eSymbiosis: Semantically Supported Industrial Symbiosis Targeting SMEs

Ontology

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Outline

Ontology

Industrial symbiosis scene

Concept and functionality of eSymbiosis platform

Addressing SME issues

Implementation of IS domain ontology

Formation of IS networks (ontology matching)

Demonstration example

Industrial Symbiosis

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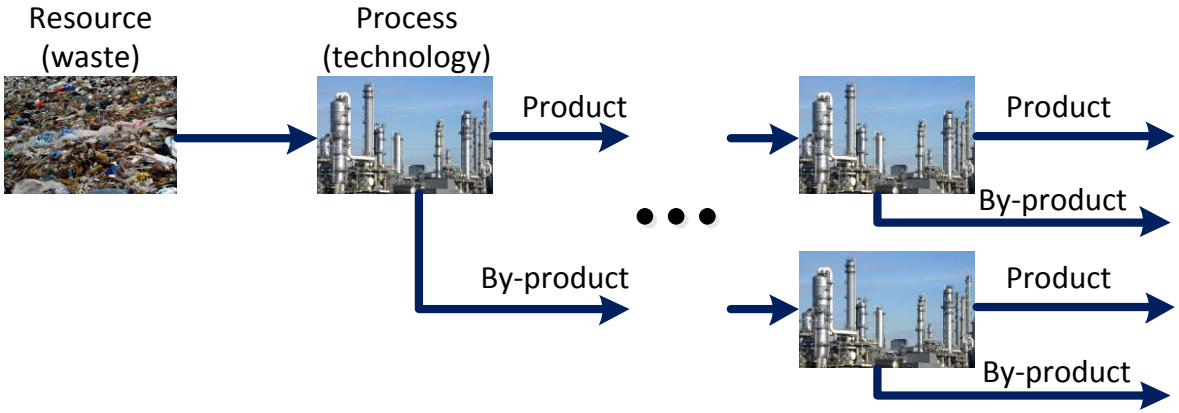
Industrial **networks** set to trade material, energy and water produced from **waste** and to gain **economic**, **environmental** & **social** benefits

Ad-hoc networks:

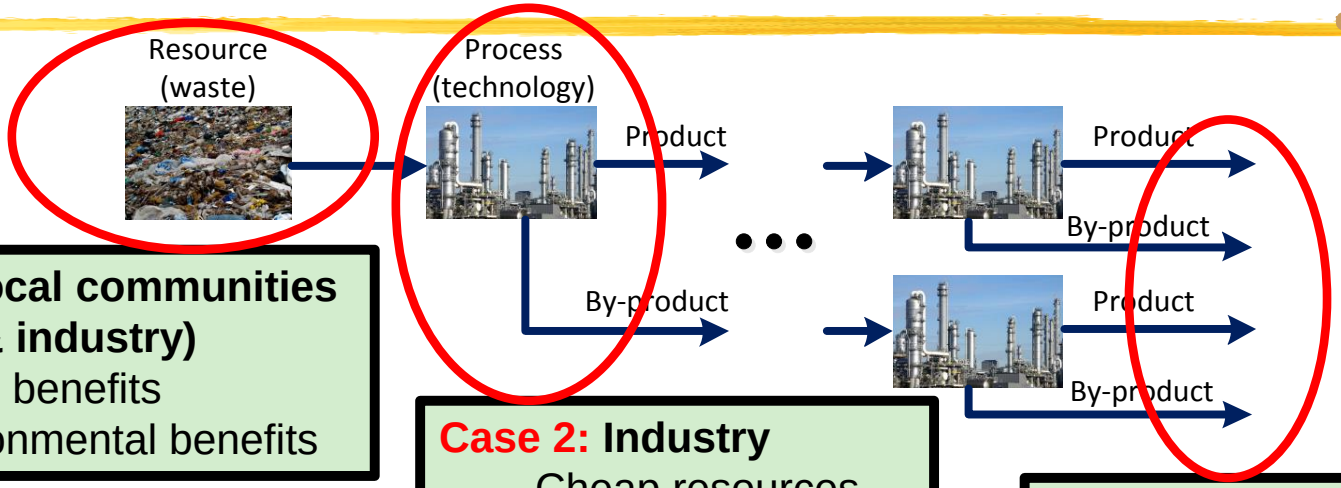
- Confined **geographical** environment (focus on local communities)
- **Short** life-time, **unpredictable** quantities, **non-standardised** composition
- Difficult to predict **benefits**
- Strong **environmental** expectation
- **Large number** of options which have to satisfy technological requirements



Raafat, T., F. Cecelja, N. Trokanas and B. Xrisha (2013). ***An Ontological Approach Towards Enabling Processing Technologies Participation in Industrial Symbiosis***, *Computers & Chemical Engineering*, 59, pp 33-46.

IS Potential

Ontology



Case 1: Local communities (& industry)
Social benefits
Environmental benefits

Case 2: Industry
Cheap resources
Economic benefits

Case 3: Planning
Targeted production
Social benefits
Environmental benefits

Still a problem:

Awareness of possibility and potential

Creating **technologically logical** options (networks) – proven (in practice) and innovative – with **non-standard and unpredictable** materials/energy/water

Selecting **the best** out of a large number of options (assessment of benefits)

Ontology engineering

Current Operation:

Manual by trained practitioners (limited scope, expensive, not innovative)

Promotion: word of mouth, workshops, one-to-one contact

Assessment of benefits: mostly from past experience & rule-of-thumb

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Complexity of IS

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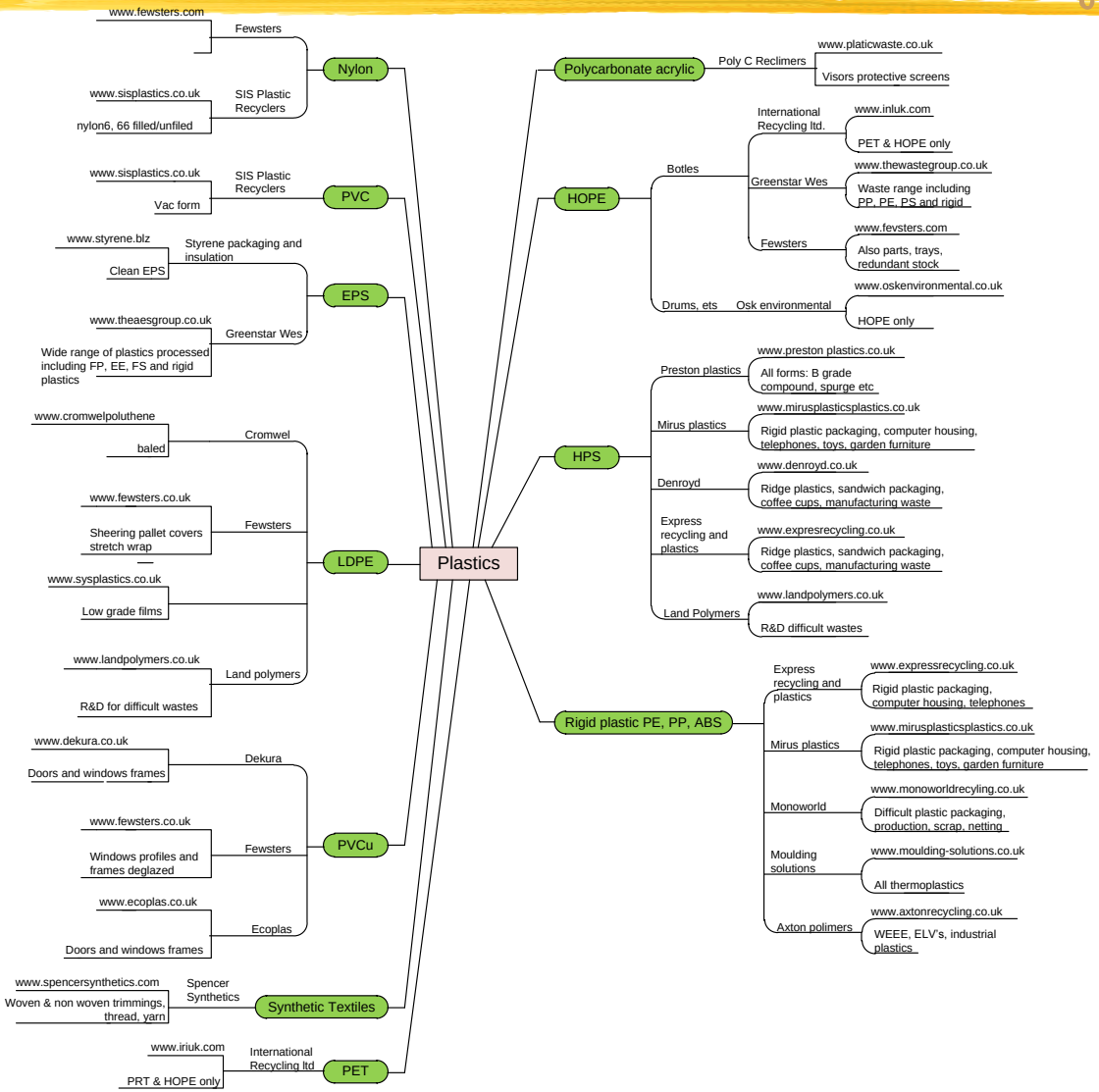


Cecelja, F., T. Raafat, N. Trokanas, S. Innes, A. Yang, M. Smith, Y. Zorgios, X. Bymi, Z. Palaskas, N. Markatos and A. Kokossis (2013). ***eSymbiosys: a technology-enabled industrial symbiosis targeting SMEs and innovation***. GIN2012 Norway

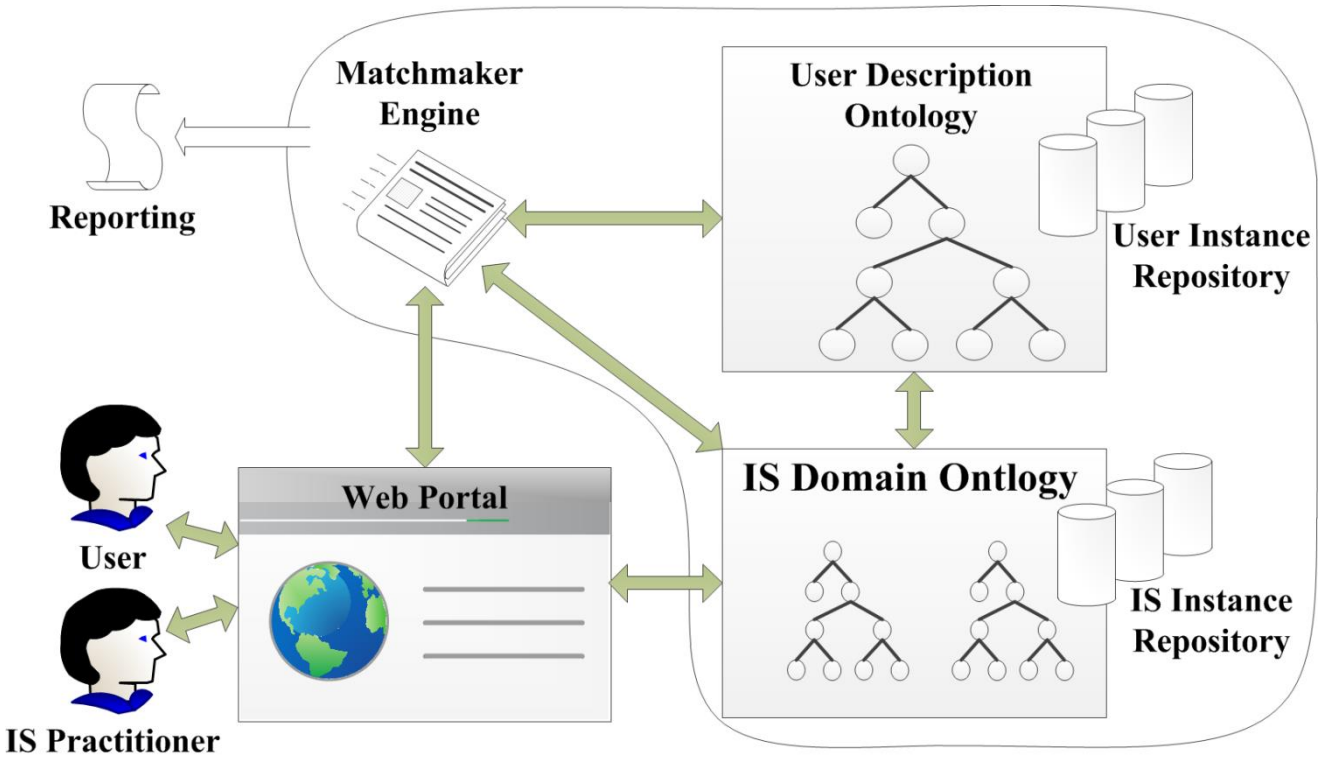
eSymbiosis Platform: Concept

Ontology

Web: easier/cheaper access, supports informed decision at any stage of IS process, and easier to promote by its nature

Semantic: proposing technologically sound options, proposing innovative options beyond past and proven experience, justifies options and enables prediction of benefits

IT: easy collection of data, better monitoring, faster and more accurate reporting,



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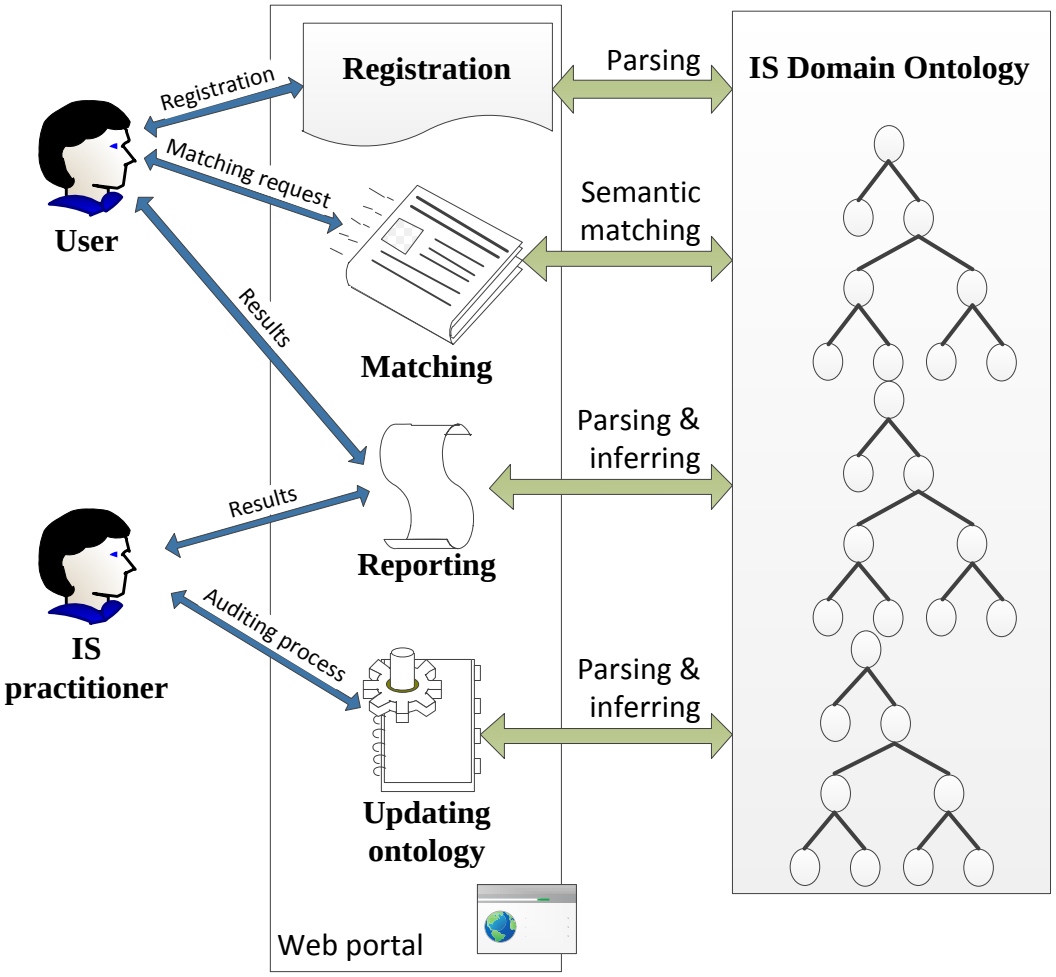
eSymbiosis Platform: Functionality

Registration: explicit knowledge (data) acquisition

Matching: formation of symbiotic networks and assessment of economic, environmental (and social) opportunities with justification

Reporting: various levels and types of reports are crated in the process of IS trading

Updating: technical provision for ontology update is implemented, auditing is still to be defined



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How Does it Help SMEs?

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SME characteristics:

Limited or no **awareness** of IS

Limited or no **awareness** of benefits

Limited resources: financial (time, manpower to start and to manage IS process), expertise (waste composition, technology ability and limitations)

eSymbiosis platform as an enabler:

WEB availability supports/enables promotion of IS (existence of IS and availability of past successful stories)

Test trial with the platform (without obligation to participate) provides the insight into potential opportunities

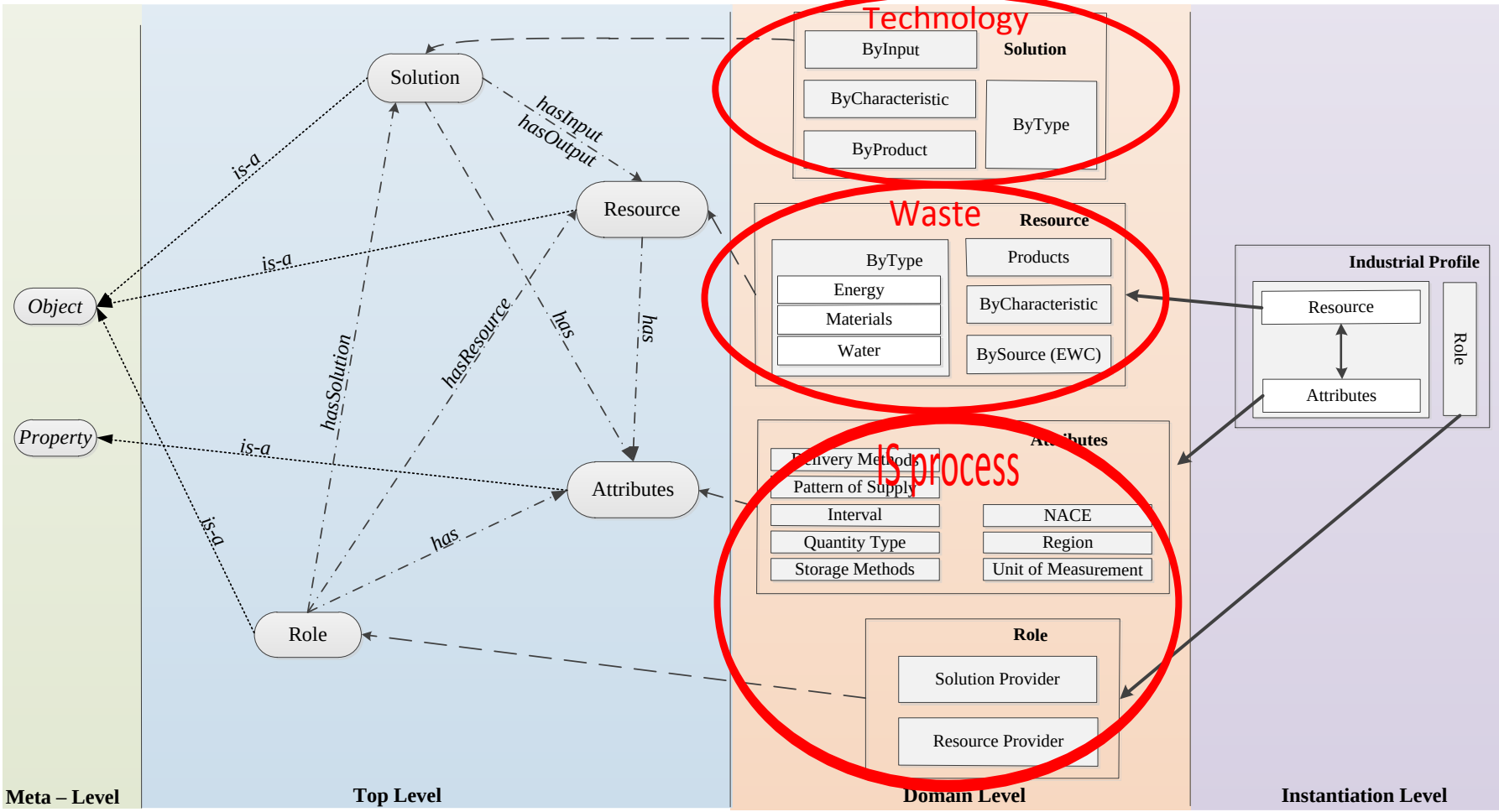
Justification of options quantifies possible benefits (tangible figures)

Access and **participation** registration are both short, cheap and constantly available

The platform addresses issues related to **linguistic** and/or **expertise** barriers

IS Domain Ontology (tacit)

Assures **technological** and **operational** relevance between resources: embedded in the structure of ontology:



Trokanas, N., T. Raafat, F. Cecelja, A. Kokosis, and A. Yang, ***Semantic Formalism for Waste and Processing Technology Classifications Using Ontology Models***. Computer-Aided Chem. Eng., 2012. 30: p. 167 - 171.

Characterisation (explicit)

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Waste :

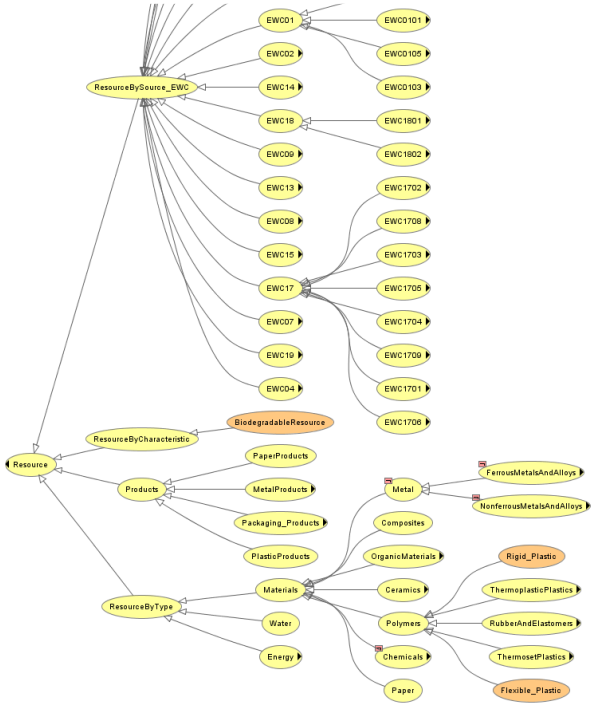
Property	Feature
hasQuantity	Operational, Environmental
hasProcessingPrice	Environmental, Economic
hasAnnualCost	Environmental, Economic
isValidFrom	Operational
isValidUntil	Operational
hasName	Operational
isBiodegradable	Operational, Environmental
isHazardous	Environmental, Operational
embededCarbon	Environmental

IS operation:

Property	Feature
geo:Lat	Operational, Environmental
geo:Long	Environmental, Economic
belongsToIndustry	Environmental, Economic
hasStorageCapacity	Operational
hasStorageMethod	Operational
hasDeliveryMethod	Operational, Environmental
isHazardous	Operational, Economic

Technology:

Property	Feature
hasQuantity	Operational, Environmental
hasProcessingPrice	Environmental, Economic
hasCO_2 emission	Environmental, Economic
isValidFrom	Operational
isValidUntil	Operational
hasByProduct	Operational, Environmental
isHazardous	Operational, Economic
hasPatternOfSupply	Operational
hasName	Operational
needsEnergy	Operational, Environmental
needsWater	Operational, Environmental
hasConversionRate	Operational, Environmental



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Data Acquisition (explicit)

Ontology

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eSymbiosis Ontology Metrics

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Targets

- Processing Technologies = 10
- Waste Streams = 5

Metrics

- Number of concepts ≈ 2000
- Processing Technologies ≥ 60
- Waste Streams = 20
- Materials Streams = 8

Matching

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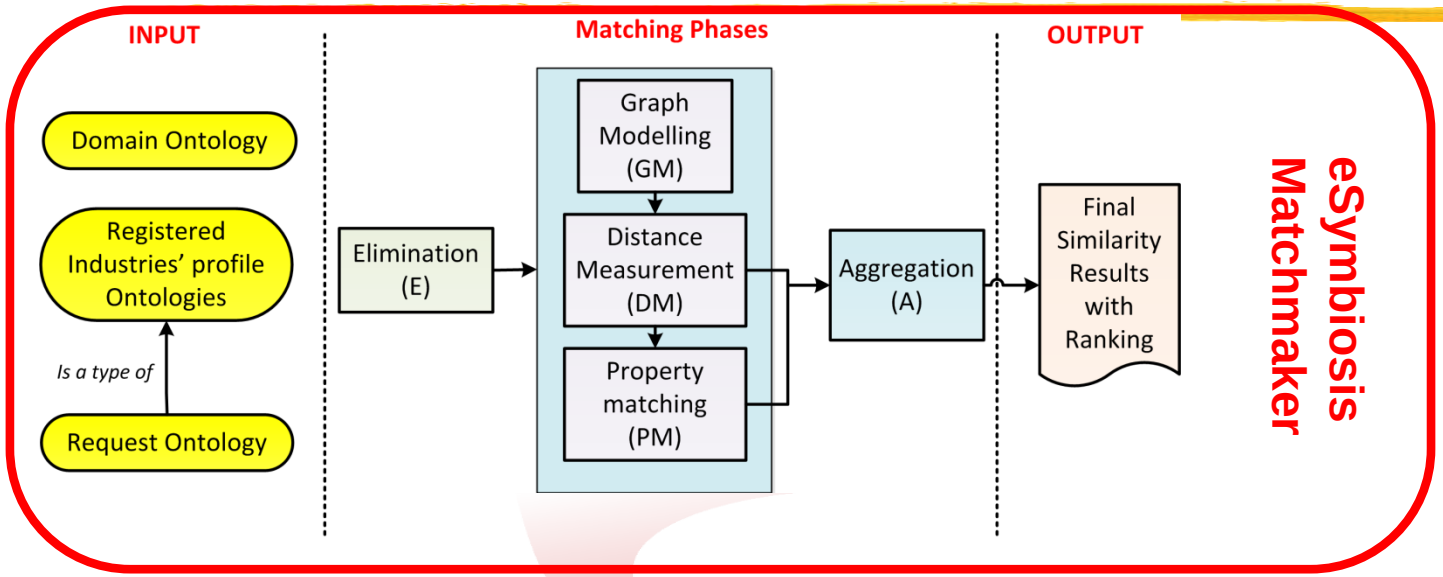

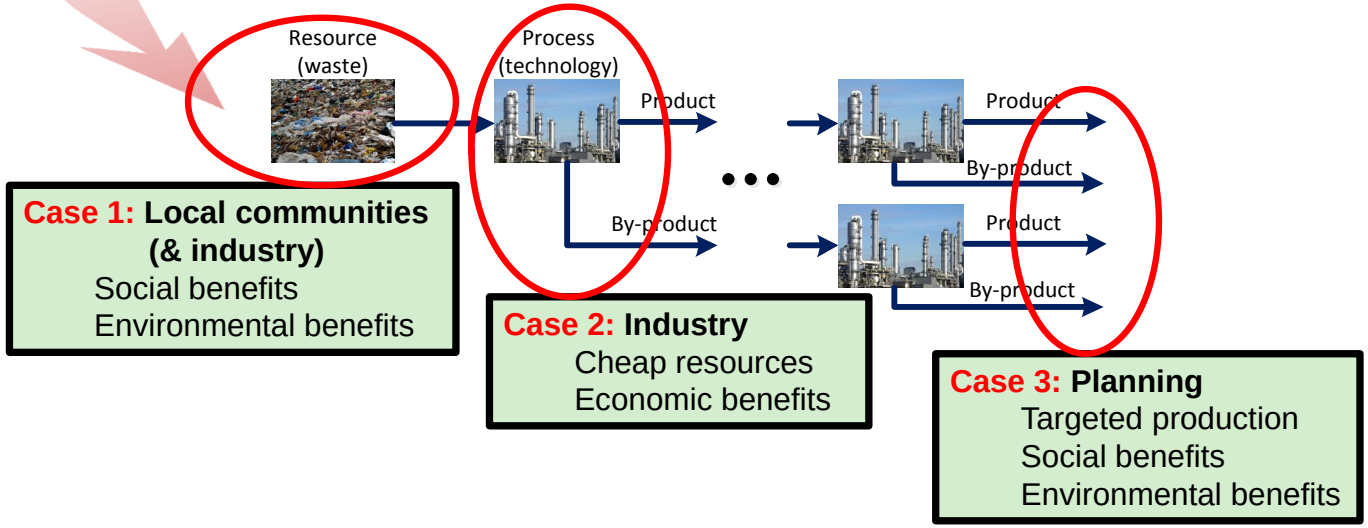

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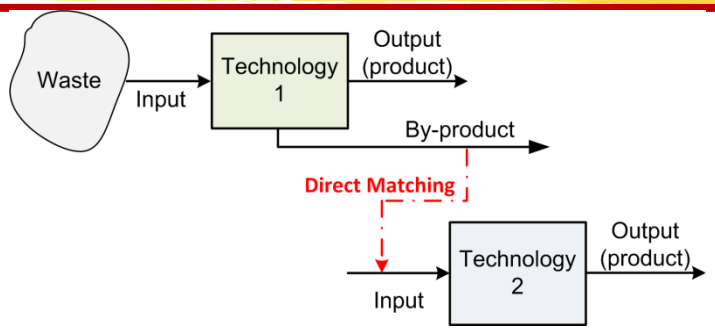
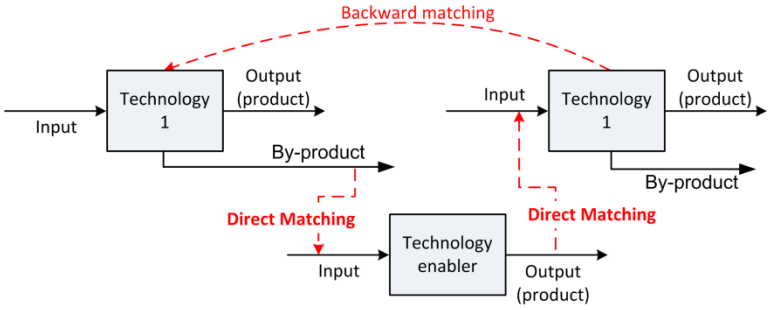
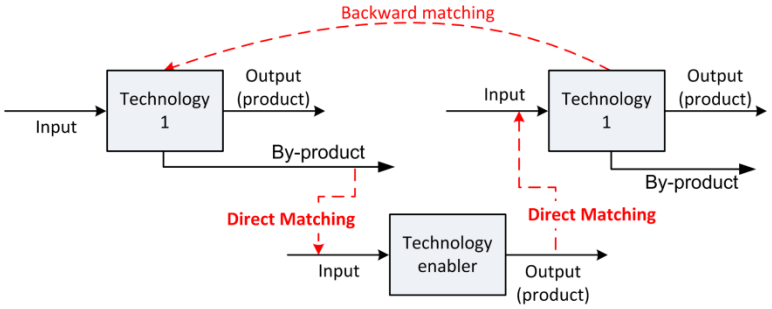
Network Formation



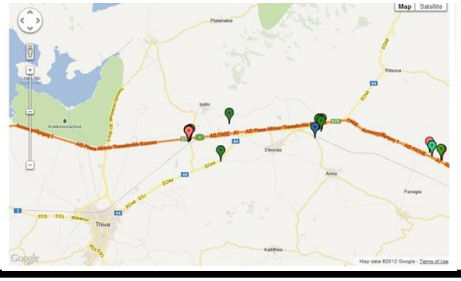
Case 1: direct **input/output** matching to provide solution to available **resource** (waste) – local community (municipality waste) or company (industrial waste) planning



Case 2: **chained** and **backward** matching to provide solution (waste) to **available resources** (technology)



Case 3: **chained** and **backward** matching to plan **targeted production**



Cecelja, F., N. Trokanas, T. Raafat, A. Korkofigas and A. Kokossis (2013). ***Ontology Engineering for the Development of Industrial Symbiosis Networks***. 2013 AIChE Annual Meeting. San Francisco, USA

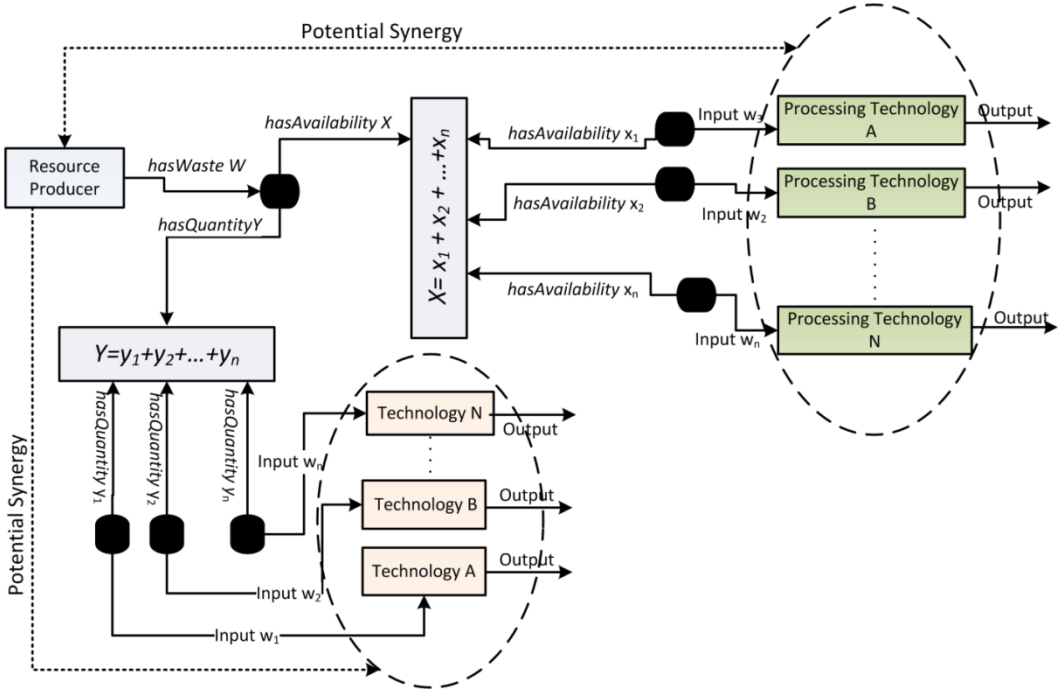
Partial Matching

Ontology

Partial matching by property decomposition:

$$\sum_{k=1}^{K} r_{i,k}\left(S_i^I, k\right) \leq r_i^I$$, K – level of decomposition of property i

We use ***hasQuantitiy*** and ***hasAvailability*** with inclusion of transportation (***hasLocation***) and storage (***hasStorage***).



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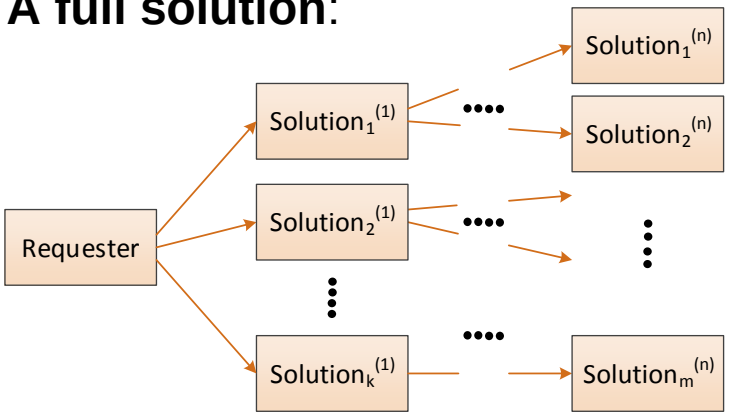
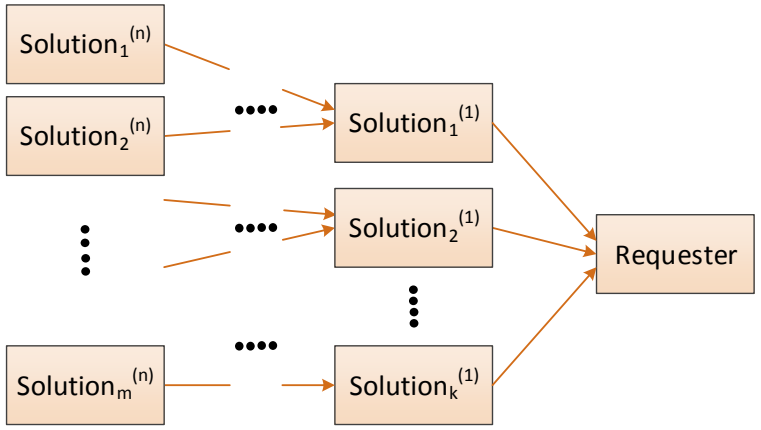
Solution Structure

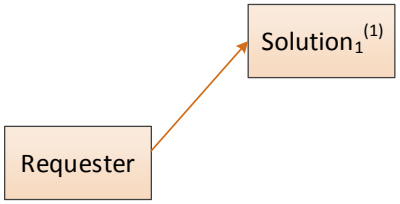
Ontology

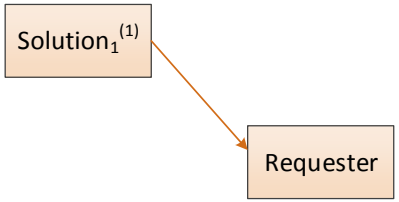
A full solution:



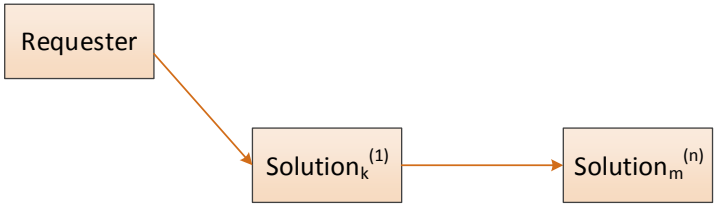


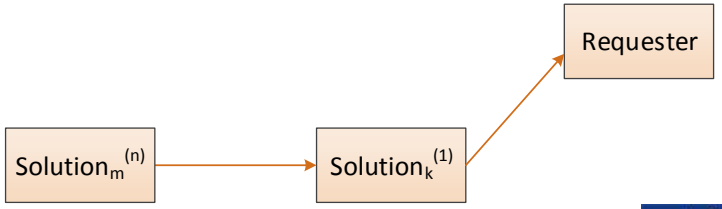
Sub-network 1 (solution 1)





Sub-network m (solution m)



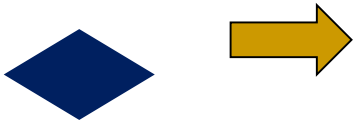


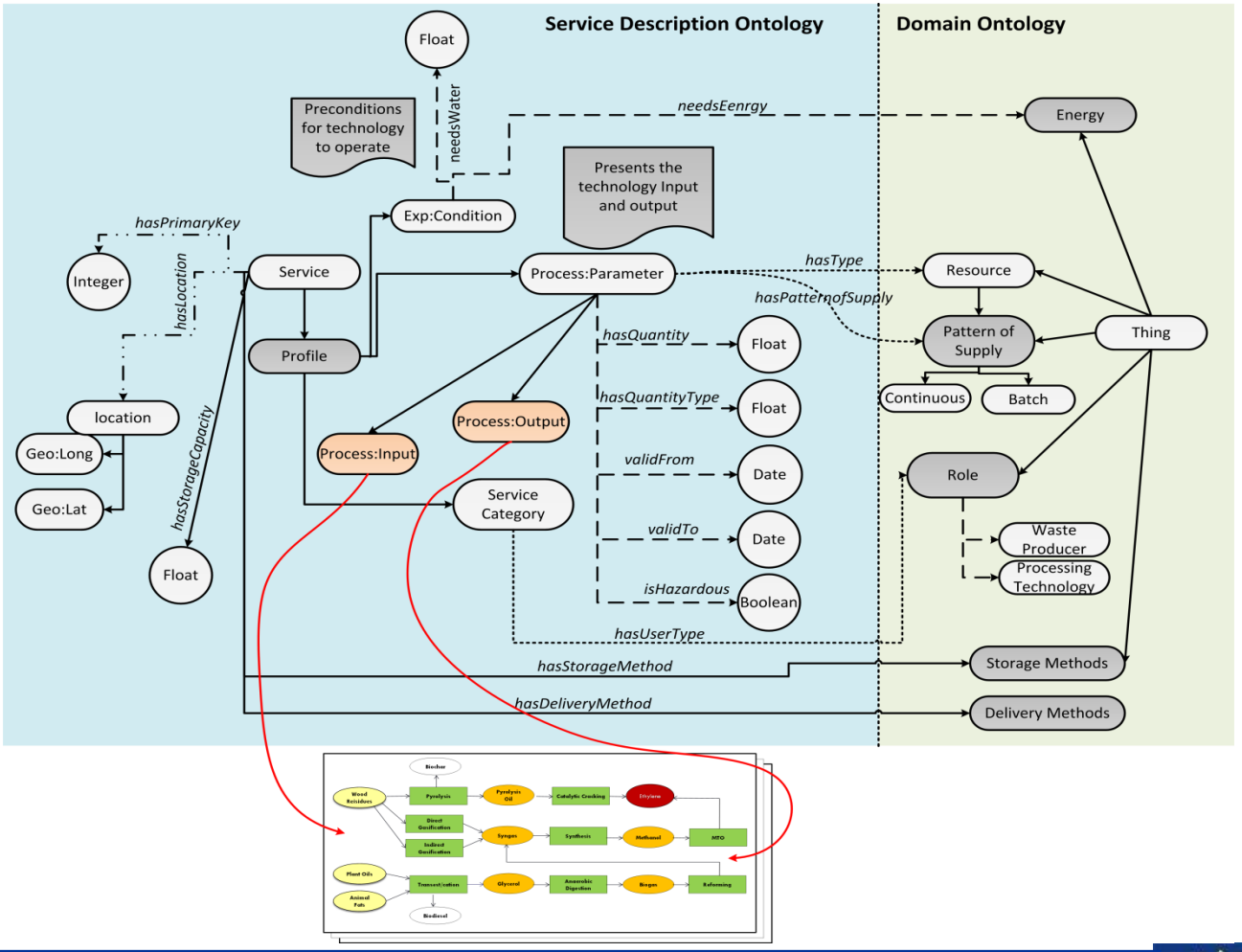
Modelling/Optimization

Ontology

OWL-S **service description** ontology used to integrate companies into **networks** and to **keep record** of properties (or models) for each company in the network

Industry A





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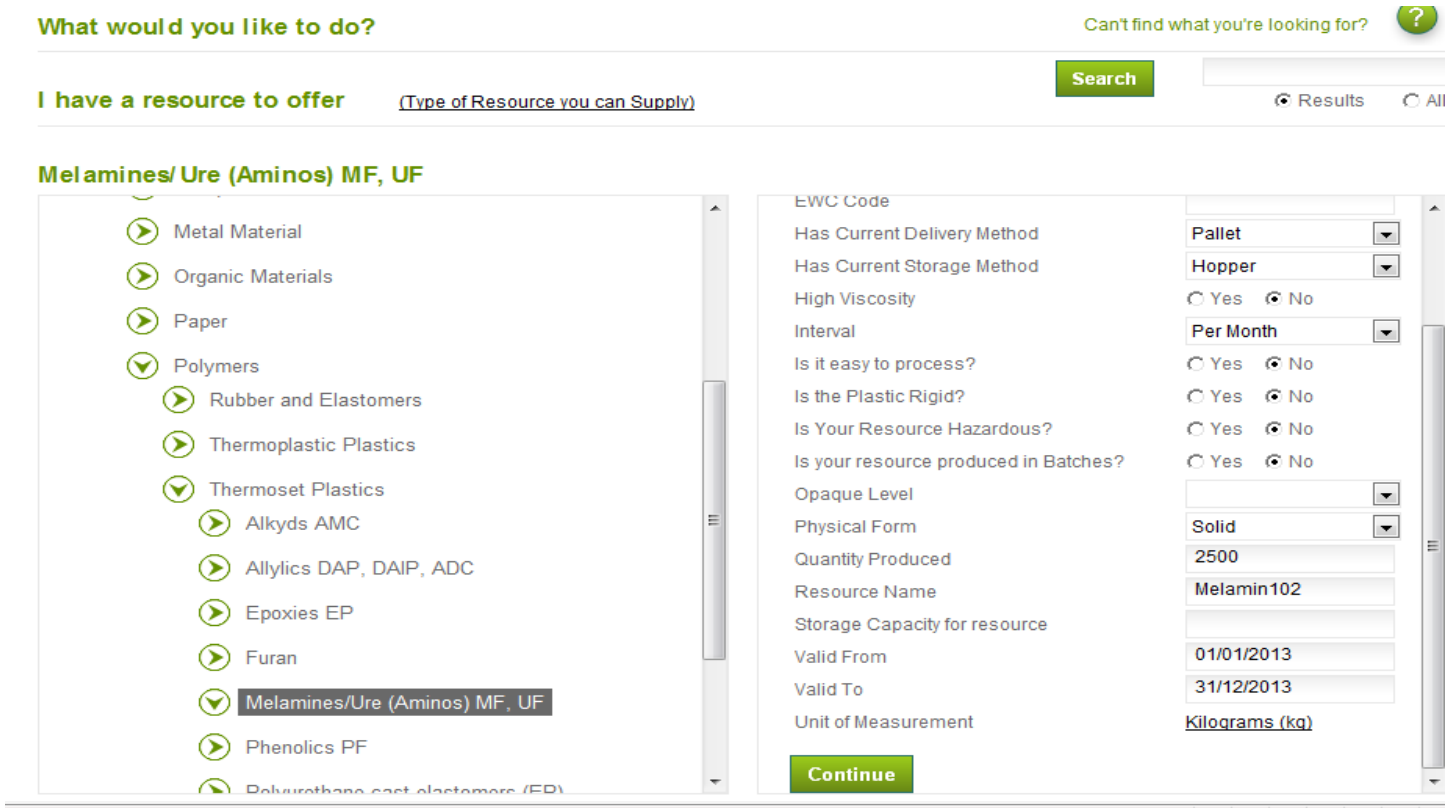
Demonstration 1

Ontology

Waste producer: a Pulp manufacturer and has **300 tonnes/year** of waste registered as **wood resource**.

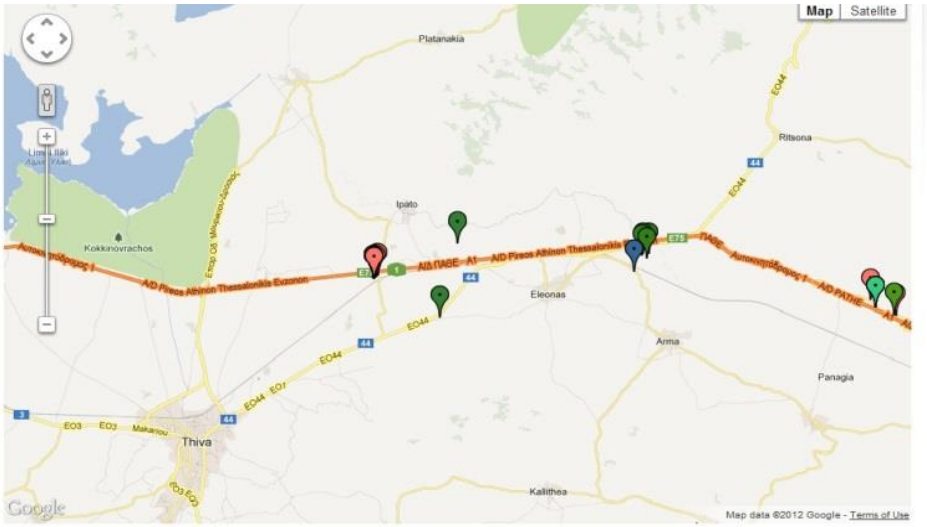


Demonstration 1

Ontology

Already registered users (after elimination):

User ID	User Type	Resource/Solution	Quantity	ValidFrom	ValidTo	Lat	Lon	PoS
1	RP	Wood	300	07/06/2013	06/04/2017	38.330	23.674	B
2	RP	EWC030301	440	21/02/2014	10/10/2017	38.320	23.622	B
3	RC	EWC030104	230	21/10/2014	13/09/2016	38.310	23.558	C
4	RC	Wood	700	18/02/2016	25/10/2018	38.339	23.609	C
5	RP	EWC030305	190	03/03/2015	10/07/2017	38.360	23.612	C
6	RP	Wooden Packaging	250	05/10/2015	05/06/2018	38.342	23.601	C
7	RC	EWC030307	560	16/10/2015	24/07/2018	38.326	23.506	C
8	SP	Anaerobic Digestion	1200	23/10/2015	11/12/2017	38.327	23.590	B
9	RP	EWC030101	100	10/12/2013	12/05/2017	38.346	23.607	C
10	SP	Wood Incineration	1000	26/07/2013	08/06/2016	38.322	23.613	B



Demonstration 1

Ontology

Matching:

User ID	User Type	Resource/Solution	Quantity	ValidFrom	ValidTo	Lat	Lon	PoS
3	RC	EWC030104	230	21/10/2014	13/09/2016	38.310	23.558	C
4	RC	Wood	700	18/02/2016	25/10/2018	38.339	23.609	C
7	RC	EWC030307	560	16/10/2015	24/07/2018	38.326	23.506	C
8	SP	Anaerobic Digestion	1200	23/10/2015	11/12/2017	38.327	23.590	B
10	SP	Wood Incineration	1000	26/07/2013	08/06/2016	38.322	23.613	B

Similarity results:

User ID	Resource/Solution	Similarity
10	Wood Incineration	0.88
8	Anaerobic Digestion	0.81
4	Wood	0.78
7	EWC030307	0.78
3	EWC030104	0.71

CO_2 saving:

User ID	Suggested Resource	Requested Resource	Quantity Exchanged	EC of suggested resource	EC of Requested Resource	Total EC (requested)	Total EC (suggested)	CO_2 Saving ($tonCO_2$)
4	Wood waste	Wood	440	0.2	0.46	202.4	88	114.4
7	Wood waste	EWC030307	440	0.2	1.00	440	88	352

Demonstration 1

Ontology

Final results:

User ID	Resource/Solution	Similarity	CO_2 Saving	Landfill Diversion	Virgin Materials Saved
7	EWC030307	0.78	352	-	-
4	Wood	0.78	114.4	440	440
10	Wood Incineration	0.88	0	-	-
8	Anaerobic Digestion	0.81	0	-	-
3	EWC030104	0.71	0	-	-

Summary

Ontology

IS domain ontology has been designed, implemented and exhaustively tested for IS performance

IS matchmaker has been designed, implemented and tested for IS performance

eSymbiosis platform has been integrated and exhaustive testing is taking place

Acknowledgement

Ontology

To the eSymbiosis partners (along with UNIVERSITY OF SURREY :

NTUA:

AVCOSystems

PI Consulting:

CLMS

… and the sponsor