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Measurement and Verification of Energy Performance Contracts

Introduction

Energy Performance Contracts (EPC) are an alternative financing mechanism to accelerate the investment in energy efficiency or energy conservation measures. They are most commonly associated with energy management for large buildings and follow a well defined path. An Energy Services Company (ESCO) agrees to undertake an Investment Grade Audit to look at opportunities, costs, and returns for a range of energy savings and cost reduction initiatives. For a building this might include energy efficient lighting, replacement of chillers and air handling units, better sealing of the building and ventilation to reduce heat loss or heat ingress, solar panels etc. The ESCO not only identifies the areas that can be improved, they also offer to fund the actual implementation of the energy improvements typically by way of loan a that is paid back via the savings – which they will contractually guarantee – over a 10 to 20 year period.

Introduction – continued

For the building owner this presents an opportunity for improvement without the need to allocate funds- cash neutral to cash positive improvement - with the savings locked in so at the end of the EPC term, all savings go to the building owner. A key element of such projects is how to measure the savings fairly for both the building owner and ESCO.

For major water and wastewater utilities the EPC route is of interest primarily as a way to keep improving performance while not raising customer charges. This is especially relevant today when funds have been depleted during the global financial crisis. Often a well designed EPC contract may link in many separate improvement projects and upgrades to capital equipment, some with strong returns, some marginal, using the pooled savings to make sure a payback is achieved overall. Funding may come from the ESCO, a bank or from state funds specifically made available for energy performance improvements.

With all of these benefits; access to "free" money; cash strapped utilities and astute ESCOs, you might think there would be many hundreds or thousands of these contracts in the water utility market. The reality is that while EPC is making some headway, there is still relatively little market penetration.

Risk avoidance, specifically the concern that the utility will end up paying for little or no benefit, seems to be blocking this otherwise ideal example of Public and Private Partnership (PPP). Comments along the lines of "complex contract wording by the ESCO to hide the fact that the utility carries all the risk" are common. To try and counter this scepticism a US Department of Energy initiative was started in 1994 to "establish international consensus on methods to determine energy/water efficiency savings and thus promote third-party investment in energy efficiency projects." The resulting document, called the International Performance Measurement and Verification Protocol (IPMVP) was released in 1997 and has been continuously updated ever since.

IPMVP Measurement Options

The IPMVP document summarizes four options for measuring energy or water savings.

Option A refers to Retrofit Isolation where only some key parameters are measured. For example replacing a halogen light with a LED light source may need only the manufacturers' data on energy consumption, or a short period of measuring power consumption before and after the change. Annual savings are estimated by multiplying the instantaneous savings with an estimate of how many hours the light would operate in a year.

Option B is for Retrofit Isolation projects where all parameters are measured. An example is an air-conditioning refrigeration unit replacement. Parameters such as outdoor air temperature, building occupancy, hours of operation, etc. are required as well as energy consumption figures for both the old and replacement refrigeration unit.

Option C refers to Whole Facility evaluations. This is used where sub-metering, i.e. isolation of the replaced system, is not possible. The protocol recommends comparing a whole year of baseline operation with a whole year of post implementation operation. Non routine adjustments will be required to allow for changes in either the facility's use or equipment over the comparison period.

Option D, Calibrated Simulation, comes into play when there is no "before" period to compare, for example when a new "green" building is being constructed for a client. Savings are determined through calibrated simulation of the energy use of a similar facility with similar use, surface area, location and occupancy. This takes considerable skill and a lot of trust between supplier and purchaser.

Derceto's Experience in Measurement and Verification (M&V)

Right from the start Derceto recognized the potential to use EPC contracts as a way to deliver the award winning Aquadapt® energy management solution at low risk to the client. The IPMVP Option C 'Whole of Facility' process seemed an ideal way to alleviate concerns the client might have on how to confirm savings were being achieved. However it soon became obvious that the IPMVP is biased towards buildings or equipment replacement and does not specifically cover concepts such as a software control system retrofit to an existing water utility.

For a water utility the energy improvement from installing a high efficiency pump and motor to replace an ageing pump set is easy to understand and could easily be evaluated under Option A of the IPMVP. The kWh per MG of water delivered by the existing equipment will be easily determined from records and electricity bills, and the kWh per MG of the replacement equipment is also easy to measure. The reduction in kWh per MG is the difference between the two kWh values (ΔkWh).

Cost saving = ΔkWh per MG x MG delivered x price per kWh.

Even in this simple example there may be issues. What if water demand drops and substantially less pumping is required? The savings per year may be lower than expected and no longer cover the EPC payments. In many ways this is analogous to building air conditioning load where external factors like weather can make comparisons between a baseline year and the current year very difficult.

Aquadapt is a complex layer of software that holistically solves the problem of scheduling production and distribution to minimize cost which adds many new measurement and verification problems. Getting consensus on how these issues will be tackled is important at the start of the project so that all parties can have confidence that the measurement and verification process is fair and transparent.

Weather, drought and water demand

There are many climatic influences and unpredictable operational requirements that affect a water utility that are not controllable by the ESCO, which introduces risk. The most obvious is weather, something unpredictable to both the ESCO and utility. In a recent case example one US utility has a 500% increase in summer water demand compared to winter, mainly for domestic and golf course irrigation. Even in a single month the water demand can increase by 50% or more from the first week to the last in spring. This water demand is totally dependent on weather. The IPMVP process allows for comparison of energy cost between years, asking for example 'is the energy cost this April higher than April in a baseline year'. Clearly if April in the baseline year was cool and wet, the energy consumption would be significantly less than a hot dry April. The opposite is also true, and the utility would be unhappy to pay out for "savings" when a low water demand April in the measurement year is the real reason for energy savings. Absolute measures based on calendar dates are not as useful as unit based comparative measures

It is better to compare periods from the baseline year with current operation where the daily demand is used as the comparison point. This can be done using daily, weekly or monthly demand. Rather than setting up baseline data using calendar dates, group daily data filtered into narrow bands of water demand, for example grouping all days that have daily demand between 20 and 25 MG. This works well when operator controls do not change markedly within the selected band of operation i.e. there is little observed seasonal or weekend change in operations.

Of course if the season has a marked effect on the way water is delivered then this must be taken into account. For example in one case a utility only has access to a low cost river source during part of the summer and operates off aquifers for the rest of the year. The times when the river is used must be segregated from the times the aquifers are used. Creating too many segregation points can be as big a problem as creating too few, for example if you want to group only days with;

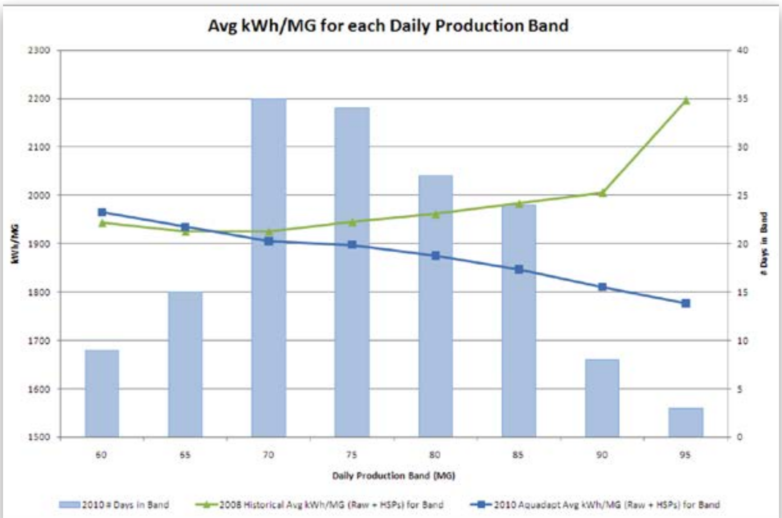
- demand within a small water demand range
- are weekends
- use only one water source etc

you might find out there are only one or two matching days in the baseline year. It is better to identify days that look similar and then confirm what common factors applied than to use rigid rules like day-of-the-week or season.

Recommendation: *Create baseline data with easily identifiable comparison blocks or bands of data. When you have a suitable sample set average the data into a single curve of kWh consumption versus time over the 24 hour day.*

Changing water production

At another utility using Aquadapt, water can be supplied into one of the largest demand zones via gravity from one treatment plant or by pumping from another lower treatment plant. As is reasonably common is such situations it is actually the pumped water that is most often used, counter to most people's predictions. The reason this occurs is that pumps can be started and stopped easily and quickly with reasonably known flow rate changes, whereas changing output from the gravity plant is more complex often involving changing settings on PRVs in the field to allow an unpredictable amount of additional flow out of the plant. Operators who need to keep storage levels within limits and pressures at acceptable levels quickly realize this is much easier to do by adding or removing a known quantity via pumps, and the gravity plants therefore tend to be underutilized.



► *Figure 1: Two production plants have different energy consumption per MG, as demand increases using the more efficient plant to deliver water leads to big energy and cost savings compared to baseline operation*

While moving production to the gravity plant seems an obvious way to generate energy cost savings it actually can be counterproductive to the ESCO unless this is carefully managed. An example should make this clear. Say in a typical 40 MG total demand day the pumped plant produced 30 MG at a cost of $9,000 in energy and the gravity plant produced 10 MG at negligible energy cost. After optimisation the same setup now produces 20 MG from the pumped plant and at a cost of $6000 and 20 MG from the gravity plant, again at almost no energy cost. What are the savings? While you might reasonably consider that $3000 has been saved, under IPMVP you might discover the savings are calculated as zero.

The gravity plant never had any cost so there is no measure of savings. The pumped plant may have also used $6000 to produce 20 MG in the baseline year, probably on a day when total demand was only 28 MG with 8 MG coming from the gravity plant. By comparing a 20 MG day at the pumped plant with a 20 MG day now it appears that no savings are being achieved. So while the utility is $3000 better off in terms of energy cost, none of this is reflected in the measurement process. Aquadapt is implemented in three large utilities where exactly this situation has occurred.

This problem was solved by using the total daily water demand as the reference point to select baseline operation. So in this example because total daily demand was 40 MGD we based energy consumption on the typical historical 30 MGD/10MGD baseline split between the plants and not the actual 20 MGD/20

MGD split that the energy optimization software achieved. This accurately captured the $3000 in savings and was fair to both us and the utility.

Recommendation: *Use daily total water demand to define the comparison point with the baseline year and not the individual pump station flows. Then allocate the production at each water treatment plant according to baseline data, do not use actual individual plant production.*

Operational requirements

The water utility may remove assets, add assets or change operations for any number of perfectly valid reasons over the M&V time period. This can be as simple as replacing a pump or as complex as shutting down the largest water treatment plant for an extended period for much needed planned or unplanned maintenance. If in the example above the gravity plant had to be shut down, and the pumped plant had to supply all 40 MG of water, the energy costs would skyrocket. The IPMVP Option C allows for Routine Adjustments and Non-routine Adjustments. In this example a routine adjustment is the use of total water demand to allow simple comparison of energy savings, but a non-routine adjustment is required to cope with the gravity plant outage.

Manual Over-rides

In previous case examples from Aquadapt implementations, issues arose when operators manually over-rode schedules, sometimes running pumps during peak tariff hours or when energy peak demand surcharges apply. An energy demand charge can have a ratchet clause from the energy provider that makes the effect of running a single pump for 15 minutes incur a substantial demand charge that lasts for 12 months, in some cases costing hundreds of thousands of dollars. Manual operation is tracked and recorded by Aquadapt, and the impact of this can be accounted for in the savings calculations.

Recommendation: *Keep detailed records of actual operation during the M&V years. This is useful to both the ESCO and the utility as it can expose costly operating practises that have been unobserved for years. Often the operators are unaware of the cost impacts of these over-rides.*

Storage levels

Energy savings are generated because of the characteristic common to almost all water utilities, the ability to store energy. Filling storage at elevated levels requires energy, generally pumping, and this energy can then be released at later times in the day to keep pressure in the distribution system under gravity flows. The capacity of the 'battery' in this case is measured by the volume of water that can be used in each storage tank. If the operating range in the measurement year is different to that either allowed or used in the baseline year, this can seriously impact savings. A common issue seen at utilities using Aquadapt revolves around acceptable storage levels. This can take two extremes. The first is documented operating levels that are more restrictive than levels actually used during the baseline period, a case of 'do what we think we do and not what we actually do'. This can be resolved by clearly presenting historical storage patterns to inform the audience and then negotiating limits matching the actual baseline.

▶ *Figure 2: Aquadapt tracks actual operation, in orange, against scheduled operation in blue, to identify when pumps are manually started, as happened here with Pump 1 at 9:30 am.*

The second extreme is the case where operators already had freedom to operate over quite wide storage levels but maintain storage within a very tight band, typically at the very top 5% of the tank. In these cases once the optimization starts and tank levels drop below 95% but still well within permitted levels there is often a perception by the operators that they need to over-ride pump schedules. While there may be genuine cases where lower storage levels are not appropriate, such as insufficient pressure at customers' water meter, these can be found during commissioning and the levels adapted accordingly.

Recommendation: *Make sure operating limits and constraints are not only reasonable, but are also achievable. Get buy-in from the managers and operators to use this available storage*.

Bad data

Inaccurate instrumentation and unreliable communications infrastructure are common in large water distribution networks. When systems are manually operated instruments are often just a dimensionless reference point for operators. When they start a pump at a pump station they see the flow meter register an increased flow that matches their expectations based on the last time they started that pump. The discharge pressure jumps up, again to a value within their expectations. The storage reservoir starts to fill. The operator than moves on to another area, mentally noting to keep an eye on the storage level so that they can shut down the pump later on.

The actual value of the flow meter and pressure meter and the units these are expressed in may mean very little, in fact these instruments could be significantly in error without any real impact on the operator's ability to control the water distribution system. It is not uncommon to find errors of 50% or more. Automation and optimization however relies on this data, it must be timely and it must be correct. The spin off benefits from having correct data spread right through the utility; planners can use the data for hydraulic model calibration; the data can be analyzed to detect water losses; asset performance degradation can be detected.

Recommendation: *Implement an instrumentation calibration program and maintain instruments just as you would with any other asset.*

Change-control

A common issue seen in previous implementations is that lack of change control in the automation system. A relatively junior technician or external contractor can very easily re-range an instrument, change its units or disable it without knowing it is a critical cog in a complex optimization solution. Other industries like oil and gas have a lot to teach the water and wastewater utilities about change control and instrumentation calibration. Nothing is as frustrating as trying to find out why something that worked yesterday is not working today, only to find that a well meaning technician has changed a pressure instrument from PSI to kPa.

Recommendation: *Implement an instrument change control system and use it*.

Electricity Metering and Market Changes

While the IVMVP process allows for "whole of facility" concepts they do recommend that sub-metering is used to identify where energy is being used. A typical water treatment plant has; offices; raw water pumps; inter-stage pumps; energy consuming treatment processes like UV and membrane filtration; and the high lift pumps delivering water at pressure into the distribution system. These are almost always on a single power meter. It is desirable to separately meter these areas, and this does not require high precision revenue billing meters, although these are now so cheap they should be considered.

Recommendation: *Consider installing sub-metering with data recording and export; preferably during the baseline year.*

Once the EPC project has been installed the energy supplier may change the contract, almost always to the detriment of the water utility. The state or federal government may change the rules, in the UK many solar PV projects suffered major losses when "feed-in" tariffs supporting green energy initiatives were suddenly withdrawn. In the US favourable differentials in energy price between day and night, making night pumping considerably cheaper than day pumping, have flattened in more recent years due to the economic downturn thereby reducing the cost benefits achieved from moving load to night periods.

In one US based Aquadapt implementation the use of real-time prices on the spot market was offered by the energy supplier and analysis showed this could drive significant cost savings. The energy bill to the utility had about 20% of charges that were fixed and relatively independent of energy consumption, with the remaining 80% dependent on spot pricing. Energy cost savings were substantial in the first year of operation, analysis showed that in fact 40% of total energy consumption had been moved from day to night compared with the baseline year and cost savings of nearly 20% achieved. In the following year the energy company changed the rules with 80% of the bill now fixed or using flat rate tariffs and only 20% actually related to spot market energy consumption. No competitive market existed, this was a monopoly provider changing the rules to the detriment of both the water utility and the ESCO.

Recommendation: *Where possible, lock in the contract with the energy supply company to align with the energy performance contracting period.*

Summary

In all EPC contracts there is always some element of risk. It is not always possible to remove all risk, or place all this risk solely onto the ESCO. The recent drought in California is a good example of an issue which neither party can control that could negatively impact on savings. When the water utility and the ESCO devise a mutually agreed process, then fairness prevails. While it is true that the ESCO has more experience with these issues and may want to use that expertise to word contracts in a way that fully protects their investment, the benefits of an ESCO funded project should be enough to allow a smart water utility, fore-armed with a little knowledge, to proceed with acceptable risk.

Recommendation: *Seek independent advice on the measurement and verification process. Consider using an independent third party to complete the audits.*

THE AUTHOR

After graduating with a Bachelor of Engineering (Electrical) Simon spent the next 21 years in control systems design, rising to become a partner in The Beca Group in 1999. In 2000 Simon used his experience of control systems and water treatment processes to design the complex software at the heart of the Aquadapt product, the world's first commercially available real-time pump scheduling optimiser. In 2002 Derceto software for Wellington City was judged the top engineering project in New Zealand by ACENZ. In 2005 he was named the "Engineering Entrepreneur of the Year" at the New Zealand Engineering Excellence Awards.

Email sbunn@derceto.com

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Derceto

For more information
please visit: www.derceto.com
or email sales@derceto.com

Derceto, Inc.
San Francisco, CA, USA
Tel: +1 4156468950

Atlanta, GA, USA
Tel: +1 7709957921

Derceto Canada Ltd.
Toronto, ON, Canada
Tel: +1 770995 7921

Derceto UK Ltd.
London, United Kingdom
Tel: +44207 3759842

Derceto Ltd.
Auckland, New Zealand
Tel: +6493737100