

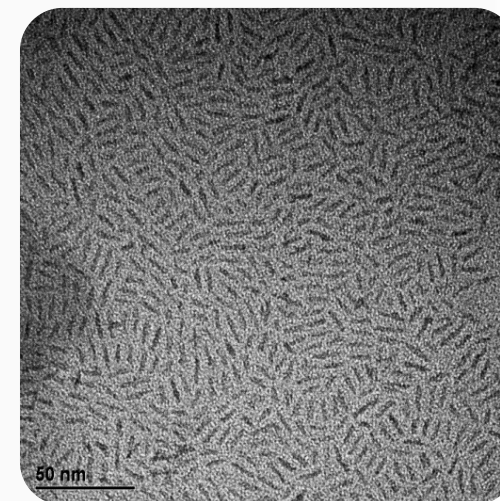
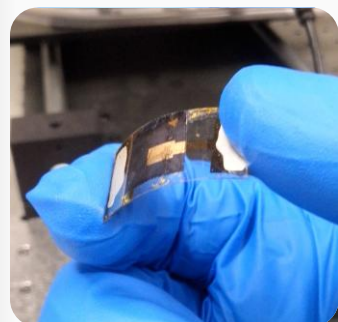
Institute of Chemistry
The Hebrew University of Jerusalem

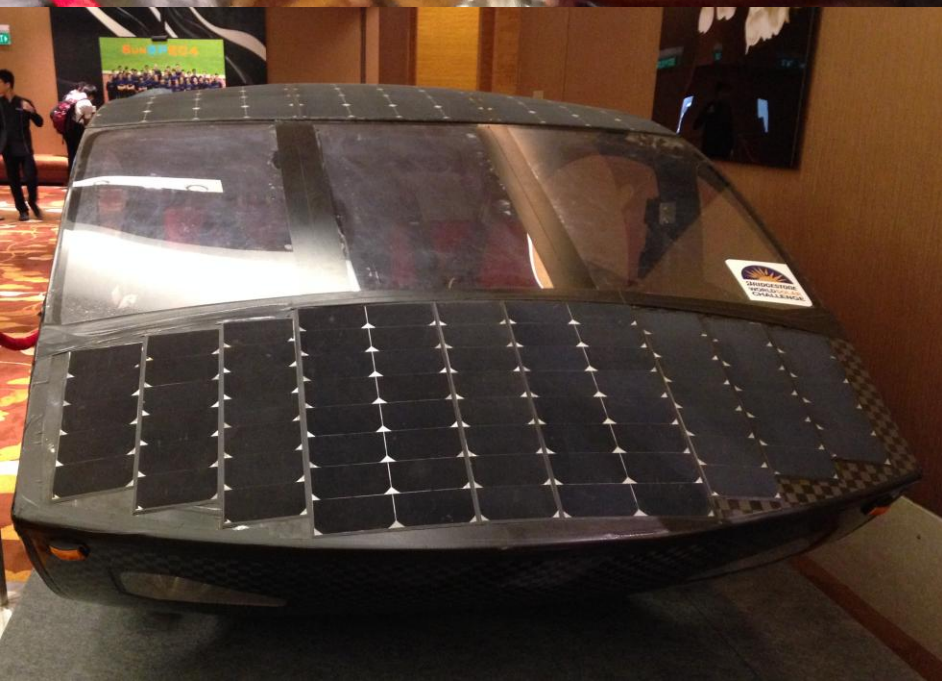


Towards a Sustainable Energy System

Lioz Etgar

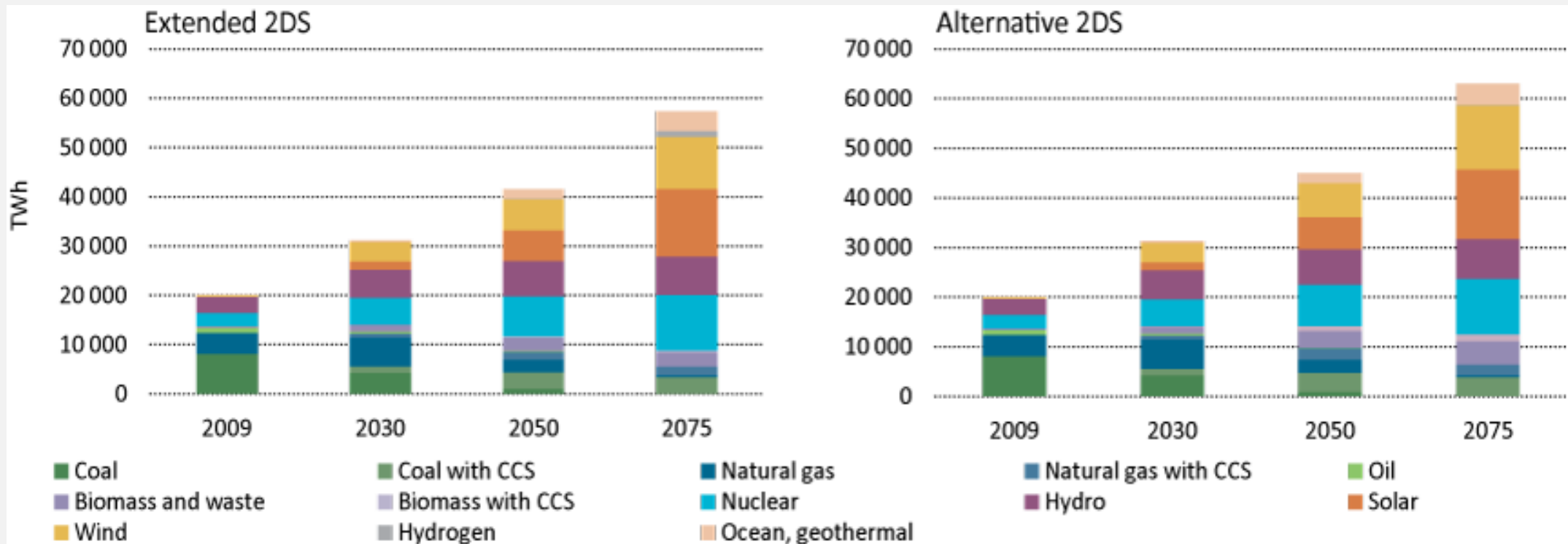
<http://chem.ch.huji.ac.il/etgar/>
lioz.etgar@mail.huji.ac.il





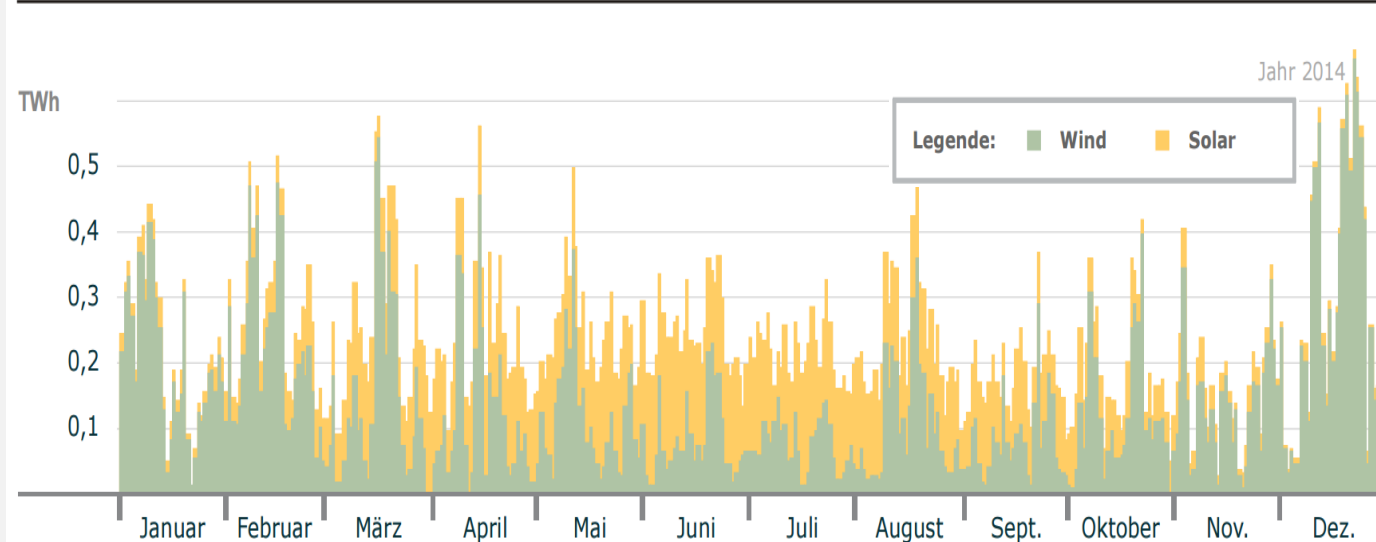
Renewable energy resources are the backbone of any sustainable future

Solar energy is by far the largest energy resource on earth



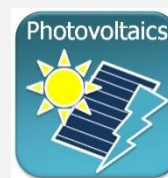
Exploiting the Power of the Sun

Daily production of solar and wind in Germany

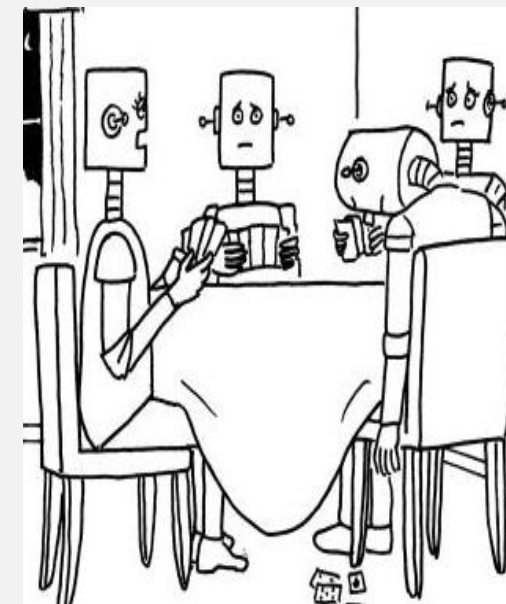


From: B. Burger, Fraunhofer ISE (2014)

- Highly efficient low cost solar energy conversion
- Batteries for short-term balancing
- Fuel-based concepts are needed for longer-term storage



Thinking
the
Energy
System



He's not much fun
in the evening
He uses solar cells

Common Challenges for PV & Solar Fuels

R&D needs for PV Technology ⁽¹⁾

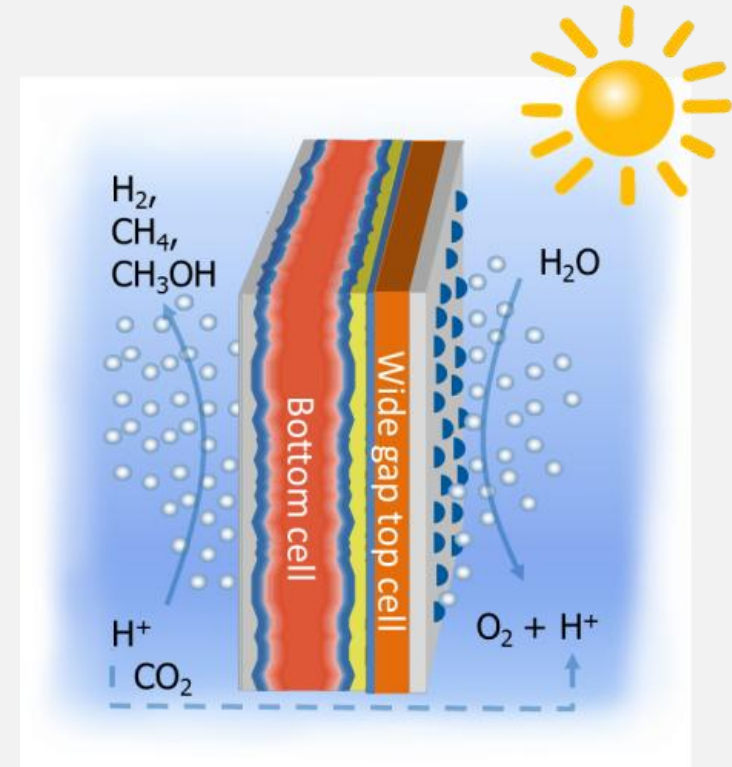
- Low-cost production processes
- **Increased efficiencies**
- **Development and innovation by e.g. new materials**
- Intelligent systems solutions

Research needs for Solar Fuels

- Earth-abundant catalysts
- **Stable and efficient light absorbers**
- Smart cell design by e.g. light management

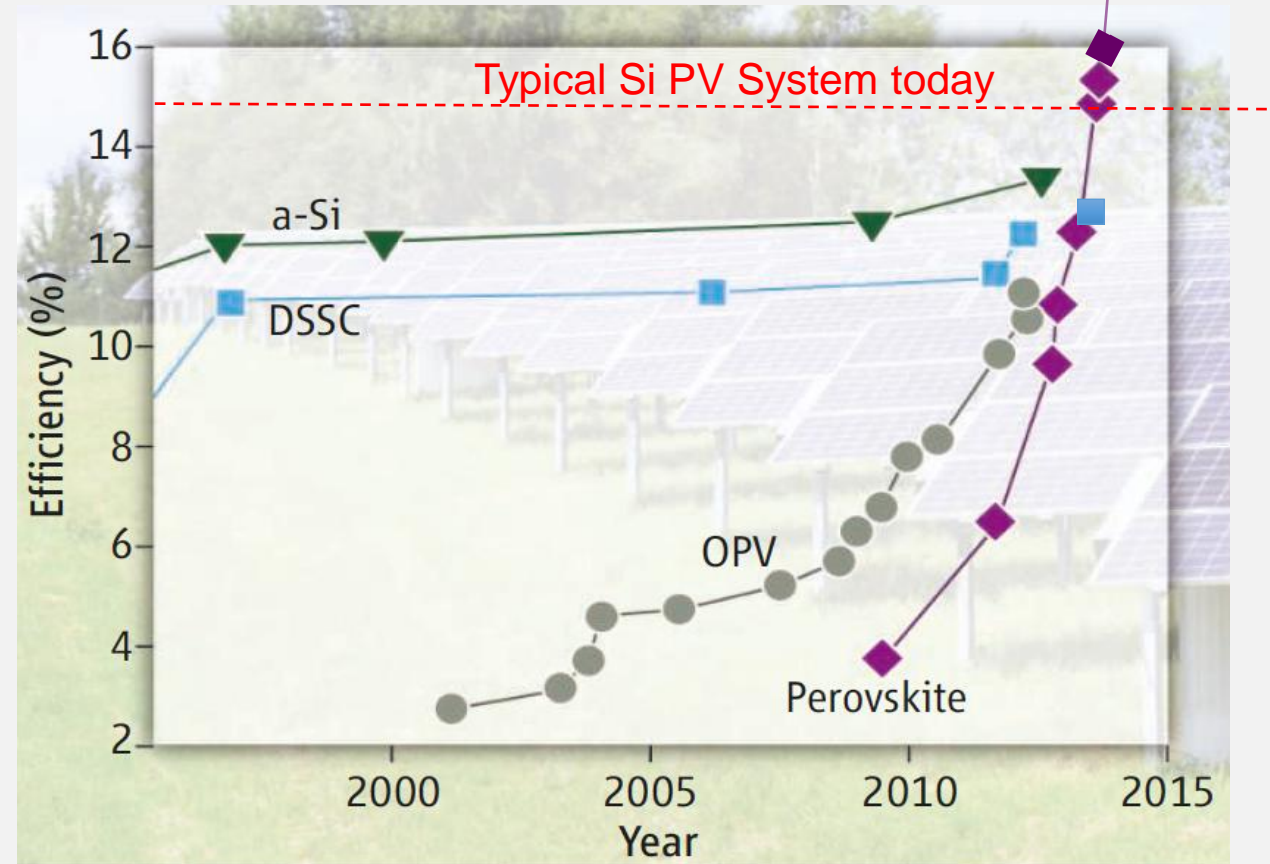
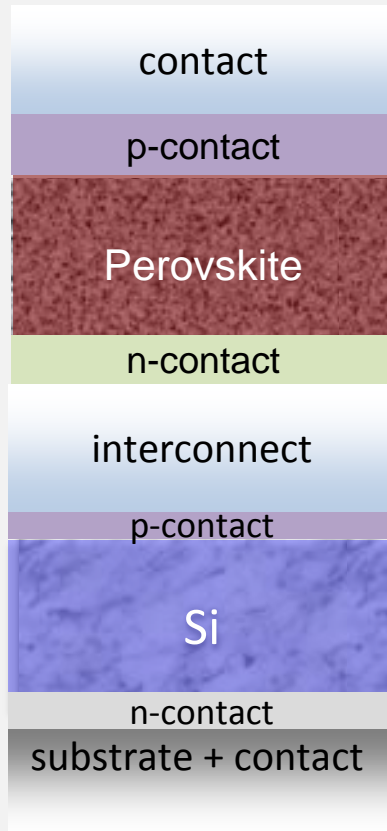
Approach:

Electricity for fuel generation by high-voltage multi-junction cells including novel wide-bandgap absorbers



Multijunction hybrid cells: going beyond 10% solar-to- H_2 efficiency and >25% photovoltaic efficiency, ***at a price we can afford***

Today's **Unique Opportunity** (1) Overcoming Limits of Today's Technology



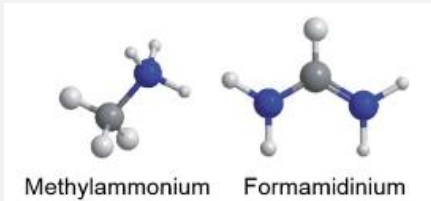
Evolution of halide perovskite solar cells

Perovskite/Si tandem cell opens up a path to efficiencies > 30%

Today's Unique Opportunity (2) & Challenges

Halide Perovskite Semiconductors

Organo- Cs,



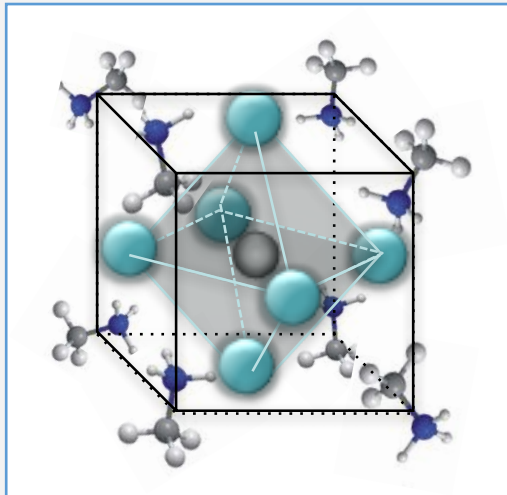
Perovskites

Metallic-

M = Pb, Sn 

Halide-

H = Cl, Br, I 



Low T processing

High quality semiconductor

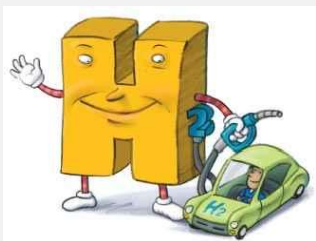
Chemical variability

- Critical Stability
- Best performance with Pb
- Interface control?

Solution requires:

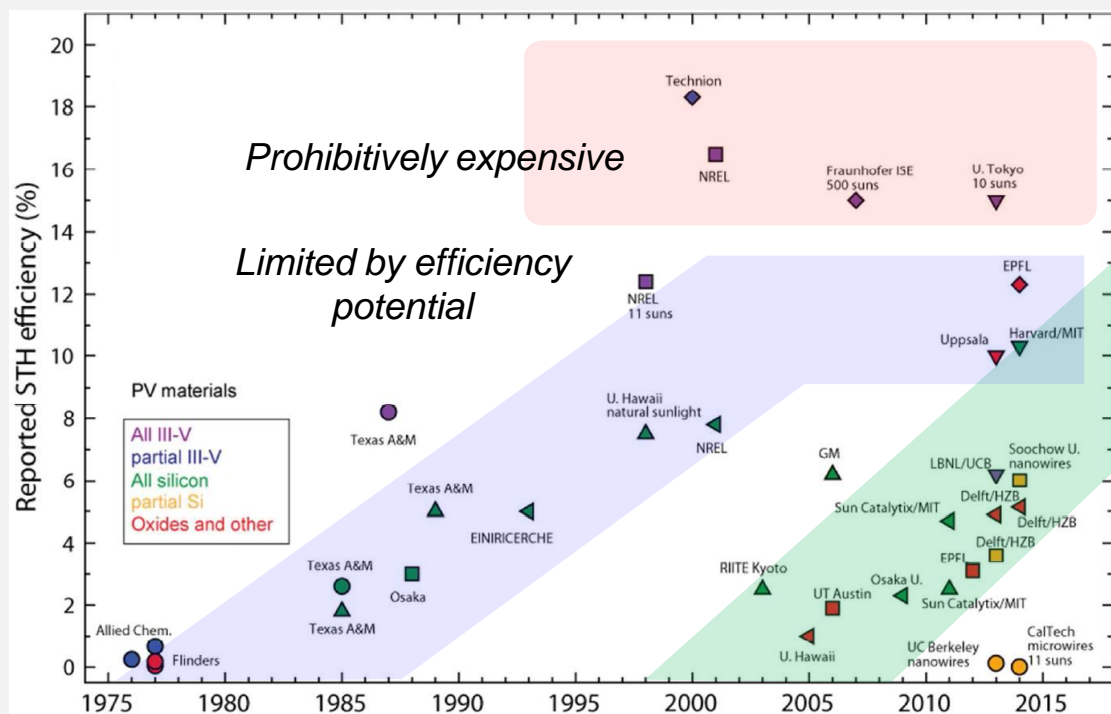
In-depth understanding and control
of materials – interfaces – devices!





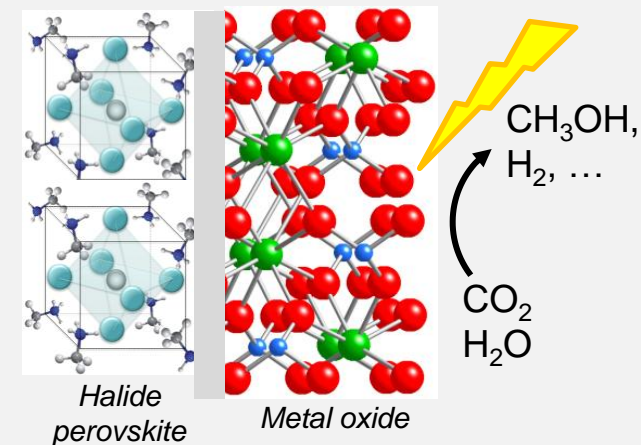
Today's Unique Opportunity (3) & Challenges

Solar Fuel Devices



Ager et al., *Energy & Env. Sci.* 8 (2015) 2811

New wide-bandgap oxide semiconductors that are **stable and efficient**



Hybrid Tandem Concept for Solar Fuels

Next-Generation Solar Fuel Devices Require:

- Discovery and optimization of **new semiconductors**
- Understanding of semiconductor / catalyst interfaces
- Strategies for managing photons, electrons, and ions

Example: BiVO₄

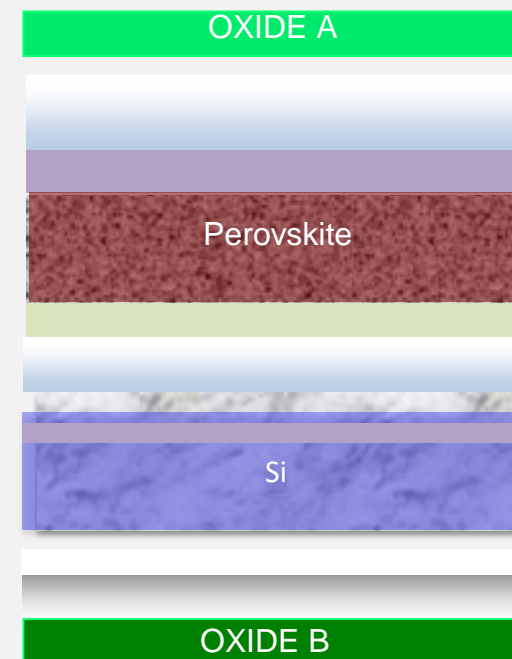
A new oxide semiconductor that now shows efficiencies close to 90% of theoretical value

Goals & Key Questions

How we design novel, **more efficient** and **stable halide perovskite & metal oxide** light absorbers?

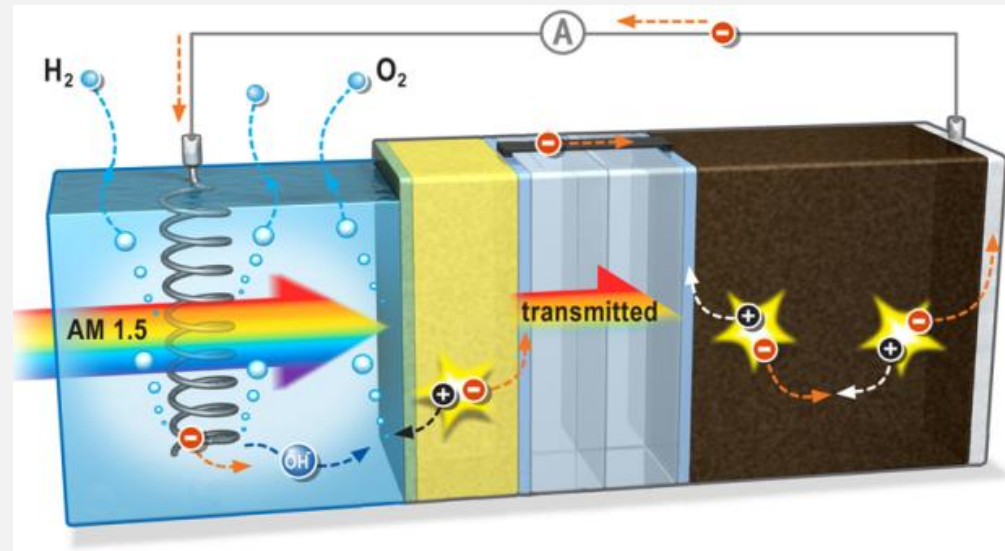
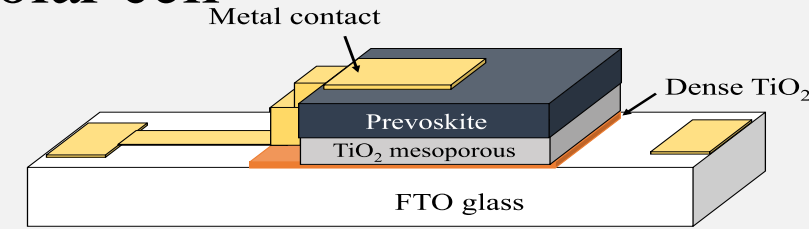
Can we **reduce efficiency losses** by **understanding** of physical and chemical processes at **interfaces**?

Can new large-bandgap **light absorbers** reach the required **solar-to-fuel efficiencies** and **chemical stabilities** needed for practical applications?



We already achieved...

- Voltage of 1.5V for single perovskite solar cell
- Efficiency of more than 20%
- Stable perovskites for high light intensity



Seizing the chance: Tackle the challenge towards highly efficient Solar Fuels

Breakthroughs with **halide perovskites** finally offer paths towards high-voltage, highly efficient, and affordable solar electricity and fuels

Scientific Challenge: Generation of **electricity** for **fuels** by high-voltage multi-junction cells that include novel wide-bandgap absorbers
⇒ **key enablers for a sustainable energy future**

Perovskites for Photovoltaics in the Spotlight: Photoinduced Physical Changes and Their Implications

...Zaban et al. Acc.Chem. Res.2016

Vapor and healing treatment for $\text{CH}_3\text{NH}_3\text{PbI}_{3-x}\text{Cl}_x$ films toward large-area perovskite solar cells

...Zaban et al. Nanoscale. 2016

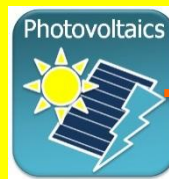
High voltage and high efficiency two dimensional perovskite

...Etgar. Et al. Advanced Functional Materials.2016

Inorganic and hybrid organo-metal perovskite nanostructures: synthesis, properties and applications,

...Etgar. Et al. Advanced Functional Materials, 2016,

**Novel
High Quality
Highly Stable
Wide Gap
Semiconductors**



Perovskites roll forward

Hodes, Cahen, Nat. Photon. 2016

Hybrid organic-inorganic perovskites

...Kronik, Hodes, Cahen, Nat. Mat. Rev. 2016

Omer Yaffe , WIS

Electrocatalysis (Menny Shalom, BGU),

Degradation of perovskites ...Visoly-Fischer, Etgar, Katz, J. Phys. Chem. Let. 2015, ChemSusCehm.2016

Thank you

<http://chem.ch.huji.ac.il/etgar/>
lioze.etgar@mail.huji.ac.il



