A case study: OP16 gas turbine on syngas derived from solid municipal waste

Ahmet Yontem, OPRA Turbines

Ahmet Yontem
Lead Application Engineer
ayo@opra.nl

Outline of today's presentation

- Waste-to-power case study
  - Landfill operation in Turkey
  - Challenge with syngas
  - OPRA solution for syngas
- Summary

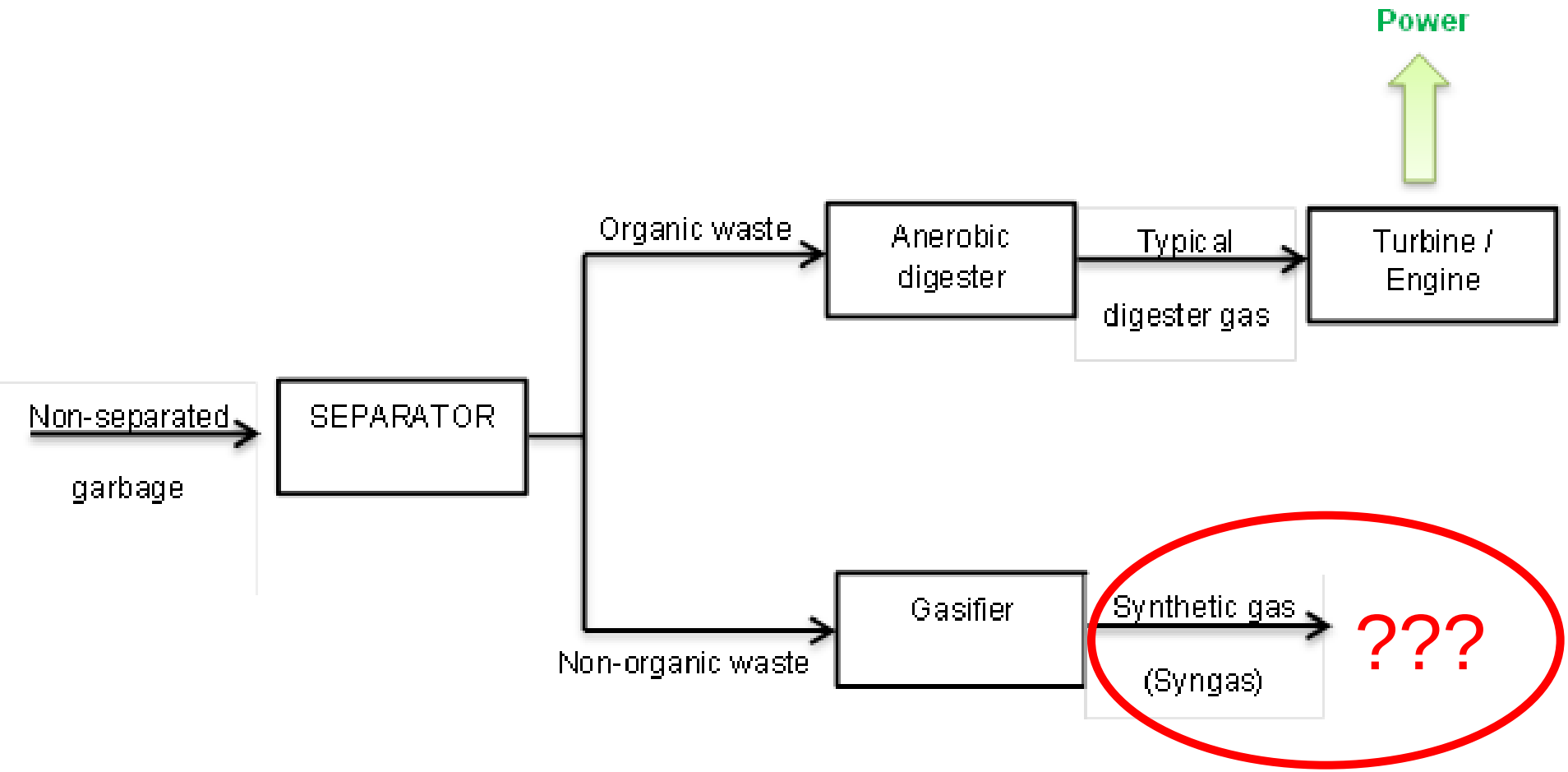
Case Study: Syngas to power at a landfill in Turkey

Operation summary at the landfill site

- No tipping fee in Turkey
- Long term kWh-PPA with government

- 8 separate landfill sites
- Base load operation
- Some of them using the thermal output
  - → Close-by shopping malls
  - → Greenhouses

Process diagram at the landfill site

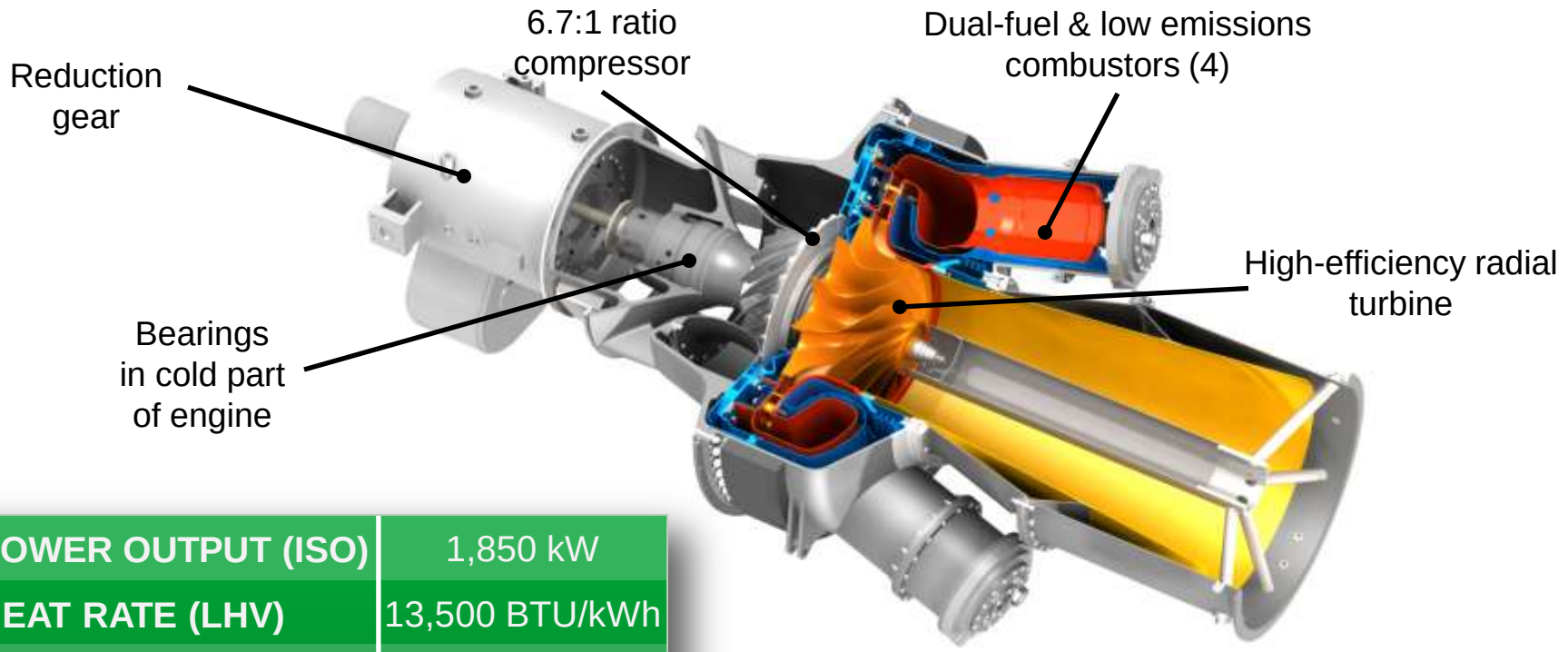


Challenges with the syngas

- Low heat content (150 BTU/scf)
  - Larger amount of the fuel needs to be handled
  - Longer time is needed to complete the burning process
- The fuels might contain unwanted components
  - Increased risk for hot temperature corrosion
- Changing fuel properties
  - Control system and hardware must enable continuous operation
- The availability of the fuel might vary over time
  - The need to be able to operate uninterrupted requires the use of a back-up fuel

This is good news...at least if you are a gas turbine engineer

Can standard OP16 burn low BTU syngas as well?



POWER OUTPUT (ISO)	1,850 kW
HEAT RATE (LHV)	13,500 BTU/kWh
EXHAUST ENERGY	~ 17 MMBTU/h
ROTOR SPEED	26,000 rpm
TBO	40,000 hours AND 3,000 starts

Special combustor technology developed for low BTU fuels

3A - Conventional combustor

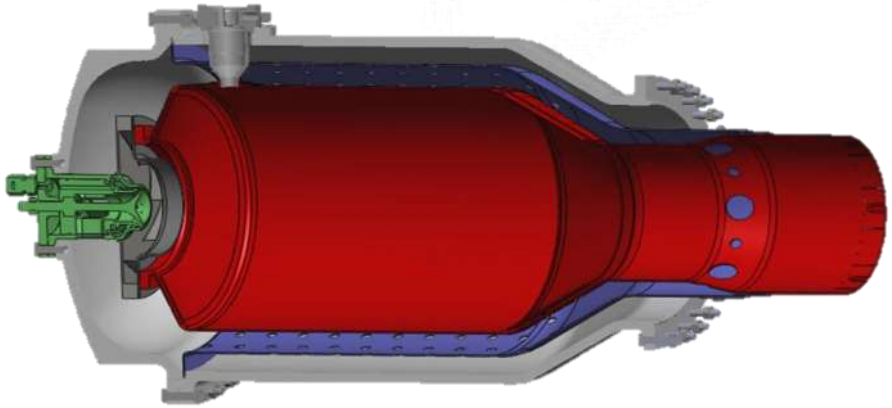
- Diffusion flame
- Film cooling
- Dual fuel operation
- Switch under full load operation

3B - DLN combustor

- Dry low emission (<15 ppmv NOx)
- Pre-mixed flame
- Impingement cooling

3C - Low calorific fuel combustor

- Diffusion flame
- Significantly larger volume
- Dual fuel operation
- Specially design for low calorific fuels (>150 BTU/scf)

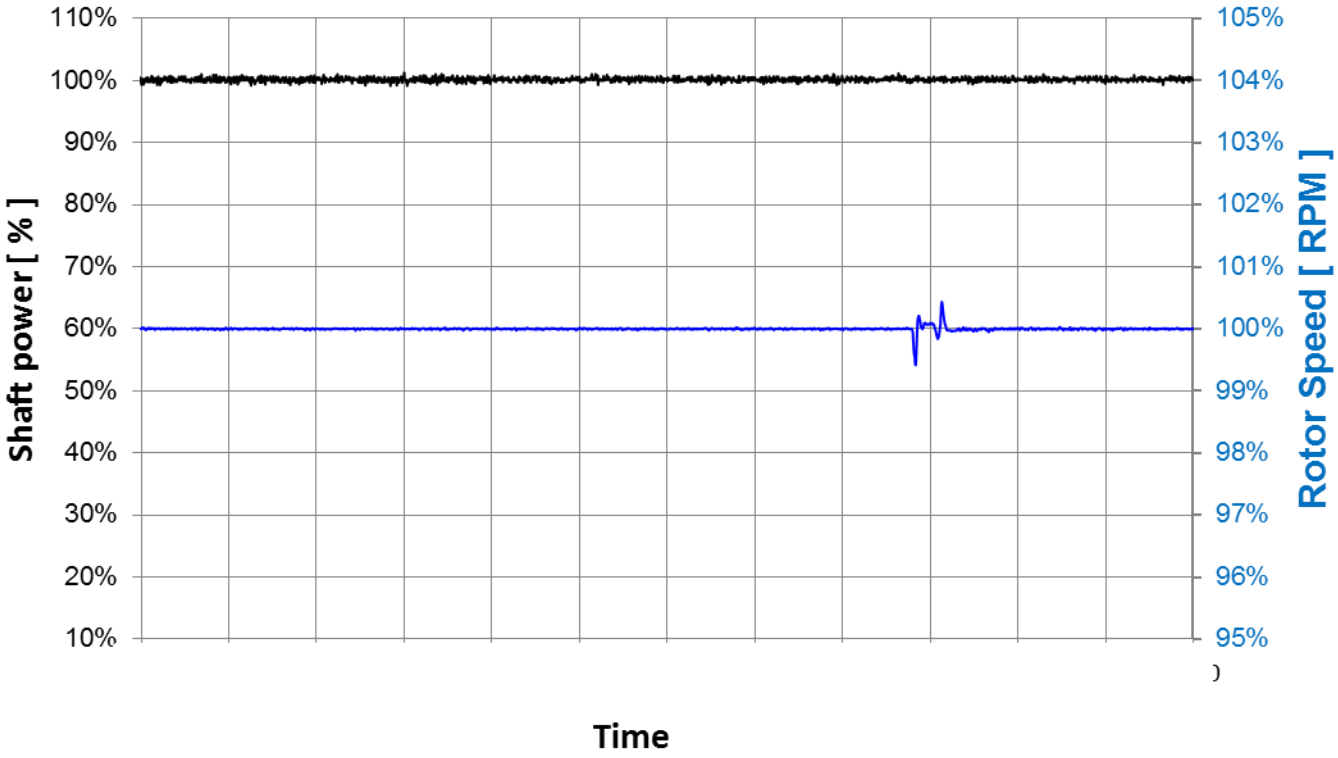


Patent pending, patent application No. US 2012/0111014

The low-calorific fuel combustor is retrofitted on the standard OP16 gas turbine

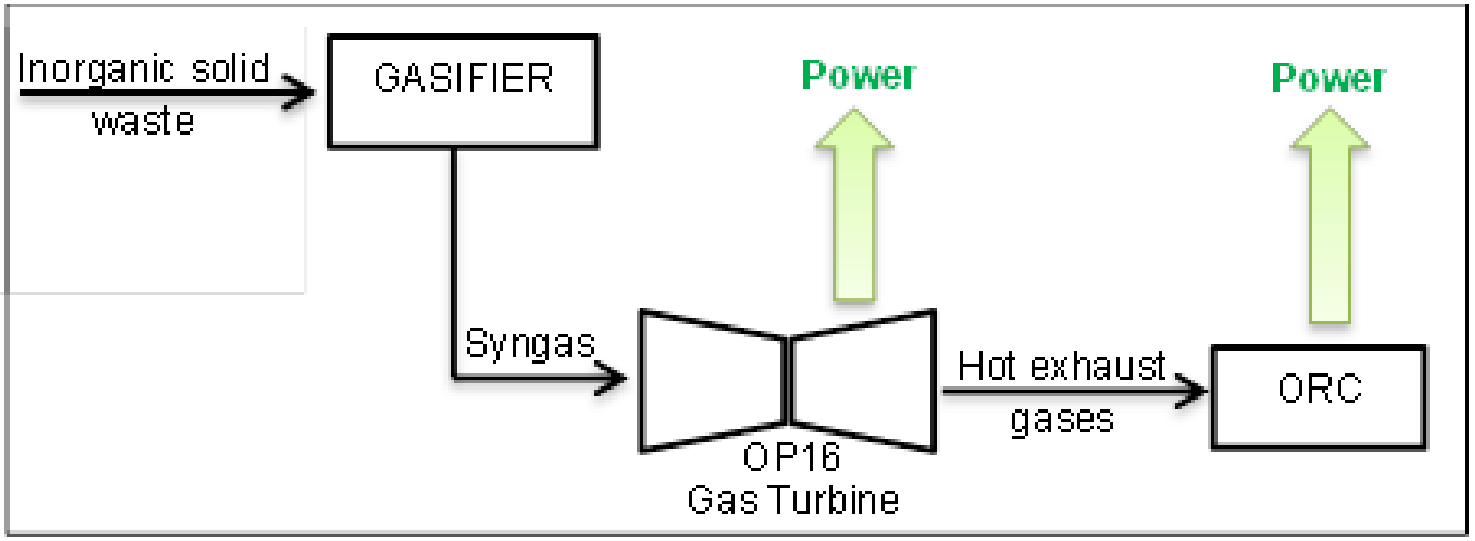
- The combustion chamber is significantly larger to increase residence time of low BTU gas
- Combustors fit on the engine without increasing the overall length
- The new combustor can operate in dual-fuel and bi-fuel mode

The OP16 switches between gas/liquid fuel (even on full load) when syngas not available



- Syngas availability changes over time
- Important to be able to operate in dual fuel mode to avoid power interruption

OP16 + ORC combined package will produce power from the low quality syngas in Turkey



- OP16 output : 1.8 Mwe & ~17 MMBTU/h
- ORC output : 0.8 MWe
- Overall heat rate (LHV) : ~9,000 BTU/kWh

Summary

- Alternative fuels provide additional challenges for the gas turbines
- A new low BTU combustor technology is developed by OPRA to efficiently burn low-calorific gaseous and liquid fuels
- OP16 + ORC combined cycle will run on 150 BTU/scf syngas at a Turkish landfill to produce base power for grid

Thank you very much

Ahmet Yontem
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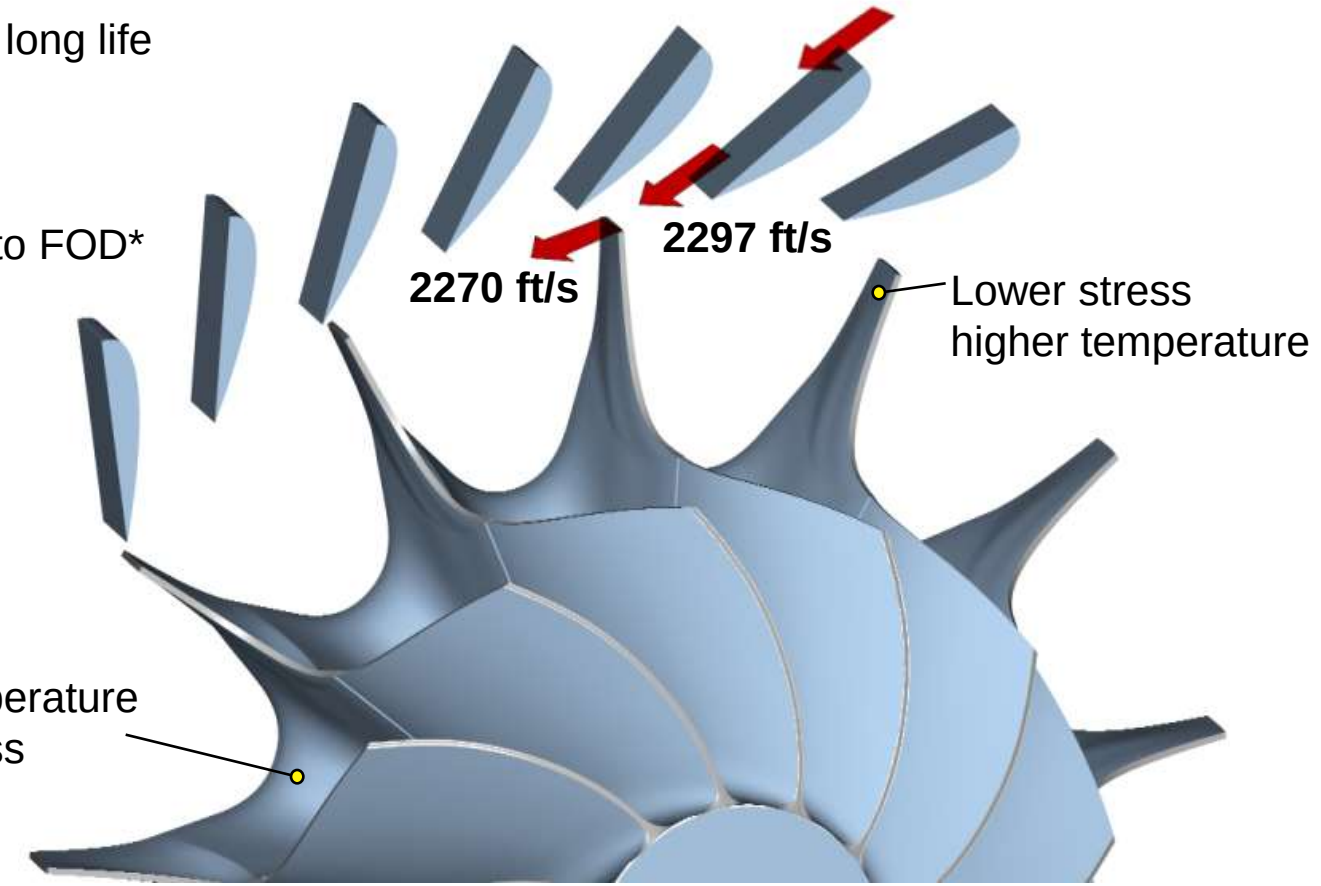
ayo@opra.nl

Robust radial gas turbine technology is more suitable for challenging fuels

- High efficiency
- Robustness and long life
- Reduced metal temperature
- High resistance to FOD*



*Foreign Object Damage

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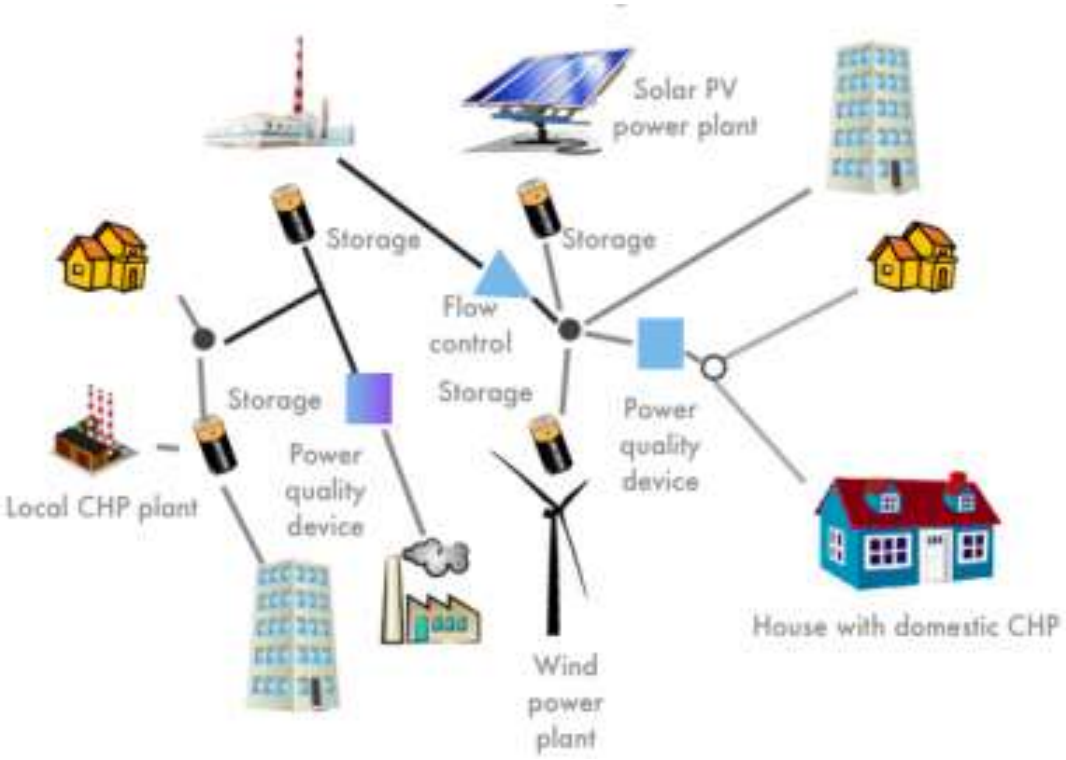
Fuel diversification is a key requirement for successful decentralized generation using smaller gas turbines

- Various fossil fuels
  - Traditional fuels
  - Flare gas
- Alternative fuels
  - Biofuel
  - Syngas
  - etc.



Why are we interested to utilize alternative fuels?

- Fossil fuels are a limited resource and we need alternatives
- Fuel price will increase with decreasing availability
- Reduce the operating costs
- Reduce the impact on the environment, e.g., convert waste into fuel
- Ensure an independent and reliable source of energy