Science-to-Business Center Eco^2 – CO_2 as building block in chemical industry

Materials valley – CO_2 workshop

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EVONIK INDUSTRIES

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Contents

Source: Science-to-Business Center Eco² (May 2012)

Evonik is one of the global leaders in specialty chemicals

Evonik figures 2011

Sales 2011	€ 14.5 billion
Adjusted EBITDA	€ 2.8 billion
Profitability (Adjusted EBITDA Margin)	19.0 %
Return on Capital Employed (ROCE)	18.7 %
Employees in 2011	33,556

Source: Science-to-Business Center Eco^2 (May 2012)

Who we are:
Evonik Chemicals Business Area R&D

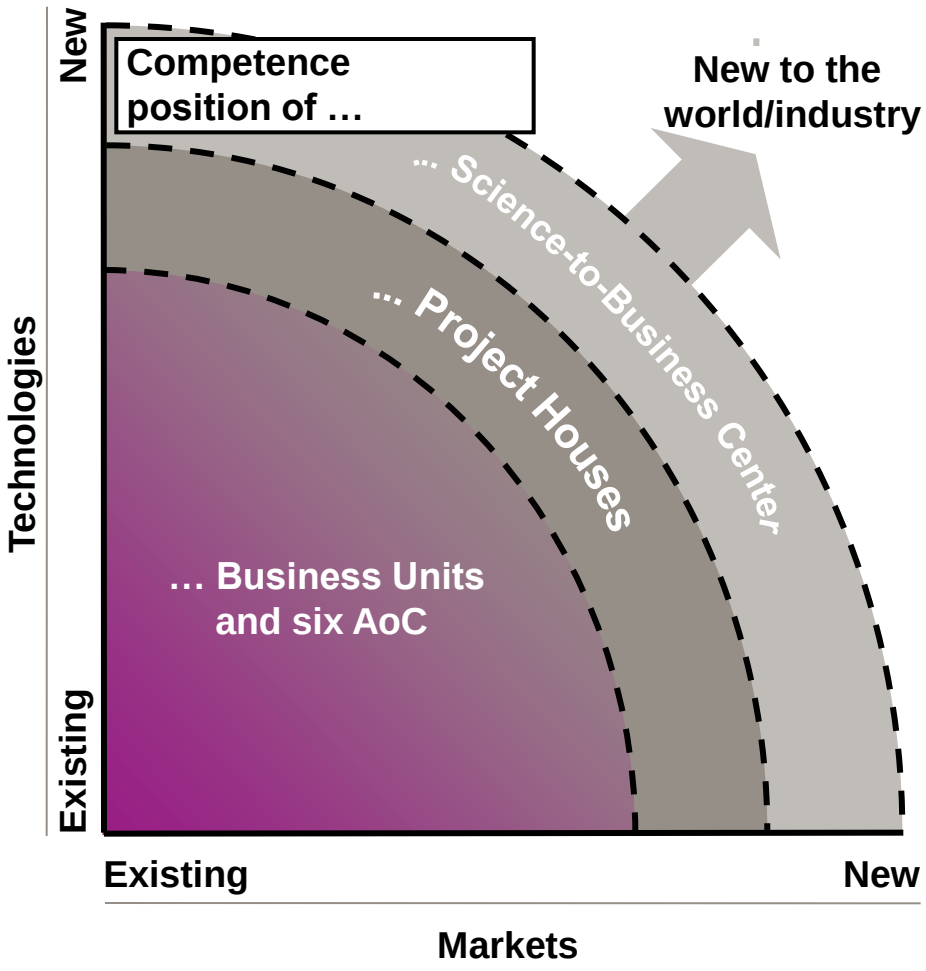
Research, development and innovation are key elements in the strategy for sustainable growth

- → **€ 365 million R&D expenses in 2011**
- → **+8 % higher R&D expenses versus 2010**
- → **Approximately 2400 employees in R&D**
- → **More than 35 R&D sites worldwide**
- → **A large number of cooperations and collaborations worldwide**

Source: Science-to-Business Center Eco^2 (May 2012)

Evonik R&D Structures – a risk adapted accelerator to stimulate innovation into profit

Position of innovation driving competences within Evonik



Creavis – *high risk*
Science-to-Business Centers
- Biotechnology (S2B Bio)
- Energy efficiency (S2B Eco[2)])

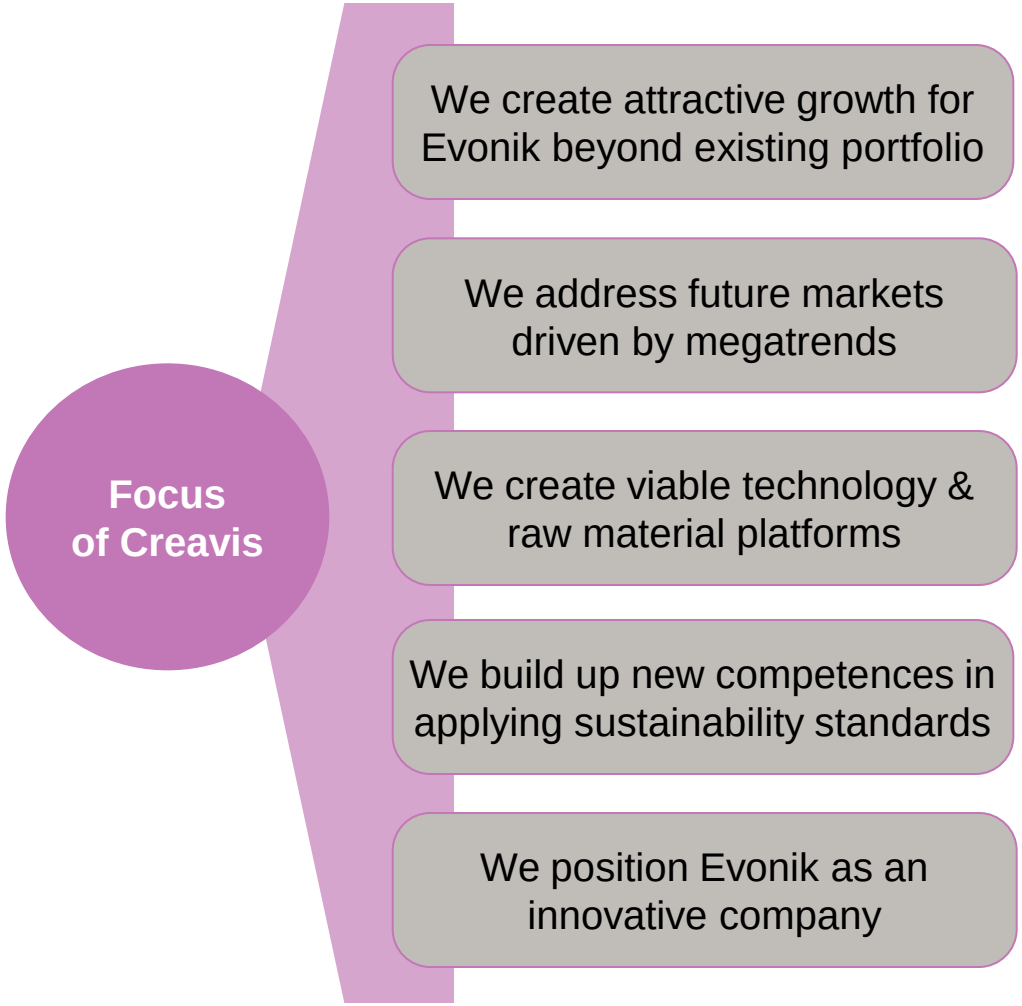
Creavis – *medium risk*
Project Houses
- Advanced Project House
- Systems Integration

BUs – *low/medium risk*
R&D activities and six Areas of Competence (AoC)

Source: Science-to-Business Center Eco[2] (May 2012)

Creavis is a leading innovation center, creating sustainable and profitable business

The focus of Creavis



Source: Science-to-Business Center Eco^2 (May 2012)

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Source: Science-to-Business Center Eco² (May 2012)

The positioning of the Science-to-Business Center Eco² is aligned with future needs

Global Business Environment

Mega Trend Categories

- Globalization
- Demo-graphics
- Con-sumption Patterns
- Resource Efficiency
- Regulation & Activism
- Wild-cards

Natural Resources & Environment Macro Trends

Accelerating natural resource demand versus increasing supply scarcity	Energy conservation and innovation	Increasing environmental issues and concerns	Global climate change	Increasing competition and conflict over natural resources & environment
				

SUSTAINABILITY TOPICS

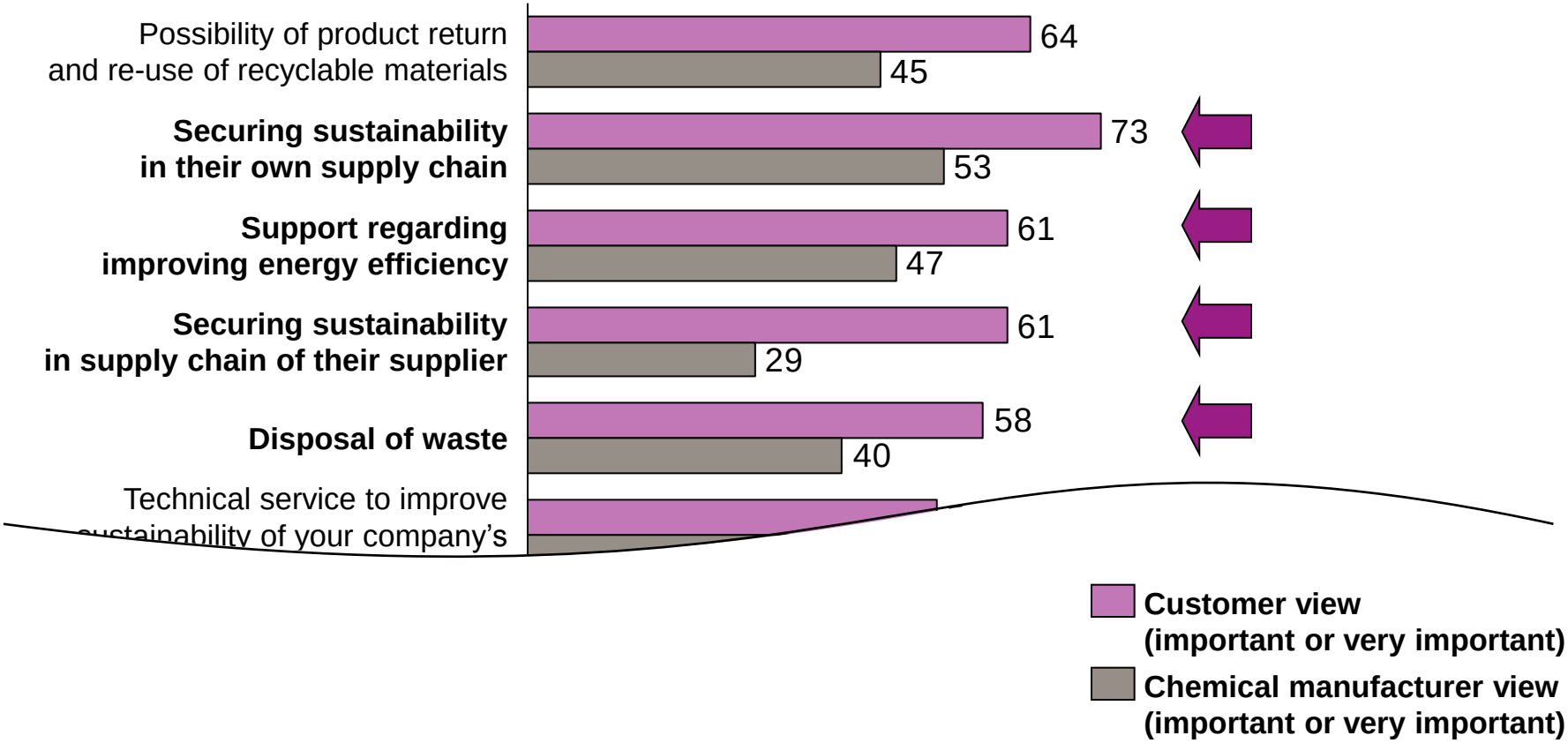
Source: Science-to-Business Center Eco² (May 2012)

Source: S2B Eco² and(A.T. Kearney)

There is a market pull for energy efficient solutions and sustainable value chains

Study

Strategic reasons for Eco²



Source: Science-to-Business Center Eco² (May 2012)

A.T. Kearney: "Chemical Customer Connectivity", Oct 2008

Science-to-Business Center Eco² is driven by the megatrend "Resource Efficiency"

November 2011

Strategic Approach of Eco²

Background

Megatrend

- **Resource Efficiency**

Approach

- **Competence development** via **multi-disciplinary** skilled and **diversity** driven **people**
- **Open innovation** in an **extensive external network**
- Cutting-edge **innovation management**

Targets

- **Significant** and **sustainable** CO_2 **reduction** at **customer** and in Evonik group
- **Midterm realization** of high share of **EBITDA potential**
- **Stakeholder communication**

Duration 2009-2013

Offering customers value-added sustainability solutions is a good way to differentiate from competitors.

Source: Science-to-Business Center Eco² (May 2012)

The S2B Eco² pools the group's energy efficiency and climate protection expertise

Science-to-Business Center Eco²

Energy Efficiency and Climate Protection

Line of Development

CO_2 Separation and Use

Energy Generation

Energy Storage

Energy Efficiency Customer Solution

Energy Efficiency Evonik Processes

Life Cycle Management

Corporate | BU´s | Services

Source: Science-to-Business Center Eco² (May 2012)

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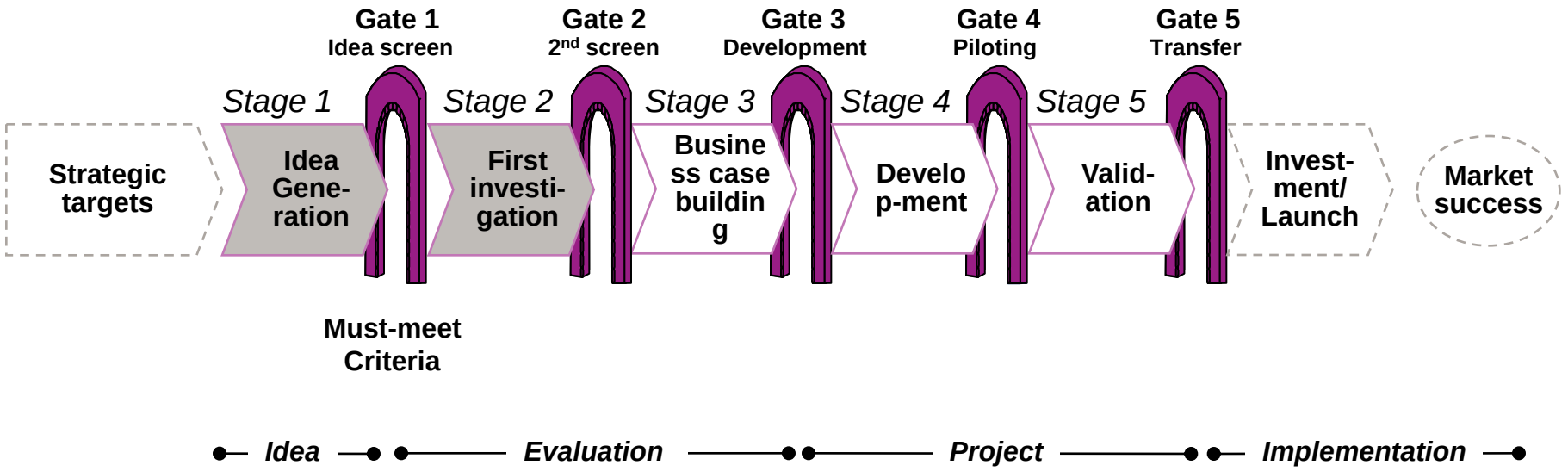
Source: Science-to-Business Center Eco² (May 2012)

The stage gate framework has been tailored to Eco²s needs

Eco² Stage-Gate-Process as overview

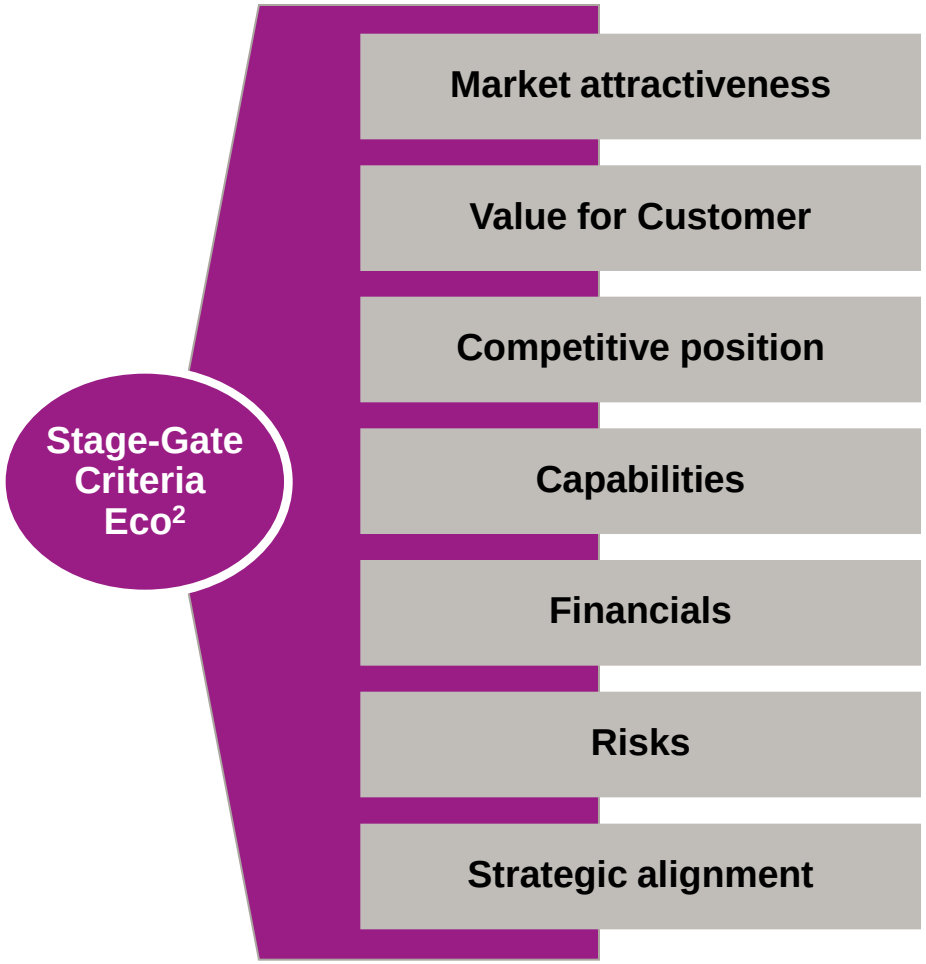


: Idea Management Process

Source: Science-to-Business Center Eco² (May 2012)

The Eco² stage gate process focuses on seven criteria for ideas or innovation projects

Gate Decision Criteria as Overview



Source: Science-to-Business Center Eco² (May 2012)

Portfolio management plays three roles to ensure strategic value maximizing decision making: strategic alignment, optimization & balance

Illustrative

General perspectives of Innovation Portfolio Management

1 Strategic Alignment

Align portfolio to **business strategy** by defining **budget allocation goals** for strategically important categories

2 Optimization

Allocate resources to **optimize the portfolio** in terms of ECV, R&D productivity, or some other **financial or non-financial metric**

3 Balancing

Balance portfolio in terms of **time, capacity utilization, or some other metric** where balance rather than linear optimization is advisable

Source: Science-to-Business Center Eco² (May 2012)

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Source: Science-to-Business Center Eco² (May 2012)

Eco² projects will be evaluated for their sustainability by Life Cycle Assessments

as per June 2011

S2B Eco² – Life Cycle Management

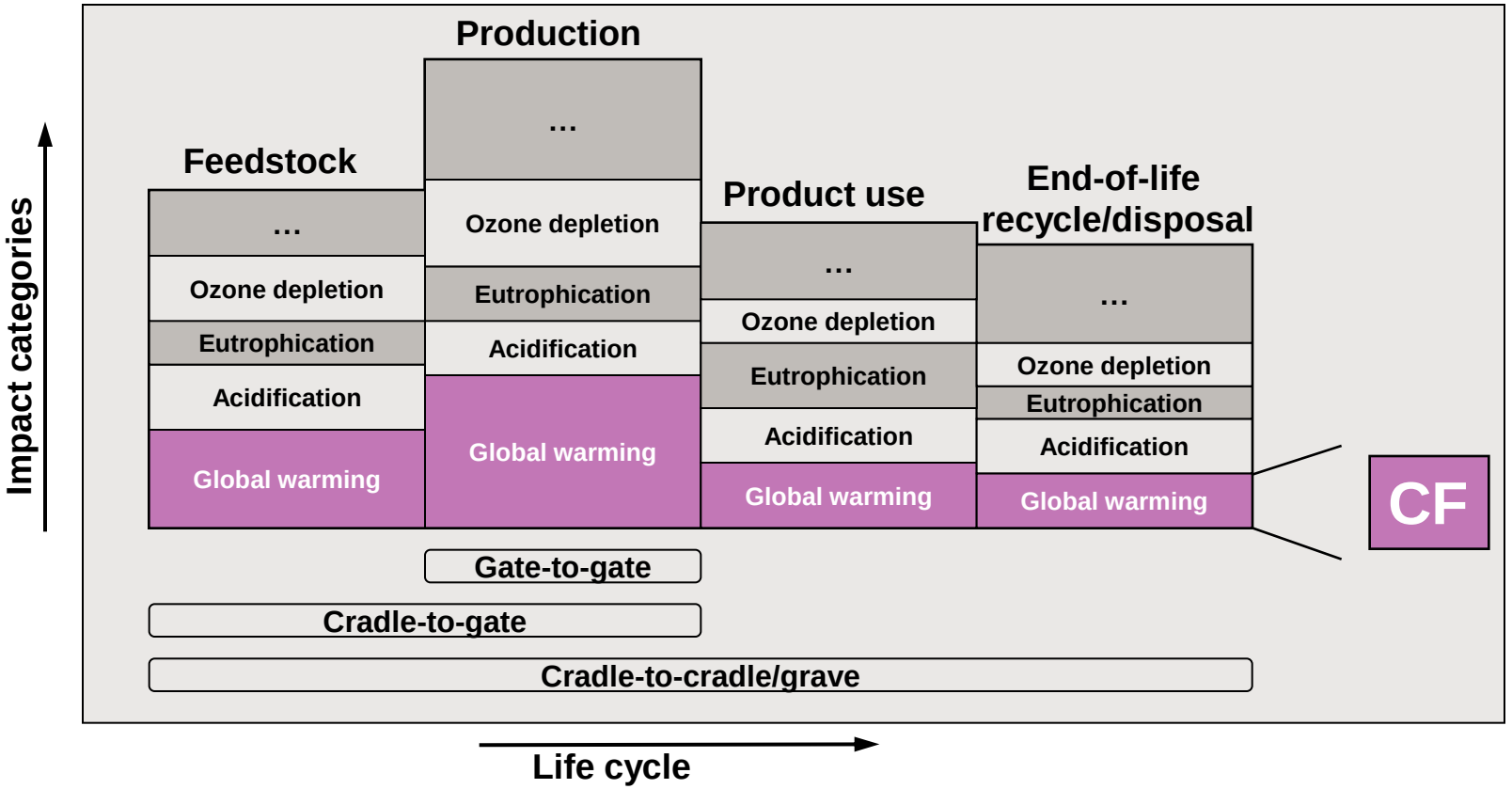
Background	Approach	Targets
• Climate protection is a public focus • Need for standardized climate and sustainability data • Innovative ideas for increased energy efficiency	• LCM as an internal corporate service platform • Corporate wide LCA standard • Sustainability evaluation from product idea to marketing	• **Transparent data basis** for **internal assessments** • **Evaluation of Evonik products and processes** concerning sustainability and climate relevance • Evaluation of an all encompassing **„Evonik Carbon Footprint“** • **CO_2-savings** in the **process** and **usage phase**

„Carbon Footprint“ will be a leading parameter for the evaluation of products and processes at Evonik.

Source: Science-to-Business Center Eco² (May 2012) LCM: Life cycle management LCA: Life cycle assessment

Life Cycle Assessments (LCAs) examine the environmental impact of products‘ full life cycles

LCA: Illustration of life cycle, impact categories and system boundaries



The methodology of the Carbon Footprint Estimation (CFE) model is similar to the existing LCA process, but focuses on the Carbon Footprint (CF)

Source: Science-to-Business Center Eco² (May 2012) CFE = Carbon Footprint Estimation

CFE model is the certified Evonik standard for evaluation of innovations regarding CO_2e

CFE workflow

CFE content

- Goal and scope
- System boundaries
- Functional unit
- Choice of allocation method
- Evaluation of Evonik Share
- Examination of in- and outputs of products‘ full life cycles

CFE quality assurance

- Identification of risks in calculation of CO_2e impacts and use of risk handling methods
- Evaluation of sources of uncertainties in data completeness, data and calculation method quality

Source: Science-to-Business Center Eco² (May 2012) CFE = Carbon Footprint Estimation

Contents

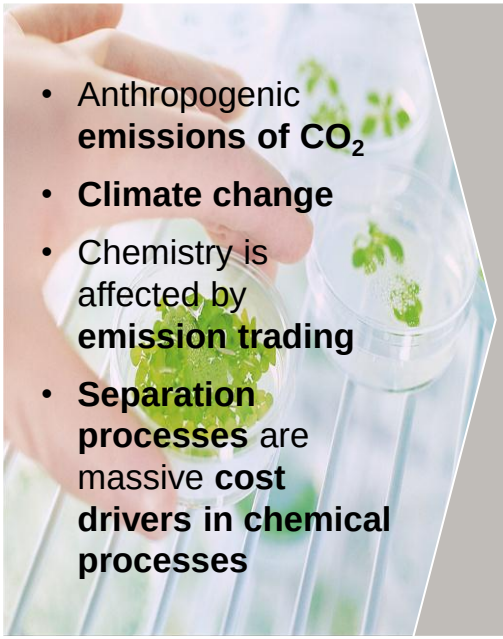
Source: Science-to-Business Center Eco² (May 2012)

We would like to use CO_2 along the chemical and biotechnological value chain

as per June 2011

S2B Eco² – Lines of Development – CO_2 Separation and Use – Energy Efficiency – Evonik Processes

Background



- Anthropogenic **emissions of CO_2**
- **Climate change**
- Chemistry is affected by **emission trading**
- **Separation processes** are massive **cost drivers in chemical processes**

Approach

- Absorption of CO_2 from gas streams with **optimized absorption materials**
- Use of CO_2 in **chemical syntheses**
- Use of CO_2 in **biotechnological processes**
- Energy efficient **separation technologies**

Targets

- Feeding **CO_2** back **into the value chain**
- Create **higher value products** for application in fields such as **transportation fuels, fertilizers, chemical feedstocks, animal feeds or others**
- Competitive processes with **lower energy costs**

Energy efficient processes and syntheses for ecological and economic benefit are key.

Source: Science-to-Business Center Eco² (May 2012)

Within two years we developed new promising absorbents and set up a simulation tool

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CO_2 Separation

Objectives

- Lower the **specific energy demand** for CO_2 separation compared to available technology[1)]
- Increasing **chemical resistance** of **absorbent** compared to available technology[2)]
- **Simulation results** of the “clean coal process“ confirms a **lower efficiency loss**
- **Life-Cycle-Assessments** confirms the sustainability of new absorbents

Results

- Over **100 chemical substances** have been validated in the lab
- **Promising absorbents were identified** in the lab and patent applications for new molecular structures have been filed
- **Simulation of total process** (CO_2 separation and power plant) has been established

Partners

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Friedrich-Alexander-Universität Erlangen-Nürnberg

UNIVERSITÄT DUISBURG ESSEN

SPONSORED BY THE

Federal Ministry of Education and Research

Source: Science-to-Business Center Eco² (May 2012) 1) MEA: 3.5 MJ/kgCO_2 ; 2) MEA :1.5 kg/tCO_2

A CO_2 capture plant was erected in the stack of a coal fired power plant to test promising absorbents in real flue gas

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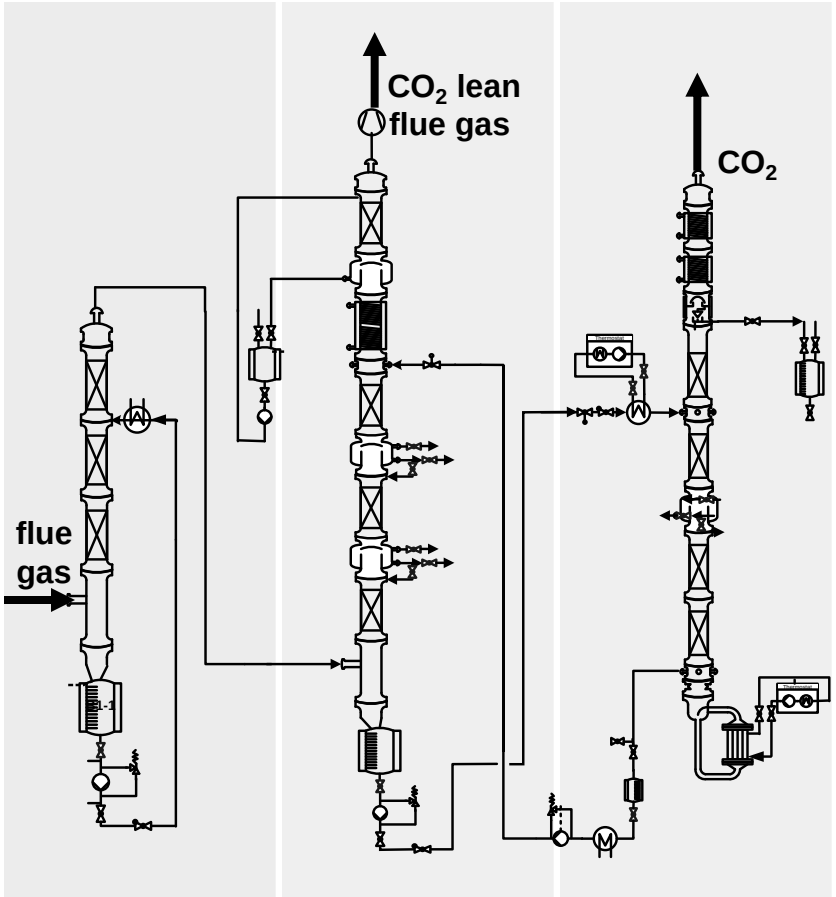
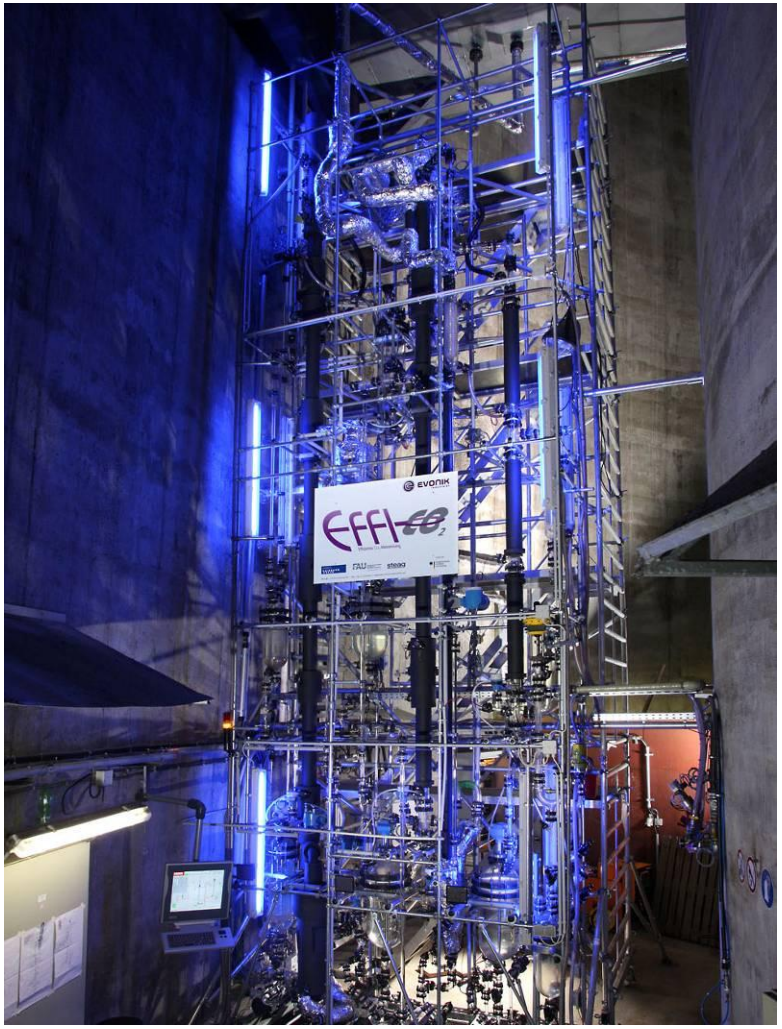
CO_2 Separation

Process technology and picture of CO_2 capture plant





Source: Science-to-Business Center Eco² (May 2012)

Investigation of all important criteria is necessary to establish a feasible CO_2 separation technology

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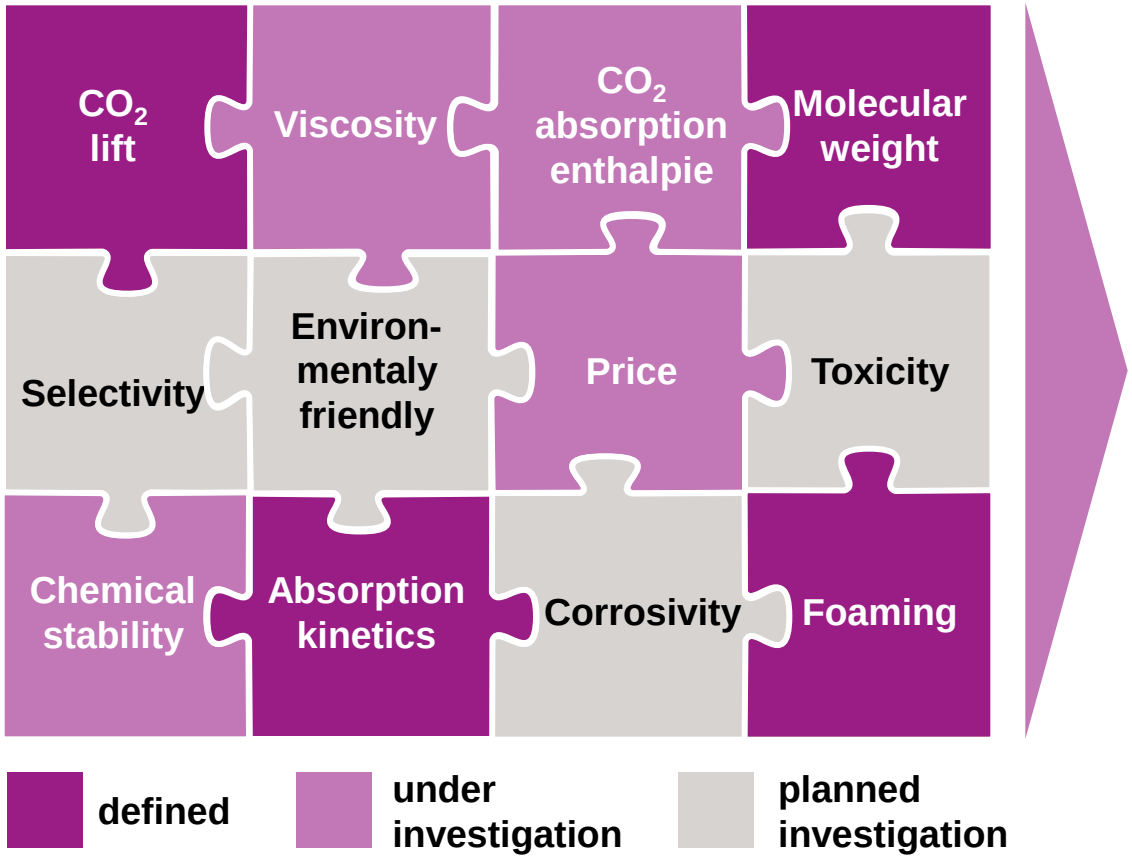
CO_2 Separation

Requirement specification for new absorbents



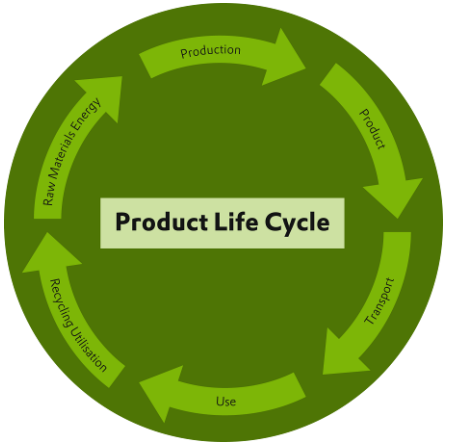
Feasible technology

Source: Science-to-Business Center Eco² (May 2012)

Utilization of CO_2 is not the key to mitigation of CO_2 emissions

CO_2 Use

Climatic impact of CO_2 utilization



- For the climatic impact of CO_2 utilization, **neither the amount of used CO_2 nor the time of fixation are crucial.**
- The **CO_2-emissions in comparison with the benchmark** are relevant. They are determined by **LCAs** considering:
  - **Cradle to gate** (same product generated in new process and benchmark)
  - **Cradle to grave** (different products in new process and benchmark for the same application).
- But: as only < 10 % of the anthropogenic emissions of CO_2 can be used in the chemical industry, the **impact of CO_2 utilization is small**.
- A significant contribution to the mitigation of CO_2 emissions can be achieved by **improvement of energy efficiency and process optimization**.

For the mitigation of CO_2 emissions, a combination of improved energy efficiency and CO_2 utilization is necessary.

Source: Science-to-Business Center Eco[2] (May 2012)

Utilization of CO_2 is economically attractive

Reasons for the use of CO_2

- **Cheap** starting material
- **Non-fossil fuel** based C_1 building block, thus lowering the dependency from fossil fuels
- **Easily available also on a long perspective**
- **No costs for CO_2 certificates**
- **Non-toxic**

Source: Science-to-Business Center Eco[2] (May 2012)

For the energy-efficient use of CO_2 as building block in the chemical industry….

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CO_2 Use

Challenge and approach of chemical use of CO_2

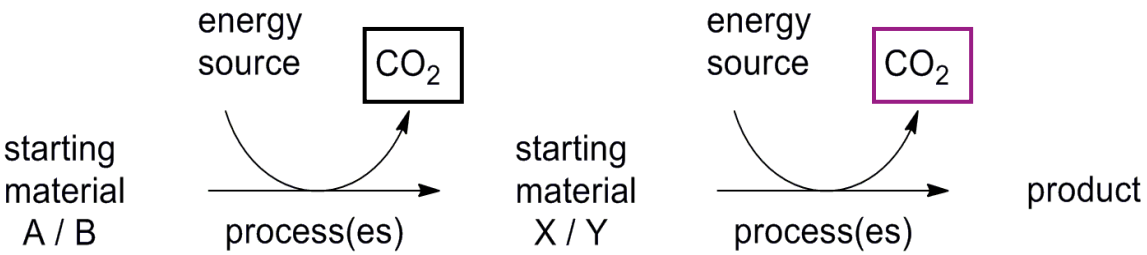
Challenge: CO_2 is extremely unreactive and its reaction consumes much energy.

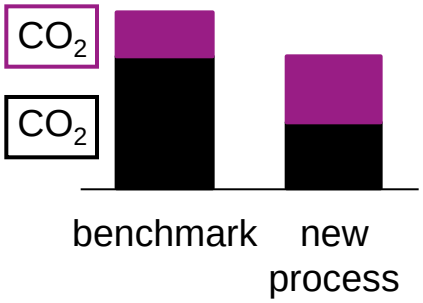
Solution: CO_2 emissions of processes using CO_2 can be lower than CO_2 emissions of the benchmark, if:

a) **acids, esters and carbonates** are synthesized (no alcohols because of CO_2 emission for reduction with H_2), and / or

b) **starting materials with small CO_2 burdens** are used; and / or

c) **Renewable energy** is used for the new processes





CO_2 emissions will be reduced – highly added value will be created

Source: Science-to-Business Center Eco² (May 2012)

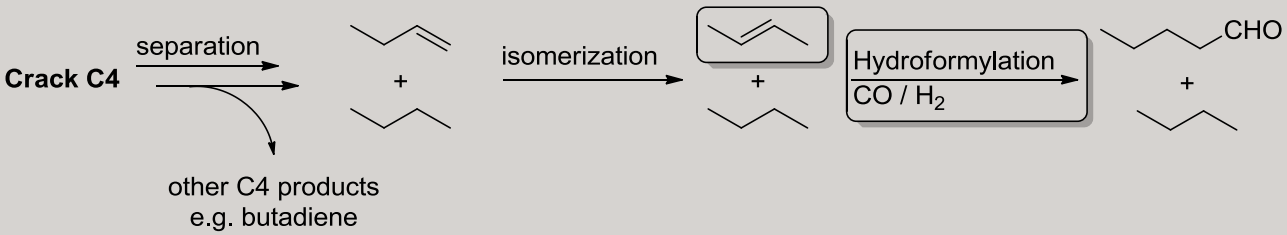
Butane and CO_2 will be used instead of butene and CO for the synthesis of valeraldehyde

VALERY

Comparison of new and benchmark synthesis for valeraldehyde

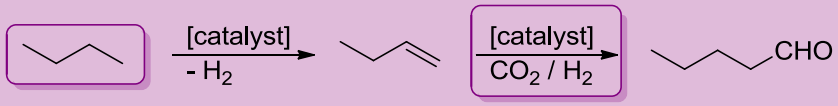
Commercial synthesis of valeraldehyde

- Important intermediate in the synthesis of **plasticizer**
- Large market potential > 300 kt/a
- Current synthesis relies on the **hydroformylation** of **butene**



New direct synthesis of valeraldehyde

- **Dehdrogenation of butane** yielding butene and H_2
- **Hydroformylation with CO_2** and one additional H_2



Source: Science-to-Business Center Eco² (May 2012)

An interdisciplinary team with a challenging task

VALERY

Targets of VALERY

- Development of technical relevant **catalysts for dehydrogenation of alkanes**
- Development of technical relevant **homogeneous catalysts for hydroformylation with CO_2**
- **Immobilisation of homogeneous catalysts** on porous support with ionic liquids
- Design of an **industrial relevant total process**
- Analysis of CO_2 saving potential via **Life-Cycle-Assessments (LCA)**

VALERY	
Budget	**€ 1.7 Mil.**
Project start	**1st of November 2010**
Project duration	**36 months**

Consortium

Source: Science-to-Business Center Eco² (May 2012)

Within H_2ECO_2 we combine the regenerative generation of H_2 with the chemical use of CO_2

H_2ECO_2

Organization of H_2ECO_2

Utilization of CO_2 as building block

Regenerative generation of H_2

Prof. Agar

Prof. Pfennig

Prof. Arlt

Dr. Martin, Prof. Brückner, Prof. Beller

Prof. Vogt

Prof. Jaegermann

Prof. Schuhmann
Prof. Muhler

Prof. Reek

EUROPEAN UNION
Investing in your future
European Regional Development Fund

This project is funded by the state North Rhine-Westphalia and co-financed by the EU

Ministerium of Innovation, Science and Research of the German State of North Rhine-Westphalia

Source: Science-to-Business Center Eco² (May 2012)

CO_2 utilisation for an economic and ecologic benefit

H_2ECO_2

Scope of H_2ECO_2

Innovative processes for using **CO_2 as building block** in chemical production will be developed.

This will allow:

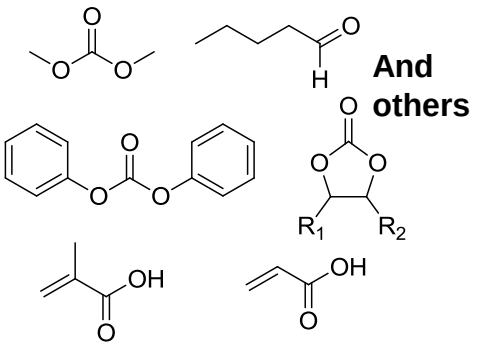
- **Reduction in CO_2-emissions**
- Broader access to **CO_2 as C1** building block
- Creation of **highly added value**

New synthesis pathways using CO_2 as raw material…

…have to be evaluated in detail concerning **thermodynamic, economic and ecologic aspects.**

…need a clearly defined **benchmark.**

…can be **energetic reasonable and economic interesting.**



Thermo-dynamic, Economy, Ecology, Catalysis, Process feasa-bility

Favored target products

Source: Science-to-Business Center Eco² (May 2012)

Life Cycle Assessments are crucial to proof sustainability of CO_2 separation and use

Scope of H_2ECO_2

Situation

- **Efficient CO_2 separation** is a prerequisites for CCS and CCU
- Potential for chemical **use of CO_2** is restricted to maximal **10 %** of total CO_2 emissions
- CO_2 is an economically attractive raw material

Challenges

- **Flue gases** from coal fired power plants **contain impurities**
- Sustainable reactions with **CO_2 as building block** must lead to **savings of CO_2 emissions** in comparison to the benchmark

Approach

- **Energy efficient CO_2 absorbents** are being developed in EffiCO_2
- **The chemical use of CO_2** is evaluated in two public funded projects
- **CFE** model as a tool **for evaluation of ideas** in terms of CO_2^{eq} emissions
- **Sustainability** of all projects have **to be prooved via Life Cycle Assessments**

Source: Science-to-Business Center Eco^2 (May 2012)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