Temple University's Microgrid and 25 Years of Lessons Learned

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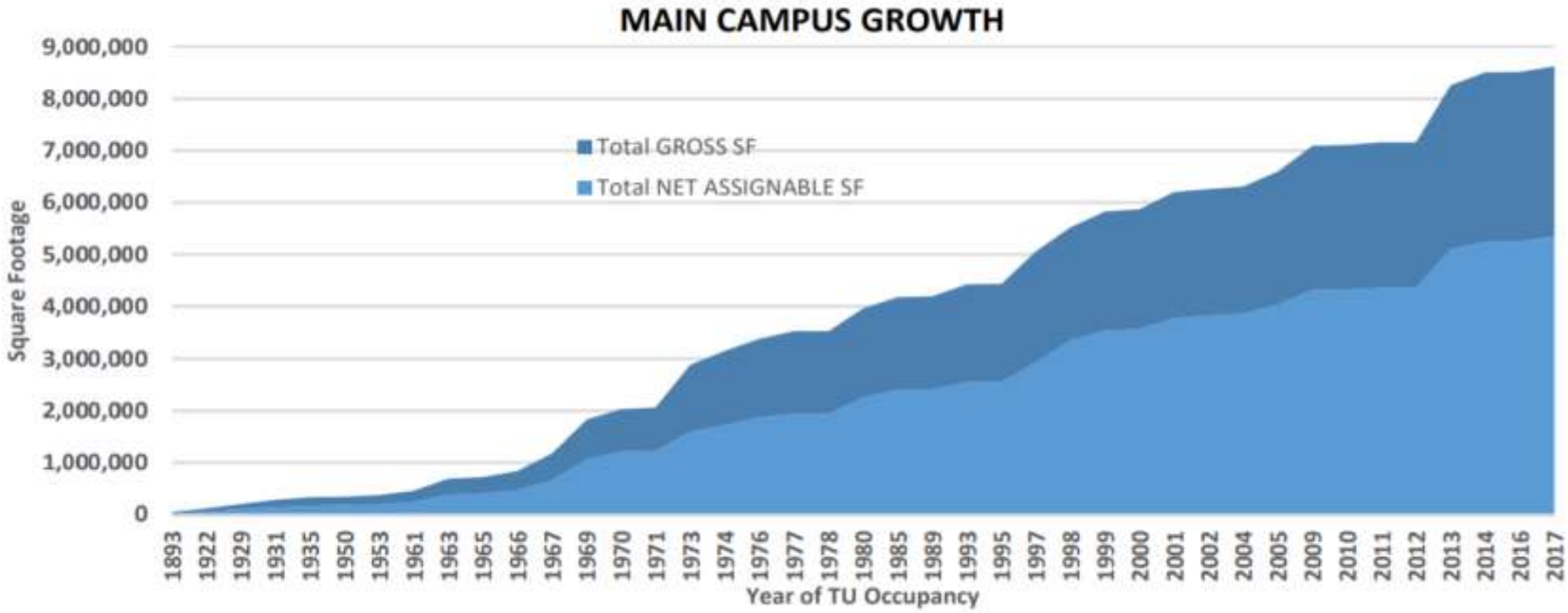
Lots of Lessons Learned After the First 25 Years!

- Temple started-up its $16million Standby Electric Generating Facility (SEGF) in 1993, to form its first 16MW microgrid
- I will go through some of the “whys”, “whats”, “hows” of this microgrid’s conception, its implementation, the results of operations, and how we communicate these results
- Has saved Temple about $67million in electricity costs since 1993 against the pre-construction predictions of approximately $75million over the same 25 years

Introduction to Temple University

- Temple operates two large campuses in economically challenged North Philadelphia (plus several satellites both US and international)
  - Main Campus 78 bldgs., 8,561,032 GSF
  - Health Sciences Campus 2 miles north of Main, 30 bldgs. 3,844,221 GSF (including hospital)
- Total undergraduate enrollment of 29,550 students
- State-related university receiving some portion of funding from Commonwealth of Pennsylvania
- Continued growth in all areas

Growth in Square Footage



Note: non-linear scale!

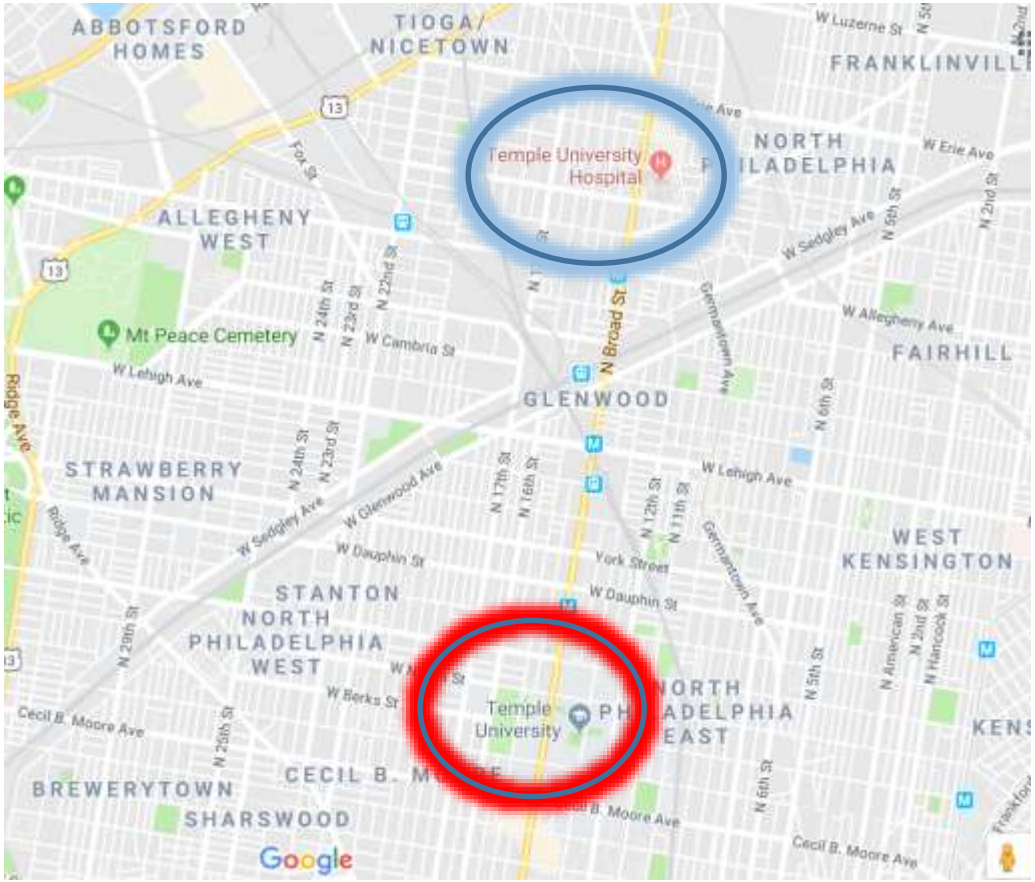
Temple – Part of Main Campus Nestled in the Neighborhoods of North Philly

Temple's Position Relative to Center City Philadelphia – about 2 miles north of City Hall, short trip to the Constitution Center and Liberty Bell.

Temple's Health Sciences Campus 2 Miles North of Main Campus – No Standby Generator Plant Here

Temple Main Campus and Health Sciences Campus – separated by about 2 miles.

No generator plant at the Health Sciences Campus



Brief Introduction of Myself

- BS in Applied Physics and Electronics
- MS in Information Science
- Energy engineer since 1988, licensed PE in PA, passed the CEM in early 1990s, LEED AP since early 2000s
- Worked for consulting energy engineers, then an ESCO, then had my own energy engineering practice that I sold, then worked at another ESCO then…
- …Energy Manager at Temple since August 2015

Introduction

- This microgrid predates my time at Temple by over 22 years and is a testament to long-range planning
- Why is it a microgrid (and not just an emergency generator)?
  - It can black start and can operate in island mode
  - It can carry much of the electric load of Main Campus, not just life safety equipment
  - Connects to approximately 47 large educational, research and dormitory buildings 6.3million gross square feet (and their support infrastructure such as boiler and chiller plants)
  - Some large loads are covered using emergency generators

Why Was It Needed?

- Up to deregulation in the 1990s Philadelphia's HT electric tariffs carried massive penalties for summer peak kW
- Temple used mostly steam absorption chillers to avoid the kW charges
- One (1) additional kW on a summer day (or night) could cost $124 over the following year due to:
  - Demand ratchets
  - Declining kWh block structure based on the peak (ratcheted) kW

Why Was It Needed? (cont…)

- Pennsylvania's industrials had been hurting badly for decades under this tariff
- Partial relief came with the Large Interruptible Load Rider ("LILR") which created an interruptible electric service
- Kurt Bresser (Temple's previous Energy Manager and now Temple's Director of Utilities and Energy Management) helped hatch "The Solution"
- Used LILR to take advantage of interruptible electric rates!

Why Was It Needed? (cont…)

- Risks in implementing were mostly due to potential regulatory and rate changes
- Contingency plans showed plant operating as a peak shaver if LILR disappeared – but with greatly reduced savings potential
- In the end LILR remained but PA deregulated wholesale power markets in the late 1990s

What Was Built?

- Conceived at the outset to allow Main Campus operations to continue in the event of a PECO “LILR” interruptible electric event
- A 16 MW natural-gas fired generator plant – twenty 16-cylinder recip engines paired up through common crankshafts driving 10 x 1600 kW electric generators
- Campus peak at the time was 12 MW – room to grow
- No heat recovery – designed only to operate as a standby electric generating facility. Today, 25 years on, there are less than 2500 hours of runtime on each engine.

Generator Plant Control Room

(Construction picture taken in 1993)

Generator Plant – Tandem Engines and End-Mount 1600kW Generator

(Construction picture taken in 1993)

What Was Built? (cont…)

- Cost of implementation was initially projected at about $12million in 1990 but changes in scope made actual cost around $16million with operation commencing in June 1993
- Electric cost savings were projected to be about $3million/year using interruptible LILR rate rider
- Bonds were issued for this and other major projects

What Was Built? (cont…)

- Net present value in 1993 dollars of 25-years savings stream $33,880,705 using bond coupon rate of 7.25% as discount rate
- Add back in initial investment of $16,000,000
- Yields net present value of plant after investment of $17,880,705 in 1993 dollars

A Word About Numbers

- Numbers are somewhat simplified
- Maintenance, financing, and fuel costs are called out where pertinent
- Demand response payments are not included

Original 1990 Analysis – Engineering Numbers

These numbers exclude operating costs but fuel and maintenance costs have been low compared to savings

MAIN CAMPUS ELECTRIC: HT vs. NIGHT RIDER

(Major account # 024-12-94-160015)

FY	HT (Base Rates)	Night Rider (BaseRates)	Cost Avoidance
90/91	$5,745,812	$2,706,800	$3,039,012
91/92	$5,934,124	$2,485,433	$3,448,691
92/93	$5,816,297	$2,572,031	$3,244,266
93/94	$5,652,511	$2,622,361	$3,030,150

Night Rider average annual cost avoidance = 55 %

Part of Original 1990 Analysis – Bonding Projection

WITH 30 YEARS OF NIGHTRIDER		TRANSFER FUND ADDTIONS TRNSF OF GENERATOR COST SAVINGS
BALANCE 7/31/91		
06/30/92	1	0
06/30/93	2	2,427
06/30/94	3	2,521
06/30/95	4	2,619
06/30/96	5	2,721
06/30/97	6	2,827
06/30/98	7	2,937
06/30/99	8	3,051
06/30/2000	9	3,169
06/30/2001	10	3,292
06/30/2002	11	3,420
06/30/2003	12	3,553
06/30/2004	13	3,691
06/30/2005	14	3,834
06/30/2006	15	3,982
06/30/2007	16	4,137
06/30/2008	17	4,297
06/30/2009	18	4,463
06/30/2010	19	4,636
06/30/2011	20	4,815
06/30/2012	21	5,002
06/30/2013	22	5,195
06/30/2014	23	5,396
06/30/2015	24	5,604
06/30/2016	25	5,821
06/30/2017	26	6,046
06/30/2018	27	6,279
06/30/2019	28	6,521
06/30/2020	29	6,772
07/01/2021	30	7,033
		126,063

Note that these estimates included 4% electricity inflation and therefore escalated rapidly towards the end

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Entering the Deregulated Era

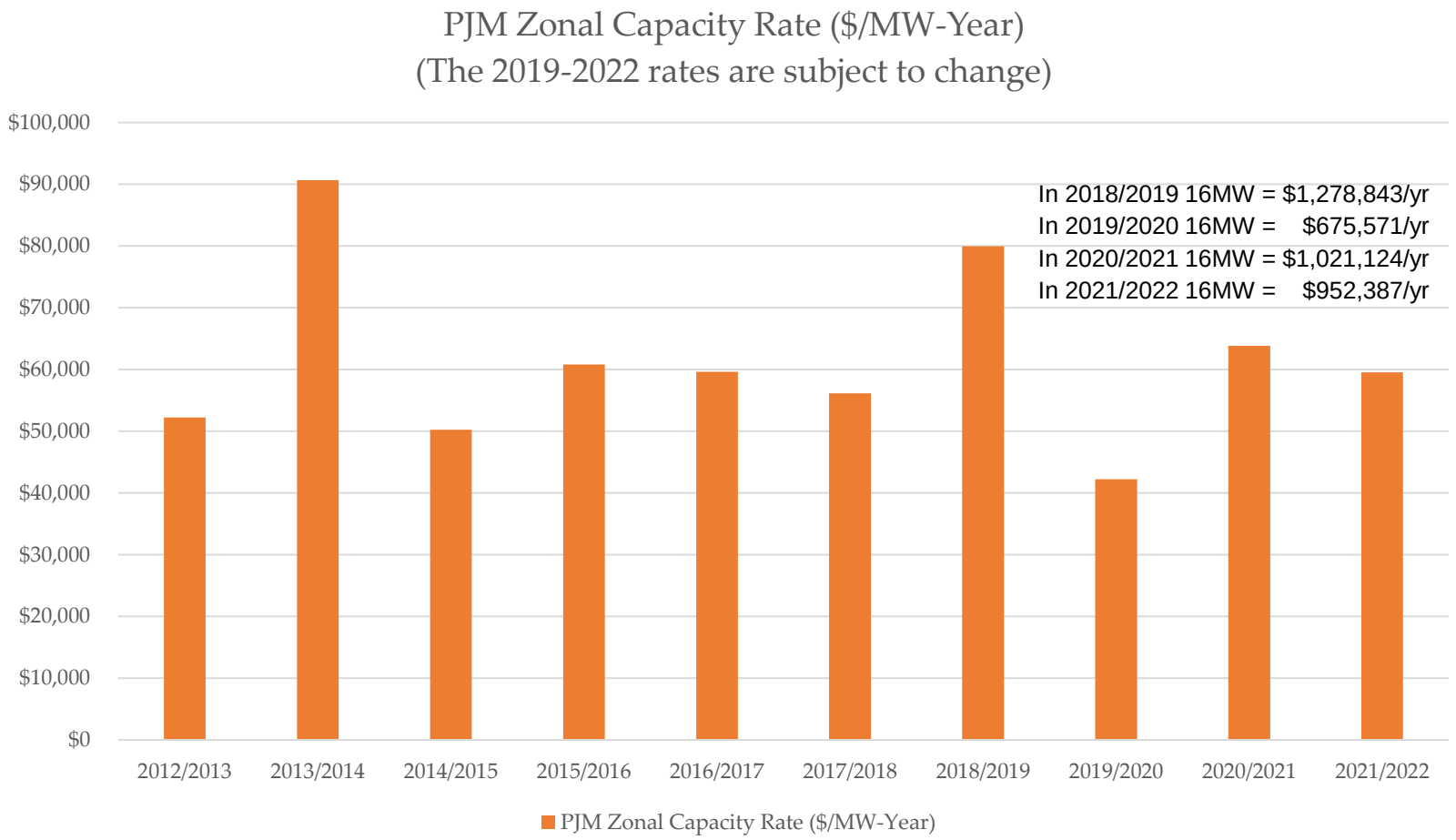
- In 1997 small steps were taken to deregulate PA's electric market, starting with residential service
- By 2009 Temple and most large commercial and industrial users were buying commodity from third party suppliers
- But high demand charges at the local Electric Distribution Company (EDC) level (PECO) were largely swapped for capacity charges at the Regional Transmission Organization (RTO) level (PJM in Temple's case)
- Capacity has to be paid for one way or another

Entering the Deregulated Era (cont…)

- Fortunately the standby electric generating facility found new life in the deregulated era
- Playing by the continually changing rules set by PECO and PJM, the generator plant continues to put electric cost management into our hands

The Deregulated Era (Cont…)

- In the 2018/2019 PJM season (June 1, 2018 to May 31, 2019) PJM capacity charges are $79,800/MW-year set from peak load contributions (PLC) on 5 coincident peak (5CP) days between June 1, 2017 and Sept 30, 2017
- By operating the plant up to about 15 times each summer (on so-called “Red Days”), 4 hours per event we avoid capacity charges of $79,800/MW-year x 16MW = $1.2million dollars this program year


PJM Zonal Capacity Rate ($/MW-Year)
(The 2019-2022 rates are subject to change)
$100,000
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
2012/2013
2013/2014
2014/2015
2015/2016
2016/2017
2017/2018
2018/2019
2019/2020
2020/2021
2021/2022
In 2018/2019 16MW = $1,278,843/yr
In 2019/2020 16MW = $675,571/yr
In 2020/2021 16MW = $1,021,124/yr
In 2021/2022 16MW = $952,387/yr
PJM Zonal Capacity Rate ($/MW-Year)

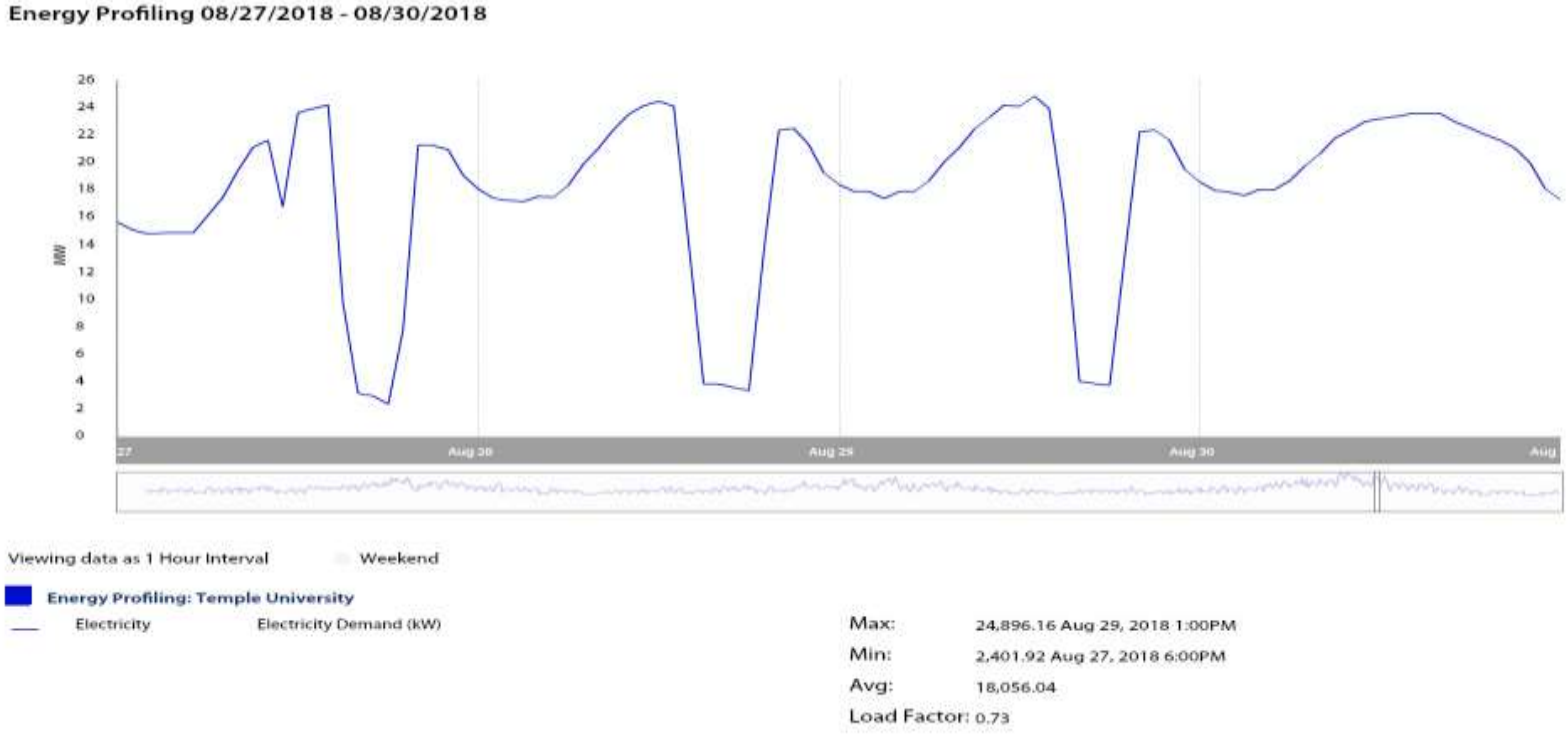
The Deregulated Era (Cont…)

- The plant also earns substantial demand response payments simply for being available at short notice
- The deregulated era created or expanded new markets which were not previously available to end-users like Temple

Results?

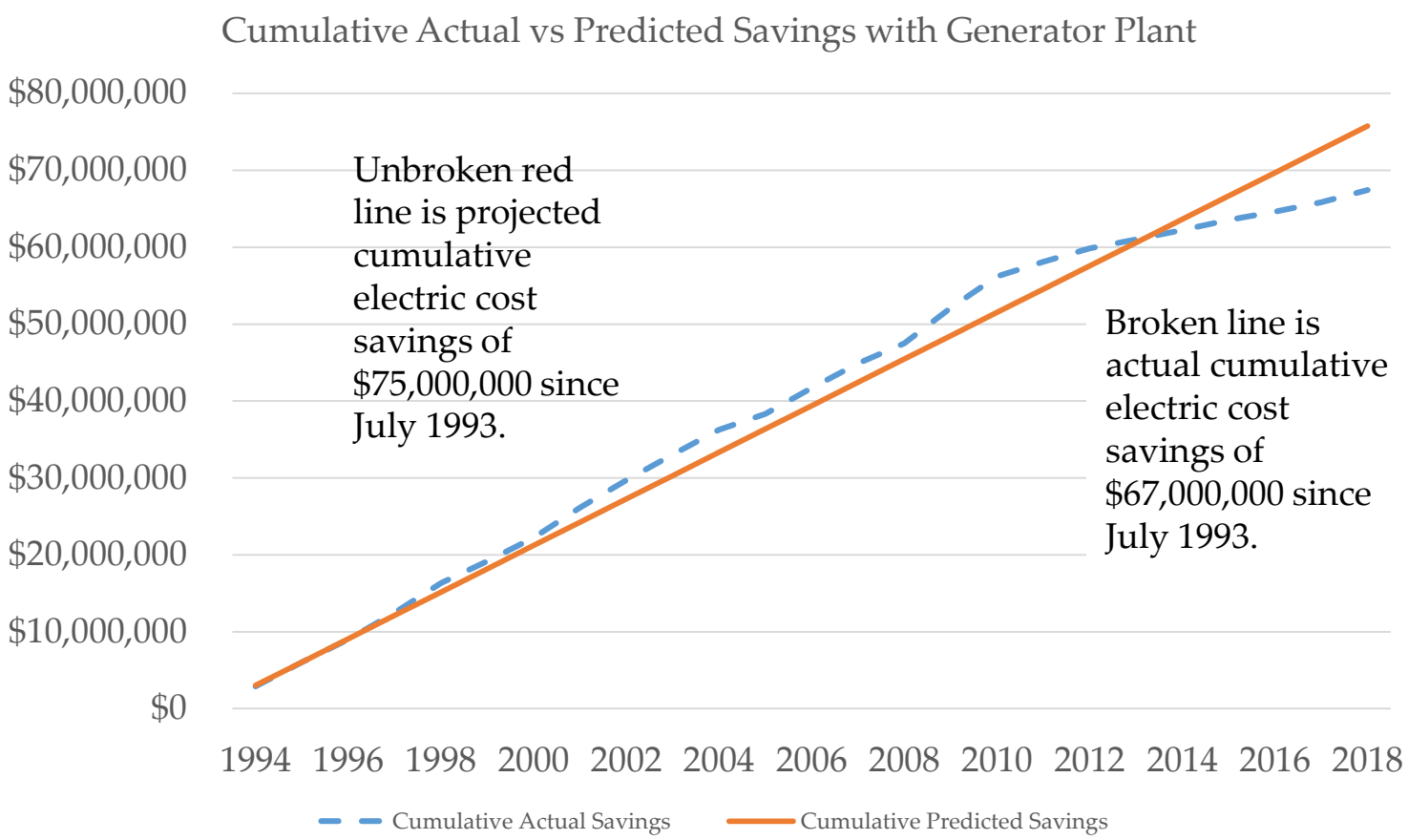
- Results were excellent from Day 1 and continue
- Today, unmodified peak load is around 22MW combined East and West sides of campus (connected to gen plant)
- In 2018/2019 PJM PLC for Main Campus was set at
- West 0.0 MW
- East 1.9 MW
- The extra few MW savings is from additional building-level load curtailment

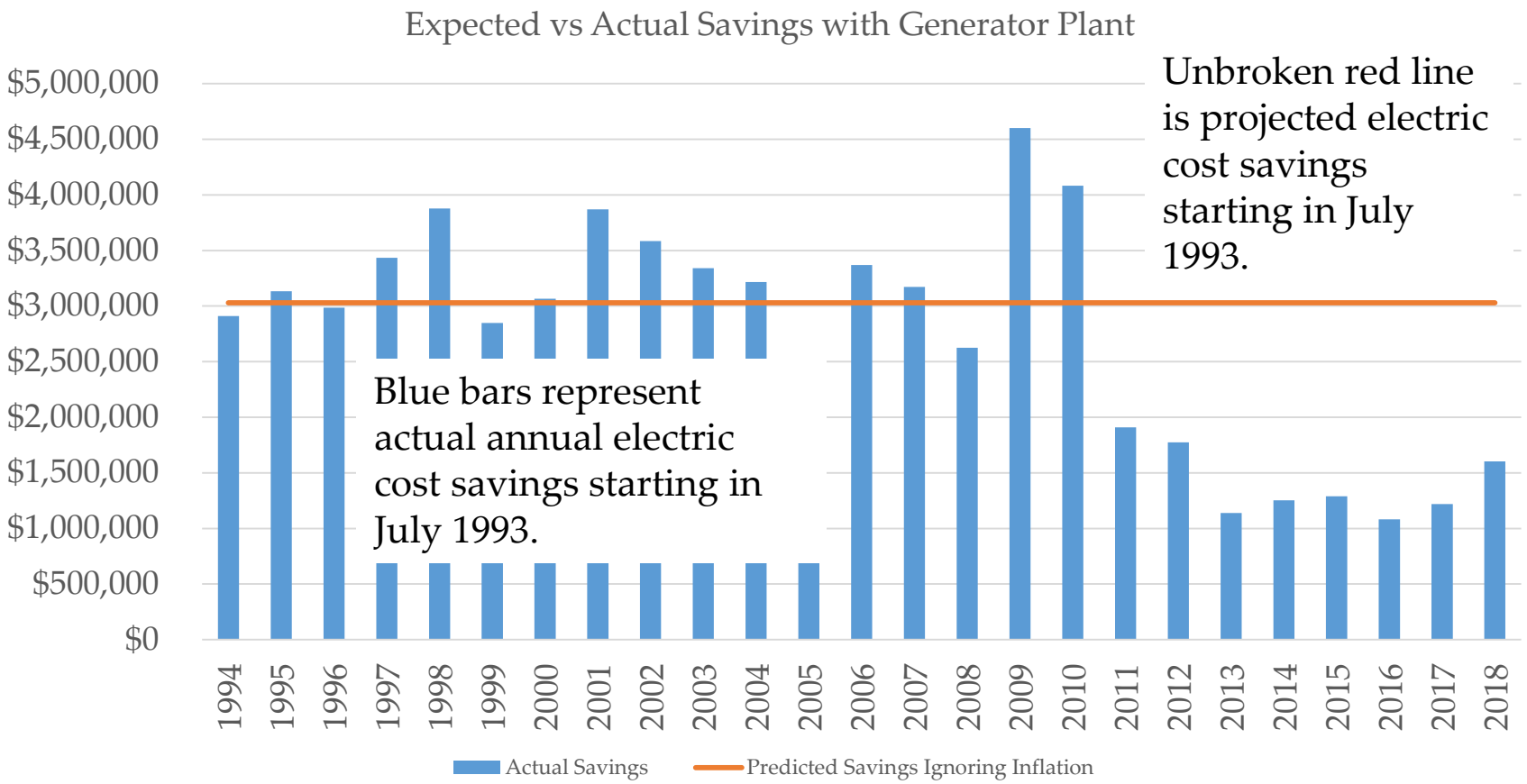
Results – View of Typical “Red Days” w/Generators



Results? (cont…)

- The contrast between Temple's Health Sciences Campus/Hospital and Main Campus only 2 miles apart and in the same PJM zone is telling
- Health Campus has no generator plant (designed but never built)
- Both campuses have similar daily peaks until "Red Days"
- Peak Load Contributions (PLCs) for 2018/2019
  - Health Campus = 17,672 kW
  - Main Campus = 1,923 kW


Cumulative Actual vs Predicted Savings with Generator Plant
$80,000,000
$70,000,000
$60,000,000
$50,000,000
$40,000,000
$30,000,000
$20,000,000
$10,000,000
$0
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Unbroken red line is projected cumulative electric cost savings of $75,000,000 since July 1993.
Broken line is actual cumulative electric cost savings of $67,000,000 since July 1993.
Cumulative Actual Savings
Cumulative Predicted Savings


Expected vs Actual Savings with Generator Plant
$5,000,000
$4,500,000
$4,000,000
$3,500,000
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
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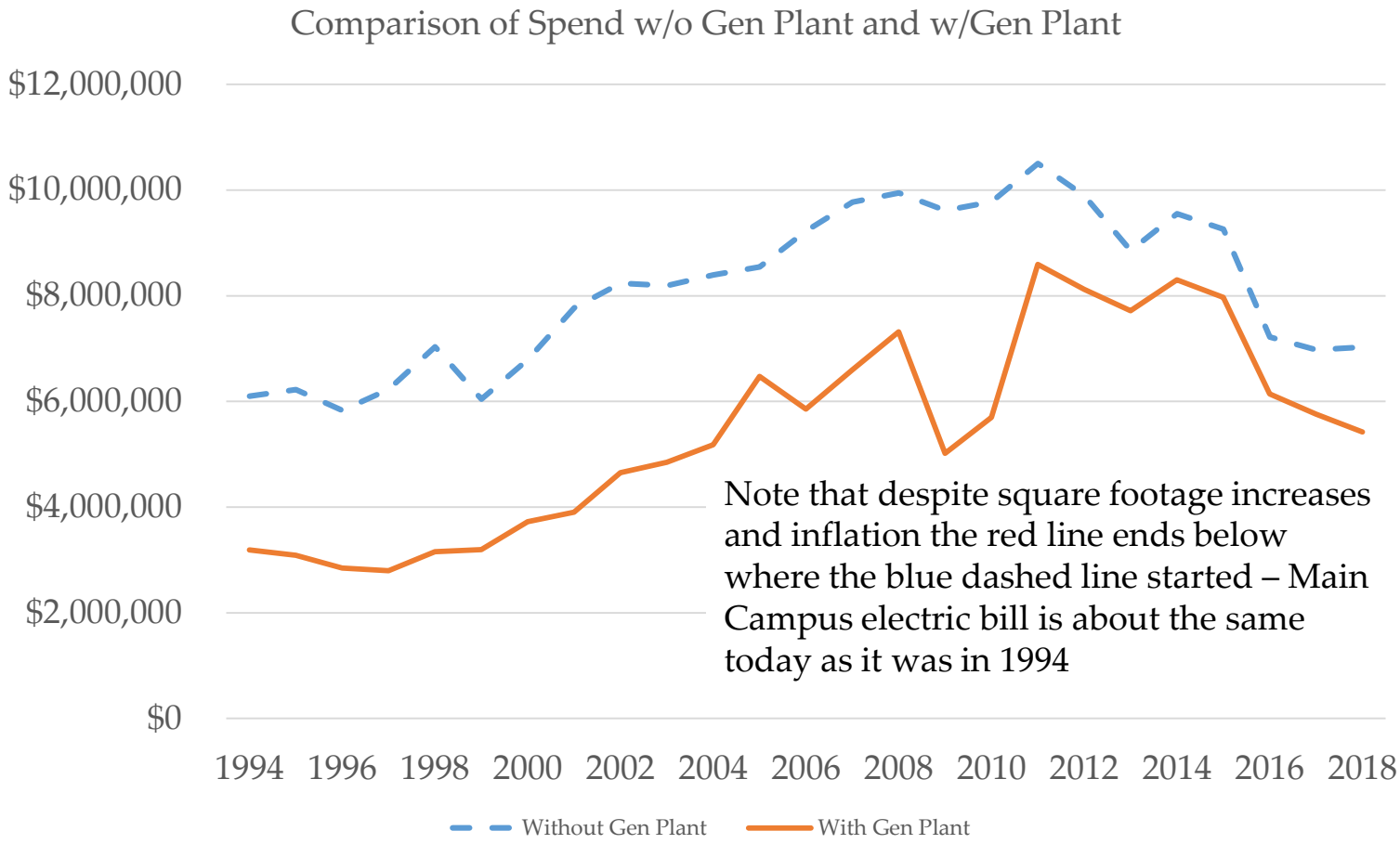
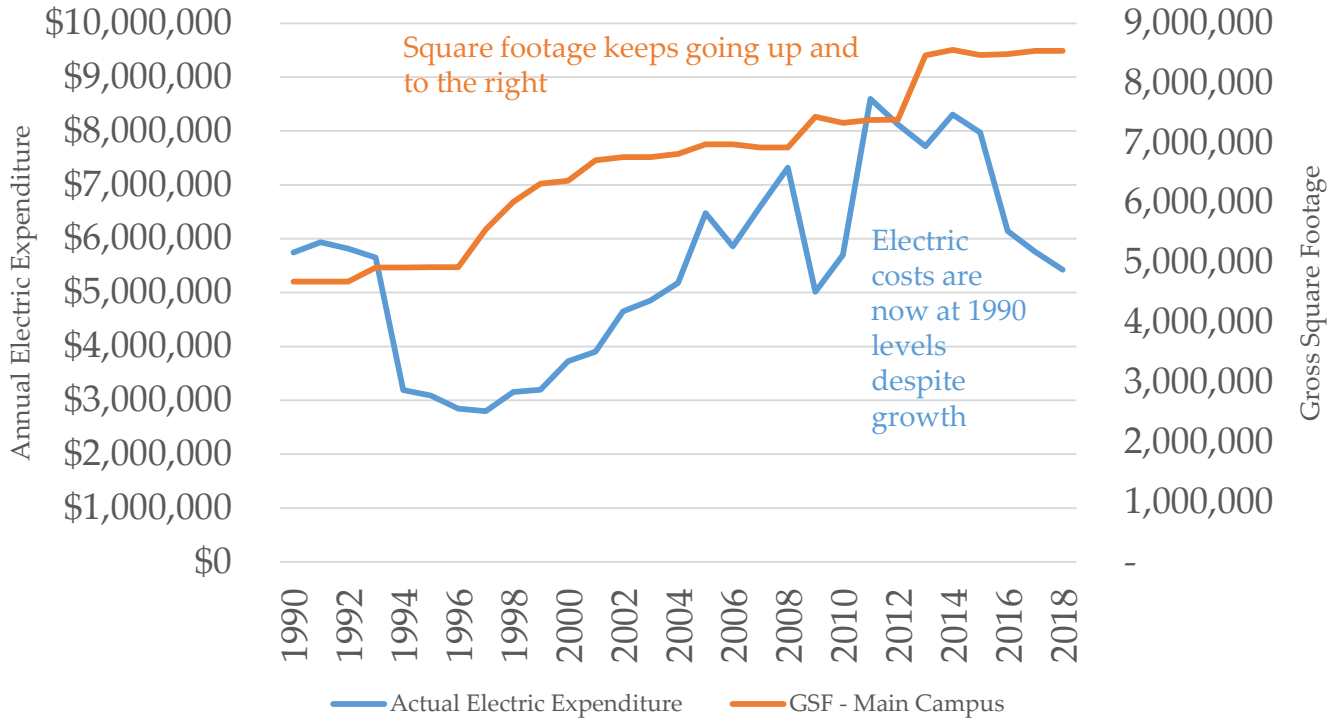
2018
Unbroken red line is projected electric cost savings starting in July 1993.
Blue bars represent actual annual electric cost savings starting in July 1993.
Actual Savings
Predicted Savings Ignoring Inflation


Comparison of Spend w/o Gen Plant and w/Gen Plant
$12,000,000
$10,000,000
$8,000,000
$6,000,000
$4,000,000
$2,000,000
$0
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Without Gen Plant
With Gen Plant
Note that despite square footage increases and inflation the red line ends below where the blue dashed line started – Main Campus electric bill is about the same today as it was in 1994

Actual Electric Expenditure vs Main Campus Gross Square Footage



What Have We Learned?

- Market forces have changed during the time Temple's microgrid has been in operation
- The rise of new markets. Temple's microgrid infrastructure allows us to participate in multiple RTO and EDC programs and markets including:
  - Peak Load Contribution (PLC) limits (our favorite, no revenue sharing!)
  - PJM Synchronous Reserves (short notice, short duration, lucrative)
  - PJM Emergency Load Response
  - PJM Economic Program (becoming ever more restrictive)
  - PECO Act 129 Demand Response at local level

Conclusions

- Looking back to 1993 what might we change?
- The plant was designed with flexibility in mind and that flexibility paid off with changes in regulations
- 25 years from now takes us to year 2044…!
- Temple's own Climate Action Plan calls for carbon neutrality by 2050
- Technology changes will help carbon goals, but power and fuel markets WILL change between now and then

Thank you

Acknowledgement and thanks to:

- IDEA for this forum
- Kurt Bresser, Temple's Director of Utilities and Energy Management for the historic data and insight
- Joe Monahan, Temple's Associate Vice President, Facilities and Operations for valuable feedback and edits
- Questions?