ENERGY GAME CHANGERS

September 18, 2018

Washington, DC



The Value and Importance of Fundamental Research in Energy

Clean, Affordable, Reliable, Resilient Electrical System of the Future

D Powering US Industry of the Future

CLEAN, AFFORDABLE, RELIABLE, RESILIENT ELECTRICAL SYSTEM OF THE FUTURE

Francis O'Sullivan (MIT) - Moderator Vladimir Bulović (MIT) – Solar William Chueh (Stanford) – Storage Virginia Wright (Idaho National Lab.) – Cybersecurity Dennis Whyte (MIT) - Fusion

Solar Energy: Can we recapture solar manufacturing by further lowering cost?

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NEARLY FREE ENERGY:

Solar PV is the only energy generation technology that has the potential to produce nearly free (<1 ¢/kWh) energy

SOLAR R&D WORKS:

Joint government-commercial-academic R&D (largely in the U.S.) has brought down the cost of solar to today's competitive level

PURSUE ADVANCED SOLAR:

U.S. has historically led in the support of solar R&D, but China now reaps the manufacturing benefits. To leapfrog ahead again, we should double down on a new generation of advanced solar technologies.

Success of U.S. Solar RD&D Over the Last 40 Years



PVs: Lowest LCOE with Potential for Further Reductions!



- For <\$10B in investment, industry revenue is now
 \$20B annually in the U.S.
- 8,000 businesses and 260,000 jobs total (downstream), larger than coal, oil, and gas extraction combined.
- Reliable path to:
 - ... combat Climate Change,
 - ... improved Grid Resilience,
 - ... boost our National Security.

Potential for **NEARLY-FREE** Energy from Solar PV

Reduce installation costs with LIGHTWEIGHT, FLEXIBLE modules



CONVENTIONAL installation

- <u>Rigid</u>, <u>fixed</u> modules
- <u>Aluminum</u> racking
- <u>Discrete</u> wiring and electronics



FLEXIBLE installation

- <u>Flexible</u>, <u>retractable</u> modules
- <u>No</u> racking
- Integrated wiring and electronics

Integration of PVs into existing surfaces could REDUCE PV cost by FACTOR of 3 !

Pursuit of ADVANCED SOLAR PVs !

- Lightweight with high power-to-weight ratios
- Flexible module formats of any form-factor
- Using **abundant** and **inexpensive** materials
- Produced at high speed and w/ high efficiency
- Engineered to absorb different colors of light







Key trends in electricity generation & storage



<u>**Grid</u>**: Can renewables + storage compete on cost with fossil fuels?</u>

Short Duration Storage for Grid: 3-10 hours



California Independent System Operator / DOE-EERE

Long Duration Storage for Grid: Days to Seasonal



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Shaner, Caldeira et al. Energy Environ. Sci. 11 (2018) 914.

Storage Game Changer

Today's battery technology for transportation

Tesla

\$200/kWh

Tomorrow's battery technology for grid storage

San Diego G&E

Looks more like a chemical plant \rightarrow < \$20/kWh

New set of challenges for grid storage will require basic energy and R&D investment to prepare for a future that runs on clean & cost-competitive electricity

Storage technologies that win on economics

Li, Chiang et al., Joule 1 (2017) 306

Grid Cyber Security

[please see attachment -ed]

Approaches to fusion have been sub-optimal

Either "too big" or "too unproven" and thus "always 30 years away"

History of "bootstrapped" breakthroughs in magnet and fusion science and technology

HTS is the disruptive technology for fusion

High-temperature superconductors (HTS) 1000x larger operating space, enabling much higher magnetic fields

current density [A/cm²] HTS 50 40 100 150 60 200 80 50 temperature [K] magnetic field [T] Superconducting operating space

From a fundamental discovery (1988) to a mature, commercially available technology produced at scale

HTS → SPARC achieves net energy gain at university/Start-up scale

Human for scale

ITER Magnetic field = 5.3 T Fusion power = 500 MW Energy gain = 10 ARC Magnetic field = 9.2 T Fusion power = 500 MW Energy gain = 10 SPARC Magnetic field = 12 T Fusion power > 50 MW Energy gain > 2

Designed using the same demonstrated physics

SPARC optimizes the path to fusion energy

high-confidence physics fast/small/ inexpensive Genera Fusior low-confidence physics (to scale)

slow/big/

expensive

Proven physics

~70x smaller than ITER

Magnet technology scales to commercial power plants

CFS company launched /w collaborative research at MIT Major domestic and international investment Start of a new energy industry... **52**

Thank you

Khaili Amine (Argonne National Lab) Robert Armstrong (MIT) Michael Aziz (Harvard) Angela Belcher (MIT) Sally Benson (Stanford) Craig Blue (ORNL) Fikile Brushett (MIT) Vladimir Bulović (MIT) Jeremy Carl (Hoover/Stanford) Yet-Ming Chiang (MIT) Christopher Chidsey (Stanford)

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