Data of the Future: Digital Cities

Thursday, July 11th, 2019

2:00 – 3:30 PM

Speakers

Harry Bergmann
Moderator
DOE

Bill Copeland
Speaker
Electric Power Board of Chattanooga, TN

Matthew Vogel
Speaker
Microsoft

Bill Copeland

Electric Power Board of Chattanooga, Tennessee

U.S. DEPARTMENT OF ENERGY

Data of the Future: Digital Cities

Digital Twin of a City Utility

Issues, science, implementation, and results

Presented at:

Better Buildings Summit

Arlington, VA

Presented by:

Bill Copeland
Electric Power Board of Chattanooga, TN

Joshua New, Ph.D., C.E.M., PMP, CMVP, CSM
Building Technologies Research & Integration Center
Subprogram Manager, Software Tools & Models
Oak Ridge National Laboratory

July 11, 2019

ORNL is managed by UT-Battelle
for the US Department of Energy

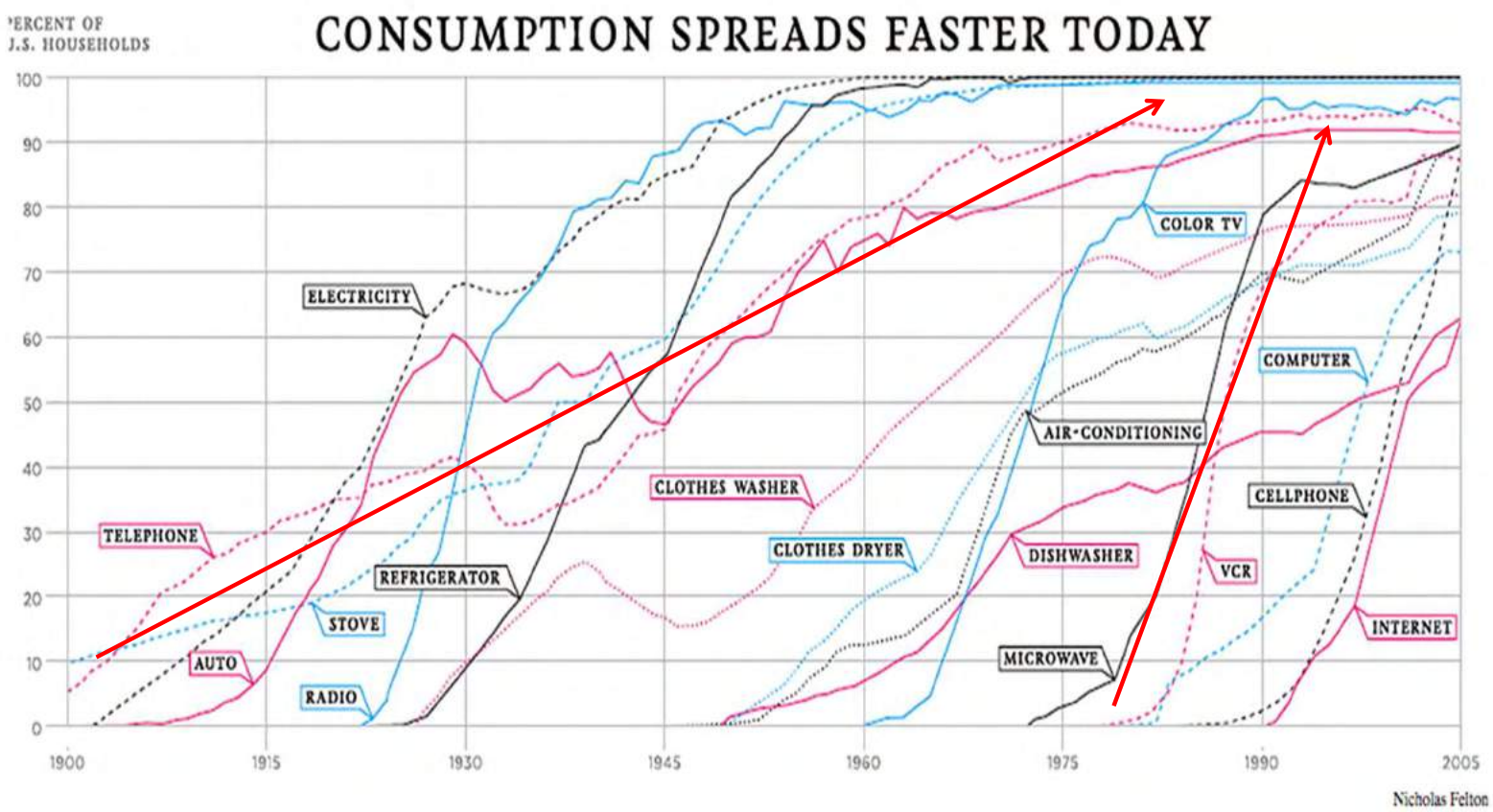
OAK RIDGE National Laboratory | BUILDING TECHNOLOGIES RESEARCH AND INTEGRATION CENTER

Strategic Research

A 21st Century Crossroads

Strategic Research

Technology Adoption Rates Accelerate



Strategic Research

Wireless Broadband IoT Age Is Upon Us

Papal Conclave 2005

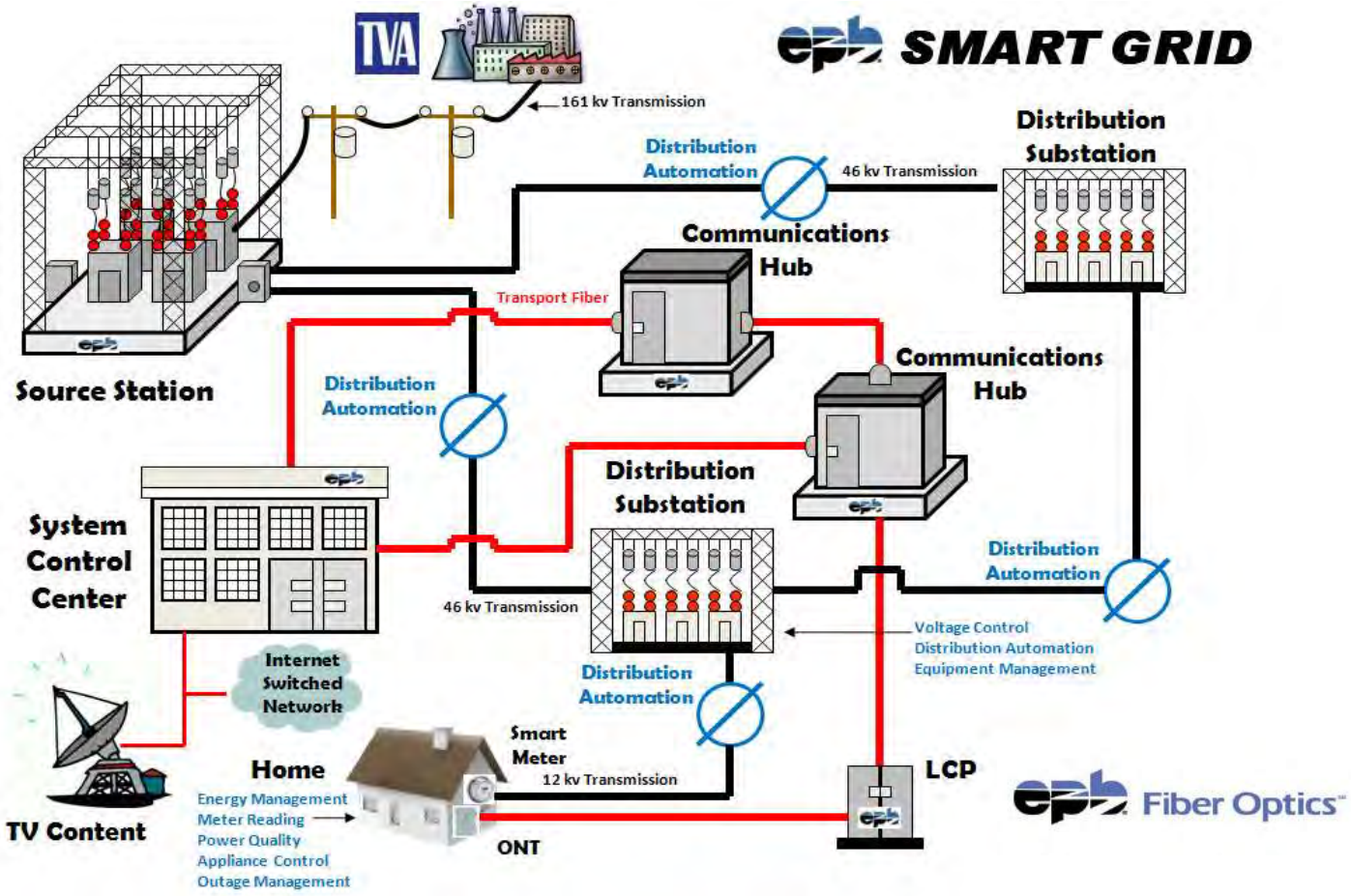
Strategic Research

Gigabit Speed Wireless Broadband
Coming Soon in 2018-2019

Papal Conclave 2013

Strategic Research

ENERGY and INTERNET NETWORKS



A New Generation of Smart Energy Appliances

2011

$250
Artificial Intelligence

2015

$5000
5KWh

Strategic Research

AUTOBEM Integrated With EPB Appliance Models

TESLA

POWERWALL

CERTIFIED INSTALLER

amazon echo

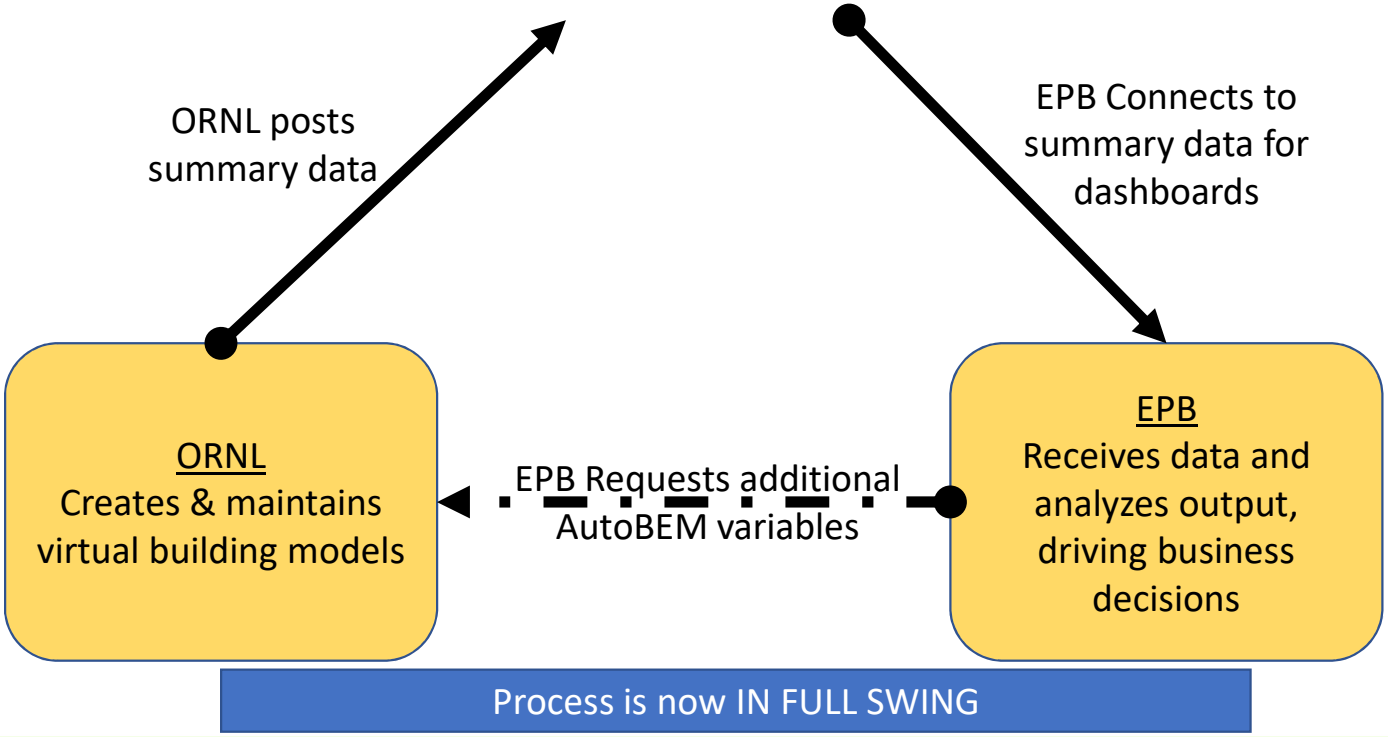
Where do Americans turn for answers we can trust?

Virtual EPB (provided by ORNL) shows the value of technology with interactive dynamic results

60246

ID	60246
DOE Building Type	SmallOffice
Num Floors	3
Percentile	87.70 %
Estimated wholesale vs retail cost	$ 9797.07
CO2 emissions	222052.32 lbs/year
Smart Thermostat - 4F cost savings	$ 1316.61
Smart Thermostat - 8F cost savings	$ 2325.84
TMY->AMY Smart Thermostat - 4F cost savings	$ 204.99
TMY->AMY Smart Thermostat - 8F cost savings	$ 103.41
HVAC Efficiency ECM	$ 1291.79
Gas HVAC ECM	$ 4276.69
Gas Water Heater ECM	$ 725.58
Heat Pump Water Heater ECM	$ 476.95
Insulation ECM	$ 736.27
Infiltration ECM	$ 1577.50
Lighting ECM	$ 2898.95

ORNL/EPB Data Coordination



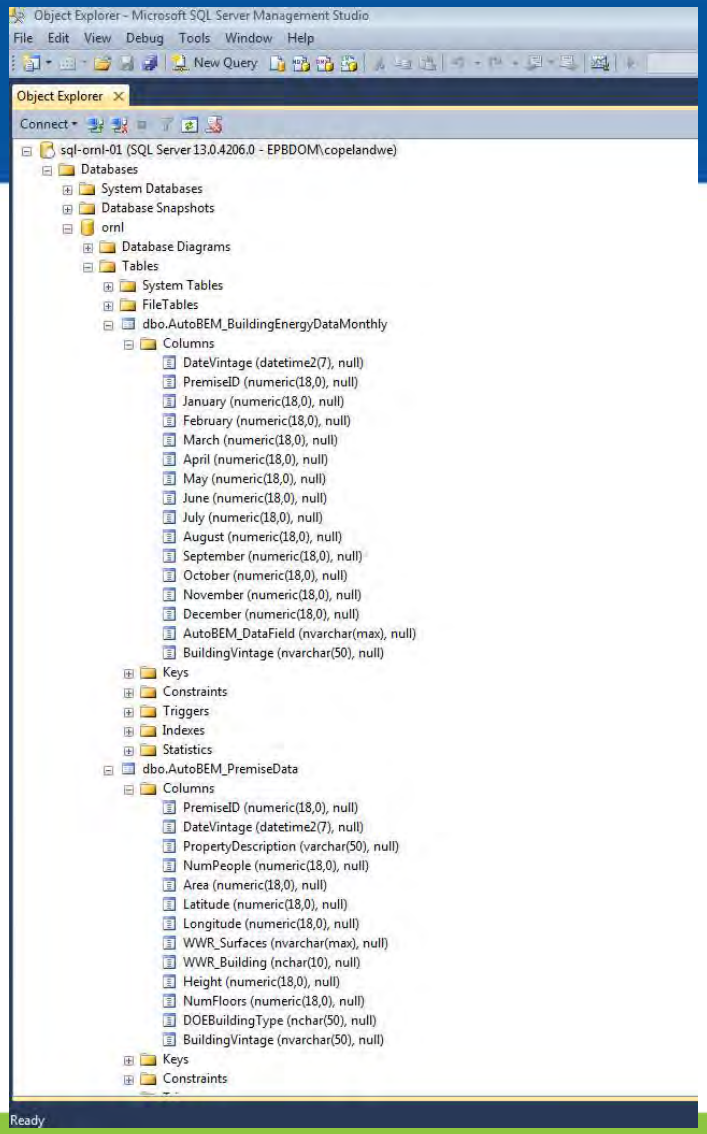
Process is now IN FULL SWING

Database status (old):

TableName: AutoBEM_PremiseData	
FieldName	***DataType***
PremiseID	Number
DateVintage	Date
Description	String
NumPeople	Number
Area	Number
Latitude	Number
Longitude	Number
WWR_Surfaces	String
WWR_Building	Number
Height	Number
NumFloors	Number
DOEBuildingType	String

TableName: AutoBEM_BuildingEnergyData	
FieldName	***DataType***
DateVintage	Date
PremiseID	Number
AutoBEMDataField	String
JanuaryDataValue	Number
FebruaryDataValue	Number
MarchDataValue	Number
AprilDataValue	Number
MayDataValue	Number
JuneDataValue	Number
JulyDataValue	Number
AugustDataValue	Number
SeptemberDataValue	Number
OctoberDataValue	Number
NovemberDataValue	Number
DecemberDataValue	Number

Need hourly granularity table, as well as vintage/scenario sensitivity



Database status (new):

AutoBEM Monthly Data joined with EPB System Data

Monthly AutoBEM Data

- **Premise Number**
- **Improvement Type**
- **Total Cost Savings ($)**
- **Monthly Costs Savings ($)**
- **Monthly Demand Svgs (KW)**

***~2.1M records for a theoretical year, all premises**

Join on Premise Number

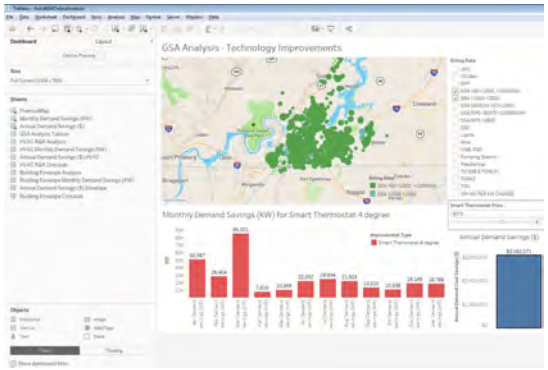
EPB System Attribute Data

- **Premise Number**
- **Service Address**
- **Latitude/Longitude**
- **XFMR information (bank, structure, etc.)**
- **Circuit, Substation, Feeder, etc.**

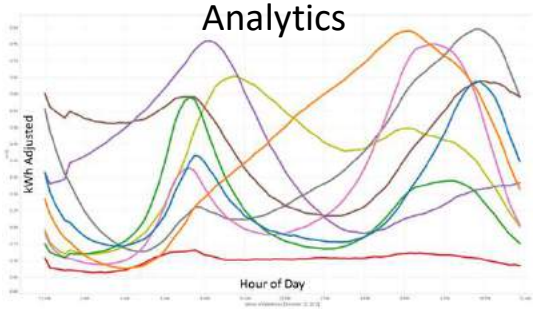
Data feeds to other EPB Systems

Distribution System Capacity Planning

Data Visualization Tools



Customer Clustering & Demand Side Management Analytics



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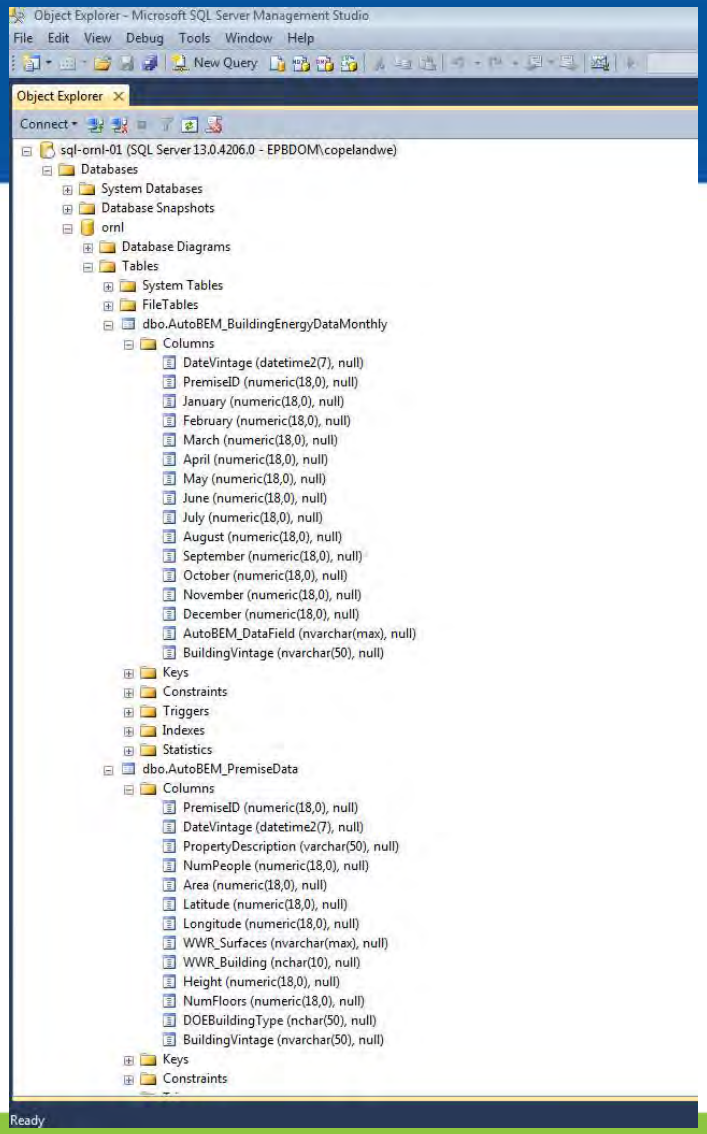
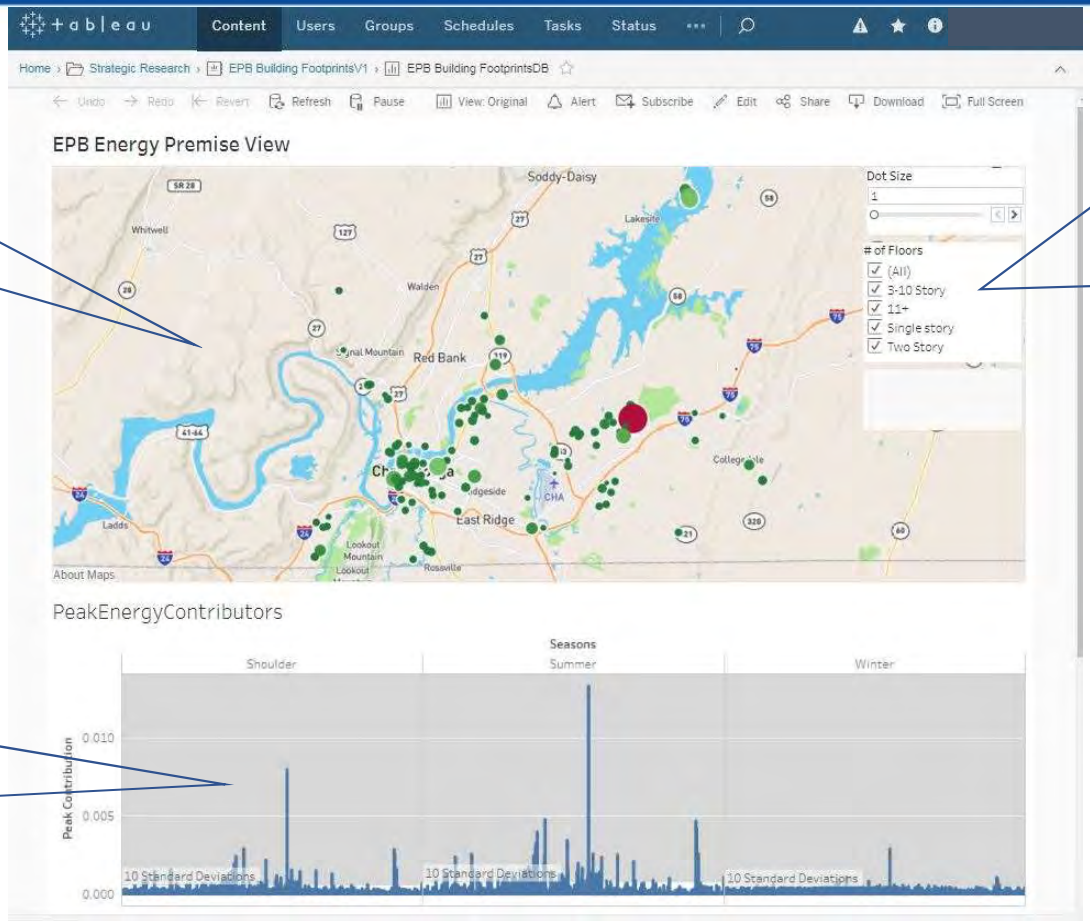


EPB's operational systems (original Dashboard)

Map showing premises, colored by AutoBEM attribute



Use of filters create an interactive experience for business users, driving business decisions

Chart showing same data, in time series format

EPB's operational systems (New Dashboards)
Smart Thermostat Value

Map showing premises, sized by Demand Value

Use of filters create an interactive experience for business users, driving business decisions

Chart showing monthly demand value

EPB's operational systems (New Dashboards)
HVAC Efficiency improvements

Map showing premises, sized by Demand Value

Use of filters create an interactive experience for business users, driving business decisions

Chart showing monthly demand value

EPB's operational systems (New Dashboards)
Structural Building Improvements

Map showing premises, sized by Demand Value

Use of filters create an interactive experience for business users, driving business decisions

Chart showing monthly demand value

EPB's operational systems
And of course downloadable crosstabs

GSA Analysis Tabluar for Smart Water Heater & Smart Thermostat 4 degree

Billing Rate	Building Id	Mail Addr Name	Service Address	Annual Demand Cost Savings ($)	SmartThermostat net cost
GSA >50 <1000, >15000KH	3195400000	ULTA	271 NORTHGATE MALL DR	$34,273	33,523
	2659310000	BLUE CROSS BLUE SHIELD...	1 CAMERON HILL CIR	$17,201	16,451
	1878960000	COVENANT TRANSPORT	400 BIRMINGHAM HWY	$14,271	12,771
	320240000	DIAGNOSTIC CENTER	2205 MCCALLIE AVE	$12,262	11,512
	1969670000	HOSPITAL CORPORATION ...	2205 MCCALLIE AVE	$12,262	11,512
	137290000	ADM MILLING COMPANY	1120 KING ST	$12,086	11,336
	137300000	CHATTANOOGA NEWS FR...	400 E 11TH ST	$12,086	11,336
	1739720000	TOP FLIGHT INC	1300 CENTRAL AVE	$9,328	7,828
	338530000	DOC-725 GLENWOOD DRI...	721 GLENWOOD DR	$9,263	8,513
	2609220000	UNIVERSITY OF TENNESS...	818 UNIVERSITY ST	$9,205	8,455
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	3003970000	AMAZON.COM SERVICES I...	7200 VOLKSWAGEN DR	$9,118	
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	643650000	TALLAN PROPERTIES CO	100 W MARTIN LUTHER KI...	$8,907	
	50000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	
	60000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	
	260000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	
	620000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	
	1210000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	
	1480000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	
	3600000	TUESDAY MORNING INC	5600 BRAINERD RD	$8,298	
	3740000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	
	3790000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	
	3970000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	
	402390000	EAST NOOGA, LLC	5600 BRAINERD RD	$8,298	

All dashboards are fully interactive for internal departments at EPB – all Tableau users are able to login to the web system and develop their own dashboards if the defaults do not answer their questions

HVAC R&R Crosstab

Building Id	Mail Addr Name	Service Address	Billing Rate	Annual Demand Cost Savin...	SmartThermostat net cost
3195400000	ULTA	271 NORTHGATE MALL DR	GSA >50 <1000, >15000KH	$78,933	77,433
525460000	PARKRIDGE HOSPITAL	2333 MCCALLIE AVE	GSA >1000 <2500	$48,567	47,067
1878960000	COVENANT TRANSPORT	400 BIRMINGHAM HWY	GSA >50 <1000, >15000KH	$29,150	26,150
592780000	U S POST OFFICE	5050 SHALLOWFORD RD	GSA >1000 <2500	$20,417	18,917
338530000	DOC-725 GLENWOOD DRI...	721 GLENWOOD DR	GSA >50 <1000, >15000KH	$18,658	17,158
643650000	TALLAN PROPERTIES CO	100 W MARTIN LUTHER KI...	GSA >50 <1000, >15000KH	$18,508	17,008
794870000	STATE OF TENN	100 MOCCASIN BEND RD	GSA >1000 <2500	$16,150	14,650
1267210000	UNIV OF TN AT CHATT	540 MCCALLIE AVE	GSA >50 <1000, >15000KH	$15,440	13,940
1173520000	STEWARD ADVANCED MA...	1220 E 38TH ST	GSA >50 <1000, >15000KH	$15,384	13,884
2718230000	CHATTANOOGA HOTEL PR...	2321 LIFESTYLE WAY	GSA >50 <1000, >15000KH	$14,881	13,381
1626980000	TENNESSEE AQUARIUM	1 BROAD ST	GSA >50 <1000, >15000KH	$14,645	13,145
1969820000	U S XPRESS ENTERPRISE	4080 JENKINS RD	GSA >50 <1000, >15000KH	$14,057	12,557
40000	EAST NOOGA, LLC	5600 BRAINERD RD	GSA >50 <1000, >15000KH	$13,663	12,163
3800000	EAST NOOGA, LLC	5600 BRAINERD RD	GSA >50 <1000, >15000KH	$13,663	12,163
3810000	CHEROKEE HEALTH SYST...	5600 BRAINERD RD	GSA >50 <1000, >15000KH	$13,663	12,163
2460690000	KOCH FOODS LLC	1835 KERR ST	GSA >50 <1000, >15000KH	$11,644	10,144
643570000	A & D HOLDINGS GP	401 CHESTNUT ST	GSA >50 <1000, >15000KH	$11,599	10,099
2609660000	PUBLIX TENNESSEE LLC	5958 SNOW HILL RD	GSA >50 <1000, >15000KH	$11,474	9,974
1947100000	METALWORKING SOLUTI...	370 LABELING WAY	GSA >50 <1000, >15000KH	$10,642	9,342
2494720000	POWERTEL/MEMPHIS INC	6730 CUSTOMER DELIGH...	GSA >50 <1000, >15000KH	$10,733	9,233
592840000	STANDIFER PLACE LLC	2626 WALKER RD	GSA >50 <1000, >15000KH	$10,699	9,199
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1604830000	LIFETOUCH NATIONAL	6104 PRESERVATION DR	GSA >50 <1000, >15000KH	$9,233	7,733
2540990000	MILLER IND TOWING EQU...	8503 HILLTOP DR	GSA >1000 <2500	$9,119	7,619
854610000	CHATTANOOGA BAKERY I...	900 MANUFACTURERS RD	GSA >50 <1000, >15000KH	$9,070	6,070
1911010000	PUBLIX TENNESSEE LLC	8544 E BRAINERD RD	GSA >50 <1000, >15000KH	$8,711	7,211
1594890000	WAL-MART STORES EAST...	2020 GUNBARREL RD	GSA >50 <1000, >15000KH	$8,226	6,726
1054560000	SILVER TREE SENIOR APT...	5465 HIGHWAY 58	GSA >50 <1000, >15000KH	$8,142	6,642
1520850000	FOOD LION, LLC	4338 RINGGOLD RD	GSA >50 <1000, >15000KH	$7,617	6,117
2623260000	JERNIGAN ROAD HILL LLC	2054 HAMILTON PLACE B	GSA >50 <1000, >15000KH	$7,405	5,905

Building Envelope Crosstab

Building Id	Mail Addr Name	Service Address	Billing Rate		
3195400000	ULTA	271 NORTHGATE MALL DR	GSA >50 <1000, >150		
3003970000	AMAZON.COM SERVICES I...	7200 VOLKSWAGEN DR	GSA >50 <1000, >150		
3003980000	AMAZON.COM SERVICES I...	7200 VOLKSWAGEN DR	GSA >50 <1000, >150		
2659340000	BLUE CROSS BLUE SHIELD...	1 CAMERON HILL CIR	GSA >1000 <2500		
2659300000	BLUE CROSS BLUE SHIELD...	1 CAMERON HILL CIR	GSA >1000 <2500		
2659330000	BLUE CROSS BLUE SHIELD...	1 CAMERON HILL CIR	GSA >1000 <2500		
2659350000	BLUE CROSS BLUE SHIELD...	1 CAMERON HILL CIR	GSA >1000 <2500		
2659310000	BLUE CROSS BLUE SHIELD...	1 CAMERON HILL CIR	GSA >50 <1000, >150		
2659280000	BLUE CROSS BLUE SHIELD...	1 CAMERON HILL CIR	GSA >1000 <2500		
2659320000	BLUE CROSS BLUE SHIELD...	1 CAMERON HILL CIR	GSA >1000 <2500		
525460000	PARKRIDGE HOSPITAL	2333 MCCALLIE AVE	GSA >1000 <2500	$3,257	2,132
137290000	ADM MILLING COMPANY	1120 KING ST	GSA >50 <1000, >15000KH	$2,714	1,589

The devil is in the data details (as usual)
Golden Opportunity for M&V activities

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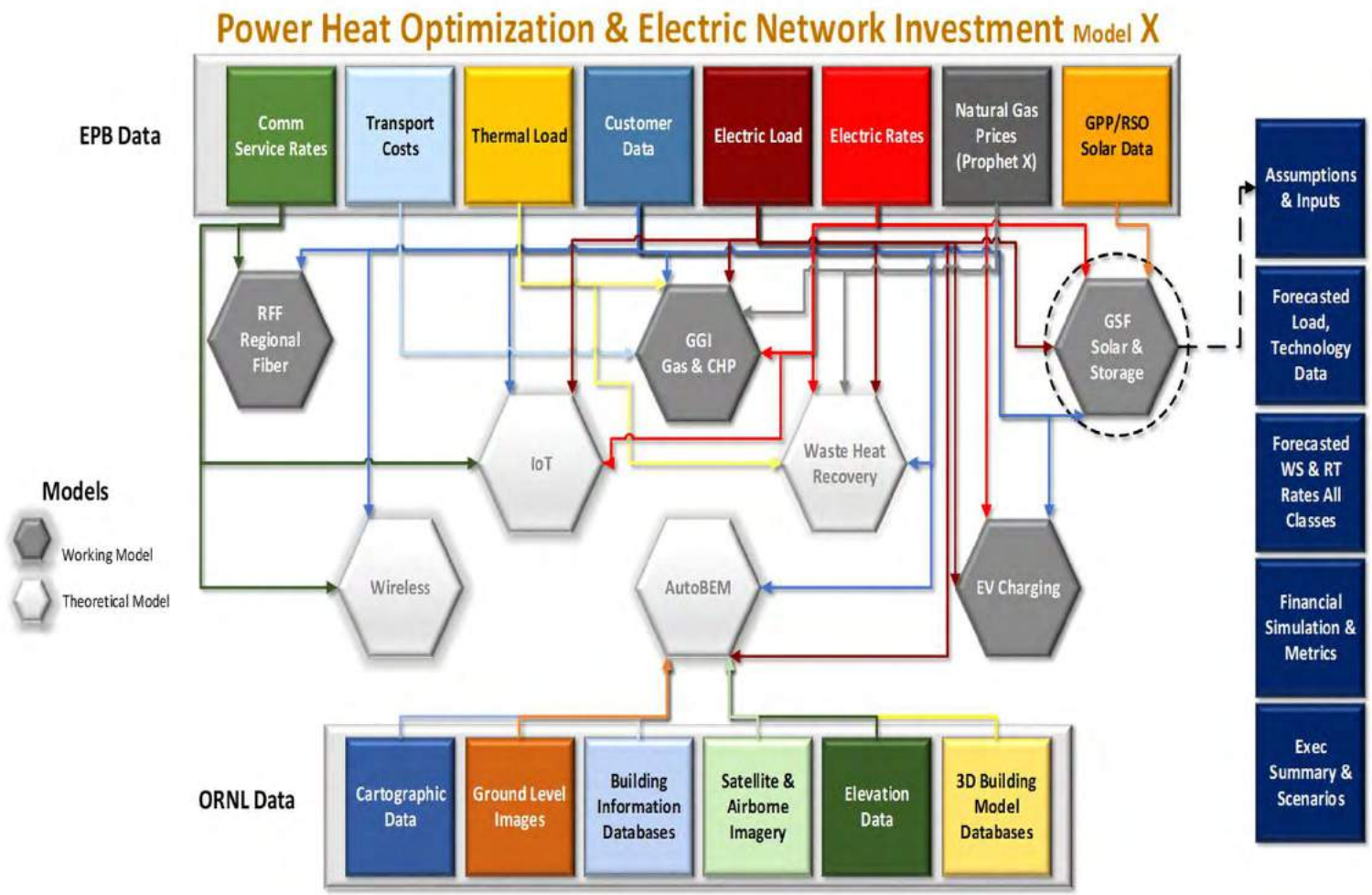
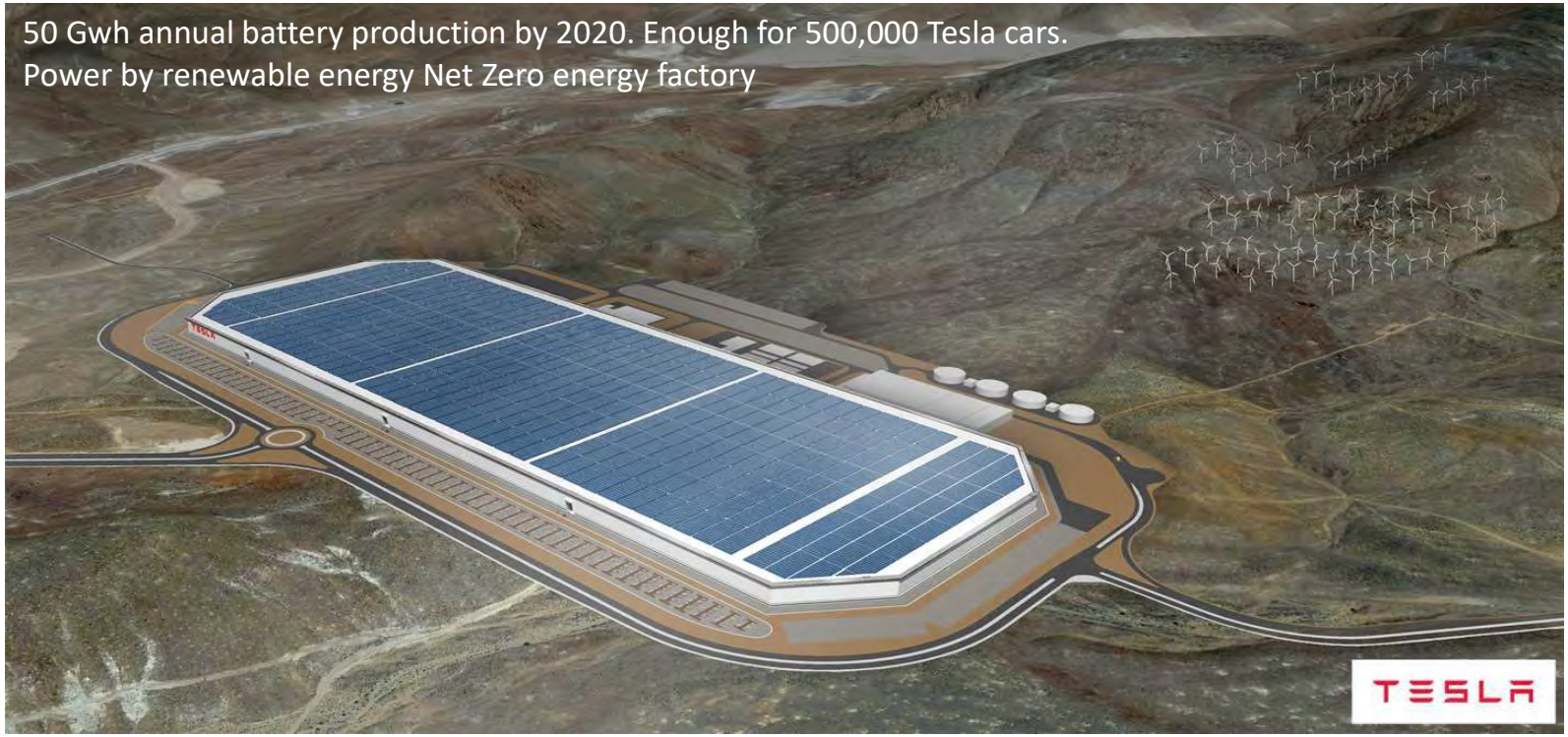


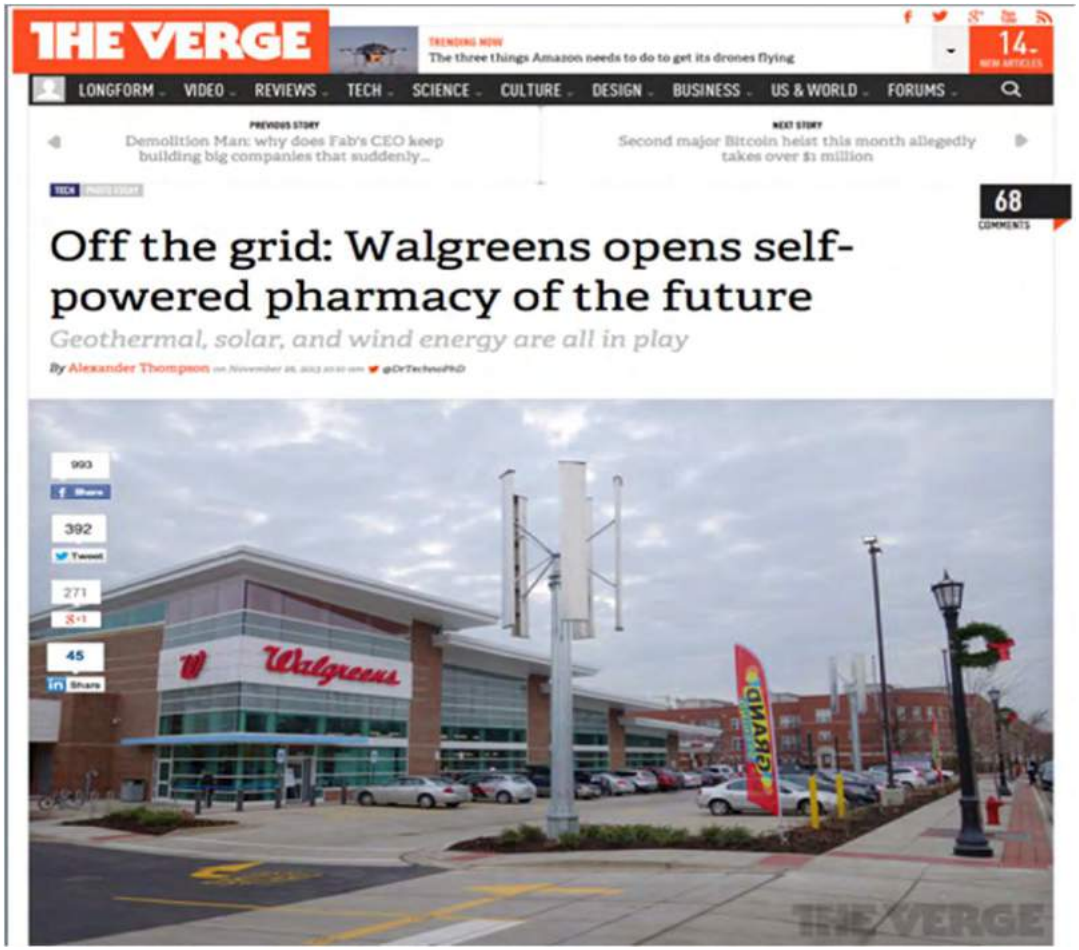
Strategic Research

The New Industrial Customer



Strategic Research

New Business Models Emerging



THE VERGE

TRENDING NOW
The three things Amazon needs to do to get its drones flying

14 NEW ARTICLES

LONGFORM VIDEO REVIEWS TECH SCIENCE CULTURE DESIGN BUSINESS US & WORLD FORUMS

PREVIOUS STORY
Demolition Man: why does Fab's CEO keep building big companies that suddenly...

NEXT STORY
Second major Bitcoin heist this month allegedly takes over $1 million

TECH PHOTO STORY

68 COMMENTS

Off the grid: Walgreens opens self-powered pharmacy of the future

Geothermal, solar, and wind energy are all in play

By Alexander Thompson on November 26, 2013 10:10 am @DrTechnoPhD

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45 Share

New Commercial Customers Rising

Open 2013
Awards 2014
No FB Post 2015

Strategic Research

Commercial Customer Net-Zero That Works

OATI Microgrid Technology Center

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Strategic Research

Residential Customer November 2016 Surprise

Why Tesla's new solar roof tiles and home battery are such a big deal

New Residential Customers Rising

Strategic Research

The The Fortune 500 Is All In - Customer Demand

CORPORATE RENEWABLE ENERGY BUYERS' PRINCIPLES:
INCREASING ACCESS TO RENEWABLE ENERGY

65 COMPANIES

48 MILLION MWH OF DEMAND FOR RENEWABLE ENERGY

$5 TRILLION IN MARKET CAP

Bloomberg, BD, Sprint, ebay, VOLVO, Etsy, Microsoft, AMD, PEPSICO, 3M, ARUP, Hewlett Packard Enterprise, adidas GROUP, P&G, LinkedIn, EQUINIX, Saunders Hotel Group, novo nordisk, Adobe, DIGITAL REALTY, STAPLES, Walmart, intuit, HILTON WORLDWIDE, Gap Inc., TD Bank America's Most Convenient Bank®, MARS, REI, Johnson & Johnson, IKEA, YAHOO!, DUPONT, LOCKHEED MARTIN, IRON MOUNTAIN, KAISER PERMANENTE, Unilever, AUTODESK, io, GM, TARGET, starwood Hotels and Resorts, amazon, vf, COX ENTERPRISES, Marriott INTERNATIONAL, Google, workday, Kellogg's, intel, Genentech, Sealed Air, vmware, Symantec, AVERY DENNISON, EMC², CISCO, salesforce, Nestlé Good Food, Good Life, ADITYA BIRLA NOVELIS, switch, Akamai FASTER FORWARD, hp

WWF | RENEWABLE ENERGY BUYERS' PRINCIPLES | WORLD RESOURCES INSTITUTE

www.buyersprinciples.org

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Some Partner With The Electric Company

amazon

Dominion Energy℠

Strategic Research

Some Do It On Their Own

SIGNAL ENERGY
CONSTRUCTORS

WE HARNESS CREATIVE ENERGY

Strategic Research

Or Hire An Energy Service Company

TENASKA®

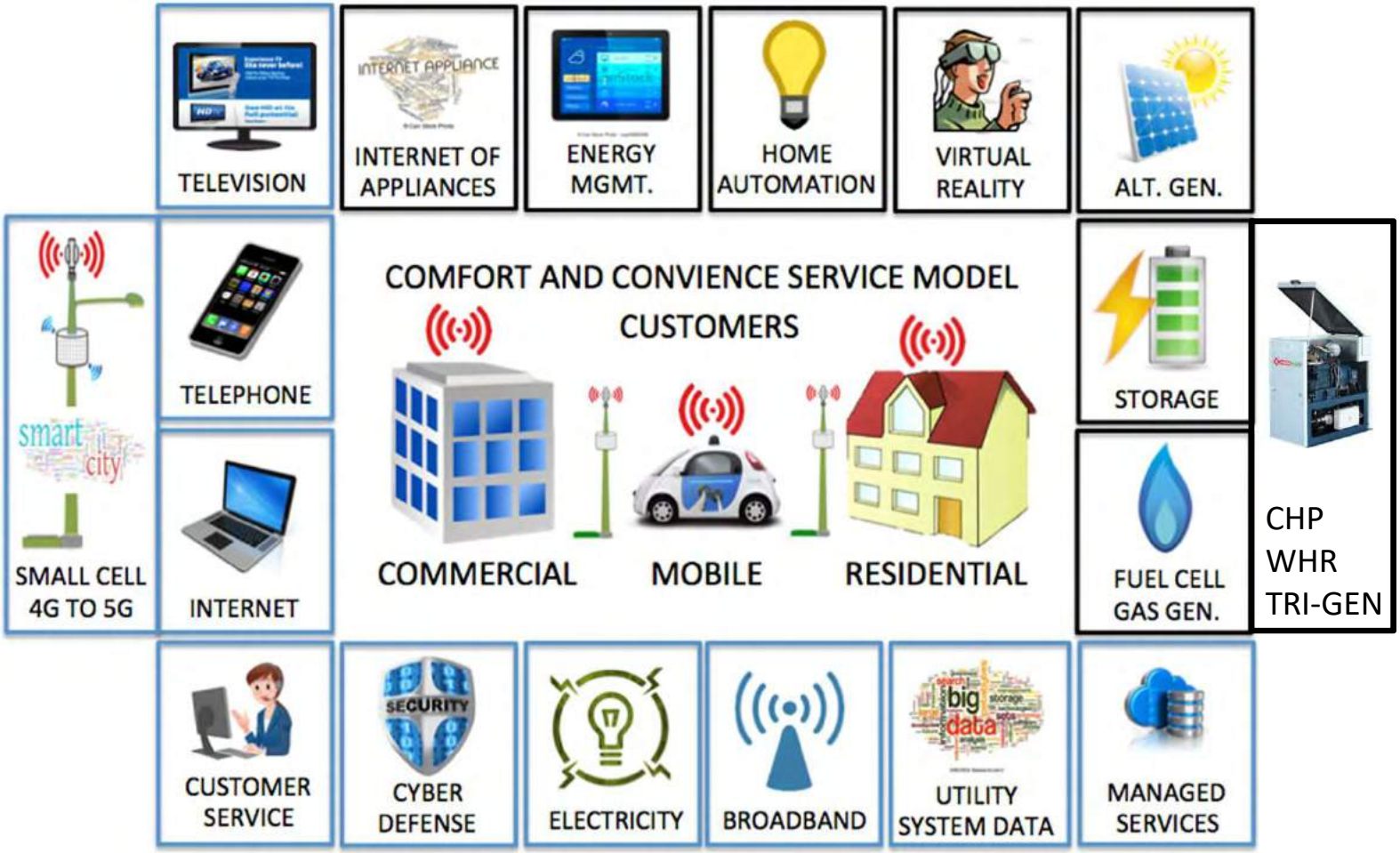
CAESARS ENTERTAINMENT®

MANDALAY BAY®
RESORT AND CASINO, LAS VEGAS

An MGM Resorts Luxury Destination

MGM GRAND
LAS VEGAS

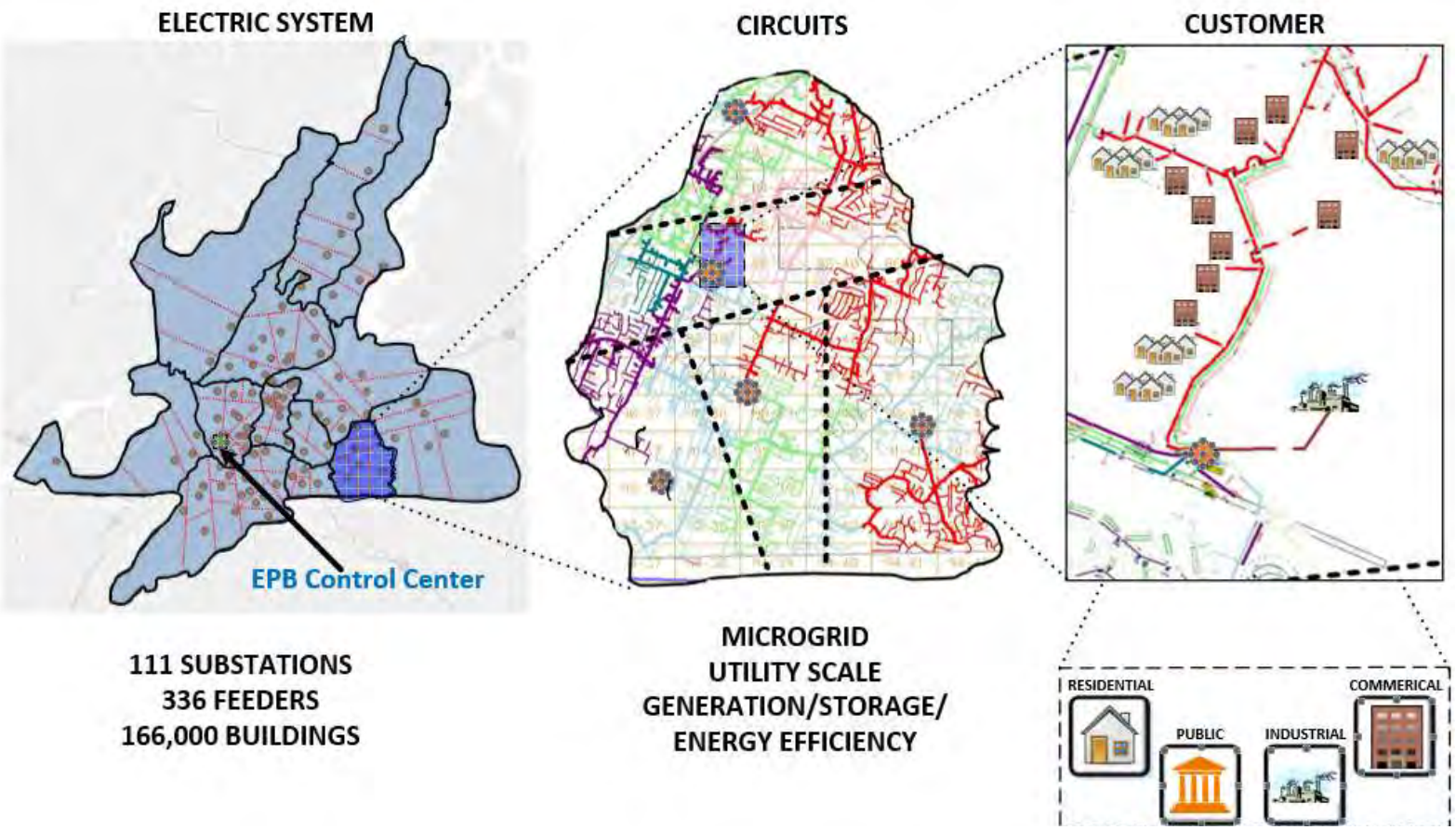
THE UTILITY OF THE FUTURE AT THE CUSTOMER PREMISE



Strategic Research

Control and Manage Load Factor Is The Key

AUTOBEM = MANAGE LOAD FACTOR



Joshua New, Ph.D., C.E.M., PMP, CMVP, CSM

- **Career**
  - 2009+ Oak Ridge National Laboratory, R&D staff
    - ETSD, Building Technology Research & Integration Center (BTRIC), Building Envelope & Urban Systems Research Group (BEUSR)
    - Urban Dynamics Institute, Resiliency Team member
  - 2012+ The University of Tennessee, Joint Faculty
- **Education**
  - The University of TN, (2004-2009), Knoxville; Ph.D. Comp. Sci.
  - Jacksonville State University, AL (1997-2001, 2001-2004) M.S. Systems&Software Design, double-B.S. Computer Science and Mathematics, Physics minor
- **Professional Involvement**
  - IEEE, Senior Member (top 8%)
  - ASHRAE, defines international building codes
    - TC1.5, Computer Applications, Voting member and officer
    - TC4.2, Climatic Information, Voting member and officer
    - SSPC169, Weather Data for Building Design Standards (24% of page count of building code), Voting member
    - TC4.7, Energy Calculations, Voting member and officer
    - SSPC140 and ASHRAE Guideline 14 involvement

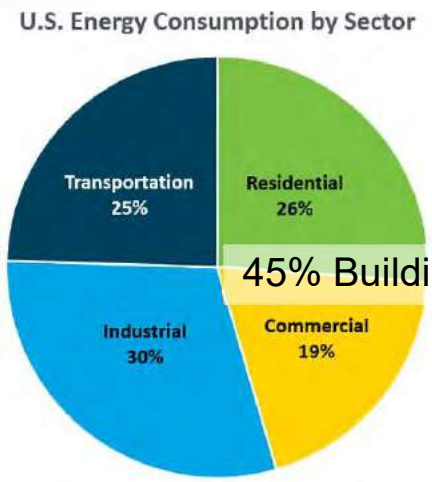
Certifications

- AEE, Lifetime Member
  - Certified Energy Manager
  - Certified Measurement & Verification Professional
- PMI, Member
  - Project Management Professional
- Certified Scrum Master

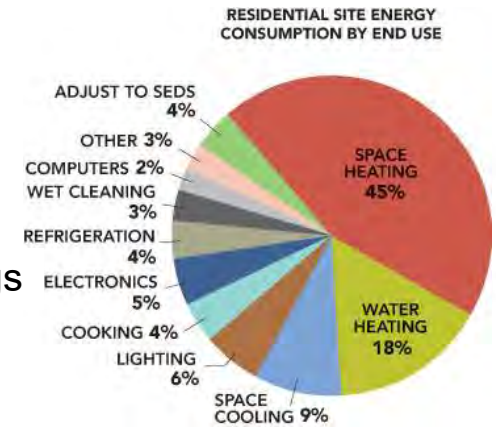
Artificial Intelligence

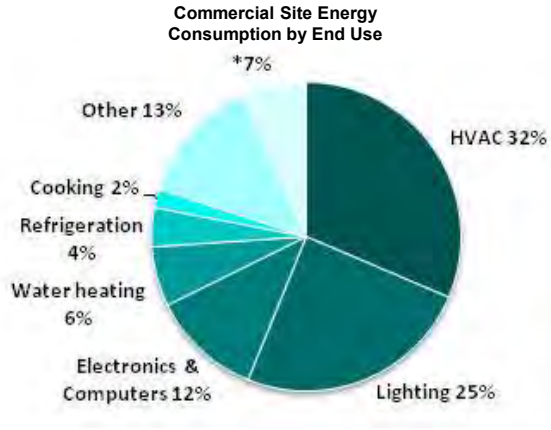
- President's National S&T Council's Machine Learning and Artificial Intelligence Subcommittee's Artificial Intelligence Consortium

Energy Consumption and Production



45% Buildings





Buildings consume 73% of the nation's electricity

Source: U.S. Energy Information Administration, January 2016 to January 2017, *Monthly Energy Review – Table 2.1*.

124 million U.S. buildings
$395 billion/yr energy bills

Goal of the DOE
Building Technologies Office:
45% energy reduction per sq. ft.
by 2030 compared to 2010 baseline

Building Energy Modeling – building descriptions + weather = estimated building energy consumption

$9B/yr – ESCO; $7B/yr – utility EE
$14B/yr – DR management systems
0.3% modified, BEM < 10% of those

ASHRAE Climate Zones

- Based on weather stations, most w/ 18+ yrs of quality data (1961-1990)

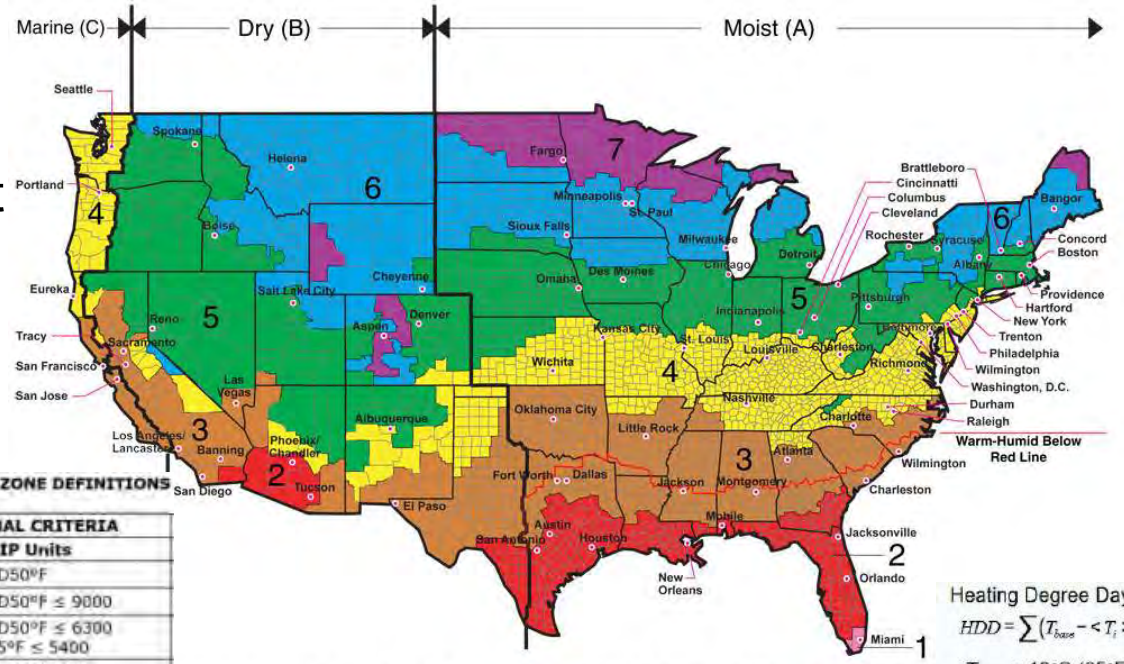


TABLE 301.3(2) INTERNATIONAL CLIMATE ZONE DEFINITIONS

ZONE NUMBER	THERMAL CRITERIA IP Units
1	9000 < CDD50°F
2	6300 < CDD50°F ≤ 9000
3A and 3B	4500 < CDD50°F ≤ 6300 AND HDD65°F ≤ 5400
4A and 4B	CDD50°F ≤ 4500 AND HDD65°F ≤ 5400
3C	HDD65°F ≤ 3600
4C	3600 < HDD65°F ≤ 5400
5	5400 < HDD65°F ≤ 7200
6	7200 < HDD65°F ≤ 9000
7	9000 < HDD65°F ≤ 12600
8	12600 < HDD65°F

Updated every 4 years (2021)

Climate Zone 0 (extremely hot):
10,800 < CDD 50°F
Int'l Energy Conservation Code (IECC) adopts for 2018 code

Heating Degree Days:

$$HDD = \sum (T_{base} - \langle T_i \rangle)^+$$

T_{base} = 18°C (65°F)

Cooling Degree Days:

$$CDD = \sum (\langle T_i \rangle - T_{base})^+$$

T_{base} = 10°C (50°F)

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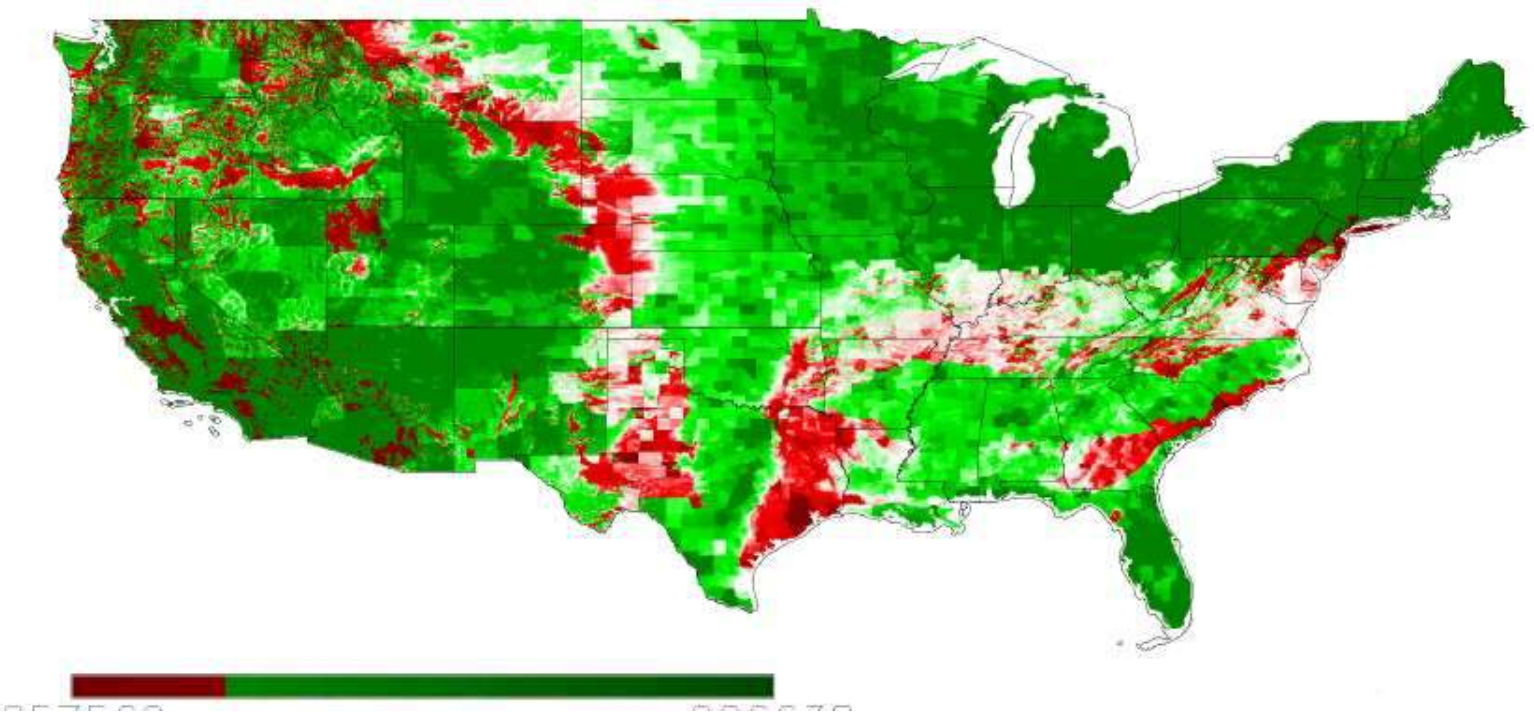
Building-adjusted CZ improvement

- What other (e.g. political) variables should be included?
- How could the nation's energy security and critical infrastructure resiliency be improved by incorporating future scenarios into the built environment?
- **How much energy and $ could be saved by having a forward-looking climate-aware building code?**



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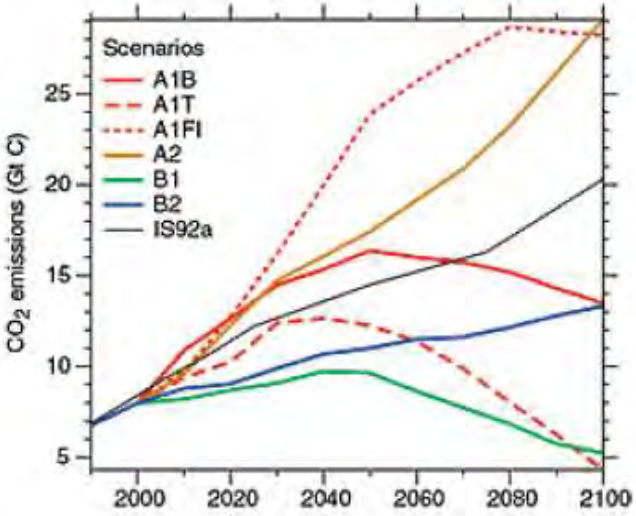
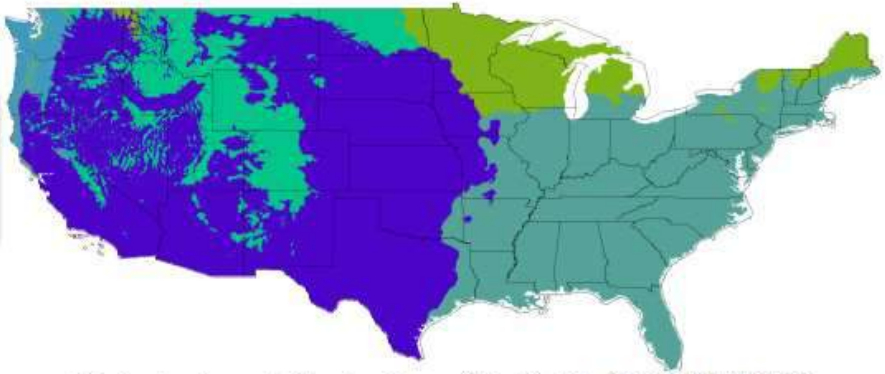
TION CENTER

Climate Change Impacts

Contemporary Period

Clustering-based Climate Zones (K=5): HadGCM A1FI 2050





Clustering-based Climate Zones (K=5): HadGCM A1FI 2100

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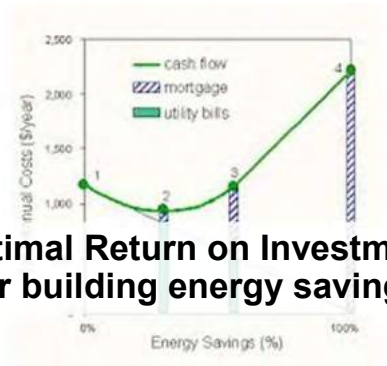
Building Energy Modeling

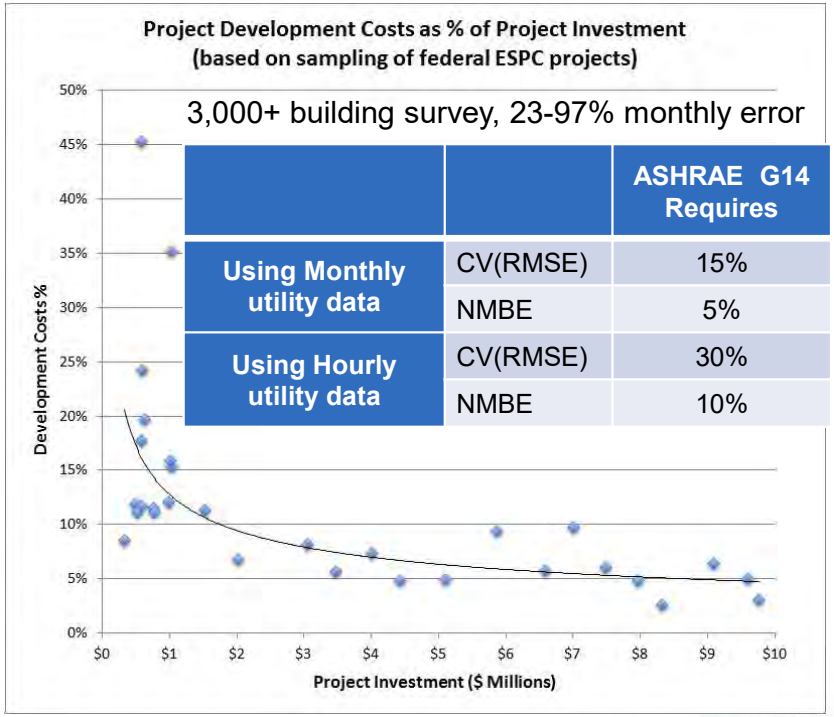


Optimal Return on Investment (for building energy savings)

Simulation Engine and Analysis Platform
U.S. Dept. of Energy
$93M, 1995–?

EnergyPlus **OpenStudio**

Free, open-source (GitHub),
free support community (unmethours.com)



		ASHRAE G14 Requires
Using Monthly utility data	CV(RMSE)	15%
	NMBE	5%
Using Hourly utility data	CV(RMSE)	30%
	NMBE	10%

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HPC scalability for desktop software

Titan is the world's fastest buildings energy model (BEM) simulator

>500k building simulations in <1 hour

130M US buildings could be simulated in 2 weeks

8M simulations of DOE prototypes (270 TB)

CPU Cores	Wall-clock Time (mm:ss)	Data Size	EnergyPlus Simulations
16	18:14	5 GB	64
32	18:19	11 GB	128
64	18:34	22 GB	256
128	18:22	44 GB	512
256	20:30	88 GB	1,024
512	20:43	176 GB	2,048
1,024	21:03	351 GB	4,096
2,048	21:11	703 GB	8,192
4,096	20:00	1.4 TB	16,384
8,192	26:14	2.8 TB	32,768
16,384	26:11	5.6 TB	65,536
32,768	31:29	11.5 TB	131,072
65,536	44:52	23 TB	262,144
131,07 2	68:08	45 TB	524,288

DING TECHNOLOGIES
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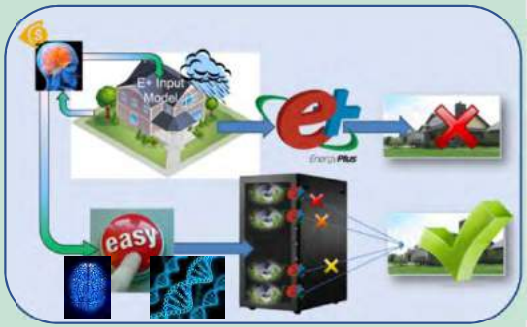
Calibration Performance – automated M&V

National HPC Resources → **Applied Research** → **Industry and building owners**

High Performance Computing

- Different calibration algorithms
- Machine learning – big data mining
- Large-scale calibration tests



Features

- Calibrate any model to data
- Calibrates to the data you have (monthly utility bills to submetering)
- Runs on a laptop and in the cloud

- 35 Publications: `http://bit.ly/autotune_science`
- Open source (GitHub): `http://bit.ly/autotune_code`

Results

		ASHRAE G14 Requires	Autotune Results
Monthly utility data	CVR	15%	1.20%
	NMBE	5%	0.35%
Hourly utility data	CVR	30%	3.65%
	NMBE	10%	0.35%

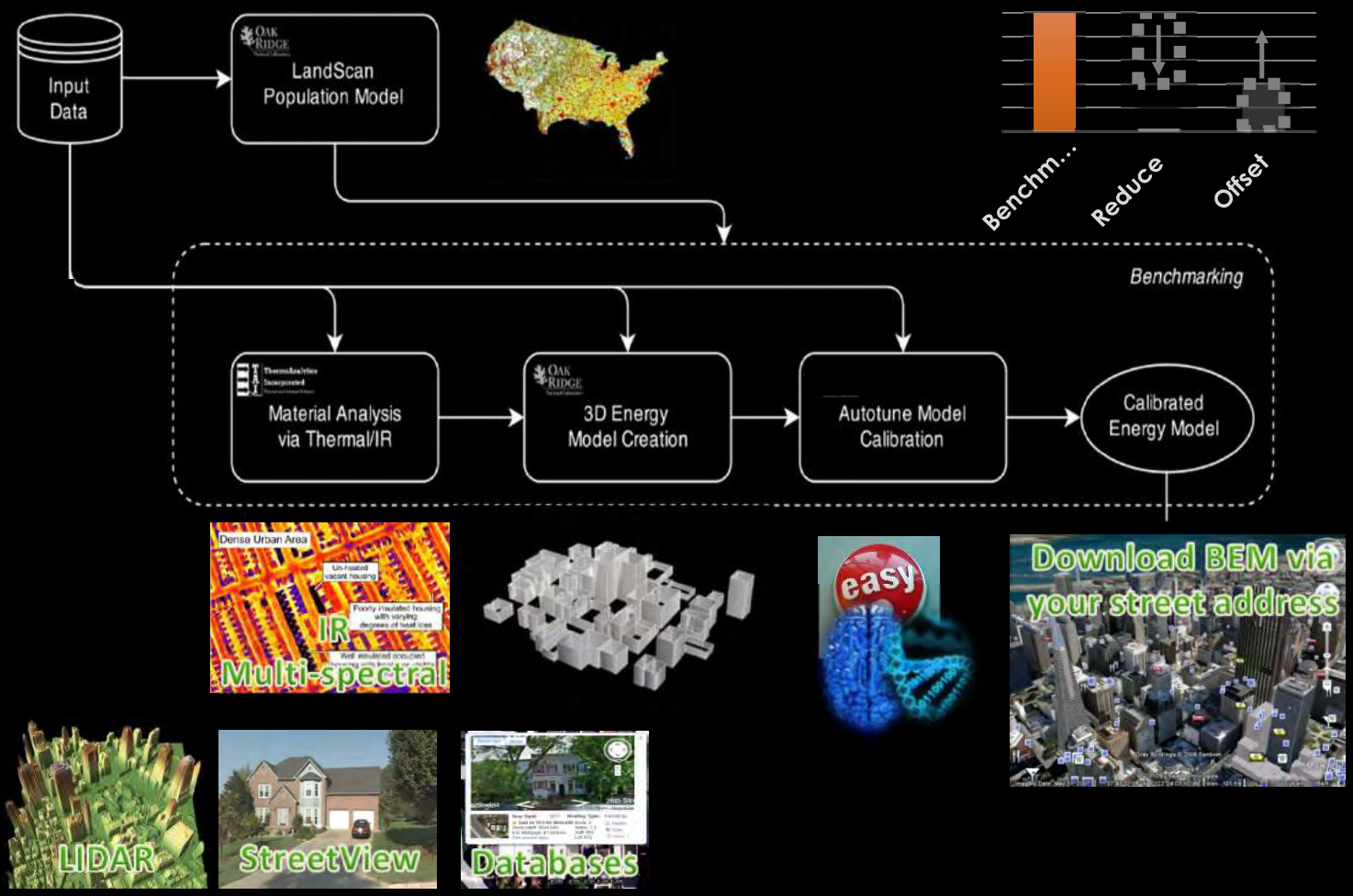
Results of 20,000+ Autotune calibrations (15 types, 47-282 tuned inputs each)

Other error metrics

Residential home	Tuned input avg. error
Within 30¢/day (actual use $4.97/day)	Hourly – 8% Monthly – 15% 3 bldgs, 8-79 inputs

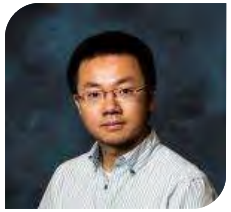
Leveraging HPC resources to calibrate models for optimized building efficiency decisions

Model America 2020 – BEM for every U.S. building



Acknowledgements

- U.S. Department of Energy
- National Nuclear Security Administration
- Oak Ridge National Laboratory
- Building Technologies Office
- Office of Electricity

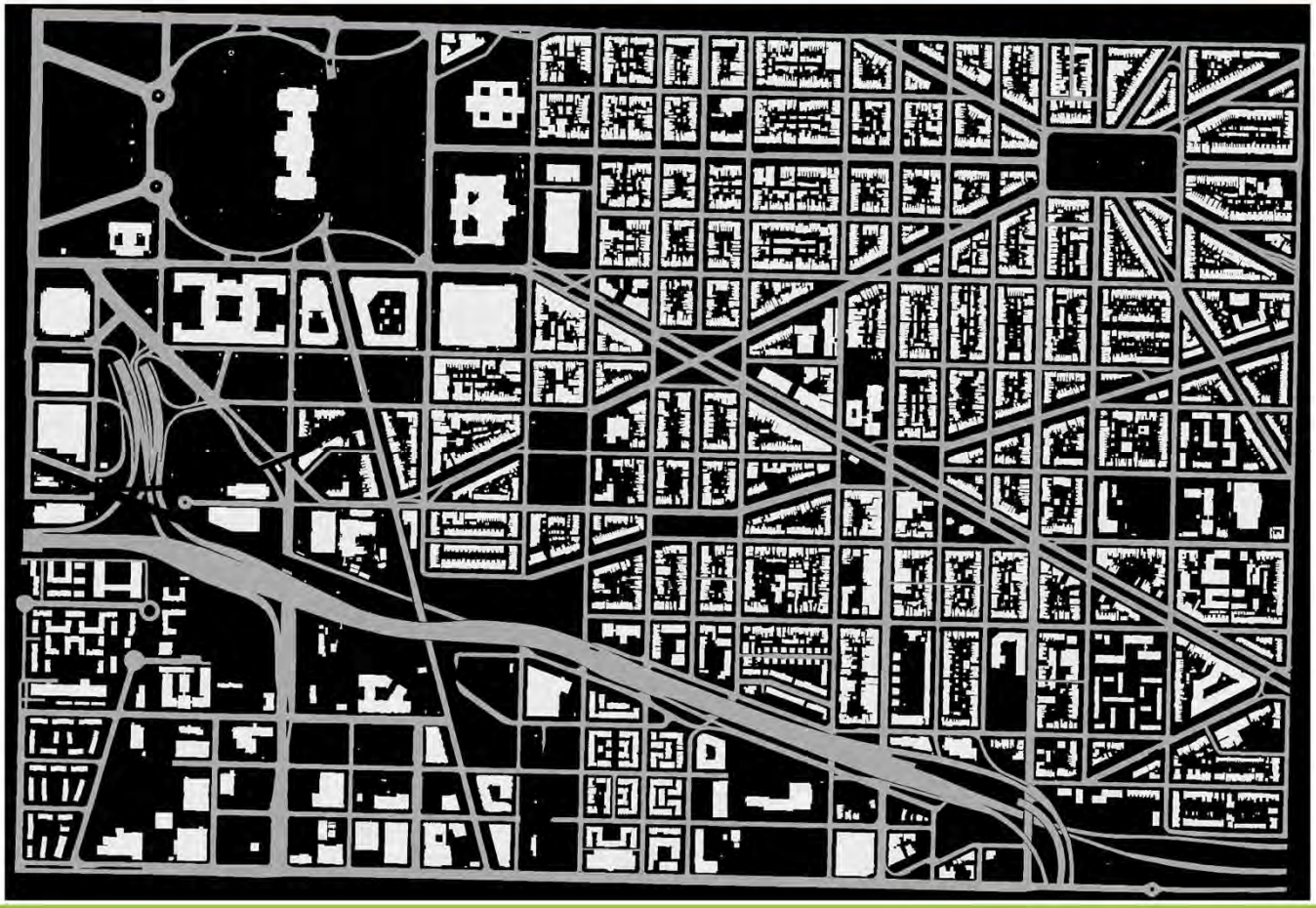


Data Sources

- Database and image sources for urban model generation
  - Satellite and airborne imagery
  - Cartographic data
  - Ground level images
  - Elevation data
  - Building information databases
  - 3D building model databases

	Short Title
Summary	Satellite imagery, including panchromatic and multispectral images
Data type	Image
Company	
Website	
Temporal resolution	Cities - 3-11 times per week
Spatial resolution	0.3 m
Measure accuracy	
Cost	$11 per sq. km
Format	GeoTiff
Mapping to building input variables	Building footprints
Mapping to area properties	Vegetated areas, road surface, buildings, parking lots
Mapping to material properties	Road pavement materials (e.g., concrete, asphalt), parking lots (e.g., gravel, soil)
Coverage of US	Over 10 million km^2 of coverage of the contiguous US
Orientation	Aerial
Existing internal software	N/A
Existing expertise	Remote sensing data analysis tool
Restrictions	N/A
Comments	

Manual Segmentation of DC



Automatic Road Extraction

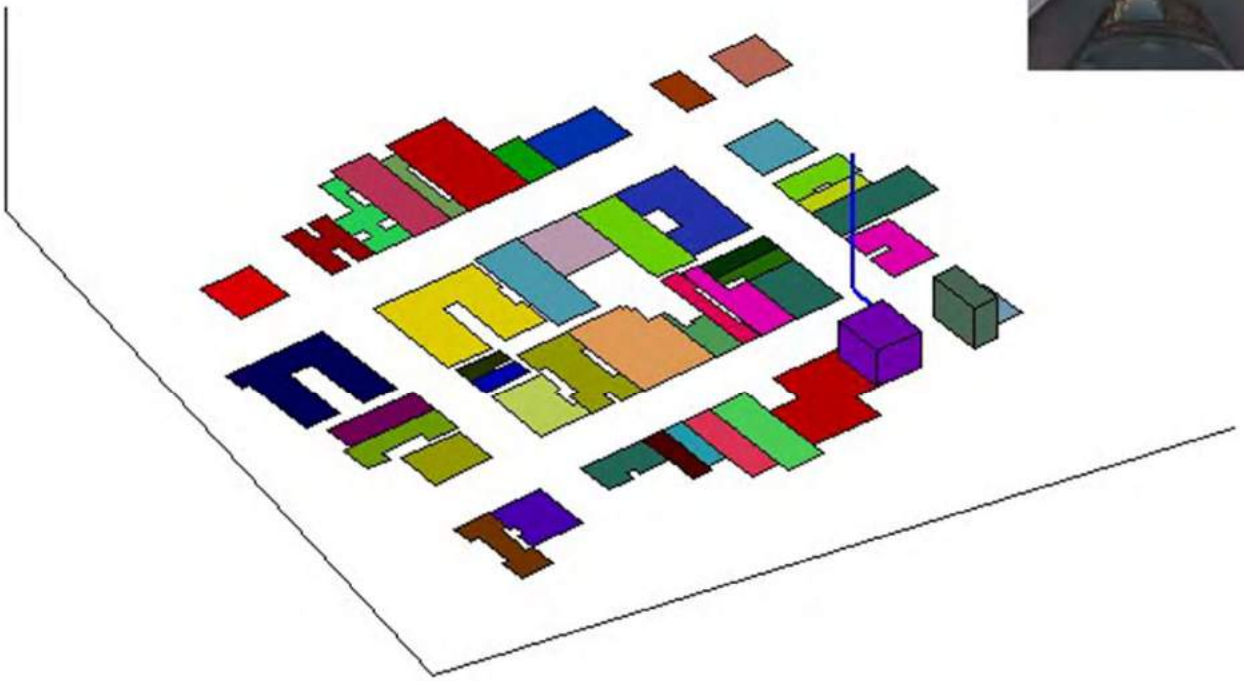
Automatic Building Footprint Extraction

Algorithm: Deep Learning extended and using GPUs for fast building footprint and area extraction over large geographical areas.

Multi-company Competition Precision/Recall – 30/35; Current Precision/Recall – 60+/60+

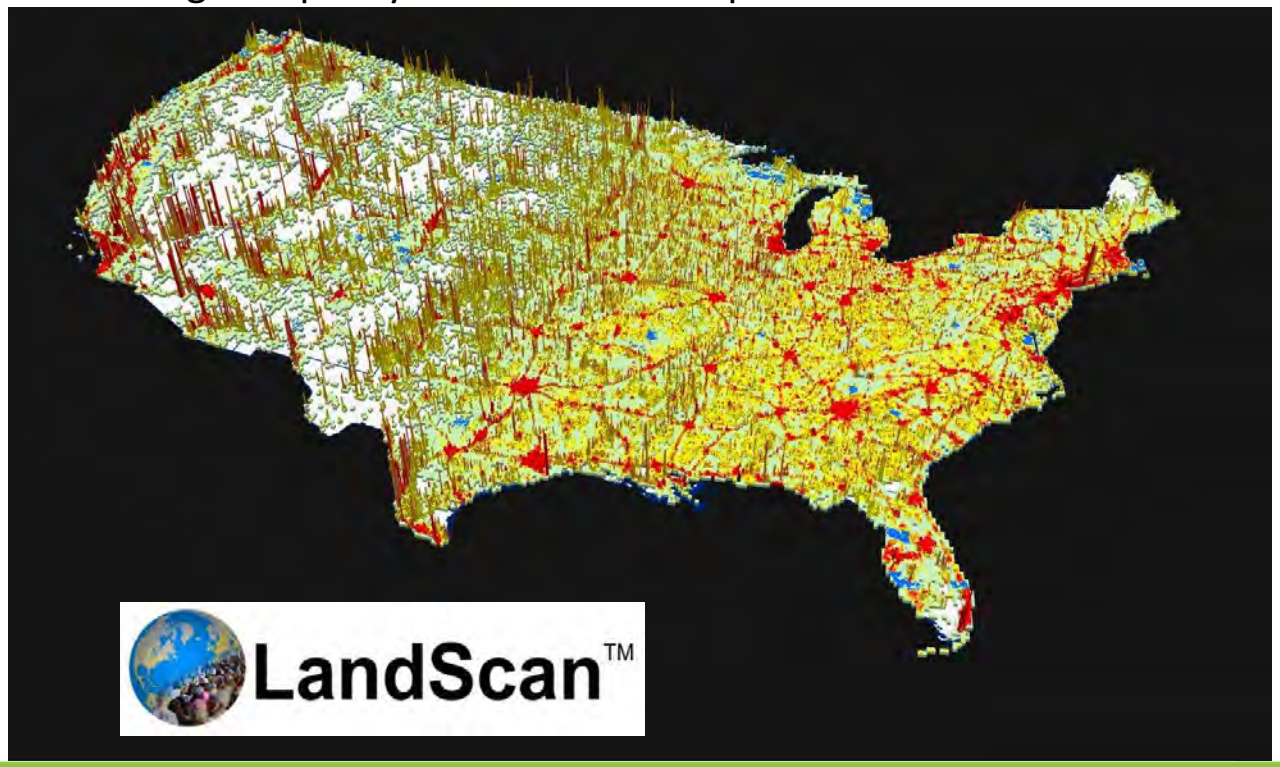
Processing Street-Level Imagery – Jiangye Yuan

3D Building Model Generation



LandScan USA – Amy Rose

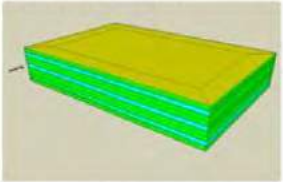
- 90-meter grid of daytime (commercial) and night time (residential) population
  - ~14 different data sources (e.g. anonymized cell phone GPS)
  - Building occupancy and schedule adaptation



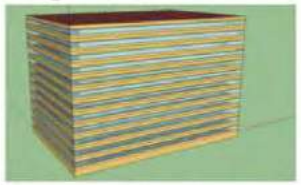
Prototype Buildings

Small Office

Medium Office

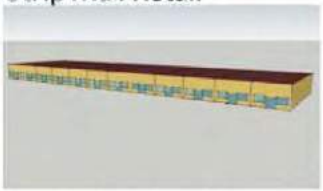


Large Office

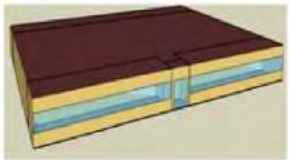


Warehouse

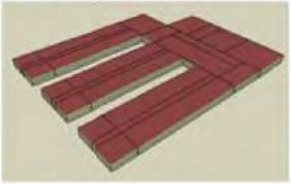
Strip Mall Retail



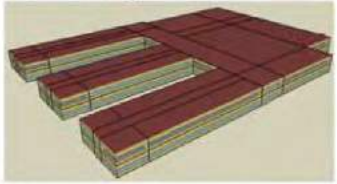
Standalone Retail



Primary School

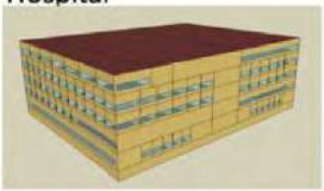


Secondary School



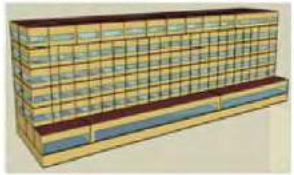
Outpatient Healthcare

Hospital

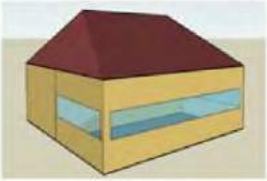


Small Hotel

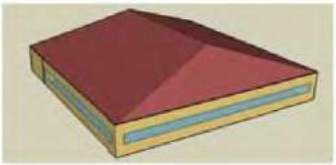
Large Hotel



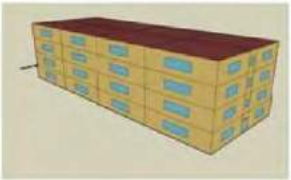
Quick-service Restaurant



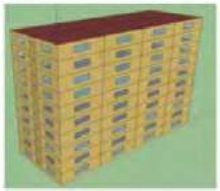
Full-service Restaurant



Mid-rise Apartment



High-rise Apartment



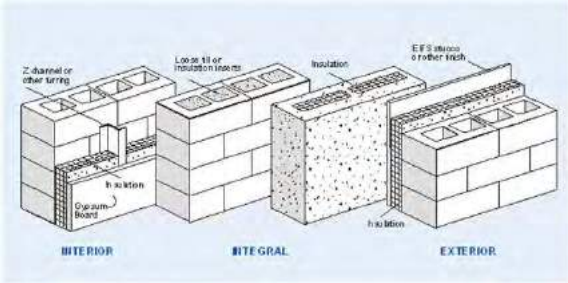
Prototype and Reference Building Updates

- 70, 80 → 90% of U.S. commercial floor space
- 16 types, 16 climate zones, 3 vintages = 768 buildings
  - 17-19+ types, 16-17 climate zones, 5-16+ vintages = 1,360-5,168 models
- ~3,000 avg. parameters per building
  - Square footage, HVAC layout, infiltration (i.e. airflow)
  - Construction (e.g. wall, layers of envelope)
  - Material properties (ASHRAE Handbook of Fundamentals)
  - Equipment and occupancy schedules

Physical Properties of Materials 33.3

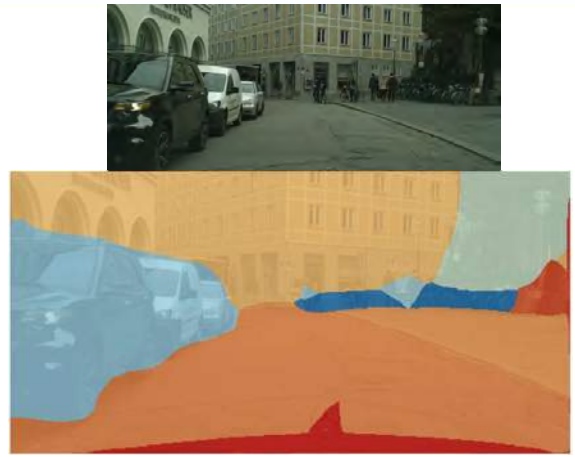
Table 3 Properties of Solids

Material Description	Specific Heat, Btu/lb·°F	Density, lb/ft³	Thermal Conductivity, Btu/h·ft·°F	Emissivity Ratio	Emissivity Surface Condition
Aluminum (alloy 1100)	0.214[b]	171[u]	128[u]	0.09[u] 0.20[u]	Commercial sheet Heavily oxidized
Aluminum bronze (76% Cu, 22% Zn, 2% Al)	0.09[u]	517[u]	58[u]		
Asbestos: Fiber	0.25[b]	150[u]	0.097[u]		
Insulation	0.20[t]	36[b]	0.092[b]	0.93[b]	"Paper"
Ashes, wood	0.20[t]	40[b]	0.041[b] (122)		
Asphalt	0.22[b]	132[b]	0.43[b]		
Bakelite	0.35[b]	81[u]	9.7[u]		
Bell metal	0.086[t] (122)				
Bismuth tin	0.040*		37.6*		
Brick, building	0.2[b]	123[u]	0.4[b]	0.93*	

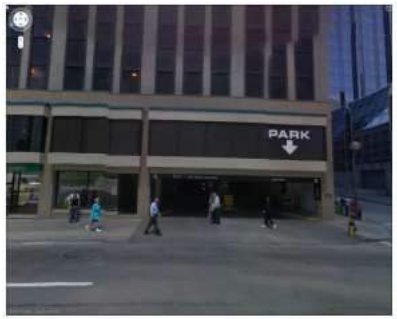


Street-level imagery (Lexie Yang)

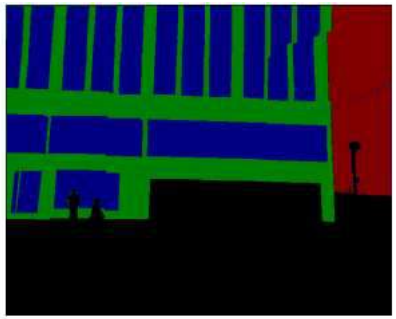
Façade Type



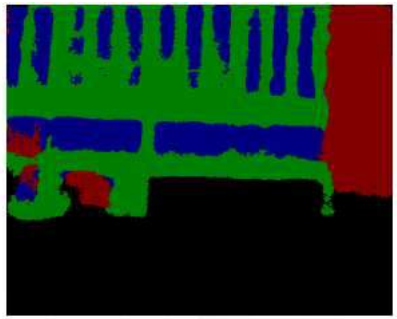
Windows (blue)
Façade (green)
Street/open (black)
Other building (red)



Input image



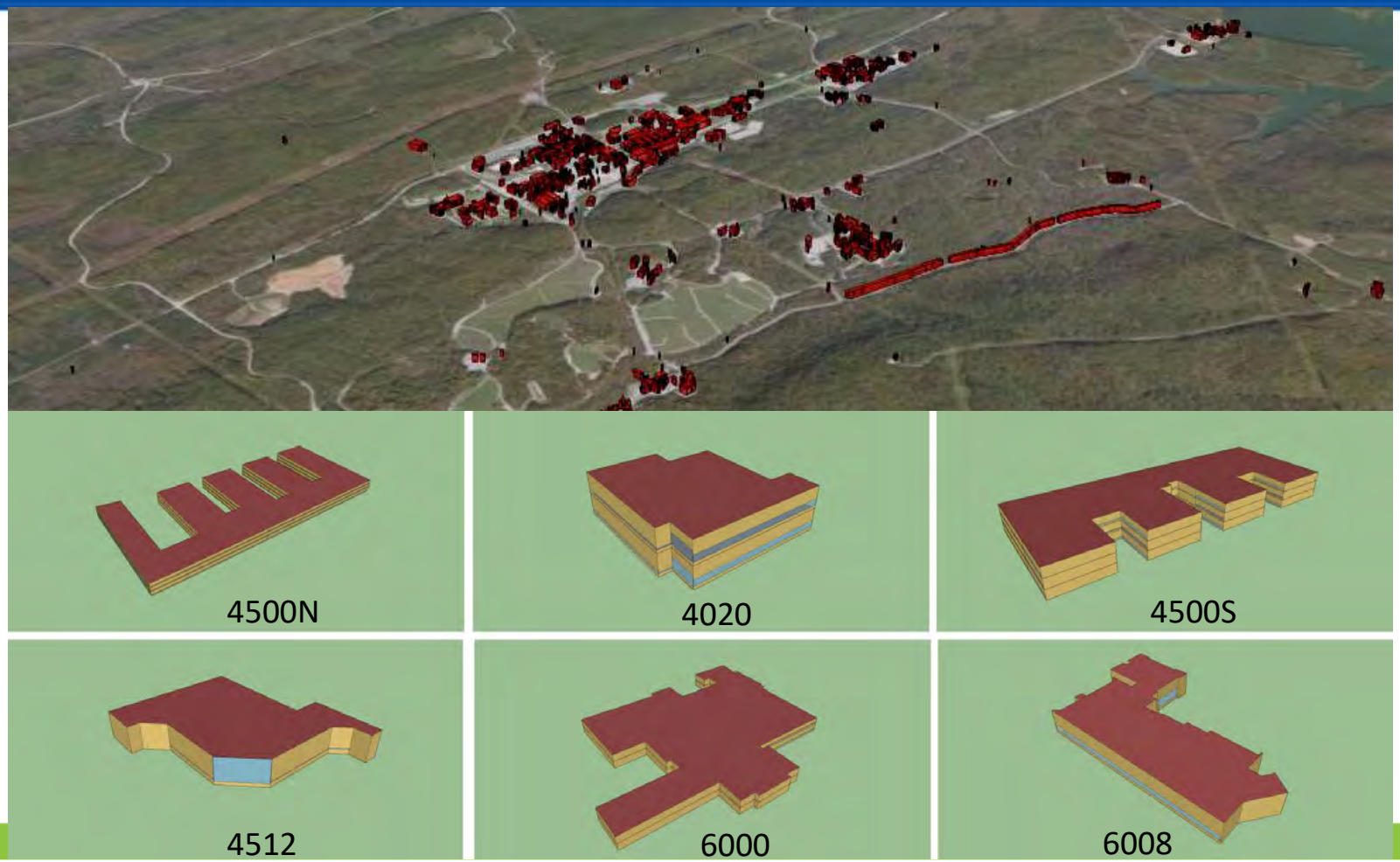
Ground truth



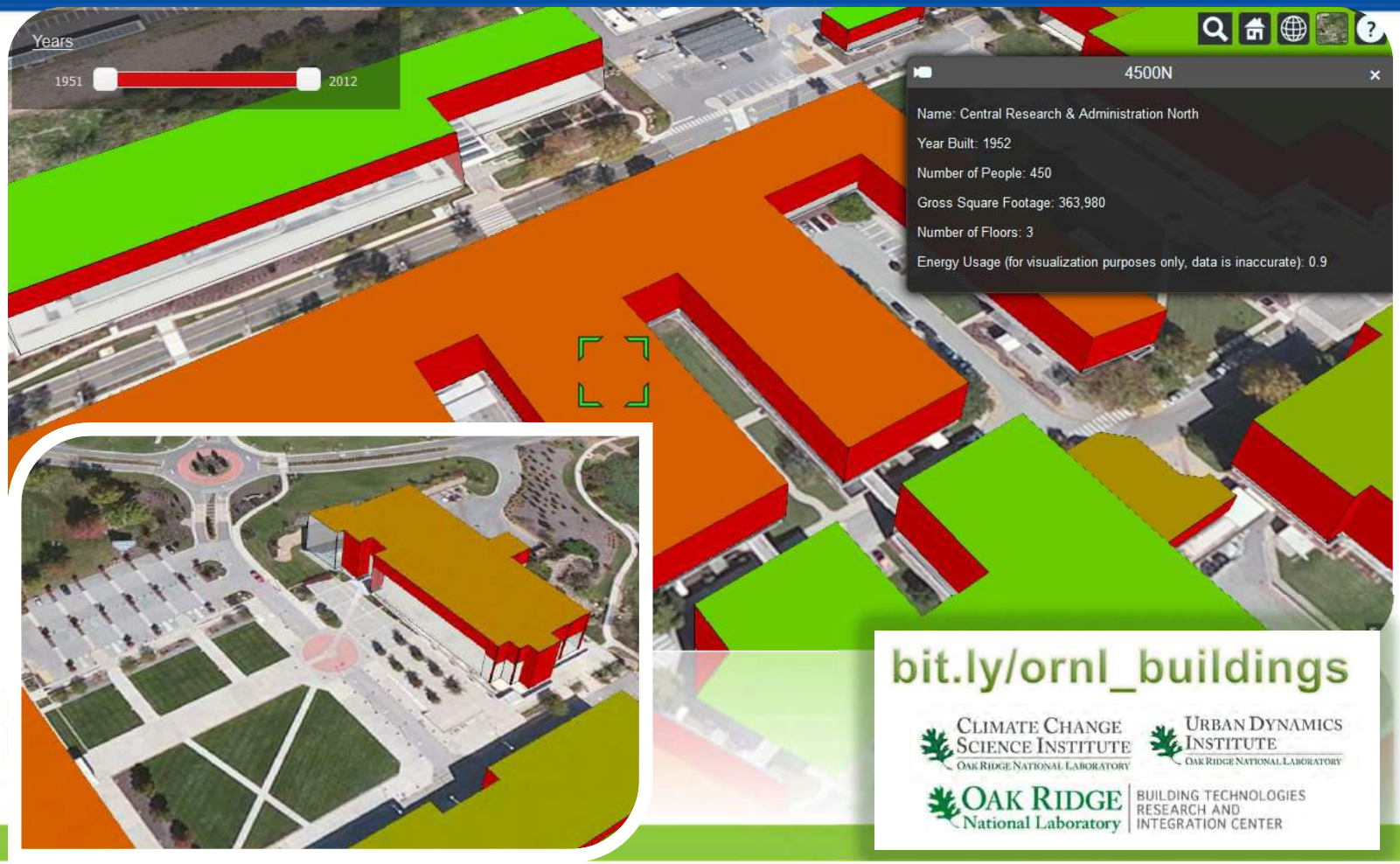
Model output

Window-to-wall ratio

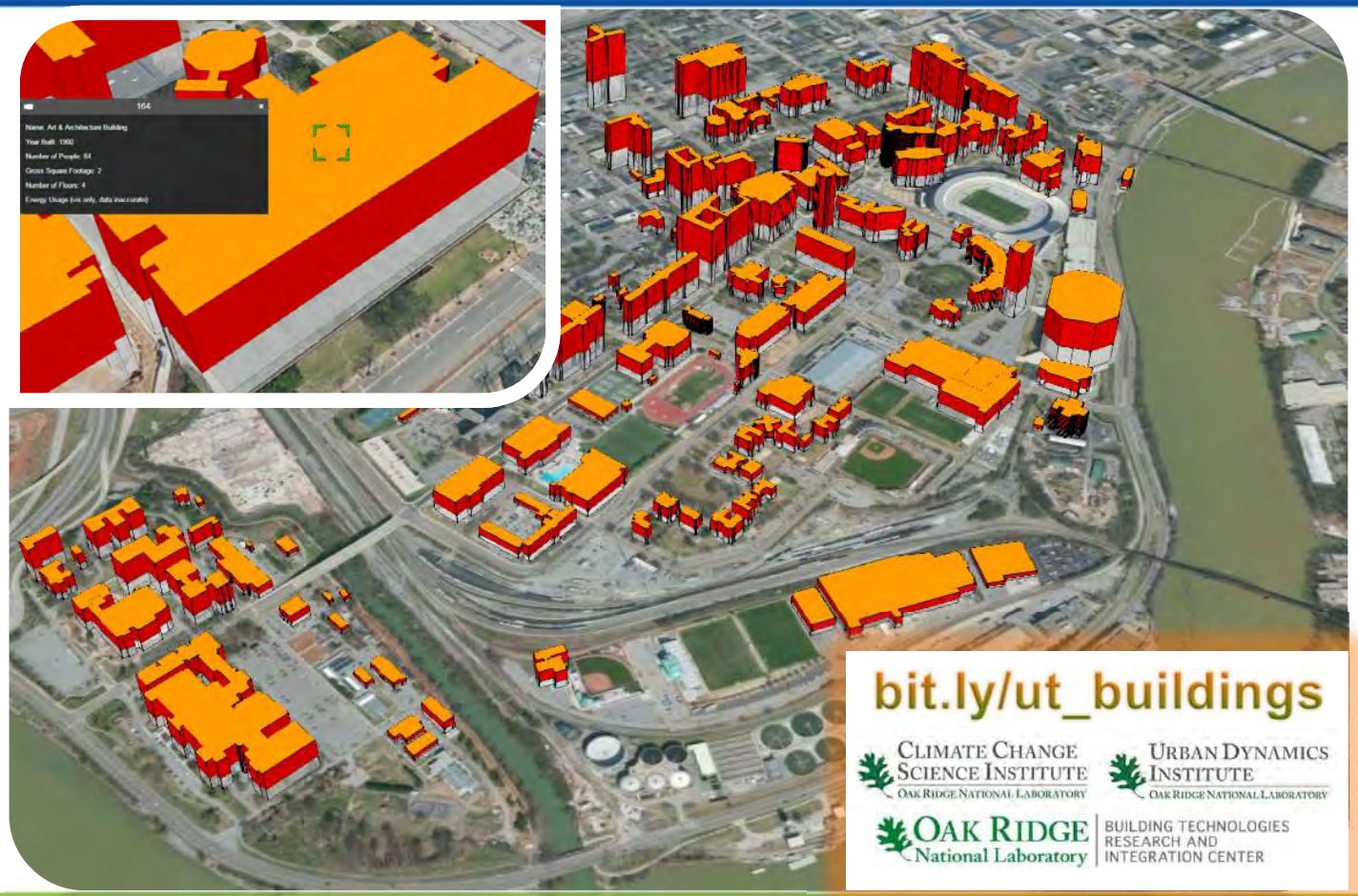
Oak Ridge National Laboratory



Oak Ridge National Laboratory (interactive)



The University of Tennessee (2 days)



Virtual EPB – bios

- Joshua New, Ph.D., C.E.M., PMP, CMVP
  - BTRIC "Software Tools & Models" responsible for development of DOE's building simulation tools, HPC, and AI for big data mining.
  - Led 62 projects (9.4/year) totaling $10M/$28M ($1.3M/yr)
    - 133/133 deliverables (44/yr) on-time and on-budget; 100+ publications (13.8/yr)

- James (Jim) Ingraham, B.S. Finance
  - EPB, VP of Strategic Research; electric utility and broadband communications; market research and data modeling

- William (Bill) Copeland, B.S. Economics, MBA
  - EPB, Director of Business Intelligence, EPB business systems, visual analytics

- Hsiuhan (Lexie) Yang, Ph.D. Civil Engineering
  - Computer vision specializing in aerial imagery
  - Machine learning for large data: NASA, AIST, NSF, DOE

- Mark Adams, M.S. Ag&Bio, Mechanical Engineering
  - Building simulation expert, EnergyPlus/OpenStudio developer

Virtual EPB Summary

- DOE's Building Technologies Office and Office of Electricity
  - Goal: create a digital twin of every building in EPB's service area
  - Final Deliverable: Simulation-informed data and valuation report for energy, demand, emissions, and $ impact to EPB for each building in EPB's service area for 5 prioritized use cases covering 9 monetization scenarios

  - 2 projects, funded and tracked separately
  - Total - $700k (OE-$450k, 41 tasks; BTO-$250k, 15 tasks + BTO: $400k FY19)
  - 56 tasks, 12 milestones, 1 Go/No-Go (passed)
  - On-schedule except for 1 technical input (High-res bldgs) and 1 task (QA/QC)
  - 3.5% over-budget

Utility Use Cases for Virtual EPB

- **Peak Rate Structure** - model peak segment customers in aggregate as disproportionate contributors to electric utilities' wholesale demand charges for more equitable rate structures.
- **Demand Side Management** – identify DSM products and grid services for better distribution grid management that allow both utilities and rate-payers to share in peak reduction
- **Grid stability services** – quantify improved load models
- **Emissions** – accurately account for emissions contributed by each building, providing enhanced abilities for utilities to best comply with national emission policies.
- **Energy Efficiency** – accurate modeling/forecasting of every building energy profile virtually in a scalable fashion allows better follow-up and more targeted energy audits/retrofits.
- **Customer Education** - better understand building's energy usage as a function of weather to provide better information during customer billing enquiries.

Energy, Demand, Emissions, and $ for 9 scenarios (Customer->EPB, EPB->TVA)

EPB buildings in Tennessee (166,944)

EPB buildings in Tennessee (166,944)

EPB buildings in Tennessee (166,944)

Chattanooga, TN (100,000+ buildings)

The AutoBEM technology "axe"

135,481 building models have been created and matched to EPB's PremiseID

Limitations: limited building types, not calibrated, will improve quarterly

QA/QC: will show how close our simulations are to 15-min data

2.3 million EnergyPlus building energy models using AutoBEM technology, Titan, cloud, and local servers to produce and analyze 13 TB of simulation data.

1. Generate baseline building – OpenStudio (1.5-3h Amazon, 30h internal)
2. Run ECM measures – OS Measure (30 mins AWS, 2h internal), Custom (1m AWS, 5m intl.)
3. Copy data to Titan – 1 min (1.2GB tar.gz)
4. Submit to Titan – 0-2 hours in queue
5. EnergyPlus simulation time – 30-45 mins (5mins/sim = 1.4 years to simulate EPB on 1 core)
6. Data transfer – 40 mins (160GB tar.gz)
7. Uncompress – 10-15 mins
8. Reformat data – 20-30 mins
9. Analysis – 5-10 mins

Time for creation, annual simulation, and analyzing "all" EPB buildings

6.5 hours (6.1h –36.5h)

Use Case - Scenarios

- ***Preliminary*** building-specific estimates of energy, demand, and cost savings totaling **$11-$35 million per year** based on 9 scenarios prioritized by EPB.

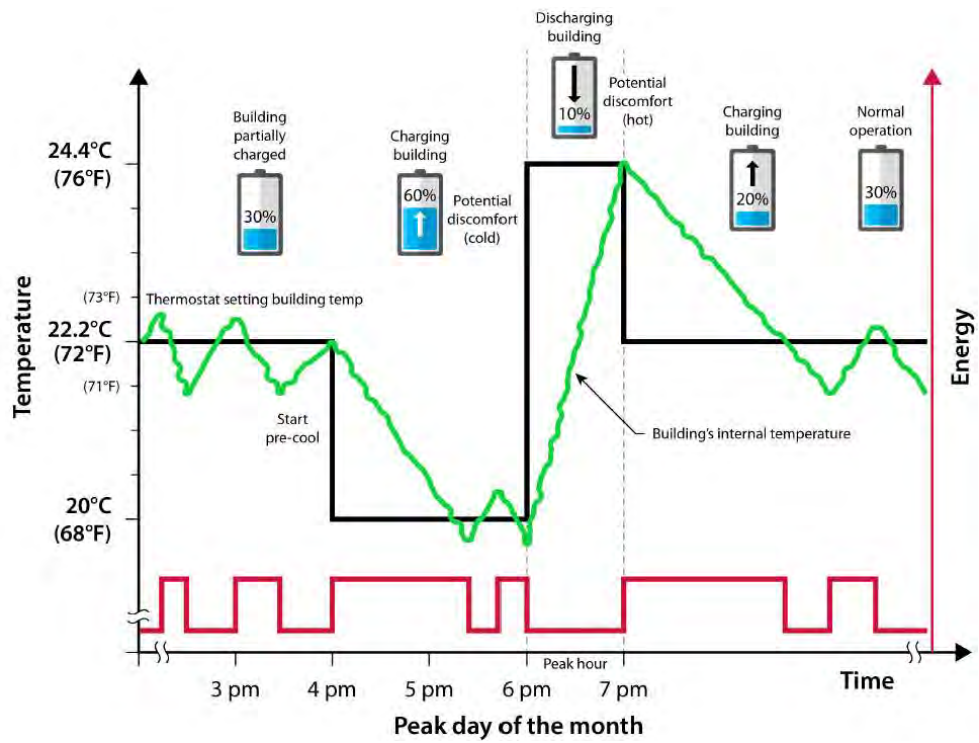
1. **Peak Rate Structure**
    1. Scenario #1a, Peak contributions for each building
    2. Scenario #1b, Cost difference, in terms of dollars per year, for all building
2. **Demand Side Management**
    1. Scenario #2a, Monthly peak demand savings, annual energy savings, and dollar savings based on rate structure for all buildings.
    2. Scenario #2b, Location-specific deferral of infrastructure cost savings potential
3. **Emissions**
    1. Scenario #3a, Emissions footprints for each building
4. **Energy Efficiency**
    1. Scenario #4a, Optimal retrofit list of independent ECMs
    2. Scenario #4b, Optimal retrofit package of dependent ECMs
5. **Customer Education**
    1. Scenario #5a, Percentile ranking of each building's EUI by building type and vintage
    2. Scenario #5b, Monthly peak demand savings, annual energy savings, and dollar savings based on rate structure for all buildings compared to AMY weather file scenario.

1a – Peak contribution percentile by type

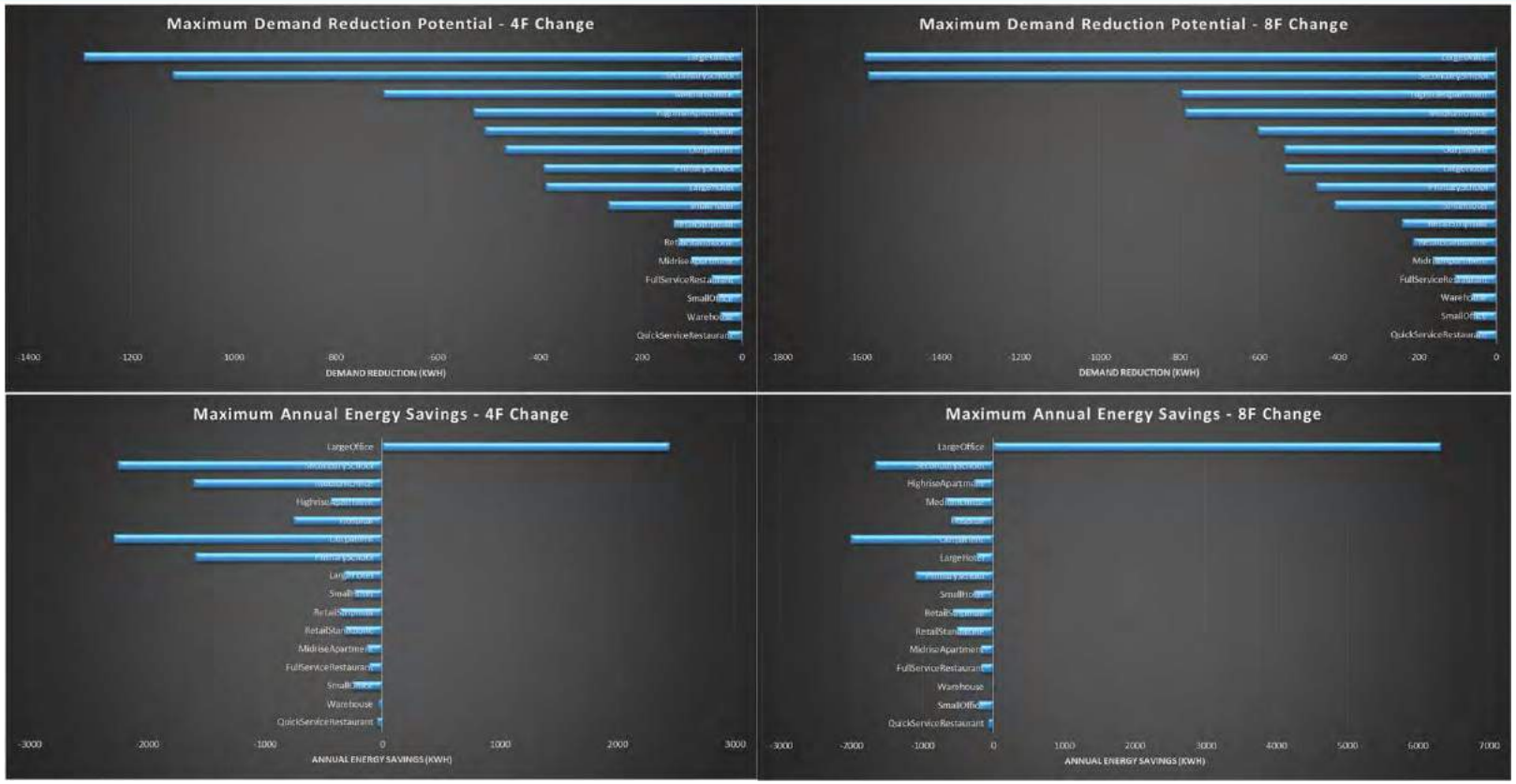
- Building ID
- Area (m^2)
- Number of Floors
- Color: Energy Use Intensity (kWh/m^2) by building type
- Min/Avg/Max by building type

Demand and emissions

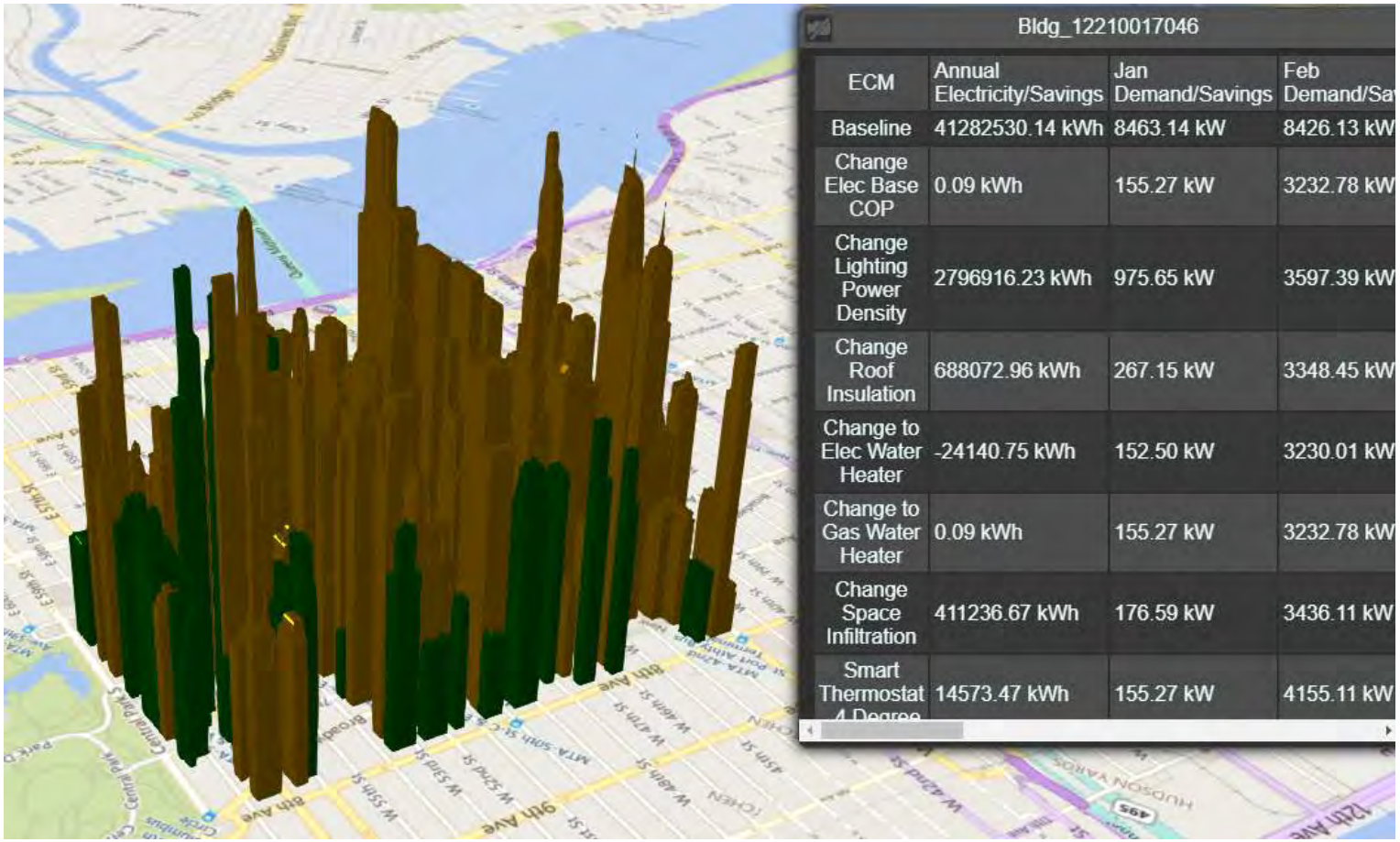
- Pre-heat/pre-cool 2 or 4 hours prior to peak demand hour each month
  - Single Heating or Single Cooling thermostat – up or down 4°F and 8°F
  - Dual Setpoint Thermostat – Average of baseline cooling and heating setpoints with a 0.5°C deadband
  - Altered thermostat values affects 38 (1-4 per building type) thermostat schedules in 518 (3-118 per building type) thermal zones for 16 different building types
- 3a: Emission Footprint for each building
  - Carbon footprint (CO_2)
  - Nitrogen oxides (NOx)
  - Sulfur Dioxide (SO_2)
  - *Methane (CH4)*
  - *Nitrous Oxide (N2O)*



2a - Smart Thermostat: Maximum Demand and Energy Reduction Potential



Virtual NYC – interactive results



Bldg_12210017046

ECM	Annual Electricity/Savings	Jan Demand/Savings	Feb Demand/Sa
Baseline	41282530.14 kWh	8463.14 kW	8426.13 kW
Change Elec Base COP	0.09 kWh	155.27 kW	3232.78 kW
Change Lighting Power Density	2796916.23 kWh	975.65 kW	3597.39 kW
Change Roof Insulation	688072.96 kWh	267.15 kW	3348.45 kW
Change to Elec Water Heater	-24140.75 kWh	152.50 kW	3230.01 kW
Change to Gas Water Heater	0.09 kWh	155.27 kW	3232.78 kW
Change Space Infiltration	411236.67 kWh	176.59 kW	3436.11 kW
Smart Thermostat 4 Degree	14573.47 kWh	155.27 kW	4155.11 kW

Virtual NYC – interactive results

Savings across 152 buildings

E=energy (MWh), D=demand (kW), [min,avg,max]

1. **Smart thermostat 2.2C (4F) pre-condition**
   E=[-72, 1.4, 525] D=[-938, 918, 13907]
2. **Natural gas water heater (80% efficient)**
   E=[0, 0, 0] D=[0, 772, 13907]
3. **Heat pump water heater (COP 2.2)**
   E=[-184, -16.4, -2] D=[-30, 768, 13853]
4. **HVAC Efficiency (COP_H 3.55 and COP_C 3.3)**
   E=[0, 0,0] D=[0, 772, 13908]
5. **Lighting Efficiency (0.85 W/ft^2)**
   E=[77, 784, 6757] D=[23, 999, 14410]
6. **Infiltration (reduce 25%)**
   E=[40, 774, 4648] D=[-0.8, 840, 14020]
7. **Insulation (R16.12 to R28.57)**
   E=[12, 204, 1600] D=[1.9, 817, 13928]

building_id	Elec_savings (kWh)	Jan (kW)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12210000247	-25559.37	5852.94	4309.38	5366.97	6592.65	4262.77	870.72	457.84	431.46	2406.69	6587.84	6630.63	6242.57
12210000469	-721.30	25.08	89.07	156.48	6.73	26.60	168.46	150.48	4.51	7.44	6.22	6.39	12.52
12210000518	-2701.65	7.76	1762.35	3394.86	22.85	550.36	2560.03	2263.61	2697.12	709.85	75.10	74.33	0.00
12210000994	-8481.05	1055.41	905.72	990.42	1474.41	848.47	196.65	194.14	3.66	548.06	1276.96	1252.69	887.56
12210001156	-5736.16	1196.35	1000.11	1101.04	1673.10	954.47	222.70	215.54	216.98	671.15	1469.96	1418.45	973.81
12210001197	546.94	77.19	407.63	1004.80	8.67	143.51	888.66	830.73	901.23	227.86	8.38	69.38	0.00
12210001252	-42452.78	7440.43	5315.70	6722.96	8265.02	6113.35	511.76	625.95	1.15	4142.70	8232.69	7282.54	6572.38
12210001490	-905.68	8.48	39.99	177.69	8.06	30.01	16.00	155.19	158.46	81.12	3.35	0.64	3.88
12210002001	-16751.35	2353.22	1774.32	2166.91	3481.47	2139.86	229.42	419.27	3.45	1610.13	3238.90	2776.87	1857.80
12210002031	-1226.89	1.96	145.84	444.87	-0.66	9.45	-496.24	63.75	116.22	-111.25	10.52	49.65	0.00
12210002047	-692.42	22.52	99.76	370.75	9.39	64.11	347.40	349.46	382.89	179.84	11.41	3.25	0.00
12210002150	30.35	60.50	255.99	806.49	3.48	66.73	812.78	689.28	5.88	147.68	3.96	77.14	0.00
12210002629	-3701.09	882.04	839.96	797.77	1059.83	717.52	153.35	140.93	1.94	482.84	970.80	1050.46	741.97
12210003200	-28557.61	2563.00	2406.68	2510.02	2962.48	2202.89	357.32	419.56	410.43	1519.44	2886.95	3028.13	2298.47
12210003292	-1583.51	4.30	1311.22	2826.54	9.47	448.83	2200.25	1916.39	2278.23	611.96	56.75	85.90	0.00
12210003302	-5519.82	119.63	2140.16	4235.07	33.48	608.39	2922.95	2597.64	2876.36	866.10	103.19	9.61	0.00
12210003314	-5708.34	4.91	2444.18	3982.02	0.71	264.42	1733.69	315.91	49.63	393.20	12.85	158.36	0.00
12210003317	-3372.72	111.52	510.91	1173.94	9.19	255.62	1086.71	950.19	1091.03	408.28	31.76	9.90	0.00
12210003333	-1604.88	1.96	84.76	221.98	5.28	6.44	21.88	212.90	20.55	82.06	2.34	5.21	0.15
12210003346	-2131.77	5.41	1474.50	3019.75	11.03	474.57	2247.52	1996.23	2414.45	577.55	42.52	74.95	0.00
12210003350	-891.15	54.48	119.26	163.76	6.54	16.33	187.35	170.99	3.96	9.51	5.52	7.50	9.59
12210003354	-17125.51	4898.93	4556.63	4387.42	5461.75	3512.42	38.73	682.57	661.52	2552.29	5508.01	5809.67	4086.09
12210003361	-1214.74	9.77	58.91	210.65	0.63	6.87	-5.49	191.78	204.65	97.66	2.19	1.29	0.45
12210003379	759.09	63.94	308.85	797.63	4.71	97.05	791.79	701.29	669.47	6.47	4.73	63.31	0.00
12210003383	2626.09	118.49	681.87	1367.29	25.09	224.15	1207.86	1043.81	2.29	341.70	64.43	95.22	0.00
12210003661	-42.89	7.47	88.91	223.08	6.93	15.57	232.71	212.10	5.81	1.05	10.39	4.12	0.09
12210003791	-676.58	1.83	108.79	273.89	4.62	-0.71	266.11	11.88	10.69	51.54	12.46	30.17	0.21
12210004115	2116.15	22.16	265.01	744.60	3.08	96.42	759.76	510.54	57.95	57.73	6.83	49.82	0.00
12210004205	1070.38	82.79	545.31	1222.73	3.25	160.14	1072.99	873.94	14.49	48.06	8.56	99.29	0.00
12210004223	380.10	38.15	95.93	354.41	15.05	76.17	337.95	319.08	361.81	192.99	36.14	1.04	0.00
12210004406	-2142.06	123.81	557.33	1385.46	15.95	278.12	1199.00	1104.96	1282.00	403.57	12.01	11.16	0.00

LiDAR vs. Microsoft Footprints (preliminary)

Microsoft releases 125 million building footprints June 28, 2018. (https://github.com/Microsoft/USBuildingFootprints)

- Goal to improve OpenStreetMap which had 30,567,953 US building footprints
- Stage 1 – Semantic segmentation (Open Source CNTK Unified Tolkkit, Deep Neural Networks, ResNet34 with RefineNet up-sampling layers, Bing overhead imagery)
- Stage 2 – Polygonization (creates walls from pixel-based classification)

Discussion with Jubal Harpster afterward

Value of MS footprints as a building data layer
116,506 unique buildings

- Largest LiDAR-derived GPS distance is ~0.1 (GPS bldg centroid and electrical meter)
- Largest MS-derived GPS distance is 0.0149 (maximum distance is ~6x smaller)

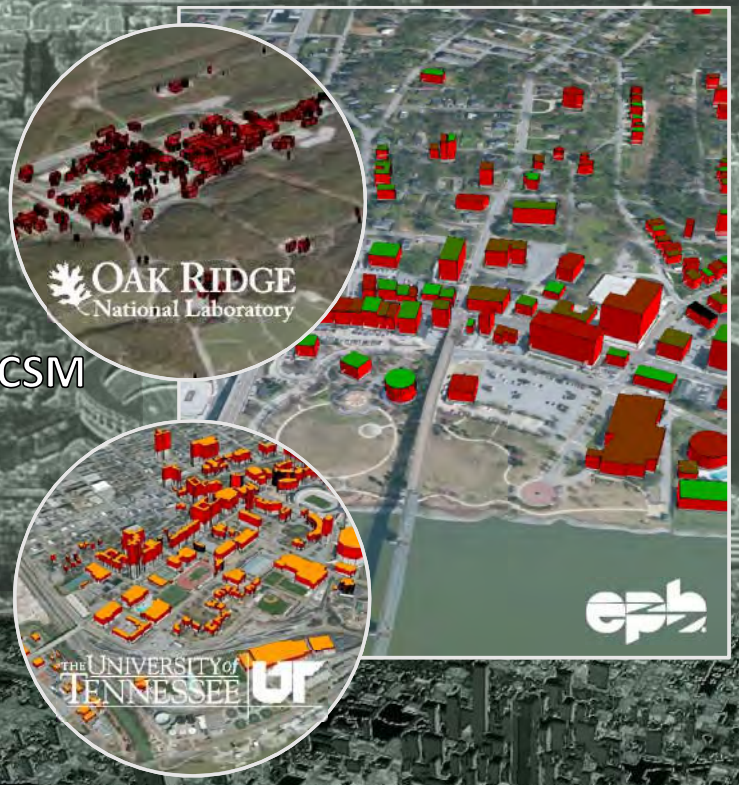
- Each building 1,024 ft^2 smaller than LiDAR (better aligns with energy use data)

	ID	AreaOld	AreaM	diff
count	1.783550e+05	1.783550e+05	1.783550e+05	1.783550e+05
mean	1.283970e+09	1.353843e+04	1.251411e+04	-1.024317e+03
std	8.634363e+08	5.693321e+04	5.332367e+04	3.197508e+04
min	1.000000e+04	1.600000e+02	9.765405e+01	-2.058451e+06
25%	5.764950e+08	2.277000e+03	2.169542e+03	-5.954823e+02
50%	1.126530e+09	3.896000e+03	3.781828e+03	-1.250858e+02
75%	1.881395e+09	7.596000e+03	7.196649e+03	3.512558e+02
max	3.230080e+09	3.451038e+06	3.251502e+06	3.008718e+06

Discussion

HPC Tools for Modeling and Simulation

Capturing building energy consumption



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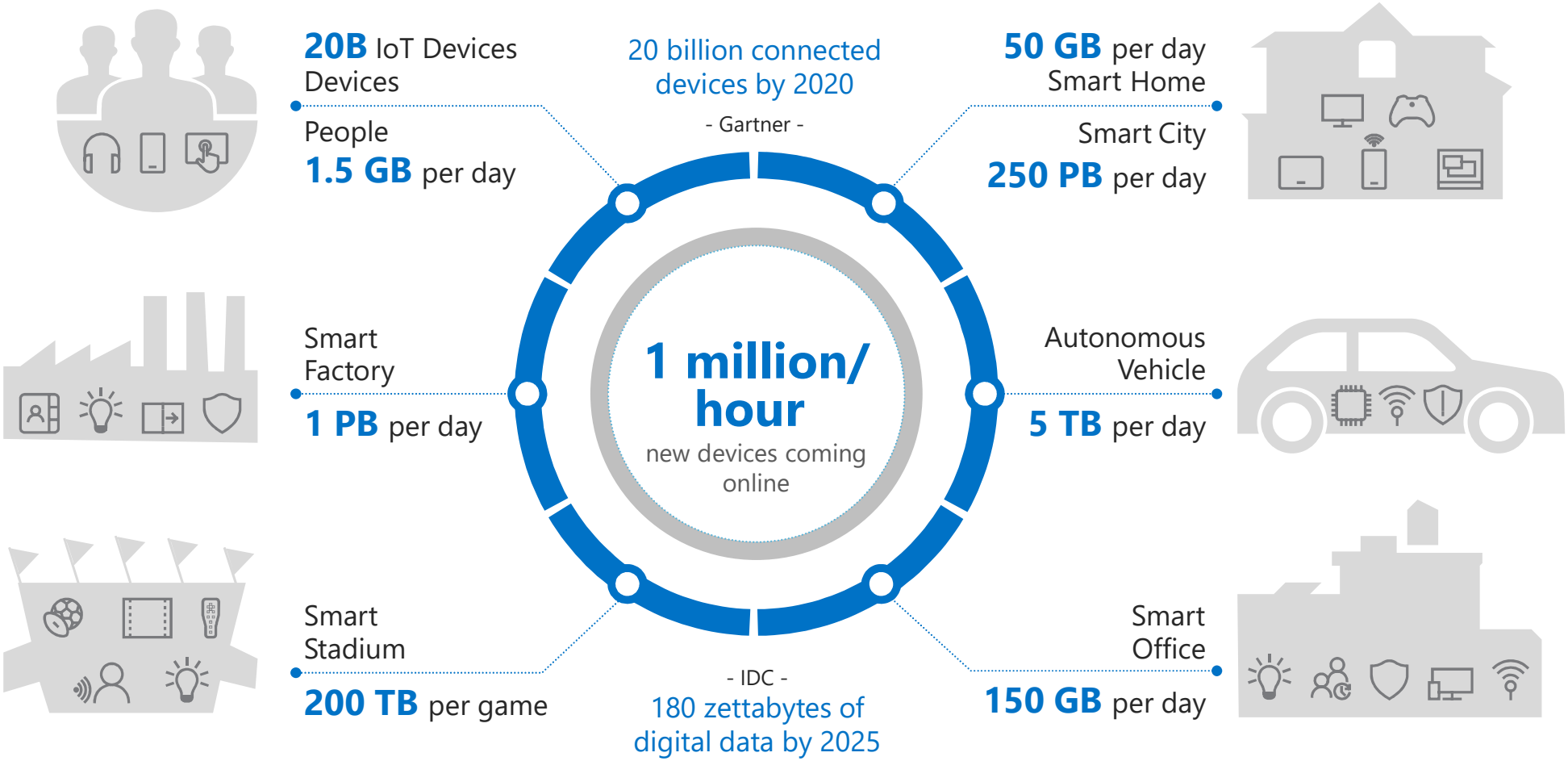
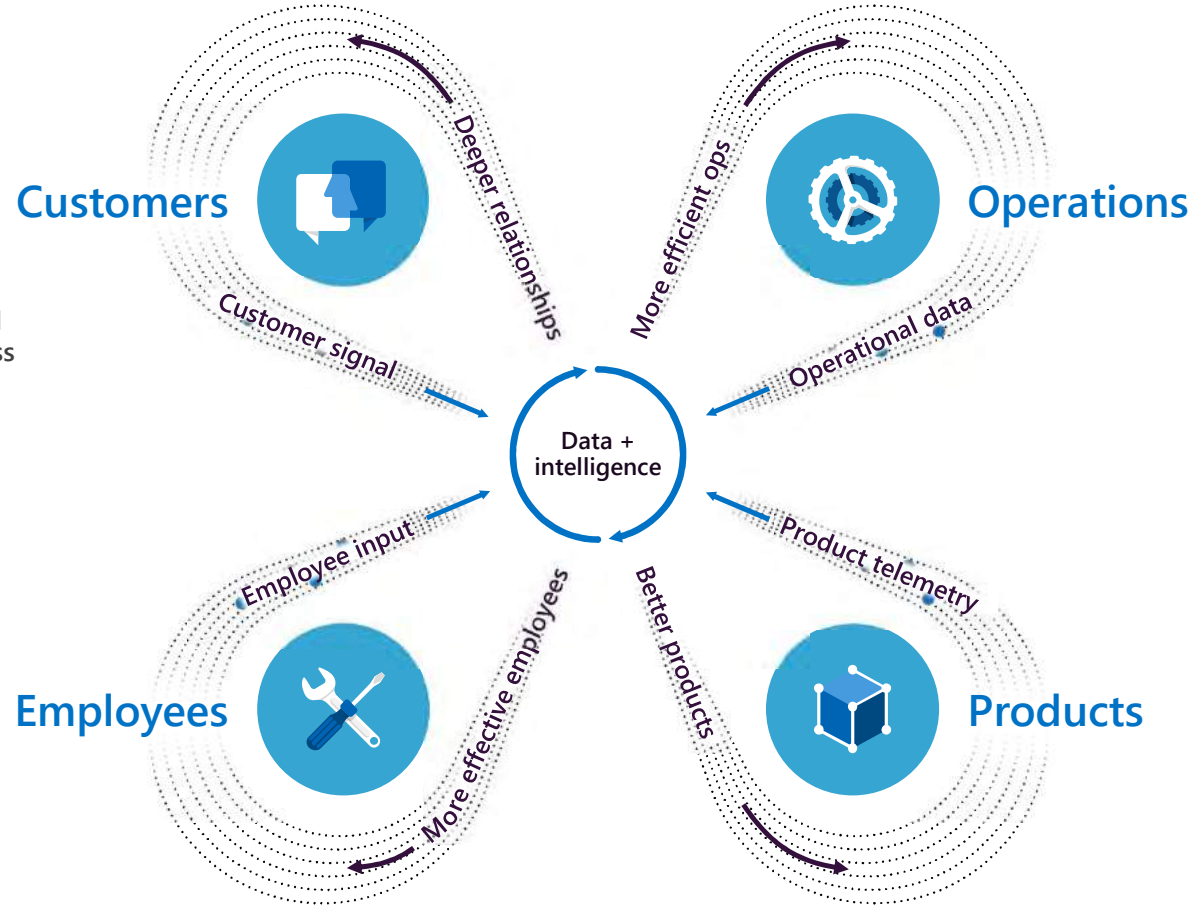
Microsoft

IoT fuels digital transformation

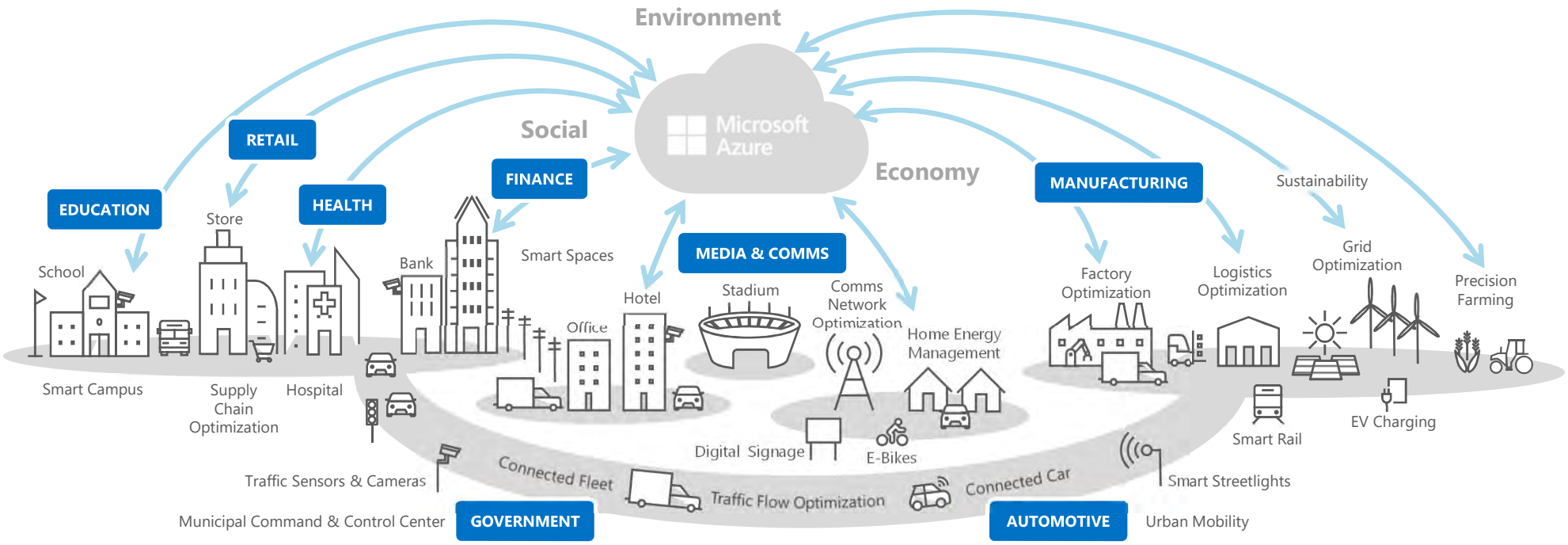


IoT enables a digital feedback loop

1. Data: Capture digital signal across business
2. Insight: Connect and synthesize data
3. Action: Improve business outcomes



Microsoft invests $5 billion in IoT



Our goal is to give every customer the ability to transform their businesses, and the world at large, with connected solutions

IoT product portfolio

Azure Security Center for IoT

Azure IoT Priority Verticals	
Azure IoT Solutions	Azure IoT Central (SaaS) Azure IoT Reference Architecture & Solution Accelerators (PaaS)
Azure Services for IoT	Azure IoT Hub, Azure IoT Hub Device Provisioning Service, Azure Digital Twins, Azure Maps, Azure Time Series Insights, Azure Stream Analytics, Azure CosmosDB, Azure AI, Azure Cognitive Services, AzureML, Azure Logic Apps, Azure Active Directory, Azure Monitor, Azure DevOps, Power BI
IoT & Edge Device Support	Azure Sphere, Azure IoT Device SDK, Windows IoT, Data Box Edge Azure Certified for IoT – Device Catalog Azure IoT Edge, Azure Stream Analytics, AzureML, Azure SQL, Azure Functions, Azure Cognitive Services

A simple view of an IoT solution

A more realistic view…

Enterprise integration

Cloud-to-device commands

Cold path analytics

Business process integration

Device recovery

Solution scale

Operations monitoring

Cost management

Internationalization

High availability

Updating devices

Provisioning devices

Device lifecycle

Transport protocols

Warm path analytics

Drivers

Things

Disaster recovery

Insights

Hot path analytics

Actions

Device updates

Data storage

Data ownership

< ---- **End-to-End Security** ---- >

On device analytics

Data visualization

HW certification

Manufacturing scale

Industry and government compliance

Device commercialization

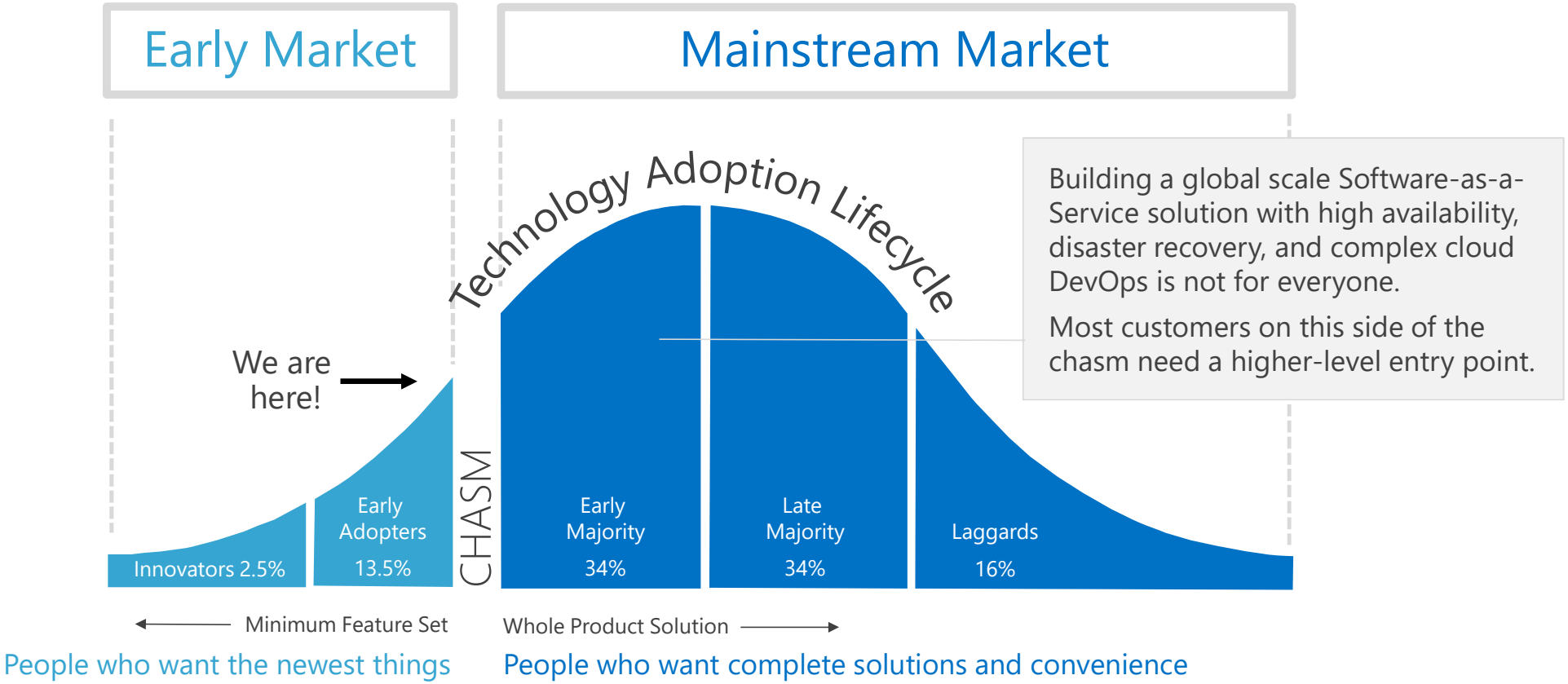
Deployment

Securing data

Fault tolerance

… and why IoT needs simplifying

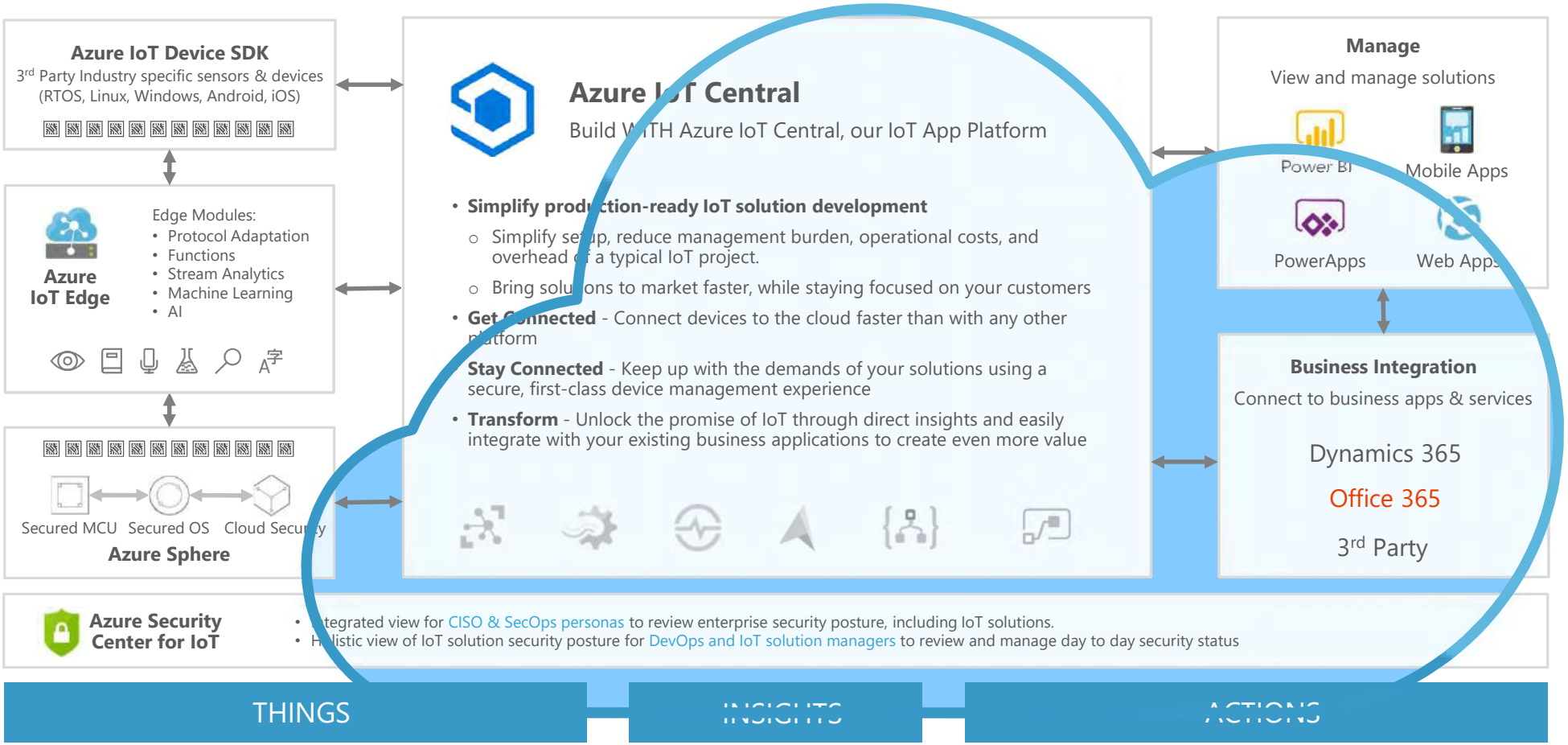
Crossing the chasm



Building a global scale Software-as-a-Service solution with high availability, disaster recovery, and complex cloud DevOps is not for everyone.

Most customers on this side of the chasm need a higher-level entry point.

Azure IoT Central



Powering Business Worldwide

Customer:
Eaton

Industry:
Power and Utilities

Size:
99,000 employees

Country:
Ireland

Products and Services:
Microsoft Azure
Azure IoT Central

Read full story here

Microsoft

"We've seen Microsoft make the cloud a core part of the company's fabric, and we trust that it will continue to lead the field in terms of cloud investment and scale."

—Michael Regelski, Senior Vice President and Chief Technology Officer – Electrical Sector, Eaton

Situation:

Eaton wanted to maintain its role as an industry technology leader and develop a set of internal platforms to support development of innovative products like its smart energy management circuit breaker (EMCB).

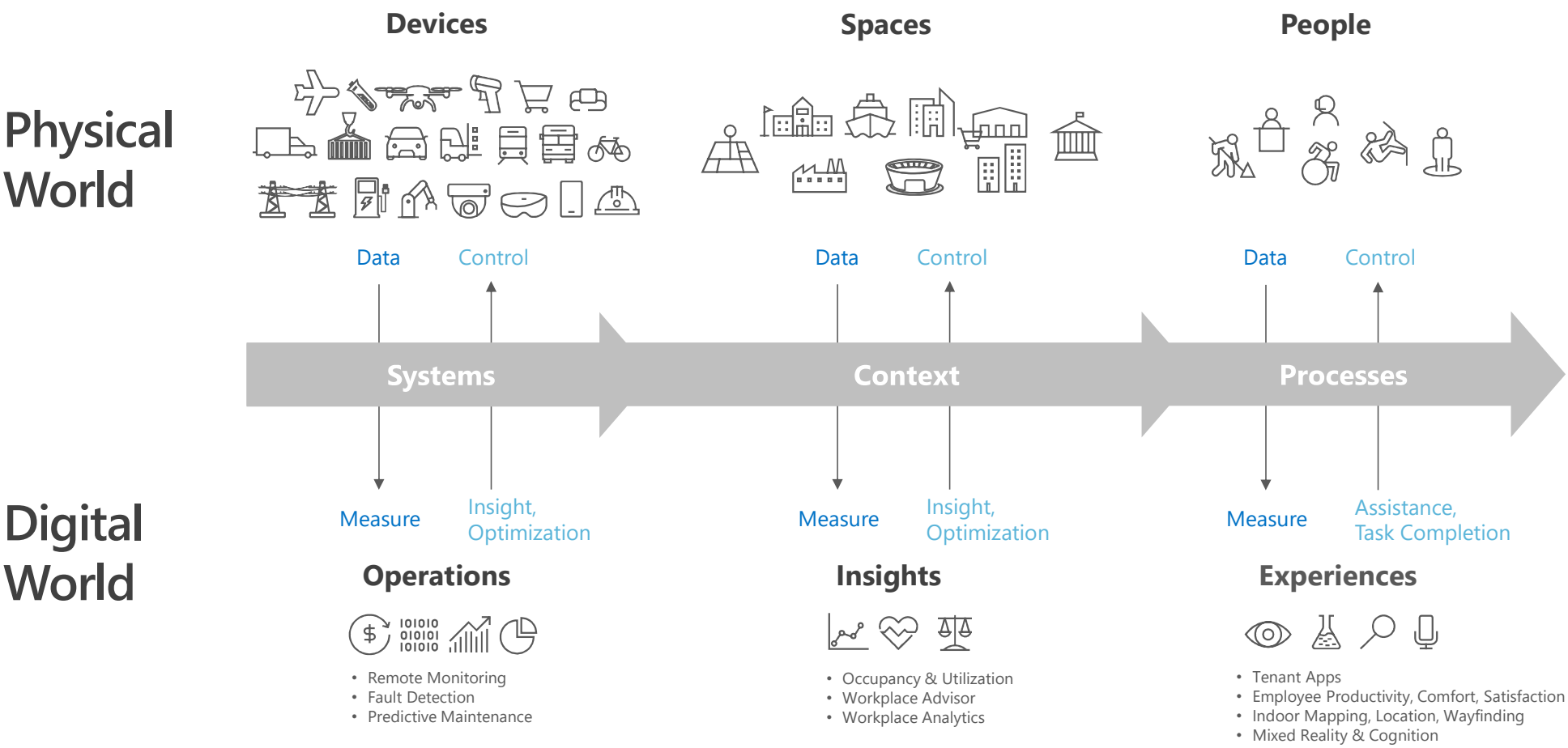
Solution:

Eaton has built multiple company-wide platforms on Microsoft Azure. The company is also looking into using Azure IoT Central as a platform for building apps that work with its connected solutions.

Impact:

The company has saved more than 1 million hours of engineering time by building applications on top of Azure and its internal platforms. Eaton has accelerated its entire DevOps lifecycle to simplify the delivery of feature enhancements, making the whole business more agile.

Digital Twins: fusing physical and digital



Growing interest in smart spaces

Market Forces	
Sustainability initiatives	Workplace trends
Pressure to minimize costs	Lease accounting rules

Audiences	Scenarios	Partners
Owners	Energy	Building Infrastructure
Operators	Space	Facility Management
Occupants	Productivity	Workplace Experience

Transformational change for grid

Market Forces	Customer Challenges
Renewable Energy ↑	Volatile Energy Demand ↑↓
Distributed Energy Resources ↑	Aging Grid - Investments ↑
IoT Devices ↑ & Digital Transformation ↑	New Scenarios ↑ (Solar, Electric Vehicle, ...)
Regulations ↑↓	Prediction Complexity ↑
Energy Price Trend ↓	Thermal Generation ↓ (Nuclear, Coal)

Fundamental Changes	
Bidirectional flow of Electric Power	Electricity Storage (large quantity)

Microsoft Confidential, For Internal & NDA Use Only

Work space → Space working

Annual cost per square foot ($):

300

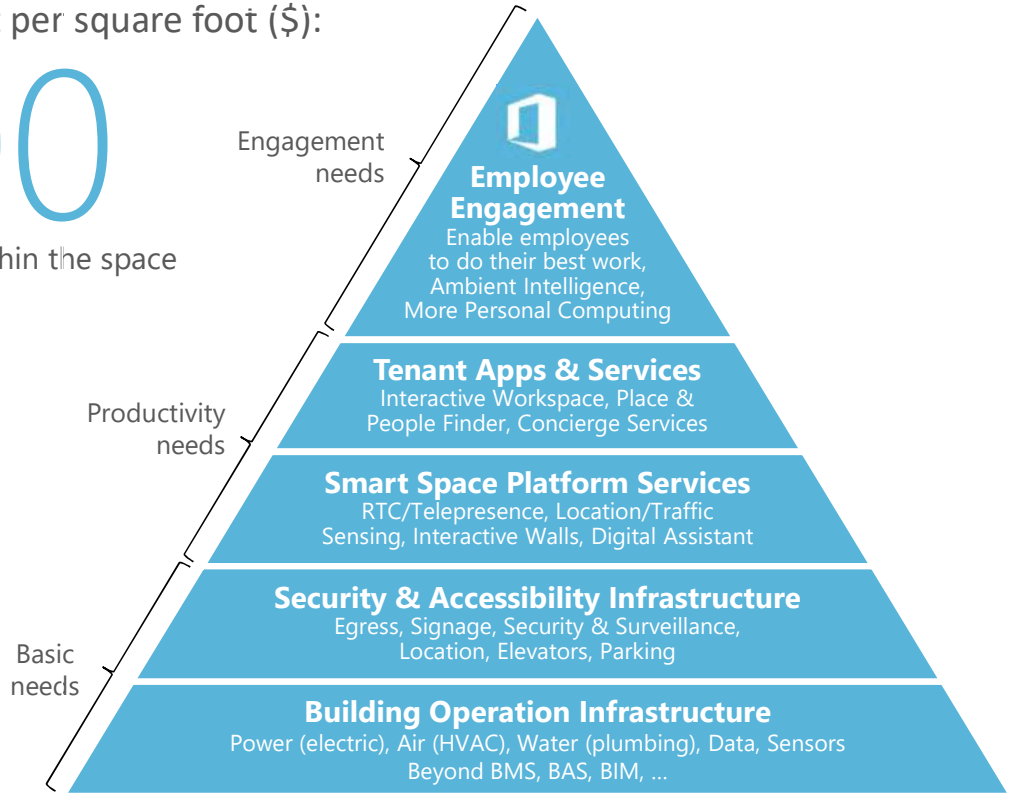
Employees within the space

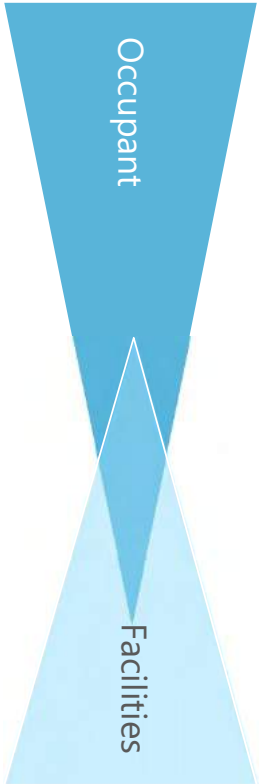
30

Leased space

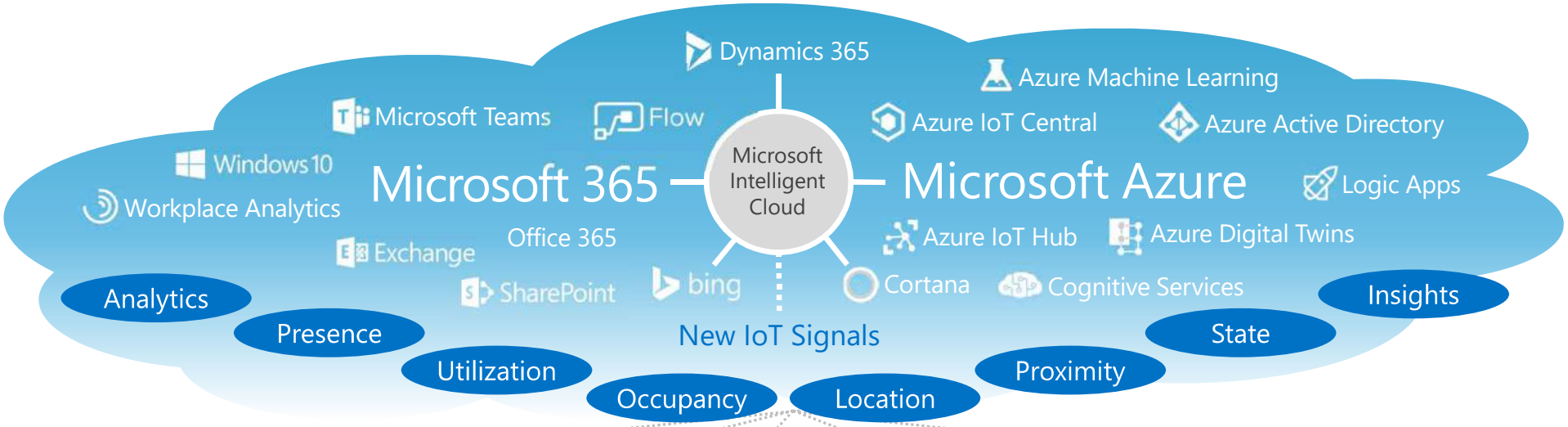
3

Energy





Microsoft intelligent cloud & IoT



Space Sensors

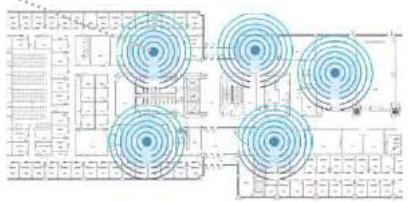
Quantified Self

Personal Sensors

Proximity

Workstation Sensors

Workspace Intelligence



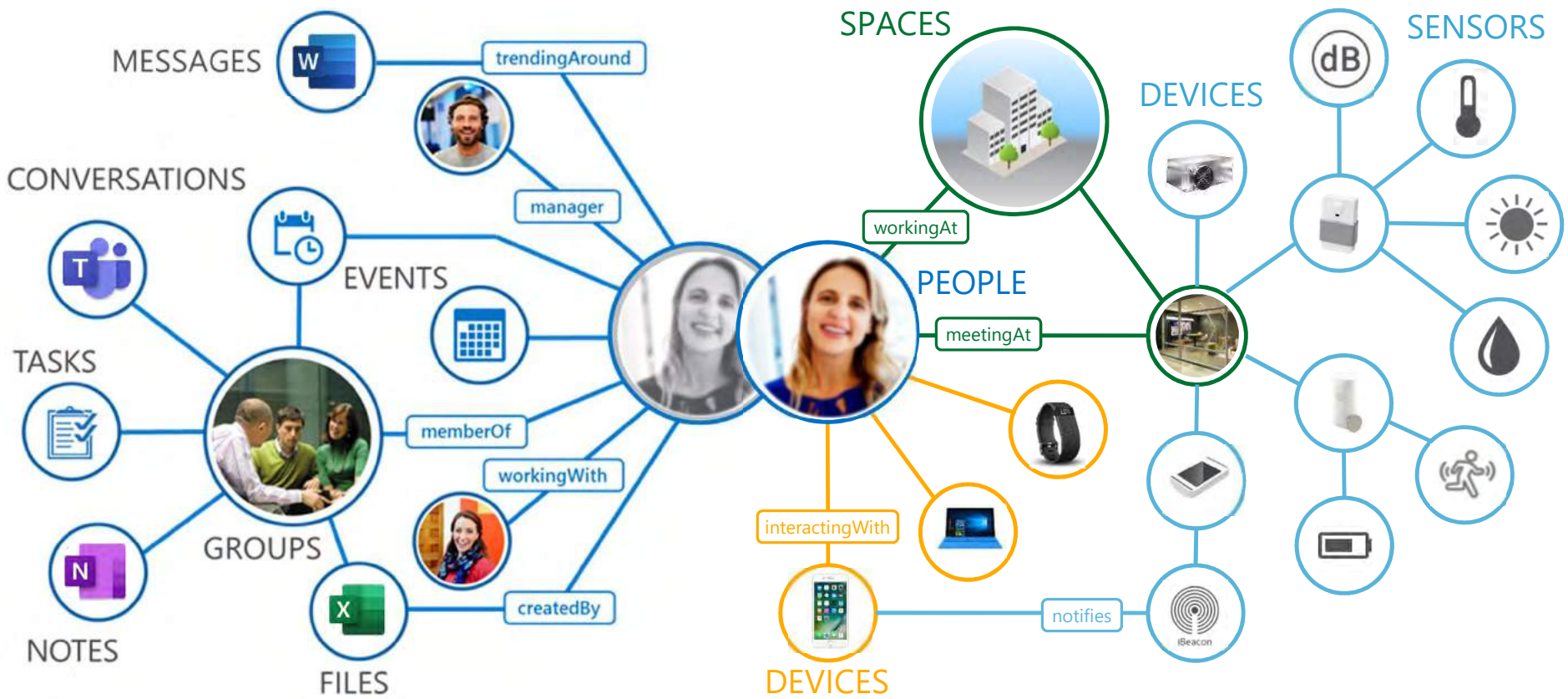
Building Sensors

Find & Fix

Meeting Room Sensors

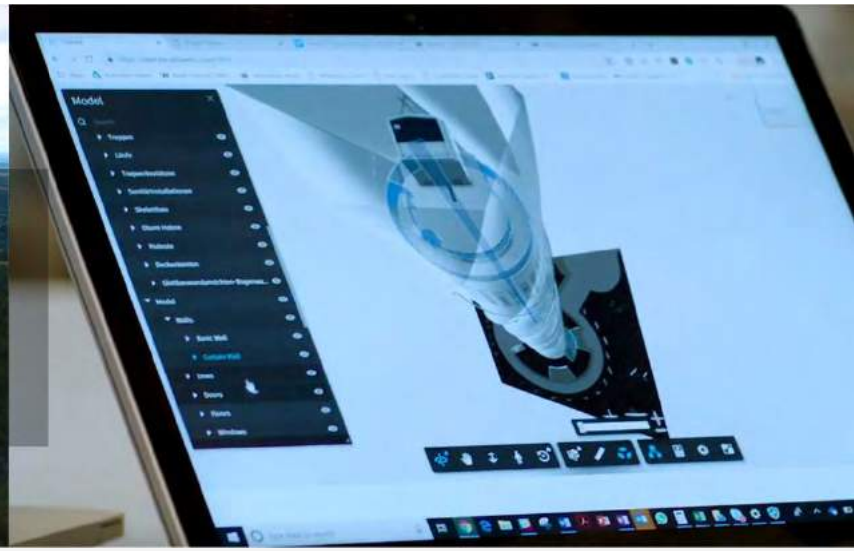
Meeting JumpStart

Spatial intelligence graph



willow
know your world

Industrialize and scale the WillowTwin™ solution through Microsoft's cloud infrastructure and extensive partner network.



Customer:
Willow

Industry:
Real Estate Software & Services

Size:
Medium (50 – 999 employees)

Country:
United States

Products and Services:
Azure Digital Twins
Azure SQL Data Warehouse
Azure Storage
Azure Stream Analytics
Azure Time Series Insights

Read full story here

Microsoft

"Willow values the relationships, insights, tools, resources and programs that Microsoft offers its partners to deliver growth."

— Joshua Ridley, CEO

Situation:

Willow's mission is to empower every person and every organization to connect with the built world in a whole new way, changing the face of buildings and infrastructure forever. Together with its employees, customers, partners and communities, the company aims to make the world more sustainable, connected, intuitive, and innovative.

Solution:

WillowTwin™ is a ground-breaking software platform that re-imagines the digital twin for the built world. WillowTwin™ integrates, analyses and manages data at scale, delivering insights to improve performance and experience of buildings and infrastructure networks.

Impact:

Harnessing the true potential of data to transform disconnected built assets into living, learning, and evolving digital twins, Willow accelerates digital transformation across both new and existing portfolios of buildings and infrastructure.

ICONICS makes smart buildings even smarter with Azure Digital Twins

Customer:
Willow

Industry:
Real Estate Software & Services

Size:
Not Available

Country:
United States

Products and Services:
Azure
Azure Digital Twins
Azure Machine Learning

Read full story here

"How do we grow our company? By leveraging the exciting new Azure Digital Twins platform to build our customers new solutions with unlimited scale, cost-effectiveness, and unprecedented insight."

— Russ Agrusa: President and CEO

Situation:

Once, building managers relied on "building whisperers" to improve the energy efficiency of their facilities. These engineers climbed onto rooftops, waded into pump rooms, and peered above ceiling tiles—inspecting and tuning each structure from top to bottom to run more efficiently.

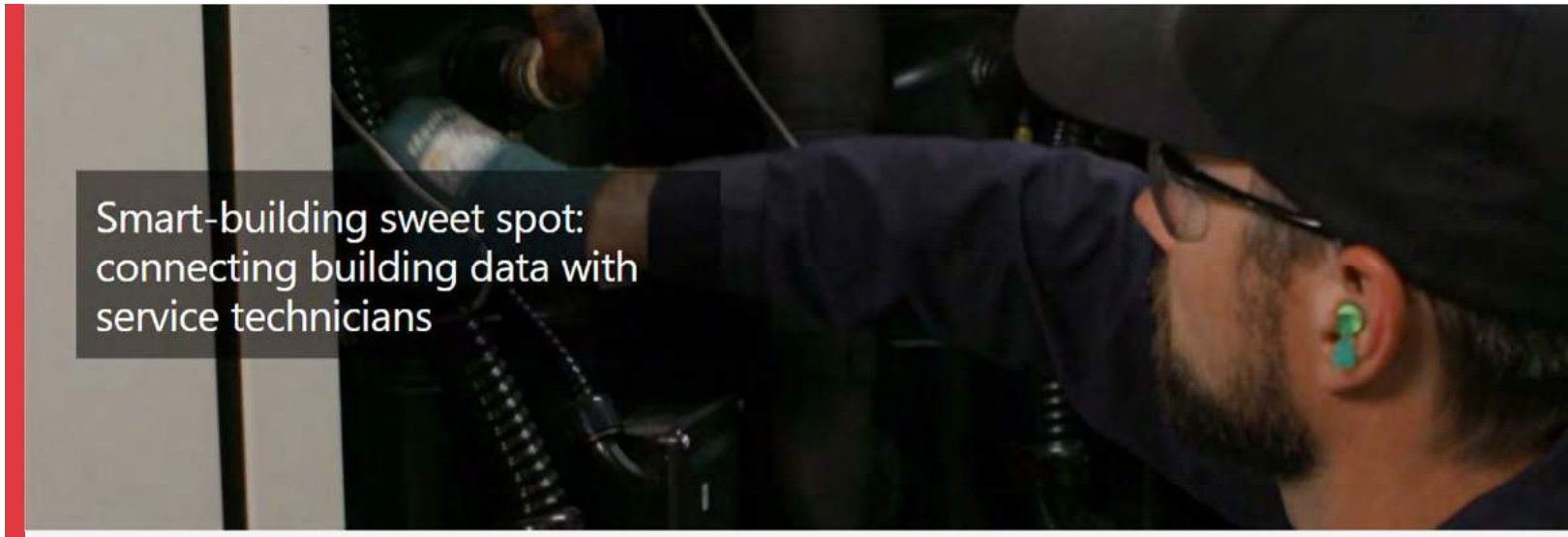
Solution:

Now organizations worldwide, including Microsoft, use ICONICS smart building software to automate and improve this optimization process. ICONICS relies on Microsoft Azure Digital Twins to boost software scalability and rapidly deliver innovative capabilities to customers, such as occupancy and spatial analytics.

Impact:

No longer must engineers manually inspect and tune buildings to run more efficiently. ICONICS smart building software collects and analyzes Internet of Things (IoT) sensor data from building management systems, giving owners visibility into their property's health, improved energy efficiency, and lower costs.

MacDonald-Miller
FACILITY SOLUTIONS®



Smart-building sweet spot: connecting building data with service technicians

Customer:
MacDonald Miller

Industry:
Professional Services

Size:
Large (1,000 – 9,999 employees)

Country:
United States

Products and Services:
Azure
Dynamics 365 for Field Service
Power BI

Read full story here

Microsoft

"With IoT-enabled Dynamics 365, we learn about—and fix—potential problems before the building maintenance manager or owner even knows they exist."

— Bradd Busick: Chief Information Officer

Situation:

Most large buildings today contain many islands of technology, typically from different vendors and completely independent of one another.

There is disconnect between the data being collected by building systems and the repair technicians who are maintaining them.

Solution:

Extend ICONICS with Microsoft Dynamics 365 for Field Service and Azure IoT services to create a connected field service solution. Now, when that furnace generates an alert in ICONICS, the alert is passed to Dynamics 365, which automatically creates a trouble ticket for our service staff.

Impact:

The technician shows up at the customer site knowing what the problem is, complete repair history and bringing the right parts and tools to be efficient, effective, and able to make a first-time fix. With IoT-enabled Dynamics 365, we learn about—and fix—potential problems before the building maintenance manager or owner even knows they exist.

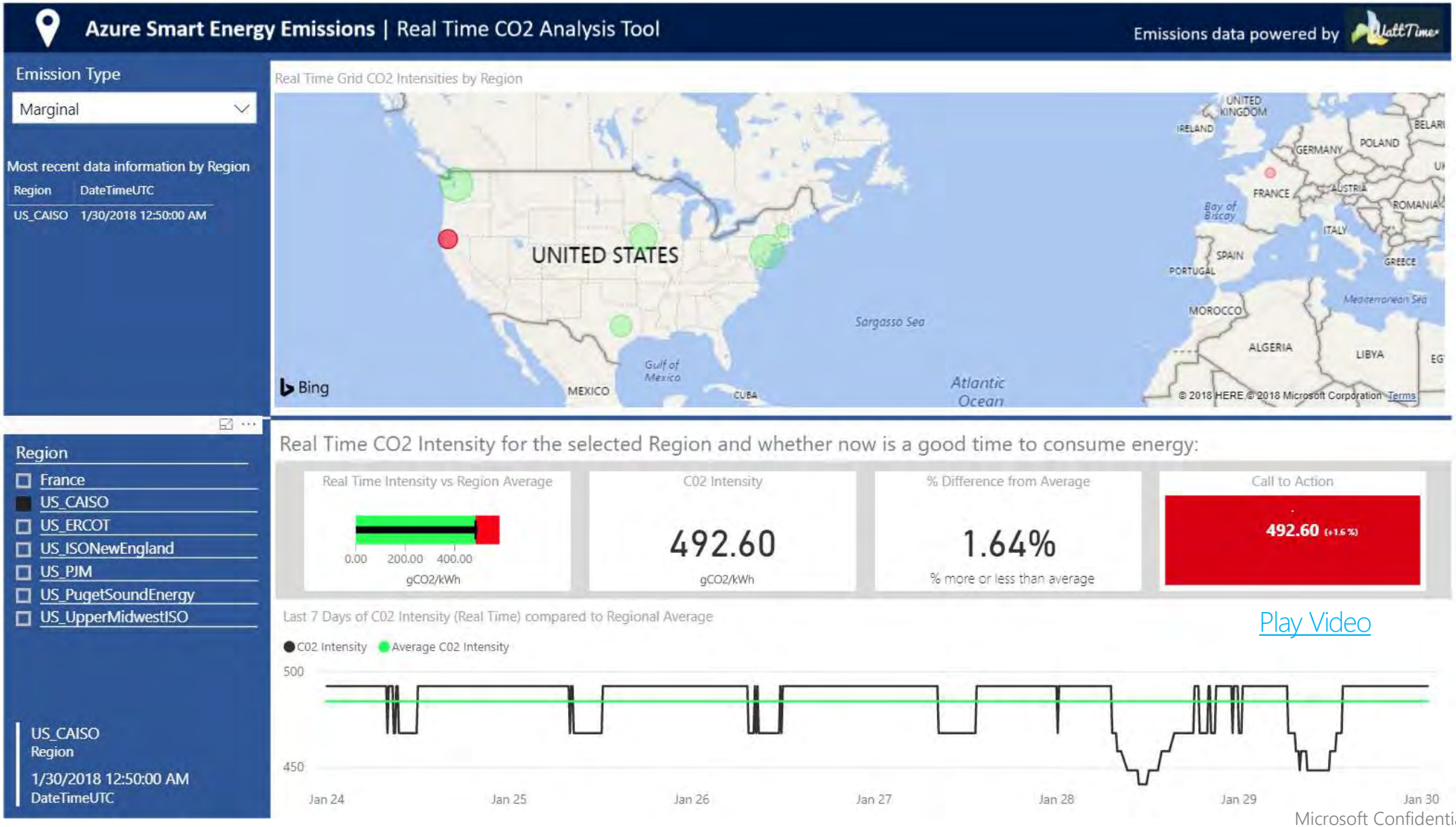
Johnson Controls and Digital Twins

https://www.youtube.com/watch?v=aAnZSfBkNZo

agder energi

Agder Energi and Azure IoT

https://www.youtube.com/watch?v=cxKphN8iVHE

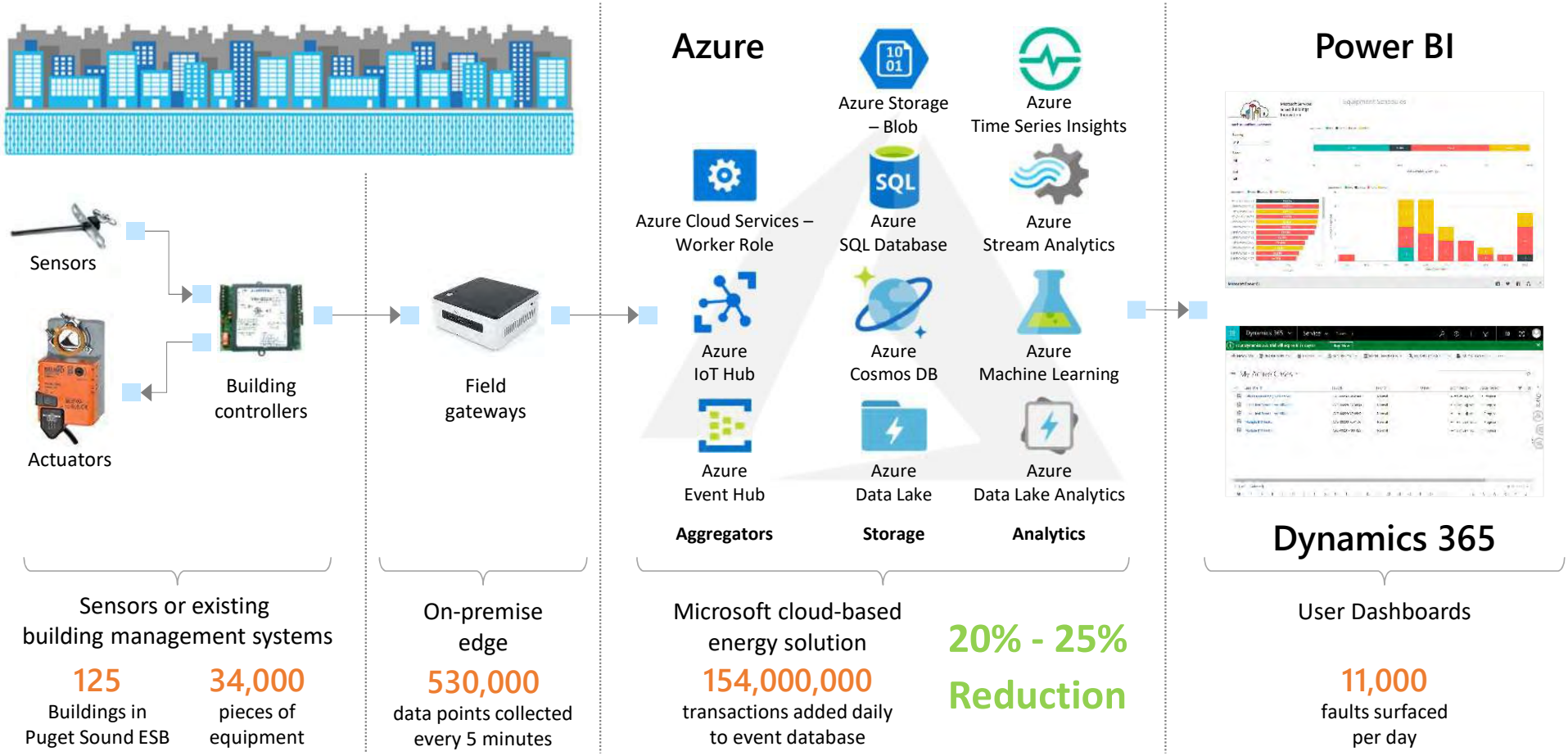


Play Video

Microsoft Confidential

We’re living it…

Smart campus & intelligent cloud



Sensors or existing building management systems

125 Buildings in Puget Sound ESB

34,000 pieces of equipment

On-premise edge

530,000 data points collected every 5 minutes

Microsoft cloud-based energy solution

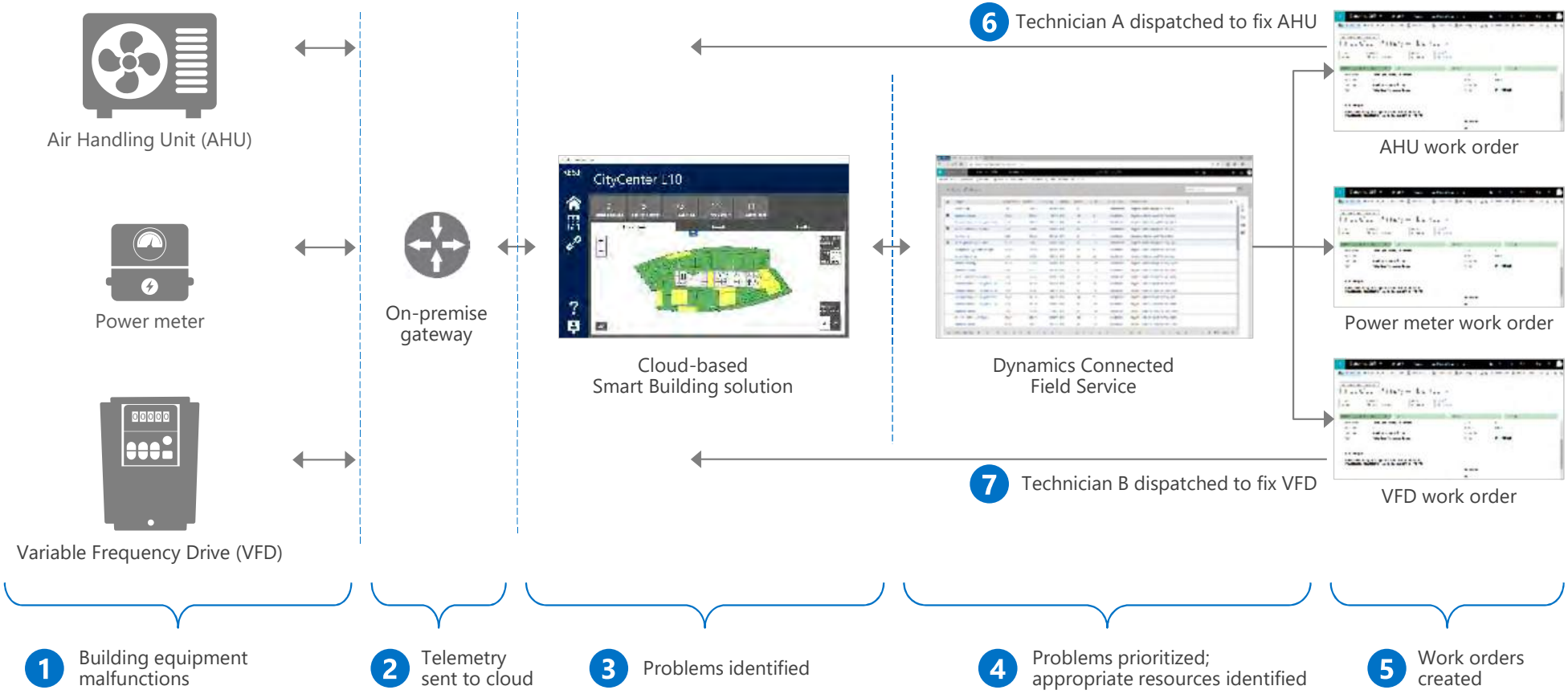
154,000,000 transactions added daily to event database

20% - 25% Reduction

User Dashboards

11,000 faults surfaced per day

Fixing the right thing with the right person, at the right time



Realcomm | IBcon 2019

Microsoft Booth and Partner Pavilion: 30+ partners showing innovation

AVNET Reach Further
AXONIZE
Bentley Advancing Infrastructure
BOSCH
CBRE
Cognizant
DOMAIN6 DIGITIZING THE REAL ESTATE MARKET
EDGE TECHNOLOGIES
ICONICS
Infosys
IoTium
Itron
KGS BUILDINGS
Johnson Controls
MTWO
LARSEN & TOUBRO
MacDonald-Miller FACILITY SOLUTIONS
PCL CONSTRUCTION
HPE POINTNEXT
realwear
SWITCH AUTOMATION
RELOGIX Workplace Performance
RIGADO
sagegreenlife
Steelcase
Trimble
view
willow know your world
wipro
yanzi

Customer momentum

BMW
Steelcase
Starbucks
willow
T-Systems
Schneider Electric
Chevron
Rolls-Royce
quorum
CBRE
BÜHLER
essity
Walmart
FUJITSU
KOHLER
coop
LIEBHERR
Walgreens Boots Alliance
PCL
JABIL
Roche
yanzi
CRESTRON
energisme
thyssenkrupp
SkyAlert
KUKA
powel
Volkswagen
ECOLAB
Purell
SANDVIK Coromant
evoqua
FINNING CAT
DUNAV NET
DUBAI WORLD TRADE CENTRE
BUNN
DRONEWORKS
ABB
DAIMLER
MARS
btt
Tetra Pak
Ford
ATF SERVICES
Schlumberger
ZPMC
COPADATA
RUPPINER KLINIKEN
GOJO
Johnson Controls
HERSHEY'S
origis
TOYOTA
GRUNDFOS
weka health solutions
HITACHI Inspire the Next
TOSHIBA Leading Innovation
ActionPoint
DELL
INDYCAR
BECKHOFF New Automation Technology
COATS
Rockwell Automation
ABUS
RAC
Mondelēz International
WEIR
Ville d'Ottignies-Louvain-la-Neuve
NAV CANADA
intel
Cummins
STEIGENBERGER AIRPORT HOTEL FRANKFURT
POLITECNICO MILANO 1863
fathym
targetbase
GE
STOCKROSE
Lufthansa
HSBC
TEXA
Panasonic
National Trust
avaterion
MÆRSK
Transport for London
THE YIELD
ABT
KONGSBERG
ATF SERVICES
bp
R.S.
Met Office
VILLAGE ROADSHOW LIMITED
Clear Bank
BENDIGO HEALTH
HISCOX
SKANSKA
asos
HarperCollins
Australian Government Department of Industry, Innovation and Science

Ecosystem momentum

IHV — Device — Connectivity Provider — ISV — Service Provider — System Integrator — Professional Services — Consulting — Solutions — Customer

Developer Community	Partner Ecosystem
Visual Studio, GitHub, hadoop, docker, php, nodeJS, Powershell, eclipse, python, ARM mbed, MySQL, Ruby, Java, mongoDB, Chef + Puppet	System Integrators & Advisors
	Devices

System Integrators & Advisors: accenture, CGI, EY, HCL, TATA, TATA CONSULTANCY SERVICES, HARMAN, T-Systems, DXC.technology, Infosys, pwc, MOQdigital, avanade, SOGETI, Cognizant, robotron, eBECS, LARSEN & TOUBRO, Reply, Capgemini, wipro, KPMG, Tech Mahindra

Schneider Electric, ABB, esri, OSI, ICONICS, Rockwell Automation, ActionPoint, Johnson Controls, COPADATA, energisme, SIEMENS, Schlumberger, DUNAV NET, SAP, codit, relayr, ptc, Honeywell, Hitachi Solutions, c3 IoT, Atos Worldline, conplement

ARROW ELECTRONICS, INC., SYNNEX, MESHSYSTEMS™, Insight, happiest minds, ICT, AVNET, Tech Data, INGRAM, Mobiliya, SIGMA, at&t

life.augmented, RENESAS, MOXA, CISCO, kontron, intel, ADVANTECH, DELL, libelium, Itron, FUJITSU, ARBOR, Raspberry Pi, Panasonic, NEXCOM, Qualcomm, cradlepoint, BECKHOFF, Hewlett Packard Enterprise, HITACHI, embedded systems, TOSHIBA, Toradex

Connecting the dots

Connected Office
Smart buildings & more productive people
https://www.youtube.com/watch?v=uhfjeVNI9b0

Connected Building
Microsoft IoT for Smart Buildings
https://www.youtube.com/watch?v=d55rBuB9D7s

Connected Grid
Smarter grid with Agder Energi in Norway
https://www.youtube.com/watch?v=cxKphN8iVHE

Connected Factory
Manufacturing
https://azure.microsoft.com/en-us/features/iot-accelerators/connected-factory/

Connected Car
Microsoft connected vehicle platform
https://www.youtube.com/watch?v=rFo4l54vlw4

Connected Agriculture
FarmBeats tracks soil, moisture data 24/7
https://www.youtube.com/watch?v=pDgjOHY7sMI
Enabling precision agriculture with AI
https://www.youtube.com/watch?v=KTvdjcU0lf8

Microsoft Azure

Productive + Hybrid + Intelligent + Trusted

Customer:
Oasen

Industry:
Nonprofit

Size:
Medium (50 – 999 employees)

Country:
Netherlands

Products and Services:
Microsoft Azure
Azure IoT Central
Dynamics 365 for Field Service

Read full story here

"Everything we build with Azure drives bottom-line cost savings, giving us more for innovation. And the beauty of Azure IoT Central is that we can test and prove easily before going live."

— Nino Marino: CIO, Oasen

Situation:

Oasen is a nonprofit social enterprise that supplies 48 billion liters of high-quality drinking water each year to 750,000 residents across the South Holland region of the Netherlands.

On average, the company replaces 40 kilometers of pipeline every year to keep the network in good shape.

Solution:

Oasen, which means 'bringer of life', is using Microsoft Azure IoT to build a smart grid infrastructure that will achieve those aims through business improvement and process automation. The company has begun extracting data from smart water meters with Azure IoT.

Impact:

In the first year Oasen was able to anticipate 50 percent of all burst water mains saving hundreds of liters of water and eliminating repair costs.

Sagegreenlife keeps living walls green with an easy-to-use IoT solution

Customer:
SageGreenLife

Partner:
Cradlepoint

Industry:
Smart Spaces

Size:
Small (1 - 49 employees)

Country:
United States

Products and Services:
Microsoft Azure
Azure IoT Central

Read full story here

"This IoT solution will allow us to put eyes and ears on the products that we didn't have before. Our promise to the customer is: you don't have to worry about anything. All you need to do is enjoy the look and benefits of this product in your space."

—Harry Eschel: Vice President of Products, Sagegreenlife

Situation:

Sagegreenlife's living walls bring the benefits and beauty of nature into man-made spaces. The company needed a way to remotely monitor their irrigation systems and ensure optimal plant wall performance but didn't have the developer expertise in-house.

Solution:

Sagegreenlife uses Azure IoT Central and Cradlepoint LTE network solutions to detect and resolve issues before they affect plant health.

Impact:

With this IoT solution, Sagegreenlife can provide an exceptional customer experience, deliver new insights across the organization, and scale its business on a highly secure, easy-to-use, customizable platform.

Microsoft Graph

http://graph.microsoft.com

Smart Building Solutions

Energy Management	Space Utilization	Occupant Experience
Building Automation Systems	Indoor Maps	Room Booking
Command and Control	Microsoft Graph	Routing
Fault Rule Diagnosis	Spatial Cognition	Meeting Jumpstart
Predictive Maintenance	Asset Tracking	Workplace Analytics
	Facilities Management	Command and Control

PCL CONSTRUCTION

Customer:
PCL

Industry:
Professional Services

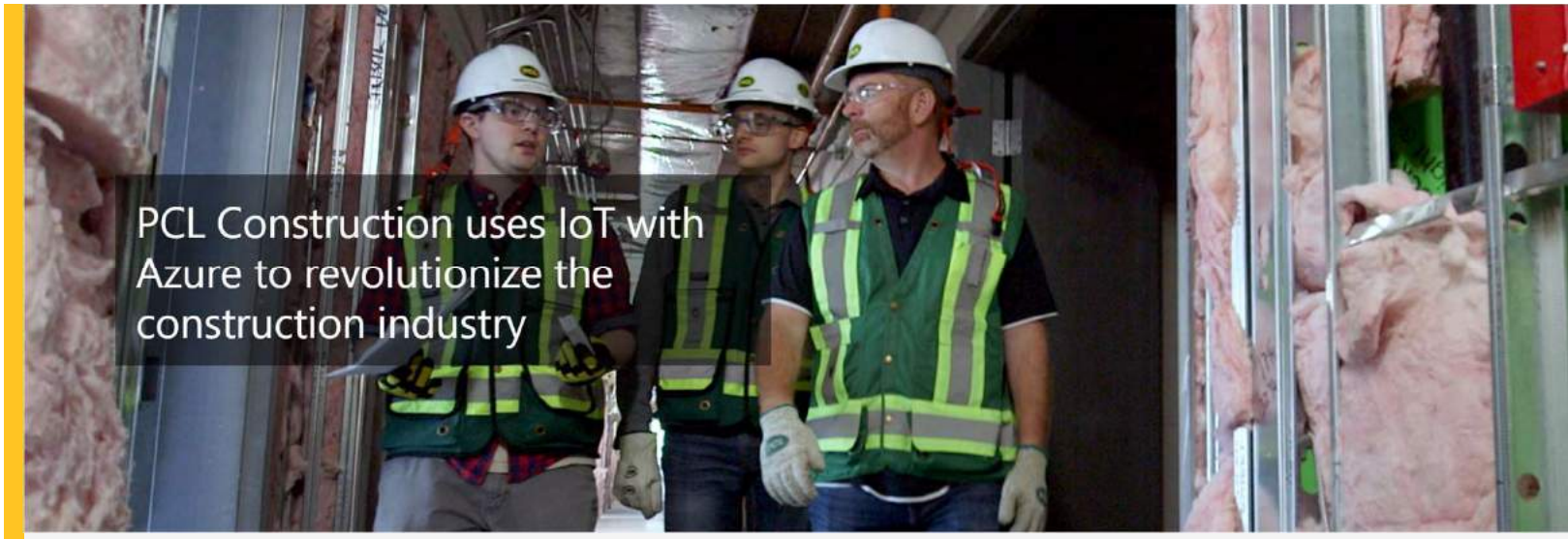
Size:
Large (1,000 - 9,999 employees)

Country:
Canada

Products and Services:
Azure
Azure Data Lake Analytics
Azure Data Lake Store
Azure Digital Twins
Azure IoT Edge
Azure IoT Hub
Azure Stream Analytics
Azure Time Series Insights
HoloLens
Power BI

Read full story here

Microsoft



"Using data from Azure IoT sensors and advanced analytics, we can increase safety, enhance productivity, and focus our efforts on improving customer satisfaction. It makes us smarter builders."

— Chris Palmer: Senior Manager for Advanced Technology Services

Situation:

PCL Construction, headquartered in Edmonton, Canada, is turning the centuries-old construction industry on its head with a push toward digital technology and cloud services.

Solution:

Using Microsoft Azure and Azure IoT technologies, PCL created the mobile-ready Job Site Insights™ application to provide a single-pane view into all aspects of construction.

Impact:

By gathering and analyzing IoT data, PCL is improving its processes to increase safety, efficiency, and productivity while positioning itself as a future-ready builder.

Steelcase

Steelcase Demonstrates the Smart and Connected Workplace with New IoT-Powered Solutions

Customer:
Steelcase

Industry:
Consumer Goods

Size:
Large: 1,000 – 9,999 employees

Country:
United States

Products and Services:
Microsoft Azure
Azure Digital Twins
Azure Time Series Insights

Read full story here

Microsoft

"We can use data to drive a better experience to help measure performance and improve employee potential. We start from the question of how can we help companies and their employees have an optimal day at work"

— Terry Lenhardt, CIO

Situation:

Steelcase worked with a growing company that was pinched for space and found that the utilization rate across their workplace was just 35 percent. Using data and analytics to reconfigure the space, they were able to increase the utilization to 51 percent in a short period of time.

Solution:

Steelcase developed a cloud-enabled space-sensing network on the Azure IoT platform. It helps organizations create workplaces that respond to people's needs while optimizing real estate investments.

Impact:

Steelcase Workplace Advisor can deliver advanced analytics around the clock, making it possible to receive real-time statistics alongside enterprise reliability and security. Steelcase then takes this information and layers their own expertise on top of it, giving organizations the ability to see exactly how their spaces are being used.

CBRE

Customer:
CBRE

Industry:
Real Estate Software & Services

Size:
Extra Large (90,000+ employees)

Country:
United States

Products and Services:
Azure
Azure Digital Twins
Azure Kubernetes Service

Read full story here

Microsoft

CBRE | host

Room Wayfinding | Room Scheduling | Room Availability | Room Amenities

"The Host mission is to increase individual well-being, personal productivity and organizational effectiveness through people-led, technology-enabled services. Put simply: our goal is to help people work smarter and delight in doing it."

Situation:

The Host mission is to increase individual well-being, personal productivity and organizational effectiveness through people-led, technology-enabled services. Put simply: our goal is to help people work smarter and delight in doing it.

Solution:

An enterprise-grade technology platform features a robust mobile experience that allows users to navigate the workplace, schedule meetings with colleagues, reserve workspaces, use food and beverage services, and access building and concierge services.

Impact:

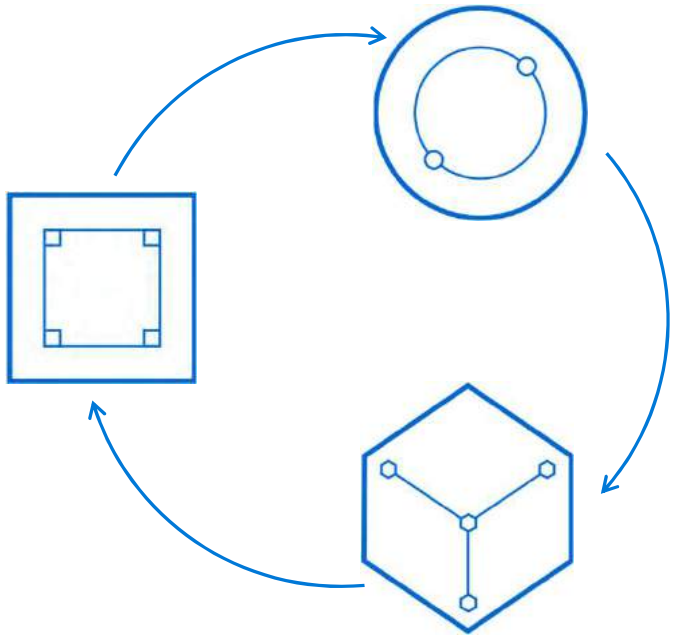
An experience platform that connects the employee to the environments, amenities and communities that matter the most. An AI-driven experiences and recommendation engine learns over time, delivering highly personalized experiences and ensures that space needs are met sustainably and efficiently for building operators.

AZURE SPHERE

An end-to-end solution for securing MCU powered devices

The **Azure Sphere OS** secured by Microsoft for the device's 10-year lifetime to create a **trustworthy platform** for new IoT experiences

New **Azure Sphere certified MCUs**, from our silicon partners, with built-in Microsoft security technology provide connectivity and a dependable **hardware root of trust**.



The **Azure Sphere Security Service** guards every Azure Sphere device; it **brokers trust** for device-to-device and device-to-cloud communication, **detects emerging threats,** and **renews device security.**

Azure Sphere builds upon and extends Microsoft's heritage of enhanced security and trustworthiness at every point in the IoT journey. With the newest class of microcontrollers, plus the OS and cloud technologies that secure them, Azure Sphere provides healthcare organizations, patients, and regulators peace of mind they can rely on.

Microsoft Confidential – Shared Under NDA Only

Resources

Overview

- Azure IoT Overview: https://azure.microsoft.com/overview/iot/
- Dynamics 365 for Field Service: https://dynamics.microsoft.com/field-service/overview
- Microsoft Workplace Analytics: https://www.microsoft.com/microsoft-365/partners/workplaceanalytics

Azure IoT Product Pages

- Azure IoT Central: https://azure.microsoft.com/en-us/services/iot-central/
- Azure Digital Twins: https://azure.microsoft.com/en-us/services/digital-twins/
- Azure Maps: https://azure.microsoft.com/en-us/services/azure-maps/
- Azure IoT Solution Accelerators: https://www.azureiotsolutions.com/Accelerators
- Azure IoT Hub: https://azure.microsoft.com/en-us/services/iot-hub/
- Azure IoT Edge: https://azure.microsoft.com/en-us/services/iot-edge/
- Azure Sphere: https://azure.microsoft.com/en-us/services/azure-sphere/
- Azure Time Series Insights: https://azure.microsoft.com/en-us/services/time-series-insights/

Questions

U.S. DEPARTMENT OF ENERGY

Thank You

Provide feedback on this session
in the Summit App!

Download the app to your mobile device or go to
event.crowdcompass.com/bbsummit19