

**Panel:** Science & Technology for Carbon-free Alternatives at the Right Price

Moderator: Stuart Bernstein, Global Head of Clean Technology, Goldman Sachs

- Solar Energy as Base Power  
**Ramamoorthy Ramesh**, Associate Laboratory Director for Energy Technologies, Lawrence Berkeley National Lab
- Deeper Efficiency and Cost Reductions for PV  
**Craig Peters**, Co-Founder, PLANT PV
- Scaling of Biofuels  
**Chris Somerville**, Director, Energy Biosciences Institute, UC Berkeley
- New Business Models for Nuclear Energy Enabled by Modular Design, Scalability and Global Markets  
**Per Peterson**, Professor, UC Berkeley
- US Thermoelectric Power Solutions  
**Matt Scullin**, CEO Alphabet Energy

**Context**

- Main technologies include solar, nuclear, biofuels, and waste heat recovery.
- Cost is the key to success. Reductions in cost can help reduce reliance on subsidies.
- Venture firms are down on hardware because of the high volumes of required capital.
- Capital is difficult to raise for energy hardware development.
- Cleantech market had a correction after 2010. More difficult to raise money now, but investors better understand the energy industry.
- Money has shifted outside of Silicon Valley and the US to family wealth, corporate strategies, and China.
- The grid of the future will grow analogous similar to cell phones in terms of interconnectedness and distribution. Need to take small steps with end products and their efficiency on the way to developing the associated microgrids.
- Market investments expect returns in ~5 years. Time to return depends on the technology. Higher barrier to entry with larger capital costs.
- Largest problem with wind power is the uncertainty of the associated policy measures.

**Solar/PV**

- Solar in US installed at ~\$2.10 USD/watt while Germany can install solar at ~\$1.40 USD/watt.
- Solar install costs heavily influenced by permitting process.
- Efficiency is still important to bring costs down, but grid integration will rely on acquiring more data about the use and function of each connected cell.
- Goal with solar is to get a flat line of provided energy at \$0.05/kWh
- Natural gas target is \$0.03/kWh.
- Storage devices are required to achieve flat line generation from intermittent renewable sources.
- Producing solar cells with the same efficiency as the market but for less money is unlikely to result in growth in the solar install base.

- US leads solar in knowledge but lags in translation of that knowledge to the market and large manufacturing scale.
- Solar achieves grid parity at \$1/watt with an assumed 20% working time.

### **Biofuel**

- US & Brazil are the two main biofuel markets
- Bioconversion seems to be the most promising route to commercializing biofuels.
- Policy mandates provide a market for biofuels, although there is still regulatory uncertainty.
- In December, BP stopped trying to commercialize biofuels.
- There is fear that Food-for-Fuel programs will increase inequity because commodity producers may sell to the most lucrative market.
- Simultaneously, biofuel production can increase food security by increasing the value of a substantial food crop.

### **Nuclear**

- Nuclear requires new waste disposal methods
- Nuclear substitutes almost directly with coal.
- Possible to deploy rapidly and at large scale with plant standardization
- Standardization should include a focus on safety and on plant manufacturing.
- Making nuclear plants larger doesn't make them cheaper.
- Material replacements (e.g. Molten salts instead of water) can increase safety of plants.
- Nuclear plants require replaceable components for easy upgrades over their lifetime.
- Smaller modular reactors with simple designs can enable larger markets and easier production scaling.
- Need to recognize the opportunity cost, environmental and social implications associated with shuttering old nuclear plants.
- Challenge with nuclear is how to scale to a significant fraction. It requires improvements and focus.
- Nuclear needs a set of best practices and innovations. Can look to biotech industry to qualify investments overlong periods of time a la FDA testing and validation.
- While removing CO<sub>2</sub> from the atmosphere is incredibly difficult, nuclear waste can be recycled or disposed of geologically. It is safe but presents a policy problem and needs to be solved regardless of expansion or contraction of nuclear energy generation.

### **Thermoelectric**

- Thermoelectrics can achieve grid parity at \$5/watt because industrial waste heat is on ~100% of the time.
- Thermoelectrics are 100x as power dense as photovoltaics.
- Geothermal energy generation requires much more research and investment in the technology to improve its viability.