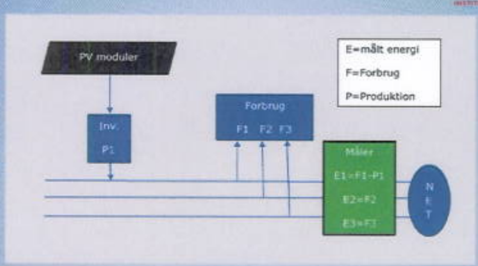
Egetforbrug of afregning



Gruppe 2: Nettoberegning hver time for alle faser Enetto = E1+E2+E3
Gruppe 4: Øjebliksværdier summeres som EForbrug= E1(pos) + E2 + E3 ; ESalg = E1(neg)

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SMA inverter med batterilager

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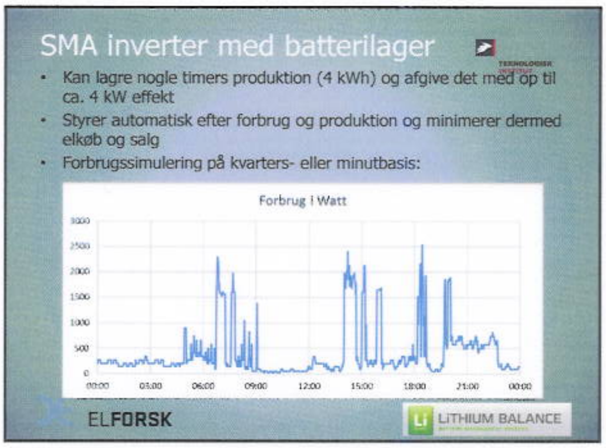
Batterilagerets opbygning
Batterikasse med LFP celler og samlet 48 V 100 Ah kapacitet. I praksis udnyttes 80% af kapaciteten, svarende til cirka 4 kWh.
ELFORSK
LITHIUM BALANCE


SMA inverter med batterilager
• Kan lagre nogle timers produktion (4 kWh) og afgive det med op til ca. 4 kW effekt
• Styrer automatisk efter forbrug og produktion og minimerer dermed elkøb og salg
• Forbrugssimulering på kvarters- eller minutbasis:
Forbrug i Watt
3000
2500
2000
1500
1000
500
0
00:00 03:00 06:00 09:00 12:00 15:00 18:00 21:00 00:00
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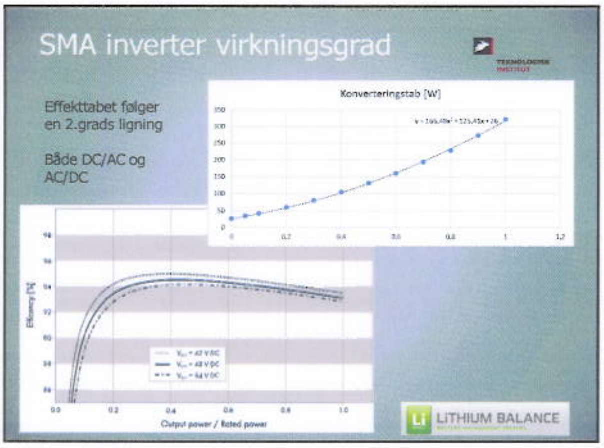
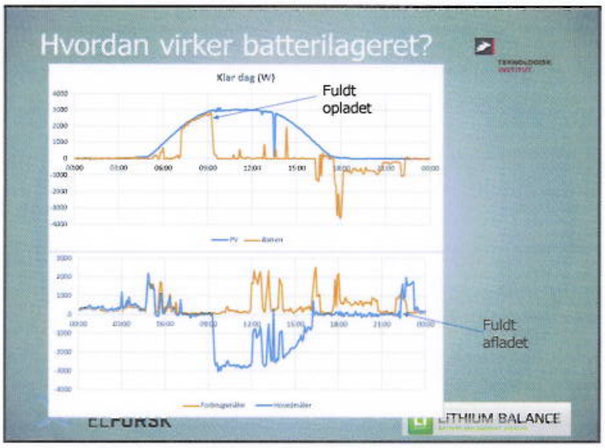
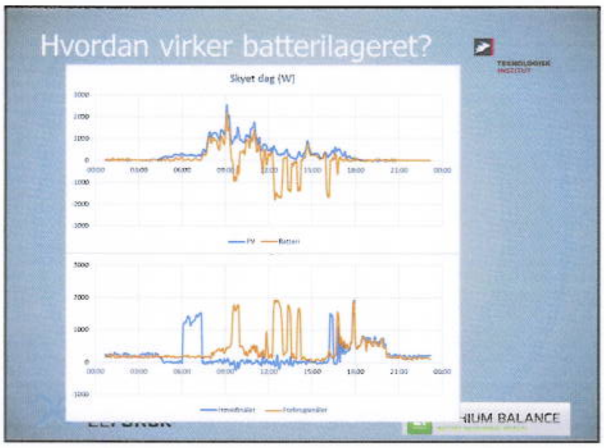
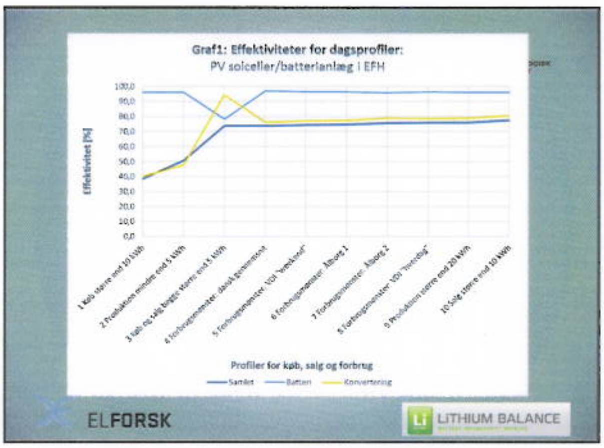
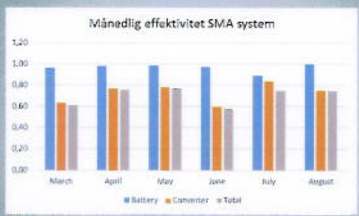

SMA inverter virkningsgrad
Effekttabet følger en 2.grads ligning
Både DC/AC og AC/DC
Konverteringstab [W]
Output power / Rated power
Efficiency [%]
LITHIUM BALANCE


Hvordan virker batterilageret?
Klar dag (W)
Fuldt opladet
Fuldt afladet
LITHIUM BALANCE


Hvordan virker batterilageret?
Skyet dag (W)


Graf1: Effektiviteter for dagsprofiler:
PV solceller/batterianlæg i EFH
Effektivitet [%]
Profiler for køb, salg og forbrug
Samlet
Batteri
Konvertering
ELFORSK
LITHIUM BALANCE

SMA systemeffektivitet



Gennemsnitlig effektivitet pr måned. Måneder med meget lave effektiviteter skal tages med forbehold p.g.a. driftsproblemer.
Tab i Danfoss inverter er ikke med, denne taber cirka 7% oveni

ELFORSK — LITHIUM BALANCE

Få timer med høj belastning

Målingen viste at omkring 30% af tabet finder sted når inverteren er ubelastet! (Stand by og sleep mode). Der er kun få timer hvor den kører med fuld effekt, det vil sige man kan roligt underdimensionere inverteren i forhold til solcelleanlæggets nominelle effekt samt det maksimale forbrug.

ELFORSK — LITHIUM BALANCE

Afslutning

- Forsøget fik en brat ende da batteriet en dag slog helt fra
- Dette skyldes sikkerhedssystemet som skal forhindre at man lader op på et batteri der har været helt afladet
- Afladningen skete i en periode uden tilsyn, hvor ladefunktionen var blevet deaktiveret og BMS systemet derefter langsomt drænede batteriet

ELFORSK — LITHIUM BALANCE

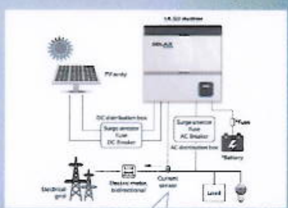
Delkonklusion SMA system

- SMA inverter og styring er velfungerende, men der er betydelige energitab forbundet med konvertering fra AC til DC og tilbage igen, især er de relative tab store ved lav belastning. Tomgangstabet har stor betydning for systemvirkningsgraden hvis forbruget er lavt i lange perioder
- Selve batteripakken har en høj cyklus effektivitet både ved stor og lille belastning
- Omkring 75% systemeffektivitet i gennemsnit i måleperioden
- Der mangler en sikkerhedsfunktion som kan redde batteriet i tilfælde af manglende opladning, for eksempel en akustisk alarm samt frakobling af alle forbrugende kredse.
- Inverteren gav en ubehagelig lyd ved opstart, hvilket vil være generende i et beboet hus

ELFORSK — LITHIUM BALANCE

Forsøgsserie med DC koblet batteri

- Formål: at se om effektivitet og virkemåde er anderledes i forhold til batterisystem #1
- Skulle have været udført med 500V batteri, men blev i stedet 50V



ELFORSK — LITHIUM BALANCE

GMDE inverter

- Trods mange forsøg leverede fabrikanten aldrig en fungerende firmware.
- Denne løsning måtte derfor opgives.
- Det leverede batteri viste desuden tegn på afgasning og blev derfor returneret.

ELFORSK — LITHIUM BALANCE

Solax inverter

- En del problemer med kommunikation med BMS
- En nødløsning blev til sidst etableret
- Andre problemer dukkede op...

LITHIUM BALANCE

Solax inverter

- Bemærk:
- Kun op/afladning med 1,3 kW

9.2 Technical Data

Model	SK-BM1300
Battery	
Battery voltage (V)	48
Battery voltage range (V)	40-58
Battery type	Lead acid battery/lithium battery
Battery capacity	100-120Ah optimized(support external expansion)
Battery charger	
Rated power (W)	1300
Max charge current (A)	25
Charge efficiency (%)	94
Charging curve	3-stage adaptive with maintenance
Battery discharger	
Rated output power (W)	1300
Max discharge current (A)	25
Discharge efficiency (%)	94
Discharge depth (%)	80% default
Battery voltage sense	Yes
Current shunt	Yes
General data	
Dimension (W/H/D)(mm)	253.7x514x168
Dimension of packing (W/H/D)(mm)	380x720x270
Weight (kg)	11.5
Gross weight (kg)	12.5
Cooling concept	Forced airflow
Noise emission	<40 dB
Operating temperature range (℃)	-20~+50 (derating at 40)
Store temperature (℃)	-20~+60
Altitude (m)	<2000
Degree of protection	IP20 (for indoor use)

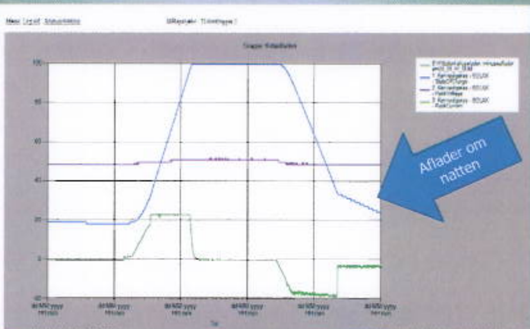
ELFORSK

Solax inverter

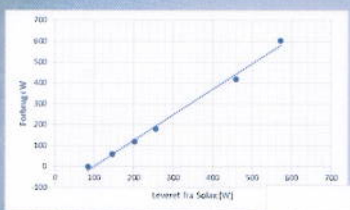
- Vi måtte opgive at bruge den elektroniske belastning da den snyder strømsensoren
- I stedet blev etableret simpel urstyring med et par halogenlamper

ELFORSK LITHIUM BALANCE

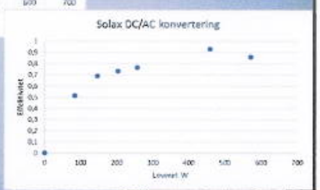
Solax Inverter



Solax inverter



Solax oplyser at det ikke er en fejl – den fungerer bare sådan at mindsteforbruget er 100W, ellers må man slukke manuelt(!)



Forsøg med ren ohmsk belastning

ELFORSK

Solax inverter

Delkonklusion for system 2:

- Det var overordentlig svært at finde en inverter i den rette størrelse og som var egnet til at køre med et eksternt Litium-Ion batteri
- Der var mange tekniske vanskeligheder og inverteren viste sig at fungere anderledes end ønsket.
- Det er for usikkert at basere systemets regulering på en simpel enfaset strømsensor, en rigtig trefaset energimåler (True RMS) er at foretrække
- Der var kraftig blæserstøj fra inverteren, som derfor ikke kan anbefales opsat i beboelsesrum.
- Den samlede virkningsgrad er endnu ikke bestemt med sikkerhed, men er ikke imponerende. Dog spares der 7% tab fra netinverter.

ELFORSK LITHIUM BALANCE

Økonomieksempler fra danske PV leverandører

System	Forskel med/uden lagring Kr	Pris i Kr pr kWh effektivt lager	Info
A	52645	8226	4,2 kWp. Med montage. Tesla Powerwall 6,4(7) kWh Li
B	27645	5759	4,2 kWp med montage. 4,8(9,6) kWh blybatteri
C	62700	9797	6,12 kWp uden montage. Tesla Powerwall 6,4(7) kWh
D	22800	4750	4,5 kWp uden montage. 4,8(9,6) kWh blybatteri

Med priser fra 5000 kr/ kWh vil der således være krav om at tjene mindst 500 kr/år pr kWh hvis man regner med 10 års tilladelig tilbagebetalingstid. (som antaget i beregningsværktøj)

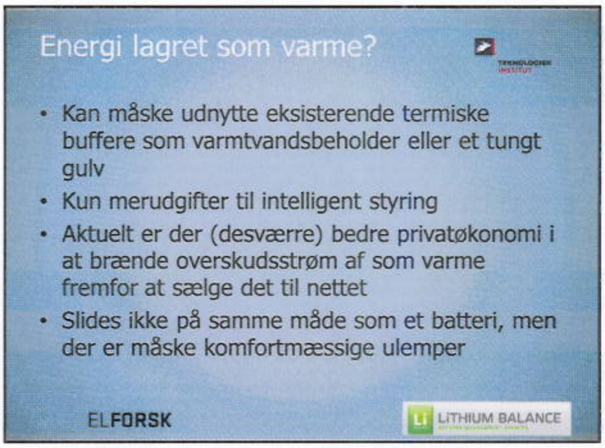
ELFORSK LITHIUM BALANCE

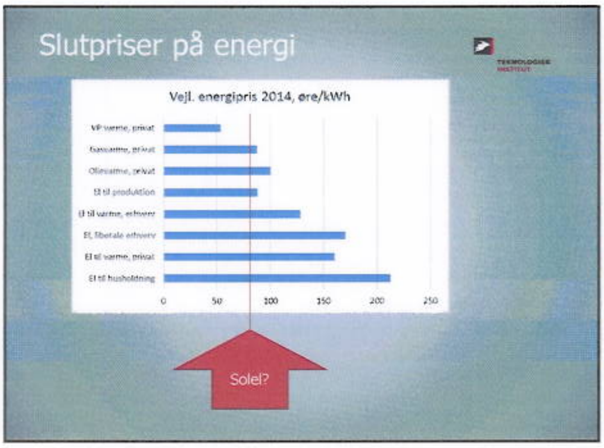
Er det en god idé?

- P.t. i bedste fald økonomisk ved afregningspriser under cirka 1 kr
- Ikke uden risiko at samle kemisk energi i et "kosteskab"
- Ved store anlæg skal man have et særligt batterirum
- Fase- og måleproblematik er ikke tilstrækkelig belyst
- Meget dynamisk marked, prisfald i vente

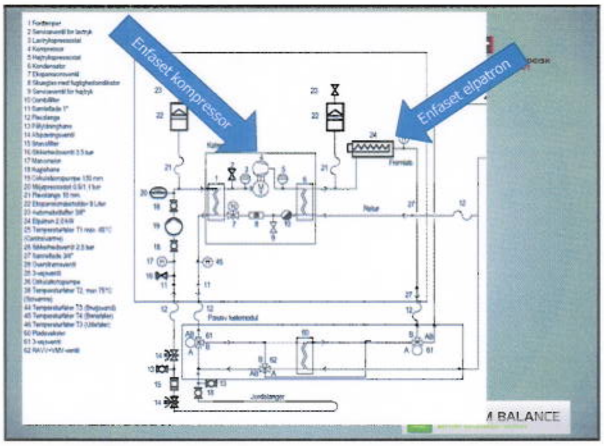
ELFORSK LITHIUM BALANCE

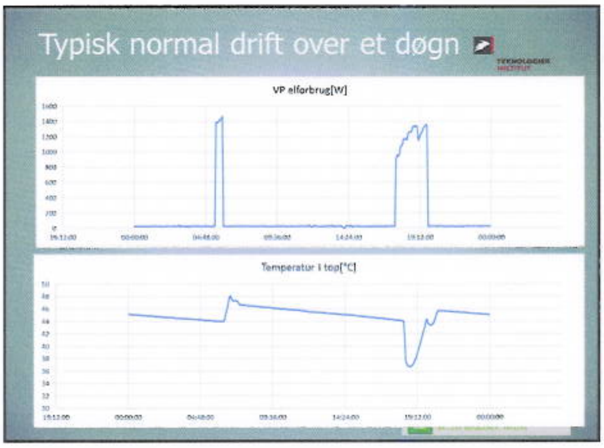

Solcelleanlæg kombineret med batterilager samt varmepumpe
Et PSO-projekt støttet af Elforsk
Deltagere: Teknologisk Institut, Lithium Balance
Ivan Katic, Energi & Klima ik@teknologisk.dk


Energi lagret som varme?
• Kan måske udnytte eksisterende termiske buffere som varmtvandsbeholder eller et tungt gulv
• Kun merudgifter til intelligent styring
• Aktuelt er der (desværre) bedre privatøkonomi i at brænde overskudsstrøm af som varme fremfor at sælge det til nettet
• Slides ikke på samme måde som et batteri, men der er måske komfortmæssige ulemper
ELFORSK
LITHIUM BALANCE

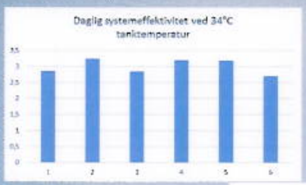

Slutpriser på energi
Vejl. energipris 2014, øre/kWh
VP varme, privat
Gasvarme, privat
Oliefyr, privat
El til produktion
El til varme, erhverv
El, liberale erhverv
El til varme, privat
El til husholdning
0
50
100
150
200
250
Sol?


Nilan varmepumpe
NILAN
GEO 6
SN: 120910–02999
Varmepumpen er en del af den oprindelige installation og ikke anskaffet specielt til projektet
Varmepumpen er optimeret for lavtemperatur gulvvarme
ELFORSK
LITHIUM BALANCE


Enfaset kompressor
Enfaset elpatron


Typisk normal drift over et døgn
VP elforbrug[W]
Temperatur i top[°C]

Målt system COP



Forsøg med standard tappeprogram (ingen rumvarme)

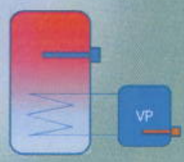
Ved høj temperatur bruger varmepumpen kun elpatron (ekstern eller intern)

ELFORSK

Hvordan virker varmelageret?

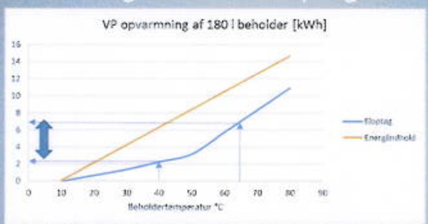
- E = M x Cp x dT. Cirka 5 kWh varme for en 180 l beholder ved dT=25K
- I princippet en simpel overstyring af termostaten, men der er grænser for hvor store udsving der er mulige af hensyn til komfort.
- Ved temperaturer over ca 50°C kunne vores varmepumpe ikke følge med, men slog over på ren elvarme!

Tanktemperatur	Målt systemeffektivitet
34	2,99
44	2,35
50	2,31
54	0,81



ELFORSK — LITHIUM BALANCE

Hvor meget el bliver optaget?

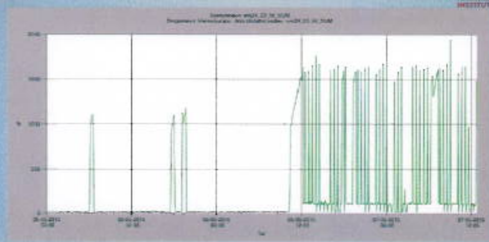


C = 4,186 kJ/kgK * 180 kg = 753 kJ/K = 0,21 kWh/K

Med en COP på 2,5 bruges 0,21/2,5 = 0,084 kWh/K el i den første del af opvarmningsforløbet. Hvis de første 40 graders temperaturstigning fra kold tank sker med VP og de sidste 30 med elpatron er forbruget E_{abs} =40 * 0,084 + 30 * 0,21 = 9,7 kWh.

ELFORSK — LITHIUM BALANCE

Driftsmønsteret afslører

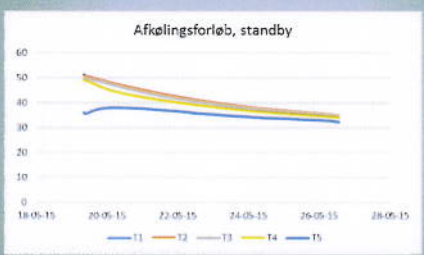


I praksis er det ikke muligt at lade kompressoren tage al den overskydende effekt fra solcelleanlægget, både på grund af den begrænsede størrelse og fordi den ikke vilkårligt kan køre op og ned i effekt. En løsning kunne være at kombinere varmepumpen med et lille batterilager som kunne tage spidserne.

ELFORSK — LITHIUM BALANCE

Varmetab

- Taber energien hurtigere end et batteri.
- Varmetabskoefficient ca. 0,9 W/K (udmærket værdi)



ELFORSK — LITHIUM BALANCE

Lagringseffektivitet

Hvis man bruger en varmepumpe med beholder som afløb for overskudsel, skal man tage hensyn til det øgede varmetab såvel som den forringede COP når varmepumpen skal varme op til en højere temperatur end ellers.

Effektivitetstabet er beregnet til 23%. Man kan sige at 77% af energien hentes tilbage som varmt brugsvand. Der er set bort fra at noget kan nyttiggøres som rumvarme og der er ikke regnet med elpatrondrift.

Beregning ved 2000 kWh varmtvands-forbrug	Gns beholder-temperatur	Gns COP	Varmetab	Elforbrug total
Reference VP	45	2,5	197 kWh	879
Dynamisk VP	55	2,0	276 kWh	1138

ELFORSK — LITHIUM BALANCE

Konklusion vedrørende termisk energilagring:

TEKNOLOGISK INSTITUT

- Varmepumpen skal være egnet til formålet, d.v.s. den skal kunne tilpasse sig over et stort temperaturområde
- Der bør sidde en elpatron direkte i beholderen, som kan opvarme det sidste stykke, hvor varmepumpen ikke kan følge med. Her skal styringen kunne slukke helt for kompressoren, som ellers bare vil levere "varme til fuglene"
- Varmtvandsbeholderen skal have en fornuftig størrelse, f.eks. over 200 l samt en god isolering uden kuldebroer. Denne størrelse vil nogenlunde kunne optage et par timers overskudsel fra et typisk solcelleanlæg på 4-5 kW.
- Styringen skal kunne begrænse hvilke perioder der skal opvarmes i, for eksempel via et signal fra solcelleanlæggets inverter eller en timer. På den måde kan man sikre sig at beholderen er kold når solen begynder at skinne og der vil være overskud af el.

ELFORSK LITHIUM BALANCE

Nye produkter vi også kunne have prøvet!

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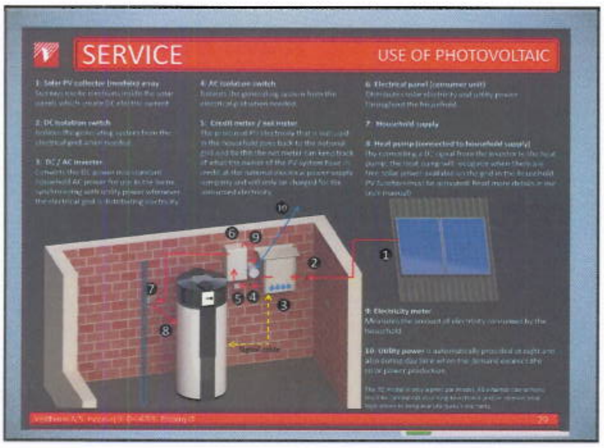
- Vesttherm brugsvandsvarmepumpe med PV funktion
- Elpatron med solcellestyring
- Akkumulerende elradiator

ELFORSK LITHIUM BALANCE



Projektindhold

- Hvordan kan elektricitet fra et solcelleanlæg udnyttes optimalt i et enfamiliehus?
  - I en fuldskala-forsøgsopstilling leverer et solcelleanlæg elektricitet til en typisk families
  - Forbrug direkte
  - og opvarmning af brugsvand – varmepumpe
  - til batterier
- Hvordan udformes og styres et sådant energi-system optimalt i et enfamiliehus?

LITHIUM BALANCE ELFORSK

LITHIUM BALANCE ELFORSK

Case 1. Tilbygning til eksisterende solcelleanlæg

LITHIUM BALANCE ELFORSK

LITHIUM BALANCE ELFORSK

Case 1. Tilbygning til eksisterende solcelleanlæg med inverter.

- Et eksisterende solcelleanlæg på ca. 3,5 kW med dertil hørende vekselretter (Danfoss) skal retrofittes, så det kan levere overskudsstrøm til hhv. batteri og varmepumpe til brugsvand.
- Der tilbygges en ensretter/lader/vekselretter (Sunny Island fra SMA), hvori el fra nettet omsættes til jævnspænding for lagring på 5 KWh lithium-ion-batteri, som opbygges af Lithium Balance. Herfra vekselrettes til levering af el til forbrug efter behov.
- Varmtvandsforbruget simuleres med et tappeprogram
- Elforbruget simuleret ved forbrug på radiatorer. Det styres af en gennemsnitlig "forbrugsprofil"

LITHIUM BALANCE ELFORSK

case 2. Til nyt solcelleanlæg uden inverter.

LITHIUM BALANCE ELFORSK

Case 2. Til nyt solcelleanlæg uden inverter.

Her leveres el fra solceller:

- Dels gennem (hybrid) inverter til vekselspænding til forbrug til husholdning eller varmepumpe
- Dels gennem hybrid-inverter (lader) direkte til lagring på batteri (forbliver på jævnspænding)
- Fra batteri gennem inverter til vekselspænding til forbrug

(Perspektiver:Kan evt. også lade fra nettet (ved billig strøm))

LITHIUM BALANCE ELFORSK

Skal andre kende til det?

Artikler i

- Ingeniøren
- Tekniq
- Jern-industri
- Råstof

Præsentationer

- IDA – energilagring til at lagre sol og vind
- Teknologisk Institut – Smart energilagring med vp og batterier
- Teknologisk Institut – Bygningsintegreret solenergi
- Intersolar..og mange flere

LITHIUM BALANCE ELFORSK

Velkommen

- Spørg – drøft - deltag

LITHIUM BALANCE ELFORSK

Konference

Avanceret energilagring 2015
- Smart energilagring med varmepumper og batterier

Praktiske oplysninger

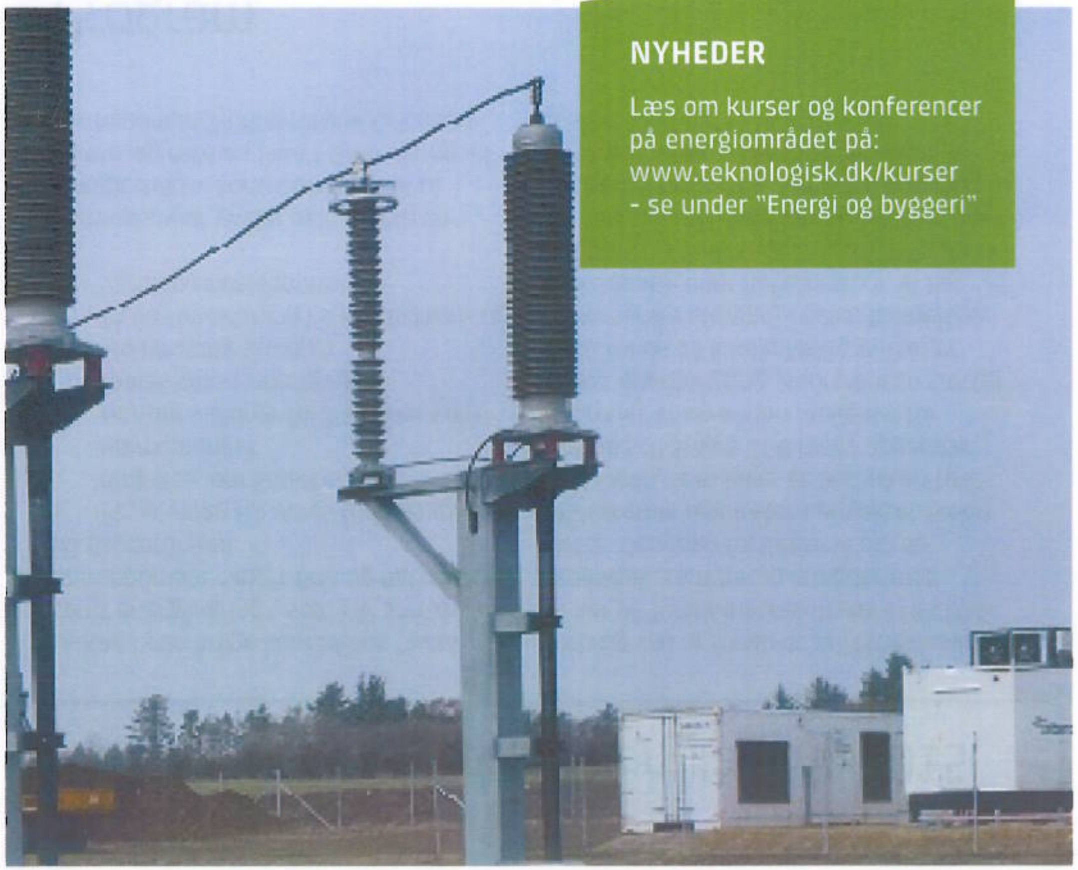
Tid og sted
1. december 2015
Kl. 09.30 - 16.30
Teknologisk Institut
Kongsvang Alle 29, Konferencesalen
8000 Aarhus C

Yderligere oplysninger
Lene Halgaard
tlf. 72 20 12 49
E-mail Isha@teknologisk.dk

NB! No Show gebyr kr. 300, -

NYHEDER

Læs om kurser og konferencer på energiområdet på:
www.teknologisk.dk/kurser
- se under "Energi og byggeri"



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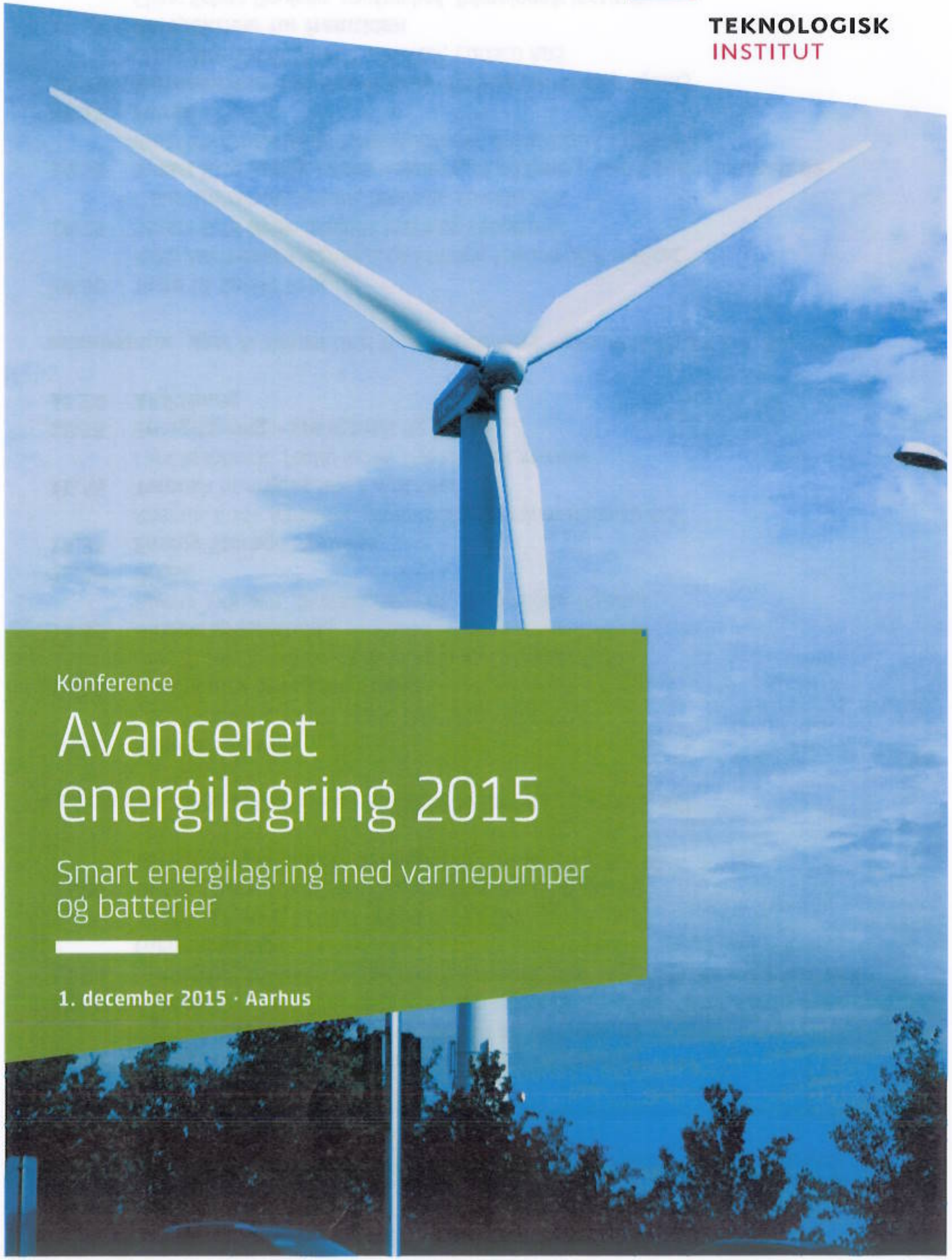


Energy Storage Systems

1st of December 2015

Illustration purpose only

Rasmus Rode Mosbæk
Project Manager| Energy Storage Systems
Mobile: +45 2365 2319
Mail: rasmus@lithiumbalance.com

LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

Lithium Balance A/S

History

BATTERY MANAGEMENT

of lithium batteries for use in

electric vehicles, machines & power storage

2006: Established

2008: DONG Energy Invests

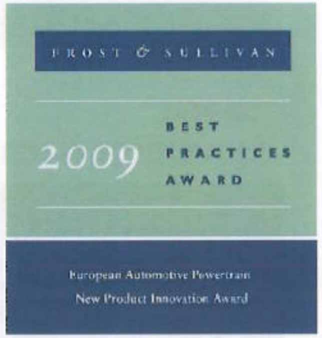
2009: Commercial launch

2011: 150 customer projects completed

2012: 1st OEM customer in production

2014: 300 projects completed

2015: ISO 9001



RED HERRING WINNER 100 EUROPE

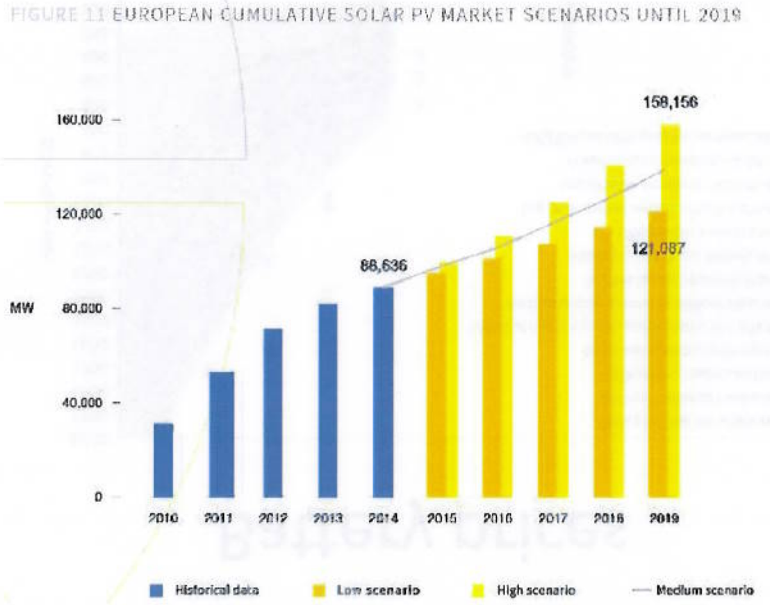
RED HERRING 100 FINALIST GLOBAL

Europe Unlimited – Award eurecan – TOP 25

Motivation for ESS for PV

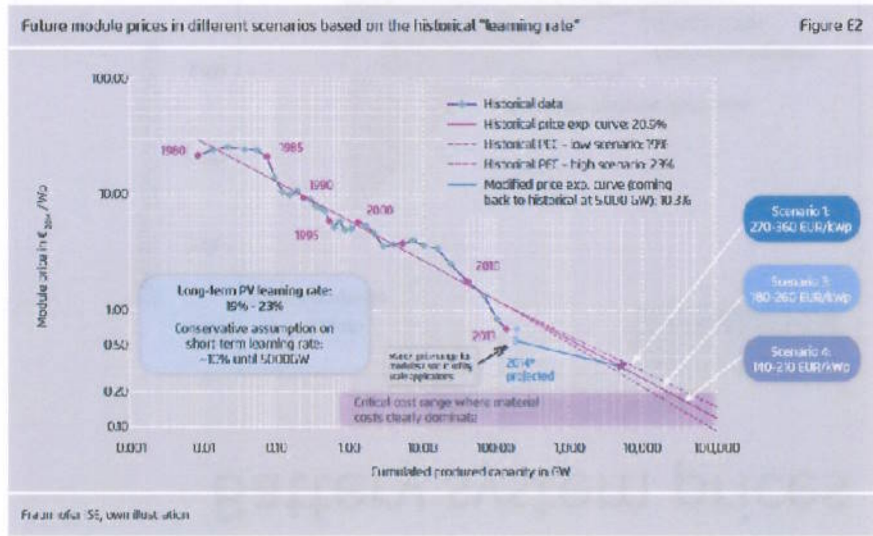
Market trends for PV

PV installations



Reference: Global Market Outlook for Solar Power 2015-2019, Solar Power Europe, 2015

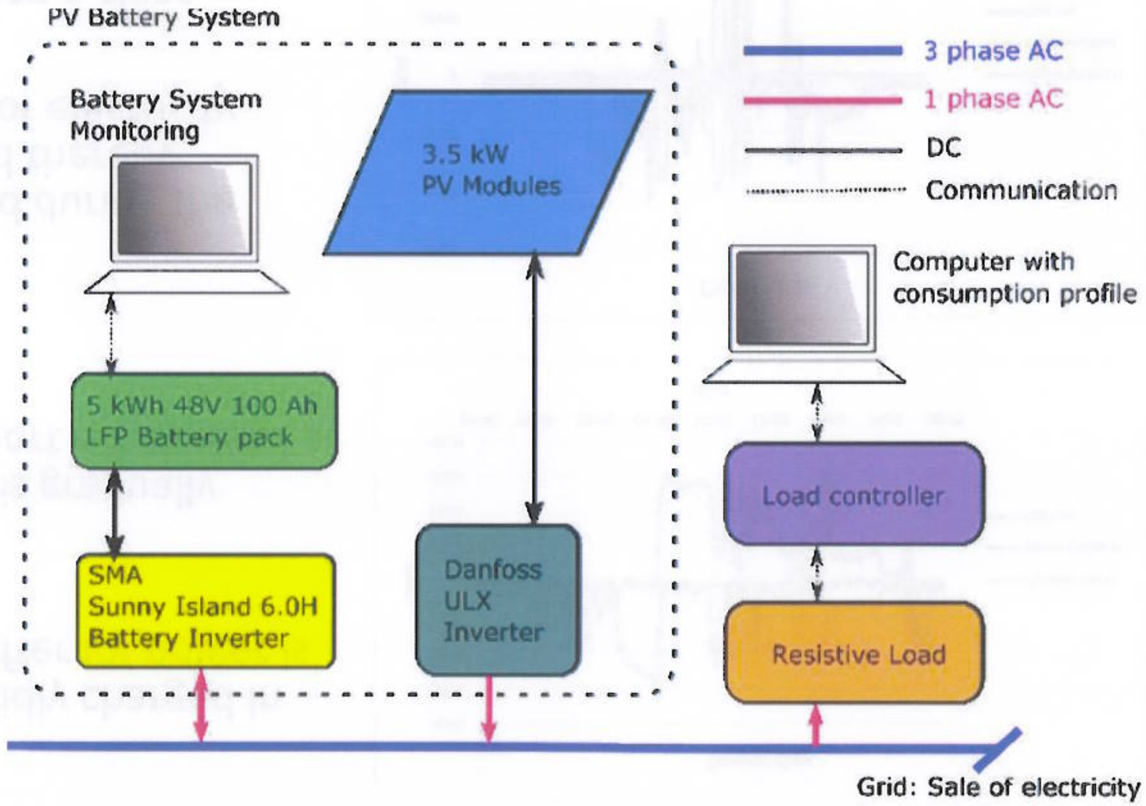
PV prices



Reference: Current and future cost of Photovoltaics, Agora Energiewende, Fraunhofer ISE, 2015

PV Battery Systems for homes

System overview



ELFORSK GRØN OMSTILLINGSFOND TEKNOLOGISK INSTITUT

LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

PV Battery Systems for homes

Economic calculations

- The calculations are done with Danish feed in tariff scheme together with the following assumptions:
  - **PV Panels:** 25 year life time
  - **Inverter:** 12 year life time
  - **Battery pack:** 12 year lifetime and 6500 cycles
  - **Electricity prices**
    - Expected a slowly increase in electricity price
    - A decrease in feed-in tariff

DANISH MINISTRY OF ENERGY, UTILITIES AND CLIMATE

- Calcalations are done for following systems with 5000 kWh/year
  - 6 kWp PV system without a battery system
  - 6 kWp PV system and 5 kWh battery system for 940 €/kWh
  - 6 kWp PV system and 5 kWh battery system for 535 €/kWh

Community Battery Energy Storage

The READY project

- 130 kWp PV energy from PVT
- 100-150 kWh battery pack
- Waste water heat pump
- Heat pump for the hot water from the PVT
- Low temperature district heating

- Smart grid integration with DONG energy's Power Hub

- The system will be designed for increased self-consumption

- Challenge: 1 energy meter pr. building

- www.smartcity-ready.eu

Boligforeningen Ringgården

READY

COWI

LiTHIUM BALANCE BATTERY MANAGEMENT SYSTEMS

AARHUS UNIVERSITY

DONG energy

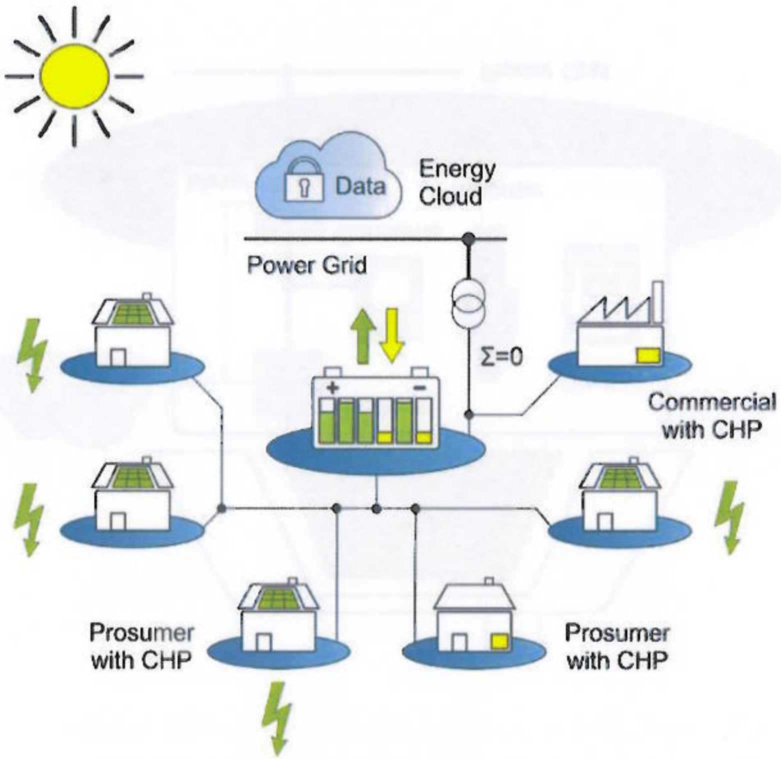
Danfoss

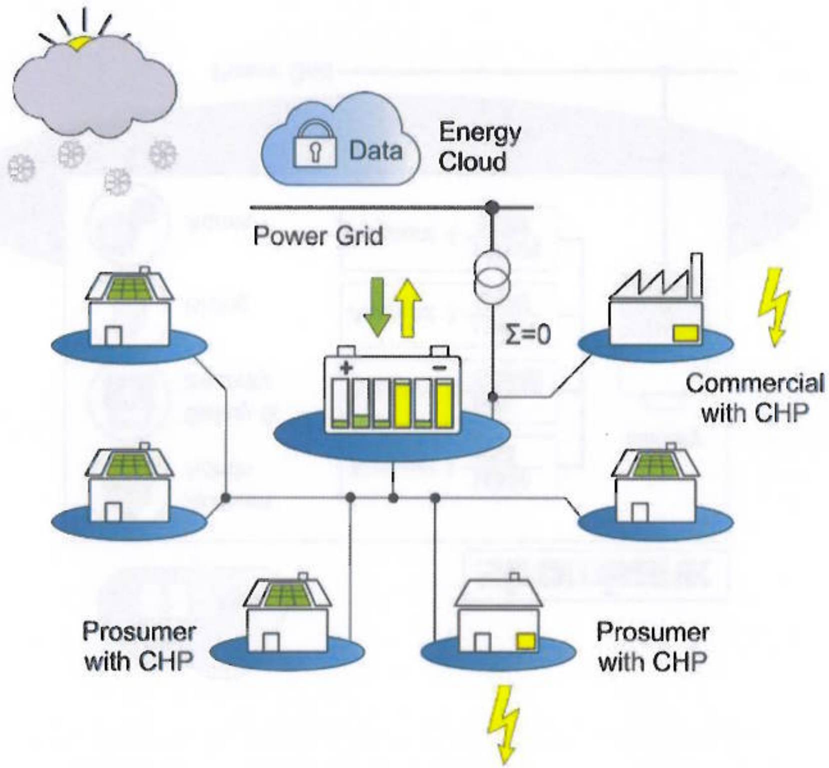
RA CELL

AFFALDVARME AARHUS Teknik og Miljø Aarhus Kommune

Community Battery Energy Storage

The Strombank project





Reference: Strombank – A Giro Account for Renewable Energy, Dr. Robert Thomann, MVV Energie AG, EES Europe Conference 2015

Battery Energy Storage Systems

Challenges

Energinet.dk: It is not allowed to supply power to the grid from a battery pack as it is considered per default as fossil power.

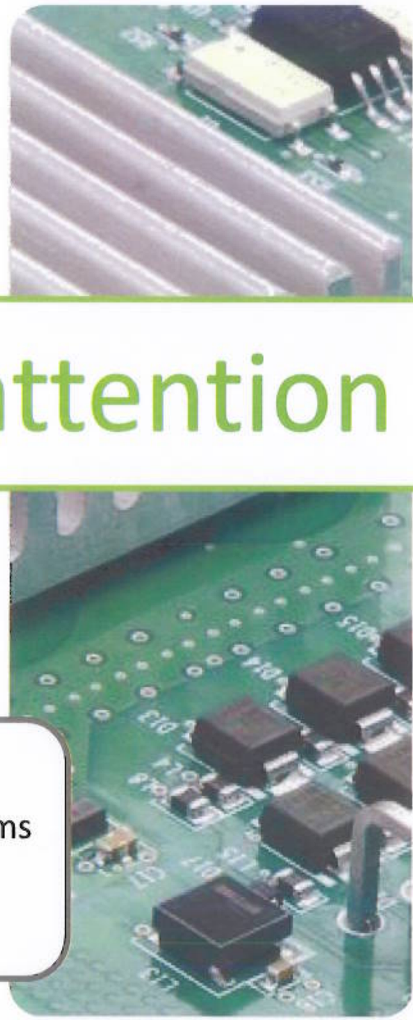
This limits Battery Energy Storage Systems installed in homes and communities to have smart interaction with the grid for providing:

- Grid support
- Voltage support
- Peak shaving
- Congestion management
- Lowering the load on grid transformers

It is not allowed to change the number of energy meters if a housing association has more than one energy meter.

We need to rethink the grid if Denmark wants to increase the share of renewables for having a fossil free energy sector in 2035.

Battery Energy Storage Systems will play a important role in a fossil free energy sector.



Thank you for your attention

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LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

Energy Storage Systems

1st of December 2015

Illustration purposes only

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Agenda

Lithium Balance A/S

History

BATTERY MANAGEMENT
of lithium batteries for use in
electric vehicles, machines & power storage

2006: Established
2008: DONG Energy Invests
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RED HERRING EUROPE WINNER 100
RED HERRING GLOBAL 100 FINALIST
eurocan TOP 25

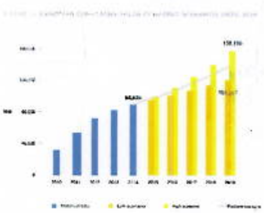
Lithium Balance A/S

Business areas

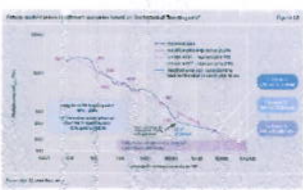
Motivation for ESS for PV

Market trends for PV

PV installations



PV prices



Reference: Global Market Outlook for Solar Power 2015-2019, Solar Power Europe, 2015

Reference: Current and future cost of Photovoltaics, Agora Energiewende, Fraunhofer ISE 2015

Motivation for ESS for PV

Market trends for batteries

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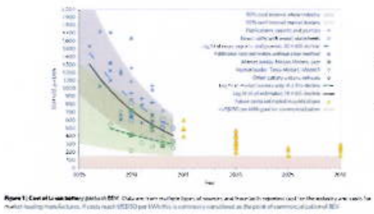
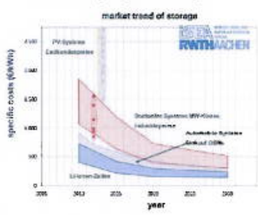


Battery system prices



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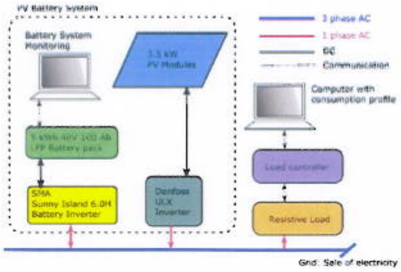
PV Battery Systems for homes

System overview



ELFORSK · GRØN OMSTILLINGSFOND · TEKNOLOGISK INSTITUT

LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

PV Battery Systems for homes

Power Flow

DANISH TECHNOLOGICAL INSTITUTE

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LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

PV Battery Systems for homes

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DANISH MINISTRY OF ENERGY, UTILITIES AND CLIMATE

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LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

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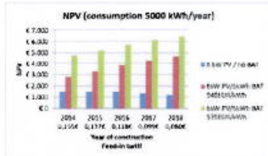
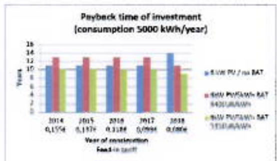
  - installation cost





LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

Community Battery Energy Storage

The READY project

- 130 kWp PV energy from PVT
- 100-150 kWh battery pack
- Waste water heat pump
- Heat pump for the hot water from the PVT
- Low temperature district heating
- Smart grid integration with DONG energy's Power Hub
- The system will be designed for increased self-consumption
- Challenge: 1 energy meter pr. building
- www.smartcity-ready.eu

Boligforeningen Ringgården · READY · COWI · LiTHIUM BALANCE · AARHUS UNIVERSITY · DONG energy · RA CELL · Danfoss

LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

Community Battery Energy Storage

The READY project

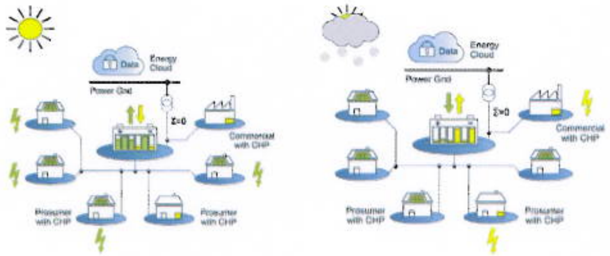
- 100-150 kWh battery pack
- A modular container sized battery pack will be developed in 2016
- Pilot demonstration unit in operation Q4 2016 in Copenhagen
- The battery pack for the READY project in Århus will be in full operation in 2018

Illustration purpose only

READY

LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

Community Battery Energy Storage
The Strombank project



Reference: Strombank – A Giro Account for Renewable Energy, Dr. Robert Thomann, MVV Energie AG, EES Europe Conference 2015

Community Battery Energy Storage
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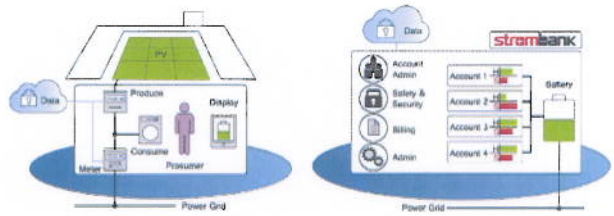

Lithium Balance A/S will be interested in a similar demonstration project in Denmark

Reference: Strombank – A Giro Account for Renewable Energy, Dr. Robert Thomann, MVV Energie AG, EES Europe Conference 2015

Battery Energy Storage Systems
Challenges

Energinet.dk: It is not allowed to supply power to the grid from a battery pack as it is considered per default as fossil power.

This limits Battery Energy Storage Systems installed in homes and communities to have smart interaction with the grid for providing:

- Grid support
- Voltage support
- Peak shaving
- Congestion management
- Lowering the load on grid transformers

It is not allowed to change the number of energy meters if a housing association has more than one energy meter.

We need to rethink the grid if Denmark wants to increase the share of renewables for having a fossil free energy sector in 2035.

Battery Energy Storage Systems will play a important role in a fossil free energy sector.

Conclusion

PV Battery Systems for homes

- A **PV battery System** was successfully **tested** in a full-size experimental platform called **EnergyFlexHouse** at Teknologisk Institut, Tåstrup.
- **Economy**
  - **NPVs are much better with a PV battery** than having a PV system without a battery pack.
  - Due to the added value of the battery packs the **payback times can be reduced** by up to 5 years compared to a PV system without battery pack
  - This could **increase motivation to invest** in PV systems with battery storage

Community Battery Energy Storage

- 100-150kWh battery pack will be demonstrated in **Århus** in 2018
- Pilot demonstration will be tested in **Copenhagen** in Q4 2016
- The **Strombank** project in Germany showed a new way of making community battery energy storage
- Improving the **legislation** for battery energy storage can increase the incentives for **housing associations**

Thank you for your attention

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PV Battery Systems and Safety

30th of November 2015 , teknologisk, Taastrup

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LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

Lithium Balance A/S

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Motivation for ESS for PV

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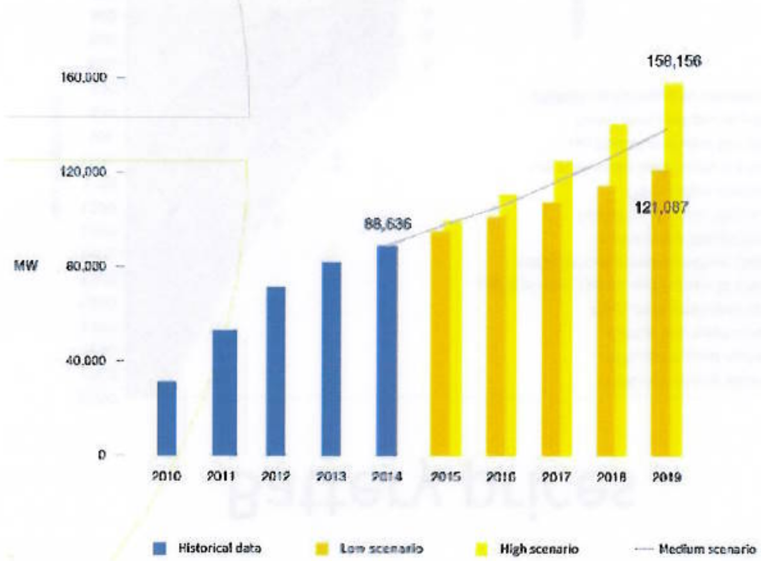
FIGURE 11 EUROPEAN CUMULATIVE SOLAR PV MARKET SCENARIOS UNTIL 2019



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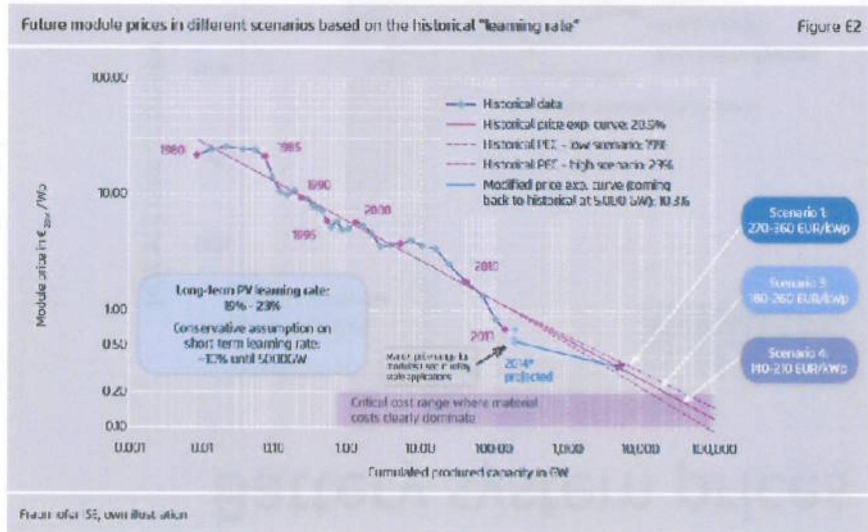
PV prices



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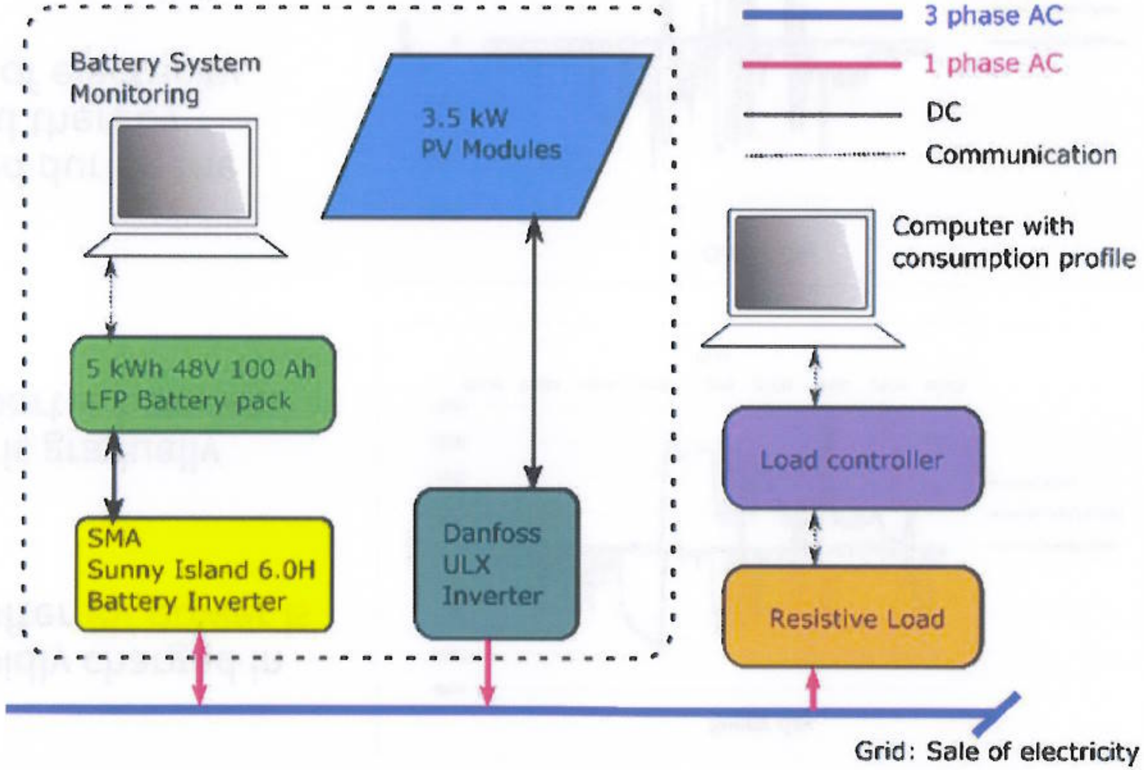
LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

PV Battery Systems for homes

System overview



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LITHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

PV Battery Systems for homes

Economic calculations

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DANISH MINISTRY OF ENERGY, UTILITIES AND CLIMATE

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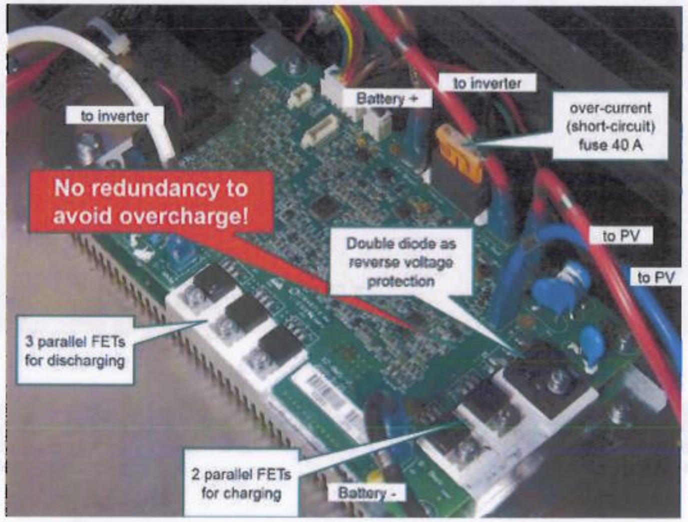
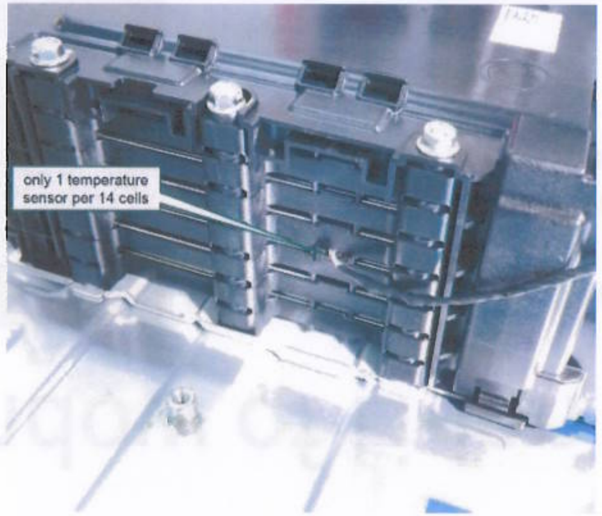
Safety

What not to do!

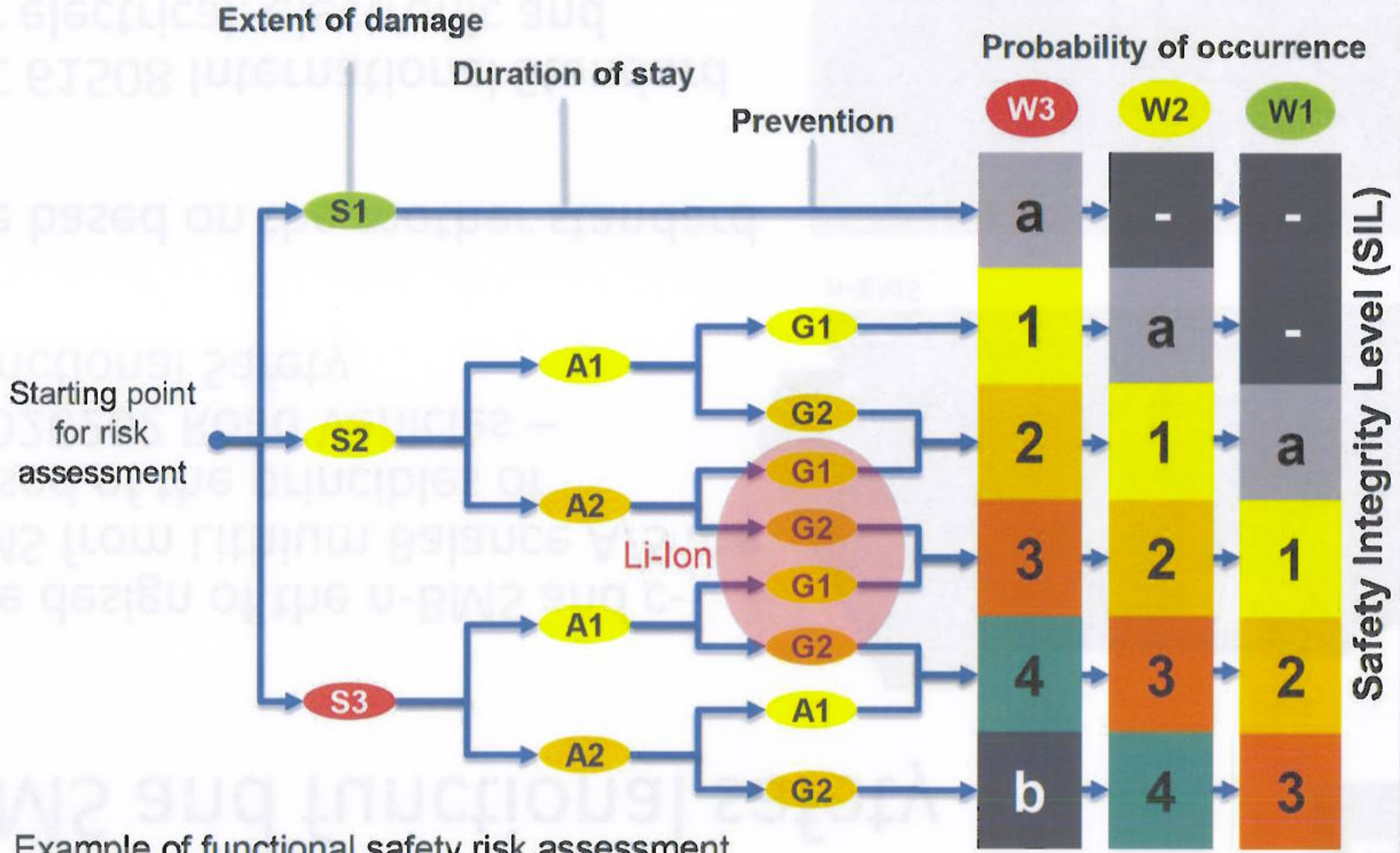




Reference: Safety Analysis according to IEC, Andreas Gutsch, Olaf Wollersheim, Thomas Timke, KIT Competence E, EES Conference, Munich 2015

Safety

Battery Safety according to IEC 61508



Example of functional safety risk assessment

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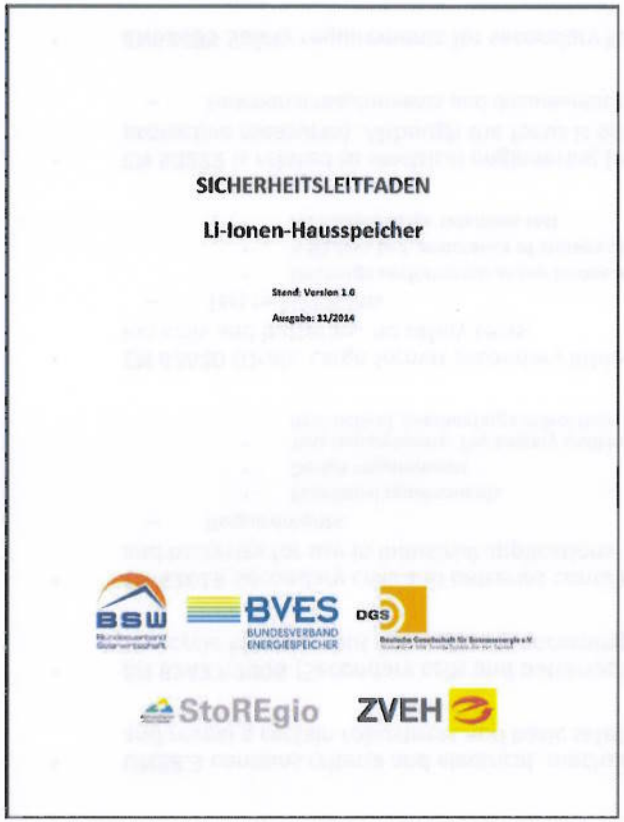
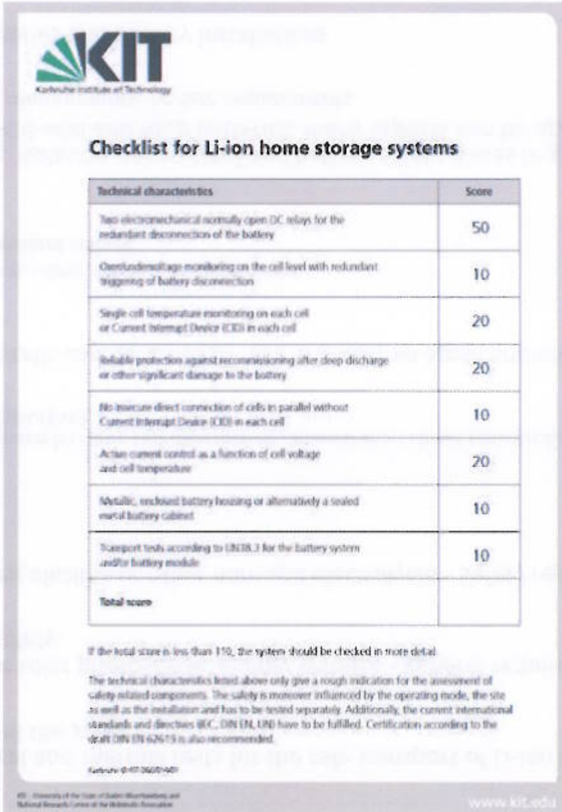
Safety

Recommendations for standards





KIT

Checklist for Li-ion home storage systems

Technical characteristics	Score
Two electromechanical normally open DC relays for the redundant disconnection of the battery	50
Over/undervoltage monitoring on the cell level with redundant triggering of battery disconnection	10
Single cell temperature monitoring on each cell or Current Interrupt Device (CID) in each cell	20
Reliable protection against recommissioning after deep discharge or other significant damage to the battery	20
No insecure direct connection of cells in parallel without Current Interrupt Device (CID) in each cell	10
Active current control as a function of cell voltage and cell temperature	20
Metallic, enclosed battery housing or alternatively a sealed metal battery cabinet	10
Transport tests according to UN38.3 for the battery system and/or battery module	10
Total score	

If the total score is less than 110, the system should be checked in more detail.

The technical characteristics listed above only give a rough indication for the assessment of safety related components. The safety is moreover influenced by the operating mode, the site as well as the installation and has to be tested separately. Additionally, the current international standards and directives (IEC, DIN EN, UN) have to be fulfilled. Certification according to the draft DIN EN 62619 is also recommended.

www.kit.edu

References:

http://www.competence-e.kit.edu/img/Sicherheitsleitfaden_Li-Ionen_Hausspeicher_11_2014.pdf

http://www.competence-e.kit.edu/downloads/Li-Ionen_Checkliste_EN.pdf

https://www.kit.edu/downloads/Datenblatt_Safety_First_EN_final.pdf

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LiTHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

PV Battery Systems and Safety

30th of November 2015

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Project Manager | Energy Storage Systems
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LITHIUM BALANCE
BATTERY MANAGEMENT SYSTEMS

Agenda

- Lithium Balance A/S
  - History
  - Business areas
- Motivation for ESS for PV
  - Market trends for PV
  - Market trends for batteries
- PV Battery Systems for Homes
  - System overview
  - Power flow
  - Economic calculations
- Safety
  - What not to do!
  - Typical operating window of Li-ion
  - Battery safety according to IEC 61508
  - BMS and functional safety
  - Recommendation for standards
  - Standards for PV Battery Systems

Lithium Balance A/S

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Lithium Balance A/S

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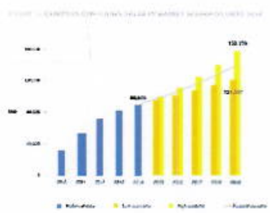
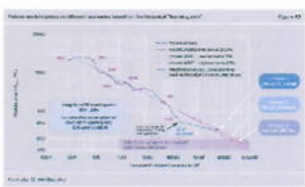
Market trends for PV

PV installations



PV prices



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Motivation for ESS for PV

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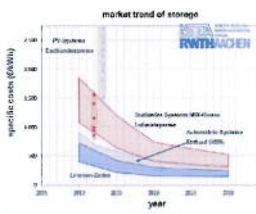
Battery prices

Battery system prices



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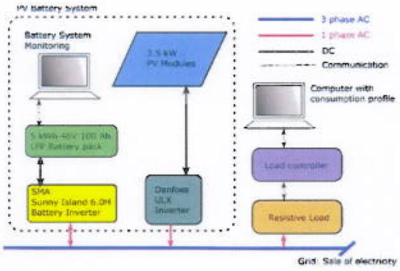
PV Battery Systems for homes
System overview



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PV Battery Systems for homes
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DANISH TECHNOLOGICAL INSTITUTE

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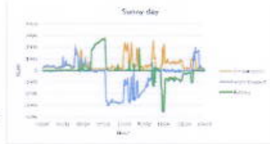

PV Battery Systems for homes
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DANISH MINISTRY OF ENERGY, UTILITIES AND CLIMATE

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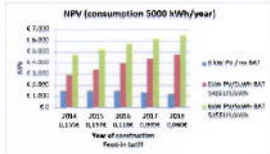
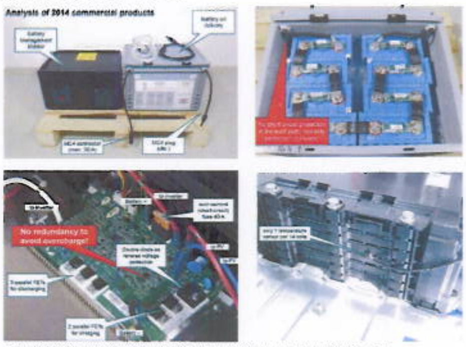
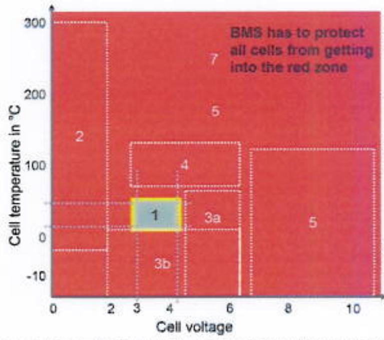


Safety
What not to do!



Safety
Typical operating window of Li-ion

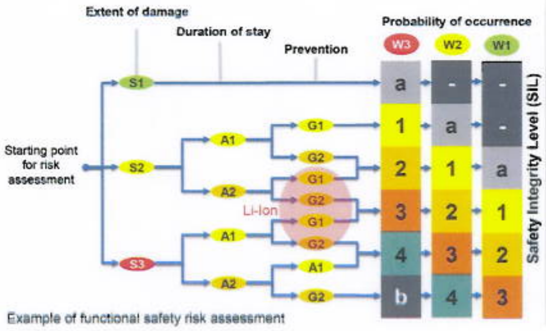


1. Safe operating window
2. Dissolution of anodes (Cu)
3. a) Li-Plating while overcharge
   b) Li-Plating while deep-discharge
4. Possible defect of SEI-layers, poss. slow thermal runaway
5. Outgassing, fire,...
6. Outgassing, fire,...
7. Thermal runaway, fire, release of oxygen from oxides,...

Outside the safe operating window, Li-ion cells change irreversibly and become insecure.

Safety

Battery Safety according to IEC 61508



Example of functional safety risk assessment

Reference: Safety Analysis according to IEC, Andreas Gutsch, Olaf Wollersheim, Thomas Tietze, KIT Competence E, EES Conference, Munich 2015

Safety

BMS and functional safety

The design of the n-BMS and c-BMS from Lithium Balance A/S are based on the princibles of ISO26262 Road Vehicles – Functional Safety

are based on the mother standard

IEC 61508 International Standard for electrical, electronic and programmable electronic safety related systems.

n-BMS

c-BMS

Safety

Recommendations for standards

References:

http://www.competence-e.kit.edu/img/Sicherheitsleitfaden_Li-Ionen_Hausspeicher_11_2014.pdf

http://www.competence-e.kit.edu/downloads/Li-Ionen_Checkliste_EN.pdf

https://www.kit.edu/downloads/Datenblatt_Safety_First_EN_final.pdf

Safety

Standards for PV Battery Systems

- **UN38.3** contains criteria and electrical, mechanical and thermal tests for the safe transport of Li-ion batteries. The tests are in part very sophisticated and reveal a certain robustness and basic safety of the system.
- **EN 62427:2006** (Secondary cells and batteries for solar photovoltaic energy systems - general requirements and methods of test) contains e.g. capacity and cycle life tests, but few aspects concerning safety.
- **EN 62619** Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for large format secondary lithium cells and batteries for use in industrial applications
  - Requirements:
    - Functional requirements
    - Design requirements
    - Test requirements: The battery shall be tested for: drop test (destructive), internal short circuit (destructive), overcharge control (non destructive), current control (non destructive), overheating control (non destructive)
- **EN 62620** (Draft, Large format secondary lithium cells and batteries for use in industrial applications) Performance tests and measuring methods for Li-ion cells and batteries, no safety tests.
  - Test requirements:
    - Discharge performance at low temperature, room temperature, high power
- **EN 50272** is related to electrical engineering (e.g. isolation, separation) and battery safety issues (e.g. transportation, installation site, charging, protective measures). Although the focus is on lead-acid and NiCd batteries, many aspects can be applied to Li-ion batteries.
  - Functional requirements and documentation requirements, no test requirements
- **EN62485** Safety requirements for secondary batteries and battery installations
- **EN 62897** Stationary Energy Storage Systems with Lithium Batteries - Safety Requirements