Operation improvements of facility for the K computer at RIKEN AICS

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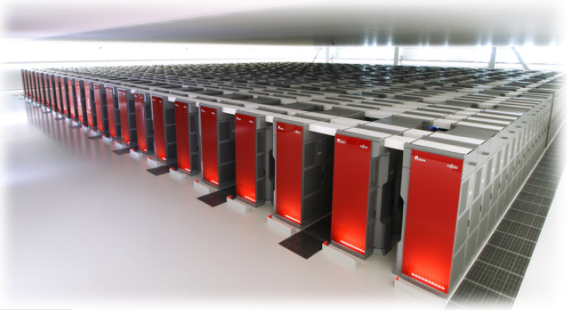
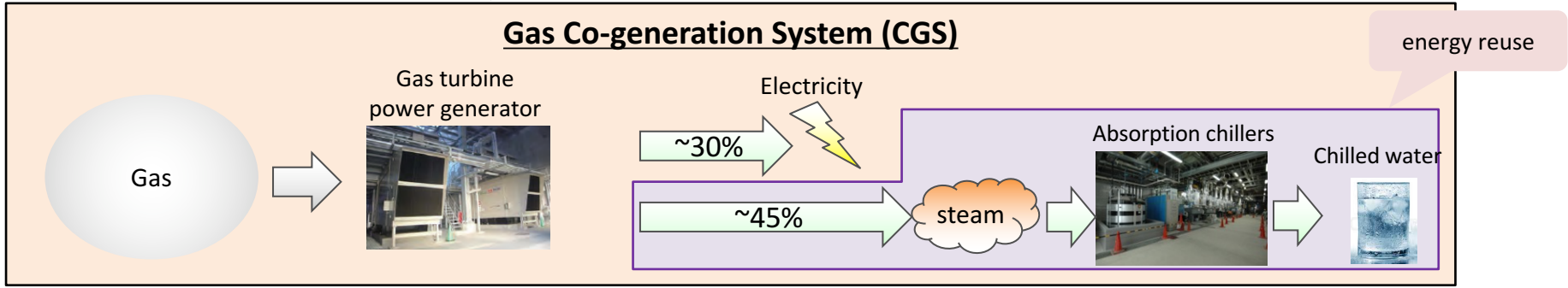
The K computer & the facility

- **The K computer:**
  - Computing Capability 10.51 PetaFlops (HPL score)
  - Power Consumption 12-15MW
  - Water/Air cooling ratio 70 : 30
  - Operation start 28 September, 2012



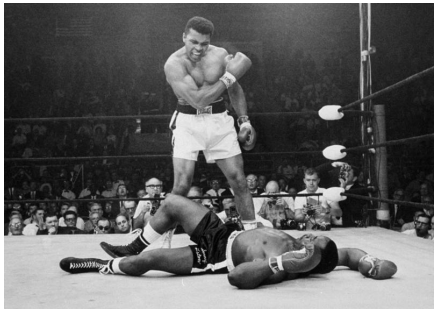
- **Facility:**
  - Gas Turbine Power Generator 5MW x 2
  - Chiller(absorption) 1700USRt(5.98MW) x 2
  - Chiller(Centrifugal) 1400USRt(4.93MW) x 2, 700USRt(2.46MW) x 2
  - Air handlers, voltage transformers, etc.

Electric power source balance
Provider: Generator = 70 : 30

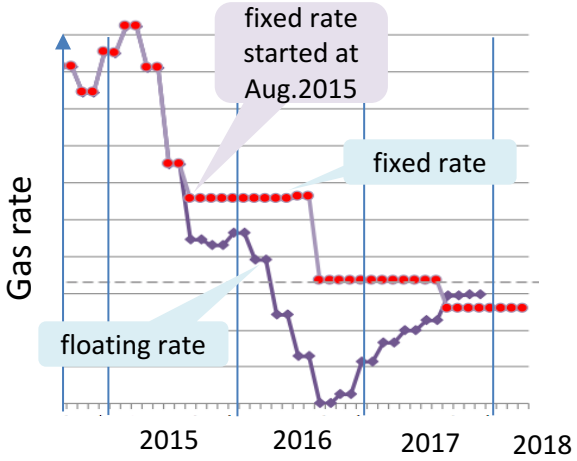


Efforts for better contract

- **Electric power**
  - A private contract with a regional power supply company until FY2016.
  - A competitor appeared for FY2017 supply contract renewal, then we introduced competing bidding.
  - ---> The challenger beat the champion then the electric power cost decreased by 10% and no minimal consumption constraint is included.
  - ---> No quality degradation observed so far.



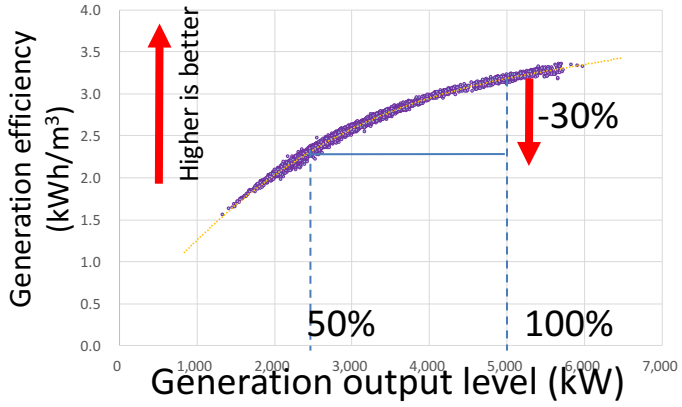
- **Gas**
  - A contract based on a floating gas rate until Jun.2015.
  - A fixed rate service has started since Aug.2015.
    - In our case, a fixed rate, which is determined 6 month ago, is applied for 1 year.
    - ---> Consequently, the fixed rate level was higher than the floating for 2 years, but the trend was reversed recently.
    - ---> If the fixed rate contract needs more cost, it is beneficial for us that no shortage/residue is guaranteed.



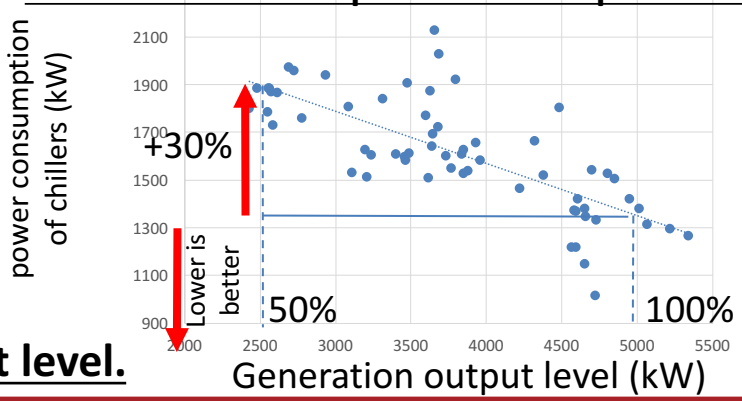
Lessons learned for CGS operation

1. Generation efficiency of gas turbine power generator increases when it is driven at higher output level.
   - ex. when generator is driven at 50% output level, efficiency decreases by 30%.
2. When power generator is driven at higher level, richer steam is also generated then power consumption of chillers can be saved.
   - ex. when generator is driven at 50% output level, power consumption of chillers increases by 30%.

Generation level vs efficiency

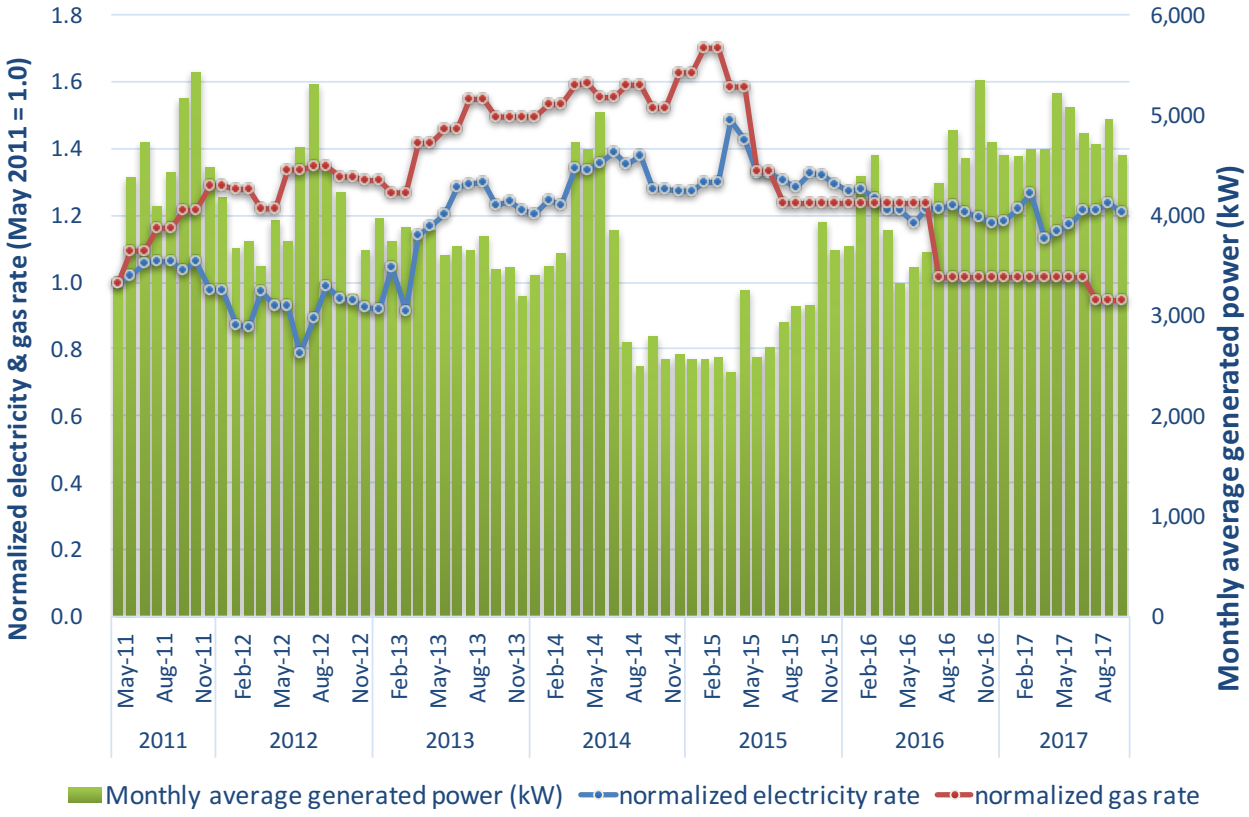


Generation level vs power consumption of chillers



Power generator should be driven at higher output level.

CGS operation improvement



- In actual operation, optimal operation could not be achieved for some periods due to higher gas rate or constraint from contract (ex. minimal power consumption)
- New power supply contract including no minimal power consumption and gas supply contract with fixed rate also help us to improve energy efficiency.

Summary

- **Efforts for better contract**
  - Competing bidding is introduced for electric power supply contract.
    - Electric power cost decreased by 10%.
    - No minimal consumption constraint.
  - A fixed rate contract for gas supply.
    - It may not contribute cost reduction but it is useful for budget implementation and stable service providing.

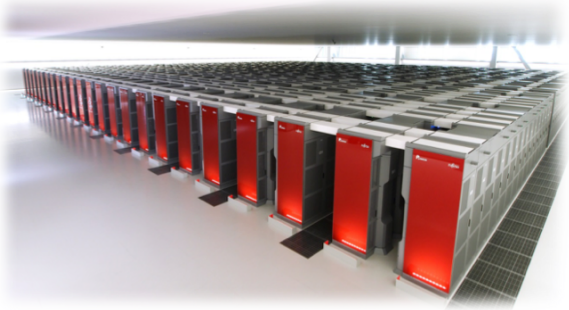
- **CGS operation improvement**
  - Gas turbine power generator should be driven at higher output level for better generation efficiency and better PUE.
  - New supply contract help us to achieve energy/cost efficient operation.

- **Other improvements (in backup slides)**
  - Optimization of air handler operation and improvement of PUE.
  - Power capping to avoid exceed: in our case

Backup slides

The K computer

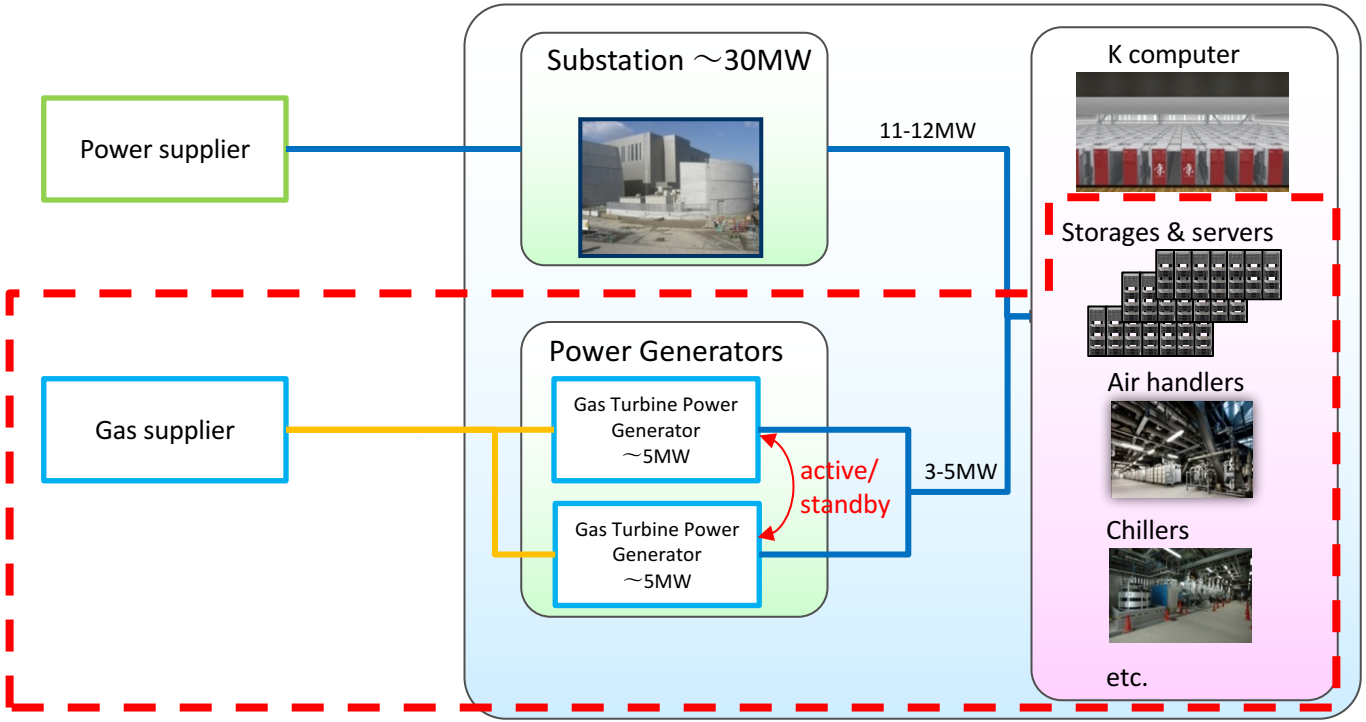
- **The K computer:**
  - developed by collaboration between RIKEN and FUJITSU in a Japanese national project.
  - has been started to operate since Sep. 2012.
  - designed to aim for a general-purpose computing.
    - no accelerators
    - richer memory/interconnect bandwidth, etc.
    - for facility, conservative but promising technologies (e.g. cold water cooling) were widely used



- **Achievements:**
  - Graph500 list : No.1 at Jun. 2014, Jul. 2015 – Jun. 2017.
  - HPCG results : No.1 at Nov. 2017, No.2 in Jul. 2015 – Jun. 2017.
  - TOP500 list : No.1 at Jun. and Nov. 2011.(#8 in the latest list)
  - Gordon Bell prize : Winner in 2011 and 2012
  - Many remarkable results for science and engineering are shown in http://www.aics.riken.jp/en/

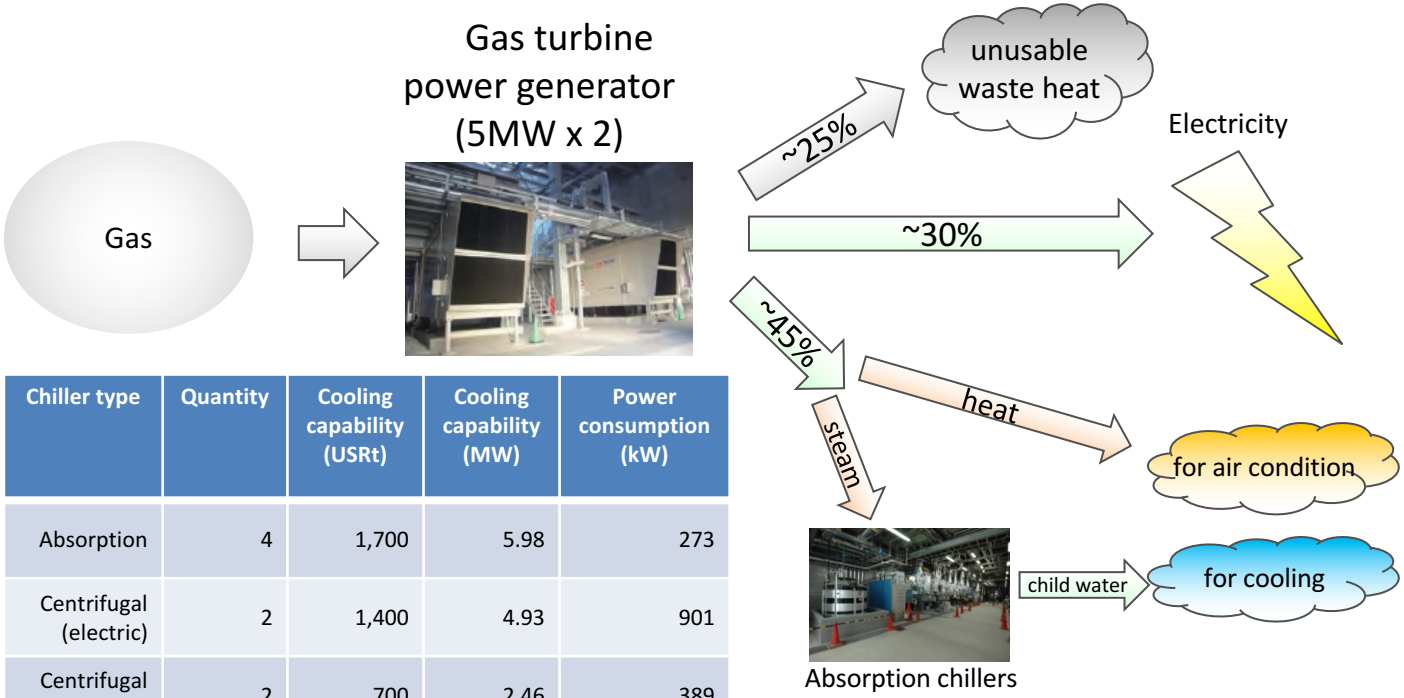
Power supply

Total power consumption:14-16MW



Power generators also work as backup power supply for storage

Gas co-generation system (CGS)

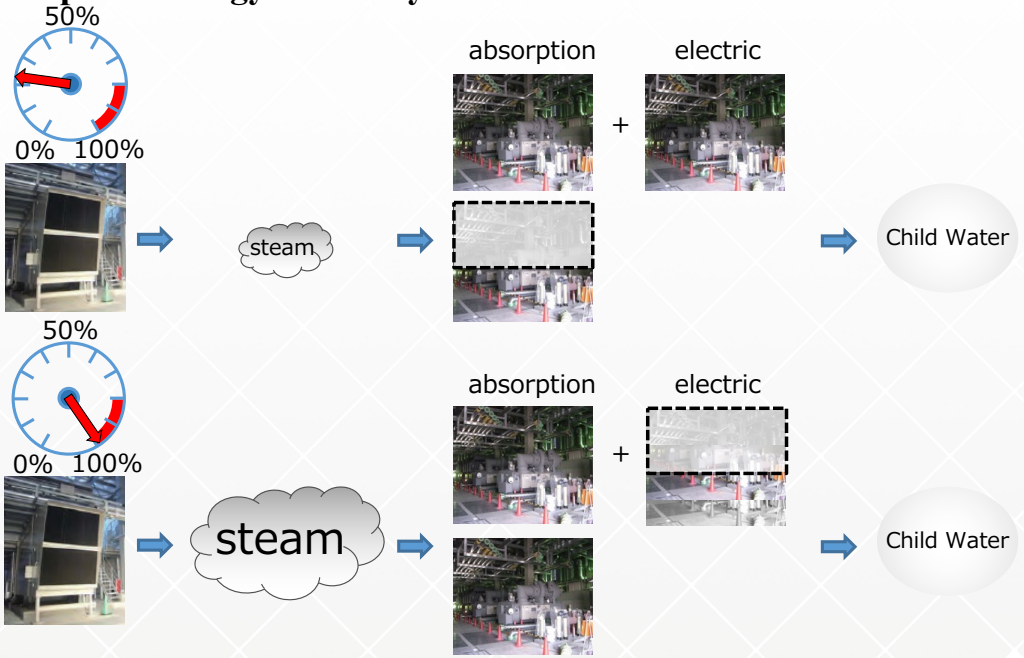


Chiller type	Quantity	Cooling capability (USRt)	Cooling capability (MW)	Power consumption (kW)
Absorption	4	1,700	5.98	273
Centrifugal (electric)	2	1,400	4.93	901
Centrifugal (electric)	2	700	2.46	389

CGS enables to achieve higher energy efficiency by re-using waste heat for cooling/heating

Efficiency of CGS

Improve energy efficiency of the chillers



- Absorption chillers work more efficient by richer steam.
- Then power consumption of chillers can be reduced.

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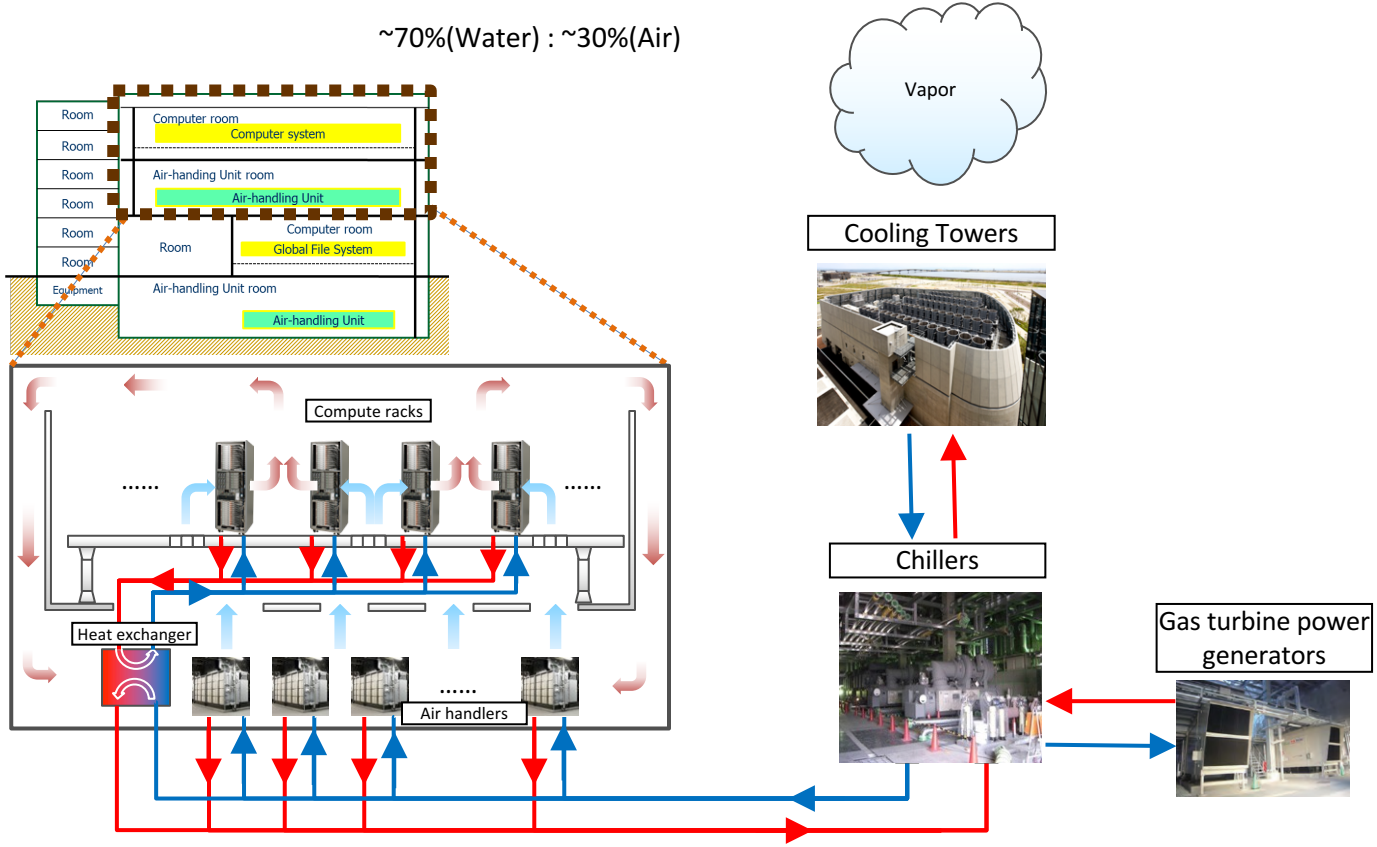
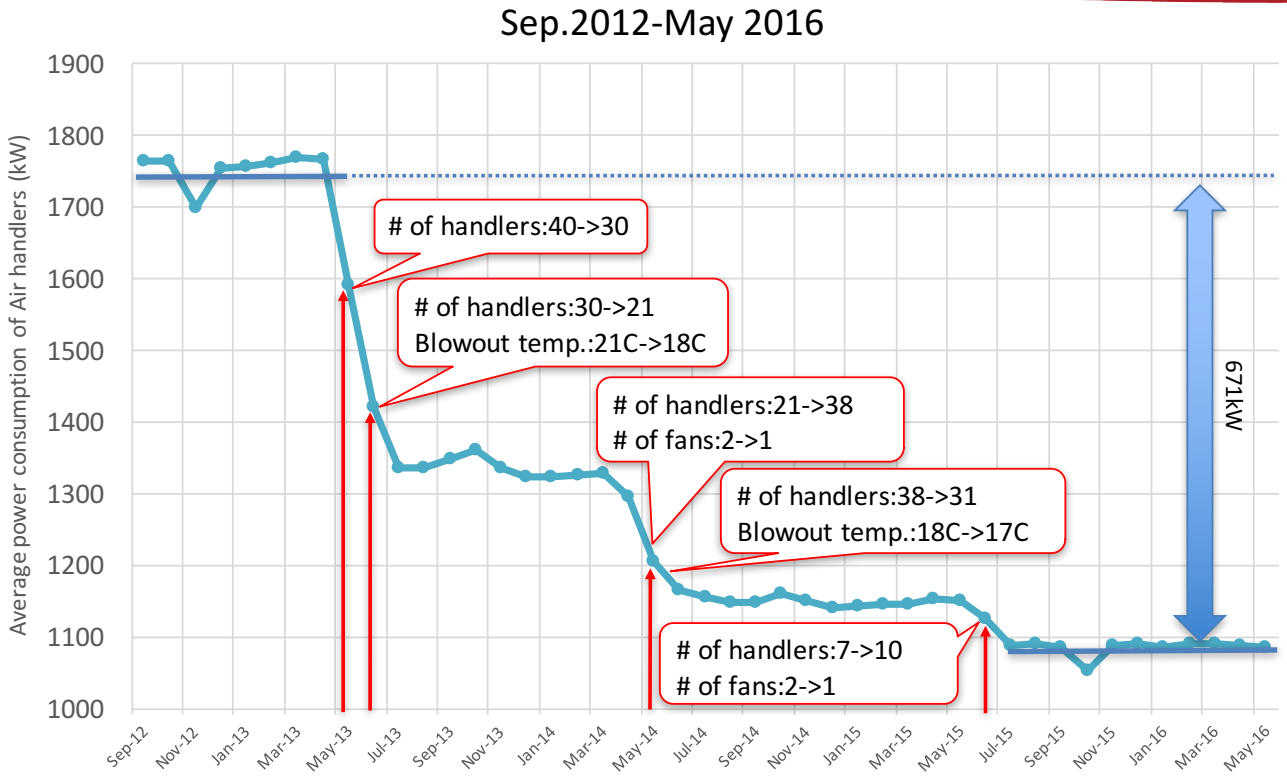
Cooling

~70%(Water) : ~30%(Air)

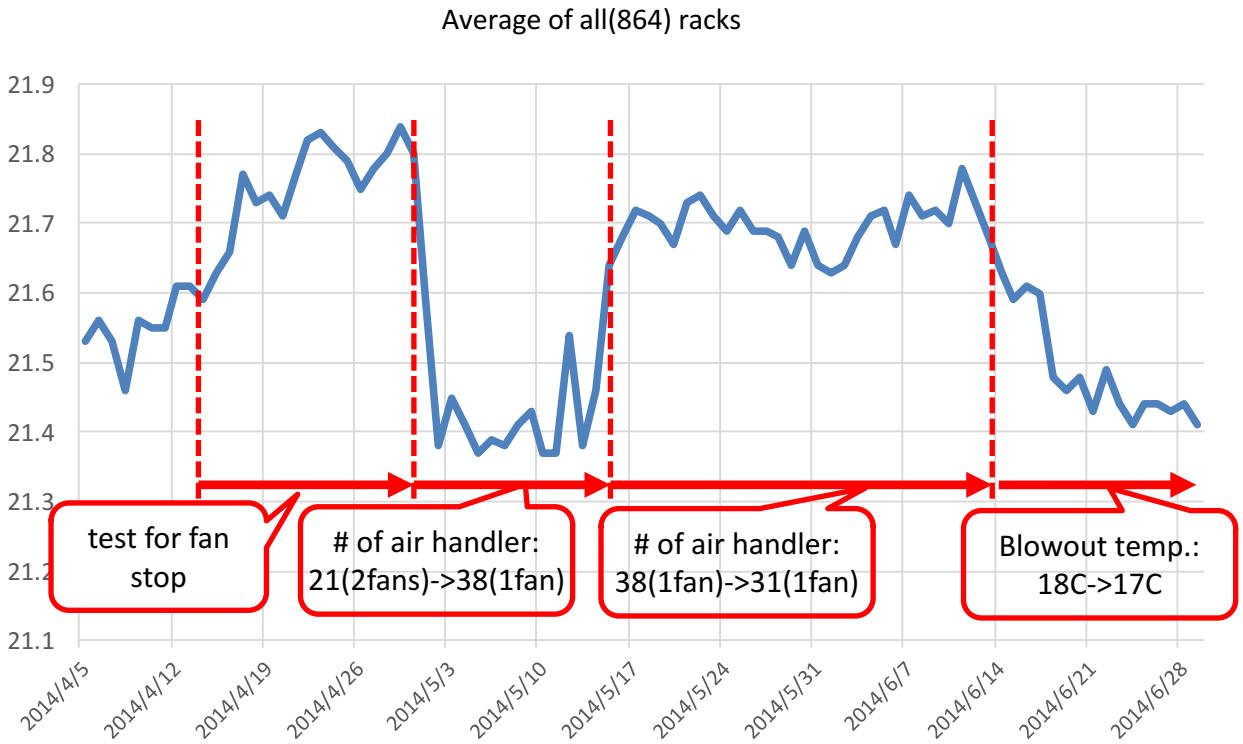


Reduction of power consumption of Air handlers



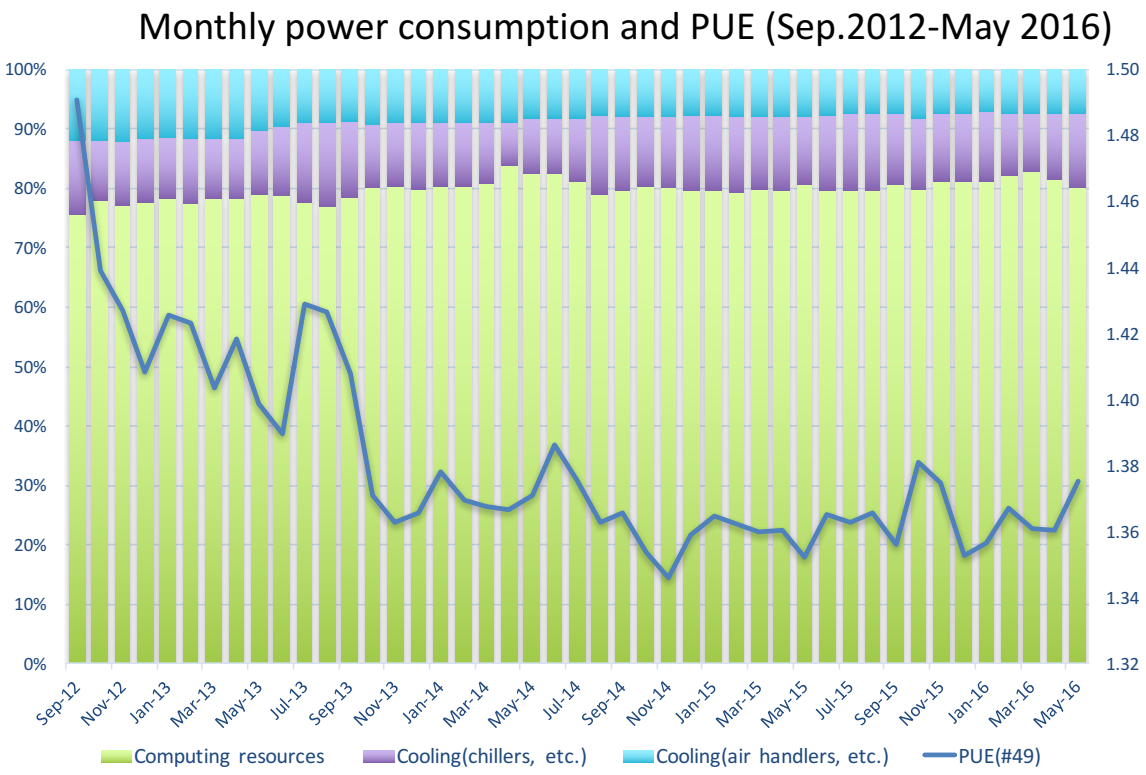
40% of power consumption of air handlers was saved!

Average rack inlet air temperature



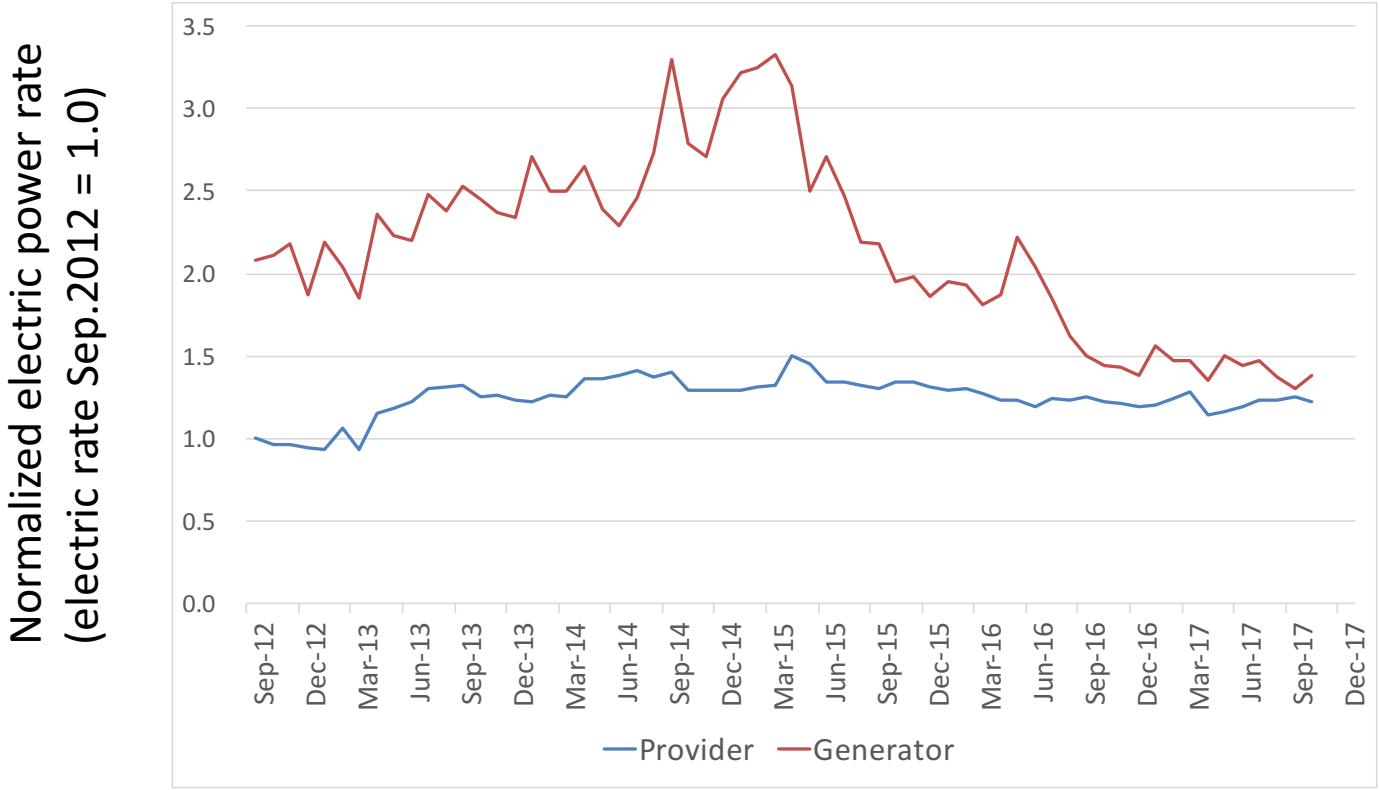
Before and after, the average inlet temperatures could be kept similar level.

Power consumption and PUE



Reduction of power consumption of air handlers contributed to decrease PUE.

Electric power cost comparison



Power capping

- **The constraint for power consumption**
  1. 30 min average power consumption do not exceed the upper limit.
     - Penalty fee depends on the exceed power x time.
  2. ~~Annual total consumption do not be less than the lower limit.~~
     - In new contract from FY2017, the constraint is not included.
- **Our strategy**
  1. Large scale job (more than 40% of full system) which cause power exceed can be executed only the 3 days per a month.
  2. User who want to execute large scale job must execute a small version (10% of full system) of the large scale job before large scale mode period.
     - We evaluate the power profile of the job and estimate the upper power consumption.
     - We consider to admit to execute the job or not. If the estimated power consumption exceed the limit, we also consider to activate 2nd power generator during the job is running.
  3. If power exceed is occur unfortunately, a monitoring system will work and the job will be killed automatically.

Since the operation based on the procedure has started, no power exceed occurred.