White Paper: Cheaper Energy For Islands and Isolated Grids

Summary

Islands and isolated grids have a strong potential to reduce energy cost using renewable energies: When replacing fossil sources (Diesel or Heavy Fuel Oil) they can simultaneously **reduce cost and carbon emissions** (by up to 1 kg CO_2/kWh). Sun and wind energy are already cheaper by at least a factor of two. As micro grids are less complex than continental ones, implementation is faster, with **lower investment and shorter breakeven time**. Climate protection and profits are no contradiction any longer.

As PV (photo-voltaic) and wind-mill installations grow, grid management must be upgraded to keep supply and demand balanced in the presence of higher volatility. Rather than relying on fossils or expensive storage for flexibility, **Demand Side Management** (DSM) can be used, such as shifting the charging process of electric cars or operation of cooling compressors to times when energy is abundant. As a result, other sectors emitting a lot of green-house gases also become cleaner.

Once islands run on renewables, new opportunities open up: **Cellular Grids** composed of connected micro grids could also help continental grids to integrate more renewables, improve reobustness and reduce cost. They are not discussed here, however.

1. Introduction

Cost of renewables have dropped substantially and continue to fall. We can now **switch from fossils to renewables and save money** at the same time. New technology will be needed to operate electric grids, the backbone of any society, on renewable energy.

Smart Technology for your energy system should provide:

- Balancing of supply and demand at any time,
- Minimum system and component cost,
- Resilience against disturbances (environment, failure, ageing, human interaction),
- Low system complexity (ease of operation, maintenance and emergency control),
- N-1 system security (in case of a single failure the system continues to work),
- Fair customer treatment (reward flexibility, protect autonomy and private data),
- Use of transparent and efficient market mechanisms,
- Protection of infrastructure and users against cyber-attacks.

We claim to provide this Smart Grid functionality at an **unmatched performance to cost ratio**.

2. Challenge

Many islands already install more renewables to reduce generation cost and dependence on fossil imports; they also create local employment opportunities. Existing sun and/or wind resources allow fast deployment of PV and wind plants whose costs continue to drop. Unfortunately, very soon a new barrier emerges: Using more volatile generation becomes difficult, and renewables are shed or curtailed (switched off). The reason for this lies in the traditional way to manage the grid – power plants supply the electricity as needed by consumers.

Ever since the first power plant was built in New York in 1882, only the supply side was managed to adapt electricity production to consumption. This is adequate for fossils plants (chemically stored energy can be burnt at any time) and became the governing paradigm **Generation Follows Consumption**. Energy harvested from sun and wind, however, depends on weather conditions - the **old Paradigm is no longer adequate**. With increasing renewables fossil plants only supply the load not served by renewables. As more PV and Wind are installed, there will be more times when these fully supply the load and fossil plants should switch off. Unfortunately, fossil generators are also needed to stabilize the grid, and other means must ensure this to when fossil plants are switched off. These other means are called flexibility options, and a typical example is energy storage.

3. Energy Storage

The technologies most widely used to store electric energy are pumped hydro and batteries. Their high cost unfortunately absorbs the savings by renewables, and soon storage investments become system cost drivers. While some bet on substantial cost reductions here, they are neither certain nor likely to come any time soon.

Fortunately, **Demand Side Management** (DSM) or load shifting is a lower cost option. Only some applications such as lighting or entertainment need instantaneous electricity. Many others produce services where this is not the case, such as drinking water supply: Water is electrically pumped to the water tap from a well or through a desalination plant. A simple water tank can decouple water and electricity consumption. Relative to the original situation, more pumping electricity is used at daytime to fill the tank, and less at night-time when stored water can be used. The same principle can be used with cooling or heating: An insulated water tank or storage room decouples the operation of a heat pump or compressor from the heating or cooling service the customer wants. Fig. 1 shows how this allows make better use of PV and reduce diesel generation or battery capacity for night-time electricity supply.

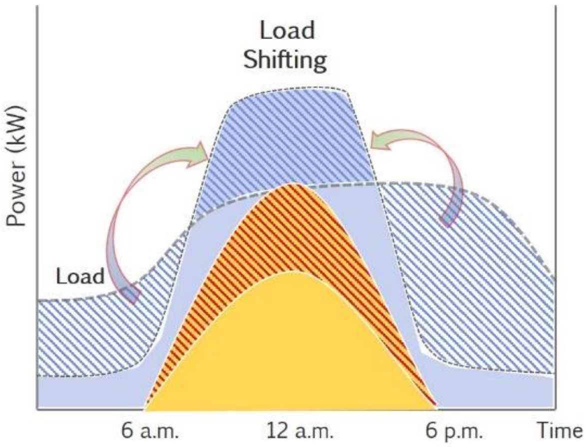

Fig. 1: Load shifting to use more PV

DSM provides the same value to the grid as a battery would, so we can call it a “virtual battery”. Energy storage cost can be as low as 1/40th of an equivalent battery, experts estimate. System cost can be reduced substantially by already available or easy-to-add “virtual batteries”. The new paradigm is to match supply and demand by adapting load: **Consumption Follows Generation**.

Many energy consuming applications are available to help reduce storage cost:

- **Heating and Cooling** (using thermal storage),
- **Electric Vehicles** (charging time depends on availability of renewables),
- **Pumping and Desalination** (using hydraulic storage),
- **Energy intensive Processes** (changing the execution time of industrial processes).

Smart use of **Customer Flexibility is the Key** to effective renewable energy systems as it minimizes total cost. DSM and Demand Response complement existing Generation Side Management. For a more detailed discussion of alternatives, refer to Annex 1.

4. Managing the Demand Side

DSM provides cheaper energy storage, and – if loads react fast enough - also helps to keep the grid stable. However, we need **New Energy Management Technologies** as the existing only managed the generation side. Electricity operators need to respond to the new opportunities and challenges this creates beyond the traditional ones:

- ✓ **Cost efficiency**
  Millions of flexible household loads can be activated (cooling, heating, white goods appliances, water supply, vehicles…). To make this economical for devices operating on some 100 Watts (e.g. fridges), technology cost per unit must drop by orders of magnitude relative to today's.
- ✓ **Sector coupling**
  New DSM potential becomes available as applications operating on fossils today are converted to electricity, such as
  - Vehicles where combustion engines are replaced by electric motors and batteries,
  - Building and water are heated by heat pumps instead of gas or oil.

Both Sectors will add Substantial Flexibility to electric grids in the very near future.

Once the cost challenge of storage is solved by virtual batteries and DSM, the remaining challenge is to **Activate and Manage this Potential**: Consumers own most of the flexible devices and appliances that can provide DSM. We therefore must **Enable and Motivate Customers** to operate their equipment in a grid-supportive way. They need to know what to do, have suitable technical means, and be given a (financial or immaterial) benefit. Then information and communication technology (ICT) can be developed to empower devices and appliances for DSM. Consumers can influence otherwise fully automatic operation of their devices if they wish.
A **Real Time Energy Market** meets all these requirements perfectly. Electricity prices will react to changes of supply and demand. They are lower when the sun shines and the wind blows, and higher in nights with no wind. Balance and thus price will change within seconds if energy mostly comes from volatile wind and sun. Consumers can react to variable prices without disclosing their motives or other private data. And only **Undisclosed Data is Guaranteed to stay Private**. Variable electricity prices are consequently recognized as the **Most important Element** of energy system transformation, as they have many benefits:

Consumers benefit from variable prices in many ways
✓ **Lower total system cost** (lower investment means lower grid fees), ✓ **Lower electricity cost** (they can use more cheap and less expensive energy), ✓ **No need to disclose private data** (so data stays private), ✓ **Customers are rewarded as they contribute**, ✓ **Prices are fair and transparent** (everybody is treated equally). ✓ **Customers keep control** (and offer flexibility that would not be made available with remote control).

5. Comparing Your Options

Consider an island or isolated grid where gensets (generators coupled to motors) operating on Diesel or Heavy Fuel Oil ensure reliable electricity supply, but at the expense of high fuel cost and CO_2 emissions. Renewable energy generation to reduce cost and emissions has been installed, and the operator has gained additional competences in using renewable energy. In this situation, a further increase in renewable generation is a strong option to meet the commercial interest of the operator, government objectives or regulatory requirements. However, questions of energy storage and grid stability must be answered in a satisfactory way. In the following, we explore the options available to managers in such circumstances. Note that the numbers and examples used are for descriptive purposes only. Precise numbers depend on the assumptions taken for future cost developments and the specific properties of the location and installation.

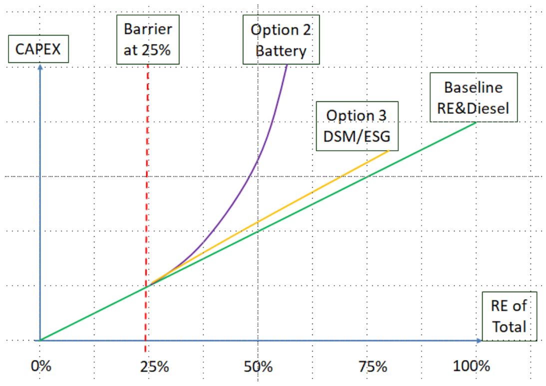

Fig. 2: CAPEX as a function of RE share

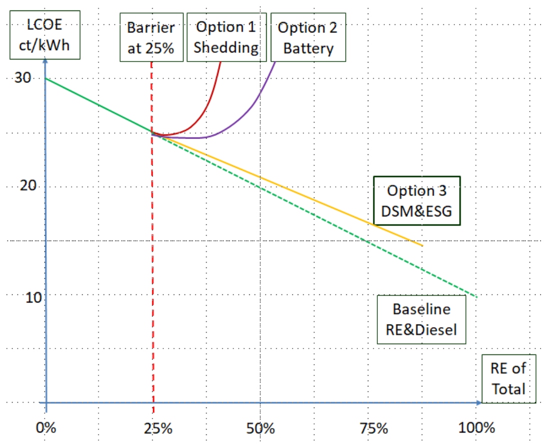

Fig. 3: LCOE as a function of RE share

In any case, more PV and/or wind generation capacity will be needed to increase the share of renewables. While they lead to an lower overall LCOE (Levelized Cost Of Energy), investment (CAPEX – CAPital EXpenditure) will be higher than for a genset/fuel system. Often the minimisation of CAPEX is also a requirement, as CAPEX increases company risk and requires financing which may be difficult to obtain.

In the following, we compare three options. Fig. 2 describes them with respect to CAPEX, Fig. 3 with respect to LCOE, both as a function of installed volatile generation (with PV and/or Wind as percentage of total generation). The baseline shows the CAPEX investment in renewable generation (PV and/or Wind) which is proportional to the renewable generation capacity. With a LCOE at 30 ct/kWh for Diesel and 10 ct/kWh for PV/Wind, the resulting baseline LCOE drops from 30 to 10 ct/kWh as renewable installation grows from 0 to 100% of total. Above 25% of renewable share, we assume that a barrier to further integration of renewables exists, so the LCOE line is dotted beyond this point.

In **Option 1** we **curtail renewable generation** that cannot be used by consumption or endangers grid stability. No additional CAPEX is needed, but more energy is shed as renewable generation grows. As less of the produced energy can be sold, LCOE quickly starts to increase again.

In **Option 2** a **battery is introduced**. Batteries have a high CAPEX as reflected in Fig. 2 which also leads to increased LCOE (battery depreciation, cycle losses). With large amounts of energy to be stored over longer time (e.g. to use PV energy at night), CAPEX and LCOE grow very quickly.

In **Option 3** we use **load shifting with Easy Smart Grid**. Investments (CAPEX) are low for storage (by existing or cheap-to-install "virtual storage") and Smart Grid (communication and control technology) with only a small impact on LCOE: It continues to drop in a much larger range.

6. Easy Smart Grid Offer

Easy Smart Grid allows better energy management by making it **easy to transmit, receive and use variable electricity prices** in island/isolated grids. Grid frequency is a technical signal that indicates grid balance which we extend to efficiently communicate variable prices to customers.

Easy Smart Grid: **Communication Technology with Unique Advantages**
➢ High robustness and resilience, ➢ High speed and system stability, ➢ Protection against cyber-attacks ➢ No smart meter communication infrastructure (AMI-Advanced Meter Infrastructure).

Easy Smart Grid **makes existing grids smarter**. We cooperate with operators and their partners (customers, suppliers, consultants) to implement pioneering high performance solutions.

Easy Smart Grid offers:
• Support in studies, demos, pilots and migration planning for specific grids, • Expand electric grid to a platform giving all customers access to variable prices, • Supply controllers (units, modules or software code) that receive variable prices and translate them into load shifting, • Support adaptation of grid controllers, smart meters and other equipment, • Technology licenses for equipment/appliance suppliers and grid operators.

7. Step by Step Migration

Variable prices are still to be introduced in most electric grids. Where they are introduced, the (analogue) world is typically represented with poor (digital) resolution: One low price/night tariff, and one high price/day tariff. While this suited a world with nuclear and fossil power plants, **Renewables need Better Digital Technology**: an increase from two to around 20 different prices, and more frequent price updates from 15 Minutes to five Seconds. **Variable End Customer Prices** are part of the **Future European Energy Market Design**. Our technology is compatible with existing grid management and allows introducing variable prices step by step:

1. **Use own flexibility first**: Many grid operators cool their computer centres and offices, or charge a fleet of electric vehicles. Some also act as water utilities with high pumping loads. No external contracts are needed to implement DSM here, and such projects allow to train staff and gather experience.
2. **Then involve few large customers** and agree flexible prices that benefit both: Customers save on energy cost, and the utility benefits from virtual storage. Organisational complexity stays low and regulatory exceptions, if needed, are few.
3. **Then offer flexible prices to more customers** until the general public gets fully involved. Those choosing variable prices benefit from the savings they help generate, others may stay with the old flat rate. These flat rates will be more expensive as they include an insurance premium against price volatility.

This migration follows a **cycle of continuous improvement**: more flexibility becomes available and more renewable energy can be used. Generation cost and green-house gas emissions fall continuously, implementation risk and investments remain low and are easy to control.
Easy Smart Grid expands its own ICT-know how with an **international partner network** to support projects with specialist skills: Experts in PV and wind energy production, electro mobility and heat pumps for flexible demand, conventional power plants for better hybrid solutions, and scientific/engineering skills to simulate systems and develop, adapt and validate smart technology.

8. Outlook

Our current challenge is to overcome the barrier at ~25% of renewables, but the migration to 100% renewables remains the ultimate goal. Our technology enables **Efficient Real Time Grid Management** and allows reducing both storage and ICT investment on the route to a fully renewable energy system. Now is the time to lay the foundation for a quickly growing installations and productive integration of renewables into the grid. We look forward to discuss with you how **we can support your ambition** to move to a sustainable, cost efficient energy supply more quickly, and provide better services for your customers.

►For more information please contact:

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Annex 1: Comparison of Different Approaches

Many solutions and suggestions exist that claim to support your journey into the renewable energy world. The following explanations will help you check for yourself if they can deliver on their promise.

Battery solutions

In most cases they are the most expensive of all available options. They avoid the need for changing the paradigm to "consumption follows generation" by allowing volatile sources to behave as if they were fossil ones (mimicking the chemical storage properties of fossils). Batteries are helpful when there is no alternative (e.g. mobile devices or cars) or to stabilize the grid for short time ("power" storage for a few minutes).

Load shedding

Load shedding protects grid infrastructure and power generators from overload. Loads are switched off on command from the control centre. Emergency protection is still needed but does not answer new needs of renewable energy systems: Increase load to utilize times of high generation.

Variable prices allow to reduce (high price) and to increase (low price) loads. They have an important advantage over central control by being able to use sensitive flexible processes. Take the example of a household fridge: Only those with sufficiently low internal temperature will react to a high price. Not all, but more than with remote control: With load shedding, some might exceed the allowed maximum temperature and cause food poisoning. As this would clearly be unacceptable, none will be used in practice.

Shedding of renewable generation (PV/Wind)

To avoid investment in scarcely used capacity for short periods of high renewable generation, it is acceptable to shed renewables for ~5% of the year (peak generation). However, it is obvious that substantial shedding of renewables can neither lower energy cost nor provide energy in times when sun and wind resources are low.

Remote control of customer devices

To avoid the effects caused by lack of knowledge on load status described above under "load shedding", such data is communicated to the control centre. This causes huge communication challenges and cost, many of which seem unsolvable: Reliability (critical data is late or corrupted), data protection (ensure that only authorized parties have access) and liability (Responsibility e.g. for food poisoning in the above example). It has been shown that remote control does not add benefit to decentral control easily implemented with variable prices, so it should be constrained to very few, system critical grid participants for emergency operation or black start only.

Virtual power plants (VPP)

Flexibility was historically provided by the generation side only. As flexibility from wind and sun are very restricted, VPP procure flexibility from the demand side and offer it on the generation side: reducing load is equivalent to increasing production. Why, however, should one circumvent a man-made barrier (flexibility only on generation side) in a complicated and expensive way when demand flexibility can be used much simpler and cheaper directly (variable prices allow direct use of demand flexibility)?

Aggregation of flexibility

Access to existing flexibility segments (in control markets and energy exchange) is difficult and expensive. The idea of aggregation is to pool smaller loads so that they can pass existing cost thresholds. However, the additional aggregation effort consumes most of the possible gain. Once variable prices are introduced, no aggregators will be needed to market end customer flexibility.

Block Chain

This technology allows to document contracts in a distributed environment. However, while block chain will surely increase cost and power consumption of computing and communication infrastructure, it not even claims to contribute to (real time) grid management. Variable prices and Easy Smart Grid provide this crucial function and also enable easy contract documentation. There is no benefit block chain could add to this.