CLEAN
MANUFACTURING

FR002

# FOCUS

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| Maintenance and Support | FR005 |

# *Roadmap*

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# STATE OF THE ART

## 01 Closed Loop Systems

- Some effort has been made to reduce consumables and recycle products at the end of life. However, there are currently few systems for re-manufacturing worn components and modules, and few systems for high-quality material recycling or uses for such material.

## 02 Total Lifecycle Approach

- Current lifecycle approaches focus on cradle-to-grave methodologies with fairly simple boundaries and do not generally include terms relating to a circular economy.

## 03 Process Planning to Optimize Green Energy Use

- Currently, process planning focuses on cost and quality, with energy use as an afterthought. Processes are not scheduled to take advantage of peak production times of green energy, meaning this energy often goes unused.

## 04 Networked Systems, Big Data and the Internet of Things

- Factory machines and systems are not completely networked, and there are many different and unlinked databases.

## 05 Green Processes and Machines

- Machine design is currently focused on low cost or high quality.

# GAP

## Closed Loop Systems

- Companies need to find a way to turn current waste streams into products and reduce reliance on raw materials. Waste needs to be reused, products should be made from recycled materials, and parts should be designed to last longer. Dismantling strategies need to be found for parts at the end of their life, and reuse/recycle strategies should be found for dismantled materials.

## Total Lifecycle Approach

- There is a need for methods that include complicated material lifecycles where material is recycled and reused multiple times. Social and economic factors could also be included.

## Process Planning to Optimize Green Energy Use

- There is a need to show that green production is at least as competitive as traditional methods. There is a lack of information on how to choose greener machines and processes, and how to optimize them for clean production. Decision support systems should include information from the total lifecycle approach to support this.

## Networked Systems, Big Data and the Internet of Things

- There is a gap in methods for linking the different systems and databases. Data security and privacy issues need to be addressed. There is also no standard set of data to gather from processes, or method for using such data to automatically optimize downstream operations in real time.

## Green Processes and Machines

- Machines which are designed to minimize energy use and raw materials are either not common or are high-cost. This can reduce take-up.

# CHALLENGE TO FILL THE GAP

## Closed Loop Systems

- Challenges include: developing methods of harvesting waste streams, such turning waste into high-value products; and developing effective technologies for recycling and upcycling components and materials at the end of their life.
- Design for sustainability should be considered to make full use of the closed loop systems. Modular products and component repair should be considered at the design stage, and systems should be designed so that upgrades and new modules can be plugged in. Products should also be designed to make use of recycled materials and upcycled components.
- A business challenge is to develop new methods of doing business that do not rely on constant product sales and consumption of raw materials.

## Total Lifecycle Approach

- The challenge is to develop methods to fairly assign the ecological costs and benefits of using recycled material and harvesting waste streams. Such methods should also include social costs as these will have an economic impact elsewhere.
- A further challenge is to develop methods of labeling products, processes and factories. Guidelines on best practice are also required to ensure that the latest technologies are used. Companies in the supply chain should be included in such labeling.
- Companies need improved decision support tools to help justify investment in greener technologies, and to allow them to minimize their ecological impact while remaining competitive.

## Process Planning to Optimize Green Energy Use

- There are technological challenges to optimizing machinery to reduce energy and consumable use while maintaining cost and quality.
- New green manufacturing processes can be developed. These can be used in place of traditional methods, or combined with them for a hybrid approach.
- There is a challenge to develop factory design methods which consider local resources (including other industries, waste streams and local energy generation methods), and which treat the factory holistically, considering all inputs and outputs, not just those from the machine tools.
- Reliable and affordable renewable energy systems need to be developed and made attractive to manufacturers looking to reduce their energy bills and ecological footprint.
- Another challenge is to develop green energy ratings for machine tools, taking into account their manufacture as well as their energy and resource consumption.
- A social challenge is to increase awareness of the cost of climate change and resource consumption and to show how businesses can contribute while remaining competitive. To raise awareness, improved education, and training packages should be developed.

## Networked Systems, Big Data and the Internet of Things

- The challenge is to develop reliable systems and databases which will seamlessly connect machines and parts. Software to mine the data gathered and to control processes based on part and machine data should also be developed.
- Another challenge is to develop robust sensors so that machines and processes become energy-aware. These sensors should link to the factory-wide network.
- There is a challenge to develop robust and reliable systems to hold manufacturing and operating history on parts which function in extreme environments. Such history can be automatically read and acted on during maintenance and repair operations.
- Decision support tools will be required to make use of the large amount of data. These will need to optimize maintenance and the scheduling of machines based on energy-use data, as well as optimizing part production based on previous part history and current machine condition.

## Green Processes and Machines

- Integrate harvesting and recycling systems in machine tools. It should also be possible to retrofit such systems to older machines.
- Manufacture machine tools using green materials, including recycled materials.
- Optimize processes to reduce energy and consumable use while maintaining cost and quality and make machines more robust and reliable to reduce scrap, through adaptive monitoring and control.
- Optimize maintenance activities to allow machines to run at maximum efficiency and to reduce scrap. Development of decision support tools for scheduling maintenance are required to reduce downtime while maintaining efficient operation.
- Machining processes should be optimized to reduce energy and consumable use while maintaining cost and quality.

# RESEARCH PRIORITIES

## Closed Loop Systems

- Develop methods of harvesting a range of waste streams, and of turning waste into high-value products. These will include effective technologies for recycling and upcycling components and materials at the end of their life.
- Design components which make use of recycled material and are easy to repair and recycle.

## Total Lifecycle Approach

- Develop methods to fairly assign the ecological costs and benefits of using recycled material and harvesting waste streams. Such methods should also include social costs as these will have an economic impact elsewhere.

## Process Planning to Optimize Green Energy Use

- Develop methods to reduce material use for specific parts during manufacture. This can be achieved either through part redesign or by the use of novel green manufacturing processes. Cost and quality of manufacture should be maintained.
- Develop methods of designing factories which can benefit from local conditions (using local waste streams as input, or to reuse their outputs). The factories should be considered holistically and the design methods should include services, energy harvesting and emissions abatement.
- Develop reliable and affordable renewable energy systems that could be used at factory sites.

## Networked Systems, Big Data and the Internet of Things

- Develop robust systems to link all parts of the manufacturing process, as well as intelligent systems which can mine and deploy the data collected.
- Develop robust data-gathering and storage systems for machines and parts.

## Green Processes and Machines

- Develop energy harvesting and recycling systems which can be retrofitted to machine tools.
- Improve monitoring and control of machines to feed data into decision support tools which can optimize machine operation and maintenance activities.

# FUTURE TRENDS

## Closed Loop Systems

- Closed loop systems will reduce the impact of manufacturing on the environment by reducing the amount of raw resources needed to make products. There is also an increasing amount of legislation relating to end-of-life disposal, making companies responsible for recycling their products and increasing the cost of sending items to landfill.

## Total Lifecycle Approach

- As closed loop systems become the norm, it will be important to include the impact of recycling and reuse when comparing different manufacturing approaches. Manufacturers will need to assign the energy use of recycling material, as well as the savings when compared to using raw materials. Furthermore, they will have to ensure that using recycled material does not make products less efficient.

## Process Planning to Optimize Green Energy Use

- Increased legislation and energy costs will drive manufacturers to reduce energy consumption and to take advantage of green energy (particularly intermittent sources such as wind and solar) by scheduling processes to run at times of peak energy production.

## Networked Systems, Big Data and the Internet of Things

- Networked systems are being more widely adopted as they allow companies to monitor every part of the factory, including products and processes, in real time. Parts can be tracked and their previous manufacturing histories used to optimize downstream manufacturing processes. Data can be mined and used to optimize production, maintenance and scheduling.

## Green Processes and Machines

- The trend is to reduce the footprint of processes and machines to save costs and reduce their environmental footprint.

# Project Partners

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