Future Solar-Powered Electrical Energy Systems

Miro Zeman

Department of Electrical Sustainable Energy
January 21, 2017
Fraction of electricity in total final energy consumption

Source: IEA 2008, EC 2011 data.html, Inaugural speech Mart van der Meijden
1900 New York 5th avenue

1913 New York 5th avenue
Mercedes-Benz 240 d 3.0
2016 Mercedes-Benz E-Class
Mercedes-Benz F 015 self-driving

Charging electric cars
Total electricity use in The Netherlands

- Required power:
  - Average: ~14 GW
  - Peak: 30 GW

Source: Centraal Bureau voor de Statistiek

Electrical energy system of today
Electricity generation: Eemshaven coal power plant
Electricity generation: Borselle nuclear power plant
Crystalline-silicon solar cells

~ 15%

~ 20%

> 25%
Global energy potential

- Solar: 23,000 TW
- Tidal: 0.3 TW
- Wave: 0.2–2 TW
- Geothermal: 0.3–2 TW
- Hydro: 3–4 TW
- Biomass: 2–6 TW
- Wind: 25–70 TW

World energy consumption (power demand of 16 TW)

- Coal: 900 TW-yr
- Uranium: 90–300 TW-yr
- Oil: 240 TW-yr
- Natural gas: 215 TW-yr

Total reserves: annually

https://commons.wikimedia.org/wiki/File:Global_energy_potential_perez_2009_en.svg
PV generation capacity

Global Cumulative Installed PV Capacity [GWp]

- Asia
- Americas
- Middle East and Africa
- Europe

~240 GWp
Large-scale PV power plants
Small-scale PV systems: Biesland, The Hague (NL) 2009
Small-scale PV systems: Heerhugowaard (NL) 2015
Tesla Solar roof
Solar cars: Nuna 8 Winner World Solar challenge 2015

http://www.nuonsolareteam.nl/
Solar Road: Colas Wattway

Large-scale wind energy

Source: TenneT, Inaugural speech Mart van der Meijden
Storage: Batteries

https://www.tesla.com/powerpack
Storage: Solar fuels

\[ \text{AM 1.5} \]

\[ \text{H}_2 \]

\[ \text{Pt} \]

\[ \text{O}_2 \]

\[ \text{Axis connection} \]

\[ \text{2-jn a-Si} \]

\[ \text{ITO} \]

\[ \text{BiVO}_4 \]

\[ \text{FTO} \]

\[ \text{Ag/Cr/Al contact} \]

\[ 4\text{OH}^- + 4\text{h} \rightarrow \text{O}_2 + 2\text{H}_2\text{O} \]

\[ 4\text{H}_2\text{O} + 4\text{e} \rightarrow \text{2H}_2 + 4\text{OH}^- \]

Power electronics: SMA products

“Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution.”

EINSTEIN
(DC) Microgrids: House of the future
(DC) Microgrids connected
Electrical energy system of the future

Energy system and society
Smart energy management
Physical system
Information technology
Big data
Open electricity market
System integration and interoperability: Transactive energy

Are you ready for the new world of transactive energy?
Transactive energy: Multi-disciplinary approach