Better Buildings®
U.S. DEPARTMENT OF ENERGY

Smart Manufacturing and Advanced Data Analytics

Wednesday, May 11

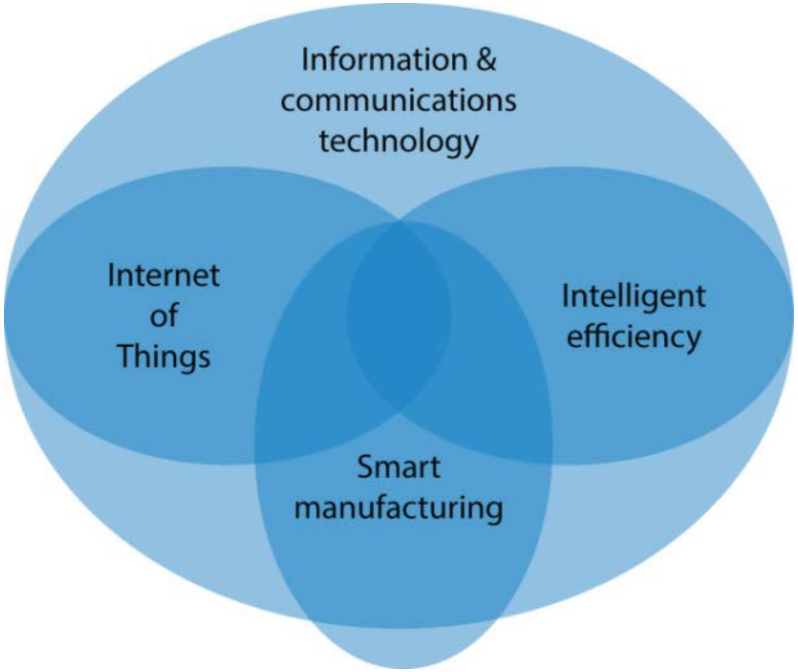
Session 1

9:45 – 11:00 am

U.S. DEPARTMENT OF ENERGY

Session Description

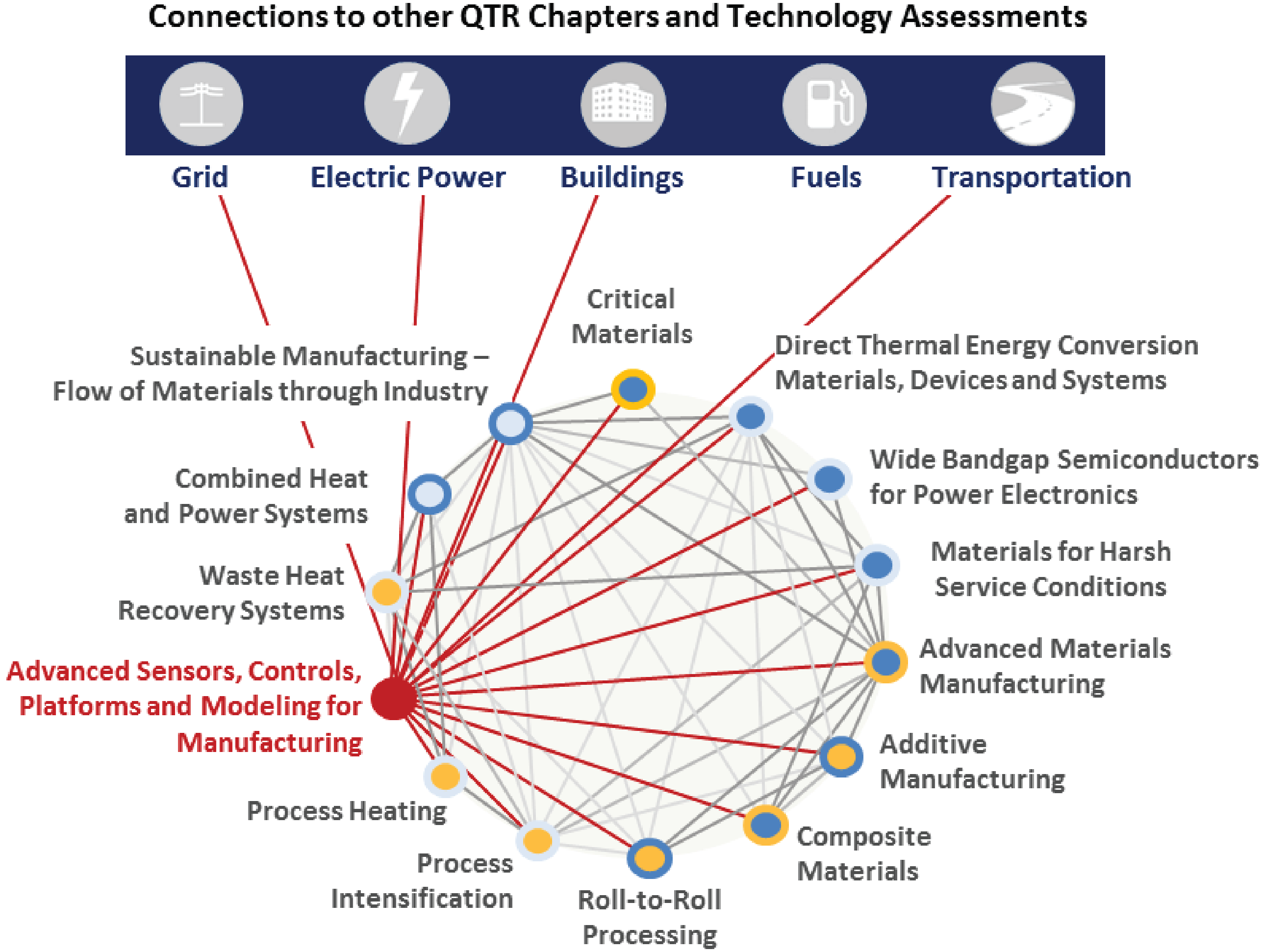
- Smart manufacturing and advanced data analytics - key to unlocking energy efficiency
- These technologies can make industry more competitive through intelligent communications systems, real-time energy savings, and increased energy productivity
- Topics Discussed - building automation system, advanced energy sub-metering, and dynamic energy dashboards



Credit: American Council for an Energy-Efficient Economy (http://aceee.org/research-report/ie1403)

Manufacturing Sector & Beyond - Smart Manufacturing Technologies Could Impact Other Sectors Too!

QTR 2015 – Technology Assessment Related to the Smart Manufacturing



Reference - Quadrennial Technology Review 2015

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Managing Energy as an Ingredient to the Manufacturing Process- Real Time Energy Monitoring

Graham Thorsteinson
Corporate Thermal Energy Platform Leader, General Mills

Managing Energy as an Ingredient to the Manufacturing Process- Real Time Energy Monitoring

Graham Thorsteinson
Graham.Thorsteinson@genmills.com
404-375-0785

GENERAL MILLS

General Mills is one of the largest food companies in the world

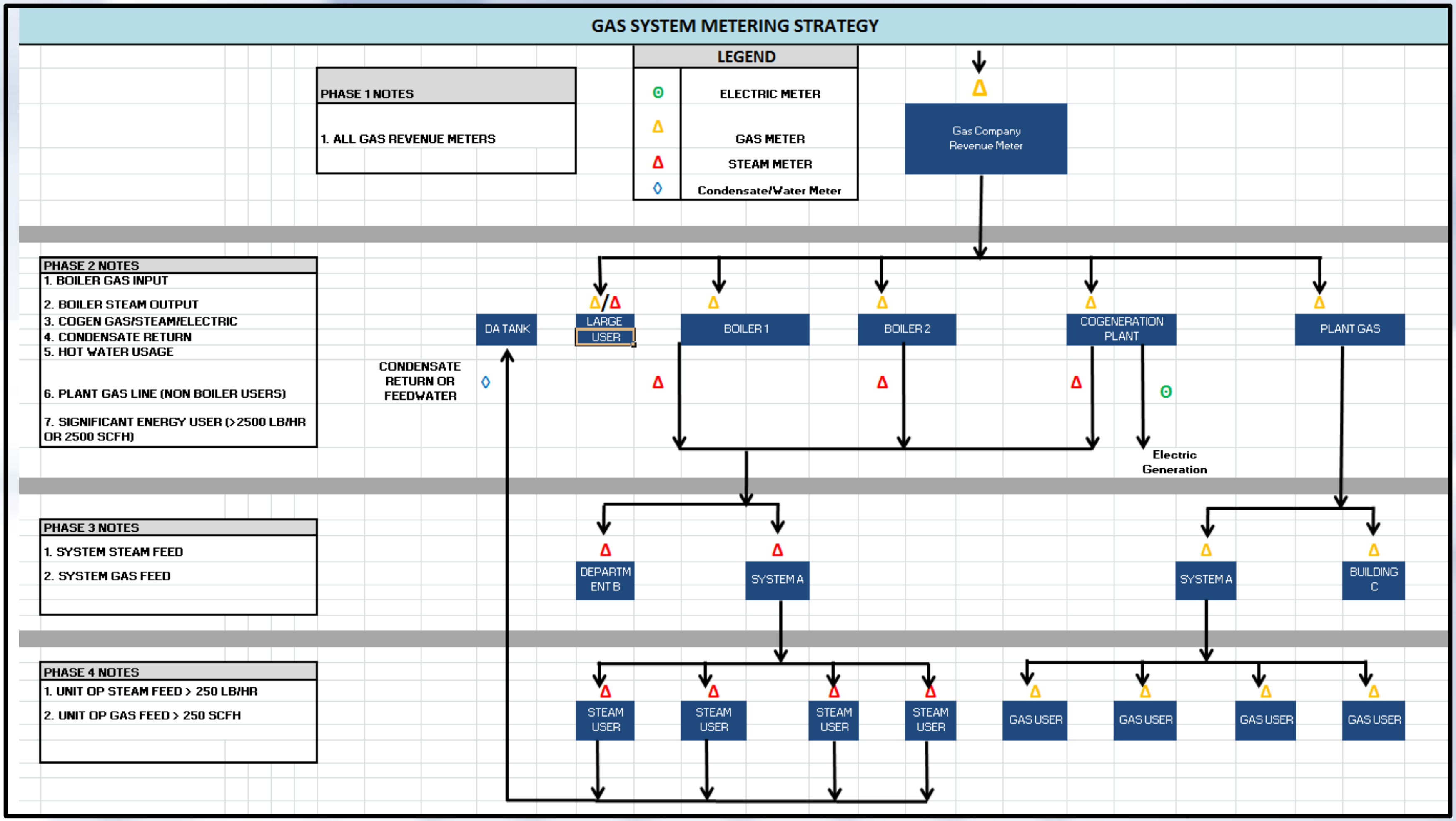
- **40,000 employees; 100 countries; $18 billion sales**

Cereal	Snacks	Baked Goods	Meals	Dairy

General Mills has Made Significant Progress in Energy Reduction

- $20 million saved in 4 years
- 11% BTU/lb reduction in 3 years
- Energy Engineers in 15 sites
- Developed Internal Continuous Improvement Energy Management Process and technical solutions

The plant commits an engineer to be the Energy lead, beginning with a metering strategy



Where is the energy used?

	% Total Energy
Electrical Allocation	61.6%
Lighting	6.0%
Compressed Air	11.0%
Refrigeration	17.0%
Utility Support Equipment	*1.0%*
HVAC	*7.5%*
Process Fans	3.0%
Pumps	4.6%
Production System 1	3.0%
Production System 2	2.0%
Large Unit Op 1	3.0%
Large Unit Op 2	*3.5%*
Gas Allocation	38.4%
Hot Water	6.0%
Boilers	12.3%
Ovens	7.0%
Production System 1	3.0%
Production System 2	2.0%
Large Unit Op 1	3.3%
Large Unit Op 2	3.8%
Building Heat	1.0%
Total Energy	*100.0%*

Understanding usage by unit op and product

Product/Unit Op	Energy/lb*
Cheerios	**70**
Cookers	10
Pellet Dryers	20
Forming	30
Finish Dryer	10
Honey Nut Cheerios	**85**
Cookers	9
Pellet Dryers	18
Forming	28
Finish Dryer	30

*These are not the actual numbers

Energy loss tools developed for all significant energy users in GMI

Question					Savings		
Does the boiler have an economizer to recover heat from exhaust gases to pre-heat feed water?	Boiler #	Projected Outlet Gas Temp	Heat Make Up Air?		MMBTU saved	$/yr saved	*Capital
	Example	260	0		24,700	$ 135,850	$ 60,000
Do boilers operate at optimum oxygen levels (1.5 to 3.0%)?	Boiler #	Future Excess Oxygen %			MMBTU saved	$/yr gas savings	*Capital
	Example	3.0%			10,833	$ 59,583	$25,000
Can boiler blow down % be improved with an RO or water chemistry improvements? Does boiler have a blow down system without automatic conductivity control?	Could boiler blow down be reduced to?			Gallons Water Reduction	MMBTU saved	Total Savings	*Capital
	1.50%			2,271,938	5667	$40,254	$ 90,000
For multiple boiler operations, have boilers been optimized for overall steam generation efficiency? Are any boilers operating at less than 30% load?	Current efficiency loss due to poor boiler loading				MMBTU saved	$/yr gas savings	*Capital
	3%				7,800	$ 42,900	$0
Are boilers left hot when not in use?	Idle boiler scfh	Hours idle			MMBTU saved	$/yr savings	*Capital
	1000	6000			6,000	$ 33,000	$5,000
Reduction in Steam Usage (Demand Side)							
Conduct an IR scan of the entire steam system including boilers (for refractory replacements or improve insulation), all steam lines and valves.	Total MMBTU/yr savings				Steam lb/yr loss reduction	Total $ saved	*Capital (also from program)
	15,000				11,538,462	$ 97,886	$100,000
Are steam traps checked every 6 months? Do you use thermostatic or inverted bucket traps in process applications instead of Float & Thermostatic (F+T)? What is your steam trap failure rate?	Failure % on last trap audit	Average Time Elapsed Between Audits (yr)		lb/yr of loss steam saved	MMBTU savings	$/yr savings	*Capital
	9%	2		12,000,000	15,600	$ 101,801	$10,000
Is your deaerator (DA) running less than 6 psi and the steam exhaust vapor cloud is no more than 4 feet high?	Steam flow to DA			lb/yr of loss steam saved	MMBTU savings	$/yr savings	*Capital
	2500			18,396,000	23,914.80	$ 156,061	$10,000
Do condensate receivers vent flash steam to atmosphere without recovering waste heat? Looking at a roof will quickly answer this question.	% flash steam savings			lb/yr of loss steam saved	Total MMBTU saved from project	$/yr savings	*Capital
	13%			15,895,648	20,664.34	$ 134,849	$200,000

Optimizing Significant Energy Users

- **Baseline usage**
- **Use Loss Tools to optimize unit operations**
  - Maintenance
  - Operation
  - Controls
  - New Technologies
  - New innovations added to existing tools to be spread to other plants
- **Set new aggressive targets**
- **Sustain performance by eliminating losses above target immediately**
  - Energy is invisible and losses can go unnoticed for extended periods

Energy is an ingredient to all production processes

- Raw Materials + energy for transformation = useful product
- Manage energy usage the same way as raw material waste
  - Actual usage – minimum required for product = $ Waste

- Integrate into the way we already operate: Zero Loss
- Energy discussed in production meetings just like equipment stops, ingredient overuse

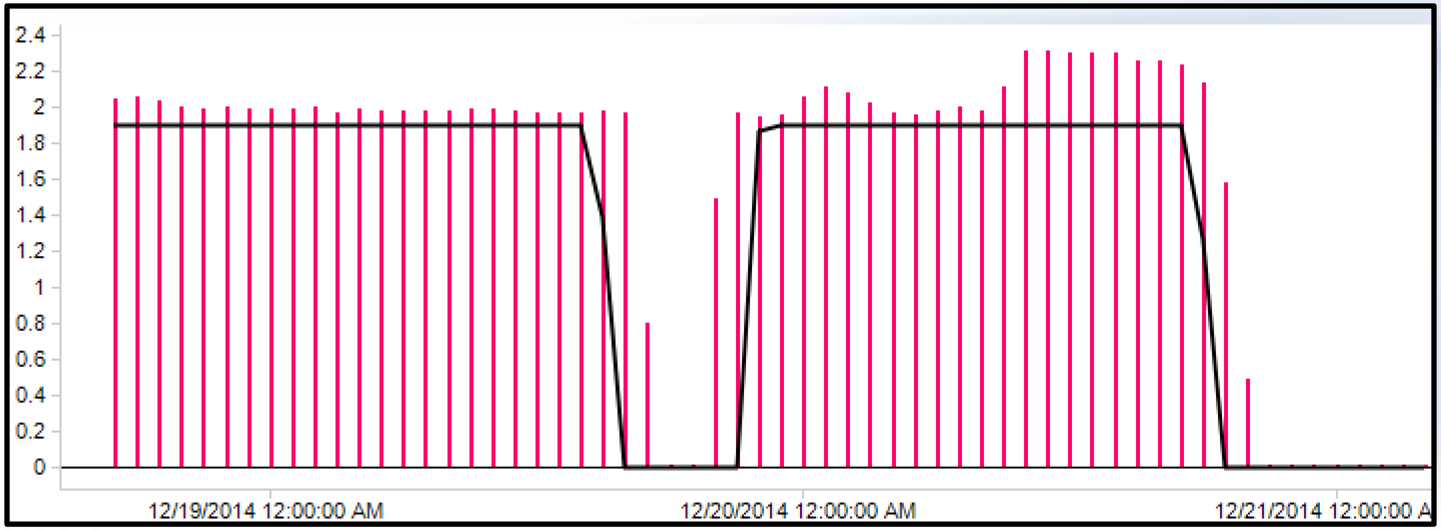
Challenges with common energy tracking systems

- Energy data without weather/production context is not actionable

- Our production tracking system is proprietary, so in order to tie energy into it, we developed our own internal solution, combining multiple external products

Energy Usage Details: Identifying Targets and Troubleshooting Losses

system_name	metername	prod_start	product_name	activity	shiftstart	Activity Time	% of Target	MQIS Lbs	Temp	Actual MMBTU/hr	Overuse ($)	Target MMBTU	Actual MMBTU
Example	Example	12/14/2014 12:27:00 AM	Example 1	NP	12/17/2014 5:00:00 AM	12:0	113 %	Examples	50.25	2.15	$23	22.80	25.83
					12/17/2014 5:00:00 PM	12:0	111 %		47.17	2.12	$20	22.80	25.39
					12/18/2014 5:00:00 AM	12:0	92 %		46.66	1.76	-$13	22.80	21.07
					12/18/2014 5:00:00 PM	12:0	105 %		48.66	2.00	$10	22.80	24.05
					12/19/2014 5:00:00 AM	10:44	104 %		49.41	1.98	$7	20.39	21.26
		12/19/2014 3:45:00 PM		CO	12/19/2014 5:00:00 AM	1:15	1000 %		49.52	1.97	$19	0.00	2.46
					12/19/2014 5:00:00 PM	5:0	1000 %		49.66	0.95	$36	0.00	4.74
		12/19/2014 10:01:00 PM		NP	12/19/2014 5:00:00 PM	6:59	103 %		50.34	1.96	$3	13.27	13.66
					12/20/2014 5:00:00 AM	12:0	114 %		50.53	2.17	$25	22.80	26.05
					12/20/2014 5:00:00 PM	1:40	121 %		49.06	2.28	$5	3.17	3.83
		12/20/2014 6:41:00 PM	Example 2	CO	12/20/2014 5:00:00 PM	10:19	1000 %		48.83	0.25	$20	0.00	2.60
					12/21/2014 5:00:00 AM	9:40	1000 %		49.00	0.57	$42	0.00	5.53
		12/21/2014 2:41:00 PM		NP	12/21/2014 5:00:00 AM	2:19	97 %		48.94	1.84	-$1	4.40	4.26
					12/21/2014 5:00:00 PM	12:0	108 %		49.59	2.06	$14	22.80	24.69



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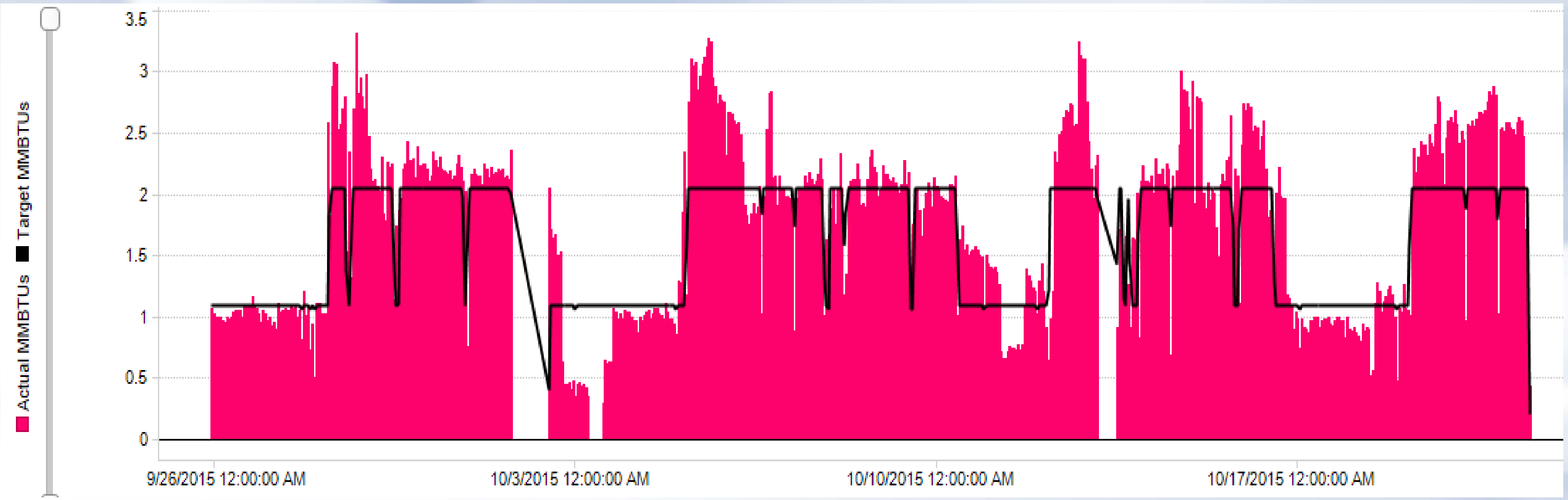
Engine Room Management Example



- **Energy Loss of $5M in 1 month**
- **Tool will eliminate this loss by enabling immediate action**

System Level Summary

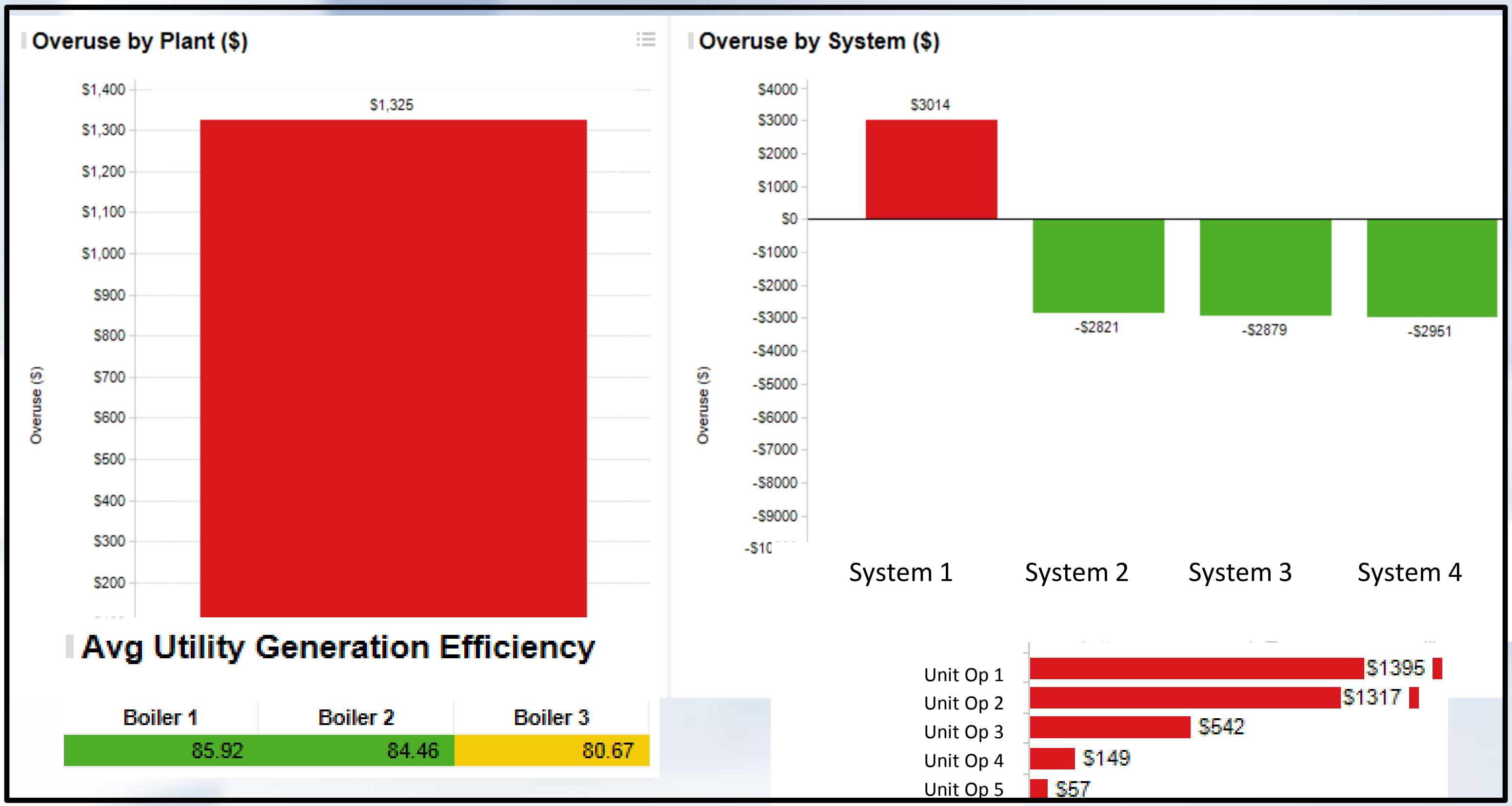
System_Name_Other	Overuse ($)	Actual MMBTUs	Kilo Gallons	% of Target	Actual Dollars
System 1	-$593	546.39	27.47	95 %	$7209
System 2	-$3825	1953.63	369.33	95 %	$22720
System 3	-$2701	1893.26	144823.30	92 %	$22063
System 4	-$1346	719.99	12.22	89 %	$10074

Meter Usage Summary

metername	Overuse ($)	Actual MMBTUs	Kilo Gallons	% of Target	Actual Dollars
Unit Op 1	$1795	542.83	0.00	164 %	$4600
Unit Op 2	$327	166.67	0.00	147 %	$1021
Unit Op 3	$250	195.00	0.00	118 %	$1653
Unit Op 4	$27	60.99	0.00	108 %	$374
Unit Op 5	$106	178.02	0.00	108 %	$1509
Unit Op 6	$10	27.37	0.00	105 %	$232
Unit Op 7	$149	166.76	0.00	104 %	$3812
Unit Op 8	$37	169.82	0.00	103 %	$1439
Unit Op 9	$3	178.43	0.00	100 %	$1512
Unit Op 10	-$2	25.87	0.00	99 %	$219
Unit Op 11	-$8	55.33	0.00	98 %	$339
Unit Op 12	-$299	307.20	0.00	90 %	$2603
Unit Op 13	-$49	48.69	0.00	86 %	$298
Unit Op 14	-$421	240.65	0.00	83 %	$2039

Shiftly Energy Management Summary:

>200 Plant Energy Meters Prioritized in 5 Seconds



Key Takeaways: The plant overused $1,300 in energy, driven by the System 1, and Unit Op 1 and 2. Boiler 3's efficiency needs to be investigated.

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Troubleshooting Summary Example

Dryers

- Exhausting too much air, check:
  - Dew point sensor/measurement
  - Inlet and outlet dampers/exhaust fan
  - Is it balance too negative?
- Condensate system, check:
  - Are traps failed open?
    - Use ultrasonic gun or CH2M
  - Is condensate draining to the floor?
  - Are trap bypass valves open?
- Poor product distribution on the belt, check:
  - Plow or feeder
- Dryer not running in centerline, check:
  - Temperatures
  - Moisture
    - Are we overdrying the product?
    - Is product coming into the dryer too wet?
  - Fan performance
  - Internal/External Doors

How can this tool used to manage energy real time?

- Energy losses prioritized at shiftly production meetings amongst stops and raw material waste based on dollars
- Assigned operations resource uses "energy troubleshooting" guide for that unit op
- Energy Engineer only involved if one of the common solutions does not eliminate the loss
  – Freeing his time to work on the next innovative solutions

Examples of energy losses that would go unnoticed longer without this system

- Dryer exhaust dampers stuck in one position
- Boiler O_2 sensor out of calibration
- Equipment not turned off immediately
- Compressed air leaks increased
- Condensate return system issues
- Systems not running in “automatic”
- More refrigeration compressors running than required for the load

Questions?

- Graham.Thorsteinson@genmills.com
- 770-788-5863

Energy Dashboards

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ENERGY

Energy Dashboards – Driving Operator Engagement in Energy

David Reid
Global Energy and Productivity Leader, Celanese

Celanese

The chemistry inside innovation™

Smart Manufacturing and Advanced Data Analytics

Energy Dashboards - Driving Operator Engagement in Energy

David Reid

Global Energy and Productivity Leader

Better Plants

U.S. DEPARTMENT OF ENERGY

Celanese Is A Global Technology And Specialty Materials Company

Celanese operates 32 manufacturing locations.

In 2015 net sales were $5.7 billion.

Based in Dallas, Celanese employs approximately 7,000 employees worldwide

Materials Solutions

$2.295 BILLION NET SALES

Leverages **chemistry**, **material science**, and applications based on **customer relationships** and insight to create **unique solutions** and value

- **Specialty thermoplastics** used in automotive, electronics, medical devices, and aesthetic applications
- **Cellulose derivatives** like acetate tow for filters and diacetate films
- **Food ingredients** including sweeteners and preservatives

Acetyl Chain

$3.503 BILLION NET SALES

Leverages **technology**, our **global production network**, and a deep understanding of **global trade flows** to create value

- **Acetic acid, vinyl acetate monomer**, and additional intermediate chemistries
- **Emulsion polymers** for paint, adhesives, waterproofing
- **EVA polymers** for flexible packaging, medical solutions

Smart Manufacturing - Food for Thought

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Smart Manufacturing is the ability for **everyone in the organization** to have the **actionable information** they need, **at the time they need it**, so that they can contribute to the **optimal operation** of the enterprise through informed, data-based decision making.

Ethan A. Rogers The Energy Savings Potential of Smart Manufacturing - 2014

- How many folks have an app on their phone which measures data usage, talk time and texts

Real Time Information – Simple Tool – Engages organization → ~$200/month

- How many have an app for energy at your plant or business?

High Complexity – 100s of Inputs – Changing Conditions

- Need
  - Tool that actively measures real time energy usage and targets
  - Actionable Information → Real Time
  - Engage the key people that manage energy

Everyone + Actionable information + Real Time → Optimal Operation

Who Needs to Know?

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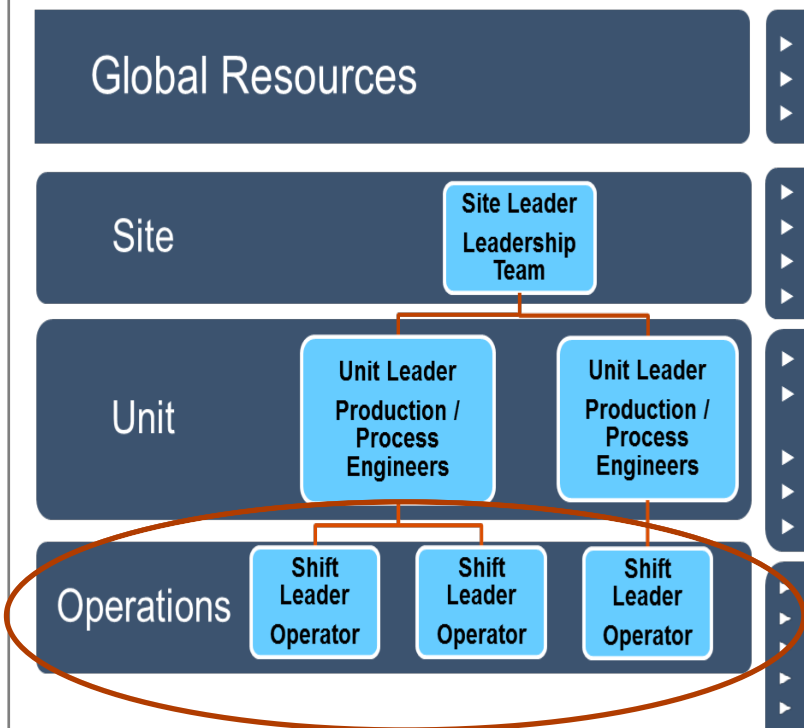
Organizational levels



Responsibilities

- Define and communicate Corporate goals
- Set Corporate guidelines
- Allocate global resources

- Set priorities and allocate resources
- Oversee energy pricing
- Alternative energy sources
- Provide dashboard and project tracking tools

- Complete understanding of energy flow
- Data analysis, statistical modelling and Six Sigma process optimization
- Step change process improvements
- Heat integration opportunities
- Provide training for operators

- Awareness of energy consumption and cost
- Understanding of dynamic targets and optimum
- Recognition and reporting of deviations
- Adjustment to performance gaps
- Development of best practices for real-time optimization
- Development of further project ideas

Under Utilized Resource for Energy Optimization

- **WHERE** are my energy consumers?
- **HOW MUCH** energy do they consume (and what is the cost)?
- **WHAT** is the optimum at any operating condition?
- **WHY** do they consume what they consume?
- **WHEN** do we have a gap in performance? … and correct it
- **WHAT** can we do to reduce consumption? …and do it!

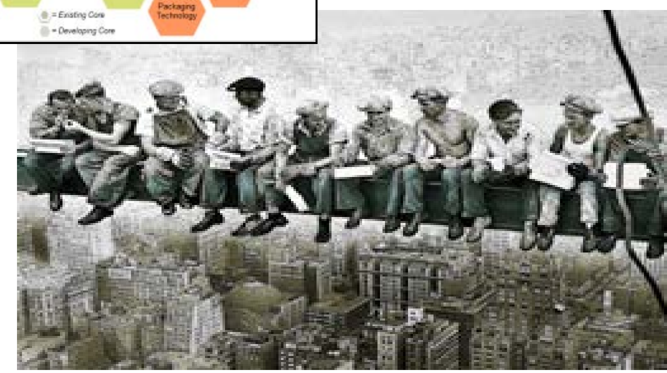
Engage Everyone in the Organization

What are the Priorities of an Operator on Shift?

- ▶ Safety
  - – Occupational and Process Safety
  - – Environmental Spills and Release
- ▶ Production
  - – Rates, Volume targets
- ▶ Quality
  - – Product Specifications
- ▶ Stable Operations
  - – Quiet Shift

⋮

- ▶ Energy Optimization
  - – Operators know the importance of energy efficiency, but …
    - – Lower priority than other things
    - – Did not have the tools to understand detailed energy performance

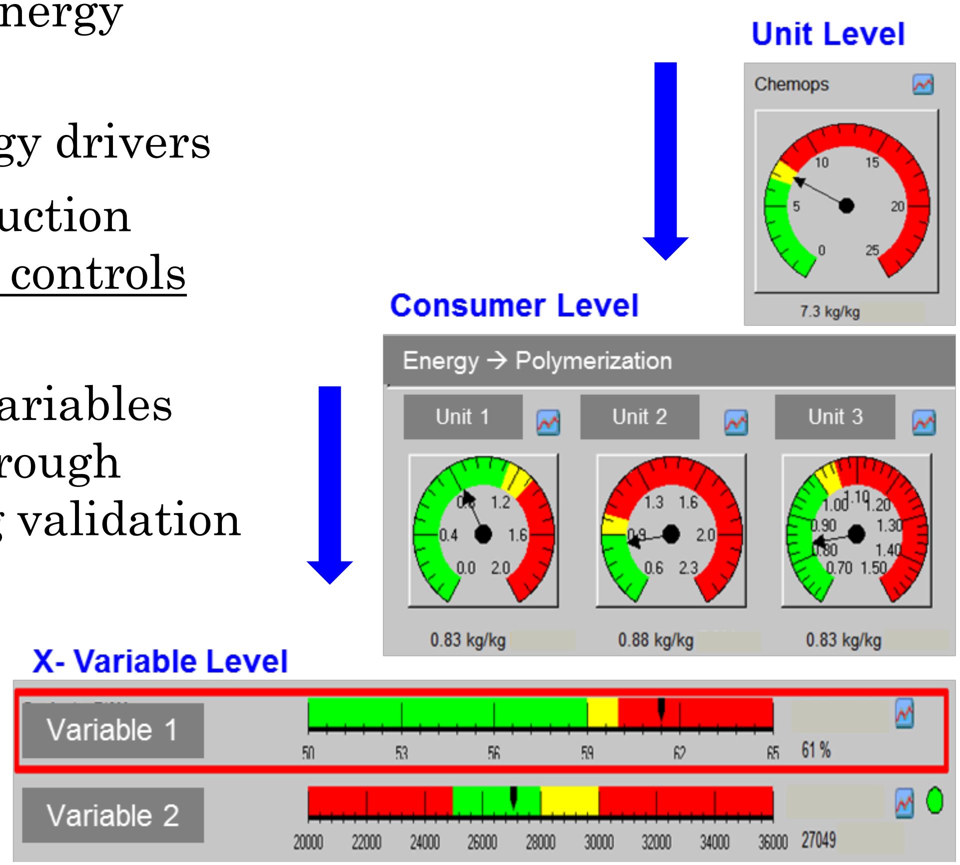


Increase the Focus on Energy without Sacrificing Other Priorities

What is an Energy Dashboard?

Effective tool for engaging operators in energy consumption and cost

- Continuous display of <u>real time</u> energy consumption / cost indicators
- <u>Drill down</u> capability to key energy drivers
- Integrated with quality and production metrics <u>incorporated in the plant controls</u> systems
- <u>Dynamic</u> energy limits and key variables affecting energy are identified through statistical modeling / engineering validation



What is measured improves.
P. Drucker

Actionable Information – Real Time

How Do We Determine the Limits?

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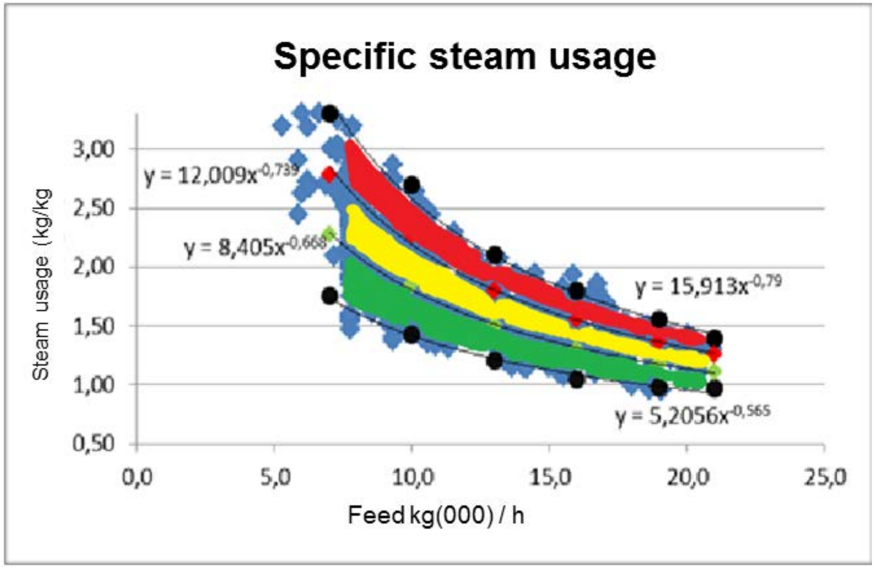
- Limits for factors change with rate, load, other factors… (Dynamic)

  This is a major improvement over standard dashboards

- Six Sigma Statistical analysis
  - Identify the process variables with significant correlation to energy
  - Develop a multiple regression energy curve – target >80% of variablity
  - Establish R/Y/G limits over a range of conditions

- The “right” limits important for accuracy AND credibility



Lower limit		Upper warning	Upper limit
Violates process boundaries	Within process boundaries and energy efficient	Within process boundaries but with bad energy efficiency	Violates process boundaries and has a bad energy efficiency

Regression Analysis: Steam vs. Production Rate, Reflux, etc.

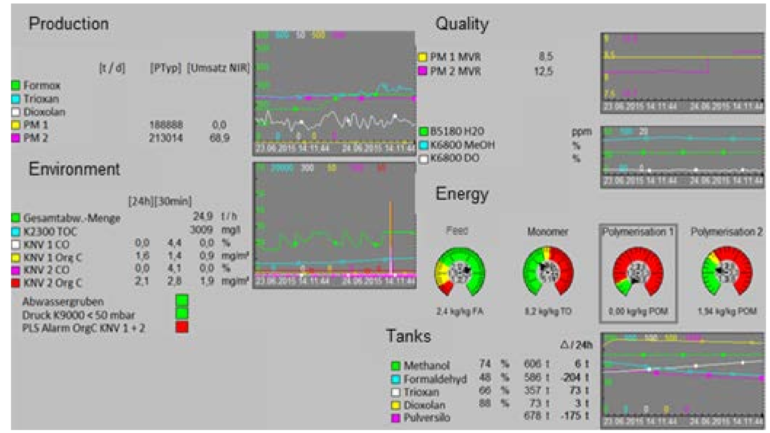
```
The regression equation is
steam = 1800 + 4292 production rate + 0,008 reflux
[kg/h] + 1,82 T bd 53 + 8,60 1/T(2480) + 5,07 c(RM1)
2480 [%]  - 334 R

S = 0,00395544   R-Qd = 97,0%   R-Qd(kor) = 95,8%
```

Advanced Data Analysis - Dynamic ranges based on statistics

Yet another senseless tool ?

BEFORE:

- Operators know the importance of energy efficiency, but had no way of knowing performance
- Opportunities to correct problems and increase efficiency are "missed"



NOW:

- Operators can see "Real Time" if the energy consumption is at the dynamic optimum – "In the Green"
- Operators can drill down into the process to see the drivers of any deviations
- Operators can diagnose and correct problems and initiate actions to move toward the optimum

Actionable Information → Optimal Operation

What Does it Take?

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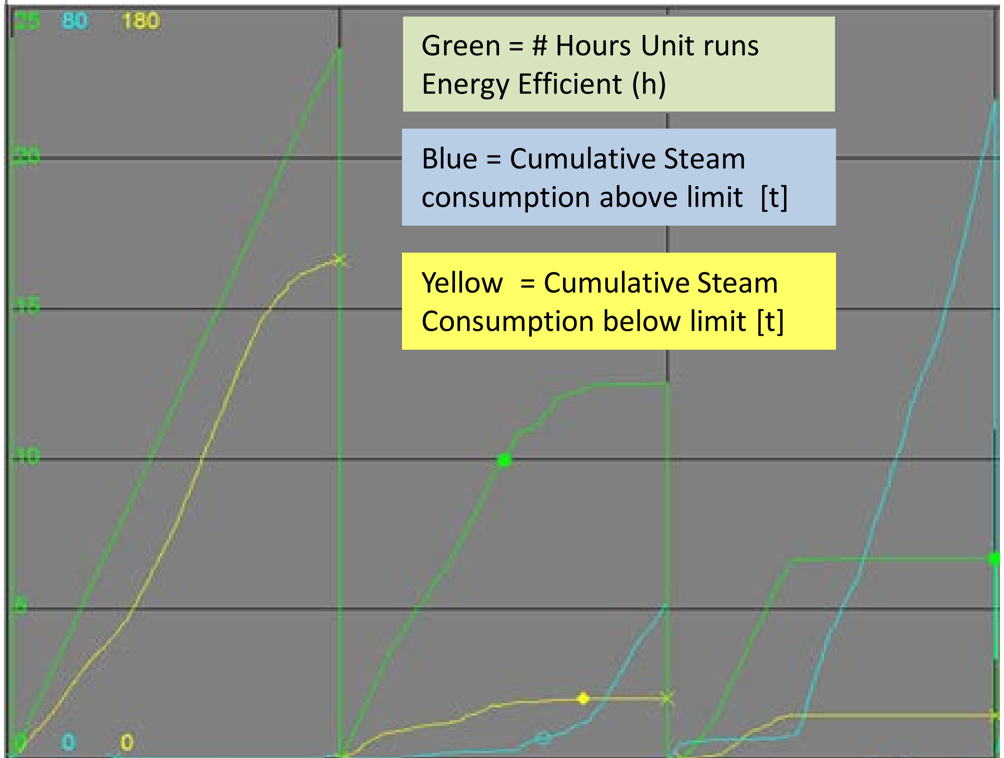
Phase	*Deliverables*	*Site Resources*
Evaluate	• Process Mapping of Key Consumers & Producers • Statistical Modeling of Energy Intensity • Process Expert Validation of Models • Engage Supervisors and Engineers • Site Energy Team Developed	Unit Engineer Site Green / Black Belt Subject Matter Experts Operators
Implement	• Create and Implement Dashboards • Develop Exception Report • Create Shift and Management Reporting Formats • Train and Documentation	Unit / Control Engineers Operators Unit Supervisors
Sustain	• Daily Report out • Best practice – Corrective Action • Regular Project Meetings to Drive completion • Incorporate Energy into Leadership Updates • Sustainability Checklist	Operators Unit Supervisors Site Energy Team

Everyone in the Organization

How Do We Sustain the Dashboard Process?



- When energy deviations occur operators diagnose the problem and document an exception report
- Shift operators report the performance from the last shift / day at shift handoff
- Energy dashboard is part of the daily morning meeting cadence
- Best Practice Root cause → Action determined and shared
- New Projects developed
  - Often NO/Low Capital

Date	KPI Exception	Type	Gap	Action	PPR	Review	Comments
6/10/2015	T101	Energy	T101 extraction tower exceeding optimum energy usage by 5% based on feed rate.	Lowered reflux FIC-101 by 3%	JR	DR	Action only partially effective. Improvement would be to adjust bottom temperature also by 1 Deg C
6/12/2015	HE302	Energy	Heat transfer rate below target when rate reduced	Optimized cooling tower pump configuration	AB	JC	Action Effective - Best Practice. Capture and communicate to all shifts
6/12/2015	Startup	Energy	Exceeded optimum range during startup of spare cooling tower	Improve startup procedure to reduce cutover time	DA	JC	Assign to Team A and process control engineer

Cadence → Sustainability

Benefits

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- Single Site Savings:
  - Real Time Action to Optimal Operation
    - $300K annual savings
    - Visibility to real-time energy consumption using dashboard
  - Identified Energy Project Opportunities
    - Over $1.5 MM
    - Most with No/Low Capital
- Best Practice Sharing
  - 8 Other sites in various stages of development
  - Using same model for performance
- A long-term effort; not once-and-done
  - Model updates when the plant changes

There is no good idea that can't be improved on
Michael Eisner

Intent Clarification

- THE DASHBOARD IS INTENDED TO:
  - Bring **focus** on energy efficiency to the unit and operator level. Safety, productivity and quality remain the TOP Priority
  - By regular use, along with exception reports, drive **incremental continuous improvement** in energy efficiency
  - With help from the Energy Management Team, **find opportunities** to improve energy efficiency by finding optimization project opportunities
  - **Help operators and supervisors** understand the balance between energy, safety, productivity and quality

- THE DASHBOARD IS **NOT** INTENDED TO:
  - Make energy a priority over quality, productivity and process safety
  - Promote constant "tweaking" of the process
  - Set expectations that operators solve all the energy problems on shift or react to all "Red" conditions.

Energy Dashboards - Takeaway

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Smart Manufacturing is the ability for **everyone in the organization** to have the **actionable information** they need, at the **time they need it**, so that they can contribute to the **optimal operation** of the enterprise through informed, data-based decision making.

Ethan A. Rogers The Energy Savings Potential of Smart Manufacturing - 2014

- Understanding and Engagement at all levels is critical to energy success
- Operators are an underutilized resource for energy management
- Dashboards provide a tool for measuring real-time energy use, dynamic gap analysis and action from operators
- Energy targets are dynamic and developed from statistical regressions of actual plant data
- Daily cadence from operations keeps them engaged and keeps it sustainable
- Other improvement projects identified – Many No Low Capital
- Dashboards are not intended to make energy a priority over quality, productivity and process safety

Everyone + Actionable information + Real Time → Optimal Operation



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The chemistry inside innovation™

Questions

Contact Information:

David Reid

Global Energy and Productivity Leader

david.reid@celanese.com


Building Automation Systems

U.S. DEPARTMENT OF ENERGY

LEED for Existing Factories: ThyssenKrupp Elevator LEED Gold Certification

Monica Miller
Sustainable Design Manager, ThyssenKrupp

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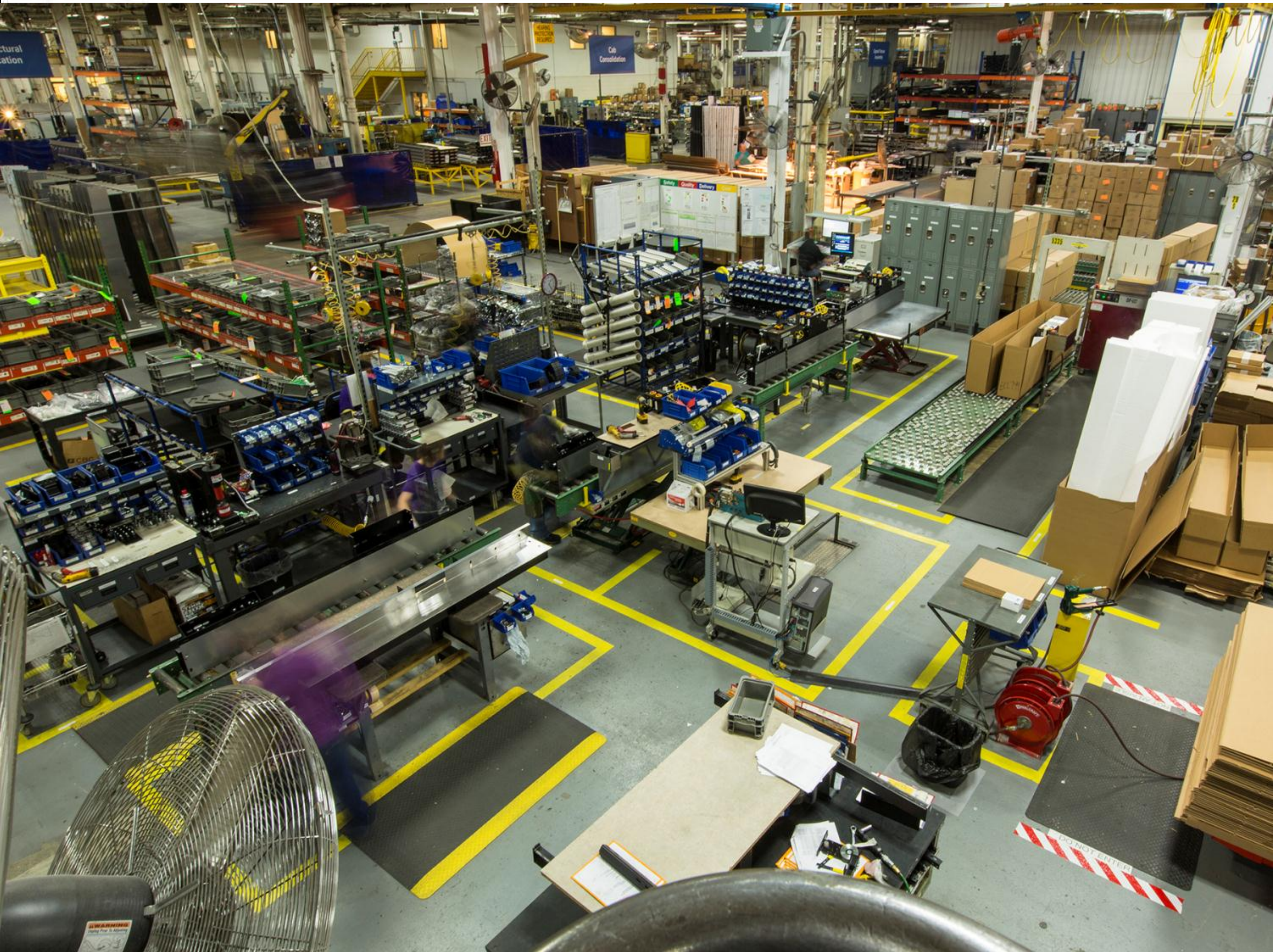
Aluminum Scrap


DANGER
TO REDUCE THE POSSIBILITY OF INJURY
DO NOT PLACE YOUR HANDS IN THE DIE AREA
1 1/16 Wrench
SAFETY GUIDELINES
HYDRAULIC PRESS BRAKE
SET UP
OPERATION
2232
1 1/16 Wrench
DANGER
Allen Wrench
EMERGENCY STOP
OPERATOR STATION
RAM UP
OFF
ON
PRESENCE SENSING GUARD
Square


QUICK-GRIP
IRWIN


OLE MISS



Cab Consolidation
Safety
Quality
Delivery
DO NOT ENTER
WARNING

DANGER
HIGH VOLTAGE
DANGER
HIGH VOLTAGE
DANGER
HIGH VOLTAGE
Wire Harness Assembly/Test
21T2
Bishamon


21Y2


REMSTAR Shuttle
43V1
43V4

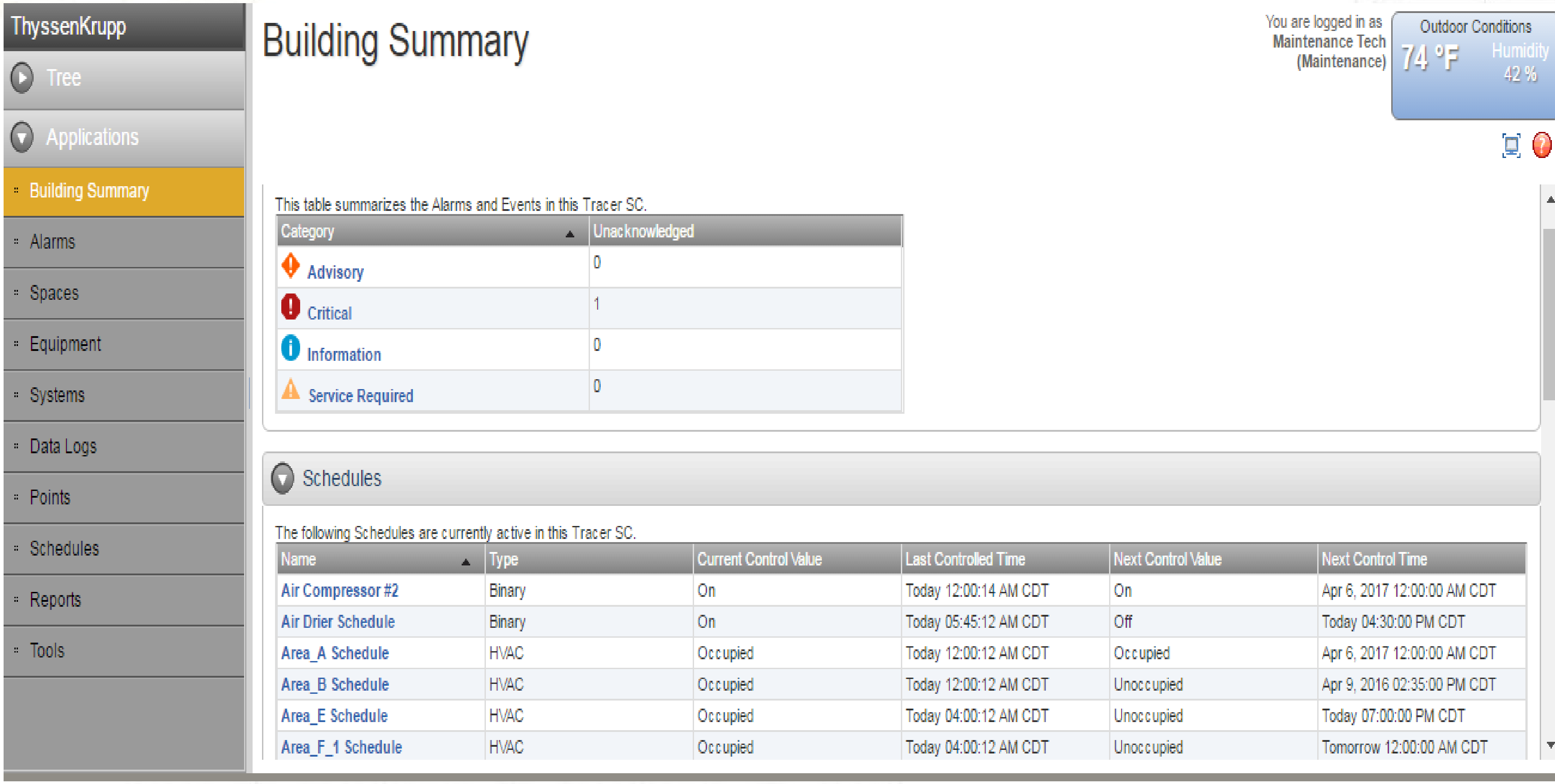

Nordson
Nordson
Nordson
Nordson
SPECTRUM II

Energy and Atmosphere – Energy Performance

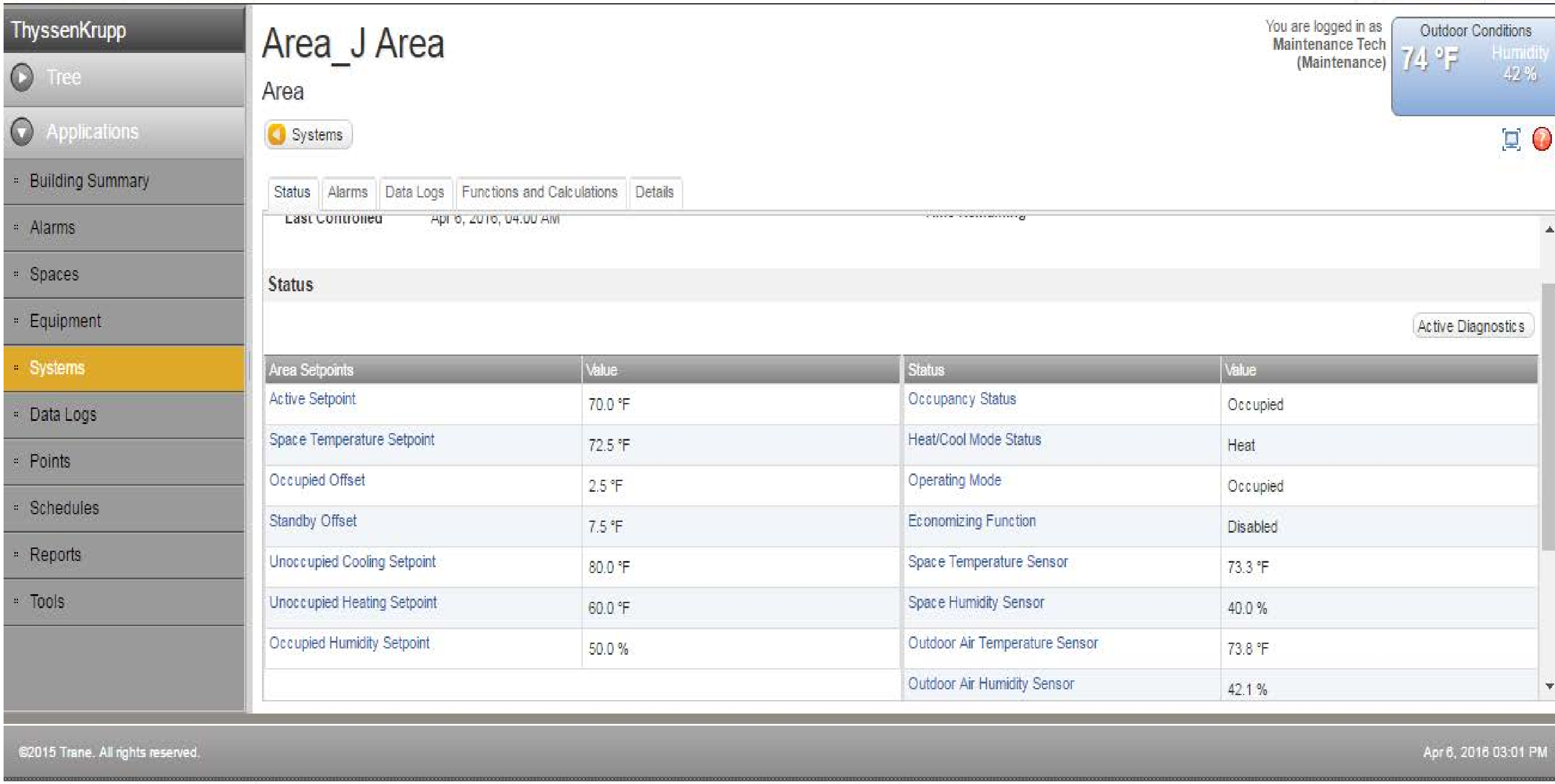
ENERGY AND ATMOSPHERE

New Building Management Systems allows us to remotely control the temperature and pressure in the plant at all times

Energy and Atmosphere – Energy Performance



Energy and Atmosphere – Energy Performance



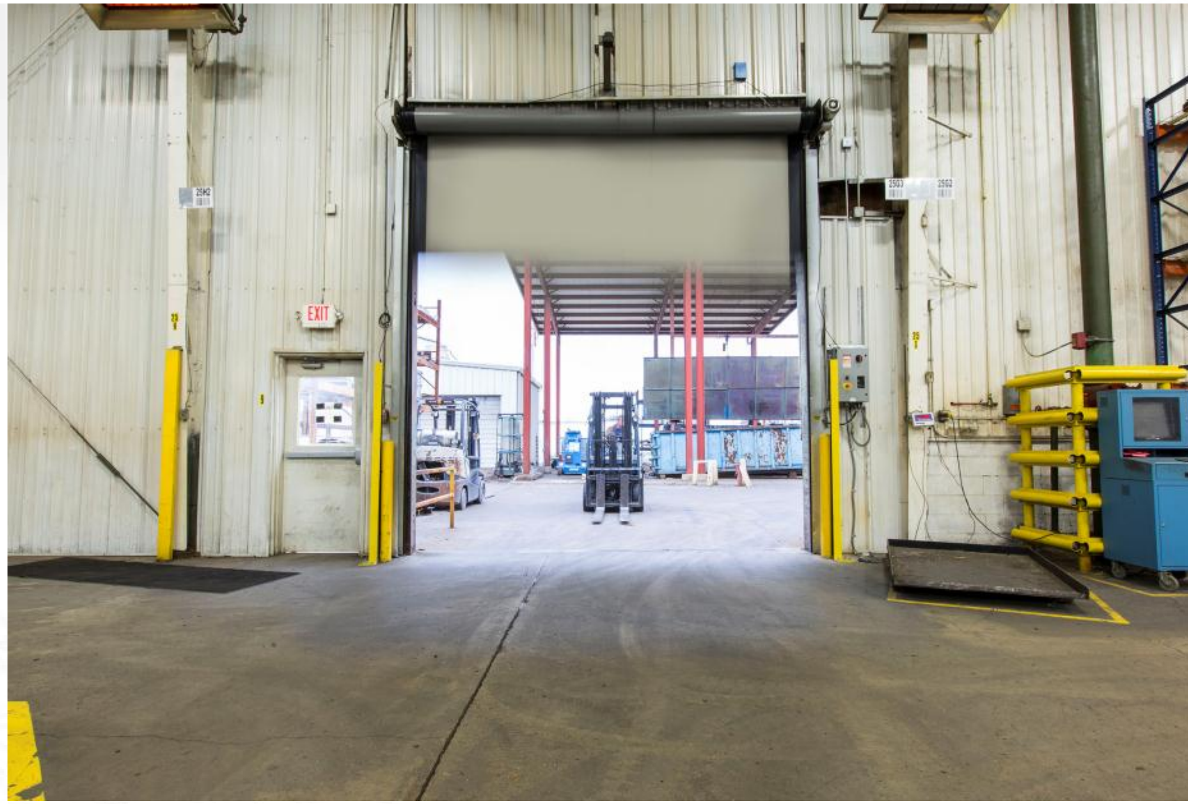
Area Setpoints	Value	Status	Value
Active Setpoint	70.0 °F	Occupancy Status	Occupied
Space Temperature Setpoint	72.5 °F	Heat/Cool Mode Status	Heat
Occupied Offset	2.5 °F	Operating Mode	Occupied
Standby Offset	7.5 °F	Economizing Function	Disabled
Unoccupied Cooling Setpoint	80.0 °F	Space Temperature Sensor	73.3 °F
Unoccupied Heating Setpoint	60.0 °F	Space Humidity Sensor	40.0 %
Occupied Humidity Setpoint	50.0 %	Outdoor Air Temperature Sensor	73.8 °F
		Outdoor Air Humidity Sensor	42.1 %

Energy and Atmosphere – Energy Performance


44C3
44C2


PAC-12
TRANE
IMPORTANT

Indoor Environmental Quality




25H2
EXIT
25G3
25G2
DYNACO


25H2
EXIT
25G3
25G2


25H2
EXIT
25G3
25G2


25H2
EXIT
25G3
25G2


25H2
EXIT
25G3
25G2


25H2
EXIT
25G3
25G2


25H2
EXIT
25G3
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1969 YEAR OUR FACTORY WAS BUILT
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65%
200 LEED GREEN ASSOCIATES
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ThyssenKrupp Elevator
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Materials & Resources	9 / 10
Indoor Environmental Quality	10 / 15
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Regional Priority Credits	4 / 4

* *Out of a possible 110 points*

Certified: 40+ points
Silver: 50+ points
Gold: 60+ points
Platinum: 80+ points

Thank you!

Q&A

U.S. DEPARTMENT OF ENERGY