Overview of the GreEnergy Project

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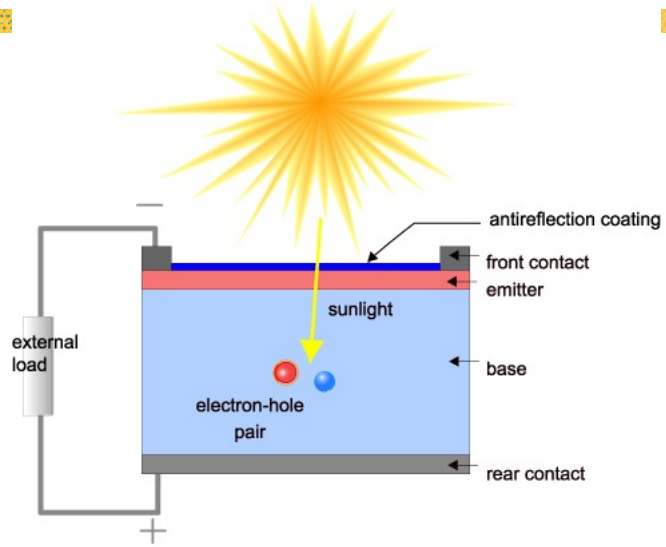
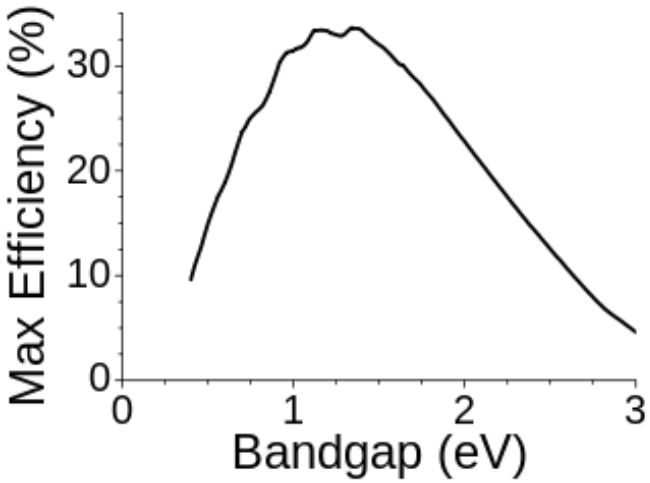
First GreEnergy workshop - Roadmap from design to production of nanoantennas based solar energy harvester 16 October 2023

GreEnergy

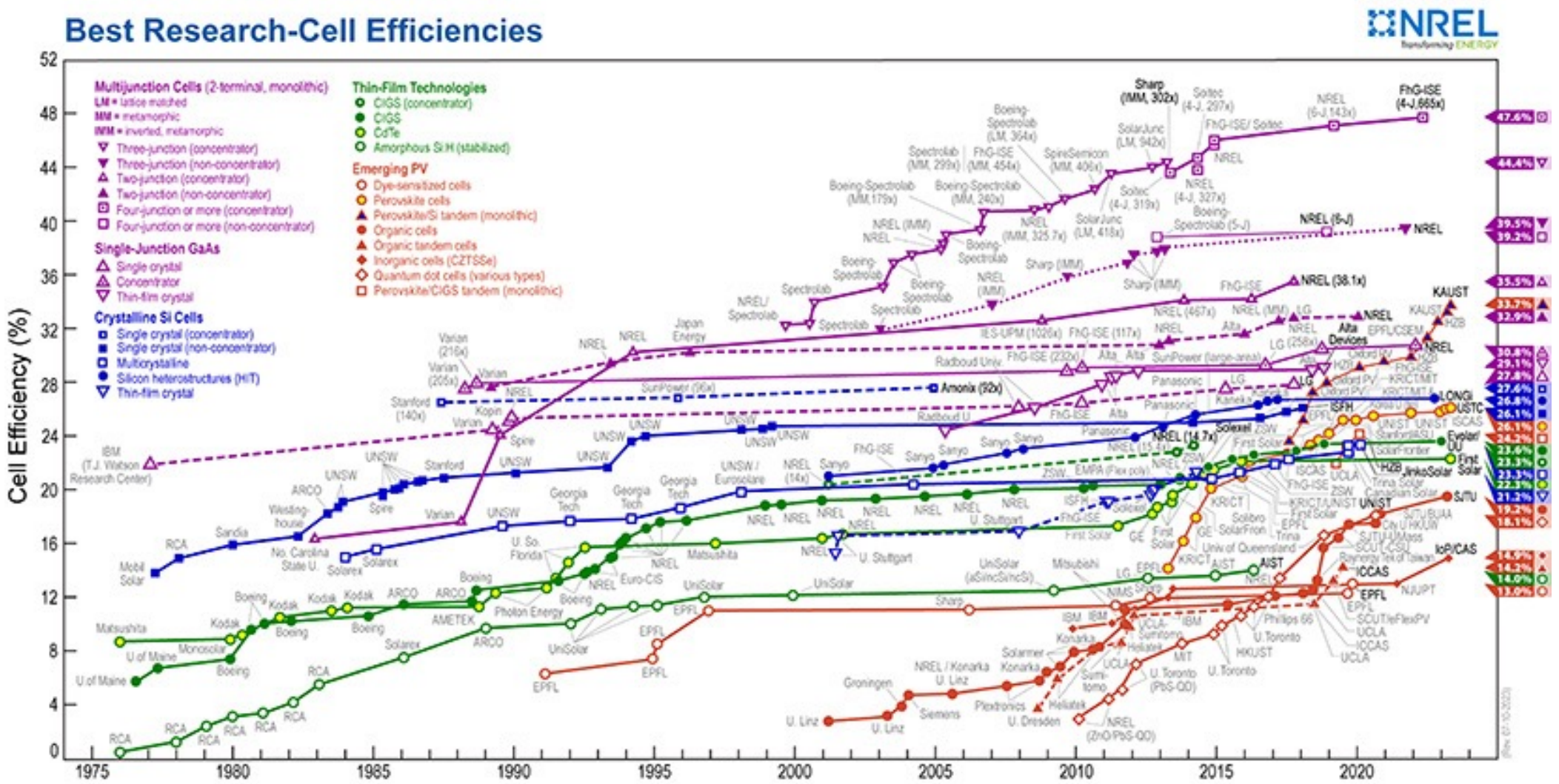
Sun Energy harvesting by a single junction PV cell efficiently

- Traditional single-junction cells with an optimal band gap for the solar spectrum have a **maximum theoretical efficiency of 33.16%,** the Shockley–Queisser limit
- Rühle, Sven (8 February 2016). "Tabulated Values of the Shockley–Queisser Limit for Single Junction Solar Cells". *Solar Energy*. **130**: 139–147. Bibcode:2016SoEn..130..139R. doi:10.1016/j.solener.2016.02.015

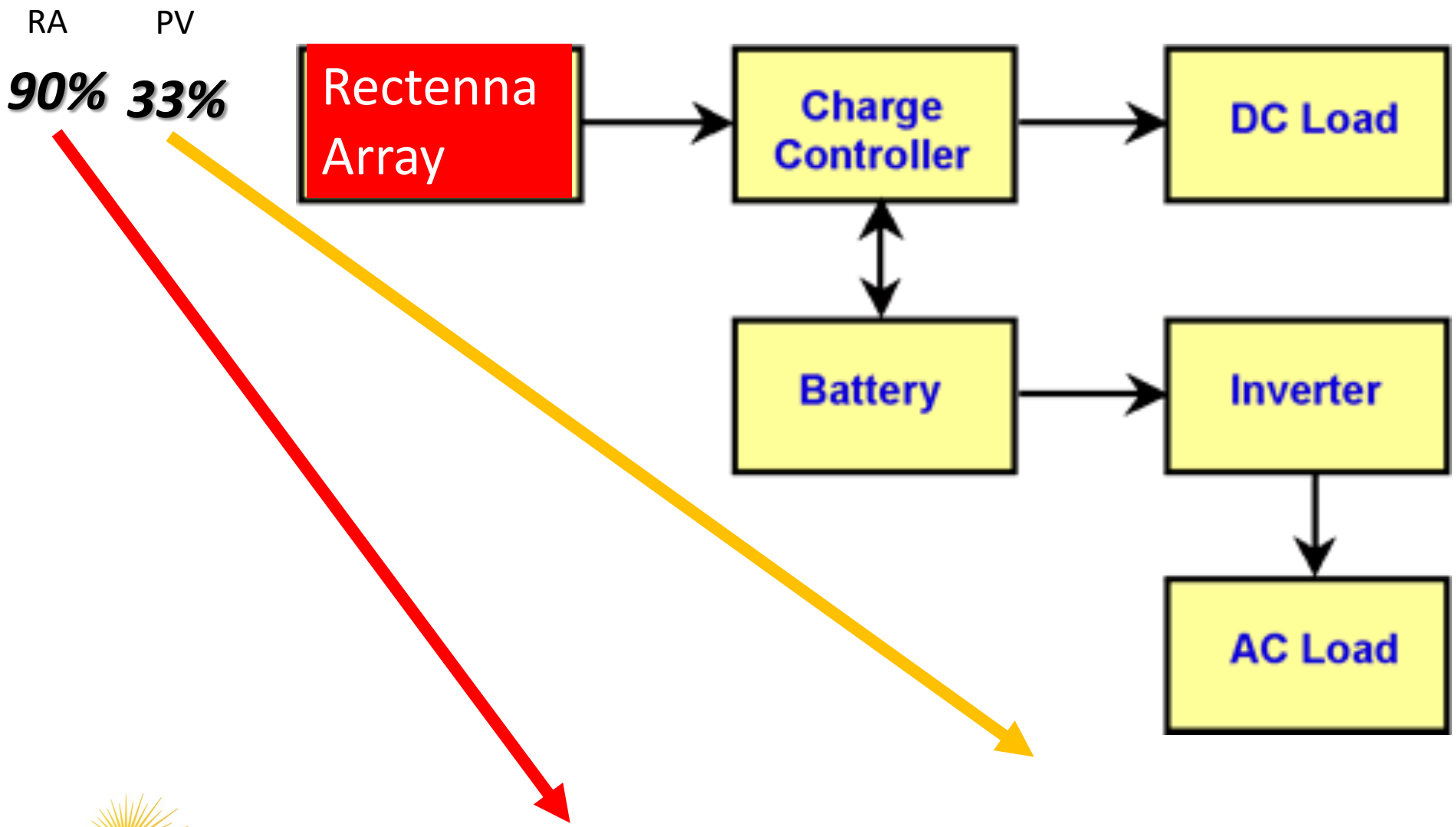




Sun Energy harvesting by a multi layers/ junctions PV cell efficiency

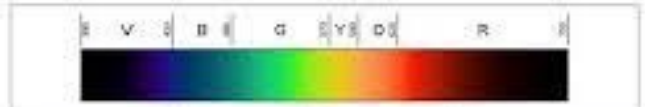


….from the PV cells to the LOAD…..efficiency drops…..



GreEnergy project challenge

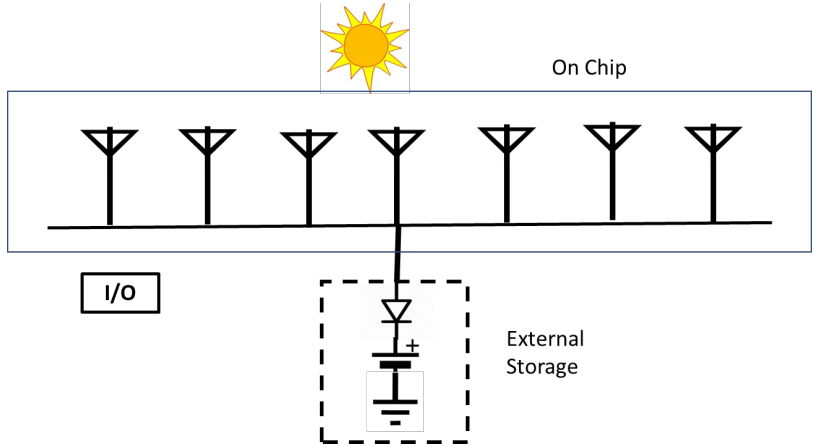
- **Photon energy** is the energy carried by a single photon. The amount of energy is directly proportional to the photon's electromagnetic frequency and thus, equivalently, is inversely proportional to the wavelength.
- Capturing the electromagnetic waves with a nanoantenna can lead to much higher efficiency……**theoretically to more than 90%.**
- In the last decade many tried but didn't succeeded to demonstrate such a nanoantenna light harvester!!!!
- Why???
  - We are dealing with very high ac frequencies (400-800THz;400-800nM)
  - No efficient rectifier exists

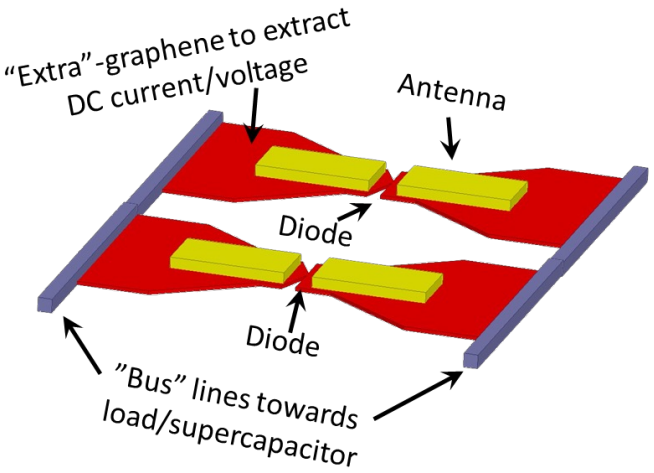


Color	Wavelength (nm)	Frequency (THz)	Photon energy (eV)
violet	380–450	670–790	2.75–3.26
blue	450–485	620–670	2.56–2.75
cyan	485–500	600–620	2.48–2.56
green	500–565	530–600	2.19–2.48
yellow	565–590	510–530	2.10–2.19
orange	590–625	480–510	1.98–2.10
red	625–750	400–480	1.65–1.98

GreEnergy Project concept

- Adopting system approach
- System architectures design
- Building a strong modelling and design group
- Two rectenna (antenna + rectifier) manufacturers (to reduce risk)
- Energy storage manufacture
- Power Management unit design and manufacturing
- Integration





GreEnergy - Factsheet

- Leibniz Institut für innovative Mikroelektronik
- University of Udine
- Chalmers University of Technology
- AMO GmbH
- SCIPROM Sàrl
- Università Politecnica delle Marche
- Aalto University
- NOGAH PHOTONICS Ltd

Horizon 2020
Call: H2020-LC-SC3-2018-2019-2020
(BUILDING A LOW-CARBON, CLIMATE RESILIENT FUTURE: SECURE, CLEAN AND EFFICIENT ENERGY)

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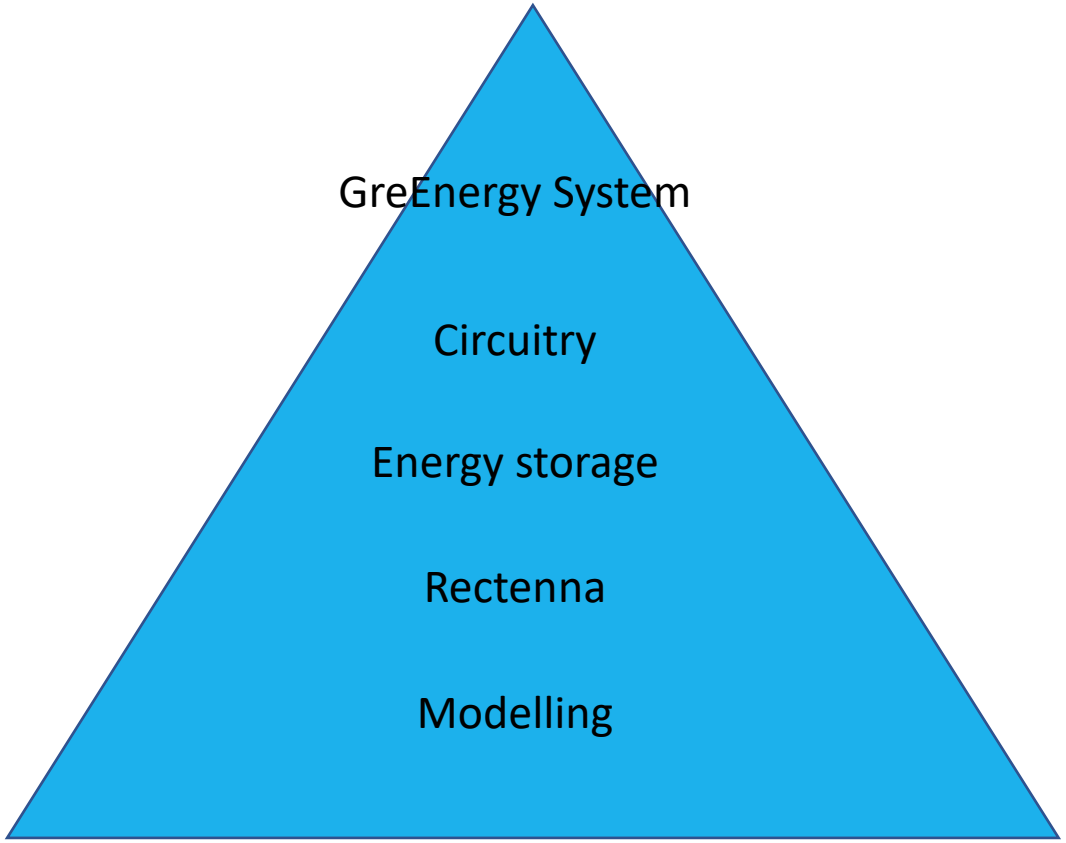
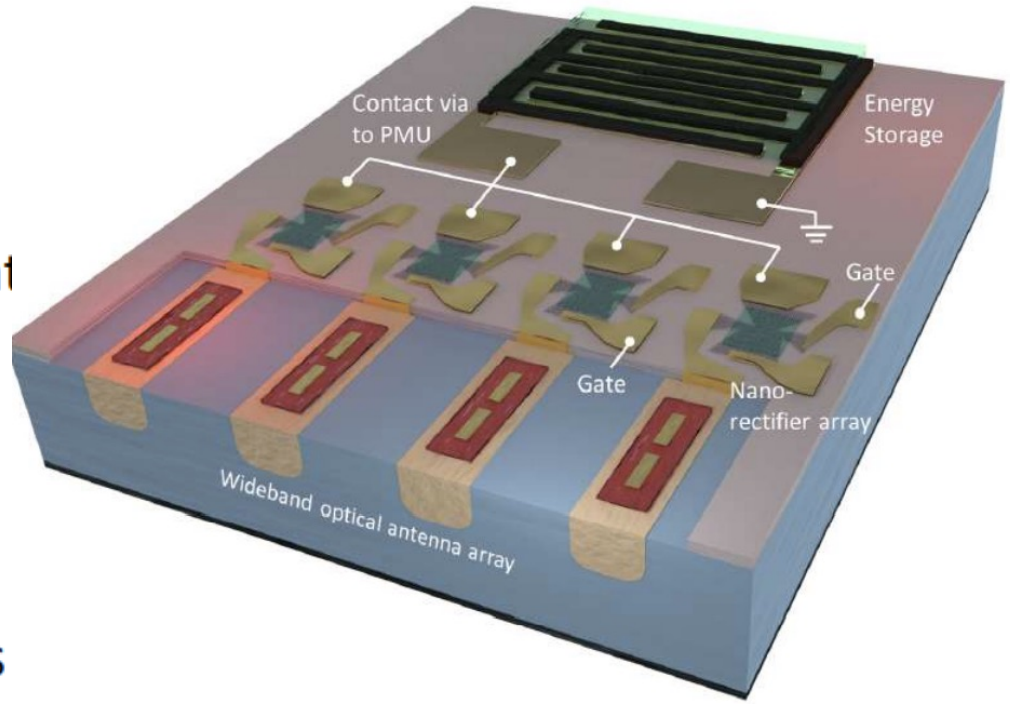
GreEnergy Project team members

- AMO – System design and rectenna manufacturing
- Aalto – Rectenna manufacturing
- Chalmers – Energy Storage & Integration
- IHP – Circuitry design
- Udine University - Modelling
- Ancona University – Modelling
- Nogah Photonics – Modelling
- SCIPROM – Management



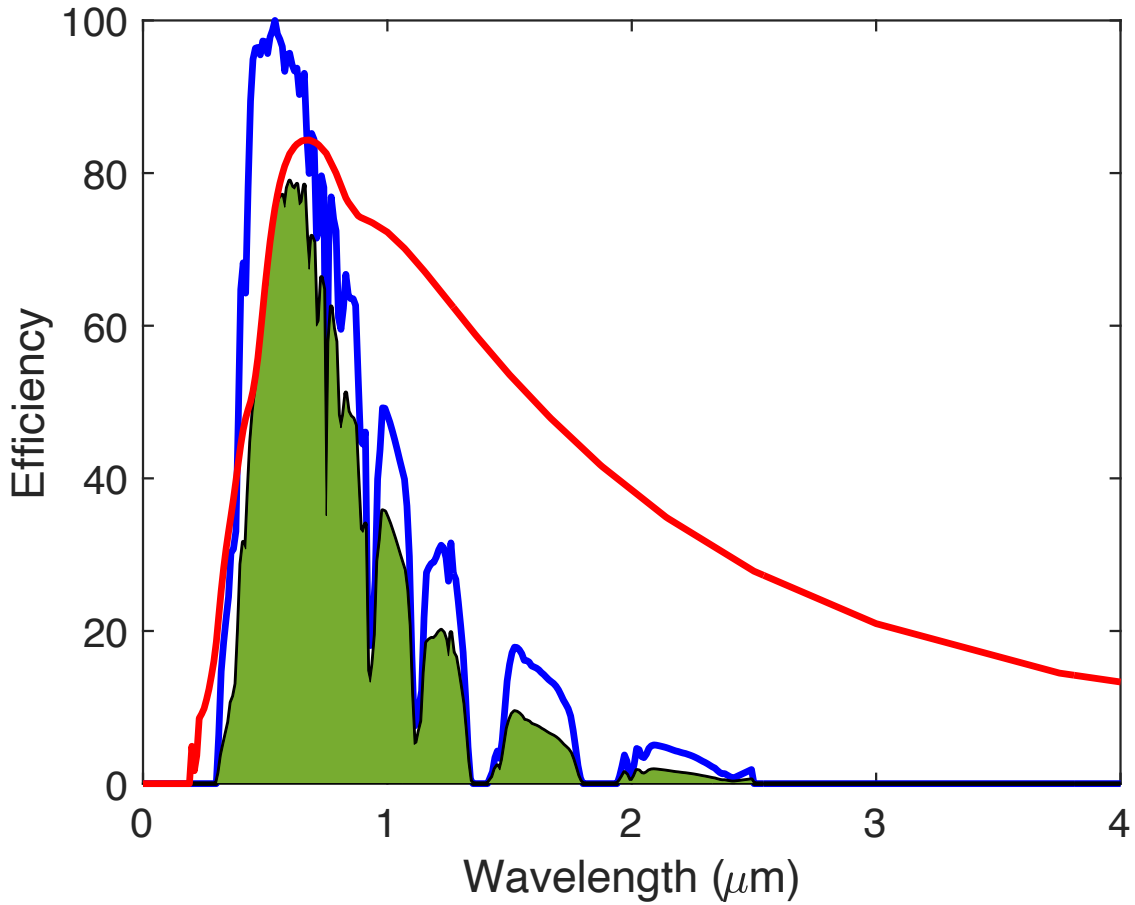
Objectives of GreEnergy

- Development of optical antenna with 20-40% energy efficiency using wide bandwidth nano-antennas
- Development of nano-rectifier and energy storage component
- Develop process for on-chip integration of antenna/rectifier with power management unit and energy storage device
- Develop prototype of integrated system, which demonstrates charging of the supercapacitor by the antenna/rectifier system

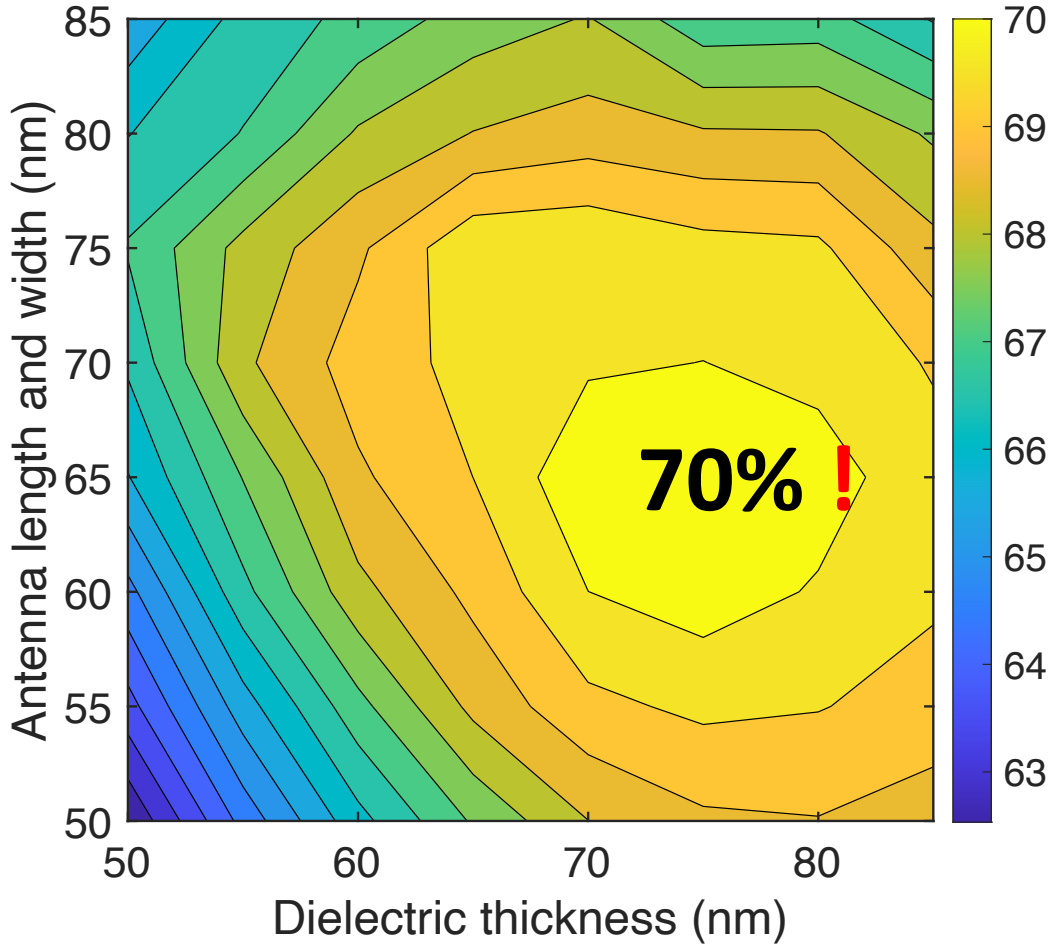


Antenna design

Antenna efficiency

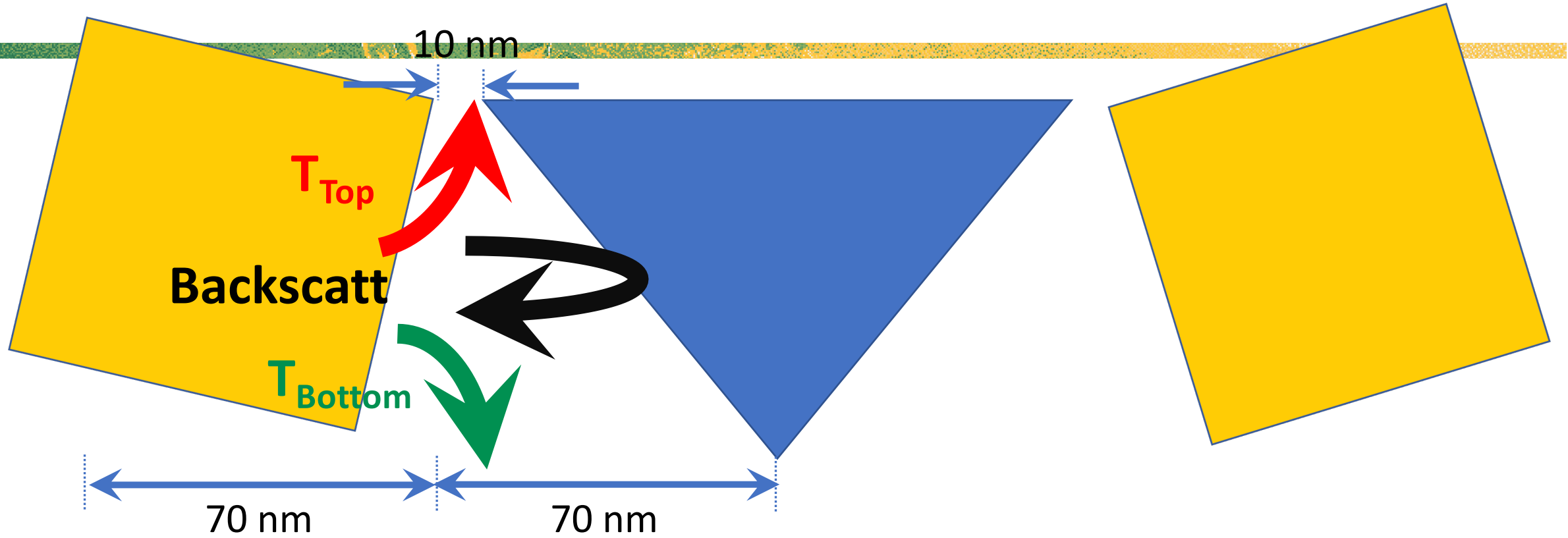


RECEIVING efficiency



30% is just dissipated or reflected

Ballistic Diode - BILLIARD COMPUTATION OF CHARGE MOTION



Trajectory	Efficiency
T_{top}	6% (previous slide 8%)
Backscattering	25% (previous 50%)
T_{Bottom}	69% - 11:1 ratio (41% - 5:1)
	Maybe more?

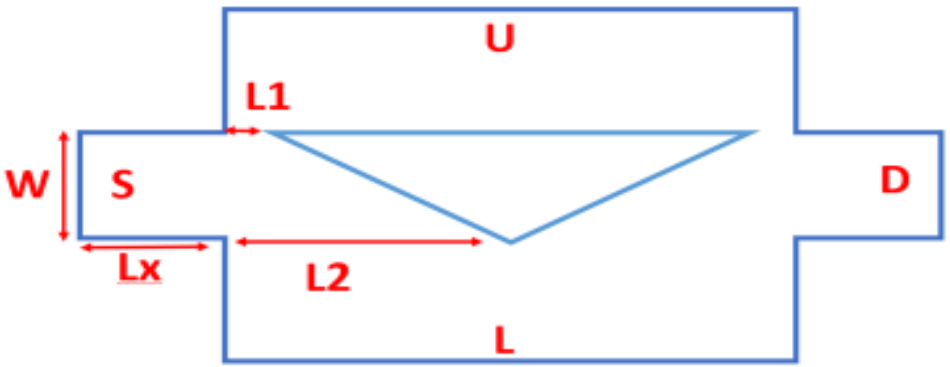
KEY POINT

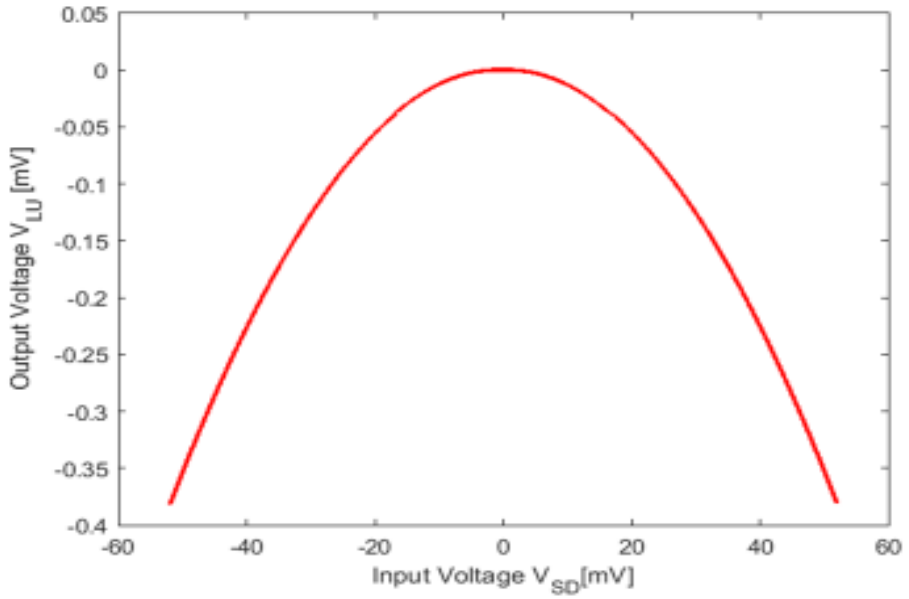
MEAN FREE PATH LENGTH

$\gtrsim$ 150÷200 nm

Ballistic diode design

4 terminal rectifier configuration under ballistic conditions





Simulations parameters:
Lx=100nm
W=800nm
L1=300nm
L2=2500nm
n= 8e11cm-2

Input resistance Rsd=370 Ω

What next

- Manufacturing Ballistic Diode and measurements
- Modelling calibration and redesign
- Rectenna (Rectifier and Antenna) manufacturing and measurements
- Modelling calibration and redesign (if needed)
- Design of rectenna array options
- Integrating a GreEnergy system (Rectenna + Energy storage) and testing
- Systems model calibration

CHALMERS UNIVERSITY OF TECHNOLOGY

AMO

NOGAH Photonics Ltd

Aalto-yliopisto

ihp

SCIPROM Science, Management & Communication

Università Politecnica delle Marche

Università degli Studi di Udine

Thank you for your attention

More information is available at **www.greenergy-project.eu**

GreEnergy

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