e-Symbiosis: a technology-enabled industrial symbiosis targeting SMEs and innovation

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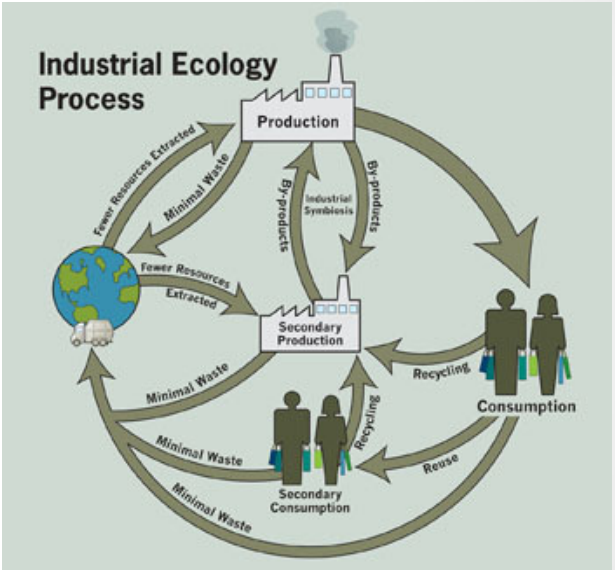
Outline

- Introduction
  - Different IS models, benefits and limitations
- Challenges and the systems approach
  - Discoveries, systematization, knowledge enablers
- Proposed systems approach
  - Real-life application domain
  - Ontology engineered application
  - Knowledge acquisition and support
- Prototype system impementation
- Work in progress and future applications

Industrial Symbiosis: what is it?

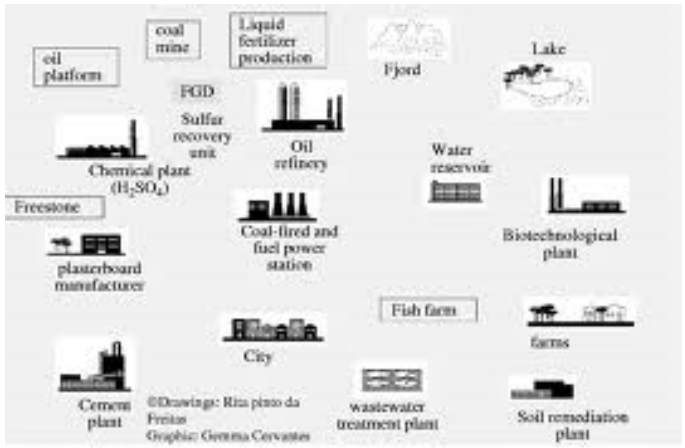
- The use of waste streams as resources to other industries (materials, energy)
- Essential part of Industrial Ecology
  - Closed life cycles
    - Material flows
    - Energy flows
- Differences from recycling
- Often preferred over recycling
  - Long recycle paths
  - Expensive footprints



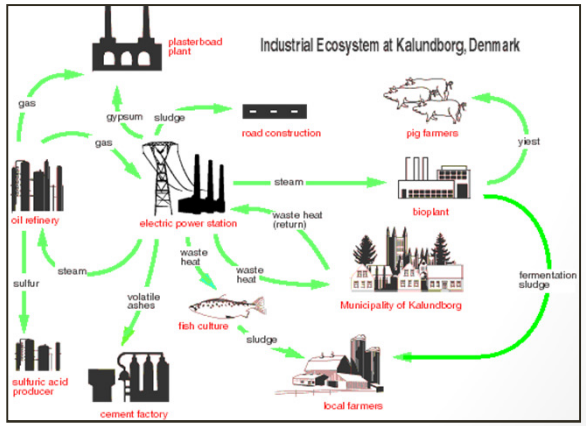
When and how it has been used so far?

Closed operational models

- City of Kalundborg (1995)
  - Fixed background: Kemira, Statoil, Asnaes Power, Gyproc Novo Nordisk
  - M$120 profits; Energy to 20,000 homes
  - Significant investment (M$60)
  - Long paypack times 9 (over 15yr)



Source: G.Cervantes



Open operational models

- Source-to-sink model
- Failure attributed as
  - Regional aspects are key for success
  - Trade complexity beyond conventional models (e.g. ebay)

- Europe: collaborative projects with national and local authorities
  - UK - National (NISP)
  - Rest of Europe: regional

Benefits from open models (NISP, UK)

- Participation:
  - 9,300 companies, 12 regions, 12,000 transactions/yr
- Economic benefits:
  - Revenues & sales – €167,5 million
  - Cost savings – €106,8 million
- Social benefits
  - Regional investment - €82 million
  - New jobs – 3,000
- Environmental benefits:
  - CO2 emissions reduction : 4.4 mt
  - Savings of virgin material: 6.2 mt
  - Water savings: 9.22 million tons
  - Diverted waste from landfill: 3.39 million tons
  - Diverted toxic from landfill: 350, 000 tons

Limitations of current state

- Synergy accomplished through
  - brute force investigation,
  - serendipitous discovery and organized workshops
- Use of knowledge
  - Intuitively dependent on practitioners' ability
  - No modelling of tacit knowledge
- Manual handling of large amount of data
  - waste, technology, industries and logistics
- Difficult to apply in rapidly increasing industrial diversity
- Limited participation of SMEs

Challenges and the systems approach

- Complex representation for concepts and properties
  - Multiple descriptions of material and energy flows
  - Significant amount of tacit knowledge (technologies, chemistries)
- Multiple roles of participants
- Unstructured information from different sources

Instead, one should

- Formalize system components and knowledge
- Synergies to produce as a matching process to optimize a selected criterion with degrees of freedom
  - Sources and sinks
  - Technologies available

Why semantics and ontology engineering?

- Fuzzy descriptions of systems components
  - Material/energy streams: fuzzy & multiple descriptions (e.g. *wood, biomass, sludge, scrap paper/ metals*; *biofuels*, *solid fuels*)
  - Technology enablers: fuzzy, incomplete links with sources and sinks (not a process flowsheet!)
- Challenges on integration
  - Primal data, text, background knowledge (chemistries, technologies, supporting material)
- Challenges on knowledge representation:
  - Aside best practice a significant potential to discover latent matches

Outline of proposed approach

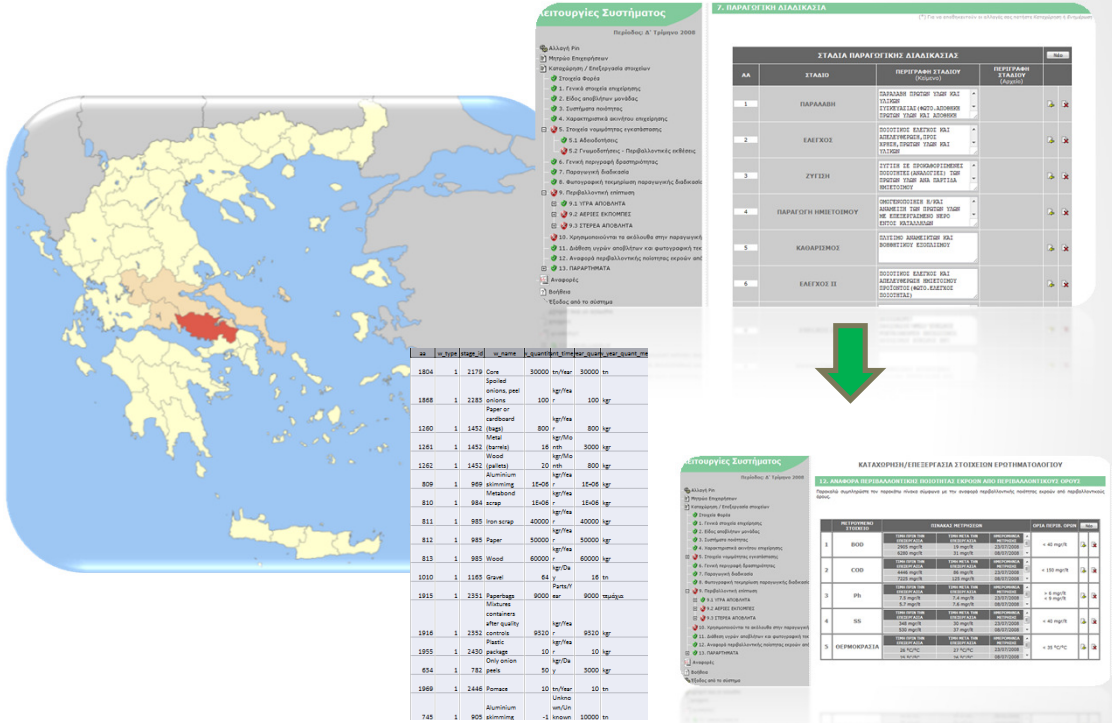
- Collection and storage of background data
  - Real-life project, 1,500 industries, > 500 technologies and >4,000 streams
- Ontology engineering
  - Represent systems components:
    - Internal data: material and energy streams, roles, technologies
    - External data: knowledge enablers, enabling technologies, text reports (e.g. best practice reports)
- Implementation: assist
  - Industries to find matching partners
  - Regions to develop and embrace technologies

(a) Domain and background data

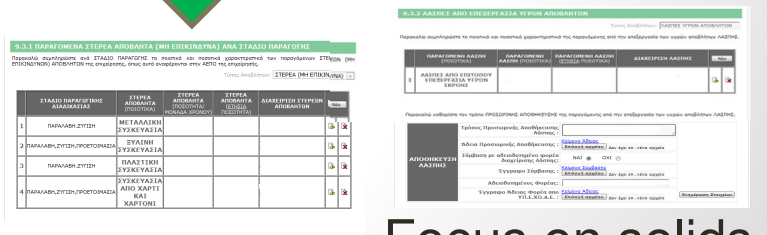
Internal and external data

- RSE (Viotia): largest industrial region
- Internal data
  - Material flows
  - Waste stream specs
  - Locations
  - Secondary data
    - Context description
    - Inspection audits
    - Commercial profile
- External data
  - Technologies
  - Knowledge base

1,500 production facilities



4,500 waste streams



Focus on solids

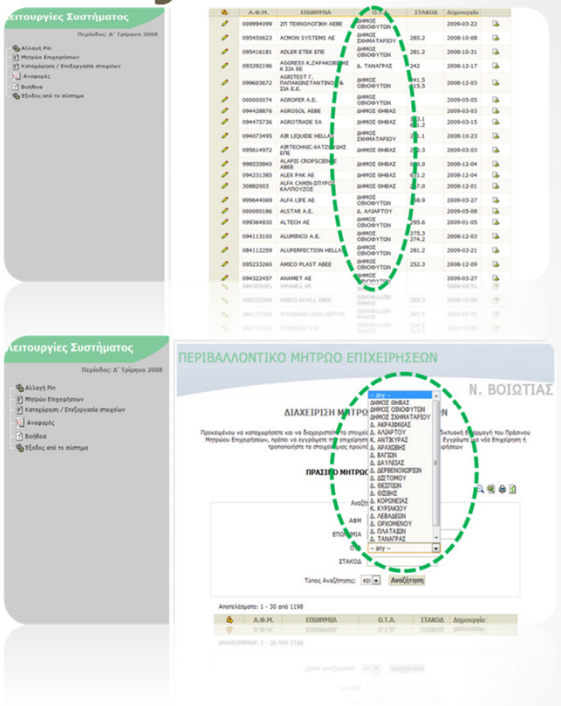
Internal primary and secondary data

- Materials

stage_id	w_name	w_quantity	ant_time_	year_quant	w_year_quant_meas
2179	Core	30000	tn/Year	30000	tn
2283	Spoiled onions, peel onions	100	kgr/Year	100	kgr
1452	Paper or cardboard (bags)	800	kgr/Year	800	kgr
1452	Metal (barrels)	16	kgr/Month	3000	kgr
1452	Wood (pallets)	20	kgr/Month	800	kgr
969	Aluminium skimmimg	1320000	kgr/Year	1320000	kgr
984	Metabond scrap	1000000	kgr/Year	1000000	kgr
985	Iron scrap	40000	kgr/Year	40000	kgr
985	Paper	50000	kgr/Year	50000	kgr
985	Wood	60000	kgr/Year	60000	kgr
1163	Gravel	64	kgr/Day	16	tn
2351	Paperbags	9000	Parts/Year	9000	τεμάχια

- Locations

THIVA
OINOFITA
SCHIMATARY
AKRAIFNIA
ALIARTOS
ANTIKIRA
ARACHOVA
VAGIA
DAVLIA
DERVENOXORIA
DISTOMO
THESPIES
THISVI
KORONIA
KIRIAKI
LEVADIA
ORCHOMENOS
PLATEES
TANAGRA
CHERONIA



- Industries

id	doy	activity	activity_code	al_fdta	edra_tk	activ_town	activ_tk	activ_town	categ_type	eg_stak	y_ty	staff	shifts	env_person_specialty	cont_person_specialty
6	FAVE ATHENS	COFFEE RAOSTING	00000	SA	2 12241	AIGALEO	32011	OINFYTA	ROASTING COFFEE	158.6	B	5	1	CHEMICAL ENGINEER	MANAGER
8	THEBES	CONSTRUCTION BOATS UP TO 12	35120	SA	3 32009	SCHIMATARI	32009	SCHIMATARI	CONSTRUCTION BOATS UP TO 12	351.2	B	44	1	N / PRODUCTION MANAGER IOs / HOSPITAL QUALITY MANAGEMENT	N / MANAGING DIRECTOR
9	FAEE ATHENS	COMMERCIAL WAREHOUSE	51431	SA	3 11145	ATHENS	32009	WINES SCHIMATARI	COMMERCIAL	000.0		56	1		FINANCIAL DIRECTOR
10	THIVON	DISTILLERY, PRODUCTION , BOTTLING AND LIQUOR TRADE	11111	SA	3 32009	SCHIMATARI	32009	SCHIMATARI	DISTILLERY, PRODUCTION & BEVERAGE BOTTLING	159.1		12	1		PRESIDENT K D / MANAGING DIRECTOR
11	THIVON	PAPER AND CARTON PRODUCTION	21210	SA	3 32009	SCHIMATARI	32009	SCHIMATARI	INDUSTRY CARTON	212.1		74	2	MECHANICAL	TECHNICIAN DIRECTOR
12	GIT PIRAEUS	CONSTRUCTION LUMINAIRES	00000	SA	3 14452	MOSCHATO-Athens	32009	SCHIMATARI	Industrial luminaires	000.0		14	1	PRESIDENT & FACTORY MANAGER	DIRECTOR
13	FAVE THIVON	BED MATTRESS, HEADBOARDS,PILLOWTOP CONSTRUCTION	00000	SA	3 0	NEW Eritrea	32200	SCHIMATARI	BED & LAYER FACTORY	361.5		48	1	PRODUCTION MANAGER	ACCOUNTANT

Industries with their stakod code, address, activity

Secondary data

- Data which may be used later. These are:
  - ✓ Toxic waste
  - ✓ Environmental records
  - ✓ IPPC Techniques
  - ✓ Liquid disposal
  - ✓ Production stages

Significant scope to improve data
- Physical properties of resources
- Volumes available to trade
- Cost of disposal

External data: best practice

- Resources
  - published and free accessible data
- Primal target site: NISP (UK)
  - About 300 cases in text form
  - http://nisp.org.uk/case_study_index.aspx
- Challenge:
  - translate cases into sharable knowledge
  - Build components compatible with reference data

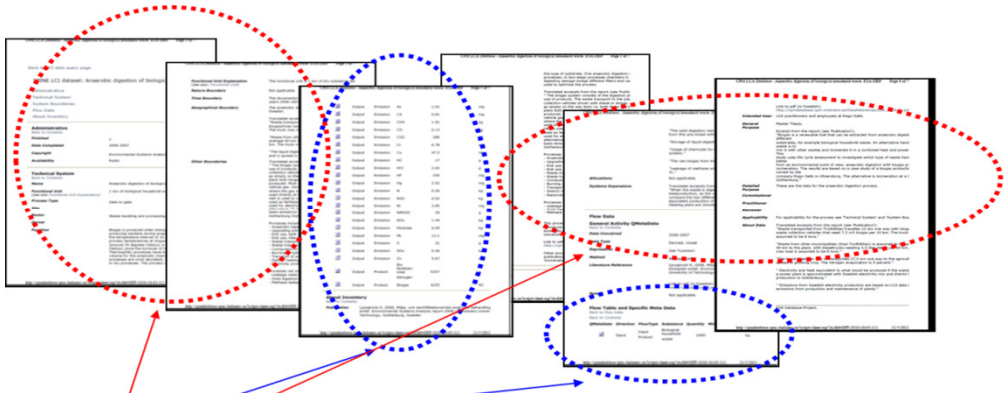
NISP in Action: Full list of CaseStudies

- Oxford University Teaches a Lesson in Recycling
- Homes Built With a Green Heart
- NISP Feeds Appetite for AD
- GWE Biogas Leads the Field
- Resource Efficiency Achieves Significant Savings
- Companies with chemistry
- Board waste finds new energy solution
- A glass act
- Staging a sustainable performance
- Mapping out route to waste reduction
- Uniform solution stacks up
- Valuable relationship building
- Turning the tables on ceramics
- Beloved zero waste goal on target
- Recipe for packaging success
- Parker zeros in on media waste
- Reuse of Insulation Materials
- Patton the back for NI construction firms
- Eggs-cellent Synergy
- Hostas to Hospices
- Looking further afield at home delivers sales abroad
- London Construction Sector Workshop 12.11.09

External data: enabling technologies

- Different resources
  - e.g. LCI db with 700 entries
  - High quality data, still very different perspective from IS

Example: biogas process



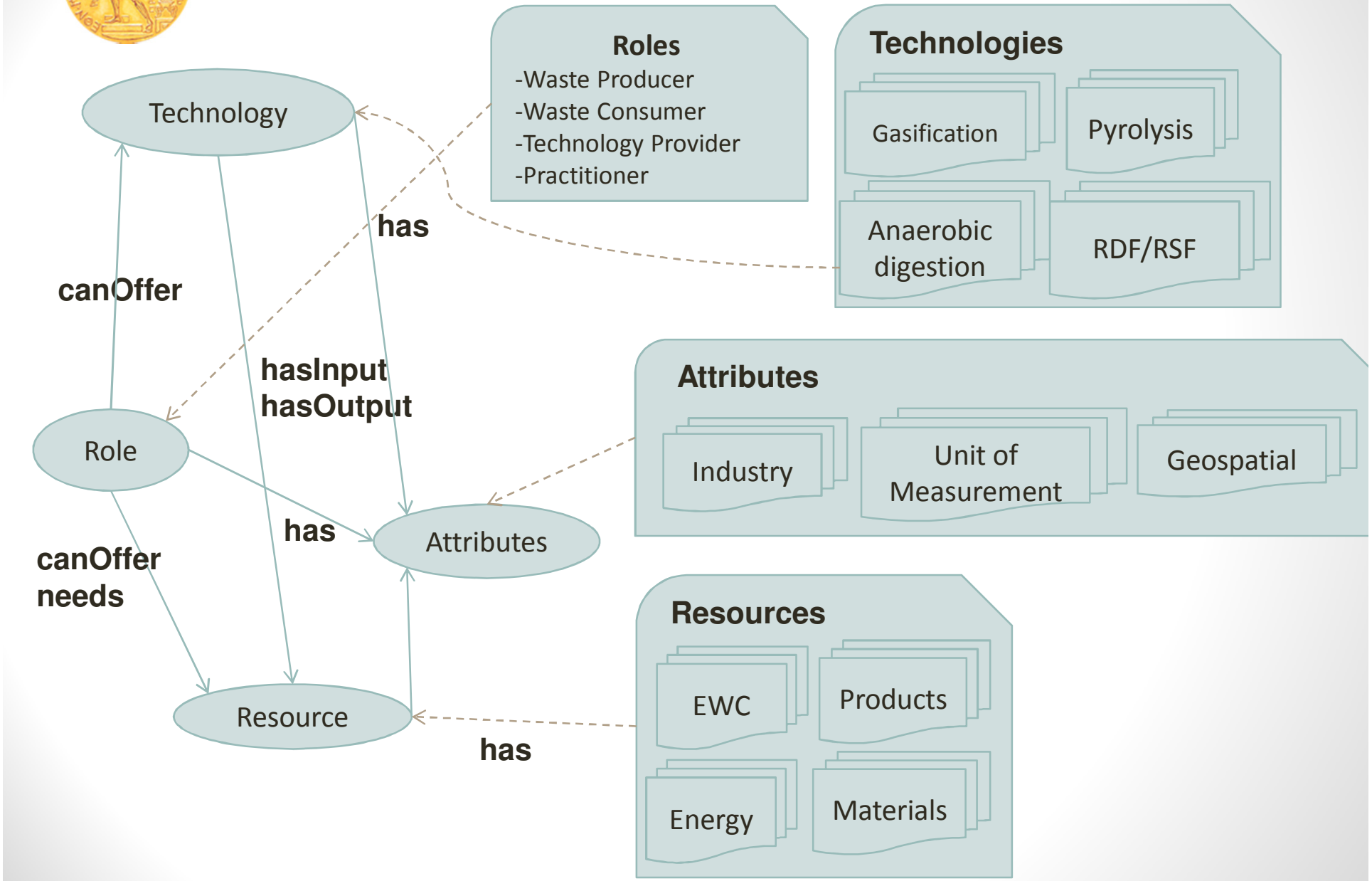
- Only part of the technology is useful
- Other part should be stored as secondary data
- Descriptions expand for over 550 processes

(b) Ontology engineering

Ontology engineering

- System representation, domain vocabulary
  - Classification, class hierarchy, properties of classes
  - Tackling heterogeneity
- Use of ontologies
  - Workflows, service description, matching process
  - Storing relevant data/information/knowledge
  - Reasoning and automation
- Modelling, populate with instances
  - implicit and explicit knowledge, knowledge in machine-understandable format
  - relations in domain of discourse

System representation

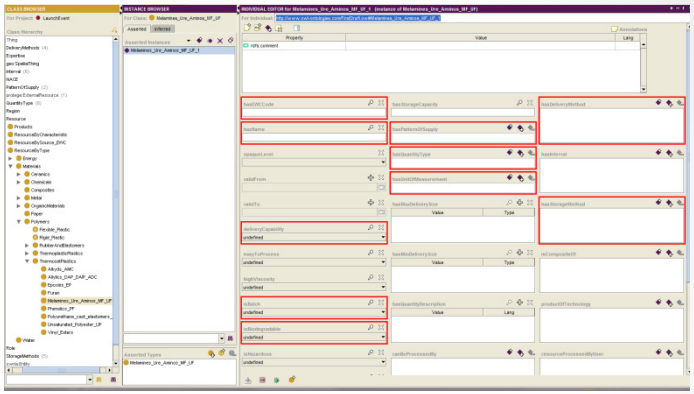


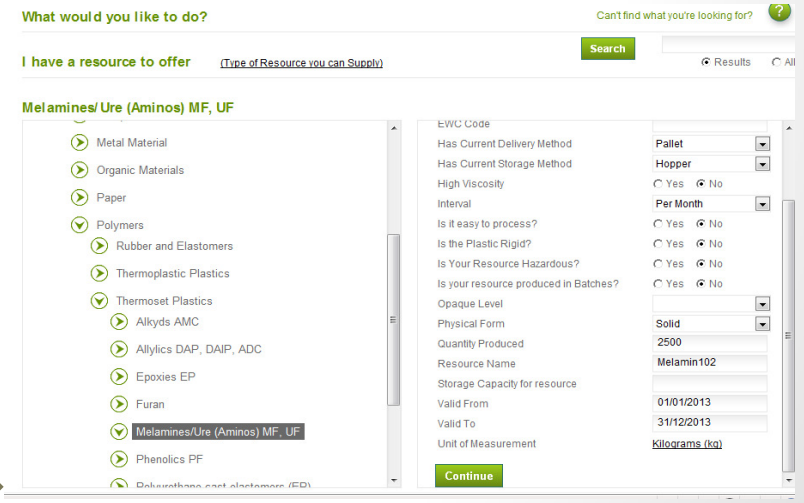
Basic classification

- **Biomass**
  - Solid Biomass
    - Wood/Wood Waste
    - Sulphite Lyes (Black Liquor)
    - Other Primary Solid Biomass
    - Charcoal
  - Liquid Biomass
    - Biogasoline
    - Biodiesels
    - Other Liquid Biofuels
  - Gas Biomass
    - Landfill Gas
    - Sludge Gas
    - Other Biogas
  - Other non-fossil fuels
    - Municipal Wastes (biomass fraction)

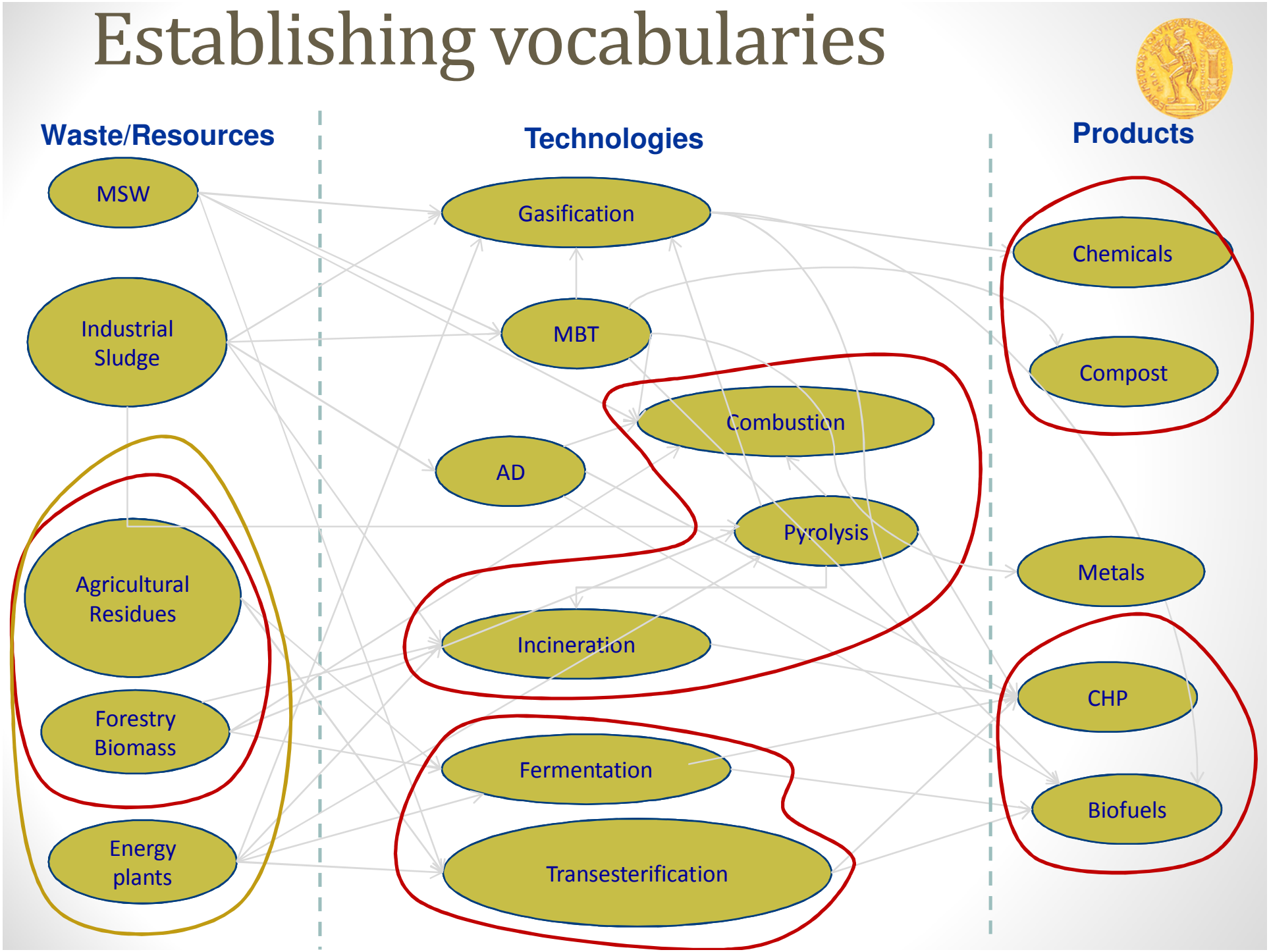
- **Organic Matter**
  - Food Waste
  - Animal Waste and Feedstock
  - Biodegradable Polymers
    - Biomass Products
      - Starches
        - Wheat
        - Potatoes
      - Ligno-cellulocic products
        - Wood
        - Paper
        - Straws

- **Technologies**
  - Pre-treatment
    - Cleaning
    - Washing
    - Shredding
    - Crushing
  - Main Conversion
    - Mechanical
    - Thermal/Thermochemical
      - Pyrolysis
      - Incineration
    - Biological
      - Anaerobic Digestion
      - Composting
    - Hybrid
  - Separation
    - Purification





Establishing vocabularies



Ontologies on workflows (registration)

- Information is translated into a semantic service description framework **(OWL-S)**
- Every user will be an instance of the OWL-S ontology
  - provides a way to describe the services offered or required by the users.
  - has been modified to incorporate properties related to the IS resources, used for matching

Capturing knowledge from best practice

Source | Material | Application | Quantity, Capacity

ΠΕΡΙΓΡΑΦΗ	ΠΗΓΗ	ΧΡΗΣΗ	ΟΓΚΟΣ	CARBON REDU
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΓΥΑΛΙ	Γυαλί από παράθυρα σε βαγόνι	Σε επιφάνειες κουζίνας	4	11
ΞΥΛΟ - ΣΥΣΚΕΥΑΣΙΑ	Ρεύματα πλαστικών, μετάλλων, ξύλου από συσκευασία	Ξύλο Στρώμνες ζώων -> animal bedding,	863	2533
ΠΛΑΣΤΙΚΑ - ΣΥΣΚΕΥΑΣΙΑ		Πλαστικό-> Ανακύκλωση ->ΠαλέτεςHDPE		
ΜΕΤΑΛΛΑ		Μέταλλα -> Ανακύκλωση		
ΠΛΑΣΤΙΚΑ - ΕΛΑΣΤΙΚΑ				
ΠΛΑΣΤΙΚΑ - ΕΛΑΣΤΙΚΑ	Δεματα ελαστικών	Κατασκευή διώρυγας	40000 λίρες	375
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΕΝΔΥΣΗ	Στολές εργατών	Αφαίρεση logos μοίρασμα σε εθελοντές	70 λίρες	19
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΚΕΡΑΜΙΚΑ	Ρεύμα κεραμικών	Ανακύκλωση (1. ανάκτηση υλικών MRF, 2. Πώληση ανακυκλώσιμων)	3936 (3880ceram,	596
ΤΡΟΦΙΜΑ	Υλικά από την παραγωγή τροφίμων	Επεξεργασία τροφίμου και χρήση για ζωοτροφή	97% of waste	1620
ΧΑΡΤΙ, ΠΛΑΣΤΙΚΑ	Απορρίμματα χαρτιού, χαρτόνι πολυαιθυλενίου	Κομποστοποίηση αποβλήτων και δημιουργία προιόντων για αγρότες	40	103
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΔΟΜΙΚΑ	Μονωτικά υλικά παλιών εγκαταστάσεων	Επαναχρησιμοποίηση σε νέες εγκαταστάσεις		
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΔΟΜΙΚΑ	Δομικά εργα (υλικά)	Σε άλλα έργα	[illegible]	270
ΞΥΛΟ - ΣΥΣΚΕΥΑΣΙΑ	Συσκευασία τυριού cheddar (ξύλινη)	Στρώμνες ζώων. Ανάμειξη με άλλα υλικά για ροκανίδι	[illegible]	37
ΤΡΟΦΙΜΑ	Απόβλητα παραγωγής αυγών (χαρτόνια ,τσόφλια)	Λίπασμα	540	1487
ΞΥΛΟ	Ανακυκλωμένο ξύλο	Βιομάζα, στρώμνες ζώων	[illegible]	5026
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΔΟΜΙΚΑ	Απορριπτόμενες γυψοσανίδες	Λίπασμα	[illegible]	2860
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΔΟΜΙΚΑ	Ανακυκλωμένα υλικά	Ανακατασκευή του κέντρου του Petersburg	3200	1500
ΜΕΤΑΛΛΑ	Κατεσκευή μεταλλικών πτερυγίων (ρινίσματα μετάλλου	Ανάκτηση μετάλλου	80	153
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΔΟΜΙΚΑ	Συντήρηση κτιρίων (σκυρόδεμα σπασμένο)			
	Υγειονομική ταφή	Αδρανή υλικά	20340	2099
ΑΔΡΑΝΗ ΥΛΙΚΑ	Εταιρία παραγωγής οπτικών μέσων -> πλεόνασμα cd	Πώληση από τις φυλακές όπου και διαχωρίζεται (κάρτα, πλαστικό)	4407	342
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΑΜΜΟΣ	Άμμος από χυτήριο	Άσφαλτος, τσιμέντο, τούβλα	498	49
ΧΗΜΙΚΑ	Παραγωγή λυματολάσπης (παραγωγή ιλύος)	Λίπασμα		
ΜΕΤΑΛΛΑ	Αντικατάσταση των railway ballast (έρμα σιδηροδρομι	Έργα οδοποιίας	99% του αρχικού υ	8
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΕΝΔΥΣΗ	Βιοτεχνία ρούχων , παπουτσιών	Υπόλοιπα υφασμάτων δίνονται σε ομάδες τέχνης και για βιοτεχνικές δραστηριότητες	225	4085
ΞΥΛΟ - ΕΠΙΠΛΑ	Έπιπλα γραφείου	Δωρεά	1	1
ΑΔΡΑΝΗ ΥΛΙΚΑ - ΔΟΜΙΚΑ	Οικοδομικά υλικά (απόβλητα)	Έργα οδοποιίας	25000	118
ΞΥΛΟ	Κατασκευαστική (κόντρα πλακέ ξύλα)	Ράμπες εισόδου, τουαλέτες	9	3

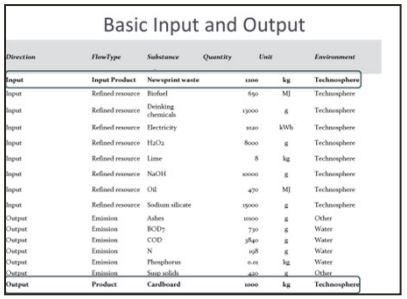
- Triplets produced for 250 cases and include
  - Source
  - Use
  - Volume
- Use of linked-objects
- Translated as properties to appropriate concepts

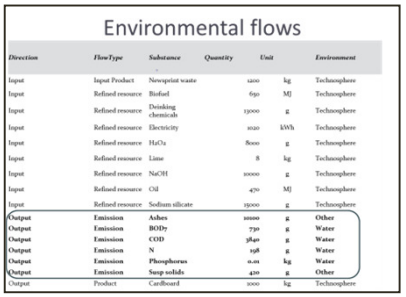
Stakod Code			Description
Main Category	1st	2nd Subclass	
01			Agricalture,livestock, hunting and related service activities
	011		Arable crops
		011.1	Cereal crops for grain and rice
		011.2	Tobacco grain
		011.3	Cotton grain
		011.4	Potato grain
		011.9	Other arable crops
		012.5	Growing seedlings
	014		Livestock
	015		Mixed farming
		016.2	Cotton ginning
15			Food and beverages industries
	151		Production processing and preserving of meat
		151.1	Production and preserving of meat
	152		Processing and preserving of edible fish and their products
	153		Processing and preserving fruits and vegetables
	154		Construction of vegetable and animal oils and fats
		154.1	Oil mill
		154.4	Production of margarine and similar edible fats
	155		Production of diary products
	156		Construction of grain mill products, starches and starch products
	157		Construction of prepared feeds
	158		Production od other kind of food

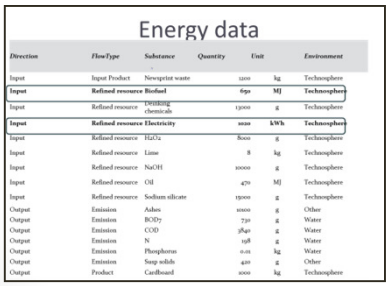
Technology blocks

- Technologies: enablers of matches
- Not readily available from external resources
- Input/output high-level representation
  - Material and energy flows
  - Cost/economics
  - Environmental indicators
- I/O irrelevant to IS match rather than the exact chemical substances involved

Technology repository







Process: Cleansing of glass containers

Input: Electricity 0.023MJ

Process: Production of fertiliser

Input: Oil, heavy fuel 2.51MJ

Process: Sorting of solid municipal waste

Input: Electricity 5750000kWh

Input: Mixed solid waste 230000ton

Output: Biowaste 28500ton

Output: Waste to incineration 149500ton

Output: Waste to landfill 23000ton

Output: Waste to recycling 29900ton

Process: Treatment of oil-contaminated waste water

Process: Cable assembly

Input: 2-deoxyinosine-5-diphosphate (DIDP) 0.051g

Process: Solid waste management

Input: Diesel fuel 138000l

Input: Mixed solid waste 230000ton

Input: Electricity 6727.7MWh

Input: Natural gas 34385m3

Output: Compost 12504.5ton

Output: Electricity 74100MWh

Process: Production of plastic strips and film

Input: Electricity 1.02MWh

Input: Ethylenevinylalcohol 0.015869565ton

Input: Fuel gas 0.00173913ton

Input: Fuel oil 0.004021739m3

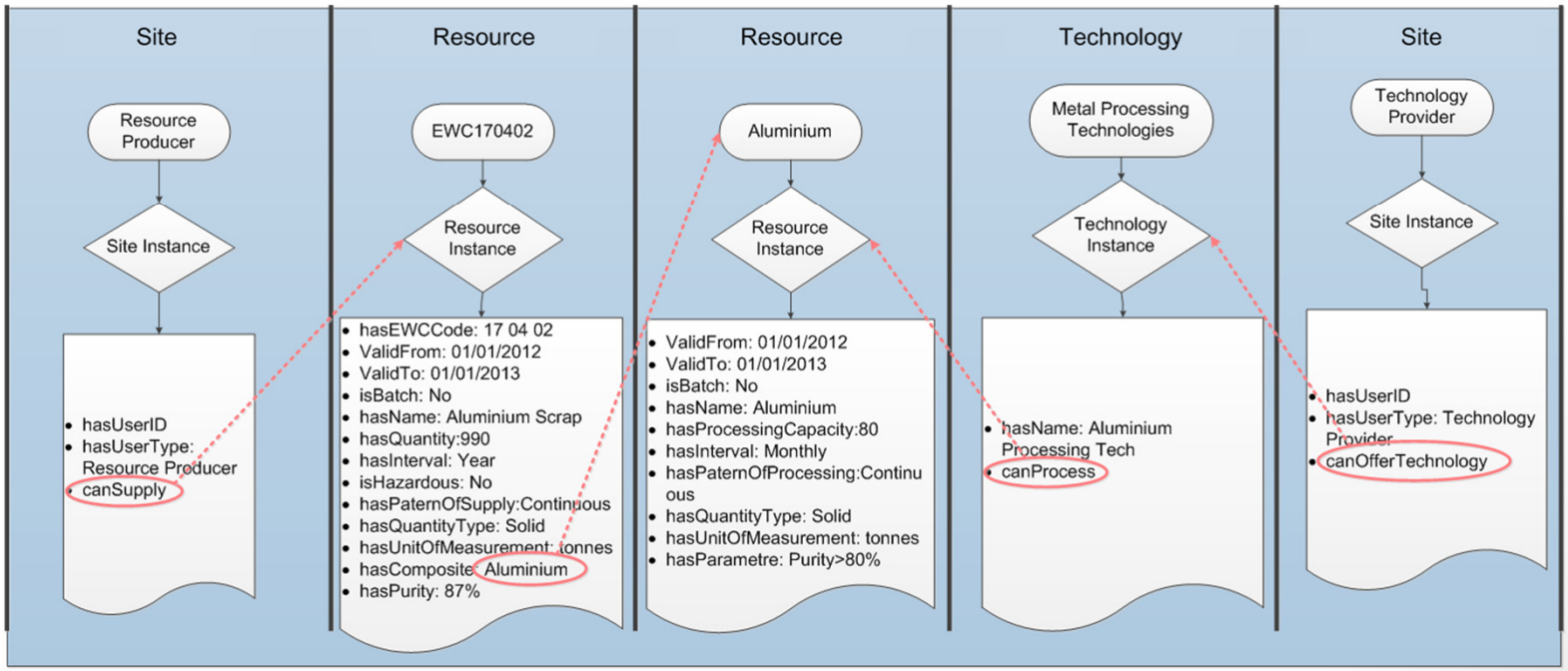
Input: HDPE 0.186304348ton

- About 500 processes available for storage

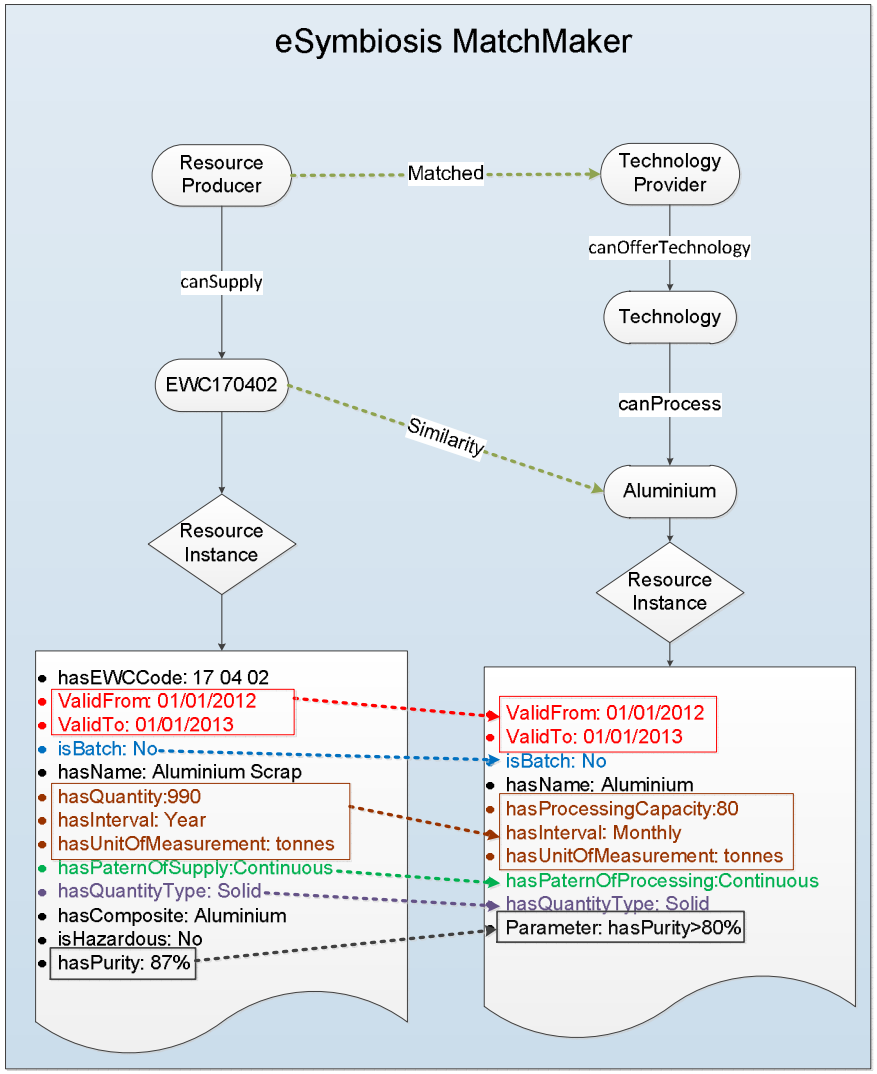
Reasoning and technology integration

Activity: Invested and co-invested steel pipes production			
Resource	Quantity	Unit/Interval	Parameters
Aluminium	990000	kgr/Year	Purity: 87%
Plastics	110000	kgr/Year	

Activity: Production (melting and casting) of copper, zinc, alloys and special alloys				
Technology	Input	Output	Parameters	Capacity/Interval
Technology 1	Aluminium	Aluminium Products	Purity>80%	80000 kg/month
Technology 2	Iron	Iron Alloys	Hardness<310	100000 kg/year



Industrial matching



How about strategic decisons?

Example: Potential to use pyrolysis

What is the potential to set up a pyrolysis unit in the region?

- Input: plastics, biomass, MSW among others
- Output: oil, biogas, biochar/coal

But,

- what is the local market for
  - Coal?
  - Gas?
  - Fuel oil?

Use of technology units

- Preliminary search indicates
  - 206 types of industries that use coal and could possibly replace it with **charcoal**
  - 196 processes that use natural gas, biogas or LPG and could possibly replace it with **pyrolysis gas**
  - 45 processes that use fuel oil and could possibly replace it with **bio-oil**
  - 51 processes that use heavy oil, petrol or gasoline and could possibly replace it with **bio-oil**
- Input/output models provide indicative flows, however, opportunities depend on specific capacities, locations and specific demands

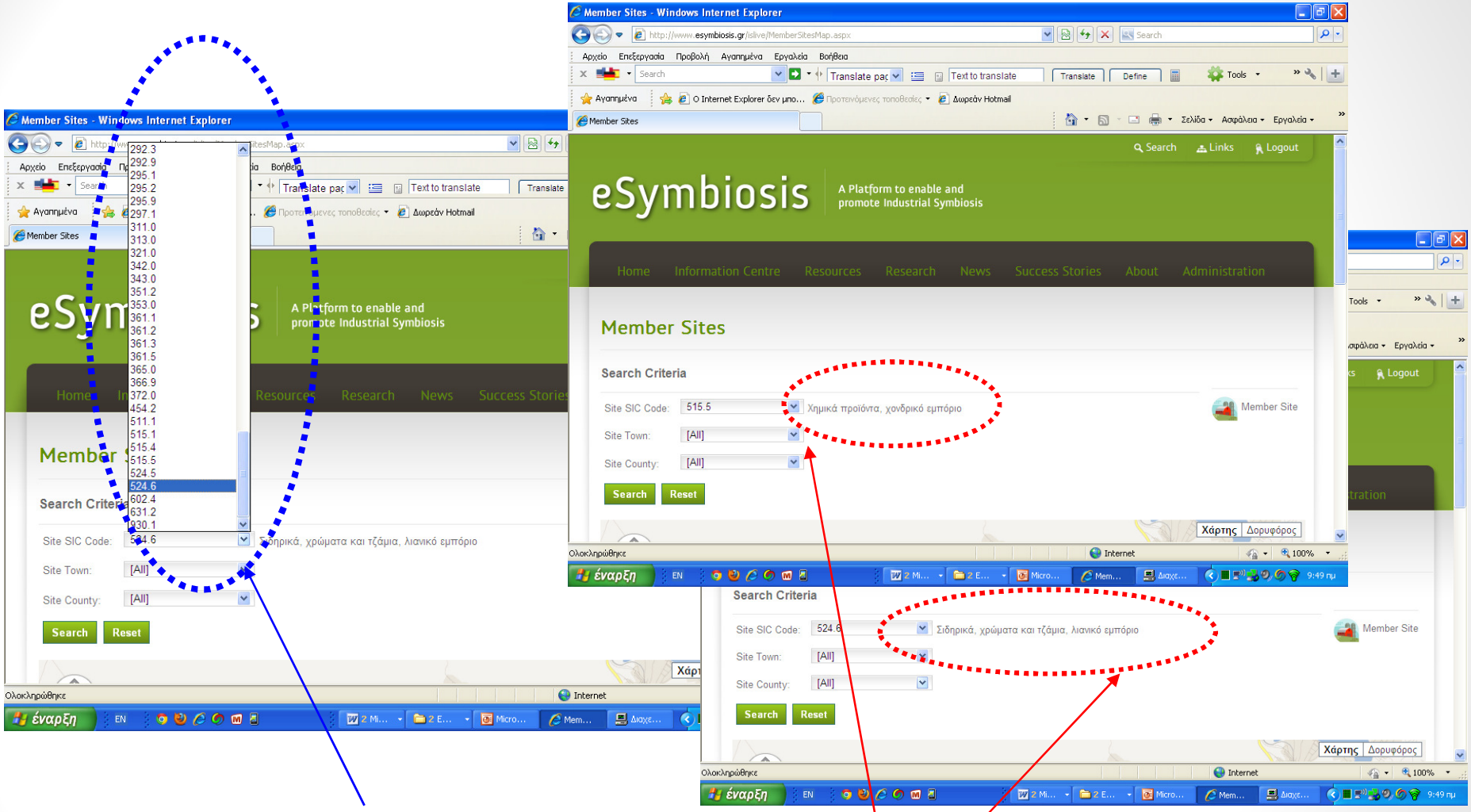
(c) Implementation and decision support

Integration steps and results

- Industries
  - Links with SIC codes, short text descriptions, number of companies
- Locations
  - Translated into long/lat locations, link with GIS system for visualization
- Materials
  - Material description (some available, still not stored)
- Pre-processing and post-technologies
  - Bottom-up approach: as driven by Viotia streams
  - Top-down: as available by technology providers and engineering teams

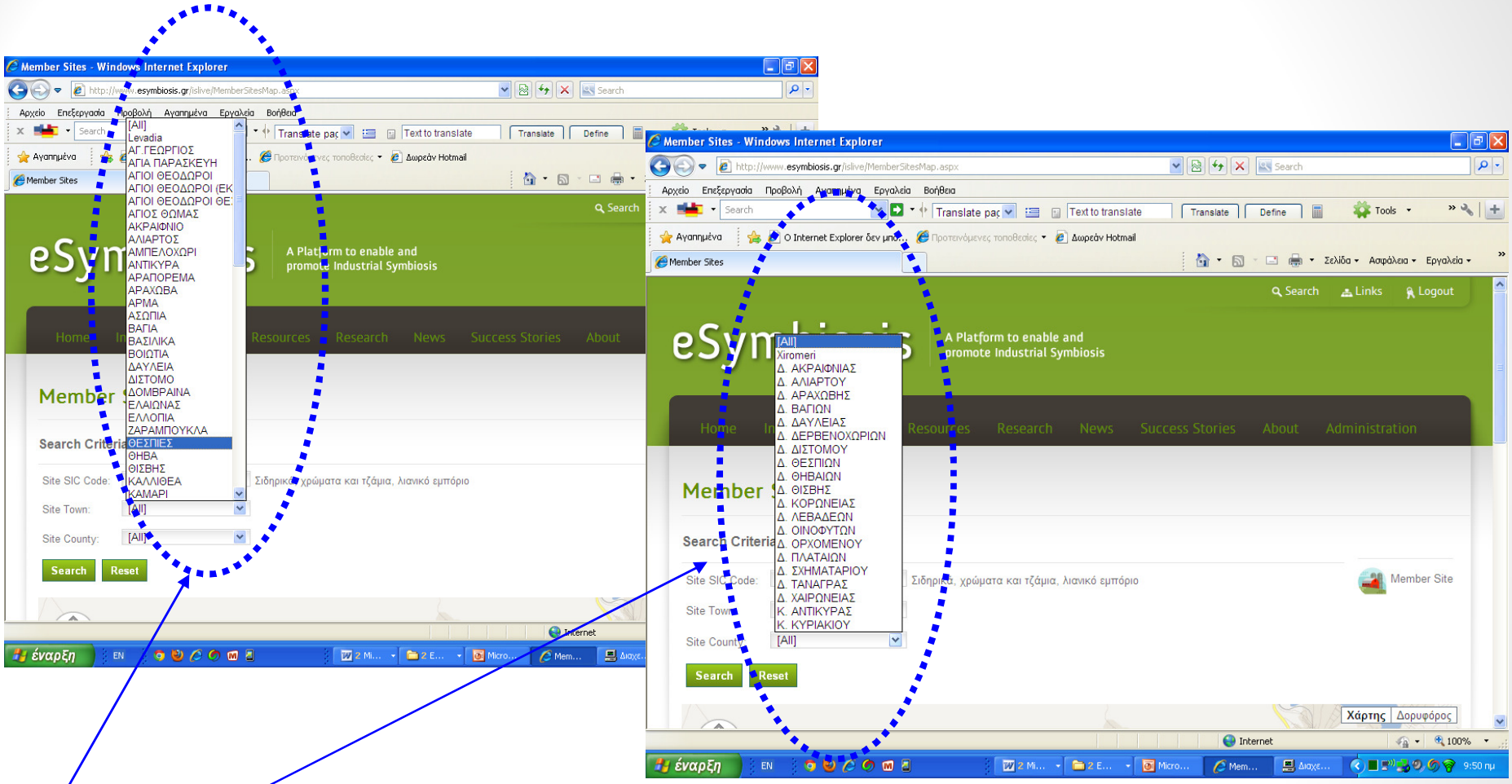
Viewing data from within the platform…

Industrial activities and sectors



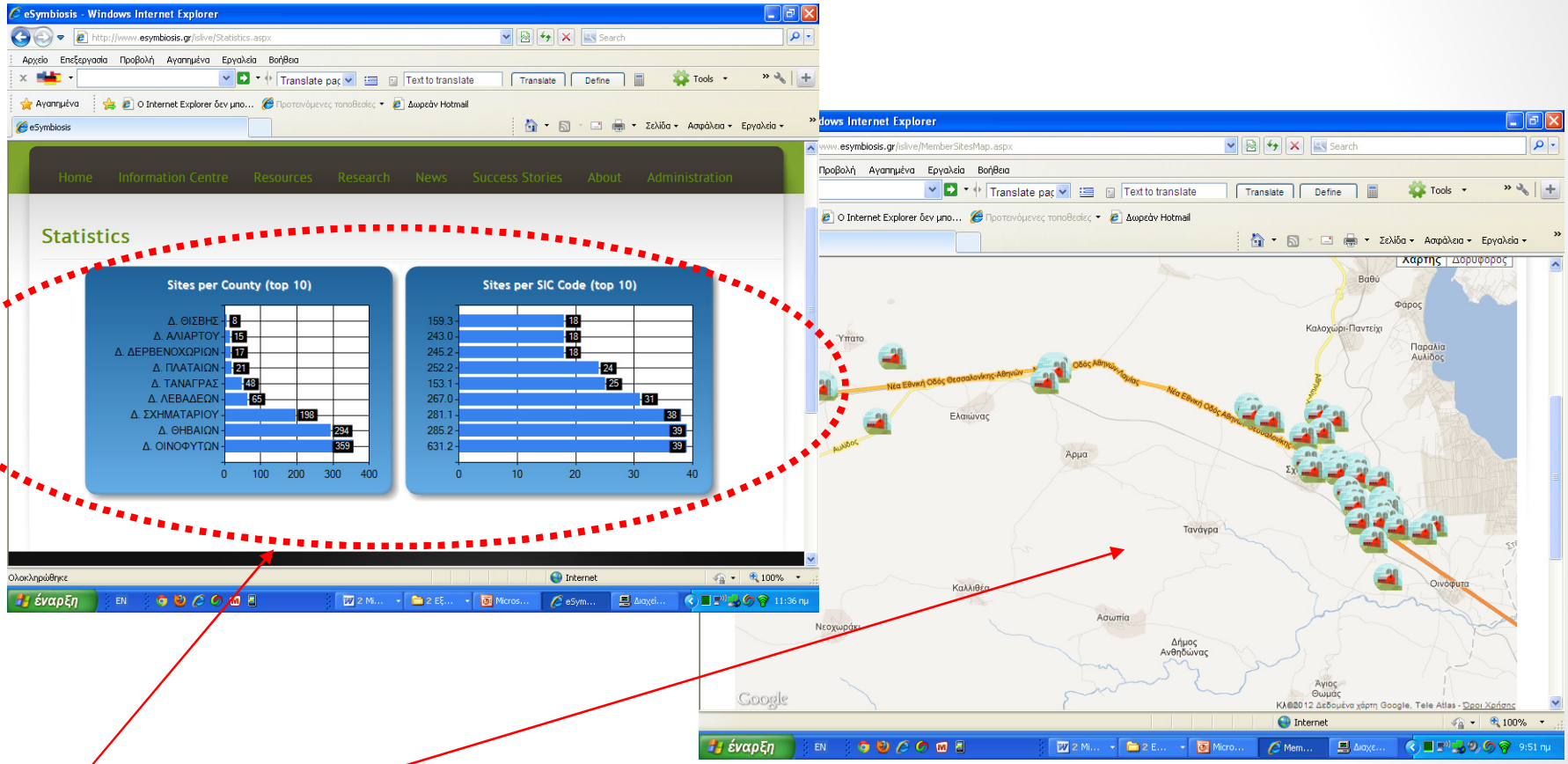
- Industrial codes (SIC)
- Industrial sectors (chemicals, steel etc)

Locations, geographical distributions



- Towns Counties and municipalities (Δ. Πλαταιών, Δ. Θηβών)

Presentation and profiles of industrial sectors

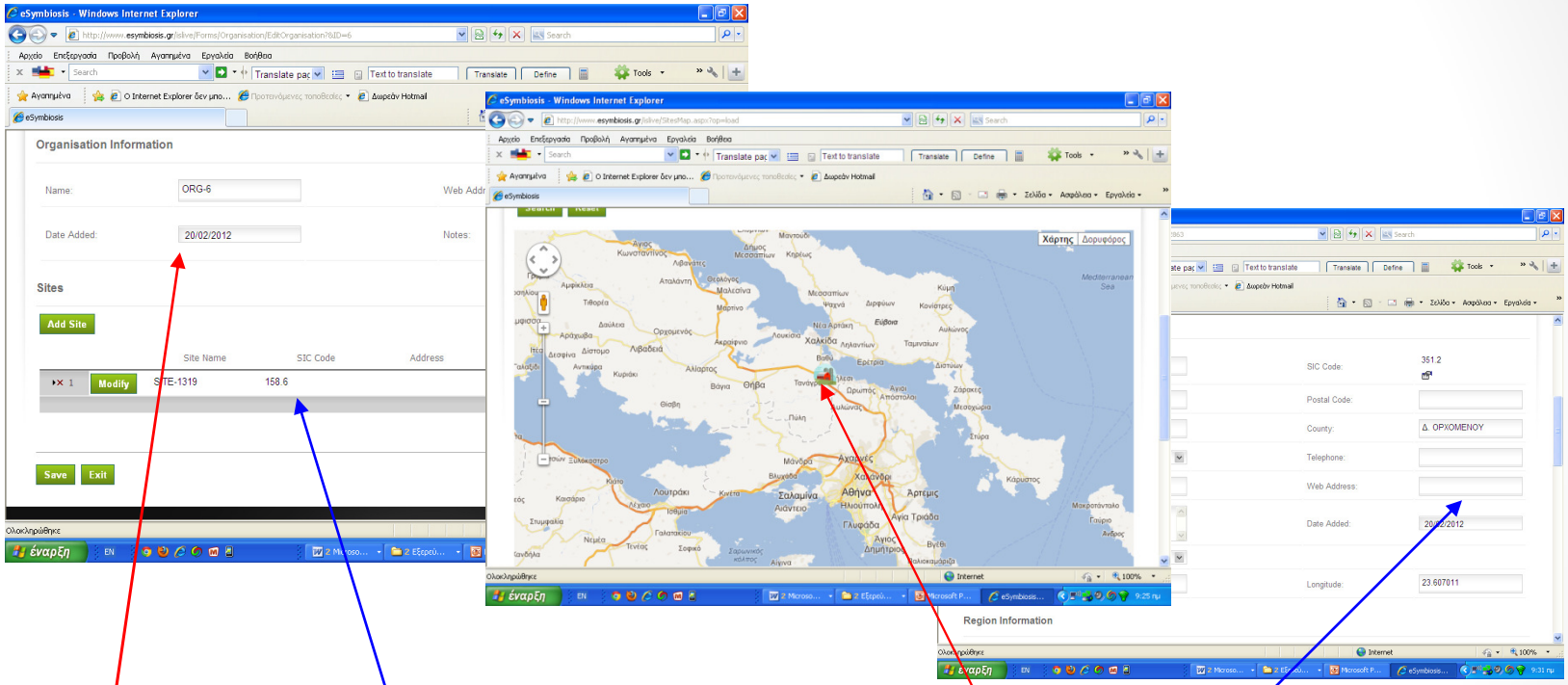


- Regional statistics
- Population of companies around selected locations

Preparing for matchmaking services

- Distinction between Individual and related sites
- Matchmaking tacit knowledge
  - Best practice and track-record: sharing world experience on symbiosis
  - Rules and analytics: assessing matches in the context of specific input and requests
- General principles
  - the more and the better quality of the input (from a company to the system), the more relevant and detailed the output (matchmaking recommendation)
  - Information to be provided in stages, scarcely in one stage
- Default output at zero input
  - Track record of applications
  - Semantics and analysis from technology models

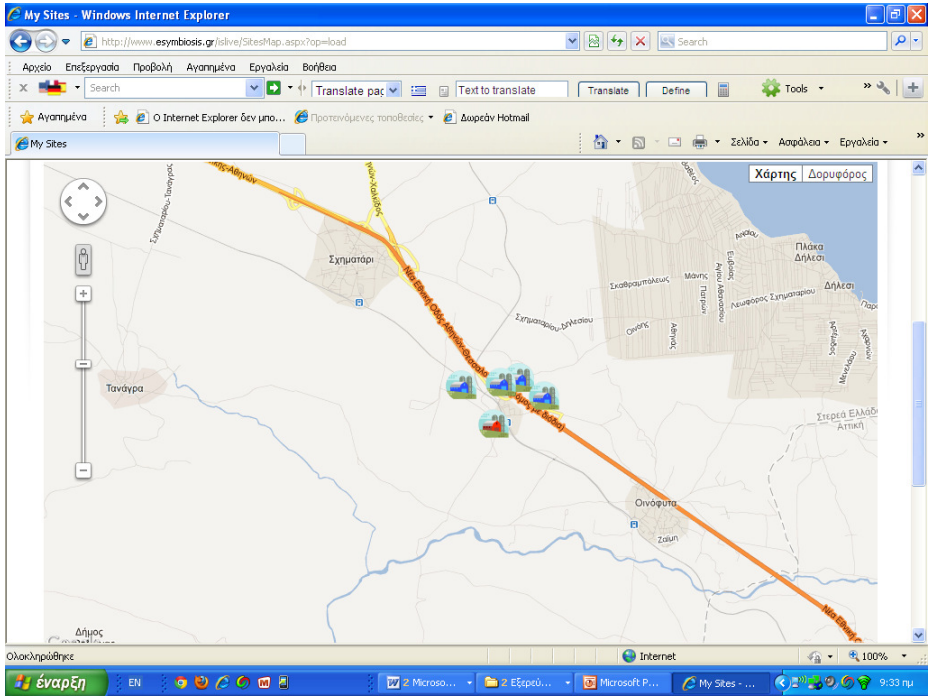
When only input is best practice …

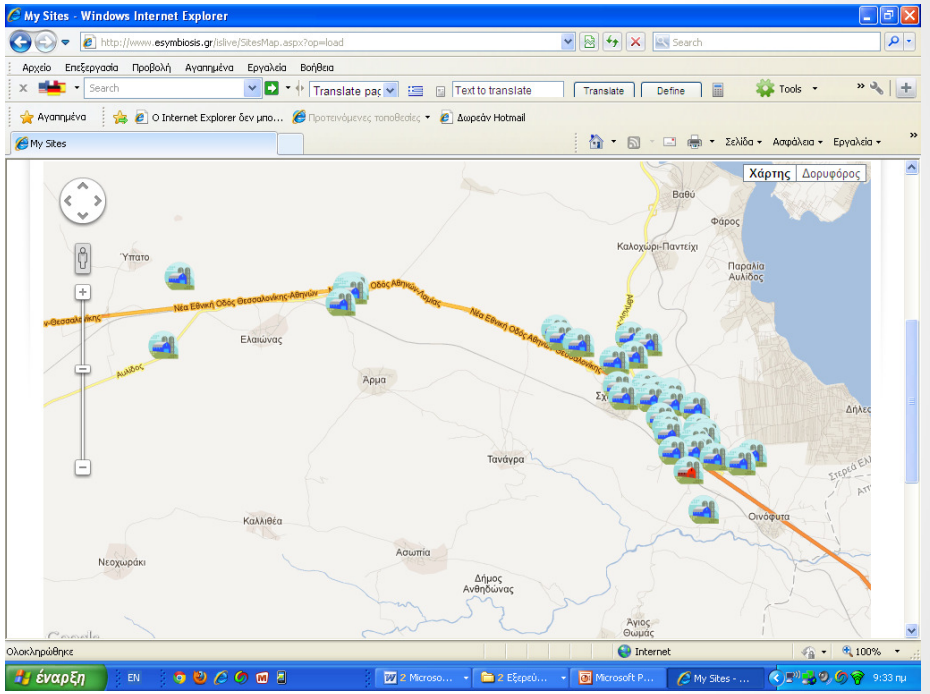


- The company (ORG-6) based in Orchomenos (Ορχομενός) enters the system with a view to assess Industrial Symbiosis potential
- Available is the
  - industrial activity of the company and
  - the distribution of industrial sectors in the geographical vicinity

Locating potential partners

- Promises use best practice with similar industries





- Sorted by
  - distance from member
  - Industrial activity
  - Linked with specific case studies

Work in progress and future work

- Work in progress
  - Development and integration
  - Advanced service layers
  - Dissemination in the regions
  - Build communities
  - Open repository of models
- Export new paradigm of Industrial Symbiosis worldwide, including feedback back UK!
- Future work
  - Targeted applications (e.g. ports)
  - Embrace societies and small-scale municipal activities (e.g. smart cities)
  - Be-spoke applications (e.g. Middle East)

Thank you for your attention

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