An assessment of High Efficiency Cogeneration in Italy, based on actual operation data

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Which technology is best suited to be employed in cogeneration?

More than six hundred generating units were analysed: *Gas turbines - Internal combustion engines - Steam turbines*

"Real life" operation data were collected for years 2011 to 2019 (more than 12.000.000 equivalent operating hours).

Efficiency indicators were calculated as weighted averages. Statistical correlation among indicators was investigated, i.a.

- *Electric efficiency;thermal efficiency;overall efficiency;Power to Heat Ratio (PTOH);Equivalent Operation Hours (Heq);Load Factor.*

High PTOH: large amount of "valuable" energy (electricity); the heat carrier (e.g., steam) was exploited efficiently, as it produced a significant amount of electricity before being further used for thermal purposes.

- ***Equivalent operating hours (Heq): number of hours during which the generating unit would have been in operation, if it had constantly been kept at maximum load.***

- Heq was in turn divided by the actual yearly operating hours (Heff). This yielded the load factor (Fc), always less than one.

- ***Heq: when close to one, it suggests that the generating was operated with few starts and stops.***

- ***Load factor Fc : if close to one, the generating unit was kept close to full load. Starts and stops took place rapidly: heat dissipation was limited.***

Technology			Electric efficiency (p.u.)	Overall efficiency (p.u.)	Load factor (p.u.)	Equivalent hours (%)	PTOH
ORC			0,13	0,23	0,94	86,23	1,40
ORC	SMALLSCALE		0,17	0,71	0,73	58,53	0,30
Microturbine			0,30	0,82	0,45	34,19	0,59
Microturbine	SMALLSCALE		0,26	0,71	0,58	47,55	0,58
Microturbine	SMALLSCALE	MICRO	0,19	0,69	0,79	43,36	0,37
Internal Combustion Engine			0,41	0,70	0,89	66,59	1,40
Internal Combustion Engine	SMALLSCALE		0,36	0,72	0,86	63,82	1,00
Internal Combustion Engine	SMALLSCALE	MICRO	0,28	0,83	0,87	54,76	0,51
Gas turbine			0,32	0,82	0,84	71,27	0,64
Gas turbine	SMALLSCALE		0,29	0,73	0,74	62,47	0,67
Back-pressure steam turbine			0,17	0,89	0,83	76,75	0,23
Back-pressure steam turbine	SMALLSCALE		0,10	0,72	0,88	77,48	0,15

Conclusions

- **Internal Combustion Engines (ICE):**
  - *Above 1 MW, very high Power to Heat Ratio (PTOH) and electric efficiency. However, both decrease with engine power. Only overall efficiency increases as capacity decreases.*
  - *Irrespective of engine power, load factor Fc is high, even if Heq is low. ICEs can be started and stopped rapidly: partial load operation is short.*
  - *Micro ICEs: strong, inverse relationship between electrical efficiency and thermal efficiency: the amount of heat wasted is low.*
  - *Regardless of engine power, electric efficiency is not significantly dependent on the year of commissioning.*
- **Gas turbines:**
  - *Good (below 1 MW) or excellent (above 1 MW) overall efficiency, but a rather low electric one.*
  - *Above 1 MW, electric efficiency does not depend significantly on the equivalent operating hours (Heq).*
  - *Below 1 MW , positive correlation: these turbines are best suited for continuous operation.*
  - *PTOH: generally lower for gas turbines than for IECs (exception: ICEs below 50 kW).*
  - *Gas turbines also seem to have reached technological maturity: electric efficiency is virtually independent of commissioning year.*
- **Steam turbines:**
  - *low electric efficiency, PTOH and load factor. Only overall efficiency is good.*
  - *Tendency to suffer from load variations (at least for the small-scale ones):*
  - *strong direct correlation between equivalent operating hours (Heq) and electric efficiency.*
  - *strong direct correlation (affecting all steam turbines, irrespective of power) between load factor (Fc) and equivalent operating hours (Heq).*
  - *Poor aptitude to variable load - Long times to reach full load after start up: not suited to intermittent operation (operational drawback).*