Nowadays more and more plants walk away from building various process systems on-site and rely on suppliers for ready to connect modules. Suppliers who are usually the manufacturers (or a proxy between a manufacturer and a contractor) deliver these process systems that are built under off-site conditions. As a result of that, modular constructions have been adopted for ease of handling in commercial use. Such a mobile construction of a process system is called “skid” in English or “anlage” in German. Skids are usually built within a frame. Depending on the dimension of a skid and logistical planning, it can fit, for example, on the back of a truck or in the shipping container [1,2].

Most factories emit a certain volume of carbon dioxide (CO\textsubscript{2}). For example power plants, oil rigs, refineries, waste incinerators, sewage treatment plants, etc. Recent climate restrictions imposed a reduction of CO\textsubscript{2} emissions to the environment. As result, a feasible way to capture the CO\textsubscript{2} was searched. Depending on the costs and size of a plant, some have decided to build CO\textsubscript{2} capture systems onsite, while others (usually smaller) have made decision to pay emission fees. CO\textsubscript{2} capture systems built onsite are usually large and may cause additional operational problems. Currently, another rare possibility is to add a compact CO\textsubscript{2} capture skid, that solution can benefit both medium and smaller factories. Demand for building reliable systems in the market caused skid manufacturers to build dedicated CO\textsubscript{2} recovery systems. Before delivery to a plant, a commercial CO\textsubscript{2} skid should be factory acceptance tested (FAT) and certified for its operational use on a manufacturer site, which is an advantage in comparison to these built on plant site without a guarantee [2].

An example of a compact module including CO\textsubscript{2} capture process is presented in articles [1,3,4]. The proposed power plant module is composed of a gas-steam cycle (with CO\textsubscript{2} separation) coupled to a CO\textsubscript{2} capture system as shown in Figure 1. The compactness of the proposed gas-steam power plant skid is achieved due to a novel small size designs of the wet combustion chamber and the spray-ejector condenser.
The working fluid exiting the WCC, which consists of 10-20% CO$_2$ vapor and 80-90% steam is directed to expand in the vapor turbine GT and the vacuum vapor turbine GT$^{vap}$. In the literature there is also the name of the gas-steam turbine in relation to the vapor turbine (GT + GT$^{vap}$) [1,3,4]. Both turbines are connected to the main shaft with the generator G, the oxygen compressor $C_{O2}$ and the expander GT$_{N2}$. The exhaust vapor leaving the GT$^{vap}$ is directed to the SEC after cooling in the regenerative heat exchanger HE. The vacuum in the SEC is generated in the result of properly sprayed nano-droplets of water through the nozzle longitudinally to the main jet, while the working fluid is sucked perpendicularly to the main jet and then immediately mixed in the path of sprayed water. In the main jet, the steam fraction is partially condensed and CO$_2$ compressed simultaneously. The mixture of water steam, liquid water, and compressed CO$_2$ leaves the SEC and raises its pressure to 1 bar entering the condensate-cooler exchanger with the separator CHE+S. In the CHE+S liquid water is cooled, while the remaining mixture of steam water and CO$_2$ is separated in the result of the main jet action in the SEC. Some of cooled water exiting CHE+S is pumped back to the SEC spraying nozzle. The rest of water is pumped back to the WCC after being preheated in the HE, while an excess of water is being removed (which is produced during combustion) [1,3,4].

![Diagram](https://via.placeholder.com/150)

**Figure 1:** The compact cycle with oxy-combustion and CO$_2$ capture, where WCC - wet combustion chamber, GT+GT$^{vap}$ - vapor turbine divided into two parts, SEC - spray ejector condenser, ASU - air separation unit, $C_{O2}$ - compressor, HE - regenerative heat exchanger, CHE+S - condensate-cooler heat exchanger and separator, CHE - cooling heat exchanger, M - motor, G - generator, $P_1$ - supply water pump, $P_2$ - water pump for cooling combustion chamber, GT$_{N2}$ - expander $N_2$, $C_{CO2}$ - CO$_2$ compressor.

In the CO$_2$ recovery part, the mixture of compressed CO$_2$ and steam from the CHE+S separator from the gas-steam cycle skid is directed to series of CO$_2$ compressors $C_{CO2}$ powered by a motor; between compressors water is condensed from the steam in the cooling heat exchangers CHE. As the result, clean compressed CO$_2$ is produced from the outlet of the CO$_2$ recovery skid.

In conclusion, the feasible way to capture CO$_2$ was presented within the compact build of power plant skid. Wide commercial application of such skids including CO$_2$ capture is the matter of certain factors, like the cost of a CO$_2$ capture skid unit, the climate regulations, the CO$_2$ emission fees, and the size of a plant. While the cost of manufacturing of a compact CO$_2$ uptake skid will possibly reduce, both the CO$_2$ fees are likely to be increased and the climate regulations be tightened with time. It can be assumed that the balance of these factors will shift toward the cost-effective application of CO$_2$ reuptake skid units. Especially smaller factories would benefit from this. From the technical view, the development progress of viable CO$_2$ capture skids is demanded to be done to maintain this trend.
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References

1. Ziółkowski P (2018) A thermodynamic analysis of a gas-steam turbine incorporating a full model of a spray-ejector condenser. Trans IFFM 139: 63-96.

2. Pentair PLC (2016) A compact enclosed skid CO\textsubscript{2} recovery system for biogas upgraders, Italy.

3. Ziółkowski P, Badur J, Kruczek HP, Nedźwiecki Ł, Kowal M, et al. (2019) A novel concept of negative CO\textsubscript{2} emission power plant, based on combustion the gas from sewage sludge gasification in a gas turbine with spray-ejector condenser. XXIV International Symposium on Combustion Processes, Australia, pp. 144-145.

4. Ziółkowski P, Badur J (2019) A study of a compact high-efficiency zero-emission power plant with oxy-fuel combustion. In: Stanek W, Gladysz P, Werle S, Adamczyk W (Eds.), ECOS, Proceedings of the 32\textsuperscript{nd} International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems, Wroclaw, Poland, pp. 1557-1568.