Establishing Baselines for Industrial Energy Efficiency Projects

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ABSTRACT

Energy efficiency program designers, operators, and evaluators often use pre-existing conditions as the benchmark against which they measure energy savings for retrofit projects. Energy codes tend to be used to define the baseline for new construction or for replacements on failure. The savings is then projected for the duration of the measure life. This paper argues that such an approach is inaccurate in some circumstances and tends to bias savings upwards compared to reality. Such application is often irrelevant for industrial process projects, where no code exists and where measures affect productivity.

The baseline is the least efficient, non-regressive, code or regulations-compliant option specific to a particular facility and application that the customer technically, functionally, and economically could have alternatively considered to deliver the post-retrofit level of production or service. The paper offers a series of definitions and a logical flowchart that energy efficiency program designers and evaluators can use to determine baseline operating conditions for industrial projects. The logic model includes consideration of such factors as:

- Energy efficiency projects that increase productivity
- Partial free ridership
- Fuel switching
- Defining baseline in the absence of energy code
- Minimum available efficiency versus market standard practice
- Measure life and remaining useful life

Evaluators, and in some cases program implementers, in California and New York have started using variations of this flowchart logic-driven approach to estimate savings.

The approaches and concepts presented in this paper are based on the experience of evaluating many industrial projects in these two states. The generalized framework described in this paper may get further refined or adapted in the future as more experience is gained in California, New York and elsewhere and as jurisdiction-specific and program-specific aspects are considered.

Background

The authors often estimate the ex post savings of industrial energy efficiency projects supported by government and utility programs. The majority of savings in such programs are often contributed by "custom" projects, meaning that the project applicant or program administrator estimates the savings for the unique project. This contrasts with projects for which the program deems savings or estimates savings based on standardized calculations with a predetermined baseline.

Planners generally expect that custom program savings estimates (ex ante savings) will be relatively robust, that is, the savings projections will be close to later evaluated (ex post) savings estimates because they are specific to the customer, application, and technology.[1] The program ex ante savings from deemed savings projects that are not project-specific would be expected to have a wider variation. In a series of recent evaluations of custom projects the authors found that evaluated savings estimates deviated widely from program ex ante estimates, worse than one would expect from deemed savings projects.[2] The impact evaluation of an agricultural and food processing program implemented in CA identified inaccurate baseline definition as the most significant source of discrepancy between program reported and evaluated savings (33% of projects), and larger than any two other factors combined (KEMA et al 2010, 70). Two impact evaluations of CA industrial programs also identified baseline characterization and inappropriate definitions of standard practices as two of the biggest reasons for low evaluated savings (Itron et al 2010, 6-36 to 6-39 and Itron et al 2009, 5-2 to 5-7). The evaluators' estimates of baseline consistently reduced savings estimates compared to the program's estimates.

Because an accurate determination of baseline conditions of custom industrial projects can lead to inaccurate, and often lower, savings estimates and affect the cost-effectiveness of industrial programs, the energy efficiency industry needs to move toward developing a set of protocols that define baseline conditions.

Entities in both California and New York have recently developed baseline methodologies (Maxwell et al 2009 and Itron et al 2010, 6-15 to 6-18).

Objective

The underlying principle for defining baseline for industrial energy efficiency projects is straightforward: *The baseline is the least efficient, non-regressive, code or regulation-compliant option specific to a particular facility and application that the customer technically, functionally and economically could have alternatively considered to deliver the post-retrofit level of production or service.* Non-regressive means that the baseline cannot be less efficient than the condition prior to measure implementation.[3] Application of this concept to individual projects can be challenging.

This paper presents a procedure that energy efficiency project applicants, administrators, and evaluators can follow to define baseline energy use for custom industrial and related projects.

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[1] The error ratio is one statistical measure of the accuracy of program estimates compared to evaluation estimates. An error ratio of 0.4 is considered to be relatively low and 1.0 relatively high. The *California Evaluation Framework*, (TecMarket Works Team 2004, 336) suggests that the an error ratio near 0.4 is likely if the program is composed of projects with fairly detailed project specific estimates and an error ratio near 1.0 is likely if the reported savings are based on deemed values that are not project-specific.

[2] Custom-oriented program error ratios often exceeded 1.0 (Maxwell and Parlin 2011).

[3] For example, if a customer needs to replace an old scrubber that uses variable speed fan control to modulate air flow, a high efficiency option, then use of the less efficient bypass control would be an inappropriate baseline for calculating savings for a new scrubber fan. The non-regression principle is used in California; some other jurisdictions do not use this component of the baseline definition because it potentially interacts with measure life and free ridership concepts and because non-energy factors such as maintenance costs can influence the technology choices.

Baseline and Free Ridership

Baseline determination is integral to the determination of free ridership, remaining useful life and measure life.

Baseline definition should determine the least efficient approach that a participant reasonably *could* have taken. Free ridership research separately determines the difference between what could have happened and *would* have happened in the absence of the program. To the extent that any of this interpretation is discretionary, the difference can be assessed as part of free ridership rather than elevating the baseline.

For example, a customer could, as a matter of corporate policy, always practice a higher level of efficiency than peers and thus choose to install an energy-saving project and receive funding from an efficiency program. The corporate policy may mean the program did not cause the savings but this should be reflected in a high free ridership factor, not a high efficiency baseline. This is so even though the customer may be implementing the same project at dozens of plants worldwide and considers it their own view of baseline, because the industry at large does not consider the option standard practice. Jurisdiction-specific interpretations may vary.

Furthermore, partial free ridership can occur when, in the absence of the program, the participant would have installed something more efficient than the baseline efficiency specified for the gross savings estimation but not as efficient as the item actually installed as a result of the program. For example, in the absence of the program, a participant may have purchased an 82% efficient boiler instead of the minimum available 80% or the program-funded 86% efficient boiler. As with full free ridership, baseline should reflect the minimum available efficiency and not the particular customer's plans absent the program.

Changes in Baseline Definition During the Measure Life

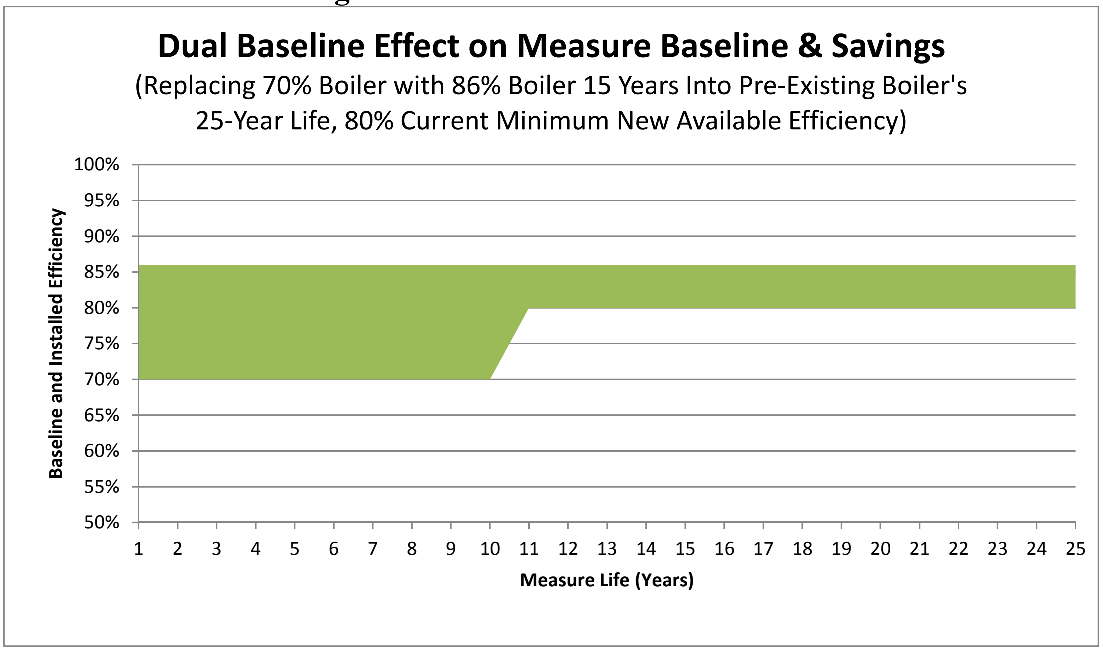
Most energy efficiency programs in the United States track and report savings based on a single savings estimate that is typically the first year savings and then assume that the savings recurs each year for the duration of the project's expected measure life. There are prominent exceptions. California projects savings separately for each year of a measure's life. New York is planning on migrating in this direction in 2011[4] and Vermont has selectively used such an approach in some cases. Most other states' efficiency programs do not address this concept.

Savings can vary for many reasons over time. The biggest reason savings vary is due to the concept of "dual baselines." Many programs define the energy efficiency baseline as current standard practice or energy code for new construction projects and use pre-retrofit conditions as baseline for retrofit projects. The approach is straightforward but does not account for "natural turnover" or company-scheduled early replacement. The dual baseline concept addresses natural turnover by only using the *in situ* condition as the baseline for the theoretical portion of the remaining useful life of the pre-existing equipment and then uses the new construction efficiency to define baseline for the remainder of the installed equipment life. Figure 1 illustrates the concept for an early boiler replacement. In the example the removed boiler had an efficiency of 70% and (theoretically) 10 years of remaining life. The current minimum available efficiency replacement boiler has a nominal 25-year life and an 80% efficiency. The program contributed

[4] The NY DPS has instructed staff to develop a savings (and cost) approach that account for savings varying over time specifically due to dual baselines (State of New York Public Service Commission, 2010, 8).

an incentive toward the installation of an 86% efficient boiler, so the savings would correspond to a 16% efficiency differential during the first 10 years of a 25-year life and 6% for the remaining 15 years. A commonly used current practice would estimate savings corresponding to the efficiency differential of 16% (86% for the new boiler minus 70% for the existing boiler) and project first-year savings to occur annually over the 25-year life.

Figure 1: Dual Baseline Illustration



Such an approach adds complexity to program tracking, evaluation, and benefit-cost calculations, and requires judgment in determining the remaining useful life as compared to using a single baseline approach. The trade-off for accepting the additional complexity is that the savings profile is more realistic and the dynamic is not otherwise captured in program or typical evaluation estimates.

For those entities not overseen by regulatory authorities that require or allow savings projections that vary by year, an acceptable reporting compromise that would capture the essence of the varied savings principle without requiring year-by-year inputs would be to perform this exercise and report a single average savings over the lifetime as annual average savings. This would have the advantage of reflecting the effect of adjusted lifetime savings, which is better than ignoring the concept altogether and simply reporting the first-year savings. A disadvantage of using the single-year adjusted average savings is that the present value of savings will not be as accurate as using the varying annual savings approach.

Using the dual baseline approach requires making two estimates that affect measure savings and cost-effectiveness. First, one must estimate the remaining useful life (RUL) of the removed equipment. What if the removed equipment age is unknown? What if the equipment is past its effective useful life but plant personnel assert that it is in fine working order and would have continued in use indefinitely? For the former issue, a solution is for programs to routinely collect the age of equipment that is removed as a matter of course during program operations, as opposed to during evaluations when it often is impossible, and develop guidelines to estimate the RUL when equipment age is unknown. For the latter, a solution would be to cap the RUL as a function of the standard life of the equipment type, for example, the greater of the remaining useful measure life for the project (standard life for equipment – years of use for removed item) and one-third of the standard life for the equipment.

RUL = greater of (std measure life – removed equipment age, std measure life / 3)

Second, one must estimate minimum available efficiency in the future. To date, evaluators have used current code as the basis for estimating future minimum available efficiency rather than forecasting energy efficiency, unless published future code changes are available. The authors consider this to be a reasonable approach.

The dual baseline analysis historically has been executed by evaluators for specific projects. To more accurately report the gross realization rate the authors recommend that programs subject to evaluation on this basis be proactive in applying the concept in tracking systems so that the effect is not always applied for the first time in evaluation if early replacements or other dual baseline drivers are likely to be part of the funded measure population.

Baseline in the Context of Changing Production Levels

Some energy efficiency measures facilitate increased production rates. The baseline for measures that increase production must account for alternative actions that could have been taken to otherwise increase production. For process measures the fundamental premise governs:

$$\begin{matrix}\textit{Annual Energy} \\ \textit{Impact} \\ \textit{(Energy/Yr)}\end{matrix} = \begin{matrix}\textit{Post-Retrofit} \\ \textit{Production Level} \\ \textit{(Units/Yr)}\end{matrix} \; x \; \left[\begin{matrix}\textit{Baseline} \\ \textit{EUI} \\ \textit{(Energy/Unit)}\end{matrix} - \begin{matrix}\textit{Post-Retrofit} \\ \textit{EUI} \\ \textit{(Energy/Unit)}\end{matrix} \right]$$

Where,

Post-Retrofit Production Level

Post-retrofit production level may be defined as the demonstrated long term production rates for the facility after the retrofit is completed. Different regulatory regions define post-retrofit production level differently. This level often is the production level measured in the year or two after installation. NYSERDA's Industrial Process Efficiency Program baseline protocols in New York allow it to be adjusted from the observed value based on pre-retrofit data or on forecasts of long-term future production levels. In California, in contrast, CPUC protocols historically have defined post-retrofit production level as the production level at the time of evaluation.[5]

[5] In a recession environment the California approach may penalize an industrial process during evaluation. During a boom period it may increase savings. California regulators' view is that ignoring the subjectivity associated with long-term forecasting is worth the trade-off so that one can develop savings estimates based on firm measureable data. Presumably over a period of decades the boom and bust effects will cancel each other out.

Baseline Energy Use Intensity (EUI)

Baseline EUI[6] is the normalized energy use per unit production that a theoretical baseline system would require to deliver the post-retrofit production level.

Post-Retrofit EUI

Post-retrofit EUI is the normalized energy use per unit production that the program-funded and installed system requires to deliver the post-retrofit production level.

It can be challenging to develop a baseline EUI in the context of increased production rates. The guiding principle in determining baseline process EUI for productivity-increasing projects is that it should be based on what the applicant otherwise technologically and economically could have done to increase production without the program-funded action(s) under the then-current market conditions.[7] If the applicant could have increased production using existing methods, such as by increasing operating hours, by increasing the processing season, or by activating other similar equipment as already was in place, and it would not have fundamentally changed the EUI, then pre-retrofit EUI can be the baseline process EUI.

If on the other hand the plant's equipment was at capacity then the project represents a market opportunity. Baseline definition should consider how else the plant, the larger corporation, or the industry as a whole would otherwise have met the increased production rate absent the funded project.

Baseline is Defined as Minimum Commonly Used Efficiency

Minimum commonly used efficiency is the minimum efficiency that one could choose to install for a particular application. It should be used to determine baseline. Most often, minimum commonly used efficiency and industry standard practice are synonymous. However, there can be circumstances in which they can differ.

Minimum commonly used efficiency is never better than industry standard practice. It can be worse, if there are a measurable number of market actors that install less than the predominant/standard practice level of efficiency. For example if a significant majority of the injection molding market buys new machines with insulated heating barrels, that could be considered "standard practice." However, if a sizeable minority buys machines with uninsulated barrels, the minimum commonly used efficiency is measurably less than standard practice and uninsulated can be considered the minimum commonly used efficiency baseline for gross savings analysis.

Conversely, baseline, while never worse than minimum technically available efficiency, sometimes must be better, if there are minimum efficiency solutions that theoretically are possible, but as a practical matter an entity would not use for the particular application. For example, throttle-controlled air compressors are available and often purchased to be base load machines. They offer the worst efficiency for part load control of screw compressors. They

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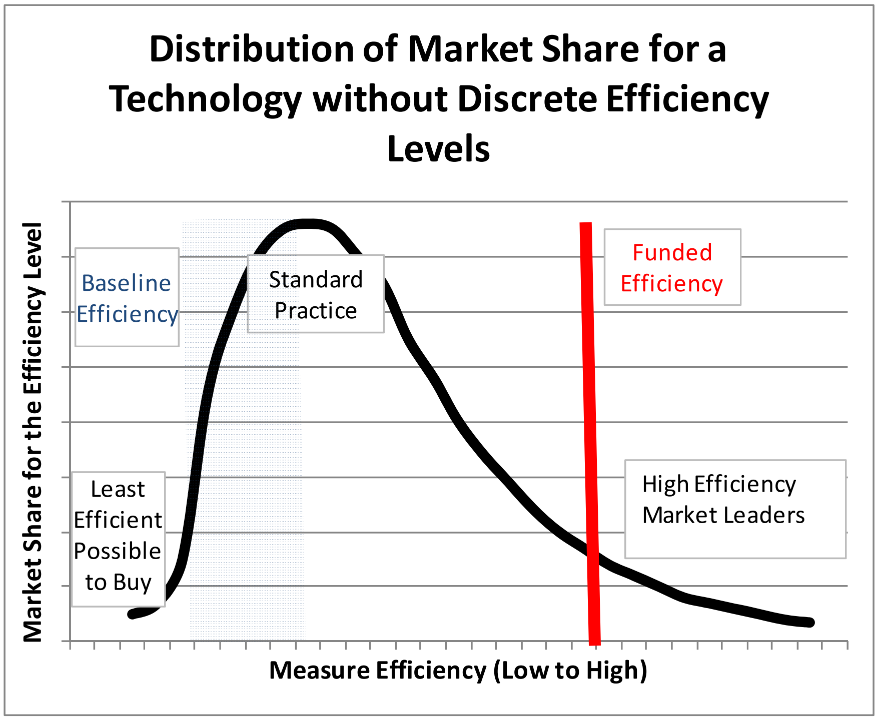
[6] In this paper we use the term energy use intensity to mean energy use per unit production, or process EUI. For offices and other commercial environments, EUI is measured as energy use per square foot.

[7] "Economically" could include consideration of a number of factors beyond measure capital cost and the annual utility bill savings. It may also include transaction time and effort, expected maintenance, training time, interest rates, or risk, for example.

rarely if ever are used for modulation in many industries, and especially not in those industries that tend to buy oil-free systems. In such a circumstance, the more efficient load-unload cycling control method should be considered the baseline, not throttling.

Figure 2 illustrates the baseline efficiency level for a theoretical technology that does not have any code or discrete gradations. The chart shows that baseline may fall between the minimum available efficiency available for sale and industry standard practice.

Figure 2: Baseline Efficiency on Efficiency Distribution Curve



For unique projects there should be evidence that it is an approach currently used in industry for the type of application under consideration. Individual customer policies, circumstances and purchasing practices should be considered. Regional practices may be applicable as well.

Program Rule Constraints

Program rules may also influence baseline definition in ways that are more practical than theoretical. In California IOU programs, for example, rules state that projects that replace "like with like" equipment are ineligible for incentives, regardless of the availability of less efficient equipment.

In Massachusetts, program rules require that natural gas efficiency projects that also involve fuel switching from oil or other energy sources define baseline as the natural gas-fired equipment that meets minimum efficiency requirements for new construction / replace on failure. It excludes the impact of fuel switching impact.

The baseline for a particular project may be higher or use a different fuel than market theory otherwise could conclude due to program rules.

Decision-Making Flow Chart

The logic flow charts in Figures 3 and 4 guide the baseline decision-making process. The first, two-page figure reflects the current NYSERDA approach to decision-making of industrial process baseline. The second flow chart illustrates CPUC-proposed[8] guidelines for use in the California IOU custom measures/projects to be implemented during the 2010-2012 program-year cycle. There are differences between the two charts. Most notably, the California flowchart addresses the remaining useful life concept, which historically has not been part of the NYSERDA framework. The NYSERDA chart invests more effort in helping decision-makers define baseline in production increase scenarios. While the reader may be drawn to detecting differences between the charts, the authors encourage focusing on the similarities. Both charts have the same logical branches for consideration of:

- New construction and replace on burnout (ROB) versus retrofit
- Consideration of applicability of code
- Recognizing the theoretical baseline must meet production requirements
- The "lower end of standard practice" (CA) and "low efficiency commonly used" (NY) definitions of technical baseline

These are the same principles discussed in this paper.

Conclusions

The baseline is the least efficient option specific to a particular facility and application that the customer technically and economically would have reasonably considered to deliver the post-retrofit level of production. Decision-making on baseline for a specific industrial process project must consider relevant codes, available alternative economic alternatives, standard practice, the regulatory policy environment, and program requirements to define baseline.

The program or evaluator should consider these factors, and the technical baseline should be separated as much as possible from the concepts of free ridership, which characterizes what the participant would have done, as opposed to the least efficient choice he or she could have made.

Baseline can vary over the projected life of a measure due to early replacement of gradually degrading equipment, anticipated changes in future market conditions or other reasons.

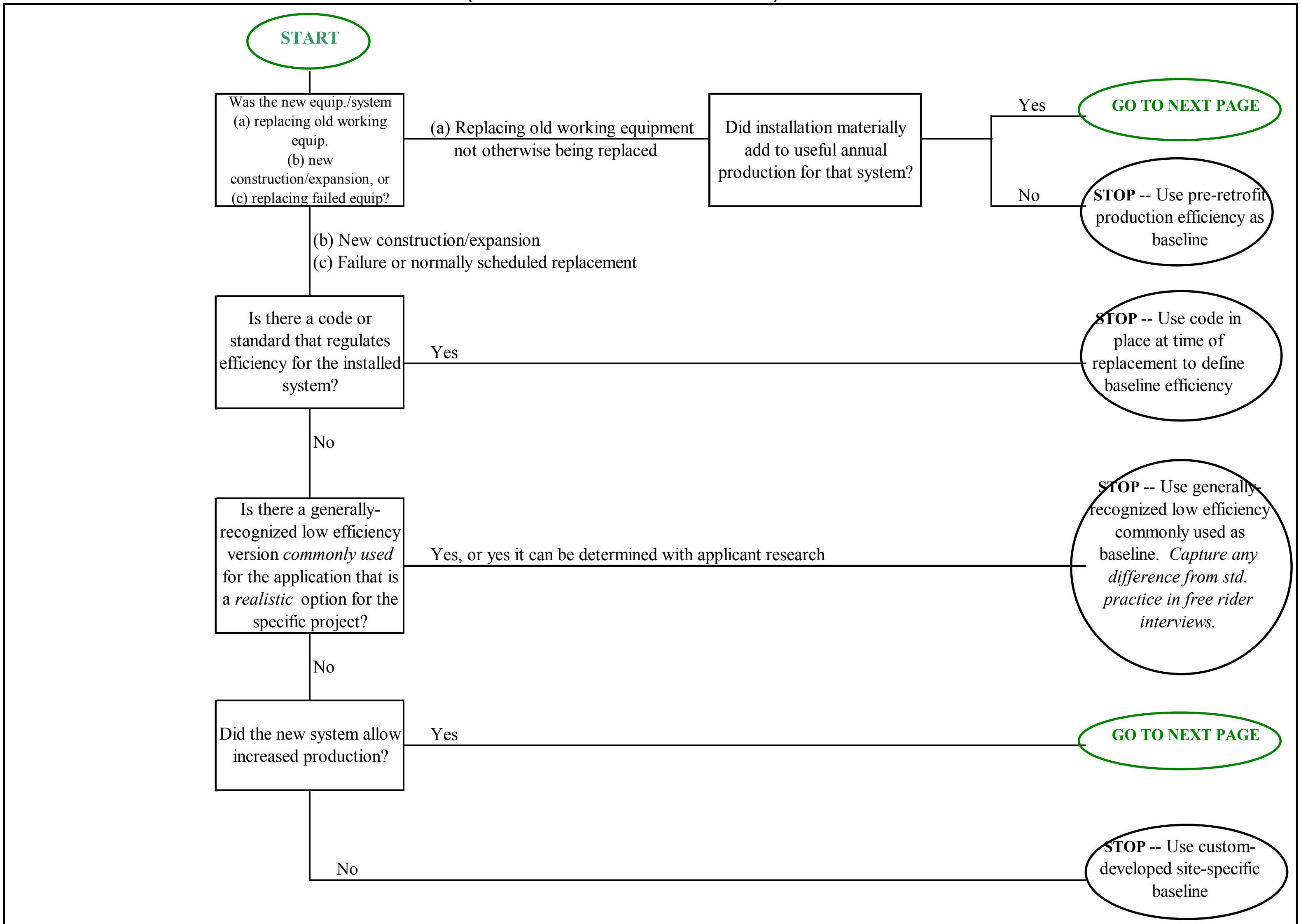
If production levels change, both the baseline and post-retrofit EUIs must be normalized per unit produced and applied to the post-retrofit level of production.

This approach takes time to apply, but using such a consistent method will result in better and more defensible program savings estimates.

[8] The flow chart in this paper is similar to the one published in the previously-cited SCE final evaluation report and used in the 2006-08 CPUC evaluation cycle. The flow chart in this paper is a proposal at the time of paper submission. A CPUC decision is expected soon.

Figure 3: NYSERDA Industrial Process Efficiency Baseline EUI Logic Flow Chart (page 1 of 2)

HOW TO DETERMINE BASELINE ENERGY USE INTENSITY (ENERGY USE PER UNIT PRODUCTION) AND EFFICIENCY FOR PRODUCTION-RELATED MEASURES



"For the application" means for the project's particular combination of system or equipment type and industry type.

Figure 3 (continued): NYSERDA Industrial Process Efficiency Baseline EUI Logic Flow Chart (page 2 of 2)

HOW TO DETERMINE BASELINE ENERGY USE INTENSITY (ENERGY USE PER UNIT PRODUCTION) AND EFFICIENCY FOR PRODUCTION-RELATED MEASURES

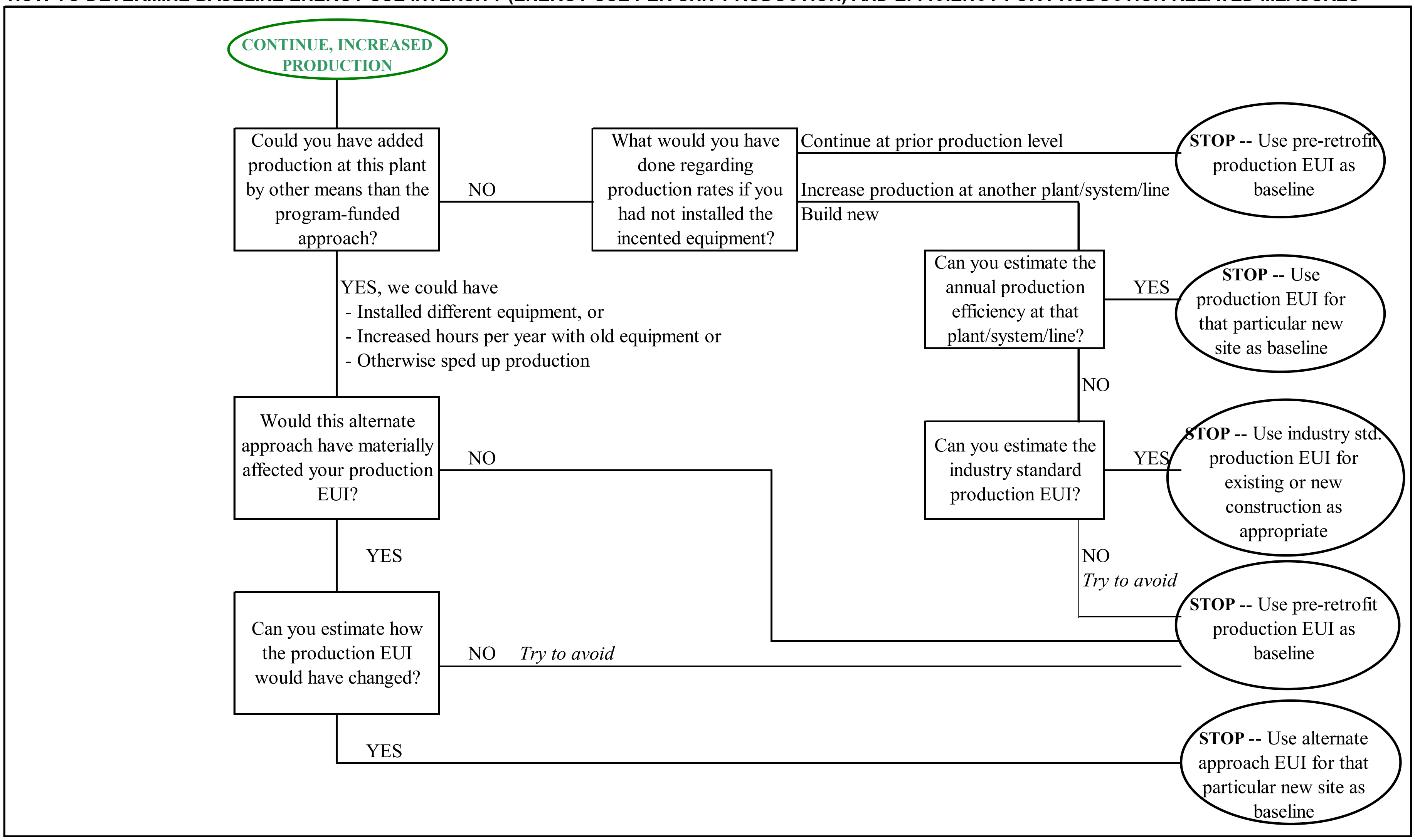
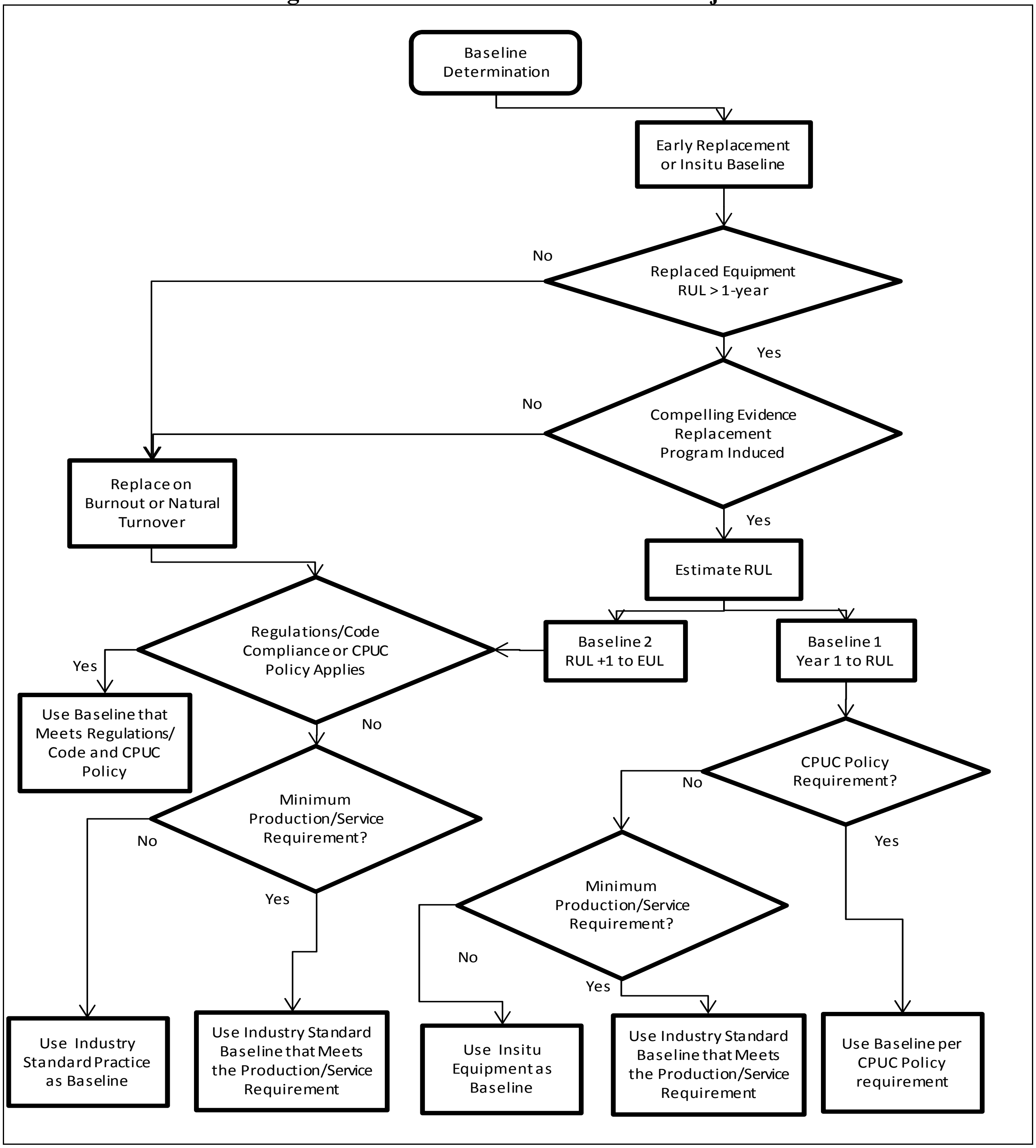


Figure 4: California IOU Industrial Project



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