NEW ENGLAND UNIVERSITY – STEAM TO HOT WATER CONVERSION STUDY

- 370 acres, 80 buildings, 2,400,000 GSF
- Existing District Heating System
  - (3) Natural gas boilers
  - 2 MW Nat Gas Recip Engine Cogen
  - Steam distribution network (1928-2015)
  - 95% of buildings hydronic
  - Small MTHW system feeding 3 buildings using cooling water circuit from cogen

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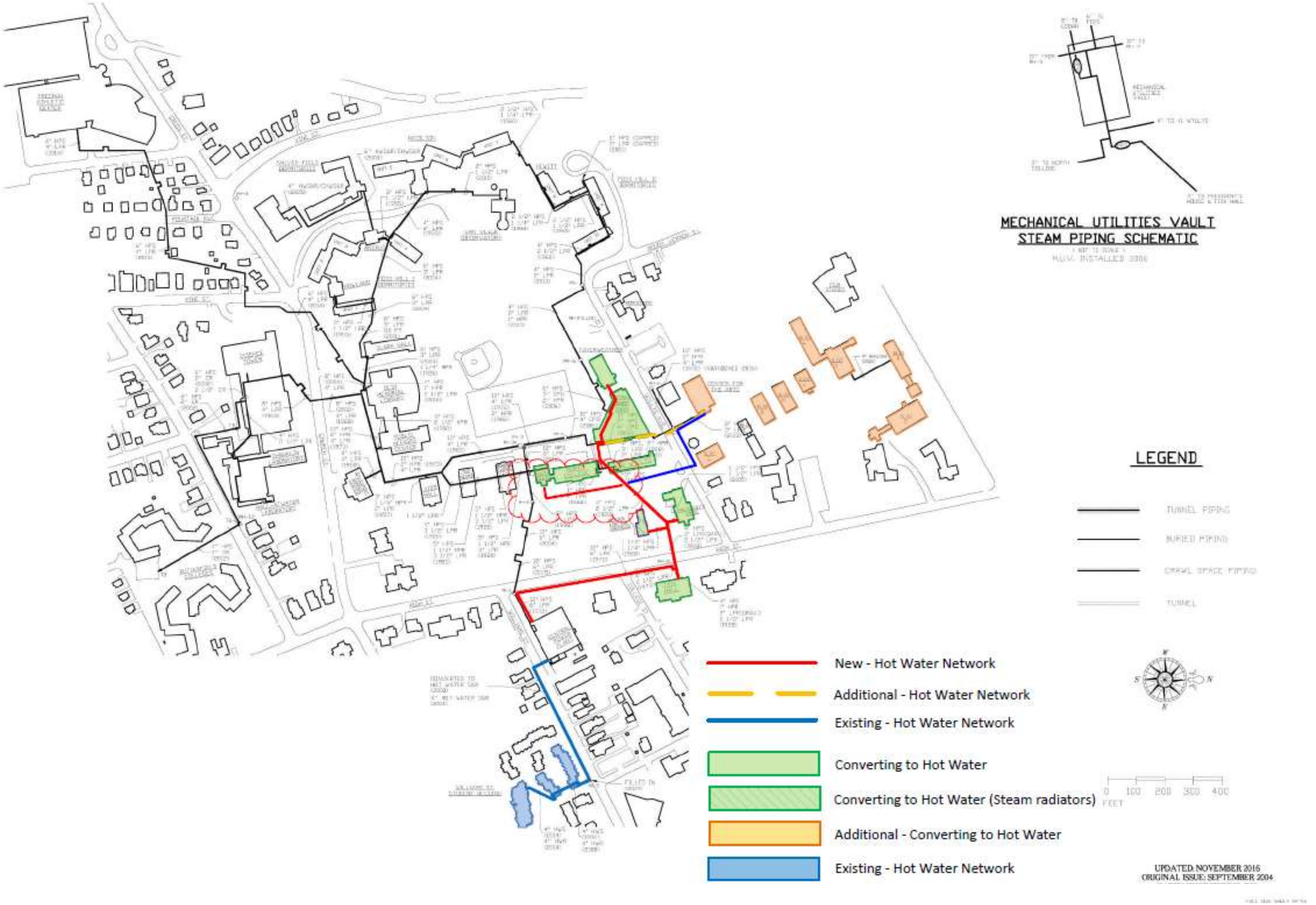

MECHANICAL UTILITIES VAULT
STEAM PIPING SCHEMATIC
LEGEND
New - Hot Water Network
Additional - Hot Water Network
Existing - Hot Water Network
Converting to Hot Water
Converting to Hot Water (Steam radiators)
Additional - Converting to Hot Water
Existing - Hot Water Network
UPDATED NOVEMBER 2016
ORIGINAL ISSUE: SEPTEMBER 2004

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PROJECT OVERVIEW

Project Scope

1,600 foot oldest section of pipe from 1928 has considerable losses

Considering converting that section to HW feeding 8 buildings

7 Buildings already hydronic

Largest building uses steam and needs conversion:

- Heating AHU's and DHW
- Requires on demand steam boiler for kitchen services

Focus on this scope but expand to full campus using $/sq ft

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RAMBOLL SCOPE

Establish heating demand for 8 buildings using square footage data and benchmark data for btu/sq ft

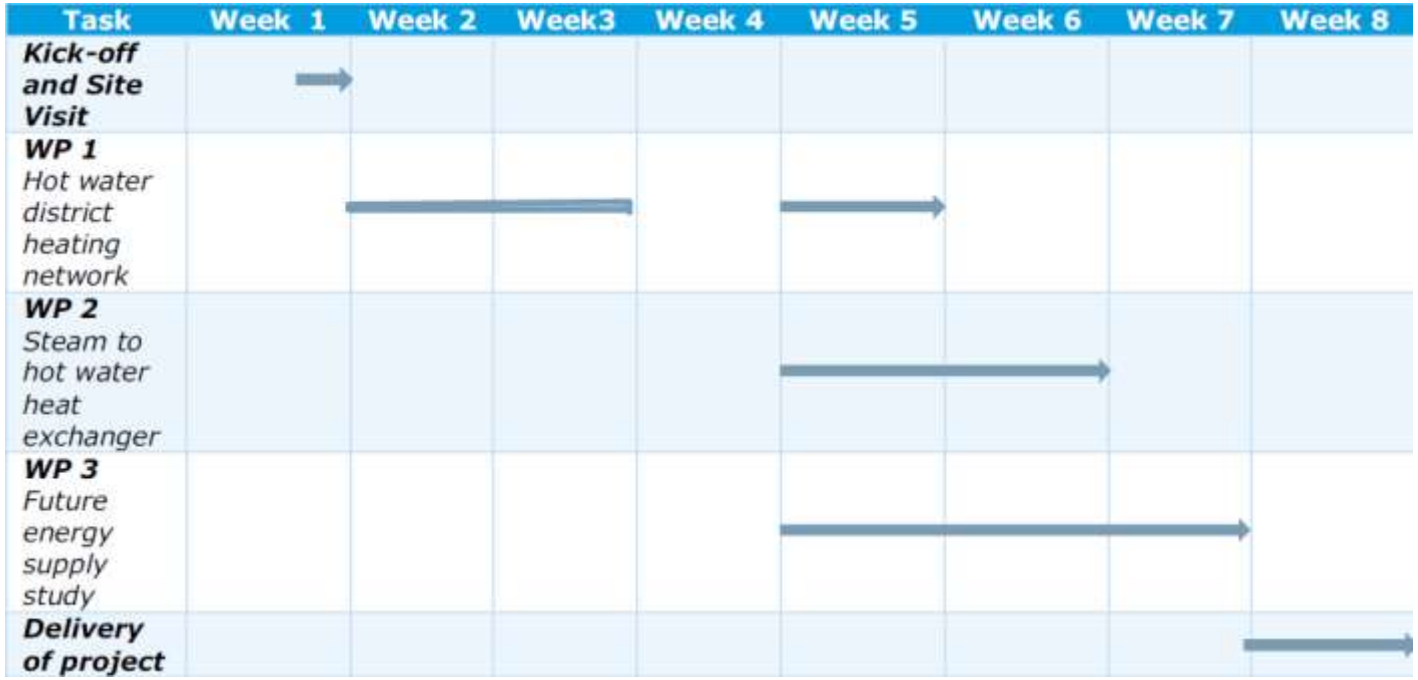
Plan routing and line sizing using Termis hydraulic model

Propose energy supply – Main ETS, hot water boiler, other??

Evaluate thermal storage

Capital cost estimate

Final report outlining options and recommendations



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- Scope defined with 3 scenarios
  - Business as usual or status quo
  - Scenario 1 – 8 buildings fed by ETS in Central Plant
    - 1B – extrapolated out to full campus
  - Scenario 2 – 8 buildings fed by natural gas fired hot water boiler
  - Scenario 3 – convert cogen HRSG to a hot water unit
    - Convert entire campus
    - Barriers identified that jeopardize Sc. 3
- CAPEX for all based on steam lines abandoned in place – no demo

Table 1: Heat Demand

Description	No. of buldings	Estimated heat demand MWh/yr	Estimated heat demand MMBtu/yr
Included in the assessment	8	3,900	13,300
Crowell Concert Hall	1	2,100	7,200
Additional steam supplied buildings	20	20,100	68,500
Total		**26,100**	**89,000**

The relevant building heat demand addressed as part of this study is 20,500 MMBtu/yr.

Table 1: Key Economic Information from Analysis

		Base scenario - Initial Conversion	Scenario 1	Scenario 2	Base Scenario - Whole Campus	Scenario 3
Heat demand in buildings	MMBtu/yr	20,473	20,473	20,473	3700	100,600
Fuel input	MMBtu/yr	36,559	26,938	23,145	187014	202,765
Fuel costs, natural gas, year 1 in operation	1000 $/yr	167	123	106	856	928
Production of electricity	MWh/yr	NA	NA	NA	2246	20,275
Purchase of addtional electricity	MWh/yr	NA	NA	NA	18029	-
Var O/M Costs energy plant, year 1 in operation	1000 $/yr	30.6	22.6	14.5	165	147
Var O/M Costs network, year 1 in operation	1000 $/yr	31.2	6.0	6.0	144	25
Total investments excl. residual value	1000 $	1,491	1,573	1,701	1491	7,929
Carbon footprint in year 1 (tons metric)	tons CO2/yr	1,940	1,429	1,228	12979	10,765
Net present value of costs, 20 years	1000 $	4,199	3,348	3,082	32784	21,923

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Table 1: Summary of Demand and Production

Description	Unit	Steam system	Hot water system
Scenarios 1 and 2			
Demand incl. hot water	MMBtu/yr	13,204	13,204
Losses in distribution system		30%	5%
Production demand from unit	MMBtu/yr	18,863	13,899
Annual fuel savings	MMBtu/yr		4,964
Scenario 3			
Demand incl. hot water	MMBtu/yr	89,000	89,000
Losses in distribution system		30%	5%
Production demand from unit	MMBtu/yr	127,143	93,684
Annual fuel savings	MMBtu/yr		33,459

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Table 1: Heat Recovery Information Received from Jenbacher

		Water	Exhaust	Units
Exhaust Gas Flow			30754	#/Hr
Exhaust Gas Temp. 'entering'			784	°F
Exhaust Gas Temp. 'exiting' (clean)			248	°F
Recoverable H/T Circuit Heat			3899000	BTU/Hr
Recoverable Exhaust Heat			4391690	BTU/Hr
Total Recoverable Heat			8290690	BTU/Hr
Exhaust Side Pressure Drop (Enalco)			4.96	in. wc
# of Passes			1	-
% Glycol		50		%
Water Side Flow		459		GPM
Water Inlet Temp (To Engine)		158		°F
Water Inlet Temperature (To Enalco)		177.5		°F
Water Exit Temperature (From Enalco)		199.5		°F
Water Side Pressure Drop (Enalco)		1.8		PSIG

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Table 1: Investment Costs

		Scenario 1	Scenario 2	Scenario 3
New ETS systems in buildings (water / water)	1000 $	263	263	1,244
New centralized ETS (Steam / water)	1000 $	139		656
Internal building conversion of [redacted] Centre	1000 $			318
Steamer in [redacted] Centre for process heat	1000 $			21
Investments in steam boilers	1000 $			-
Investments in heat only boilers	1000 $		240	-
Tank thermal energy storage	1000 $			100
Convertion to hot water on engine	1000 $			586
Conversion to hot water system	1000 $	1,200	1,200	5,004
Refurbishment of steam system	1000 $			-
TOTAL CapEx excl. residual value	1000 $	1,601	1,703	7,929

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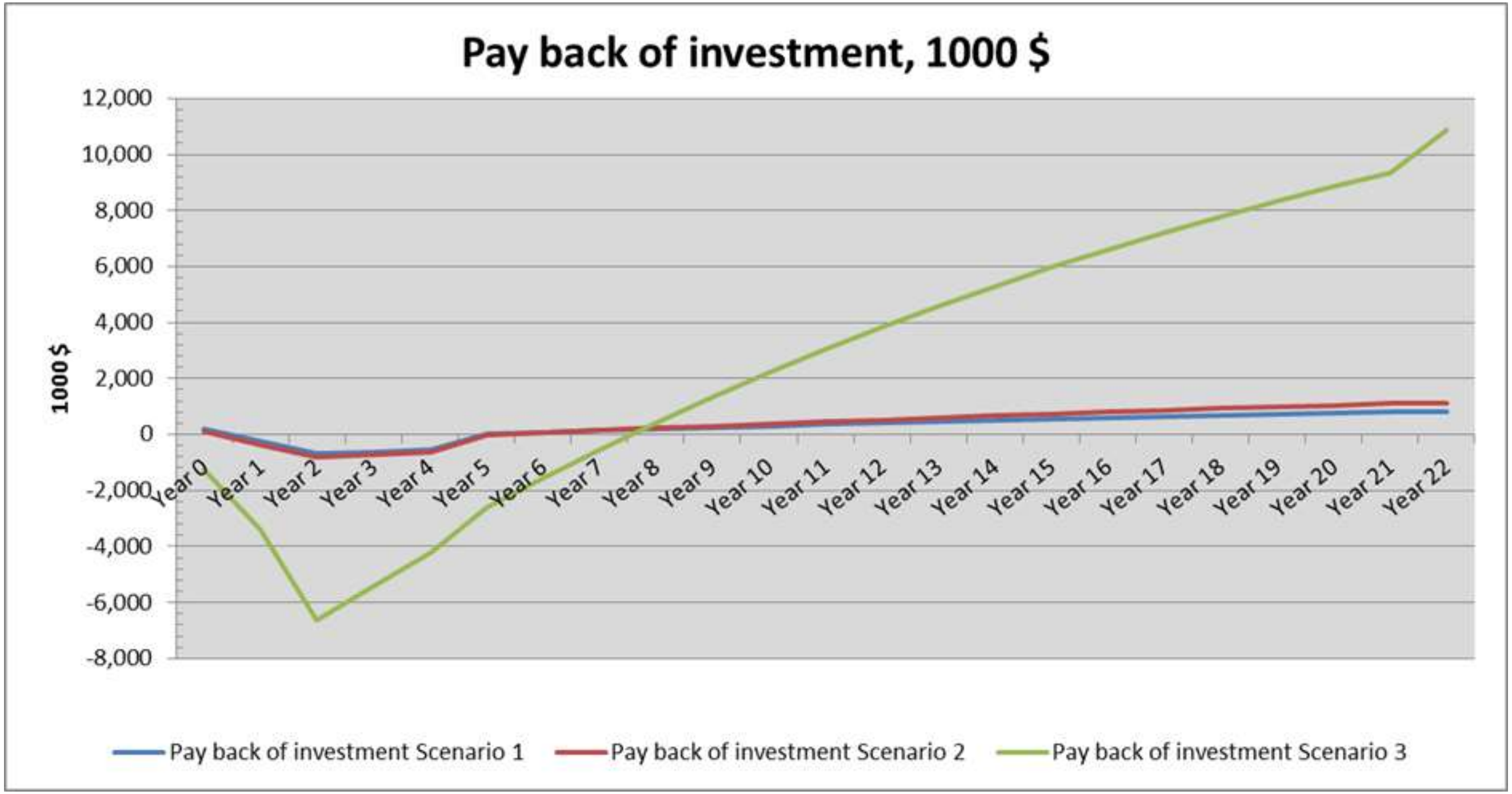

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- Recommended next steps
  - Select 1 or 2 preferred scenarios
  - Hourly modelling in energyPRO to ensure lowest possible costs when heating, cooling, and electricity is integrated
  - Preliminary design of the system
  - Cost benefit analysis incl. CAPEX and OPEX estimates +/- 10%
  - Meeting with WU 1/25/18

- Conduct analysis to provide a greater degree of details for the following:
  - Full conversion to hot water
  - Co-production of heating / electricity
  - Inclusion of thermal storage
  - Potential co-production of heating / cooling. Potential seasonal storage
  - Implementation and phasing of a hot water network
  - More details of the potential trench of the hot water network
  - CapEx to a higher degree based on local prices working with contractor

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