Platform Abstracts

Consequential modelling in policy-making, Input-Output databases, and economic models

1
Welcome and introduction by symposium and session chairs
B. Weidema, The ecoinvent centre; M. De Rosa, BONSAI / Agroecology

2
Direct Disposal vs Reprocessing of Used Nuclear Fuels: A LCA Study for Decision Support in the UK
A. Paulillo, University College London / Department of Chemical Engineering; M. Pucciarelli, University College London / Chemical Engineering; R. Clift, University of Surrey / Centre for Environmental Strategy; S. Palethorpe, J. Dodds, National Nuclear Laboratory; A. Milliken, Sellafield Ltd.; P. Lettieri, University College London / Chemical Engineering
The UK Government is clear on the important role nuclear may play in the UK's future energy mix, as a clean, secure and reliable source of energy; and it predicts that nuclear could contribute up to 40-50% under the best possible future scenario for the industry. At present, the UK operates a "nominal" Twice-Through Cycle (TTC): Used Nuclear Fuels (UNF's) are reprocessed at Sellafield site, where fission products are separated from Plutonium (Pu) and Uranium (U) and transformed in a final, manageable waste form suitable for disposal. The TTC cycle is just "nominal" because recovered U and Pu are not currently reused in the cycle. The UK and its nuclear industry are entering a critical phase where crucial decisions are to be taken. The Nuclear Decommissioning Authority (NDA) is a non-departmental public body, whose purpose is to ensure decommissioning and clean-up of UK's nuclear legacy sites, has recently announced that reprocessing of UNFs will cease. The government and the NDA, however, have yet to take a final decision on the future of the UK nuclear fuel cycle, and thus, at present, several options are possible. The approach for the disposal of solid Higher Activity Wastes (HAWs) has been already agreed - but not yet implemented - by the Government. This envisages disposal in a deep repository built several hundred metres underground in a geologically stable environment. This study is part of a wider project whose aim is to evaluate and compare the sustainability of several possible nuclear waste and UNF management options with the aim of supporting both the NDA and the UK Government in their decision-making process. Here, we focus on the two options for management of UNF's: direct disposal and reprocessing. The latter envisages reuse of plutonium and uranium in the form of MOx (Mixed Oxide Fuel), which it is assumed will displace production of an equivalent amount of enriched uranium. This study is defined as a prospective LCA to emphasise the time perspective that looks beyond the present in a potential near future. A consequential LCA perspective is adopted, but only short-term marginal effects are considered. These include first order direct physical effects, but not second and third order effects, whose time-response is much larger and goes beyond the time perspective adopted.

3
Should policy-makers stimulate the recycling of rare earth elements from fluorescent lamps?
D. Schrijvers, University of Bordeaux; P. Loubet, CyVi-ISM / ISM CyVi; G. Sonnemann, University of Bordeaux / ISM CyVi
Rare earth elements (REEs) are often considered as critical materials. They are needed in the transition towards cleaner technologies, but Europe is dependent on the supply from China. The European Commission has therefore formulated a strategy to strengthen the European REE supply chain, which encompasses the recycling of REEs from fluorescent lamps. However, is this recycling beneficial for the environment? This is assessed with a consequential LCA. The functional unit of the LCA is the production of 1 kg of recycled YOX. This phosphor contains the REEs yttrium and europium. By-products of the recycling process are lanthanum, cerium, terbium, and some residual europium. A comparison is done with the production of 1 kg of primary YOX. Modeling of REEs in consequential LCA is challenging, as they are uniquely mined as co-products from each other. The production volume of primary REEs is only determined by the demand for neodymium, dysprosium, and yttrium. Several REEs, such as lanthanum and cerium, are produced in surplus. There is a shortage of terbium and europium. As a consequence, the marginal suppliers of the REEs vary between primary ores, stockpiles, and the use by their marginal users, respectively. The marginal user of europium is a fluorescent lamp that can compete with halogen lamps (scenario 1) or LED lamps (scenario 2), which have different lifetimes and energetic efficiencies. The results demonstrate that the market situation of the REEs has a large influence on the environmental impacts and benefits of the recycling process. Recycling is environmentally preferable over the production of primary YOX when the additional availability of the by-product europium results into an increased production of fluorescent lamps that substitute halogen lamps. However, recycling of YOX is environmentally disadvantageous when the increased availability of europium for fluorescent lamps results in a delayed implementation of more energy-efficient LED lamps. The analysis could be further improved by including supply constraints and marginal applications of REEs due to geopolitical factors. This case study is exemplary for the relevance of consequential LCA to inform policy makers on investment strategies, by considering the market situation of each element and the relative environmental performance of applications that are affected by the availability of critical materials.

4
Calculating CFP elasticities. A case study for meat consumption in Spain
G. Forero, Universidad del Tolima; N. Sanjuán, Universitat Politècnica de València / Food Technology; C. Sabán, J. Ribal, Universitat Politècnica de València
In the last few years, meat production and consumption is giving cause of concern due to its effects both on public health and climate change. Among the political instruments to mitigate the effects of meat production the implementation of food taxes arises as an effective means to change consumer behaviour towards more sustainable diets. Nevertheless, the effects of those taxes must be evaluated. As a first step to assess the consequences of meat taxation in Spain, this study aims at proposing a tool to calculate how price variations modify the carbon footprint (CFP) of meat consumption, taking into account different kinds of meat. Measuring how a change in the price of a food affects its CFP implies to calculate an elasticity. In this case, measuring how the CFP of meat changes when there is a change in the price of a specific kind of meat. For our analysis, five kinds of meat were considered: pork, beef, chicken, lamb and others. Information related to prices and food consumption have been gathered from the *Panel of household food consumption* in Spain over a twelve-year period (2004-2015). Product CFP has been collected from the *Barrilla CFN database*. The estimation of different types of elasticities (cross, own-price, expenditure) has been made by using a Linear Almost Ideal Demand System Model (LAIDS). For all the products, the own-price elasticities have a negative sign, implying a rational behavior in terms of the economic theory. As for the cross-price elasticities, the results are no conclusive due to the existence of different values and signs, which make possible to distinguish between substitutes and complements goods. The expenditure elasticities evidence the existence of normal and luxury goods. By applying the cross elasticities of a specific type of meat we can find out the consumption variation of all the meat types when the price is increased by 1%. This process has been repeated for all meat types and all the CFP elasticities have shown to be negative. This means that, for example, a 1%-increase in the price of beef implies that the meat CFP in Spain will drop 0.19%. The proposed method allows the changes in meat CFP due to price changes to be found, and it can be applied to any kind of food. This method is a static one, and an extension of this analysis can be implemented from a dynamical approach, in which the prices of all the studied foods can be simultaneously changed.

5
Future consequences of strategies for household waste management in Copenhagen, Denmark
C. Cimpan, University of Southern Denmark / SDU Life Cycle Engineering; J. Nedenskov, ARC Amager Resource Center / Environment and Debvelopment; I. Leisner, Amager Resource Center (ARC); H. Wenzel, SDU / SDU Life Cycle Engineering
Interactions between waste management systems and surrounding societal and technology systems are often crucial to long-term environmental efficiency of waste management strategies. However, the integration of comprehensive future framework scenario modelling in consequential life cycle assessment (cLCA) studies is not widely performed, and less so in waste LCA studies, despite being necessary to avoid potential technological lock-ins, considering that waste management infrastructure can have extensive technical and economic lifetimes. The case research presented here evaluated several avenues by which the five municipalities, constituting the geographical entity – City of Copenhagen (plus Hvidovre municipality), could enhance resource management efficiency in their systems for management of household waste and then assessed potential long-term implications for climate change impact (measured as GWP) for these avenues. In order to account for the long-term dimension of waste management strategies, foreground scenario systems (representing the above avenues) were assessed within the frame of future, predictive and exploratory, background scenarios. This included a timeline between 2015 and 2035. Short- to long-terms energy marginals (electricity and heat) were determined based on energy systems analysis performed on the Central-Nordic European electricity system and respectively the greater Copenhagen district heating system (DHS). Marginal biomass supply, which is projected to be an essential energy source for electricity but especially heat production, was modelled based

on different future narratives regarding global bioenergy development (resulting in different scale of biomass demand) and global enforcement of land governance (resulting in marginal biomass supply with different climate impact). Results displayed an overwhelming sensitivity for the climate impact potential of waste management systems to the future development of the energy system and, in particular, the source of woody biomass marginal supply. Nevertheless, the foreground systems compared in this work performed in a robust way in all future background variations, i.e. systems did not change rank over time, showing an overall clear preference for enhanced material resource cycling.

6

Linking the Swiss Times Energy System model to consequential life cycle assessment, the case of stationary batteries and their consequences in the Swiss energy system

L. Vandepaer, Université de Sherbrooke / Paul Scherrer Institute / Department of Civil Engineering / Laboratory for Energy Systems Analysis; E. Panos, Paul Scherrer Institute / Laboratory of energy systems analysis; C. Bauer, Paul Scherrer Institute / Laboratory for Energy Systems Analysis; B. Amor, Universite de Sherbrooke / Civil Eng

A suite of open source tools is used to link the Swiss Times Energy System model (STEM) to consequential life cycle assessment (CLCA). This approach allows achieving a connection that is more systematic, more transparent and more easily reproducible than existing attempts. The case of stationary batteries and their consequences in the Swiss energy system is studied. The open-source tools used are Brightway2, an LCA framework written in the Python programming language, and Wurst an industrial ecology Python package. The technologies available in STEM are mapped to LCA datasets from primary data and the Ecoinvent v3.3 database. The technological parameters (e.g. efficiencies and lifetime) used in the energy system model and in the life cycle inventory are harmonized. Future consequential electricity mixes from 40 different countries are injected into the background database to match the prospective scope of this assessment. LCA scores for each technology represented in STEM are calculated using the ReCiPe impact assessment method. These results are stored in a data-frame compatible to the STEM format for data input. The LCA midpoint indicators are declared as new objects into the STEM framework and the LCA scores are added as new attributes to the various technologies using the data-frame. Different energy scenarios describing the future electricity and heating sectors of Switzerland are produced using STEM. Each of the scenarios is then generated in two versions, one with batteries and the second one without batteries. The comparison of the runs with and without the storage units allows determining the changes they cause in the energy system. The environmental impacts of these changes are then calculated using the LCA indicators integrated at the previous stage. The several energy scenarios generated enables to evaluate how these changes may vary according to different plausible future of the Swiss energy system. This study provides new insights on the integration of energy system models and consequential life cycle assessment. The use of Brightway 2 and Wurst provides a great flexibility in manipulating and connecting the different frameworks. It also fosters transparency and reproducibility as the Python codes for the various steps is made available. Moreover, the stationary batteries are considered as an endogenous variable of STEM and the changes that they cause are determined through the energy system model.

7

A framework for Consequential IO-LCA: cross-sectoral substitution effects due to an increased demand for bioplastics

N. Escobar, University of Bonn / Institute for Food and Resource Economics ILR; M. Bruckner, Vienna University of Economics and Business / Institute for Ecological Economics; J. Börner, University of Bonn / Institute for Food and Resource Economics ILR

Demand for and technological innovation towards advanced bio-based products add a new dimension to the food vs. fuel debate. Both novel biomass applications and substitution among existing uses at global scale can result in changes in cropland area in unexpected regions. Based on the potential of Input-Output (IO) to estimate Land Use Change (LUC) effects that propagate along supply chains, we develop a framework for Consequential IO-LCA (C-IO-LCA). It is illustrated with an increased bioplastic demand in a hypothetical region, by using a simplified 3-region IO table. Thus, the Functional Unit (FU) is an additional demand for bio-polyethylene (bio-PE) of 1 t in *region 1*. This triggers imports of sugar-based ethylene from *region 2*, with an increase in the production of sugarcane, delivering both sugar and molasses during the refining. Molasses can be either used for ethanol production or as animal feed. The livestock sector is also included to capture indirect LUC effects from inter-regional feedstuff linkages. A *co-product occurrence table* and a *co-product substitution table* are implemented, based on technical conversion coefficients and substitution potentials. As a result, supply of sugarcane in *region 2* increases from 160 t to 198 t; delivering an additional production of molasses of 2.6 t, 1.1 t of which are used in the livestock sector of *region 2*. Total crop requirements for the FU are then calculated as (1) the sum of total production in the baseline, plus (2) additional production due to the increased demand, plus (3) production to satisfy additional co-product occurrence, plus (4) changes due to co-product substitution. Overall, there is an expansion in the area diverted to sugarcane in *region 2* of 0.54 ha; while a reduction in this region's demand of other feedstuffs is observed, generating an indirect LUC of 0.08 ha. The substitution of corn for molasses in *region 2* also causes a distant effect on land use in *region 3* through trade, which would not have been detected from an atributional perspective. Results are, however, strongly influenced by assumptions on co-product substitution potentials and co-product occurrence, requiring further scenario and sensitivity analyses. The C-IO-LCA framework allows for indirect LUC due to cross-sectoral co-product substitution effects to be quantified from an economy-wide perspective; but subject to fixed physical conversion and substitution relations between commodities, consistent with the LCA methodology.

8

Moderated plenum discussion

Marginal suppliers and temporal aspects of consequential LCI modelling

9

Introduction by session chair

M. Brander, University of Edinburgh

10

Marginal electricity supply mixes and their integration in version 3.4 of the ecoinvent database

C. Bauer, Paul Scherrer Institute / Laboratory for Energy Systems Analysis; L. Vandepaer, Université de Sherbrooke / Paul Scherrer Institute / Department of Civil Engineering / Laboratory for Energy Systems Analysis; K. Treyer, Paul Scherrer Institute; C. Mutel, Paul Scherrer Institute / Laboratory for Energy Systems Analysis

Electricity supply is often a key contributor to life cycle environmental burdens of products and services. Due to increasing global trade, value chains are getting more and more international and therefore, LCA practitioners need accurate LCI data for power supply worldwide with a high geographical resolution. Up to now, the availability of such high-quality data for consequential life cycle assessment (CLCA) was very limited, which represented a major shortcoming for CLCA. With the recently released version v3.4 of the ecoinvent database, this shortcoming could be mitigated: We introduced new long-term marginal electricity mixes, i.e. markets, for 40 countries, covering a share of almost 70% of global marginal generation. These long-term marginal mixes reflect the installation of new generation capacities as a consequence of increasing electricity demand (and replacement of existing capacities) and are quantified based on the expected change in power generation between 2015 and 2030 on a country level. We aimed at maximum consistency and used projections from the European Commission for EU-28 countries and from IEA for non-European regions, as well as a few country-specific data sources. All of those are based on "business-as-usual" scenarios without any major change in national or international policies. The results show substantial differences compared to previously available data: The new marginal mixes are cleaner in most of the countries, which currently still heavily rely on fossil fuels, but aim at increasing shares of renewables; the new marginal mixes are often less clean in countries which already now use substantial amounts of hydro and/or nuclear power, which are in general not projected to be expanded due to limited potential and acceptance. Sensitivity analysis – i.e. consideration of different time frames and other scenarios than business-as-usual for quantification of marginal mixes – shows that whether selecting alternative time frames and scenarios makes a decisive difference or not in terms of LCA results often depends on the country. In general, using shorter time frames leads to higher burdens of CLCA electricity mixes, since expansion of clean technologies such as wind, photovoltaic or geothermal power is expected to be accelerated after year 2025. Using a "450ppm-scenario" representing a more stringent climate protection policy results in marginal mixes with higher shares of renewables, thus reducing the burdens.

11

Why regional detail is key for consequential LCA and how to improve it - the case of biogas and rail transport

S. Pfister, ETH Zurich / Institute of Environmental Engineering; A. Haas, C. Oberschelp, ETH Zurich
Consequential LCA depends on identification of marginal technology use as a function of a demand. In the past, spatial detail has been widely neglected in LCI development, but it is essential for consequential LCA, since marginal technology is highly depending on the region: e.g. additional electricity in Germany might be nuclear, while in China it is coal and hydropower. Modern Life Cycle Inventory (LCI) databases like ecoinvent v3 have a global coverage, but generally a low regional resolution, except for electricity markets. However, in ecoinvent, industrial activities are connected by “market activities”, which are based on the production volumes of the producing activities. Apart from the electricity sector, where extensive regionalization efforts have been undertaken, market activities in ecoinvent are predominantly modelled as global markets. In this study the industry-by-industry input-output-table of the Exiobase MRIO database is used to increase the regional resolution of the ecoinvent LCI database. New LCI unit process datasets are created for all regions in Exiobase, based on corresponding datasets in the ecoinvent database. The unit process datasets are matched to their encompassing industry sector using the International Standard Industry Classification (ISIC). The economic relation between the industry sectors from Exiobase is then employed to re-link the newly created unit process datasets. All processes in ecoinvent are allocated to respective regions in Exiobase and in case without direct match, the processes from aggregated regions are copied for all Exiobase regions within these regions (e.g. RoW and GLO). This results in a matrix of ~307’000 x 307’000 cells. Because every process in the resulting “technosphere” matrix has a clearly defined location, the supply chain includes origins of input processes as reflected by multiregional exchanges in Exiobase. Consequently regionalized marginal technologies can be utilized – directly from ecoinvent’s consequential version or manually. We show the results of our approach for improved regional resolution on the inventory level of rail transport and biogas production, which then allows to apply the region specific marginal technologies throughout the supply chain. The differences are significant. In order to improve the quality for consequential assessments, MRIO data developed for consequential modeling should be applied in future, as it will increase the representativeness of this approach.

12

Defining geographical market boundaries of construction materials: a sensitivity analysis of modelling assumptions

M. Buyle, University of Antwerp / Faculty of Applied Engineering; M. Pizzol, Aalborg University / Planning; A. Audenaert, University of Antwerp / Faculty of Applied Engineering

A key assumption in consequential LCA is that only specific activities will be affected by a change in demand for a product, the so-called marginal suppliers. These suppliers must be identified by taking into account (geographical) market boundaries, a number of constraints and the suppliers’ potential to adjust production capacity. In this study an algorithm was developed for geographical market boundaries definition that should be applicable consistently across different products, and the effect of making specific modelling choices was investigated. A diverse set of construction products was then selected to verify the general applicability of the algorithm and the robustness of the results, i.e. aggregates (sand and gravel), cement, sawnwood, particle board and steel. Four scenarios were investigated to determine the effect of some key modelling assumptions when applying the algorithm. The resulting compositions of the geographical market boundaries were compared and the effect of the modelling choices on the size of the geographical market boundaries was estimated via regression analysis. Regarding the composition of the markets, there is a clear overlap between the scenarios but some differences can be observed. The modelling choices do affect the size of geographical market boundaries to a great extent, but these markets are relative stable over time. The proposed algorithm and corresponding sensitivity analysis is an attempt to gain insight into the effect of modelling choices in the context of defining geographical market boundaries for consequential LCA. It can in principle be applied to any product for which trade and production data are available. The proposed algorithm helps to identify marginal mixes on a consistent and transparent way, to improve the robustness of the results in future consequential LCAs.

13

A procedure to sidestep the lack of data for waste-based product systems

R. Sacchi, Aalborg University / Planning Department; E. Prosman, Aalborg University / Centre for Industrial Production

With an increasing share of industries that rely on the use of waste material to subsitute the need for virgin resources, it is paramount that the CLCI modeling of the material supply identifies the correct waste treatment activity affected by the removal of available material from the market. This work suggests CLCA practitioners a three-step procedure to model the sourcing of waste material for which the available market data does not allow to clearly identify the marginal treatment activity. The overall idea relies on the use of information surrounding the raw material the waste product stems from, for which data is generally more accessible. The procedure is applied to the sourcing of fly ash, the volatile part of the coal combustion residues. The results show a contrasted landscape for fly ash availability and affected waste treamtent technologies across EU countries, as an amount of fly ash is withdrawn from their respective market. It is suggested that the sourcing of fly ash to be used in a product system may sometimes be done at the expense of other reuse options, if the sourcing location is not ideal. Opposed to attributional LCI modeling where the supply of waste material is generally free from any enviromental burden, this approach provides a better decision support for green procurement in general and for the product systems that rely extensively on the use of waste materials in particular.

14

The challenges of time-differentiating life cycle inventories

T. Gibon, Luxembourg Institute of Science and Technology (LIST) / Environmental Research and Innovation; T. NAVARRETE GUTIERREZ, Luxembourg Institute of Science and Technology (LIST) / ERIN; T. Schaubroeck, N. Médoc, Luxembourg Institute of Science and Technology / Environmental Research and Innovation; Y. Pigné, Universite du Havre; L. Barna, INSA Toulouse / LISBP; E. Benetto, Luxembourg Institute of Science and Technology (LIST) / Environmental Research and Innovation

Conventionally, LCA consists in inventorying all needed natural resource and emission amounts occurring over a product’s life cycle, lump-summing them in so called life cycle inventories, and thereof calculating impacts as if they all happened at the same point in time. However, time differentiation would provide the following benefits: (a) an overview of when processes, emissions/resources and impacts occur, which is relevant for supply chain management, and (b) a better characterization of impact as the extent of the impact may depend on the timing of emissions causing it. Conceptual frameworks have already been developed that cover time differentiation. The project presented here, DyPLCA (Dynamic Process-based LCA), goes a step further by (1) having introduced an improved framework for differentiating life cycle inventories over time, (2) offering a web-based software tool, (3) including a complete life cycle inventory database for which temporal information has been collected, (4) applying life cycle impact assessment methods and (5) offering user-friendly visualization of the output. For the purpose of DyPLCA, temporal parameters were assigned to each process of ecoinvent 3.2. This temporal database is preliminary but supports the application to a complete database as a proof of concept. The respective linkage with the calculation tool, based on a graph search algorithm, has been established and is currently operational. The calculation tool requires parameters that are foreign to static LCA frameworks: time steps, starting time, numerical calculation threshold... Results can then be exported and loaded into a visualisation module. Through various case studies, the temporal database, the calculator, and the visualisation modules are presented here. We show that the results are of interest for products and services involving long-term infrastructures (e.g. construction, mobility), seasonal processes (e.g. agriculture), and processes with emissions occurring on an acute or chronic fashion. Remaining challenges include: time characterisation of transportation processes, integration of time-differentiated impact assessment methods, and computational limitations leading to a truncation of emissions covered for a given life cycle system.

15

Consequential modelling of the carbon footprint of bioenergy technologies in a Danish renewable energy strategy

H. Wenzel, SDU / SDU Life Cycle Engineering; R.D. Grandal, Energinet.dk; L. Hamelin, University of Southern Denmark / SDU Life Cycle Engineering

This study integrates energy system analysis (ESA) and econometric modelling in consequential LCA in order to qualify, and quantify, the marginal biomass supply for the bioenergy part of the future Danish energy system in various scenarios from higher to lower biomass dependency of the system. A total of 16 bioenergy technologies is studied, and each technology is assessed by quantifying the consequence of its presence in the whole energy system. A main acknowledgement from the study is that the carbon footprint of a bioenergy technology does not mainly depend on its own energy efficiency and greenhouse gas emissions seen in isolation, but to a higher extend by its influence on the whole-system efficiency, and especially its influence on the whole-system dependency on overall biomass input – bearing in mind that biomass can be a key source of greenhouse gas emissions in a fully renewable energy system. Moreover, the carbon footprint of a bioenergy conversion pathway was found to depend largely on the nature and origin of the marginal biomass supply, which in turn is judged to depend on background conditions, such as the global scale of biomass demand and the type and global enforcement of land governance and GHG emission governance, as well as on the nature and composition of the energy system in which the biomass conversion pathway is applied. The nature of the biomass supply, i.e. the marginal biomass, and its dependency on the scale of global biomass demand, was modelled in GLOBIOM through applying different assumptions on biomass market prices – where higher market prices reflect higher demand. Further, different degree of greenhouse gas governance was reflected through different CO_2 quota prices. A probable marginal was sought through looking at an incremental change in biomass price (from 5 to 8 US$/GJ ab forest). Within this incremental change of biomass market price, the model predicted the responding

land use change to be an increase in plantation area at the expsense of 'other' land which in GLOBIOM comprises savanna and cerrado as main land categories responding to demand increase.

16
Moderated plenum discussion

Views on consequential EPDs and PCRs

17
Relevance of attributional and consequential information for environmental product declarations
B. Weidema, The ecoinvent centre

18
Panel discussion and audience participation session
B. Weidema, The ecoinvent centre

Co-product substitution and other aspects of consequential LCI modelling

19
Welcome and introduction by symposium and session chairs
G. Castelan, PlasticsEurope / LCA; P. Fullana, Universitat Pompeu Fabra UPF / UNESCO Chair in Life Cycle and Climate Change Escola Superior de Comerç Internacional ESCI

20
Consequential assessment of Greek yogurt acid whey treatment
G. Thoma, University of Arkansas / Department of Chemical Engineering; J. Burek, University of Arkansas / Chemical Engineering; D. Kim, University of Arkansas / Department of Chemical Engineering; P. Tomasula, W. Yee, USDA ARS
Over the past 10 years, Greek yogurt has surged to the 50% share of the total U.S. yogurt market, from marginal rates to the most competitive modern yogurt technology today. To obtain thick consistency, it is necessary to separate acid whey by straining or centrifuging, both of which produce acid whey. Because of acid whey separation that allows for thicker consistency, the Greek yogurt has higher environmental impact than other yogurt types. Producers pay farmers to take raw acid whey for use in animal feed or fertilizer, based on the premise that whey is a waste product with little value (Smithers 2008). Few Greek yogurt producers treat acid whey using the anaerobic digester to produce biomethane. Biomethane can be injected into a liquefied natural gas (LNG) grid or used to produce electricity in a cogeneration plant. More importantly, Greek yogurt producers are developing processes to turn acid whey into a range of dairy products, which are a source of calcium, protein, and essential amino acids. These products can be sold at a high margin on consumer markets. The purpose of this work is to compare environmnetal impact of Greek yogurt production using existing and new pathways to value-added products or biomethane from acid whey. In baseline scenario, processor transports acid whey to be used as animal feed. Baseline scenario is compared against production of biomethane and against membrane technologies used to extract protein and lactose powders from acid whey. The environmental assessment was performed using a consequential life cycle assessement (LCA). Biomethane, cogeneration, and acid whey membrane treatment options were built using the SuperPro Designer© software. Processes to concentrate and dry acid whey include microfiltration (MF), reverse osmosis (RO), nanofiltration (NF), diafiltration (DF), ultrafiltration (UF), enzyme treatment (E), neutralization (N), and spray drying (SD). Products were acid whey powders (AWPs), acid whey permeate powder (AWPP), and acid whey delactosed powder (AWDP). Reduction of climate change impact of Greek yogurt production is not achieved using biomethane and electricity at the yogurt processing plant. This is unexpected because most dairy studies favour anaerobic digestion to reduce environmental impact.Finally, all membranes technologies show a reduction in environmental impact of Greek yogurt plants. This is primarily due to replacing protein from the global soybean meal production in animal feeds.

21
Micro-scale consequential inventory modeling - a case study from metallurgic production
H. Lambrecht, Pforzheim / Institute for Industrial Ecology; H. Hottenroth, T. Viere, Pforzheim University / Institute for Industrial Ecology
The scientific discourse on consequential life cycle assessment (CLCA) is largely focusing on macro- and meso-scale decision settings in political and research contexts. The presented case of a metallurgic production line reveals limitations of attributional life cycle assessment (ALCA) even within "micro"-scale settings: In the considered operative decision context ALCA would lead to erroneous conclusions concerning ecological improvement options. This paper contributes to the collection of consequential life cycle case studies, in particular by exploring the field of micro-scale consequential life cycle assessment and by addressing the challenges of integrating life cycle assessments with actual production and product planning and optimization. For the given production line, an inventory model of the foreground system has been built using optimization-aided material and energy flow analysis. The model can be evaluated both in a consequential and in an attributional sense. Interestingly, both approaches yield contradicting results. The explanation for this paradox are interdependencies of material and energy flows as well as capacity and other constraints within the production line that cannot be taken properly into account by ALCA. In conclusion, life cycle assessments aiming at system and product improvements might require entirely different modeling approaches compared to more accounting and reporting-oriented use cases. Key words: consequential versus attributional modeling, decision situation, optimization,

22
Consequential LCI modeling of chemicals in wastewater: including avoided nutrient treatment
I. Muñoz, 2.-0 LCA consultants
Treatment of organic chemicals in urban wastewater treatment plants (WWTP) through biological treatment requires availability of nitrogen and phosphorus in order for microorganisms to build up their biomass. However many chemicals do not contain in their molecules these nutrients (consider a chemical with the formula $C_xH_yO_z$). In this case microorganisms need to obtain nutrients from an alternative source, mainly NH_4-N and PO_4-P already available in wastewater. In consequential life cycle inventory (LCI) modelling terms, these nutrients present in wastewater constitute non-fully utilised materials, and their consumption from wastewater should be credited with the avoided treatment they would have otherwise been subject to. These credits are not quantified by current WWTP models used in LCA and the objective of this work is to quantify them, taking into account the variability induced by differences in wastewater treatment levels in different countries. We illustrate the quantification of nutrient credits for the chemical ethanol (C_2H_6O) in two countries with different wastewater treatment realities: Denmark and India. We use the model WW LCI v2 to obtain an LCI for discharging ethanol to wastewater in these two countries, and we extract from the model's mass balances the amounts of NH_4 and PO4 consumed. WW LCI v2 does not currently provide a systematic calculation of credits associated to consumption of nutrients, but they can be calculated by: Obtaining from WW LCI v2 the LCIs for treating ammonium and phosphate, in the two countries, for each treatment level: septic tanks, primary treatment, secondary treatment and tertiary treatment. Linking to the LCI of ethanol obtained from WW LCI v2 the inputs of -X g ammonium and -Y g phosphate consumed in each of the above-mentioned treatment levels. We assessed the results for ethanol in three impact categories at mid-point level: greenhouse-gas (GHG) emissions, freshwater eutrophication and marine eutrophication. The avoided treatment of ammonium and phosphate have outstanding effects on the ethanol's marine eutrophication and freshwater eutrophicaton scores in both countries, where the overall result becomes a beneficial one (credits bigger than burdens). In GHG emissions, for ethanol containing biogenic carbon, the credits reduce emissions by 45%. The results also show that the magnitude of these credits is closely linked to the regional or country-specific wastewater treatment realities.

23

The enabling effect of ICT including secondary consequences - illustrative case study on videoconferencing

K. Chomkhamsri Wolf, M. Wolf, maki Consulting GmbH

Information and Communication Technology (ICT) is widely argued to have a strong enabling effect by replacing conventional products or improve other systems in form of measurement and control technologies, leading to overall more energy-efficient and environmentally sound solutions ([1], [2], [3]). A frequently named example is videoconferencing replacing person travel, with the Climate change impact reductions many times higher than the videoconferencing impact. More detailed life cycle based studies (e.g. [4], [5]) confirm the general message. However, also these studies do not capture secondary consequences that mostly counter-act the direct benefits of replacing travel. This paper presents a simplified, illustrative case study from consumption perspective for policy information - including estimates of key secondary consequences - on "Replacing long-distance meetings by videoconferencing at an assumed medium-sized PUR-foam mattress manufacturing company X, based near Munich (Germany)". An ISO 14040-44 based methodology has been used to estimate the overall climate change potential effect. A state-of-the art videoconferencing technology is modelled, against the most economic plane travel. Three secondary consequences are considered in addition: waste heat of videoconference room equipment requires cooling (or saves heating), time-saving of the employee due to reduced travel frees productivity and cost savings due to cheaper meetings allow for additional production/consumption by company. The overall net impact on climate change is estimated at 442 CO_2-eq. for the six hour of videoconference instead of person travel, i.e. the change to videoconferencing results in a higher overall impact. Not considering the secondary consequences, it would have been -368 CO_2-eq. The freed working time and cost savings result in more production (and consumption), in this example more than counterbalance the videoconference direct savings. The undoubted benefits of ICT for mankind aside, it is possible and necessary to quantitatively estimate the secondary effects for macro-level studies and policy decision support. The effects can be very relevant, surely cannot by default be ignored. Key for the result from consumption perspective is the fact that "money is preserved" and freed work productivity leads ultimately to additional production and consumption, what can more than counterbalance the direct enabling effect on a global level.

24

Consequential LCA of an organic photovoltaic charger - decision support for an environmentally-beneficial product use

S. Weyand, TU Darmstadt / Institue IWAR, Chair of Material Flow Management and Resource Economy; E. Glogic, University of Bordeaux; M. Tsang, Three Pillars Consulting / ISM CyVi; G. Sonnemann, University of Bordeaux / ISM CyVi; L. Schebek, Technische Universitaet Darmstadt / Institute IWAR Material Flow Management and Resource Economy; S. Young, University of Waterloo

Recent attributional life cycle assessment (LCA) studies of organic photovoltaics (OPV) indicate that electricity generated by OPV is more environmental-friendly than by commercialised silicon PV technologies. The direct environmenal impacts of OPV are lower for the typical application of a solar module as well as for the new application of a mobile charger (Tsang et al., 2015, 2016) [1,2]. The indirect impacts associated with the use and the generated electricity are not considered in these studies. For this reason, we investigate the indirect environmental impacts of an OPV mobile charger depending on the country-specific daily sun hours and analyse the environmental responses of the substituted electricity mixes in six European countries. We use consequential LCA to analyse the product system for charging a mobile phone which is on the one hand the life cycle of an OPV charger with 10W capacity from cradle-to-grave and on the other hand the substituted electricity from the grid. The functional unit of charging the phone with 10Wh electricity (over a period of 5 years) is realised by the reference flow of an averaged 10 Wh produced by the OPV charger or 10 Wh from the country-specific low-voltage electricity mixes in the selected countries: Norway and Spain. The minimum use-frequency indicates for consumers how often they need to use their OPV charger to be environmentally-beneficial towards the electricity mix. Whereas Spanish consumers can easily use the OPV charger as an environmental-beneficial product, for Norwegian consumer the OPV charger can hardly used as such.

25

Understanding the impact of interventions in food waste prevention, valorisation and disposal

N. Unger, University of Natural Resources and Life Sciences Vienna / Institute of Waste Management; J. Davies, E. Holtz, RISE Research Institute of Sweden / Agrifood and Bioscience; F. De Menna, University of Bologna / Department of Agricultural and Food Sciences; S. Scherhaufer, University of Natural Resources and Life Sciences, Vienna / Institute of Waste Management; M. Loubiere, Deloitte Sustainability; M. Vittuari, University of Bologna / Department of Agricultural and Food Sciences; K. Östergren, RISE Research Institute of Sweden / Agrifood and Bioscience

Each step in the food supply chain can generate side-flows, i.e. material flows that were not the main motivation for setting up the supply chain. These side-flows can have positive or negative economic value, depending on market demand. One part of the European REFRESH project focuses on LCA and LCC methodology aspects regarding the assessment of prevention, valorisation and disposal of side-flows from the food supply chain. The body of scientific literature and guidance documents on LCA is vast. However, it became apparent that despite that, this knowledge is not applied in actual case studies. This shows a clear gap in the information flow between people developing and discussing methodology and those applying them. This project aims to address this bottleneck by promoting the application and interpretation of LCAs in context of side-flows valorisation from the food supply chain, building on existing knowledge. The literature review [1] highlighted gaps in the goal and scope definition. The REFRESH guidance document [2], therefore, provides a number of decision trees, check lists and examples that help guiding the assessor and stimulate her/his critical thinking throughout the process. Building on the REFRESH guidance document, an Excel tool is developed to assess the greenhouse gas impacts of small scale interventions (CLCA) to selected side-flows, e.g. apple pomace. The tool aims to educate, communicate and raise awareness of the impacts/benefits of food side-flow valorisation and determining drivers. A number of large scale intervention studies (C-LCA) are currently scoped. Nowadays, LCA has developed into a mainstream tool performed by a range of stakeholders, not all them having time and access to follow scientific methodology discourses. REFRESH will contribute to 'demystifying' key challenges in ALCA and CLCA for mainstream LCA users, empower the assessor to critical thinking and thus ensure that the quality of LCAs and their interpretation in actual decision making context is improved and transparency increased.

26

Moderated plenum discussion

Model uncertainty and quality assurance in LCA

27

Introduction by session chair

R. Hischier, EMPA / Technology and Society Lab

28

Error propagation on consequential inventories: Yes We Can

M. Pizzol, Aalborg University / Planning; R. Sacchi, Aalborg University / Department of Planning

Error propagation via Monte Carlo simulation is commonly used in LCA models to determine how the uncertainty of the model input parameters propagates to the model output. A complication exists in the case of error propagation on consequential LCIs, that by applying the substitution method allow for the possibility of obtaining negative LCIA results. E.g. a negative carbon footprint. When Monte Carlo simulation is performed on such inventories, the distribution of the results can in principle lay on either side of the zero mark or spread across it. Using a standardized approach to describe and report these results (e.g. assuming that results of the error propagation are by default normal or lognormal) would lead to serious inaccuracies and better approaches are thus needed. This study investigates how frequently such cases occur and proposes appropriate methods for the reporting of consequential LCI uncertainties in studies using error propagation. A Monte Carlo simulation with 1,000 iterations was performed using IPCC's GPW100a impact assessment method to determine the carbon footprint of one unit of each of the 12,135 processes contained in the consequential version of the ecoinvent v3.3 database (market activities were ignored). The results were then analyzed to identify: how many of the resulting distributions were fully positive, fully negative, and crossing the zero; how well the normal or lognormal distribution fitted the results; and which other continous distributions among those available provided the best fit for the results. Results showed that applying Monte Carlo simulation to consequential LCIs returns distributions that cross the zero mark in 13% of cases, and that 35% of the simulated processes results in a distribution that can neither be described as normal nor

lognormal. Two analysis & reporting strategies are then suggested: 1) testing for the results' distribution fit with several known distribution types 2) using percentile-based description of the distribution and report these data instead of traditional descriptive statistics. The former case ensures accuracy but requires resources (e.g. statistical software or knowledge), the latter case is a "one fit all" solution that does nort require much resources but is less accurate.

29

Overview of methodological challenges associated with LCI modelling of biofuels: A practitioner's perspective

F.E. Kiss, Faculty of Technology, University of Novi Sad / Faculty of Technology

The aim of this research is twofold. Firstly, to give an insight into methodological issues that need careful attention when LCA is used for evaluating biomass-based fuels such as biodiesel, and secondly, to demonstrate through series of case studies the extent to which a choice between various LCI approaches may influence LCA results. In order to do so, fifteen different LCI analyses of rapeseed biodiesel were performed; each representing one of the possible inventory modelling choices. One of the LCI analyses represents the base case scenario which, regarding the modelling assumptions, follows the recommendations of the Directive 2009/28/EC. Other modelling scenarios diverge from the base case scenario in only one variable, i.e. LCI modelling choice. The results of the scenarios are analysed and compared allowing to quantify the extent to which a specific modelling assumption may influence the results relative to the control scenario. The results show a large difference in global warming impact (0.9–4.6 kg CO_{2eq}?kg^{-1}) of biodiesel with a high sensitivity to the method used to solve the problem of multifunctionality, the assumptions made regarding direct and indirect land use change modelling, and uncertainties associated with N_2O field emissions. Temporal issues, such as the assumed "carbon payback period" as a result of LUC, and the assumed period between carbon uptake and release, have also major impact on bioenergy LCA. Furthermore, LCA results of biofuels are very sensitive to the chosen baseline compared to which the land use and land use change related impacts are estimated. The main challenge for LCA practicants in the field of bioenergy is the lack of precise guidelines which take into account the specificity of bioenergy modelling and needs of the biofuel sector. These guidelines should be developed for each of the differentiated archetypal goal situations, e.g. for the purposes of attributional and consequential modelling. An important source of confusion is the ISO 14040 standard which allows using several methods to address the same methodological issue and mixes elements of attributional and consequential LCA within the same LCI modelling framework. Acknowledgement: This research was supported by the Ministry of Education, Science and Technological Development of Serbia (Project No: OI-172059).

30

System boundaries in CLCA and the link with uncertainty - A case study on mobility policies in Luxembourg

P. Baustert, Luxembourg Institute of Science and Technology LIST; T. Schaubroeck, Luxembourg Institute of Science and Technology LIST / Research Group EnVOC; T. NAVARRETE GUTIERREZ, Luxembourg Institute of Science and Technology (LIST) / ERIN; T. Gibon, E. Benetto, Luxembourg Institute of Science and Technology (LIST) / Environmental Research and Innovation

Life Cycle Assessment (LCA), whose goal is to assess the environmental impact of a system or product over its life cycle, has been argued appropriate to answer various research questions such as: "Are electric cars more environmentally friendly than conventional internal combustion engine cars and what are the important parameters deciding this?". However in the past the ambiguity of such research questions led to the development of two fundamentally different interpretations and approaches: Attributional LCA (ALCA) and Consequential LCA (CLCA). It is of course the research question that determines the system of cause-effect chains that needs to be modelled to link a product with to its environmental impact, where an attributional research question leads to a different system than a consequential one. Systems and their boundaries, delimiting them from their surroundings, are thus only abstractions of reality. While methodological aspects of the consequential system boundary have been addressed in the past, the uncertainty arising from relating research question and resulting system boundary is less addressed. To this end we first discuss this issue in general before exemplifying it in the context of a case study on mobility. In general, various issues of uncertainty related to system boundaries are: misconceptions (or blind ignorance) and value diversity leading to false or contestable exclusions and inclusions; and inevitable modelling simplifications excluding certain processes (e.g. those deemed of lower significance) or falsely including them (e.g. due to convenience or model artefacts). We seek to investigate these boundary issues in the context of an agent-based modelling CLCA case study on the environmental impact of different mobility scenarios for the cross border commuter population in Luxembourg. By adapting an existing model three separate uncertainty issues are planned to be investigated using scenario analysis: various model simplification assumptions (e.g. full inclusion of decision makers such as the government through a feedback mechanism), the uncertainty arising from value choices (e.g. using cultural theory perspectives on indicator time horizons) and the potential error related to an inappropriate research question (e.g. using an attributional system boundary for a consequential study).

31

Reducing uncertainties in LCA of battery storage by unifying inventory data

J.F. Peters, Helmholtz Centre Ulm / Resources, Recycling, Environment and Sustainability; M.J. Baumann, Karlsruhe Institute of Technology (KIT) / Institute for Technology Assessment and Systems Analysis; M. Weil, Karlsruhe Institute of Technology KIT / Institute for Technology Assessment and Systems Analysis ITAS

Evaluating new battery technologies like Sodium-Ion batteries, but also future evolutions of the existing lithium-ion battery (LIB) technology (solid state, new cathode and anode materials) requires comparing them with current state of the art of LIB. However, the available life cycle assessments of LIB with different chemistries stem from independent studies, which use significantly different assumptions regarding battery layout and battery periphery (e.g., battery management system, cooling system, cell and pack housing). Thus, the results of these studies cannot be compared directly and can neither be used as benchmark for future assessments of new battery technologies. In order to overcome this problem, we recompile the existing primary life cycle inventory data (LCI) for the principle LIB chemistries in a modular way. This allows using the same inventory datasets for common battery components and plausible average values for common parameters. Thereby, the environmental impacts associated with the production of different battery chemistries can be assessed on a common base, reducing modelling uncertainties and providing an improved comparability between studies. Apart from that, it allows quantifying the influence of modelling uncertainties on the comparability of different studies and provides an improved base for technology benchmarking of future batteries. This common LCI base is then used for a prospective assessment of a sodium based battery technology (Na-Ion) in comparison with existing LIB under a cradle-to-gate perspective. It can be observed that different assumptions and modelling approaches used by existing studies can overrun the differences between battery chemistries completely. Above all the approach for modelling the cell manufacturing energy demand, but also for the electrode binder and the battery management system influence the results significantly. The unification of inventory data reduces these modelling uncertainties and can be considered essential for battery technology benchmarking and avoids potentially misleading conclusions when comparing the environmental impacts associated with the production of different Li-Ion and post Li-Ion battery chemistries. In this context, the sodium-ion battery seems to be a promising development under environmental aspects, especially under resource depletion and toxicity aspects.

32

Climate assessment of energy measures in buildings

A. Lätt, I. Adolfsson, IVL Swedish Environmental Research Institute; T. Ekvall, IVL Swedish Environmental Research Institute Ltd; M. Hagberg, IVL Swedish Environmental Research Institute

We present a method for prospective and consequential climate assessments of measures to conserve or generate electricity, heat or cooling in Swedish buildings. This method is based on interlinked models of the building energy system, the district heating and cooling system, the electricity system, and the fuel life cycles. The impact of the energy measure on the demand for electricity, fuel, heat and cooling in the building is modelled hour by hour, taking into account the local climate. We model the impact of a marginal change in demand for heat and cooling on the district heating/cooling system using historic hourly data on temperature and production volume of heat and cooling in the system, taking into account the production capacity and dispatch order of existing plants. Three scenarios for future marginal electricity production are generated through variations in an energy systems model consistent with an international 2 degree scenario. The climate impact of most fuels is estimated based on published LCAs; however, the climate impacts associated with heat from waste incineration is estimated using three scenarios for the alternative fate of the waste. We apply the method in case studies to calculate the climate impact of energy measures such as the installation of a heat pump, a heat-recovery system, or improved insulation in a building located in any of three default district heating systems.

33

A mass-balanced approach to reduce modelling uncertainties in LCAs of woody products

M. De Rosa, BONSAI / Agroecology; M. Pizzol, Aalborg University / Planning; J. Schmidt, Aalborg University / Department of Planning; M. Brandão, KTH - Royal Institute of Technology

The sensitivity of LCA results to modelling assumptions is rarely addressed although it may be significant. This is particularly true for LCAs of bio-based product with

a long rotation time such as wood. Previous studies recommended the dynamic account of carbon emission and sink because their time-dependent profile may have a relevant climate effect. However, time-dependent LCI data are often not available to LCA practitioners. The choice of a climate indicator is not the only one introducing modelling uncertainties: carbon foot printing requires the choice of a time horizon and woody biomass require defining further aspects such as accounting for indirect Land-use Changes (iLUC) effects, the carbon pool included etc. In this study we developed a simplified parametric model that can be easily adapted to different case study. The model provides a time-dependent inventory of CO2 emission and sink necessary to use a dynamic climate indicator. The model guarantees a full mass balance and allows the users to choose basic key parameters such as rotation time, thinning operations and wood type. We applied the model to the case study of 1 km3 of spruce and used the time-dependent inventory of CO2 fluxes to perform a carbon footprint and to assess the sensitivity of the result to four modelling choices: the inclusion of iLUC effects; the choice of time horizon, the choice of climate indicator and of the carbon pool. We obtained eight scenarios by modifying the modelling assumptions for the same case study to ensure the full comparability of the results. The parametric model facilitates the dynamic account of carbon emissions and sink and provides LCA practitioners with a valuable tool to obtain time-dependent LCI data while maintaining the mass balance. The comparison of the eight scenarios demonstrates that modelling assumptions have a significant effect on results. In particular, the iLUC is non-negligible compared to the variability introduced by other modelling choices. Results were particularly sensitive to the choice of a static or dynamic climate indicator as well as to the specific indicator and the time horizon. A time-dependent climate indicator is always preferable while the choice of time horizon and type of climate indicator depends on the goal and scope of the study. The choices of the carbon pool introduced a lower model uncertainty. Yet, all carbon pool should be included in the study when data are available.

34
Moderated plenum discussion

Challenges for teaching consequential LCA and communication of results

35
Working against intuition: 12 years of experience with unlearning at the Danish Advanced LCA course
M. Pizzol, Aalborg University / Planning; B.P. Weidema, Aalborg University / Department of Planning; S. Løkke, Aalborg Unversity / Depertment of Planning and Development; J. Schmidt, Aalborg University / Department of Planning
"You must unlearn what you have learned." Says master Yoda to Luke Skywalker in The Empire Strikes Back movie. This zen-ish quote can nicely summarize the 12 years of experience with teaching consequential LCA at the "Advanced LCA" PhD course at Aalborg University. Learning consequential LCA can be challenging because of the need to rethink some preconceptions, already settled ways of understanding and doing LCA, and this may at times require to work against intuition. Without a proper introduction to consequential LCA modelling, it's quite strange to think that the impact of demanding 1 kg of natural leather is in fact the impact of producing 1 kg of syntethic leather, or that a process can have a negative carbon footprint. We made a retrospective analysis of teaching materials (exercises, slides, assignments), teaching methods, and course evaluations for the "Advanced LCA" PhD course that has been offered annually at Aalborg University since 2005 with a variable number of students (15-30). We present a showcase of examples to illustrate how our teaching approach has developed over the years in response to what worked and what did not work in tackling the challenges in unlearning attributional perceptions of LCA in order to learn consequential LCA and its sometimes counterintuitive results. Results show how the course evaluation rating has improved over time, showing especially an increase in the appreciation of the plenary discussions, reflecting the change from a more confrontational juxtaposition of attributional and consequential perspectives towards a softer approach placing the students' own arguments more centrally in the discussion. Increasing the use of Problem Based Learning required more organization and resources (e.g. designing group-specific exercises, additional time for feedback) but allowed to close the gap from theory to practice and to stimulate discussion on concrete problems in LCA practice. Summarizing 12 years of experience with teaching consequential LCA shows an increasing success with very structured exercises and group work, combined with open plenum discussions using audience participation tools. These reflections should help LCA teachers in making better LCA courses in the future.

36
Panel discussion and audience participation session
M. Pizzol, Aalborg University / Planning

Poster Abstracts

Poster session

P01
Can consequential LCA stimulate sustainable decision-making? A case study from the recycling of a steel production residue.
A. Di Maria, KU Leuven / MTM; K. Van Acker, KU Leuven
Effective policy instruments must be put in place to incentivize industrial symbiosys (IS) Choosing the most environmentally efficient and economically cost-effective policy measure can prove to be challenging, as decision-making involves trade-offs between economic and environmental aspects. Therefore decision-making should be supported by tools able to combine the environmental and economic consequences of new IS practices. Within the LCA framework, the effectiveness of the attributional approach in evaluating new IS strategies has been discussed. The attributional LCA is based on the underlying assumption that the process involved in the life cycle are operated under steady-state conditions and the investigated life cycle is not connected with other markets. This intrinsic limitation makes attributional approach debatable for tackle IS issues, since the fundamental role of policy related question and interconnections between different markets In this paper, the attributional and consequential analysis of IS between the steel and concrete sector is presented. In particular, Stainless Steel Slag (SSS) is a residue occurring during the production of stainless steel. Today, SSS is must be chemically stabilized before its disposal in landfill or its recoverering as low quality aggregates. However, since SSS contains valuable metallic oxides, it could be chemically activated to produce new construction materials. The scope of the study is therefore to evaluate and compare the results of an A-LCA and a C-LCA for a relevant case of IS strategy implementation, represented by the recycling of stainless steel residues to produce new construction materials. The A-LCA results describes the environmental impacts directly related to the recycling process, indicating the more sustainable solution among the possible recycling routes. C-LCA enlarged the analysis on the environmental consequences of the supply of new recycled products from SSS, indicating that the changes in the construction blocks market are the driving the final results of the whole system, while almost no environmental benefits are achieved if SSS are only recycled as low quality aggregates. These results can support a more informed policy making process, aiming at increasing an environmentally sustainable synergy between steel and concrete sectors

P03
Consequential and attributional LCA of LNG production
K. Boonen, A. Vercalsteren, VITO
In many countries, associated natural gas, extracted together with petroleum, is flared. One of the reasons is the difficulty to transport it to potential users. In this LCA, the production of liquefied natural gas (LNG) from associated natural gas, the distribution to consumers in remote locations and the use for industrial heating is investigated. This is done from a consequential and an attributional perspective. It is found that the LNG production is expected to have a positive effect on the environment for all impact categories considered, except one. The sign of the effect is equal for the consequential and attributional approach; however, the magnitude varies greatly. The environmental savings are generally much larger for the consequential model, for two reasons. First, in the case of the consequential LCA model, the benefits of the avoided flaring are given entirely to the investigated system, while in the case of the attributional model, part of these benefits are allocated to the co-extracted petroleum. Also the impact of the combined extraction is partly allocated to the natural gas extraction. Second, taking into account the impacts avoided thanks to the use of the by-products is more favourable than allocating only part of the impact of the production process to the main product, LNG.

P05

Consequential or attributional LCA in support of policy making? Strengths and limitations of both approaches to tackle the urban scale

N. Mirabella, K. Allacker, KU Leuven / Department of Architecture

To date, cities are increasing in number and dimensions worldwide at an unprecedented rate. Half of global population is residing in cities and this share is expected to reach up to 66% by 2050 [1]. In addition to this, they are complex and dynamic entities, that concentrate the majority of services and economic activities. Urban systems consume a great amount of materials and energy, and produce waste and pollutants [2]. Furthermore, cities are part of larger networks and are often dependent on the surroundings, especially in a context of *glocal* economy, their influence goes well beyond their territorial or administrative boundaries. This is particularly true for the environmental burdens associated to all the activities responsible to sustain urban life, e.g. consumption goods produced in one country but purchased and used in another. Thanks to their density in terms of people and energies, scientists and policy makers consider cities as the priviliged hub of interventions in favour of sustainability [3]. Notwithstanding, the holistic accounting of urban environmental impacts is still immature [4]. The Life Cycle Thinking approach is promising in accomplishing this task, and Life Cycle Assessment (LCA) plays an important role, as it can provide support to policy-makers towards more transparent and evidence-based decisions [5]. However, several issues are still open and basic methodological refinements (e.g. system boundaries, functional unit, allocation procedures, etc.) are necessary. Last but not least, if an LCA-based method is used, it is relevant determining whether an attributional (A-LCA) or a consequential LCA (C-LCA) is most appropriate. Indeed, a C-LCA is designed to generate information on the consequences of actions [6] and can be more accurate and comprehensive in evaluating the effect of a policy and/or scenarios at the urban scale [5]. Neverthless, applications of LCA at the urban scale are missing and studies conducted at territorial level stressed that a C-LCA is suggested only if the territory support strategical activities at a higher (e.g. regional) level, otherwise an A-LCA is recommended [7]. The aims of the present contribution are: i) providing insights in the current state of art of environmental assessment at the urban scale; ii) presenting strong and working points for the application of A-LCA and C-LCA; iii) defigning a proposal based on the emerged possibilities and limits offered by both approaches.

P06

Dynamic LCA of stationary battery systems in a renewable-based decentralized grid

M.J. Baumann, Karlsruhe Institute of Technology (KIT) / Institute for Technology Assessment and Systems Analysis; J.F. Peters, Helmholtz Centre Ulm / Resources, Recycling, Environment and Sustainability; M. Weil, Karlsruhe Institute of Technology KIT / Institute for Technology Assessment and Systems Analysis ITAS

A major challenge for hybrid micro grids is the fluctuating generation behavior of decentralized sources as photovoltaics and wind turbines that correlate only poorly with loads. Energy storage is becoming increasingly important for decentralized electricity systems, and batteries are considered as one of the key technologies for this purpose. However, their production is costly and associated with significant environmental impacts, why continuous efforts are made in order to decrease them. Furthermore, different battery technologies are available, each with its specific advantages and disadvantages. Conventional LCA are not able to consider the dynamic load and charging conditions of different applications and thus only give a very simplified picture of the true environmental impacts of a battery for a given application. The load profile has a fundamental impact of the depth of discharge of the batteries and therefore on their lifetime, determining the required battery replacements over the lifetime of the application. Thus, the consideration of application-specific dynamic operation profiles increases considerably the significance of life-cycle assessments of stationary battery systems. We apply a combination of techno-economic assessment, energy system optimization and size optimization to determine life-cycle costs and environmental impacts of different battery technologies in a decentral application. Different renewable energy sources with dynamic load profiles are considered in order to point out the importance of choosing the appropriate battery for this specific application. The size optimization determines the best trade-off between battery oversizing and increased battery replacements under economic aspects. It turns out that battery life is a determining factor for the overall environmental performance. This is not only due to the amount of battery replacements required, but also due to oversizing needed for battery types with low cycle lives in order to reduce degradation effects. Most lithium-ion batteries, but also the sodium nickel chloride battery show a good performance, while valve regulated lead acid batteries seem to be less recommendable due to low cycle life and low charge-discharge efficiency. For redox flow batteries, a high dependency on the desired application field can be pointed out.

P07

Dynamic Life Cycle Inventories: coupling experimental design and LCA for the eco-design of an extrusion process.

R. Julio, J. Albet, INP-ENSIACET; D. Medrano, Universidad Nacional de Lanús / DESARROLLO PRODUCTIVO Y TECNOLOGICO; C. Sablayrolles, INP-ENSIACET

Fossil resources and rare metals rarefaction involve drastic changes in our production ways. Modern industries need to apply an innovative system based on sustainable development and circular economy. Developing biorefineries is crucial, to promote processes using and valorizing renewable resources. Nevertheless, it is necessary to determine the best set of operating conditions for the eco-design of chemical and biorefinery processes. The main limit to eco-design such processes is certainly the lack of specific data. To face this issue, it is possible to couple the fields of process modelling and simulation with Life Cycle Assessment. Indeed, simulating a process can lead to obtain detailed mass and energy balances. Thereby, these balances can be used to perform an environmental Life Cycle Assessment, but also an economic assessment and an improvement of the production yields. This integrated assessment of a process through economic, environmental and technological considerations can be a powerful tool based on Life Cycle Thinking for decision support. This methodology and its associated tools have been tested on an extrusion process. Indeed, to valorize agricultural wastes, wheat bran and straw have been extruded in order to recover hemicelluloses, which could then be used to produce biofilms. The second order polynomial equation model used to simulate extrusion process is obtained thanks to experimental design methodology. The semi-empirical model is based on specific experiments and can predict flowrates, production yields, detailed biomass composition or the required energy, in function of some operating parameters such as raw materials ratio, or screw rotation speed for instance. Coupling process modelling and simulation to LCA could lead to perform dynamic Life Cycle Inventories, and so to have a better understanding of links between elementary flows and environmental impacts categories. Moreover, this methodology permits to work with more specific, precise and reliable foreground data. By predicting specific data with semi-empirical models especially developed for the assessed process, a significant progress can be performed in the data quality. Thus, it also can develop the integration of two paramount concepts in the decision making process: (1) Life Cycle Thinking and (2) Sustainability with simultaneous assessments of economic viability, environmental performance and productivity of a process.

P08

Eco-efficiency of Second Life Applications of Lithium Ion Traction Batteries

H. Schmidt, Esslingen University of Applied Sciences / Institute of Sustainable Energy Technology and Mobility; M. Flad, W. Guth, Esslingen University of Applied Sciences

Second Life (SL) applications for used Lithium Ion Traction Batteries (LITBs) could be a possible concept to reduce battery related costs and environmental impacts and therefore improve the eco-efficiency of LITBs. Eco-efficiency describes the combination of ecological and economic evaluation criteria to enable a holistic assessment of products, processes or technologies and to identify optimization potentials. For the ecological assessment, preliminary analyses of the study will be completed with comparative Life Cycle Analysis (LCA) of different application scenarios. From the economic point of view, the study analyses whether LITBs can be applied economically such that the Total Cost of Ownership (TCO) of a Battery-electric Vehicle (BEV) can be improved. Profitable second life (SL) applications include, amongst others, provision of primary control and house storage systems in combination with a photovoltaic system. A potential economic value for the use of SL batteries against new batteries can be found. The success factors for SL applications are: *i)* A high share of the battery costs compared to the total investment costs, *ii)* A long operating time of the SL battery (SLB), and *iii)* Low absolute SLB costs. A TCO reduction potential (with profitable SL applications) of 3.4% is determined along with comparable reductions of the acquisition costs of a BEV with, e.g., 7.3% for a Nissan Leaf Visia. Compared to recycling, the economic SL applications are preferred because recycling is currently not economically feasible. The reuse of a LITB can reduce the TCO of a BEV and, thereby, support a faster market penetration of BEVs – however, potential effects on the TCO are limited. To identify the most eco-efficient applications and the range of the possible improvements, next steps include detailed analyses based on not only real options valuation but also LCA.

P09

Energy demand and greenhouse gases emissions assessment of PV panels recycling process in Spain

I. Herrera, CIEMAT / Energy Dpt Energy Systems Analysis Unit; I. Istrate, Universidad Rey Juan Carlos / Environmental Engineering; D. Garrain, CIEMAT / Energy Dpt Energy Systems Analysis Unit; Y. Lechon, Energy Dpt Energy Systems Analysis Unit / Energy

PV power capacity installed will increase considerably in the next decades and the sustainability of this source of energy will depend on the end-of-life management of PV panels. It is expected that the high potential environmental benefits encourage the consolidation of the circular economy principles in the PV industry. Within this context, the objective of this study was to analyse GHG emissions and primary energy demand of a recycling process of mc-Si PV modules in Spain and to compare with the manufacturing step. The process is based on mechanical (disassembly and shredding) and thermal (separation of EVA; with energy recovery) treatments.

Aluminium, glass and copper are treated in specific recycling plants, while polymers (back-sheet and junction box) are incinerated for energy recovery. Recycling of mc-Si cells has been excluded, and finally, solar cells are disposed of in a sanitary landfill. Through the analysis of the end-of-life approach, relevant reduction of both GHG emissions and primary energy demand of the whole life cycle of mc-Si PV modules are observed due to the recycling integration.

P10

Environmental performance of SIAM technology under Mediterranean climatic conditions

Y. Lorenzo, CETaqua, Water Technology Centre / Environment and Socioeconomics; M. Ruiz Mateo, I. Gutierrez-Prada, M. Calvet, A. Silva, CETaqua, Water Technology Centre; D. Marin, CETaqua, Water Technology Centre / Environment and Socioeconomics

Anaerobic biological processes are environmentally friendly due to the production of biogas and lower waste sludge production than the conventional processes using aerobic processes. Nevertheless, some issues should be resolved in order to broad the use of anaerobic processes for treating sewage at ambient temperatures in mild climates: i) The low temperature of sewage may impede the completion of the process; ii) The difficulty of nitrogen removal, and iii). The presence of dissolved methane in their effluents, which represents an important environmental problem in terms of greenhouse gas (GHG) emissions.A very interesting approach, which could be used to reduce both nitrogen content of the wastewater and GHG emissions of anaerobic processes, might be based on the use of biological methane oxidation coupled with denitrification processes. The LIFE SIAMEC project proposes the use of an integrated anaerobic-aerobic membrane novel technology called SIAM that also produces high quality that could be easily reused. This study intends to evaluate the environmental benefits of the proposed technology in comparison with the existing WWTP of Cabezo Beaza (Murcia, Spain). To do so, life cycle assessment (LCA) was the selected methodology to quantify the environmental burdens of the prototype and the full scale WWTP. Special focus has been put on GHGs emissions monitoring and minimization opportunities. The availability of experimental GHG emissions data allowed to obtain an accurate carbon footprint of the novel technology and to provide a benchmark in comparison with the existing alternatives. The results obtained throughout the analysis of both systems suggest that even though the indirect carbon footprint of SIAM technology is slightly higher, mainly due to the higher energy use (pilot scale), the overall footprint of the prototype is lower. The impact of direct GHGs emissions in the real WWTP, mainly N_2O produced in the biological reactor (nitrification-denitrification processes), cause its elevated overall carbon footprint. With respect to the eutrophication impact category, ENEI indicator has been used to cast light on the environmental benefits of both wastewater treatments alternatives. The results showed that the performance of the SIAM technology was lightly superior than the one obtained by the real WWTP.

P11

Electricity from biogas in Italy: Environmental consequences related to the elimination of economic subsidies

j. bacenetti, State University of Milano / Department of Environmental Science and Policy; G. Falcone, Università degli Studi Mediterranea di Reggio Calabria / Dipartimento di Agraria

The Anaerobic Digestion (AD) is recognized as one of most viable way to produce bioenergy, also contributing to reduce the GHG emissions and the amount of wastes above all if livestock husbandry secondary products and crop residues are used. In the last decade, several studies dealt with the biogas production via AD from an environmental point of view, deepen the burdens strictly linked to life cycle of biogas production but underestimating the multi-functional role that biogas-to-electricity systems could play in the agricultural sector. AD can be realized using different feeding mix, chosen, primarily in function of maximization of profit according to technical and economical feasibility of process. The granting of national incentives for the increasing of share of renewable energies, pushed several entrepreneurs to undertake the biogas production activity, making partnerships with farmers in order to displace ordinary cultivated land management to energy crops. In Italy, in the last 20 years, above all in the norther regions, thanks to a favorable subsidy framework, around 1800 AD plants fed with agricultural feedstock were built. Despite the higher supply cost, due to the level of subsidy (280 €/MWh of electricity fed into the national grid for plants built before the 2013), several plants are fed mainly with dedicated crops and the maize silage is the most used biomass. The future scenarios of bioenergy production could change considerably when the incentives will cease. In fact, for all bioenergy plants fed with dedicated crops, revenues could not cover supply costs for feeding and then the suspension of incentives could cause the cessation of activities. The aim of this study is to analyze the consequences related to a change in the actual subsidy framework for renewable energies and, in particular, the elimination of the grants for biogas production. More in details, to evaluate the environmental effects related to (i) the substitution of renewable energy with non-renewable energy or (ii) the maintenance of plants fed with dedicated crops by substituting the feeding mix with pig and cow slurry a consequential life cycle assessment (cLCA) was performed. The effects of future scenarios were evaluated with a partial equilibrium model. The achieved results can support the decision of policy makers in order to drive the future towards more sustainable direction.

P12

Improved modeling of substitution in consequential LCA by the use of market prices

D. Schrijvers, University of Bordeaux; P. Loubet, CyVi-ISM / ISM CyVi; G. Sonnemann, University of Bordeaux / ISM CyVi

Substitution is a modeling technique that is inseparably linked with consequential LCA. We model effects of substitution when we produce co-products, by-products, or recycled materials. In other words: when a dependent co-product is produced. There has been an ongoing discussion on how to improve the modeling of substitution effects. Advanced methods often use price elasticities, but these data are often unavailable or do not represent the level of detail or the time horizon that is required for the LCA, and the effects that price elasticities represent are limited. We propose a procedure that uses market-price ratios to model the effects of substitution in consequential LCA. The market-price ratio (A) is calculated between the dependent co-product and the material or product that it substitutes. If these products have the same price (i.e. $A = 1$), full substitution is modeled, according to the end-of-life recycling method. If the price is different (i.e. $A \neq 1$), the following possible reasons must be evaluated: 1) A product is displaced in a different market segment due to a reduced functionality, quality, or a different image, 2) downstream drawbacks and/or benefits take place, which should be integrated into the calculation of the market-price ratio, and 3) if the user of the dependent co-product experiences a financial benefit, the demand for the dependent co-product is (partly) constrained. The latter implies that there is a surplus of the material and alternative waste treatment is affected. It is demonstrated that this simple approach improves the modeling of recycled glass, plastics, and even rare earth elements that do not have a direct substitute, such as europium. Factor A shows several benefits over the use of price elasticities: market prices are often available for different material grades and can be determined on a case-by-case basis. Market prices can represent products that are directly traded between two actors, as in this situation demand constraints can be relevant as well. Besides, the market-price ratio stimulates the modeling of downstream effects caused by the use of a dependent co-product in the life cycle inventory, which is often neglected in practice. Finally, this approach provides the perspective to put a price on externalities, which would improve the representation of factor A.

P13

Interpreting LCA results in models with high variability and potential scenarios - the wider impact of the AQUAVALENS project

C. Torres, Universitat Rovira i Virgili; F. Castells, Universitat Rovira i Virgili / Chemical engineering department; M. Figueras, Universitat Rovira i Virgili

Life Cycle Assessment (LCA) can be applied to a variety of activities, services and products, giving rise to new challenges in the assessment and interpretation phase due to the peculiarities of each system: data availability, uncertainty, temporal and geographical resolution, sensitivity to unsettled parameters, etc. In the presented study we show an example on how the mentioned features can be managed in the interpretation of the results. The systems to be evaluated are the novel platforms developed under the project AQUAVALENS for the detection of pathogens in drinking water. The aim of the project is to enable the water system managers, to better control the safety of water supplies by using these newfangled technologies. Carbon Footprint (CFP) is calculated using as Functional Unit (FU) the processing (preparation and detection of specific microorganism i.e. virus, E. coli etc) of one water sample. The sources of primary data are the project partners thus the data collection and feedback strategies must be tailored to overcome the communication barriers and ensure the understanding of the findings to non-expert audience. Three types of detection platforms designed and manufactured by the producer partners are tested experimentally in suix European locations by different end-user partners. Parametric uncertainty derived from the variation and stochastic errors of the input data in the model is analysed. Besides two secenario analyses are conducted considering type of vehicle in the sampling transport and electricity mix production for the energy consumption. In the whole life cycle of the product, the use phase is by far the major contributor in constrast with the manufacturing phase. AQUAVALENS methods would reduce approximately 65% the CFP of the conventional methods for the analysis of pathogens from the three kingdoms in a sample (a set of especies of bacteria, parasites and viruses). The Relative Standard Deviations indicate that AQUAVALENS platforms scores have higher uncertainty than conventional procedures since they are more dependent on the input with the highest variability that is the transport. The estimated reduction of the CFP considering the parametric uncertainty and the potential scenarios (two alternatives in type of vehicle in sampling transport and the three alternatives in electricity production mix) would be 66.2% as central value (mode) in the range [58.7 % - 73.7 %].

P14

Investigating mitigation opportunity of switching to organic rice paddy production from traditional method using CLCA

A. Jimmy, North South University / Environmental Science and Management; M. Sujauddin, North South University; M. Hossain, Chalmers University of Technology

Rice production in Bangladesh is large – sitting at fourth position in the top producers of rice in the world, the nation is pushing the 40 million metric ton mark in total rice production. Hence there is a dire need to improve the overall performance of rice paddy production in Bangladesh, in context to environment. A consequential life cycle assessment will give a holistic picture of influence, a decision can have on the product system chain, for example how the product system will be influenced due to a change in decision, such as switching from traditional agricultural practice to organic agricultural practice to grow the paddy rice. The benefits that arise from avoided use of fertilizers and chemicals are evident from this alternative scenario analysis is evident as most of the indicators show significant decrease in burden. From the absence of urea application alone, almost 10% of global warming potential burden can be reduced. This is due to resulting decrease in production of Urea, as a consequence of the decision to stop its application. Given the difficulty in applying CLCA in a developing country due to unstable economy and unpredictable demand, this study is the first of its kind from this region.

P15

LCA as tool to direct research in the water cycle

T. van den Brand, KWR Watercycle Research Institute / Water systems and technology; R. Hofman-Caris, KWR Watercycle Research Institute; A. Butkovskyi, Wageningen University WUR Univ of Valencia UV; B. Hofs, Evides

In the water sector much research is conducted regarding environmental issues; such as resource recovery and lowering the total (CO_2) footprint. A life cycle assessment (LCA) analysis can be performed to evaluate the environmental impact of a new process or scenario in which resources are recovered, without having to invest in intensive and expensive technical research. This LCA study demonstrated that research should be focussed on the baricum concentration in the wastewater for the shale gas wastewater treatment process and for the recovery of flocculant is should be focussed on the quality of the recovered flocculant. In this study LCA has shown to be an effective tool to evaluate the direction of research within the water sector, evaluate possibilities for resource recovery and determine environmental impacts of processes.

P16

LCA of magnesium recovery processes for decision support in REMAGHIC EU-project

M.I. González Hernandez, Fundación CIDAUT / Material Producto Proceso; J. Garcia, Grupo Antolin

REMAGHIC (New Recovery Processes to produce Rare Earth - Magnesium Alloys of High Performance and Low Cost, in the frame of SPIRE project) is focused on contributing to Europe's rare earth recovery and magnesium recycling technologies, improving the efficiencies of these processes and advancing the technology readiness levels for a new generation of industrial processes that will produce sustainable competitive alloys for automotive and aeronautics industries, and biomedical sector. The main objective of this work was the environmental assessment of the new technologies for recovering magnesium (Mg) developed in REMAGHIC. The evaluation of the effective environmental performance of this new recovery technology supported the decision making process of selecting the most promising routes to be applied in the upscaling process of the new production of Mg+REE alloying ingots (this activity is still under development). The scope of the Mg recovery technologies developed within REMAGHIC was the assessment of the environmental profile of the production of a one kilogram ingot of recovered magnesium, to be alloyed with rare earth, from the available types of Mg wastes in Grupo Antolin facilities. The magnesium recovery process, were based on remelting technologies. The waste streams were rejected parts, Biscuits & Gates, overflows; and dross & sludges. In the project, a recovery system is being defined to obtain high quality secondary Mg ingots, from magnesium wastes. Through LCA models, footprint of different technical options have been analyzed and taken into account for decision making. That allows studying the impact that alternative technical solutions within REMAGHIC Mg recovery system, in order to properly define the pilot plant where validate the developed process. Scenario analysis was implemented in order to assess how the results of the LCA vary if the model is set up in different ways: a) employment of different composition for refining salts, b) varying the balance of wastes as raw materials, c) varying the energy sources to provide the thermal energy needed; d) varying the stirring system in the melting crucible, and e) selecting different configuration of cover gases to use in different stages within the recovery system. The LCA assessments were carried out following the standard ISO 14040/14044

P17

Life-cycle assessment of table grapes in Austria - three case studies

B. Mairinger, University of Natural Resources and Life Sciences Vienna; I. Kral, AlpS GmbH; A. Gronauer, University of Natural Resources and Life Sciences Vienna / Division of Agricultural Engineering; G. Piringer, University of Natural Resources & Life Sciences / Dpt. of Sustainable Agricultural Systems

Table grapes are beginning to be grown in Austria, but no life-cycle assessments (LCA) on table grapes has been found in literature. The objective of this work was an estimate of the potential environmental impacts of producing 1 kg of table grapes and the development of impact mitigation options. It used a "cradle-to-gate" LCA (from vine planting to primary consumer) to study three naturally or organically managed case study vineyards in Eastern Austria, and one hypothetical reference vineyard. The global warming potential (GWP100) of the four vineyards ranged from 0.30 to 1.05 kg CO2-eq/kg grape, with a strong dependency on annual grape yield. The main contributing processes varied between vineyards, including machinery use, the production of packaging materials and mineral fertilizer production. Options to reduce the impacts of table grape production in the vineyards studied here include the use of modern, efficient machinery, a less material-intensive packaging system and optimal fertilizer use. In the vineyard with the highest total GWP100, just replacing the old tractor with a modern model would reduce the grapes' total carbon footprint by 38.5%.

P18

Managing uncertainty in LCA of innovative processes to recover rare earth elements in REMAGHIC project

A. Salles, Fraunhofer Institute for Chemical Technology ICT; S. Sgarioto, Relight italia; L. Yurramendi, Tecnalia Research Innovation; F. Forte, Katholieke Universiteit Leuven; M.I. González Hernandez, Fundación CIDAUT / Material Producto Proceso

The REMAGHIC (New Recovery Processes to produce Rare Earth - Magnesium Alloys of High Performance and Low Cost, in the frame of SPIRE program) project aims at contributing to Europe's rare earth recovery and magnesium recycling technologies, improving the efficiency of these processes and advancing the technology readiness levels of a new generation of industrial processes to produce new and more sustainable alloys for the automotive, aeronautical, and biomedical industries. The main objective of this work was the environmental assessment of the new technologies developed in REMAGHIC for recovering rare earth elements (REE). The evaluation of the effective environmental performance of these new recovery technologies supported the decision-making process of selecting the route to be applied in the upscaling process of the new production of Mg+REE alloying ingots (this activity is still under development). The environmental assessment was carried out following the ISO 14040/14044 standard. The rare earth recovery processes developed within REMAGHIC, with focus on Yttrium, Cerium and Lanthanum, were based on hydrometallurgical (Relight), pyrometallurgical (Tecnalia), ionometallurgical and solvometallurgical (KUL) technologies. The waste streams were fluorescent lamp phosphors, Cathode Ray Tube, and Nickel Metal Hydride batteries. Modelling LCIs that assured robust results proved challenging, due to uncertainties about the quality of the data, mainly because some project partners were working in innovative processes (i.e. low TRL). Most uncertainties stemmed from partners working in different TRL in a same process route and from the consumption of specific chemicals, for which the obtainment processes were not found in the available LCA databases. One solution for these issues was to have the partners with higher TRL support those with lower TRL, with their knowledge and experience, in extrapolating their information (e.g. resource consumption). In addition, the unavailable obtainment processes for the chemicals were created based on literature research. Finally, every decision regarding the extrapolation/estimation of data was supported by chemical experts and owners/suppliers of the relevant equipment. This approach reduced the uncertainties of the inputs/outputs from the processes developed within REMAGHIC and will allow its LCA group to assess the up-scaling process of Mg+REE alloying ingots while still assuring a good data quality.

P19

Marginal energy carriers - a Swedish perspective

T. Ekvall, IVL Swedish Environmental Research Institute Ltd; I. Adolfsson, A. Fråne, M. Hagberg, IVL Swedish Environmental Research Institute; M. Wråke, Energiforsk; L. Youhanan, IVL Swedish Environmental Research Institute

We discuss how to model the production of energy carriers (fossil fuel, renewable fuel, waste as fuel, residual heat, district heat, and electricity) affected by a marginal increase in their use in Sweden. Much of the discussion is valid also for energy use in other countries, since many energy carriers are traded on an international or global market. Marginal fossil fuel can simply be modelled as the average fossil fuel extracted at the time horizon of the LCI. Modelling renewable fuel is more complicated. Unprocessed solid biofuel are currently traded on a regional market. A marginal increase in demand can affect the quantity of unused forest residues or produced energy crops depending on the regional land use. Refined solid biofuel, and possibly future unprocessed biofuel, can be transported far and the marginal production has to be identified on an international marke. A marginal change in the use of waste as fuel in Swedish waste incinerators is likely to affect the import of waste. A marginal increase in the import is likely to affect a mix of landfilling of primary or secondary waste, biological treatment, and waste incineration in other

European countries. In the future, it might also affect materials recycling. The impact of a change in the use of district heat can be complex and strongly depends on the local district-heating (DH) system. It also varies with the outdoor temperature, which, in turn, varies with time and local climate. Short-term impacts of a well-defined marginal change in heat demand can be estimated through the use of energy models, if the DH system(s) affected is known. The marginal impacts are highly uncertain, however, when effects on DH investments are taken into account or when the DH system affected is not known. A marginal Swedish increase in electricity use is currently not likely to affect investments in new power plants, due to existing overcapacity in the North European electricity system. With some exceptions it is instead likely to affect the utilization of fossil fuel in existing plants. It can possibly affect also decisions to shut down old power plants. An increase in future electricity demand is likely to affect utilization and production capacity in a complex mix of technologies. This mix is highly uncertain, but some aspects of it can be investigated through the use of dynamic optimising energy models.

P21

Socio-economic analysis based on a life cycle perspective: the comparison of existing and emerging production process for trimethyl phosphite

B. Brunklaus, S. Stahl, RISE Research Institute of Sweden / Energy and Circular EconomySustainable Society Energy and Environmental Systems Analysis; K. Lorentzon, RISE Research Institute of Sweden; J. Berlin, RISE Research Institute of Sweden / Energy and Circular EconomySustainable Society Energy and Environmental Systems Analysis

Socio-economic analysis (SEA) is a methodology developed for chemical risk management and decision making, derived from tools like the Cost benefit analysis, or the Multi-criteria analysis. Since the latest ECHA guideline for SEA in 2011, a number of studies have been performed, while seldom with a life cycle perspective and seldom on production processes. This socio-economic analysis (SEA) is based on earlier Life cycle assessment on the production process of trimethyl phosphite (TMPi) including risk of fire/explosion and life lost. Trialkyl phosphites are important intermediates in the chemical industry in a large variety of applications, including crop protection, flame-retardants and plastics production. Among the existing technologies for the production process of TMP there are the tertiary amine process (TEA) and the transesterification process. Among the new innovative technologies, there are the TRYALKYL process, part of the EU Life project TRIALKYL. In this SEA study, the existing TEA production process is compared with the new TRIALKYL process for the production of TMP. The current evaluation is based on laboratory data and design of the pilot line, while the final evaluation will be based on industrial data on pilot line. The evaluation includes mainly economic, health, environmental and social impacts in accordance to the latest ECHA guidelines for SEA. The results of the SEA analysis are economic benefits and risk presented as scenarios, such as the “non-use scenario” for the Trialkyl production process and the “applied for use scenario” for the TEA production process. The results have shown that socio-economic analysis based on life cycle perspective and the inclusion on fire/explosion and life lost are useful for the health and environmental assessment and beneficial for the understanding of chemical risk management and decision making. So far, the results have shown that despite the cost of a new production plant, the EU society benefits significantly from the shift to the Trialkyl process due to the improved benefits within human health and the environment.

P22

Stochastic modelling using the Monte Carlo simulation for life cycle inventory of the rare earth elements (REEs) in beneficiation rare earth waste from Covas mining site, Portugal case study

B. Bieda, AGH University of Science and Technology / Management; K. Grzesik, AGH

This paper deals with the stochastic modeling based on the Monte Carlo (MC) simulation, used to the life cycle inventory (LCI), in order to evaluate uncertainty of the inventory of the rare earth elements (REEs) recovery from the secondary materials processes production applied to the tailings from COVAS mining site located in Portugal, case study. In this study uncertainty analysis is conducted using Oracle Crystal Ball® (CB) software for performing MC simulation. Chemical elements used in this study are: cerium(Ce), lanthanum (La), neodymium (Nd) and tungsten (W), based on the results in the production of a concentrate and tailing.[1]. Uncertainty was modeled using probability distributions. The probability distribution for the Ce, La, Nd and W were considered to be log-normal, according to the criteria proposed by Sonnemann et al. [2].The output report provided by CB, after 10,000 runs, is reflected in the frequency charts and summary statistics [3]. As a result of the MC simulation, confidence intervals estimating the values of the Ce, La, Nd and W elements have been formed. The aim of the study is to present the performance of MC simulation by using CB for LCI applied to rare earth elements (REEs). Probabilistic technic based on the log-normal distributions is presented. The results of this study could be used as the first step in performing a full LCA of the REEs recovery process chain. Also the results can improve current procedures and can help practitioners and decision makers in the REEs beneficiation processes management. [1] Menard Y, Magnaldo A. 2017. ENVIREE – Deliverable 2.1 - Report on the most suitable combined pre-treatment, leaching and purification processes. http://www.enviree.eu/fileadmin/user_upload/ENVIREE_D2.1.pdf. Accessed 10 July 2017. [2] Sonnemann G, Castells F, Schumacher M. 2004. Integrated Life-Cycle And Risk Assessment For Industrial Processes. London, New York, Washington, DC, GB, USA: Lewis Publishers Boca Raton. 362 p. [3] Bieda B. 2012. Stochastic Analysis in Production Process and Ecology under Uncertainty. Heidelberg Berlin, Germany: Springer-Verlag) 168 p. *Acknowledgement* - This publication and research was completed within ENVIREE project (ENVIronmentally friendly and efficient methods for extraction of Rare Earth Elements from secondary sources) funded by NCBR, within the 2nd ERA-NET ERA-MIN Joint Call Sustainable Supply of Raw Materials in Europe 2014.

P24

Water-Energy-Food-Climate Nexus approach for food waste management decision: the case study of the fish canning industry

J. Laso, Universidad de Cantabria / Chemical and Biomolecular Engineering; M. Margallo; I. García-Herrero, Universidad de Cantabria / Chemical and Biomolecular Engineering; P. Fullana, A. Bala, Universitat Pompeu Fabra UPF / UNESCO Chair in Life Cycle and Climate Change Escola Superior de Comerç Internacional ESCI; C. Gazulla, Lavola Cosostenibilidad; I. Vázquez-Rowe, Pontificia Universidad Catolica del Peru / Civil Engineering; A. Irabien, Universidad de Cantabria / Chemical and Biomolecular Engineering; R. Aldaco, University of Cantabria

Increasing awareness is being worldwide addressed in recent years to food security. Food systems depend heavily on land, water and energy resources and contribute sifnifincantly to greenhouse gas (GHG) emissions and other environmental impacts. In particular, food systems have been estimated to be responsible for 20-30% of the anthropogenic GHG emissions. Moreover, over 1.3 billion metric tons of supplied products are wasted or lost annually throughout the food supply chain (FSC) that are equivalent to about one-third of the total global food production and produce 3.3 Gtonnes of CO2 eq. The reduction and/or management these food losses is one of the main concerns of the European legislation. The Waste Framework Directive 2008/98/EC established a mandatory management principle for municipal waste, the so-called “waste hierarchy”. According to this classification, waste prevention is the most preferable option, while landfilling leads to the last resort waste treatment. However, waste prevention is not always possible, adopting other management measures such as disposal, incineration and valorisation. The latter is directly linked with the circular economy approach that enables economic growth while optimizing the consumption of natural resources. This concept aims to keep the added value in products, materials and resources for as long as possible and minimizing waste generation. Proper food losses (FL) management and how quatify the consumption of natural resources and the environmental impacts generated are a concern that has been studied in the last years. However, this work aims to go further proposing a new approach to assess different FL management alternatives based on the nexus water, energy, food and climate systems by means of an integrated Water-Energy-Food-Climate Nexus Index (WEFCNI). This index, which allows a more integrated planning, development, policy-making, monitoring and evaluation of different sectors, can be applied to any sector. In this case, the case study is focused on the FL management of the anchovy canning industry. In particular, three management alternatives were analysed: valorisation using FL as animal feed by means of valorisation, incineration and landfilling.

Keyword Index

Author Index