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# J-Park Simulator – An intelligent system for information management of eco-industrial parks

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- Applying Industry 4.0 concepts for EIP developing.
- Hierarchical framework for information modelling of EIP
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- Conclusion and future work

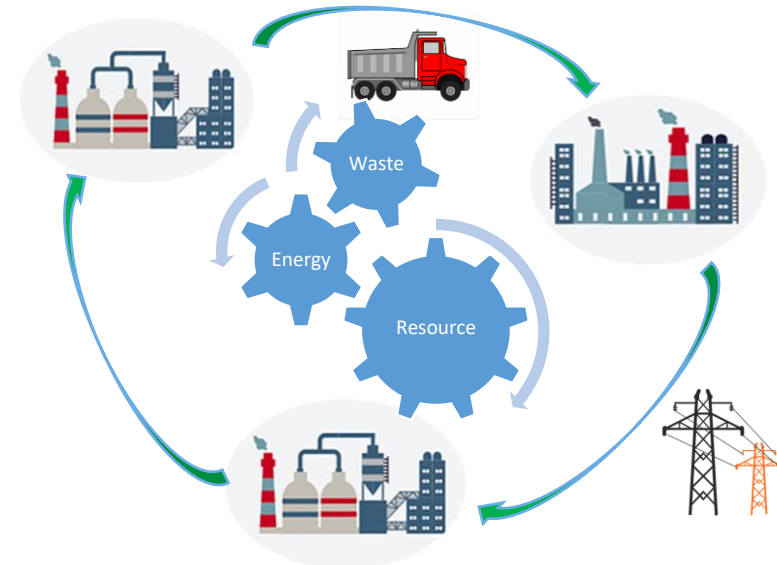


# Motivation

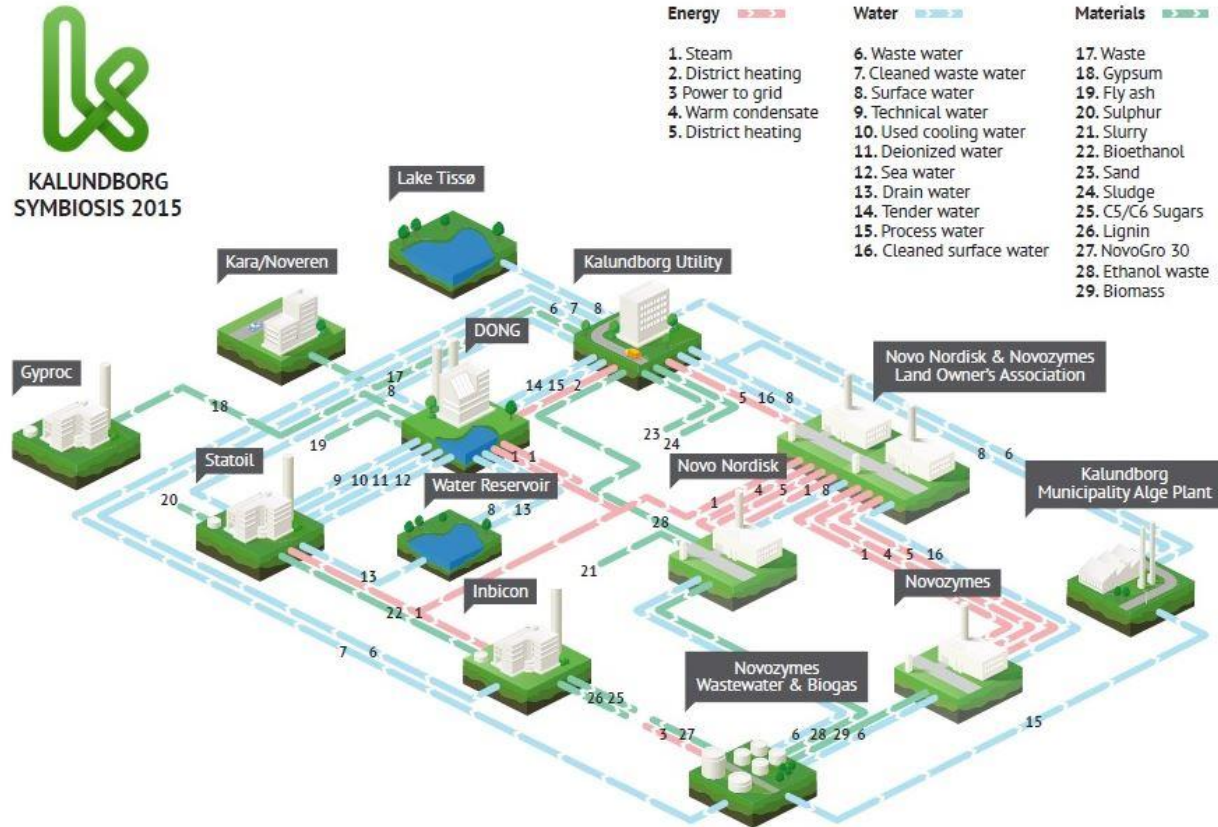
**Eco-industrial park (EIP):** a cluster of businesses that collaborate with each other and the local community to efficiently share resources, and to reduce waste and pollution.



Jurong Island, Singapore



# Objective: Resource conservation & Environmental preservation



Kalundborg Eco-Industrial Park (Denmark)

# Challenges:

- **Big data volume**

- Data generated by the represented entities is ever-growing. These data need to be stored and analysed in order to recognize patterns, trends as well as system behaviour.

- **Distributed storage**

- Knowledge about particular technical system is usually managed and maintained by experts from the corresponding organization.

- **Syntax heterogeneity**

- Engineering knowledge is usually represented and stored in a diversity of information media.

- **Semantic heterogeneity**

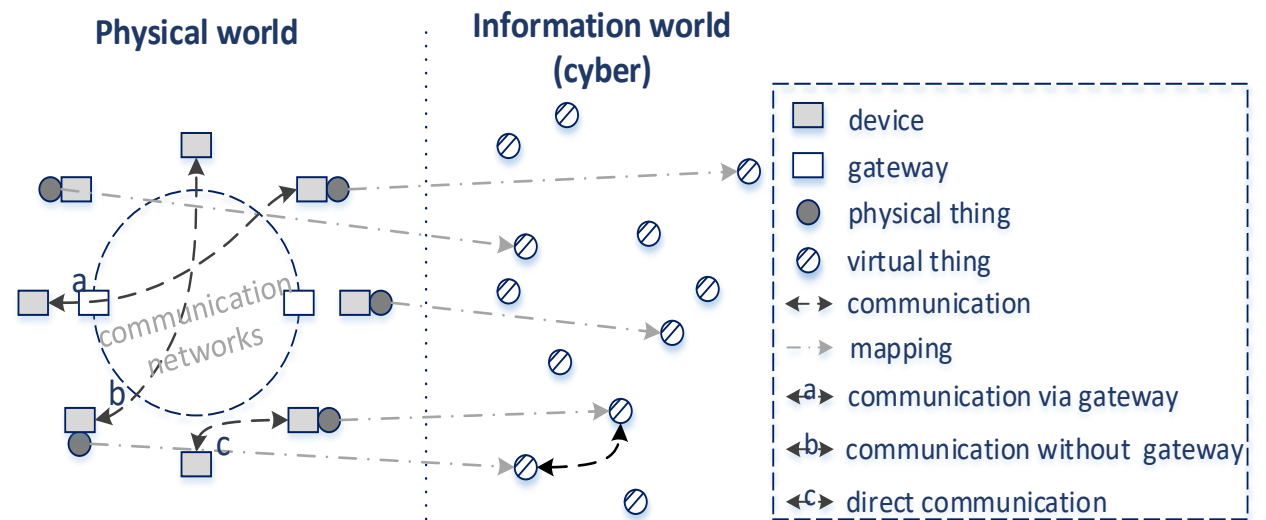
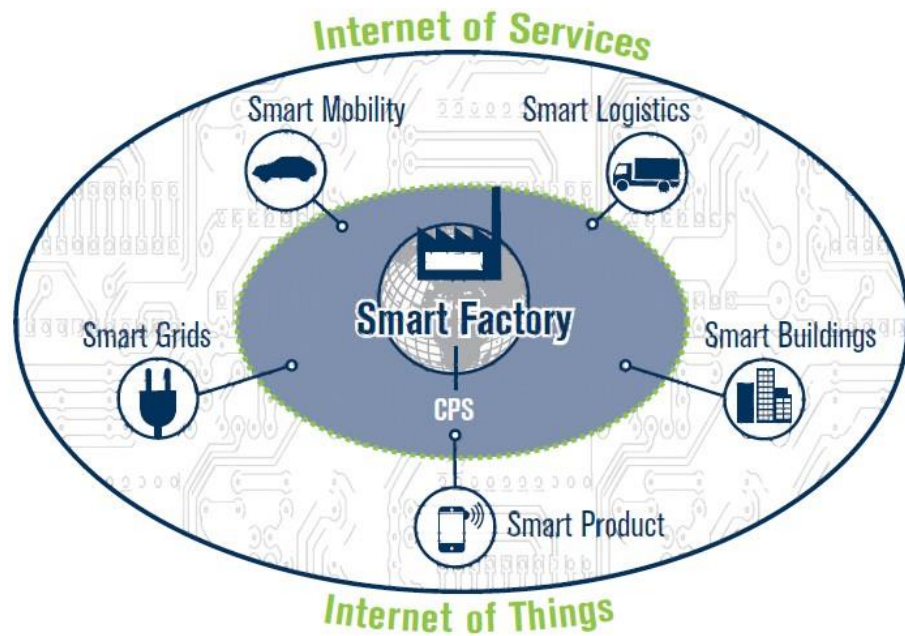
- Normally, knowledge about the specific engineering design processes is known implicitly to the participating designers.



# Applying Industry 4.0 concepts for EIP developing

It allows the formulation of a global network connecting the machinery, factories, and warehousing facilities as Cyber-Physical Systems (CPS).

- ✓ Distributed information system
- ✓ Cloud computing



Technical overview of the IoT [1]

# Ontology technology

An ontology is an explicit formal specification of concepts and relationships that constitute knowledge in the concerned domain of expertise. It's widely utilized as an effective tool for knowledge base developing of virtual systems.

Ontology languages: XML – eXtensible Markup Language

RDF(S) – Resource Description Format (Schema)



# Resource Description Framework (RDF)

RDF identifies things using Internationalized Resource Identifiers (IRIs), and encodes information in triples (Subject-Predicate-Object) .

Title	Artist	Country	Company	Price	Year
Empire Burlesque	Bob Dylan	USA	Columbia	10.90	1985

```
<?xml version="1.0"?>

<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:cd="http://www.recshop.fake/cd#">

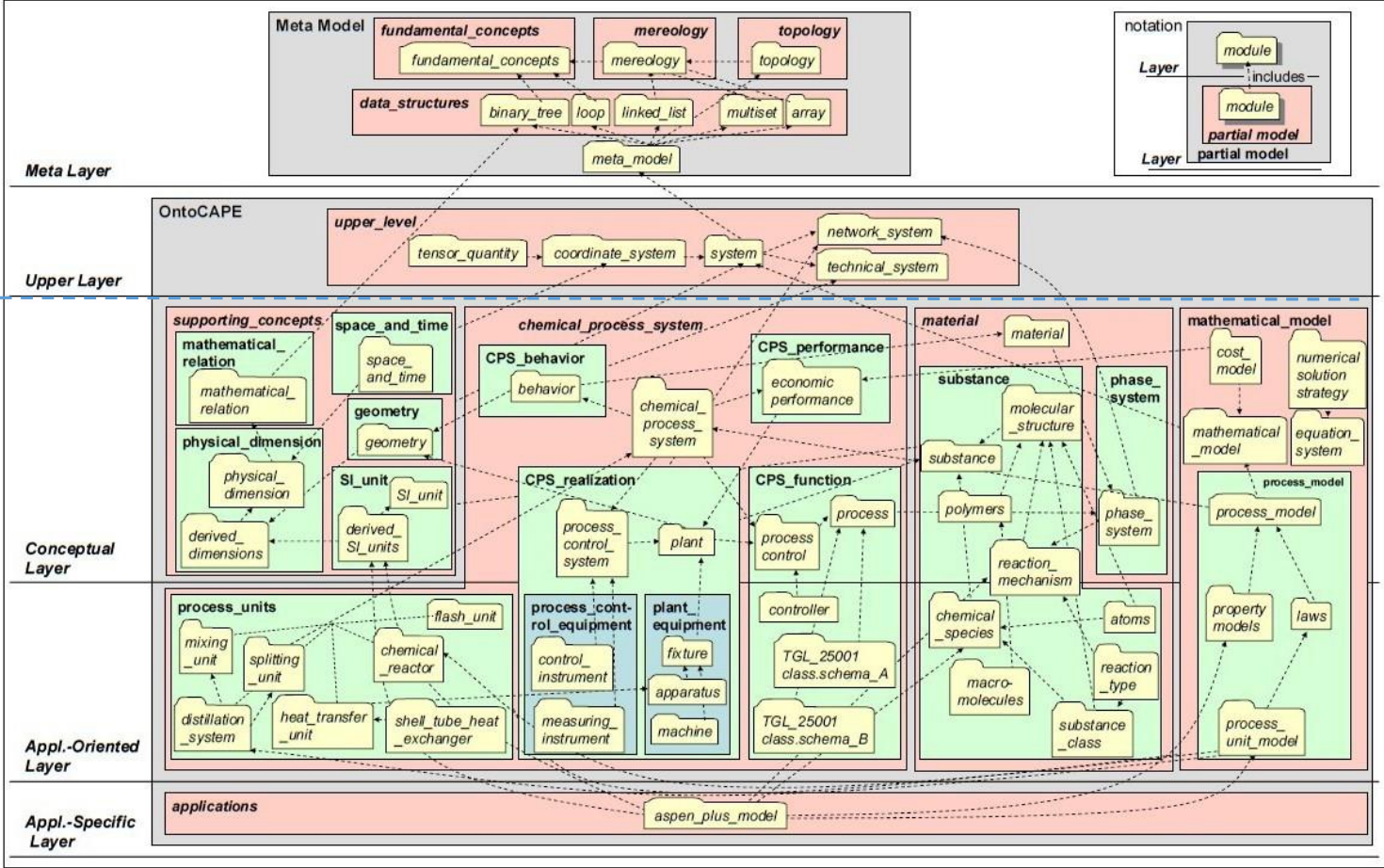
  <rdf:Description
    rdf:about="http://www.recshop.fake/cd/Empire Burlesque">
    <cd:artist>Bob Dylan</cd:artist>
    <cd:country>USA</cd:country>
    <cd:company>Columbia</cd:company>
    <cd:price>10.90</cd:price>
    <cd:year>1985</cd:year>
  </rdf:Description>
```



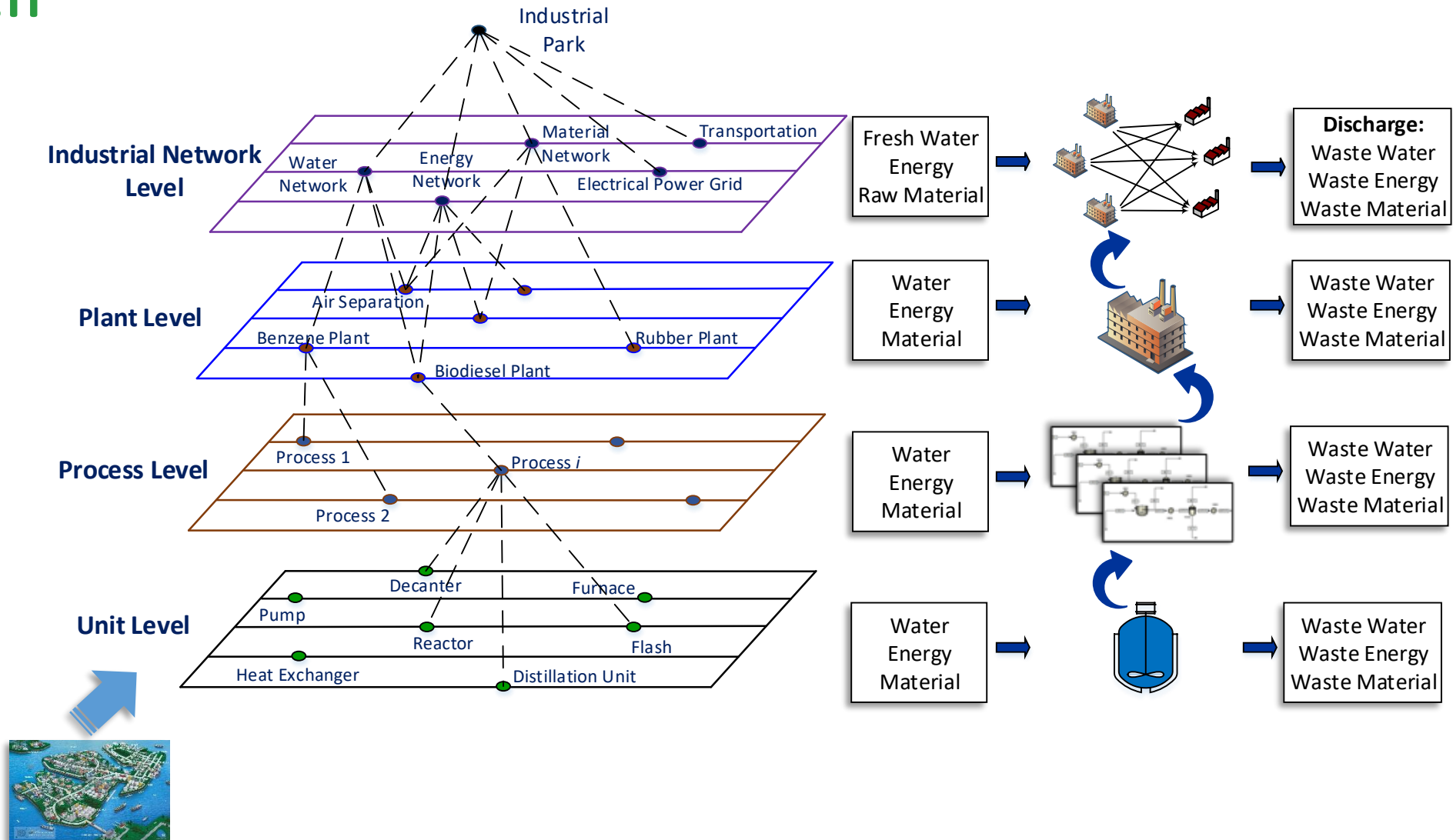
# OntoCAPE: a general-purpose ontology for applications in the domain of Computer-Aided Process Engineering (CAPE).

**Extendable**  
(can be extended to other domains)

**Specific application**  
(chemical processes)

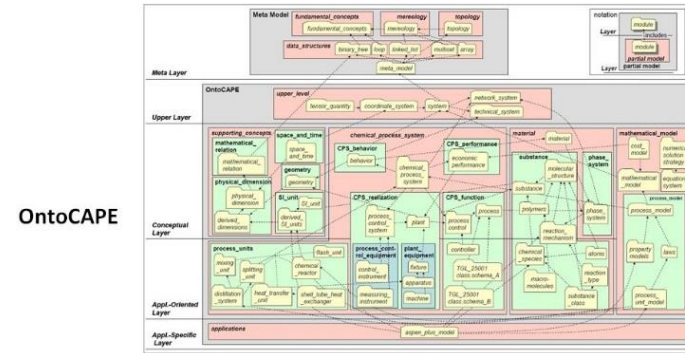


# Hierarchical framework for information modelling of EIP

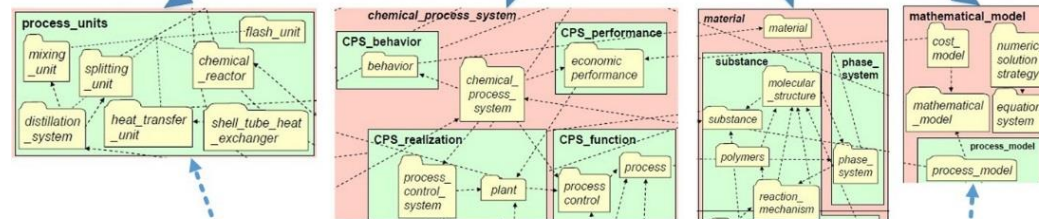


# Applying OntoCAPE to represent:

- Unit operations
- Chemical process systems



Sub-ontologies

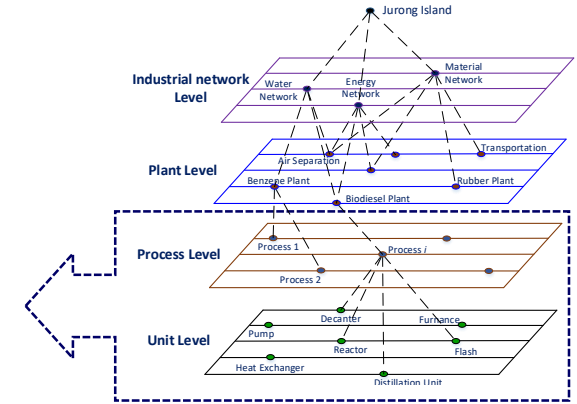
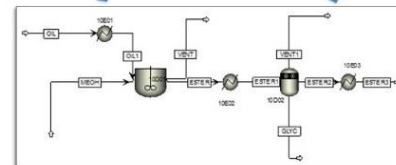


Unit Operations

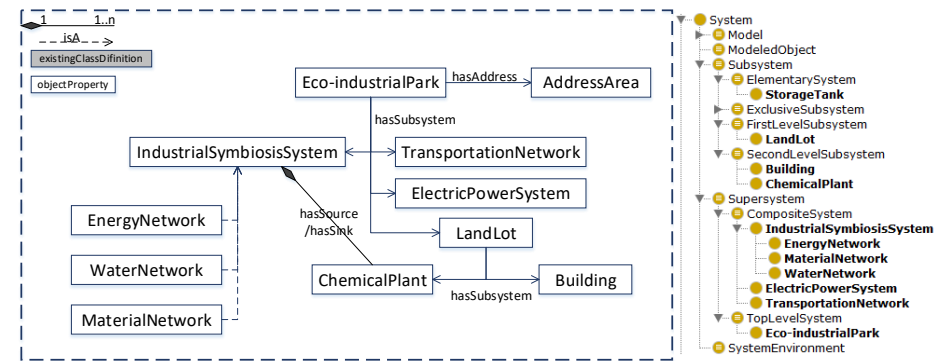
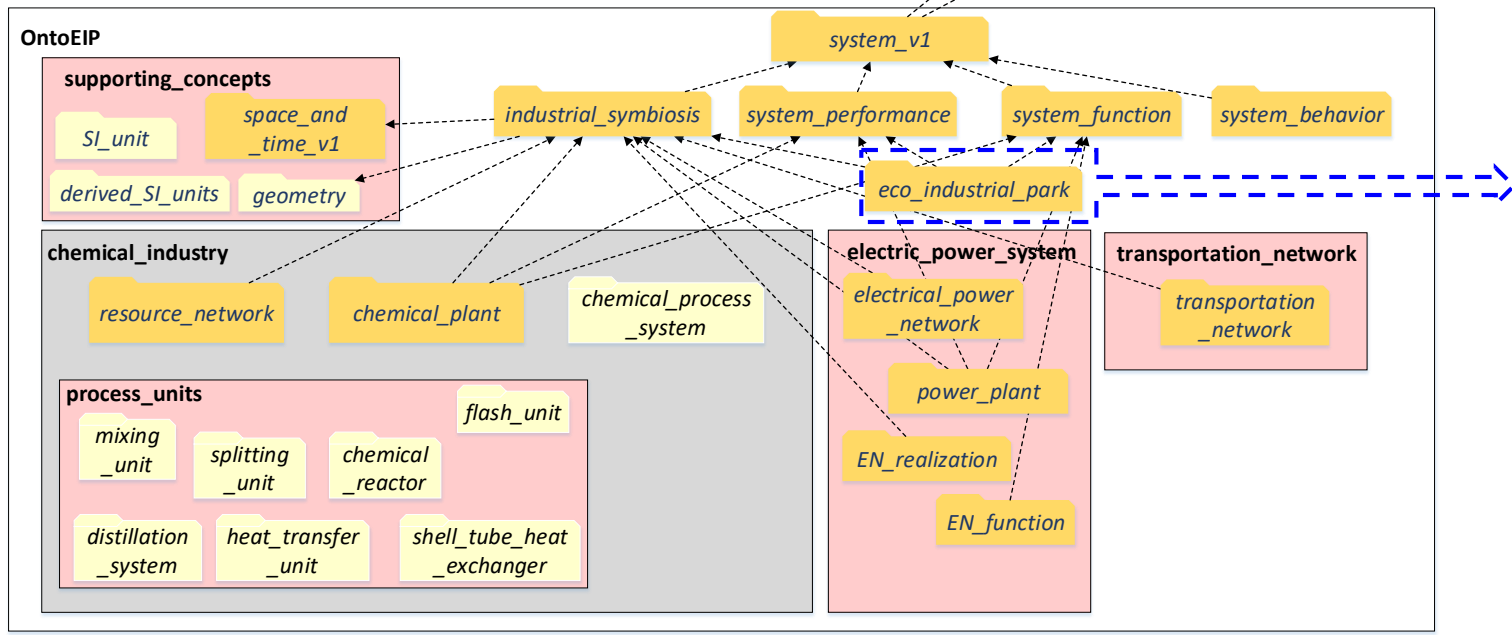
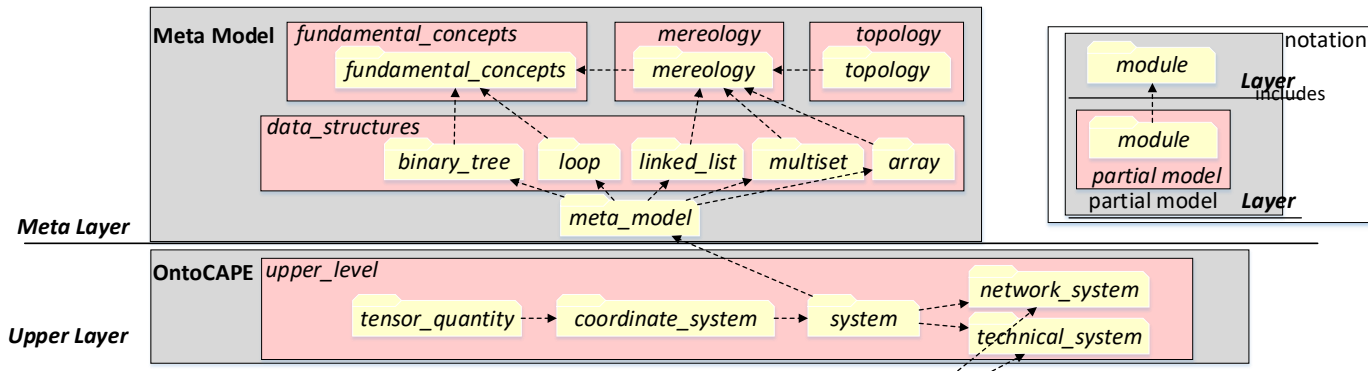
Chemical Process

Materials

Mathematical model



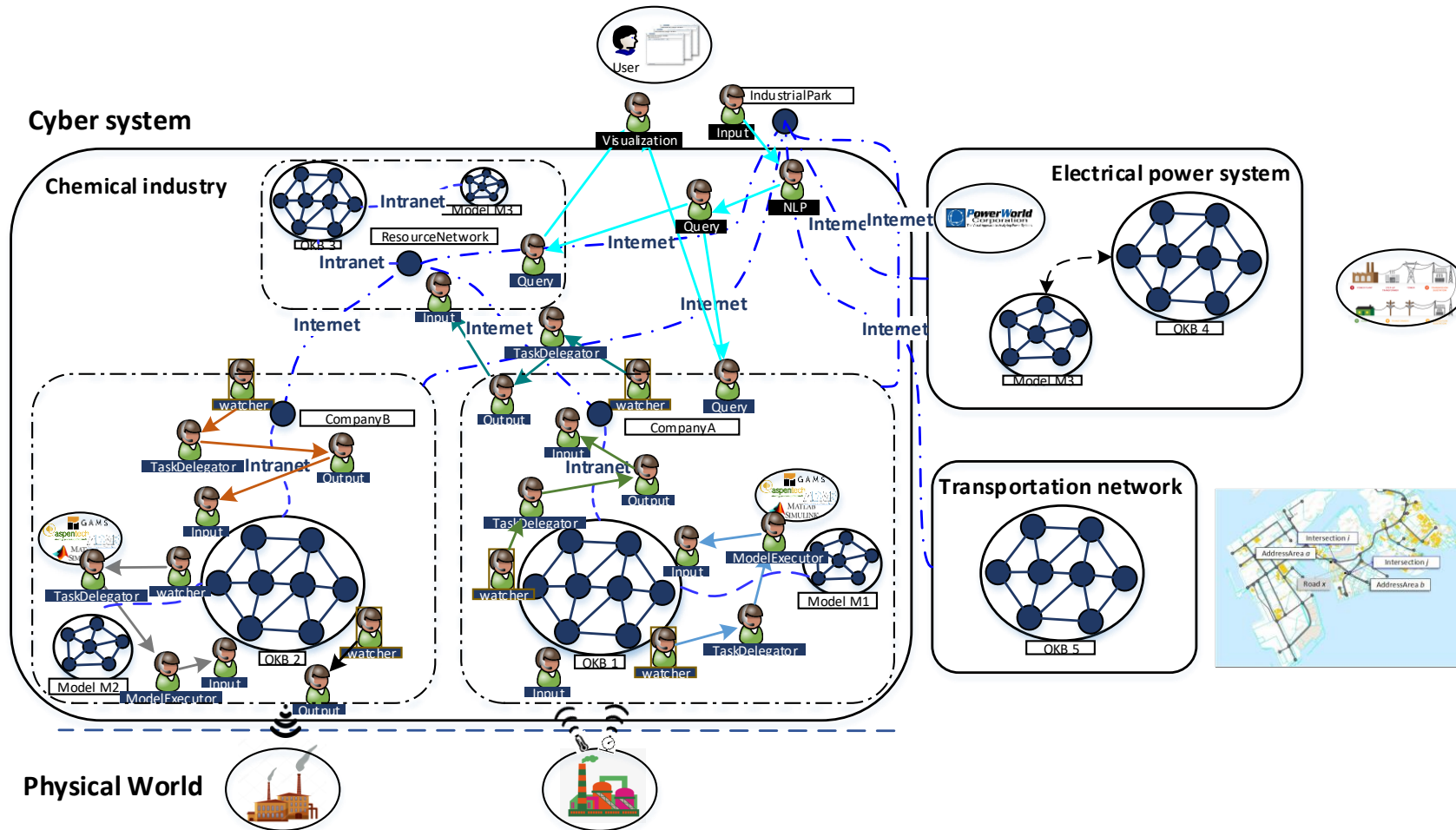
# Extending OntoCAPE to represent eco-industrial park



The ontology is available here:  
<http://www.theworldavatar.com/OntoEIP/Eco-industrialPark.owl>



# Ontology enabled decentralized information management framework for J-Park Simulator



# Sample code for a chemical plant

IRI of the ontological knowledge base

```
<owl:Ontology rdf:about="http://www.ChemicalPlantA.com/ChemicalPlantA.owl">| IRI of the chemical plant ontology
  <owl:imports rdf:resource="http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl"/>
</owl:Ontology>
<p15:ChemicalPlant rdf:about="http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl#ChemicalPlantA">
  <p10:isOwnedBy>
    <p10:Organization rdf:about="http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl#CompanyA"/>
  </p10:isOwnedBy>
  <j.0:produces>
    <j.0:Product rdf:about="http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl#CelaneseVinylAcetateMonomer">
      <j.2:hasPrice>
        <j.2:Price rdf:about="http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl#PriceOfVinylAcetateMonomerByCelanese">
          <j.1:hasValue>
            <j.1:ScalarValue rdf:about="http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl#V_PriceOfVinylAcetateMonomerByCelanese">
              <j.1:hasUnitOfMeasure rdf:resource="http://www.theworldavatar.com/OntoEIP/OntoCAPE/OntoCAPE/supporting_concepts/SI_unit/derived_SI_units.owl#USD/ton"/>
              <j.1:numericalValue rdf:datatype="http://www.w3.org/2001/XMLSchema#float">
                >210.0</j.1:numericalValue>
            </j.1:ScalarValue>
          </j.1:hasValue>
        </j.2:Price>
      </j.2:hasPrice>
      <p10:hasName rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
        <VinylAcetateMonomer></p10:hasName>
    </j.0:Product>
  </j.0:produces>
  <j.0:produces>
    <j.0:Product rdf:about="http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl#CelaneseAceticAcid">
      <p10:hasName rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
        >AceticAcid</p10:hasName>
      <j.2:hasPrice>
        <j.2:Price rdf:about="http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl#PriceOfAceticAcidByCelanese">
          <j.1:hasValue>
            <j.1:ScalarValue rdf:about="http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl#V_PriceOfAceticAcidByCelanese">
              <j.1:numericalValue rdf:datatype="http://www.w3.org/2001/XMLSchema#float">
                >500.0</j.1:numericalValue>
              <j.1:hasUnitOfMeasure rdf:resource="http://www.theworldavatar.com/OntoEIP/OntoCAPE/OntoCAPE/supporting_concepts/SI_unit/derived_SI_units.owl#USD/ton"/>
            </j.1:ScalarValue>
          </j.1:hasValue>
        </j.2:Price>
      </j.2:hasPrice>
    </j.0:Product>
  </j.0:produces>
  ...
</p15:ChemicalPlant>
</owl:Class>
</owl:Ontology>
```

Chemical plant

Company

Price of the product

Product

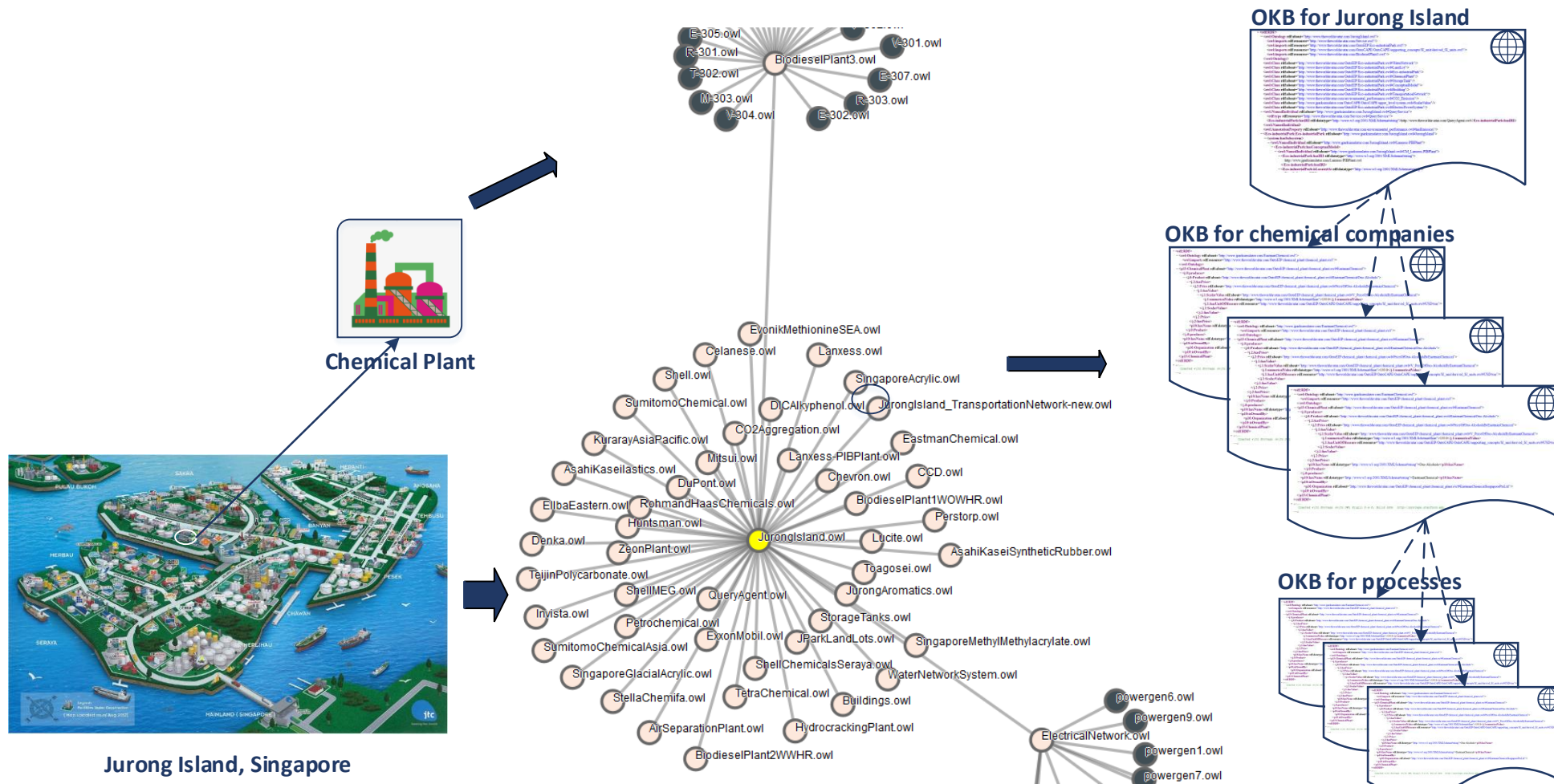
Chemical process system

```
<system:hasSubsystem>
  <system:ChemicalProcessSystem rdf:about="http://www.ChemicalPlantA.com/ChemicalPlantA.owl#VinylAcetateMonomerProduction">
    <Eco-industrialPark:hasConceptualModel>
      <Eco-industrialPark:ConceptualModel rdf:about="http://www.theworldavatar.com/OntoEIP/Eco-industrialPark.owl#CM_VinylAcetateMonomerProduction">
        <Eco-industrialPark:hasIRI rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
          http://www.ChemicalPlantA.com/VinylAcetateMonomerProduction.owl</Eco-industrialPark:hasIRI>
        </Eco-industrialPark:ConceptualModel>
      </Eco-industrialPark:hasConceptualModel>
    </system:ChemicalProcessSystem>
  </system:hasSubsystem>
  ...
```

IRI of a chemical process system as a subsystem of the plant

# Ontological knowledge base for Jurong Island:

<http://www.theworldavatar.com:82/visualizeJurong>



The current version of ontological knowledge base for Jurong Island is available at: <http://www.theworldavatar.com:82/visualizeJurong>



# Natural language based information query

Query in natural language

List all the chemical plants that produce benzene



Input



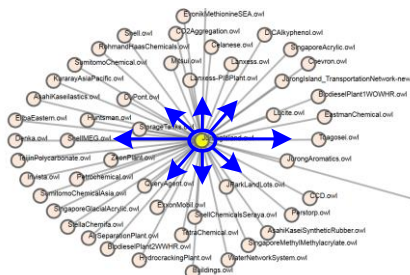
NLP

SPARQL syntax

```
PREFIX chemical_plant:<http://www.theworldavatar.com/OntoEIP/chemical_plant/chemical_plant.owl#>
PREFIX system_function:<http://www.theworldavatar.com/OntoEIP/system_aspects/system_function.owl#>
PREFIX system:<http://www.theworldavatar.com/OntoEIP/upper_level/system_v1.owl#>
PREFIX system_performance:<http://www.theworldavatar.com/OntoEIP/system_aspects/system_performance.owl#>
PREFIX syst:<http://www.theworldavatar.com/OntoEIP/OntoCAPE/OntoCAPE/upper_level/system.owl#>
SELECT ?entity ?product
WHERE {?entity a chemical_plant:ChemicalPlant
?entity system_function:produces ?product
?product system:hasName 'Benzene'}
```



Query



Result

chemical_plant	product
ExxonMobilChemical	Benzene
JurongAromaticsCorporation	Benzene



Visualization

# Conclusion and future work

This paper presents insights on developing a cyber-infrastructure system, called JPS, for the design and operation of EIP, in order to exploit synergies for resource, energy, and emissions savings.

Ontology technology is employed to streamline the massive heterogeneous information sets, and to construct a decentralized information managing system.

An object-oriented bottom-up methodology is presented to model the system, resulting in a hierarchical representation of the EIP (from unit level to process level, plant level and industrial network level).



Thank you for your attention!

