Energy Storage Systems (ESS) Design and Installation – an Australian Context

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All Energy Australia 2016

ESS Trials and Tribulations

- Question –

So what does it take to get an ESS installed in Australia?

- Answer –

1. At this point in time, a lot of time and effort on the part of the designer and installer; and
2. A lot of money from a willing customer (relatively speaking)

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ESS Trials and Tribulations

Why the high time, effort and cost?

- These systems are still "new" in the domestic and commercial sectors particularly in grid connected applications
- There are many new technologies entering the market including:
  - advanced lead acid, lithium, aqueous salt, vanadium, zinc-bromide and hydrogen with more new technologies in development.

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ESS Trials and Tribulations

Why the high time, effort and cost?

- New ESS technologies due to their nature are assumed to be inherently **unsafe**.
- New ESS technologies vary widely in their performance characteristics.
  - They are not readily interchangeable and must be designed with appropriate control, management and power interfaces to avoid **safety hazards and performance issues**.
  - They must be selected to suit the **load and charge profiles** applicable at their intended installation
  - They must comply with the **regulatory and operating requirements** of the power supply system/s into which they are connected.

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Step 1 – System Specification

- So, what do we need to correctly specify our ESS?
- Load profile

  (i.e. the Energy “Expense Budget”)
  - Peak Load?
  - Average Load?
  - Total Energy Consumed?
  - Daily variations?
  - Seasonal variations?
  - Annual variations?
    - (e.g. increased/decreased load over time as use changes)

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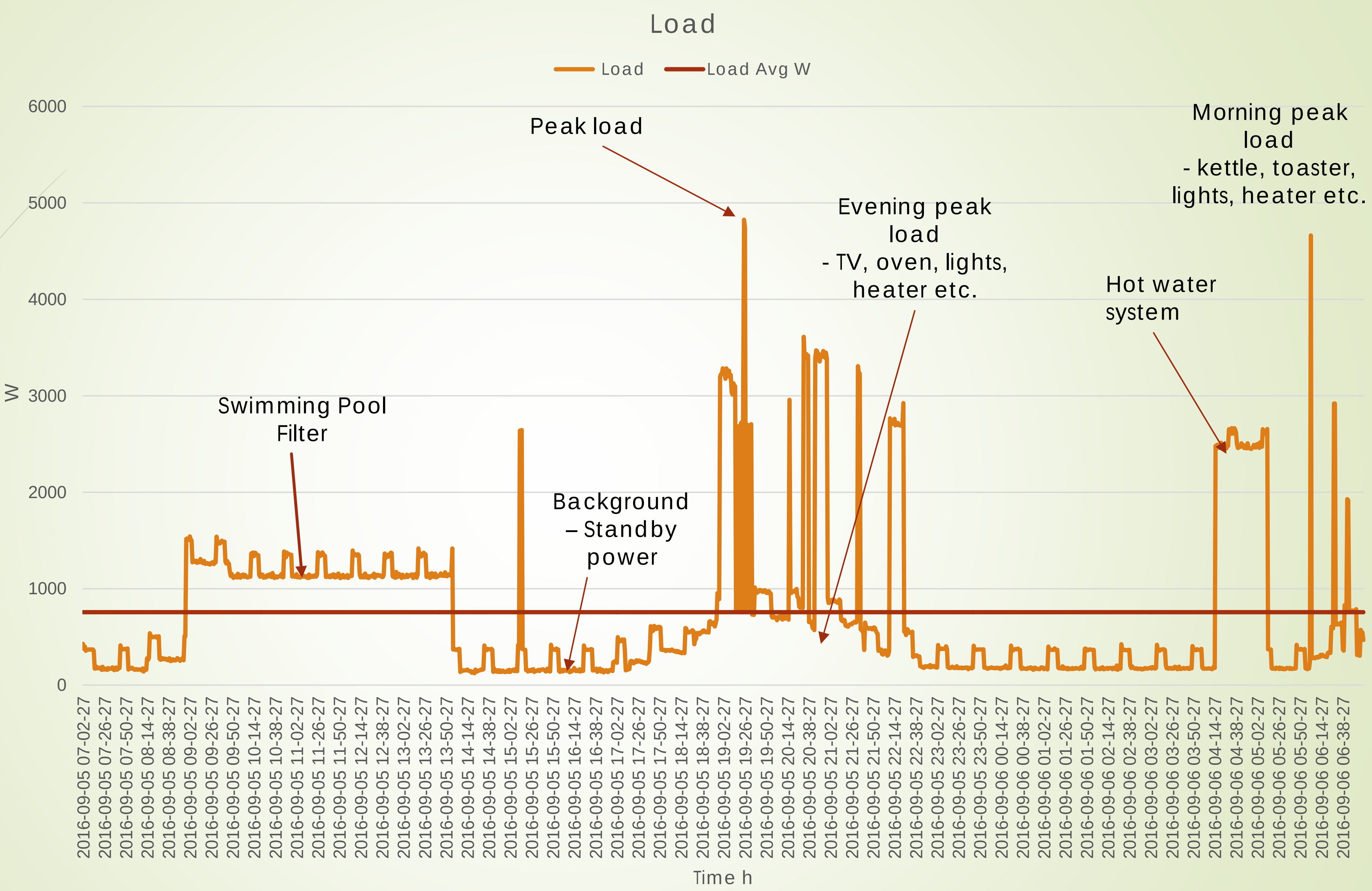

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Step 1 – System Specification

- Charge profile

  (i.e. the Energy “Income Budget”)

  - Peak Photo Voltaic (PV) input?
  - Average PV input?
  - Total PV energy delivered?
  - Daily variations?
  - Seasonal variations?
  - Annual variations?
    - (e.g. system performance degradation over time)

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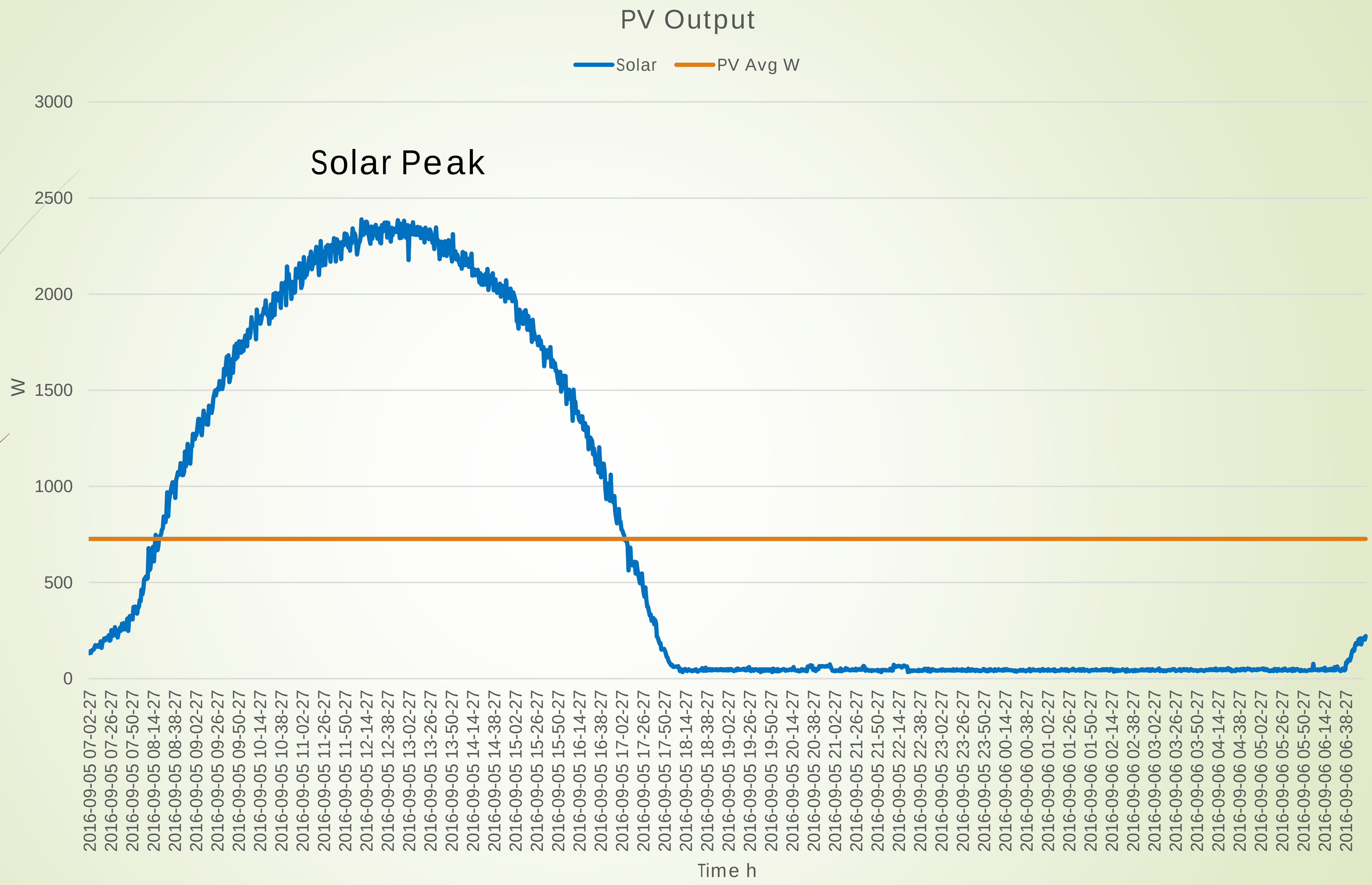

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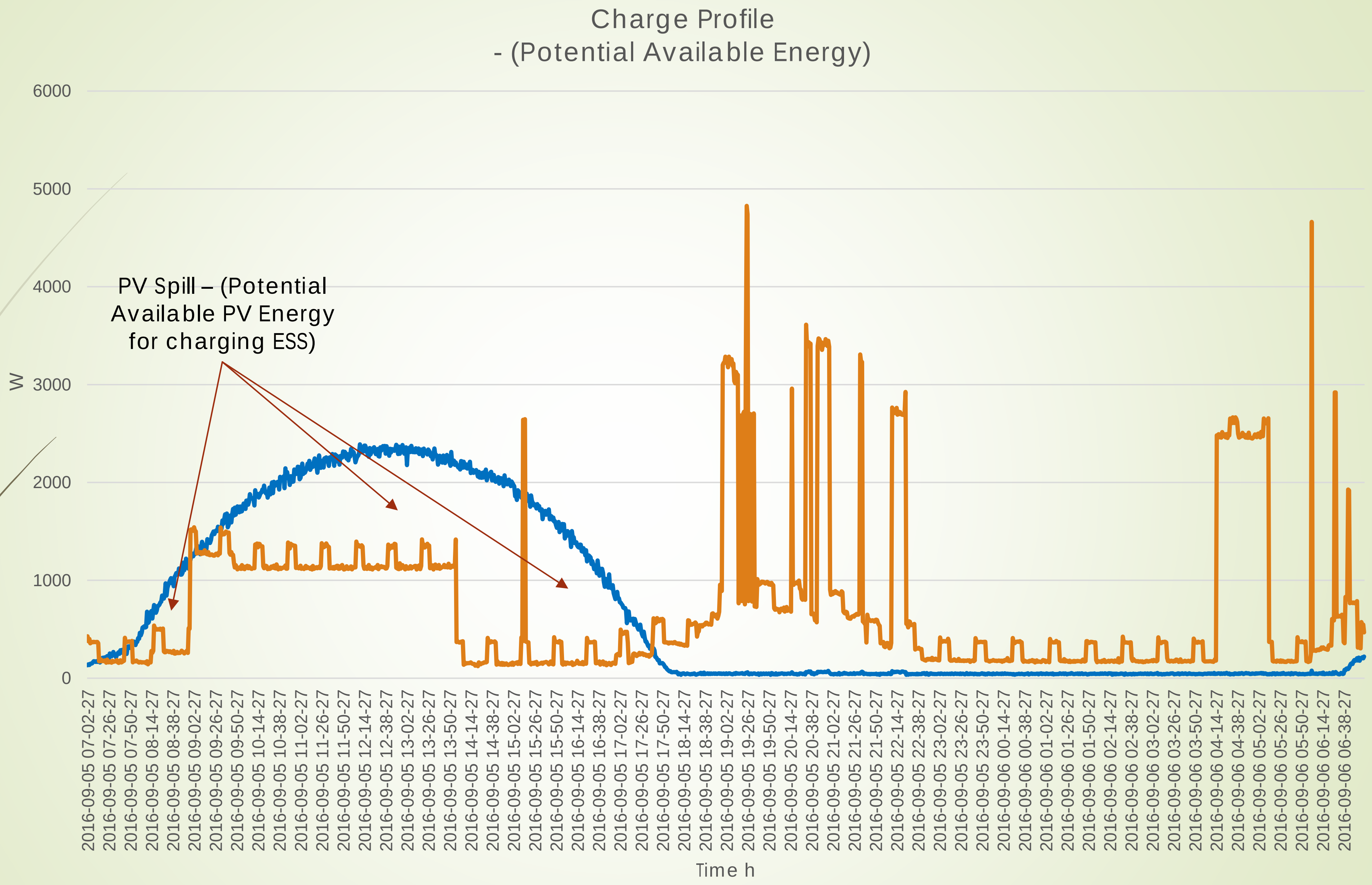
Step 1 – System Specification

- Spill profile – (Potential Available Energy)



Charge Profile
- (Potential Available Energy)
6000
5000
4000
3000
2000
1000
0
W
PV Spill – (Potential Available PV Energy for charging ESS)
2016-09-05 07-02-27
2016-09-05 07-26-27
2016-09-05 07-50-27
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Step 1 – System Specification

- Charge Profile
  - How long, how much, when to charge?
  - How many C/D cycles per day?
  - Demand side management?
  - Islanded vs non-islanded operation?

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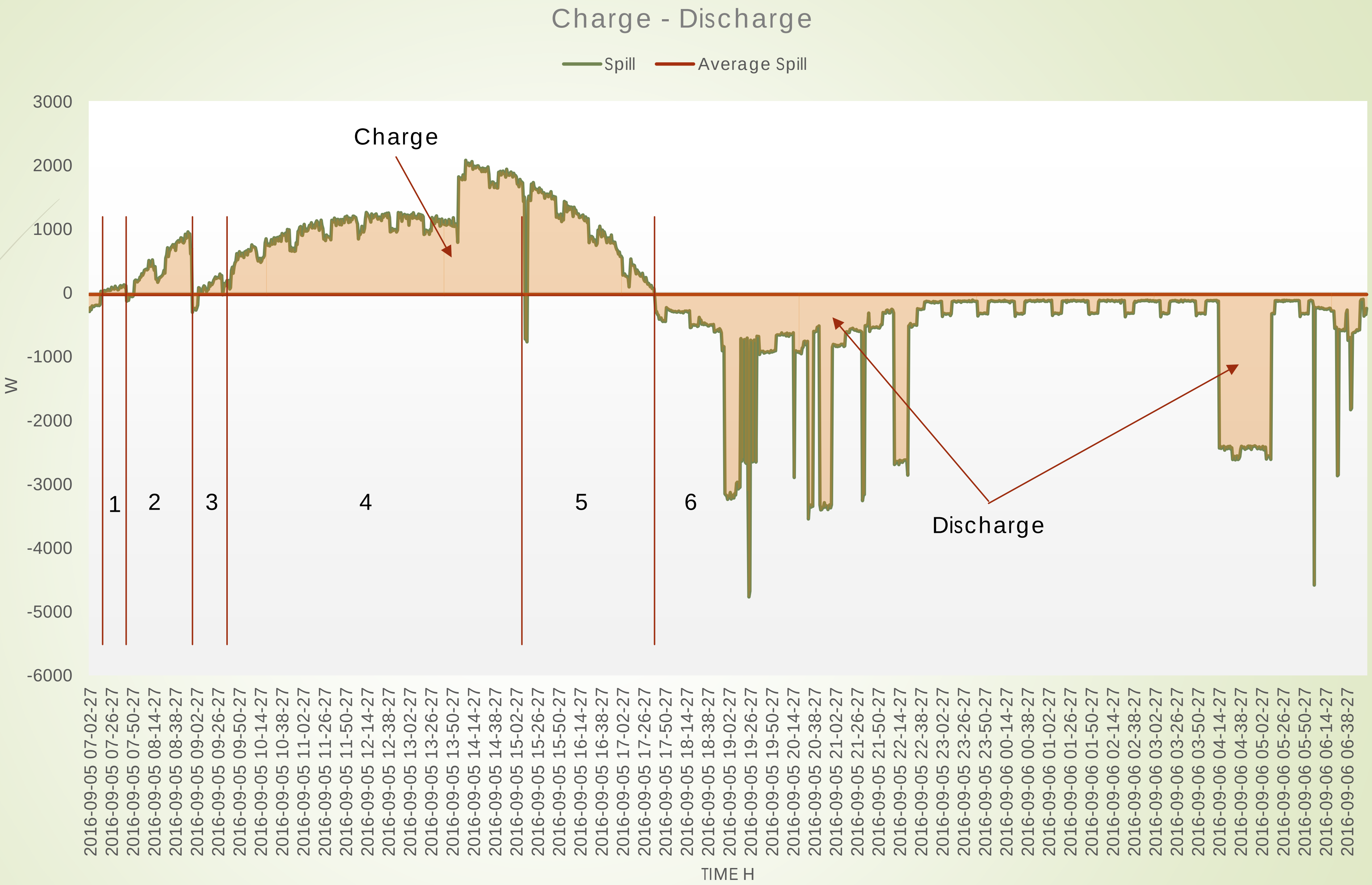

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Step 1 – System Specification

- Discharge Profile
  - How long, how much, when to discharge?
  - How many C/D cycles per day?
  - Demand side management?
  - Tariff management? (e.g. flat rate, time of use?)
  - Islanded vs non-islanded operation?

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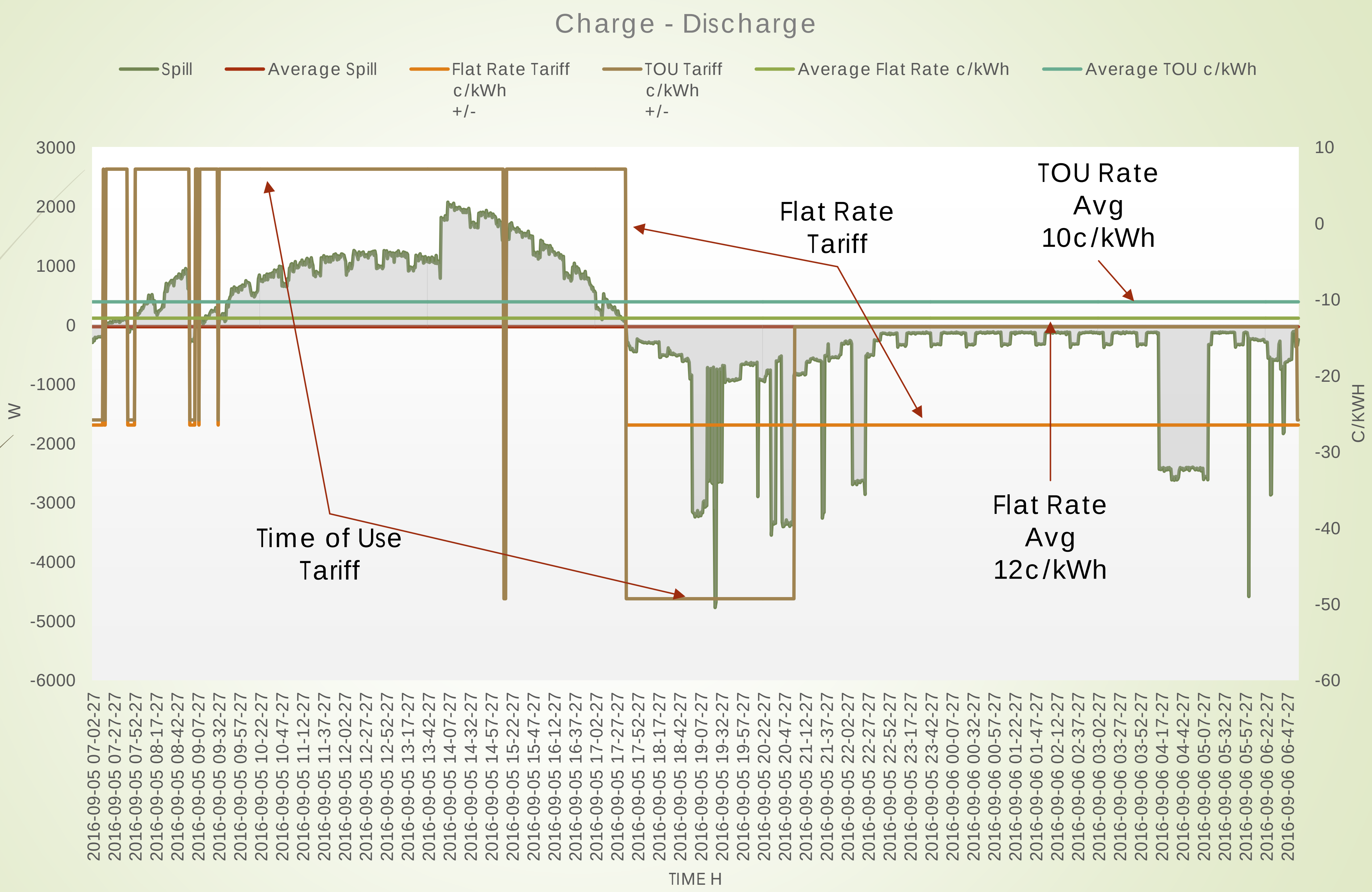

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System Specification – Essential Data Summary

Opportunity Overview		
Customer		
Address		
Contact		
Location (add coordinates if solar present)		
VAR or Direct or Developer?		
Transaction type: Product Sale or Energy Service Agreement (ESA)		
Geography/Terrain		
Single Line Drawing Attached?		
Load Profile Attached?		
Interval Data Available? If yes, check type	☐ type 8760 ☐ type 3504	
If no, has request been made to install data loggers?	☐ Yes ☐ No	
Power Generation Profile Available?	☐ Yes ☐ No	

Attribute	Select	Notes
Power	☐ 30kW ☐ 50kW ☐ 250kW	
Capacity	☐ 4 hour ☐ 6 hour	
Output	☐ AC ☐ DC	
Output Voltage AC	Voltage______ ☐ 1 Ph ☐ 3 Ph	
Frequency	☐ 50Hz ☐ 60Hz	
Output Voltage DC		
Architecture Type	☐ AC-coupled ☐ DC-coupled ☐ Mixed	
Average daily enegy usage		
# of cycles/day		
Dispatch Optimization Capabilities Required		

Ambient Temperatures	Max________ Min________	
Isolated islanded grid operation	☐ Yes ☐ No	
Communications	☐ Modbus/TCPIP ☐ GSM/GPRS	
On site Generation	☐ PV ☐ Wind ☐ Fuel Cell ☐ DG ☐ Other - explain	
Multiple Units Control	☐ Yes ☐ No	
Box Type	☐ Corrugated ☐ Flat	
Peak load		
Load type - give complete decsription of load type. *Linear/Nonlinear Resistive/Capacitive/ Inductive/Combination Continuous/Non-continuous/ Intermittent/ Periodic Balanced/Non-balanced Single phase/Three phase Flat/Variable*		

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Step 2 – System Design and Selection

- What ESS technology best achieves the requirements as defined in the System Specification?
- Key variables to consider:
  - Customer budget
  - Usable stored energy capacity (kWh)
  - Maximum energy delivery (kW) and duration (secs/mins/hours?)
  - Maximum charge rate (kW, Volts/Amps)
  - Number of Charge/Discharge cycles per day
  - Life of ESS in cycles / hours run / total energy throughput (kWh) as applicable
  - DC or AC connection
  - ESS location and ambient conditions (indoor vs outdoor, city vs regional/remote area)
  - Finance costs as applicable
  - ESS Levelised Cost Of Energy (LCOE) vs Customer current energy cost

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Step 2 – System Design and Selection

- Customer budget
  - A 3-5kW, 7-10kWh ESS will set a typical Australian customer back by between $10,000 to $25,000 installed (excluding any rebates that may apply)
  - Need to ask how many customers are prepared to pay this amount of money up front for an ESS?
    - Especially given the Levelised Cost of Energy (LCOE) is between $0.35 - $0.80 / kWh over the life of the system when considering Net Present Value (NPV) at a nominal 5% discount rate.
  - Your nominal system sizing may make great use of the available PV spill and/or TOU off peak tariff if connected to the grid, but an astute customer will have cause to think twice before buying the system at these prices.
  - **Conclusion:** Your customer needs to be in an area or have a need where your price makes sense (e.g. their current cost of energy that will be retrieved from an ESS is >$0.35 / kWh such as TOU peak lopping or they need a reliable backup power supply)

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Step 2 – System Design and Selection

- Usable stored energy capacity (kWh)

  How much of the energy stored in your ESS can actually be retrieved and used?

  - For example, a Valve Regulated Lead Acid (VRLA) Absorbent Glass Matt (AGM) sealed lead acid deep cycle battery will permit recovery of between 40% to 50% of the energy actually stored in it on a regular charge/discharge cycle basis to achieve the manufacturer's nominated design life/warranty of upto 12 years or ~ 4000 C/D cycles with a retained capacity of >70%.

  What does this actually mean?

  - For this example using the VRLA AGM battery it means you need twice as many batteries to support the nominal discharge cycle load and maintain compliance with the manufacturers warranty over the design life of the batteries.

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Step 2 – System Design and Selection

- Usable stored energy capacity (kWh)

  Other battery technologies offer different stored energy capacities:

  - Lithium based batteries – Upto 90% Depth of Discharge (DoD) per cycle with a warranty of 10 years or ~ 4000 C/D cycles therefore requiring ~ 1.1 x the number of batteries to match the nominal discharge cycle load. (i.e. ~ half the number of VRLA batteries for the same load).
  - Aqueous salt based batteries – Upto 100% DoD per cycle with a warranty of 5 years or ~ 3000 C/D cycles therefore requiring half the number of VRLA batteries for the same load.
  - Flow batteries – Upto 100% DoD per cycle with a warranty depending on technology varying between 3 years for daily C/D cycle or ~ 1000 cycles to 10 years and unlimited C/D cycles.

Step 2 – System Design and Selection

- Usable stored energy capacity (kWh)

  Conclusion: Too much variation!!

  How to select the best ESS technology for my Customer's Load?

  - Consider Total Usable Energy Throughput (E_{Total}) per battery.
  - E_{total} = V x Ah x C x DoD x n / 1000 kWh
    - Where:
    - V – Rated Volts at battery terminals
    - Ah – Rated battery Amphere Hours
    - C – Rated Cycles of charge/discharge
    - DoD – Rated Depth of Discharge for warranty period
    - n – Efficiency of each charge/discharge cycle energy in vs energy recovered

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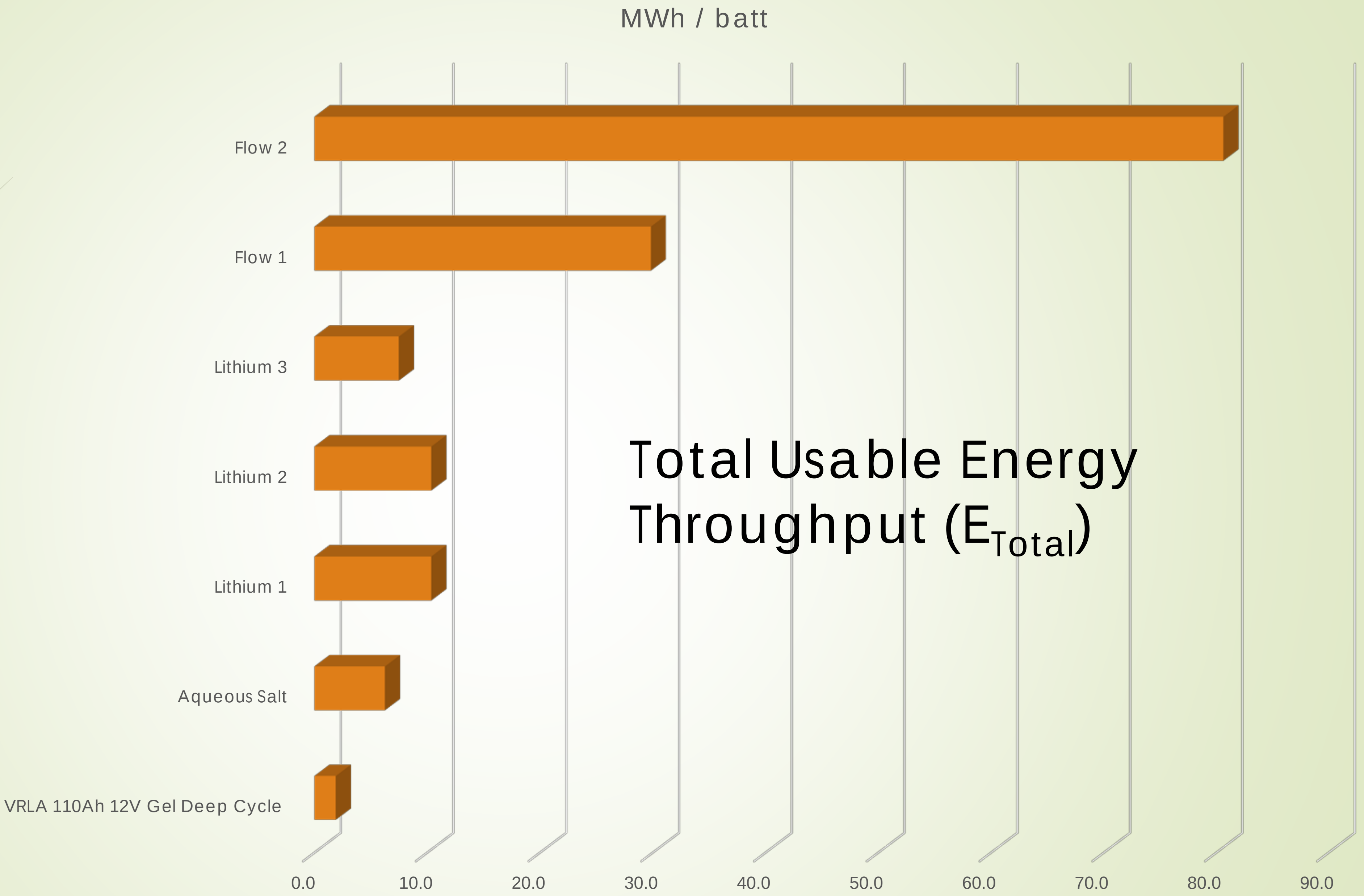
Total Usable Energy Throughput (E_{Total})



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Step 2 – System Design and Selection

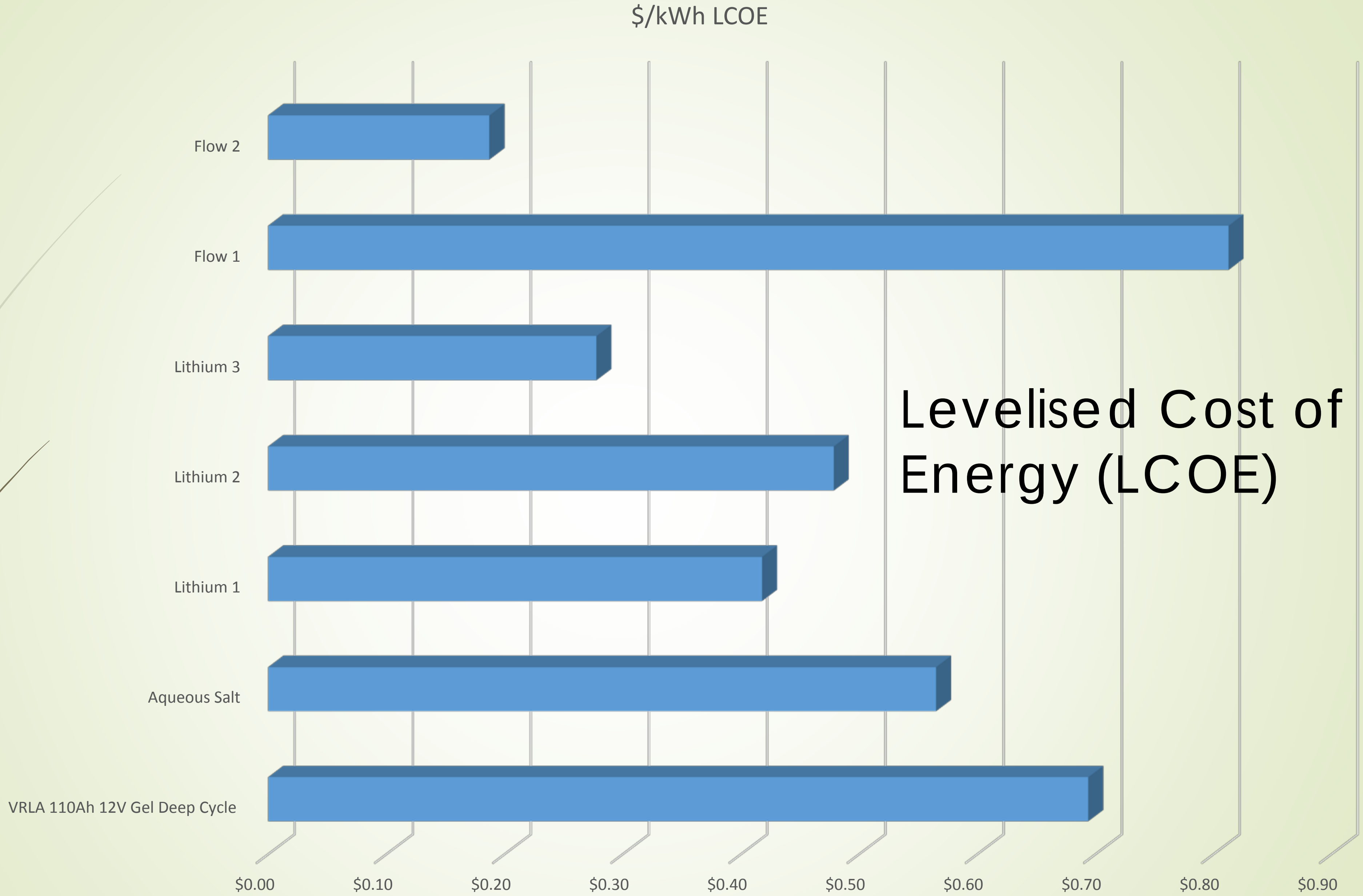
- Usable stored energy capacity (kWh)

  Conclusion: Too much variation!!

  How to select the best ESS technology for my Customer's Load?

  - Consider Total Usable Energy Throughput (E_{Total}) per battery.
  - Now consider Levelised Cost of Energy (LCOE) $/kWh

Levelised Cost of Energy (LCOE)



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Step 2 – System Design and Selection

- Usable stored energy capacity (kWh)

  Conclusion: Too much variation!!

  How to select the best ESS technology for my Customer's Load?

  - Consider Total Usable Energy Throughput (E_{Total}) per battery.
  - Consider Levelised Cost of Energy (LCOE) $/kWh
  - Now match these back to your Customer's budget and load to obtain best value within their budget

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Step 2 – System Design and Selection

- What ESS technology best achieves the requirements as defined in the System Specification?
- Key variables to consider:
  - ☑ Customer budget
  - ☑ Usable stored energy capacity (kWh)
  - ☑ Maximum energy delivery (kW) and duration (secs/mins/hours?)
  - ☑ Maximum charge rate (kW, Volts/Amps)
  - ☑ Number of Charge/Discharge cycles per day
  - ☑ Life of ESS in cycles / hours run / total energy throughput (kWh) as applicable
  - ☑ DC or AC connection
  - ☑ ESS location and ambient conditions (indoor vs outdoor, city vs regional/remote area)
  - ☑ Finance costs as applicable
  - ☑ ESS Levelised Cost Of Energy (LCOE) vs Customer current energy cost

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Step 3 – Local vs Imported Product?

- If importing, need to consider:
  - Freight and insurance
  - Customs and taxes
  - QA in manufacture
  - Lead time
  - Delivery delays
  - Obligation of importer for compliance with regulations –
    - **Key Issue:** leverage with foreign manufacturer/supplier to achieve compliance without impacting warranty
- **Conclusion**: While offshore product may be cheaper to purchase, you bear the risk in getting it here and ensuring it is compliant with local regulations. (More on regulations later)
- In some cases there is no option but to import to achieve system specification within budget and delivery timeframe

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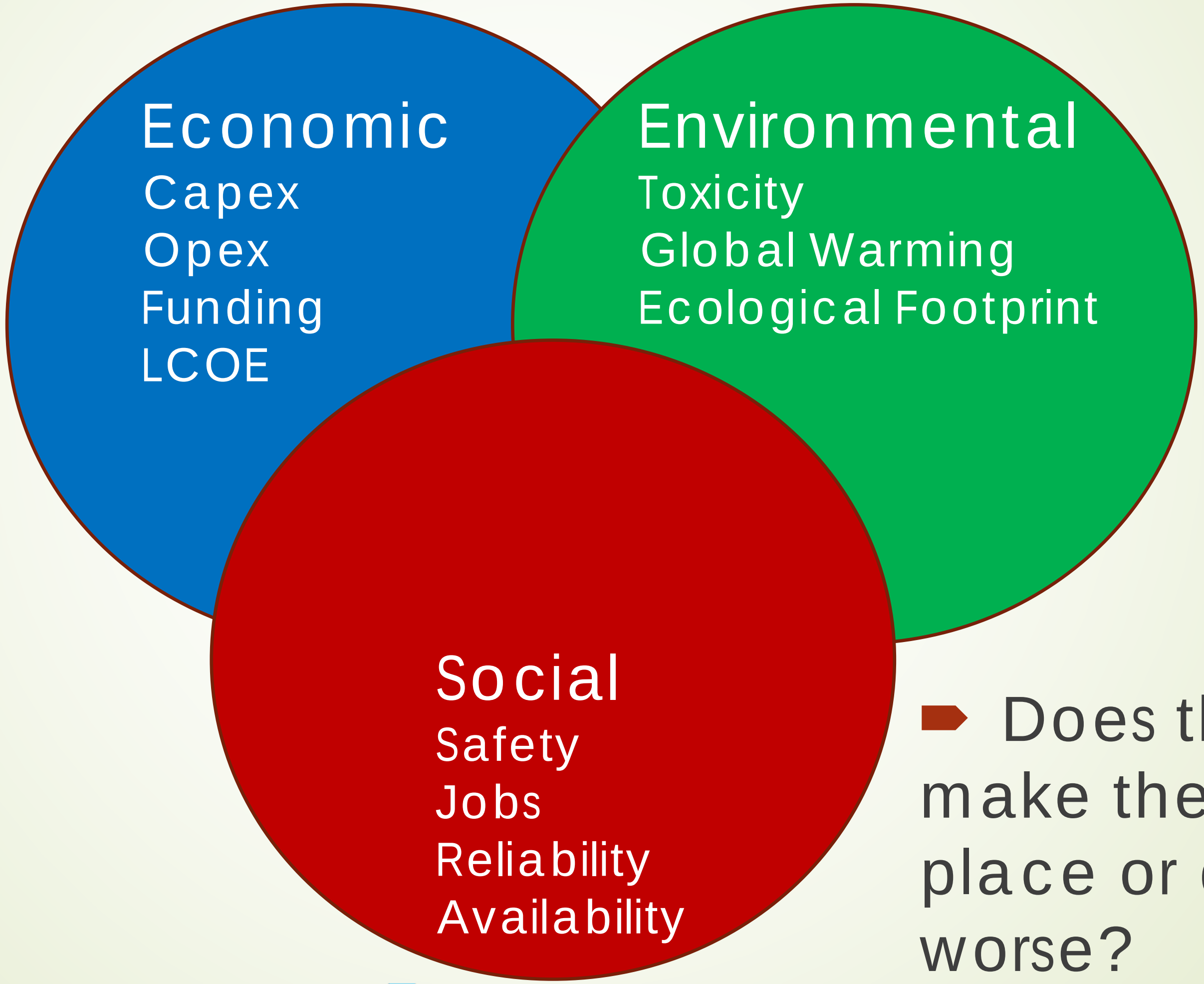
Step 4 – Triple Bottom Line Sustainability?



- Does the selected ESS make the world a better place or does it make it worse?

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Step 4 – Triple Bottom Line Sustainability?

- Why should I or my Customer care about this?
  - **Economically sustainable** – Can the proposed ESS be delivered:
    - at a capital cost that the Customer can afford and wont regret having paid in 5 years time when new cheaper technologies will likely be available?
    - at an operating cost that the Customer can afford and wont regret paying in 5 years time when improved technologies will likely be available?
      - Consider – Availability, Reliability, Warranty/Maintenance and Finance costs in determination of LCOE over the design life of the ESS.
      - **How long will the ESS remain in service???**

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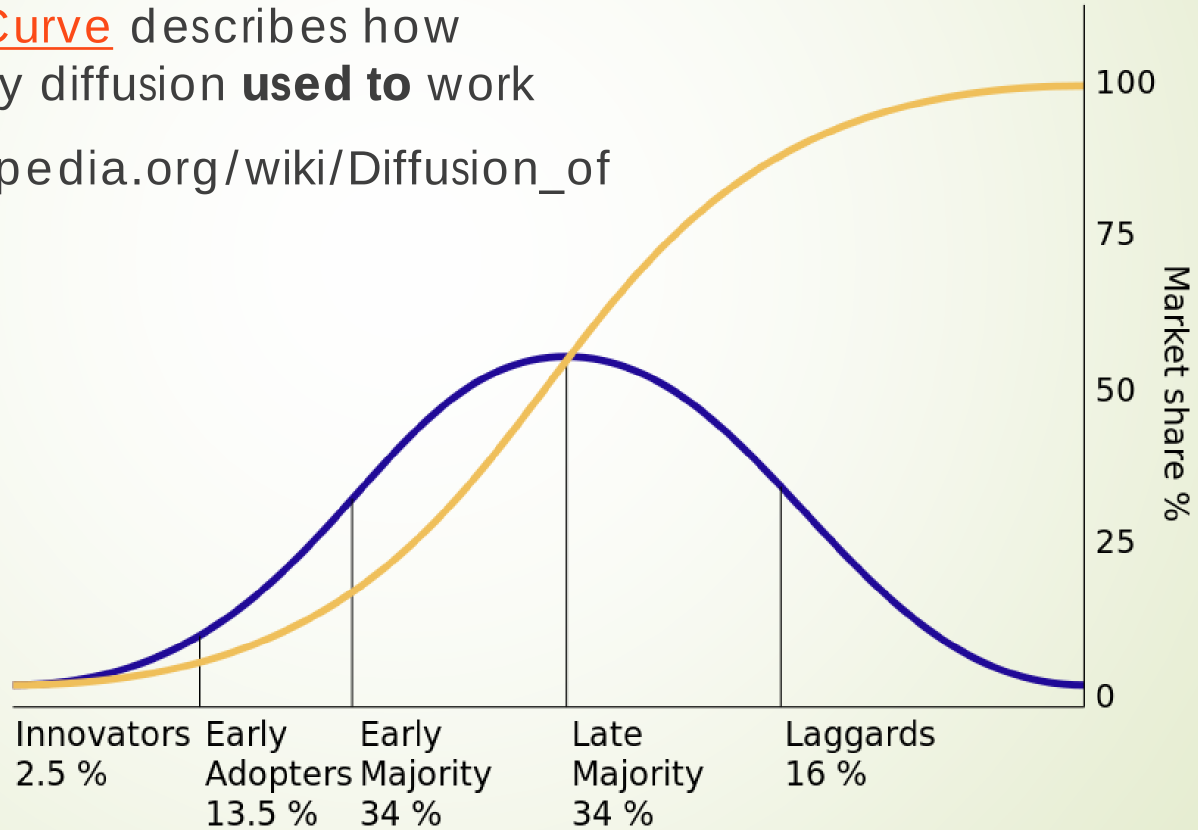
Adopting new tech and clean tech - how quickly will (can) the world change?

(Professor Ray Wills http://www.raywills.net/rtwtechadopt.html)

- Roger's S Curve describes how technology diffusion **used to** work

http://en.wikipedia.org/wiki/Diffusion_of_innovations



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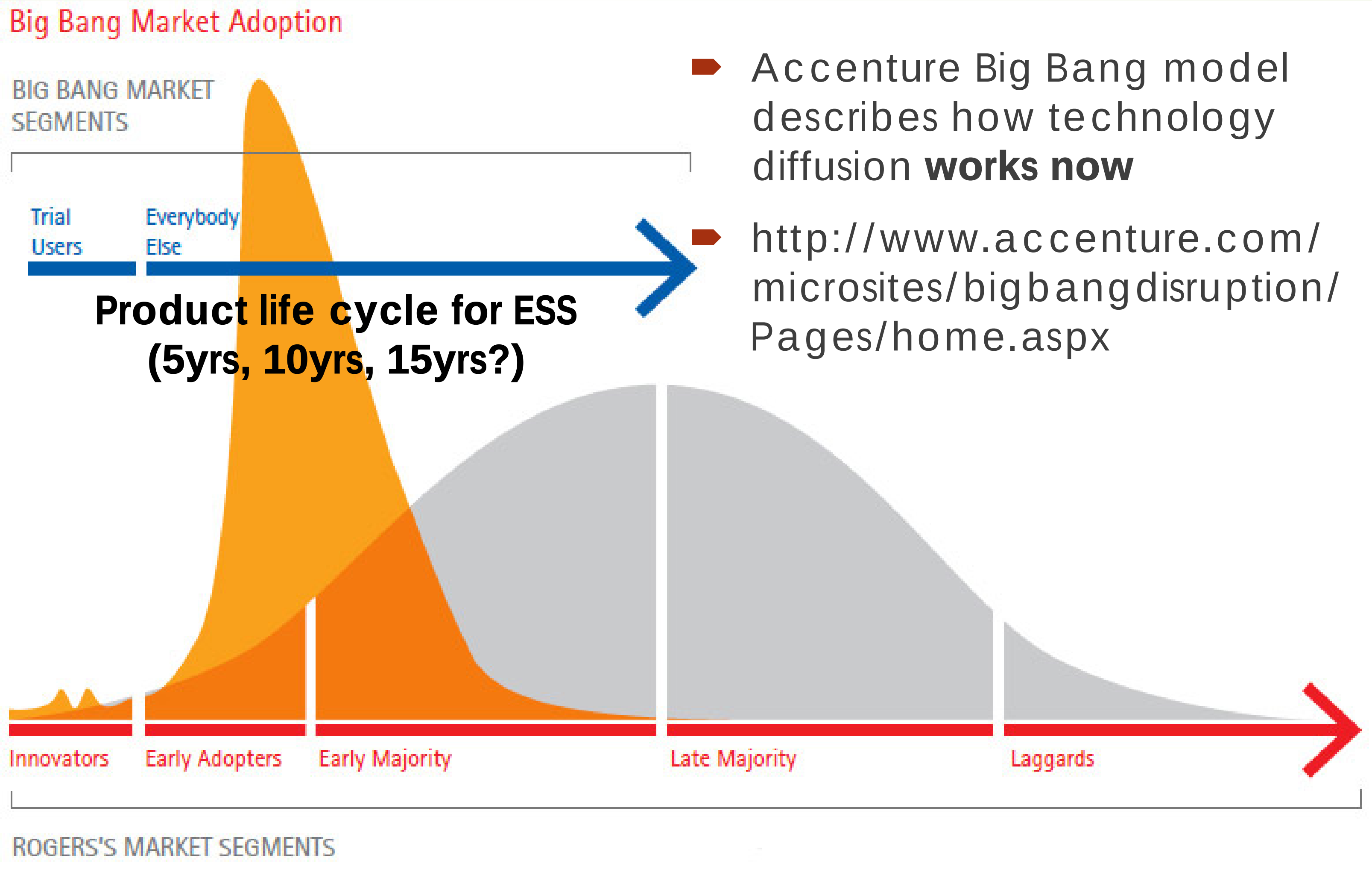
Adopting new tech and clean tech - how quickly will (can) the world change?

(Professor Ray Wills http://www.raywills.net/rtwtechadopt.html)



- Accenture Big Bang model describes how technology diffusion **works now**
- http://www.accenture.com/microsites/bigbangdisruption/Pages/home.aspx

Step 4 – Triple Bottom Line Sustainability?

- Why should I or my Customer care about this?
  - **Environmentally sustainable** – What is the relative ecological impact of the proposed ESS vs alternatives in terms of:
    - Non recoverable embedded energy in electrolyte and materials?
      - Consider ability to **Reduce, Reuse, Recycle**
    - Toxicity?
      - Consider ecological impact of ESS chemicals and materials from spills during service life and when disposed at end of ESS life. (Most ESS use **strong acids and heavy metals** in construction and electrolyte)
    - Global Warming Potential? (Equivalent **CO2 emissions**)
    - Ecological footprint? (proportion of global land/water use and pollution)

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Step 4 – Triple Bottom Line Sustainability?

- Why should I or my Customer care about this?
  - **Socially sustainable** – Will the proposed ESS provide power when the Customer wants it for as long as they want it?:
    - What happens if they try to draw too much or for too long?
      - Consider Customers load profile now and over the design life of the ESS and how the ESS will manage and respond to this and any temporary excursions.
    - Grid supply faults?
      - Consider islanded ESS operation vs non-islanded.
    - Electrical faults on Customers side of meter box?
      - Consider how the ESS will manage and respond to this to protect people, environment and Customer's premises from electrical, fire and chemical/toxic materials hazards.

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Step 4 – Triple Bottom Line Sustainability?

- Why should I or my Customer care about this?
  - **Socially sustainable…** – Can the Customer safely and reliably use and operate the ESS over its design life?:
    - Aesthetics of ESS and physical safety/segregation of people and animals (including vermin)
      - Consider location, size and type of physical installation of ESS. (e.g. indoor vs outdoor, access prevention/control, wall mount vs floor mount, emergency access etc.)
    - Maintenance and Operation requirements?
      - Consider ESS Customer interface (remote vs local) and ease of use, display and understanding of faults and alarms and access to maintenance/warranty/operational support (phone, internet, local technician etc.)

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Step 5 – Legal and Regulatory Compliance/Approvals

- So, we have an ESS that is "fit for purpose" from the Customers perspective, but have all potential hazards been identified and addressed? Consider:
  - People,
  - Environment and
  - Assets
- Include the Customers family and pets, visitors, neighbours, house/business premises, grid supply system, adjacent park, swimming pool, stormwater drains etc.

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Step 5 – Legal and Regulatory Compliance/Approvals

Energy Storage Safety – "Responsible installation, use and disposal of domestic and small commercial systems". Task 1B Report by CSIRO for Clean Energy Council (CEC) funded by Australian Renewable Energy Agency (ARENA), 13 November 2015

Key Points:

- Australian standards for energy storage and connection to the electricity network are limited and incomplete.
- The standards available cover a variety of grid and off-grid connections, vehicle-to-grid connections, demand response and so on.
- Determined action in response to fire hazards [of lithium ion batteries] is ongoing, … most guidelines to date have been written using data from lithium-ion cell incidents in portable devices, rather than large installations of stationary battery storage systems.
- For the domestic battery storage market, there is a need to develop new standards that cover installation, smart communication, training and maintenance, transportation, safety and emergency guidelines, and requirements for environmental safety and recycling.

Step 5 – Legal and Regulatory Compliance/Approvals

- **Electrical Hazards**
  - Generally well documented, understood and managed for appliances that **consume** electricity
  - Less well documented, understood and managed for ESS that store energy and **generate** electricity (other than PV systems and small portable AC generators). Consider:
    - short circuit across battery terminals,
    - DC vs AC currents behaviour and electric shock impact on people, animals and materials coming into contact with ESS.
    - Separation and segregation of voltages,
    - Insulation
    - Etc.

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Step 5 – Legal and Regulatory Compliance/Approvals

- **Electrical Hazards…**
  - For ESS, the following should be consulted and complied with:
    - Relevant state Energy Safety (or equivalent) energy regulatory authority Acts and Regulations for electrical installations.
    - In Western Australia, the following apply:
      - Energy Safety Act 2006
      - Energy Safety Regulations 2006
      - Electricity Act 1945 (most parts)
      - Electricity (Licensing) Regulations 1991
      - Electricity Regulations 1947
      - Electricity (Supply Standards and System Safety) Regulations 2001

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Step 5 – Legal and Regulatory Compliance/Approvals

- **Electrical Hazards…**
  - For ESS, the following standards should be consulted and complied with **as applicable**:
    - AS/NZS 1170.2 – Structural design for wind
    - AS/NZS 1768 – Lightning protection
    - AS 2676-1992, Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings
    - AS/NZS 3000 – Electrical wiring rules
    - AS 3011-1992, Electrical installations — secondary batteries installed in buildings
    - AS 4029-1994, Stationary batteries — lead-acid
    - AS 4086 - Secondary batteries for SPS. Part 2: Installation and maintenance.
    - AS/NZS 4509.2 – Design of stand-alone power systems
    - AS 4777 parts 1 and 2 – Grid connection of energy systems via inverters – Installation and Inverter Requirements
    - AS/NZS 5033 – Installation and safety requirements for solar PV arrays
    - AS/NZS 5603 - Stand-alone inverters —Performance requirements
    - Draft AS/NZS 5139 - Safety of battery systems for use in inverter energy systems

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Step 5 – Legal and Regulatory Compliance/Approvals

- **Environmental Hazards**
  - ESS can contain heavy or toxic metals such as nickel, cobalt, cadmium, vanadium and lead, which can be harmful to the environment if disposed of in landfill or if spills enter water ways or ground water e.g. via drains or run-off.
  - ESS also generally use strong acids which pose a safety hazard to exposed people, environment and materials from spills or incorrect disposal at end of life.
  - In Australia, used ESS are classified as either:
    - hazardous waste; or
    - dangerous goods

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Step 5 – Legal and Regulatory Compliance/Approvals

- **Environmental Hazards…**
  - For ESS, the following should be consulted and complied with as applicable:
  - Dangerous Goods Classes

    Class 8 – Corrosives

    - Corrosives are substances which by chemical reaction degrade or disintegrate other materials upon physical contact.

    Class 9 – Miscellaneous dangerous goods

    - Miscellaneous dangerous goods are substances, materials and articles which during transport present a danger and/or hazard not covered by other classes. This class includes, but is not limited to, environmental hazardous, transported at elevated temperatures, and miscellaneous articles.

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Step 5 – Legal and Regulatory Compliance/Approvals

- **Environmental Hazards…**
  - For ESS, the following should be consulted and complied with:
    - Relevant state Environmental (or equivalent) regulatory authority Acts and Regulations for ESS installations.
    - In Western Australia, the following apply:
      - Dangerous Goods Safety Act 2004
      - Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007
      - Dangerous Goods Safety (Road and Rail Transport of Non-Explosives) Regulations 2007
      - Dangerous Goods Safety (General) Regulations 2007

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Step 5 – Legal and Regulatory Compliance/Approvals

- **Environmental Hazards…**
  - For ESS electrolyte, maintenance and end of life waste disposal, the following should be consulted and complied with:
    - Relevant national and state Environmental (or equivalent) regulatory authority Acts and Regulations for ESS installations.
    - Hazardous Waste (Regulation of Exports and Imports) Act 1989
    - In Western Australia, the following also apply:
      - Waste Avoidance and Resource Recovery (WARR) Act 2007
      - Waste Avoidance and Resource Recovery (WARR) Regulations 2008

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Step 5 – Legal and Regulatory Compliance/Approvals

- **Grid Connection Approval**
- Ausgrid - The inverter being installed as part of the solar or battery storage system must be approved to Australian Standard 4777 for grid connected energy systems via inverters.
- Other grid operators are similar with appropriate approval required for ESS that are intended to feed energy back into the grid (either as dispatchable power or under renewable energy buyback scheme due to hazards and technical issues that may be created in grid or consumers mains).

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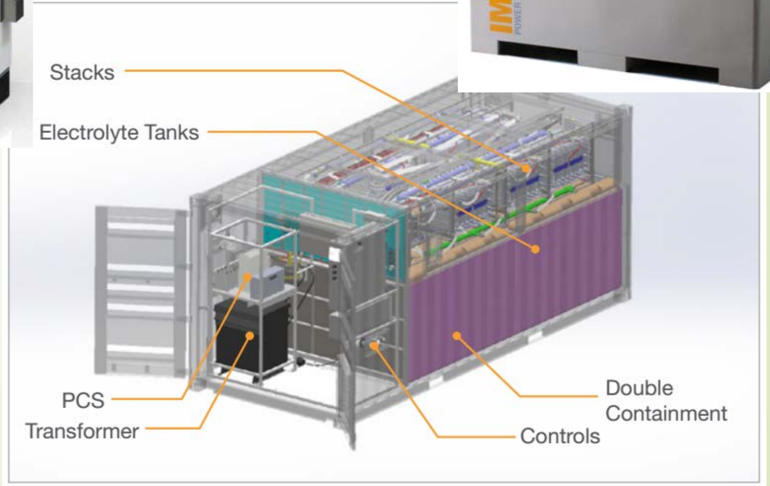
Step 5 – Legal and Regulatory Compliance/Approvals

- **Local Government and Other Approvals** (e.g. Fire and Emergency Services)
  - International Fire Engineering Guidelines - Section 1.2.6 (Review of hazards)
  - Building Code of Australia (BCA) Part E1.10 Provision for special hazards.
  - In Western Australia - Health (Public Buildings) Regulations 1992 relating to battery rooms (as applicable)

Your ESS is approved!
Was it worth the effort?

Redflow ZBM



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