Symbiosis between Industry and Agriculture

How industries can supply agricultural greenhouses

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Global agricultural production should increase by 70% to meet the food demands of a world populated with ca. 9.1 billion people in 2050, Bruinsma J., 2011

Global Agro-Ecological Zone (GAEZ v3.0) analysis suggests that there are vast acreages of suitable but unused land in the world (about 1.4 billion ha) that can potentially be exploited for crop production; however, these lands are distributed very unevenly across the globe, deemed to have very little or no land for expansion 2012.

globally available fresh water resources exceed current agricultural needs but due to their patchy distribution, an increasing number of countries, are experiencing severe water scarcity, Fischer, G., 2011

Iran : food self- sufficiency.

Ramin Roshandel, Department of Energy Engineering, Sharif University of Technology, 15/10/2019
The question **is not** if we should develop **greenhouses** or not!

but is **how to respond to such a demand** if it came into consideration?
Symbiosis Concept

Living Together!

Industrial symbiosis

Engages traditionally separate industries (entities) in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products, *Services and Information*

Reduce raw material and energy resources

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Symbiosis Vs. Recycling

Recycling can be a part of IS, but the concept of symbiosis is much wider than just recycling

- System approach (capturing, transportation, conversion, storage, distribution,...)
- Network concept (supply point, demand points)
- Beyond Material (energy, water, services, information,..)
- Keep independencies
- Social aspects (trust, Autonomy, Cooperation, Competence)

Kalundborg Symbiosis

Denmark

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Optimization framework

Optimization framework is developed to extend this approach

Integrates GIS, optimization and simulation framework for optimal greenhouse design and location in Switzerland

GIS analysis

Land availability and suitability

Energy supply models

Energy and power supply (temporal, spatial)

Optimization problem

Energy demand models

Energy and power demand (temporal, spatial)

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Energy demand model: heat

Heat demand model is a dynamic model
Minimum temperature is used

Heat demand (Energy and Power)

Greenhouse characteristics

Heat demand Model

Climate conditions

Peak Power demand for 1 hectare greenhouse

Heat demand Model

Greenhouse type: Venlo
Surface heat conductivity = 4 W/m².K
Minimum Indoor Temperature = 18°C
Ventilation coefficient = 2.16-6.16

60×110 cells
Energy supply model

Waste heat recovery from waste incinerators in Switzerland

Einheitliche Heizwert- und Energiekennzahlenberechnung der Schweizer KVA nach europäischem Standardverfahren, 2016

Marton 2012, KEZO
Key points from energy analysis

1. Averagely, around Swiss incinerators 1.87 MW (1.4-2.87) heating peak power is needed per hectare of greenhouses.

2. Total theoretical waste heat potential from waste incinerators is 6894 GWh or 861 MW heating power

3. Considering available heating power, 300 hectare greenhouse can be supplied.
Land suitability analysis

- CORINE Land Cover
- Agricultural area (arable lands, heterogeneous agricultural area)
- Geometric accuracy, 100 m
- Switzerland is extracted by mask
- ESRI and GeoTiff

https://land.copernicus.eu/pan-european/corine-land-cover
Conclusions

1. **Optimum Location of greenhouses** affected by energy supply, energy demand and available suitable land

2. **Waste heat potential from waste incinerators in Switzerland to supply greenhouses for Zero Food Import Scenarios (tomato, lettuce and cucumber):**
   
   - **Energy:** 10% of the waste heat
   - **Peak power:** 60% of the waste heat
Outlooks

- **Integrated biogas plants/greenhouse systems**: heat and CO$_2$ demand-supply models
- **Net zero energy greenhouses**: Photovoltaic power plants Agro-complex systems, demands are beyond greenhouse
- **Entities viewpoint**: economic justification, business plan
- **Comparison**: Iran and Switzerland
Application of manure based biogas as heat source for greenhouses
System Analysis

Manure → Biogas facility → CHP → CO₂ → Electricity → Electricity Market (Grid)

Manure → Biogas → Heat → Crop

Electricity → Heat → Greenhouse → Food Market

CO₂ → Digestate → CO₂

Farm
Carbon Footprint of Greenhouse Products

First Approach
Modelling the carbon footprint of greenhouses with 12 month production

Model Greenhouses

Supplementary Lighting Model
Method I: Lighting Plan
Method II: Target DLI

Second Approach
Carbon Footprint of greenhouse case studies with supplementary lighting

Carbon Footprint of the consumption mix

Tomato  \( \text{gr CO}_2 \text{ eq. /kg}_{\text{tomato}} \)

Cucumber  \( \text{gr CO}_2 \text{ eq. /kg}_{\text{cucumber}} \)

Lettuce  \( \text{gr CO}_2 \text{ eq. /kg}_{\text{lettuce}} \)

Supplementary Lighting Model

Greenhouse Infrastructure (A typical Venlo)  
(aluminum, steel, concrete, glass)

Greenhouse Agriculture  
(fertilizer, pesticide, CO\textsubscript{2} enrichment)

Greenhouse Energy  (waste heat)  
(electricity for Lighting and water pumping)
Scenarios

Different stages in comparison of two scenarios

### Carbon footprint of greenhouses with 12 month production

<table>
<thead>
<tr>
<th>Stage</th>
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<tbody>
<tr>
<td>Structure</td>
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<tr>
<td>Fertilizer</td>
</tr>
<tr>
<td>Lighting</td>
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<tr>
<td>CO₂ enrichment</td>
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<td>Water use</td>
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<td>Other Impacts</td>
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### Carbon Footprint of the consumption mix

<table>
<thead>
<tr>
<th>Category</th>
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<tbody>
<tr>
<td>Farm machinery use</td>
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<tr>
<td>Fertilizers</td>
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<tr>
<td>Greenhouse heating</td>
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<tr>
<td>Emissions to air</td>
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<td>Storage</td>
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<td>Transport</td>
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<tr>
<td>Water Use</td>
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<td>Other Impacts</td>
</tr>
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<td>Greenhouse Structure</td>
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</tbody>
</table>
Comparison of two scenarios

Greenhouse heating is the **most significant** contributor

Transport impacts are relatively low

Lower impacts for Lettuce due to its **open filed** origin
به‌مانند آماده‌ی دفتر

ظکاپت بی‌حجار باقیت