

# The Circular Economy – some (in)convenient truths and policy lessons

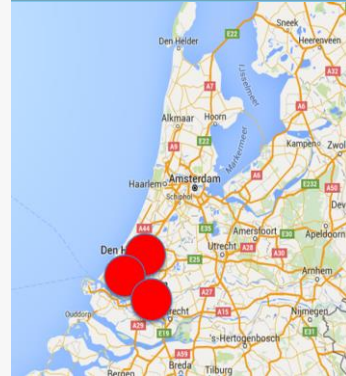
Prof. Arnold Tukker

Professor of Industrial Ecology

Scientific Director, CML, Leiden University / senior researcher, TNO

Chair, Leiden-Delft-Erasmus Centre for Sustainability

Simposio Internacional en Crecimiento Verde y Política Económica  
(International Green Growth Symposium), Bogota, 18 and 19 July 2017



Universiteit  
Leiden  
The Netherlands

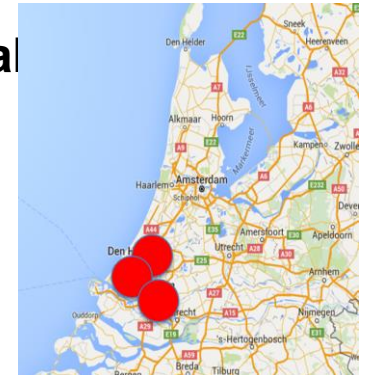
**TU Delft** Delft  
University of  
Technology

Erasmus  
University  
Rotterdam

The Erasmus University logo, featuring the word 'Erasmus' in a stylized, cursive font.

# Where I come from

- **Chemist by training, PhD in LCA and Policy research**
- **Ministry of Environment (1988-1990)**
- **TNO (large not for profit research organisation, 1990- now, 30% since 2013)**
- **Director and professor, Institute of Environmental Sciences CML, Leiden University (90 staff, 2013-now, 70%)**
  - Circular economy and resource-efficiency
  - Biodiversity and Natural Capital
- **Chair, Leiden-Delft-Erasmus Centre for Sustainability (virtual 3 universities, about 200 researchers, 2015-now)**



Why circularity and green growth?

# Global resource use at 7% growth

Doubles global economy every 10 years...

..10-fold every 35 years

After about

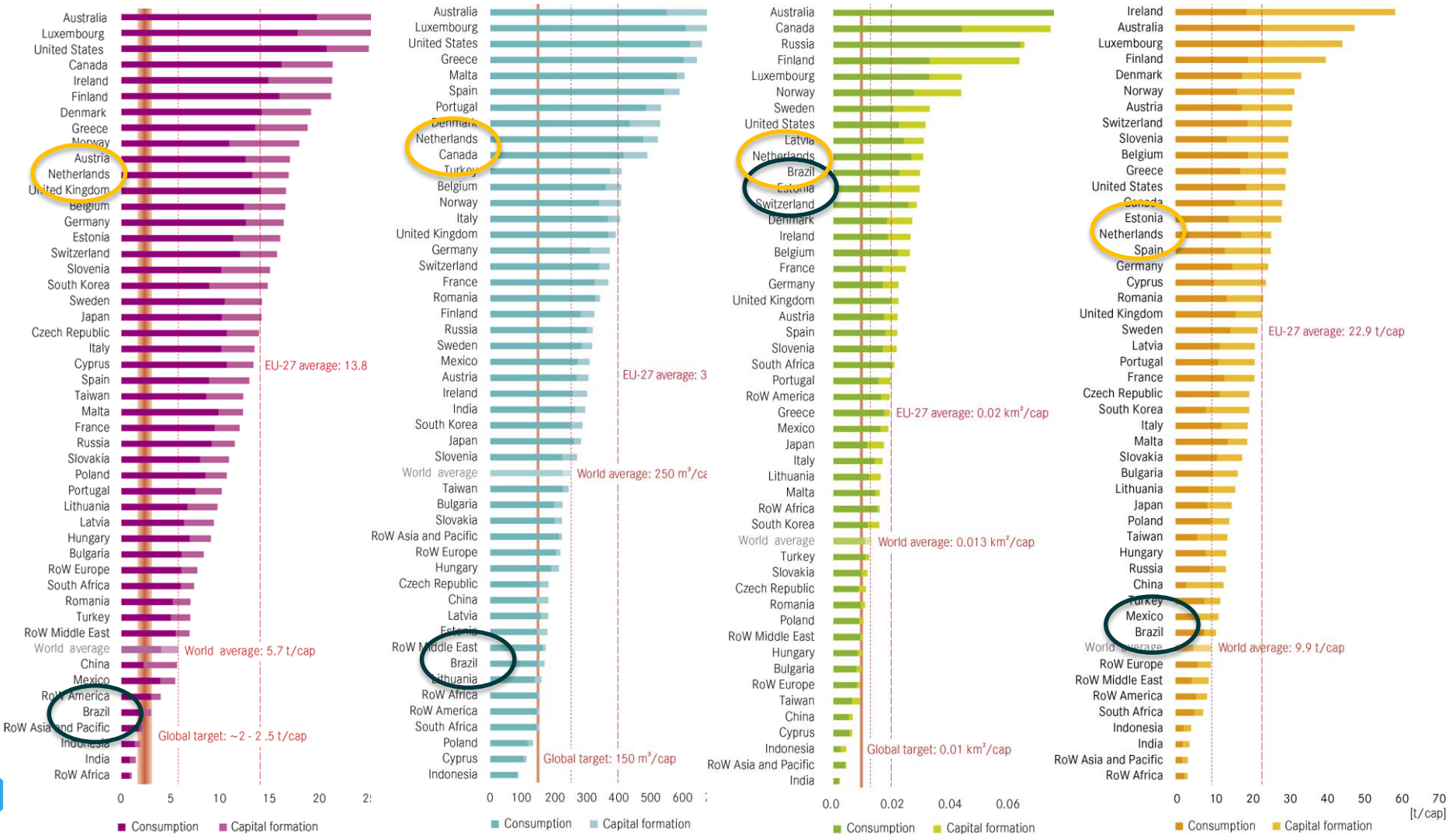
- 100 yr: an amount of energy equal to the full solar influx on earth
- 200 yr: all water on Earth, including sea water
- 300 yr: a resource volume equal to the whole earth crust
- 400 yr: an oil barrel the size of the earth

At 3%, these numbers roughly double

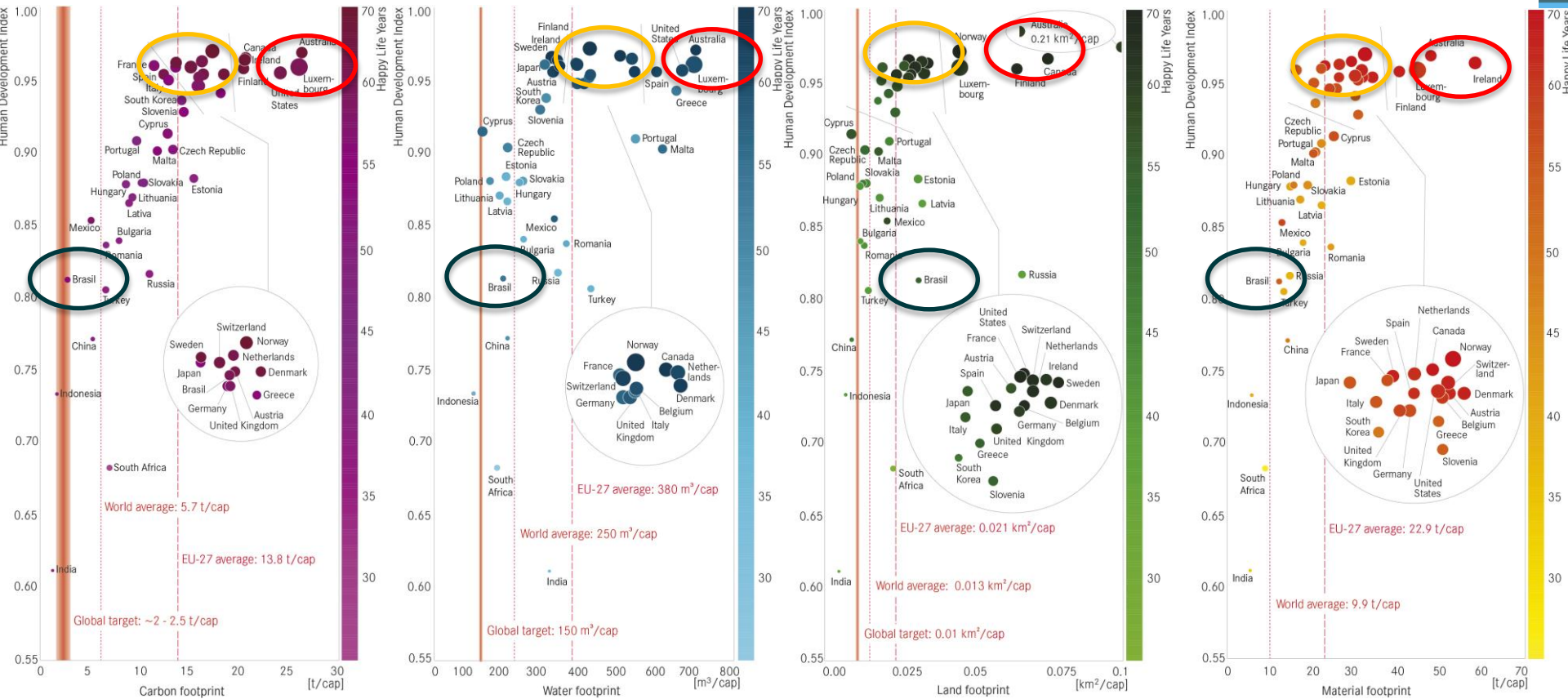


# A circular economy – some (in)convenient truths

# Fact 1: Rich = high carbon, water, land and material needs for satisfying consumption ('footprints')

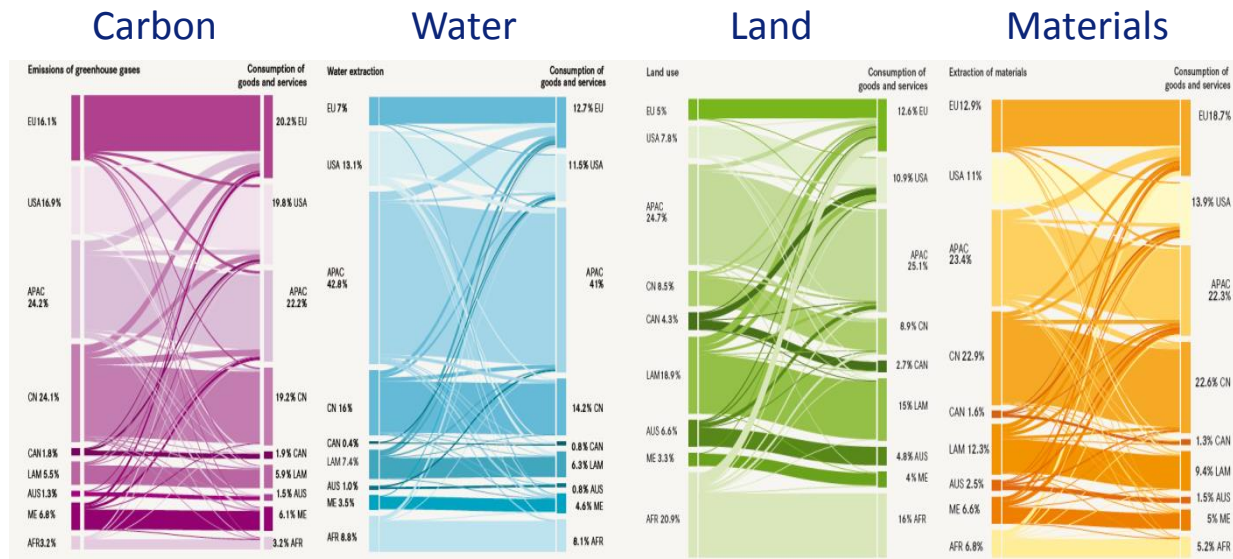


# Fact 2: After a threshold, more GDP gives not a better Human Development Index



# Fact 3: Both Europe as Asia are vulnerable with regard to resource competition'...and LA will be too if they grow as fast!

- Asia
  - China alone uses e.g. already 50% of steel and cement in the world
  - Particularly India and Indonesia still must grow to reach Western wealth levels
- Europe
  - On ALL indicators: more resources needed for consumption as we produce
  - We now still make more money and can pay for it...but Asia is becoming smart and competitive too, and fast!



Left: resources/emissions produced

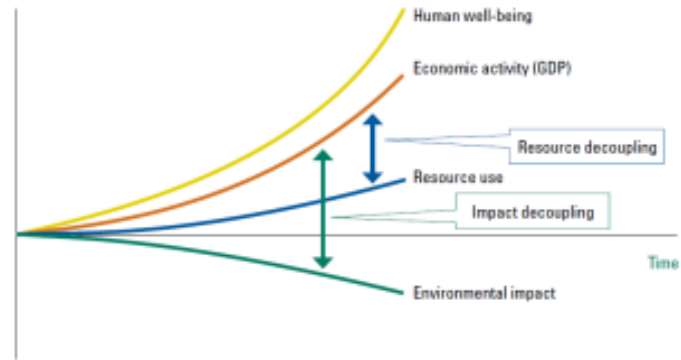
Right: resources/emissions needed for consumption



# Key answer: doing more with less

- **EU Circularity package**

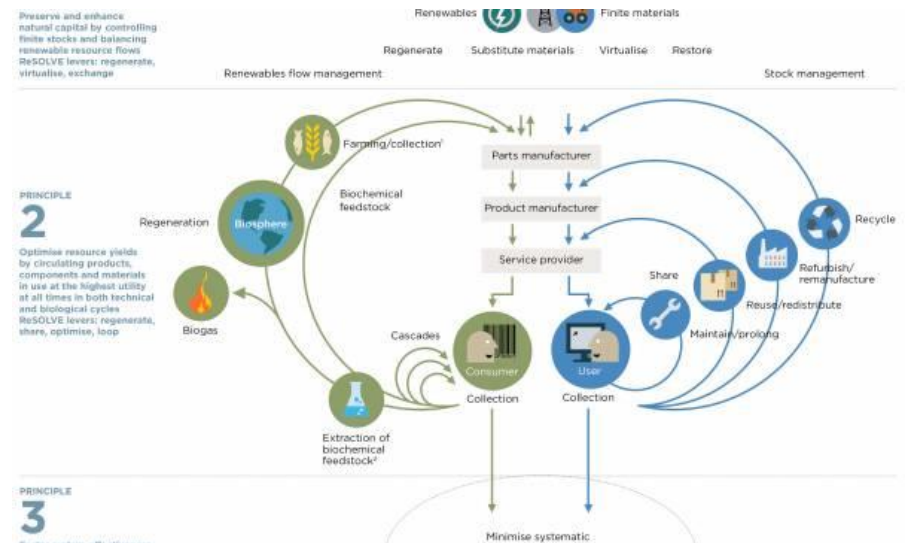
- ‘Decoupling’
  - Enhance quality of life
  - With less growth of GDP
  - With less resource use
  - And minimal emissions
- ‘Circularity’
  - Prolonging product life
  - Repair
  - Re-use
  - Remanufacturing
  - Recycling



Source: UNEP International Resources Panel

- **EU Raw materials initiative**

- Enhance knowledge base (EIT KIC Raw materials)
- Enhance normal and urban mining in Europe



Source: Ellen MacArthur Foundation

# Inconvenient truth 1: there is a limit to resource-efficiency or decoupling

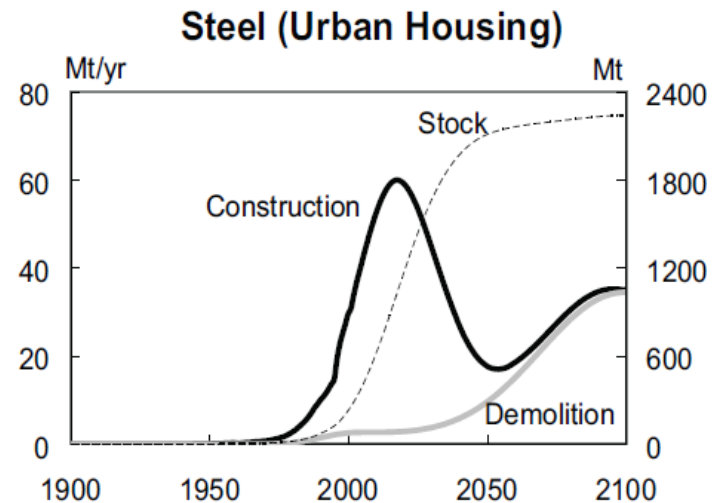
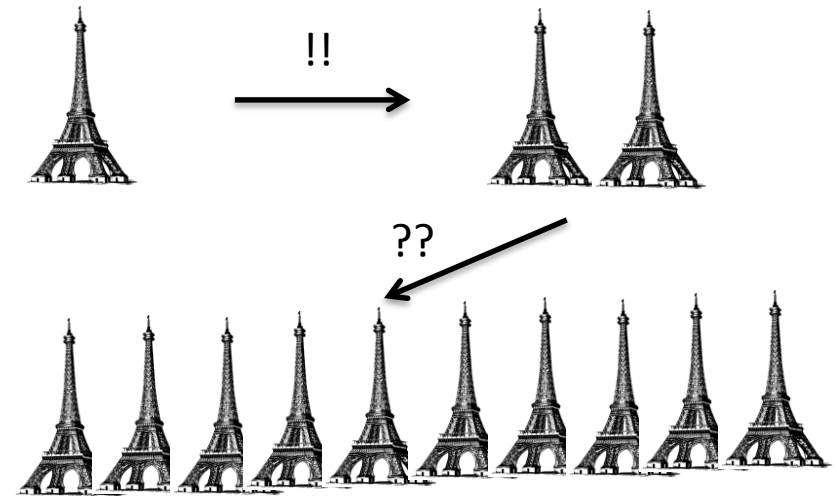
Assume zero resource use growth

- 7% economic growth a year -> 7% more resource-efficient a year?
- Every 10 years: doubled economy, hence halving resource use per Euro?
- In 100 years: transport services of your 1000kg car must be delivered using the materials in a Dinky toy



# Inconvenient truth 2: a growing economy inevitably needs virgin materials

- Growing economies build new infrastructure....
- ....so even if materials use is now so efficient you can build TWO Eiffeltowers from the old one...
- ....if 10 cities want an Eiffeltower, you need still 5 times more, new materials
- Even with the best recycling you will have some degradation.....
- .....so energy to upgrade



# However, we must start the transition now!

Circularity may not buy us *eternal* growth

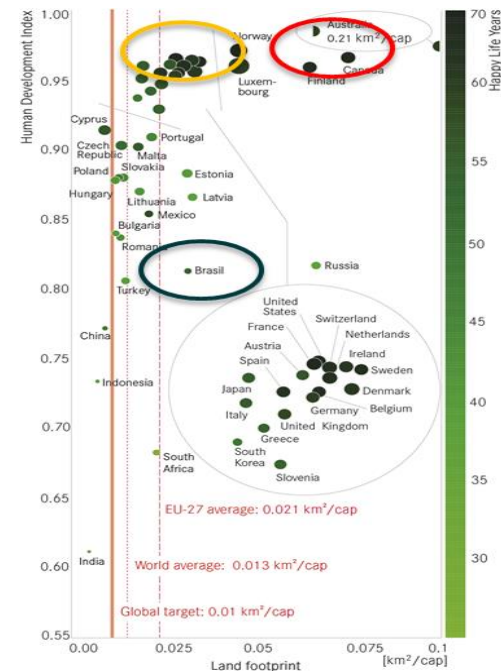
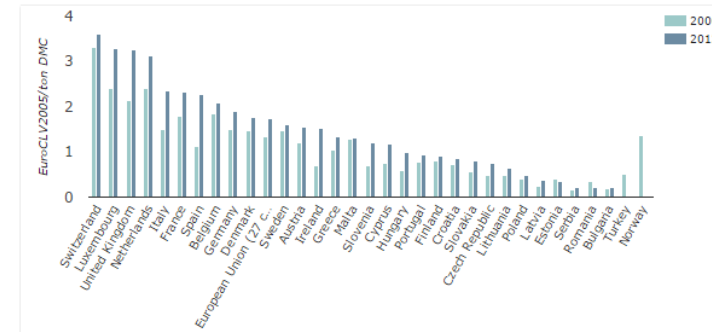
But it will give up to 20 times more wealth

- Circularity: 4-5 times more economic activity in the same planetary limits
- Focus on Human Development: 4 times more wealth with the same level of economic activity

And we have to start now

- Transitions take time
- Investments now create lock ins
- So invest in circular, green growth now!

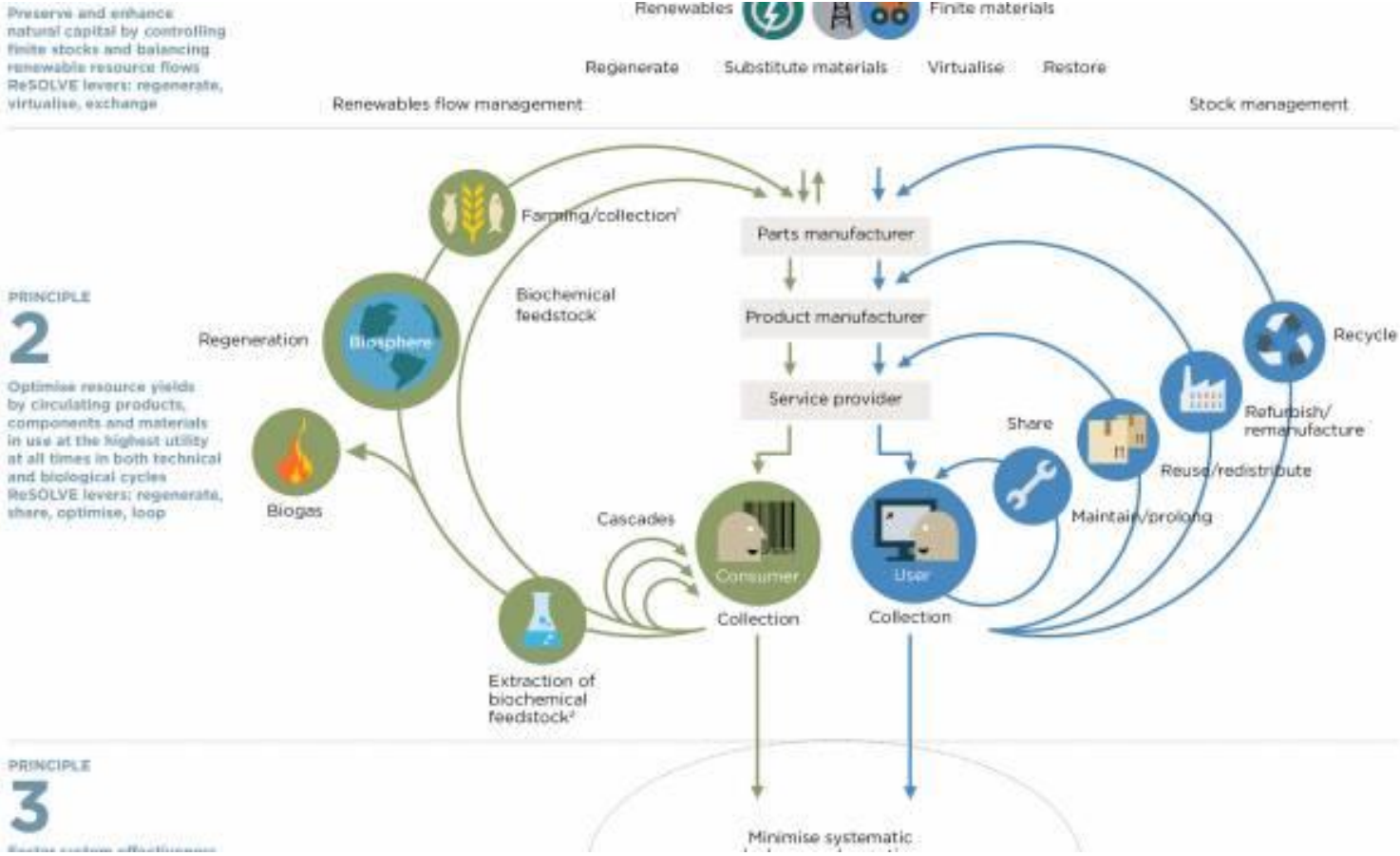
Figure 3: Resource productivity (GDP/DMC) in 32 European countries (2000 and 2012)



# How to make the transition to a circularity

# What is circularity?

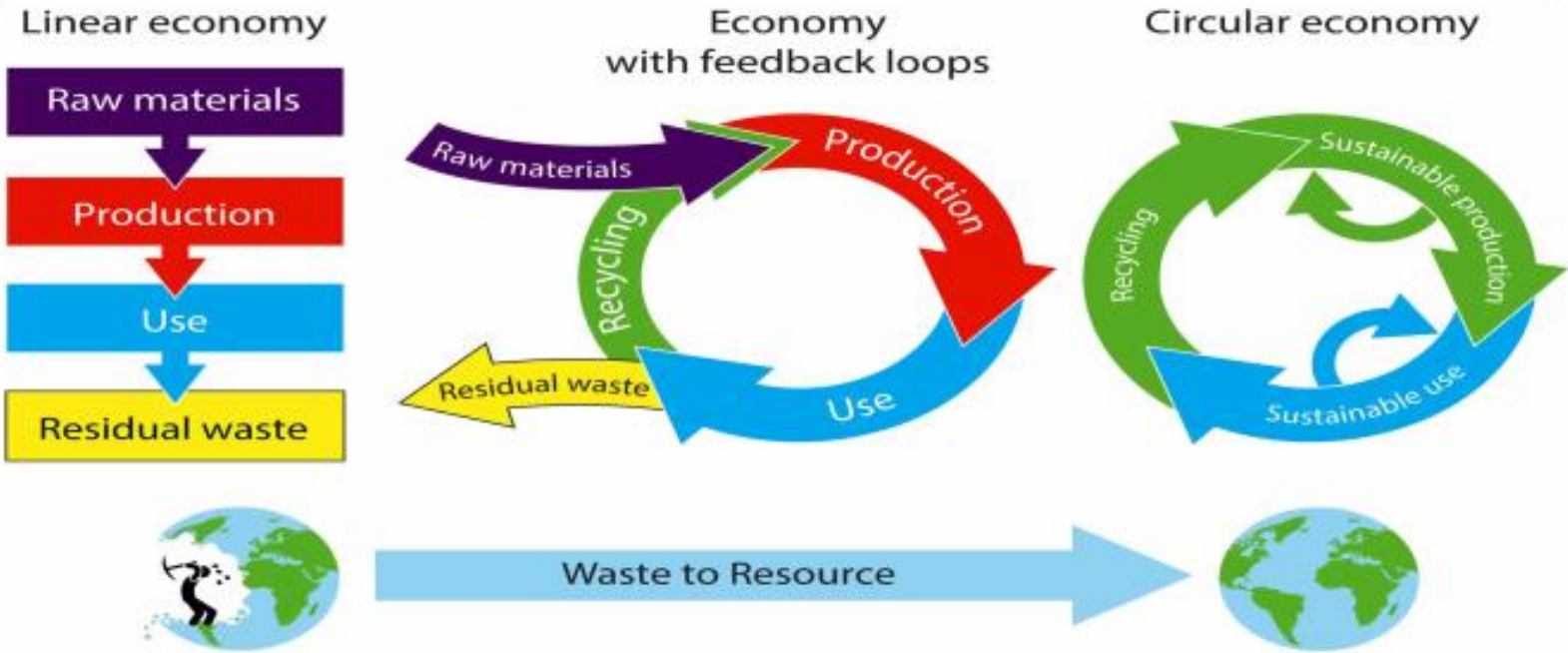
- Prolonge product life, Repair, Re-use, Remanufacture, Recycle



Source: Ellen MacArthur Foundation

Or, differently shown:

# From a linear to a Circular Economy



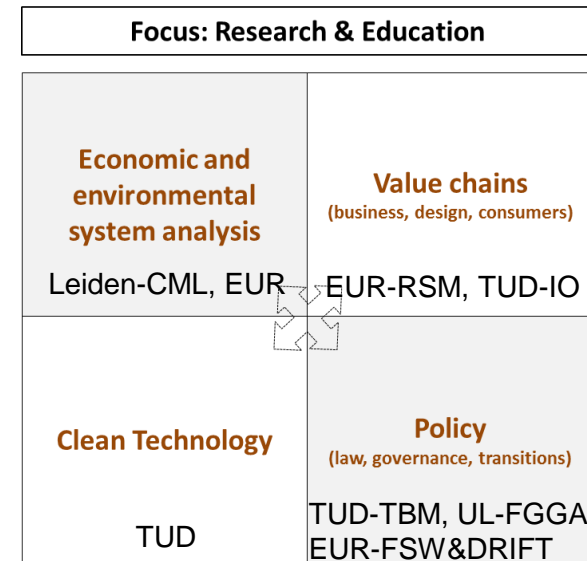
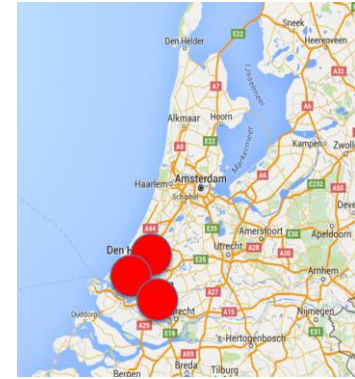
# Four knowledge fields

1. Environmental & economic system analysis:
  - Current material flows & value added creation
  - ‘Hot spots’ and scenarios for improvement
  
2. New, circular technologies and designs
  - That reduce primary resource use
  
3. New, circular business models/value chains
  - That support circular technologies and designs
  
4. New policy & governance
  - Markets alone often will not deliver circularity

## Central in crucial activities I am involved

- Leiden-Delft-Erasmus Centre for Sustainability
- EU PhD Training Network Circuit (15 PhDs)

Leiden-Delft-Erasmus Centre for Sustainability





**Natural resource use & economics**

# Changes to circularity – how to measure it?

- Economic & Industrial ecology tools**
  - LCA, Material flow analysis, Input-output
  - For assessing resource use hot spots.... and improvement options

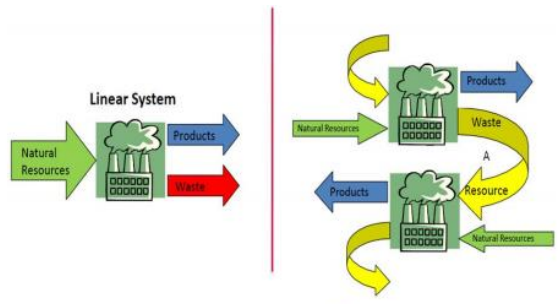
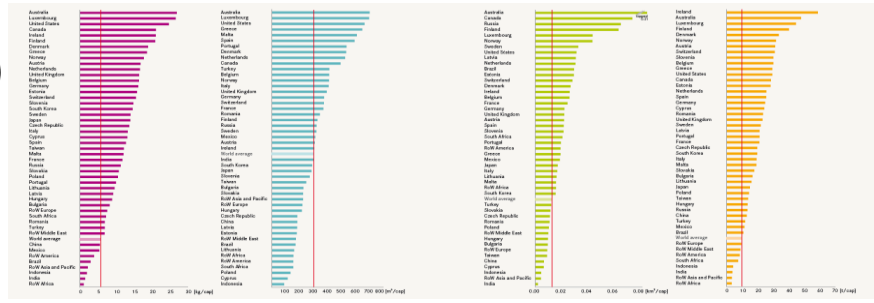


Figure 2-2 Schematic image of industrial symbiosis

- Country footprints (e.g. Exiobase MR Environmental Input Output database)**
  - Carbon
  - Water
  - Land
  - Materials



- Priorities (80% of impacts)**
  - Food -> reduce animal food
  - Mobility -> reduce cars, flights
  - Electrical appliances -> energy efficient
  - Housing, heating and cooling

|             |             | Industries  |             |             |           | $Y_{\cdot,A}$ | $Y_{\cdot,B}$ | $Y_{\cdot,C}$ | $Y_{\cdot,D}$ | $q$ |
|-------------|-------------|-------------|-------------|-------------|-----------|---------------|---------------|---------------|---------------|-----|
| Products    | $Z_{A,A}$   | $Z_{A,B}$   | $Z_{A,C}$   | $Z_{A,D}$   | $Y_{A,A}$ | $Y_{A,B}$     | $Y_{A,C}$     | $Y_{A,D}$     | $q_A$         |     |
|             | $Z_{B,A}$   | $Z_{B,B}$   | $Z_{B,C}$   | $Z_{B,D}$   | $Y_{B,A}$ | $Y_{B,B}$     | $Y_{B,C}$     | $Y_{B,D}$     | $q_B$         |     |
|             | $Z_{C,A}$   | $Z_{C,B}$   | $Z_{C,C}$   | $Z_{C,D}$   | $Y_{C,A}$ | $Y_{C,B}$     | $Y_{C,C}$     | $Y_{C,D}$     | $q_C$         |     |
|             | $Z_{D,A}$   | $Z_{D,B}$   | $Z_{D,C}$   | $Z_{D,D}$   | $Y_{D,A}$ | $Y_{D,B}$     | $Y_{D,C}$     | $Y_{D,D}$     | $q_D$         |     |
| W           | $W_A$       | $W_B$       | $W_C$       | $W_D$       |           |               |               |               |               |     |
|             | $E_A$       | $E_B$       | $E_C$       | $E_D$       |           |               |               |               |               |     |
| C & L       | $Capital_A$ | $C_B$       | $C_C$       | $C_D$       |           |               |               |               |               |     |
|             | $Labor_A$   | $L_B$       | $L_C$       | $L_D$       |           |               |               |               |               |     |
|             | $NAMEA_A$   | $NAMEA_B$   | $NAMEA_C$   | $NAMEA_D$   |           |               |               |               |               |     |
|             | $Agric_A$   | $Agric_B$   | $Agric_C$   | $Agric_D$   |           |               |               |               |               |     |
| Environ Ext | $Energy_A$  | $Energy_B$  | $Energy_C$  | $Energy_D$  |           |               |               |               |               |     |
|             | $Metal_A$   | $Metal_B$   | $Metal_C$   | $Metal_D$   |           |               |               |               |               |     |
|             | $Mineral_A$ | $Mineral_B$ | $Mineral_C$ | $Mineral_D$ |           |               |               |               |               |     |
|             | $Land_A$    | $Land_B$    | $Land_C$    | $Land_D$    |           |               |               |               |               |     |

Exiobase (orange: country Input-Output table incl. final demand; green: trade between countries; grey: emissions and resource extraction by sector)

- 43 countries + 5 Rest of continents
- 160 sectors
- 30 emissions
- 80 resources
- Water, land
- 15 types of labor, added value

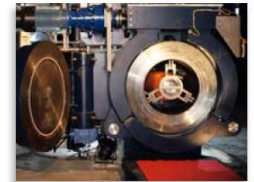
# Changes to circularity – what technologies?

- **Developing technologies enabling**
  - Low impact and efficient mining
  - Low-impact industrial production
  - ‘Engineering out’ critical materials
  - Reducing complex composition of products and materials
  - Developing high-strength, low-weight materials
  - Design for life time extension, re-use, repair, remanufacturing, recycling of products and materials

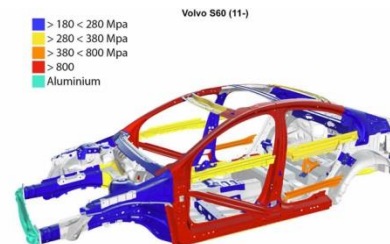


## DyeCoo: waterless dyeing

Launch of the first commercial dyeing machine that uses supercritical carbon dioxide instead of water



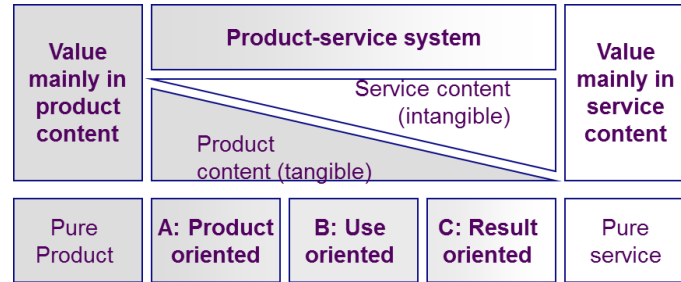
Production machine



High strength steel for lower weight cars

# Changes to circularity – new business models?

- **Circular business models and consumer behavior**
  - Needs new business models: based on value creation, not product sales
  - Needs new business competencies, cultures, strategies
  - Particularly in B2C consumer acceptance of new business models is key



Light: Pay-per-lux



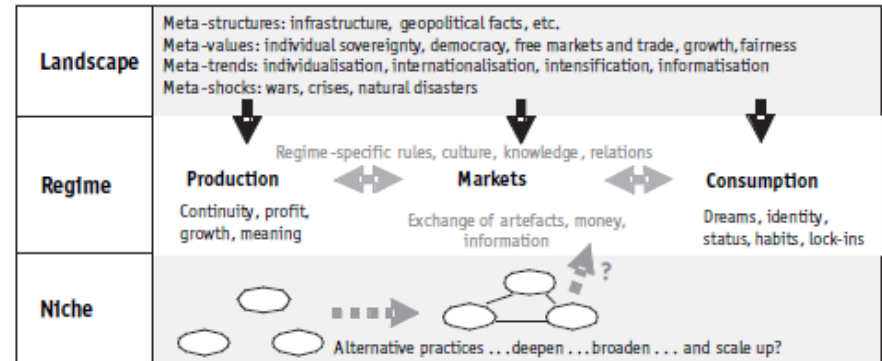
Copiers: pay-per-print, design for component re-use



Cars: sharing

# Changes to circularity – what policies?

- Economic systems are inert
  - ‘Regime’: sunk costs and interests of existing players in the value chain
  - ‘Landscape’: a myriad of ‘taken for granted’ frameworks, like free markets and individual choice
  - ‘Niches’ or new models often immature
- Often, policy must bring change
  - Regulation: bans on landfill, certification of sustainable production of e.g. coffee
  - Tax adjustment: from labor to resources
  - Room for experiments: learning how new systems work
- Policy: in my view the key challenge



# Example: history of circularity in the Netherlands

- **1970's – few laws and policies, no enforcement**
  - Landfill was cheap, Illegal dumping cheapest
  - Investment in hazardous waste incineration not profitable
  - Many scandals on dumping chemical waste and ground and water pollution
- **1980s – waste laws, start of planning and enforcement**
  - Quality standards for waste technologies and landfill
  - State support for building hazardous waste incineration (too risky for industry)
  - Enforcement program started and Waste plans with capacity regulation started (ensured investments in waste management were profitable)
- **1990s – strategic waste programs**
  - Identification of priority wastes (e.g. building and construction, electronics, packaging)
  - Targets for reduction and re-use set by government, backed by parliament
  - Roundtables with industry on HOW to realise these targets -> support policies per waste stream (e.g. deposit system for cars, electronics)
  - General measure: high landfill tax -> stimulated recycling
- **Result: Netherlands is best in class in Europe in re-use and recycling – via a mix of regulation, taxation and interactive policy**
- **We must now make the step from good waste management to circularity**

# Potential for collaboration between the Netherlands and Latin America on circularity

# Applied research and business collaboration

- **‘Circular hotspot’ initiative of the Netherlands**
  - Platform for Dutch businesses that excel in circularity
  - That aim to collaborate internationally
  - Recent Foro Economía Circular in Bogota with contributions from Dutch Government and others
  - Dutch Embassy is very supportive in this
- **Aruba and TNO’s Aruba office**
  - Aruba wants to become a sustainable, carbon-neutral island
  - Dutch research organisation TNO supports this and has an office there with LATAM nationals

# Research collaboration

LATAM, China and Indonesia are priority regions for Leiden University

Already good joint PhD programs with China and Indonesia – stipend PhDs from LATAM very welcome!

Example – EU Marie Curie Innovative Training Network on circularity with

- 15 PhDs
- Supervision & training – 6 international school periods
- 4 years (2016-2020)

With no less as 5 Hispanic PhDs – your future Green Growth leaders?



Leiden University Latin American & Caribbean Centre

3rd meeting Leiden-GRULAC  
Visit to Faculty of Science by H.E. Ambassadors from Latin America and Caribbean countries  
May 15th 2017

Gorlaeus Laboratoria, Einsteinweg 55, 2333CC Leiden



- Patricia Garcia-Martin (Aston/Spain),
- Beatriz Pozo Arcos (Linköping/Spain),
- Glenn Aguilar (Leiden/Costa Rica),
- Juana Camacho Otero (NTNU/Colombia)
- Carlos Siguenza Sanchez (Leiden/Mexico)



# Conclusions – building a circular economy

# Conclusions

## Circularity

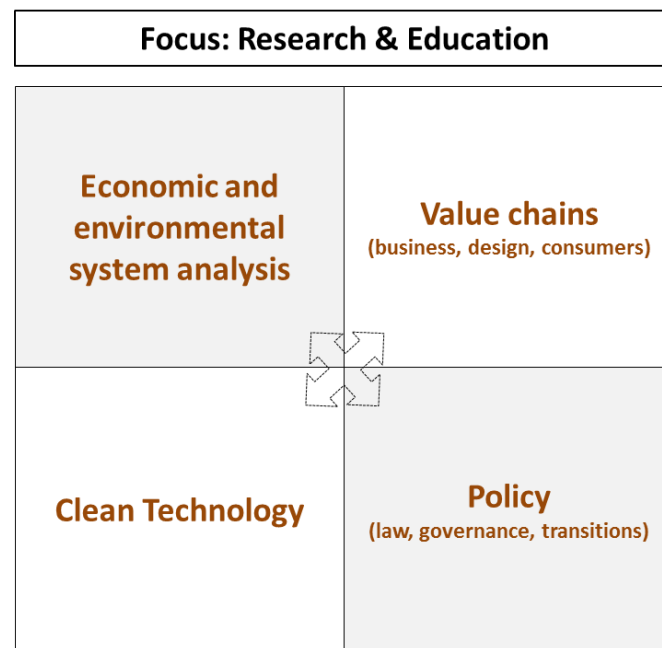
- Long-term must to avoid resource fights
- Must start now to avoid lock in

## Clear role for business

- New technological solutions
- New business models

## But policy cannot sit idle

- Always think in four areas (systems, technology, value chains, governance)
- Develop smart policies based on bottom-up initiatives, market adjustments, rules



# Thanks for your attention and regards from my staff doing LATAM-related research!



Valentina Prado  
University Lecturer



Glenn Aguilar  
PhD Candidate



Angélica Mendoza  
PhD Candidate



Pablo Sigüenza  
PhD Candidate



Nadia Soudzilovskaia  
Assistant Professor



Ellen Cieraad  
University Lecturer



C. Felipe Blanco  
PhD Candidate



Milagros Barceló  
PhD Candidate



Daniel Arenas  
Post-doc



Sofia Gomes  
PhD Candidate



Amie Corbiin  
PhD Candidate



Arnold Tukker  
Professor &  
director

# Reserve slides

# ..what is what CfS and I try

- **My own history**

- Ministry of Environment (1988-1990)
- TNO (1990-2013)
  - Many different topics on innovation, policy, environment, indicators
  - PhD with prof. Jacqueline Cramer, '98
- Leiden University, CML (2013-now)

- **Leiden-Delft-Erasmus CfS on circularity**

- Technology (TUD)
- Value chains (TUD-IO, EUR-RSM)
- Governance (All)
- Systemic economic & environmental analyses (UL-CML, EUR-Ec.)
- *Education: Industrial Ecology, Sustainable Design, Technology, Business, and in future : Governance of Sustainability*

15 Mio Euro in major EU projects on global economic-environmental databases, with Eurostat, UN SD, OECD, EEA

3 Mio Euro in major EU projects on sustainable consumption and business models. Member EIT KIC Raw Materials

Focus: Research & Education

Economic and environmental system analysis

Value chains  
(business, design, consumers)

Clean Technology

Policy  
(law, governance, transitions)

EU funded Marie Curie Training Network, 15 PhDs, 4 Mio Euro, 2016-2020 covering most of these fields

Dozens of TNO policy studies, study on circular product policy for the Dutch EU presidency

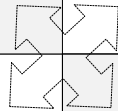
# Leiden-Delft-Erasmus for Sustainability - focus on Education, Research and Valorisation

**Focus: Research & Education**

**Application: Knowledge & Innovation**

**Economic and environmental system analysis**

**Value chains**  
(business, design, consumers)



**Clean Technology**

**Policy**  
(law, governance, transitions)

**Raw Materials**

**Urban Systems**

**Production  
Consumption  
Chains**

# With no less as 5 Hispanic PhD students

- Patricia Garcia-Martin (Aston/Spain),
  - Beatriz Pozo Arcos (Linköping/Spain),
  - Glenn Aguilar (Leiden/Costa Rica),
  - Juana Camacho Otero (NTNU/Colombia)
  - Carlos Siguenza Sanchez (Leiden/Mexico)
- 
- ...the future Green Growth leaders for your region?



# A Leiden Exemplar: Rudolph Pabus Cleveringa

- **Professor of Law at Leiden University, 1927-1958**
- **Lecture on 26 November 1940, WWII**
  - The Germans planned to fire all Jewish professors, including his mentor, promotor and colleague prof. Eduard M. Meijers
  - Cleveringa took over the class of Meijers making a now famous protest speech
  - Cleveringa was put in jail for 6 months and later taken hostage but like Meijers survived
  - US Medal of Freedom, voted 'Greatest Leiden University Person'
  - Seen as the exemplar of 'Praesidium libertatis'
- **How Leiden University honors him**
  - Annual lecture & Cleveringa Chair
  - Lectures by Leiden professors abroad

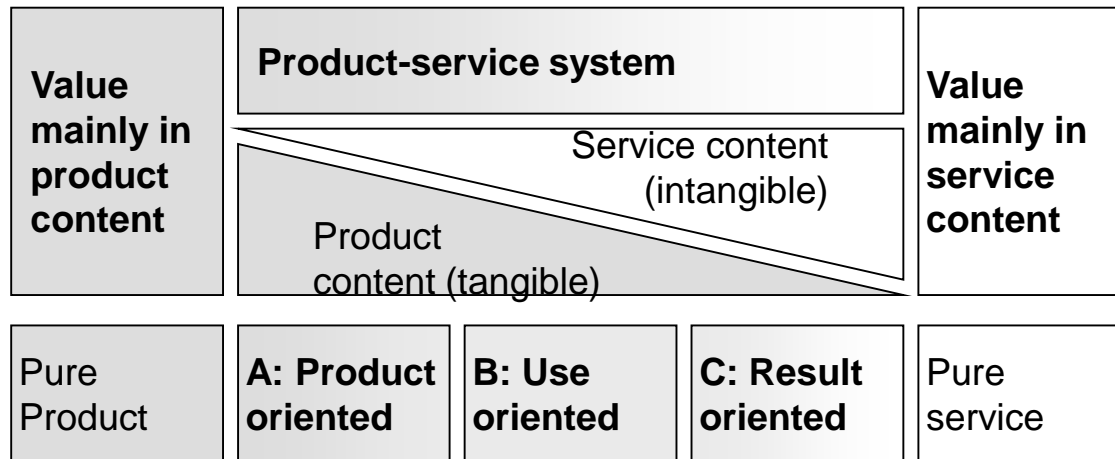




# Inconvenient truth 3: scarcity will not drive it – on the short term

| Type of resource                       | % global extraction | Basis for planetary limits   | Required resource-efficiency gains   | Reference  |
|--|---------------------|--|--|--|
| <b>Metal ores, industrial minerals</b> | <b>10%</b>          | Absolute scarcity (varies by metal).   | <b>Mixed</b><br>(important market failures)  | EC (2010); Kleijn (2012), Graedel and van der Voet (2010).             |
| <b>Fossil fuels</b>                    | <b>20%</b>          | CO <sub>2</sub> emission targets: Factor 5-10 reduction for 2° C target                    | <b>Factor &gt;10</b><br>(for the 2° C goal)  | IPCC (2007), Stern (2006), Meinsausen et al. (2009)                    |
| <b>Construction minerals</b>           | <b>40%</b>          | Absolute scarcity less relevant  | <b>Limited</b><br>(unless energy intensive materials)  | WRI (2006)   |
| <b>Biomass</b>                         | <b>30%</b>          | Max human appropriation of net primary production. HANNP = now 30-35% of available biomass | <b>Factor 2</b><br><br>(with 50% more agricultural production in 2050 means a 25% reduction of current pressures; more if stopping biodiversity loss requires reductions in land, water and biomass use) | Vitusek et al. (1986), Haberl et al. (2007).                           |
| <b>Land</b>                            | p.m.                | Available bioproductive land   |  | Erb et al. (2009), OECD/FAO (2009); Nature (2010a and b), WWF (2010)   |
| <b>Water</b>                           | p.m.                | Renewable supply (by region) 2030: Global 'water gap' of 40%                               |  | Hoekstra and Chapagain (2007), Water resources group / McKinsey (2009) |

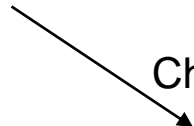
# Product Service Systems: a classification



Car sales....



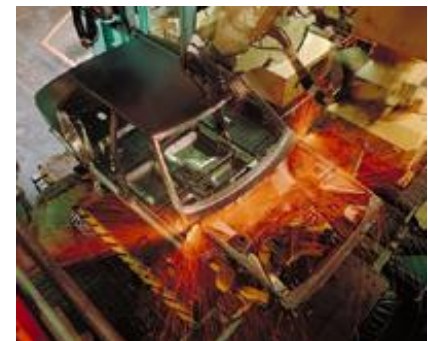
+ financing and maintenance



Car sharing system



Chemical management services

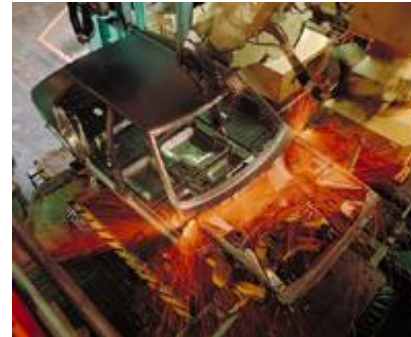


# Some examples that worked....

- Douwe Egberts Coffee Services
  - Avoids fights on dirty kitchens etc.
  - Easy for management
  - Puts DE in power node
- Chemical management services
  - Incentives low use of chemicals
  - ..but does not work in Germany, where firms want to keep control on hazards themselves
- Catering and cleaning services for offices



DE was a coffee maker, not a machine builder nor machine leasing company...but they improved greatly their power in the value chain of coffee provision



# Some examples that saw problems

|  |   |
|--|---|
| <p><b>ABB and ‘power by the hour’</b></p>          | <ul style="list-style-type: none"> <li>• Electricity efficient motors, but expensive -&gt; result oriented service</li> <li>• Sales people sold on volume, not expecting rising energy price</li> <li>• Result: ABB had multi-year contracts with losses</li> </ul> |
| <p><b>Ahrend and office furniture PSS</b></p>      | <ul style="list-style-type: none"> <li>• Leasing and re-furbishing may be interesting</li> <li>• ‘But hey, look – we have a production plant. We went back from 3 to 2 shifts, and cannot afford ourselves going back to 1”</li> </ul>                              |
| <p><b>British Airways outsourcing catering</b></p> | <ul style="list-style-type: none"> <li>• Caterer squeezed out personnel, that went on strike</li> <li>• BA could not influence this situation</li> <li>• In 2007, BA had to fly for weeks without meals</li> </ul>  |
| <p><b>Performance contracts with Police</b></p>    | <p>...difficult if performance quality has important intangible aspects...<br/>         ...in some countries you see police agents fining pedestrians walking through red lights by the end of month, to ‘make their target’</p>                                    |
| <p><b>Complex DBFO contract system</b></p>         | <p>...Design-Build-Finance-Operate: high transaction costs &amp; higher risks – if you operate a swimming pool, can you kick out annoying youth?</p>  |



# Drivers for PSS – it's the business case (**or not**)

## **BUSINESS**

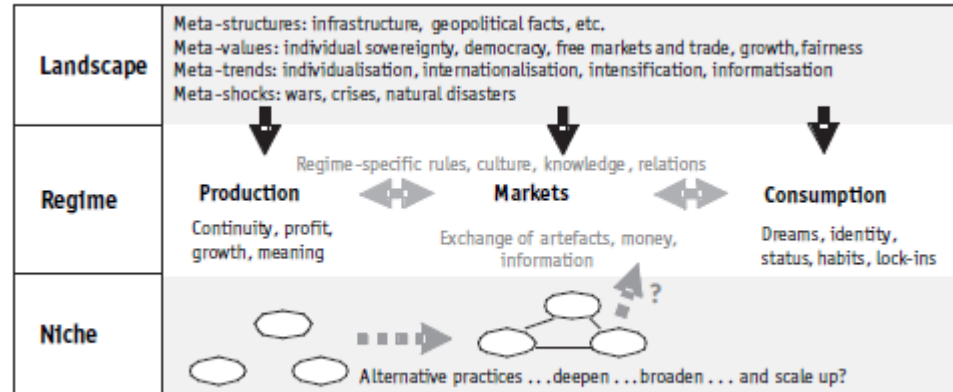
- **Value**: Co-creating user value versus market risk
  - Tangible value
  - **Intangible value**
- **Costs**: Minimizing system costs versus financial risk
  - Use of resources
  - **Transaction costs**
  - **Capital costs, risk profile, and ambiguity of the offering**
- **Power and dynamics**: Other benefits versus investment and capability risk
  - Power in the value chain / potential to capture value
  - Speed of innovation, learning, and option value
  - **Investment in new core capabilities, cannibalisation and loss of synergies**

## **ENVIRONMENTAL:**

- Product oriented = marginal,
- Use-oriented = Factor 2,
- Function oriented = Factor X

# Changes to circularity – institutional boundaries

- **Governance, policy, regulation & transitions**
  - Production-consumption systems are inert
    - ‘Regime’: sunk costs, sunk habits and relations in the value chain
    - ‘Landscape’: a myriad of ‘taken for granted’ frameworks, like free markets and individual choice
    - New practices (e.g. PSS) stay often in niches
  - We need concepts that can make systems more fluid and sustainable



# Changes to circularity – what governance?

## ■ Governance: some key approaches

- Markets (tax labor->resources)?
  - Price signal solve things
  - Legitimacy for such measures
- Top-down government?
  - Planning possible, determined systems
  - Legitimacy for such measures
- Bottom up actions from the Energetic society?
  - EMF, WBCSD, entrepreneurs
  - High profile actions aimed at changing mindsets: Dutch Urgenda
- Stalemate and waiting for disaster?

|  |   |
|--|---|
| <b>Fatalist</b><br><u>'First, disaster must happen'</u><br><br>-No governance; wait for events creating windows of opportunity<br>-Actors in stalemate over means and ends             | <b>Hierarchist</b><br><u>'Let's put a man on the moon!'</u><br><br>-Top-down central management<br>-Government has power or legitimacy; means and ends clear  |
| <b>Individualist</b><br><u>'Sustainability through the Market'</u><br><br>-Price and tax policy<br>-Legitimacy for such policy; ends known; market can solve all remaining bottlenecks | <b>Egalitarian</b><br><u>'A good transition arena will do it'</u><br><br>-Multi-actor Arena process; learning-by-doing action research<br>-Means and ends to be clarified; no dominant actor; actors tend to agree on rough direction of change |

# The future we want, and the present we have

## What we want

- An economy based on justice, exploiting people nor planet
- A world where people can live in dignity
- A world where people can live in peace



## Our current world

- An economic system that is not sustainable
  - Carbon: to a 7°C world or 80% reduction by 2050
  - Water: 40% shortage by 2030
  - Biodiversity: mass extinction, we use 35% of biomass
- Large difference in wealth, billions of poor
- Pressure on resources that may prompt conflicts

