ECOS 2015

Operations and investment optimisation in steam networks

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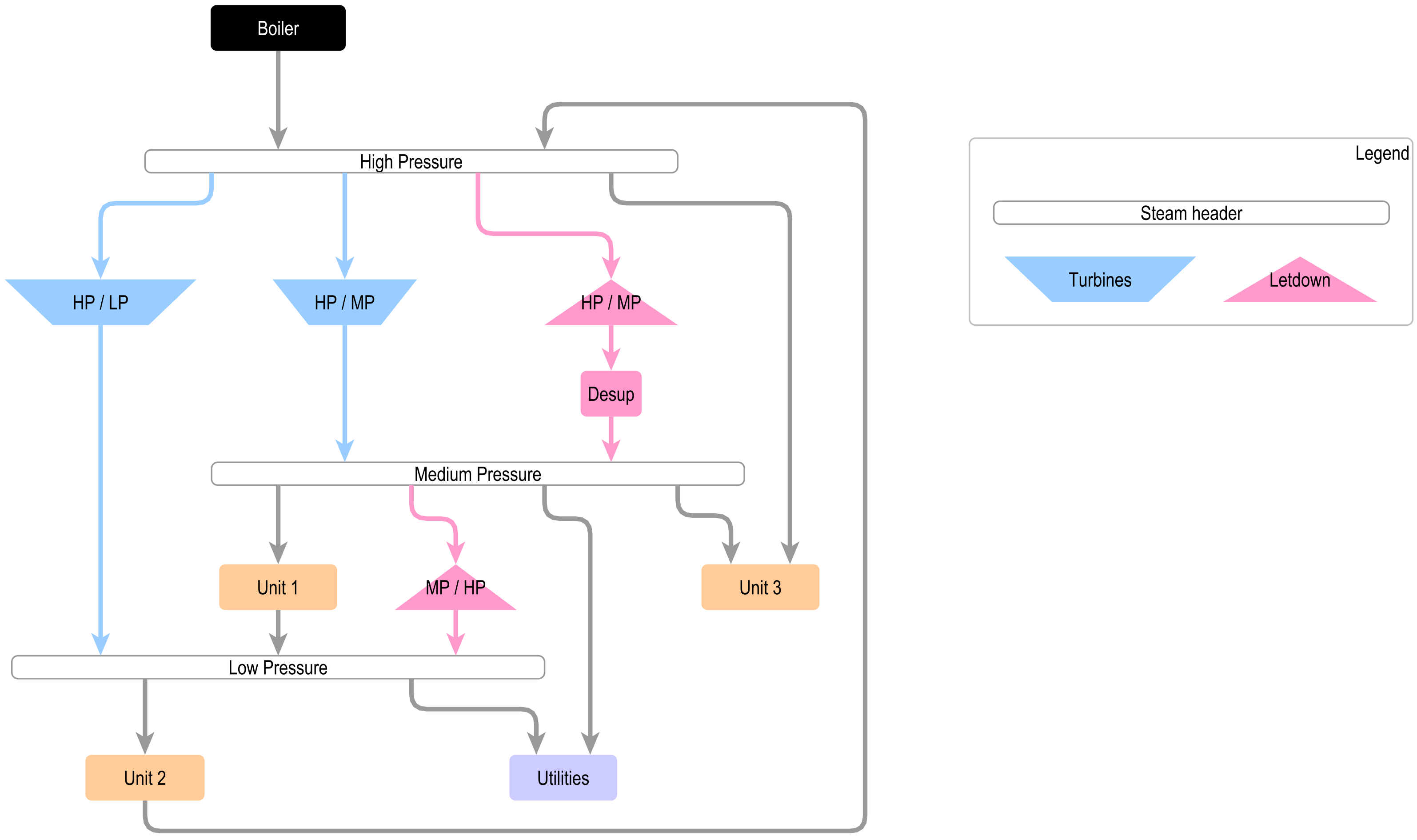
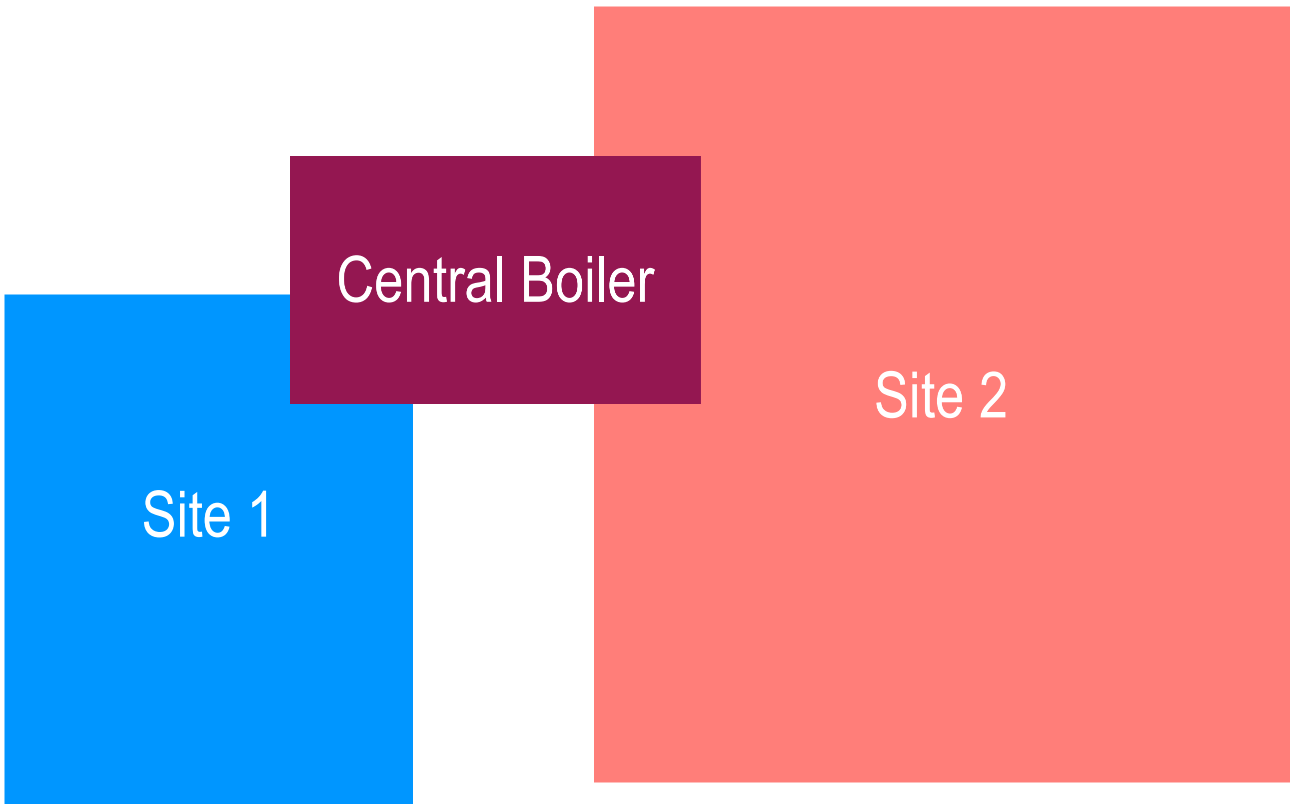
Optimal network operations & Resilient investments

Optimal operations	Optimal distribution of steam from producers to consumers through a steam network
Undercapacity & load shedding	Optimal operations facing under capacity
Optimal investments	Designing least cost solutions
Operations with boiler failures	Simulation of boiler failures to identify realistic network operations
Steam network resilience	Identifying and evaluating resilient investment solutions

Steam networks



Petrochemical and refining cluster



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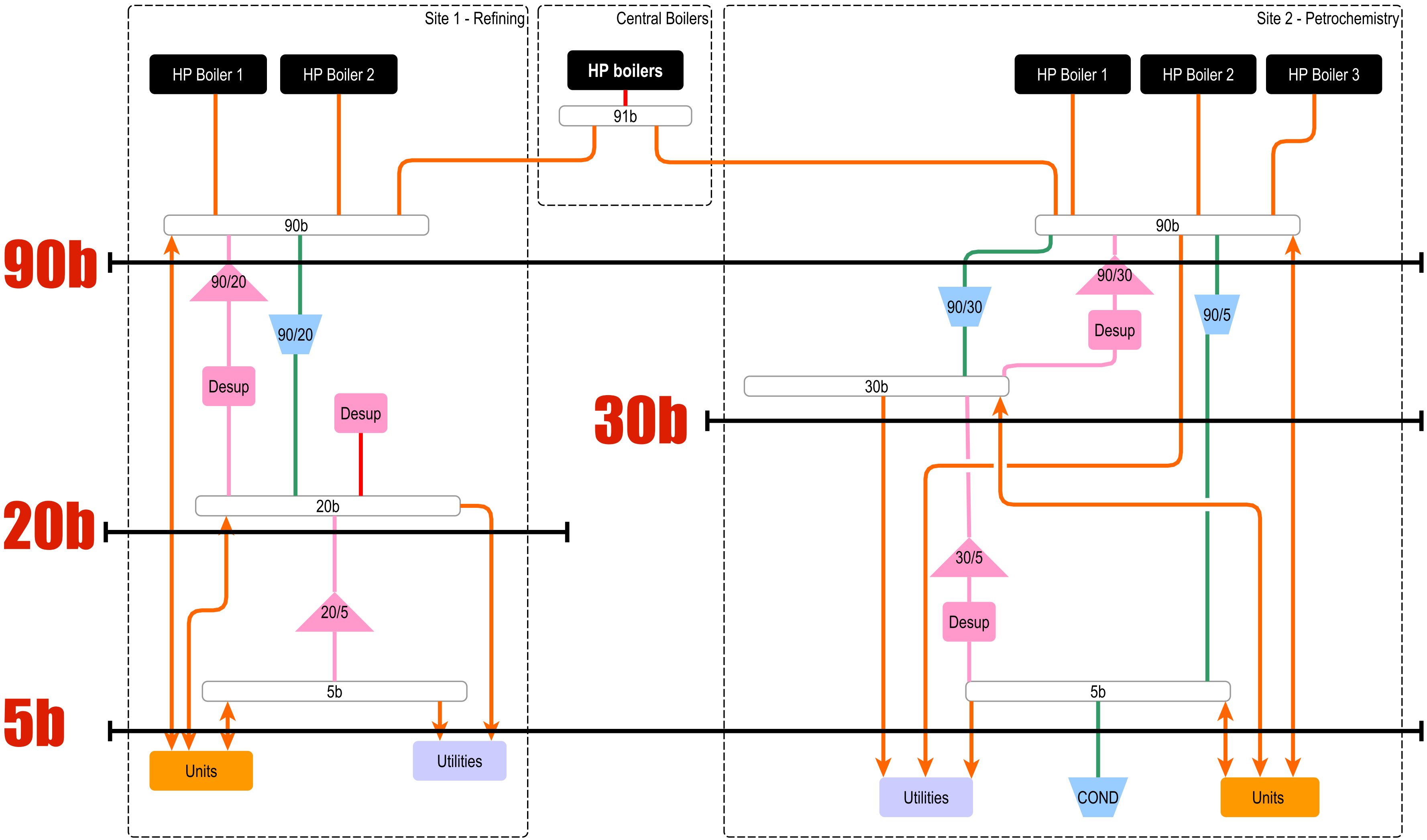
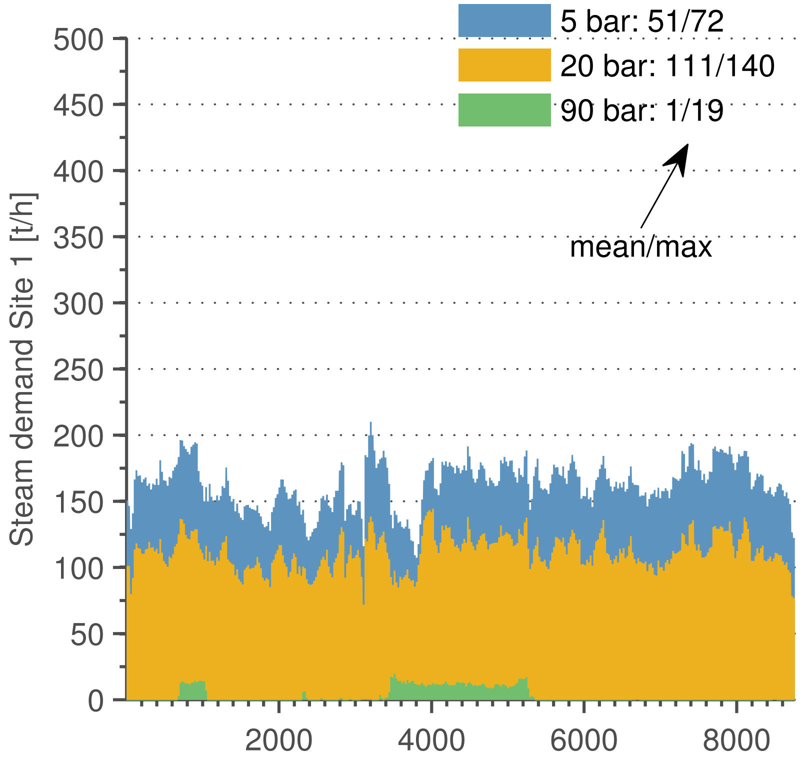
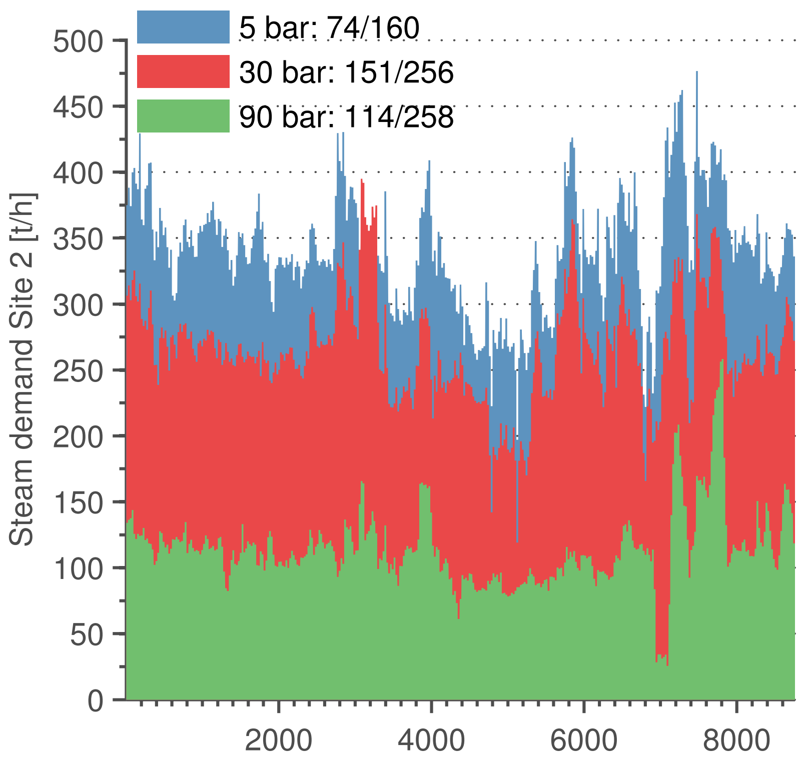


Demand = consumption - internal production

Site 1
Mean demand: 163 t/h
Max demand: 207 t/h
Available capacity: 180 t/h



Site 2
Mean demand: 339 t/h
Max demand: 475 t/h
Available capacity: 390 t/h



Operations optimisation

- **match production and consumption**
- **produce electric safety net**
- **avoid atmospheric venting**

- **minimise operational costs**
  maximise turbine use
  activate letdowns + desuperheaters if demand high

self regulating in a ‘healthy’ steam network but not trivial!

MILP formulation

- header mass balance
- turbines: constant isentropic efficiency
- letdowns: steam outlet is multiplied by a factor [1.03 - 1.1]

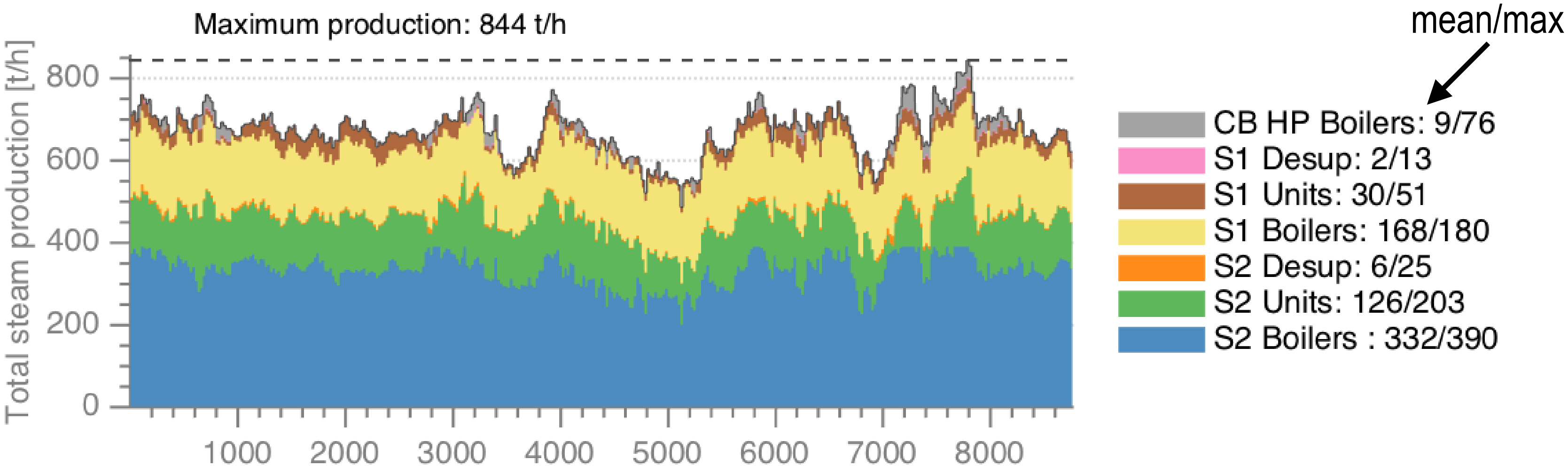
- boilers production is variable
- process units consumption/production is set as a parameter

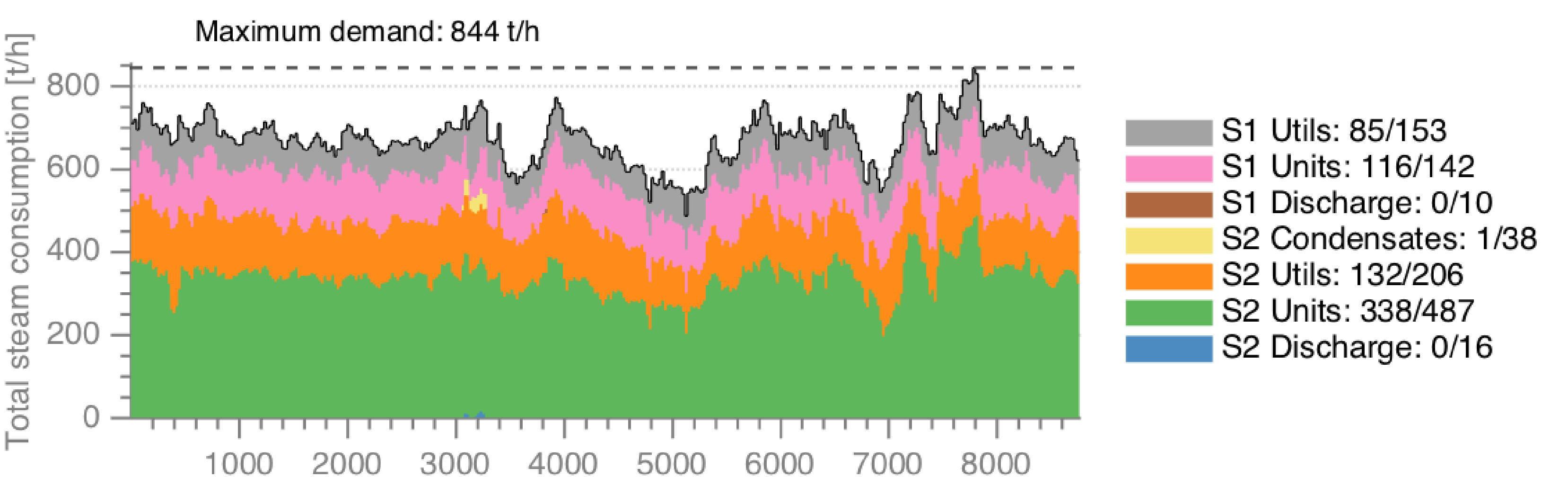
- objective: minimise operational costs

$$Obj = \min \mathbf{OPEX}$$

Case study - optimal operations

natgas: 20 €/MWh





costs, load duration curves,…

Undercapacity

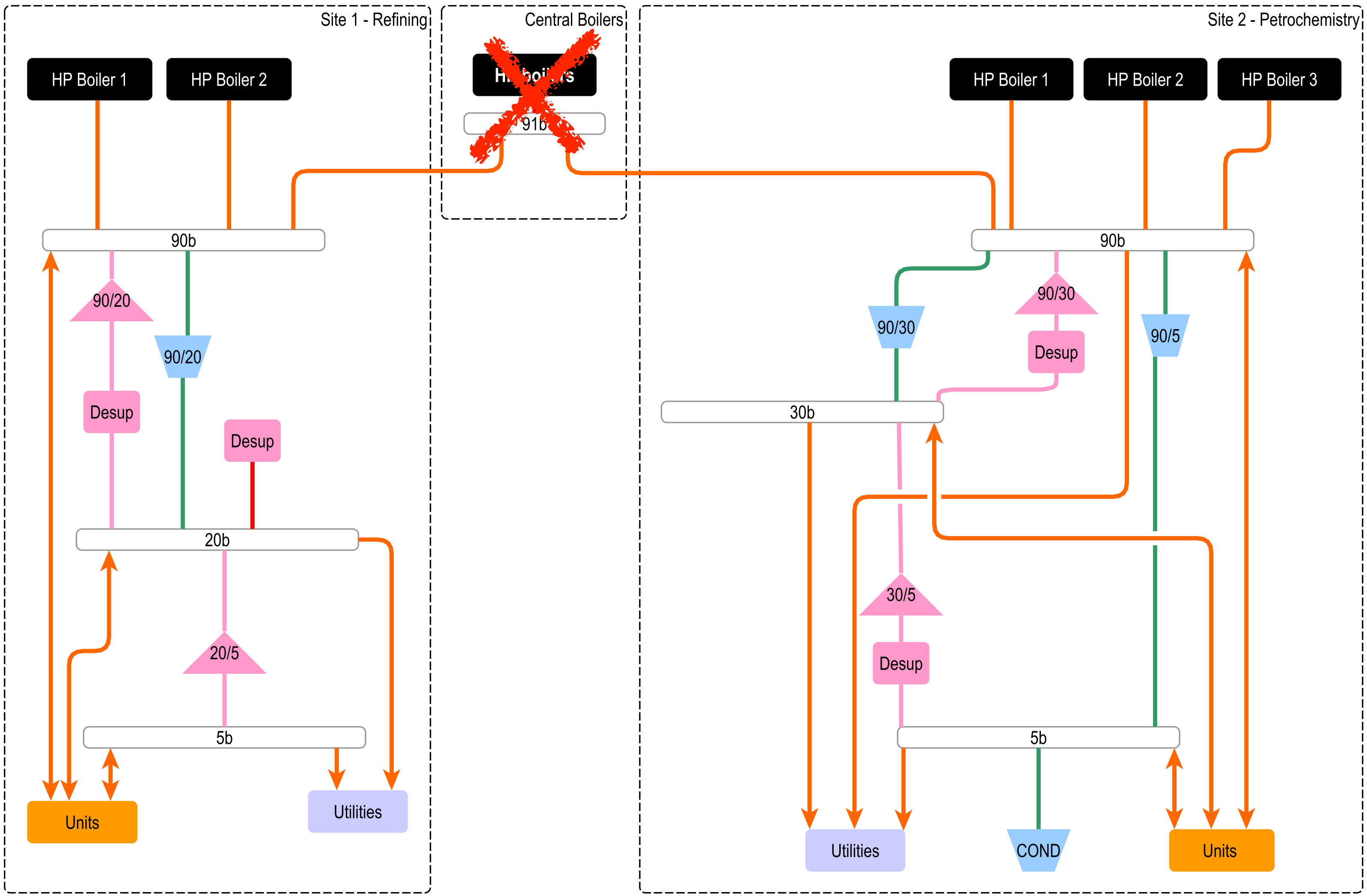
demand > available capacity

- **extreme weather events**
  steam pipes drenched in water leading to condensation
  cold winds
- **boilers offline**
  planned maintenance and turn arounds
  unplanned boiler trips
- **exceptional demand**
  unit startups
  ageing catalysts/processes
- **combinations of events**

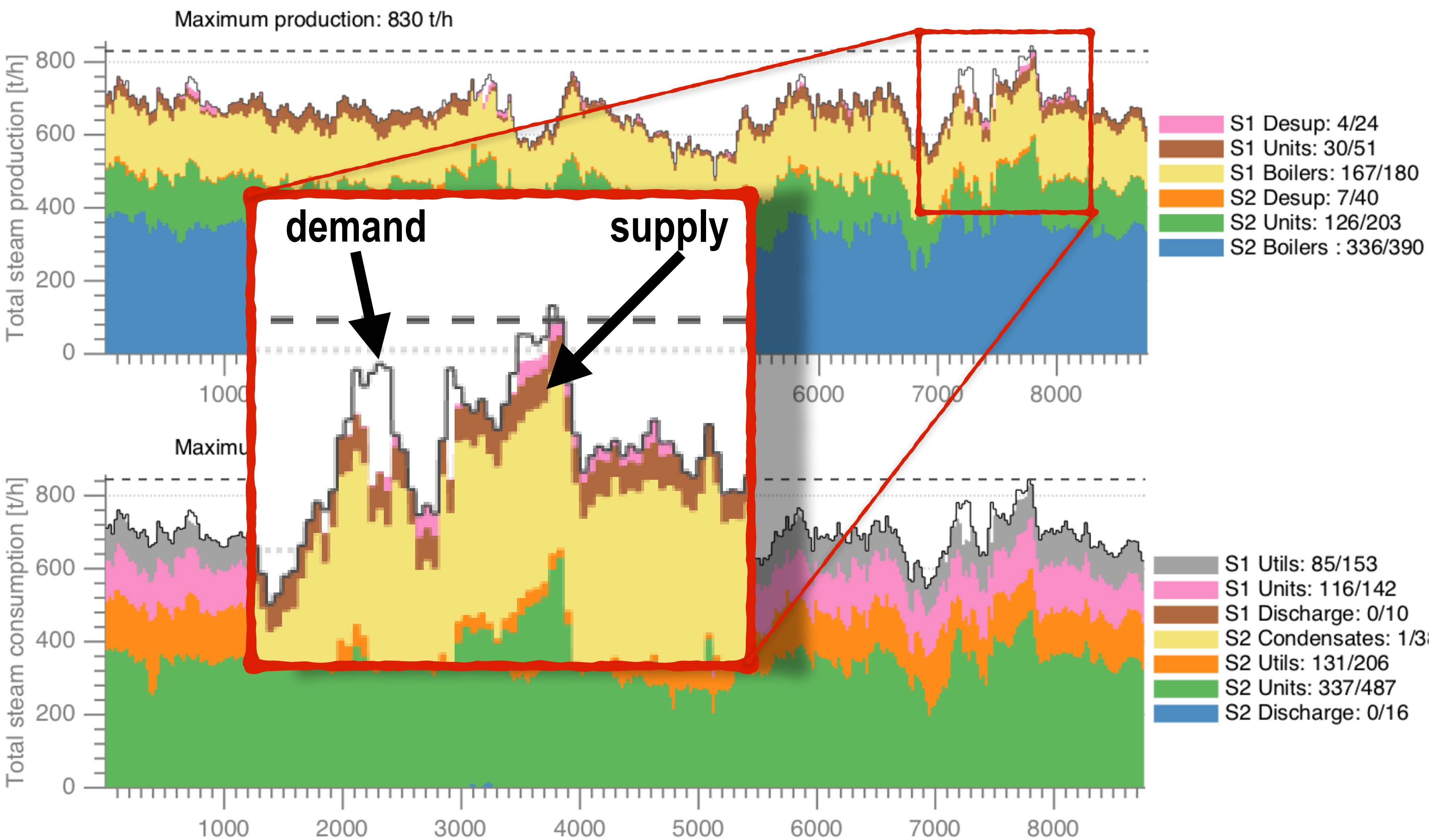
load shedding - taking units offline

- **unit activation as integer variable**
- **penalty costs**
  a financial penalty is applied for each unit taken offline
- **shedding priority**
  units go offline in a specific order (order of importance)

Petrochemical and refining cluster

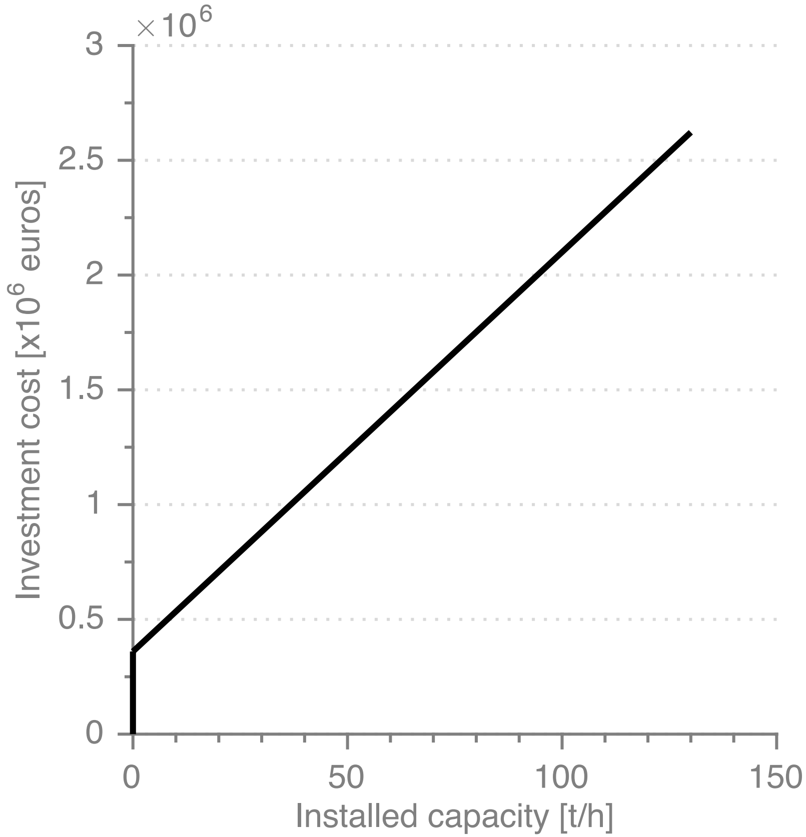


Case study - permanent boiler failure

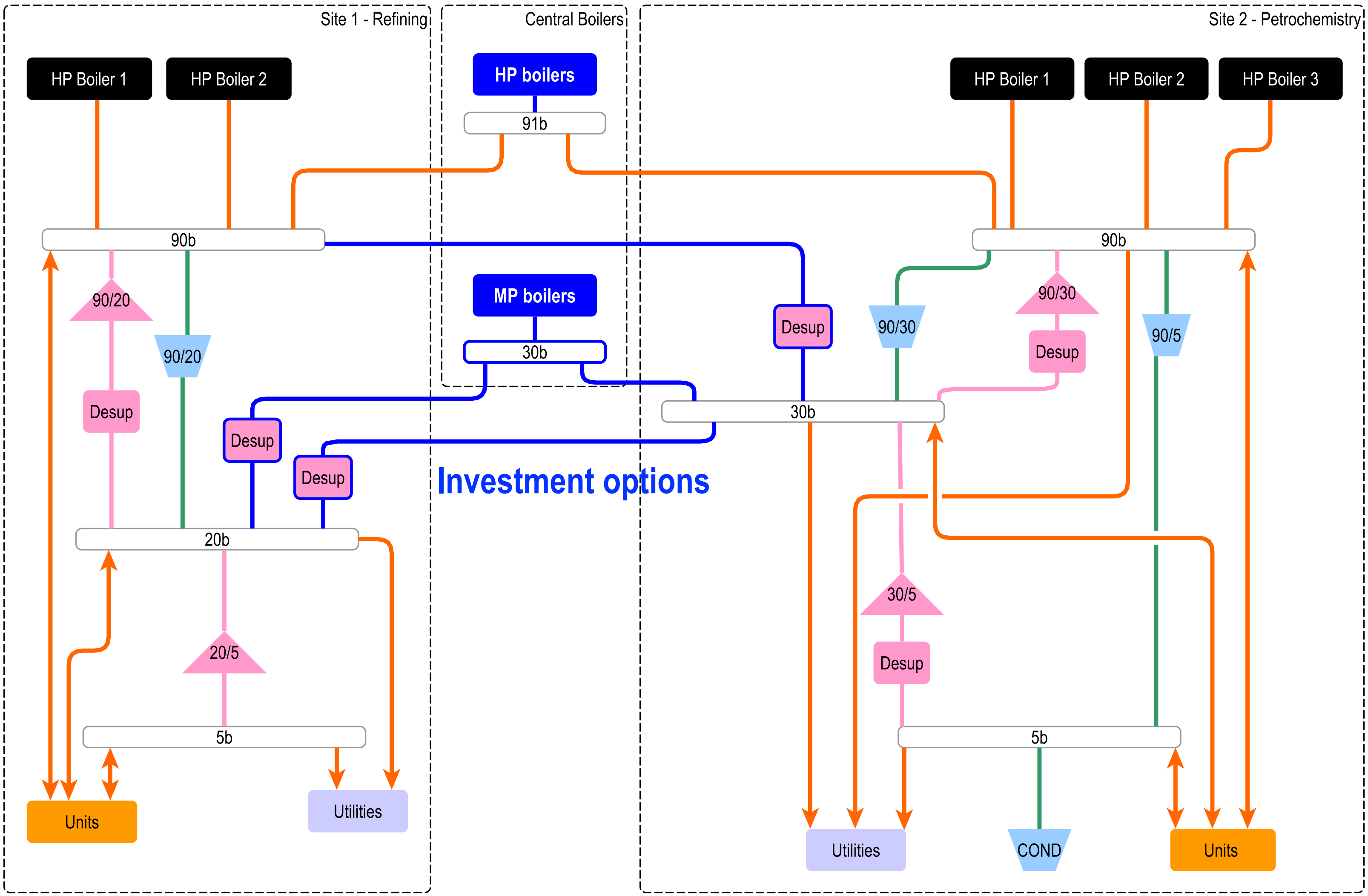


Investment optimisation

- identify least cost investments to supply steam
- fixed and variable investment costs

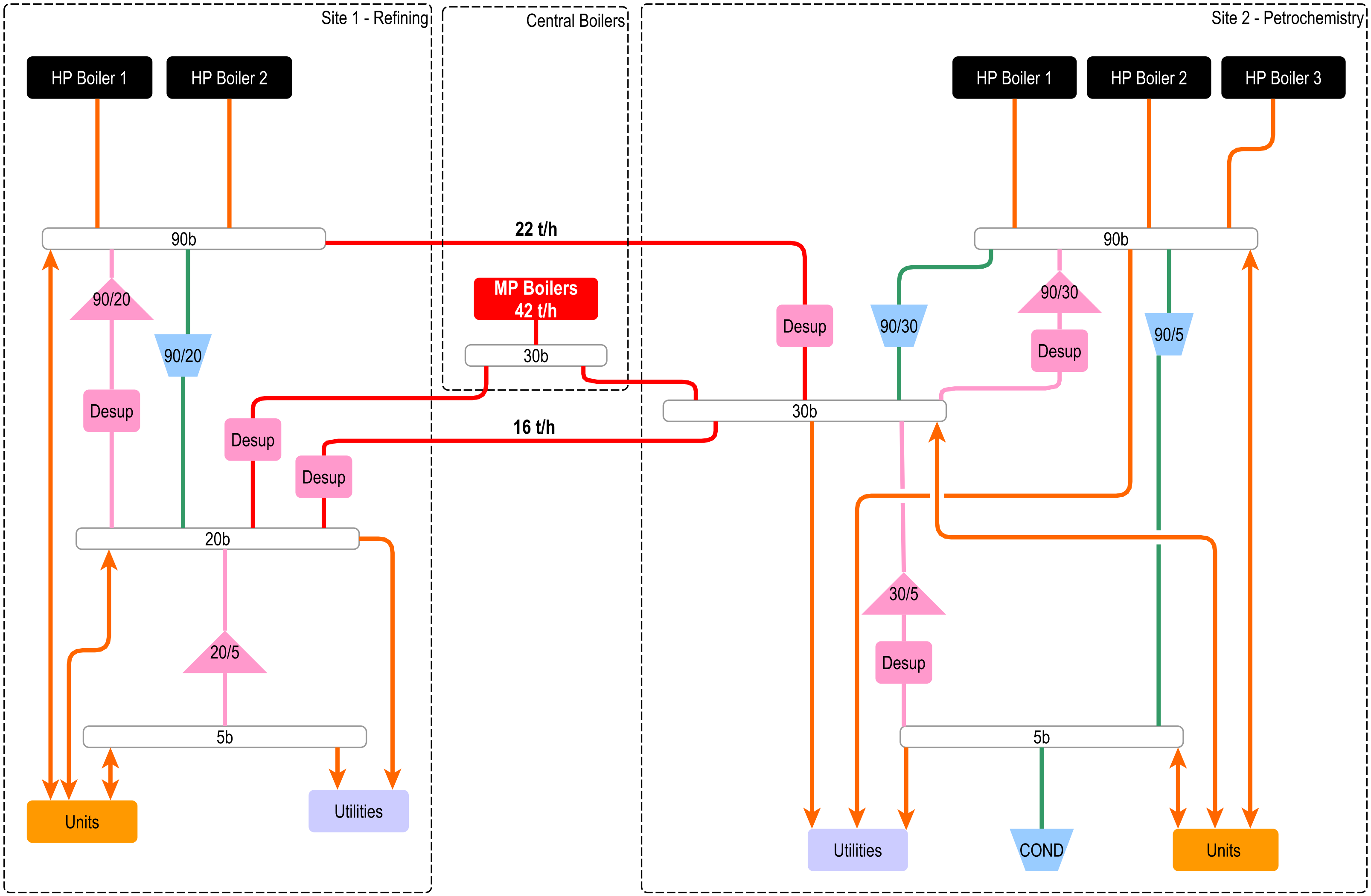


Case study - investment options to replace Central Boilers



$$Obj = \min \sum_{n} \mathbf{CAPEX_n} + \sum_{nt} (\mathbf{OPEX_{nt}} + \mathbf{PENALTY_{nt}})$$

Case study - optimal choice in equipments



Dealing with boiler maintenance

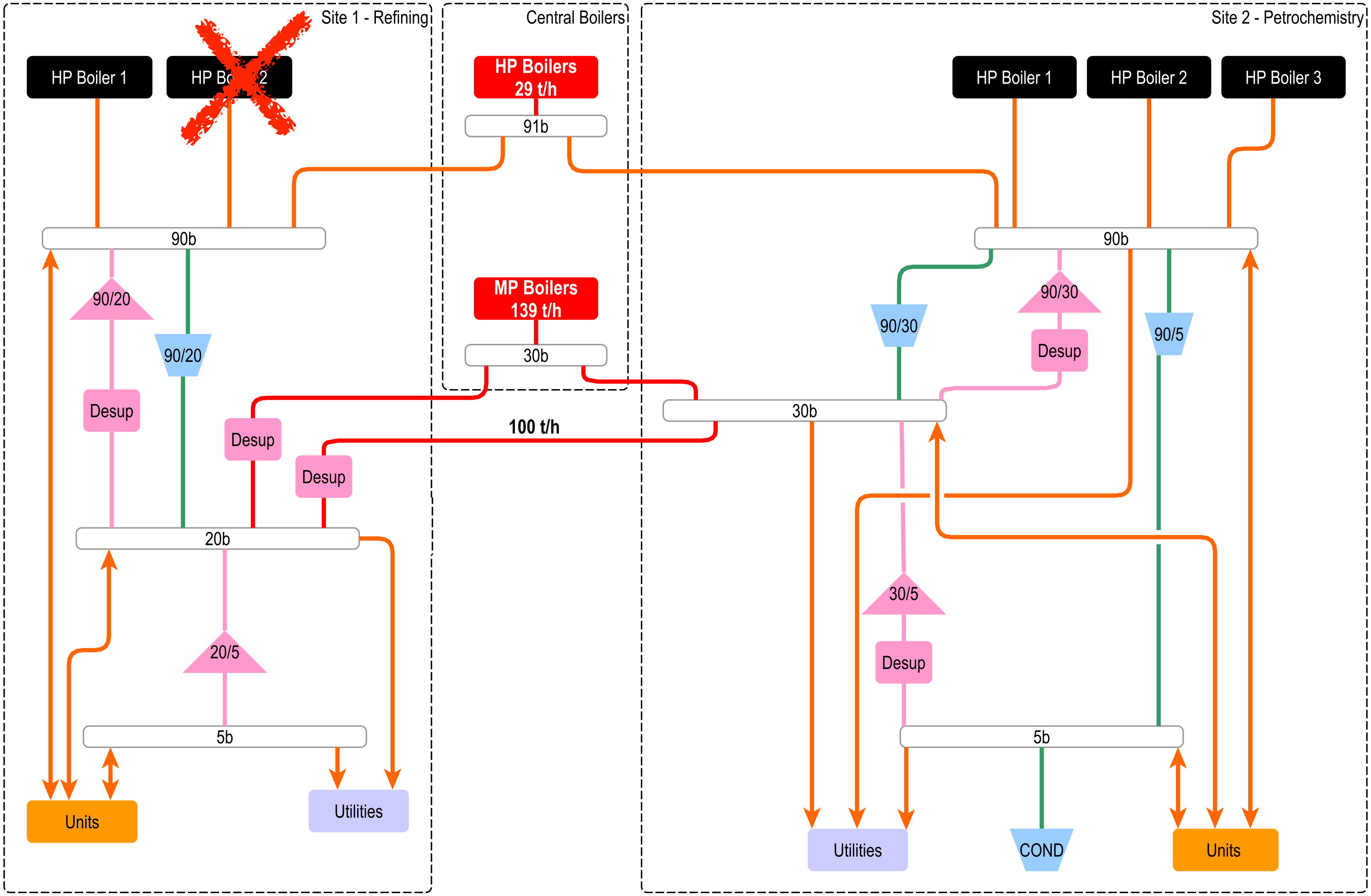
- **oversized systems**

  overcome unexpected events

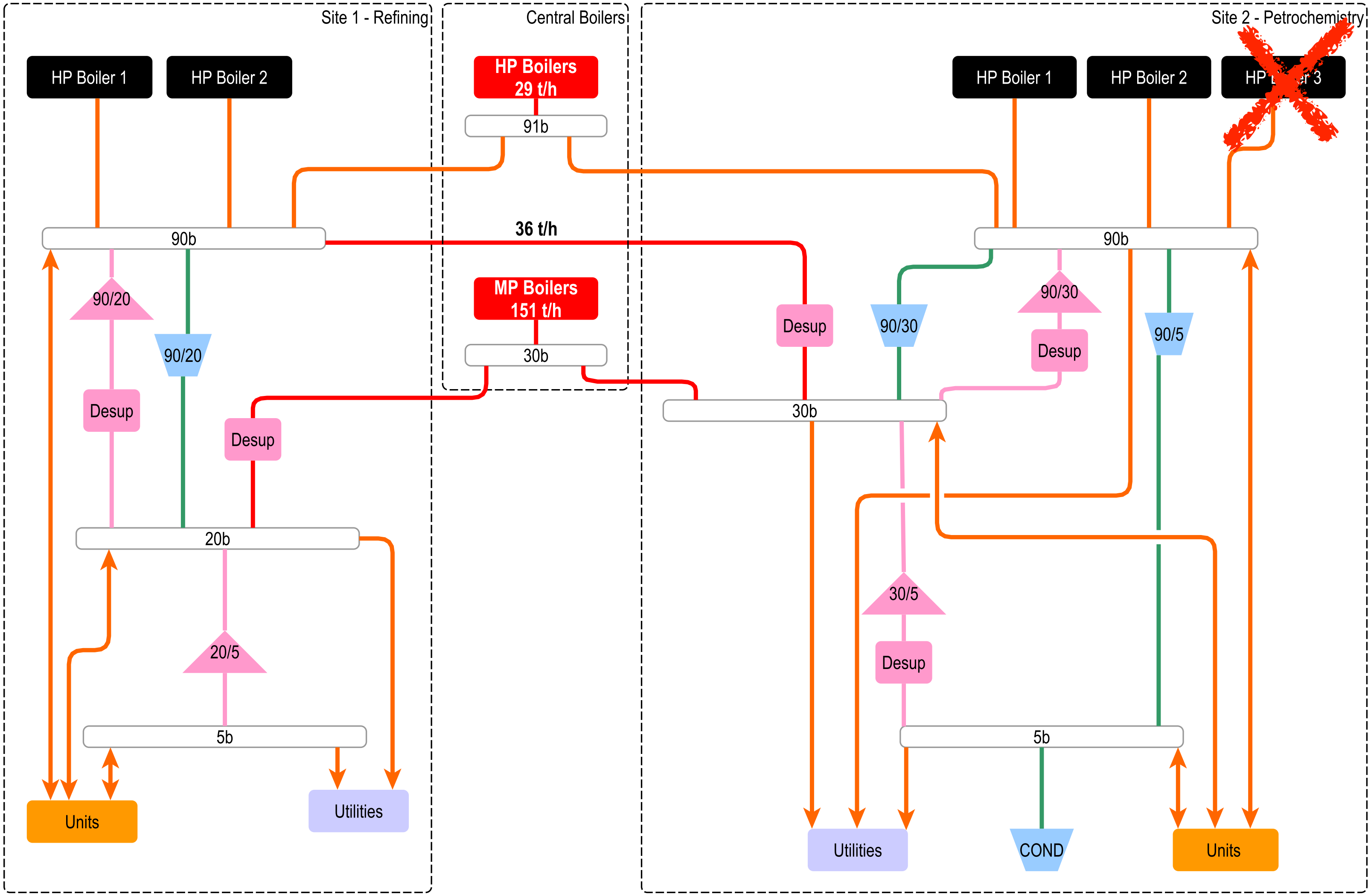
  allow normal operations under extreme conditions

  planned maintenance operations

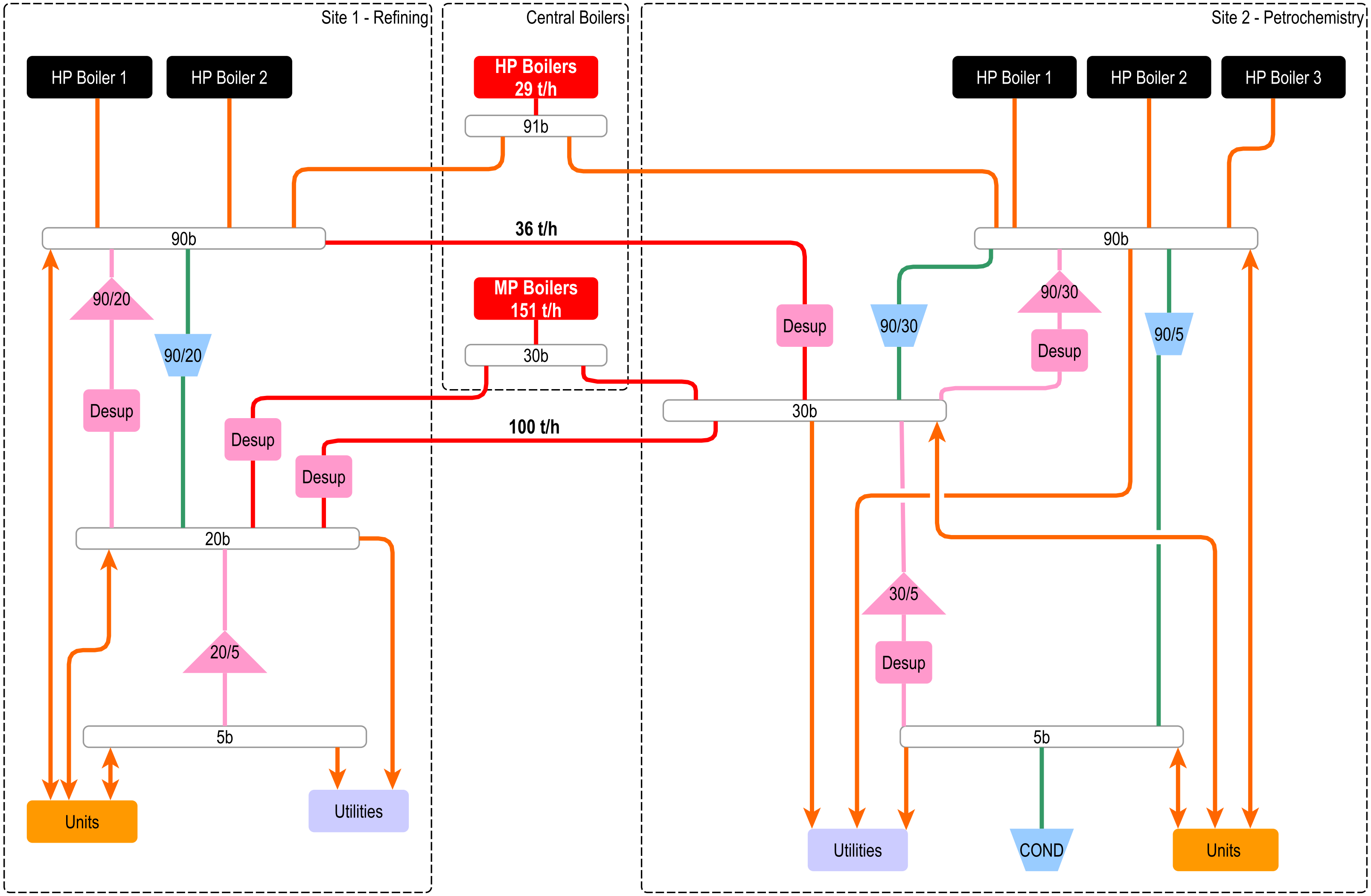
Case study - maintenance?



Case study - maintenance?



Case study - proposed resilient investment



Total CAPEX: 4.1 x10^6 €/yr

Investments
Demonstration

Dealing with boiler failures

Boilers fail…

- **failures can occur randomly**

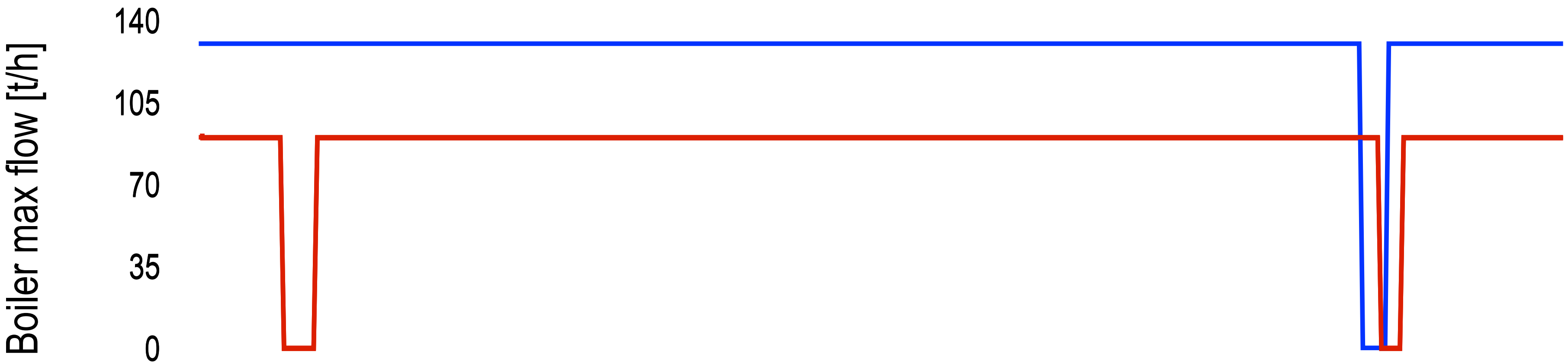
  maintenance is planned

  boiler trips are not

  murphy's law

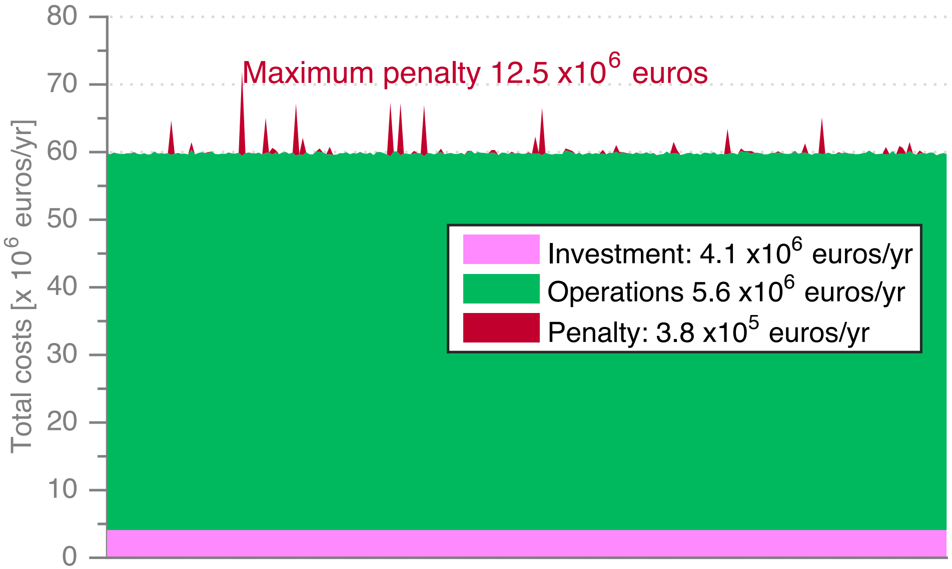
How to define resilience

- **ability to supply steam despite boiler trips**
- **network operability**
- **network simulation**



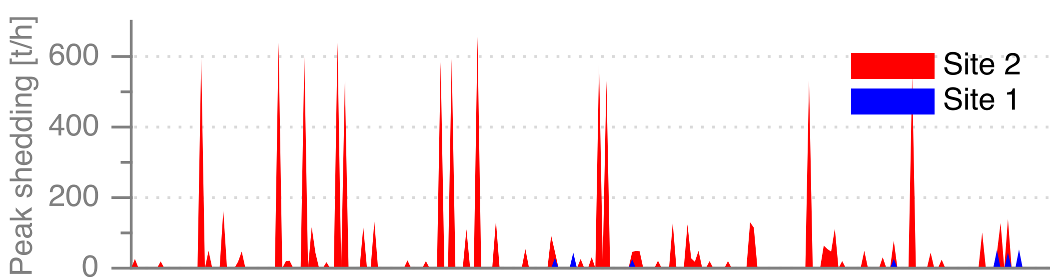
Case study - simulation of random boiler failures

Simulated costs



CAPEX : 4.1 x10^6 €/yr
Design OPEX: 55.4 x10^6 €/yr
Simulated OPEX: 56.1 x10^6 €/yr
Standard deviation: 1.4 x10^6 €/yr

Peak shedding

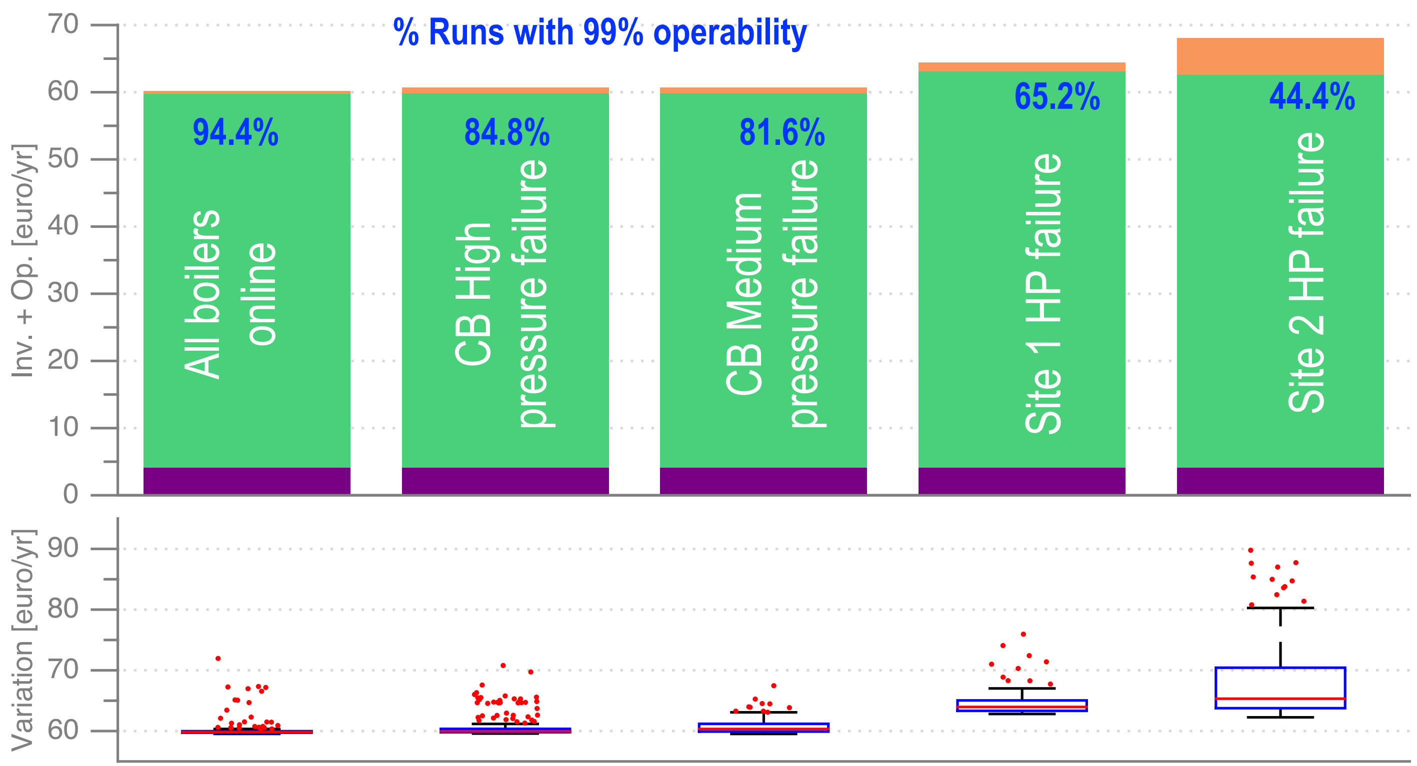


94.4% of runs have 99% operability

Case study - sensitivity analysis / single boiler failure

[expected costs x10^6 €/yr]

Penalty:	0.4	0.8	0.9	1.3	5.5
Operations:	55.7	55.7	55.7	59.0	58.4
Investment:	4.1	4.1	4.1	4.1	4.1
Total:	60.2	60.7	60.7	64.4	68.0



Conclusion and outlook

accomplished

- **operations optimisation**
  optimal equipment choice
  load shedding
- **investment optimisation**
- **network simulations**
  evaluation of network resilience

weakness

- **linear vs. non linear**
- **costing**

further work

- **key performance indicators**
  e.g. Loss of Load Probability
- **design of optimally resilient systems**
  algorithm to optimally design investment supestructure

Thank you for your attention