Opportunities for combined heating and cooling

A case study from Nestle Halifax

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Director of Innovation
Star Refrigeration Ltd

STAR REFRIGERATION

Neatpump
LOW CARBON HEATING...NATURALLY

Why bother?

www.thisismoney.co.uk

Supply of energy

www.thisismoney.co.uk

Nestlé UK Halifax

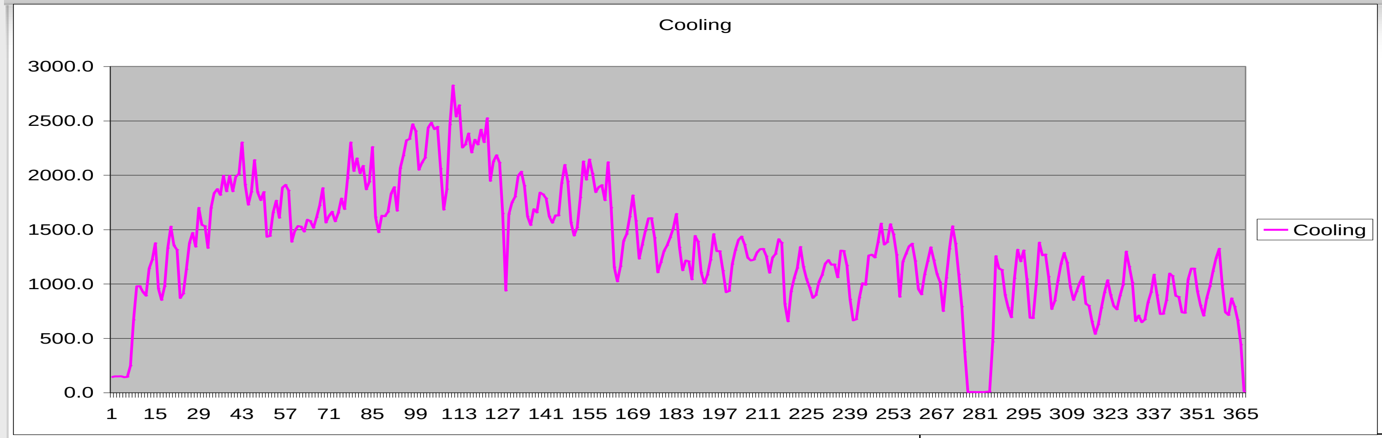
The Nestlé UK Halifax site covers approximately 3.0 hectares

In 2008 the site..

- Produced circa 30,000 tons of confectionery brands
- Multiple packaged glycol chillers with poor COPs utilised HCFC R22
- Was committed to the phase-out of R22 by 2010
- Generated 59,500 lb/hr (27,000kg/hr) of steam using coal fired boilers with low efficiency levels, circa 56%
- Was the last in Nestlé Zone Europe to use coal combustion for steam generation

Old Coal Fired Boiler House

Future Cooling Systems Options

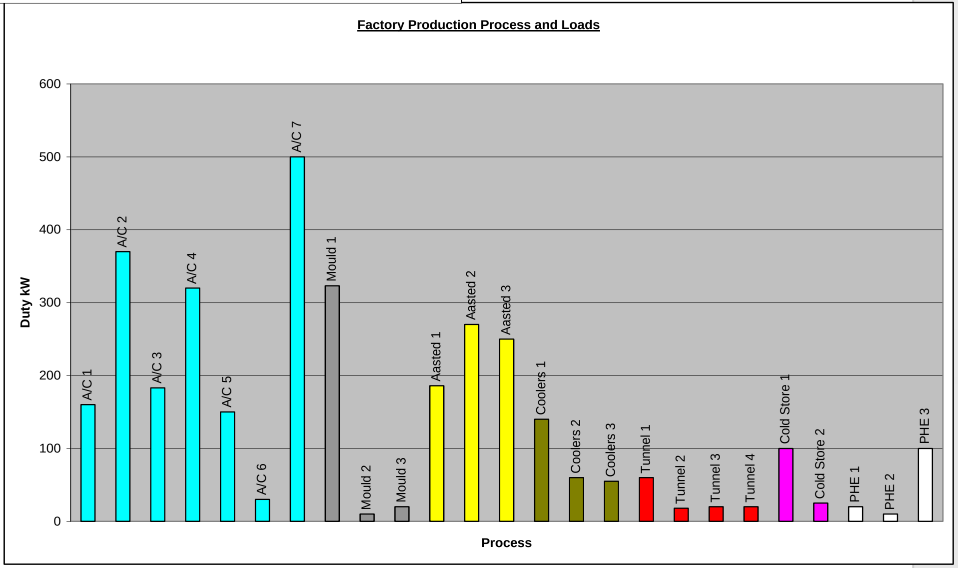


Refrigerants Policy
Natural Refrigerants = Ammonia

Central plant

Low charge design

Allowed radical re-design of chilled glycol system



Allowed development of the concept to maximise the capture & use of waste heat

Future Heating Systems Options

Option 1 – Central Gas Fired Boiler House

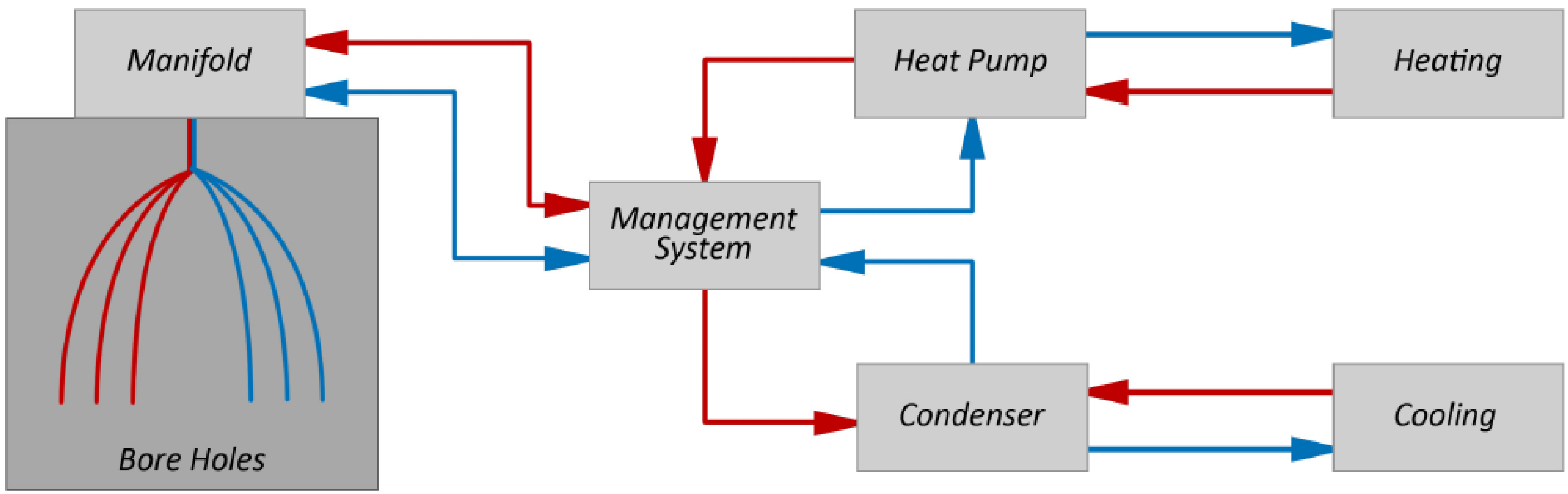
+ Simplest solution
+ Lowest capital cost
+ Compliance with UK air quality legislation
- Without existing site steam distribution upgrade overall steam system efficiency not improved

Option 2 – Combined Heat & Power (CHP) Plant

+ 1.5MW_e CHP system could deliver supplementary electricity & enough steam for site needs
+ Compliance with UK air quality legislation
- Without existing site steam distribution upgrade overall steam system efficiency not improved
- Flexibility of steam delivery to match future production patterns
- Uncertainty over future energy production benefits from CHP

Future Heating Systems Options

Option 3 – Geothermal Storage & Harvesting System



+ Infrastructure for both cooling & heating
+ Incorporating ammonia refrigeration & heat pump technology
+ Compliance with UK air quality legislation
- High capital costs
- Bore hole arrays required use of large area of available land leading to unacceptable limitations on future use

Future Heating Systems Options

Option 4 – Steam Migration & Thermo Coupling

Steam Migration – moving from a single high grade steam generation source to multi-temperature generation systems suited to end user specific applications

Thermo Coupling – tying heat extracted at relative low temperature from site cooling demand to high temperature needs via heat pump technology

Future Heating Systems Options

Option 4 – Steam Migration & Thermo Coupling

Heat Load	Duty	Load %		Temp. °C	Temp L/M/H
Calorifiers	(823 kW)	33%		60- 90	M
Domestic Hot Water	(89 kW)	3%		50 - 60	L
CIP Calorifiers	(131 kW)	5%		80 – 90	M
Cookers	(813 kW)	32%		120 – 125	H
Bowl Washers	(252 kW)	10%		60 – 90	M
Other	(151 kW)	6%		60 – 90	M
Losses	(277kW)	11%		All	LMH
TOTAL	(2536 kW)	100%			LMH

Assessment of Cooling & Heating Options

Technology	Energy	PVC (15years)	Qualitative Score
Central Gas Fired & R717 Chillers	5.26GJ/tonne	£23,368k	15
CHP & R717 Chillers	7.87GJ/tonne	£22,045k	19
Geothermal & Packaged R717 Chillers	2.13GJ/tonne	£17,197k	23
Migration & Thermal Coupling	3.93GJ/tonne	£20,243k	13

Old and New

STAR REFRIGERATION

<u>Old Plant</u>

Installed 1988

Cooling Capacity 18,435MBtu/hr @ +32ºF
5.4MW @ 0ºC

12off R22 DX packaged air cooled chillers

4off Fixed Speed Primary Glycol Pump

16off Fixed speed Secondary Pumps

Glycol +5degC to 0degC

COP Summer: 2.82
COP Winter: 3.8

<u>New Plant</u>

Installed 2010

Cooling Capacity 10,242MBtu/hr @ +32ºF
3.0MW @ 0ºC

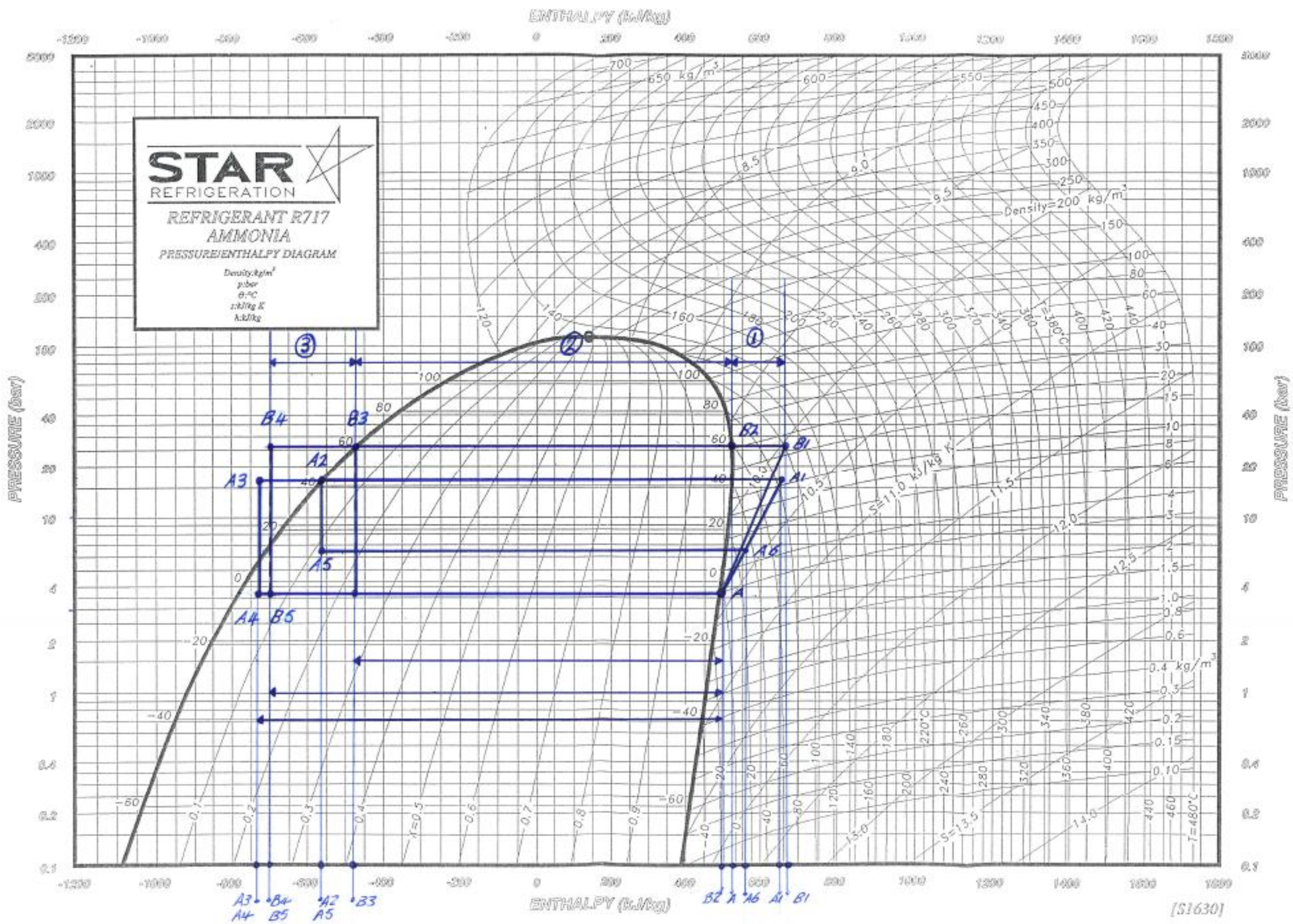
Heating Capacity 4,267MBtu/hr @ 140ºF
1.25MW @ +60C

1off Common Low Charge NH3 system
4x Screw Compressor PU's incl x2 HP Units
VSD Primary and Secondary Pumps

4x Flat bed Air Cooled Condensers
1x Flat bed Air Cooled Oil Cooler
1x CIP and CL Waste Heat Recover PU

COP Cooling only: 4.0
COP Heating and Cooling: 6.38

Ammonia System P-H Diagram



Ammonia System Key Features

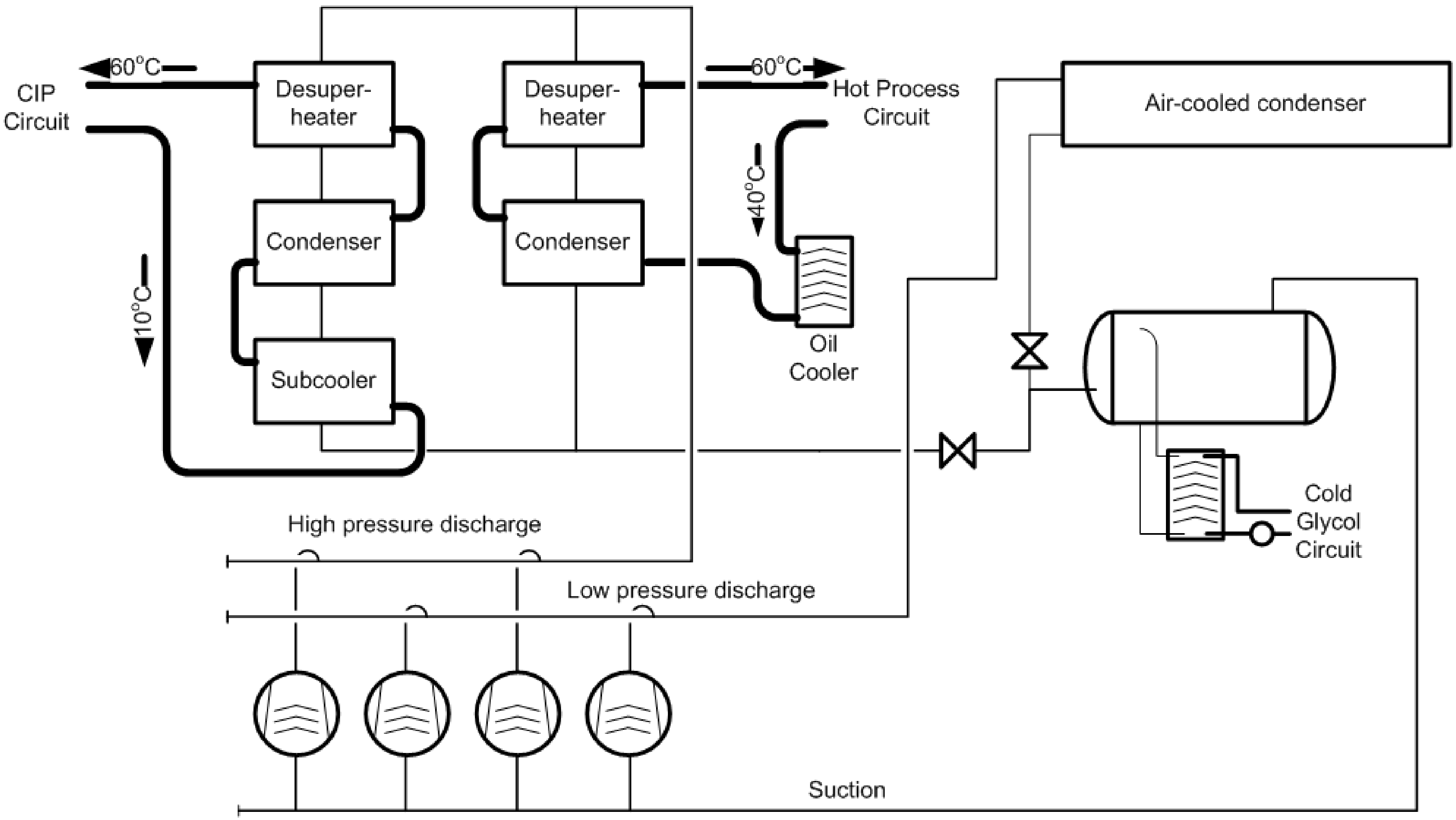
- Compressors matched to their primary function – cooling & heating or cooling only
- Separate high grade heat recovery packaged units for ‘once through total loss’ loads and the ‘closed loop circuit’ loads
- Ammonia screw compressors operating at high pressure
  Circuit design developed with three levels of system allowable pressure:
  1. 500psi (35bar) – heat pump compressors & heat recovery packages
  2. 360psi (25bar) – cooling only compressors, condensers, economiser
  3. 250psi (17bar) – PHE evaporators & surge drum set
- The compressor control strategy
- Low refrigerant charge
- Air-cooled condensers operating with VSD fans

Screw Compressor Packaged Units

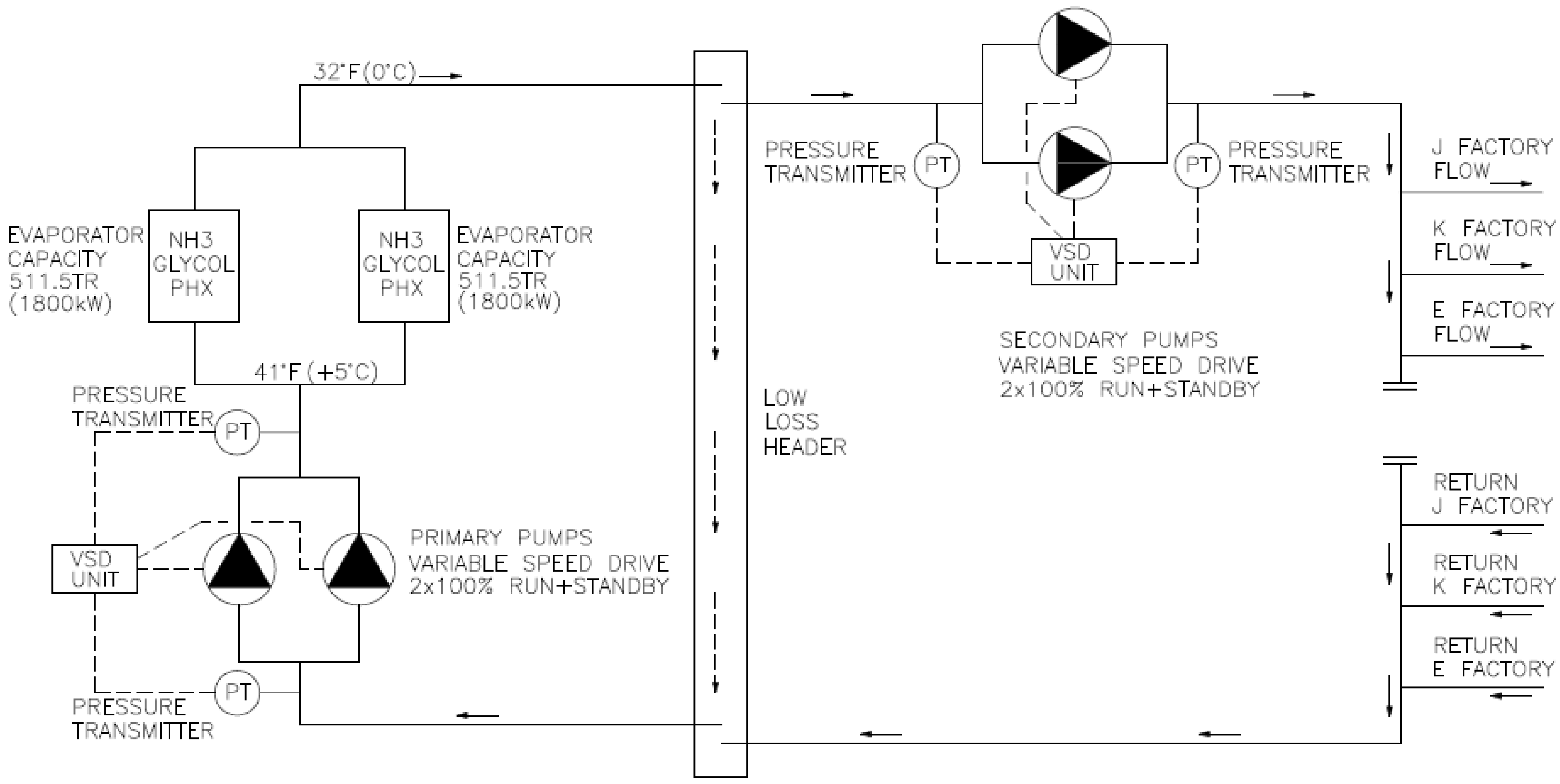
New Ammonia Cooling and Heating Plantroom

New Condenser Area

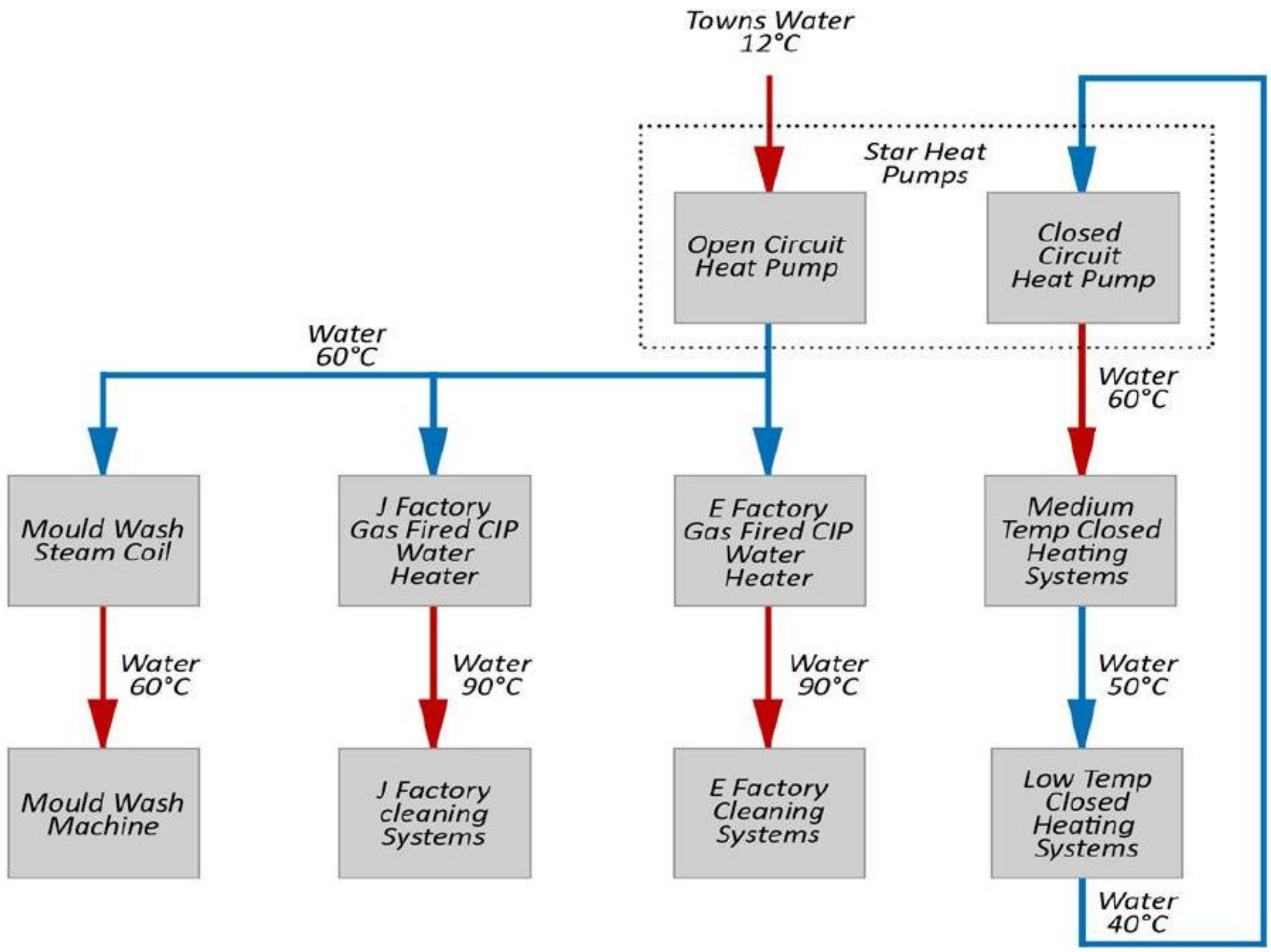
Food Factory Heating System



Re-Configured Chilled Glycol Circuits



The Heated Water Process Streams



CIP Hot Water Storage Tanks

Overall Operating Cost Benefit

	2008	2011	Annual Reduction
Capital Investment		$6,300,000 £4,200,000	
Energy	$2,700,000 £1,800,000	$1,290,000 £860,000	$1,410,000 £940,000
Operational Cost	$570,000 £380,000	$120,000 £80,000	$450,000 £300,000
CO_2 - CCL	$495,000 £330,000	$247,500 £165,000	$247,500 £165,000
Water	$108,000 £72,000	$70,500 £47,000	$37,500 £25,000
Total	$3,765,000 £2,510,000	$1,657,500 £1,105,000	$2,145,000 £1,430,000

Exchange Rate assumed $1 = £1.50

Overall Environmental Benefits

	2008	2011	Annual Reduction	Annual Reduction %
Production Volume	31,900 tons (US) 29,000 tonnes	31,900 tons (US) 29,000 tonnes		
Energy per unit of Production	5.422 MBtu/ton 5.20 GJ/tonne	3.013 MBtu/ton 2.89 GJ/tonne	2.429 MBtu/ton 2.33 GJ/tonne	45%
CO_2	22,000 tons (US) 20,000 tonnes	10,615 tons (US) 9,650 tonnes	11,385 tons (US) 10,350 tonnes	52%
HCFC	2,605 lb 1,184 kg	304 lb 138 kg	2,301 lb 1046 kg	88%
Particulates	3,872 lb 1,760 kg	0 lb 0 kg	3,872 lb 1,760 kg	100%
Water	13,825,970 gal (US) 52,337 m^3	9,094,385 gal (US) 34,426 m^3	4,731,585 gal (US) 17,911 m^3	34%

Post Installation Performance

- The Ammonia plant is now providing 750kW of waste heat to pre-heat towns water to the factory at +60degC whilst meeting the sites process cooling demand

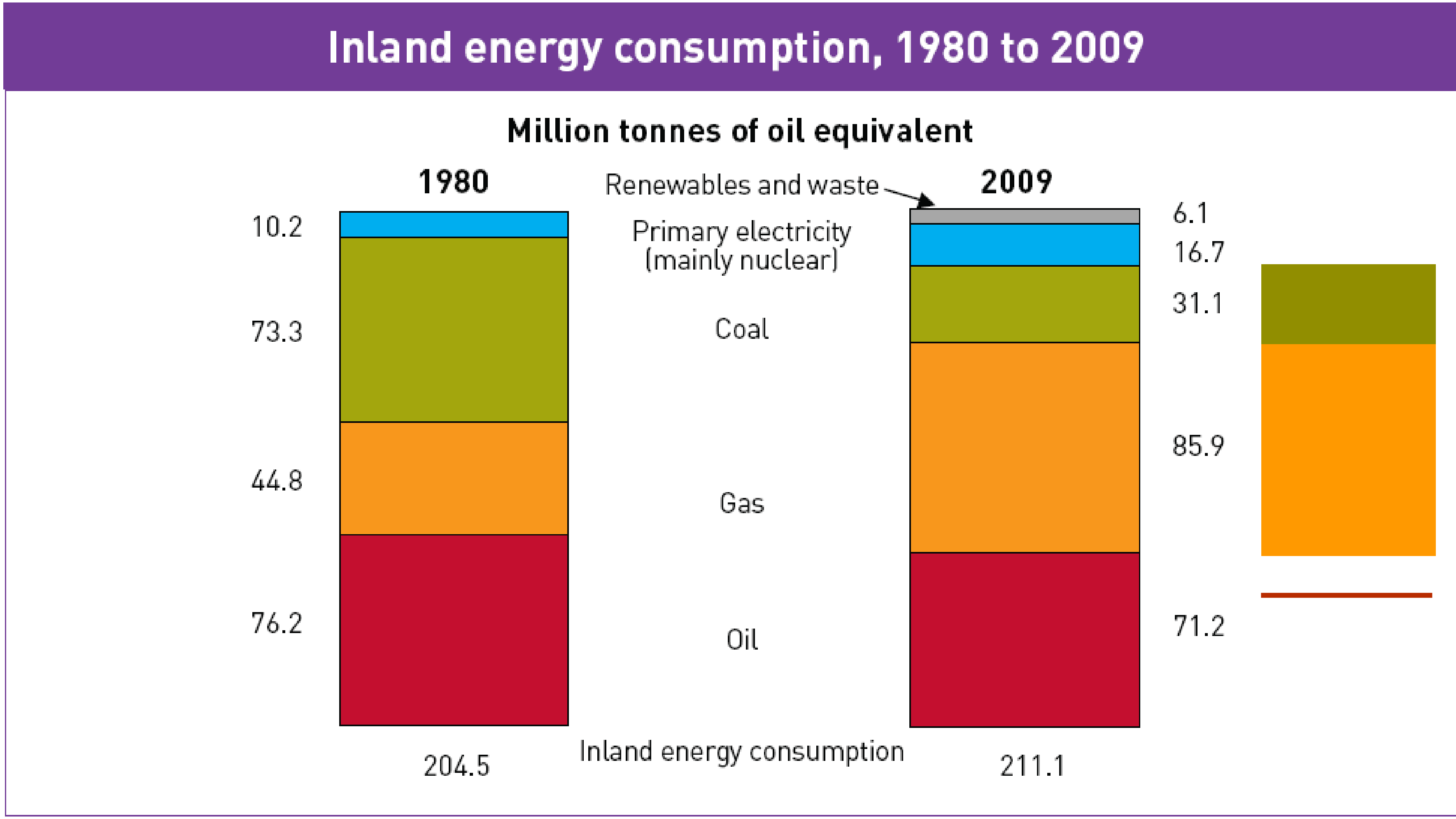
- The new refrigeration plant showed a 39% reduction in power consumption over the same 15 week calendar period between July and October for 2009 and 2010.

- In November 2010 site commissioned the Closed-Loop heating circuits. More waste heat from the Ammonia plant is being utilised. It is estimated the 250kW currently utilised is set to double in line with design

- The site is on target to achieve the level of savings identified in the cost benefit analysis

- The capital cost of the project will be recovered within 4 years

UK Energy consumption



Figures from DECC, "UK Energy in brief, 2010"

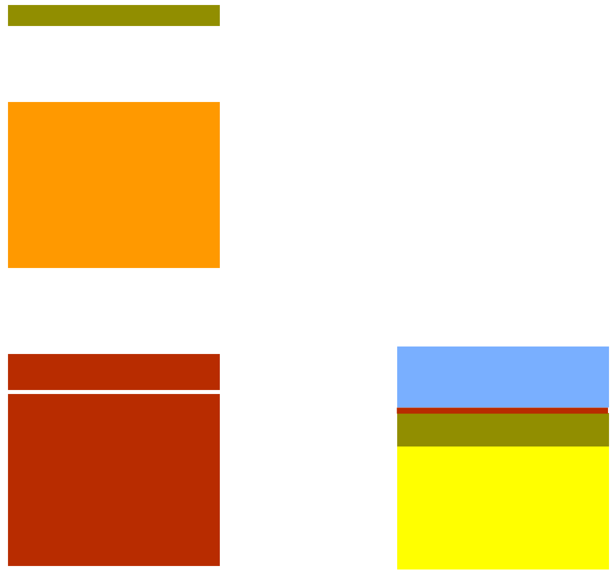
UK uses of energy

Split out fuel used to generate electricity

and remove the oil used for transport

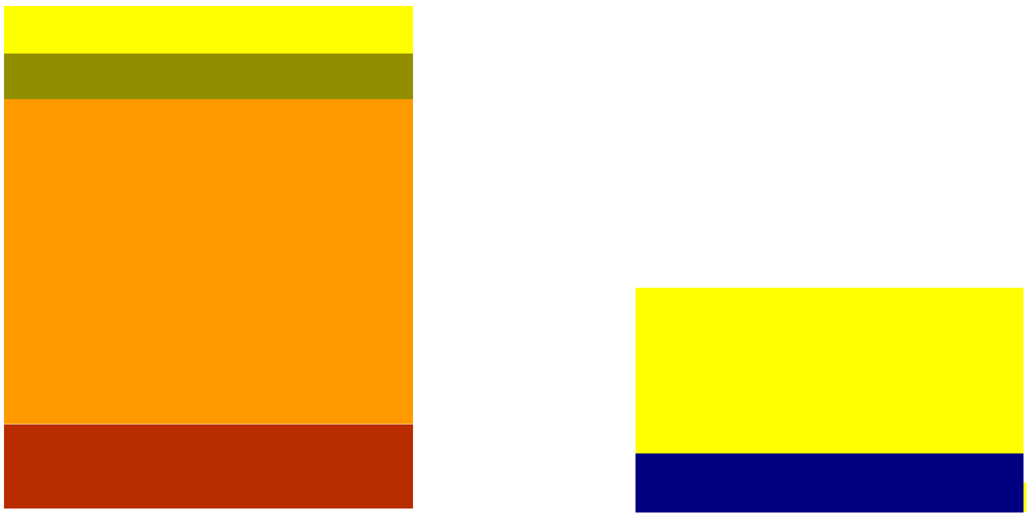
Then convert the fuel to electricity………

30.5% of all energy use is fossil fuel for heating, 18% is electricity (some of which is used for heating too!)



Figures from DECC, “Digest of United Kingdom Energy Statistics, 2010”

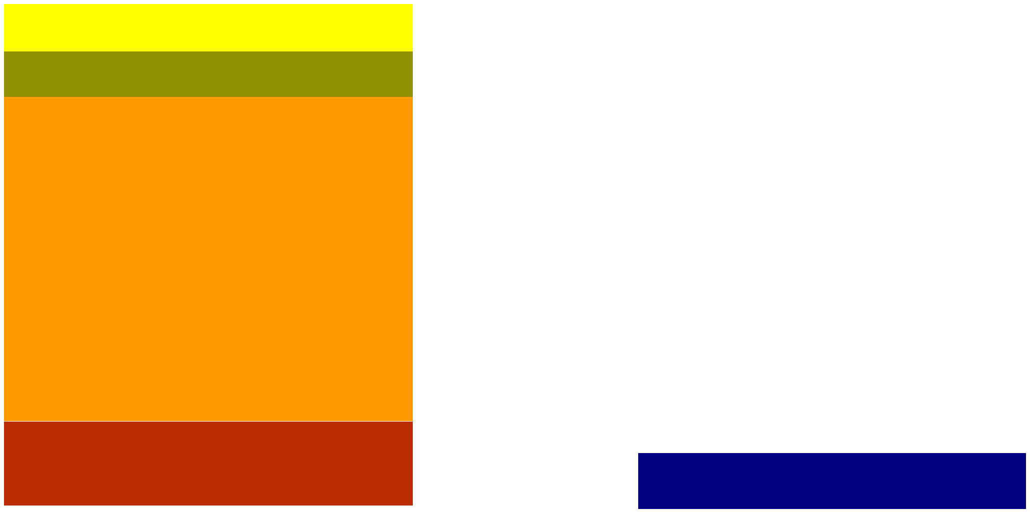
Heating vs Cooling



About 1/9 of the electricity used is for refrigeration and air-conditioning, including chillers. If we take an average CoP of 2 for all systems then the heat load is twice the electrical input.

All of the remaining fossil fuel and some of the electricity is used for heating

Heating vs Cooling



It looks as if the demand for heating is about nine times higher than the demand for cooling. The market for heat pumps is huge!

At present heat pumps are being designed and sold by refrigeration people – we need a bigger vision!

Summary of Heating loads

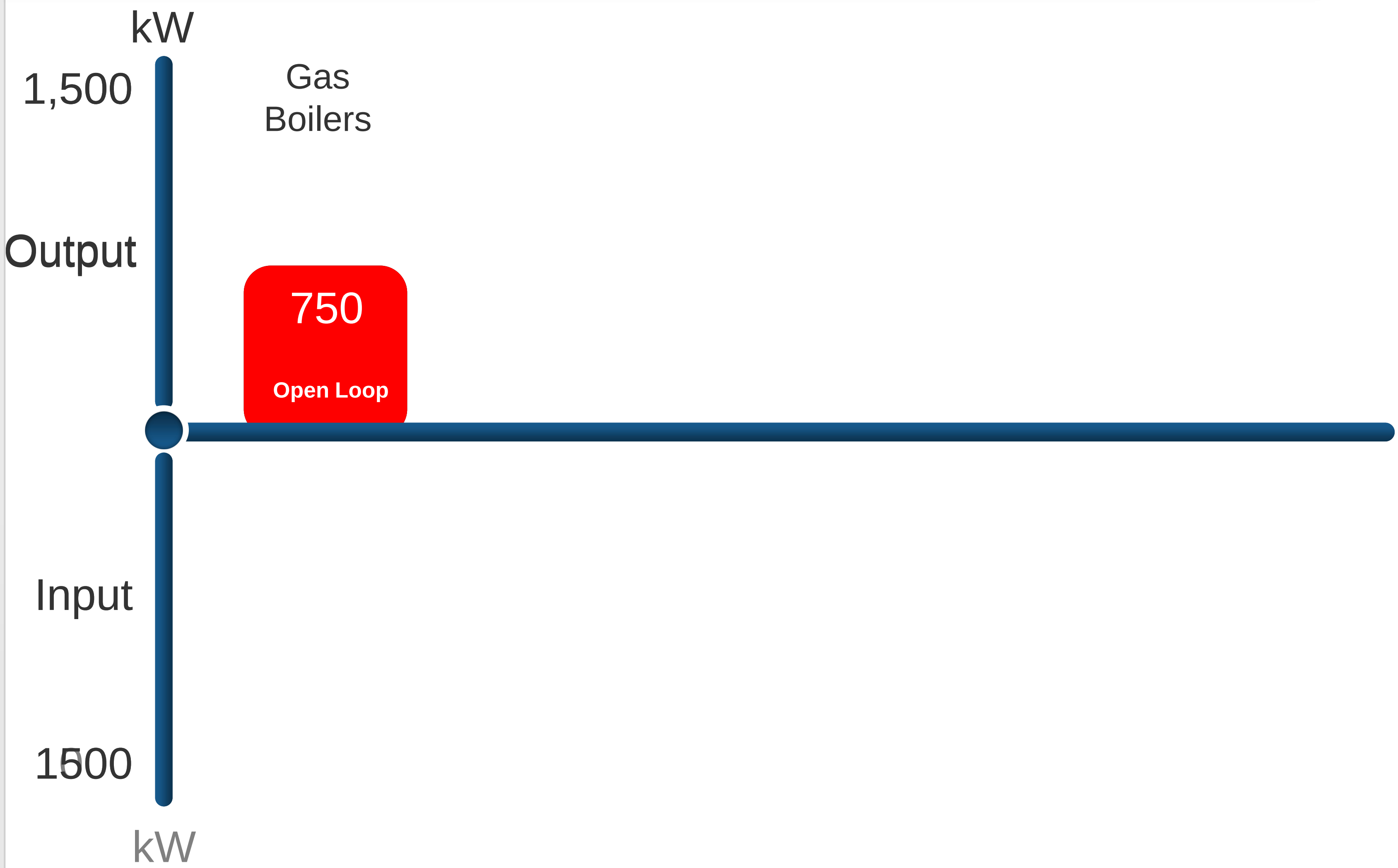
There are two independent hot water circuits: The Clean in Place circuit has a high load but is used intermittently. The closed loop circuit provides heat to the chocolate moulds during production and is used continuously.

	CIP circuit	Closed loop circuit
Water inlet (^{o}C)	10	40
Water outlet (^{o}C)	60	60
Water flow rate (kg/s)	3.57	5.95
Heating Duty (kW)	745	500
% in desuperheater	10.4%	10%
% in condenser	75.6%	75%
% in subcooler	14%	15%*

Conclusions

- Perkins Cycle heating is a great way to reduce CO_2e
- Deployment of these systems is pinned to fuel price
- We need to learn to think of heating systems giving “free cooling”, not the other way around
- Heating without using the cooling is OK – we just have to get used to the idea
- Selling the free cooling as a utility is an even better idea!

Conventional versus Heat Pump



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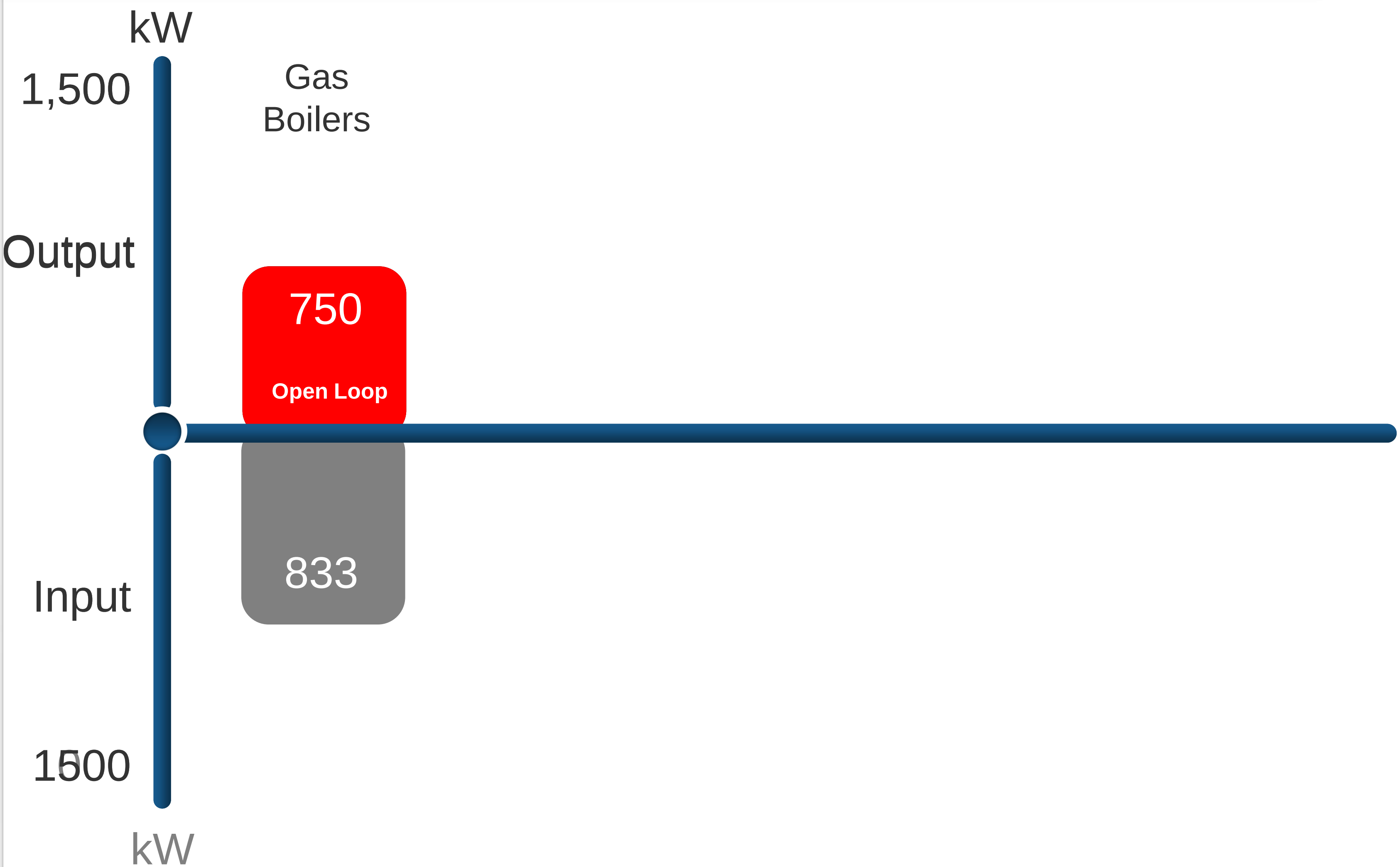

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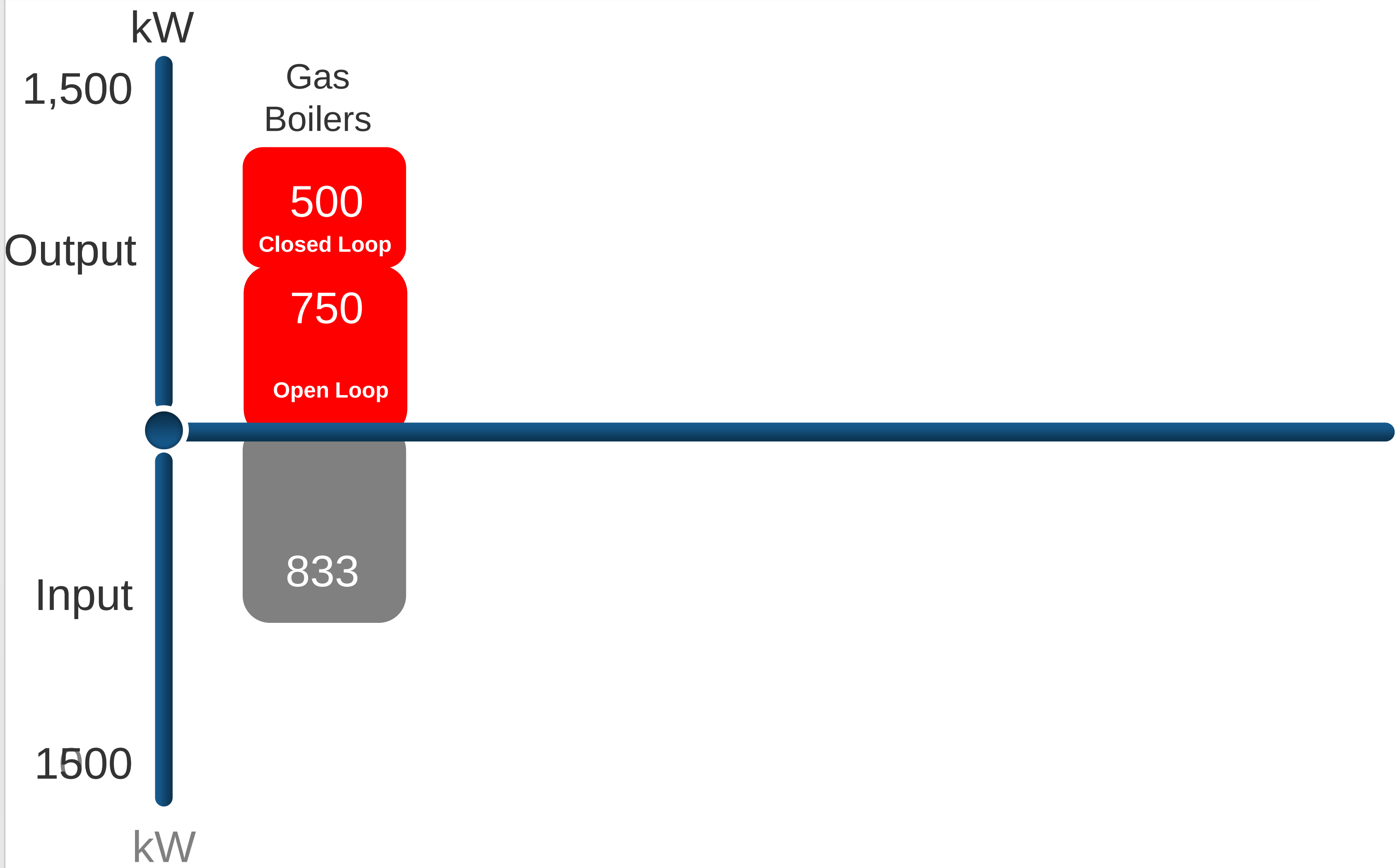

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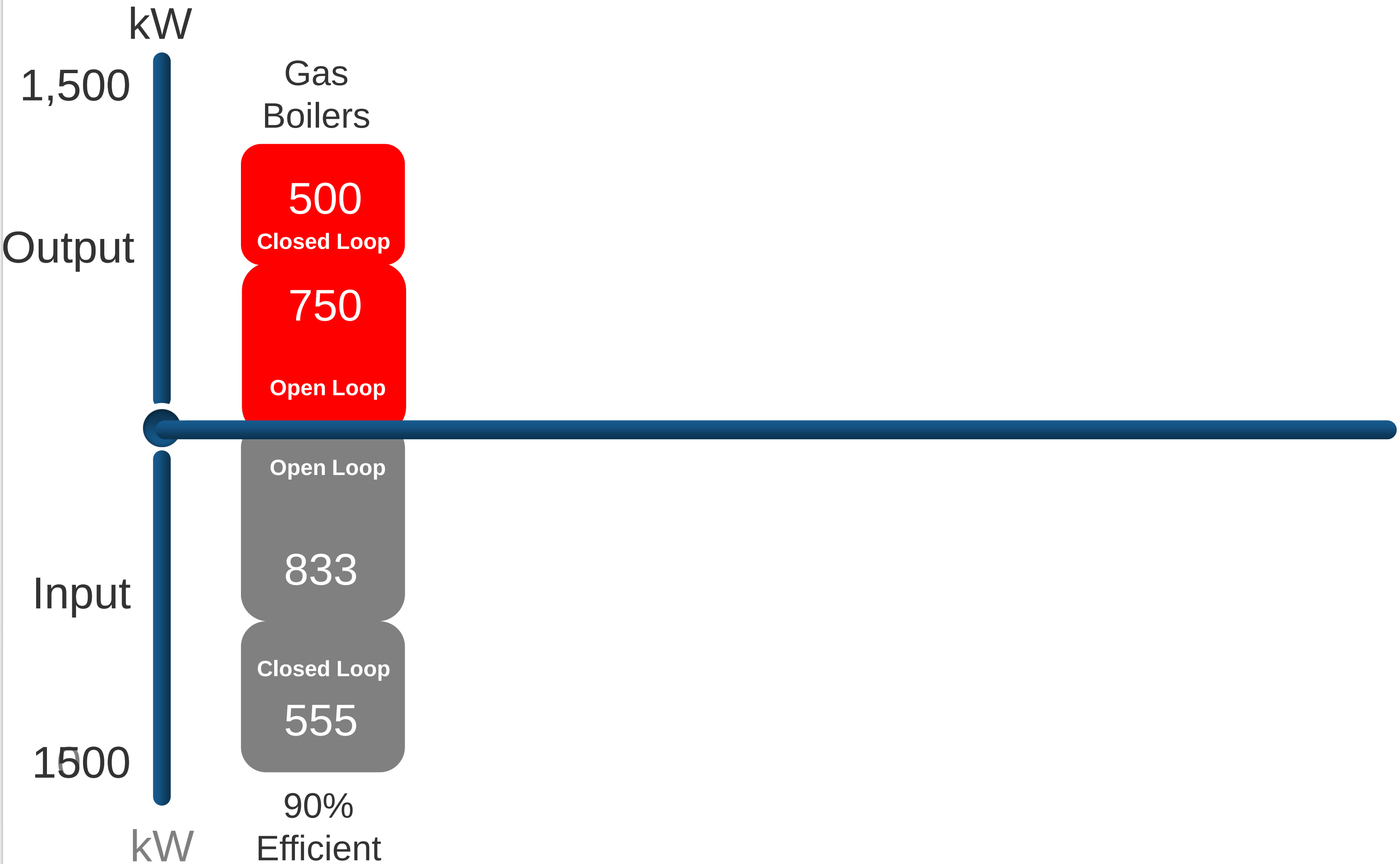

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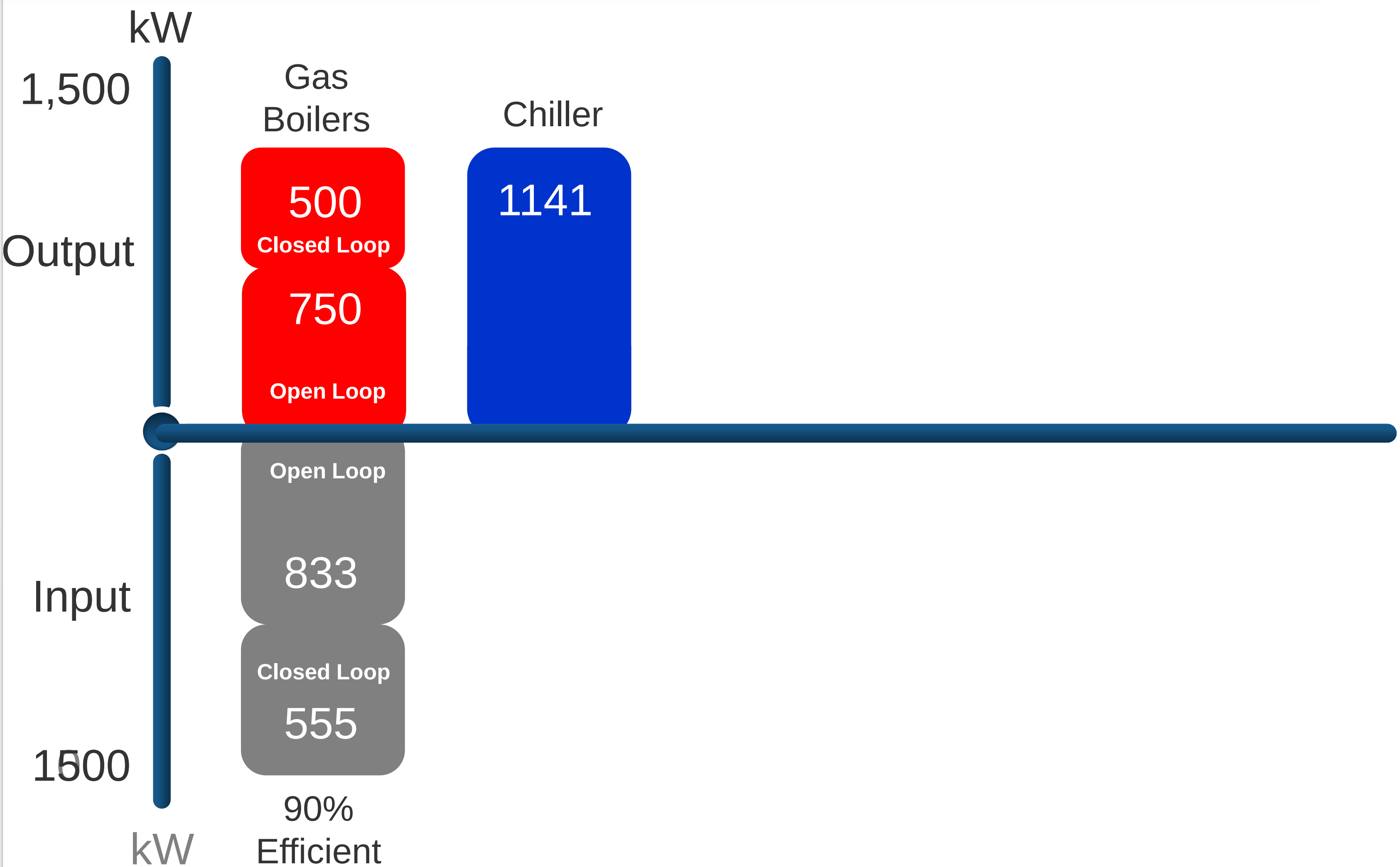

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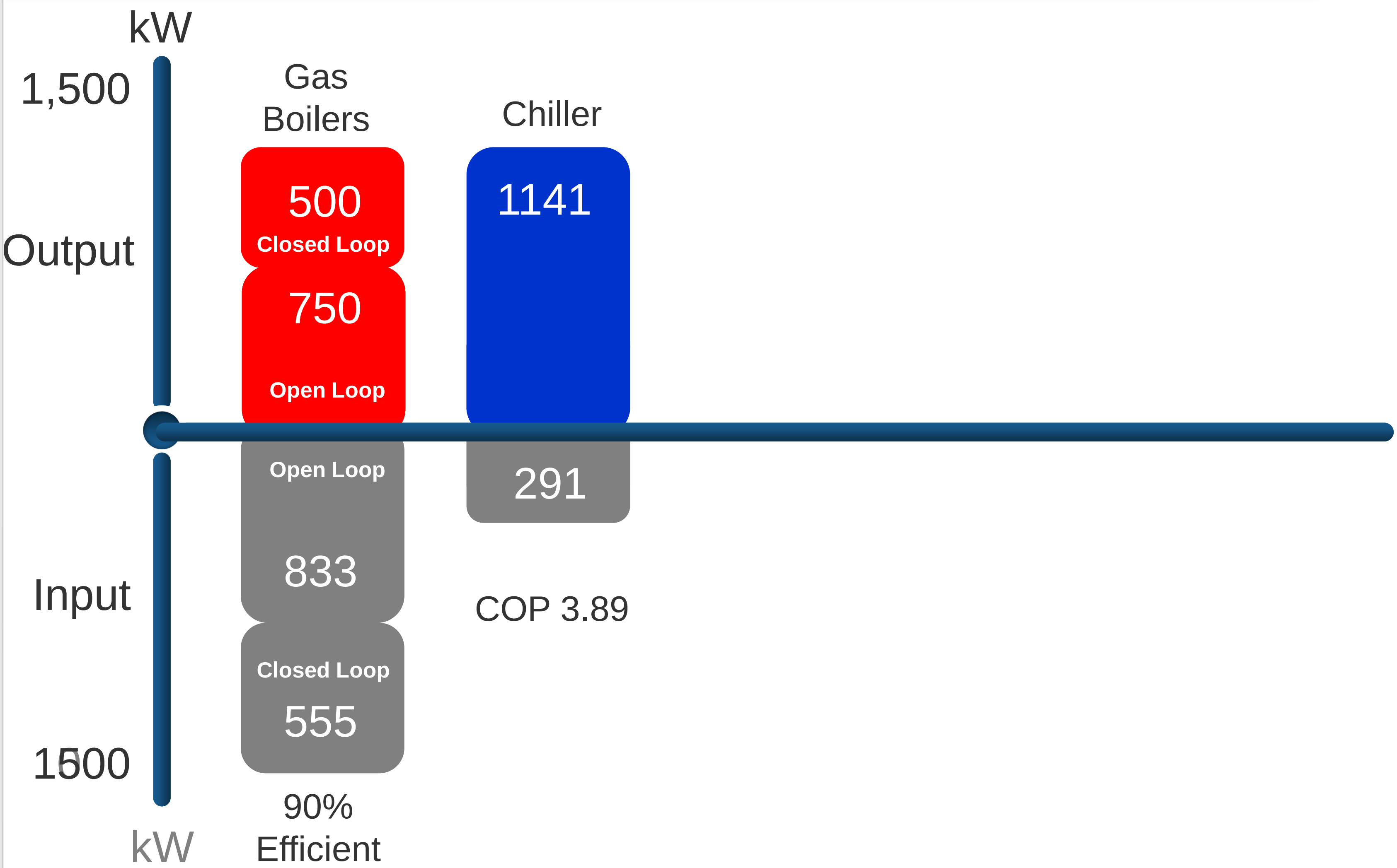

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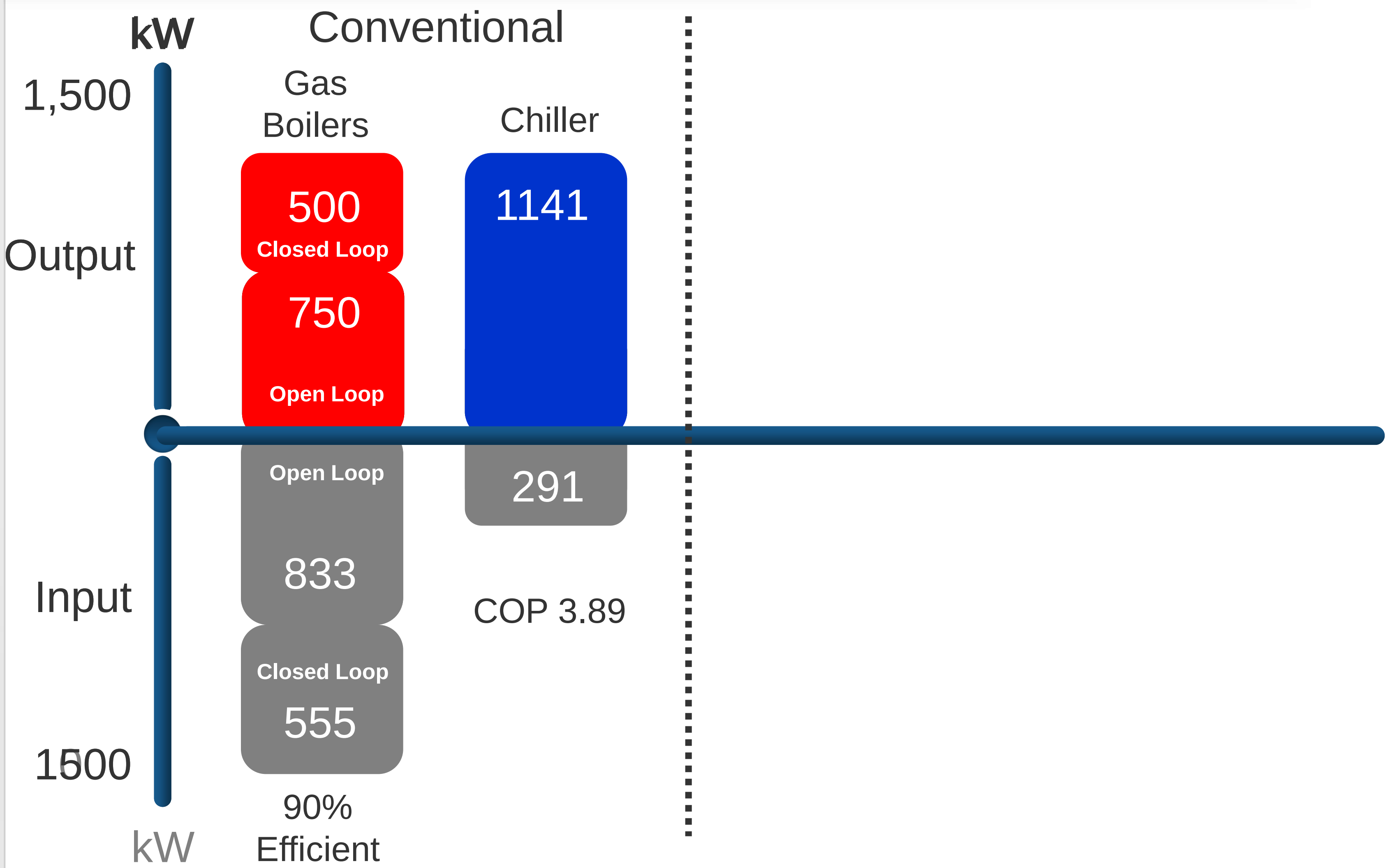

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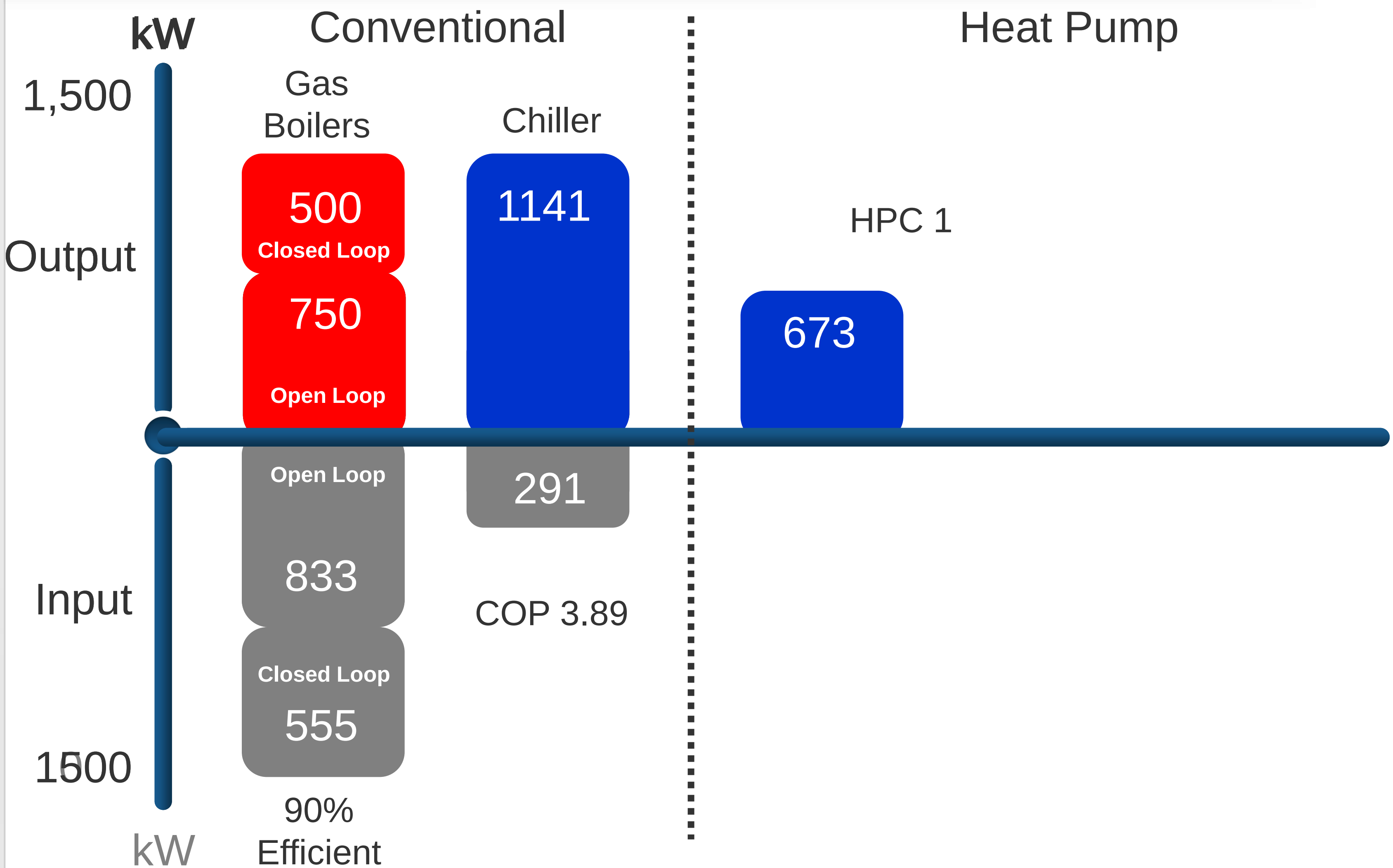

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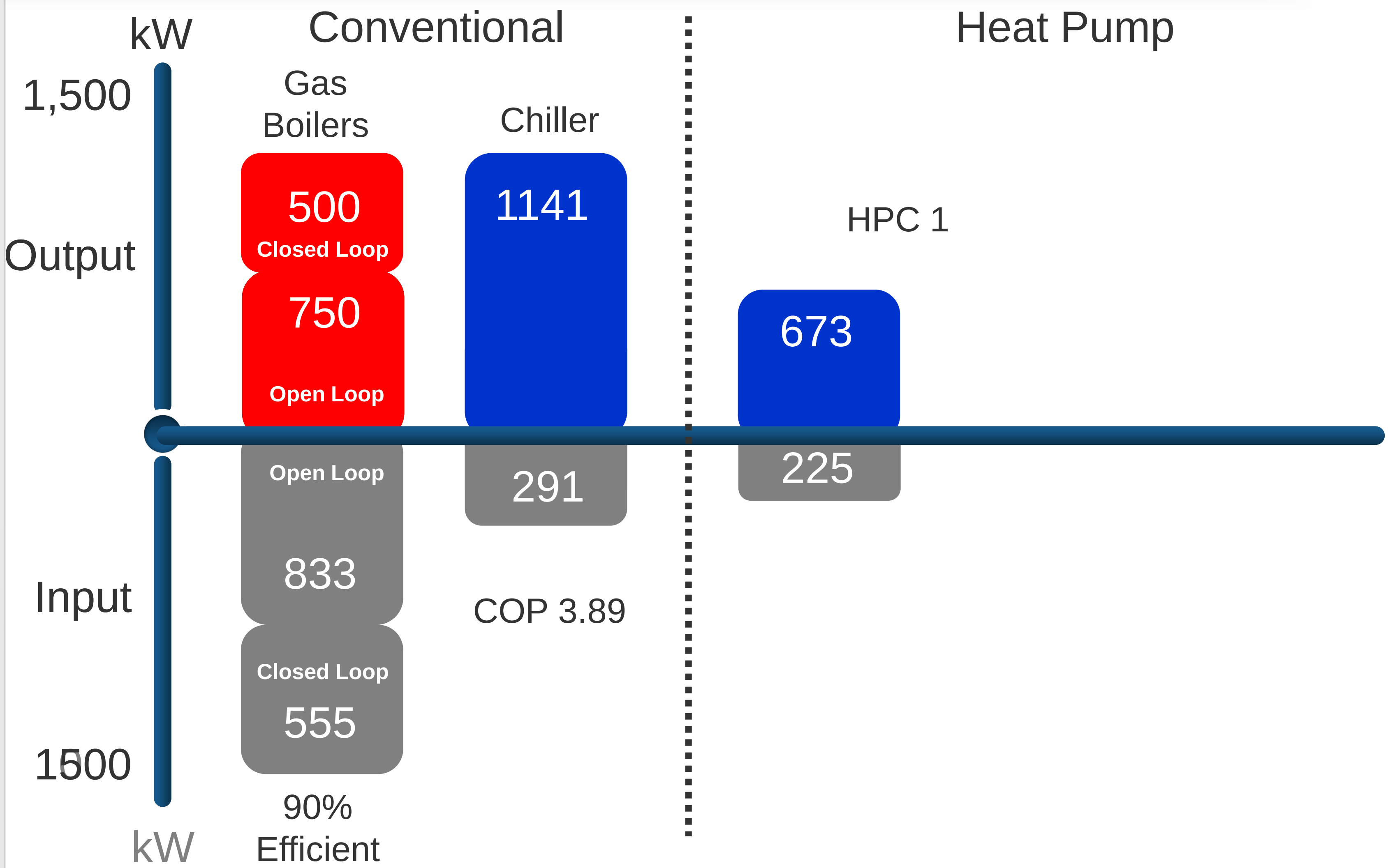

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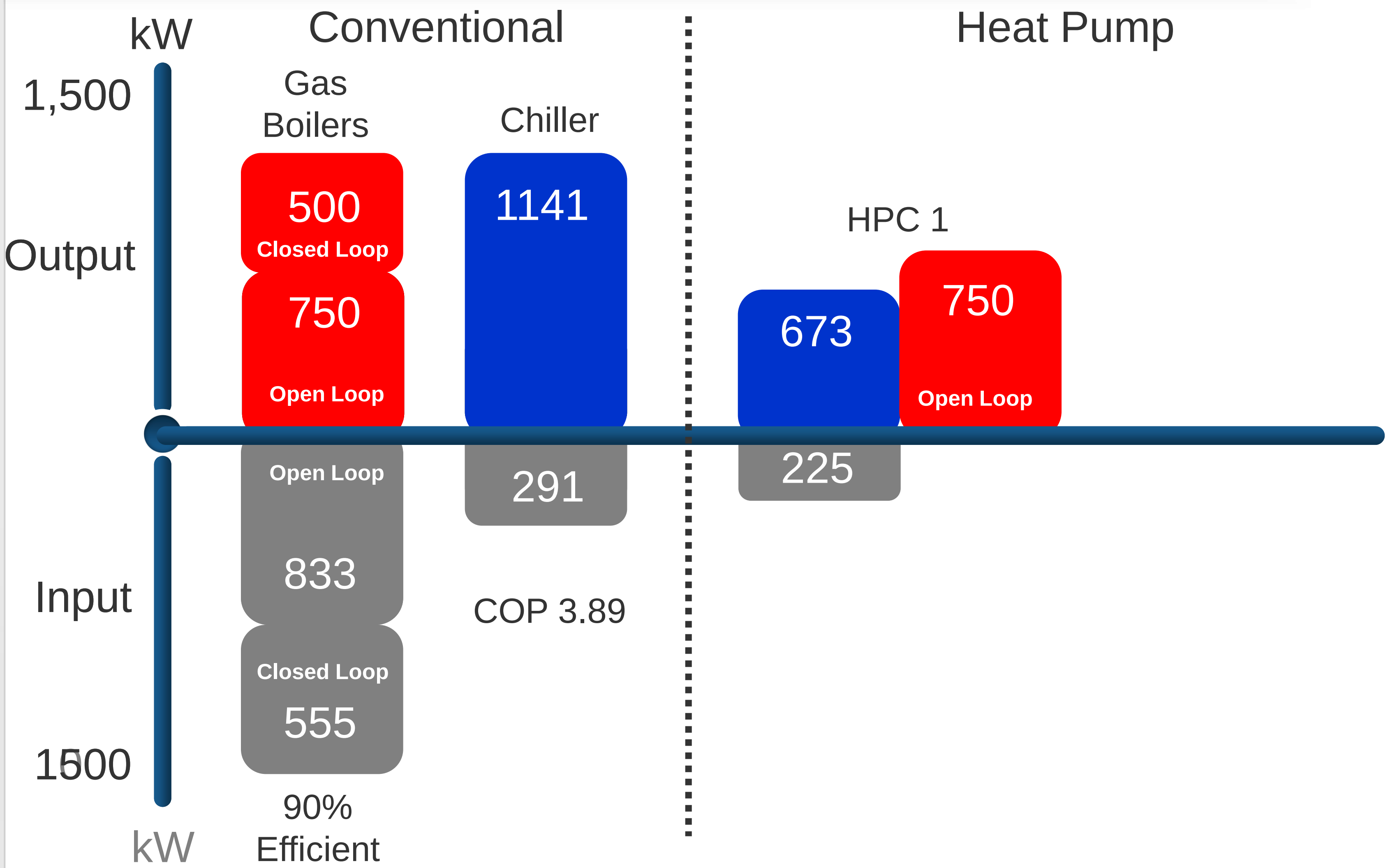

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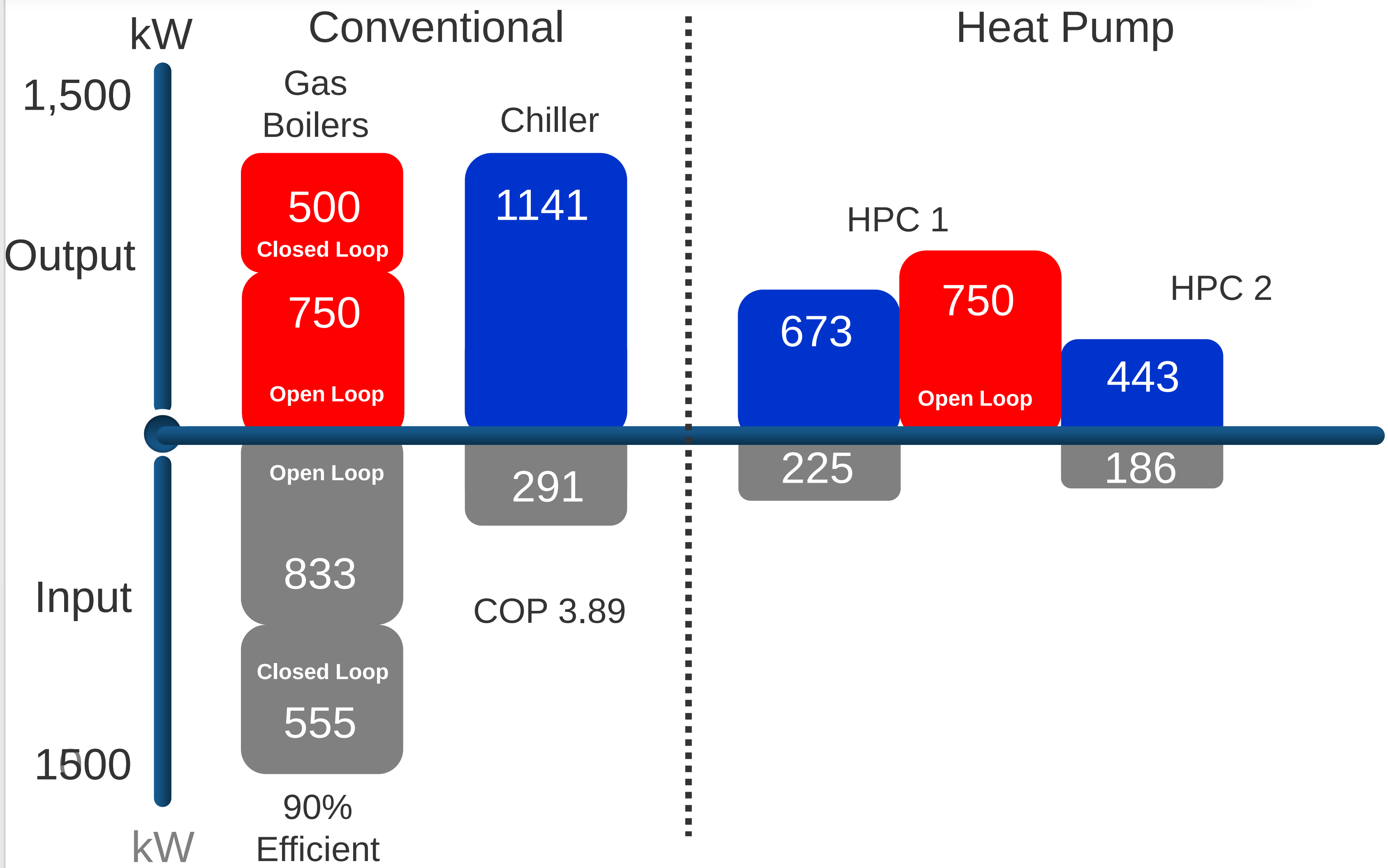

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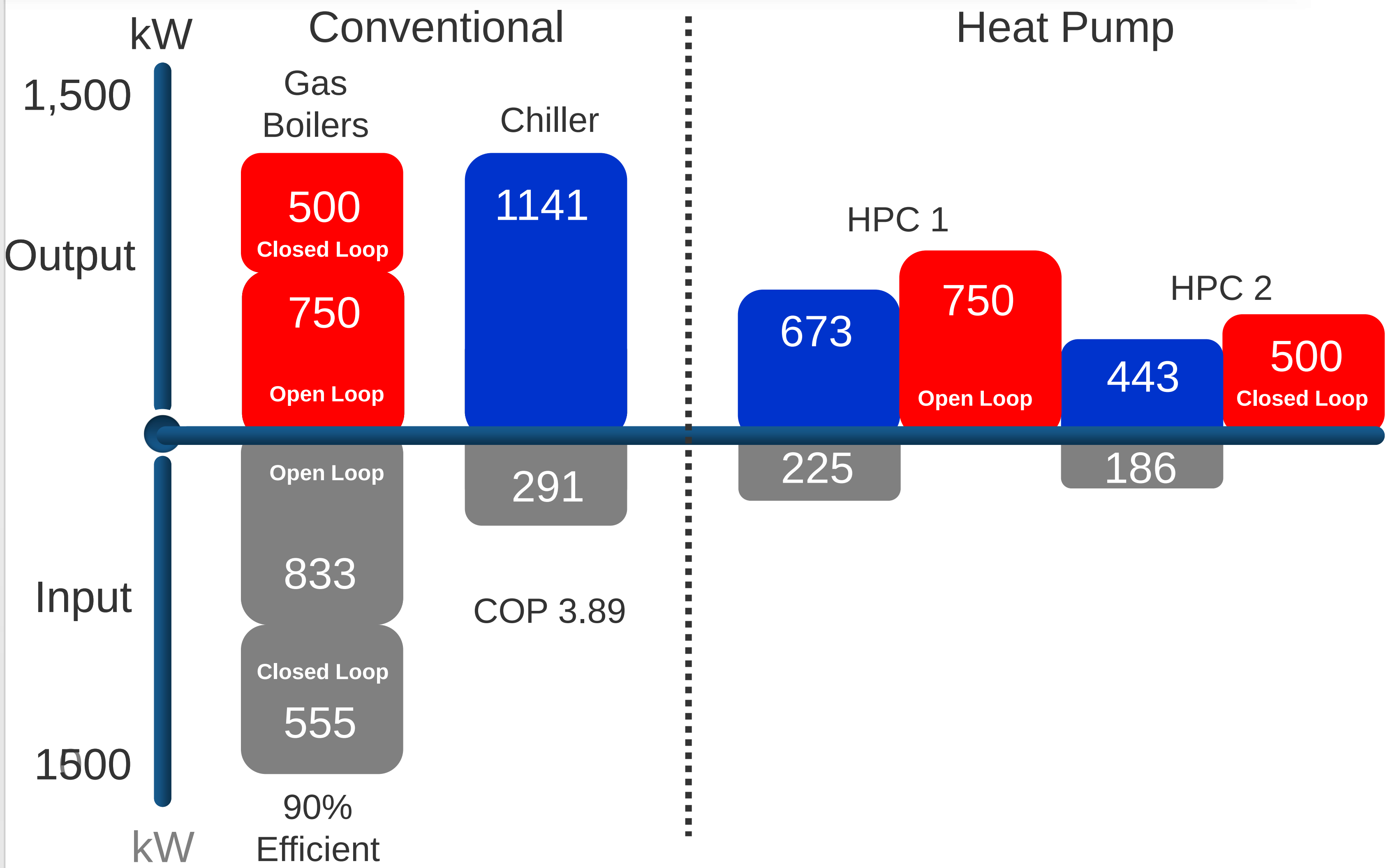

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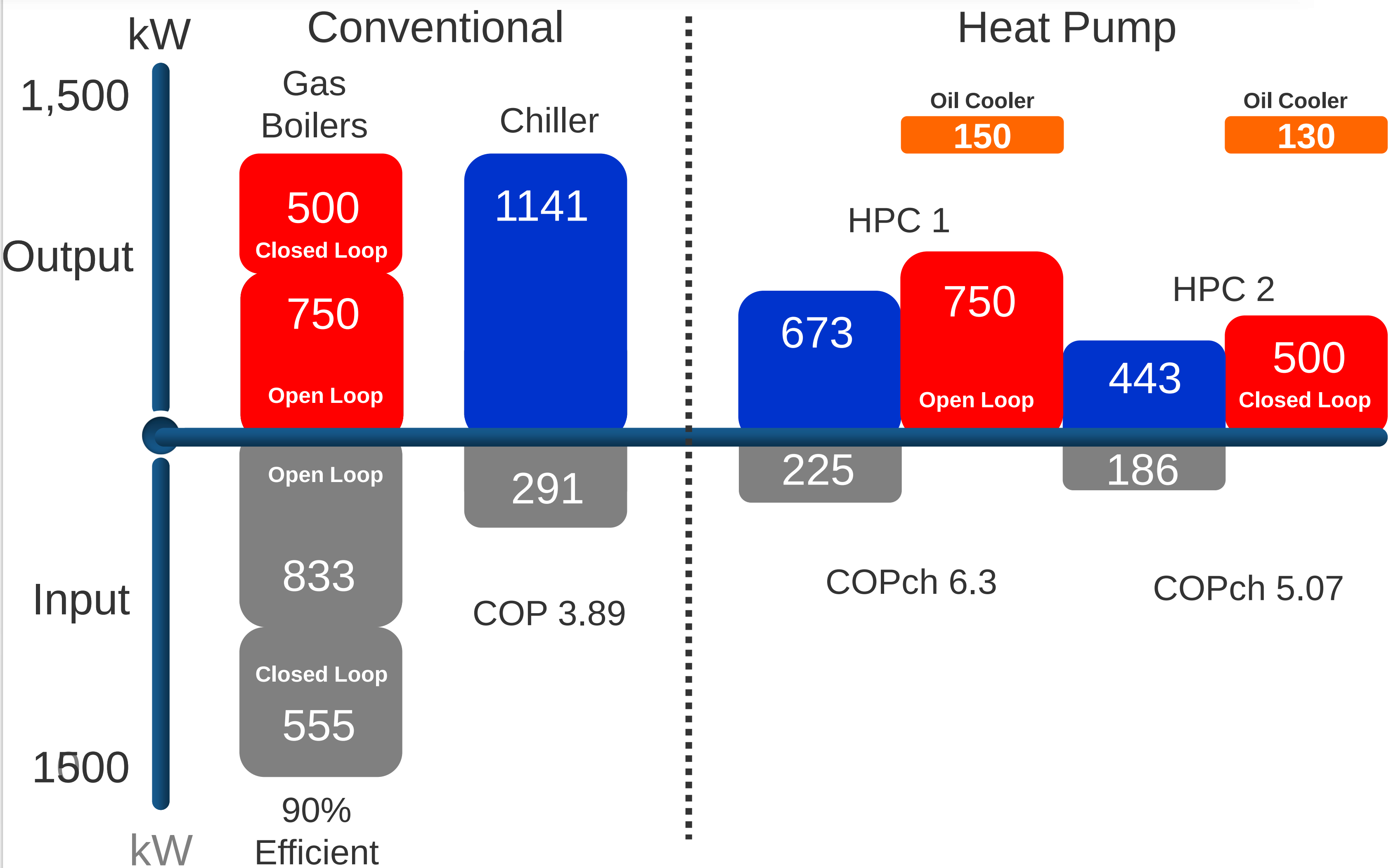

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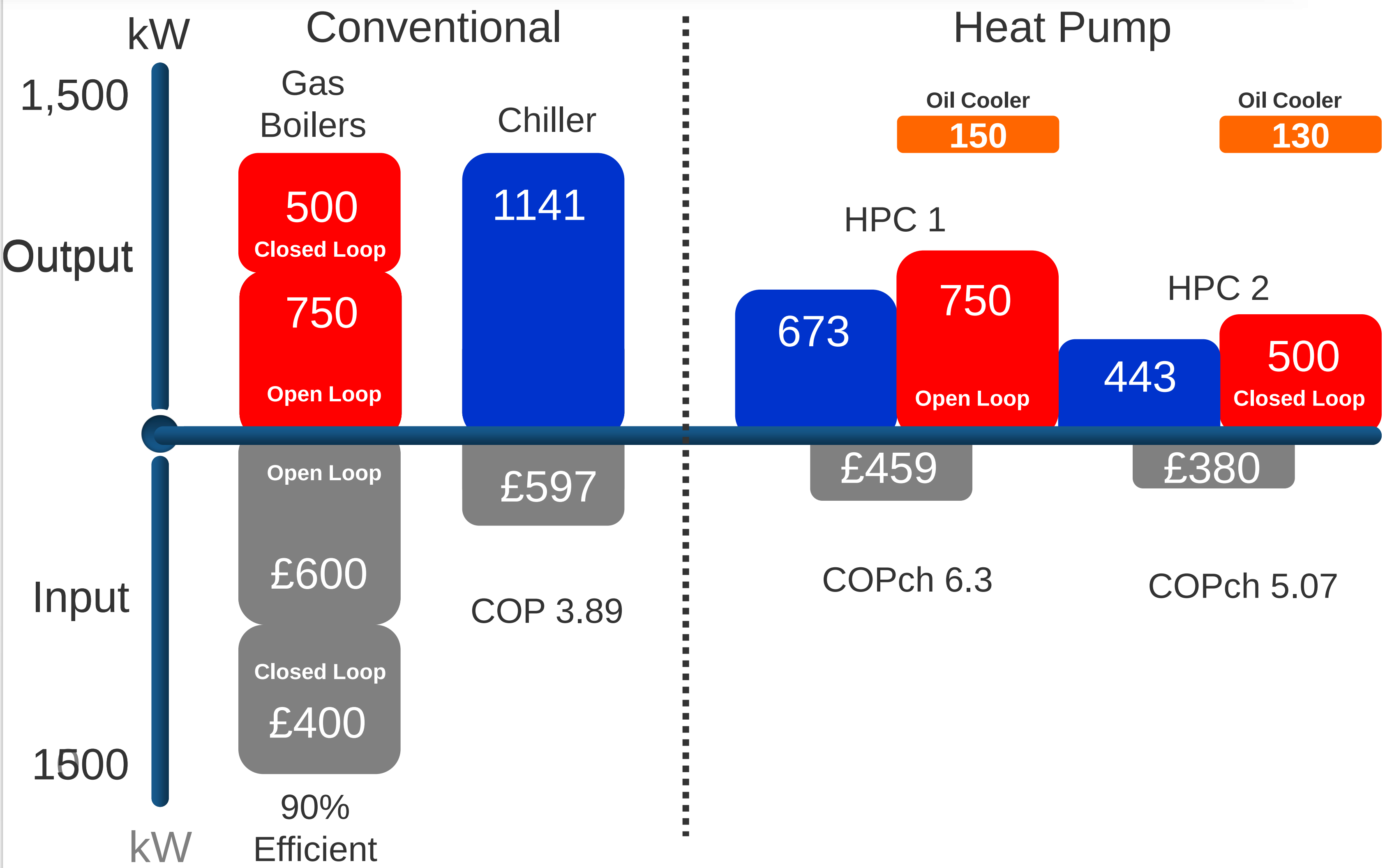

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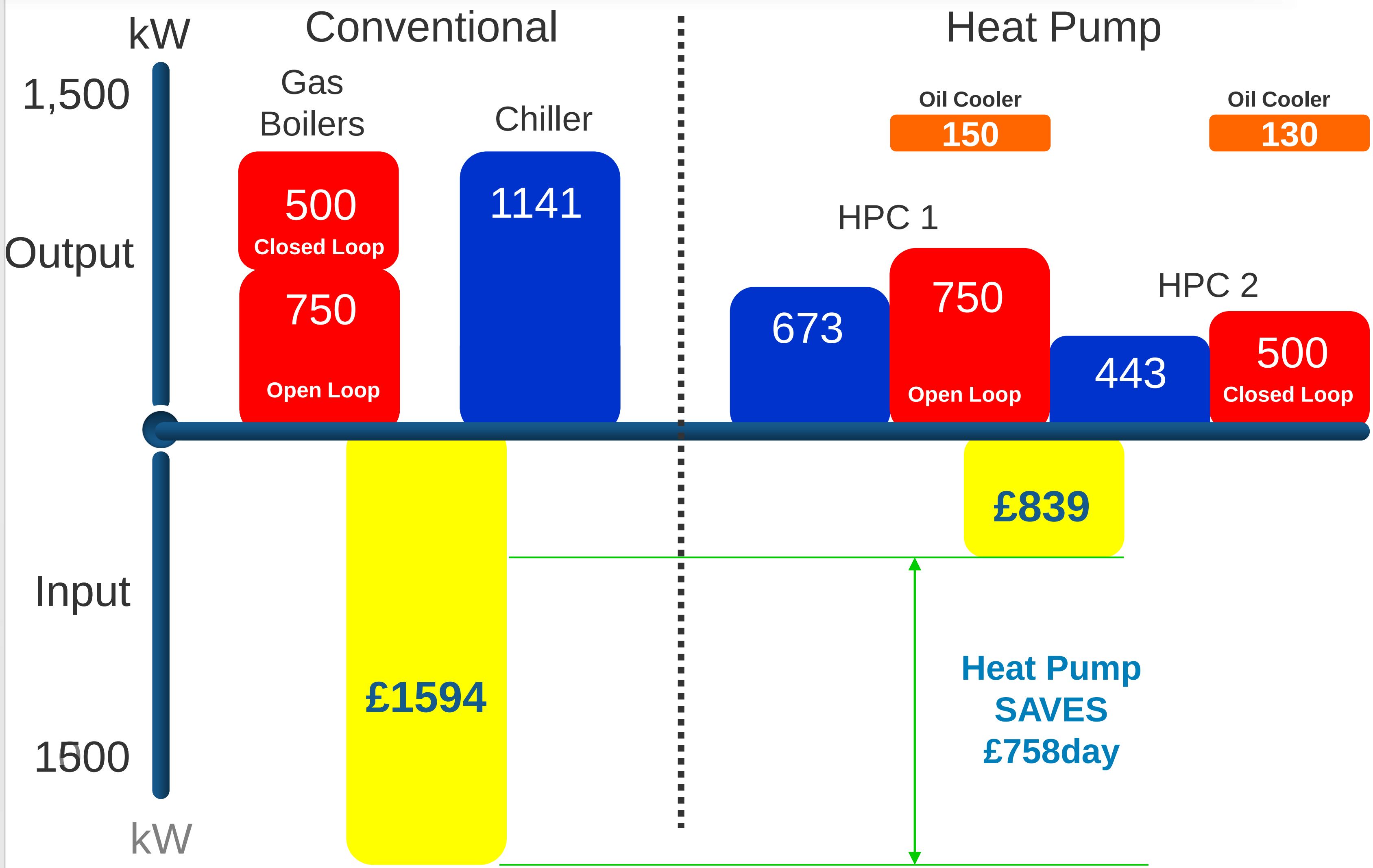

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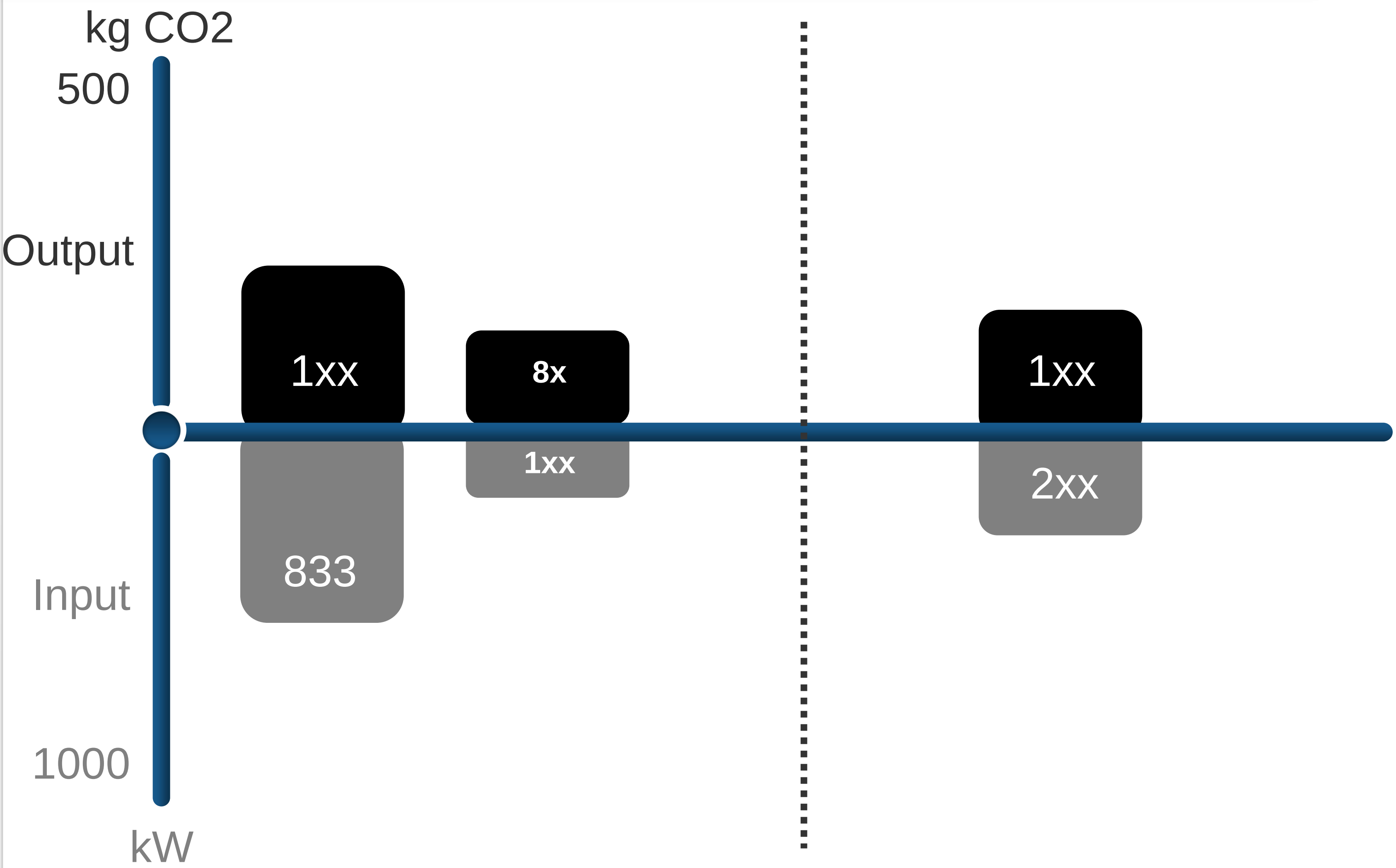


So what does the future of Ammonia look like?

Air

Water

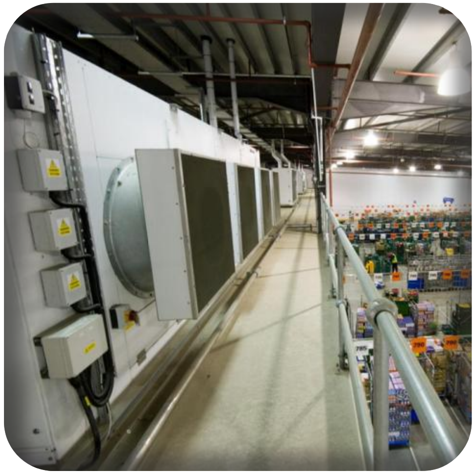
218kW – 784kW

235kW – 857kW

Adiabatic

Chilled water +4C
Glycol -10°C

Applications to be embraced not ignored



Why Ammonia?

Natural Refrigerant

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Natural Refrigerant

Low Charge

Why Ammonia?

Reduced Running Cost

Low Charge

Natural Refrigerant

STAR REFRIGERATION

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Maintenance and Longevity

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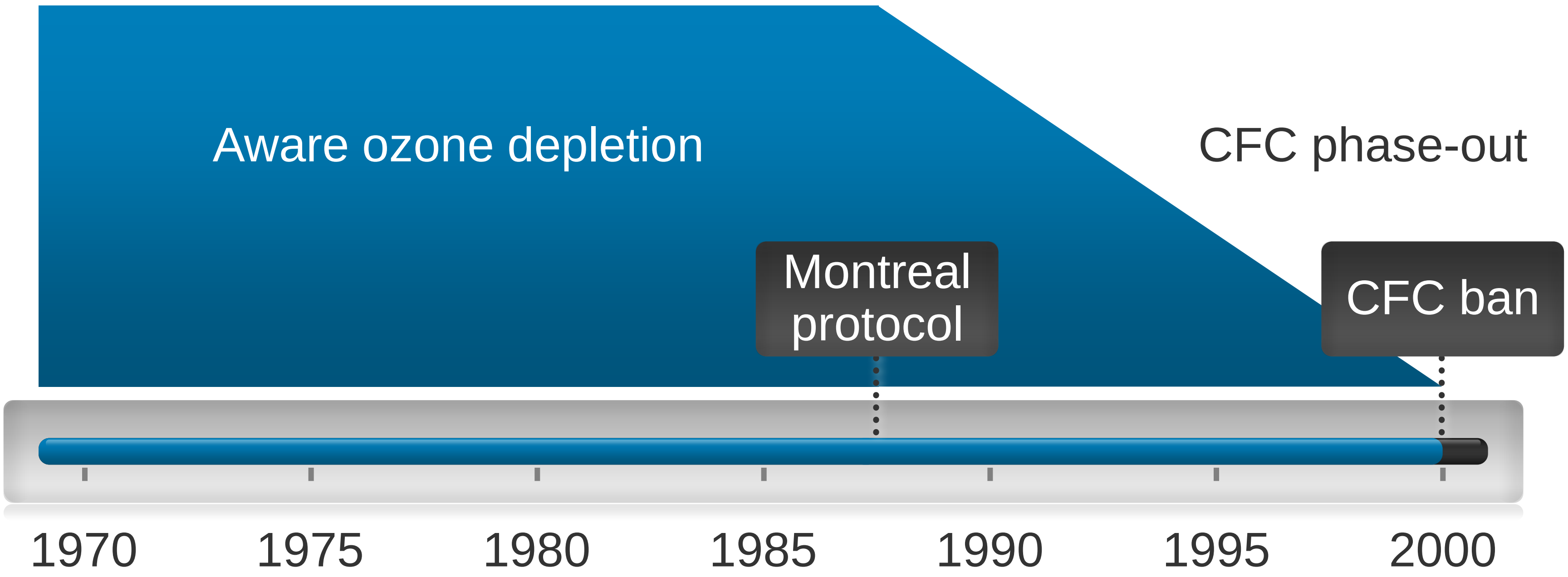
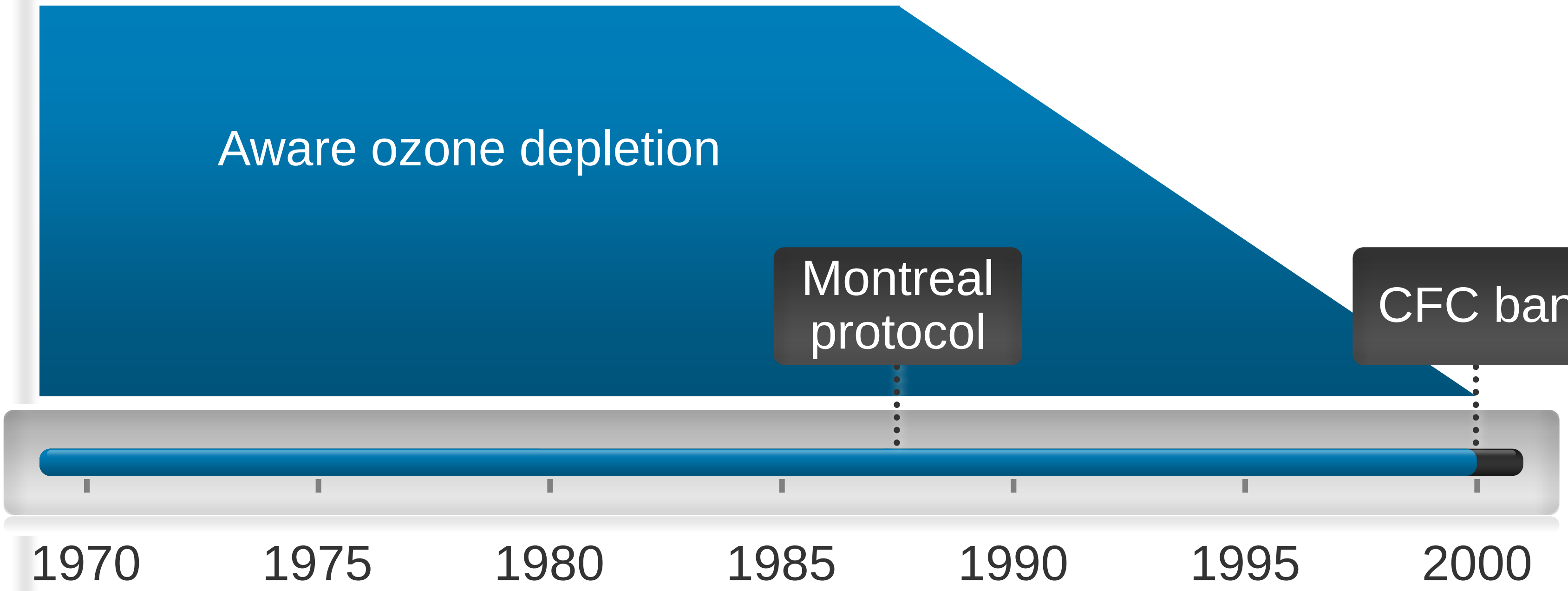
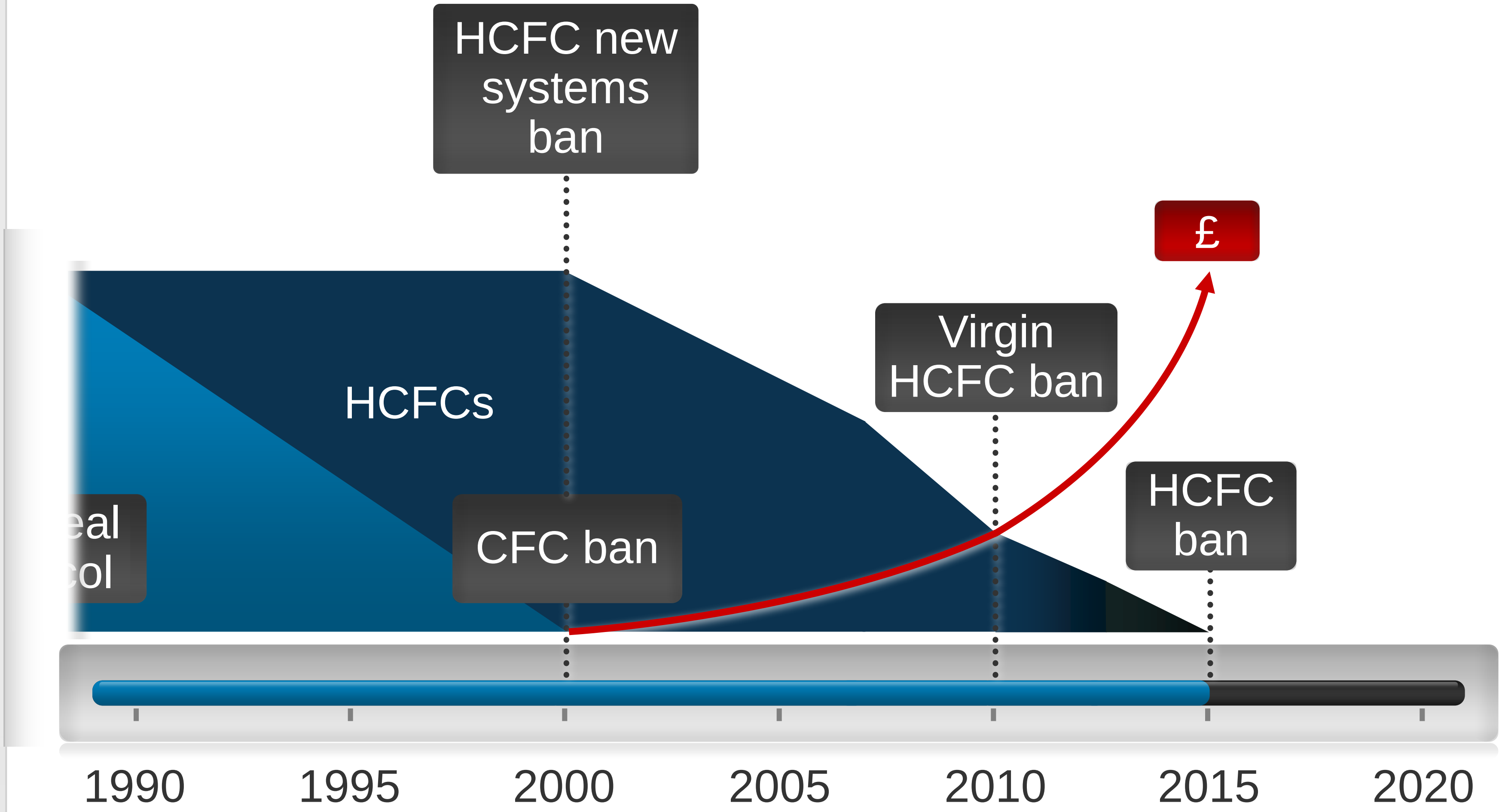
Refrigerant Timeline



HCFCs


Aware ozone depletion
Montreal protocol
CFC ban
1970
1975
1980
1985
1990
1995
2000

HCFCs


HCFC new systems ban
£
Virgin HCFC ban
HCFCs
HCFC ban
eal
col
CFC ban
1990
1995
2000
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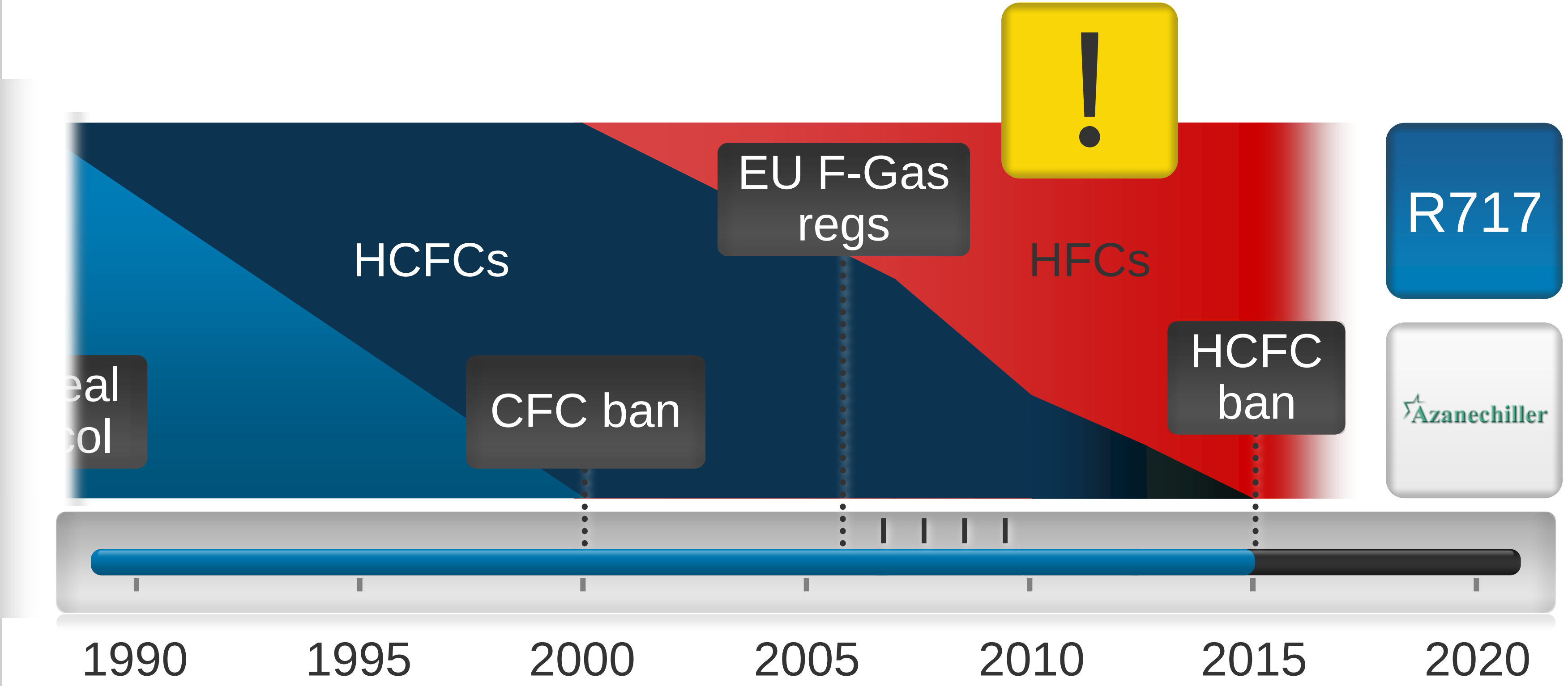
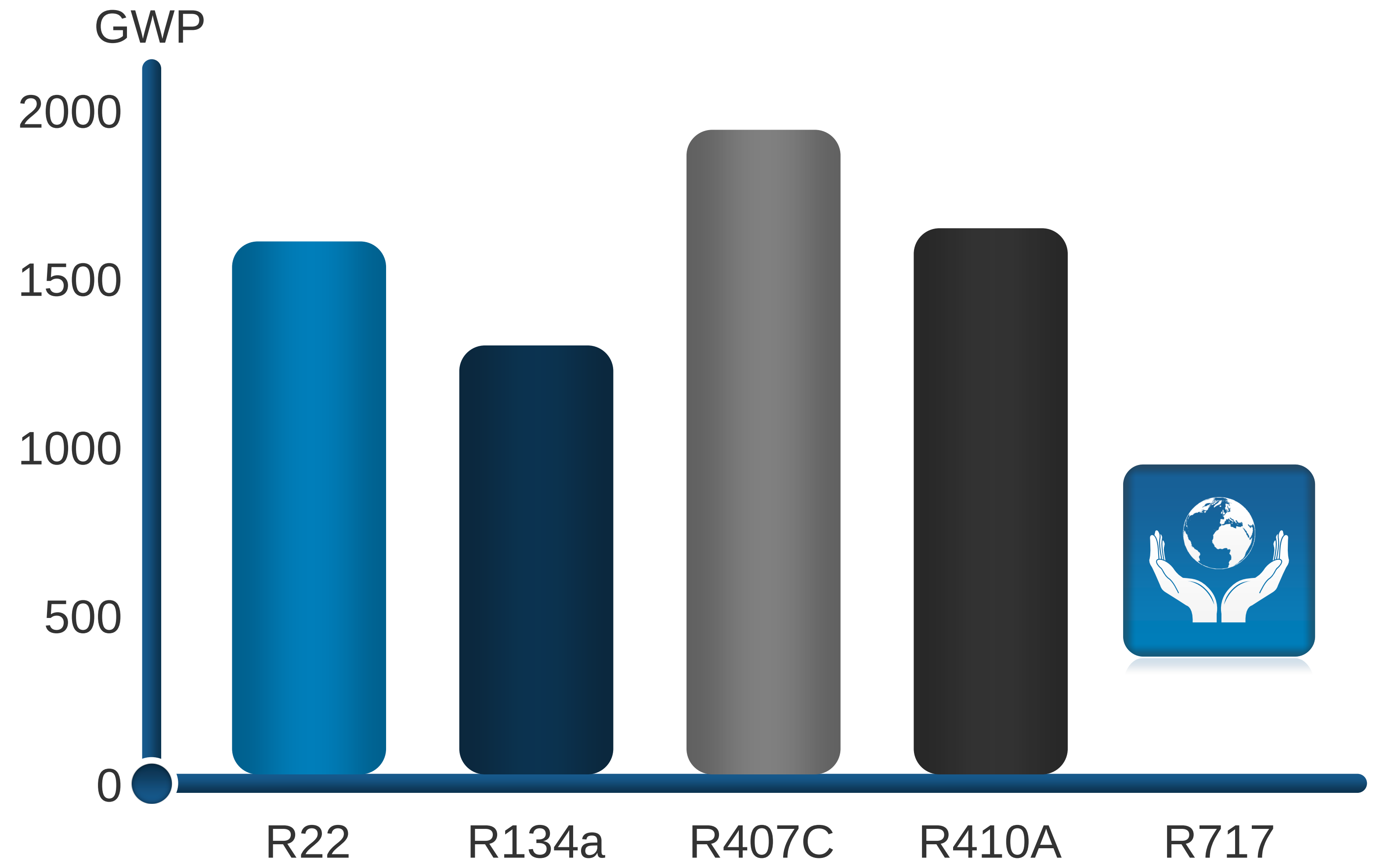
2010
2015
2020

HFCs

" HFCs will only be used if other environmentally friendly alternatives are not available" - UK



Global Warming Potentials



Ammonia Experience

STAR REFRIGERATION

Proven Product

Natural Refrigerant

Proven Product

Why Ammonia?

Low Charge

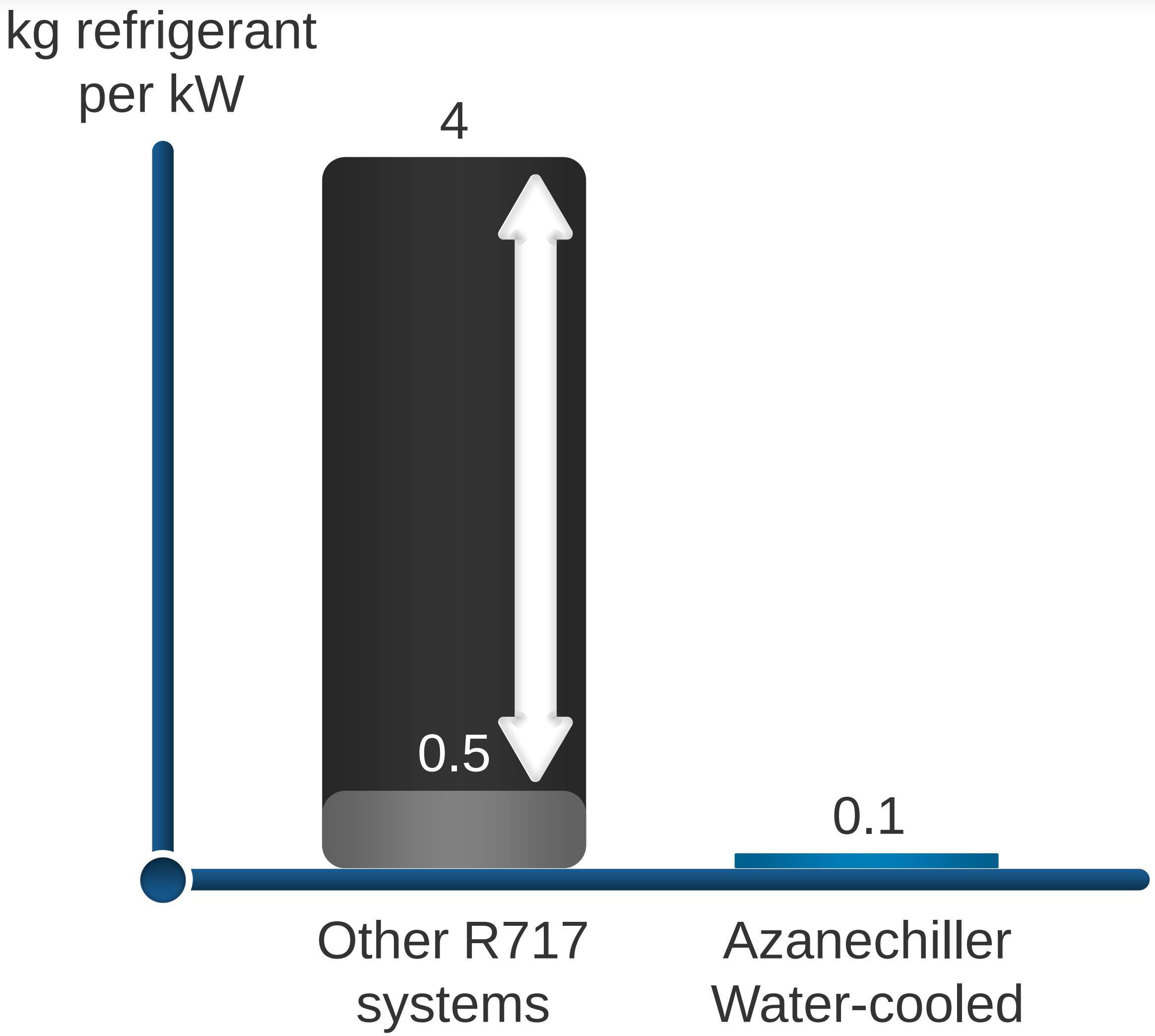
Maintenance and Longevity

Reduced Running Cost

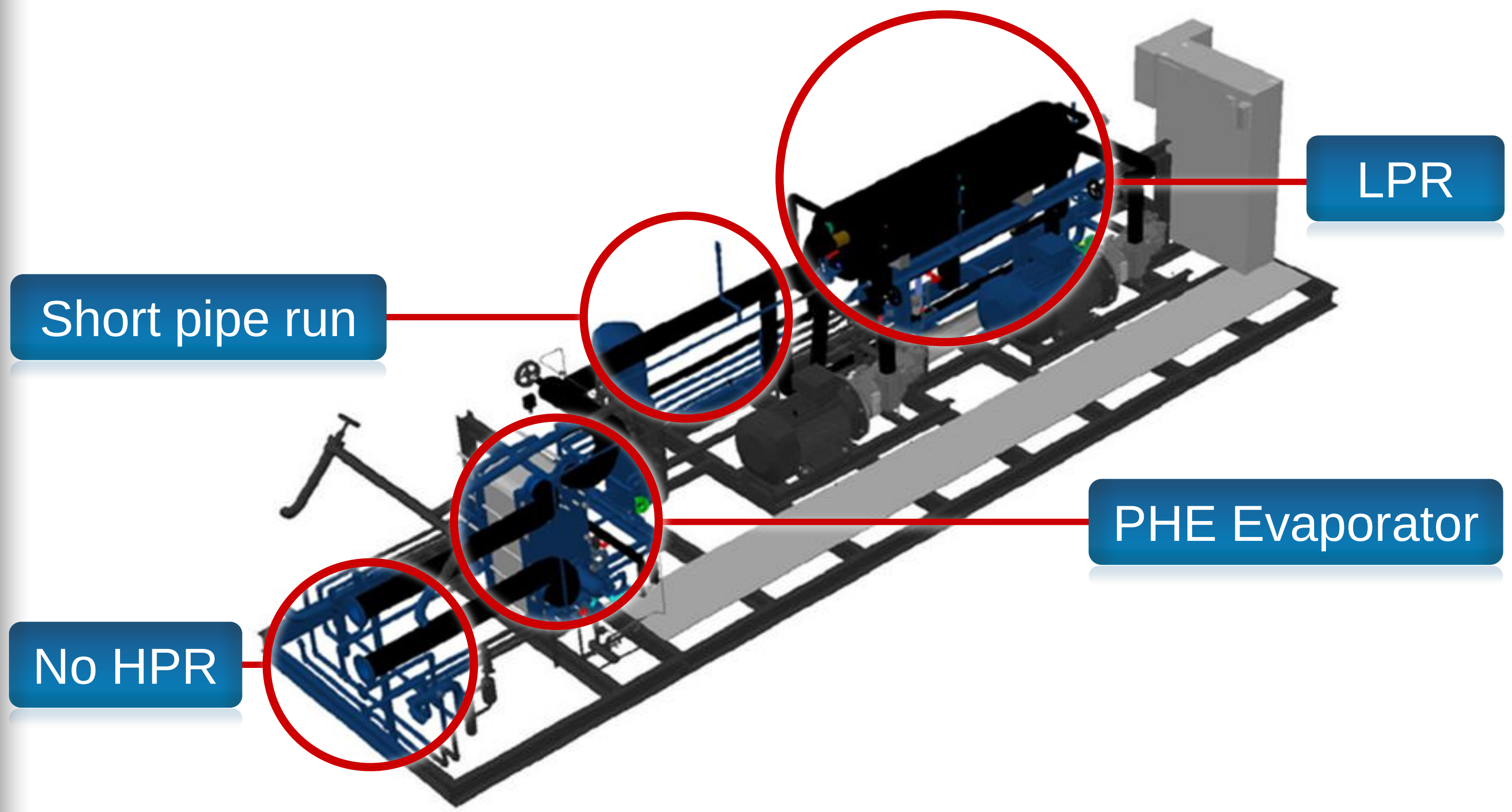
Ammonia – The Misconceptions

Ammonia – The Reality

Low Charge

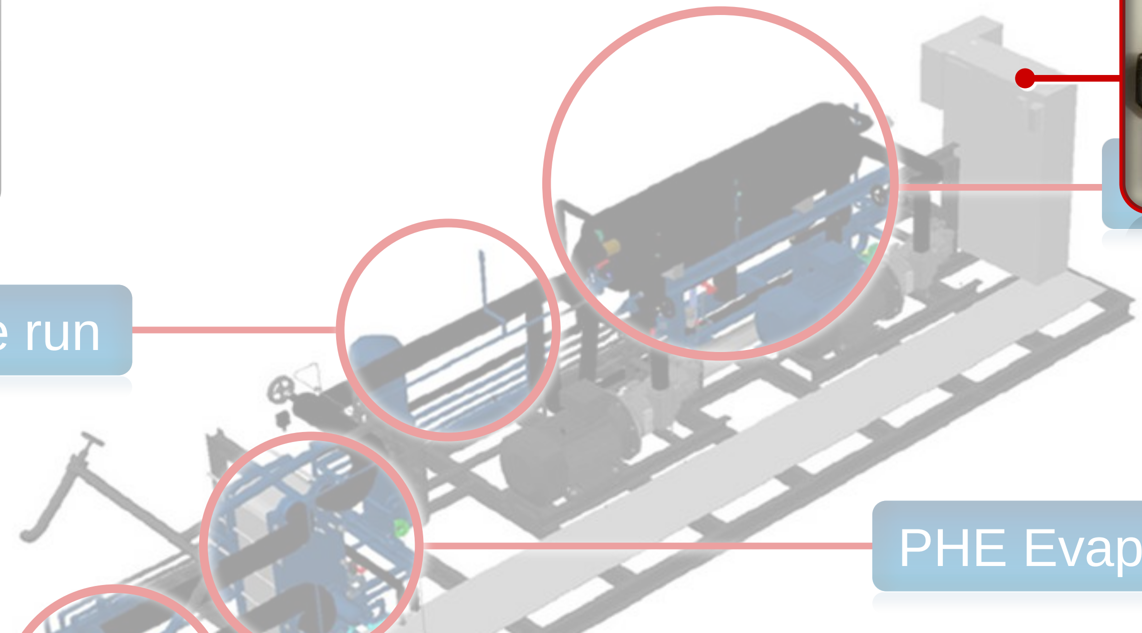

kg refrigerant
per kW
4
0.5
0.1
Other R717
systems
Azanechiller
Water-cooled

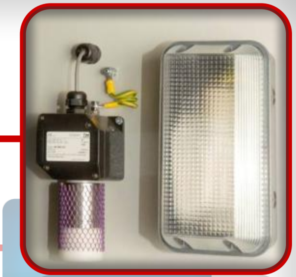
Low Charge



Safety and Compliance

CE





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Great Ormond Street Hospital

Natural Refrigerant

Proven Product

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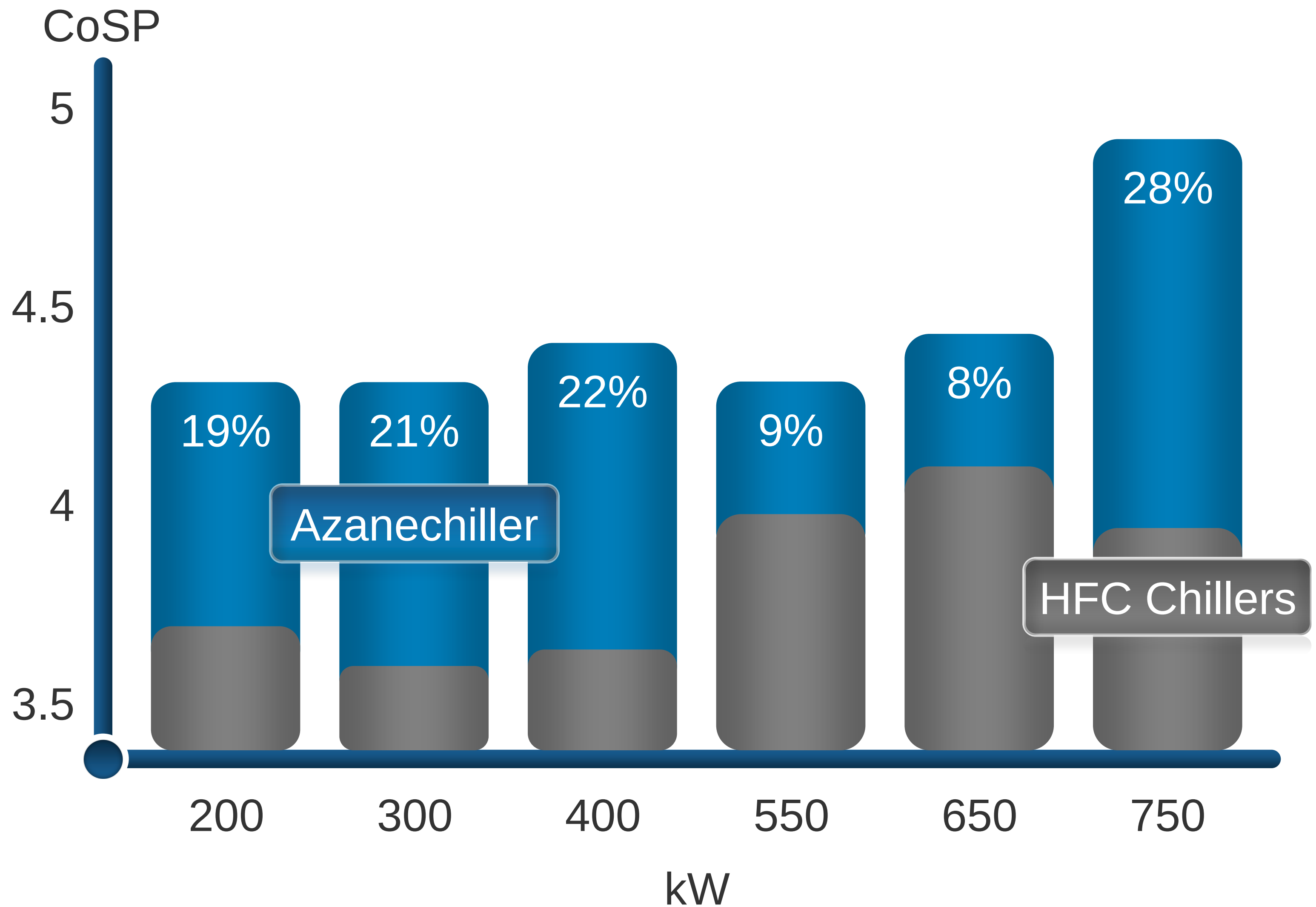
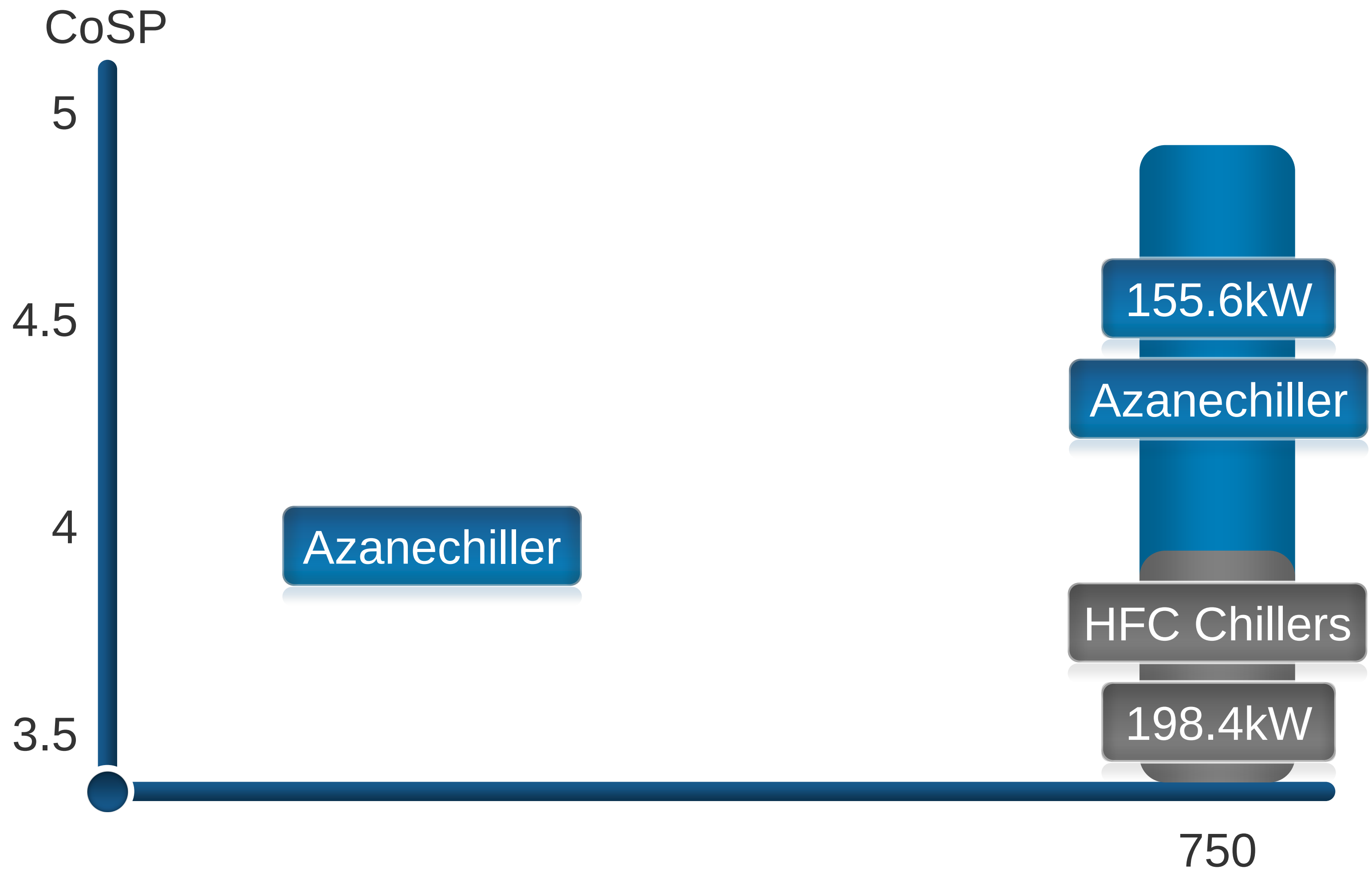
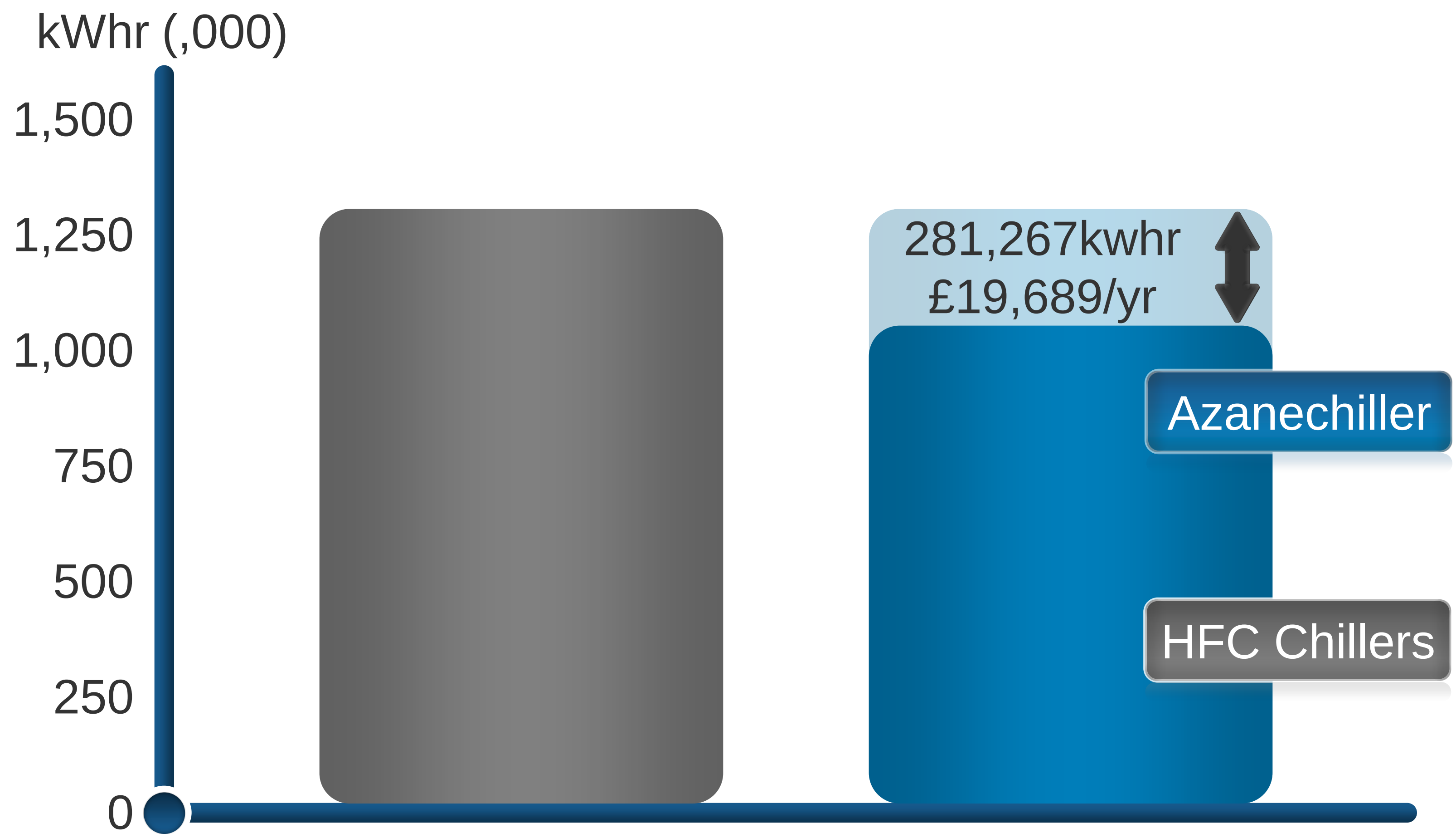
Coefficient of System Performance



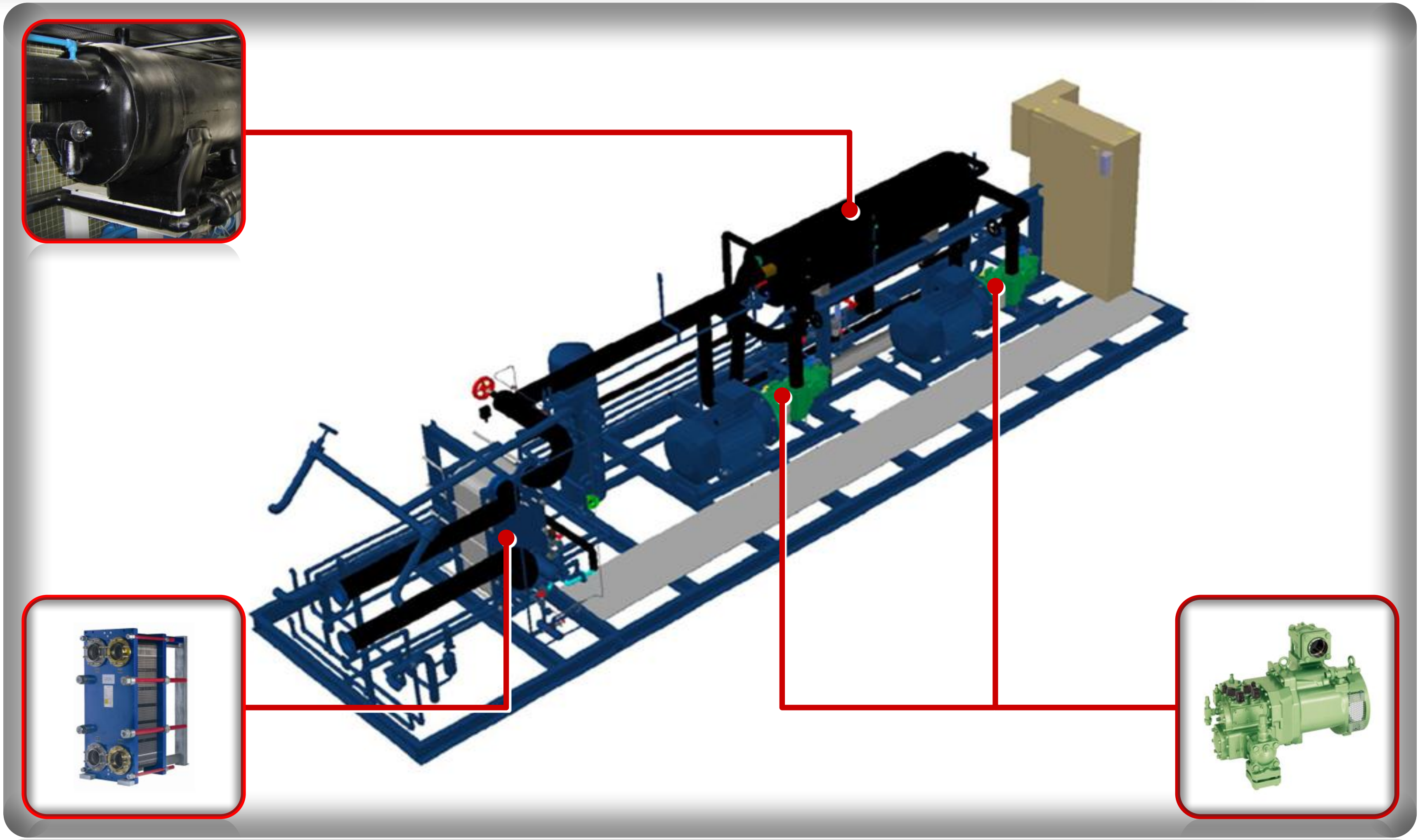
Increased Efficiency



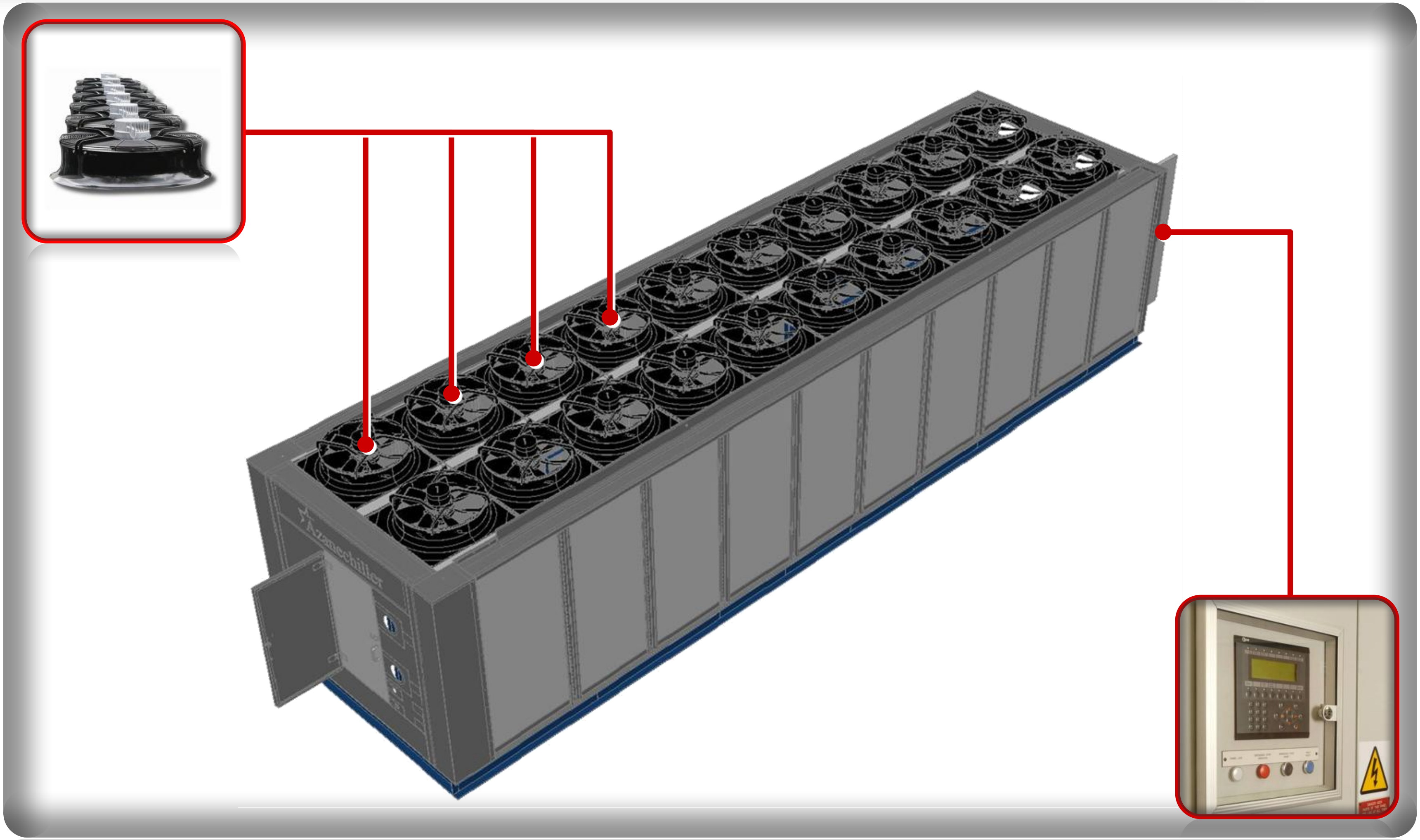
Reduced Running Costs



High Efficiency



High Efficiency



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Proven Product

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Reduced Running Cost

Natural Refrigerant

Proven Product

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Low Charge

Maintenance and Longevity

Reduced Running Cost

Proven Product

Whitehall Place

Extended Warranties

Manufacture | Commission | Testing | Ready

Natural Refrigerant

Proven Product

Low Charge

Why Azanechiller *?*

Maintenance and Longevity

Reduced Running Cost

Think Differently-District Cooling and Desalination