Seminarios del Doctorado en Ciencias Exactas e Ingeniería

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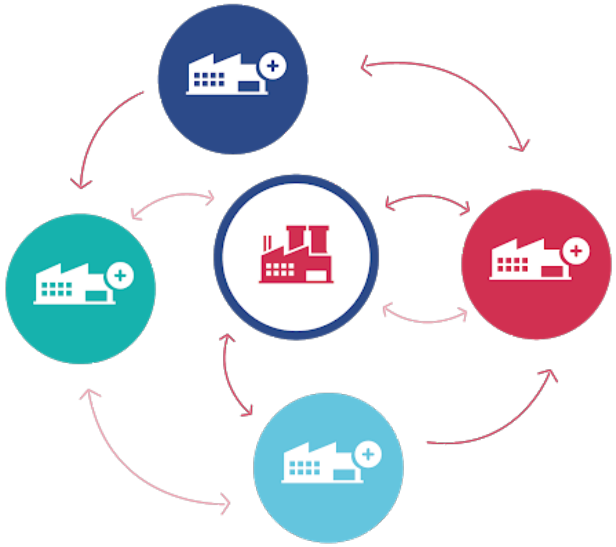
13 mayo 2021

Tema

- **Estrategias de simbiosis industrial para el diseño de sistemas productivos sustentables**



Objetivo general

Realizar tareas de investigación y desarrollo en el área de soporte a la toma de decisiones para la implementación de estrategias de **simbiosis industrial** (SInd), teniendo en cuenta simultáneamente aspectos técnicos, económicos, ambientales y sociales.

Objetivos específicos

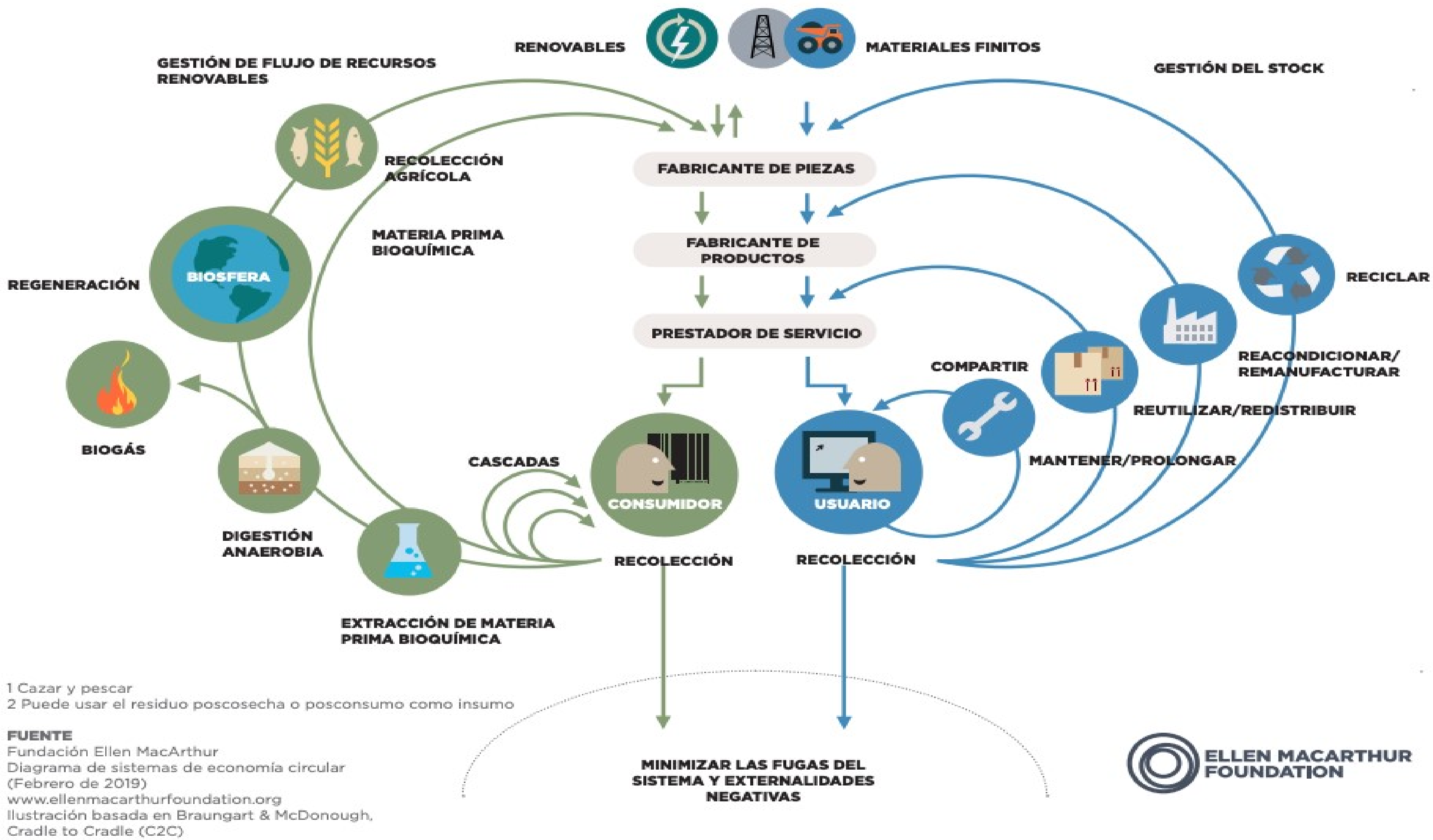
1. Desarrollar **estrategias de optimización basadas en programación matemática** para resolver cuestiones relacionadas con la SInd de plantas que originalmente operan de manera independiente.
2. Demostrar la utilidad práctica de los algoritmos y métodos que se desarrollen mediante **aplicaciones académicas e industriales**, con especial intensidad en el sector productivo regional basado en la biomasa.

- Una **economía circular** es un sistema regenerativo en el que la entrada de recursos y la salida de desechos y emisiones, más las pérdidas de energía, se minimizan al disminuir los consumos
- Se promueven recirculaciones de materiales y energía.

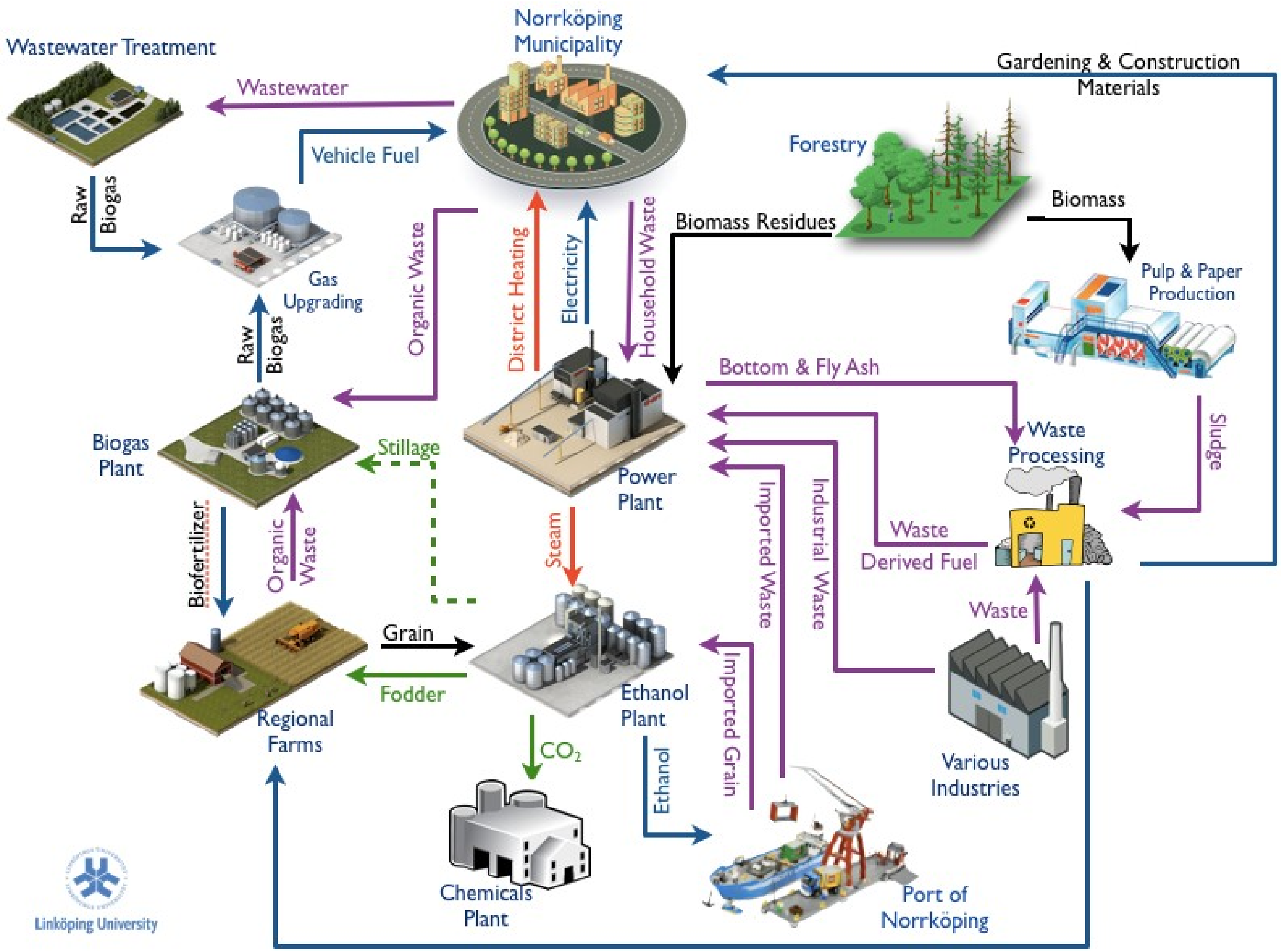
Concepto EL

Esto tiene un claro contraste con una **economía lineal** que es un modelo de producción de extraer, fabricar y desechar.

Concepto EC


RENOVABLES
MATERIALES FINITOS
GESTIÓN DE FLUJO DE RECURSOS RENOVABLES
GESTIÓN DEL STOCK
RECOLECCIÓN AGRÍCOLA
MATERIA PRIMA BIOQUÍMICA
FABRICANTE DE PIEZAS
FABRICANTE DE PRODUCTOS
PRESTADOR DE SERVICIO
REGENERACIÓN
BIOSFERA
BIOGÁS
DIGESTIÓN ANAEROBIA
CASCADAS
EXTRACCIÓN DE MATERIA PRIMA BIOQUÍMICA
CONSUMIDOR
USUARIO
RECOLECCIÓN
RECOLECCIÓN
COMPARTIR
MANTENER/PROLONGAR
REUTILIZAR/REDISTRIBUIR
REACONDICIONAR/ REMANUFACTURAR
RECICLAR
MINIMIZAR LAS FUGAS DEL SISTEMA Y EXTERNALIDADES NEGATIVAS
1 Cazar y pescar
2 Puede usar el residuo poscosecha o posconsumo como insumo
FUENTE
Fundación Ellen MacArthur
Diagrama de sistemas de economía circular
(Febrero de 2019)
www.ellenmacarthurfoundation.org
Ilustración basada en Braungart & McDonough, Cradle to Cradle (C2C)
ELLEN MACARTHUR FOUNDATION

- **SInd** => factor propicio clave para lograr una economía circular
- las empresas independientes colaboran para **compartir servicios y recursos a fin de reducir los desechos y los costos, aumentar ganancias y reducir el impacto ambiental** (Laybourn y Morrissey, 2009)
- **La producción de una planta industrial será la entrada para otras plantas**, lo que puede mejorar los beneficios ambientales y económicos mediante la reutilización eficiente de los recursos materiales y energéticos (Martin y Eklund, 2011; Abdallah et al., 2012).



Se promueven recirculaciones de materiales y energía.

Referencia: V. Kuchinow, Fundadora y Directora de SÍMBIOSY

- La economía de la provincia de Tucumán y del Noroeste Argentino (NOA) es básicamente **agroindustrial**.

- En Tucumán, las dos actividades productivas principales tienen su origen en el cultivo de la **caña de azúcar** y del **limón**.

- SInd: naturaleza renovable de la materia prima permite obtener un abanico de productos y los desechos, a menudo constituidos por materia orgánica, pueden usarse como fuentes de energía para abastecer esos mismos procesos.

- Por lo tanto, desarrollar un enfoque de SInd en el área de la industria basada en la biomasa será un importante aporte a la bioeconomía provincial.

- Realizado una investigación de antecedentes
- **Planteo de un modelo de programación matemática tipo mixto-entero (lineal)**, a modo de prueba de concepto

Ingenio destilería

Citrícola

SInd

Papelera

Digestión anaeróbica

Tto efluentes

Residuos poda

Journal of Cleaner Production 64 (2014) 513–534

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Design of the optimal industrial symbiosis system to improve bioethanol production

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A R T I C L E I N F O

Article history:
Received 22 June 2012
Received in revised form
17 July 2013
Accepted 26 July 2013
Available online 14 August 2013

Keywords:
Industrial symbiosis system
Bioethanol production
Combined heat and power (CHP)
Closed loop production network
Bioenergy-based industrial symbiosis
Sustainability

A B S T R A C T

The emergence of environmental and sustainability regulations, such as Kyoto protocol, Energy Policy Act and the increasingly limited availability of fossil fuels has brought the notion of gradually substituting petroleum products with bioethanol into the limelight. Even though, bioethanol is one of the cleanest sources of energy, a major concern of bioethanol production is its economic feasibility. Industrial symbiosis is one of the sustainable strategies that can help to reduce bioethanol production and logistic costs. In industrial symbiosis, traditionally separate plants collocate in order to efficiently utilize resources, reduce wastes and increase profits for the entire industrial symbiosis and each player in the industrial symbiosis. This paper focuses on developing optimal configurations of bioenergy-based industrial symbiosis under certain constraints, such that the bioethanol production cost (or profit) is reduced (or increased). A decision framework that combines the Linear Programming models and large scale Mixed Integer Linear Programming model is proposed to determine the optimal configuration of bioenergy-based industrial symbiosis and to design the optimal network flows of various products in the bioenergy-based industrial symbiosis. A case study has been conducted to study the efficiency and effectiveness of the proposed model and the results suggest significant increase in profitability for biorefinery plant and the rest of the players in the bioenergy-based industrial symbiosis system.

Sensitivity analysis is also conducted to provide deep understanding of the proposed bioenergy-based industrial symbiosis system and to identify the factors that might impact the performance of biorefinery

$$\mathrm{Xu}^i_{\mathrm{ip}\in l_i,t} = \sum_{\mathrm{op}\in k_i} F\left(\mathrm{Xp}^i_{\mathrm{op}\in k_i,t}\right) \quad \forall i, \forall \mathrm{ip}, \forall t \tag{A.19}$$

Assumptions are made to use combined technologies at plants. For example, CHP plant and cement plant often use co-combustion technology to reduce environmental impacts and to gain economic benefits. Such combined technology for input products is given by Eq. (A.20). For such products, Eq. (A.19) does not hold.

$$\sum_{\mathrm{ip}\subset l_i} \mathrm{Xu}^i_{\mathrm{ip}\in l_i,t} = \sum_{\mathrm{op}\in k_i} F\left(\mathrm{Xp}^i_{\mathrm{op}\in k_i,t}\right) \quad \forall i, \forall t \tag{A.20}$$

The amount of waste produced is equal to the amount of waste disposed for any given time period is given by Eq. (A.21).

$$\mathrm{Xp}^i_{\mathrm{op}\in w_i,t} = W^i_{w_i,t} \quad \forall i, \forall w_i, \forall t \tag{A.21}$$

Appendix A2. MILP model formulation for BBIS system

The MILP model is developed to obtain optimal configuration of the BBIS system. Eq. (A.22) represents total savings where A.22(a)–A.22(k) are the part of objective function. Eq. (A.23) is a constraint that enables to consider only those solutions that have savings for each plant. Eq. (A.24) forces the inclusion of all the anchor tenants in BBIS. Eq. (A.25) gives the decision maker flexibility to select the number of plants that should be included in BBIS. This is provided such that the decision maker can make decisions based on the constraints such as space and financial availability to form BBIS system. Eqs. (A.26)–(A.37) represent the constraints for output products, and Eqs. (A.38)–(A.50) represent the constraints for input products.

The objective function is the maximization sum of the savings of all the plants throughout the planning horizon. Z_i^{BBIS} is the profit of each plant in BBIS. It consists of total revenue obtained by selling output products to market and coalition plants (in BBIS) minus total operational cost that include input product purchase cost, production cost of output products, inventory holding cost, backorder cost, delay cost and waste disposal cost. Z_i^{SA} is the result from LP model (Eq. (A.1)) which is profits of each plant when operating in

$$\mathrm{A.22(c)} = \sum_{\mathrm{op}\in k_i\cup b_i\cup w_i} \sum_t \mathrm{PC}^i_{\mathrm{op},t}\mathrm{Xp}^i_{\mathrm{op},t}$$

The total inventory holding cost for output products (A.22(d)) is calculated as follows:

$$\mathrm{A.22(d)} = \sum_{\mathrm{op}\in k_i\cup b_i\cup w_i} \sum_t H^i_{\mathrm{op},t} I^{i+}_{\mathrm{op},t}$$

Total backorder cost for output products in a given time period horizon (A.22(e)) is calculated as follows:

$$\mathrm{A.22(e)} = \sum_{\mathrm{op}\in k_i\cup b_i\cup w_i} \sum_t B^i_{\mathrm{op},t} I^{i-}_{\mathrm{op},t}$$

Total cost of input products purchased from market (A.22(f)) is calculated as follows:

$$\mathrm{A.22(f)} = \sum_{\mathrm{ip}\in\{k_j\cup b_j\cup l_i\}} \sum_t C^{\mathrm{mkt},i}_{\mathrm{ip},t} X^{\mathrm{mkt},i}_{\mathrm{ip},t}$$

Total cost of input products purchased from market under contract from market (A.22(g)) is calculated as follows:

$$\mathrm{A.22(g)} = \sum_{\mathrm{ip}\in\{k_j\cup b_j\cup l_i\}} \sum_t \mathrm{CC}^{\mathrm{mkt},i}_{\mathrm{ip},t} \mathrm{XC}^{\mathrm{mkt},i}_{\mathrm{ip},t}$$

Total cost of input products purchased from coalition plant (A.22(h)) is calculated as follows:

$$\mathrm{A.22(h)} = \sum_{\mathrm{ip}\in\{k_j\cup b_j\cup w_j\}} \sum_t C^{j,i}_{\mathrm{ip},t} X^{j,i}_{\mathrm{ip},t}$$

Total cost of input products that can be held during a given time horizon (A.22(i)) is calculated as follows:

$$\mathrm{A.22(i)} = \sum_{\mathrm{ip}\in\{k_j\cup b_j\cup w_j\cup l_i\}} \sum_t H^i_{\mathrm{ip},t} I^{i+}_{\mathrm{ip},t}$$

Total delay cost while procuring input products in any time period (A.22(j)) is calculated as follows:

$$\text{Max } Z = \sum_{i=1}^{g} W_i \left(Z_i^{\text{BBIS}} - Z_i^{\text{SA}} Y_i \right) \tag{A.22}$$

where

$$Z_i^{\text{BBIS}} = \text{A.22(a)} + \text{A.22(b)} - \text{A.22(c)} - \text{A.22(d)} - \text{A.22(e)} - \text{A.22(f)} - \text{A.22(g)} - \text{A.22(h)} - \text{A.22(i)} - \text{A.22(j)} - \text{A.22(k)} \forall i$$

The revenue obtained by selling final products and by-products to the market (A.22(a)) is calculated as follows:

$$\text{A.22(a)} = \sum_{\text{op} \in k_i \cup b_i} \sum_{t} P_{\text{op},t}^{i,\text{mkt}} S_{\text{op},t}^{i,\text{mkt}}$$

The revenue obtained by selling final products, by-products and waste product to the coalition plant (A.22(b)) is calculated as follows:

$$\text{A.22(b)} = \sum_{\text{op} \in k_i \cup b_i \cup w_i} \sum_{t} P_{\text{op},t}^{i,j} S_{\text{op},t}^{i,j}$$

The total production cost of output product for the entire time period horizon (A.22(c)) is calculated as follows:

$$\text{A.22(c)} = \sum_{\text{op} \in k_i \cup b_i \cup w_i} \sum_{t} \text{PC}_{\text{op},t}^{i} \text{Xp}_{\text{op},t}^{i}$$

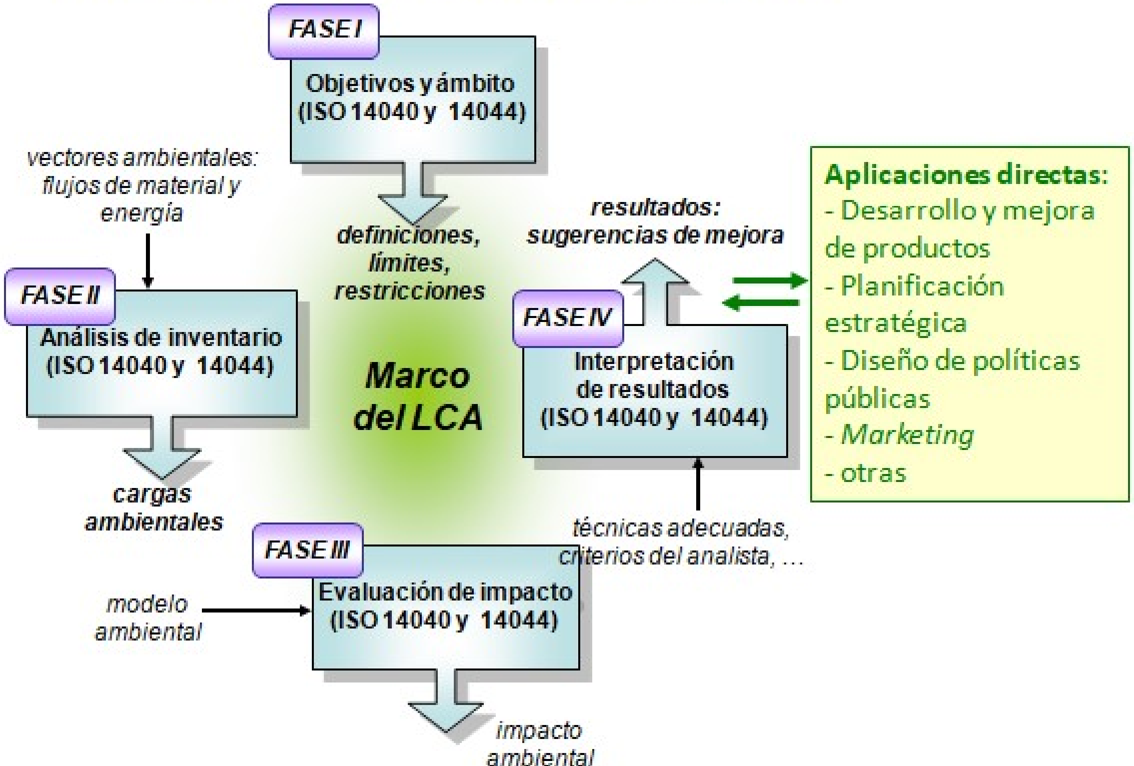
The total inventory holding cost for output products (A.22(d)) is calculated as follows:

$$\text{A.22(d)} = \sum_{\text{op} \in k_i \cup b_i \cup w_i} \sum_{t} H_{\text{op},t}^{i} I_{\text{op},t}^{i+}$$

ANÁLISIS DE CICLO DE VIDA

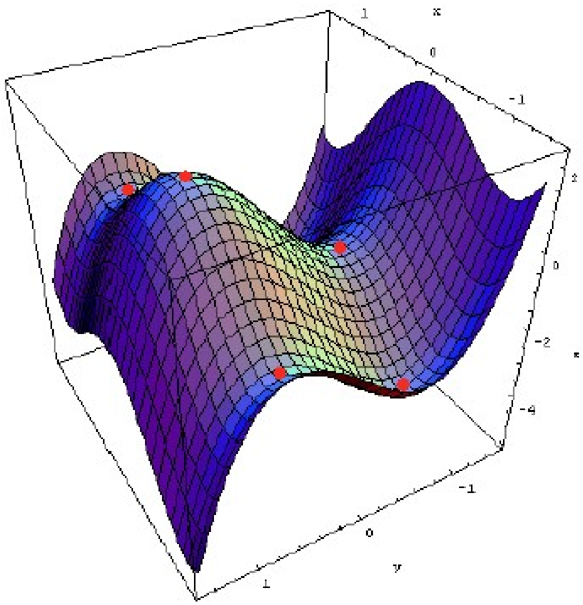
Life-Cycle Assessment (LCA)

Fases de un estudio de LCA



OPTIMIZACIÓN MULTIOBJETIVO

Búsqueda de un óptimo



Función objetivo 1 — *Indicadores económicos*

Función objetivo 2 — *Indicadores ambientales*

Función objetivo 3 — *Indicadores sociales*

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Programación matemática

Horas de Cursos

- **2014**. He finalizado la Maestría en Métodos Numéricos y Computacionales en Ingeniería de la FACET, por lo se realizará el pedido de convalidación de horas en la primera reunión de la Comisión de Supervisión de Tesis.
- **2020**. He realizado y aprobado la Diplomatura en Derecho Ambiental, de la UBA, acreditando 189 horas, las cuales se hallan también para la convalidación.

Muchas Gracias