Evaluation of energy supply options for CMU

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Introduction

- Distributed generation (DG) in combined heat and power (CHP) applications is a significant fraction of generation in some systems (6% in the Netherlands).
  - Utility companies have incentive to cooperate
  - Policies must allow for flexible ownership and operations
  - Recapture of waste heat crucial to economics
- Thermal demand of U.S. buildings: less heat more cooling
  - Less opportunity for waste heat recapture
- Can absorption cooling be used with DG to create a CHCP system that might be economically advantageous?

Approach

- CMU energy supply system
  - Electricity bought from grid (60% coal, 38% nuke/hydro, 2% gas)
  - 20% of electricity is wind (5% total energy)
  - Heat from district heating system (85% coal, 15% gas)

- Replacement of district heating system being considered
  - Base system (coal heat and grid electricity with wind purchase)
  - Gas-fired heat and grid electricity (more generalizable)
  - Onsite, gas-fired electricity generation with waste heat recapture
    - Compression chilling (current)
    - Absorption chilling

- Simulation model: 15-year NPV (2003-2017)
- Emissions – mass and reduction credit values

Heat to Power Ratio (HPR)

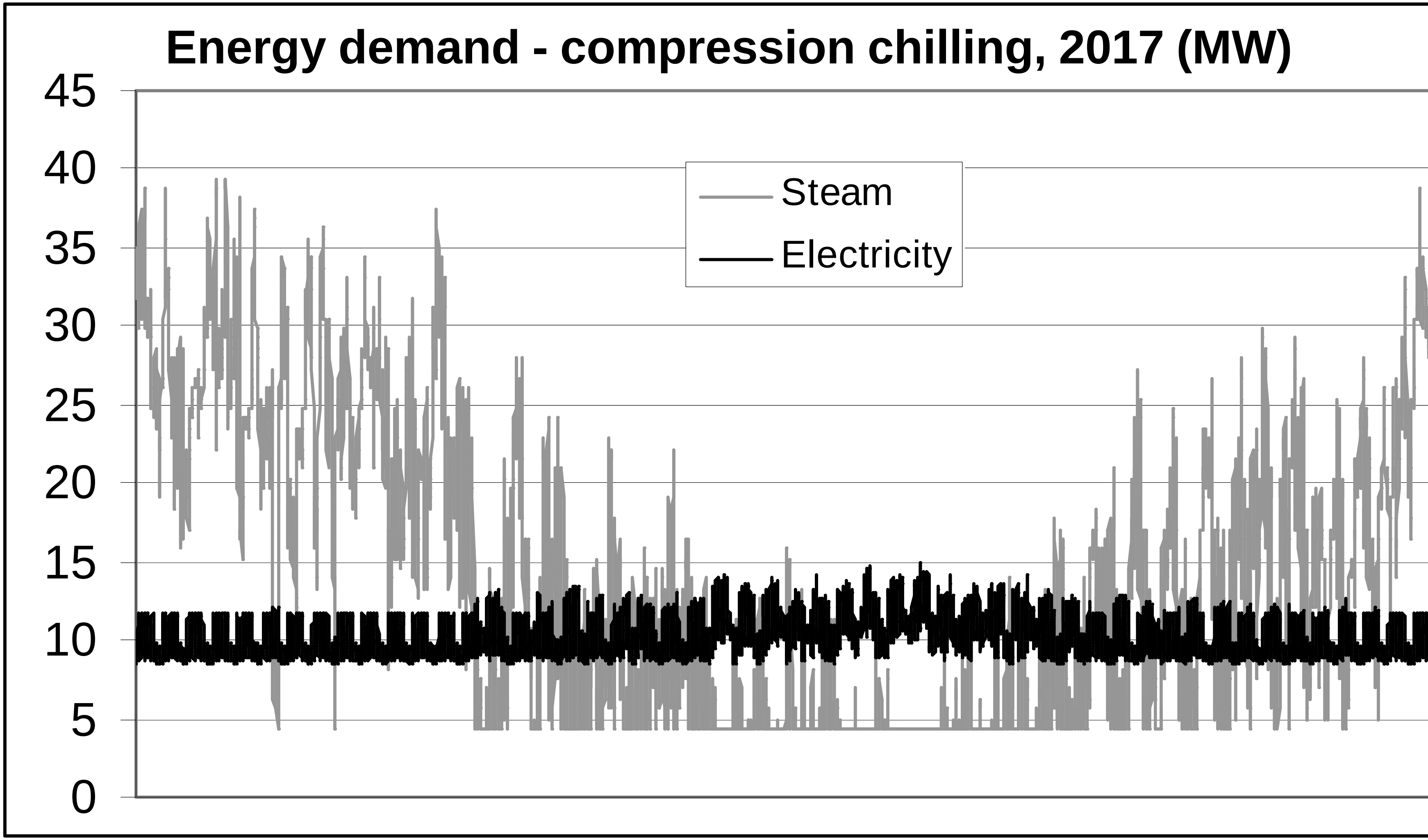
- Crucial parameter for matching energy supply and loads

- Typical average values for two states:
  - NY avg. = 2.3, NY coldest = 7, FL avg. = 1.1, FL hottest = 0.5

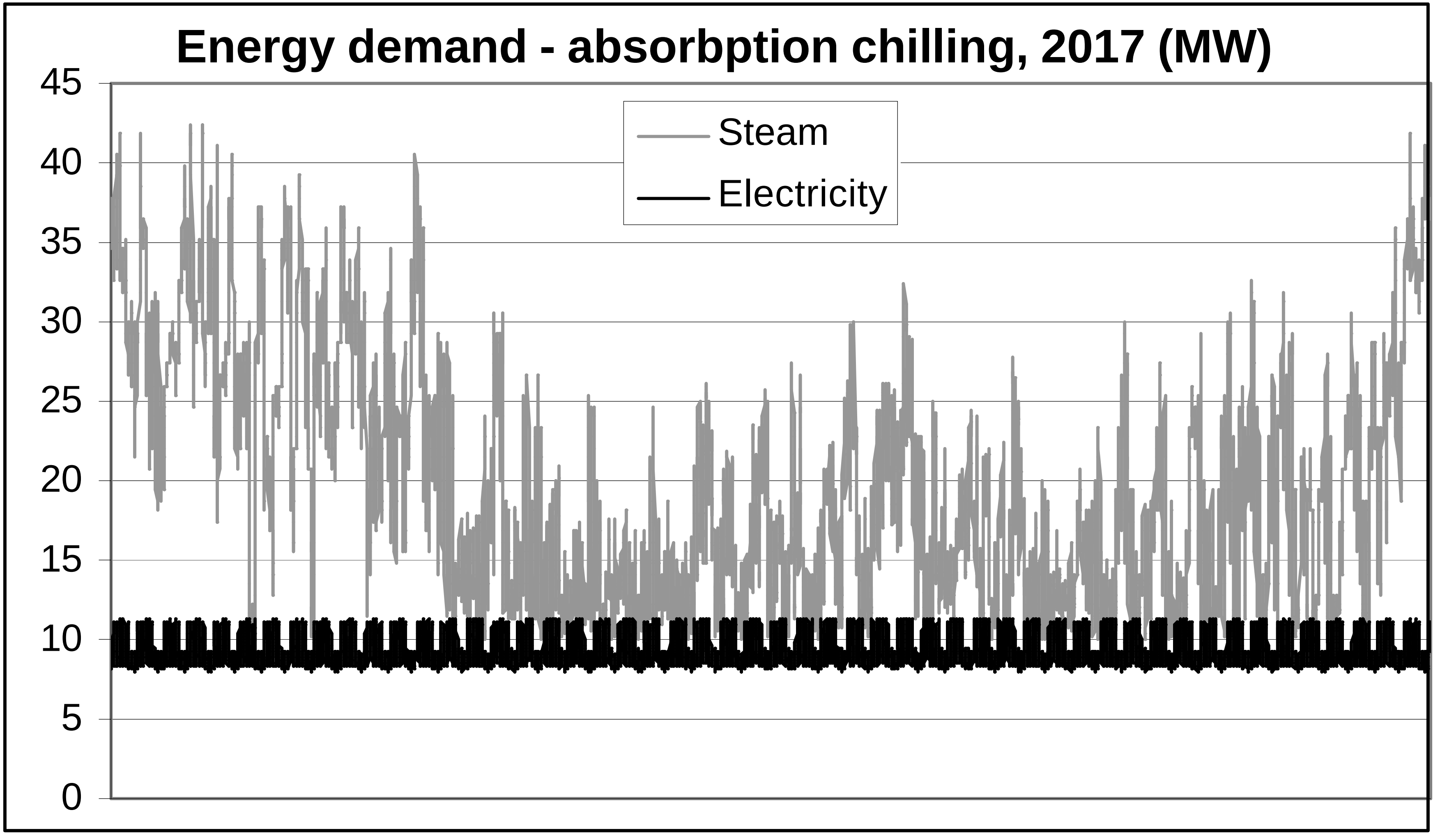
- Inherent values for different generation technologies:
  - Fuel cell 1.4
  - Diesel ICE 1.6
  - Gas ICE 2.1
  - Gas Turbine 2.0
  - Micro Turbine 2.6

- ICE exhaust temperatures sometimes too low to drive absorption chillers

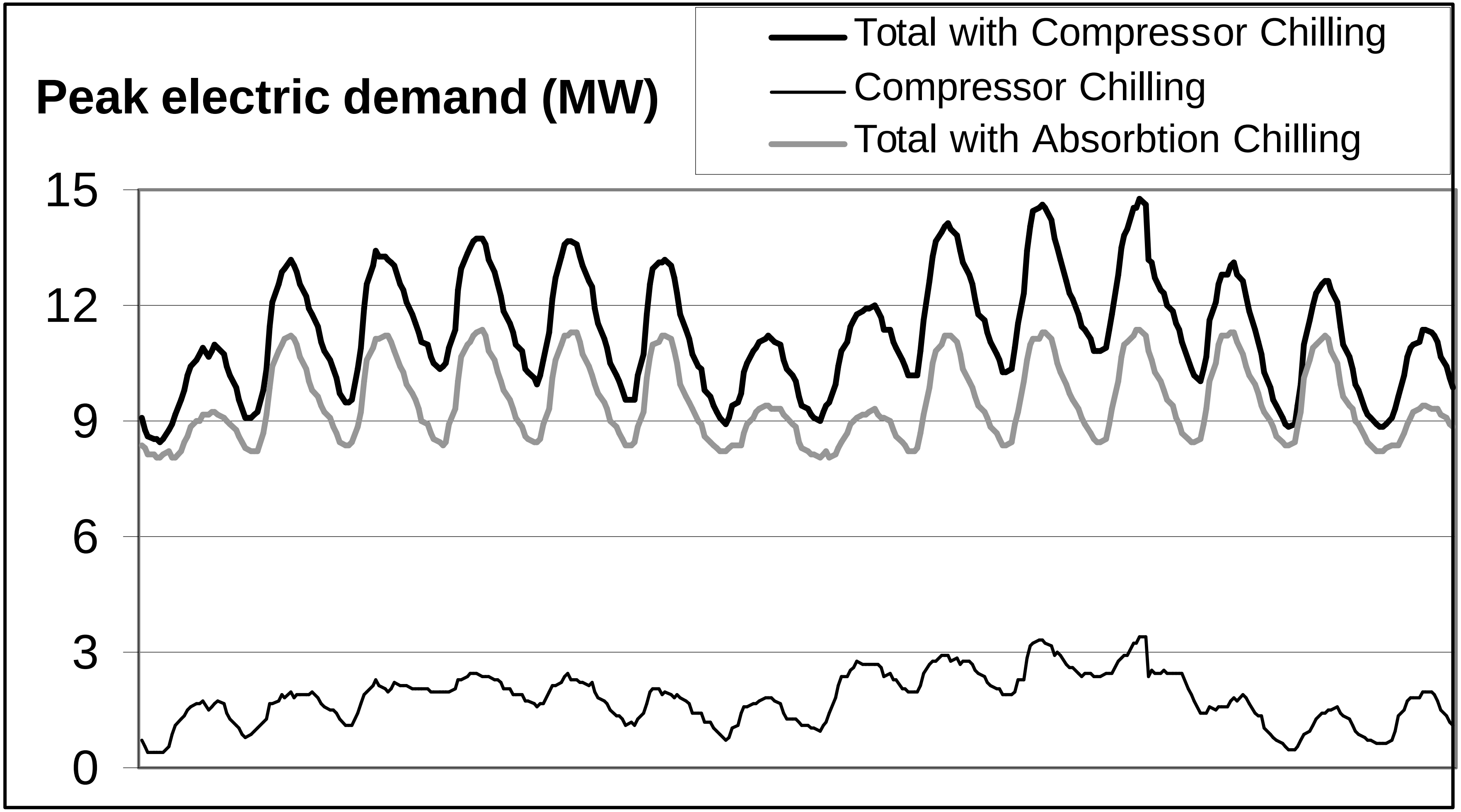
Data – Energy Demand (1)



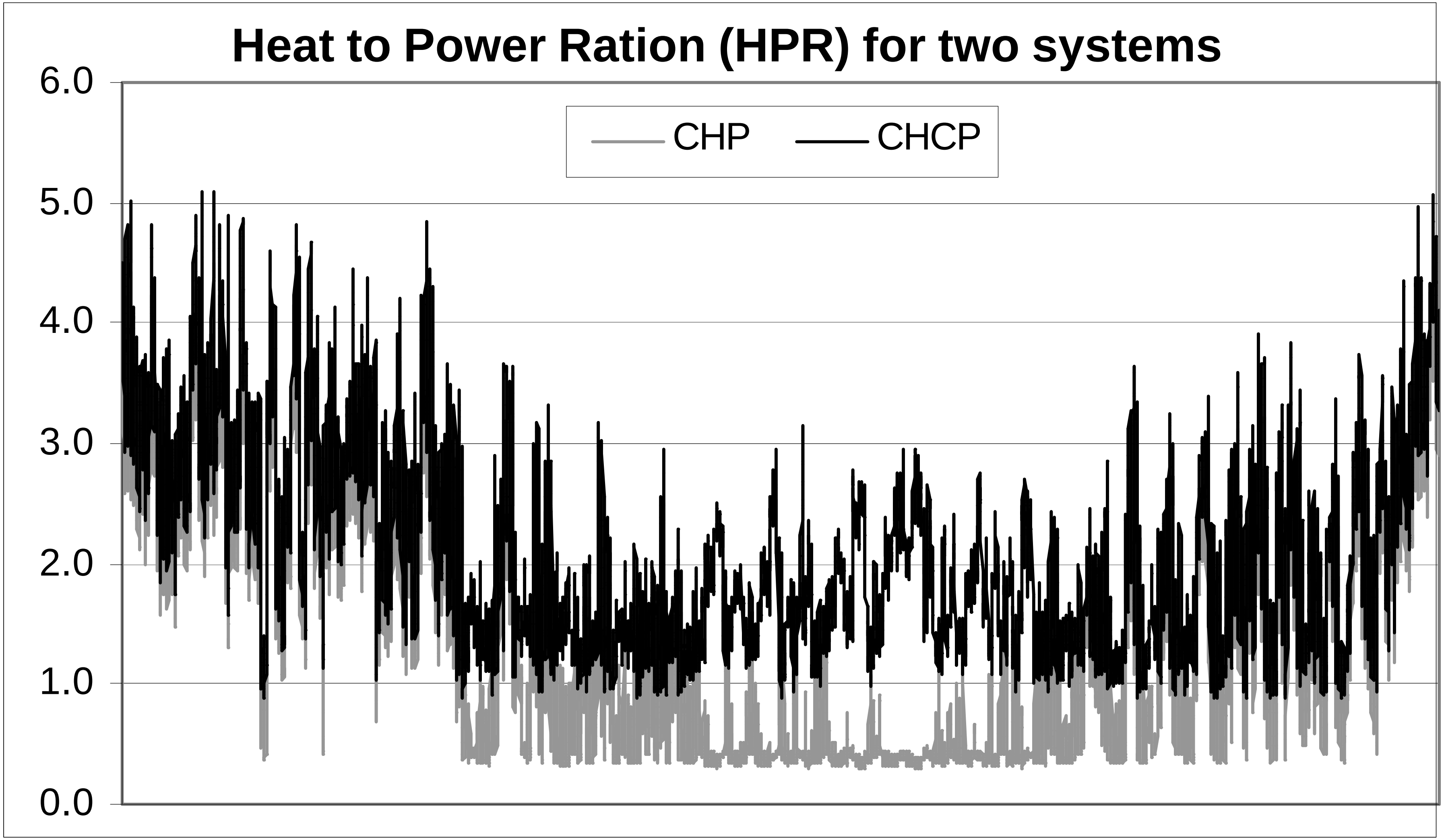
Data – Energy Demand (2)



Data – Energy Demand (3)



Data – HPR



- Peak heating demand sets system size

Simulation

- Excel/Visual Basic
- Set input parameters (demand growth, capital and fuel costs, equipment specifications)
- Set operating strategy
  - Native Baseload
  - Native Steam and/or Electricity Demand
  - Full Capacity
- Meet hourly demand (8760 x 15)
- Calculate NPV, fuel consumption, emissions

Baseline Costs

- Current prices:
  - Gas ~$6/Mcf,
  - Electricity ~7¢/kWh with a $10/kW demand charge
  - Steam ~$8/Mcf

- FY 2001 CMU energy bill = $8.4Million
  - NPV = $100M - $200M (depends mostly on power price)
  - model assumptions (3% growth, r = 2.5%, n = 15 years)

- Demand charge for 13MW peak (avg.) = $130,000/mo.
  - NPV = $24 Million (included in energy bill above)

Initial Results

- Two baseline systems
  - Current system: coal heat + grid electricity
  - Gas heat system: gas heat + grid electricity (similar to coal + grid w/ wind power purchase)

- System
  - 2 x 7.5MW Solar Turbine "Taurus" gas turbines
  - 1 x supplemental gas boiler

- Operating Strategies

  1) CHP, Native Steam and Power

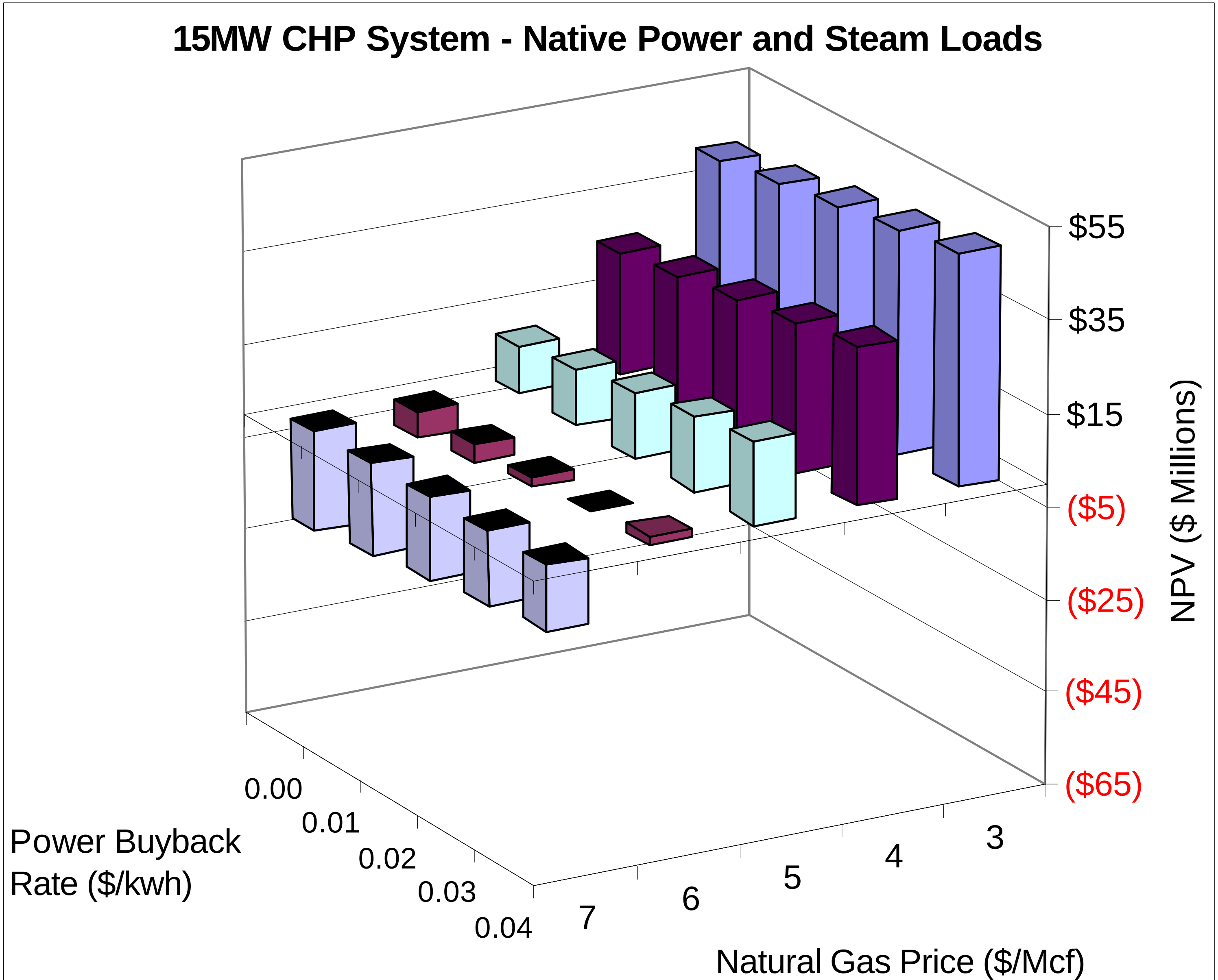
  2) CHCP, Native Steam and Power

  3) CHCP, Full Capacity

Limitations

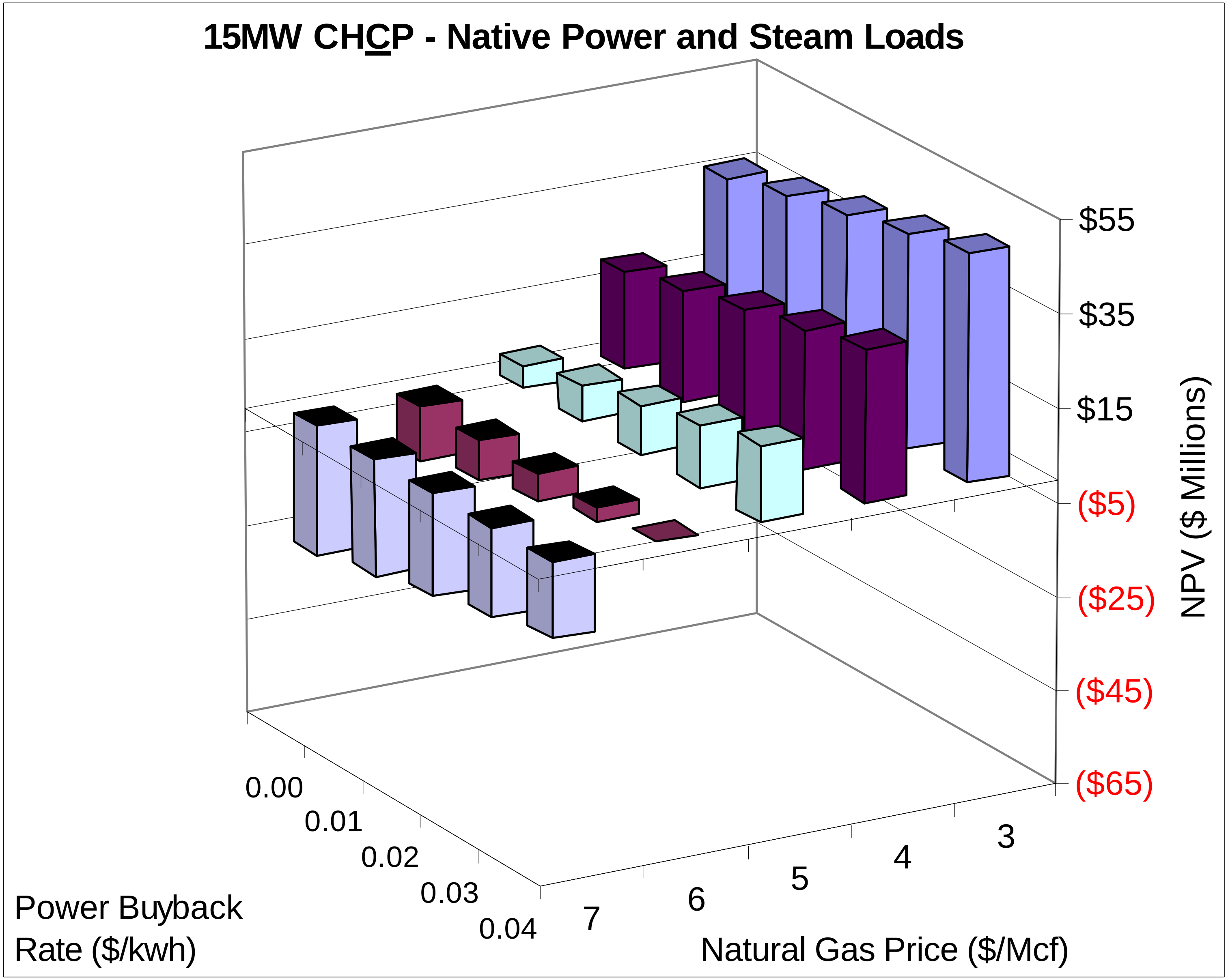
- Emissions
- Demand charge reduction and backup charge
- Part-load performance
- Double-effect absorption chiller
- Deterministic
  - Gas price
  - Power price
  - Allowance prices

NPV 1



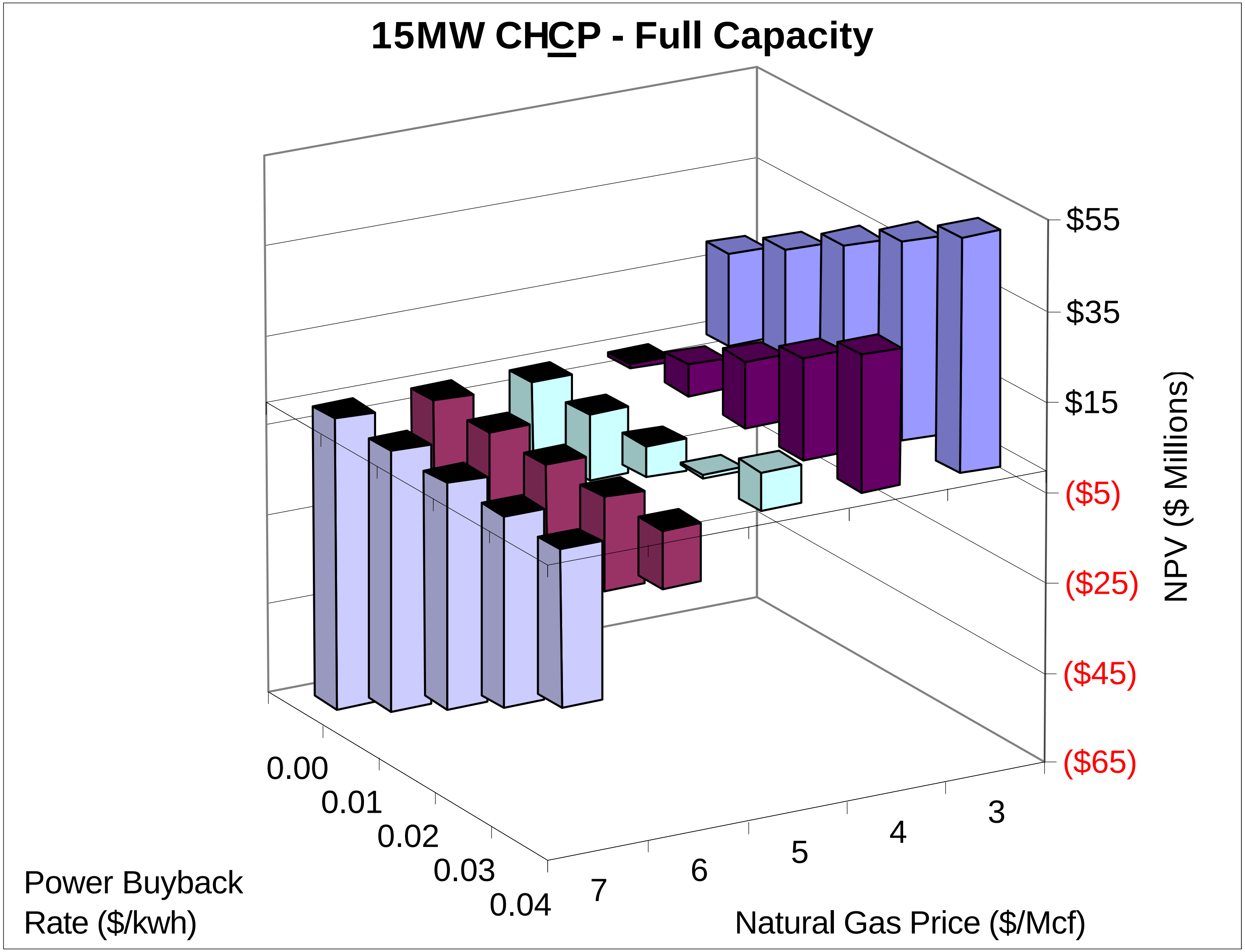
15MW CHP System - Native Power and Steam Loads
$55
$35
$15
($5)
($25)
($45)
($65)
NPV ($ Millions)
0.00
0.01
0.02
0.03
0.04
Power Buyback Rate ($/kwh)
7
6
5
4
3
Natural Gas Price ($/Mcf)

NPV 2



15MW CHCP - Native Power and Steam Loads
$55
$35
$15
($5)
($25)
($45)
($65)
NPV ($ Millions)
0.00
0.01
0.02
0.03
0.04
Power Buyback Rate ($/kwh)
7
6
5
4
3
Natural Gas Price ($/Mcf)

NPV 3



15MW CHCP - Full Capacity
$55
$35
$15
($5)
($25)
($45)
($65)
NPV ($ Millions)
0.00
0.01
0.02
0.03
0.04
Power Buyback Rate ($/kwh)
7
6
5
4
3
Natural Gas Price ($/Mcf)

Fuel Consumption (GJ)

	Gas	Coal	Other (nuke/hydro)	Total
Coal heat, grid electricity	13,000	850,000	210,000	1,100,000
Gas heat, grid electricity	340,000	520,000	210,000	1,100,000
CHP – native load	920,000	-66,000	-27,000	830,000 (78%)
CHCP – native load	910,000	-93,000	-37,000	780,000 (73%)
CHCP – full capacity	1,400,000	-400,00	-160,000	830,000 (77%)

- Negative values are energy not consumed due to power export

CO_2 emissions

	Emissions ($ktons\ CO_2$)	Change, Coal Baseline (Gas Heat or Grid w/Wind)	Annual Credit Revenue ($10/ton CO_2, Coal baseline)	NPV (n=15, r=2.5%)
Coal heat + grid electricity	240			
Gas heat + grid electricity (or coal + grid w/wind)	210	-12% (0%)	$140,000	$16M
1 - CHP native load	81	-66% (-61%)	$780,000	$12M
2 - CHCP native load	71	-70% (-66%)	$830,000	$12M
3 - CHCP full capacity	23	-90% (-89%)	$1,100,000	$2M

- Onsite generation backs out baseload coal
- Wind purchase about –4% CO_2 emissions, NPV about -$1M

Some practical concerns

- Bellefield partners (Pitt, UPMC, Phipps, etc.)
- Current legal structure, management, and labor force
- Duquesne Light Company interest/cooperativeness
- Value of grid support or reliability
- Capital requirements
- Modularity/advanced energy conversion
- Building As Power Plant integration (i.e. remote DG-CHP)

Fuel Consumption (GJ)

		Gas	Coal	Other (nuke/hydro)	Total
Coal heat and grid electricity	Onsite Offsite **Net**	13,000 0 **13,000**	323,000 523,000 **850,000**	0 210,000 **210,000**	**1,100,000**
Gas heat and grid electricity	Onsite Offsite **Net**	13,000 323,000 **340,000**	0 520,000 **520,000**	0 210,000 **210,000**	**1,100,000**
CHP native load	Onsite Offsite **Net**	920,000 0 **920,000**	0 -66,000 **-66,000**	0 -66,000 **-27,000**	**830,000** (78%)
CHCP native load	Onsite Offsite **Net**	910,000 0 **910,000**	0 -66,000 **-93,000**	0 66,000 **37,000**	**780,000** (73%)
CHCP full capacity	Onsite Offsite **Net**	1,400,000 0 **1,400,000**	0 -66,000 **-400,00**	0 -66,00 **-160,00**	**830,000** (77%)

- Negative values are energy not consumed due to power export