# Novel Direct Fired $sCO_2$ Power Cycle with Integration of $H_2$ Combustor


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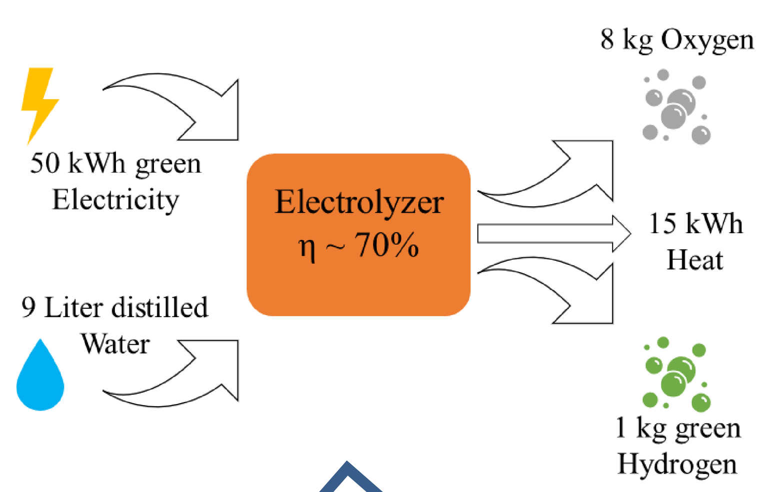
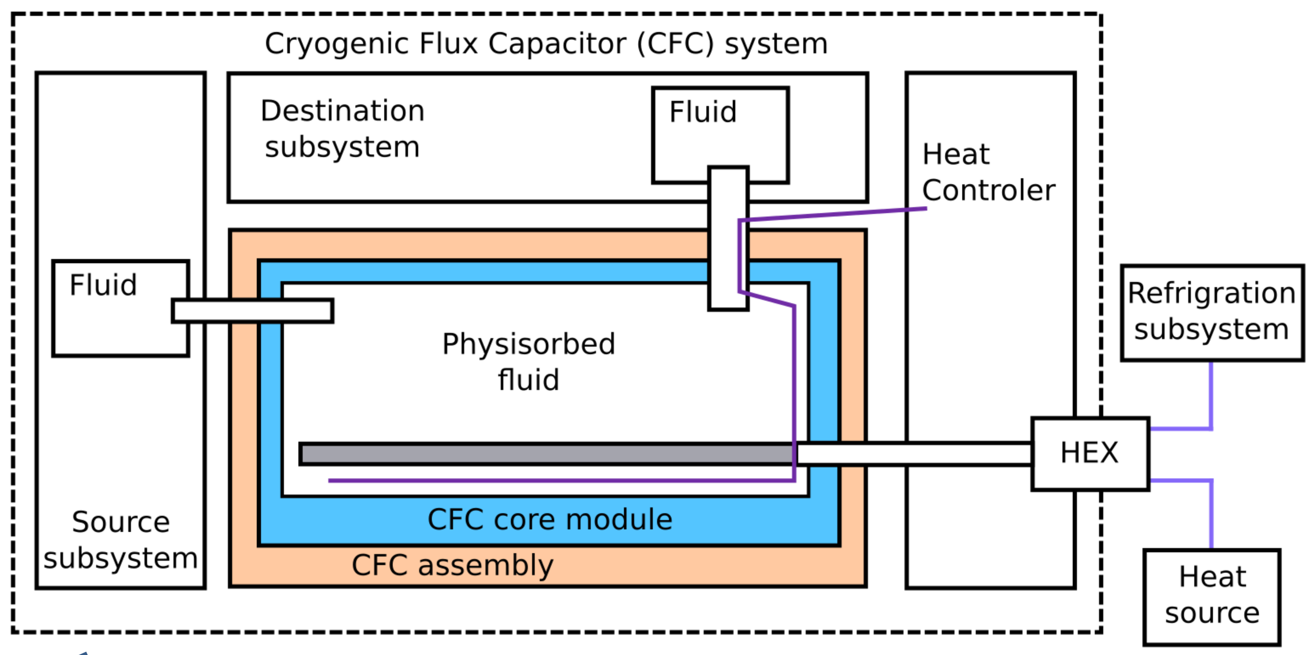
The decarbonization of the energy industry is a key topic of our time. Deep decarbonization can be achieved via several different ways, e.g., carbon capture, waste heat utilization, or new generation and hybrid power systems. However, with the growing population, the demand for energy will also rise which comes with associated pollution and $CO_2$ emission. Hence, "zero emission" power systems will be necessary to achieve the overarching goal. The next generation of power systems may still produce cheap energy or heat for commercial, residential, or industrial sectors, with minimal effect on the operation cost. One of the promising power-conversion cycles is the supercritical carbon dioxide ($sCO_2$) power cycle. The $sCO_2$ power cycles have high efficiency for a higher turbine inlet temperature, and have compact size compared to steam or helium power cycles and can be design as indirect or direct fired system. Further, it has the capability to be used with different fuels such as Hydrogen [1]. Hydrogen is another technology that has the capability to enable to production of "zero emission" power [2, 3]. The combination of the $sCO_2$ power system and the hydrogen technologies will create a very efficient system which has the advantages of no emission of NOx and $H_2S$ and can be operated with very higher turbine inlet temperature. However, the main disadvantage of hydrogen fueled systems is water which is not readily available across the globe [3]. This work is focused on the design and optimization of a novel direct fired $sCO_2$ power cycle with integration of $H_2$ combustor and demonstrate feasibility of the proposed hybrid power systems from first and second laws of thermodynamics point of view. The system combines advantages of both systems, very higher cycle efficiency, compactness, low capital cost, high $H_2$ separation and storage efficiency, and combustion without any emission.

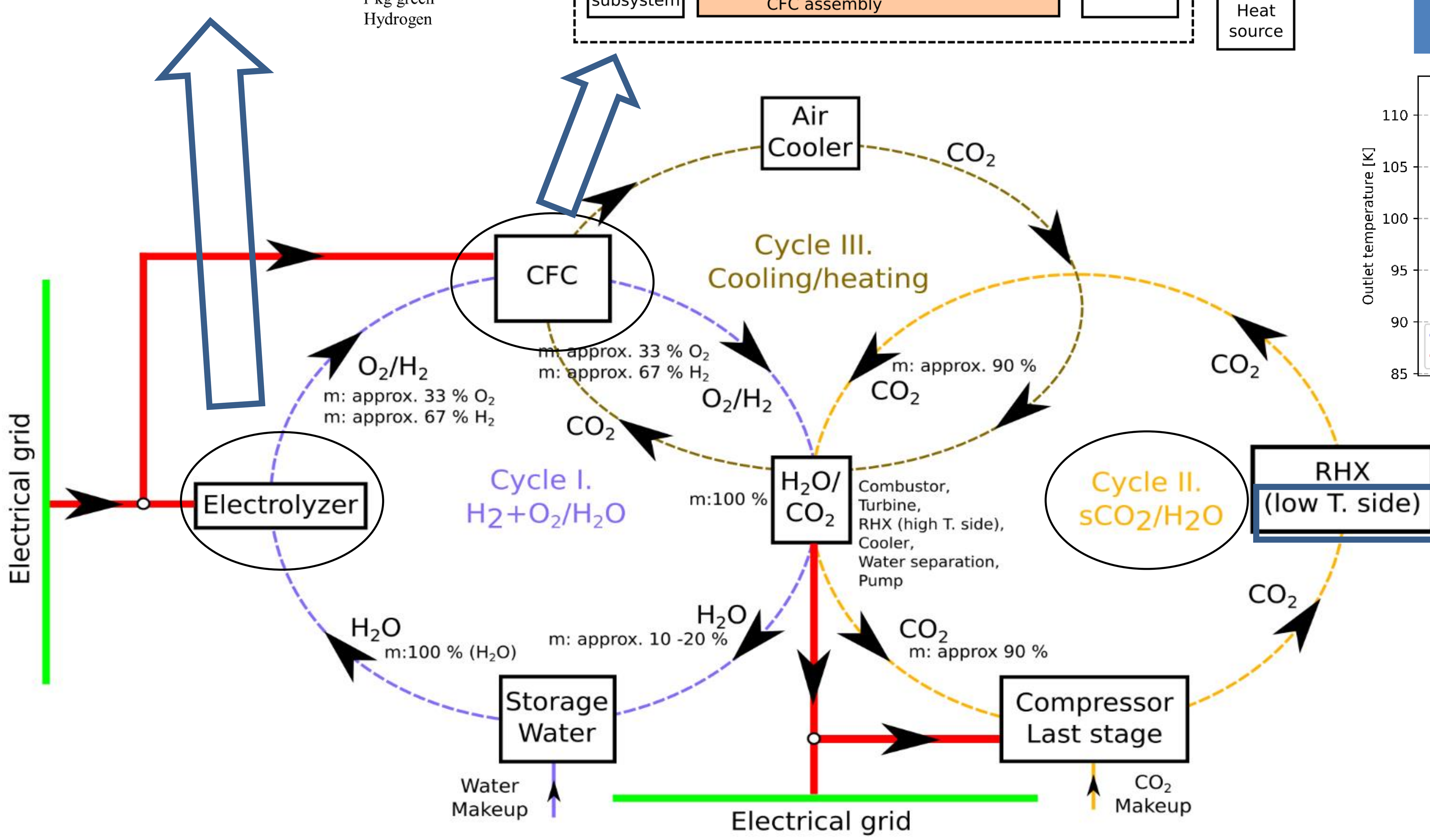


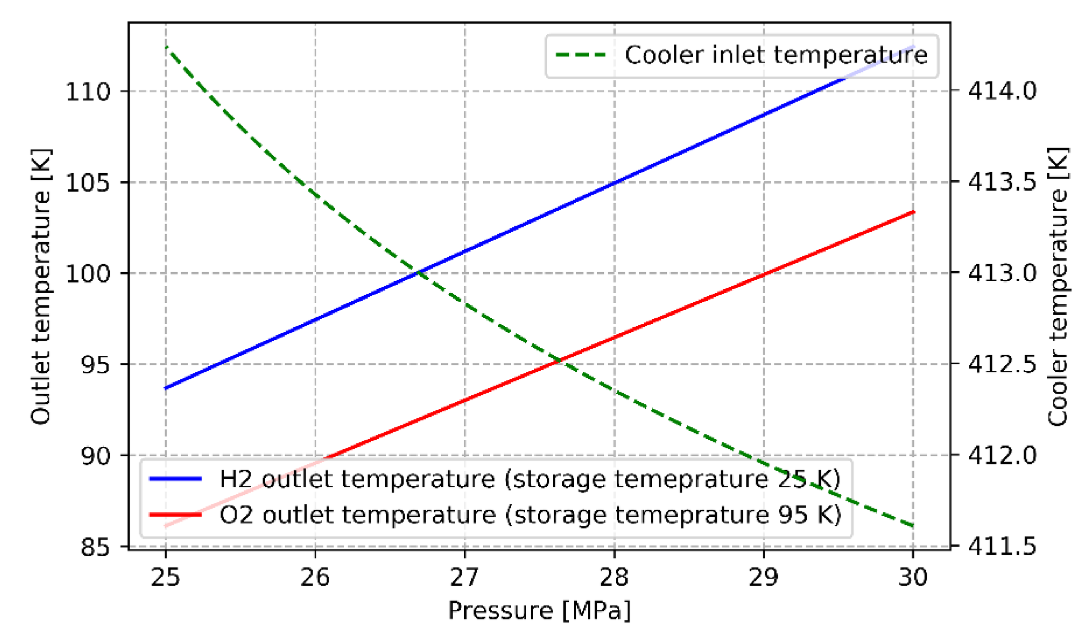



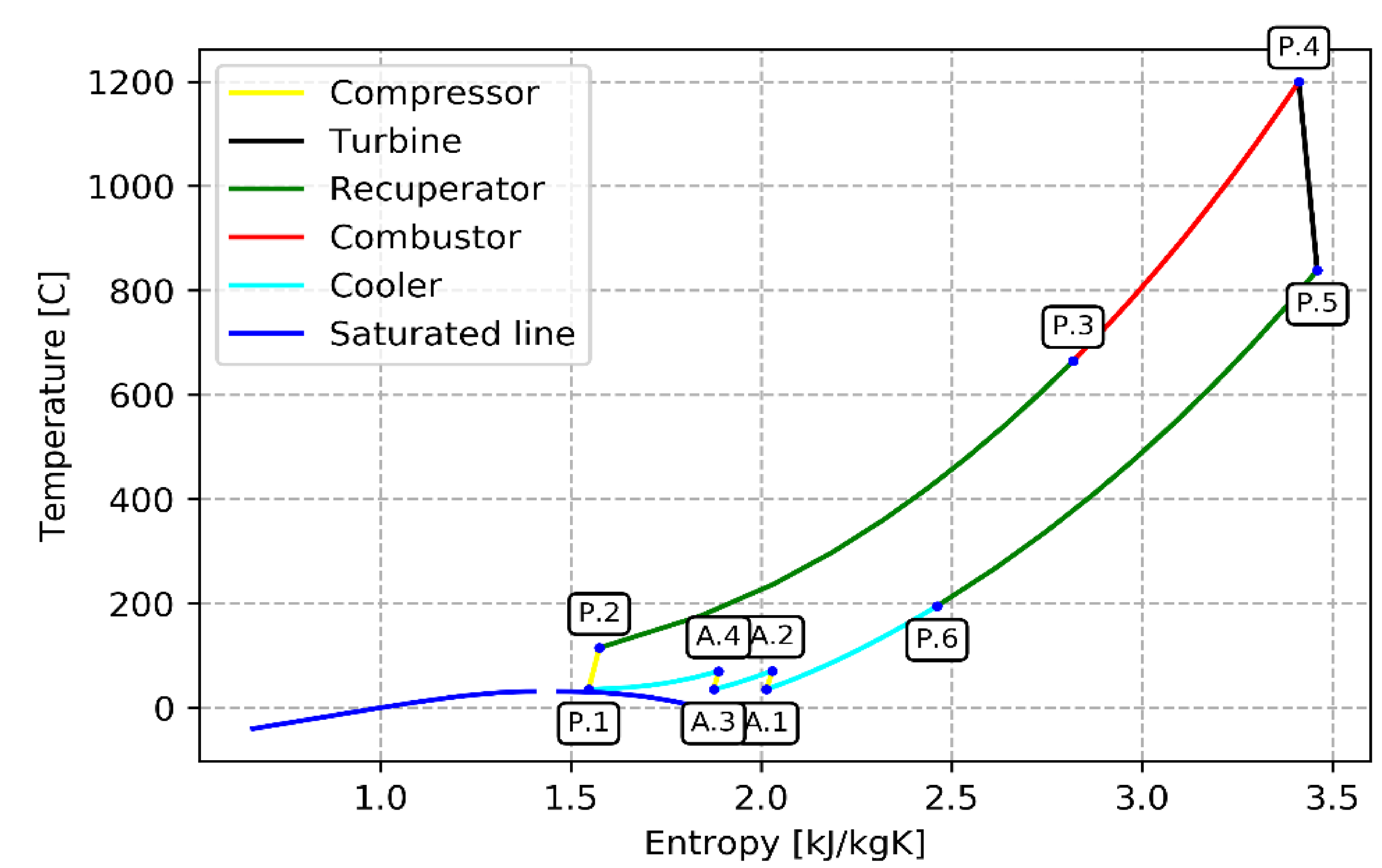

| System | Advantages | Disadvantages |
|---|---|---|
| Gas turbine | Cost, efficiency | $H_2S$, $H_2O$, NOx, |
| Oxy-combustion Direct-fired $sCO_2$* | Higher TIT | $H_2S$, $H_2O$, NOx, $H_2O$ separation unit ASU unit |
| Indirect $sCO_2$ | No impurities, closed system | Lower TIT based on heat source (PHX limitation) |
| $H_2/sCO_2$ direct-fired | <u>No NOx, $H_2S$,</u> <u>Very Higher TIT</u> <u>Can be integrated with electrolyzer closed water cycle and CFC** storage system</u> | <u>$H_2O$,</u> <u>$H_2O$ separation unit</u> |

*Fuel is Natural gas – CH4

**CFC is Cryogenic flux capacitor [4]




- The system is a closed system with $H_2$, $O_2$, $sCO_2$, and $H_2O$ subsystems
- No emission of the NOx and $H_2S$
- Very higher maximum operation temperature (TIT) – $sCO_2$ power cycle
- The power cycle can be integrated with electrolyzer closed water cycle and CFC storage system
- Integrated load shifting capabilities without excessive water demands through recycling


[1] Vesely L, Otto M, Kapat J. " $H_2/O_2$ direct fired $sCO_2$ Power System coupled with Electrolysis and Storage". 2022. Energy Conversion and Management – under review

[2] Otto M, Sargunaraj MP, Riahi A, Kapat J. "A Novel Long-Duration Hydrogen Storage Concept Without Liquefaction and High Pressure Suitable for Onsite Blending." 2021. Proceedings of the ASME Turbo Expo 2021: Turbomachinery Technical Conference and Exposition. ASME.

[3] Otto M, Chagoya K, Blair R, Hick S, Kapat J. "Optimal Hydrogen Carrier: Holistic Evaluation of Hydrogen Storage and Transportation Concepts for Power Generation, Aviation, and Transportation". 2022. Journal of Energy Storage.

[4] Ahmad K. Sleiti, Wahib A. Al-Ammari, Ladislav Vesely, Jayanta S. Kapat, Thermoeconomic and optimization analyses of direct oxy-combustion supercritical carbon dioxide power cycles with dry and wet cooling, Energy Conversion and Management, Volume 245, 2021, 114607, ISSN 0196-8904, https://doi.org/10.1016/j.enconman.2021.114607.

[5] Swanger AM, Fesmire JE. "Cryogenic Flux Capacitor for Advanced Molecular and Energy Storage Applications". In IOP Conference Series: Materials Science and Engineering 2020 Mar 1 (Vol. 755, No. 1, p. 012051). IOP Publishing.