Preface

The 1973 Arab oil embargo with its associated gas lines was the first energy shock for the US. This led to President Gerald Ford launching a government funded program dedicated to US energy independence. This energy independence program was continued under President Jimmy Carter with an emphasis on renewable nonpolluting energy sources such as solar and wind. In 1975, Solar Technology International was formed in California to bring silicon solar cells down from space for terrestrial applications.

In a solar cell, sunlight is converted directly into electric power, the most valuable form of energy. This is a very elegant option with two outstanding advantages.

- There are no moving parts and semiconductor devices have almost no need for maintenance.
- No fuel is necessary eliminating almost all negative environmental impacts.

By 1980, Solar Technology International was the first to manufacture 1 MW of terrestrial solar modules per year. However, unfortunately, while President Carter had installed solar panels on the White House rooftop, President Ronald Reagan then removed them in 1980 and launched a new unspoken energy policy for the US where the US would defend access to the oil in the Middle East with military action if necessary. The first Middle East oil war eventually followed in 1991 when Iraq invaded Kuwait.

Meanwhile there was a Green Movement in Germany, Japan, and the US with homeowners buying terrestrial solar modules for off grid and grid connected applications. By 1999, terrestrial solar modules generating 1 GW of electricity were in operation around the world.

By the end of 2012, 100 GW of solar electric power had been installed around the world using solar cells including now large utility central power stations. We are now in the middle of a solar revolution. Chapter 1 herein recites the history of this solar cell revolution noting not just the history of the scientific cell and module research innovations but also noting the important roles played in policy and financial investments made by different governments at different times during this revolution up to today.

The arguments in favor of renewable energy are described in Chap. 2 with a discussion of Peak Oil and even the potential of a natural gas bubble over the next 5–10 years. Climate change is obvious with evidence of the glaciers melting and environment impacts such as Super Storm Sandy and Typhoon Haiyan. For evidence of pollution from coal, one only needs to look at the pictures of haze in Beijing and Shanghai on the TV news.

The technical aspects of solar cells are presented in Chaps. 3 and 4. Chapter 3 discusses the various types of solar cells and modules and systems and their production status today and Chap. 4 describes how solar cells work and emphasizes the importance of single crystal semiconductors for achieving high cell efficiencies.

The dominant solar cell module in the market today is the crystalline silicon (c-Si) solar module. That core technology is described in detail in Chap. 5. Installed system prices for that c-Si technology have now fallen to $2.50 per W and are continuing to fall. There are clear technical paths for continued cost reductions.

A dream for over 30 years now has been the idea that noncrystalline thin film cells will lead to even lower installed solar residential and utility system prices. Unfortunately, for scientific reasons explained in Chap. 4, this dream has not turned into reality because the conversion efficiencies of noncrystalline thin film cells are limited. Nevertheless, there have been outstanding achievements in this field. I have been using an Eco-Drive wristwatch as well as a simple calculator for years now powered by amorphous silicon photovoltaic cells. There has also been another outstanding spinoff application of amorphous silicon semiconductor devices as large area Field Effect Transistor drive circuits for liquid crystal displays. These displays are in our I-Pads, Cell phones, flat screen, TV and computer screens. This technology is described in Chap. 6. This is an example of two interacting revolutions in solar cells and displays.

Chapters 1–6 in this book describe an unstoppable solar cell revolution that is already well underway. The second half of this book describes things that are technically possible but still will require political will and financing to come to full completion.

One path for cost reduction for solar utility systems is by the use of concentrated sunlight systems. The idea is that optical elements like mirrors and plastic or glass lenses are cheaper as large area collectors than single crystal cells and that they can be used to dilute the cost of still higher efficiency solar cells at the focus of these optical elements. This Concentrating PhotoVoltaic (CPV) technology can take one of two forms with either low concentrating systems (LCPV) using 24 % efficient silicon cells or with high concentration systems (HCPV) using 44 % efficient multijunction cells. These concepts are described in Chap. 7. SunPower Corp. is having notable success with the LCPV concept with a recent announcement of an order for 70 MW of solar electric power. Chapter 8 tells the story of the development of the 40 % efficient multijunction solar cell from this author's point of view.

As noted in Chap. 1 and 2, there has been a continuing debate between the oil, gas, coal, and nuclear main stream energy groups, the incumbency, and the renewable energy advocates, the insurgency. The incumbency group has been very strong in the US as evidenced by the second Iraq war in 2003 and the unfortunate fact that the US lost its initial leading position in c-Si PV to China in 2005. The criticism by the incumbency has been that renewable energy is too expensive. This argument is now losing ground, as the first eight chapters of this book hopefully illustrate.

The incumbency argument is now shifting to the statement that solar and wind are both too intermittent. Energy storage is a solution to this problem and is already being implemented. However, there is potential help from a second ongoing revolution, the introduction of electric vehicles (EVs) as commute vehicles replacing gasoline powered cars. EVs are driven approximately 2 h to work and back each day. For the remaining 22 h, they are either sitting in a parking lot at work or they are in the home garage. Solar and/or wind can be used to charge their batteries at work and then those batteries can be used to power the home appliances at night. This vehicle to grid idea is described in Chap. 9.

While the US lost its position in PV manufacturing to China, there is still innovation going on in the US and Europe. As described in Chaps. 10 and 11, PV cells can also be used in multiple hybrid applications. For example, infrared sensitive PV cells or Thermo Photo Voltaic (TPV) cells can be used to convert infrared thermal energy from glowing objects into electricity in cogeneration applications. Natural gas heated glowing ceramic elements in home heating furnaces in cold climates can be used in homes to generate heat and electricity with 90 % conversion efficiencies. In addition, these IR cells can capture radiation from glowing steel billets in steel mills to generate electricity reducing the amount of coal burned in China.

A last very imaginative augmentation of solar energy is described in Chap. 12. This application is another example of potential interactions between two ongoing revolutions with surprising potential benefits. One of the challenges that solar energy faces is associated with the fact that solar energy is limited to daytime hours. A Space Power Satellite (SPS) capable of providing solar electric power economically for 24 h per day has been a dream for decades. However, the SPS concept is very complex since it assumes multiple energy conversion steps and includes specially constructed ground microwave receiver stations. In Chap. 12, an alternative is described. A constellation of 10 km diameter mirror arrays in a sun synchronous orbit at an altitude of 1,000 km deflecting sunbeams down to terrestrial solar power fields at dawn and dusk can provide 3 additional hours in the morning and another 3 additional hours in the evening. The key is that larger and larger terrestrial solar fields, photovoltaic or trough concentrated solar power, are already being built all around the world. Mirrors deflecting sunbeams down to earth is a much simpler concept. A surprising convergence of two technologies under development is now possible, i.e., lower cost access to space and the ongoing construction of larger and larger solar power fields. If this concept is implemented in the future, the hours of solar electricity production in sunny PV fields around the world can be potentially increased to 14 h per day with an increase in the solar field capacity factor to 58 % and a reduction in the cost of renewable pollution-free solar electricity to below 6 cents per kWh.

The second half of this book describes some exciting possibilities. An outstanding problem has been access to financing for these new ideas. The money in the hands of the financial community has tended to favor the status quo incumbency energy technologies (as most recently, "fracking," for example). Hopefully the young and older educated readers of this book will find the new ideas presented here intriguing enough to work for the political will and financing to make them become a reality. We can all strive for a peaceful bright and sunny energy future.

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