PROGRAM facts

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Vision 21

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Applying Industrial Ecology Principles Brings Revolutionary Improvements to the Energy Plant of the Future

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Synopsis:

Industrial ecology, as applied to Vision 21 energy plants, aims to economically meet or exceed environmental goals while systematically examining materials and energy use, focusing on industry's role in reducing environmental burdens. By promoting an environmentally acceptable life cycle, through feedstock flexibility, product flexibility, and synergistic linkages, an industrial ecology approach moves beyond being just another academic exercise—instead becoming a smarter way to achieve environmental, economic, and social objectives at minimum cost.

What is Industrial Ecology?

Industrial ecology (IE) is a growing field that systematically examines all levels of materials, energy uses, and flows in products, processes, industrial sectors, and economies. This requires considering energy plants as a whole, inclusive of the environment and the communities in which they are located. An industrial plant designed with IE principles might contain many feedback loops to reduce material emissions, improve efficiency, and reduce energy leakage.

IE practices share some important general characteristics. IE is *proactive*, initiated and promoted not because of pressure by external factors, but rather because it is in industry's own interest and in the interest of the surrounding systems. It is *designed*; much of the materials and energy flows are defined by decisions made early in the design process. Despite this, IE practices are *flexible*, and may change as manufacturing processes and opportunities evolve, and as new limitations arise from scientific and ecological studies. IE is also *encompassing*—demanding approaches that cross industrial, national, and cultural barriers.

Tools for IE practices are still being developed, although many of the current tools have been borrowed from traditional practices. These include life-cycle analyses, environmental impact assessments, and clean production practices. Modeling and simulation tools that will reduce the costs and technical risks of complex projects are being developed. These tools will provide an opportunity to move from *learning by doing* to *learning before doing*.

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What is Vision 21? What is Industrial Ecology in the Vision 21 Context?

Vision 21 is a long-range, industry-driven research and development initiative to develop fossil-fuel-based energy plants—plants so clean that they will produce near-zero emissions. Vision 21 energy plants may use fossil fuels in combination with other domestic resources—producing transportation fuels, synthesis gas, hydrogen, and high-value chemicals in addition to electricity.

The focus is on the underlying technologies necessary to design these ultra-clean energy plants. These technologies will address some of the current market drivers, which include:

- a recognition that fossil energy needs to be part of the future energy mix,
- the need to solve environmental concerns associated with fossil fuel use,
- restructuring the energy industry with previously under-invested R&D development and new market players,
- a recognition that future options have value (e.g., the hydrogen economy).

Artist's Rendition of a Vision 21 Energy Plant

Vision 21 plants feature flexible modular designs and incorporate a market-driven product slate. In a typical Vision 21 plant, the feedstock is gasified using oxygen produced with low-cost air separation membranes, the resultant fuel gas is cleaned, and power is produced with gas and steam turbines and fuel cells. The design is so efficient that even the heat remaining in steam turbine exhaust may be used to generate steam for process heating. A Vision 21 plant might also be based on combustion, especially combustion with oxygen rather than air.

Gasification-based Vision 21 plants will provide the *option* of coproduction; however, this option would only be chosen when it makes economic sense and lowers the cost of producing electricity. Multiple plant designs will be evaluated by virtual simulation, but DOE believes the choices concerning products and feedstocks should be based on market and economic forces rather than the imposition of preselected technologies.

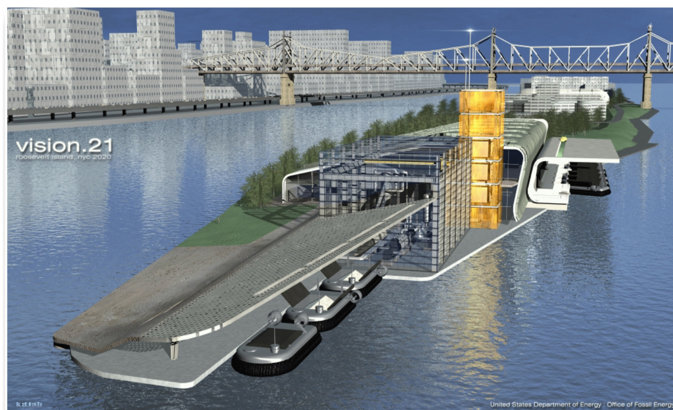
Because technology changes rapidly, specific types of plants or plant configurations are not being emphasized. What the market favors in 15-20 years may be much different from what the market favors now. Industry involvement, beginning at the planning stages, is necessary to ensure that new technologies will be relevant to the market. Industry answered the call—meeting with Government representatives at the first Vision 21 industry workshop, they identified technologies that will most likely be needed in future Vision 21 plants, regardless of future plant configurations. At a second workshop, a 15-year technology roadmap was developed to provide a plan for achieving Vision 21 objectives. A sampling of the technologies they identified, as well as the IE characteristics, are shown below.

IE is *proactive* not *reactive*.

- Advanced sensors and controls for highly integrated Vision 21 plants; new algorithms that use state-of-the-art hardware to assure reliable performance, optimum efficiency, and low emissions.
- Computational modeling and virtual simulation.

IE is *designed in* not *added on*.

- Gas separation technologies, for example, membranes that can be used to separate oxygen from air, hydrogen from syngas, and CO_2 from combustion products.
- High-temperature heat exchangers, such as alloy-tube exchangers capable of heating steam or air.
- Gas stream purification systems, capable of operating at high temperatures for removing constituents that may corrode or erode downstream components.
- High-performance combustion systems, both suspension-fired and fluidized bed.
- Fuel cells and fuel cell/turbine hybrids.
- Advanced materials for high-temperature applications in aggressive environments. Functional materials needed for gas cleanup or separation.
- Environmental control technology for low-NO_X emissions, control of fine particulate matter, and management of by-products from Vision 21 plants; improved concepts for CO_2 capture and separation.



Artist's conception of a Vision 21 plant set on island in harbor, rendition by k+d. lab, inc.

IE is *flexible* not *rigid*.

- Fuel-flexible, thermally efficient gasification—to allow the use of low-cost feedstocks.
- Fuel-flexible combustion turbines and engine systems, especially turbines and engines capable of operating on coal-derived gases or hydrogen, and advanced combustion turbines.
- Product-flexible coproduction of chemicals, fuels, or heat.

IE is *encompassing* not *insular.*

- Advanced fuels and chemicals development; systems and catalysts for fuels and chemicals production; hydrogen production and storage.
- Combination of power production and chemical/fuel production, which takes advantage of synergies.

Vision 21 has unique systems integration issues. Systems engineering addresses issues concerning the configuration of Vision 21 plants, the design of components, subsystems, and subsystem interconnections. Good systems engineering ensures that components and subsystems are compatible, that the design of the plant is as simple as practicable, and that plant capital and operating costs are as low as possible. Improved computer control strategies will help ensure good startup performance, operability, and reliability. Additionally, computer design and simulation tools will aid in designing individual components and subsystems, and in evaluating the performance of integrated Vision 21 systems.

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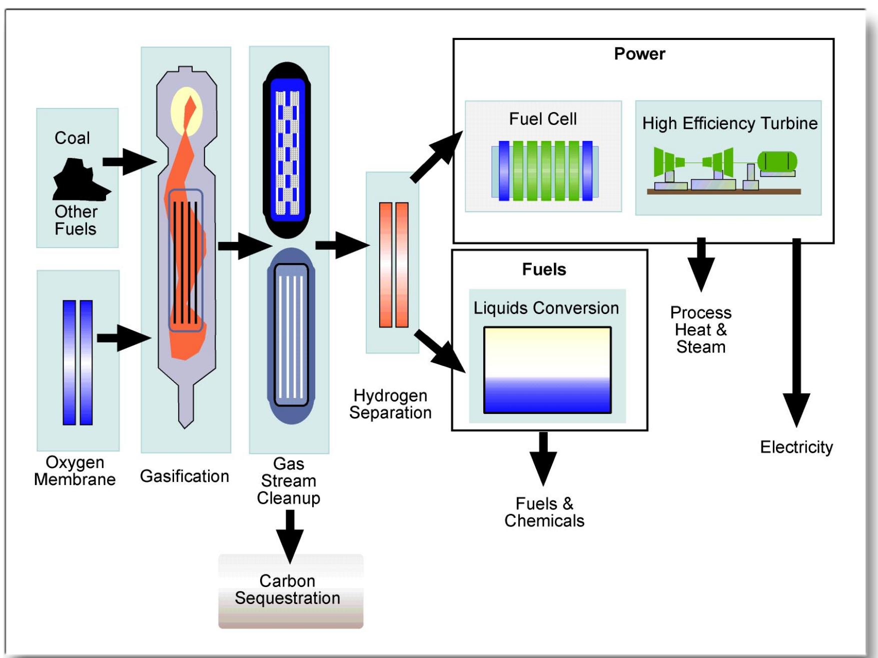
What's Next?

NETL will conduct a continuing series of focused workshops for separate technology areas—sharing R&D results, updating and refining R&D needs, and encouraging industry's interest and involvement.

Conclusions

Industrial Ecology principles are changing the approach to designing Vision 21 energy plants, and will spur innovative and revolutionary changes for efficiency, environmental performance, and cost competitiveness. The new and spin-off technologies that spring from this program will provide the public, industry, and commercial enterprises with unforeseen benefits. Because it crosscuts and integrates across all U.S. DOE Fossil Energy Product Lines, the Vision 21 program presents the best opportunity for the application of industrial ecology.



Block Diagram of Vision 21 Plant

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