Solar Electricity Services in the Developing World

1 Title: Solar Electricity services in the developing world

Official summary: There are more applications of **stand-alone solar electric systems** than there are apps for smartphones. The developing world needs a good number of these systems and has the solar resource to justify them.

This talk will outline key approaches for developing **quality commercial solutions**. Not the cheapest or most sophisticated, but those truly **fit for purpose**: for the people, their needs and the environments in which they live.

Presented on 28th November 2016 to Engineers Without Borders at University of Exeter and Falmouth University, Penryn Campus (Cornwall, TR10 9FE).

2 Martin Bellamy Collage of experience and projects

- Professional Engineer for 29 years
- Degree in Engineering Physics (June 1995)
- Worked directly within the solar PV industry since January 1999
- Specialist areas: Stand-alone PV solutions; Developing world energy markets; Thin-film PV technology.
- Provides training, product design and strategic business support to PV manufacturers, industry suppliers, and the international investment sector.

3 Overview

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4 The 'developing world'

Even the terminology can be emotive:

- Lesser-developed or Under-developed nations
- Pre-industrialised economies
- Emerging economies
- 3rd world. (**Do you know what the 2nd world is?)**

Don't get hung up on political correctness. Make a positive impact and the title doesn't matter.

I will make lots of references to terminology within society as a whole.

- Multitude of misunderstandings, presumptions, simplifications and incorrect information.
- Just as there are incorrect arguments and false logic, there is bad morality.

Financial assessments: GDP (PPP) takes the costs of living into account. This explains why GDP (PPP) is used to measure the quality of life in a country. (**gross domestic product** and **Purchasing Power Parity**).

5 Why energy access matters

There is widespread agreement that 'modern energy services' (which basically means electricity and electrical services) is essential to poverty alleviation as well as social and economic development.

The debate is about which services to provide and in what form. The entire discussion is routed in the language of cost – which typically compromises quality and value.

Quote from IEA World Energy Outlook:
http://www.worldenergyoutlook.org/resources/energydevelopment/

6 Energy Access in numbers NASA lights at night

Figures from IEA World Energy Outlook:
http://www.worldenergyoutlook.org/resources/energydevelopment/

- In today's digital and interconnected world, energy-poverty is increasingly close in scale to poverty.

7 One type of energy people London lights from the air

The industrialised world is, in many ways, defined by its DEPENDABLE networked electricity.

There are no unreliable networked grids and 'off-grid' is a choice.

It is impossible to have a grounded discussion about energy services provision without first discrediting the mains grid – central generation format.

8 Four types of energy people 4 DW types of energy people

I use four areas to describe the relationship of people to mains electricity **in the developing world**:

- Reliable networked grids ~The Industrialised world (3.5bn)
- Unreliable networked grids Developing world cities (~1.3bn)
- Limited mains electricity access Semi-rural ~1bn
- Off grid (no reasonable access to mains electricity) ~1.2bn

- Those already using the mains: ageing infrastructure, massive inefficiency & waste, disconnection of the users from the impact of their demands.
- Those new to the mains: urbanisation, corporate dependency, national fuel dependency, etc.
- Those with no direct access to mains: fuel dependency, health & safety, cost and low user value.

9 The Grids Don't Work NEW SECTION

NOTICE THAT ALL ENERGY IS REFERENCED TO THE GRID…

10 Grid electricity cannot work Immapancy – Africa scale

Map image can be found by searching: immappancy by Kai Krause

- The grid format is inappropriate because:
  - Land size, terrain, environment
  - Cannot address the problem because it cannot be made reliable. Without reliability, value is undermined.
  - High maintenance - skills requirement (people and training), equipment, safety.

- ***Although the grid format meets the needs of millions and even tens of millions, it cannot meet the current or emerging needs of billions***

11 Delivering electricity Central generation doesn't fit

Central generation uses very large generators (relative to points of consumption) and lots of distribution infrastructure (cables, power conversion, etc.)

- Central generation and associated transmission infrastructure is simply too expensive and impractical for the huge geographic regions without existing mains electricity.
- Central generation are typically very large, costly and highly skilled civil engineering projects. They require significant skilled operation & maintenance and large distribution infrastructure – also costly and needing skilled O&M.
- Central generation is geographically limited in value.

- There is a simple reason central generation does not work in the DW: there are too many people wanting electricity.
- New generation capacity encourages migration.

12 Out of date option Out of date option

- Literally for the industrialised world
  - Much of the industrialised world electricity infrastructure is over 40 years old.
- Figuratively for the developing world
  - National fuel dependency – even for those not benefiting from it.
  - Inappropriate use of money and effort.
  - Diverts from better solutions

13 Holing back progress

Our global energy system is not logical. But it is very resilient to change…

14 Delivering electricity - badly Grid inefficiency graphic

- Waste energy from generation is often lower than shown (though above 50%). Transmission however nearly always has higher losses (10% to 25% depending on distances and infrastructure age).
- With only 20% to 30% of the original energy delivered to our homes and businesses, we then waste most of it by using (cheap) inefficient appliances – as part of a lazy lifestyle.

- The financial and environmental impact of delivering fuel to the power station is not included...
- Highly skilled workforce required just for operation
- Workforce needed over the entirety of the network

15 Of course fuel is a problem

- We cannot use fossil fuels for electrical infrastructure in the developing world. Even if it were possible, we are only creating more dependency.

- There are now 7 billion humans. In 1990 there were 5.3bn. In 1980 there were 4.5bn (when the USA and Europe had built most of their electricity infrastructure...)
- There are several hundred million extra electricity users compared to just 10 years ago... Dependency on oil has created a host of serious problems.
- The climate is changing; the only debate is over why. Even if we have fossil fuels far into the future, we cannot afford to use them as we are doing.
- Increasing demand
- Limited availability of fossil fuels
- Energy security
- Ageing infrastructure
- Climate change
- **International politics – human rights**

16 How fuel is used – off the grid

- The main sources of energy for over 1.5 billion people: candles, Kerosene/paraffin, wood & charcoal, batteries (disposable and rechargeable), diesel.
- Solar and other sustainable technologies have started to be used but are still a small sector.
- Fuels mean issues of health, cost, safety, environmental damage, and dependency on limited resources.
- Two thirds of adult female lung-cancer victims in developing nations are non-smokers

17 Global fuel dependency

- In terms of global percentage contribution, energy from solar is tiny. In fact all renewables account for only around 15%. So why use them? Why are they so important?
- As with all PV solutions, the value is not in how much electricity is generated, it is how much fuel, pollution and other costs are saved.

The true value of PV is not yet being utilised.

- Being dependent on a finite resource is crazy

Those most dependent (industrialised world) – who have the greatest influence on global energy – are too comfortable and as a result have the least motivation to do something about it.

Those who suffer the most from fuel – and have the greatest motivation for change – have the least influence.

18 Climate is not a concern — Glacier melting cartoon

Of course it should be, but global action is minimal in proportion to the potential consequences.

- Destroying our only home is stupidity. If this is not a motivator, what can be?

19 Ethical motivation doesn't work — Earth above fire

Focussing on fuels is to make the point that its implications are not sufficient motivators for change.

- Or for convincing people of a better way: product, habit, recipient of money
- When addressing future energy solutions (developing world or otherwise), we need to operate against how the world is, not how the world should be.

People do not value something unless that something requires personal effort to obtain or results in personal negative impact if not valued.

20 Pushing LED lighting

The motivation of avoiding fuel dependency has not worked in the developing world.

Promotion of small solar PV lights to replace kerosene were based on fuel arguments – for a decade…

- **Push**: healthier, safer, no dirty fuel dependency
- **Pull**: Instant on, No flicker, free light (the attractive propositions in the eyes of the users)
- It's important to appreciate that funding for solar lights needed the push arguments though.

21 Disposable batteries

Environmental, as well as cost and logical arguments, fail to motivate industrialised societies.

- Developing world – didn't see the value in an alternative to kerosene
- Industrialised world doesn't seem to act on the value of rechargeable batteries
- Eneloop rechargeable AAA = 2000 times the use of a disposable. Ready to use out of the pack. A cost of ~£2 versus >£1000.

22 Nobody wants electricity anyway — Young Frankenstein

- Up until the mid 2000s there was a simple problem: no one needed 'energy'. They had energy.
- Mobile phones changed this. Now people specifically want electricity
- But actually, they don't. They want communication – they just need electricity to obtain it.

23 People want services — Lots of appliances and devices

- Appliances and devices convert electricity into a service of some kind
- Entertainment, hot food, cold drink, light, communication, hot air, hot surface (iron).
- The majority of people and households need a small range of electrical services.

24 Know your options — EWB super taxonomy chart

- Don't be prejudiced by familiarity. You will always know one technology better than others.

25 Be cautious — EWB Engineering in Development: Energy

- EWB Energy is about:
  - Assessing the problem
  - Understanding who, what, where, when and how
  - Not making the same mistakes that so many well-intentioned people make
- Free to download on the EWB website: EWB-UK Engineering-in-Development publications
- Hardcopy available for £20 (£5 goes to EWB). Authors did not and do not receive any money.

26 Solar photovoltaics – PV NEW SECTION

- This talk is about solar PV.
- Stand-alone PV is representative of the renewable energy's value for the developing world.
- It also faces many of the general challenges faced by renewable energy in the wider world.

27 Two main solar technologies

- The basics: the **word 'solar' is used for lots of things**: pedal bikes, hosepipes and air fresheners.
- It means '**relating to or determined by the sun'**
- Planetary solar system, the solar calendar, or solar energy; and, of course, solar technology.
- The last of these contains a great deal of variety. But by far the most common examples are *thermal* and *photovoltaic*s.
- Solar **thermal** technology utilises the **Sun's energy for heating and cooking**.
- Photovoltaics, or PV, is **the direct generation of electricity from light**.

28 Sunlight energy is the fuel

- Actually 'daylight' is a better term. PV does not need direct sunlight in the traditional sense.
- But 'daylight' is still light from the sun.
- PV cells generate electricity in direct proportion to the sunlight intensity hitting their surface.
- The more sunlight that is available, the more valuable or cheaper a given PV solution becomes.

29 There is no fuel shortage

- "In 90 minutes, enough sunlight strikes the earth to provide the entire planet's energy needs for one year." [The International Energy Agency's *Solar Energy Perspectives* (2011)]
- While world consumption rises each year, the quote nevertheless serves to illustrate the vast resource available to us.
- Energy from the sun will continue for millions of years.
- The sun's energy is free, abundant and predictable.
- **Ocean Thermal Energy Conversion** (**OTEC**)

30 Predictable generation

- The popular criticism is 'the sun doesn't shine at night'. Well, actually it does.
- Remember there is always sunlight energy hitting Earth, just not for a whole day in the same place.
- Energy storage is easy – we all carry batteries around with us.
- The problem is storing very large amounts of power – which we don't need to do…

- Sunlight energy can be predicted with a high degree of reliability.
- Data is available free of charge from a number of sources such as NASA, European Union and several academic institutions.
- Sunlight energy is stable over a wide geographical area – such as a country. By contrast, wind power for example varies enormously between street level and the top of a building.

31 The main PV technology groups

- **Space cells**: very efficient but expensive. Designed for higher insolation levels than on Earth. Must be super reliable.
- **Concentrator cells**: similar to space cells. Heat and cost are the issue. Also require tracking of the sun = moving parts = reduced reliability.
- **Crystalline** = silica sand. The most widespread technology. Like the car engine, not the best material, but low cost and plentiful because we have been making it for so long.
- **Thin-film glass** = generally better than crystalline (shade tolerance, heat, orientation) and lower environmental impact. But we don't make enough of it yet so less efficient and more expensive.
- **Thin-film flexible** = the future of PV for portable and personal goods. Difficult to make, and poor commercial development decisions have held it back.

32 Why PV is so important

- PV can be used in urban and rural locations.
- PV has no moving parts and is very resilient against environmental conditions.
- PV can be personal and utility scale; from watches to power stations.
- The fuel – sunlight – is free, abundant and very predictable.
- No noise at all – not even a slight hum.
- Maintenance is mostly cleaning the solar panels – like cleaning a window. No special tools, materials or chemicals are required. Maintenance is non-skilled.
- The energy required to make a PV panel is generated by that panel is less than a few years. PV panels typically have 25-year performance warranties. Nearly all materials can be recycled.

33 The PV market NEW SECTION

The reason for looking at the PV market is to appreciate some of the problems for stand-alone solutions in the developing world.

- The **PV sector is illogical**…
  - The metrics of capacity (Wp) is analogous to the car industry selling miles per hour.
  - the language of 'value' ($/Wp) is at best misleading, at worst meaningless.
  - the primary application of the technology (grid-connection) does not utilise the core value: versatility.

34 Grid-connected PV systems

- Also called grid-tied systems.
- Over 95% of all PV technology is used for this type of system.
- This sector undermines the core value of PV: versatility.
- If the mains grid is not present, or is not operating correctly (within voltage and frequency limits), the PV system will shut down – by law.
- **All mains grids around the world are dependent on coal, gas or nuclear fuel. All grid-tried renewable energy systems are therefore dependent on these fuels...**
- In hot climates, peak PV generation coincides with peak demand (air conditioners).

35 Grid-connected sectors

The value proposition is the same for all: cost of electricity. Secondary = green electricity and other 'non-tangibles'.

- **BIPV** = Building Integrated PV. This is where PV replaces part of the building fabric- typically roof tiles, windows or louvers/Brise soleil.
- **Residential or domestic installations** are the most common systems and range from a few hundred Watts to a few thousand (kW). They are also considered to be the future for grid-connected PV because they can reduce demand from central generation and transmission.
- **Small commercial** systems range from a few kW to 10s of kW.
- **Large commercial** systems are approximately 100kW to over a MW.
- **Utility scale** systems can be over 100MWp.

  As recently as 2005 there were only a few of this scale of installation. Today they are the preferred installation type for PV manufacturers but require significant planning, installation, operation and most critically, financing.

36 'Off-grid' PV systems

- Note the term 'off-grid' implies an alternative to the grid. 'Autonomous' is technically most accurate. 'Stand-alone' is (hopefully) becoming the preferred term.
- All stand-alone systems work the same way: PV charges the battery during daylight hours and the battery supplies power to the load at any time.
- Originally, all PV systems were stand-alone solutions.
- The value of these systems lies in the cost of the alternative energy solution. For example, if a telecoms transmitter needs to be located on top of a mountain, it could be hundreds of thousands of dollars to install a mains grid supply. It is not likely that a diesel generator could be refuelled regularly enough, and so PV becomes the most valuable solution – even if the suppliers is making several hundred per cent margins. This is exactly how the PV industry came to be (in the 1970s and 80s).

37 Example stand-alone applications

- There are hundreds of applications and thousands of solution sizes.
- Satellites are the most iconic application. Calculators probably the most well-know.
- Stand-alone solutions do not usually require subsidies.
- Original applications were largely commercial / Industrial (monitoring, telecoms, Oil & gas).
- Emerging markets present very different – stronger - value propositions for solar.

38 Stand-alone PV sectors

It is difficult to categorise stand-alone PV systems because there are so many existing and potential types.

I use the following, because they encompass the most commonality in design and implementation.

- Bespoke designs – in the range of a few hundred Watts to a few tens of kWs.
- Regional solutions – a few Watts to a few hundred Watts.
- Portable and consumer solutions – mWs to tens of Watts.

39 Bespoke designs

- These are the largest and most difficult PV systems to design, but the most valuable.
- Usually designed for a specific location, load power requirement and level of reliability.
- These systems should be designed for at least 15 years with batteries lasting 5 to 10 years.
- Significant design knowledge is required to produce very reliable systems.

40 Regional solutions

- Can be thought of as 'one design for multiple locations'
- These system designs are produced in modest volumes and deployed as a 'solution in a box'.
- Performance is defined by sunlight, which not only makes installation important but also limits the geographical range within which a given system will be effective.
- Value is determined by the offset costs of the alternative energy solution; if there is one.
- Thin-Film PV has major benefits over crystalline for this type of solution.

41 Portable & consumer products

- There are hundreds, maybe thousands of these products. Very few work effectively. Performance is as much about user understanding as anything else.
- The user defines both energy generation and consumption
- It is essential to convey understanding to the user, and to set their expectations appropriately.

42 Energy Services for the Developing World NEW SECTION

We will use PV as an example, but the developing world presents challenges to all energy options.

43 Hundreds of applications

In basic terms, anything that can operate from battery power can utilise a stand-alone PV system.

- The purpose of these three slides is to convey the enormous range of potential applications – and therefore value propositions for stand-alone PV systems.

44 Common generic services

- Remember that it is energy services that hold value, not electricity on its own.
- Think of the value each area represents to our everyday lives – and therefore the potential value to those who do not yet have access to them.

45 Sectors of society

The goal is not for stand-alone energy specialists to think of applications. The goal is for specialists within a given sector to understand that there is a dependable energy solution available for the services they know hold value.

46 Distributed Solutions – off-grid

Stand-alone PV is extremely versatile. Other technologies hold enormous value, but are limited in one way or another.

- biofuels can be used for cooking and heating but are not practical for electricity generation.
- Hydro-electric: geographically dependent, requires civil engineering and skilled maintenance.
- Wind: civil or structural engineering issues, limited predictability and skilled maintenance required.
- Solar thermal and solar cooking: effective, but limited in their scope of applications.
- Fuel generators: are much more fuel-efficient and have lower emissions, but they still create a dependency on fuel. They are also noisy and require skilled maintenance.

PV cannot solve all energy requirements, but the overall energy access challenge cannot be solved without PV.

47 Ideal for the developing world

The value proposition for stand-alone PV is incredibly high.

- 1/3 of the world's people do not have reliable mains electricity – nor do they need it...
- Just as these regions have moved straight to mobile communications without needing fixed-line infrastructure, so will they adopt distributed stand-alone energy and not mains networks.
- PV is the single highest value technology there is for these regions. No subsidies are needed – but they are available...

BUT:

- 'PV' has a bad reputation due to poor implementation – past and present
    - For industry: it is known as reliable and high value
    - For the DW: it is known as expensive and unreliable

The method of implementation is critical

48 Bigger is not always better

Actually, the opposite is true.

- PV manufacturers favour utility-scale systems, but they hold the lowest inherent value for the technology.
- These systems compete with every other form of generation – and carry the same dependencies on transmission infrastructure, finance, management, etc.
- The PV industry trend towards larger modules has restricted other areas of the market – especially stand-alone applications.
- Remember, they are dependent on fossil fuels (used for mains grid base load generation).

49 Local ownership

It is well established: for any project to have a lasting impact in the developing world, there must be ownership by the beneficiaries.

50 Correct PV use is essential

- Stand-alone PV epitomises this: it won't work at all without correct use.
    - Put the PV panel in the sun, make sure it is clean and unshaded.
    - Make sure it is plugged into the thing it should be charging.
- PV won't offer high value without care and engagement

51 User displays

- User displays can help with engaging the user in operation. But…

52 Maintenance

- Aspects such as maintenance, care and end-of-life disposal are more difficult to convey.
- Even for fixed installations, and even for low-maintenance PV, there is still a requirement to take care of the system.

53 User engagement is critical

- Bigger is, by definition, distant from users – geographically and emotionally.

We will never be appropriately motivated to respect our energy services until either personal effort is required to obtain them, or if widespread suffering emerges from using the service itself. The developing world experiences both realities: the former where utility grids are not present; the latter from the grids.

54 How to engage users?

- They are the most important part of the system. So effort is worth it.
- Talk to and involve people from the very start of any potential project. Ensure you understand what they need (and want). Ensure they understand the value of what is proposed.
- Remember, the user wants light, communications, entertainment, etc. – not electricity.

55 It doesn't have to be a burden

- User interfaces such as LED indicators allow personal energy control (just like the battery indicator on a mobile phone).
- For broader subjects, find keen individuals who can convey information to others. Set up community groups to whom information can be exchange and who will ensure others are informed.

User engagement must be a consideration in all aspects of design and supply.

56 Designing Energy Services Solutions NEW SECTION

Not power supplies. Not products.

57 Holistic solutions

Design the entire system as one – not a power supply that supplies unknown or inefficient equipment.

Energy efficiency is essential. This means what is being powered, how and by whom.

- Energy efficient equipment – the first consideration, and the primary requirement
- Integrated design – where all components are harmonized with energy efficiency
- Involving the user – encouraging efficient operation using displays and other notification equipment

The diagram shows the losses of using an inverter, when in most cases they are simply not needed.

58 Efficient equipment

- Reduce cost & increase value with energy efficiency
- Example: rural refrigeration in central Africa, with a 5 year operational life.
    - Typically: a standard, glass-fronted retail refrigerator is used
      The associated stand-alone PV system will cost ~$40,000
    - Ideally: an energy efficient refrigerator is purchased (with the same storage capacity)
      The PV system will then cost ~$4000
- Potential cost saving apply for nearly all applications

59 Inefficient people

- We are all inefficient – we use grid electricity.
- Enable the user to understand the impact of their actions – financial, practical (they run out of light, or the TV stops at the critical moment).

60 It is not just about functionality

- Products and solutions must be practical to use.
- They must be convenient as far as possible.
- They must be desirable.

61 Fitness for purpose?

- You may have to select products for a given requirement. This means fully appreciating the requirement, the users, their environment, etc.
- Only then are you able to assess the appropriateness of a product: its fitness for purpose.
- Quality means fitness for purpose (it does not mean expensive).
- Selecting from a range of potential products is a difficult exercise.

62 It can't always be elegant

- Don't get hung up on aesthetics – recipients will be more interested in function and operational life.

(Camels are the most practical way of transporting vaccines across or into desserts.)

63 Understand product use

- Approx. 1995 – the Argus 2 was released by a British company called EEV.
- The sole customer was the UK Fire Brigade – who were invited for feedback.
- EEV expected technical insight into limitations, high demands for the battery life, the weight and size of the product.
- The first and most vocal criticism was the strap length! With the strap around the neck, when the product was released it swung straight into the groin area…

64 Safety matters

- Seek professional guidance and approval.
- There is no such thing as 'common' sense when it comes to safety.

65 Understand logistics

1. Imperial Rome built the first long distance roads in Europe (and England) for their legions.
2. chariots were made for Imperial Rome, they were all alike in the matter of wheel spacing.
3. Roman war chariots formed the initial ruts, which everyone else had to match for fear of destroying their wagon wheels.
4. So the wheel spacing became fixed to fit the roads. The 'roman' roads have been used ever since.
5. English expatriates built the US railroads.
6. The first rail lines were built by the same people who built the pre-railroad tramways, and that's the gauge they used.
7. The United States standard railroad gauge of **4 feet, 8.5 inches** (143.51 cm) is derived from the original specifications for an Imperial Roman war chariot.
8. Space Shuttle: two big booster rockets attached to the sides of the main fuel tank. These are solid rocket boosters, or SRBs.
9. The SRBs are made by Thiokol at their factory in Utah. The engineers who designed the SRBs would have preferred to make them a bit fatter, but…
10. The SRBs had to be shipped by train from the factory to the launch site.
11. The railroad line from the factory runs through a tunnel in the mountains, and the SRBs had to fit through that tunnel.
12. The tunnel is slightly wider than the railroad track.
13. Imperial Roman army chariots were made just wide enough to accommodate the rear ends of two war horses. (Two horses' arses.)
14. So, a major Space Shuttle design feature of what is arguably the world's most advanced transportation system was determined over two thousand years ago by the width of a horse's arse.

THIS IS PROBABLY NOT TRUE! BUT THE ROCKETS HAD TO GO THROUGH THE TUNNEL NONETHELESS.

66 Regional standards

- They can help as well as hinder. Be careful to assess which standards apply.

67 Risk assessment

- For yourself, anyone involved is implementation, and of course the users.
- Electrical, chemical, mechanical, environmental.

68 Product design considerations

- These are just examples. There are many more – both general and specific to the project.

69 Language and expectations NEW SECTION

- Do the people you are trying to help actually want what you think they need?
- Perception of value is highly personal and reputations can be illogical

70 Mixed messages

- The general public (rich or poor) have little understanding of grid electricity, let alone something marginal such as solar PV.
- Overall, neither mainstream media or focussed groups are helping the situation.

71 Vested interest groups

- In the case of solar, it is the PV industry that has caused many of the problems we have with language and perception.
- There is resistance to change from vested interest groups for sure, but that resistance is only effective because the push for change is so weak.

72 Society…

- 'Big oil' hasn't helped, but people are the problem – and the solution if enough people group together.
- We want to help the world but only if it doesn't have a detrimental impact on our privileged and comfortable lifestyles.

73 We fear change

Resisting the uptake of cleaner energy, or even a lack of proactive attitude, is not logical. It is human.

74 Greater understanding

- No one wants energy. We want what energy enables.
- PV value lies in the value of solutions. Enabled by PV, not solar powered.
- As energy efficiency increases, the inherent value of PV increases.

75 Small changes, large savings

- Small savings at the point of consumption mean big fuel and pollution savings across grid networks.
- An energy efficient light bulb might save 50 Watts at the point of consumption but could save thousands at the point of generation.

Small actions by consumers can have large impacts. This principle can apply to many aspects of energy services provision.

76 Change the language

- We need to move away from the (PV) language of Watts, dollars per Watt, (cell) efficiency and technological references. To one of received value and overall impact.
- For example, PV module conversion efficiency (which is low) is most quoted, yet system efficiency (proportion of generated energy that can be utilised) is very high.

77 This is off-grid PV

Arguably one of humanity's greatest achievements is only possible because of PV.

78 But so is this…

- But the most visual applications are often very poor.
- We need to change perception and widespread opinion…

79 One day, everyone will use solar NEW SECTION

Anyone who uses satellites is already using a solar-enabled service: Sat-nav; GPS; satellite TV, etc.

80 The future of solar

- There are hundreds of new technology advancements being made across the globe. Some will not make it, some will change the way we think and use energy.

81 PV in our lives

- Think of rechargeable batteries. 20 years ago the only one most people used was in their car. Now, most of us have several about our person and are increasingly dependent on them. PV can charge these, power our houses and take care of the energy needs that save the most time, pollution, cost and external dependency.
- When PV reaches the necessary level of performance, everyone on the planet could have a need to use it.

PV is a good technology sector to be involved in!

82 PV brand emergence

- There is no technology end-goal. PV will always be in development: efficiency; cost; volume; yield; life; form; etc.
- There is no solar brand, despite the industry being 40 years old and having a >$100bn turnover.
- The first solar brand could well be a Thin-Film technology utilised in the developing world stand-alone market. The brands will be 'enabled by PV' and a complete solution brand.

83 Don't wait for technology

- Future technology is already here. We have it in our pockets.
- We waited for communications, computing, logistics, etc.

All the technology in the left hand side image (from 1995) now fits in our pockets.

84 Apply what we have

It is the manner in which technology is used that defines its value.

85 Learn to improvise

- The world is not a clean laboratory.
- You will not always have the ideal tools, materials, conditions, help, etc.

Practice at every opportunity. Familiarity leads to insight, insight leads to innovation and adaptation.

86 Be humble

- You are not saving the world. But you can be part of the solution rather than the problem.
- You can be making a net positive impact rather than a net negative one.

87 Thank you

End.