Unical/Lattner White Paper:

Unparalleled Life Cycle Savings: Solar Thermal Technology and Condensing Boilers

Sutherland D. Junge
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The Lattner Group, Inc.
830 33rd Ave. SW, Suite G
Cedar Rapids, IA 52404
(319) 899-4881
sutherland@lattnerhotwater.com
www.lattnerhotwater.com
www.facebook.com/lattnerhw

Why Solar Thermal and Condensing Boilers?

Solar thermal and condensing boiler technologies, when integrated, generate hot water more cost-effectively than any other combination of technologies. Otherwise known as STaCB systems (Solar Thermal and Condensing Boiler), solar thermal and condensing boiler systems generate significant life cycle savings and value for buildings owners and occupants. Through a combination of incentives, long useful lives, and energy efficiency, STaCB systems more than overcome their upfront costs. They also offer a hedge against volatile energy prices and regulatory risk. The purpose of this paper is to illustrate these cost savings.

What are typical applications for STaCB systems?

STaCB systems produce hot water for in-floor radiant heating, swimming pools, snowmelt, and domestic hot water systems. These are defined as low return or low inlet temperature systems, in which solar thermal panels and condensing boilers operate most efficiently.

Life Cycle Costs

It's easy to dismiss the upfront cost of a STaCB system as too high. But, as with most capital investments, the upfront cost of a STaCB system is only one variable in the actual cost equation. In fact, operating cost over the life of the system is the most important variable. There are other important variables as well, such as tax incentives and rebates, useful life of the equipment, operating principle, regulatory risks, and the value of competitive advantage. The sum of these variables, in present day dollars, is the actual cost or the life cycle cost of the STaCB system.

The life cycle costs of a STaCB system can be broken down into seven categories: (1) Equipment and installation, (2) incentives and rebates, (3) useful life, (4) operating principle, (5) energy, (6) regulatory costs and risks, and (7) competitive advantage.

For the purpose of illustration, consider a small, new commercial structure (or residence), approximately 3,200 square feet in size, located in a northern climate. The maximum possible load, including domestic hot water, is 50 Btus per hour per square foot[1] or 160,000 Btus per hour total. The owner has the option of a STaCB system with radiant heat and domestic hot water or a conventional forced-air furnace and water heater.

The life cycle cost of the STaCB system is:

1. Equipment and Installation – The installed cost of a 160,000 Btu output STaCB system, including four evacuated tube solar thermal panels, condensing boiler, radiant floor heating, and 80 gallon domestic hot water tank is approximately $42,000.[2] This is a little more than twice as expensive as a system including a furnace and water heater.

	STaCB	**Conventional**
Installed Cost	$42,000	$18,000

2. Incentives & Rebates[3] – The STaCB system in our illustration qualifies for an energy efficient commercial buildings tax deduction of $2,000,[4] IRS permitted five year modified accelerated cost recovery (MACRS depreciation– ask your accountant) equal to approximately $2,000, a

$15,000 state tax credit,[5] an energy investment tax credit of $4,000,[6] and a $400 rebate from the local utility.[7] The first two of these incentives are deductions. The second two are credits. The last incentive is a rebate.

If the average revenue generated or collected per square foot of this building is $25.00[8] per year, then the gross revenue is $80,000 per year.

First, we address the deductions. The deductions are subtracted from the gross revenue. The adjusted revenue is $76,000. If the corporate tax rate is 12%,[9] then the deductions save approximately $480.

Second, we address the credits. Again, if the corporate tax rate is 12%, then tax liability excluding the tax credits is $9,120. Including the tax credits, the tax liability is $0. In fact, the tax credits are larger than the tax liability. For the purposes of our illustration and to avoid complicated tax law, we will assume the actual value of the tax credits is simply $9,120.

Third, we address the rebate. It's a simple cash rebate of $400.

Including all incentives, the net installed cost is:

	STaCB	**Conventional**
Installed Cost	$42,000	$18,000
Deductions	($480)	$0
Credits	($9,120)	$0
Rebates	($400)	$0
Net Installed Cost	$32,000	$18,000

While the STaCB system qualifies for all of these incentives, it's sometimes difficult to secure them with state and federal agencies. Paperwork, permits etc. are required. Experienced local manufacturer's representatives and contractors will help make securing incentives significantly less difficult.

Some STaCB systems won't qualify for as many incentives as our illustration. Incentives vary by geography, size, and use. Some incentives expire and some change with political change. It's important to take advantage of available incentives while they are accessible.

3. Useful Life – The useful life of a condensing boiler is 20 years. The useful life of a solar thermal panel is 20 years. The useful life of a traditional water heater and furnace system is 10 years. It should go without saying, consistent care and maintenance are important for all heating equipment.[10]

The installed replacement cost in today's dollars for each system over the duration of a 30-year mortgage (commercial or residential) is:[11]

	STaCB	Conventional	
Solar Thermal	$11,250	n/a	
Condensing Boiler	$7,970	n/a	
Domestic Hot Water Tank	$1,350	n/a	
	n/a	$4,900	Water Heater
	n/a	$5,600	Furnace
	$20,570	$10,500	

Using a discount rate of 3% and a time horizon of 30 years,[12] the replacement cost of both systems in today's dollars:

	STaCB	Conventional
Present Value	$8,500	$4,300

This illustration does not account for future incentives. It's very likely incentives will exist at the time of replacement, but it's difficult to project how future incentives will affect our life cycle costing here.

	STaCB	Conventional
Net Installed Cost	$32,000	$18,000
Useful Life Cost	$8,500	$4,300
Total	$40,500	$22,300

4. Operating Principle – The operating principle in a STaCB system is important to consider for the following reasons:

    - STaCB systems operate as "modulating" devices. For example, the condensing boiler modulates fuel consumption based on system demand. As the demand for heat in the system increases, the condensing boiler consumes more gas and outputs a greater number of Btus. The condensing boiler will modulate up and down over a wide range of Btu outputs, matching the system load. This maximizes operating efficiency. Conventional furnaces are ON/OFF devices. They cannot meet systems loads as cost-effectively, efficiently, precisely, or quickly.

    - STaCB systems automatically give the solar thermal panel priority in terms of producing Btus and matching the load. In other words, STaCB systems will attempt to match the load with only the Btus produced by the solar thermal panels. If a system can't match the load with only the solar thermal panels, then it will activate the condensing boiler. In essence, the condensing boiler will act as a supplementary heat source. This ensures maximum system operating efficiency and lowest possible input cost.

5. Energy – Before we calculate our energy input costs, we need to recognize the fact that hydronic heating systems consume significantly less energy to produce the same conditions or comfort level inside a commercial building or home. According to John Siegenthaler, P.E., "energy usage average[s] 40% greater in homes with forced-air heating."[13] In terms of Btu

load, then, we need to account for the difference in efficiency to arrive at the energy requirements required to produce the same comfort level.

	STaCB	**Conventional**
Required Btus	160,000	160,000
Heating Btus[14]	136,000	136,000
Accounting for System Inefficiency	N/A	40%
Required Output Btus from Heating System	160,000	250,000[15]

Another way to think of this inequality: The STaCB system will be used far less frequently or at a lower output than the conventional system to produce the same comfort level. This does not imply that it's acceptable engineering practice to undersize the STaCB system. It simply means that the conventional forced-air system works much harder and in a cost-ineffective manner.

The reasons for this are:

- Conventional forced-air systems leak a significant amount of energy. Leakage can also create pressure changes, inefficient air circulation, and worst-case scenario dangerous air quality conditions.

- Hydronic heating systems radiate heat from the floor upward or from convectors outward, as opposed to conventional forced-air systems that push heated air downward from the ceiling. Because heat naturally rises, forced-air systems have difficulty delivering heat to the space we occupy nearer to the floor. The heat produced by forced-air systems is highly stratified, warmest conditions at the top and coolest conditions at the bottom.

Next, we consider the operating efficiencies of both systems. The efficiency of the STaCB system will depend on the load. As mentioned earlier, the STaCB system will automatically recognize the solar thermal panel as the primary heat source. In low load conditions, the solar thermal panels will do a greater percentage of the work thus increasing combined efficiency.

Again, for the purpose of our illustration, we assume both systems are operating at maximum load. From the STaCB perspective, this is a conservative approach given that the STaCB system is least efficient at maximum load.

We calculate input costs based on condensing boiler efficiency of 97% and solar thermal panel efficiency of 100%.[16] Solar panels are 100% efficient in the sense that they require no input gas to produce hot water.[17]

At maximum load and considering the number of solar thermal panels we have accounted for in our installation costs, the solar thermal panels produce approximately 12% of the required Btus. The condensing boiler produces approximately 88% of the required Btus. In terms of calculating input costs at full load, we can completely discount the solar thermal panels since they require zero energy input (from the utility). Thus, in terms of our life cycle input costing, only the energy consumption of the condensing boiler is important.

The estimated efficiency of a typical forced-air furnace is 80%.[18] The estimated efficiency of a typical water heater is 65%.[19] At any load, the combined efficiency is 78.32%.

Given these efficiencies and the fact that we don't need to calculate input costs for the solar thermal panels, the comparative hourly energy consumption at full load (to achieve identical comfort levels) is:

	STaCB	**Conventional**
Hourly Energy Consumption in Btus	145,000	319,203
Hourly Energy Consumption in Therms	1.45	3.19

In other words, conventional systems require more than two times as much energy to achieve the same level of comfort.

To calculate our life cycle input costs we further assume:

- The seasonal average cost of natural per therm is $0.90;[20]
- Each system operates an average of 12 hours per day;
- 365 days per year;
- Again, we use a time horizon of 30 years that corresponds to the length of a typical commercial or residential mortgage;
- Again, we use a discount rate of 3% to calculate the present value of all cost cash flows.

	STaCB	**Conventional**
Present Value of Energy Costs	$71,000	$156,000

This is not surprising given that conventional systems consume more than twice as much energy. The difference is $85,000!

One last thought on energy inputs: Energy, in the form of natural gas in our illustration, is subject to considerable volatility. The cost of natural gas and its demonstrated volatility affect owners' and/or occupants' net cash flow (and the value of the structure itself, as discussed below) to the extent that high-energy prices have caused mortgage defaults. In fact, commercial and residential mortgage originators are beginning to price energy risk into their models and interest rates. Solar thermal (in particular) and condensing boiler technology can provide a hedge against energy volatility, interest rate increases, and defaults.

6. Asset Valuation – Cost savings and improved net cash flow increase asset value. After incentives and in today's dollars, the additional value created by installing the STaCB system:

	STaCB	Conventional
Net Installed Cost	$32,000	$18,000
Useful Life Cost	$8,500	$4,300
Present Value of Energy Costs	$71,000	$156,000
Total	$111,500	$178,300
Additional Value	**$66,800**	

Reiterating, this is $66,800 additional value in today's dollars for a 3,200 square foot structure. If we assume the market value per square foot is $150,[21] then the base value of the structure in our illustration is $480,000. If the additional value of the STaCB system is $66,800, then our total value is $544,800. This is an increase in value of approximately 14% over the base value of the structure.[22]

The return on investment is also compelling:

	STaCB	Conventional
Net Installed Cost	$32,000	$18,000
Useful Life Cost	$8,500	$4,300
Total	$40,500	$22,300
Additional Cost	$18,200	
Additional Value	$66,800	
ROI	**367%**	

7. Regulatory Costs and Risks – Most of us in the boiler industry are well aware that regulations are constantly changing. From permissible NOx emissions to efficiency requirements, it seems as though regulations are changing on a yearly basis. In addition, regulatory agencies and rule-making commissions often create "grandfather" periods that are seem unreasonably short, particularly for small business owners.

   That said lower NOx emissions and higher efficiencies are good for our health and environment. The problem is that regulations are changing so fast that even manufacturers have difficulty keeping pace. It's impossible to predict how fast and how much regulation will change over the next 30 years or over the course of a building's useful life. The best way for a builder, owner, or occupant to protect him or herself is to install equipment that exceeds current regulations in terms of emissions and efficiency. In this way, the builder, owner, or occupant is again hedging, but this time against regulatory risk.

   It's interesting or perhaps disconcerting to note that we know the price of the hedge (it's the net cost of the equipment, operating cost etc. in today's dollars), but the risk we're hedging against is indeterminate. What's the cost of replacing a conventional system three years from now when it's no longer compliant with regulations? What if a regulatory change requires higher energy efficiency equipment to be installed in a mechanical room that wasn't designed for it?

8. Competitive Advantage – Beyond cost, value, and risk, energy efficiency and low energy input costs create a significant competitive advantage for building and homeowners. Building owners can market energy efficiency and the cost-effectiveness of leasing space in their buildings. In fact, many studies have found that higher rents and occupancy rates more than offset the cost of energy efficient equipment.

   Homeowners have a competitive advantage in that energy efficient homes are easier to sell.

   There's also soft dollar value associated with the social perception of "green" building. Green buildings, LEED certified buildings etc. attract businesses and owners who might otherwise select a competitor's building. Many of these businesses market their own products with "green" features.

   It's difficult to quantify these competitive advantages and they certainly aren't accounted for by mortgage originators and appraisers, but there's no doubt these competitive advantages exist and add value to energy efficient buildings.

Final Thoughts on Our Illustration

We've made many assumptions in the preceding sections. These assumptions are based on our industry experience, our location, our costing, and highly reputable third-party research.

Even when we changed our model, the present value and return on investment of the STaCB system in our illustration was compelling. We changed the installed equipment cost, efficiencies for each piece of equipment, leakage for the forced-air furnace, incentives, cost per therm of natural gas, useful lives, discount rate, and combinations of these variables. As long as we made reasonable changes, we achieved a net positive return on the STaCB system.

There were two notable exceptions. When the price of natural gas fell below $0.40 per therm the solar system didn't yield a positive return on investment. The condensing boiler still yielded positive return on investment, albeit a small one.

When we changed the proportion of Btus supplied from solar to condensing gas boiler, in favor of solar, the return on investment eventually fell to zero. The expense of the solar equipment and installing it offset the increased efficiency. Through testing the model, we found the optimal mix of solar to condensing gas boiler was approximately 20:80. This is due to upfront cost, as well as the ratio of domestic hot water production to heating load.

Lastly, STaCB systems aren't as attractive to owners and occupants who intend to sell their property or occupy their property for short periods. The argument can be made that STaCB systems add value and therefore increase sale price, but it's difficult to make a compelling argument when the period of ownership or occupancy is less than five years. Even with incentives, it takes longer than five years to achieve a real payback.

Conclusion

For all the reasons above, combined solar thermal and condensing boiler technologies are the most cost-effective means of generating hot water for hydronic space heating and domestic hot water. These technologies are readily available and thoroughly proven. If you're committed to reducing life cycle costs, adding value, and creating competitive advantage for your building, then please contact:

The Lattner Group, Inc.
dba Unical/Lattner
Attn: Sutherland
(319) 899-4881
sutherland@lattnerhotwater.com
www.lattnerhotwater.com
www.facebook.com/lattnerhw

About the Author

Sutherland D. Junge is a fifth generation boilermaker. His great, great grandfather founded Lattner Boiler Company in 1918.

Sutherland's current position is "Division Leader" at Unical/Lattner. Prior to this position, he served as "Vice President of Sales & Marketing" at Lattner Boiler Company.

Sutherland graduated from The University of California at Berkeley with a B.A. in Architecture. He earned an M.B.A. from the Tippie School of Management at The University of Iowa.

Sutherland has contributed to HPAC magazine. He continues to write, present, sell boilers, and grow the Unical/Lattner business.

Links to other white papers

The Aluminum Advantage: Strong, Form-Able, Conductive, Corrosion Resistant
Ten Differentiating Features of The Unical/Lattner Heat Exchanger
The Advantages of Mod/Con Boilers in Climates with Wide Temperature Ranges

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[1] This is the average maximum possible load for the given climate according to the US Energy Information Administration.
[2] This is based on Unical/Lattner installed equipment costs. All products and services are included. New construction.
[3] Public sector incentives based on energy efficiency contribute to the cost-effectiveness of STaCB systems. Rebates, tax deductions, and grants are examples of the many programs available. Visit the Database of State Incentives for Renewables & Efficiency (DSIRE™) for a state-by-state listing of incentives. www.dsireusa.org. These incentives are based on programs available to commercial building owners and occupants. Residential incentives similar in structure and value, but not identical.
[4] Federal Energy Efficient Commercial Buildings Tax Deduction 26 USC 179D
[5] Iowa Tax Credit S.F. 2342
[6] Federal Energy Investment Tax Credit 26 USC 48
[7] MidAmerican Energy
[8] This is average price per square foot for office space in Iowa. The average price will vary significantly by location.
[9] Average corporate tax rate for Iowa.
[10] According the Consumer Energy Center (www.consumerenergycenter.com), traditional tank-type water heaters have average useful life of little more than 10 years, and much less in hard water areas. With proper care, the useful life of a condensing boiler is up to 20 years. Solar

thermal panels have useful lives exceeding 15 years. Both condensing boiler and solar thermal panel manufacturers offer protracted warranties, providing consumer protection for the useful lives of their respective products.

[11] Estimates are based on Unical/Lattner installed cost for STaCB systems and widely available installed costs for conventional systems.

[12] We use a conservative discount rate of 3% to account for inflation. The period is 30 years based on our 30-year mortgage assumption. Some equipment or most equipment will be replaced before the 30-year mortgage matures. Again, we're creating conservative estimates so we apply the maximum reasonable discount.

[13] Siegenthaler P.E., John. *Modern Hydronic Heating*. Third edition. Delmar Cengage Learning. Copyright 2012. Page 6.

[14] ENERGY STAR/US Environmental Protection Agency estimates that 15% of home energy consumption can be attributed to production of domestic hot water. Only the forced-air subsystem in the conventional system is subject to 40% losses.

[15] Calculation: 136,000/0.60=226,000. Then adding the domestic water heating load back in: 226,000+24,000=250,000.

[16] Condensing boilers achieve 97% efficiency in full condensing mode when return water temperature is less than 131°F.

[17] Solar thermal panels are not 100% efficient in terms of converting the sun's energy into hot water. Also, depending on the type of solar thermal panel and the type solar hot water circulating system used, there may be minimal input costs related to consumption of electricity for pumping and control.

[18] US Department of Energy. *Understanding the Efficiency Ratings of Furnaces and Boilers*. www.energysavers.gov.

[19] American Council for an Energy-Efficient Economy (ACEEE). *Water Heating*. www.aceee.org.

[20] US Department of Energy. Energy efficiency requirements for ENERGY STAR rating. Assumptions. www1.eere.energy.gov. The US Bureau of Labor and Statistics uses $0.907 per therm. However, the cost of natural gas varies based on geography, consumption etc.

[21] $150 per square foot is based on single story commercial construction in Iowa. The value per square varies greatly by location and use.

[22] For an explanation of how to appraise and energy efficient building and to read more about the "soft dollar" valuation of energy efficiency buildings, refer to IMT's paper entitled *Recognition of Energy Costs and Energy Performance in Real Property Valuation*. http://www.imt.org/uploads/resources/files/Energy_Reporting_in_Appraisal.pdf