The Solar Revolution

Erik Stensrud Marstein
Center Director

Forskningsrådet – October 19th 2017

SUSOLTECH
The Norwegian Research Centre for Sustainable Solar Cell Technology

Research Center for Sustainable Solar Cell Technology

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

Main message

- Potential to solve THE problem?
- Large scale?
- Low cost?
- Business?
- Employment?
- Environmentally friendly?

Main message

- Potential to solve THE problem? YES
- Large scale? YES
- Low cost? YES
- Business? YES
- Employment? YES
- Environmentally friendly? YES

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Main message

- Potential to solve THE problem? YES
- Large scale? YES
- Low cost? YES
- Business? YES
- Employment? YES
- Environmentally friendly? YES

Main remaining question:

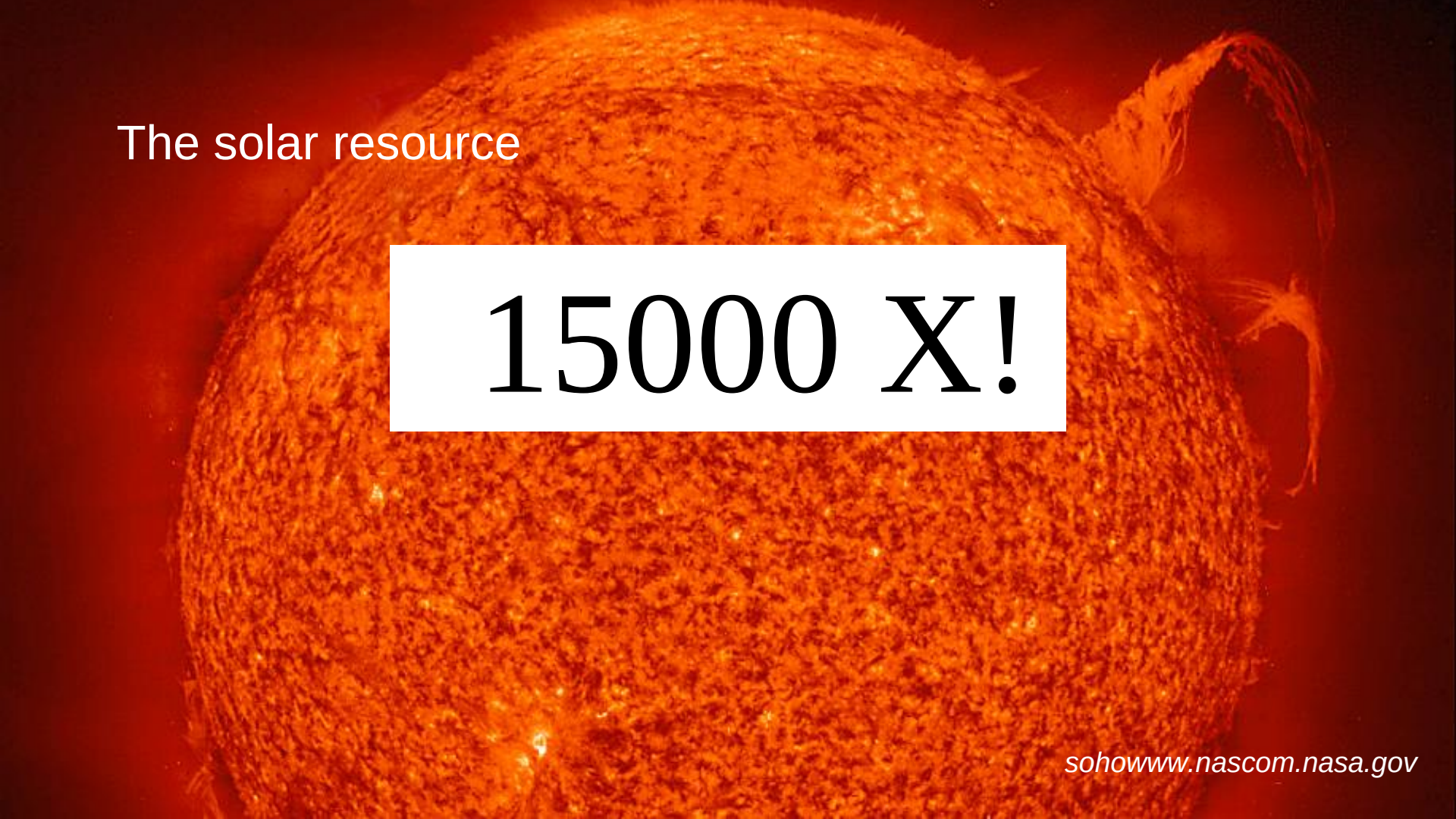
How do we make the most out of this BRILLIANT solution?

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

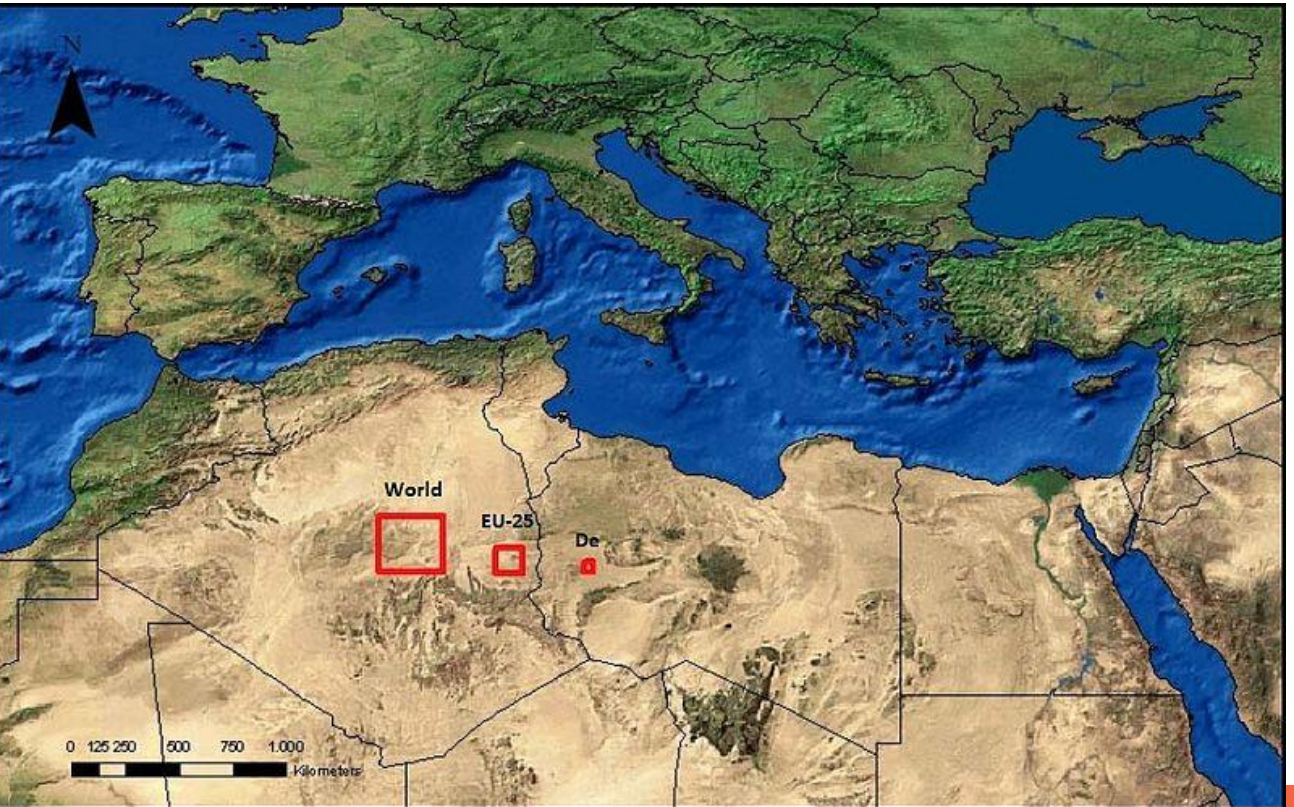
The solar resource

15000 X!



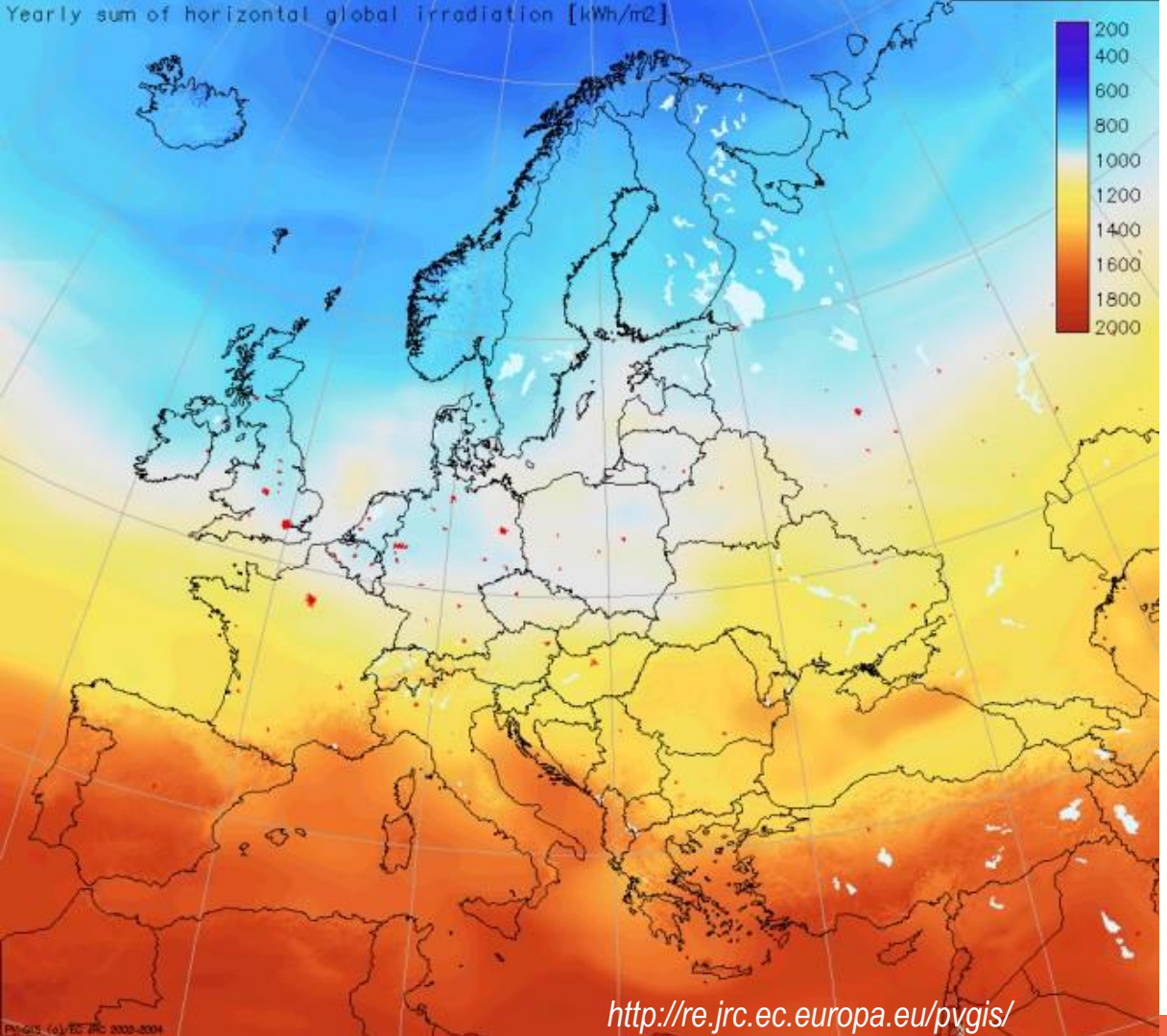
sohowww.nascom.nasa.gov

More than enough space…



SUSOLTECH
The Norwegian Research Centre for Sustainable Solar Cell Technology

Based on DLR data



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

General traits

+ Our biggest resource
+ Renewable
+ Distributed

- Variable
- Distributed
- “Different”

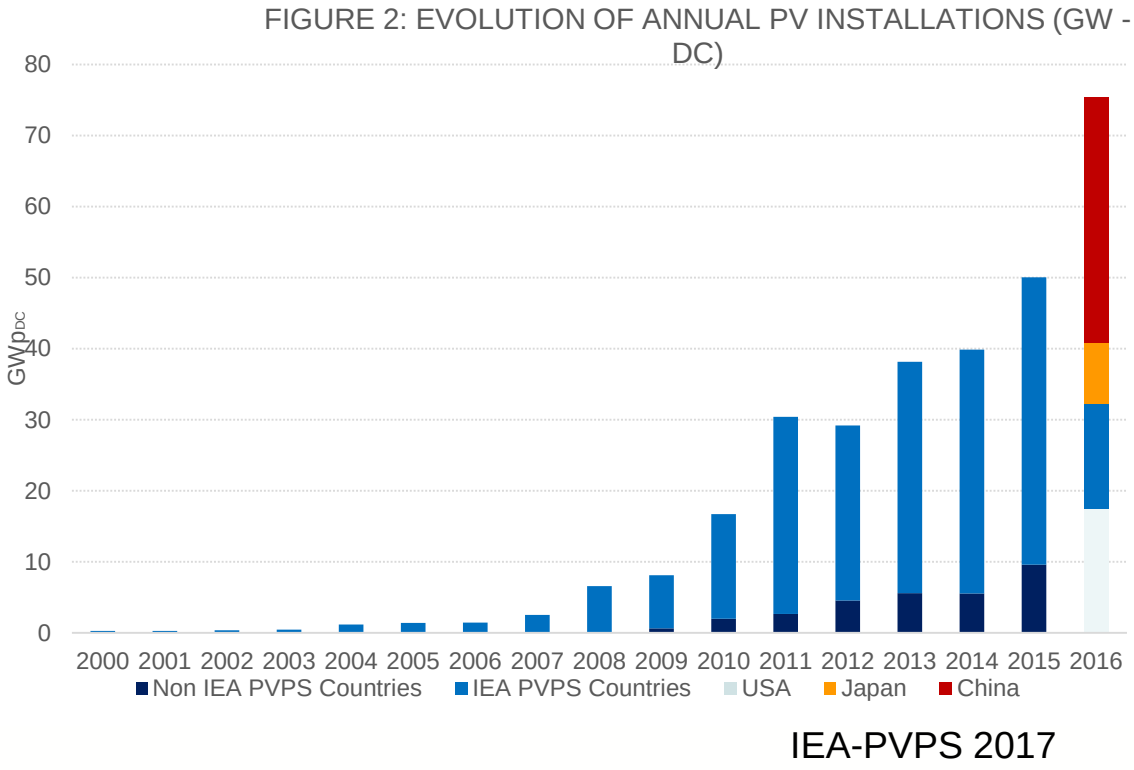
SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

More general traits

- Investment costs significant
- Operation & maintenance costs relatively low
  - Work in progress…
- Extremely scaleable
- Very attractive option for end users
  - Production cost «irrelevant»
  - Electricity bill the main competition
  - Highly confusing and potentially very disruptive
  - …and then you add an app and a battery…

The world of solar cells 2017 – a snapshot



IEA-PVPS 2017

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Intermezzo: IEA

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.

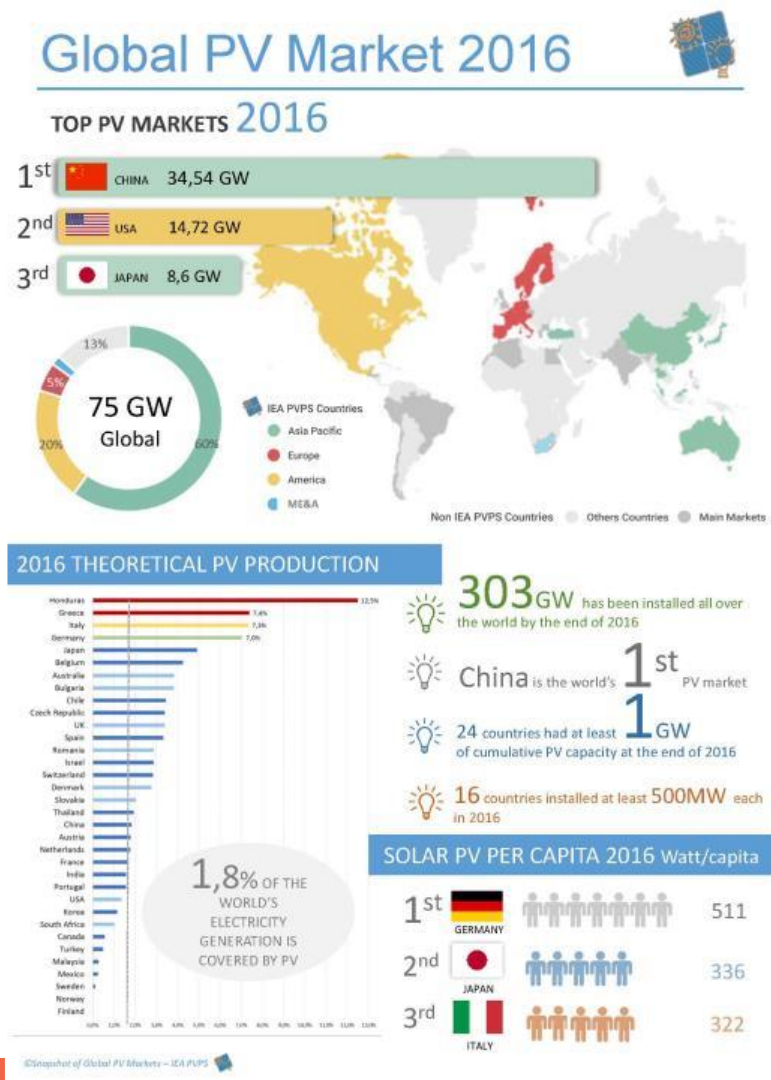
Boosted by a strong solar PV market, renewables accounted for almost two-thirds of net new power capacity around the world last year, with almost 165 gigawatts (GW) coming online, according to the new report, *Renewables 2017*. Renewables will continue to have a strong growth in coming years. By 2022,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

TABLE 1: TOP 10 COUNTRIES FOR INSTALLATIONS AND TOTAL INSTALLED CAPACITY IN 2016

	TOP 10 COUNTRIES IN 2016 FOR ANNUAL INSTALLED CAPACITY		TOP 10 COUNTRIES IN 2016 FOR CUMULATIVE INSTALLED CAPACITY	
1	China	34,5 GW	China	78,1 GW
2	USA	14,7 GW	Japan	42,8 GW
3	Japan	8,6 GW	Germany	41,2 GW
4	India	4 GW	USA	40,3 GW
5	UK	2 GW	Italy	19,3 GW
6	Germany	1,5 GW	UK	11,6 GW
7	Korea	0,9 GW	India	9 GW
8	Australia	0,8 GW	France	7,1 GW
9	Philippines	0,8 GW	Australia	5,9 GW
10	Chile	0,7 GW	Spain	5,5 GW

IEA-PVPS 2017/Scatec Solar



What do the numbers mean?

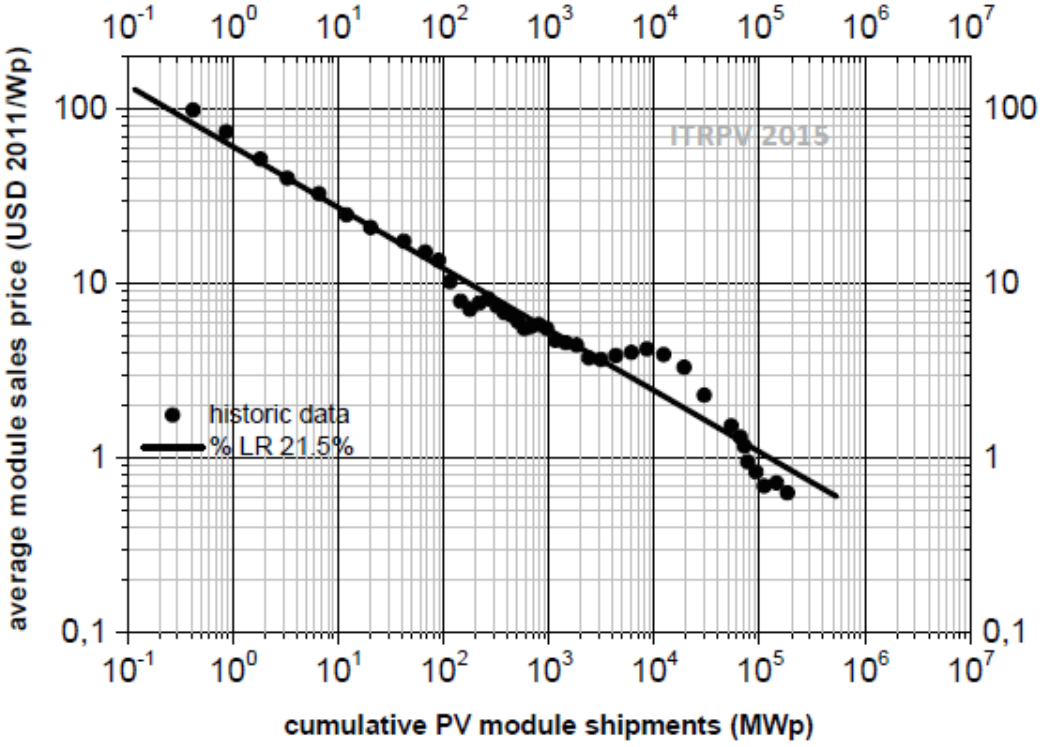
75 000 MW_p/y ~ 500 km^2/y

15 – 20 billion solar cells/y

~ 1 unit/production line/second(-ish)

75 000 MW_p/y ~ 100 TWh/y

The solar revolution – cost

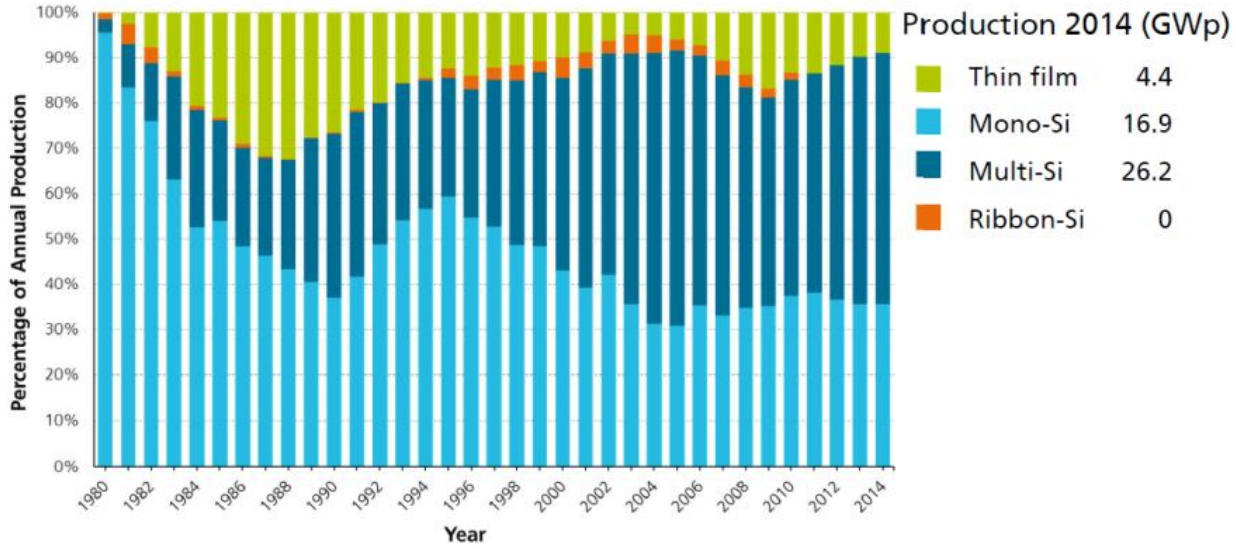


ITRPV 2015

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Silicon-based solar cell technology



Data: from 2000 to 2010: Navigant; from 2011: IHS (Mono-/Multi- proportion by Paula Mints). Graph: PSE AG 2015

Fraunhofer ISE

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Silicon-based solar cell technology

- Crystalline Si technology completely dominate today
  - Rapid roll-out demonstrated!
  - Decent efficiencies
  - Robust technology
  - Extra PRO: this is a Norwegian speciality!

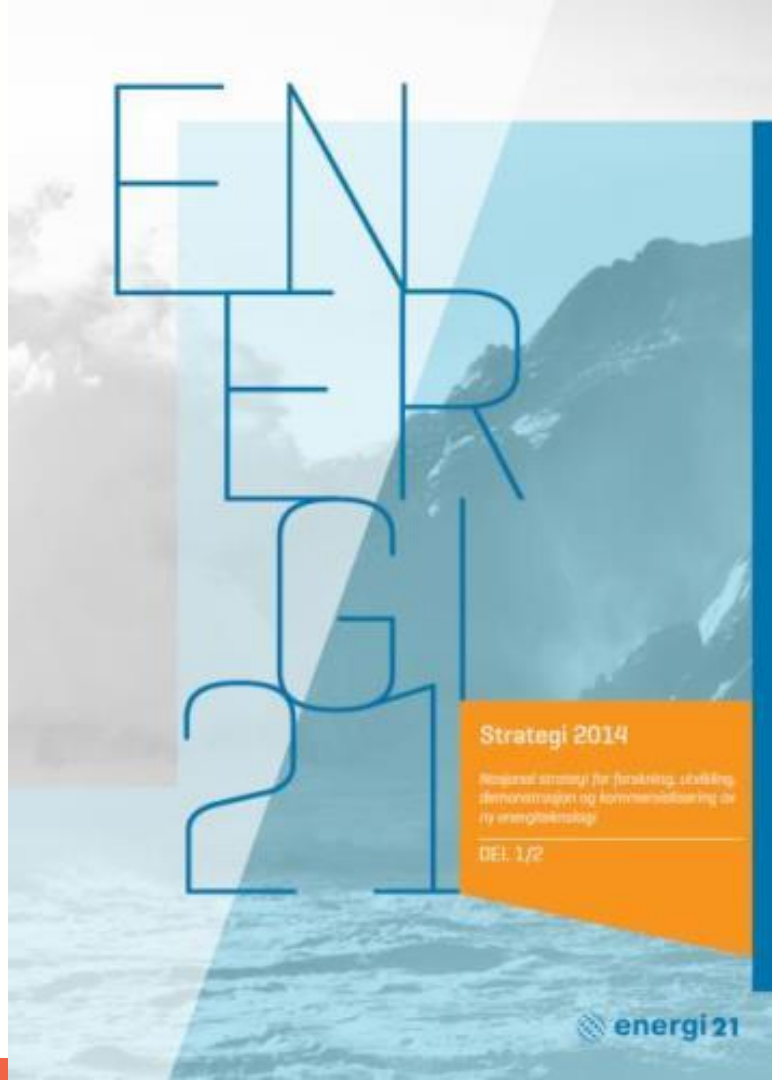
- Efficiency is requried to balance the BOS costs
  - At least in «normal» use, many niche opportunities also exist

- Efficiencies on the rise!
  - Evolutionary developments are extremely effective
    - Good tradition for evolutionary developments in Norway!
  - Revolutionary concepts have hitherto struggled to grow with the market

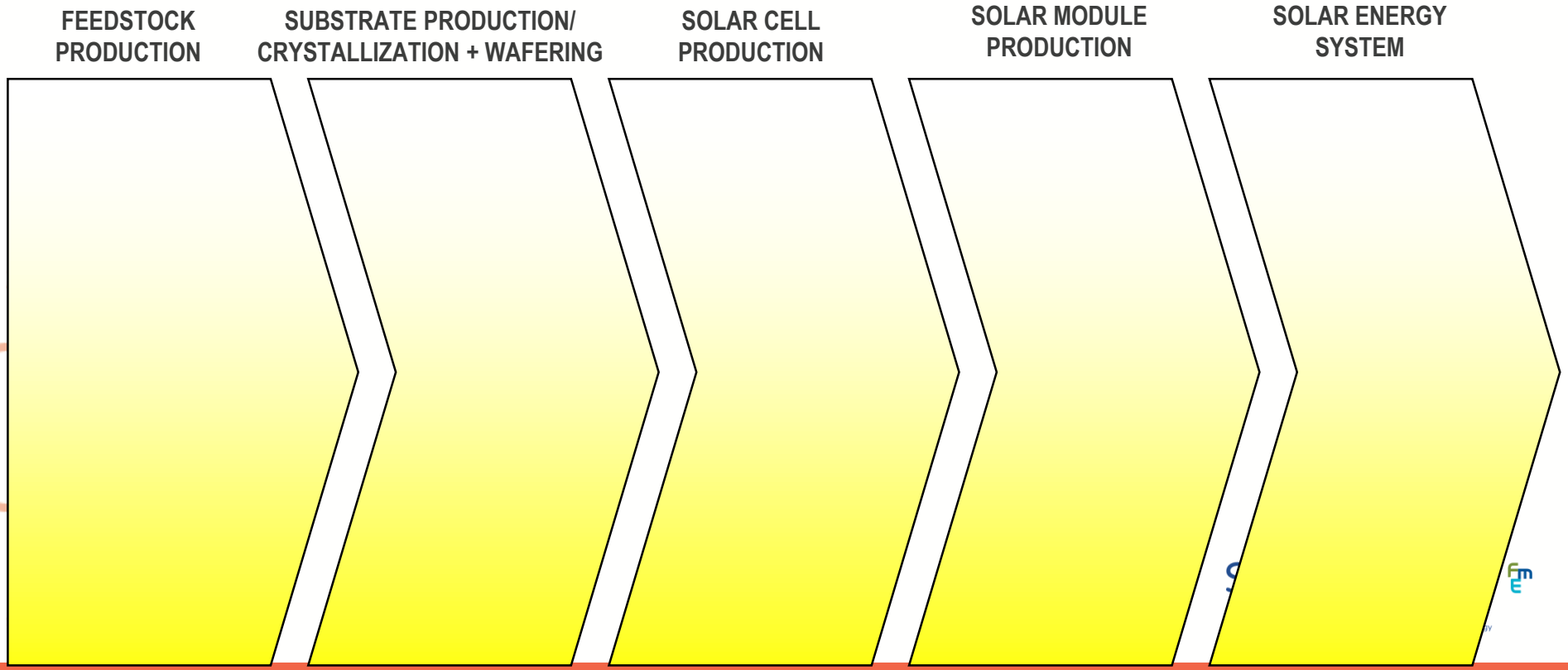
SUSOLTECH
The Norwegian Research Centre for Sustainable Solar Cell Technology

A Norwegian perspective

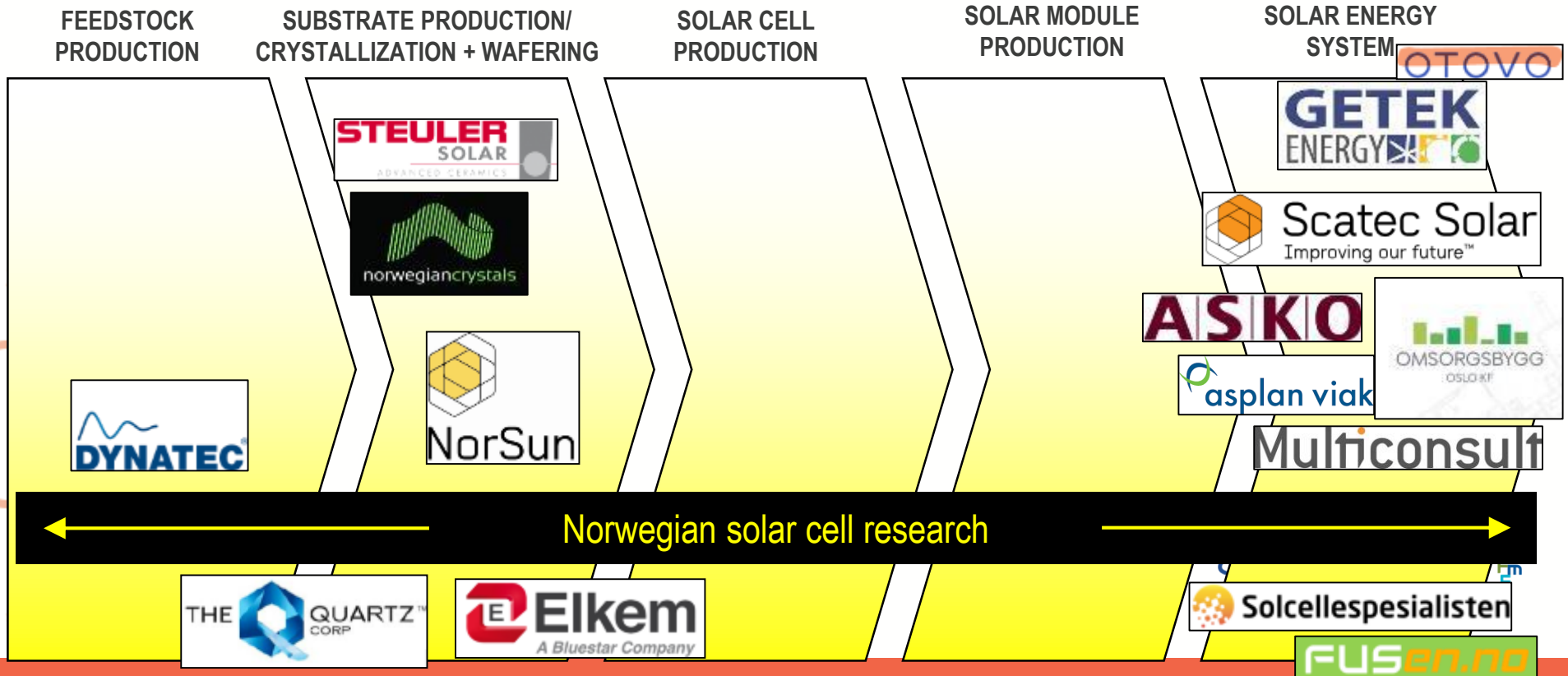
- Energi21 – Solar one of 6 proritized topics in (non-fossile) energy research



Commercial opportunities



Commercial opportunities



R&D need/opportunities

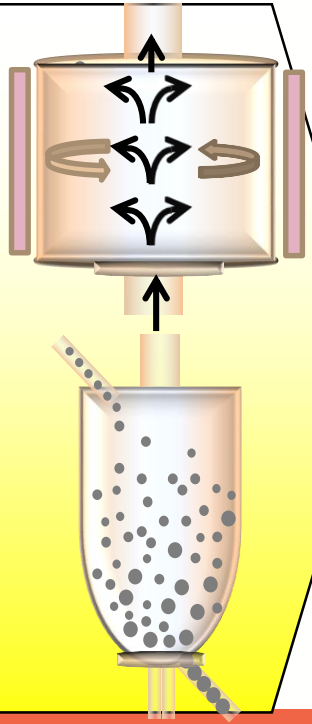
FEEDSTOCK PRODUCTION

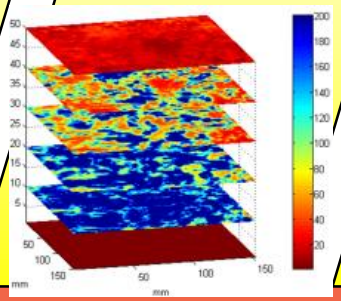
SUBSTRATE PRODUCTION/ CRYSTALLIZATION + WAFERING

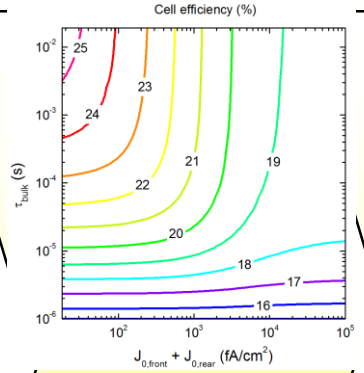
SOLAR CELL PRODUCTION

SOLAR MODULE PRODUCTION

SOLAR ENERGY SYSTEM

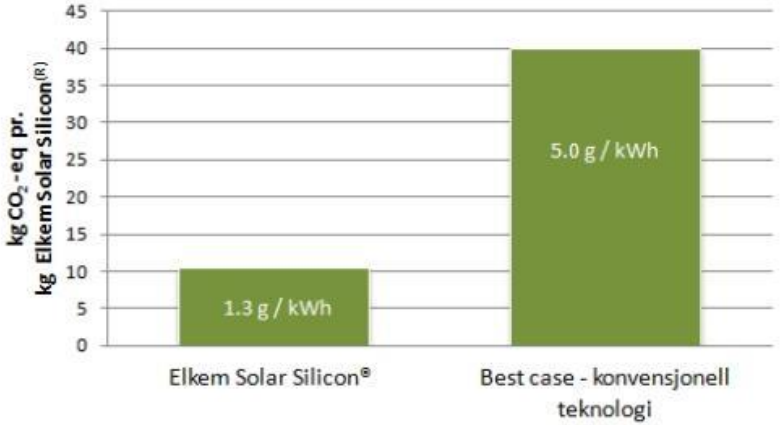






Elkem Solar

- Capacity: >7500 tons/y of Si
  - ~1 GW_p of solar cells
- Factory in Fiskaa (Kristiansand)
- New factory for ingot production opened at Herøya in 2016
  - 60 jobs
- Extremely energy efficient
  - Contracts won in Japan and France due to lowest CO_2 footprint
  - 1000000 tons of CO_2 saved every year from 1 year of production!
- Needs R&D!
  - Improved field performance



Norsun

- Producer of high quality Si wafers for global market
  - Qualified for use by several of the most challenging producers in the World!
  - High level of automation
- Is currently investing in new wafer technology in Årdal
  - Further incremental process improvements
- Needs R&D!
  - Cost reduction
  - Product quality

SHARP

SANYO Panasonic

Trina solar

SUNPOWER

VOLTEC solar

HEVEL SOLAR

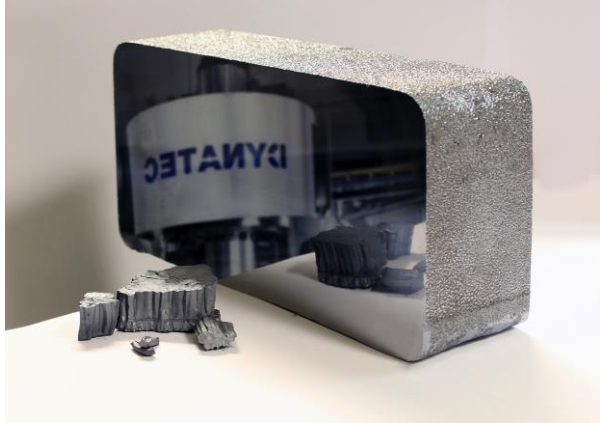
AUO AUO Crystal

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Dynatec

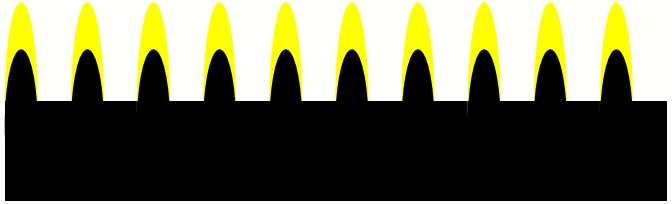
- A machine builder recently moving into the solar cell industry
- Revolutionary new Si production technology
  - Recent demonstrations
    - Extremely low energy use
    - Extremely rapid growth/production
    - Extremely low capital cost
- Works to start first production site
- Needs R&D!
  - Process
  - Material quality



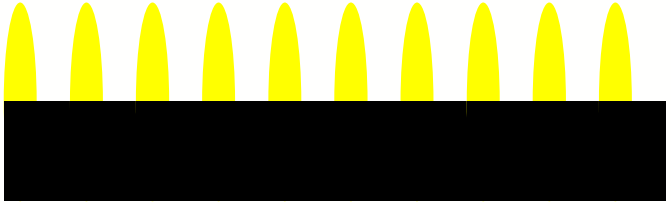
Scatec Solar

- Globally leading installer of solar power plants
  - Strong international presence!
  - South Africa, Brazil, Honduras, Brazil, USA, Czech republic, Mali, Rwanda, Egypt, Jordan
  - Multi-GW_p portfolio
- Involves other Norwegian companies in production
- Needs R&D!
  - Operation
  - Forecasting
  - Scatec Solar Innovation Challenge

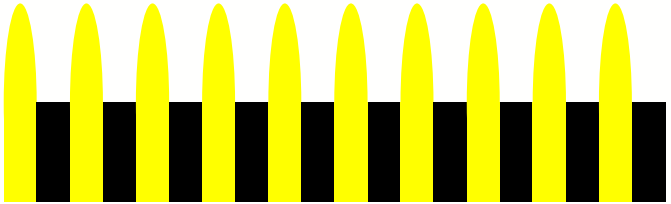
What is next?



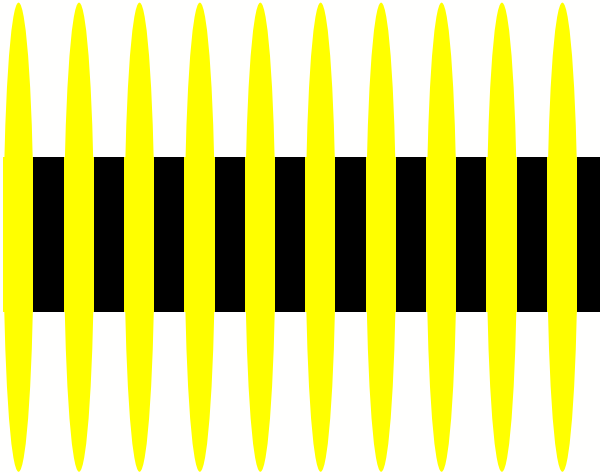
YESTERDAY



TODAY



TOMORROW



FUTURE SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

What is next?

- Forecasting
- Demand side management
- Interconnection/infrastructure
  - Markets, geographical spread
- Storage and energy conversion
  - Batteries
  - Hydrogen
- Backup
- New «ecosystems»
- (more) sustainable hybrids
  - PV + X
  - Floating PV

TESLA

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Main message

- Potential to solve THE problem? YES
- Large scale? YES
- Low cost? YES
- Business? YES
- Employment? YES
- Environmentally friendly? YES

Main remaining question:

How do we make the most out of this BRILLIANT solution?

SUSOLTECH

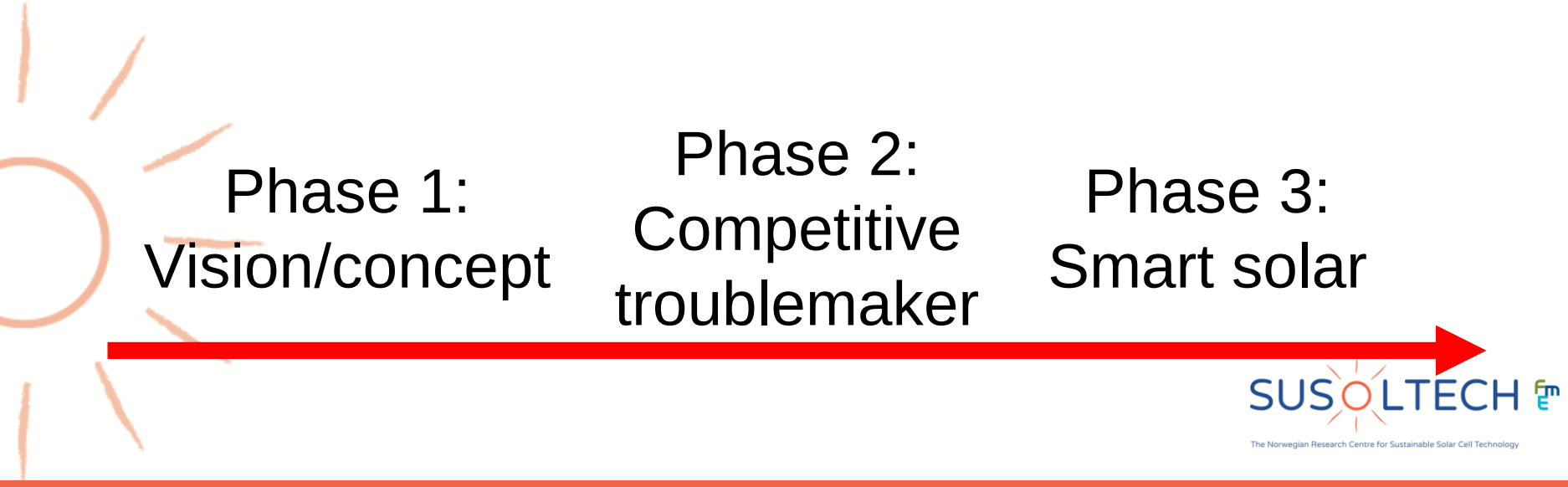
The Norwegian Research Centre for Sustainable Solar Cell Technology

Thank you for your attention!

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Solar cell history?



SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

New business models

- «Old skool»
  - Somebody else makes power, I buy at whatever price is demanded
  - Somebody else is responsible for fixing problems
- Solar v 1.0
  - I make my own power and reduce overall costs
  - I am responsible for fixing problems
- Solar v 2.0
  - I make my own power and reduce overall costs
  - Someone else is responsible for fixing problems
- Solar + battery
  - All of a sudden I am an energy trader, price optimization
  - Islanding or grid-connection two options

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

What does this mean for industry?

- The combination of solar cells, batteries and «digitalization» is EXTREMELY powerful
  - Increasingly powerful power customers (large and small)
  - Large scale: redefinition of «power plant»
    - Virtual power plants
    - Conditioning
    - Utilities are changing practice and strategy
      - «New» power companies emerge
  - Local scale: redefinition of energy «use»
    - Building owners are changing
    - Builders and architects are changing
    - Opportunities both at home and abroad
    - Emergence of the «prosumer»

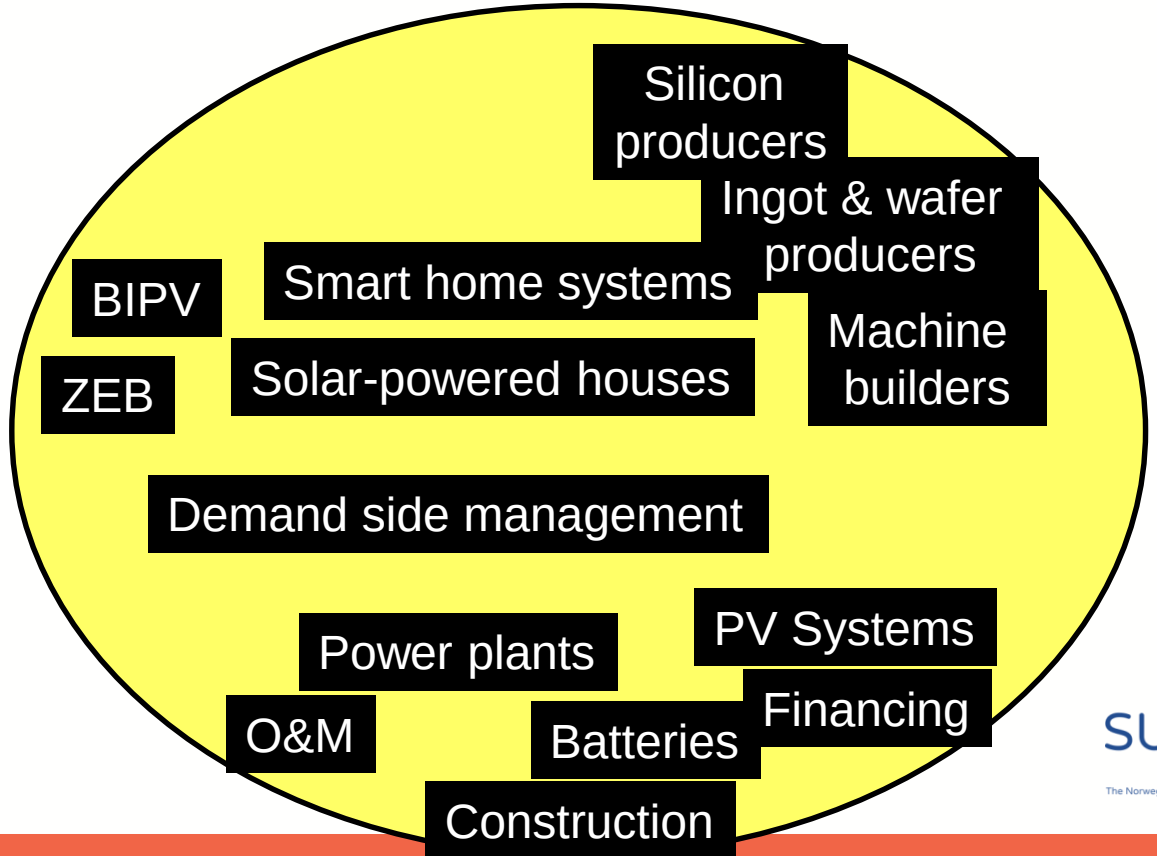
SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

A new reality

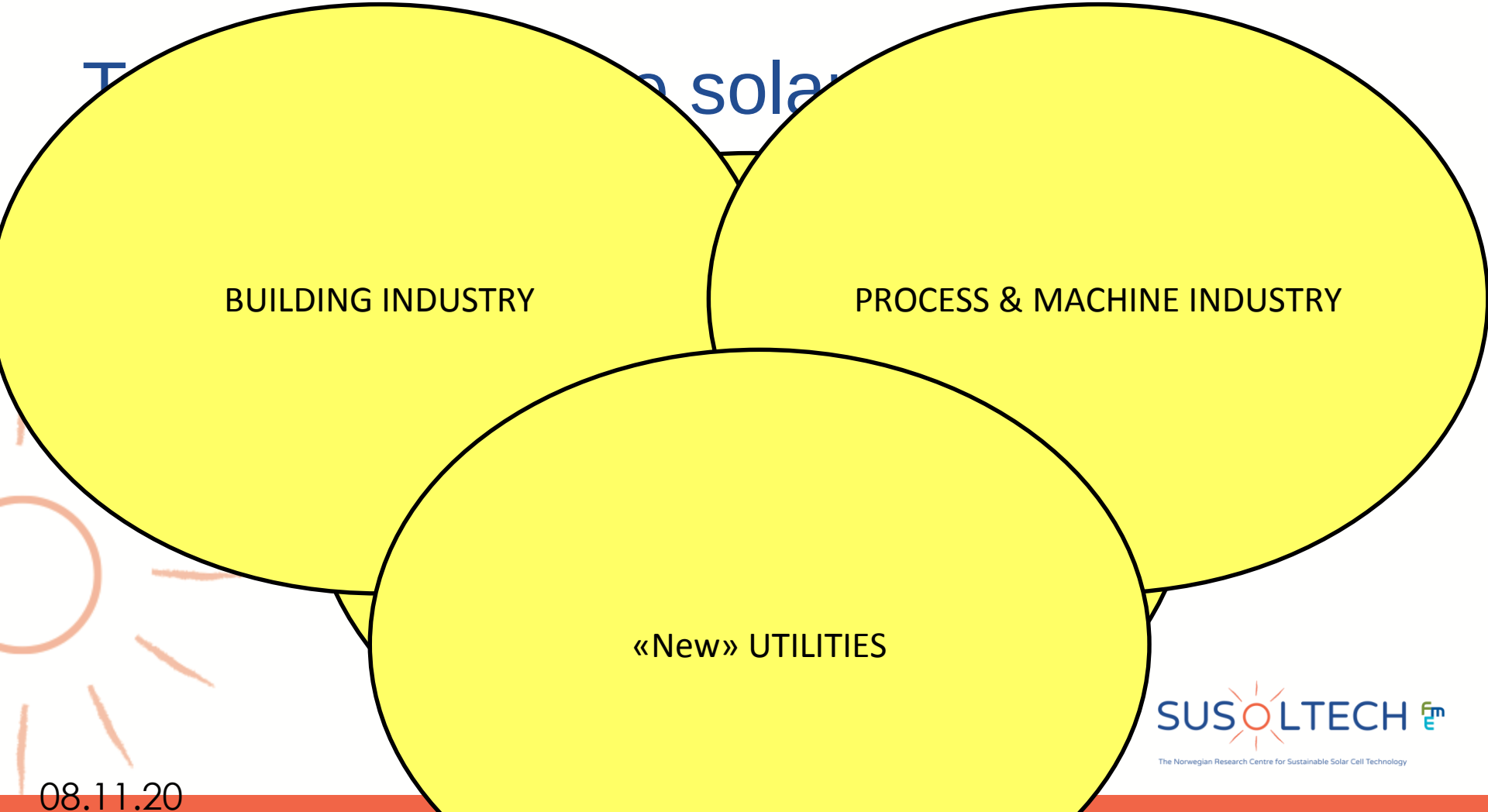
- Solar cells work
  - If you want to buy something «big», solar energy delivers
  - If you want cheap electricity, solar energy delivers
- Batteries are coming
  - Renew/expand transmission grid OR build local capacity and regulation?
  - Where there is no good grid today: will there ever be one?
- Customers/energy users are (slowly) becoming concient
  - Choices, alternatives, values…

Today – «The solar cell industry»



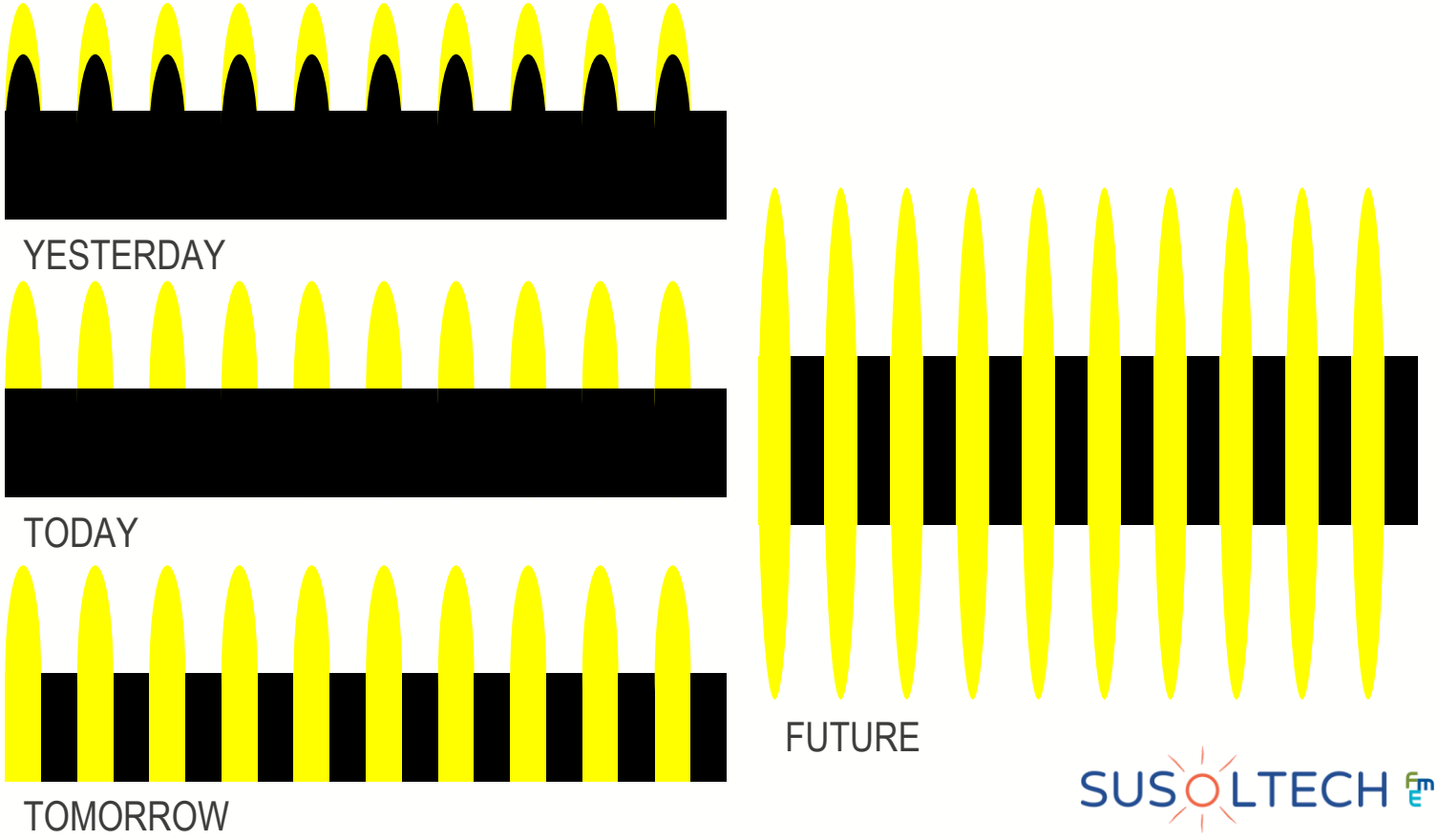
SUSOLTECH
The Norwegian Research Centre for Sustainable Solar Cell Technology

T… solar



SUSOLTECH
The Norwegian Research Centre for Sustainable Solar Cell Technology

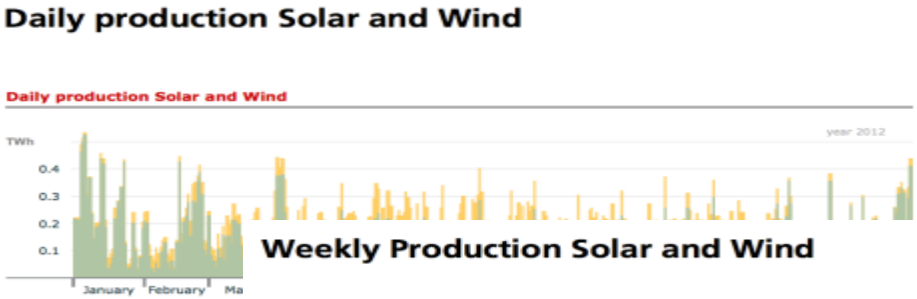
How to think big enough?

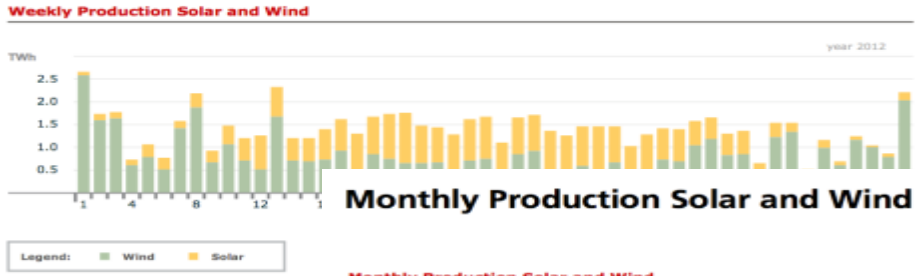


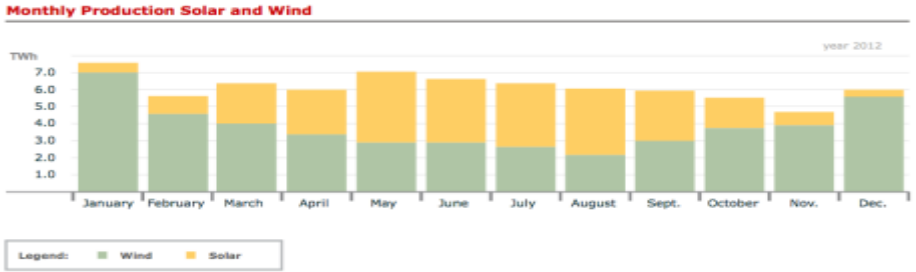
SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

How to think big enough?







How to think big enough?

- Forecasting
- Demand side management
- Interconnection/infrastructure
  - Markets, geographical spread
- Storage and energy conversion
  - Batteries
  - Hydrogen
- Backup
- New «ecosystems»

TESLA

SOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Other challenges

- Complex political goals
  - Energy + environment + employment + research + …
- How to develop a sustainable power mix
  - Utilities are slowly being suffocated
  - kWh value dropping, is capacity a way to go?
- How to replace the «right» power plants
  - How to «tax» emissions?
- Human perception
  - Time constants
  - Uncertainty and risk evaluation
- No policy = policy!
- …

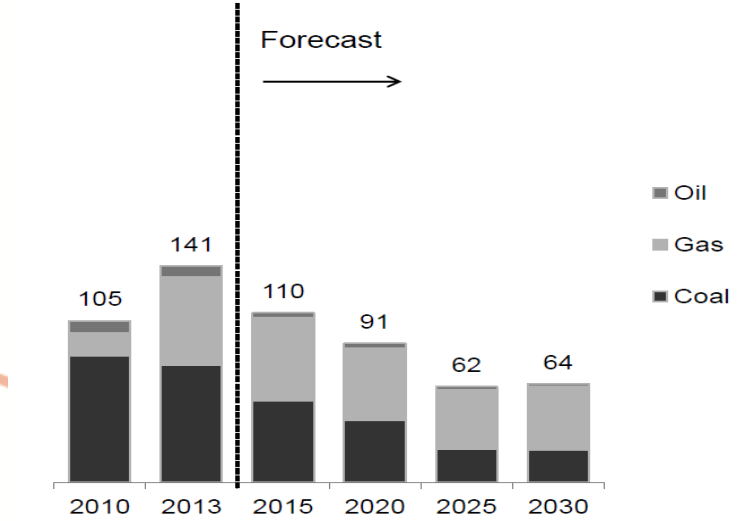
SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

GLOBAL GROSS POWER GENERATION CAPACITY ADDITIONS, 2010–30 (GW)

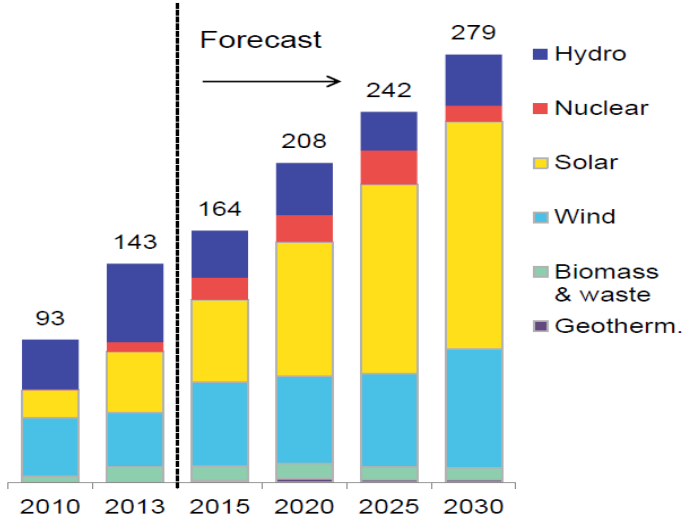
Bloomberg NEW ENERGY FINANCE

FOSSIL FUEL



te: Underlying data is from GREMO 2014

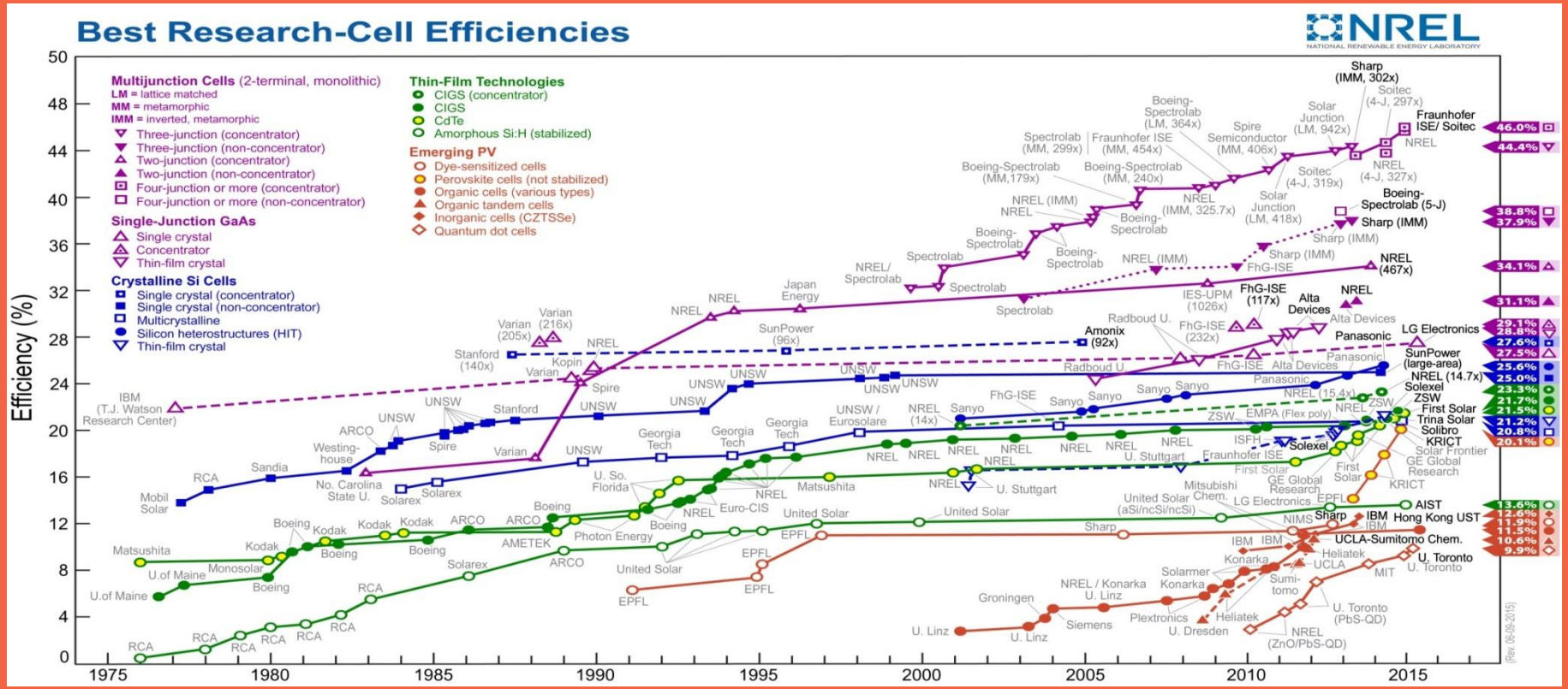
CLEAN ENERGY



Source: Bloomberg New Energy Finance

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology



Data: NREL (2015)

08.11.20

Solar cells – final remarks

- Solar cells are now increasingly mainstream
- Solar electricity costs make it competive in many markets
- Subsidies have been crucial
  - Sufficiently large markets
  - Predictable price development
  - Smart phasing out put pressure on producers
- Solar cell impose a new electricity market structure
  - Power plants are often small and privately funded
  - Increased awareness among customers
  - Variable electricity prices

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Agenda

- What is SUSOLTECH?
  - What is an FME?
- Who is SUSOLTECH?
  - The consortium
- Why SUSOLTECH?
  - A brief history
- What will SUSOLTECH do?
  - Center structure
  - Goals
  - Plans

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

What is SUSOLTECH?

- Full name:

  Research Center for Sustainable Solar Cell Technology

- Short name: FME SUSOLTECH

- FME = ?
  - 8 (5+3) year RCN-funded flagship project
  - Funding scheme
    - RCN: 50%
    - Industry partners: 25%
    - Research partners: 25%
  - FME SUSOLTECH is 1 of only 8 techn. FME centers

SUSOLTECH FME
The Norwegian Research Centre for Sustainable Solar Cell Technology

Thank you for the attention!

SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

The Norwegian Research Centre for Sustainable Solar Cell Technology