DEVELOPMENT OF INDUSTRIAL SYMBIOSIS

(A way to make Industrial Waste Synergies in Gujarat)

Gujarat Cleaner Production Centre
(Established by Industries & Mines Department, Govt. of Gujarat)
Address: Block No: 11-12, 3rd Floor, Udhyog Bhavan, Gandhinagar
Phone: + 91 79 232 44 147
Email: gcpc11@yahoo.com, info@gcpcgujarat.org.in

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The term **'industrial symbiosis'** was coined in the small town of Kalundborg, Denmark, where a well-developed network of dense firm interactions was encountered. The primary partners in Kalundborg, including an oil refinery, a power station, a gypsum board facility, and a pharmaceutical company, share ground water, surface water, wastewater, steam, and fuel, and they also exchange a variety of by-products that become feedstocks in other processes. High levels of environmental and economic efficiency have been achieved, leading to many other less tangible benefits involving personnel, equipment, and information sharing. Many other examples of industrial symbiosis exist around the world and illustrate how the concept is applied.

Industrial symbiosis is part of a new field called industrial ecology. Industrial ecology is principally concerned with the flow of materials and energy through systems at different scales, from products to factories and up to national and global levels. Industrial symbiosis focuses on these flows through networks of businesses and other organizations in local and regional economies as a means of approaching ecologically sustainable industrial development. Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity.

There are many elements of industrial symbiosis such as energy and water cascading, cogeneration, and materials exchange. It examines tools such as input/output matching, stakeholder processes, and materials tracking. The article discusses how industrial symbiosis is a useful umbrella term because it can describe exchanges across entities regardless of whether they are collocated, located near one another but not contiguous, or located within a broader spatial area such as regionally.

Three types of symbiotic transactions can occur among industries: (i) utilizing waste as raw material inputs from others (by-product exchanges) (ii) sharing utilities or access to services (such as energy or waste treatment) (iii) cooperating on issues of common interest such as emergency planning, training or sustainability planning. Industrial symbiosis offers an analytical framework for understanding how groups of firms cooperate in the pursuit of competitive advantage by managing their resources in a sustainable manner.

Industrial symbiosis is the use by one company or sector of by-products, including energy, water, logistics and materials, from another. **Simple examples** include the use of food waste from the catering sector to feed farm animals, or the use of non-toxic industrial waste to produce energy through incineration. However, in a developed economy with many industrial activities, many different by-products are generated, and the range of potential uses for them can be equally diverse.

This will helps in:

- Diverting / reusing huge quantity of industrial waste from landfill
- Generating new generate new sales opportunities
- Reducing carbon emissions
- Cutting costs for disposal, storage, transport etc
- Reducing load of regular monitoring of waste to regulatory authority
- Creating and safeguarding new jobs
- Saving huge quantity of virgin material, water and energy
- Reducing negative environmental and climate change impacts and improving resource efficiency
- To develop sound action plan for waste re-utilization
- Developing new policy for “ Recourse Efficient Gujarat”

Industrial Symbiosis Case Studies

1. Kalundborg, Denmark

The history of Kalundborg really began in 1961 with a project to use surface water from Lake Tissø for a new oil refinery in order to save the limited supplies of ground water (Christensen, 1999). The city of Kalundborg took the responsibility for building the pipeline while the refinery financed it. Starting from this initial collaboration, a number of other collaborative projects were subsequently introduced and the number of partners gradually increased. By the end of the 1980's, the partners realized that they had effectively "self-organized" into what is probably the best-known example of a working industrial ecosystem, or to use their term – an industrial symbiosis.

PARTICIPANTS IN THE INDUSTRIAL SYMBIOSIS

In addition to several companies that participate as recipients of materials or energy, the ecosystem today consists of six main partners –

- **Asnæs power station** - Part of SK Power Company and the largest coal-fired plant producing electricity in Denmark.
- **Statoil** - An oil refinery belonging to the Norwegian State oil company. UNEP Environmental Management for Industrial Estates: Case Study/Kalundborg - 2 Information and Training Resources.
- **Novo Nordisk** - A multi-national biotechnology company that is the largest producer of insulin and industrial enzymes.
- **Gyproc** - A Swedish company producing plasterboard for the building industry.

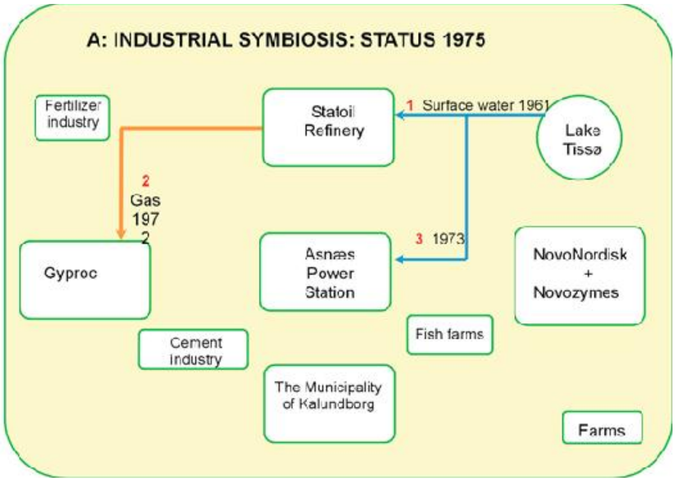
- The town of Kalundborg, which receives excess heat from Asnaes for its residential district heating system.
- Bioteknisk Jordrens - A soil remediation company that joined the Symbiosis in 1998.

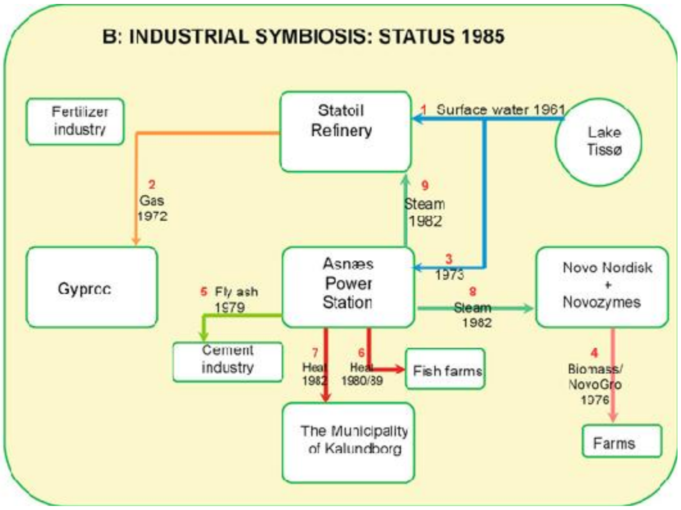
MATERIAL & ENERGY FLOWS – A SERIES OF BY-PRODUCT SYNERGY PROJECTS

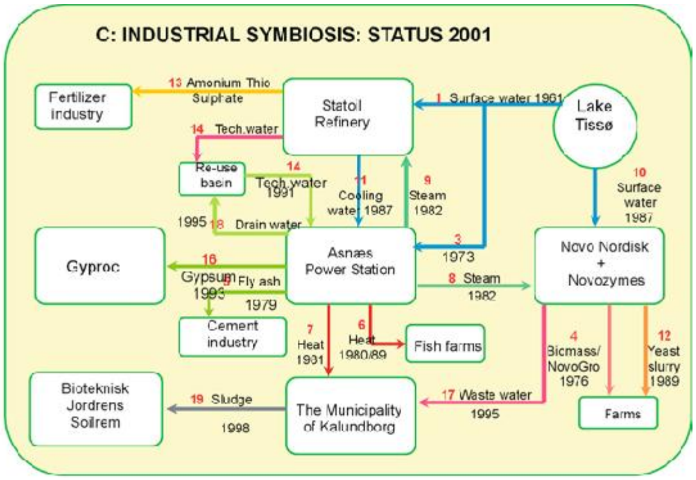
It is important to understand initially that water is a scarce resource in this part of Denmark and is therefore systematically valorized. As we mentioned above, in order to reduce consumption of ground water, Lake Tissø has become the main source of water for the industrial partners in Kalundborg. The reduction in the use of ground water has been estimated at close to 2 million cubic meters per year (Christensen, 1999). However, in order to reduce overall water consumption by the partners, the Statoil refinery supplies its purified wastewater as well as its used cooling water to Asnæs power station, thereby allowing this water to be "used twice" and saving additionally 1 million cubic meters of water per year. Asnæs power station supplies steam both to Statoil and Novo Nordisk for heating of their processes. By functioning in a co-generation mode, the power station is able to increase its efficiency.

Excess gas from the operations at the Statoil refinery is treated to remove sulfur, which is sold as a raw material for the manufacture of sulfuric acid, and the clean gas is then supplied to Asnæs power station and to Gyproc as an energy source. In 1993 Asnæs power station installed a desulfurization unit to remove sulfur from its flue gases, which allows it to produce calcium sulfate (gypsum). This is the main raw material in the manufacture of plasterboard at Gyproc.

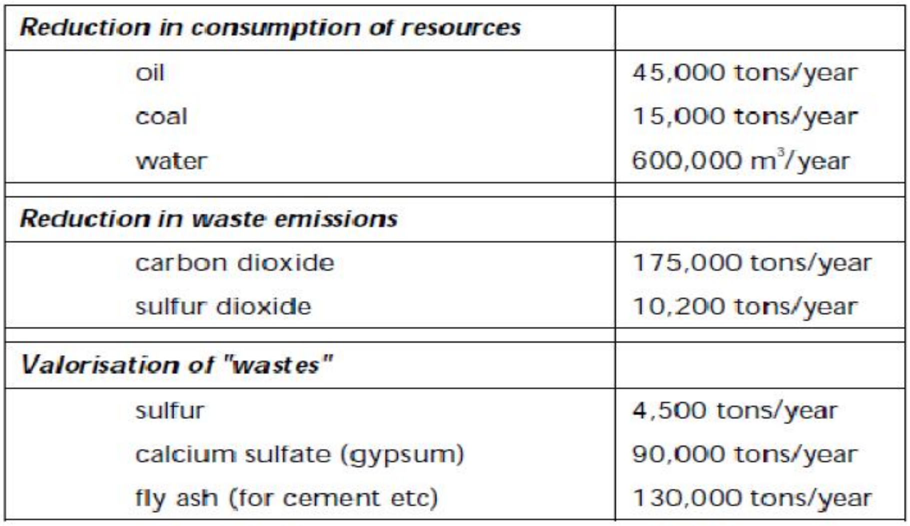
By purchasing synthetic "waste" gypsum from Asnæs power station, Gyproc has been able to replace the natural gypsum that it used to buy from Spain. In 1998 approximately 190,000 tons per year of synthetic gypsum were available from the power station. Novo Nordisk creates a large quantity of used bio-mass coming from its synthetic processes and the company has realized that this can be used as a fertilizer since it contains nitrogen, phosphorus and potassium. The local farming communities use more than 800,000 cubic meters of this liquid fertiliser each year as well as over 60,000 tons of a solid form of the fertilizer. Finally, residual heat is also provided by Asnæs power station to the district heating system of the town. The system functions via heat exchangers so that the industrial water and the district heating water are kept separate. UNEP Environmental Management for Industrial Estates:


A: INDUSTRIAL SYMBIOSIS: STATUS 1975
Fertilizer industry
Statoil Refinery
1 Surface water 1961
Lake Tissø
2 Gas 1972
3 1973
Gyproc
Asnæs Power Station
NovoNordisk + Novozymes
Cement industry
Fish farms
The Municipality of Kalundborg
Farms


B: INDUSTRIAL SYMBIOSIS: STATUS 1985
Fertilizer industry
Statoil Refinery
1 Surface water 1961
Lake Tissø
2 Gas 1972
9 Steam 1982
Gyproc
Asnæs Power Station
3 1973
Novo Nordisk + Novozymes
5 Fly ash 1979
8 Steam 1982
Cement industry
7 Heat 1982
6 Heat 1980/89
Fish farms
4 Biomass/ NovoGro 1976
The Municipality of Kalundborg
Farms


C: INDUSTRIAL SYMBIOSIS: STATUS 2001
Fertilizer industry
13 Amonium Thio Sulphate
Statoil Refinery
1 Surface water 1961
Lake Tissø
14 Tech.water
Re-use basin
14 Tech.water 1991
11 Cooling water 1987
9 Steam 1982
10 Surface water 1987
1995 18 Drain water
Gyproc
Asnæs Power Station
3 1973
Novo Nordisk + Novozymes
16 Gypsum 1993
5 Fly ash 1979
8 Steam 1982
Cement industry
7 Heat 1981
6 Heat 1980/89
Fish farms
4 Biomass/ NovoGro 1976
12 Yeast slurry 1989
Bioteknisk Jordrens Soilrem
19 Sludge 1998
The Municipality of Kalundborg
17 Waste water 1995
Farms

The Experience of Kalundborg



Reduction in consumption of resources	
oil	45,000 tons/year
coal	15,000 tons/year
water	600,000 m^3/year
Reduction in waste emissions	
carbon dioxide	175,000 tons/year
sulfur dioxide	10,200 tons/year
Valorisation of "wastes"	
sulfur	4,500 tons/year
calcium sulfate (gypsum)	90,000 tons/year
fly ash (for cement etc)	130,000 tons/year

The investment needed to put the different material and energy exchanges in place has been estimated at $75 million. This is the cost of the 18 projects established up to and including 1998. Keeping in mind that each exchange is based on a separate contract between the two partners involved, revenues can be estimated as coming from selling the waste material and from reduced costs for resources. The partners estimate that they have "saved" $160 million so far (Christensen, 1999). The payback time of a project is less than 5 years on average. Therefore a second lesson is that a more rational utilization of resources can save money.

A third point is that the symbiosis in Kalundborg essentially "organized itself" over a relatively long period of time using sound financial criteria to decide which projects would be put in place. It is always tempting to want to re-engineer an industrial system in a "top-down" manner so that it becomes closer to a true ecosystem. As UNEP Environmental Management for Industrial Estates: Information and Training Resources. Case Study/Kalundborg – 5 Frosch has noted however (Frosch 1992), in such a carefully planned and integrated industrial system the individual parts would be too closely linked and dependent on each other, rendering it fragile and hence likely to collapse. He has expressed his preference for an industrial system that self organizes in order to accomplish the minimization of waste, while recognizing that there may be a need to help to "stock" the industrial ecosystem with certain types of company in order to create a better balance, either by providing information on business opportunities or supporting start-ups. Interestingly, although Kalundborg epitomizes the self-organization described by Frosch, it has in its turn been criticized by others for being fragile because it has too few partners and each is therefore too dependent on the others. A fourth lesson is that the close proximity of the partner companies has undoubtedly helped in terms of reducing the cost of infrastructure to facilitate material exchanges, such as pipelines. However, it has also been pointed out that the proximity of the human partners was crucial in developing the co-operation needed to make the symbiosis work (Christensen, 1999). These lessons from the

Industrial Symbiosis can clearly be applied in an industrial estate with similar benefits. Côté and Hall (1995) have identified the following objectives for applying such an approach to industrial estates –

- Conservation of natural and financial resources
- Reduced production, material, energy, insurance and treatment costs and liabilities
- Improved operating efficiency, quality, population health and public image
- Potential income through the sale of waste materials.

2. Alberta, Canada (Material and Energy Exchanges)

The nature of material / or energy exchanges occurring in this region include documented evidence of both existing and potential synergies. The existing synergies are one that:

- Involves the petrochemical companies. For example, ethylene plants which processes ethane, a product of natural gas to ethylene oxide/ethylene glycol, polyethylene, and ethylene dichloride/vinyl chloride/polyvinyl chloride. Whereas details of potential synergies are summarized below as:
- Production of energy from biomass, cogeneration and co-firing.
- Utilization of sulphur and high sulphur coke.
- Utilization e.g. ash, fly ash, wood ash for agricultural enhancement.

3. Brownsville / Matamoros Eco-Industrial Parks, Texas (U.S.A.)

The description of the nature of symbiotic relationships that exist between the companies in the Brownsville / Matamoros region was based on the operations of these companies in the system. The following exchanges were described:

- The refinery sales its residual oil to the asphalt company.
- The company sells limestone to the asphalt company.
- The discrete parts manufacturer sells scrap plastic to the recycler. Purchases plastic pellets from the plastic recycler.
- The textile company sales plastic to the plastic recycler.
- The auto parts manufacturer begins selling scrap plastic to local recycler.
- The ballast manufacturer sells scrap asphalt to the asphalt company for mixing with its virgin materials.

4. Burnside Eco-Industrial Park, Canada.

The following material exchanges occur in the Burnside Eco-Industrial Park:

- Substitution of used crumpled, compacted recycled paper for foam packaging.
- Implementation of a solvent management program with VOC reduction targets.
- Reuse of excess brown paper packaging.
- Use of recycled / refurbished material and equipment in projects.
- Reuse of plastic barrels and waste pallets in-house.

5. Gladstone Industrial Area Network (GAIN).

In the Gladstone Industrial Area Network (GIAN), the existence of the network contributed to the realization of some waste exchanges and resource synergies, including for instance:

- Bauxite residue used for treatment of acid sulphate soils.
- Fly ash used for cement production.
- Use of waste acid from Ticor to neutralize bauxite residue dam.

6. Golden Horseshoe, Canada.

Existing synergies in the Golden Horseshoe Industrial Symbiosis project include the following:

- Use of carbon black as EAF additive.
- Use of oxide sludge as raw material in cement manufacture.
- PVC residue used in shoe sole manufacture.
- Alternative fuel from the use of butadiene.
- Use of CO2 in the medical and beverage industries.
- Liquid nitrogen used to rehabilitate polymers.
- Manufacture of cargo pallets from polyethylene/polypropylene by-products.
- Use of polymer residuals in roof coatings.
- Use of spent caustic in pulp and paper manufacture.
- Use of fly ash in cement manufacture.
- Use of cellophane scrap in oil well operations.
- Cogeneration of steam and power from use of wood chips.
- Use of hydrogen gas as fuel in cogeneration plants.

7. Guayama, Puerto Rico.

Existing synergies in the Guayama Industrial Symbiosis project include among others the following:

- Production of steam by power plant which is utilized by the refinery.
- Re-use of water among the industrial sectors.
- Use of special fly ash from coal in cement production.

8. Kawasaki Zero Emission Industrial Park, Japan.

The existing synergies involving the exchange of materials among participating companies in the Kawasaki Zero Emission system are as follows:

- Use of fly ash in cement manufacture.
- Use of plastics as injection material in blast furnaces of iron works.
- Recovery of home waste electronics appliances.
- Use of incineration ash in the production of molten slag.

- Conversion of gasification treated shredder dust to carbon dioxide and hydrogen which are generated to chemical plants for the manufacture of products such as ammonia, methane, and methanol.

9. Kwinana Industrial Area (KIA).

The synergies already in place in the Kwinana Industrial Area are quite diverse. These include the following:

- Hydrochloric acid from pigment plant used in ammonium chloride production by chemical plant.
- Carbon dioxide from chemical plant for utility gas providers.
- Use of gypsum from chemical plant in alumina refinery.
- Use of hydrogen from oil refinery in bus trial.
- WWTP wastewater used by alumina refinery.
- Cogeneration plant at oil refinery.
- Cogeneration plant at titanium dioxide pigment plant.
- Use of water from chemical plant by pigment plant.

10. Map Ta Phut Industrial Estate, Thailand.

The existing symbiotic relationships among firms participating in the Map Ta Phut Industrial Estate project are as follows.

- Petrochemical plant receiving electricity and steam from cogeneration plants.
- Use of bottom and fly ash in production of cement and bricks.
- Use of carbon dioxide in dry ice production.
- Use of waste oil as alternative fuel in cement kiln and oil paint manufacture.
- Use of off-grade, short chain polymers in candle and wax colour production.
- Reuse of spent solvent in thinner production.
- Use of ferrous chloride and hydrochloric acid in ferric chloride production.
- Use of scale, dust and refractory materials in cement production.

11. Montreal, Canada.

The existing synergies in the Montreal Industrial Region include the following:

- Use of Ferric and Ferrous Sulphate from steel industry for animal feed, fertilizers etc manufacture by Stablex.
- Use of sodium sulphate in the pulp and paper industry.
- Use of caustic soda from refinery in the pulp and paper and smelter industry.
- Used oils from various industries as smelter for energy.
- Used of biologic sludge from petroleum refinery and pulp and paper industry for soil beneficiation.
- Sulphuric acid from sodium chlorate laboratory used in lead smeltering.
- Use of calcium-based materials (e.g. steel slag) for neutralization.

12. National Industrial Symbiosis Programme (NISP), UK.

The nature of documented synergies in the Mersey Bank Industrial Symbiosis Programme is described as follows:

- Use of potassium hydroxide in the neutralization of fluoride-containing stream to generate potassium fluoride effluent.
- Use of off-spec protein production for biological waste treatment.
- Re-use of fluorine-based wastes.
- Recycling of sodium nitrate.
- Use of fatty acid distillation residues in cement kilns manufacture.

13. North Texas, USA.

The existing synergies in the North Texas Industrial Eco-System project according to NJCAT (2001) include the following:

- 130,000 tons of steel slag used in place of lime (single plant operation)
- 120,000 tons of Auto Shredder residues (ASR) mined for metal reclamation and ASR remaining after metal recovery used for power generation.
- 37,500 pounds of sludge saved from landfills and municipal water systems.

14. Ora Eco-Park, Norway.

In the Ora Eco-Park, Norway, examples of current symbiotic interactions among participating companies according to Thoresen (2001) involves: steam, condensate return, hot and cold water, waste sulphuric acid, iron sulphate waste, polyester waste, wood chips for energy production, filter waste, industrial waste, and sludge.

15. Rotterdam, The Netherlands.

The nature of material flows in the Rotterdam industrial symbiosis project is predominantly Heat and water inclined according to the Regional Council of Etelä-Savo (2006).

16. Sarnia-Lambton, Canada.

The following describes the existing by-product synergies in the Sarnia-Lambton Industrial Ecosystem project:

- Power / steam cogeneration project.
- Use of desulphurized gypsum from power station in gypsum board plant.
- Cascading of by-product steam.

17. Styria, Austria.

The nature of existing synergies in the Styria by-product synergy project according to Schwartz et al., (1997) is described as follows:

- Use of waste heat from power plant for district heating.
- Use of power plant gypsum in cement manufacture.
- Use of ash from paper production in mining operations.
- Use of blast furnace sand in cement manufacture.
- Use of petrol coke in cement manufacture.
- Use of flax residues in the ceramic industry,
- Use of wood residues in paper manufacture.
- Use of textile waste in stone and ceramic industry.
- Use of steel slag as construction material.

18. Tampico, Mexico.

Existing synergies in the Tampico industrial system include the following:

- CO2 recovery.
- Spent butadiene usage.
- Hydrochloric acid recuperated.
- Use of polymer resins for construction materials.
- Cleaning and recycling of empty chemical drums and barrels.
- Ferric chloride recuperated for external sales.
- Process changed chemical stock usage.
- Fabric glass usage.
- Mine tails usage.
- PVC residues used in shoe sole manufacture.
- Waste-to-energy conversion.

19. Tilbury Eco-Industrial Park, Canada.

The nature of by-product synergy in the Tilbury Industrial park is described as follows:

- Use of fly ash in cement manufacture.
- Co-generation and recovery of thermal energy.
- Use of biomass waste in agriculture.
- Use of food related waste as inputs for living machine system.
- Recovery of zinc ash and metal pails from Argo Protective Coating

Financial Assistance to Implement Cleaner Production

Gujarat Industrial Policy 2015

Schemes of Assistance for Environment Protection Measures
Resolution No: GID-102014-922884-G, Dated: 19.01.2015

Scheme No: 1 Scheme for Assistance for Environment Management

Sr. No	Eligibility Activity	Quantum of Assistance per Project
1	Implementation of Cleaner Production Technology in place of existing process such as substitution & optimization of raw material, reduction in water consumption or energy consumption or waste generation.	Up to **35 % of cost of plant & machinery** with ceiling of **Rs. 35 Lacs** during the operative period of the scheme **for MSME.** Up to **10 % of cost of plant & machinery** with ceiling of **Rs. 35 Lacs** during the operative period of the scheme **for Large.**
2	Any other environment management project with use of Clean, Efficient and Innovative Pollution Control Equipment	Up to **25 % of cost of plant & machinery** with ceiling of **Rs. 35 Lacs** during the operative period of the scheme **for MSME.** Up to **10 % of cost of plant & machinery** with ceiling of **Rs. 35 Lacs** during the operative period of the scheme **for Large.**

Scheme of Assistance for Common Environment Infrastructure
Resolution No: GID-102014-922945-G, Dated: 19.1.2015

Scheme No: 4 Scheme for Development of Green Estate

Sr. No	Activity	Assistance
1	Assistance for preparation of site master plan for relocation / retrofitting of existing pollution industrial units into Green Industrial Estate as per the direction of GPCB / MoEF	75 % assistance maximum Rs. 80.00 Lakh
2	Assistance for set up / relocation / retrofitting of existing polluting industrial units into Green Industrial Estate	25 % of capital cost or maximum Rs. 25.00 Cr

Gujarat Cleaner Production Centre