What the heck do these fancy Industry 4.0 technologies actually do for me?

By KIC

One reason the Industry 4.0 / Smart factory technology trend in electronics manufacturing is moving slowly is due to developers like us not having done a good job demonstrating the concrete impact on users, along with the proven benefits and a solid ROI. Another result of our vague, highfalutin and pretentious message (See? There we go again! We could use more understandable words such as: Snobbish, pompous, grandiose, high-sounding, overblown...), is that potential users get the impression that investing in these technologies is overwhelming, risky, and very expensive. And they have little information about concrete benefits.

This article seeks to drive the discussion down to a practical level of measurable benefits to the electronic manufacturer. It will also show that embarking on the Industry 4.0 journey is less like Legos, where the final block creates a whole, and more like planting trees. You may want to build a forest, but each individual tree creates value along the way. The specific technologies and benefits that we will draw on relate to our own expertise in reflow, wave and other thermal processes in the SMT assembly and semiconductor industries, but there are direct analogies up and down the production line and the factory as a whole.

What is your end goal?
Before embarking on our journey, it is important to define the high-level objective (the end results) of an electronic manufacturing factory to avoid confusing activities with results.

The ultimate objective:
To manufacture products at required quality (or better), deliver them at the requested time at the relevant price, while controlling costs at a level that yields a sustainable profit to the electronics manufacturer.

A company may have additional unique business goals such as increasing profit, moving into higher margin products etc.

It is important to keep this in mind because everything else is a means to this end. An EMS company for example, is not in the business of buying SMT placement machines. That may be a requirement to achieve its goals, but it remains a means to an end, and it needs to be managed accordingly.

What is possible with today’s Industry 4.0 / Smart factory technologies?
Reduce cost
Let’s start with what everybody is focused on: Costs.
To reduce costs it is helpful to first identify sources of unnecessary costs. Think about waste. Wasted production time and engineering time. Scrap is wasteful, so is rework. Longer than necessary audits, using more electricity and nitrogen than required are a waste. The list goes on.

When running ROI studies, production uptime, (or lack thereof), is usually the biggest factor. Studies from the SMT industry in the US indicate that the average production line in that country spends more time doing no assembly than actually running production. Why is that? Set up time, changeover time, yield troubleshooting time, and machines waiting for parts are the biggest contributors. Today’s Industry 4.0 smart factory technologies allow for off-line programming and optimization, line balancing and optimization, real-time dashboard from all machines and processes available on all authorized computers and mobile devices anywhere. A relatively new capability is the closed loop, wherein the SPI machine monitors output from the screen printer and then makes machine adjustments on the fly based on printing results and trends. In other words, rather than waiting for a defect to occur, or a process to go out of control, the machines monitor each other and make continuous adjustments to keep production running in spec. Another recent example of machine communication in real-time is illustrated by V-One where continuous reflow and profile data communicate with AOI to help troubleshooting defects. All of these capabilities aim at improving productivity/equipment utilization through faster setup, changeover, troubleshooting, and part replenishment.

In the world of reflow soldering the oven needs to process the assembly within specified profile limits. Automatic profiling systems measure the process continuously and in real-time, compare them to the established process window and provide actionable data, alarms, warning, line shut-down and more. The elimination of manual spot checks, with its inherent tendency to interrupt production, increases uptime. Automatic SPC charting acts as an early warning system where an oven trending towards the process limits can be flagged for adjustment during the next scheduled downtime. Sharing the data via the factory IT network with mobile devices
and a central hub, such as MES, enables engineers and technicians to quickly troubleshoot a yield issue to its root cause. The data also tends to reveal where in the oven or process the problem originates. This leads to a faster troubleshooting, quick remedies, and less downtime. It also all but eliminates scrap and rework due to an out of spec process. Engineers and technicians need quality data to make good decisions. Today the problem is not lack of access to data in most factories, but too much data. Hence software needs to provide relevant information, insight, and actionable data.

Reflow Oven & Wave Soldering optimization software has a multifaceted functionality. It allows for much faster setup of a brand-new PCB assembly production run, a more robust process, and it reduces or even eliminates reflow oven changeover time. It does this by quickly identifying a single oven recipe (zone temperatures and conveyor speed) among billion alternatives (that is billion with a b) that can process all, or most, of the various assemblies in-spec. It also attempts to identify whether other conveyor speeds can handle the outlying assemblies without changing the zone temperatures. While an oven may need 30 minutes to stabilize on a new set of temperatures, the conveyor speed will change in seconds. Again, the listed capabilities improve equipment utilization.

**Quality**

Scrap and rework are expensive, and rework may also affect your quality. A computer company in California years ago tracked all manufactured PCB motherboards throughout their lifespan. These were very expensive PCB boards where field failures would be reported and sent back for refurbishment. Their internal study concluded that the boards that had undergone rework were much more prone to field failure over time. In other words, even though the reworked boards had undergone the same rigorous testing as those boards that were right the first time before shipment, apparently a latent weakness had been introduced. Quality is not only a matter of first pass yield, but long reliability during operation in the final product. Auto manufacturers have known this for a long time. That is why many of them no longer accept rework. Real-time dashboards mean visibility into each process, leading to focus, process control, improvements, and “making it right the first time”.

The ROI for such new capabilities is readily calculated. Image 1 Below is an example of a simple, yet effective, ROI calculator.
Reduce wasted engineering time

A study conducted by Tech-Clarity in 2014 (Reference 1) indicated that engineers spent 32% of their time on non-value-added work. Figure 2 shows the time distribution of the different non-value-added tasks.
The frustrations they encountered were many, and they ranked their activities from highest to lowest level.

Frustration ranking
1. Information gathering
2. Documentation
3. Planning
4. Negotiating
5. Support Counseling
6. Problem solving
7. Thinking
8. Other
An older Canadian study (Reference 2) researched how engineers in an aerospace company spent (and wasted) their time. Results below in Image 3.

![Image 3 Engineering Time Break-Down](image)

This is an area where Industry 4.0 smart factory technologies shine. The overused expression “Data at your fingertips” comes to mind. In the reflow world, you can search on a product ID, customer name, timeframe, production line number, process outliers, and a host of other criteria, and instantly find the data you seek in your current and historic production regardless of which line(s) performed the production. As stated above, the data and insight lead to faster troubleshooting. Creating a report for your customer (EMS client), or your boss, is done in seconds or minutes, not hours or days. Even better, set them up with a Password protected link to a specific folder, and they can self-serve to their heart’s content without bothering the engineer at all. Spending excessive time searching for relevant data is rapidly vanishing.
As more electronic products are becoming “mission critical” and as poor quality is expensive, this trend has moved beyond high reliability electronics into the mainstay of manufacturing.

**Reduce electricity use.**
Sustainable manufacturing is one of the goals of the Industry 4.0 smart factory trend. The biggest electricity user in the production line is the thermal process. Several case studies (ref 3.), have shown that the use of optimization software for reflow oven setup not only achieves a robust process, but can reduce electricity use by up to 15%. This is an instant, and likely permanent, effect on all your reflow ovens, all the time.

Increased productivity also saves electricity as an idle machine still consumes electricity. (It also promises lower capital equipment cost and footprint in that a factory with 4 or 5 production lines can eliminate one line when reaching a 25% productivity improvement).

**Other company goals**
**Satisfy current customers and become attractive to new ones.**
Process control and production traceability are hot topics in certain segments of the electronic manufacturing industry: Automotive, Telecommunication, Medical, and Military for example. But now interest is spreading beyond that. Investing in comprehensive traceability tools may allow you to grow your revenue by attracting new customers. For reflow that means not only to verify that the oven was running the correct recipe, but that the process was in spec at all times. This is measured by the PCB profile against the relevant process window/process
tolerances. Making it right the first time and to automatically document it, make for happy customers.

**Higher profitability**

Such level of process control and traceability may also help you move up the food chain to higher reliability/higher margin business.

Needless to say, higher revenues, improved productivity, and lower costs lead to higher profits.

**Step by step implementation – The Industry 4.0 Starter Kit**

You do not need to turn your whole company into a smart factory all at once. By doing it piecemeal you will improve your operations a little at the time, while your risk and investment requirements stay low. One word of caution, even a smaller Industry 4.0 like project may impact your operations in unforeseen ways. Perhaps the biggest issue is the impact on your people. For example, your OT (Operational Technology) team is likely a gung ho group with an appetite for risk and interested in transitioning you into the 21st century. Their data however must flow through the company’s IT network. Your IT guys tend to be more risk averse. (You likely want them to be. After all they are tasked with keeping your data safe and fending off hackers, ransomware, viruses etc.) The two groups will need to work together to allow safe utilization of Industry 4.0 technologies and data. This is yet another reason why you want to start small.

The concept is to introduce a low-cost system that exposes you to most of the Industry 4.0 smart factory related technologies, and hence impacts. In the example of the day – reflow – this entails an ecosystem of oven setup and optimization software, real-time process control, data analytics, connectivity to the factory’s MES system, and perhaps machine to machine connectivity with AOI machines, traceability and sharing capabilities etc. Should it all completely fail, you have only suffered a small investment loss and some engineering hours. Should it be successful, your reflow process immediately reaps the benefits listed above. But perhaps the most valuable outcome is to go through the learning curve, make your mistakes and figure out how to overcome them. Once implemented on your reflow ovens you will be in a great position to introduce Industry 4.0 throughout the factory, faster, more effectively, and with lower risk.

**Conclusion**

All the Industry 4.0 smart factory technologies described above are already mature. There are several additional excellent technologies available and not included in this limited article. The future promises more powerful data analytics, extreme automation, Artificial Intelligence, Augmented Reality, Digital twins and much more. Regardless of fancy technologies, they are only tools to help you reach your goals.

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Reduction of Non-Value-Added Work in Engineering
Tech-Clarity, Inc. 2014

Ref 2.
Where design engineers spend/waste their time 
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Ref 3.
https://kicthermal.com/technology-information/white-papers/reducing-power-consumption-by-selecting-optimal-oven-recipes/
Reducing Power Consumption by Selecting Optimal Oven Recipes
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