Module III

SUSTAINABLE ENGINEERING

Topics Discussed

- Environmental management standards:
- ISO 14001:2015 frame work and benefits
- Scope and goal of Life Cycle Analysis(LCA)
- Circular economy, Bio-mimicking
- Environment Impact Assessment (EIA)
- Industrial ecology and industrial symbiosis.

Environmental Management Standards (EMS)

Environmental management system (EMS) refers to the management of an organization's environmental programs in a comprehensive, systematic, planned and documented manner

It enables an organization to control impact of its activities, product or services on natural environment

Environmental management is not the conservation of the environment solely for the environment’s sake, but rather the conservation of the environment for humankind’s sake

Implementation of an EMS is a voluntary approach for improving environmental performance

Purpose of an EMS

An EMS brings together the people, policies, plans, review mechanisms, and procedures used to manage environmental issues at a facility or in an organization.

EMS

EMS mainly serves the following functions:

1. Serves as a tool to provide a systematic way of managing an organization's environmental affairs
2. Gives order & consistency for organizations to address environmental concerns
3. Focuses on continual improvement of the system

EMS framework

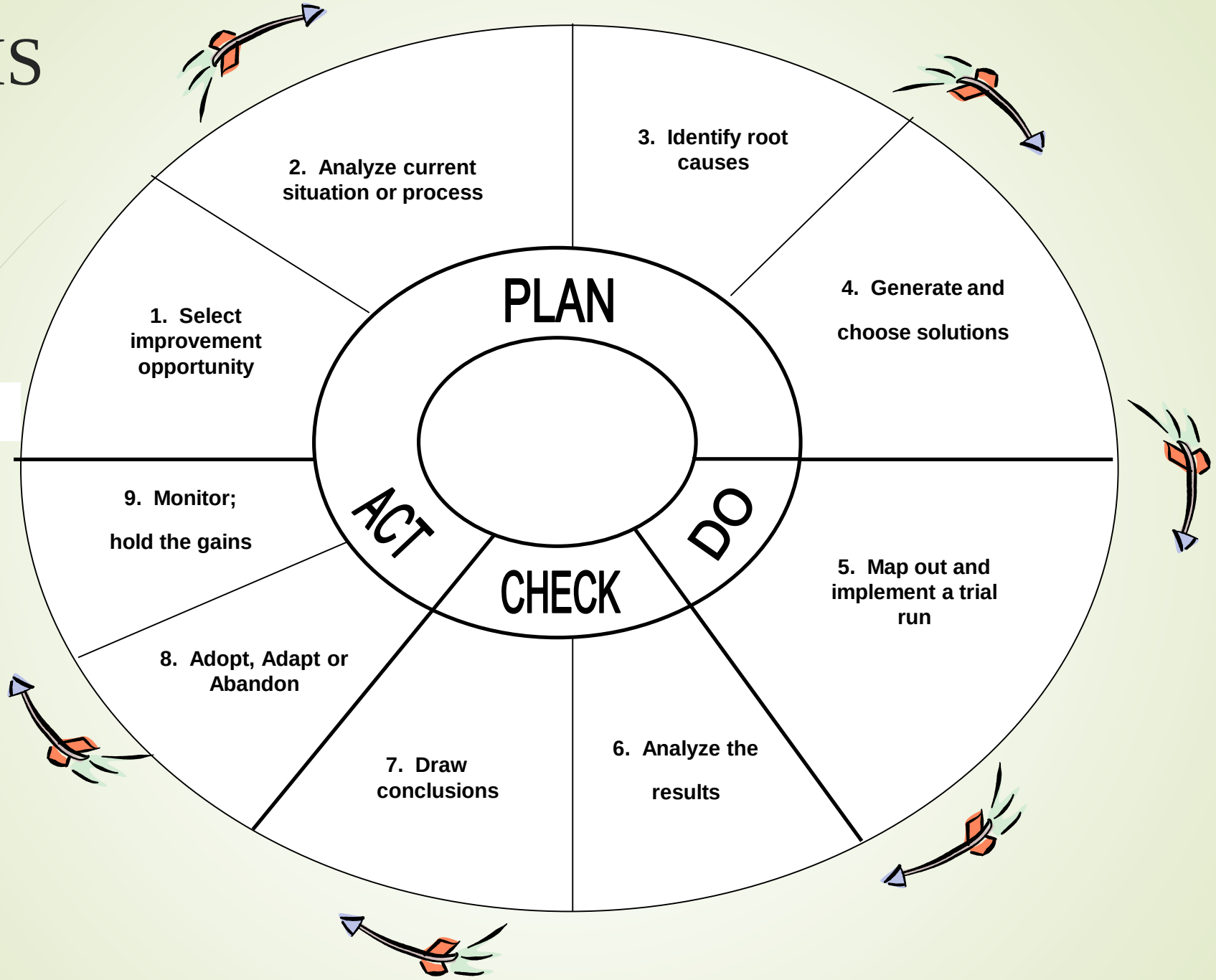
- The EMS framework follows a PLAN-DO-CHECK-ACT (PDCA) cycle

- If this cycle is adhered to constantly, it leads to continuous improvement of the system
- An EMS can also help address non-regulated issues, such as energy conservation, and can promote stronger operational control and employee stewardship

EMS

Plan	**Planning, identifying environmental aspects and establishing goals in accordance with the organisations environmental policy**
Do	Implement the planned processes which includes training and operational control
Check	Checking (monitoring) and corrective actions
Act	Reviewing, includes progress review and actions to make changes which continually improve performance of environmental management system

EMS


Start
1. Select improvement opportunity
2. Analyze current situation or process
3. Identify root causes
4. Generate and choose solutions
5. Map out and implement a trial run
6. Analyze the results
7. Draw conclusions
8. Adopt, Adapt or Abandon
9. Monitor; hold the gains
PLAN
DO
CHECK
ACT

EMS


Policy & Commitment
Planning
Implementation & Operation
Checking & Corrective Action
Management Review

EMS framework

Basic Elements of an EMS:

- Reviewing the company's environmental goals
- Analyzing its environmental impacts and legal requirements
- Setting environmental objectives and targets to reduce environmental impacts and comply with legal requirements
- Establishing programs to meet these objectives and targets
- Monitoring and measuring progress in achieving the objectives
- Ensuring employees' environmental awareness and competence
- Reviewing progress of the EMS and making improvements

Key EMS benefits

- Improved environmental performance
- Reduced liability
- Competitive advantage
- Improved compliance
- Fewer accidents
- Employee involvement
- Improved involvement
- Improved public image
- Enhanced customer trust
- Better access to capital

"We view the establishment of an EMS as a process that forces us to better organize our priorities and projects and to identify problems and exposures before they occur"

Environmental Management Standards & ISO 14000

- The ISO 14001 standard is the most important standard within the ISO 14000 series
- ISO 14001 specifies the requirements of an environmental management system (EMS) for small to large organizations
- An EMS is a systemic approach to handling environmental issues within an organization
- The ISO 14000 family of standards provides practical tools for companies and organizations of all kinds looking to manage their environmental responsibilities

Range of ISO	Subject
ISO 14000 - 14009	Environmental Management System
ISO 14010 - 14019	Environmental Auditing
ISO 14020 - 14029	Environmental Labelling
ISO 14030 - 14039	Environmental Performance Evaluation
ISO 14040 - 14049	Life cycle Assessment
ISO 14050 - 14059	Terms and Definition
ISO 14060	Environmental Aspects in Product Management

Environmental Management Standards & ISO 14000

- ISO 14001 maps out a framework that a company or organization can follow to set up an effective environmental management system
- It can be used by any organization regardless of its activity or sector
- ISO 14001, International standard for environment management system, is based upon three main principles:

1. Prevention of environmental pollution
2. Compliance with environmental regulations
3. Continuous improvement of environmental performance

Requirements of ISO 14001

- **Environmental policy** - Develop a statement of your organization's commitment to the environment. Use this policy as a framework for planning and action
- **Planning - Environmental aspects -** Identify environmental attributes of your products, activities and services. Determine those that could have significant impacts on the environment
- **Legal and other requirements** - Identify and ensure access to relevant laws and regulations (and other requirements to which your organization adheres)
- **Objectives and targets** - Establish environmental goals for your organization, in line with your policy, environmental impacts, views of interested parties and other factors

Elements of an ISO 14001 EMS

- **Environmental management program** - Plan actions to achieve objectives and targets

Implementation and Operation

- **Structure and responsibility** - Establish roles and responsibilities and provide resources
- **Training, awareness and competence** - Ensure that your employees are trained and capable of carrying out their environmental responsibilities
- **Communication** - Establish processes for internal and external communications on environmental management issues
- **EMS documentation** - Maintain information on your EMS and related documents

Elements of an ISO 14001 EMS

- **Document control** - Ensure effective management of procedures and other system documents
- **Operational control** - Identify, plan and manage your operations and activities in line with your policy, objectives and targets
- **Emergency preparedness and response** - Identify potential emergencies and develop procedures for preventing and responding to them

Elements of an ISO 14001 EMS

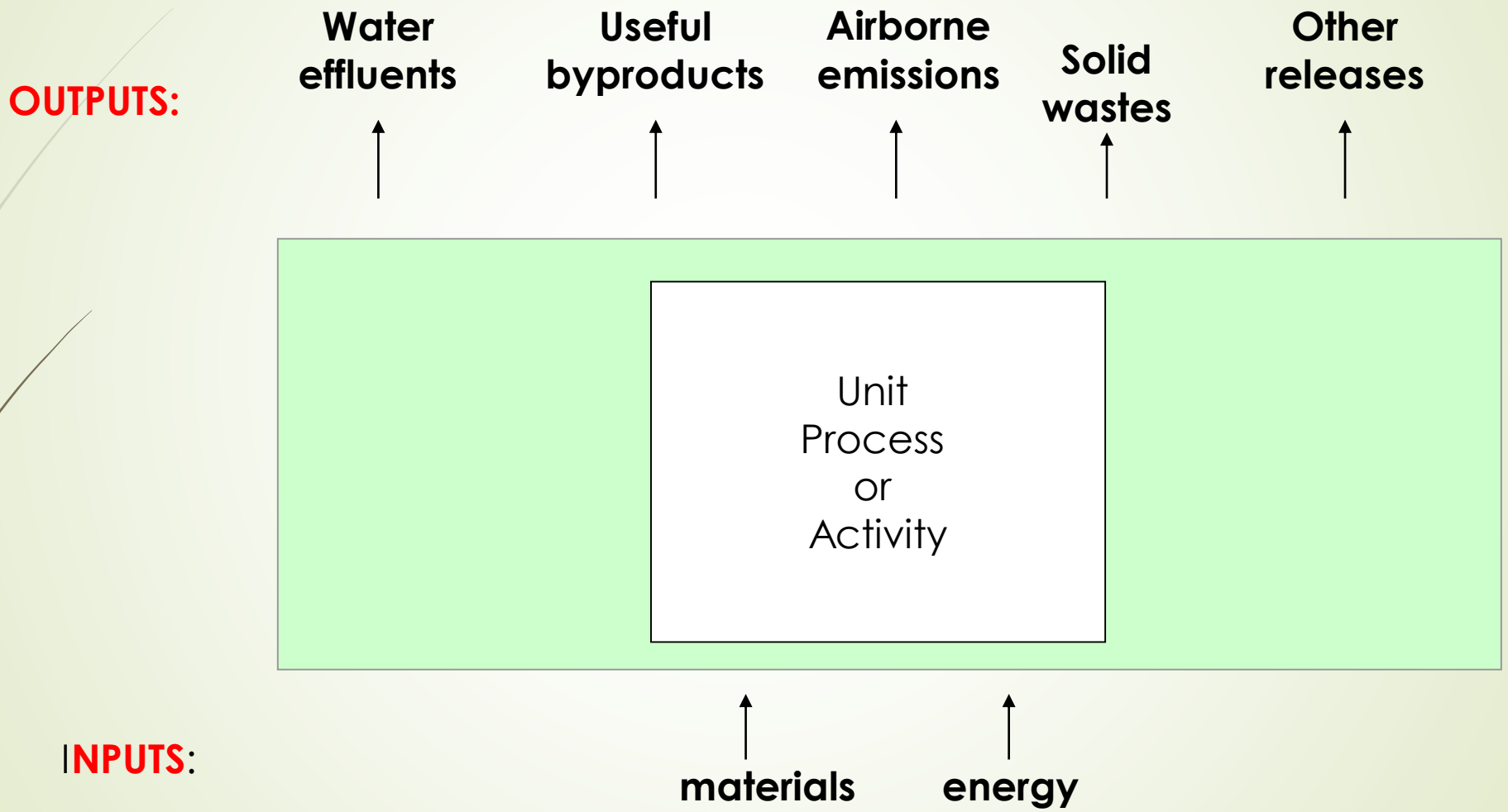
Monitoring and Measurement

- **Non- conformance and corrective and preventive action** - Identify and correct problems and prevent recurrences
- **Records** - Keep adequate records of EMS performance
- **EMS audit** - Periodically verify that your EMS is operating as intended.
- **Management review** - Periodically review your EMS with an eye to continual improvement

Life-cycle Analysis(LCA)

- LCA is an approach that covers the whole life cycle of a product or service, usually from " cradle to grave" i.e. from raw materials extraction to manufacturing, packaging, distribution, use and end of life
- Life-cycle analysis (LCA) is a method in which the energy and raw material consumption, different types of emissions and other important factors related to a specific product are being measured, analyzed and summoned over the products entire life cycle *from an environmental point of view*.
- LCAs started in the early 1970s, initially to investigate the energy requirements for different processes.
- LCAs are considered to be the most comprehensive approach to assessing environmental impact.

Process-based LCA



Lifecycle Assessment (LCA)

- ISO 14040-14043 is considered to be the LCA standard.
- ISO defines LCA as: **‘A technique for assessing the environmental aspects and potential impact associated with a product by compiling an inventory of relevant inputs and output of a product system and evaluating the potential environmental impacts associated with those inputs and outputs and interpreting the results of the inventory analysis and impact assessment phases in relation to objective of study”**

LCA Steps

Generally, a LCA consists of four main activities:

1. Goal definition (ISO 14040):
   - The basis and scope of the evaluation are defined.

2. Inventory Analysis (ISO 14041):
   - Create a process tree in which all processes from raw material extraction through waste water treatment are mapped out and connected and mass and energy balances are closed (all emissions and consumptions are accounted for).

3. Impact Assessment (ISO 14042):
   - Emissions and consumptions are translated into environmental effects.
   - The are environmental effects are grouped and weighted.

4. Improvement Assessment/Interpretation (ISO 14043):
   - Areas for improvement are identified.

Life Cycle Assessment (LCA) - Scope and Goal

Goal

- By examining a product over its life cycle, appropriate decisions can be arrived at, to avoid / reduce the environmental impact.
- Achieve efficient use of resources and energy thereby lowering overall production costs and environmental impacts

Why do life cycle assessment?

- Minimise the magnitude of pollution
- Conserve non-renewable resources
- Conserve biological systems
- Develop and utilise the cleaner technology
- Maximise and recycling the raw materials and waste
- Apply the most appropriate pollution prevention and/or abatement technologies

LCA USE

LCAs are used:

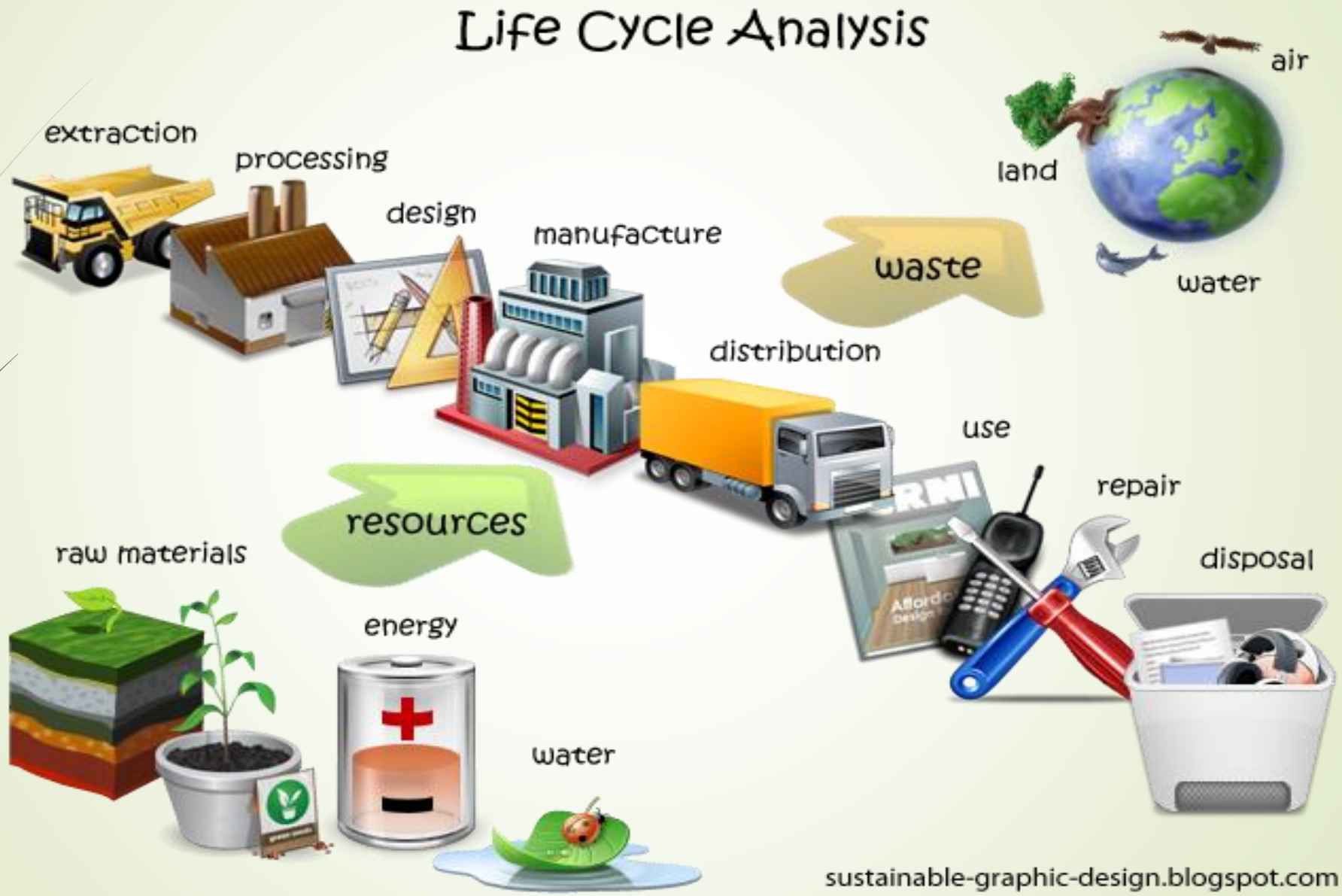
- in the design process to determine which of several designs may leave a smaller “footprint on the environment”, or
- after the fact to identify environmentally preferred products in government procurement or eco-labeling programs.

- Also, the study of reference or benchmark LCAs provides insight into the main causes of the environmental impact of a certain kind of product and design priorities and product design guidelines can be established based on the LCA data.

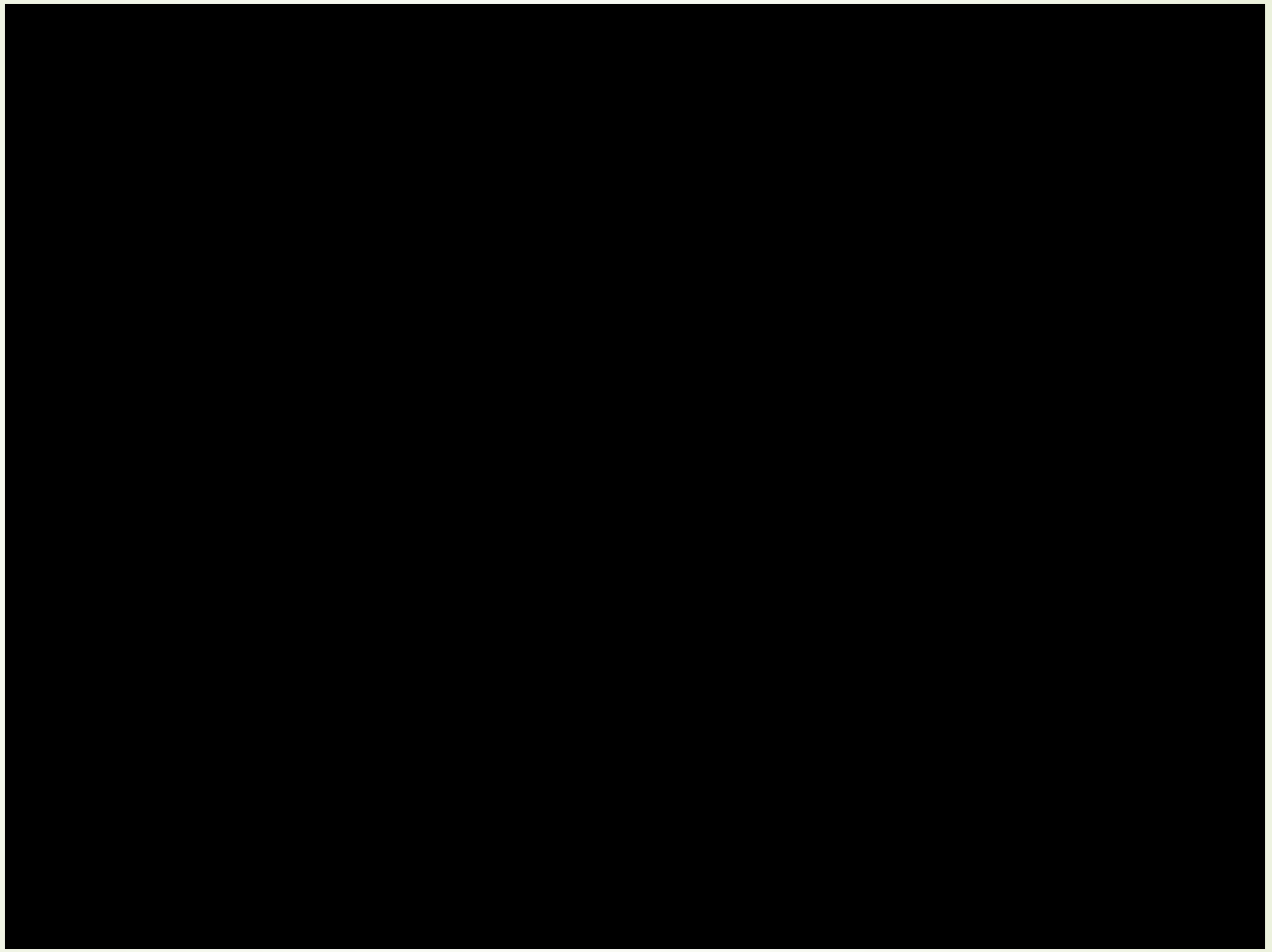
WHAT CAN BE DONE

1. Product or project development and improvement
2. Strategic planning
3. Public policy making
4. Marketing and eco-declarations

LCA of Plastic bottle



Toyota Prius - Life Cycle Assessment



Video url - https://www.youtube.com/watch?v=CVa4GBze3tU

Environment Impact Assessment

What is EIA?

- Environmental Impact Assessment (EIA) is a systematic process to identify, predict and evaluate the environmental effects of proposed actions and projects.
- The process of EIA is applied prior to major decisions and commitments being made.

- In EIA , broad definition of environment is adopted where social, cultural, economic and health effects are considered as integral part.
- EIA is applied primarily to prevent or minimize the adverse effects of major developmental proposals, such as power stations, dams and reservoir, industrial complexes …
- EIA promote environmentally sound and sustainable development through the identification of appropriate enhancement and mitigation measures

Which type of projects under go EIA?

- Agriculture
- Construction (Road networks, Malls, Townships, Dam etc)
- Industries
- Electrical projects
- Waste disposal
- Any developmental projects around Protected Areas / Nature Preserves
- Clean Development Mechanism CDM projects

Objectives of EIA

- Predict environmental impact of product
- Find ways and means to reduce adverse effects
- Refine/shape the proposed project to suit the local environment
- Present the predictions and options before the decision makers

Procedures of EIA in India

- Project Description
- Screening
- Scoping and consideration of alternative
- Baseline Studies
- Impact prediction, assessment and mitigation measures
- Preparation of EIA report
- Public Hearing
- Reviewing EIA report and decision making
- Monitoring the clearance condition

Benefits and Advantages of EIA

The main are:

- Lower project costs in the long-term
- Increased project acceptance
- Improved project design
- Informed decision making
- Environmentally sensitive decisions
- Increased accountability and transparency
- Reduced environmental damage
- Improved integration of projects into their environmental and social settings

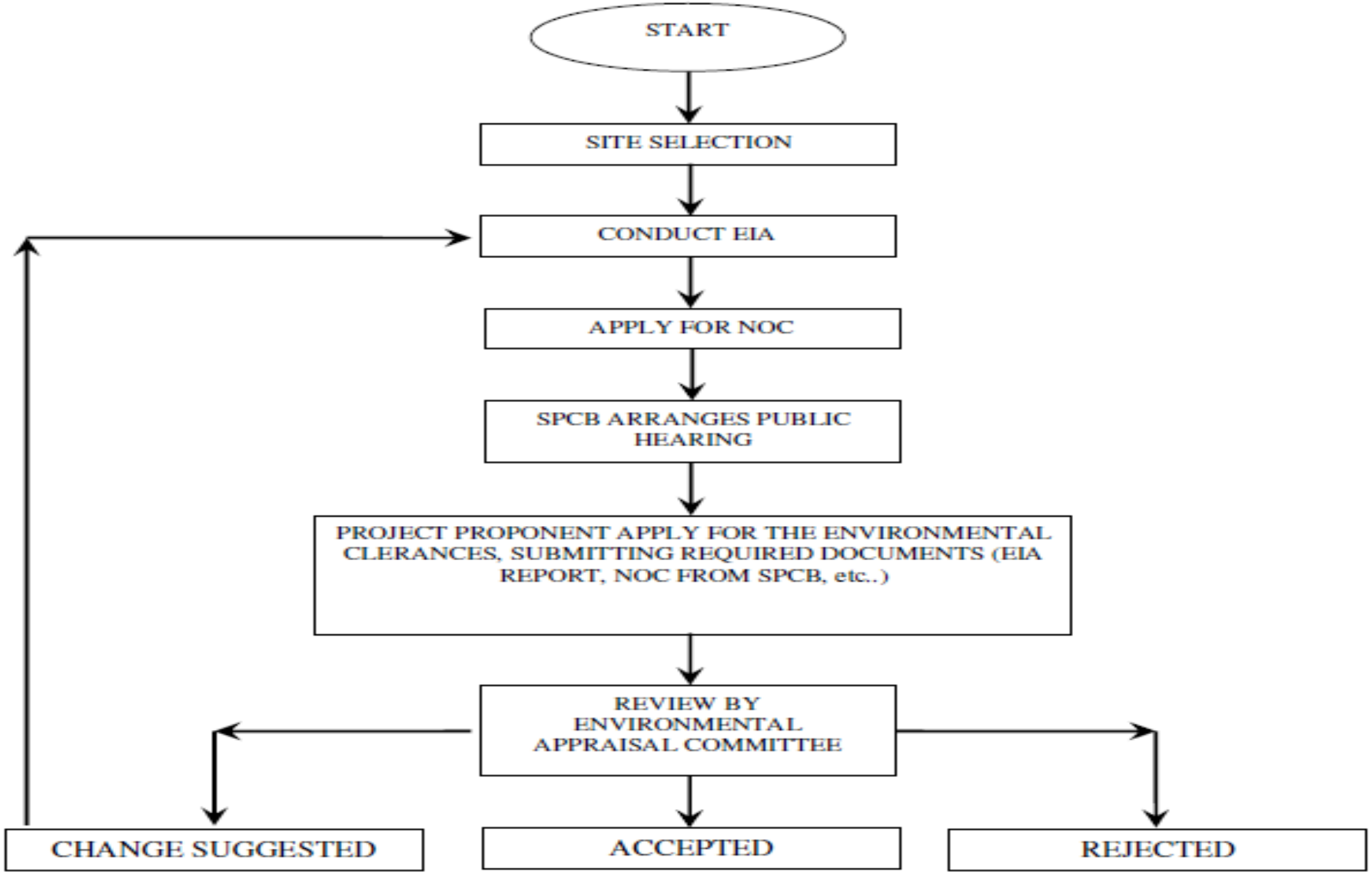


Figure-1
Generalised Flow Sheet of the EIA Process

Biomimicry
--- Innovation Inspired by Nature

- **Biomimetics or biomimicry is the imitation of the models, systems, and elements of nature for the purpose of solving complex human problems**
- Living organisms have evolved well-adapted structures and materials over geological time through natural selection.
- Biomimetics has given rise to new technologies inspired by biological solutions at macro and nanoscales.
- Humans have looked at nature for answers to problems throughout our existence. Nature has solved engineering problems such as self-healing abilities, environmental exposure tolerance and resistance, hydrophobicity, self assembly, and harnessing solar energy.

Janine Benyus – **TED Talks**

Video url - https://www.ted.com/talks/janine_benyus_biomimicry_in_action?language=en

What is biomimicry?

- From
  - bios, meaning “life” + mimesis, meaning “to imitate”
- Biomimicry = to imitate life

Studying a leaf to invent a better solar cell is an example of this “innovation inspired by nature.”

How Does Nature Work? (Principles)

Nature …

- **runs on sunlight**… that's why we call it the "solar system"
- **uses only the energy it needs**… and stores the rest
- **fits form to function**… consider the lilies of the field
- **recycles everything**… what happened to all those leaves that fell in the forest last fall?
- **rewards cooperation** … like nectar for honeybees
- **banks on diversity**… e pluribus Unum
- **demands local expertise**… knowing what's at hand
- **curbs excesses from within**… the essence of sustainability
- **taps the power of limits**… optimizing not maximizing

The History of Biomimicry

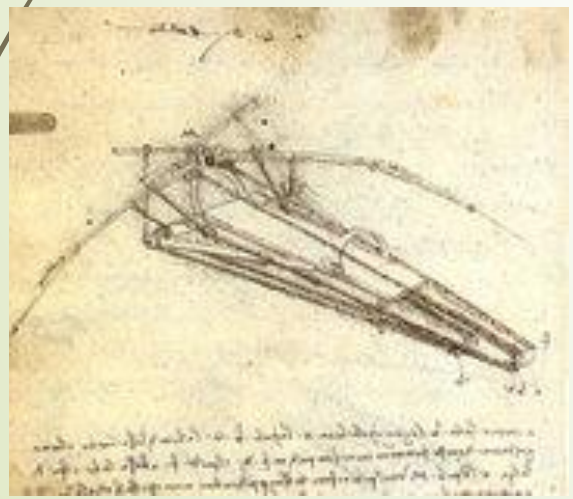
Leonardo da Vinci

Fascinated by the phenomenon of flight, **Leonardo da Vinci** produced detailed

studies of the flight of birds,

and plans for several flying machines, including a helicopter powered by four men (which would not have worked since the body of the craft would have rotated) and a light hang glider which could have flown.

On January 3, 1496 he unsuccessfully tested a flying machine he had constructed.



Leonardo's Flying Machine

Solving Nature's Mysteries

Energy – The Mighty Power of Leaves

Leaves convert sunlight into energy.

Solar cells convert sunlight directly into electricity (energy). Basically, when light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This energy is then formed into an electrical current.

Kingfishers

Biomimicry Samples

The Tokay gecko is easily climbing up and down the vertical surfaces

The **Tokay gecko's** unique toe pads enable it to climb vertical surfaces.

Gecko toes are covered with millions of fine, keratinous filaments called setae. Each seta, just 30-130 nanometers long, branches into about 1000 spatula-shaped tips about 0.2-0.5 nanometers long.

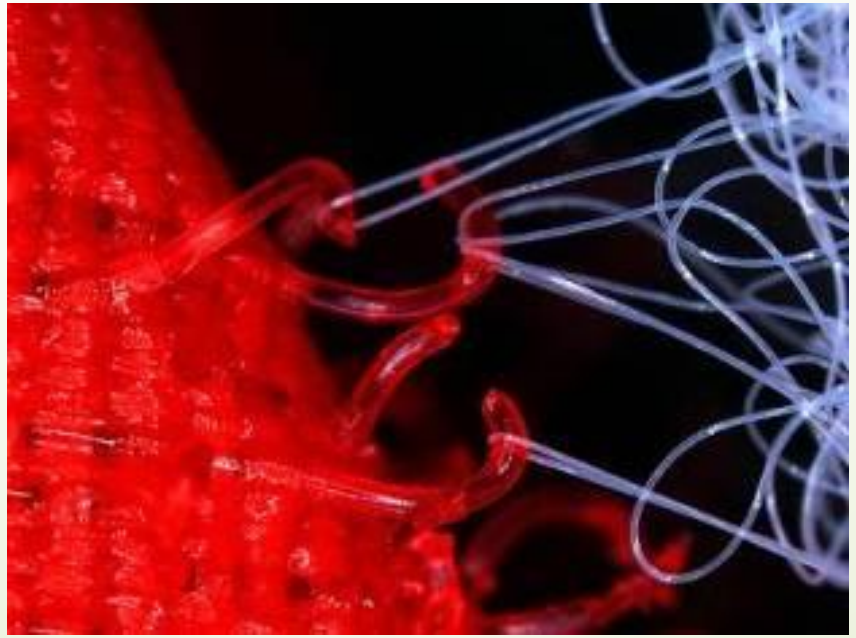
The Fly Wall

Velcro fastening was invented in 1941 by Swiss engineer George deMestral, who took the idea from *the burrs that stuck to his dog's hair*.

Under the microscope he noted the tiny hooks on the end of the burr's spines that caught anything with a loop - such as clothing, hair or animal fur.

The 2-part Velcro fastener system uses strips or patches of a hooked material opposite strips or patches of a loose-looped weave of nylon that holds the hooks.

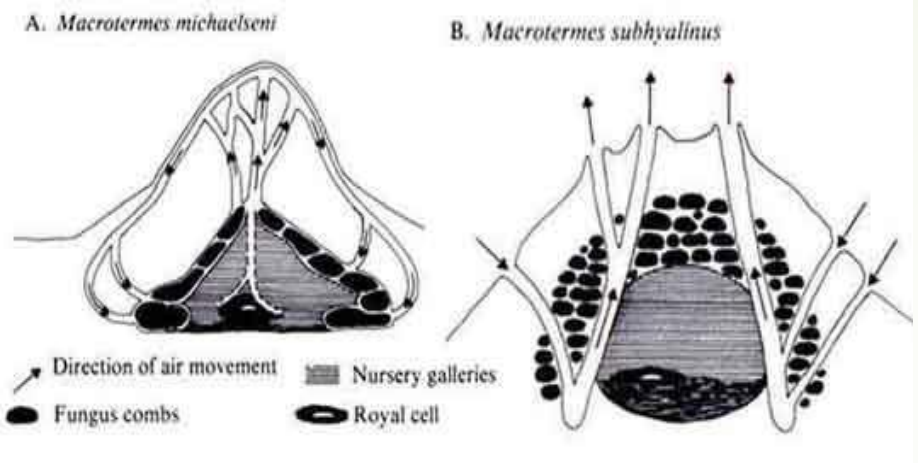
Those hooks on the burr plant gave the idea to create VELCRO



Passive Cooling

- The high-rise Eastgate Centre building in Harare, Zimbabwe was designed to mimic the way that those tower-building termites in Africa construct their mounds to maintain a constant temperature.
- The insects do this by constantly opening and closing vents throughout the mound to manage convection currents of air - cooler air is drawn in from open lower sections while hot air escapes through chimneys.
- The innovative building uses similar design and air circulation planning while consuming less than 10% of the energy used in similar sized conventional buildings!

Termites (No air conditioning…)

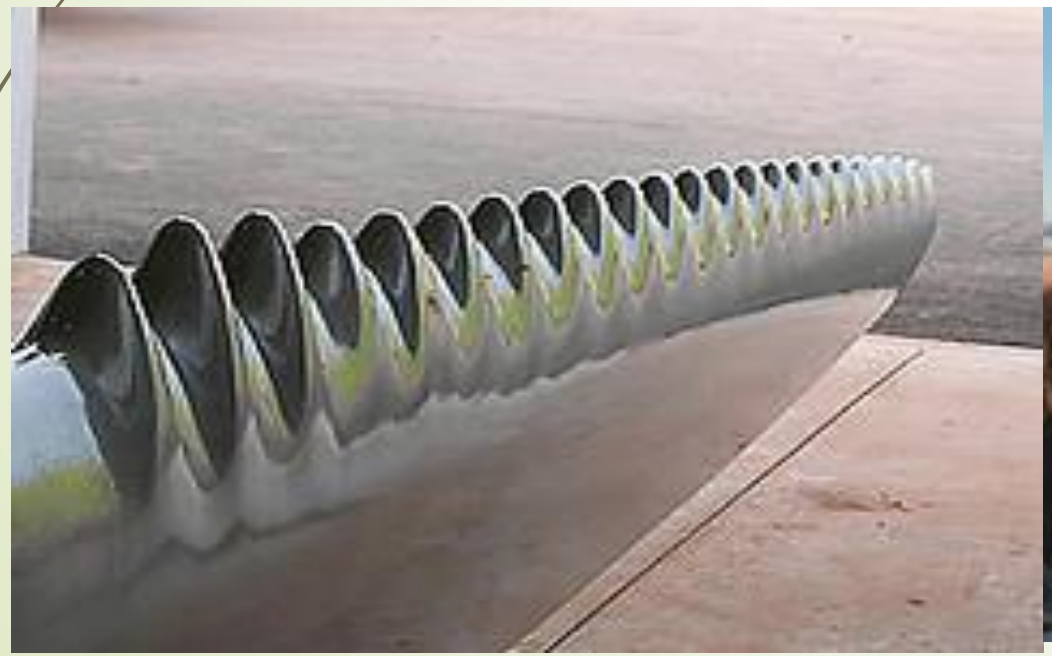


Whalepower Wind Turbine

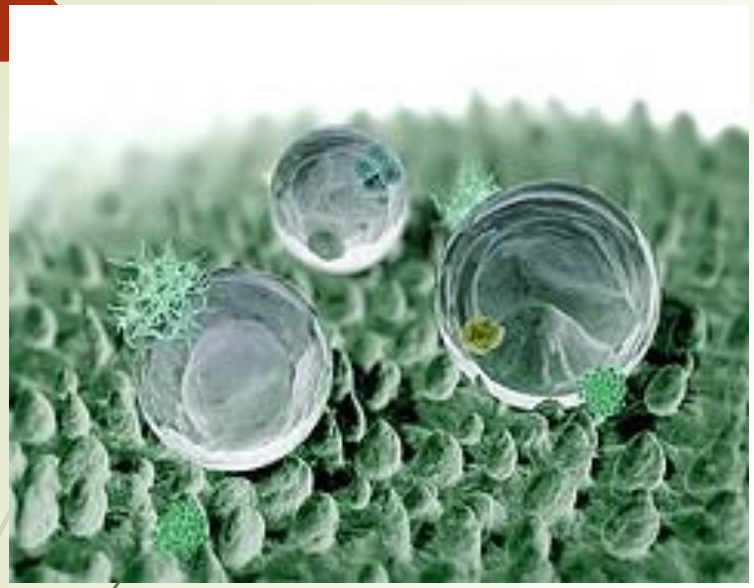
Inspired by the flippers humpback whales use to enable their surprising agility in the water, WhalePower has developed turbine blades with bumps called tubercles on the leading edge that promise greater efficiency in applications from wind turbines to hydroelectric turbines, irrigation pumps to ventilation fans.

Compared to smooth surface fins, the bumpy humpback ones have 32% less drag and an 8% increased lift in their movement through air or water.

Using such blades to catch the wind as communities and nations switch to renewable sources could provide a 20% increase in efficiency that will help to make wind power generation fully competitive with other alternatives.



Lotus Effect Hydrophobia



The Lotus Effect: The surface of lotus leaves are bumpy, and this causes water to bead as well as to pick up surface contaminates in the process. The water rolls off, taking the contaminates with it.

Researchers have developed ways to chemically treat the surface of plastics and metal to evoke the same effect.

Applications are nearly endless, and not just making windshield wipers and car wax jobs obsolete.

The Golden Streamlining Principle

A company called PAX Scientific out of San Rafael, California has been developing air and fluid movement technologies based on such beautiful and recurring natural designs as the Fibonacci sequence, logarithmic spirals and the Golden Ratio. These shapes align with the observation that the path of least resistance in this universe isn't a straight line.

Put all this together and you get the "Streamlining Principle," being applied to fans, mixers, impellers and such that move air and liquids around in systems.

Such fans on motors, compressors and pumps of all sizes and in all applications could save at least 15% of all the electricity consumed in the US.

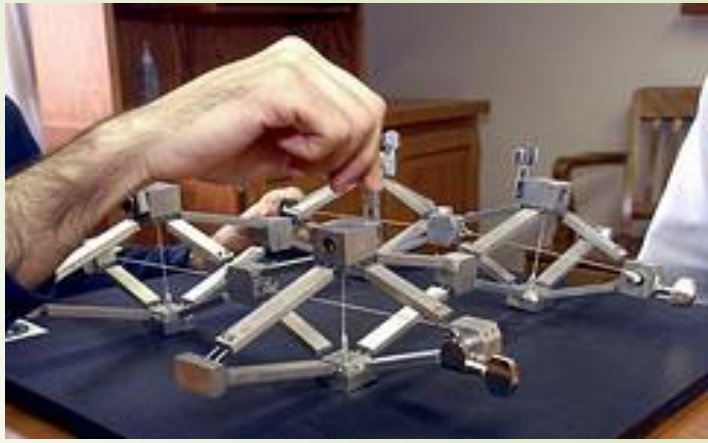
Artificial Photosynthesis

We all learn about photosynthesis in school, the way that green plants use chlorophyll to convert sunlight, water and carbon dioxide into carbohydrates and oxygen.

The quest to reproduce the process technologically is called Artificial Photosynthesis, and is envisioned as a means of using sunlight to split water into hydrogen and oxygen for use as a clean fuel for vehicles as well as a way to use excess carbon dioxide in the atmosphere.

The process could make hydrogen fuel cells an efficient, self-recharging and less expensive way to create and store energy applicable in home and industrial systems.

Morphing Aircraft Wings



Using inspiration from both birds and fish, scientists from Penn State University developed Morphing Airplane Wings that change shape depending on the speed and duration of flight.

Different birds have differently shaped wings useful for the speeds at which they fly, as well as for sustaining flight speeds over long distances using the least amount of energy.

The scientists built a compliant, shape-changing truss understructure for the wings, then covered it with scales that can slide over one another to accommodate the in-flight shape changes.

When deployed in new aircraft (and drone) models, the wings are expected to conserve fuel and enable faster flights over longer distances.

Friction-Reducing Sharkskin

Inspired by the evolved ability of shark's skin to reduce drag by manipulating the boundary layer flow as the fish swims, researchers are developing coatings for ship's hulls, submarines, aircraft fuselage, and even swimwear for humans.

Based on the varying shape and texture of shark's skin over its body, Speedo's Fastskin FSII swimsuits made their appearance at the Bejing Olympics and may have helped US swimmer Michael Phelps to his record eight gold medals in that competition, and the rest of the team as well.

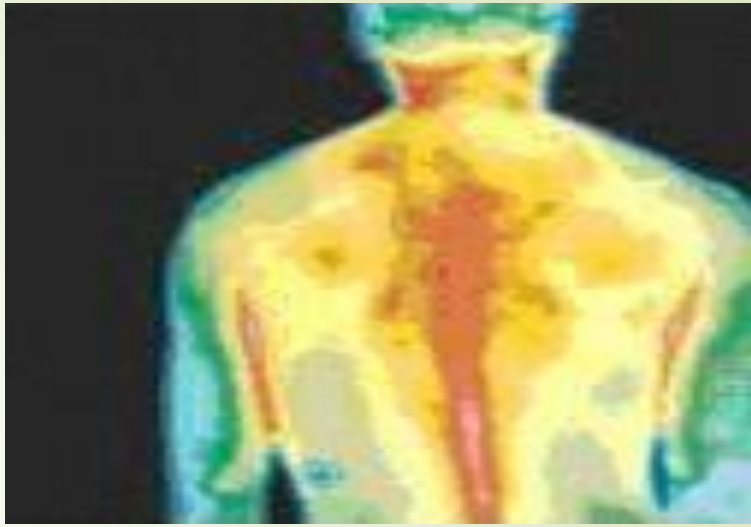
And now there are the new suits (43 world records at the 09 word championships)!

Glo-Fish

Glow-in-the-dark aquarium fish may not fulfill a needful ecological role at the present time, but they're a fun - and lucrative - application of fluorescent proteins discovered in jellyfish while researchers are busily developing further biochemical tools from this Nobel Prize winning discovery.

The protein can be attached to other molecules of interest so they can be followed for understanding of their functions in living organisms, very useful in medical research.

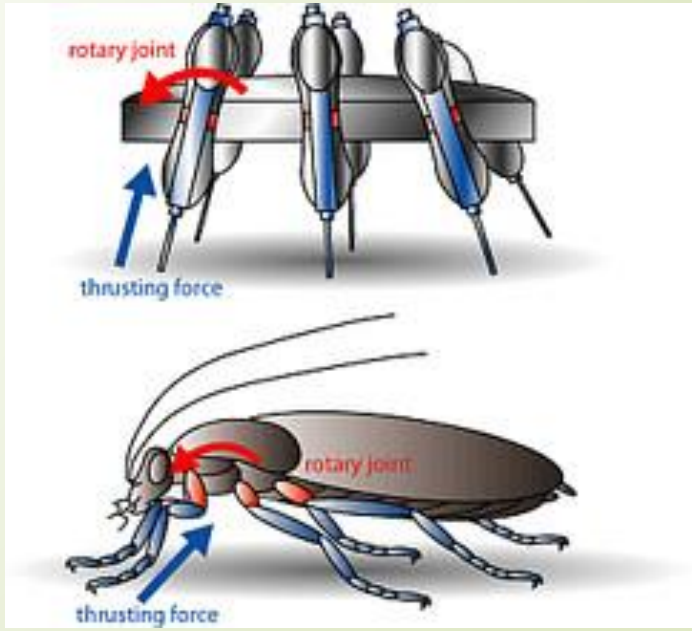
For the fish, the proteins serve the purpose of simply being very cool - they come in several colors!



Insect-Inspired Autonomous Robots

While most of us are accustomed to thinking about futuristic robotics as something that looks and moves just like a human, humans are probably not the best biological model for really useful robots.

For mobility, insect-like ability to cover varied terrain, climb surfaces and provide stability seems to work better. Insect eyes offer greater resolution and panoramic range for exploring places people cannot go, and the ability to quickly adapt to changing environments (or even to spy on enemies undetected) make those annoying toy insect robots a forerunner for future applications in exploration and defence.



Butterfly-Inspired Displays

By mimicking the way light reflects from the scales on a butterfly's wings, the Qualcomm company has developed Mirasol Displays that make use of the reflected light principle with an understanding of how human beings perceive that light.

Using an interferometric modulator [IMOD] element in a two-plate conductive system, the display uses near-zero power whenever the displayed image is static while at the same time offering a refresh rate fast enough for video.

Perfect for 'smart' hand-held devices, already deployed in many, and a battery-saver extraordinaire!

Box fish

A boxfish has certain aero/hydrodynamic features in its body shape which makes it more efficient in traveling through the water using less energy.

Because of the streamline features of the boxfish, it produces less drag for its movement.

So, there is a lot of possibility to design a passenger car by implementing the aerodynamic features on the car shape for improving the energy efficiency.

https://www.sciencedirect.com/science/article/pii/S1876610219312007
https://slate.com/technology/2015/03/mercedes-benz-bionic-car-boxfish-stability-and-agility-paradox-finally-solved.html

It turns out Nature is FULL of good ideas for how to solve human challenges!

What possibilities can you imagine?

What creatures will inspire you?

Circular economy

- A circular economy is an *economic system of closed loops* in which raw materials, components and products lose their value as little as possible, renewable energy sources are used and systems thinking is at the core.

https://en.wikipedia.org/wiki/Circular_economy

- **1. Closed cycles**
- In a circular economy, material cycles are closed following the example of an ecosystem.
- There is no such thing as waste, because every residual stream can be used to make a new product.
- Toxic substances are eliminated and residual flows are separated into a biological and a technical cycle.
- Producers take back their products after use and repair them for a new useful.
- In this system, it is therefore not only important that materials are recycled properly, but also that products, components and raw materials remain of high quality in these cycles

- **2. Renewable energy**
- Just like raw materials and products, energy also lasts as long as possible in a circular economy. The circular economic system is fed by renewable energy sources.
- Because it is not possible to recycle energy, there is no mention of energy cycles or energy cycles, but of 'cascade type energy flows'.
- An example of this is the co-production of heat and power.

- **3. Systems thinking**
- The circular economy does not only require closed material cycles and renewable energy, but also systems thinking.
- Every actor in the economy (company, person, organism) is connected to other actors.
- Together, this forms a network in which the actions of one player influence other players.
- To take this into account, the short and long term consequences must be taken into account in choices, as well as the impact of the entire value chain (Ellen MacArthur Foundation, 2015a).

Industrial Ecology

- Deals with the relationship between “Industry” + “Ecology”.
- The word ecology is derived from the Greek *oikos*, (*household*) and *logy* (*the study of*).
- Ecology can be broadly defined as the study of the interactions between the abiotic and the biotic components of a system.

Industrial Ecology

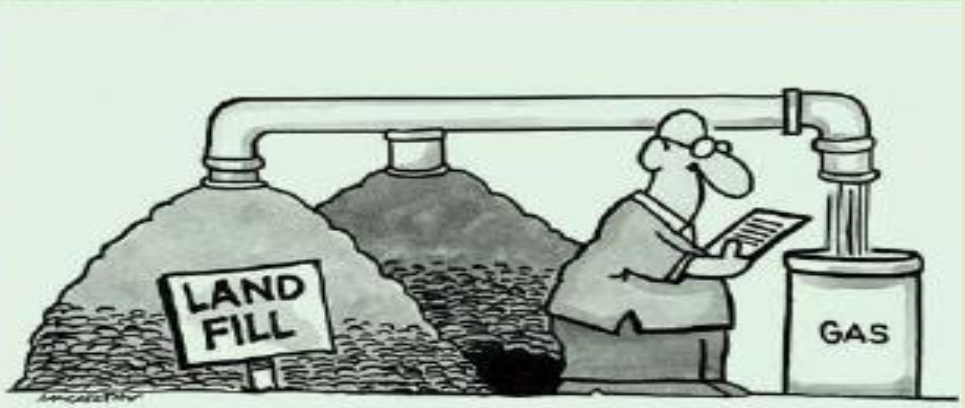
- Industrial ecology conceptualises industry as a man-made ecosystem that operates in a similar way to natural ecosystems, where the waste or by product of one process is used as an input into another process.
- Industrial ecology interacts with natural ecosystems and attempts to move from a linear to cyclical or closed loop system

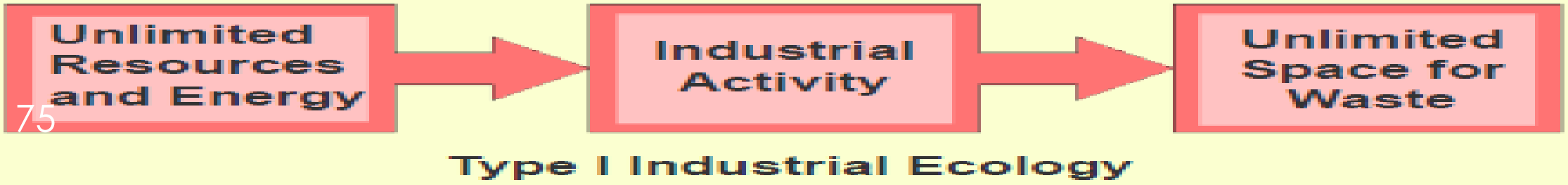
Defining Industrial Ecology

- *"industrial ecology is the study of the* interactions between industrial and ecological systems; consequently, it addresses the environmental effects on both the abiotic and biotic components of the ecosphere".
- "an effort to reduce the industrial systems' environmental impacts on ecological systems."
- "an emphasis on harmoniously integrating industrial activity into ecological systems."
- "the idea of making industrial systems more efficient and sustainable by emulating natural systems"
- closely related concepts – industrial ecosystems, industrial metabolism, industrial symbiosis etc.

Goals of Industrial Ecology

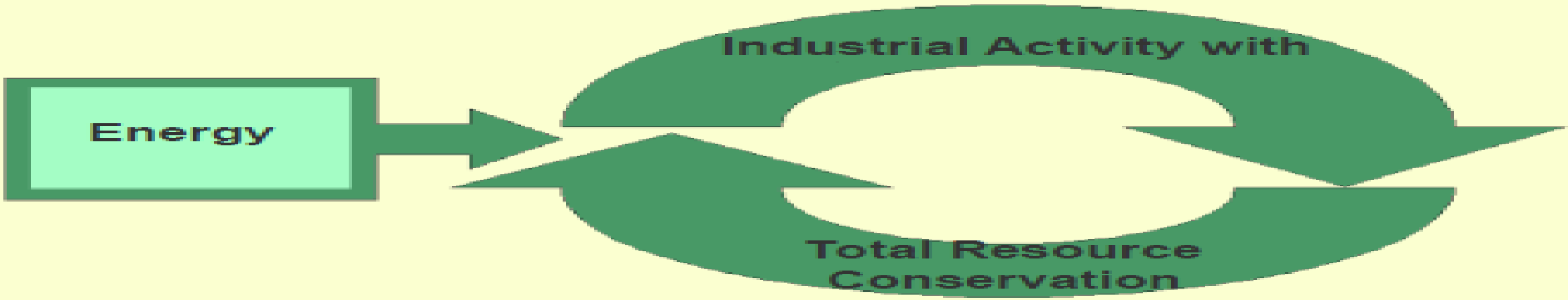
- To promote sustainable development at the global, regional, and local levels.
- The sustainable use of resources.
- Preserving ecological and human health.
- Promotion of environmental equity (Intersocietal)
- Minimal use of nonrenewable resources.
- High degree of interconnectedness and integration that exists in nature





Type I Industrial Ecology

Type II Industrial Ecology



Type III Industrial Ecology

Industrial Ecology

Industrial Ecology India Part 1 (10.28 min)

https://www.youtube.com/watch?v=EOexAnElGa4

Industrial Ecology India Part 2.avi (1.5 min)

www.roionline.org

Industrial Symbiosis

- Industrial Symbiosis mimics the natural ecosystem by setting up a system of recirculation of residual materials from industrial processes or discarded products from consumer matter.
- Industrial symbiosis can be defined as sharing of services, utility, by products in industrial sectors to add value, reduce costs and improve the environment.

The same principle can be extended to industries…

Industrial Symbiosis:
One company's waste is another company's treasure.

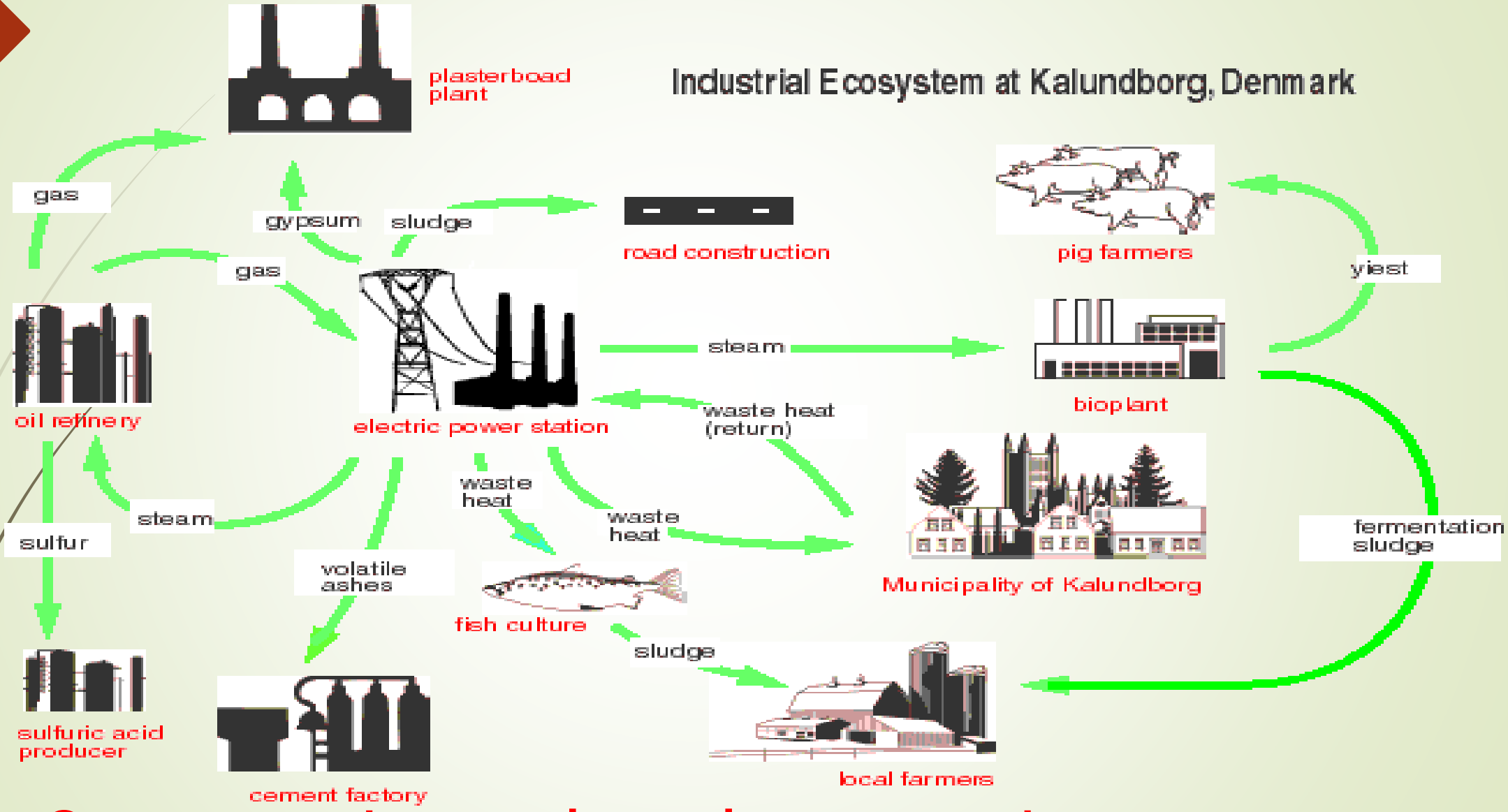
Industrial Symbiosis typically is pursued in a limited area, in a municipality or industrial area in a municipality.

The Kalundborg Case

Kalundborg municipality

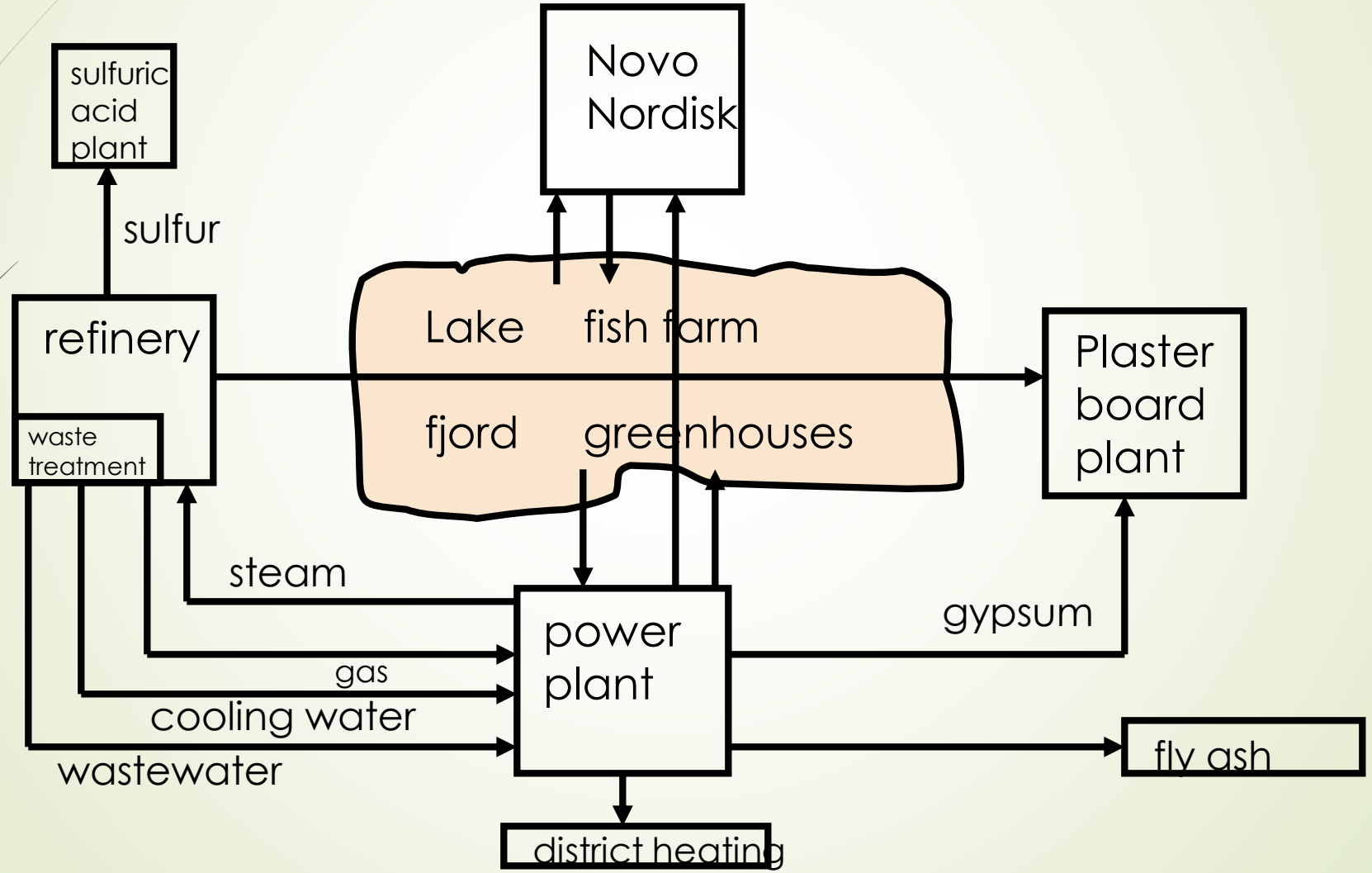
- power plant and an oil refinery
- gypsum board manufacturing plant
- pharmaceuticals plant
- biotechnical plant for production of enzymes
- plant for remediation of polluted soil
- waste handling company, fish farm and the surrounding farming community.

Industrial Symbiosis



One company's waste is another company's treasure

Kalundborg Industrial Park



A&S, 2002

Energy Cooperative Systems

- In Kalundborg, the Power Station produces heat for the city of Kalundborg and process steam for the oil refinery and for the enzymes factory.
- The combination of heat and power production results in a 30% improvement of fuel utilization compared to a separate production of heat and power.
- District heat has replaced approx. 3,500 small oil-fired units.

Biomass Recycling

- The use of residual biological material is worldwide the most typical kind of industrial symbiosis. A plant that has biological material as a residual product tries to sell it rather than pay for its destruction.
- Sludge is a major residual product stemming from the municipal water treatment plant in Kalundborg. The sludge is utilized at the soil-remediation plant as a nutrient in the bioremediation process.

Water Recycling in Kalundborg

- The Kalundborg Region, as well as its industrial companies, is a large consumer of water. This is why the Symbiosis companies are seeking to recycle as much water as possible.
- The Power Station has, for example, reduced its total water consumption by 60%.
- The consumption of lake water has been reduced by 50% by recycling of the wastewater from the power plant.

Gas and Inorganic Material Recycling

- The desulphurisation plant of the Power Station removes sulfur dioxide (SO_2) from the flue gas, producing about 200,000 tones of gypsum on a yearly basis.
- The gypsum is sold to the gypsum company that manufactures gypsum board products for the construction industry.

Necessity

- Collective benefits by diverse industries is much greater than the sum of benefits of any individual industry.
- Accelerates the transition from a linear system towards a circular system(to achieve a low carbon ,sustainable economy)
- Mitigates global warming, emphasis on recycling of water, energy and materials and eases long distance transport.

References

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