# Adapting Open Standards for Sustainable Engineering Supply Chain

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NIST Workshop on Sustainable Manufacturing: Metrics, Standards and Infrastructure
National Institute of Standards and Technology
October 14, 2009

# *A Supply Chain (Structural Steel)*

Producers (Mills)

Service Centers

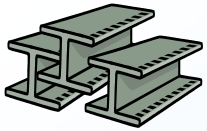
Fabricators

Erectors

**Material flow**

**Material flow**

**Material flow**



Carbon footprint? Wastes? Emissions to air and water?

# *Information Sharing and Supply Chain*

Producers (Mills)

Service Centers

Fabricators

Erectors

**Material flow**

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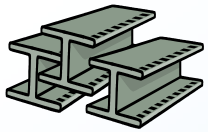

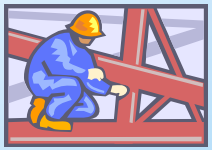

**Information flow**

Web services

Web services

# *Presentation Outline and Scope (Focus: SME Companies)*

- Open Standards for Supply Chain Modeling:
  - Supply Chain Operations Reference (SCOR) Framework
  - GreenSCOR Framework
- Open Standards for Process Modeling and Web Services
  - Business Process Modeling Notation (BPMN)
  - Business Process Execution Language (BPEL)
  - Web Service Definition Language (WSDL)
  - Simple Object Access Protocol (SOAP)
- Open Source Software Tools for Web Services
  - Eclipse's BPMN Modeler, BPEL Editor
  - Apache's Tomcat, Orchestration Director Engine (ODE), Axis and Struts Servlets
  - Liferay portal, MySQL, Hibernate, …

**Modeling**

**Representation**

**Implementation (SC Collaborator)**

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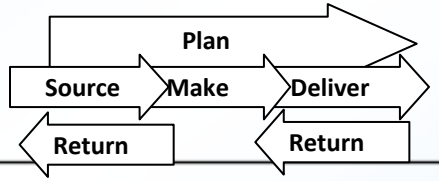
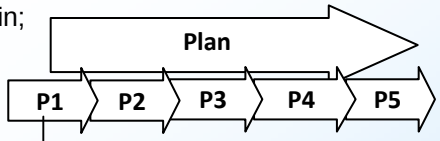
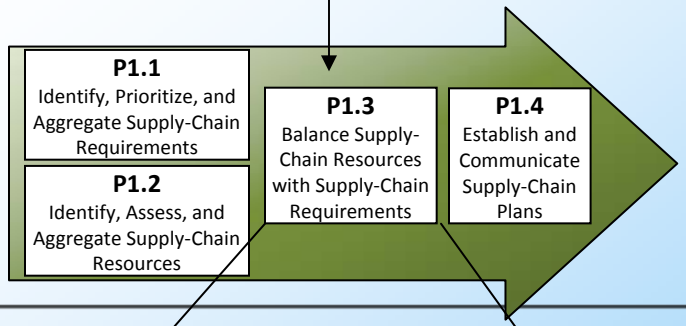
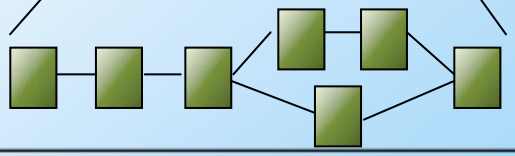
# *Supply Chain Operations Reference (SCOR) Framework*

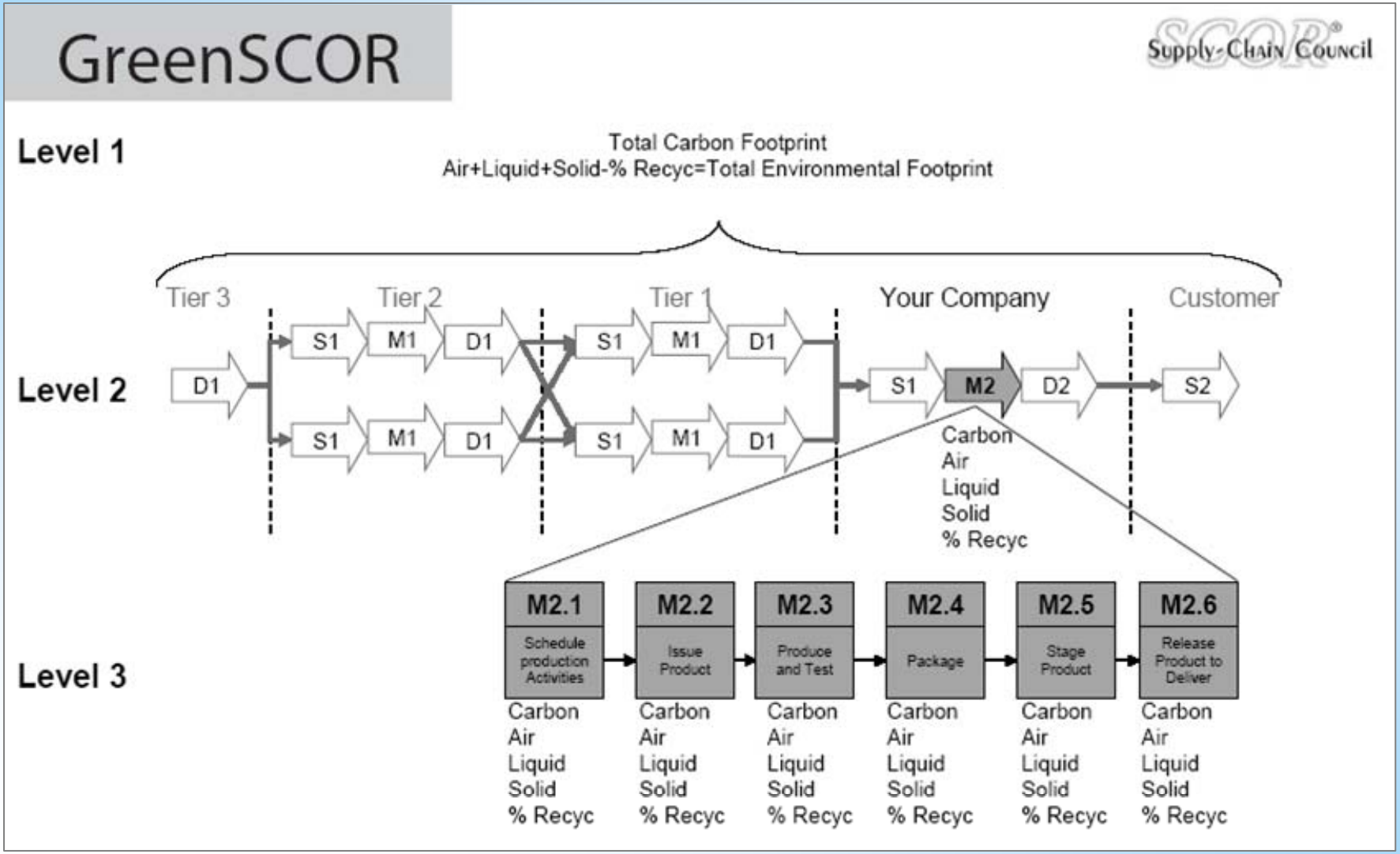
(Ref: Supply Chain Council (SCC), 1996)

- Uses:
  - **Supply Chain Network Modeling**
  - **Performance measurement**
  - Benchmarking and best practices
- Five basic supply chain operations:
  - **Plan** : balance resources to meet the supply chain requirements
  - **Source** : manage the procurement, delivery, receipt, and transfer of subassemblies and products
  - **Make** : transform products to a finished state
  - **Deliver** : order management, transportation management, and distribution management
  - **Return** : post-delivery customer support
- Performance metrics (524)
  - Cycle time – planning, sourcing, production, delivery
  - Documentation
  - % Orders delivered on-time (shipping documents, accuracy, condition)
  - Shipping
  - etc..

# Four Levels of SCOR Framework

| | Level # | Level Description | Schematic |
|---|---|---|---|
| SCOR Model | 1 | Top Level (Process Types) |   |
| | 2 | Configuration Level (Process Categories) | S1: source stocked product; S2: source MTO product; S3: source ETO product;<br>M1: make-to-stock; M2: make-to-order (MTO); M3: engineer-to-order (ETO);<br>D1: deliver stocked product; D2: deliver MTO; D3: deliver ETO; D4: deliver retail<br>P1: plan supply chain;<br>P2: plan source;<br>P3: plan make;<br>P4: plan deliver;<br>P5: plan return<br>   |
| | 3 | Process Element Level (Decompose Processes) |   |
| Not in SCOR Model | 4 | Implementation Level (Decompose Process Elements) |  |

# GreenSCOR Framework




(Supply Chain Council (SCC). *Supply Chain Operations Reference (SCOR) Model, Version 9.0*, 2008.)

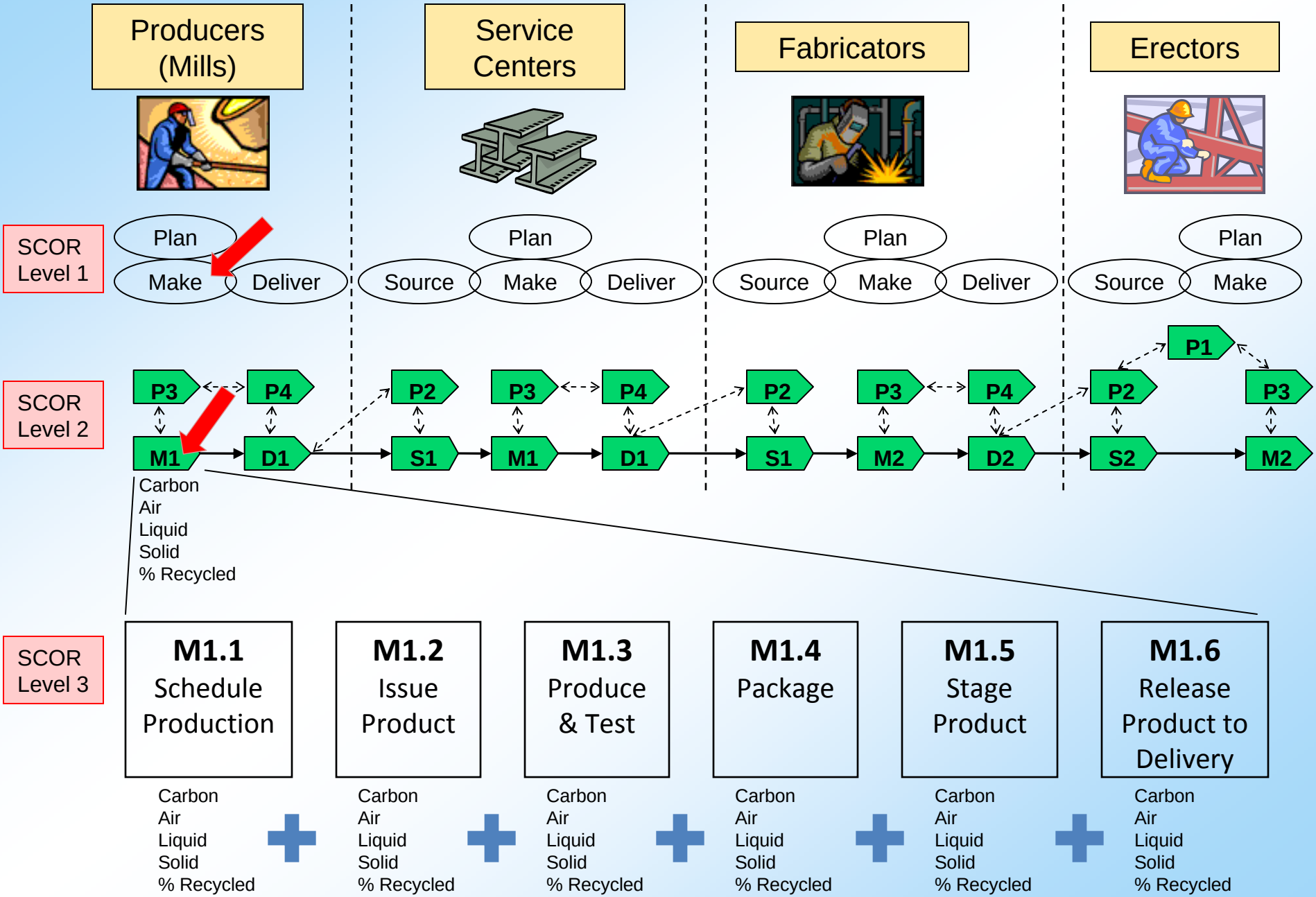
# *GreenSCOR Framework*

- Based on the SCOR framework
- Additional performance metrics:
  - **Carbon footprint** (tons $CO_2$ equivalent)
    - Based on (1) energy consumption, (2) fuel type and consumption, or (3) process throughput
    - Or, actual emissions
  - **Air pollutant emissions**, e.g. COx, NOx, SOx, Volatile Organic Compounds (VOC) and Particulate, the major air pollutants that US EPA tracks (tons or kg)
  - **Liquid waste generated** (tons or kg)
  - **Solid waste generated** (tons or kg)
  - **% Recycled waste** (per cent)

**(1) Total Carbon Footprint (e.g. product, component)**

**(2) Total Environmental Footprint (e.g. product, component)** = air emissions + liquid waste + solid waste x (1 - % recycled)

# Performance Measurements using GreenSCOR



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Representation

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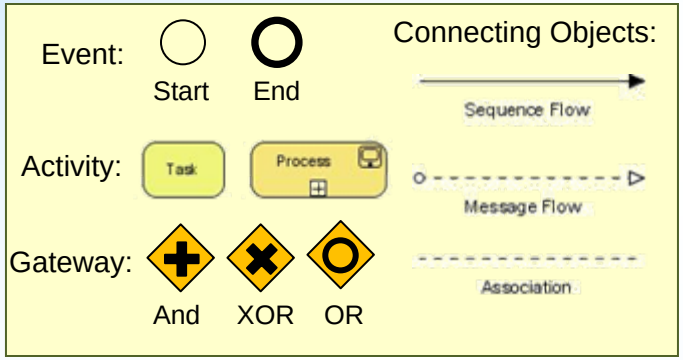
# SCOR Level 3 and 4 Modeling

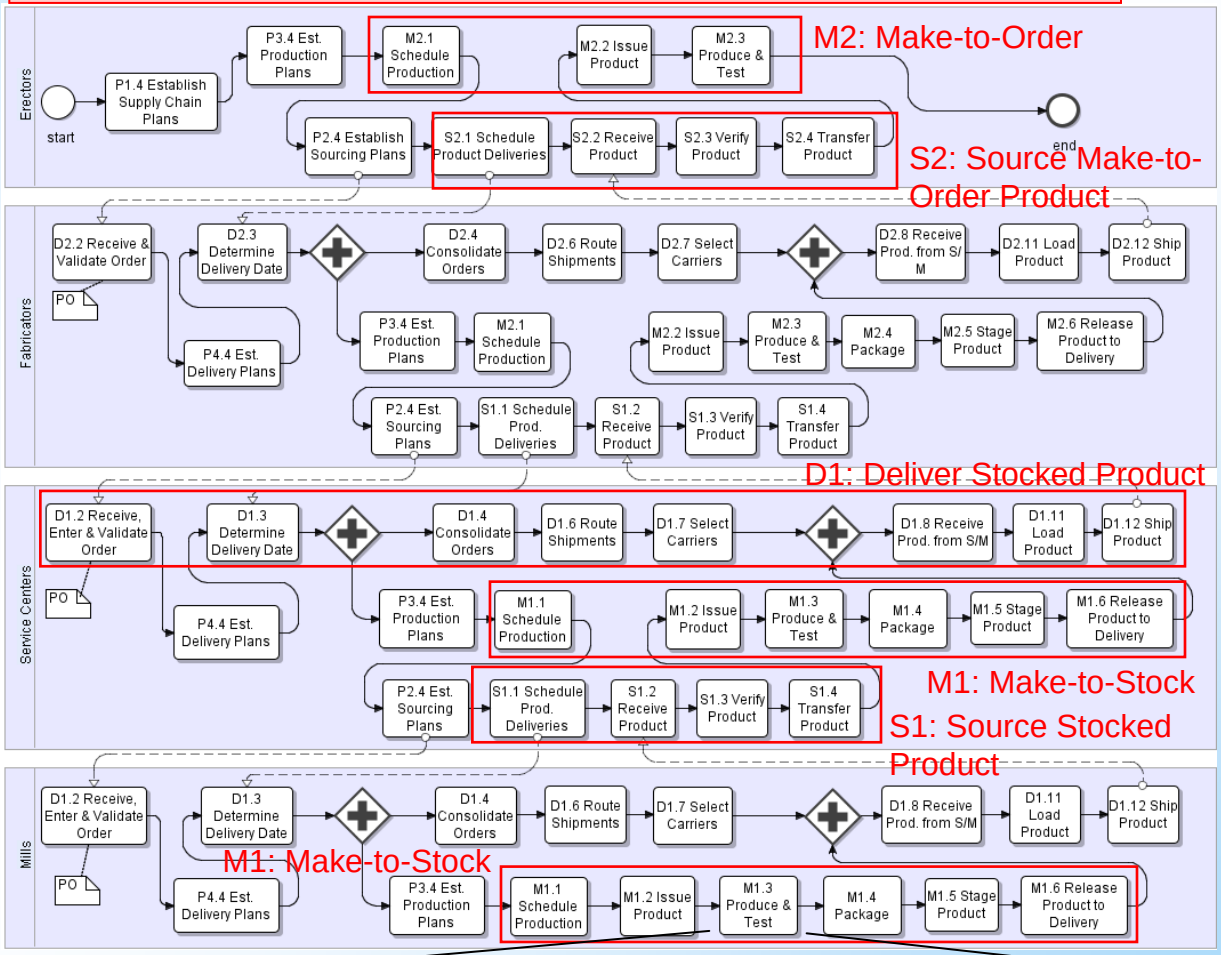
## Business Process Modeling Notation (BPMN):

Elements:

- **Flow Objects:** Events, Activities, Gateways
- **Connecting Objects:** Sequence Flow, Message Flow, Association
- **Swimlanes:** Pool, Lane
- **Artifacts:** Data Objects, Group, Annotation

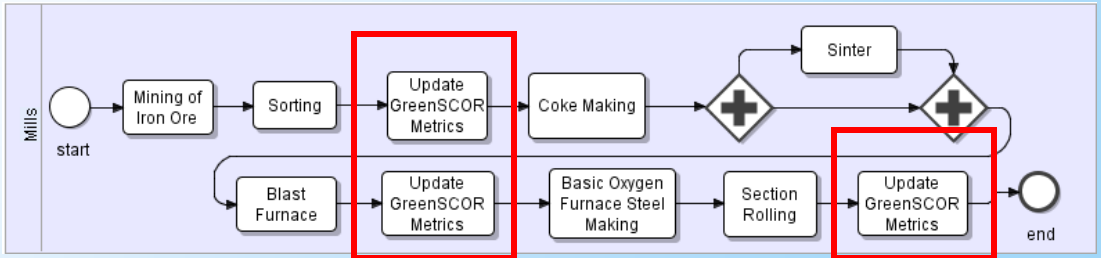



SCOR Level 3 model *(a collection of SCOR Level 3 processes)*




SCOR Level 4 model *(implementation of a SCOR Level 3 process)*

M1.3 Produce & Test



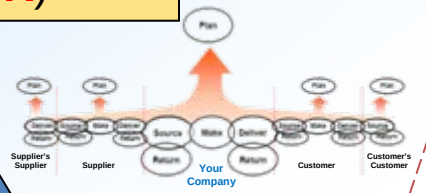
# *Collaborative Systems with Open Standards*

## System Design

## System Implementation

Supply Chain Network Modeling (e.g. **SCOR**)

Web Services Mechanisms and Protocols (e.g. **SOAP**)

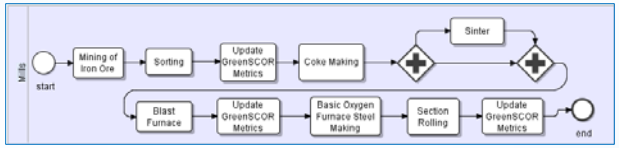



Process Modeling and Definition (e.g. **BPMN**, UML, PSL, PetriNet, IDEF0)

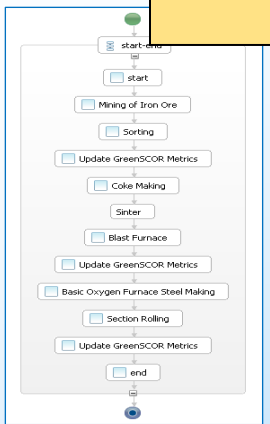
Process Execution (e.g. **WS-BPEL**, WS-CDL)

Data Formatting (e.g. **WSDL**, STEP, IFC)

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<wsdl:definitions
xmlns:soap="http://schemas.xmlsoap.org/wsdl/soap/"
xmlns:tns="http://eig.stanford.edu/GreenSCOR"
xmlns:wsdl="http://schemas.xmlsoap.org/wsdl/"
xmlns:xsd="http://www.w3.org/2001/XMLSchema" name="GreenSCOR"
targetNamespace="http://eig.stanford.edu/GreenSCOR">
 <wsdl:types><xsd:schema
targetNamespace="http://eig.stanford.edu/GreenSCOR">
 <xsd:element name="ReportGreenSCOR">
  <xsd:complexType><xsd:sequence>
  <xsd:element name="organization" type="xsd:string" />
   <xsd:element name="process"
type="xsd:string"></xsd:element>
   <xsd:element name="item" type="xsd:string"></xsd:element>
   <xsd:element name="value" type="xsd:double"></xsd:element>
   <xsd:element name="unit" type="xsd:string"></xsd:element>
   <xsd:element name="CO2e" type="xsd:double"></xsd:element>
   </xsd:sequence></xsd:complexType>
  </xsd:element>
 </xsd:schema></wsdl:types>
 <wsdl:message name="ReportGreenSCORRequest">
  <wsdl:part element="tns:ReportGreenSCOR" name="parameters"/>
 </wsdl:message>
   :
   :
</wsdl:definitions>
```




**(BPMN Modeler – Eclipse)**




**(BPEL Editor – Eclipse)**

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Modeling

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Implementation (SC Collaborator)

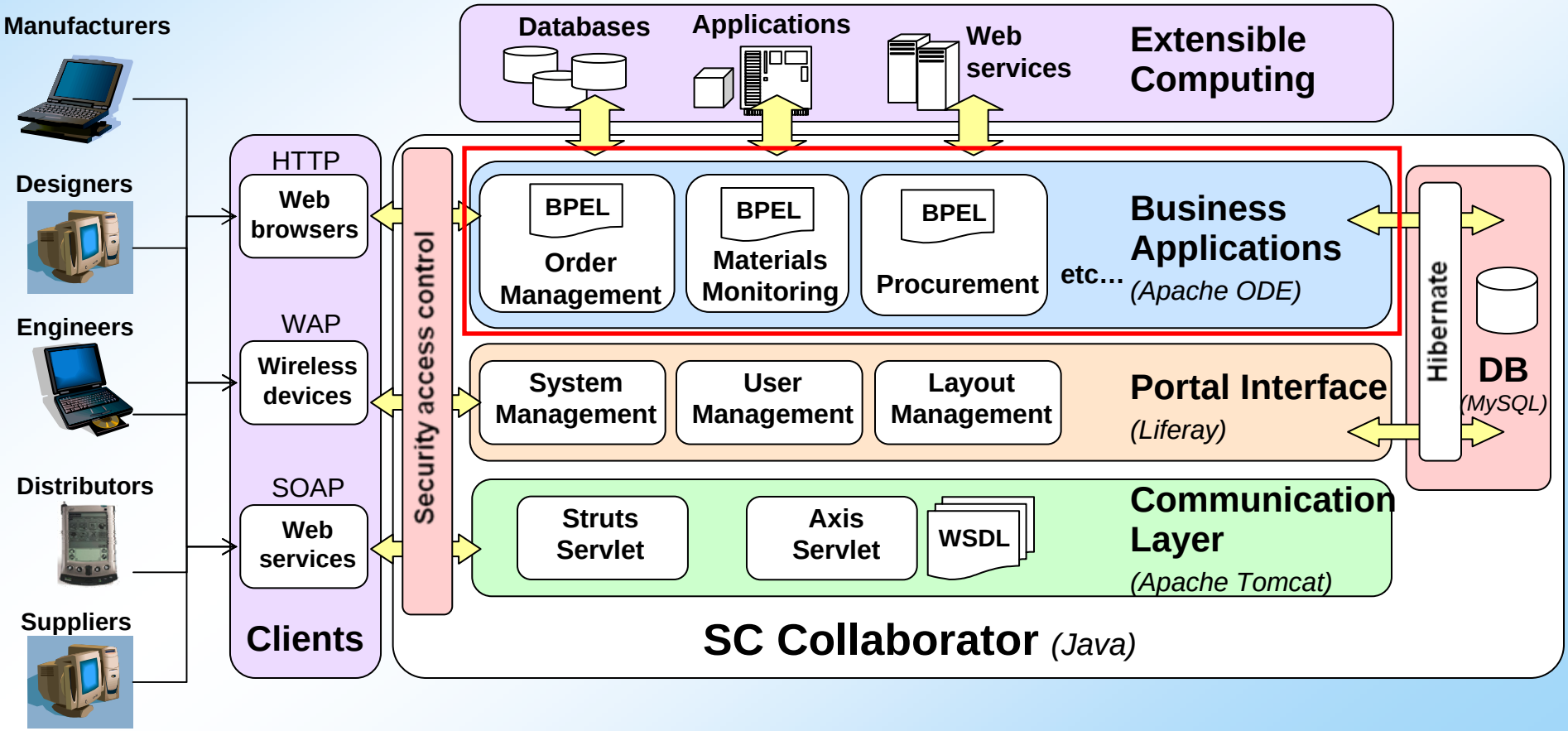
# SC Collaborator – A Prototype Implementation

**Open standards :**

SOAP, WSDL, BPEL

**Open source software:**

- Apache Tomcat, Struts framework, Axis framework: communication
- Liferay Portal System: user interface
- MySQL, Hibernate framework: database support
- Apache ODE engine: BPEL engine



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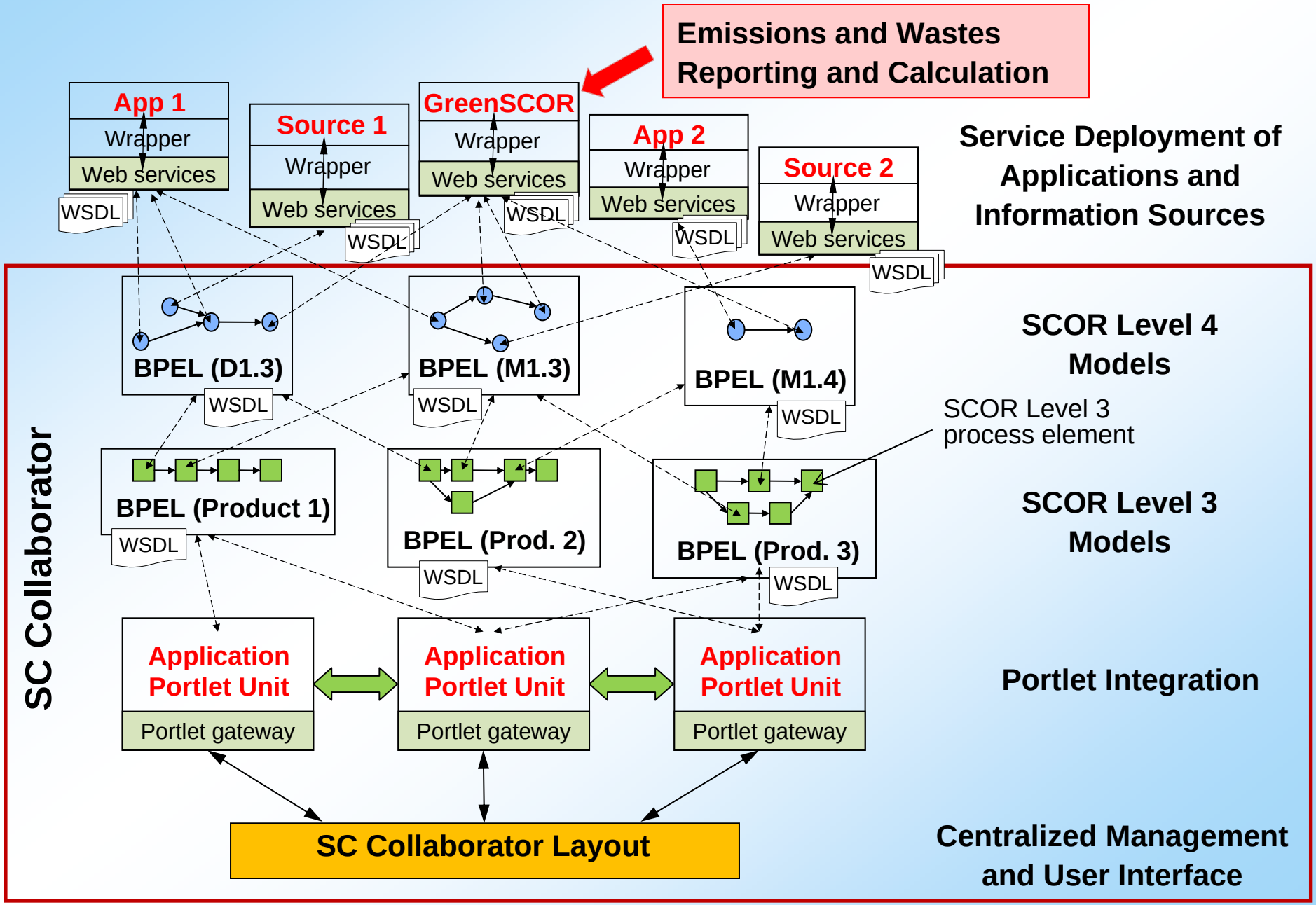
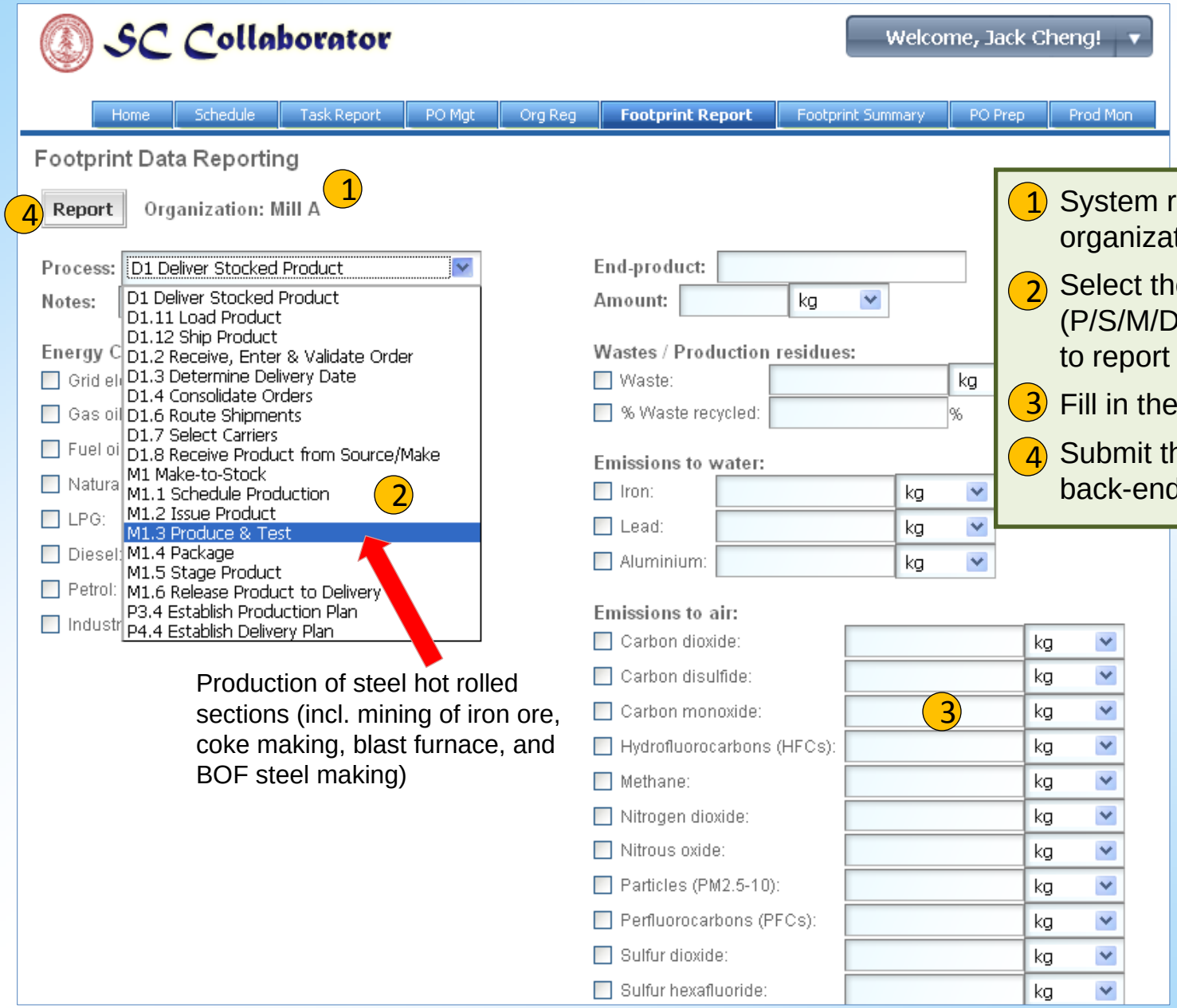


# Reporting Carbon and Environmental Footprint




Production of steel hot rolled sections (incl. mining of iron ore, coke making, blast furnace, and BOF steel making)

1. System recognizes your organization when you log in
2. Select the SCOR Level 2 (P/S/M/D) or Level 3 process to report
3. Fill in the numbers
4. Submit the numbers to the back-end inventory

# EU LCA DataSet

- (http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm)

**Process data set: Steel hot rolled section; blast furnace and electric arc furnace route; production mix, at pl**

Table of Contents: Process information - Modelling and validation - Administrative information - Inputs and Outputs

## Process information

### Key Data Set Information

| | |
|---|---|
| Location | GLO |
| Geographical representativeness description | Data set is based on average<br>Other upstream data (e.g. iror |
| Reference year | 2000 |
| Name | Base name; Treatment, stan<br>Steel hot rolled section; blast |
| Use advice for data set | The data set includes the bur<br>manufacturing and End-of-Lif<br>data set requests contact the<br>www.eurofer.org; the World S<br>data): www.apeal.org. |
| Technical purpose of product or process | A steel section rolled in a hot<br>can be found on the market fo<br>bridge trusses, vertical highw |
| Classification | Class name / Hierarchy level<br>Materials production / Metals |
| General comment on data set | Good data quality. Data collec<br>standards, and consistency-c<br>data modified by worldsteel fo<br>based on worldsteel site spe |
| | Copyright? Yes |

### Quantitative reference

| | |
|---|---|
| Reference flow(s) | steel hot rolled section; blast |

### Time representativeness

| | |
|---|---|
| Data set valid until: | 2009 |
| Time representativeness | Annual average, site-specific<br>processes will require adjust |

## Inputs and Outputs

### Inputs

| Type Of Flow | Classification | Flow | | | source type | Data derivation type / status |
|---|---|---|---|---|---|---|
| Elementary flow | Resources / Resources from ground / Non-renewable material resources from ground | calcium carbonate | 0.093533831 kg (Mass) | 0.093533831 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Resources / Resources from ground / Non-renewable energy resources from ground | crude oil; 42.3 MJ/kg | 1.79696488356 MJ (Net calorific value) | 1.79696488356 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Resources / Resources from ground / Non-renewable material resources from ground | dolomite | 0.024527527 kg (Mass) | 0.024527527 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Resources / Resources from ground / Non-renewable energy resources from ground | hard coal; 26.3 MJ/kg | 7.40871861798 MJ (Net calorific value) | 7.40871861798 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Resources / Resources from ground / Non-renewable material resources from ground | inert rock | 0.2054359372 kg (Mass) | 0.2054359372 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Resources / Resources from ground / Non-renewable element resources from ground | iron | 0.3081539058 kg (Mass) | 0.3081539058 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Resources / Resources from ground / Non-renewable energy resources from ground | natural gas; 44.1 MJ/kg | 2.48111879069694 MJ (Net calorific value) | 2.48111879069694 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Resources / Resources from water / Renewable material resources from water | water | 3.485375378 kg (Mass) | 3.485375378 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Resources / Resources from ground / Non-renewable element resources from ground | zinc | -0.004223832 kg (Mass) | -0.004223832 | Mixed primary / secondary | Unknown derivation |

Crude oil: 1.797 MJ
Coal: 7.409 MJ
Natural gas: 2.481 MJ

### Outputs

| Type Of Flow | Classification | Flow | Resulting amount | Mean amount | Data source type | Data derivation type / status |
|---|---|---|---|---|---|---|
| Product flow | Materials production / Metals and semimetals | steel hot rolled section; blast furnace and electric arc furnace route; production mix, at plant | 1 kg (Mass) | 1 | Mixed primary / secondary | Unknown derivation |
| Waste flow | Wastes / Production residues | waste (unspecified) | 0.449876076 kg (Mass) | 0.449876076 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | 2,3,7,8-tetrachlorodibenzo-p-dioxin | 3.98519E-12 kg (Mass) | 3.98519E-12 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | ammonia | 0.00016259 kg (Mass) | 0.00016259 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | cadmium | 6.53063E-8 kg (Mass) | 6.53063E-8 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | cadmium | 3.80813E-9 kg (Mass) | 3.80813E-9 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | carbon dioxide | 1.099686982 kg (Mass) | 1.099686982 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | carbon monoxide | 0.013261505 kg (Mass) | 0.013261505 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | chemical oxygen demand | 3.91037E-5 kg | 3.91037E-5 | Mixed primary / | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | chromium | | | primary / | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | chromium | | | primary / | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | hydrogen chloride | | | primary / | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | hydrogen sulfide | | | primary / | Unknown derivation |

Steel section: 1 kg
Waste: 0.45 kg
Carbon dioxide: 1.1 kg
Carbon monoxide: 0.013 kg

# EU LCA DataSet

| | | | | | | |
|---|---|---|---|---|---|---|
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | carbon dioxide | 1.099686982 kg (Mass) | 1.099686982 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | carbon monoxide | | | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | chemical oxygen demand | | | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | chromium | | | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | chromium | | | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | hydrogen chloride | | | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | hydrogen sulfide | 3.24944E-5 kg (Mass) | 3.24944E-5 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | iron | 0.000117068 kg (Mass) | 0.000117068 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | lead | 2.39986E-6 kg (Mass) | 2.39986E-6 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | lead | 1.96417E-7 kg (Mass) | 1.96417E-7 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | mercury | 1.09549E-7 kg (Mass) | 1.09549E-7 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | methane | 0.000719562 kg (Mass) | 0.000719562 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | nickel | 5.30354E-8 kg (Mass) | 5.30354E-8 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | nitrogen | 1.64656E-5 kg (Mass) | 1.64656E-5 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | nitrogen dioxide | 0.001686861 kg (Mass) | 0.001686861 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | nitrous oxide | 4.81014E-5 kg (Mass) | 4.81014E-5 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | non-methane volatile organic compounds | 0.000130676 kg (Mass) | 0.000130676 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | particles (> PM10) | 6.78043E-5 kg (Mass) | 6.78043E-5 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | particles (PM2.5 - PM10) | 0.000614392 kg (Mass) | 0.000614392 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | phosphate | 1.55295499E-5 kg (Mass) | 1.55295499E-5 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | sulfur dioxide | 0.002049177 kg (Mass) | 0.002049177 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to air / Emissions to air, unspecified | zinc | 1.3516E-5 kg (Mass) | 1.3516E-5 | Mixed primary / secondary | Unknown derivation |
| Elementary flow | Emissions / Emissions to water / Emissions to fresh water | zinc | 3.06178E-7 kg (Mass) | 3.06178E-7 | Mixed primary / secondary | Unknown derivation |

Iron: 0.0001171 kg
Methane: 0.0007196 kg
Nitrogen dioxide: 0.0016869 kg
Nitrous oxide: 4.81014E-5 kg
Particles (PM2.5-10): 0.0006144 kg
Sulfur dioxide: 0.0020492 kg

# Reporting of Carbon and Environmental Footprint

**Data from EU LCA data sheets**

SC Collaborator

Welcome, Jack Cheng!

Home | Schedule | Task Report | PO Mgt | Org Reg | **Footprint Report** | Footprint Summary | PO Prep | Prod Mon

Footprint Data Reporting

Report | Organization: Mill A

Process: M1.3 Produce & Test

Notes:

Weight of steel sections produced

End-product: Steel section CS36-M10-20-40-5

Amount: 11528 kg

**Carbon Footprint**

Energy Consumption:

| | | |
|---|---|---|
| ☐ Grid electricity: | | kWh |
| ☐ Gas oil: | | tonnes |
| ☑ Fuel oil: | 20715 | MJ |
| ☑ Natural gas: | 28602 | MJ |
| ☐ LPG: | | kWh |
| ☐ Diesel: | | tonnes |
| ☐ Petrol: | | tonnes |
| ☑ Industrial coal: | 85408 | MJ (tonnes / kWh / MJ) |

**Environmental Footprint**

Wastes | Production residues:

| | | |
|---|---|---|
| ☑ Waste: | 5186 | kg |
| ☐ % Waste recycled: | | % |

Emissions to water:

| | | |
|---|---|---|
| ☑ Iron: | 1.35 | kg |
| ☐ Lead: | | kg |
| ☐ Aluminium: | | kg |

Emissions to air:

| | | |
|---|---|---|
| ☑ Carbon dioxide: | 12677 | kg |
| ☐ Carbon disulfide: | | kg |
| ☑ Carbon monoxide: | 153 | kg |
| ☐ Hydrofluorocarbons (HFCs): | | kg |
| ☑ Methane: | 8.3 | kg |
| ☑ Nitrogen dioxide: | 19.4 | kg |
| ☑ Nitrous oxide: | 0.55 | kg |
| ☑ Particles (PM2.5-10): | 7.08 | kg |
| ☐ Perfluorocarbons (PFCs): | | kg |
| ☑ Sulfur dioxide: | 23.6 | kg |
| ☐ Sulfur hexafluoride: | | kg |

Example (coal):
85408 x 1.188
= 101,457 kg $CO_2$

Example (methane):
(20 yr) 8.3 x 72
= 597.6 kg $CO_2$e
(100 yr) 8.3 x 25
= 207.5 kg $CO_2$e

Global Warming Potential

Defra's GHG conversion factors (April 2008)

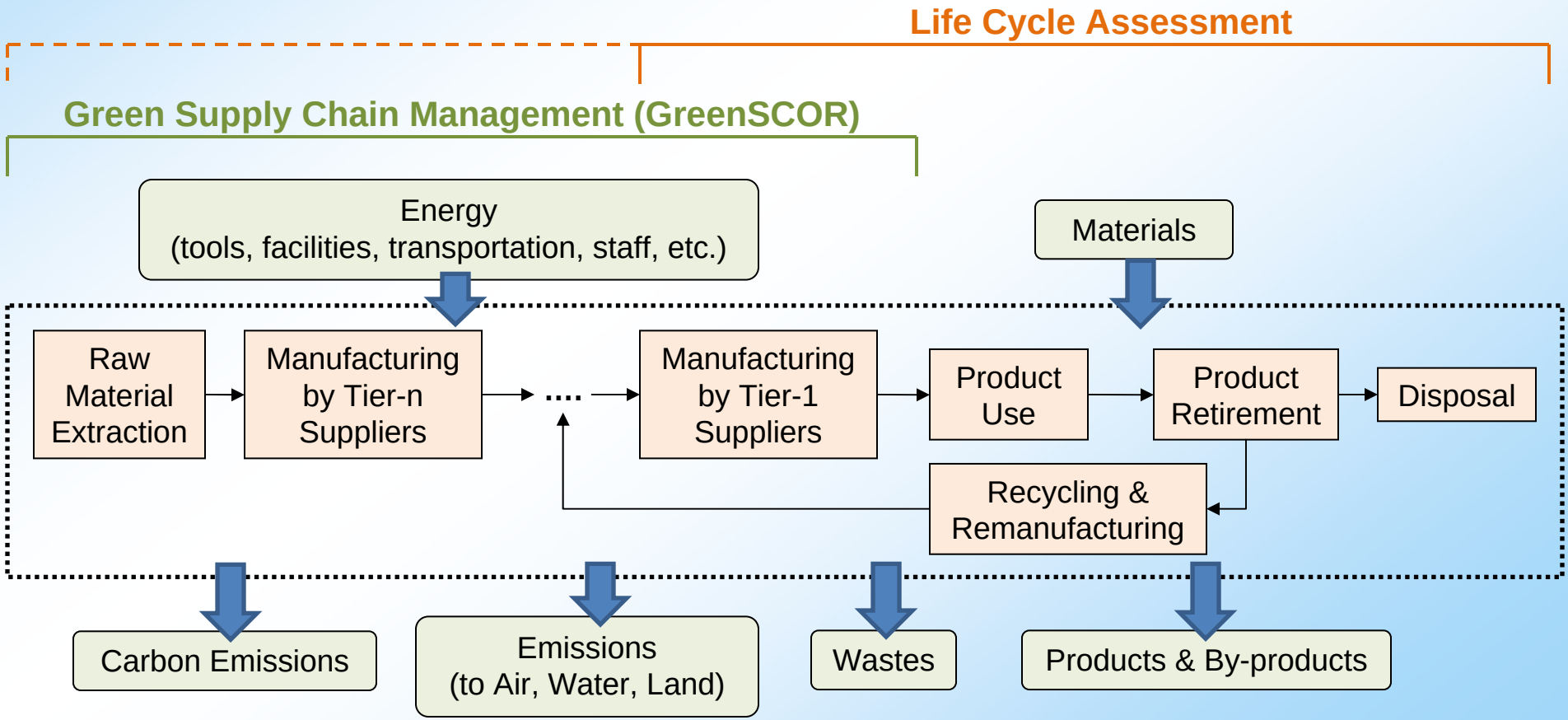
| | Units | kg $CO_2$/unit |
|---|---|---|
| Fuel oil | MJ | 0.965 |
| Natural gas | MJ | 0.666 |
| Industrial coal | MJ | 1.188 |

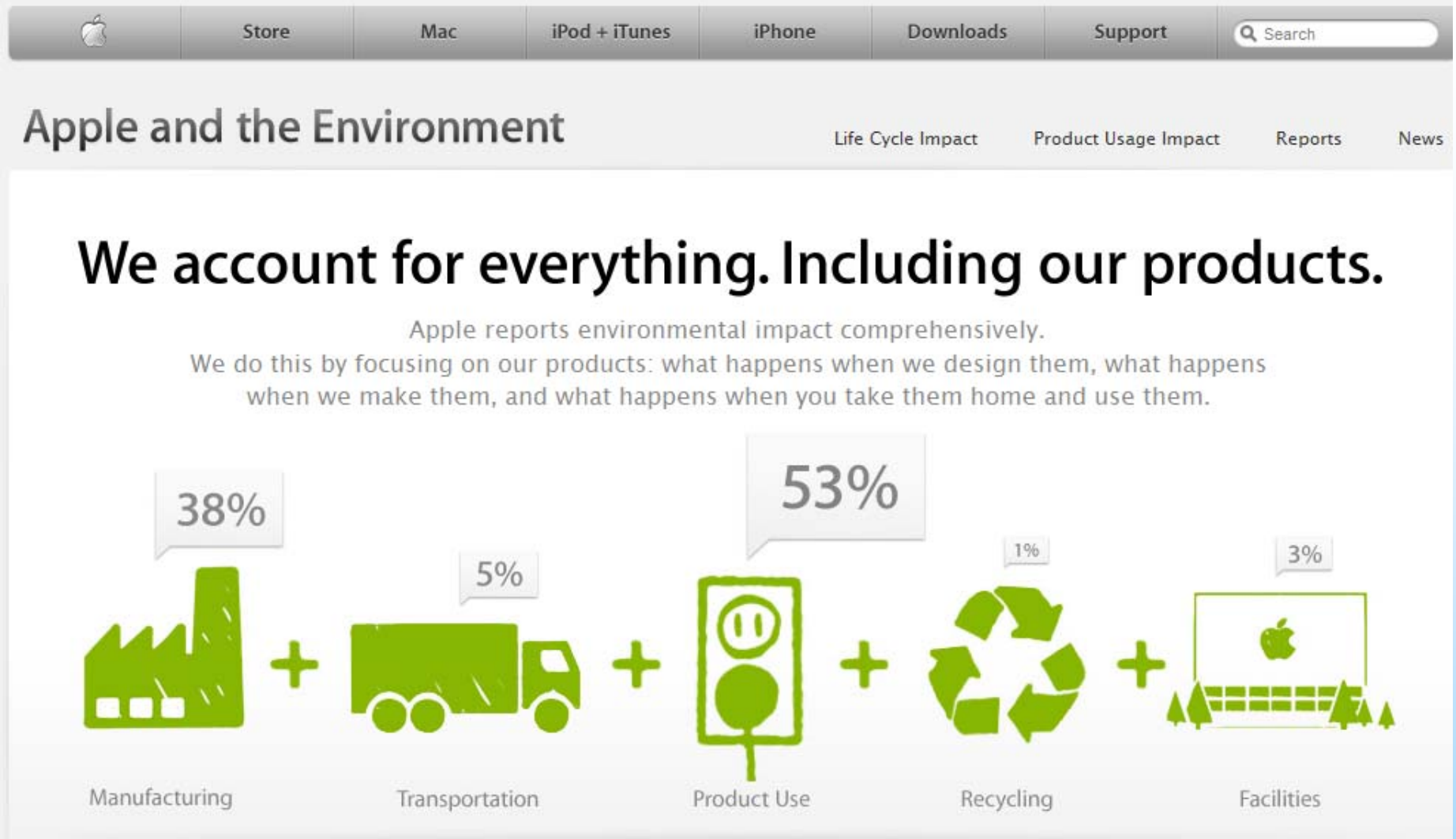
# *Discussion*

- Open Standards -- facilitates prototype implementation of sustainable engineering supply chain
- GSCM framework – Compatibility with companies' processes and environmental management systems?
- Data, Case Studies, Interoperability -- Data collection throughout supply chains can be difficult and costly? Sharing of data and case studies among companies? Data interoperability among application services?
- Metrics, Standards and Regulations – Performance measures and standardization of metrics, regulation compliance infrastructure?
- Usage and End-of-Life consideration -- total environmental impacts throughout entire product life cycles

# *Green Supply Chain Management (GSCM) and Life Cycle Assessment (LCA)*

- LCA usually does not consider the environmental impacts of suppliers (n-th tier suppliers)
- GSCM usually focuses on supply chain operations (planning, sourcing, production, delivery, and return activities) but not use and re-manufacturing
- LCA + GSCM (+ social responsibilities)






http://www.apple.com/environment/

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# Thank You for Your Attention

## Comments and Suggestions!

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