One can’t oversimplify the challenge or the solutions. Amidst the complexity and facts, muddled by a large dose of vested interest advocacy, today’s politicians and their advisors are looking for simple soundbite solutions. It is little wonder energy and climate policies in many jurisdictions are plagued by spin and ruptured by a gulf between partisan policies. All this is reason for the failure of most industrialised nations to deliver a resilient energy-climate policy mix.

Even if an international ‘agreement’ to decarbonise the energy sector is reached, will individual nations be able to deliver? Many economists say so. But this seems (a) not sufficient in the absence of convenient, large-scale and affordable low-carbon alternatives to fossil fuels; and (b) highly improbable given the different socio-economic status of nations. The scale of the challenge, the higher cost of renewable technologies and the barriers for non-renewables like nuclear and CCS, means a carefully crafted mix of policy interventions and public sector investments are going to be required for most nations. These will not be achieved in the current political setting of most democratic nations.

The road out of Paris needs a price on carbon, investment in all available, affordable low-carbon technologies and massive behavioural change among individuals. Here are five suggestions to get us on track:

- Accept that the task of decarbonising the economy is a massive challenge.
- Be prepared, though not readily accept, that atmospheric CO₂ concentrations greater than 450 ppm is a very plausible outcome.
- Incentivise higher energy productivity through efficiency, conservation and management of demand profiles.
- Separate the means from the end. The goal is to limit global warming to less than 2°C above preindustrial levels, not to end the use of fossil fuels or achieve 100% renewables.
- Recognise and accept the role for transitional solutions, e.g. replacing low efficiency coal-fired generators with natural gas or even with high efficiency coal, provided there is a robust and credible plan for future retrofit of CCS

The road out of Paris is reached, will individual nations be able to deliver? Many economists say so. But this seems (a) not sufficient in the absence of convenient, large-scale and affordable low-carbon alternatives to fossil fuels; and (b) highly improbable given the different socio-economic status of nations. The scale of the challenge, the higher cost of renewable technologies and the barriers for non-renewables like nuclear and CCS, means a carefully crafted mix of policy interventions and public sector investments are going to be required for most nations. These will not be achieved in the current political setting of most democratic nations.

As we head into the COP21 meetings in Paris, I thought I would join the chorus of commentators providing us with their views on what can, should or will be possible. But I am focused on the road out of Paris because what exercises my mind most is the delivery of the required transformation, that is the intended outcome of any ‘agreements’ achieved.

THE ROAD OUT OF PARIS...

A massive transformation is required. Many major economies are currently restating their commitment to stabilising global temperature rise at no more than 2°C above preindustrial levels. This 2°C goal was formally adopted in 2010 by the 195 member countries of the UNFCCC. For this to occur, it is likely that we will need to maintain atmospheric CO₂ concentrations below 450 ppm or to reduce net global carbon emissions to zero before the end of the century. This may yet prove to be impossible, and so we need to prepare for the possibility of 550 ppm and temperature rises a little higher.

Effectively aligning climate and energy policy really is the problem from hell. It’s enormous in scale and complexity, long-term, non-linear and the impacts are non-uniform with consequences for equity and justice. Furthermore, these consequences are interconnected and unpredictable. Understanding the problem and designing solutions requires deep, integrated scientific assessments but these must be multidisciplinary.

Scientists must separate the means from the objective. Even if integrated assessments were highly reliable, it seems to me that scientists, economists and policy makers often struggle to disentangle their values from the facts. This leads us to advocate for certain solutions over others, to predict rapid falls in performance and costs for one solution but not another, and to rationalise certain risks and uncertainty as acceptable. A climate scientist, unskilled in the technology and engineering of energy systems, should be saying, “I don’t care which technology gets us there, in fact, give me all of them!”, not making bold predictions for the future efficiency of photovoltaics and costs of batteries to render nuclear and CCS as irrelevant.

What we need is a price on carbon, investment in all available, affordable low-carbon technologies and massive behavioural change among individuals. And for this we need to advocate for certain solutions over others, to rationalise certain settings?
IEA RELEASES WEO SPECIAL REPORT ON ENERGY AND CLIMATE CHANGE

In the introduction to its Special Report, the IEA draws attention to the global setting driving energy and climate change policy today. It notes that COP21 is fast approaching and that momentum is building, for example as witnessed by the historic US-China deal. Remarkably that energy production and use accounts for two-thirds of global greenhouse-gas emissions, it calls for the energy sector to cut emissions, while powering economic growth, boosting energy security and increasing energy access. The report centres on the four pillars that it considers vital for a successful outcome at COP21:

1. Peak in emissions – set the conditions which will achieve an early peak in global energy-related emissions. This includes measures to increasing energy efficiency in the industry, buildings and transport sectors, reduce the use of the least-efficient coal-fired power plants and prohibit their construction, increase investment in renewable energy technologies in the power sector (from $270 billion in 2014 to $400 billion in 2030), phase out fossil-fuel subsidies to end-users by 2030, and reduce methane emissions in oil and gas production. Notably, the measures vary across regions depending on resource base, infrastructure and activities.

2. Five-year revision – review contributions regularly, to test the scope to lift the level of ambition. Situations (the carbon budget) and solutions (innovations) are rapidly evolving, thus a review enables governments and industry to keep up with events and help build investor confidence.

3. Lock in the vision – translate the established climate goal into a collective long-term emissions goal. This serves to reinforce future expectations, guide investment decisions, provide an incentive to develop new technologies, drive needed market reforms and spur the implementation of strong domestic policies, such as carbon pricing.

4. Track the transition – establish a process for tracking energy sector achievements. This would provide clear evidence of results, reassuring the international community that others are acting diligently, and identify countries that are struggling with implementation, enabling assistance to be provided if needed.

To download the report click here
To download the presentation click here

BG, BP, ENI, SHELL, STATOIL AND TOTAL JOIN FORCES AND CALL FOR A PRICE ON CARBON

In an unprecedented joint initiative, six of Europe’s major oil and gas companies have come together and called for governments to provide their companies with clear, stable, long-term, ambitious policy frameworks to “reduce uncertainty and help stimulate investments in the right low carbon technologies and the right resources at the right pace.” Addressed to the UNFCCC Executive Secretary and the President of the COP21, the letter comes in the lead up to the December COP21 UNFCCC climate meetings in Paris.

As outlined in the letter, the companies believe that a price on carbon is central to climate and energy policy frameworks. “If governments act to price carbon, this discourses high carbon options and encourages the most efficient ways of reducing emissions widely, including reduced demand for the most carbon intensive fossil fuels, greater energy efficiency, the use of natural gas in place of coal, increased investment in carbon capture and storage, renewable energy, smart buildings and grids, off-grid access to energy, cleaner cars and new mobility business models and behaviors.”

Ultimately the six companies called on governments, including during the UNFCCC negotiations in Paris and beyond, to introduce national or regional carbon pricing systems (where they do not yet operate) and establish an international framework that could eventually connect these regional and national systems.

To view the letter click here

TESLA AND THE AFRICAN ENERGY MARKET

Tesla’s residential Powerwall battery storage system caused quite a stir when it was unveiled in April this year. Amid announcements that the output of the Powerwall had been increased (2kW to 5kW) without altering the price, as well as Tesla’s expectation that the Powerpack system designed for utilities and large industrial customers will actually be the main game-changer, Tesla’s batteries are now being hailed in some countries as a major technology that could help transition from fossil fuels to renewables.

In many African regions chronic, daily power cuts are not out of the ordinary and fossil fuel-based generators are relied upon as a backup source of power. The introduction of storage as a backup device could pave the way for both on-grid and off-grid communities that have access to solar energy yet still rely heavily on diesel generators.

Ultimately, in these regions affordability is a key barrier. Pooling storage technologies among communities, as opposed to the individual household level, may help to reduce the prohibitive costs of battery storage in these communities. Government subsidy schemes could also potentially help to lesson costs, although this risks undermining the original intent to transition towards less emissions-intensive sources of energy, and could also result in countries facing increased economic burden.

In reality, the technology has far to come if it is to truly provide households with 24/7 power. Perhaps scientists and engineers will devise a system to store enough energy to ration out power throughout the night when the sun isn’t shining. The problem remains that prolonged periods of wet and overcast weather will limit the utility of solar PV with batteries. A backup of always-available energy will always be required.
GLOBAL ENERGY NEWS

INTERNATIONAL STUDENT ENERGY SUMMIT 2015

More than 600 students from over 100 countries recently came together in Bali to participate in the 4th International Student Energy Summit (ISES2015). Part of a suite of initiatives run by Student Energy, the Summit is a global forum that focuses on sustainable resource management and the role that students will play in defining the future of energy development.

The topic for the conference was “Connecting the Unconnected”, and sessions focused on this theme under the broader pillars of technology and innovation, global energy dynamics and markets and regulation, ultimately highlighting the need for a multidisciplinary approach to the world’s energy opportunities and challenges.

The conference highlighted the fact that the global community is still grappling to reconcile the tension between energy access and climate change. Suleiman Jasir Al-Herbish, Director-General of the OPEC Fund for International Development (OFID) contributed to the debate, stressing the importance of adopting a technology-neutral approach despite the conflict with using fossil fuel-based sources and climate change.

Naming poverty as the most serious environmental problem facing the world, he called for the use of any energy source that is superior to animal waste. He summed up his position by urging people not to overcomplicate the debate – provide what can be offered now to the vast populations in need, and keep looking for better options and solutions.

Sri Mulyani Indrawati, Managing Director and Chief Operating Officer of The World Bank reinforced the need to reconcile energy accessibility and climate change. She noted that for sustainable development “big coal” need not be the answer, and that the goals of access and emissions reductions can and must be aligned. Identifying as major obstacles the challenge of establishing a market for renewables and efficiency via political policies, and how to connect the huge injection of funds required with the capital market and long-term investment, she called for innovation to drive affordability, a policy environment that supports accessibility and sustainability, and consideration of the governance of state-owned enterprises and companies to contribute to solutions.

Dr Kaveh Madani, from Imperial College London, spoke of the interconnected nature of energy with all other aspects of life. Highlighting the need to employ a systems perspective, and a “system of systems approach”, he emphasised the need to move from energy security to human security. For example, if one has energy but no water, they are not secure. He also suggested a shift away from the donor-recipient relationship by identifying the strengths of the developing world, what these regions have to offer and opportunities for trade by linking local issues with global issues and addressing challenges cooperatively.

Other interesting perspectives from the conference:

- **Mixed messages about the role of gas in the transition.** The revolution in the US was created by rather unique conditions that may not be replicated elsewhere. For China, coal is considerably cheaper now and will be for the foreseeable future, at which point it was suggested there will be a jump directly to renewables rather than needing gas for the transition.
- **Behaviours and attitudes need to be considered when forming policy.** Examples have shown time and time again that paying or subsidising people risks undermining any original purpose or intent that existed, which may have been related to moral grounds or environmental concerns. Changing attitude does not always equate to changing behaviour. Ultimately there is no universal solution, and the focus should be on small changes and outcomes to empower local and indigenous solutions.

POWER RENTAL MARKET FORECAST TO DOUBLE, PARTLY THANKS TO THE QATAR 2022 WORLD CUP

With much of the emphasis placed on capital costs of power generation technologies, little consideration is given to the value of the power rental market. The global value of the power equipment rental market hit $8.7 billion in 2014, and is expected to reach $17.4 billion by 2020. This is according to a recent report by GlobalData, which analysed the global power rental market focusing on countries with large demand for power rental equipment (including the US, Mexico, Brazil, Nigeria, Saudi Arabia, UAE, Qatar, Oman, China, India, Bangladesh, Myanmar, Vietnam and Indonesia).

The report found that the value of the Middle East power rental market will double between 2014 and 2020 to reach $2.8 billion, exhibiting the largest growth globally. However, all this depends on whether Qatar remains the host nation for the FIFA 2022 World Cup. According to GlobalData’s senior power analyst Siddhartha Raiha, “with the World Cup planned for Qatar in 2022 and the 2020 World Expo in the UAE, significant investments have been made in these countries’ infrastructure development. These include Qatar’s investments of more than $200 billion in developing its rail and highway network and ports, in turn boosting its power rental market.

“On the other hand, losing the World Cup could significantly impact the planned flow of such investments and government spending directed towards the country’s large-scale infrastructure development and construction sector, subsequently hindering the predicted growth in its power rental project revenues.” If Qatar retains the World Cup, it will still have a number of other hurdles to overcome. Its power rental market, predominantly comprised of fossil fuel-based diesel generators, will likely require costly upgrades in order to meet strict efficiency and emissions standards.

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SIEMENS SIGNS ITS LARGEST EVER DEAL WITH EGYPT WORTH $9 BILLION

Announced during Egyptian President Abdel Fattah El Sisi’s trip to Germany earlier in June, the German engineering giant Siemens will provide $9 billion worth of gas-fired plants and wind power installations to Egypt. This will add 16.4 GW of capacity to the grid, increasing Egypt’s power generation capacity by 50%. Specifically this will be in the form of 3 x 4.8 GW natural gas-fired combined cycle power plants, and 12 wind farms comprising 600 turbines with a total installed capacity of 2 GW. The project, expected to be completed in just over 3 years, also involves building a blade manufacturing plant that will train and employ 1,000 people.

Egypt is currently going through one of its worst energy crises in decades as ageing state-run infrastructure fails to meet rapidly growing demand, resulting in power cuts. The deal is the result of a memorandum of understanding that was announced in March at the Egypt Economic Development Conference. According to Siemens President Joe Kaeser, “with these unprecedented contracts, Siemens and its partners are supporting Egypt’s economic development by using highly efficient natural gas and renewable technologies to create an affordable, reliable and sustainable energy mix for the country’s future.”

The order is good news for Siemens and its gas and power division, which has faced difficult times as competition from renewable energy businesses intensifies in Europe; a fact that was highlighted just last month when Mr Kaeser noted he had resigned himself to never selling another gas turbine in Siemens’ home country following Germany’s switch to renewable energy.

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WATER-ENERGY-CARBON LINKS IN HOUSEHOLDS AND CITIES: A NEW PARADIGM

Water-related energy use in cities is significant, accounting for some 13% of Australia’s electricity use and 18% of Australia’s natural gas use. Most of this energy use results from heating water in households and industry, and C3GRID projects energy expenditure for urban water will rise 500–700% by 2035. To address this challenge UQ has partnered with the Smart Water Fund (Melbourne Water Sector) in an ARC linkage project. Using information from individual households to simulate water-related energy use at district-scale (approximately 20,000 households), a geo-database for simulations will be developed to assist in understanding how changes in technology uptake or behaviour influence water use, energy use, carbon emission and costs to households.

To date 7 individual households in Victoria and Queensland have been comprehensively monitored using surveys, interviews and high resolution water and energy metering to understand how each household performs. The biggest influences are showers, efficiency losses, and clothes-washers. In the Victorian households 15–30% (7–21 kWh/hh/d) of total household energy use was water-related, but in some Queensland households this increased to more than 50% (as less energy is used for space heating).

Another factor to consider is water temperature. A review of water temperature in Melbourne Water’s supply network found variations in temperature of up to 8°C within relatively short distances. In the households studied this difference in temperature translated into 2.5–5 kWh/hh/d energy use for heating impact for this group of houses or around 4–15% of total household energy use. This has implications for a number of Australian standards, including solar hot water system design. Melbourne households use some 13 kWh and 45kWh per day for electricity and gas respectively.

For consumers, the project builds greater knowledge around how to reduce energy use and costs. For example if appliances (e.g. clothes- and dish-washers) can connect to hot water from renewable sources (such as solar or heat pumps) using a hot water inlet to the appliance (rather than having only a cold water inlet) then this can help maximise use of renewable energy, reduce demand for electricity, and often reduce greenhouse gas emissions and operating costs.

For water utilities, the future may be to provide not only water of a certain quality but also at specified temperatures to meet their customers’ needs. For example, commercial customers may want either cooler or warmer water based on their processes if they realise the impact this has on their energy bills. For energy utilities there is the potential to improve energy demand forecasting and strategies for combined asset efficiency.

The project is also exploring emerging technologies and trends that can reduce both water and energy use. This includes new, high efficiency appliances (e.g. recirculating showers, waterless clothes-washers), adjusting delivered water temperatures (e.g. identifying locations where cooler or warmer water is required), investigating whether solar hot water systems or rainwater tanks are more efficient when considering impacts on water and energy use, and energy implications for integrated water cycle planning.

For more information visit Smart Water Fund Knowledge Hub, or contact Dr Steven Kenway at kenway@uq.edu.au

2015 BARRY MURPHY SCHOLARSHIPS IN NUCLEAR ENERGY

Through the generous support of UQ Alumni Barry Murphy, the Faculty of Engineering, Architecture and IT (EAIT) has established the Barry Murphy Scholarship in Nuclear Energy. The purpose of the scholarship is to encourage and support meritorious engineering students to undertake a semester of international exchange to further their interests and studies in nuclear engineering. Applications are open to UQ undergraduate students studying a Bachelor of Engineering in any field associated with chemical, civil, electrical, mechanical or mining engineering disciplines.

For eligibility criteria and the application form, click here. Applications close on 1 September 2015, at 5pm.

GEOENGINEERING COULD HELP LIMIT RISING SEA SURFACE TEMPERATURES

A recently published study in Nature Climate Change involving UQ has found that geoengineering could reduce the threat of rising sea temperatures and mass bleaching of coral reefs. In collaboration with the Carnegie Institution for Science, the University of Exeter and the UK Hadley Centre, the study found that Solar Radiation Management (SRM) could limit rising sea surface temperatures.

Involving the injection of gas into the stratosphere to form microscopic particles that reflect energy from the sun, according to Professor Peter Murby from UQ it was established that “the benefits of SRM, over the standard CO2 reduction scenario, are dependent on the sensitivity of corals to changes in seawater acidity.” Resolving sensitivity thus remains of key importance.

The study compared a hypothetical SRM geoengineering scenario to the most aggressive future CO2 reduction strategy considered by the Intergovernmental Panel on Climate Change (IPCC). Findings showed that despite increasing ocean acidification, coral reefs coped much better with geoengineering. Ultimately, Professor Peter Cox from the University of Exeter concluded that “we need to either accept that the loss of a large percentage of the world’s reefs is inevitable or start thinking beyond conventional mitigation of CO2 emissions.”

For more information visit Smart Water Fund Knowledge Hub, or contact Dr Steven Kenway at kenway@uq.edu.au

UPCOMING EVENTS

15th Energy in Western Australia Conference
26–27 August, in Perth
Hosted by the Australian Institute of Energy, the 2015 theme is “smart energy”. Speakers will explore and engage with conference attendees on a range of diverse and relevant matters such as energy technology, competitiveness, and equity as industry and consumers interact with regulators, policy makers, and financiers on the delivery of diverse energy products and services.

NSW Resources & Energy Investment Conference 2015
27–28 July, in Sydney
This biennial conference keeps industry informed about mineral and mining exploration and development, energy, METs and renewables in NSW.

Power & Energy Africa 2015
27–29 August, Dar-es-Salaam, Tanzania
Spread over a period of 3 days, the event brings together decision makers and influencers as well as technical experts and professionals from leading companies involved in the power and energy generation, transmission and distribution sector within Africa and around the globe.

Brazil Windpower 2015
1–3 September, Rio de Janeiro, Brazil
Brazil Windpower, the largest wind energy event in Latin America, offers excellent business opportunities, in addition to conference programme sessions focused on issues relevant to the wind sector.

Eastern Australia’s Energy Markets Outlook 2015
15–18 September, in Sydney
This year’s 4th annual Eastern Australia’s Energy Markets Outlook conference will again bring together Australia’s leading policy makers, industry, peak representative bodies, respected analysts and end users to work towards satisfactory and sustainable outcomes for all concerned.

ATSE Unconventional Gas Conference 2015
22–23 September, in Sydney
Unconventional gas is an issue of profound national importance, which has the potential to impact on Australia’s future property, exploration and production has encountered opposition in many areas of Australia due to a number of complex reasons. Debate will be informed by the technical and scientific experience of industry and government, and speakers from NGOs and community groups.

All-Energy Australia Conference
7–8 October, in Melbourne
The Clean Energy Council has announced a strategic partnership with All-Energy Australia to bring to ATRA’s Power & Energy Conference and Expo to the nation’s largest renewable energy event.

UQ RESEARCH NEWS
Overview

- Solar power plants convert solar radiation into electricity. There are two broad types:
  1. Concentrating solar thermal power (CSP): converts solar radiation to heat and then to electricity
  2. Solar photovoltaic (PV) power: converts solar radiation directly into electricity

Solar PV technology

- Sunlight contains photons of different energies (colours of light or wavelengths):
  1. Photons of energy less than the band gap of the photovoltaic material do not generate electricity, and in low light conditions there are fewer photons
  2. Photons of energy greater than the band gap generate electricity but the extra energy is turned into heat
  3. Photons within the band-gap are able to generate electricity
    - Commercial solar PV modules are rated for the amount of power they produce in Watts under standard conditions of 1 Sun defined as the AM1.5G spectrum 1000W/m² at 25°C.

- CSP technology uses direct radiation, whereas PV technology uses both direct and diffuse radiation
- Operation is restricted to daylight hours (with low cloud cover), and output varies between seasons but thermal or electrical storage can be added to allow generation of electricity when the sun is not shining
- Annual capacity factors of up to 25–35% and 20–30% are achievable for CSP and PV technology, respectively. This can be increased with storage and recently a CSP plant in Spain achieved ~ 80% for a limited period under optimal conditions
- Africa, Australia, the Middle East and America (west coast) have the highest solar radiation per unit area.

Solar PV modules

- Individual PV cells are connected in series, mounted in modules and then fixed together in larger arrays (panels) to generate DC electricity
- Modules are connected in series to form a string in order to increase the voltage of the system. This reduces resistance losses across electrical connections and wiring
- Crystalline silicon solar cells are most prevalent in the market with ~ 80% share and deliver typical module efficiencies of between 15 and 21%. Thin film solar panels made from materials such as CdTe deliver efficiencies of ~ 15% but are slightly cheaper.
- Multi-junction cells made from compound semiconductors are the most efficient and have reached > 40% but are very expensive and only work well under concentrated light conditions.
- PV systems consist of two parts – PV modules and the balance of system (BOS) components
- A combiner box is used to feed DC electricity to an inverter which converts DC electricity into AC for end use

Solar radiation spectrum

- Visible light is in the range of 400–700 nm
- Ultraviolet light is in the range of 100–400 nm
- Infrared light is in the range of 700–10000 nm

Projected output of 250MWte CSP plant in California

Global mean solar irradiance

Cell Module Array
PV balance of system refers to site preparation, mounting structures and electrical components

- PV frames, support elements, ground support structures and base blocks for the inverter are all part of the mounting structure
- The inverter to convert DC to AC electricity, and the transformer to adjust the voltage
- Electrical cabling and interconnectors to ensure the electricity can be transmitted to the required source

Tracking

- Tracking is best suited to locations with a high level of sunlight where land costs are low (as tracking usually increases the land required)
- Additionally, tracking requires additional mechanical equipment and maintenance during operation, also increasing costs
- The added costs vary depending on tracking type, and can potentially be offset by the increase in output

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Storage systems increase capacity factors and can also help improve power quality and provide grid support

1. Mechanical – pumped storage, compressed air energy storage (CAES), flywheels
2. Thermal – steam, phase change materials (granite, hot rocks, ice), molten salt
3. Electrochemical – batteries, fuel cells
4. Electrical – supercapacitors, superconducting magnetic energy storage (SMES)
5. Chemical – hydrogen, synthetic natural gas

- Capacity (MW) and duration of energy storage (MWh) are the two important metrics when evaluating any storage system
- Criteria for assessing storage technology includes storage capacity (MW–GW), safety, size and weight, life efficiency and capital costs per unit

- Pumped storage and CAES currently offer the largest capacity and duration energy storage options
- Batteries, including flow batteries, can be used for short and medium duration solutions
- Flywheels and certain batteries can be used for shorter duration and power quality solutions

Frequency Regulation

- Purpose: Maintain a constant grid frequency
- Purpose: Mitigate system ramping
- Purpose: Reserve (spinning reserve)
- Purpose: Back-up power

Community Energy Storage

- Purpose: Neighborhood back-up
- Purpose: Emergency
- Purpose: Power quality
- Purpose: Distribution
- Purpose: Distribution stability, electric vehicles, residential renewables

Residential Energy Storage

- Purpose: Residential back-up
- Purpose: PV integration

Peak Shifting

- Purpose: Alternative to peaking gas power plant in
- Purpose: Annual peak shaving
- Purpose: Reserve (spinning reserve)

Load Leveling

- Purpose: Energy and/or re-configurable capacity timing
- Purpose: Reserve
- Purpose: Reserve
- Purpose: Reserve

Acknowledgment: Thanks to Professor Paul Meredith for his assistance with this section.

Sources: EPRI, SolarNavigator, TVA, UNSW, USDOE, 3Tier