En eller annen flott tittel om solceller som Halvard lovet bort

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Senterdirektør – FME SUSOLTECH
Forskningssjef – IFE

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Research Center for Sustainable Solar Cell Technology

(«FME SUSOLTECHs»: 2017 – 2025 ~ 250 MNOK)

Glass og Fasadeforeningen
PVA TePla
UNIVERSITY OF AGDER
NTNU
Norwegian University of Science and Technology
REC
norwegiancrystals
SINTEF
OMSORGSBYGG OSLO KF
STEULER SOLAR ADVANCED CERAMICS
FUSen REN ENERGI TIL ALLE. ALLTID
NORGES BONDELAG
CODE ARKITEKTUR
equinor
NMBU Norges miljø- og biovitenskapelige universitet
THE QUARTZ CORP
IFE Institute for Energy Technology
NorSun
DYNATEC
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Agenda

- Hvordan funker en solcelle?
- Historikk – hva er egentlig nytt?
- Fremtiden
  - Spådommer
  - Teknologitrender

Hvordan funker en solcelle?

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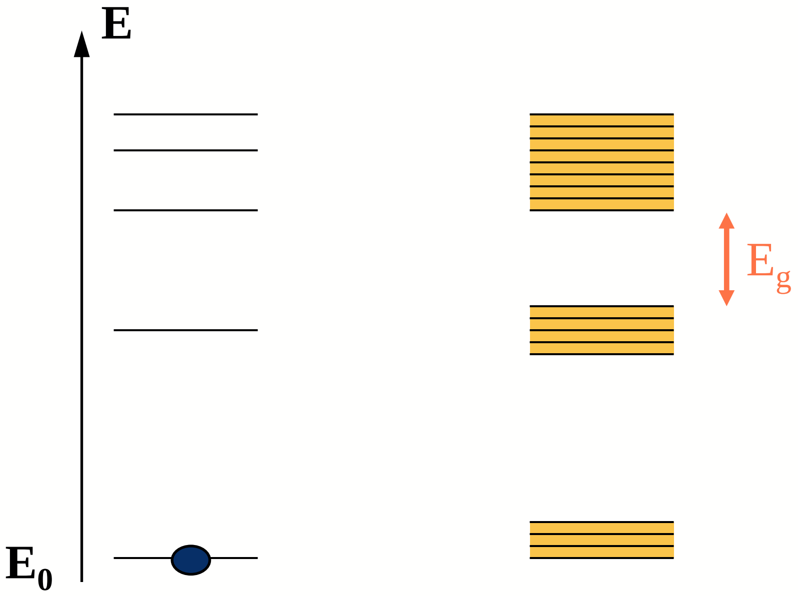
Solcellematerialer



Sollys

- Lys kan beskrives ved hjelp av partikler: **fotoner**.
- Fotonets energi er entydig bestemt av dets **bølgelengde**.

$$E_{phot} = hc/\lambda$$

  - E_{phot} er fotonenergien i eV
  - hc er 1.24 eV/µm
  - λ er bølgelengden i µm

- Desto mer energi, desto kortere bølgelengde.

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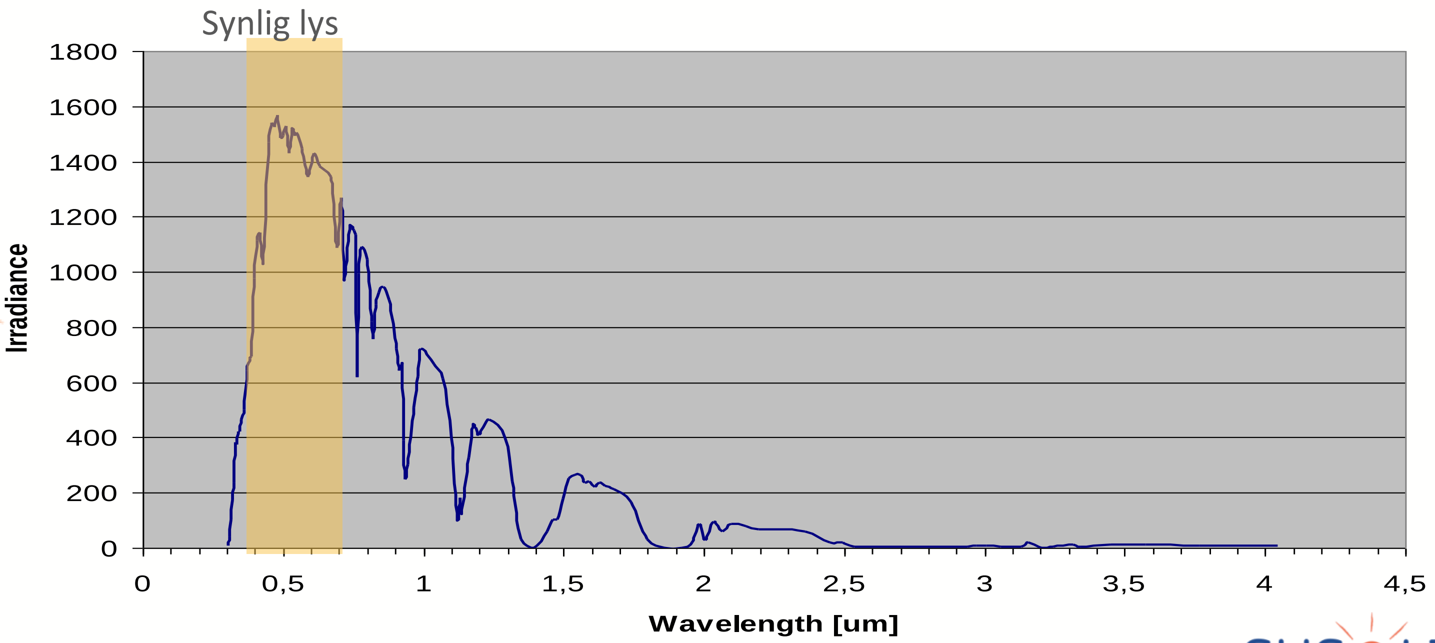
Min venn solen

Sollys



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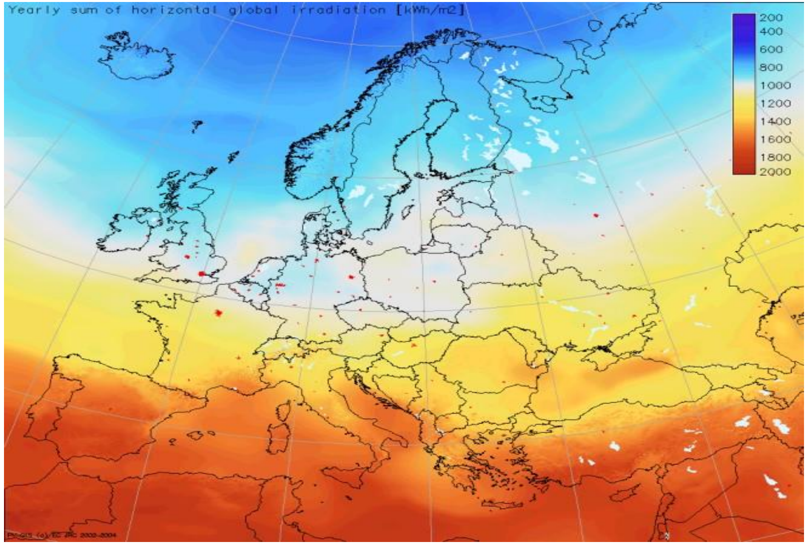
Solenergi

- Kartet viser årlig sum av solinnstråling på en horisontal flate.

- Relativt store, lokale variasjoner
  - Sahara: ~2 500 kWh/m²
  - Lillestrøm: ~ 900 kWh/m²



http://re.jrc.ec.europa.eu/pvgis/

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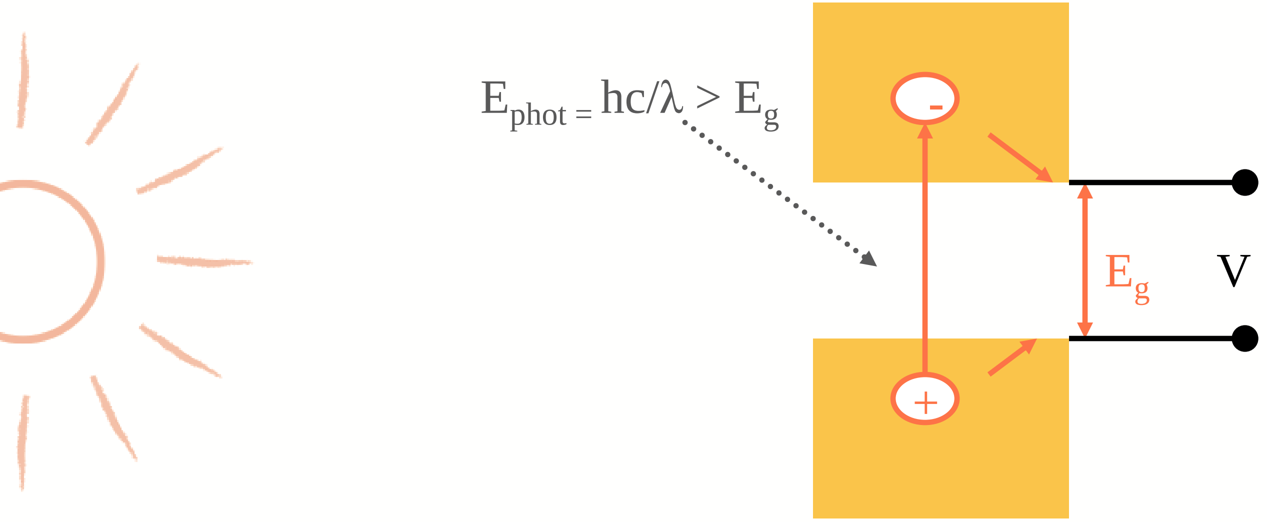
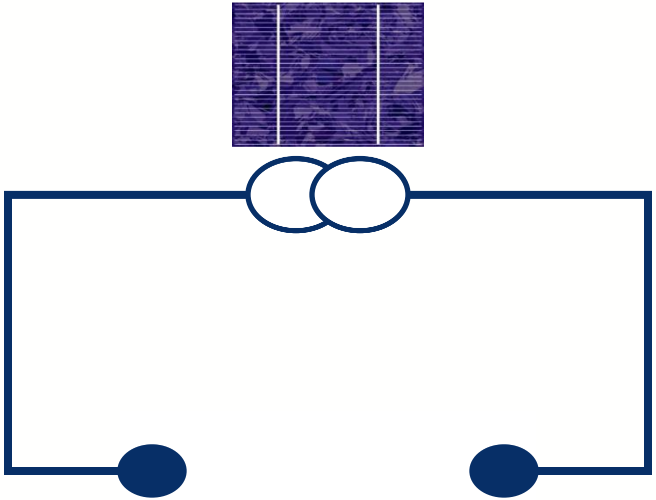
Fotovoltaisk (PhotoVoltaic = PV) energiomforming



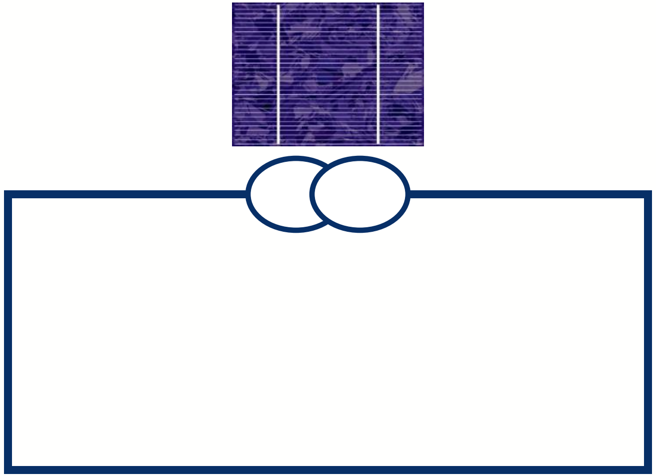
Viktige solcelleparametere

- Åpenkretsspenning V_{OC}
- Kortslutningsstrøm J_{SC}
- Virkningsgrad η

V_{OC}



I_{SC}



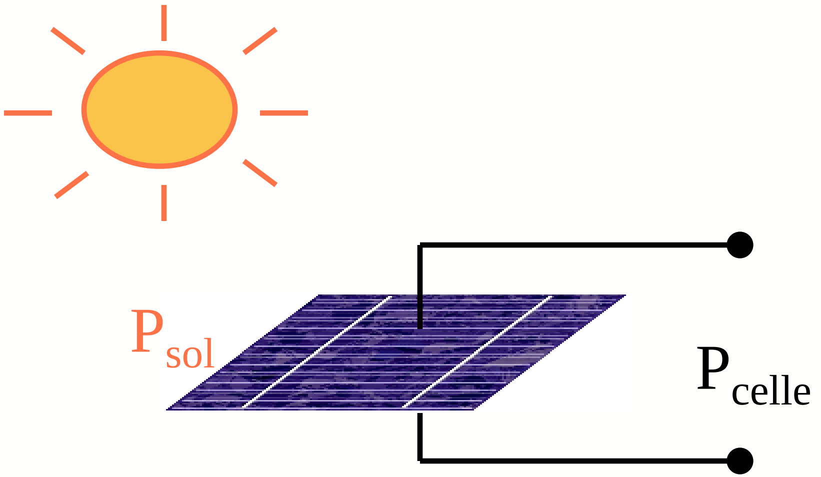
η

- Virkningsgraden (η) til en solcelle er forholdet mellom den effekten av den elektriske energien den leverer og effekten i (alt!) lyset som treffer den:

$$\eta = P_{celle} / P_{sol}$$

- P_{cell} er bestemt av

$$P_{celle} = I \cdot V$$



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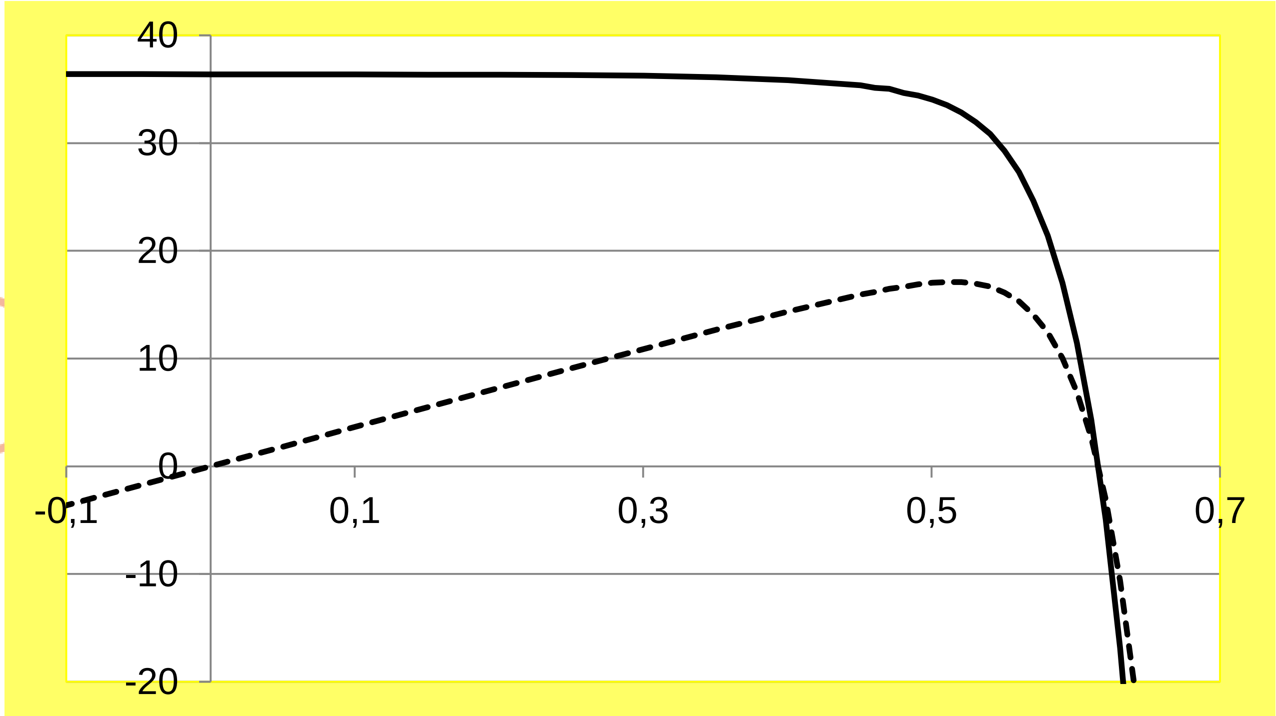
Typiske solcelleparametere



SETTINGS:

Cell Area:	156,25 cm^2
Temperature:	25 ^oC
Sun Intensity:	100 mW/cm^2

CELL PARAMETERS:

Efficiency:	17,1 %
Voc:	615 mV
Jsc:	36,4 mA/cm^2
FF:	76,4 %
V_{mp}:	511 mV
J_{mp}:	33,5 mA/cm^2
J_{01}:	$5{,}6 \cdot 10^{-10}$ mA/cm^2
J_{02}:	$1{,}3 \cdot 10^{-4}$ mA/cm^2
R_s	$2{,}5 \cdot 10^{-3}$ Ω
R_{sh}:	26,2 Ω

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So far so good…

Vi kan omdanne sollys direkte til elektrisk energi!

Woohoo?

So what?

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Historikk – hva er egentlig nytt?

Solcellehistorie (gammalt ræl)

Year	Event
1839	Photovoltaic effect in electrolyte (Becquerel, F)

Image: Wikipedia

Solcellehistorie (gammalt ræl)

Year	Event
1839	Photovoltaic effect in electrolyte (Becquerel, F)
1873	Photovoltaic effect in solid state - Se (Smith, UK)

Smith, Willoughby
Nature **7**, 303 (20 February 1873) | doi:10.1038/007303e0
Effect of Light on Selenium During the Passage of An Electric Current
BEING desirous of obtaining a more suitable high resistance for use at the Shore Station in connection with my system of testing and signalling during the submersion of long submarine cables, I was induced to experiment with, bars of selenium, a known metal of very high resistance...

Image: Wikipedia

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Solcellehistorie (gammalt ræl)

Year	Event
1839	Photovoltaic effect in electrolyte (Becquerel, F)
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1883	Large area solar cell – thin film Se (Fritts, USA)

The current, if not wanted immediately, can be either stored where produced, in storage batteries, . . . or transmitted a distance and there used"

Fritts 1883

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Image: Wikipedia

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1954	6% Si solar cell (Chapin/Bell Lab, USA)

Bell System Solar Battery Converts Sun's Rays into Electricity!

Bell Telephone Laboratories invention has great possibilities for telephone service and for all mankind

Images: Wikipedia

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1954	6% Cu_2S/CdS solar cell (Reynolds/US Air Force, USA)
1956	6% GaAs solar cell (Jenny/RCA Lab, USA)
1958	Vanguard I – first solar powered satelite

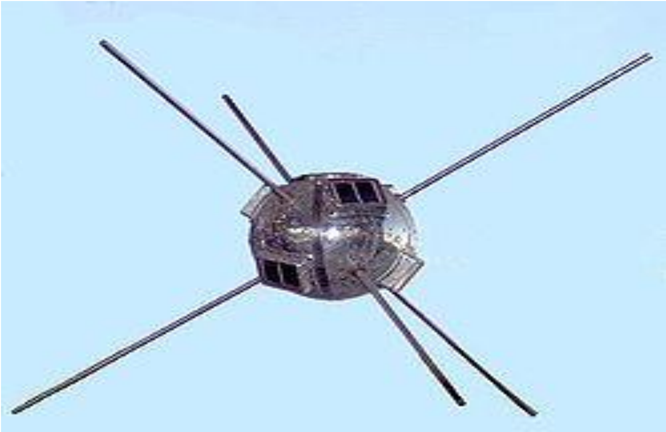

Image: Wikipedia

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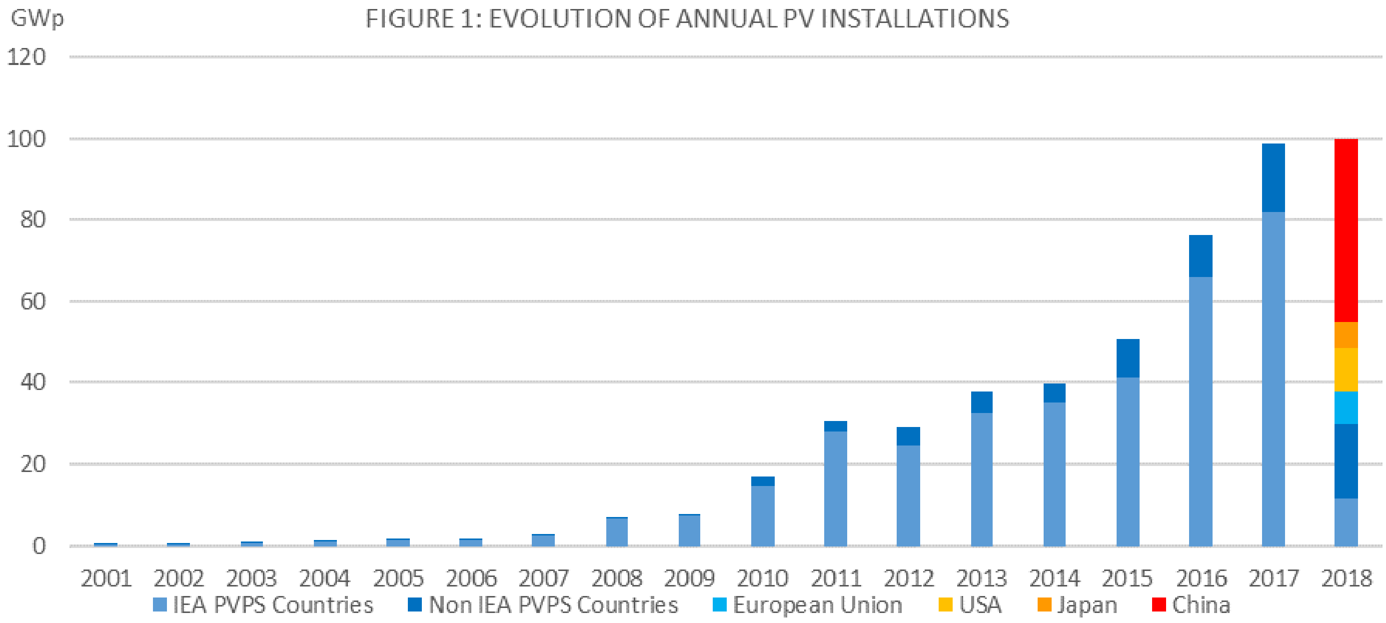
Gjesp…

Solcellehistorie (mer moderne)



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Kilde: IEA-PVPS 2019

Solcellehistorie (mer moderne)

International Energy Agency

Solar PV grew faster than any other fuel in 2016, opening a new era for solar power

4 October 2017

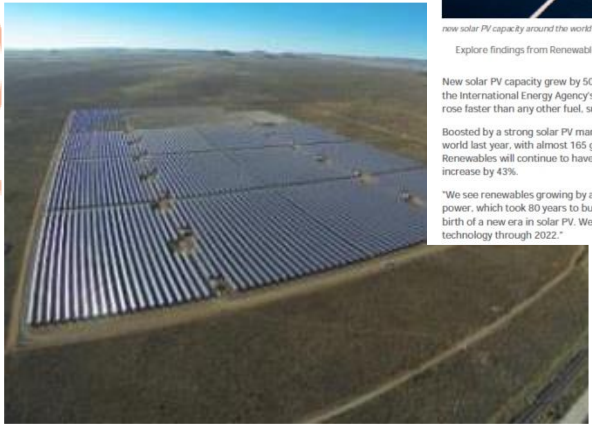
Last year, new solar PV capacity around the world grew by 50%, reaching over 74 gigawatts (Photograph: Shutterstock)

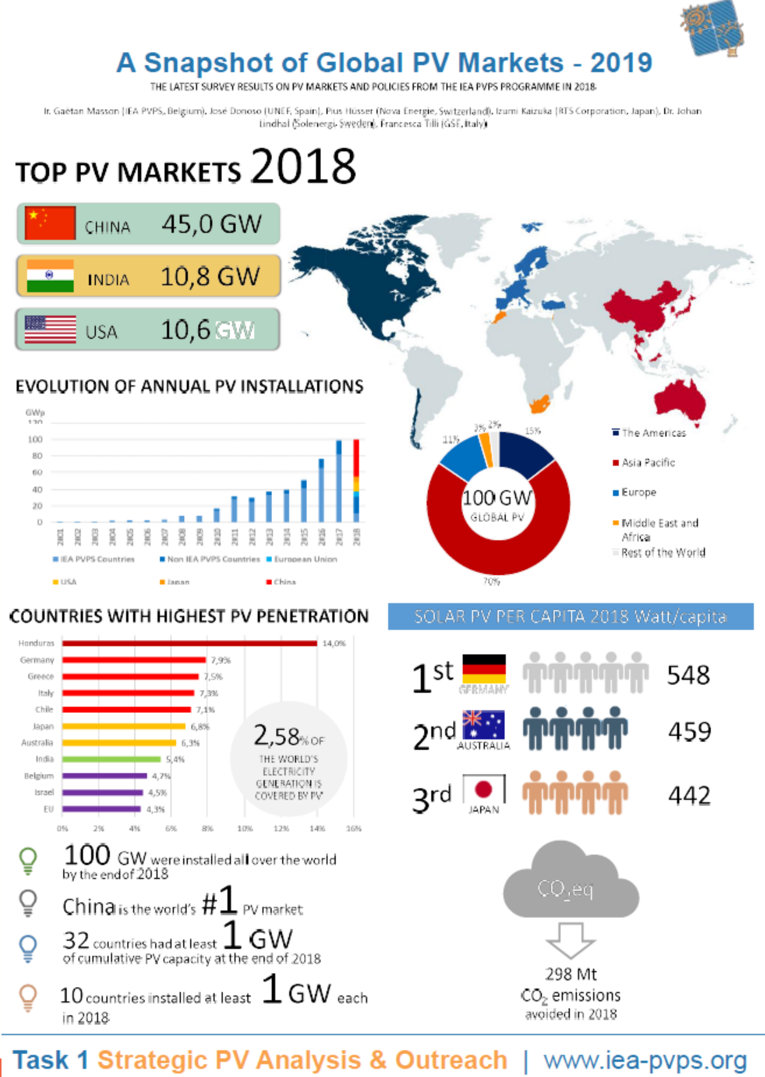
Explore findings from Renewables 2017

New solar PV capacity grew by 50% last year, with China accounting for almost half of the global expansion, according to the International Energy Agency's latest renewables market analysis and forecast. For the first time, solar PV additions rose faster than any other fuel, surpassing the net growth in coal.

Boosted by a strong solar PV market, renewables accounted for almost two-thirds of net new power capacity around the world last year, with almost 165 gigawatts (GW) coming online, according to the new report, *Renewables 2017*. Renewables will continue to have a strong growth in coming years. By 2022, renewable electricity capacity should increase by 43%.

"We see renewables growing by about 1,000 GW by 2022, which equals about half of the current global capacity in coal power, which took 80 years to build," said Dr Fatih Birol, the executive director of the IEA. "What we are witnessing is the birth of a new era in solar PV. We expect that solar PV capacity growth will be higher than any other renewable technology through 2022."





Source: IEA-PVPS 2018/Scatec Solar/IEA 2019

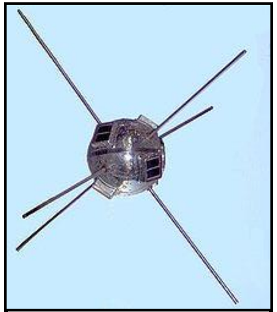
Solcellehistorie

BEQUEREL
1839

The current, if not wanted immediately, can be either stored where produced, in storage batteries, … or transmitted a distance and there used

FRITTS
1883

BELL LABS
1954



VANGUARD 1
1958

«OIL CRISIS»
1973 - 1986

SCANWAFER
1996

1 GW_p
2002

10 GW_p
2008

100 GW_p
2012

500 GW_p
2018

1825 | 1850 | 1875 | 1900 | 1925 | 1950 | 1975 | 2000 | 2025

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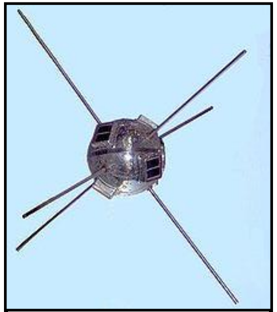

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VISJON OG VITENSKAPELIG GRUNNLAG | TIDLIG KOMMERSIALISERING | SOLINDUSTRI

Intermezzo:

Hva er 100 GW_p egentlig?

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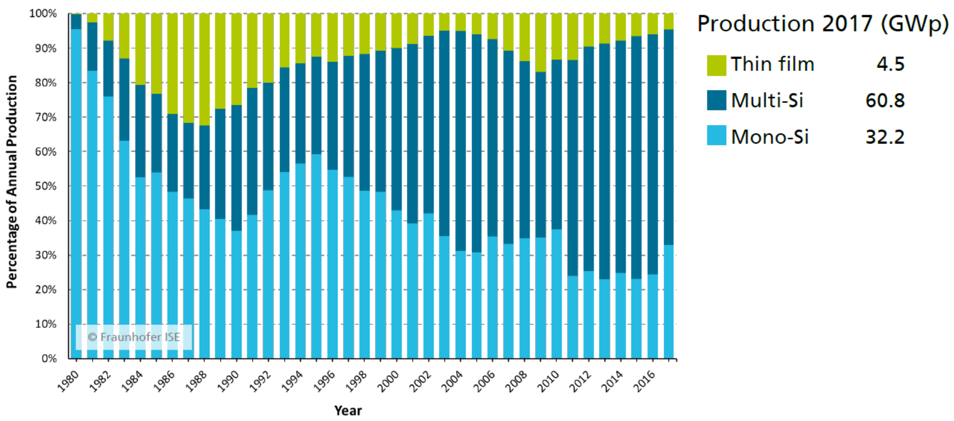
100 GW_p er (fortsatt) silisiumbasert!

PV Production by Technology
Percentage of Global Annual Production



Data: from 2000 to 2010: Navigant; from 2011: IHS (Mono-/Multi- proportion from cell production). Graph: PSE GmbH 2018

Fraunhofer ISE

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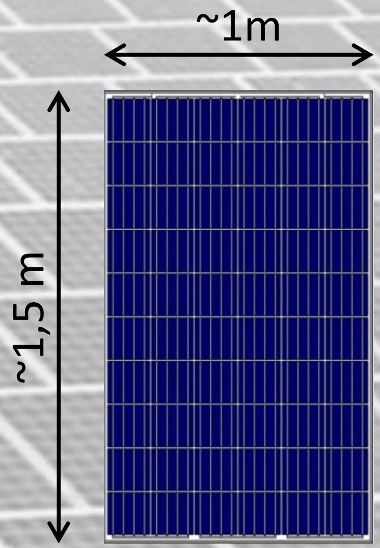
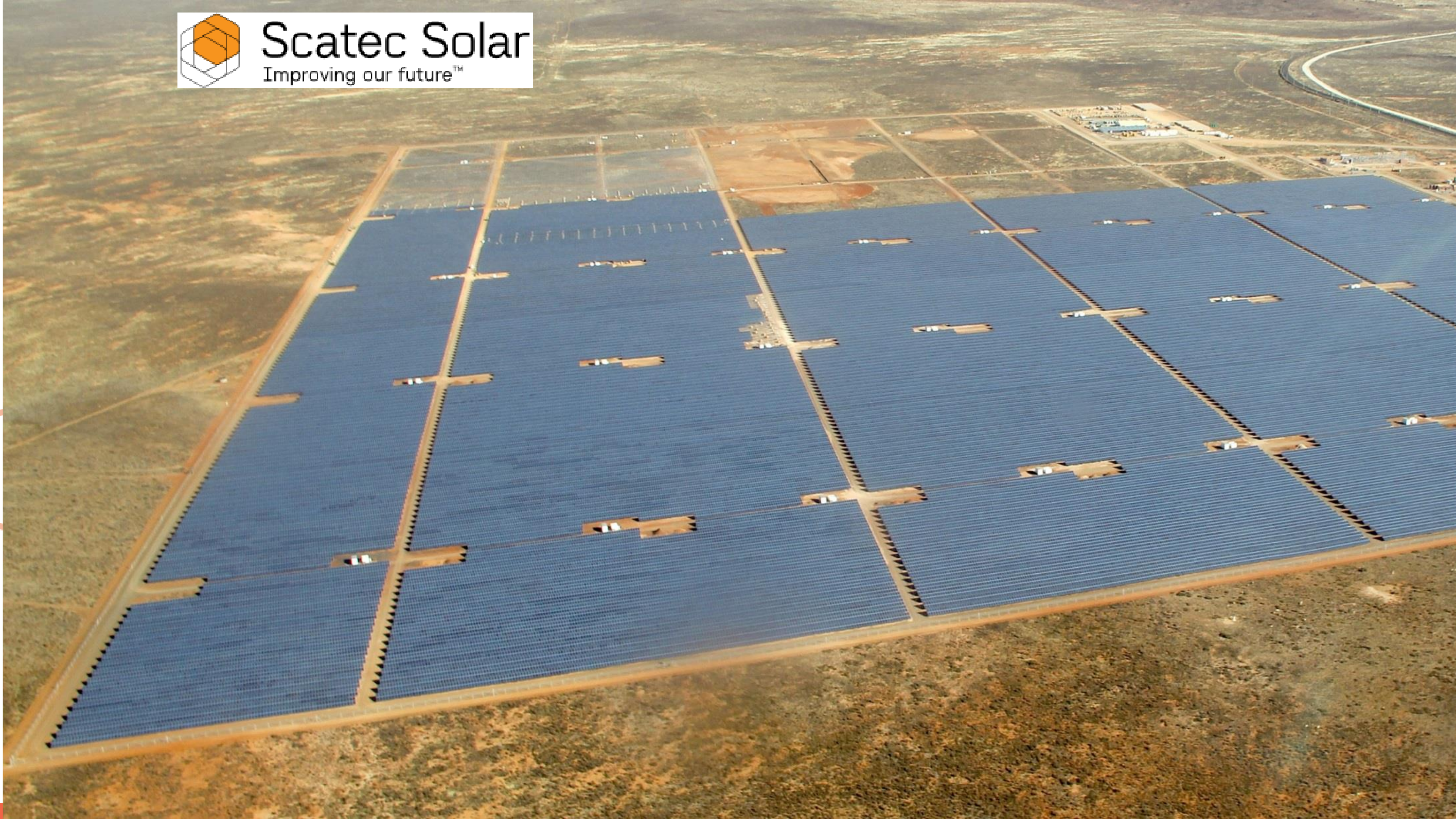
100 GW_p

- ~400 millioner solcellepaneler



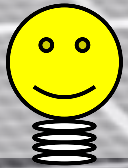

Scatec Solar
Improving our future™

100 GW_p

- ~500 000 tonn med SUPER-rent silisium
- ~25 milliarder wafere som gjøres om til ~25 milliarder solceller

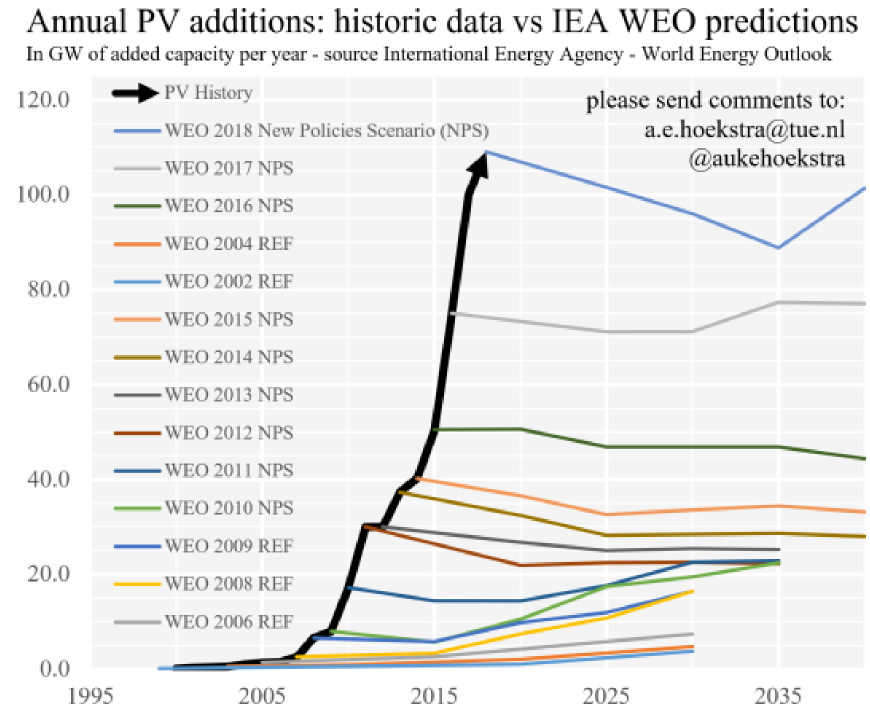
100 GW_p

- ~2 milliarder meter aluminiumsprofil
  - 50-isj ganger rundt ekvator
- ~600 km^2 glassplater
- > 100 TWh/år



Fremtiden

D’ække lett å spå, ass…



Kilder: Hoekstra 2018

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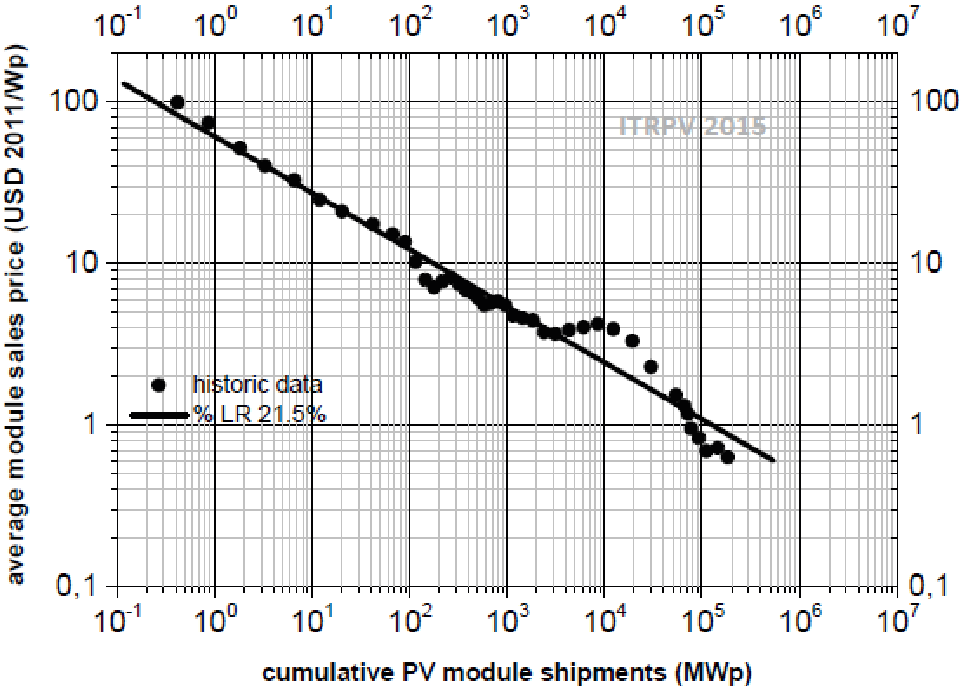
Dingseøkonomi: nyttig basis for absurd vekst



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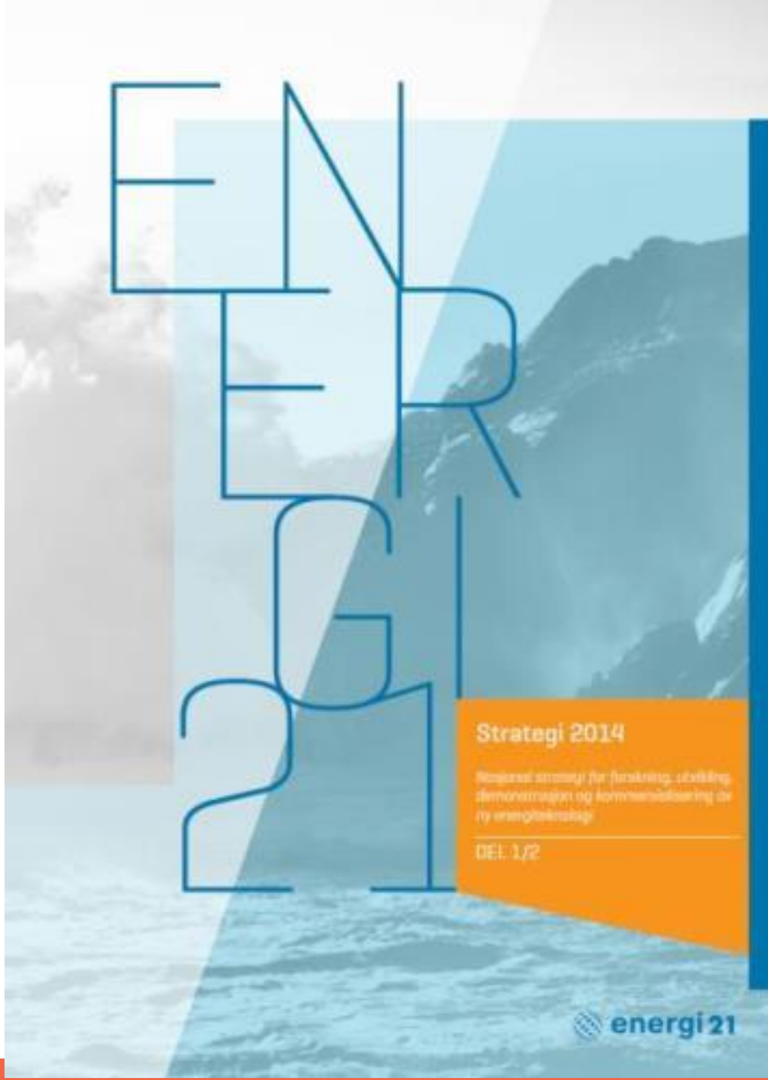
Kilde: ITRPV 2015

Teknologitrender

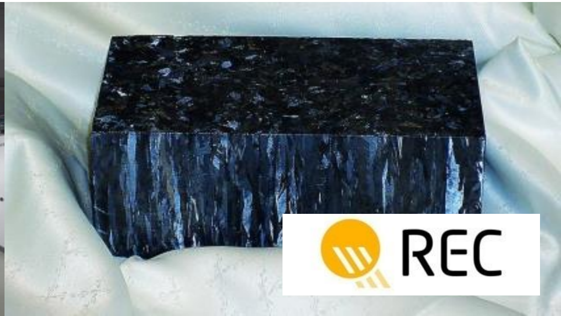
- Høyeffektive, silisiumbaserte solceller
- Bærekraft
- Solcellekraftverk
- Bygningsintegrert solkraft (BIPV)
- Flytende solkraft
- Den store utfordringen



Høyeffektive silisiumbaserte solceller

- Silisium størst
- Høyeffektive solcellearkitekturer rulles ut
  - PERC, HJT, IBC
- Høy virkningsgrad krever nestenfeilfrie materialer
  - Norsk mulighet: vi KAN silisium!
- Tandemsolcellen – spesielt silisiumversjonen
  - Stort hopp i virkningsgrad mulig

Si



Bærekraft

- Silisiummaterialer laget i Norge inntil 2018 (feedstock, ingot, wafer) var kjernen i solcelleanlegg med en total produksjonskapasitet på 6.4 GW_p
- Hvert eneste år produserer disse (mye) mer enn 6 TWh
- Dette gir en årlig reduksjon i utslipp fra kraftproduksjon på hele 6 Mtons CO_2!
- **Norsk spesialitet: bærekraftig produksjon av silisium**

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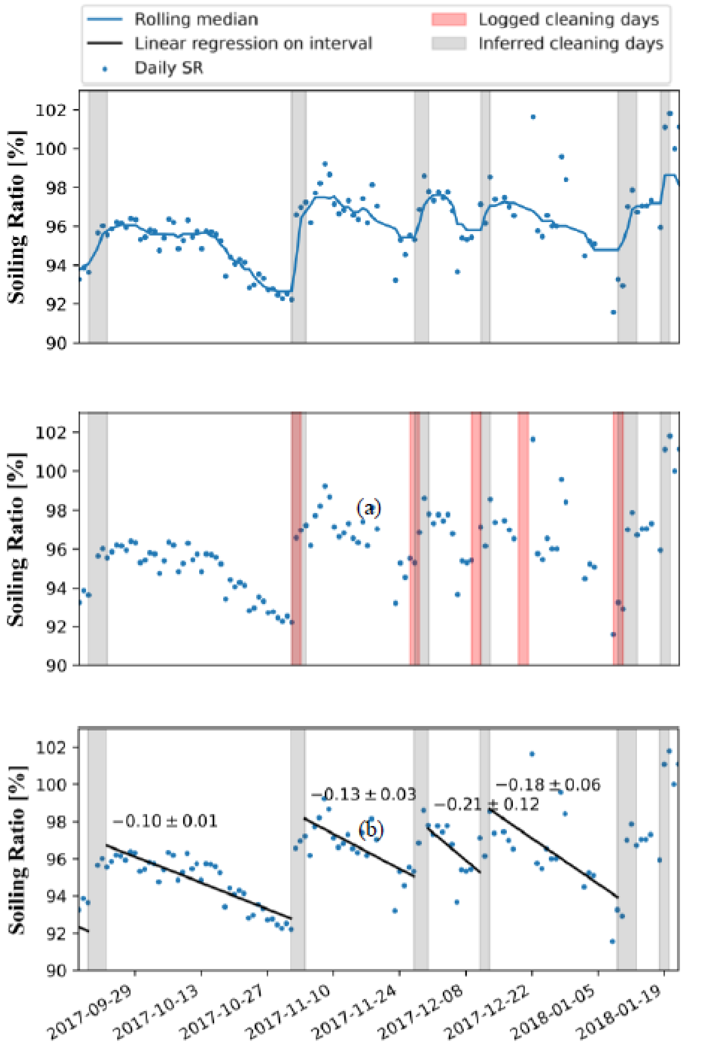
Solcellekraftverk

- Tullete mange komponenter

- Økt kompleksitet
  - Energilagring
  - Hybridisering

- Datadreven drift og vedlikehold
  - Ytelses- og tilstandsanalyse
    - Big data
    - AI
    - Avbildningsteknologi
    - Droner

- Veldig spennende tid i solbransjen
  - Vi lærer dette nå!



Source: Skomedal (IFE) 2019

Bygningsintegrert solkraft (BIPV)

- Store fordeler kan realiseres
  - Substitusjon
  - Synergier under installasjon
  - Rekordlave installasjonskostnader
  - Rekordlave karbonfotavtrykk

- Norge virkelig langt fremme
  - Byggestandard
  - Bevisste bygningseiere
  - Kompetente installatører

Source: FUSen

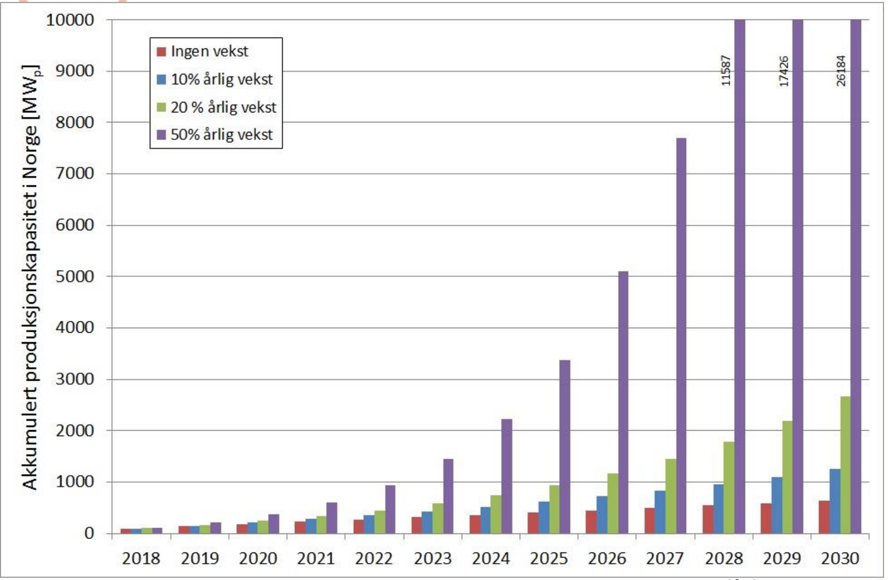
Flytende solkraft (f-PV)

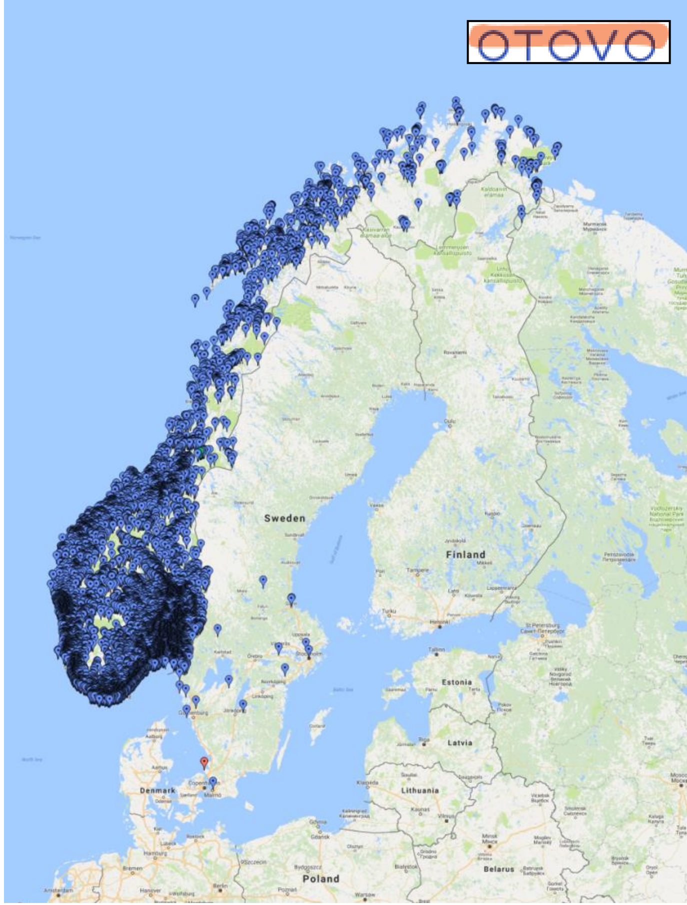
- Nytt, raskt voksende segment
- Kombinerer kunnskap i solkraft og maritim sektor
  - ...og oftere og oftere også kompetanse i vannkraft
  - Midt i blinken for Norge
- Viktige positive effekter
  - Landtilgang
  - Kjøling
  - Kostnad

Source: OceanSun

Optimister, men ikke helt på jordet…

- Eksponensiell vekst er kult…
- …men MÅ jo stoppe før eller senere…





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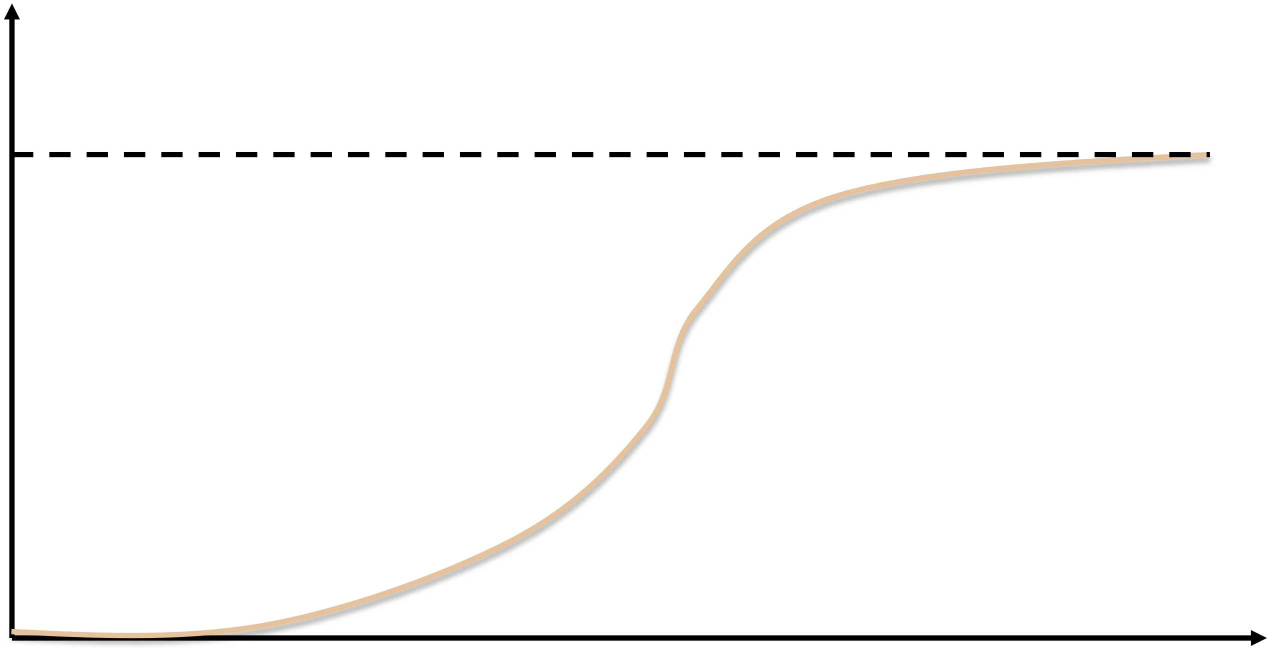
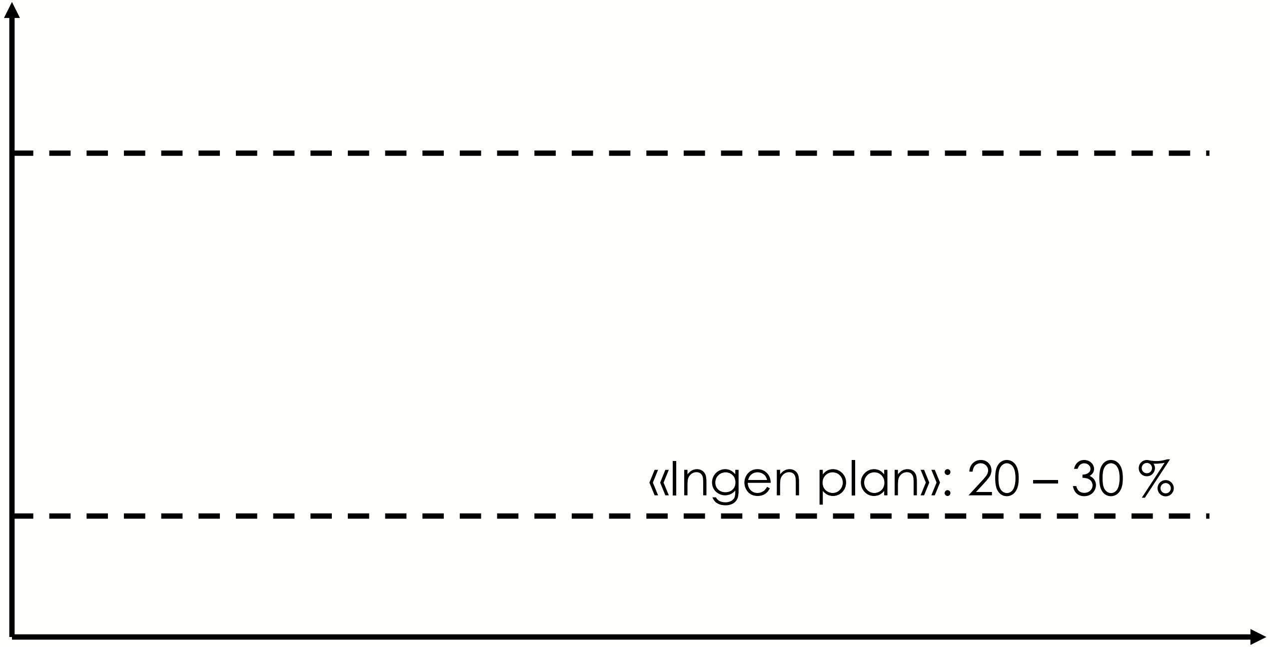
Kilde: Marstein (NTVA) 2018, Otovo

Plausibel utvikling (-isj)



Terskelnivåer



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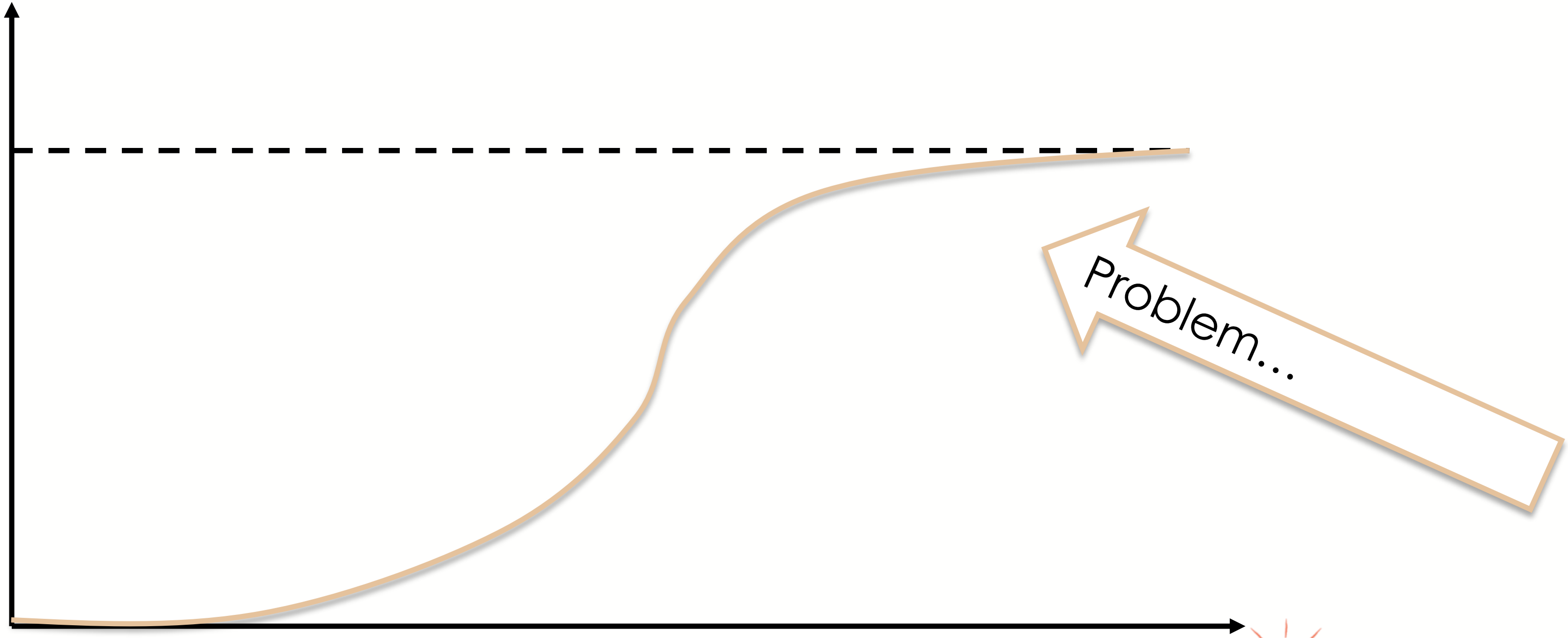

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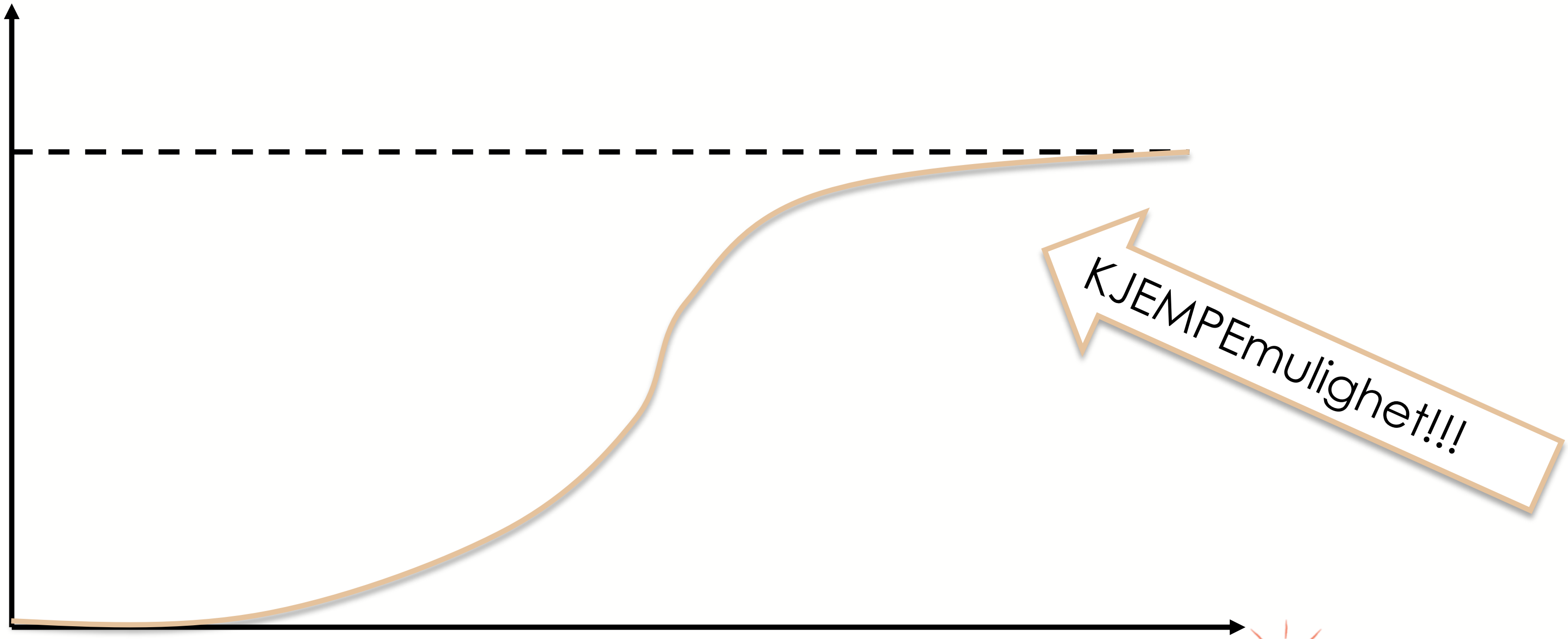
Terskelnivåer



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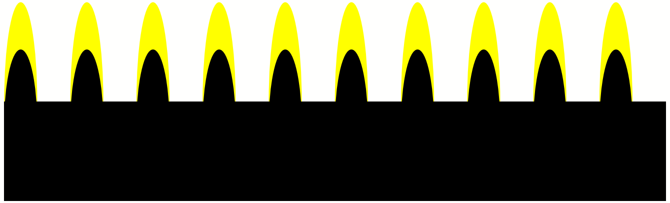
Hva må elevene deres fikse?



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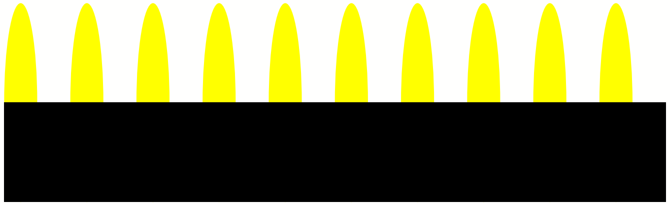
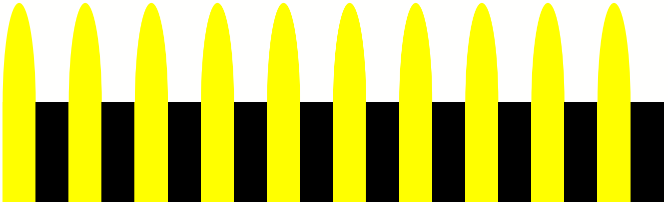


I dag



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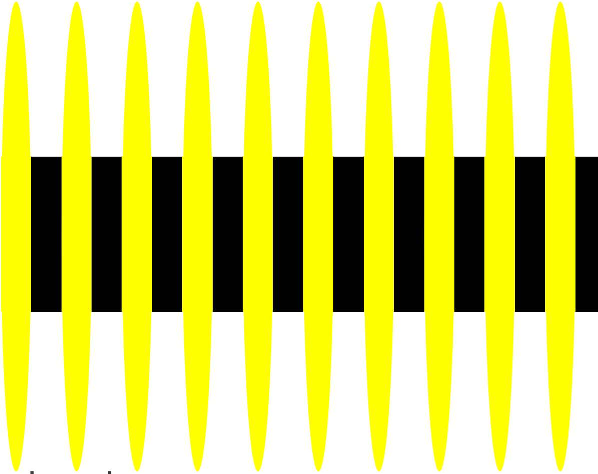

Løsningen

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Tusen takk for oppmerksomheten!

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