**Advanced Cycles**

With the rapid rise of renewables (in the European Union they account for about 80% of the new capacity in a 2030 scenario), there is a need to provide back up power and grid stabilization while

* increasing overall cycle efficiency
* reducing water consumption
* reducing CO2 footprint
* managing wear and tear on equipment due to intermittent usage

An answer to those needs are advanced cycles, not only looking at them from a pure thermodynamic point of view but also looking at system integration opportunities of different technologies that can cater to those needs. Considering current installed capacity (traditional power plants) will continue to serve in a 2030 energy scenario and beyond, particular attention will need to be devoted to upgrade and conversion applicability.

Most advanced cycles gas turbines are interconnected to other systems and components, or processes such as for example high temperature fuel cells or solar air heaters. So the integration often requires a change in mass flow rates of compressor or turbine as well as changing composition of the working fluid. Most GTs currently on the market are not designed for this type of process integration. Future R&D activities should therefore target the development of concepts for “easy-to-integrate” and flexible gas turbines, since otherwise each cycle would need its specific gas turbine adaptation.

For efficient and meaningful cycle evaluation reliable numerical simulation tools are indispensable.

* A tool or system of tools that allow the analysis of advanced integrated cycles without the need to manually iterate be- tween power plant simulation and process modelling tools. This will avoid errors and should also result in a faster analysis and evaluation process.
* Tools well-suited for transient analysis of the process, as gas turbines are increasingly used to balance energy demand and the growing share of fluctuating renewables in the grid. Furthermore is it necessary to combine components with very different response characteristics in energy systems. Higher complexity and higher flexibility needs during start-ups and transients support this requirement.
* Tools for life cycle analysis in terms of costs as well as environmental impact (CO2 and other emissions and impacts accumulated over the entire lifetime) as a base for standard evaluation of concepts.

Ranking high on the promising advanced cycles list, sitting at different Technology Readiness Levels, we can find:

* Wet cycles
* Alternative fluids
* Exhaust Gas Recirculation
* Allam cycle
* Hybrid cycles with Fuel Cells
* Power plants hybridization with batteries
* Low grade heat recovery with heat pumps

**Wet cycles**

Wet cycles are processes with extraordinary high water content in the work fluid. Water might be either added before the combustor (e.g. humid air turbine or TopCycle (Figure 3), in the combustor itself (e.g. Cheng Cycle) or after it (e.g. for power augmentation). 🡪 Der TopCycle ist nicht zwingend Wet!

Here stability of the combustion process with high water content and close to stoichiometric conditions is of course an issue.

The materials and coatings of the gas turbine have to be tested regarding their ability to withstand the wet conditions. Most probably new materials and coatings have to be developed for this application.

**Alternative fluids**

The use of other working fluids than air, such as supercritical CO2 or organic compounds such as cyclopentane, is an issue which requires additional R&D efforts. In this context topics of interest might be:

External heat source integration be it either coming from external combustion, allowing the use of various fuels and at the same time reducing the overall process complexity by avoiding extra efforts and components for fuel preparation/ treatment, CSP field or nuclear reactor.

High efficiency, high temperature heat exchangers with optimized heat transfer and, depending on the fluids used, possibility for easy cleaning to reduce the effect of degradation.

Last but not least the transient behavior and the sensitivity versus Ambient conditions have to be investigated (for example for the trans-critical CO2-Cycles with a complex mass flow management or Oxyfuel processes with high complexity).

**Exhaust Gas Recirculation**

Using Exhaust Gas Recirculation (EGR) as a method for enhanced CO2 capture and sequestration by increasing the content of CO2 in the exhaust gas of the GT is also a cycle under evaluation. EGR is already used by Mitsubishi Heavy Industries for NOx control in J-series GTs with a Turbine Inlet Temperature (TIT) of 1700°C. This technology is thus close to commercial use.

**Allam cycle**

Another approach to enable better CO2 capture and control/eliminate NOx emission is the Allam cycle. The Allam Cycle is a so called Oxyfuel process, where the Fuel is burnt with pure Oxygen. It provides high CO2 concentration flue gas. The CO2 can be separated much easier by just condensing out the combustion water content.

**Hybrid cycles**

Hybrid cycles, combining different electricity production technologies (e.g. fuel-cell/gas turbine hybrids (Figures 7 & 8)) or renewable based power generation with fossil fueled generation should also be developed better. Here plant integration and plant control (especially in transient operating modes) is a challenge. The combination of solar heat input to a natural gas fired GT is a particular technology which shows great promise.

**Power plants with integration of storage**

Another system approach to solving the renewable intermittence issue is the integration of storage capabilities into existing power plants . This could be either batteries (used e.g. for time shift, peak loads, load leveling, faster ramp rates or grid service support) or high temperature heat storage (to be used during later discharge e.g. as second heat source for the combustor) or medium temperature heat storage (as a fuel saver by preheating the working fluid).

**Low grade heat recovery with heat pumps**

Another systemic approach can be to couple heat pumps to existing power generation systems and thermally upgrade the waste heat such that it can be used more effectively in the bottoming cycle.