

**Benefits of Supercritical Fluid Technology**  
**in the context of Industrial Ecology and Industry 4.0:**  
**Some challenging new pharmaceutical and biomedical applications**

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In order to respond to the current environmental and societal challenges, industry is undergoing a transformation. The concept of Industry 4.0 or industry of the future illustrates this new industrial revolution initiated over the last decade. Today, the fourth industrial revolution is associated with an end-to-end digital integration within a Smart Factory. The key technologies of Industry 4.0 are Cyber-Physical-Systems and the Internet of Things and Services.

It is interesting to come back to the driver of the fourth industrial revolution, which is the tendency for the **production of customized products** using more **flexible and adaptable structures**, while improving **energy and resource efficiency**. The major goal is to implement innovative clean production methods that save materials and energy, thus allowing better management of resources, reduction of effluents and development of new products. In order to overcome the variability of raw materials as well as the fluctuation of markets for final products, and to move towards product customization, Industry 4.0 production tools are characterized by versatility and modularity. Indeed, to ensure production flexibility, the trend is to favor modular units and to reduce the size of reactors and facilities in order to move towards more compact units. Large centralized production sites are being replaced by smaller sites, delocalized and closer to markets. This allows a real individualization of the products, as well as the possibility to develop “local” products. Furthermore, modular units allow for evolutionary capacity production. The production of a new product can be launched in small quantities and the number of modules can be multiplied to increase production over time. This reduces the financial risk since the investment is spread over time. It is an interesting solution for less industrialized areas, in both emerging and developed countries. Another benefit of this modularity is linked to the operational safety of the production sites. By reducing the size of the installations, the risk of accidents is limited and in the event of an accident, the impact is also reduced. The resilience of the facilities is improved since the chances of returning to normal operation are greater in a relatively

shorter period of time. Finally, a certain versatility of these modular units is sought in order to reuse all or part of the unit for other uses/applications.

Industrial units and processes using supercritical fluids can meet the above-mentioned requirements and criteria of Industry 4.0, generating renewed interest in supercritical fluid technology.

Some examples of the use of supercritical fluids in the pharmaceutical and biomedical sectors will illustrate these points. Applications of different Technology Readiness Levels (TRL) will also be presented.