



Engenharia de  
Produção

# A contribuição da USP na transição para a Economia Circular

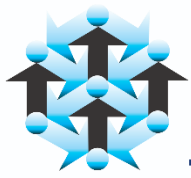
Prof. Assoc. Aldo Roberto Ometto  
Grupo de pesquisa em Engenharia e Gestão do Ciclo de Vida



Escola de Engenharia  
de São Carlos



Universidade  
de São Paulo

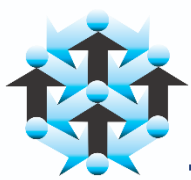


# Agenda

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1. Introdução
2. USP como Pioneer University
3. Considerações





# USP – São Carlos

> Escola de Engenharia de São Carlos (EESC)



> Departamento de Engenharia de Produção (SEP)



> Núcleo de Manufatura Avançada (NUMA)



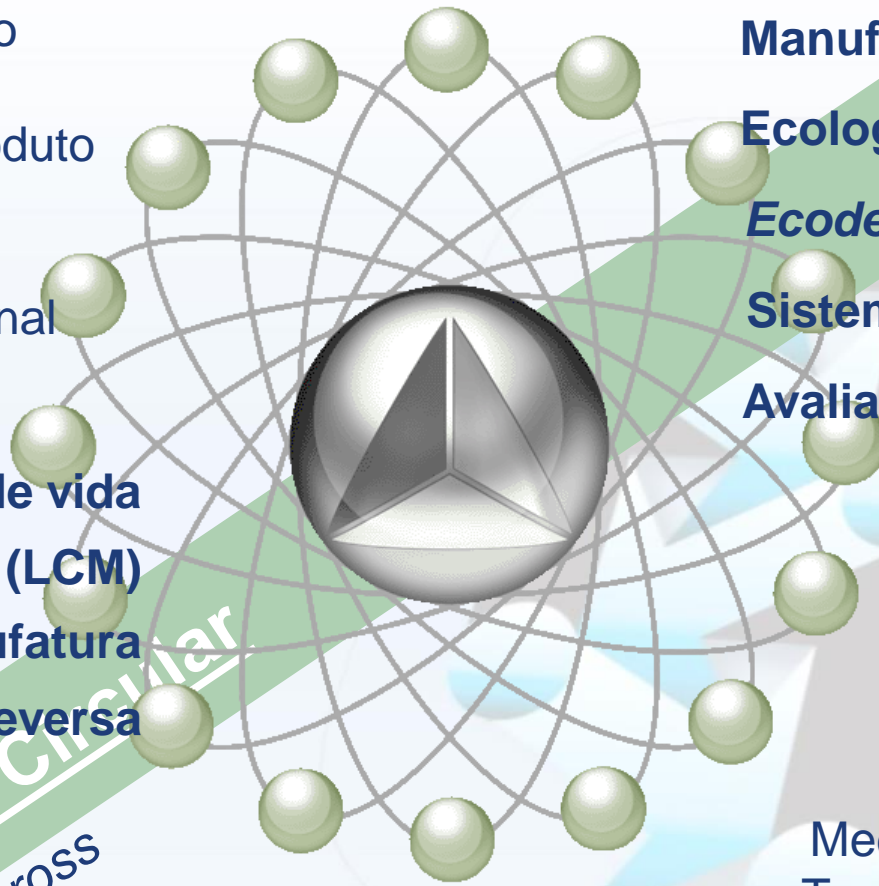


# Competências do NUMA

Otimização do processo de manufatura  
Gestão por processos de negócio  
Gestão ágil de projetos  
Gestão de conhecimento  
Gestão da qualidade  
Desenvolvimento de produto  
Gestão de mudanças  
Gestão de projetos  
Modelagem organizacional  
Modelo de maturidade

**Engenharia do ciclo de vida**  
**Gestão do ciclo de vida (LCM)**  
**Remanufatura**  
**Logística Reversa**

**Economia Circular**  
Disciplina cross



**Ecoinovação**

**Manufatura sustentável**

**Ecologia industrial**

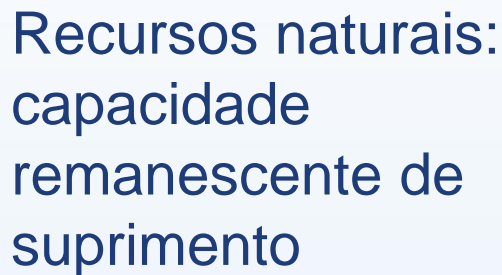
**Ecodesign**

**Sistema Produto-Serviço**

**Avaliação do ciclo de vida**

Logística  
Six Sigma  
Automação  
Produção enxuta  
Redes colaborativas  
Medição de desempenho  
Tecnologia da informação  
Melhoria contínua

Gestão do ciclo de vida de produtos (PLM)



**Remaining years  
until depletion of  
known reserves  
(based on current  
rate of extraction)**

- 5-50 years
- 50-100 years
- 100-500 years

1 <b>H</b> 1.0079																	2 <b>He</b>
3 <b>Li</b> 6.941	4 <b>Be</b> 9.0122											5 <b>B</b> 10.811	6 <b>C</b> 12.011	7 <b>N</b> 14.007	8 <b>O</b> 15.999	9 <b>F</b> 18.998	10 <b>Ne</b> 20.180
11 <b>Na</b> 22.990	12 <b>Mg</b> 24.305											13 <b>Al</b> 26.982	14 <b>Si</b> 28.086	15 <b>P</b> 30.974	16 <b>S</b> 32.06	17 <b>Cl</b> 35.453	18 <b>Ar</b> 39.948
19 <b>K</b> 39.098	20 <b>Ca</b> 40.078	21 <b>Sc</b> 44.956	22 <b>Ti</b> 47.887	23 <b>V</b> 50.942	24 <b>Cr</b> 51.996	25 <b>Mn</b> 54.938	26 <b>Fe</b> 55.845	27 <b>Co</b> 58.933	28 <b>Ni</b> 58.693	29 <b>Cu</b> 63.546	30 <b>Zn</b> 65.38	31 <b>Ga</b> 69.723	32 <b>Ge</b> 72.64	33 <b>As</b> 74.922	34 <b>Se</b> 78.96	35 <b>Br</b> 79.904	36 <b>Kr</b> 83.798
37 <b>Rb</b> 85.468	38 <b>Sr</b> 87.62	39 <b>Y</b> 88.906	40 <b>Zr</b> 91.224	41 <b>Nb</b> 92.906	42 <b>Mo</b> 95.94	43 <b>Tc</b> 98	44 <b>Ru</b> 101.07	45 <b>Rh</b> 102.91	46 <b>Pd</b> 106.42	47 <b>Ag</b> 107.87	48 <b>Cd</b> 112.41	49 <b>In</b> 114.82	50 <b>Sn</b> 118.71	51 <b>Sb</b> 121.76	52 <b>Te</b> 127.6	53 <b>I</b> 126.905	54 <b>Xe</b> 131.29
55 <b>Cs</b> 132.91	56 <b>Ba</b> 137.33	57 <b>La</b> 138.905	58 <b>Hf</b> 178.49	59 <b>Ta</b> 180.948	60 <b>W</b> 183.84	61 <b>Re</b> 186.21	62 <b>Os</b> 190.23	63 <b>Ir</b> 192.22	64 <b>Pt</b> 195.08	65 <b>Au</b> 196.97	66 <b>Hg</b> 200.59	67 <b>Tl</b> 204.38	68 <b>Pb</b> 207.2	69 <b>Bi</b> 208.98	70 <b>Po</b> 209	71 <b>At</b> 210	72 <b>Rn</b> 222
87 <b>Fr</b> 223	88 <b>Ra</b> 226	89 <b>Ac</b> 227	90 <b>Rf</b> 261	91 <b>Db</b> 262	92 <b>Sg</b> 266	93 <b>Bh</b> 264	94 <b>Hs</b> 277	95 <b>Mt</b> 268	96 <b>Ds</b> 271	97 <b>Rg</b> 272	98 <b>Uub</b> 289	99 <b>Uut</b> 288	100 <b>Uuq</b> 289	101 <b>Uup</b> 288	102 <b>Lv</b> 293	103 <b>Uus</b> 289	104 <b>Uuo</b> 294

58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu
140.12		140.91		144.24		144.91		150.36		151.96		157.25		158.93		162.50		164.93		167.26		168.93		173.05		174.96	
90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr
232.04		231.04		238.03		237.05		244.06		247.07		251.08		262.11		267.12		288.10		291.10		297.10		298.10		289.10	

1																	2				
H																	He				
1.0079																					
3	4															5	6	7	8	9	10
Li	Be															B	C	N	O	F	Ne
6.941	9.0122															10.811	12.011	14.007	15.999	18.998	20.180
11	12															13	14	15	16	17	18
Na	Mg															Al	Si	P	S	Cl	Ar
22.990	24.305															26.982	28.086	30.974	32.06	35.45	39.948
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36				
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr				
39.098	40.078	44.956	47.867	50.942	51.996	54.938	55.935	58.933	58.933	63.546	65.38	69.723	72.64	74.922	78.96	79.904	83.798				
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54				
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe				
85.468	87.62	88.906	91.224	92.906	95.94	98	101.07	102.91	106.42	107.87	112.41	114.82	117.87	121.76	127.60	126.905	131.29				
55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72				
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn				
132.91	137.33	138.905	178.49	180.95	183.84	186.21	190.23	192.22	195.08	196.967	200.59	204.38	207.2	208.98	209	210	222				
87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104				
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Lv	Uus	Uuo				
223	226	227	261	262	263	264	276	288	289	294	295	296	297	298	315	315	315				

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 144.91	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 244.06	95 Am 243.06	96 Cm 247.07	97 Bk 247.07	98 Cf 251.08	99 Es 252.08	100 Fm 257.10	101 Md 258.10	102 No 259.10	103 Lr 262.10

SOURCE: Professor James Clark, Green Chemistry, The University of York



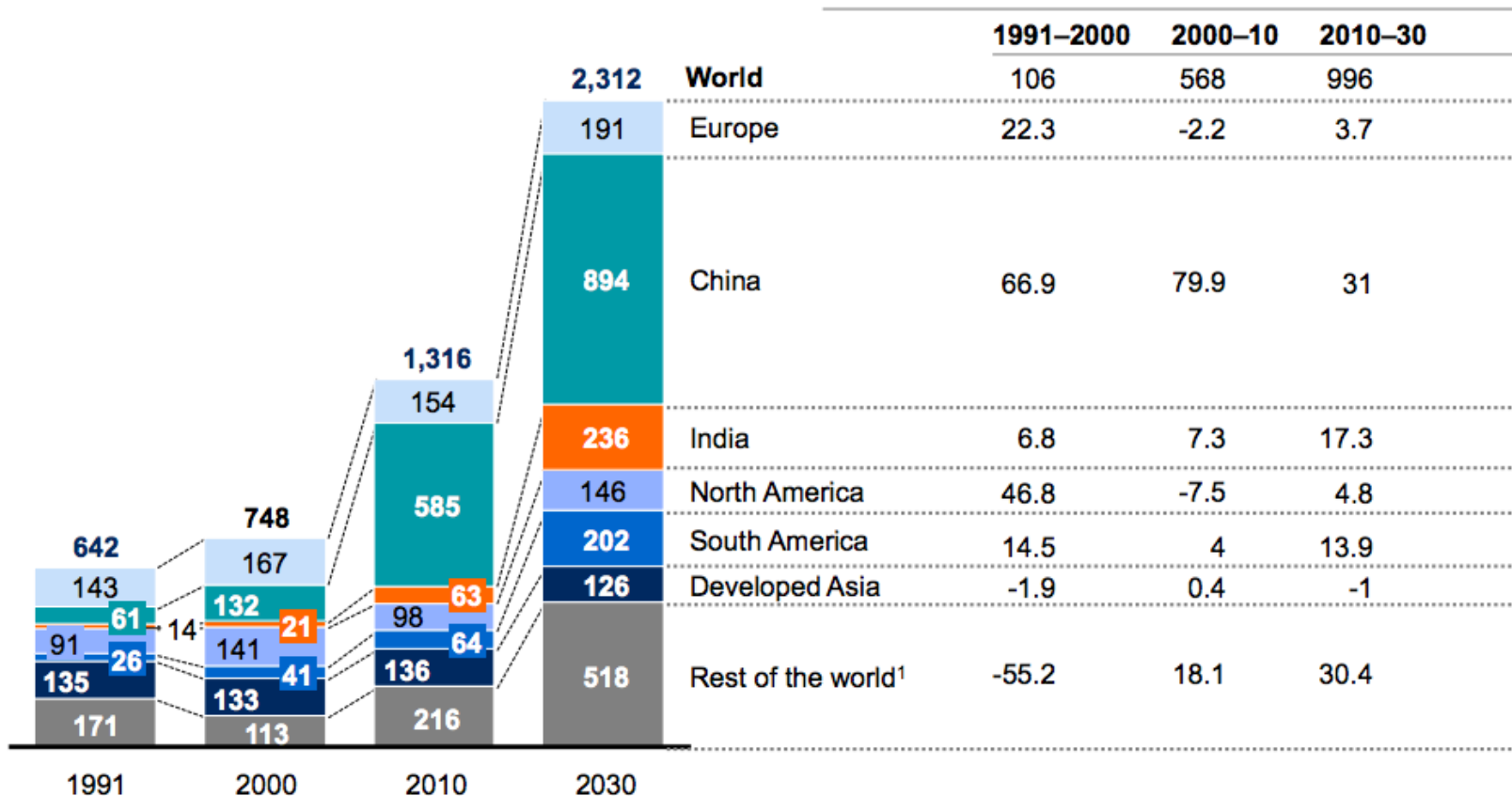


## Global steel demand is expected to increase by more than 75 percent from 2010 to 2030, driven by emerging markets

### Finished steel demand

Million tons

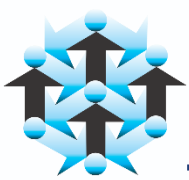
#### Demand growth and regional contribution to growth % of incremental demand



1 Includes the Commonwealth of Independent States, Middle East and North Africa, sub-Saharan Africa, and Oceania.

NOTE: Numbers may not sum due to rounding.

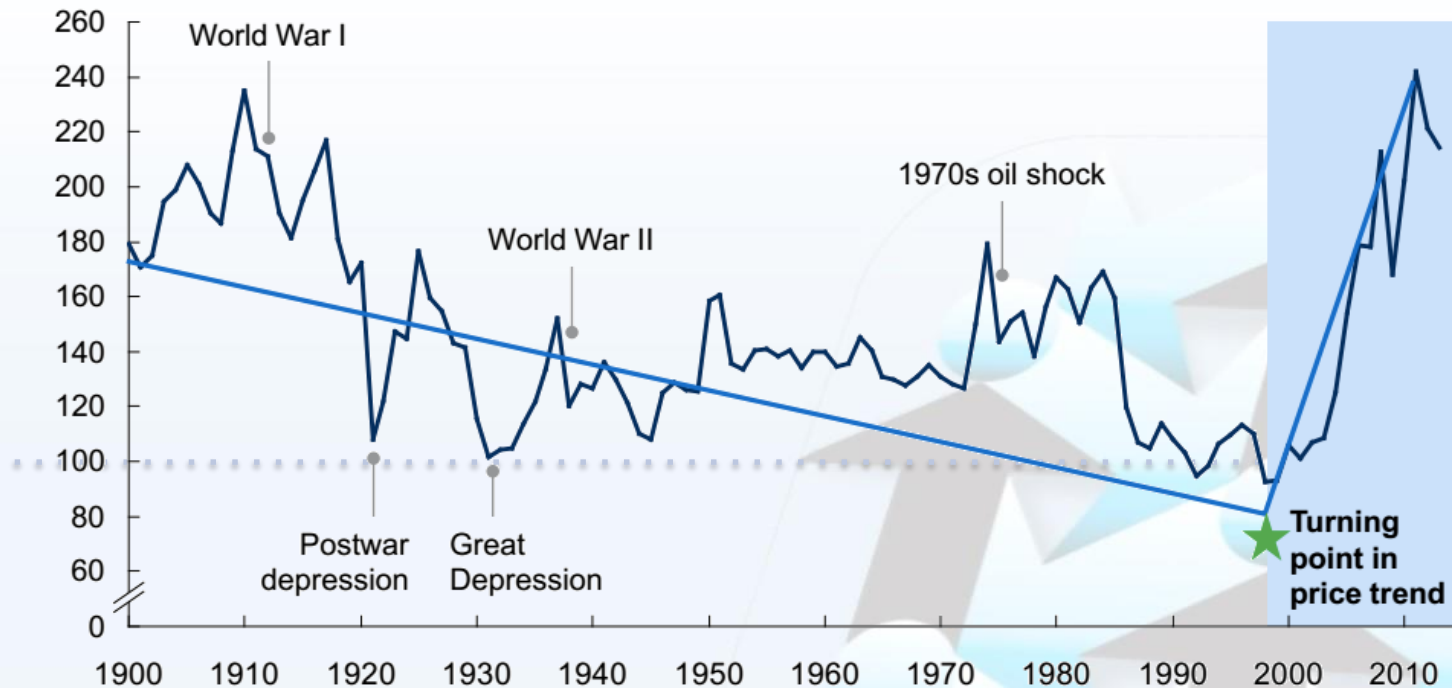
SOURCE: McKinsey analysis; McKinsey Global Institute analysis



# O valor dos produtos básicos

## McKinsey Commodity Price Index<sup>1</sup>

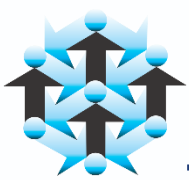
Real price index: 100 = years 1999–2001<sup>2</sup>



1 Based on arithmetic average of four commodity sub-indexes: food, non-food agricultural raw materials, metals, and energy.

2 Data for 2013 are calculated based on average of the first three months of 2013.

SOURCE: Grilli and Yang; Pfaffenzeller; World Bank; International Monetary Fund; Organisation for Economic Co-operation and Development statistics; Food and Agriculture Organization of the United Nations; UN Comtrade; McKinsey Global Institute analysis



# O valor das commodities

**Since 2009, resource prices have rebounded quicker than global economic output**

Indexes<sup>1</sup>

— World GDP  
— MGI Commodity Index



<sup>1</sup> Nominal data indexed to 1Q2007.

SOURCE: Oxford Economics; World Bank; International Monetary Fund; Organisation for Economic Co-operation and Development; Food and Agriculture Organization of the United Nations; UN Comtrade; McKinsey Global Institute analysis





# Mudanças nos Modelos de Negócios

**MIT Sloan**  
Management Review

**RESEARCH  
REPORT**

WINTER 2013

In collaboration with

**BCG**

THE BOSTON CONSULTING GROUP

FINDINGS FROM THE 2012 SUSTAINABILITY & INNOVATION  
GLOBAL EXECUTIVE STUDY AND RESEARCH REPORT

## The Innovation Bottom Line

How companies that see sustainability as both a necessity and an opportunity, and change their business models in response, are finding success.

By MIT Sloan Management Review and The Boston Consulting Group

### 10: Where do you see profit from sustainability? (Please choose all that apply.)

Innovation advantage – identifying better solutions early

67%

Intangible benefits

52%

Cost advantage with their sustainability efforts

51%

Price premium for their sustainability positioning

35%

Outsized market share for their sustainability positioning

28%

### 5: What elements of the business model has your company changed in connection with sustainability? (Please choose all that apply.)

Product/service offering

40%

64%

Value chain processes

35%

56%

Organizational structure

30%

51%

Cost model

29%

46%

Target segments

24%

37%

Revenue model

18%

30%

No business model change

25%

Average of all

Average of respondents  
with changed business model

# A Economia Circular

## PRINCÍPIO 1

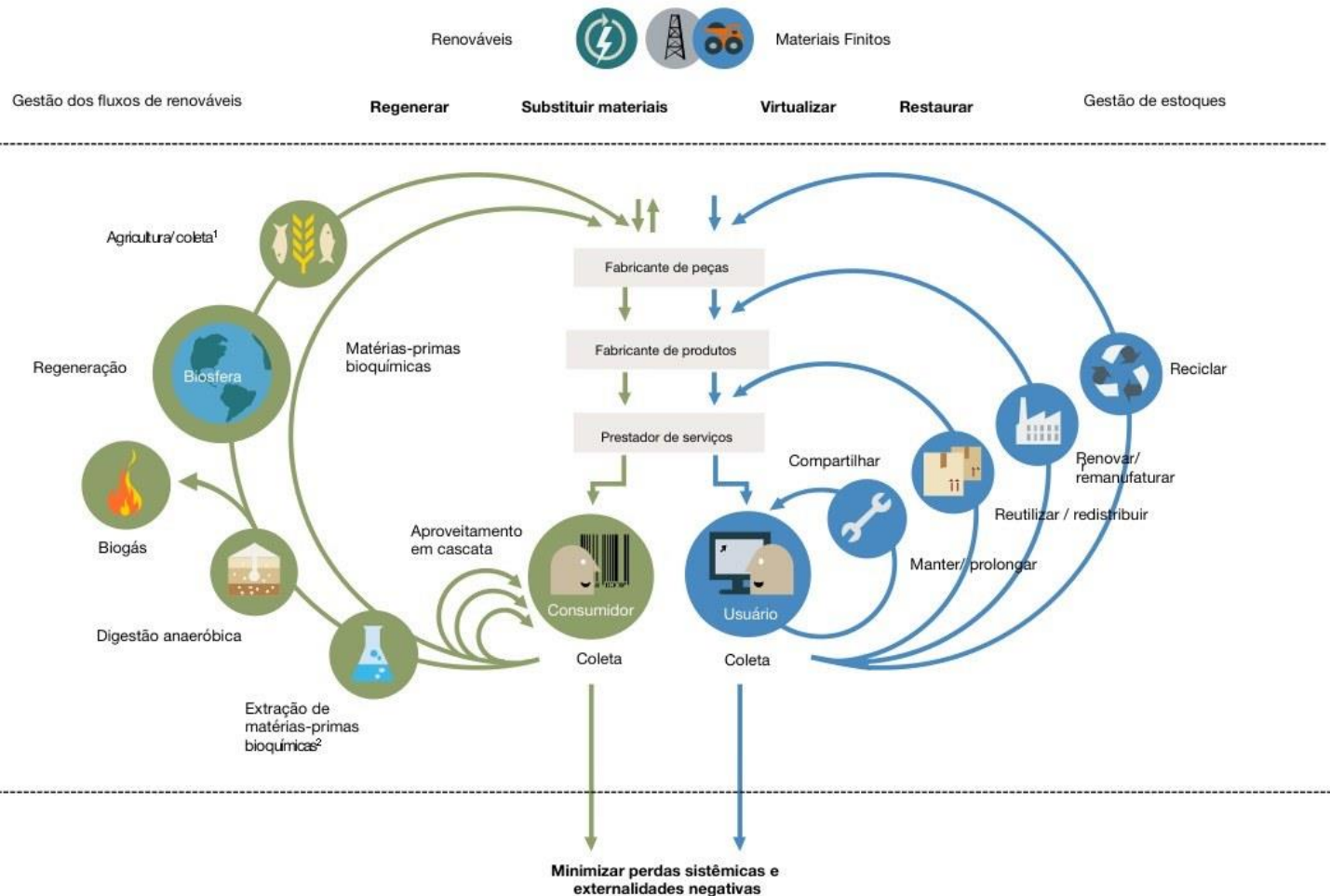
Preservar e aumentar o capital natural controlando estoques finitos e equilibrando os fluxos de recursos renováveis.

## PRINCÍPIO 2

Otimizar a produção de recursos fazendo circular produtos, componentes e materiais no mais alto nível de utilidade o tempo todo, tanto no ciclo técnico como no biológico.

## PRINCÍPIO 3

Fomentar a eficácia do sistema, revelando as externalidades negativas e excluindo-as dos projetos.



<sup>1</sup> Caça e pesca



# Agenda

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1. Introdução

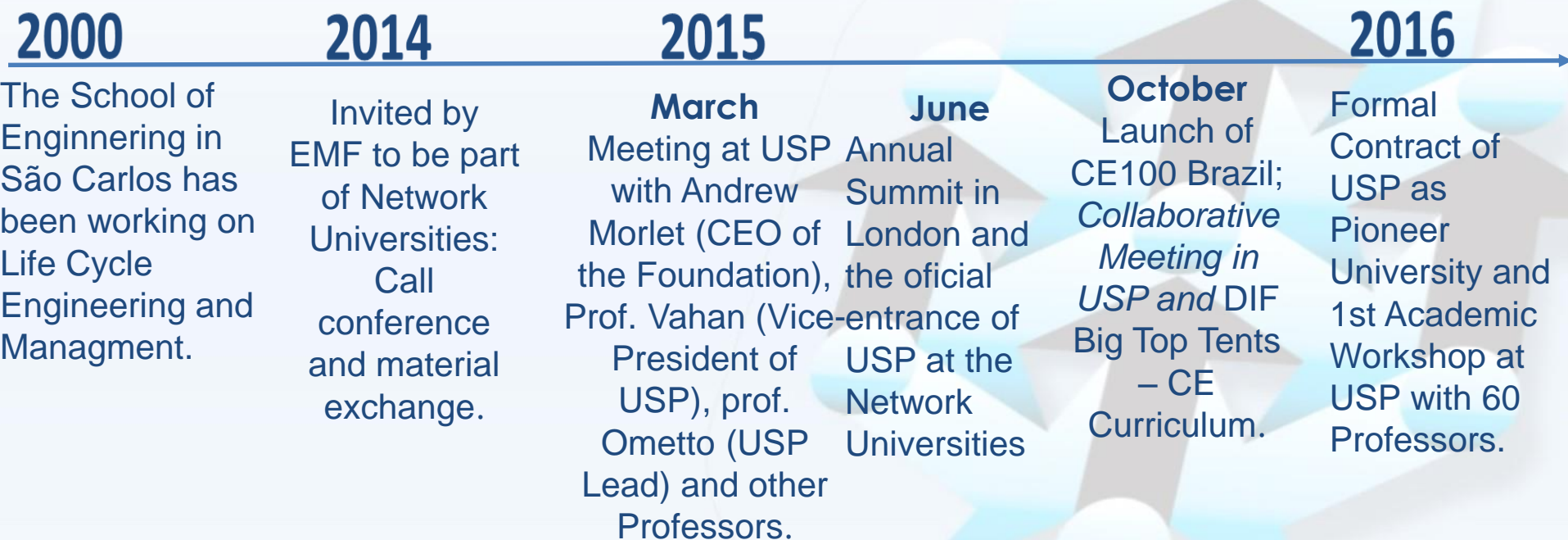
2. **USP como Pioneer University**

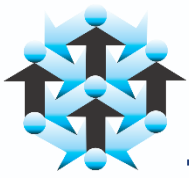
3. Considerações





# USP





# Ellen MacArthur Foundation Network Universities

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**By showcasing relevant academic work globally this programme aims to enable collaborative ventures and knowledge exchange across policy makers, business and academia outside the Foundation's formal programmes.**

Bangor University  
Georgia Institute of Technology University  
Johannes Kepler University (JKU) Linz  
Loughborough University  
Northumbria University  
Rotterdam University of Applied Sciences  
Skema Business School  
TU-Berlin  
UC Davis  
Universidad de Chile  
**Universidade de São Paulo**  
Universidad Nacional de Quilmes  
Universiteit Gent  
Universite de Montreal  
University of Edinburgh  
University of Queensland  
University of Sheffield  
University of Strathclyde  
University of Technology Sydney (UTS)  
Worcester Processing Institute (WPI)





# Pioneer Universities

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**Pioneer Universities are an international network of higher education institutions developing truly pioneering and innovative circular economy-orientated research or teaching programmes.**





# Pioneer Universities



## Pesquisas & Análises



## Capacitação

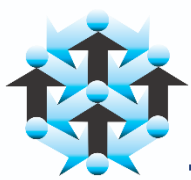


## Networking



## Colaboração





# Unidades da USP participantes

## São Carlos Campus

- **School of Engineering (LEAD)**
- **Institute of Architecture and Urbanism**
- **Institute of Mathematical and Computer Sciences**
- **Institute of Physics**
- **Institute of Chemistry**

## • Piracicaba Campus

- **Luiz de Queiroz School of Agriculture**

## São Paulo Campus

- **School of Arts, Sciences and Humanities**
- **School of Communications and Arts**
- School of Physical Education and Sport
- School of Nursing
- **School of Engineering**
- **School of Architecture and Urbanism**
- Faculty of Pharmaceutical Sciences
- **Law School**
- **School of Economics, Business and Accounting**
- **School of Education**
- Faculty of Philosophy, Languages and Literature, and Human Sciences
- School of Medicine
- School of Veterinary Medicine and Animal Science
- School of Dentistry
- School of Public Health
- Institute of Astronomy, Geophysics and Atmospheric Sciences
- Institute of Biosciences

## São Paulo Campus

- Institute of Biomedical Sciences
- Institute of Physics
- Institute of Geosciences
- Institute of Mathematics and Statistics
- Institute of Psychology
- Institute of Chemistry
- Institute of International Relations
- Oceanographic Institute



# Unidades da USP participantes

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## **Bauru Campus**

- School of Dentistry

## **Lorena Campus**

- School of Engineering

## **Pirassununga Campus**

- **School of Animal Science and Food Engineering**

## **Ribeirão Preto Campus**

- School of Physical Education and Sport
- College of Nursing
- School of Pharmaceutical Sciences
- Law School
- **School of Economics, Business Administration and Accounting**
- Faculty of Philosophy, Sciences and Letters
- Medical School
- School of Dentistry

## **Specialized Institutes**

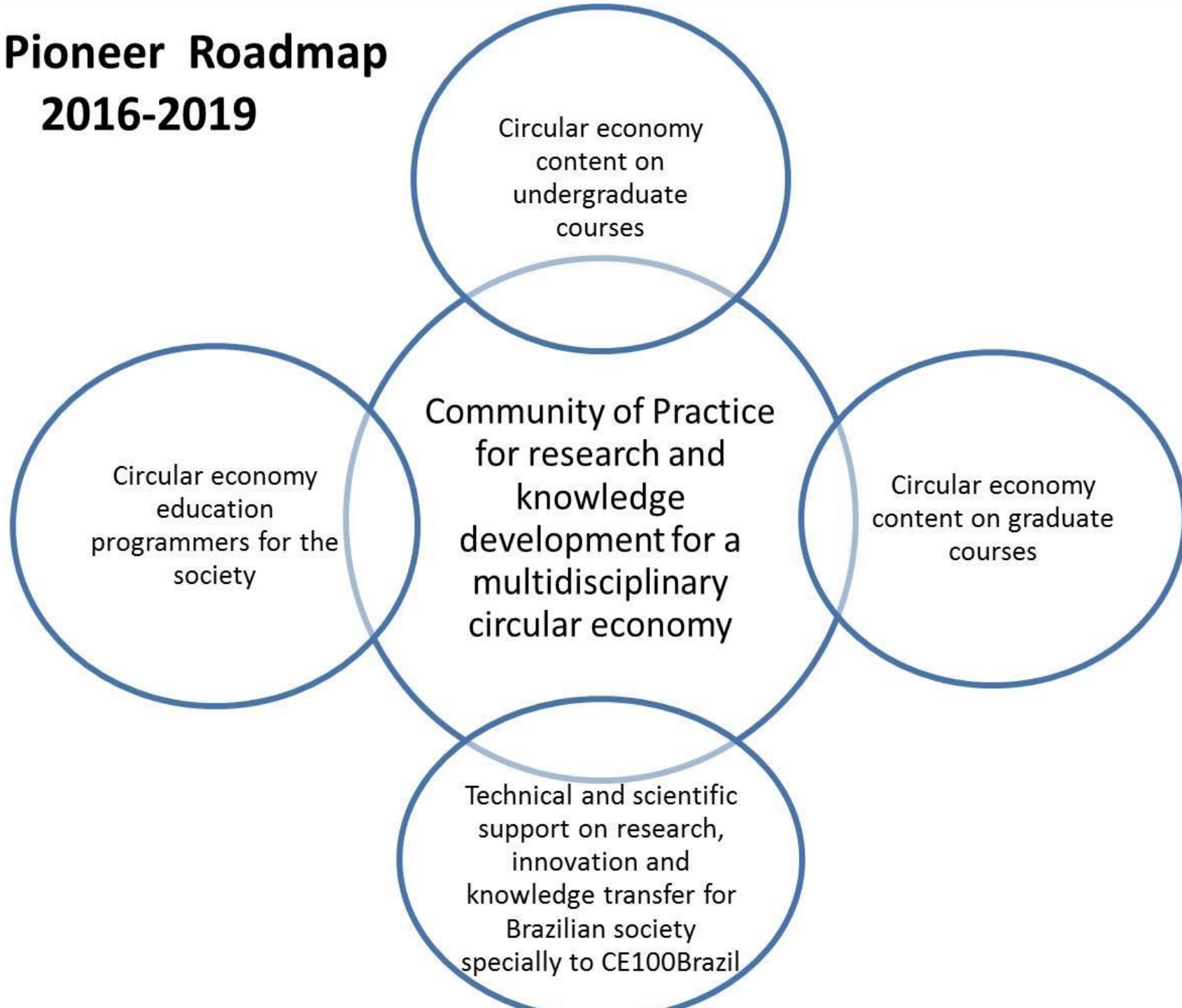
- Center for Marine Biology
- Center for Nuclear Energy in Agriculture
- **Institute of Energy and Environment**
- **Institute of Advanced Studies**
- **Institute of Brazilian Studies**
- Institute of Tropical Medicine – São Paulo

## **Museums**

- Museum of Archaeology and Ethnology
- Museum of Contemporary Art
- Museum of Zoology
- Paulista Museum



# USP Pioneer Roadmap 2016-2019







# Eco-innovation Implementation Process

## PREPARE

Identify the sectors, markets and companies that you will target and demonstrate to them how your eco-innovation services will help to address the key sustainability challenges and opportunities they face.

## SET STRATEGY

Engage with the Client to build a better understanding of how the company operates today, refine your understanding of the sustainability challenges and opportunities, and formulate a new business strategy.

## SET BUSINESS MODEL

Generate new business model options and operational innovation ideas that are aligned with the business strategy and the capabilities of the company, then select the best option to take forward.

## BUILD ROADMAP

Define a roadmap of operational projects towards implementation of the selected strategy and business model and define the scope and requirements of the first project.

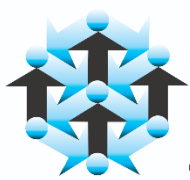
## IMPLEMENT

Define a roadmap of operational projects towards implementation of the selected strategy and business model and define the scope and requirements of the first project.

## REVIEW

Reflect on the performance on the first project, capture lessons learnt, and revise the strategy and business model as necessary in readiness for the next iteration of implementation activities.





# Product Lifecycle Management: Body of knowledge

**Publications, Cases, Practices, Methods, Lectures (+ 18 other classes)**

**Knowledge portal: free access !**



<http://www.portaldeconhecimentos.org.br/>

**VEDUCA (online courses): free access !**



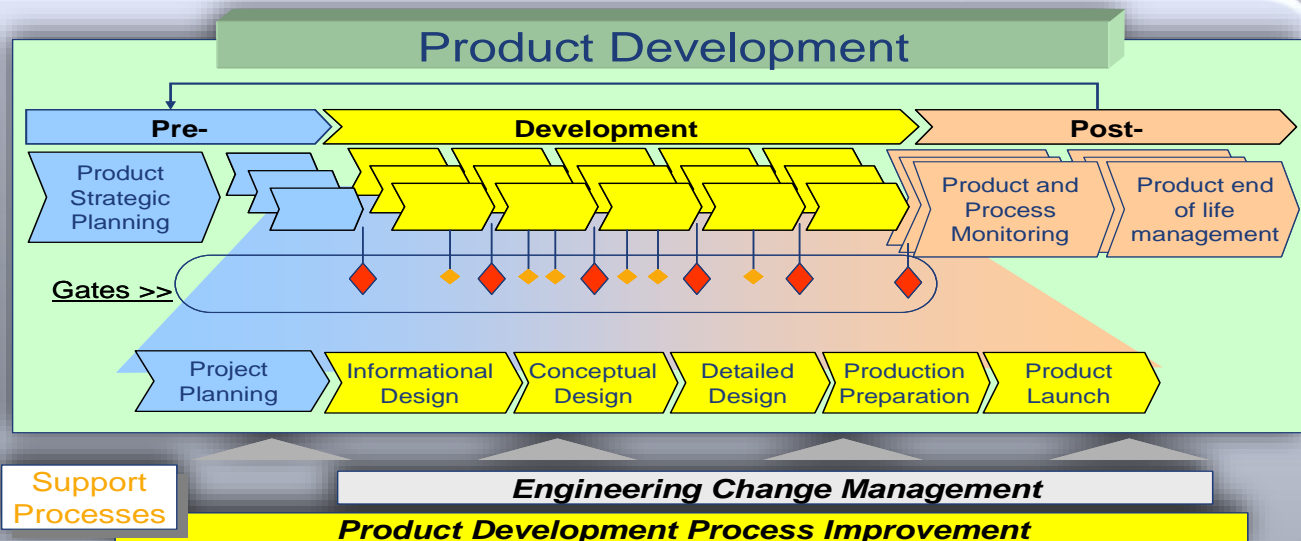
**NPD and Project Management courses**

**NPD online reference model: free access !**



<http://www.pdp.org.br/>

**NPD reference model**





# Ecodesign successful industrial case in Brazil

Engineering study of Ecodesign (Design for Environment)  
applied to the lifecycle of a multifunctional made by HP in Brazil



25% of recycled plastic



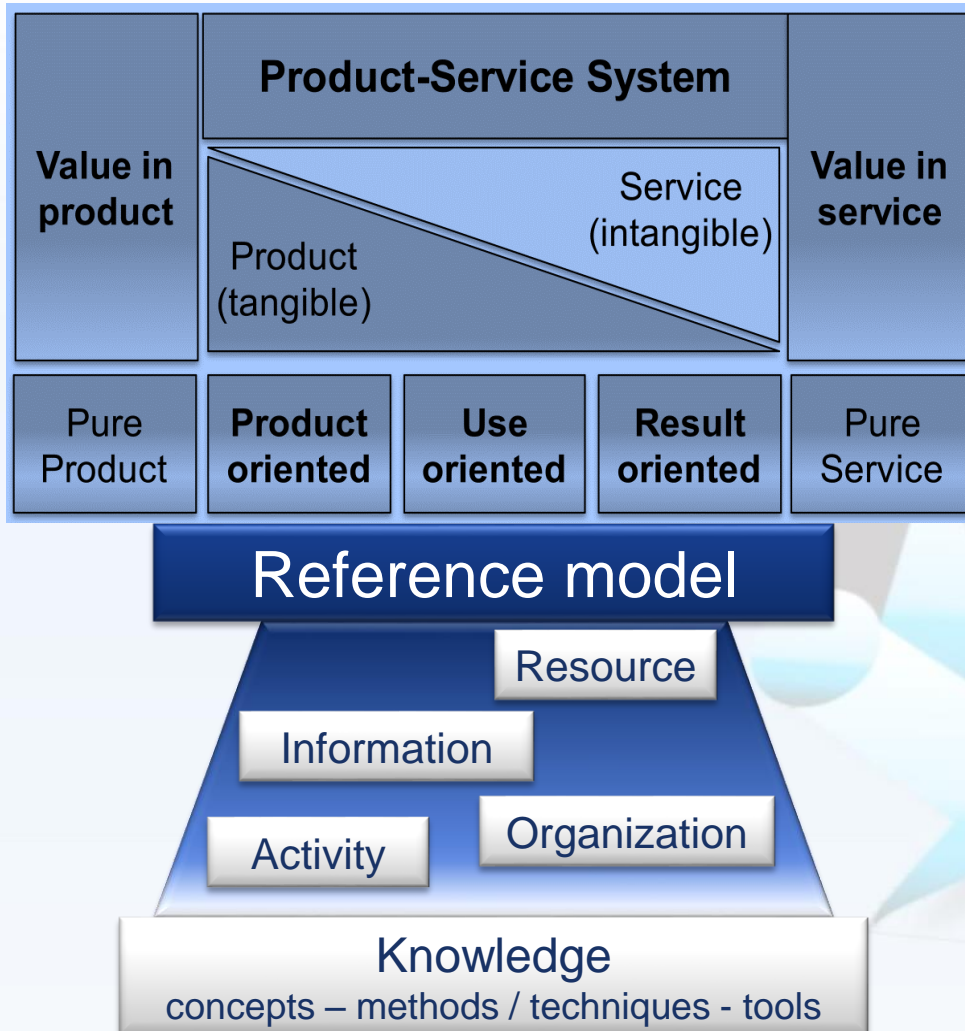
20% of recycled plastic



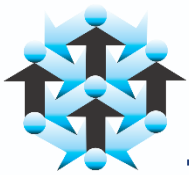


# Reference Model for Product-Service Systems (PSS)

**Goal:** Develop a reference model for Product-Service System (PSS) development process.







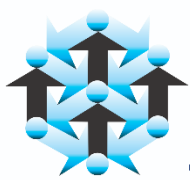
# IoT, Industry 4.0 and Circular Economy

**Goal:** Environmental assessment and on line monitoring of manufacturing processes based on. IoT, Industry 4.0 and Circular Economy



- Environmental on line monitoring
- Graphical interface
- Report and file generation
- Historical data collection
- Life Cycle Management





# Remanufacturing oriented production equipment development



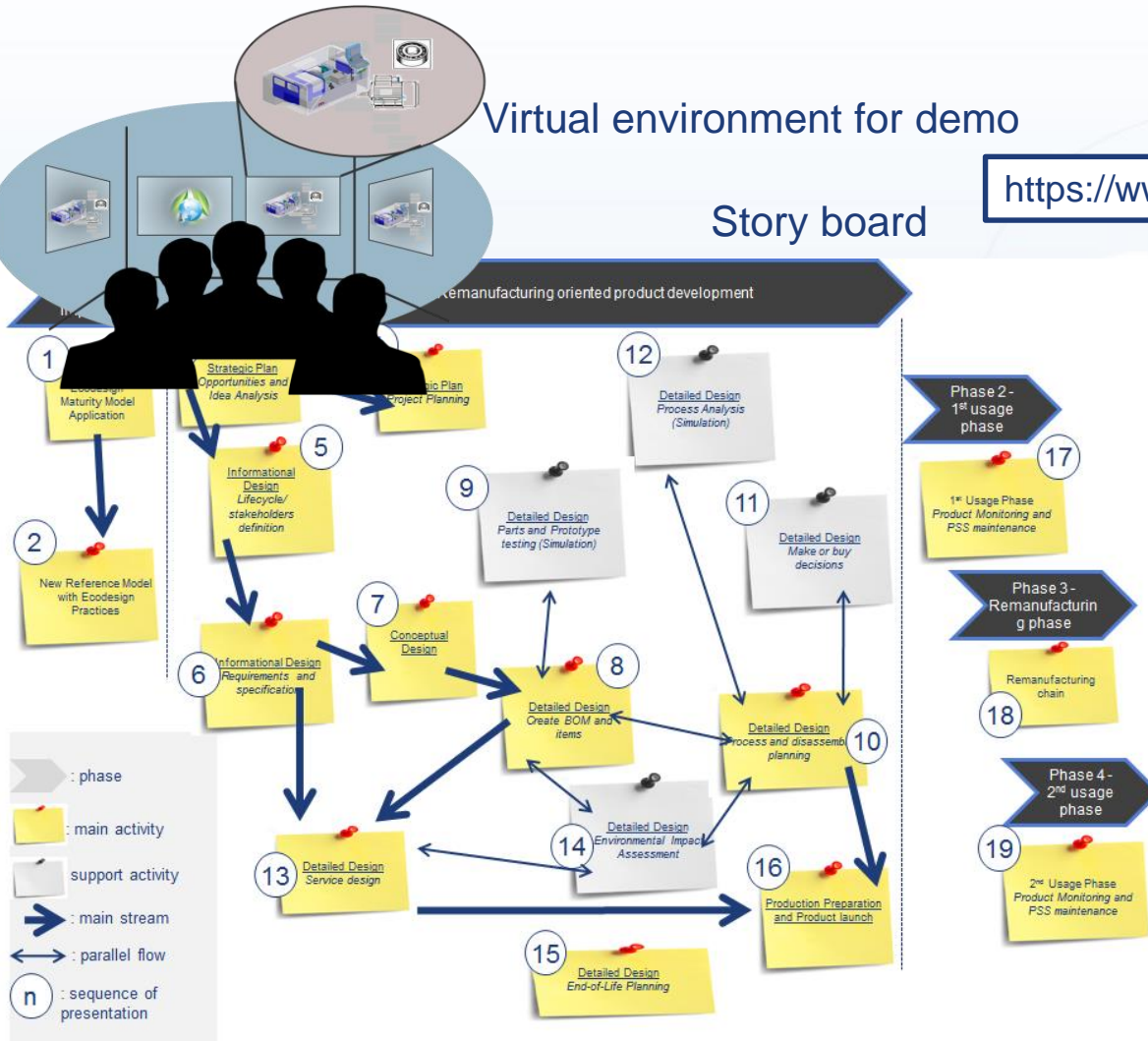
**Goal:** to propose a reference model for developing remanufacturing oriented production equipment. Demonstration of a grinding machine development



Virtual environment for demo

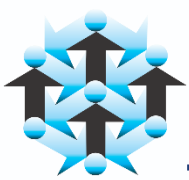
Story board

<https://www.youtube.com/watch?v=626IF5nKQzY>



Machine Monitoring Control System towards remanufacturing





# Web-guidelines for developing business models for remanufacturing



**Goal:** to assist companies in creating their own tailor-made remanufacturing business model.

<http://bragecrim2.wix.com/remanufacturing>



## REMANUFACTURING KNOWLEDGE AND PRACTICE

HOME

KNOWLEDGE DATABASE

GUIDELINES

Theoretical aspects

Scenarios for remanufacturing

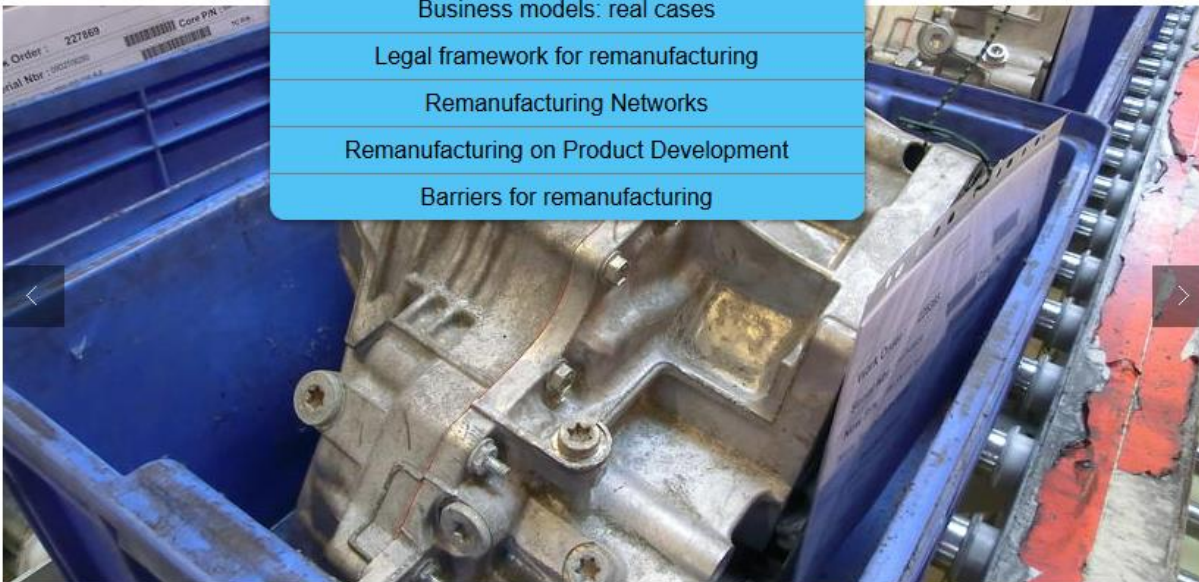
Business models: real cases

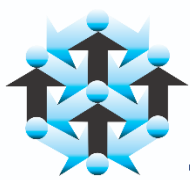
Legal framework for remanufacturing

Remanufacturing Networks

Remanufacturing on Product Development

Barriers for remanufacturing

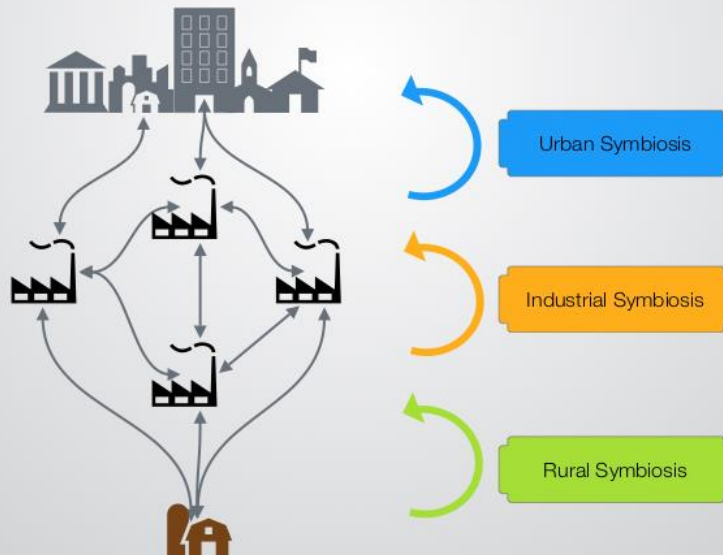
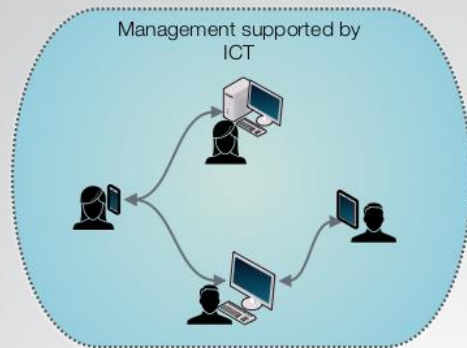




# Eco-innovation in SMARTPARKS: sustainable strategies and methods to promote industrial, urban and agricultural symbiosis in Brazil and Spain

## ECO-INNOVATION IN:

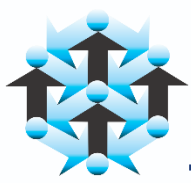
- Social and institutional structures
- Business models and strategies
- Organizational structures
- Products
- Process
- Technologies



## COMPETENCES AND METHODS FOR ECO-INNOVATION

- |                    |                  |                        |               |
|--------------------|------------------|------------------------|---------------|
| Industrial Ecology | Ecodesign        | Performance Management | Policy Making |
| Urban planning     | Circular Economy | Life Cycle Engineering | ICT           |

**Partners:** University of Sao Paulo (USP), Federal University of Sao Carlos (UFSCar) and Autonomous University of Barcelona (UAB)



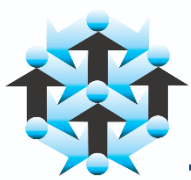
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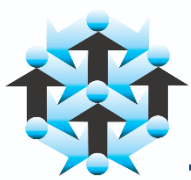
# Muitas oportunidades e desafios

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- Impacto Positivo
- Eficácia sistêmica
- Políticas Públicas
- Tecnologia
- Desenvolvimento de Produto
- Big Data
- Indústria 4.0
- Planejamento urbano
- Mudança Cultural
- ....



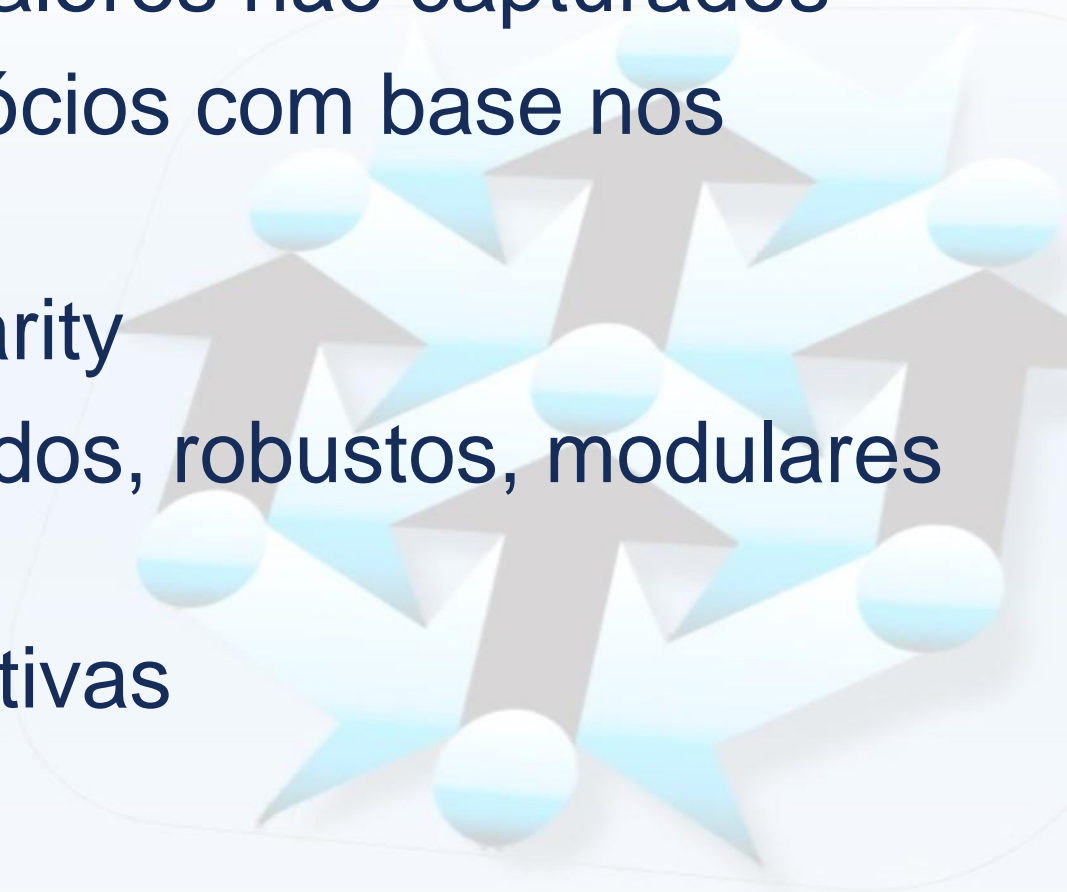


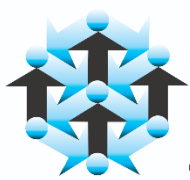


# Caminho...

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- Visão Sistêmica
- Descoberta de Valores não capturados
- Modelos de Negócios com base nos serviços
- Design for circularity
- Sistemas integrados, robustos, modulares e inteligentes
- Inovações disruptivas
- Cooperação





Muito Obrigado

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