Introduction

Session 6: Sustainability from the beginning – the pharmaceutical example

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LEUPHANA
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Chemistry and Pharmacy

„The real emissions … are not the emissions within the production but the products themselves.“

📖 Eberhard Weise, former CEO of Bayer AG, in: Held M. (Ed.), Leitbilder der Chemiepolitik, Campus Verlag 1991, S. 55-64

Chemistry and Pharmacy

Molecules

Synthesis

Reactions

- Catalysis
- Solvents } costs/savings:
- Waste } door opener for sustianable chemistry
- …

Consumer products

Important industrial stakeholders

Products and Waste

$$E = \frac{\text{kg (waste + by products)}}{\text{kg products}}$$

E-factor = (mass of inputs - mass of outputs) ÷ mass of product

	Production (t / year)	E-value
Oil refinery	$10 - 10^8$	ca. 0,1
Bulk chemicals	$10^4 - 10^6$	<1,5
Fine chemicals	$10^2 - 10^4$	5 – 50
Pharmaceuticals	**10 – 10**	**25 - >100**

📖 Sheldon R; Green Chemistry, 1994, 2007

Solvent Selection

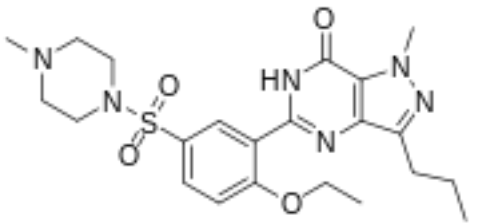
http://www.rsc.org/suppdata/gc/c0/c0gc00918k/c0gc00918k.pdf

	Few issues (bp°C)	Some issues (bp°C)	*Major* issues
Chlorinated	….before using chlorinated solvents, have you considered TBME, isopropyl acetate, ethyl acetate, 2-Methyl THF or Dimethyl Carbonate?		Dichloromethane ** Carbon tetrachloride ** Chloroform ** 1,2-Dichloroethane **
Greenest Option	Water (100°C)		
Alcohols	1-Butanol (118°C) 2-Butanol (100°C)	Ethanol/IMS (78°C) t-Butanol (82°C) 1-Propanol (97°C) 2-Propanol (82°C) Methanol (65°C)	2-Methoxyethanol **
Esters	t-Butyl acetate (95°C) Isopropyl acetate (89°C) Propyl acetate (102°C) Dimethyl Carbonate (91°C)	Ethyl acetate (77°C) Methyl acetate (57°C)	
Ketones		Methyl isobutyl ketone (117°C) Acetone (56°C)	Methyl ethyl ketone
Aromatics		p-Xylene (138°C) Toluene ** (111°C)	Benzene **
Hydrocarbons		Isooctane (99°C) Cyclohexane (81°C) Heptane (98°C)	Petroleum spirit ** 2-Methylpentane Hexane
Ethers		t-Butyl methyl ether (55°C) 2-Methyl THF (78°C) Cyclopentyl methyl ether (106°C)	1,4-Dioxane ** 1,2-Dimethoxyethane ** Tetrahydrofuran Diethyl ether Diisopropyl ether **
Dipolar aprotics		Dimethyl sulfoxide (189°C)	Dimethyl formamide ** N-Methyl pyrrolidone ** N-Methyl formamide ** Dimethyl acetamide ** Acetonitrile

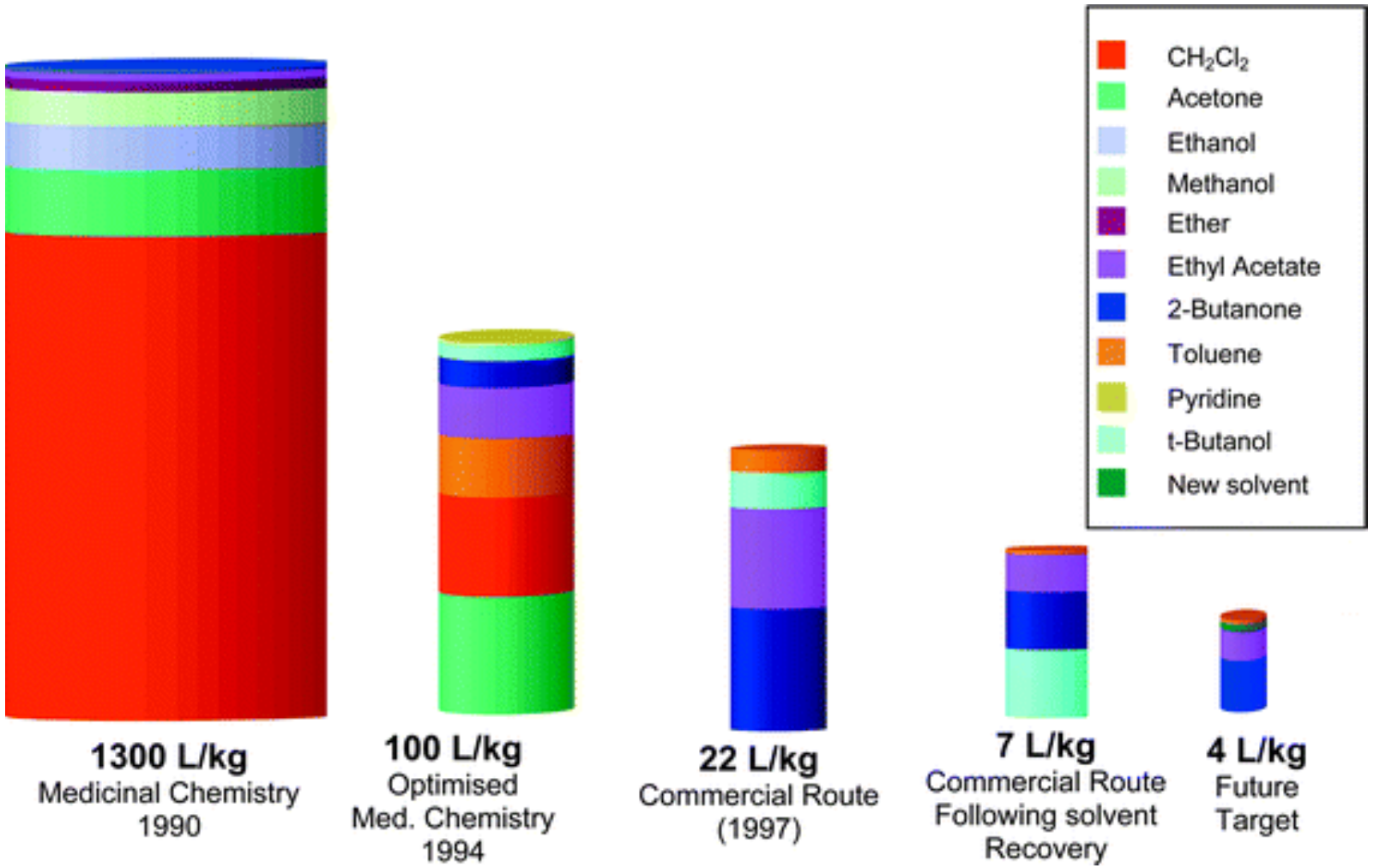
** = EHS Regulatory Alerts: please consult the detailed solvent guide and the GSK Chemicals Legislation Guide for more information

GSK SSG-MC-02 September 2010

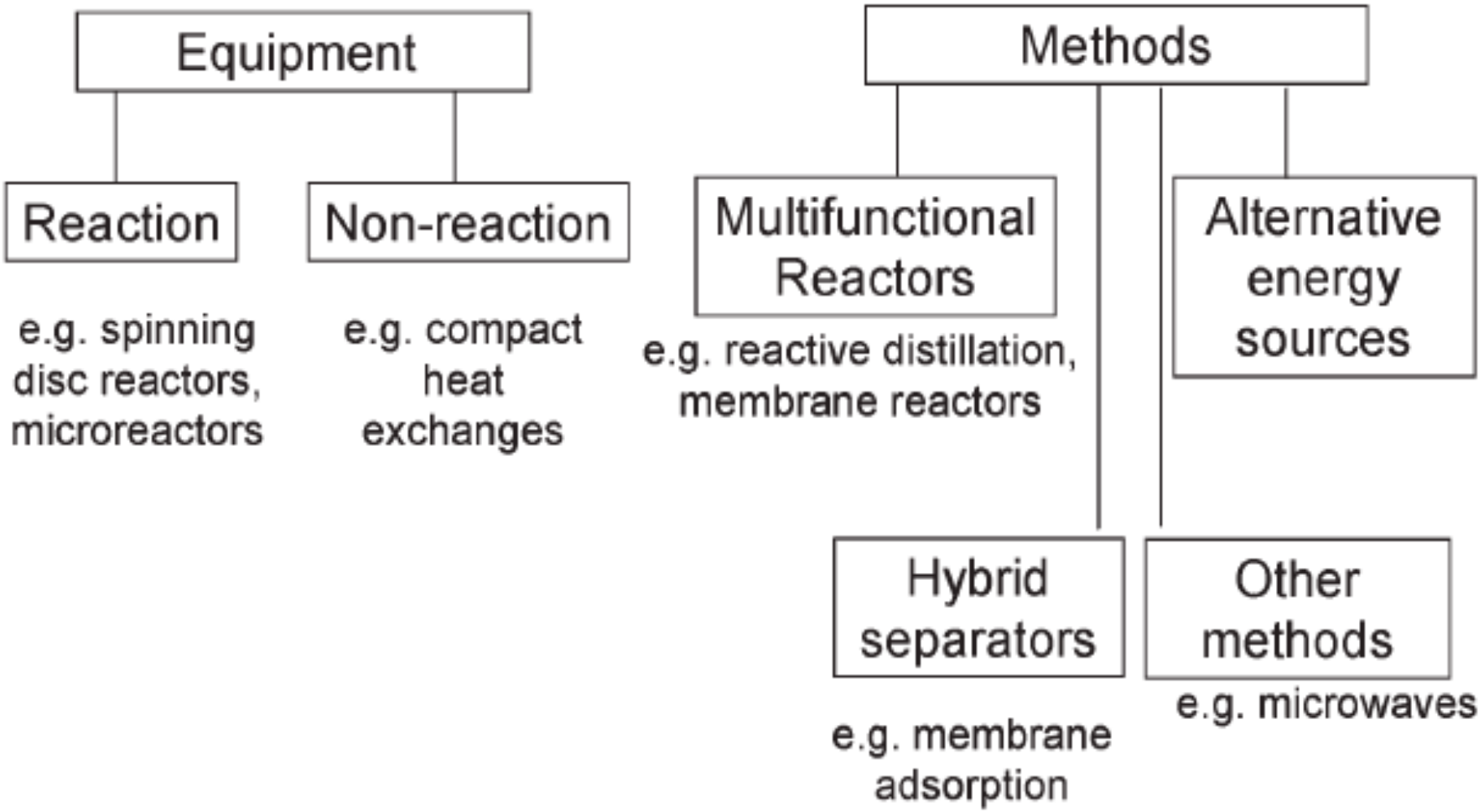
Sildenafil Synthesis Solvent Waste



Dunn, P.: Green Chem. 2004, 6, 43-48

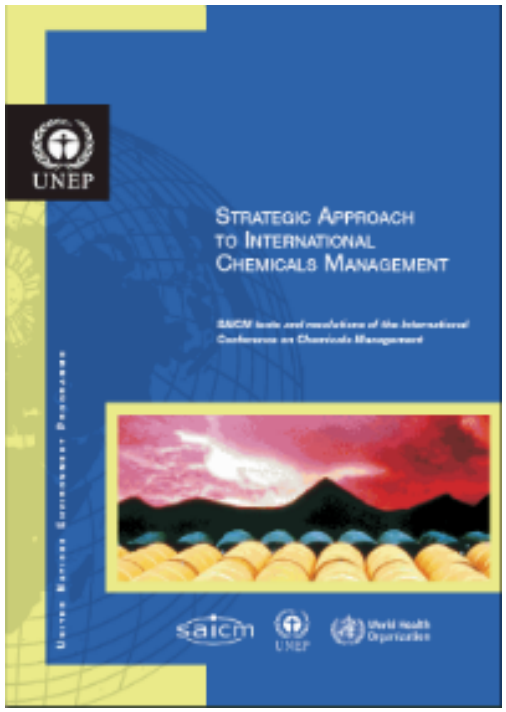


Process Intensification



SAICM

- Strategic Approach to International Chemicals Management

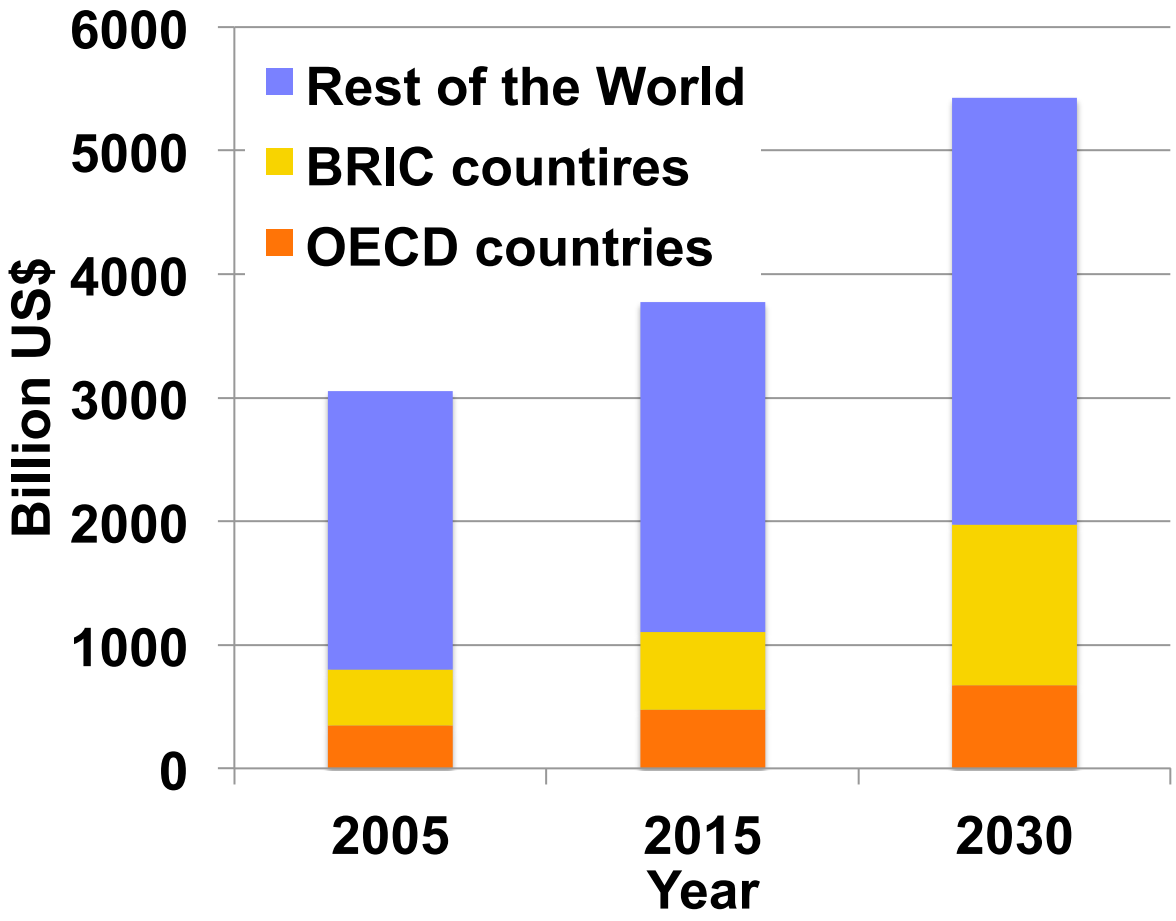


http://www.saicm.org/images/saicm_documents/saicm%20texts/SAICM_publication_ENG.pdf

The Future

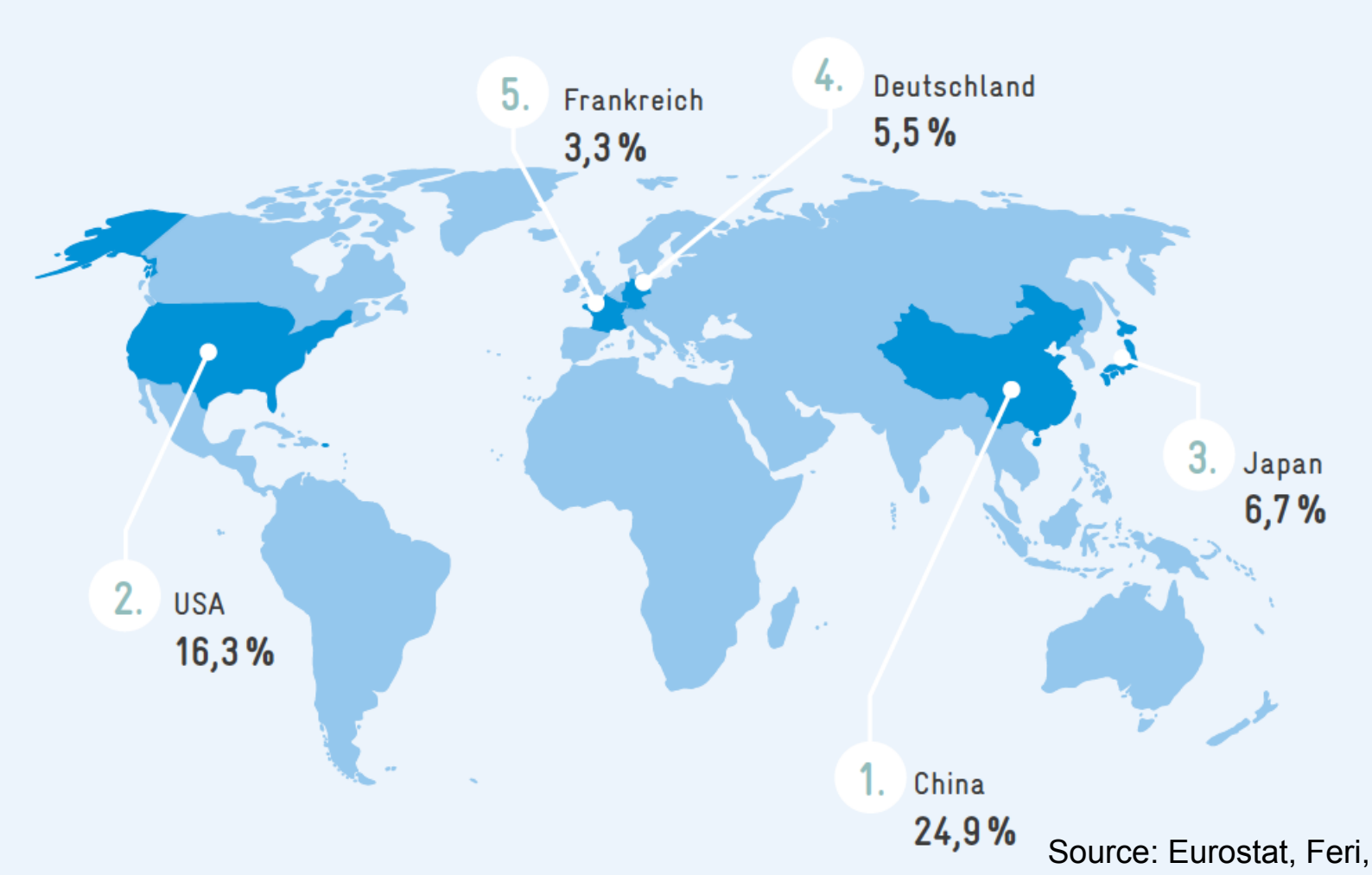
- Increasing population
- Increasing living standard
- Increasing age
- Climate change

Production of Chemicals



Source: OECD Environmental Outlook to 2030 (OECD 2008)

Chemicals Industry‘s Share of the World Market



Source: Eurostat, Feri, VCI