Innovation During the First 25 Years!

- In the early 1990's Temple's Energy Team knew they wanted to take full advantage of newly created interruptible electric rates
- Engineering calculations showed an immediate reduction of about 50% ($3million/year) in electric bills were achievable
- Analysis showed a new generator plant would pay off in about 4 years
- Largely uncharted territory, but decisive action was taken!

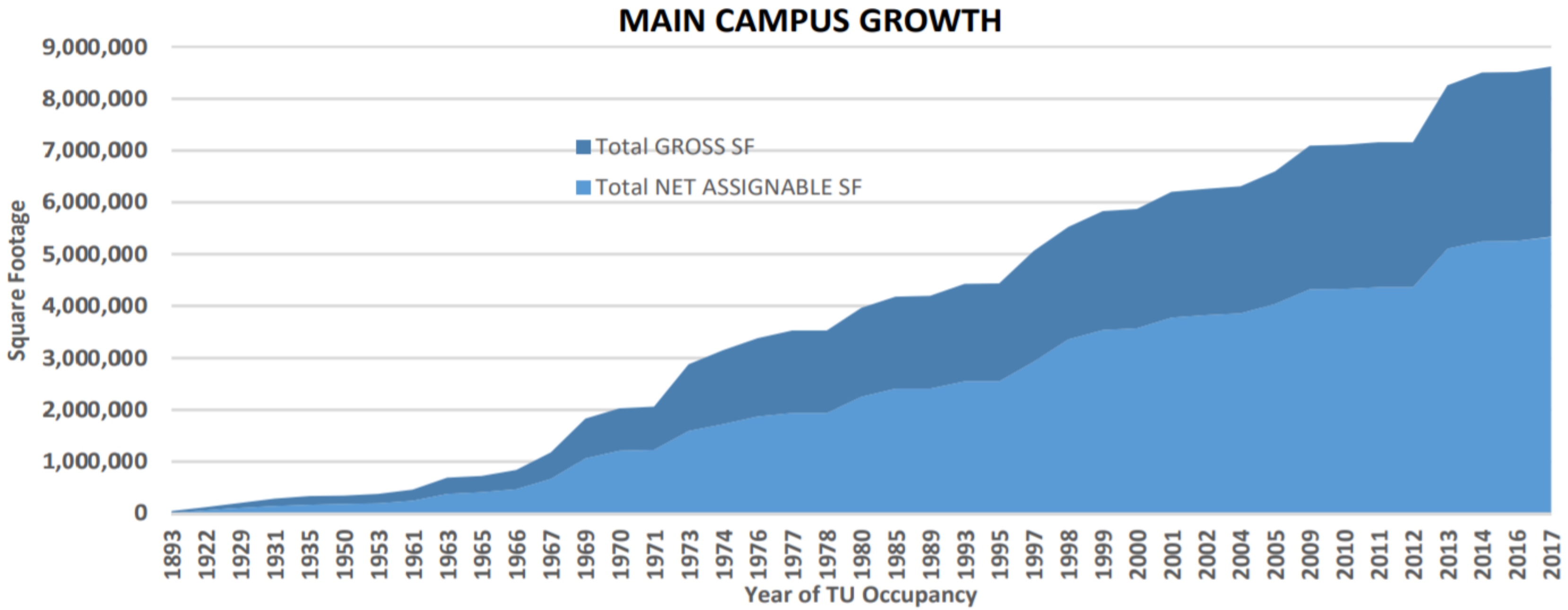
Innovation During the First 25 Years! (Cont…)

- Temple started-up its $16million Standby Electric Generating Facility (SEGF) in 1993, to form its first 16MW microgrid
- Facility has saved Temple about $67million in electricity costs since 1993 against the pre-construction predictions of approximately $75million over the same 25 years
- The following slides go into more detail about how this was achieved, changes along the way, and lessons learned

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!

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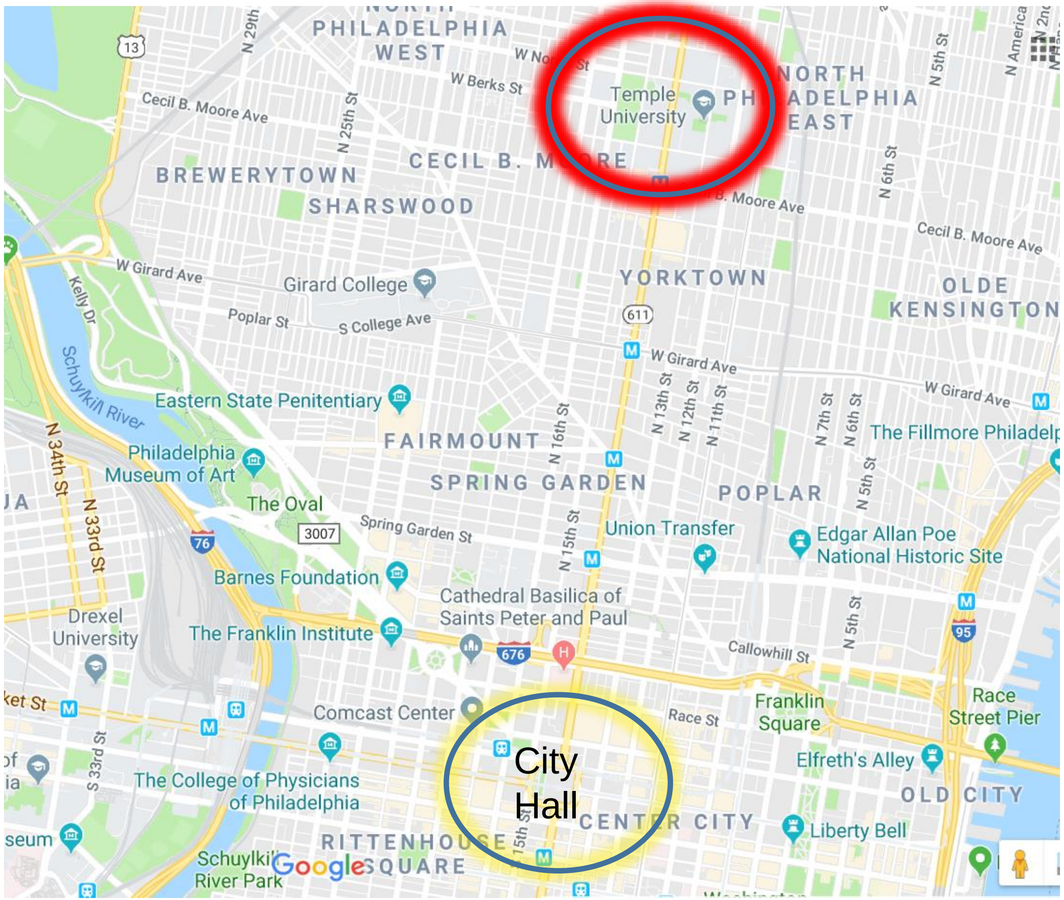
Temple – Part of Main Campus Nestled in the Neighborhoods of North Philly

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



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!

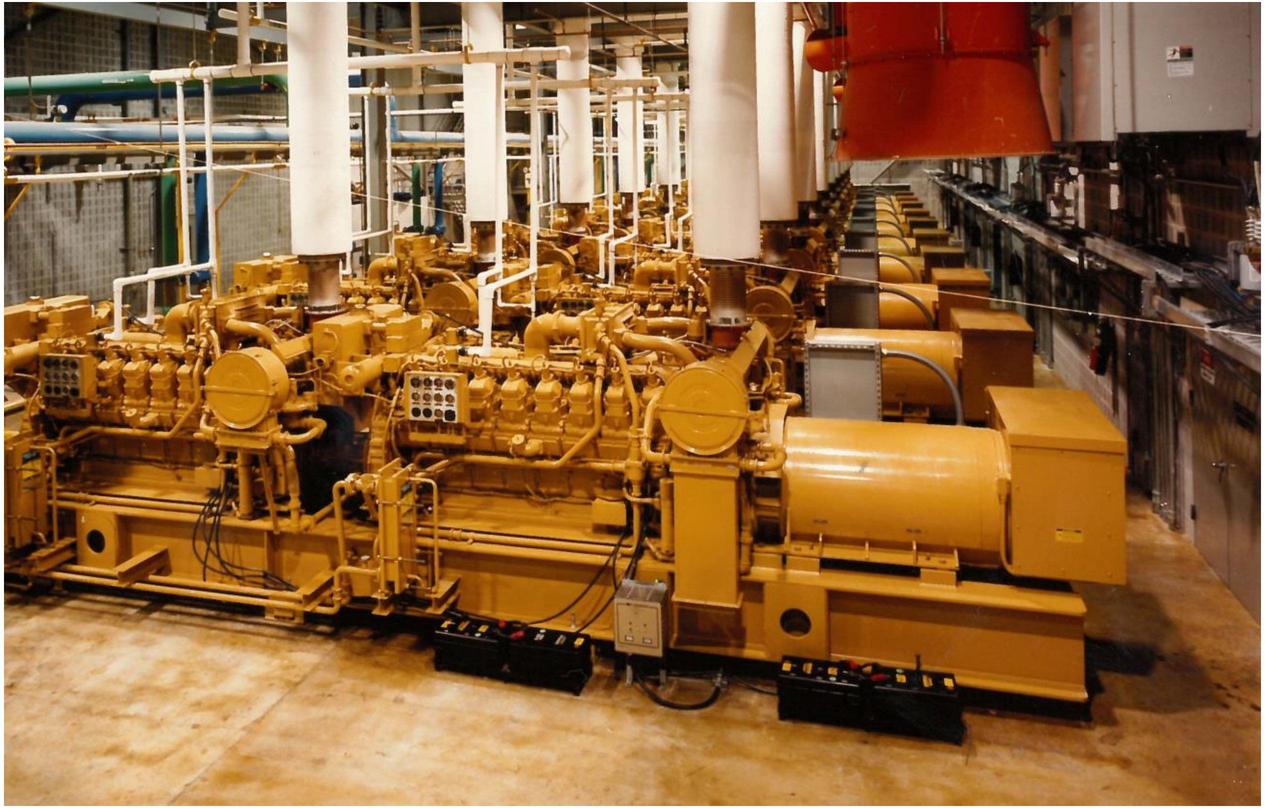
What Was Built?

- 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
    - 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

TRANSFER

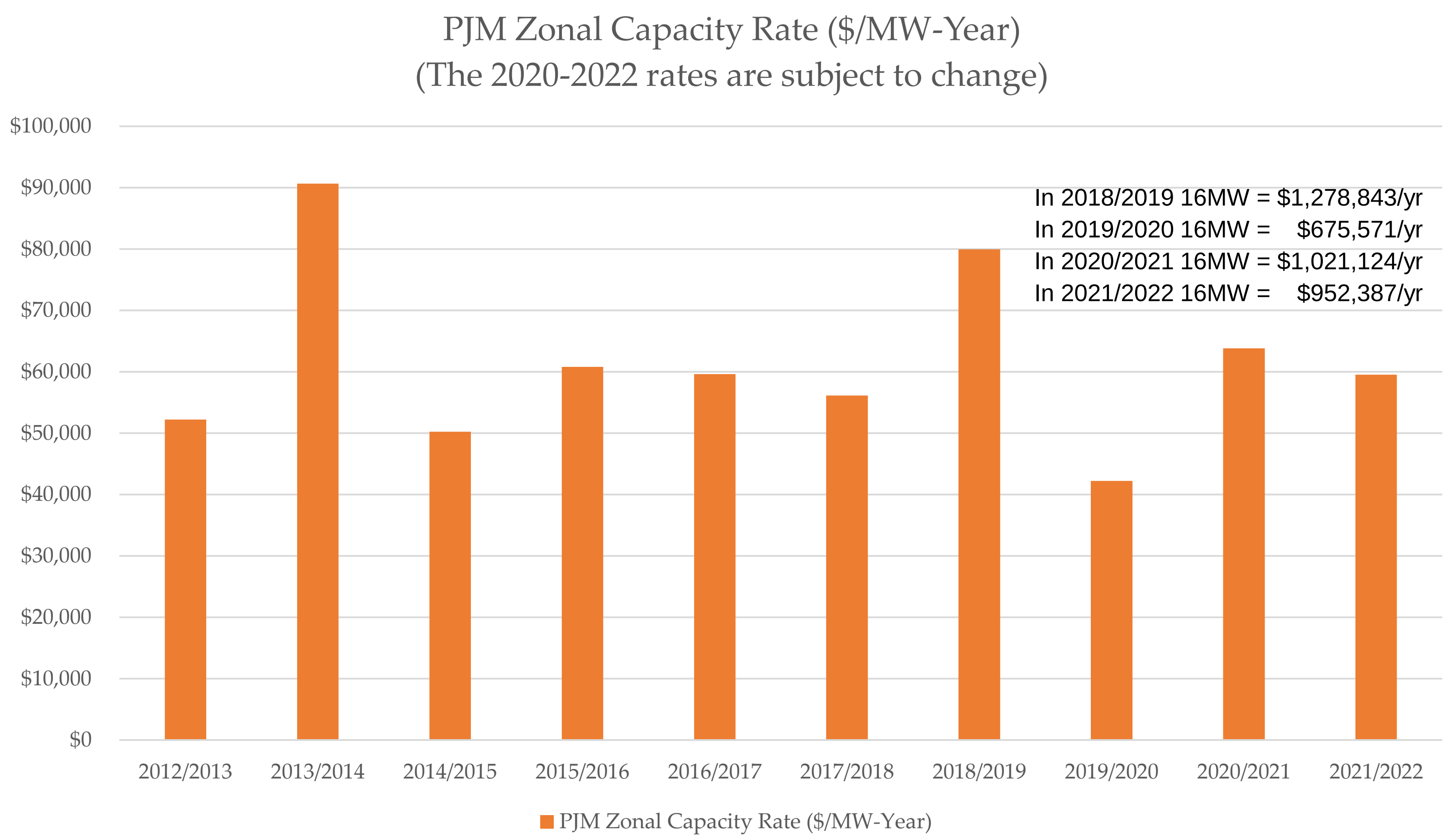
FUND ADDTIONS

WITH 30 YEARS OF NIGHTRIDER		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

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



Deregulation

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

Innovative Aspects

- In the 1990s most engineers (including me!) were evaluating and recommending CHP (combined heat and power) systems
- Temple bucked the trend, the team noted that the LILR interruptible rates would yield excellent savings with far less runtime!
- Less runtime meant less sensitivity to fuel prices
- Maintenance is easier to schedule because air permits are only for 500 hours/yr, leaves 8260 hours/yr for maintenance

Innovative Aspects (Cont…)

- Currently, after 26 years the engine run-hour meters show about 2500 hours, or about 100 hours/year on average
- A CHP of similar vintage would be registering over 200,000 hours by now
- The penalties for under-performance or non-performance are significant for either a CHP plant or Temple's SEGF

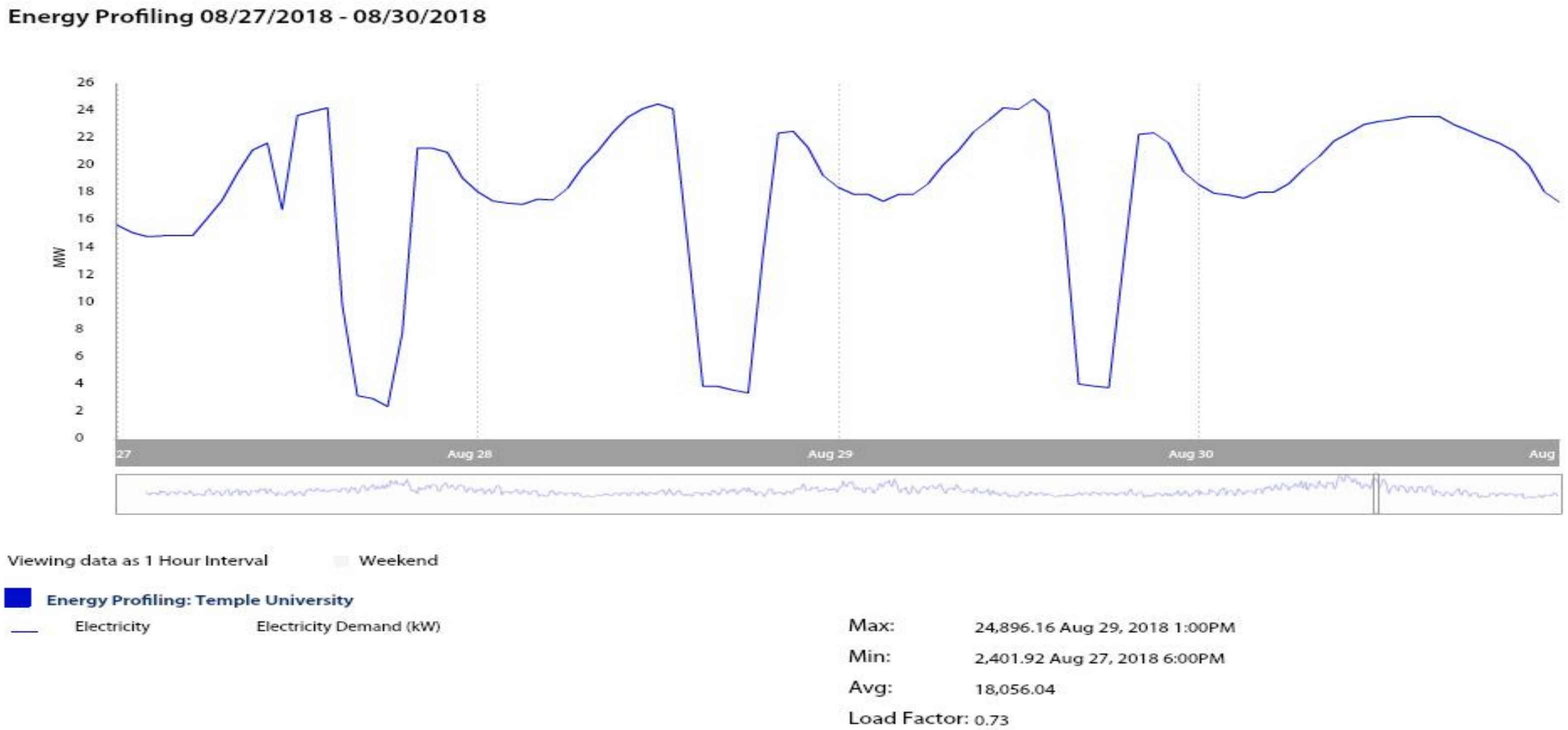
Innovative Aspects (Cont…)

- In summary, the novel aspects, especially in 1992, were:
  - Creating a quiet plant suitable for a residential neighborhood
  - A high electrical output per dollar of investment
  - Flexible operating modes
  - Black start capabilities
  - Operate islanded from utility or in parallel with utility
  - No heat recovery due to limited hours of operation
  - All fueled on natural gas

Results

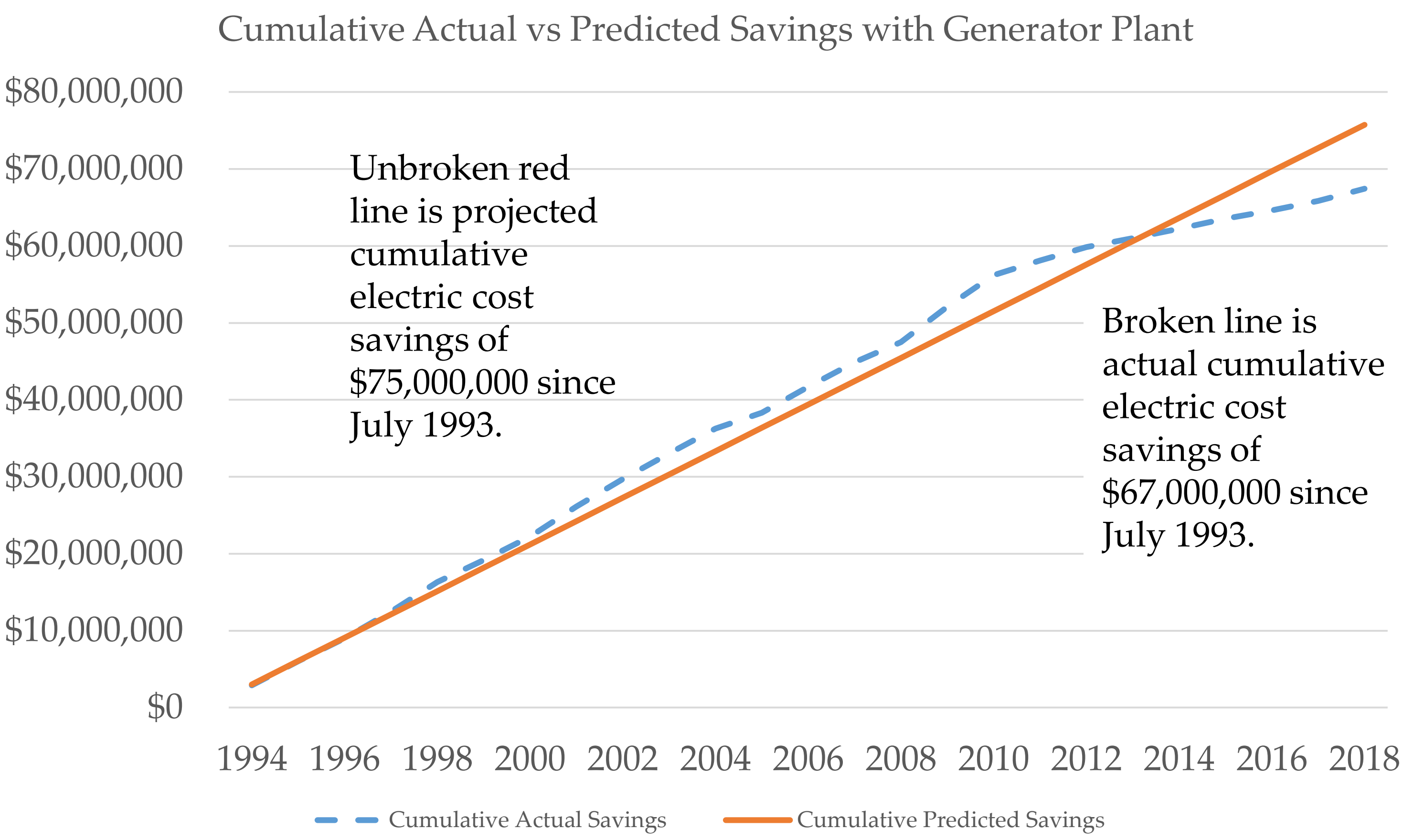
- The Temple Standby Electrical Generating Facility provides Societal Good
- The plant competes directly in the PJM markets
- Its continued operation helps avoid "gold-plating" of the grid by providing redundancy
- Its operation potentially displaces electric generated by other dirtier fuels including diesel (the Temple plant operates on natural gas)

Results – View of Typical "Red Days" w/Generators



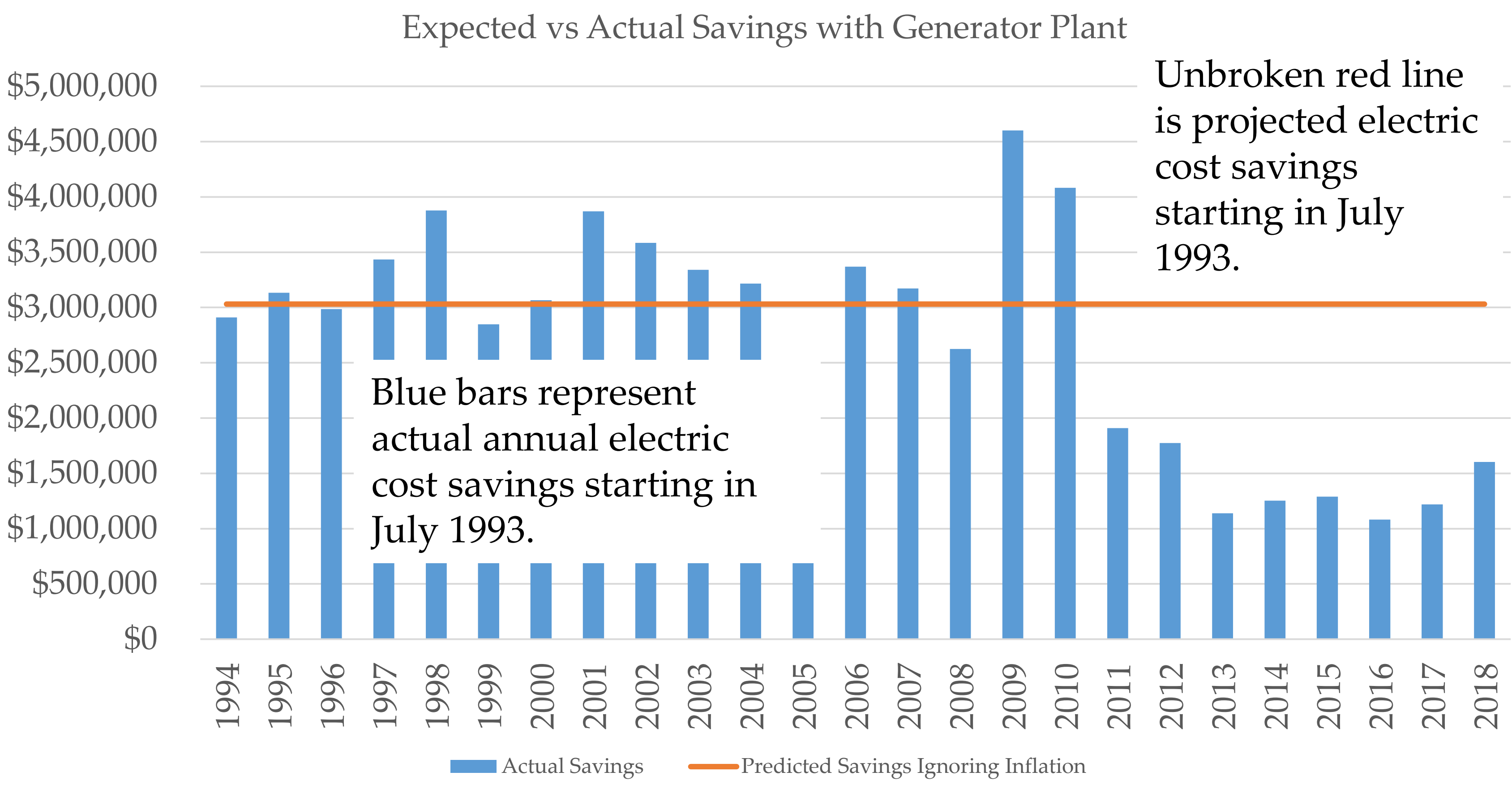
Results (cont…)

- 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

Results

Results


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
2008
2009
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2011
2012
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2014
2015
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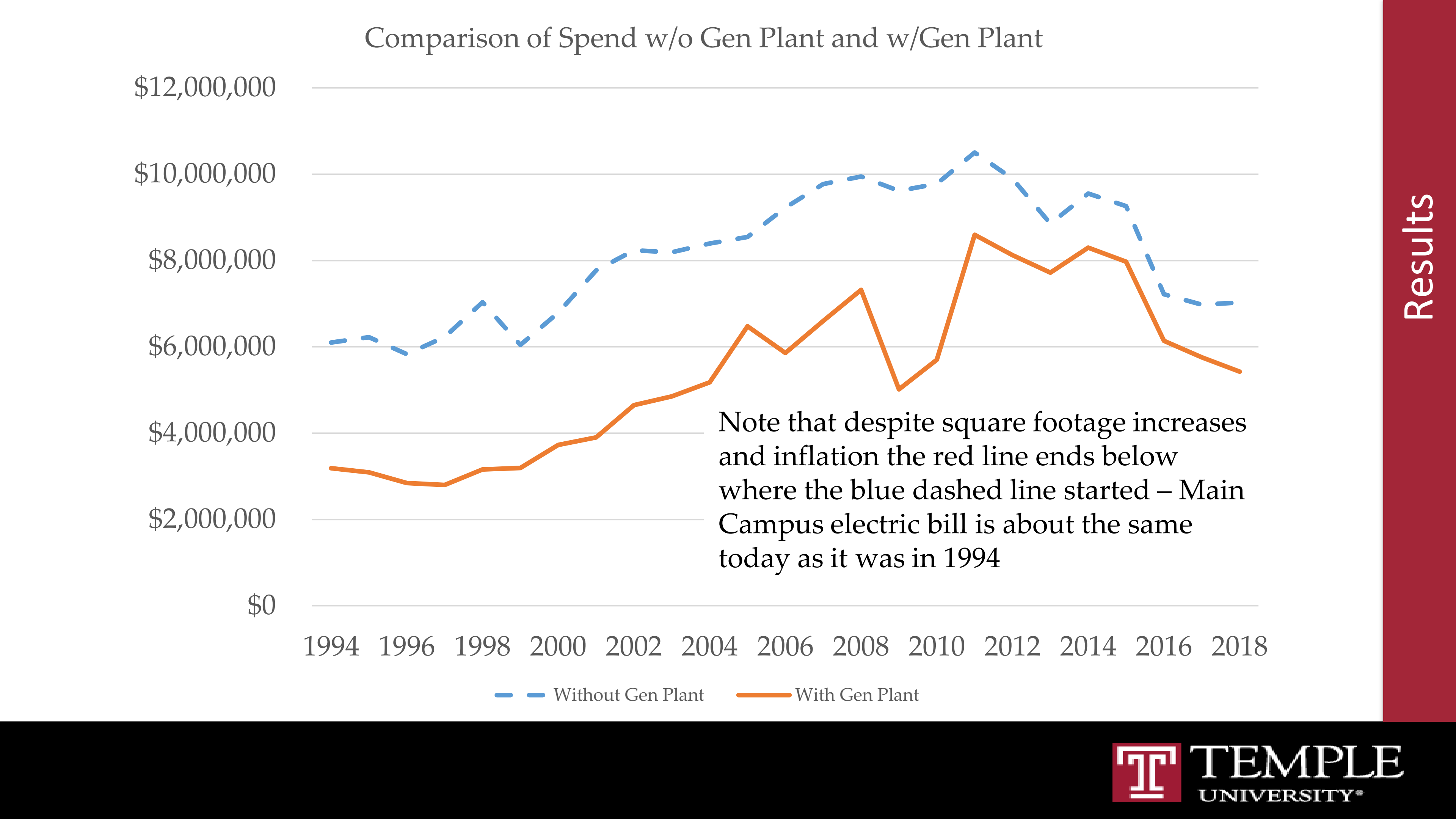
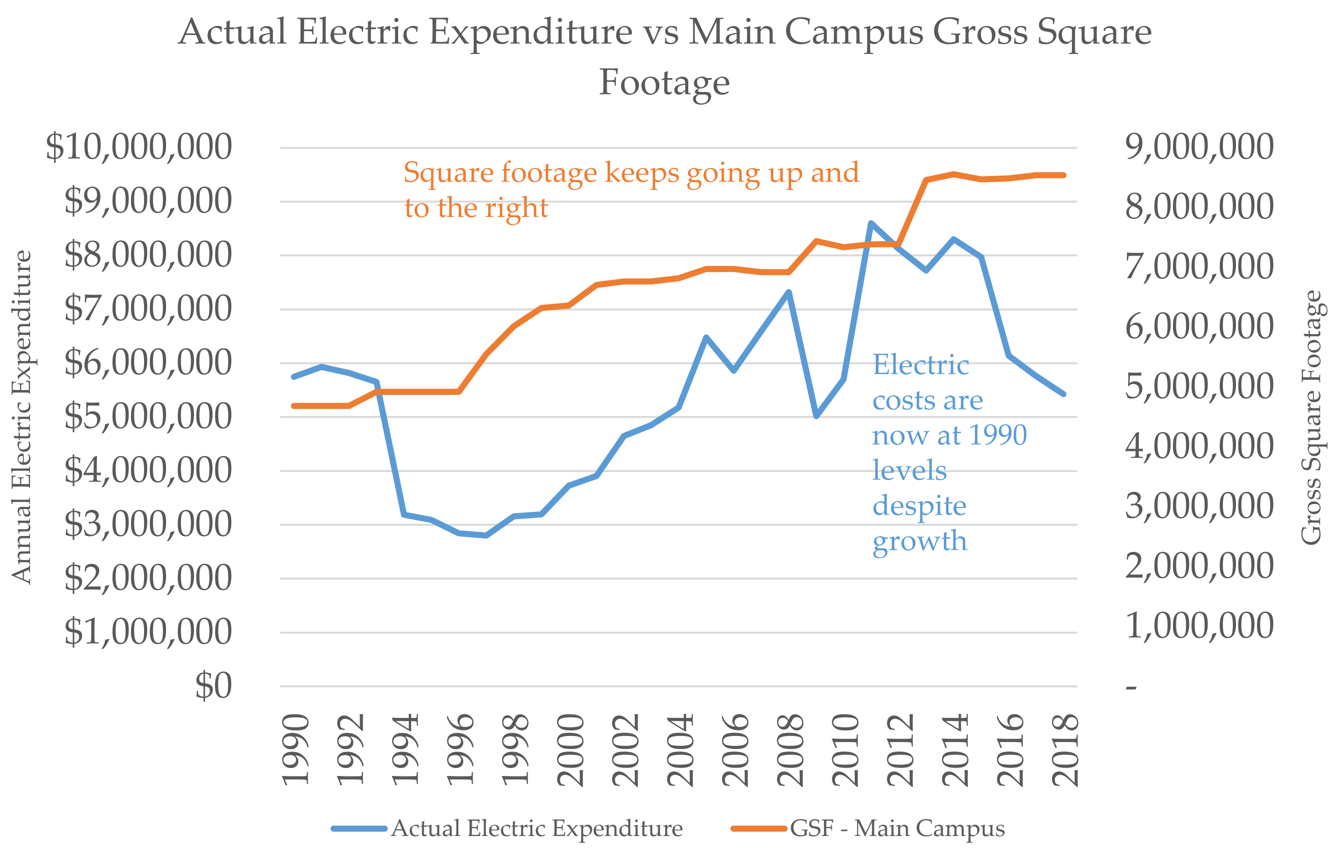
2017
2018
Actual Savings
Predicted Savings Ignoring Inflation
Blue bars represent actual annual electric cost savings starting in July 1993.
Unbroken red line is projected electric cost savings starting in July 1993.


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
Results



Results

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What Have We Learned?

- The uncertainties and changes to tariffs over the years demonstrate that flexibility is key
- It was far from certain that the interruptible electric rate rider would persist. Deregulation was on the horizon but its format was unknown
- When deregulation did arrive electric prices were driven down, capping the available universe of savings for a standby plant like Temple’s (but Temple’s plant had already paid for itself at that point)

What Have We Learned? (Cont…)

- Electric deregulation opened 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

Presentation is available by email. Scan the QR Code or email me at andrew.holden@temple.edu

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