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Path Exchange Method for Hybrid Life-Cycle Assessment

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Problem Description

The objective of the research is to develop a method for hybrid analysis in which production paths in input-output analysis are replaced by process analysis, to elaborate the theoretical and mathematical basis for this method, and to explain or demonstrate its operation.

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Supervisor: Edgar Hertwich, EPT

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MASTER THESIS

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Path-exchange method for hybrid life-cycle assessment

Konstruksjon av et hybrid livssyklusinventar gjennom utskifting av verdikjeder/produksjonsspor

Background

Hybrid life-cycle assessment combines detailed data on the processes describing important parts of a value chain with input-output data describing minor inputs, service inputs, and hence a "background" system. Integrating these two data sources in a full hybrid methods is not straight-forward, as situations arise where inputs are counted twice, once in the process description and once in the input-output description. Various methods to avoid this double-counting or correct for it have been developed by Manfred Lenzen, Anders Strømman, and others. These methods are demanding and vary in their advantages and disadvantages.

Objective

The objective of the research is to develop a method for hybrid analysis in which production paths in input-output analysis are replaced by process analysis, to elaborate the theoretical and mathematical basis for this method, and to explain or demonstrate its operation.

The following questions should be considered in the project work:

1. How can the production path of a specific input to the production of a commodity of interest in an input-output analysis be identified and its contribution traced?

2. How can that path be replaced or supplemented by process-based description?

3. Show the process flow diagram of a simple example of the new process, going down at least two layers.

4. How does the proposed method differ from other methods for correcting for double-counting?

The student may also dwell on the economic interpretation of the hybrid method from an input-output perspective.

A progress plan *(Planned activities and scheduled progress)* shall be submitted to the responsible subject teacher/supervisors for comments within 14 days after the candidate has received the project description.

The work shall be edited as a scientific report, including a table of contents, a summary in Norwegian, conclusion, an index of literature etc. When writing the report, the candidate must emphasise a clearly arranged and well-written text. To facilitate the reading of the report, it is important that references for corresponding text, tables and figures are clearly stated both places. By the evaluation of the work the following will be greatly emphasised: The results should be thoroughly treated, presented in clearly arranged tables and/or graphics and discussed in detail.

The candidate is responsible for keeping contact with the subject teacher and teaching supervisors. According to "Utfyllende regler til studieforskriften for teknologistudiet/sivilingeniørstudiet ved NTNU" § 20, the Department of Energy and Process Engineering reserves all rights to use the results in connection with lectures, research and publications.

The report must be submitted to the Department in 3 complete, bound copies. Further, a separate page must be submitted, giving a short summary of the work and stating the author's name and title of the project work. This information will be used in case of the work being referred to in journals, and must not exceed one typed page with double spacing. Additional copies should be given directly to the supervisor(s) involved in the project according to agreement with the supervisor(s).
A CD with a complete copy of the main report in Word-format or similar, shall be submitted to both the subject teacher and the Department of Energy and Process Engineering.

The main report from the project work shall be submitted to the Department of Energy and Process Engineering.

NTNU, January 15th 2009

Johan E. Hustad
Department Manager

for Edgar Hertwich
Subject teacher/Supervisor

External contact/supervisor: Manfred Lenzen, University of Sydney

Abstract

To keep process-specificity while extending system boundaries hybrid techniques were developed allowing the micro structure of the important parts of a system to be revealed at the same time the entire economic system in which the system is embedded to be covered. Despite the substantial improvements bestowed by hybrid techniques some downsides still hold. Tiered hybrid LCA first does not model feedbacks whereas the relationship between the process-based system and the input-output based system is interactive and second it may suffer from double counting incidents as a process may be instigated in both the IO and LCI data. Integrated hybrid LCA overcomes those aforementioned pitfalls but only at a price of high labor and data intensity. This work aims to elaborate a new hybridisation method that avoids previously mentioned drawbacks. This technique is designed to not operate anymore at the matrix level as is the case for current hybridisation techniques but at the structural path level, *per se* the finest level of detail possible for the disaggregation of the Leontief inverse, and as such an *ad hoc* basis to carry out an hybrid analysis. It is argued that the method presented here constitutes a culmination amongst hybridization techniques. Its operability and capabilities are demonstrated before an interpretation from an input-output vantage point is carried out on a case-study not to be found in the literature, a comparison across the faculties of a university.

Preface

This work constitutes the last stone of my Master of Science of Industrial Ecology at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway carried out in parallel with my five-year Engineering Degree at the Ecole Centrale Nantes (ECN), Nantes, France as part of a double degree programme conducted under the Top Industrial Managers for Europe (T.I.M.E.) exchange programme. It was completed within the premises of the University of Sydney, Sydney, Australia at the Centre for Integrated Sustainability Analysis (ISA), an environmental consulting company, founded and run by Dr. Manfred Lenzen, which aim is to develop analytical tools and techniques toward a better assessment of systems upon the Triple Bottom Line.

First and foremost, I would like to convey all my heartfelt acknowledgements to Dr M. Lenzen, first for having believed in my competences, second for all the insights into IO, LCA and hybrid LCA he provided me with during my stay at ISA, third for all the technicalities in terms of VBA programming and Excel commands he taught me, and last for all the professional opportunities he opened up to me. I would also like to truly thank the people I worked with here at ISA and that participated to make my stay a great personal and professional achievement. Amongst them, I would particularly like to thank Dr C. Dey for all his precious time he shared with me during allocation procedures. Likewise, I would like to thank D. Latimer, University of Sydney Utility Information System Project Manager, for his help regarding the collection of on-site environmental data. At last, I also would like to thank G. English, financial integrity and support unit accountant at the University of Sydney who, along with Dr M. Lenzen, helped me up with the processing of financial data. Furthermore I would also like to thank H. Brattebø, programme director of the MSc of Industrial Ecology, NTNU, Trondheim, Norway for his incessant words of encouragement, C. Solli, consultant at and co-founder of Misa, Trondheim, Norway, for having given me the contact of Dr M. Lenzen, T. Larssen, higher executive officer, NTNU, Trondheim, Norway, for having helped me to remotely register my thesis, and to all the Indecol students and the Indecol department *per se* for I found among them and there what I was looking for before enrolling into this master. At the very last, I would like to dearly thank my parents, and in a larger extent my relatives and beloved ones, for their daily though unconscious involvement in all my achievements.

On the flip side of the coin I also take advantage of this tribune to manifest my incomprehension in respect of Dr E. Hertwich, NTNU Industrial Ecology programme director, former professor of mine in *Energy and environmental consequences*, and, above all, my supervisor, for not having looked at my work a single time, for not having answered most of my e-mails and for having despised me throughout the last two semesters in the course of which he supervised me. As a matter of fact this work has thus never been corrected, emended or reviewed by any third party whatsoever. While it makes no doubt divulging these deeds expose me to repercussions I would forgo my honour not mentioning them. At any rate, without presuming of the quality of this work, the fact that it forms the basis of a paper co-authored with Dr M. Lenzen, input-output analysis co-editor for the Journal of Industrial Ecology, Chair of Sustainability Research at the University of Sydney and author of numerous world-class papers on IOA and hybrid LCA already confers me the intellectual cachet I look for.

Sydney, New South Wales, Australia June 22, 2009

Olivier Michel Baboulet

Table of Content

List of Figures

List of Tables

1. Introduction

The quantitative assessment of the environmental load of a given system is usually performed either using input-output analysis or life cycle analysis (IOA and LCA in the following) depending on the scale of the system under study. The former is favoured at the macroscopic level since it is affected by a high level of aggregation in industry and commodity classifications but possesses good system boundaries completeness while the latter is at a microscopic scale as it enjoys a good level of detail on foreground processes but suffers from incomplete system boundaries. In addition and as a consequence of its system boundaries incompleteness an LCA study will most likely lead to an underestimation of the total environmental burden (Lave, Cobas-Flores et al. 1995; Suh 2004). Second, the lack of consistency in drawing boundaries from one system to another leads to practical difficulties toward their comparative assessment as the equivalence of their boundaries is difficult to prove and subsequently influences their rankings and brings about misleading conclusions (ISO 1997). To deal with these two issues of boundary selection and completeness hybrid methods combining both IOA and LCA were developed, extending system boundaries while keeping process specificity. Notwithstanding the substantial improvements bestowed by hybrid LCA techniques some downsides still hold. Integrated hybrid analysis remains data- and time-intensive (Suh 2004) while tiered hybrid analysis may suffer from double-counting incidents (Strømman, Peters et al. 2009).

This work aims at developing a new hybridisation approach - that does not anymore operate at the matrix level but at the structural path level, *per se* the finest level of detail possible for the disaggregation of the Leontief inverse, and as such an *ad hoc* basis to carry out an hybrid analysis - that avoids aforementioned hybridisation techniques drawbacks. To do so a reminder of both IOA and LCA frameworks will be performed which in turn will logically enable us to carry out a review of current hybridisation methods. In the same breathe relevant calculus and algebraic tools will be prompted before the theoretical and mathematical background this new hybridisation technique leans upon is elaborated. Then the operability of this method, first proposed by Treloar (Treloar 1997), and validated by Crawford (Crawford 2008), will be demonstrated upon a case-study chosen to be the University of Sydney. The accent will be put on the way data were collected and processed before practicalities proffered by the method along with its drawbacks, if any, are presented. To finally dwell on the economic interpretation of this method from an input-output perspective, a cross-comparison amongst the University of Sydney's thirteen faculties will be performed. At last results will be thoroughly discussed before the conclusions regarding the viability of this method - denominated *PXCH method* which stands for Path eXCHange method - as a hybridisation technique are rendered.

2. Theoretical and mathematical framework

To gain insight in the improvements this new hybridisation technique brings about, it is of prime importance to understand both the mathematical and theoretical pillars it leans upon. This implies displaying elements of theory for input-output analysis, life cycle analysis, and hybrid analysis as well as elements of theory for one of the tool it requires, structural path analysis. Consequently, the necessary mathematical backgrounds will be brought up in the following.

2.1. Input-output analysis

Input-output analysis is an analytical framework which primary purpose was to reflect the intertwined monetary relations between industries within an economy (Leontief 1936). During the last decades this framework has continuously been enhanced to deal more explicitly with environmental issues (Isard, Bassett et al. 1968; Ayres and Kneese 1969; Isard 1972; Forssell and Polenske 1998). More recently with the implementation of structural path analysis (Crama, Defourny et al. 1984; Defourny and Thorbecke 1984) into input-output studies deeper insights of environmental issues were reached such as the extraction of embodied energy paths in the Australian residential building sector (Treloar 1997), the identification of environmentally important intersectoral flows (Weber and Schnabl 1998), and the structural decomposition analysis of GHG emissions (Wier 1998) among others.

An input-output model starts with transaction records between industries within a national economy, described mathematically by a transaction matrix **Z** such that $\mathbf{Z}_{ij}$ indicates the amount of domestic industry output purchased by industry *j* from domestic industry *i* in monetary terms. By assuming that each industry produces only one distinct output, a square transaction matrix **Z** is obtained. It is a convention in input–output economics that the transaction matrix is converted into a coefficient matrix, which is either called the *direct intersectoral requirements* or *coefficients* matrix and is generally denoted **A** in the literature. Denoting **g** the total industry output vector, an industry-by-industry direct requirements matrix, **A**, is then defined by

$$\mathbf{A} = \mathbf{Z}\hat{\mathbf{g}}^{-1} \qquad \textbf{(1)}$$

The hat (ˆ) makes a diagonal matrix out of a vector, such that $\mathbf{g}_i$ is located at $\hat{\boldsymbol{g}}_{ii}$ and $\hat{\boldsymbol{g}}_{ij}=0$ whenever $i \neq j$. $\mathbf{g}_i$ indicates the amount of the total output by industry *i*, which is the sum of the total output of the industry that is consumed by domestic industries, households and export. Consequently, an element of the direct requirements matrix $\mathbf{A}_{ij}$ shows the amount of industry output *i* required by industry *j* to produce a *unit* of its output.

An equality:

$$\mathbf{g} - \mathbf{A}\mathbf{g} = \mathbf{f} \qquad \textbf{(2)}$$

holds in a national economy where the total amount of domestic industry output produced **g** minus the total industry output consumed by domestic industries **Ag** (intermediate demand) equals the amount of industry output consumed by final consumers and export **f** (Leontief 1941). Rearranging, and provided that the Leontief inverse exists (see (Suh and Heijungs 2007) for necessary and sufficient conditions), it yields:

$$\mathbf{g} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} \qquad \textbf{(3)}$$

Assuming further that the input structure of each industry does not change when it changes its scale, meaning that input coefficients are *scale-insensitive*, the total amount of industry output **x** required by an arbitrary final demand for industry output **y** is calculated by:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \qquad \textbf{(4)}$$

This assumption of scale-insensitiveness reflects a fixed relationship between a sector's output and its inputs. In other words, *economies of scale* are ignored, and the system operates under what is known as *constant returns to scale* (e.g.: tripling all inputs will triple output, cutting inputs in half will halve output) (Miller and Blair 1985).

In addition to the conventional compilation of monetary intersectoral flows between industries, environmental input-output analyses also require the compilation of extra information on inputs of *production factors* into intermediate demand. The result of a generalized environmental input-output analysis is an $M \times N$ matrix of *factor multipliers*, that is embodiments of M production factors (such as energy, resources, and pollutants) per monetary unit of final consumption of commodities produced by N industry sectors. A multiplier matrix **m** can be calculated from an $M \times N$ production factors matrix **q** and from an $N \times N$ direct requirements matrix **A** according to:

$$\mathbf{m} = \mathbf{q}\ (\mathbf{I} - \mathbf{A})^{-1} \qquad \textbf{(5)}$$

where **I** is the $N \times N$ identity matrix. The equation above holds inasmuch as the Leontief inverse exists. An element $\mathbf{q}_{ij}$ of **q** represents the amount of production factor *i* required by industry *j* to produce a basic value unit of its output, while an element $\mathbf{m}_{ij}$ of **m** represents the amount of production factor *i* required in all (producing and supplying) industries to produce a basic value unit of final demand from industry *j*. Finally, *the factor inventory* **Q** of a given monetary activity vector **y** is then simply a $M \times 1$ vector such that:

$$\mathbf{Q} = \mathbf{my} \qquad \textbf{(6)}$$

The basic computation of IOA described above is based on the assumption of one distinct output by each industry. In practice, however, each industry produces primary products and secondary products as well as scrap. Furthermore, the output by each industry does not have to be unique to that industry, so that the commodity produced by an industry may also be produced by another industry. Input–output accounts based on commodity instead of industry output have been developed by improving the basic accounting scheme known as supply and use framework (Stone, Bacharach et al. 1963). This supply and use framework has since enabled the creation of a commodity-by-commodity-based input–output model (Raa, Chakraborty et al. 1984; Raa 1988; Jansen and Raa 1990; Steenge 1990; Londero 1999) – which will be resorted to in this work.

2.2. Life cycle analysis

Two approaches can be distinguished within the process analysis: the *process flow diagram* approach and the use of *matrix notation* (Suh and Huppes 2005). Both are meant to evaluate environmental impacts of products, services and/or systems holistically including direct and supply-chain impacts.

In a process flow diagram approach, process-specific data for each process in a product system are compiled and remaining successive upstream inputs are considered to have negligible impact. Process flow diagrams show how the processes of a product system are interconnected through commodity flows. In this framework, boxes generally represent processes, while arrows indicate the commodity flows. Using plain algebra, the amount of commodities required to supply a certain functional unit is obtained, and a life cycle inventory (LCI in the following) is calculated by multiplying by the amount of environmental intervention required to produce them. However, in this approach both the number of processes that are involved in the product system and the order of upstream processes are limited so that the branches of the "process tree" come to a finite end, whereas virtually all processes are inter-linked in the supply-demand web of a modern economy. Thus, an LCI compiled using a process-flow diagram exhibits inherent system incompleteness.

Another approach uses matrix notation in describing the relations between processes and computing LCIs (Heijungs 1994; Heijungs and Suh 2002). In this approach, each column of the technology matrix is occupied by a vector of inputs and outputs per unit of operation time of each process, including the use and disposal phase. The LCI is calculated by inverting the technology matrix and multiplying it by an environmental matrix (Heijungs 1994). This algorithm has advantages in representing infinite orders of upstream process relations, which cannot be achieved using the process flow diagram approach, and it has been utilized by a number of software and public LCI databases so far. However, those relations are limited to the processes that are included within the chosen system boundary. Thus, as in process-flow diagrams, the number of processes involved in this approach is limited and inclusion or exclusion of processes is decided on the basis of subjective choices, resulting in a system boundary problem.

2.3. LCA versus IOA

The systems that LCA and IOA deal with have a lot in common. However, despite those similarities, a few important differences hold. One of the advantages of IOA over LCA is that such data are regularly compiled as parts of national statistics. Input-output analysis can take into account capital goods (for application see (Moriguchi, Kondo et al. 1993)) and overheads (such as head offices, marketing, company cars, lunchrooms, etc.) as inputs to a product system, which are often deliberately left out by most of process LCIs. For instance Ikaga (Ikaga, Tonooka et al. 1998) compiled an inventory database for Japanese construction sector, which accounts for capital inputs by internalizing the capital expenditure and depreciation data in the input-output tables. This "capital effect" is thought to be particularly significant for service industries. Note, however, that capital expenditure can vary significantly from one year to the following due to the low frequency of purchases of long-lived and expensive structures and equipment. Hence, the capital component in LCIs might be incorrectly estimated in years with atypical capital expenditure.

But IOA has its own problems including the high level of aggregation in industry or commodity classifications. Since even the most disaggregated input-output table combines products and production technologies that are heterogeneous in terms of input materials and environmental intervention generation, input-output analysis on its own is less adequate for detailed LCA studies, especially of industry-atypical products. Furthermore, even if the production technology employed is the same, institutional variations can lead to significant aggregation errors. An example of this effect was presented by Grunwald (Grunwald, Coenen et al. 2001) in their study of cumulative emissions of a passenger car. The ammonia emissions obtained by input-output analysis were some 40 times higher than those obtained from process analysis. A closer look revealed that almost the whole difference stems from food used in the lunchrooms and business meals over the whole process chain. Lunchrooms in Germany are obligatory by legislation for larger companies, so that lunching activities will be regarded as industrial process for the larger companies, while the same is done as private consumption activities, and, thus, their environmental consequences will not be imputed to the product.

Moreover, monetary value, the most commonly used representation of inter-industry transactions in input-output tables, can distort physical flow relations between industries due to price inhomogeneity. Another important source of uncertainties in input-output analysis includes, but is not limited to, import assumption and uncertainties due to data age. Total input requirements using single-region domestic input-output tables are usually calculated assuming that the imported commodities are produced using the same technology and structure of domestic industries. Thus, results of input-output analyses of countries that rely heavily on imports are subject to a relatively high uncertainty. Available input-output tables are generally several years old; thus, assessing rapidly developing sectors and new technologies may introduce errors because of base-year differences between the product system under study and input-output data.

Finally, an important source of error is the incompleteness of sectoral environmental statistics, which are often a disparate combination of models and reports in which small- to medium-sized enterprises, mobile sources, and nonpoint sources may only be registered in part.

Furthermore, both process-based approaches generally neglect the input of capital goods, which can result in significant underestimation in LCIs. This is particularly true for service industries where capital inputs can be significant. Process analysis is generally seen as more specific than input-output analysis, yet more labour- and time-intensive, and suffering from a systematic *truncation error*, which is due to the delineation of the product system under study by a finite boundary and the omission of contributions outside this boundary.

Although the input–output model covers a wider system, including all interactions between industries within a national economy, the result is an average value of a set of processes, while LCA also has a fundamental problem of truncation (Lave, Cobas-Flores et al. 1995). With the aim of combining the strengths and reducing the weaknesses of each method hybrid analyses that combine process and input-output analysis have been developed.

2.4. Hybrid LCA

The virtue of a hybrid LCA lies on the complementary nature of process-analysis and input–output analysis: the system definition becomes more complete and process-level details are preserved at the same time. In other words, the micro structure of the important parts of a system is revealed while the entire economic system in which the system is embedded is covered. The methodological framework has its roots in energy-economic modelling of the 1970s (Bullard, Penner et al. 1978).

In these studies, input-output modelling supplied information for sector typical products or processes, while all remaining processes were modelled using process data (Suh 2004). Such a hybrid approach for a full life cycle assessment was first used by Moriguchi (Moriguchi, Kondo et al. 1993). Wilting (Wilting 1996) empirically investigated a hybrid energy analysis method and compared the outcomes with those of an input-output energy analysis. Over time three interrelated ways of conducting a Hybrid LCA have been developed (Suh and Huppes 2005).

2.4.1. IO-based hybrid LCA

This hybrid technique is carried out by further disaggregating important input-output sectors when more detailed sectoral monetary data are available (process and trading information) and then linked to the detailed process-based foreground system. However, since a national input-output table represents only pre-consumer stages of a product life-cycle based on domestic industries, use and end-of-life stage should be added to the results from disaggregated input-output table.

Its mathematical representation is as follow:

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}^{ff} & \\ \mathbf{A}^{nf} & \mathbf{A}^{nn} \end{bmatrix} \tag{7}$$

where $\mathbf{A}^{ff}$ represents the *foreground processes requirements matrix*, $\mathbf{A}^{nn}$ the *input-output* (background*) technology coefficients matrix* and $\mathbf{A}^{nf}$, the *upstream cut-off matrix* or in other words the upstream inputs of commodities from the background system $\mathbf{A}^{nn}$ to the foreground system $\mathbf{A}^{ff}$ (Strømman, Peters et al. 2009). There is no feedback from the foreground system to the background economy (i.e.: $\mathbf{A}^{fn}$=0) because the underlying assumption of such a model is that product flows associated with the foreground system and the functional unit are too small compared to the flows prevailing on a national level and/or are produced solely for final demand and as such not part of the intermediate demand.

To obtain satisfactory results with this technique, a *sine qua none* condition for the foreground system is to be developed enough to outweigh aggregation errors inherent to input-output data (ISO 1997). One such study is the comparative LCA of different fuel tanks realised by disaggregating the input-output sector that manufactures the products that were to be compared by Joshi (Joshi 1999).

2.4.2. Tiered hybrid LCA

Tiered hybrid analysis utilises process-based analysis for the use and disposal phase of products as well as for several important upstream processes, while the remaining input requirements are calculated separately with IO-based LCA. In other words, higher order requirements of the product system under study are covered by IOA while the direct and downstream requirements and substantial lower order upstream requirements are investigated through a detailed process analysis (for application see (Hondo, Nishimura et al. 1996; Munksgaard, Pedersen et al. 2000)).

Its mathematical representation is as follow (Strømman, Peters et al. 2009):

$$\mathbf{A} = \begin{bmatrix} \mathbf{A}^{ff} & & \\ \mathbf{A}^{pf} & \mathbf{A}^{pp} & \\ \mathbf{A}^{nf} & & \mathbf{A}^{nn} \end{bmatrix} \tag{8}$$

where $\mathbf{A}^{ff}$, $\mathbf{A}^{nf}$, $\mathbf{A}^{nn}$ bear the same meaning as in IO-based LCA and $\mathbf{A}^{pp}$ represents the *background processes requirements matrix* and $\mathbf{A}^{pf}$ the upstream inputs of background processes to foreground processes. $\mathbf{A}^{pf}$ and $\mathbf{A}^{nf}$ symbolises the links between the foreground system and the two background requirements (processes and economy) matrices. This system can also be modelled by two separate smaller systems, containing only the foreground and process system (standard process-based LCA), and the foreground and input-output system (input-output based LCA), respectively (see Eq. 4 in (Strømman, Peters et al. 2009)). Note that these two smaller systems will yield different results because of different background databases.

2.4.3. Integrated hybrid LCA

This technique devised by Suh and Heijungs (Heijungs and Suh 2002; Suh 2004), supported by the Ecoinvent database, and used in the SimaPro LCA software is the most sophisticated form of hybridisation at the matrix level (as opposed to the *PXCH method* which is an hybridisation technique operating at the path level; refer to section 2.6). The process-based system is represented in a technology matrix by physical units per unit operation time of each process while the input-output system is represented by monetary units. This model is derived from a make and use framework for both the process-based and the input-output-based system by linking them through flows crossing the border between the two systems via downstream and upstream cut-offs matrices. The interconnection is located at upstream and downstream cut-off points where process data are not available. The mathematical representation of this comprehensive integration of a physical functional flow based micro-level system with a monetary, commodity-based broader economic system following Suh's notations is (Suh 2004):

$$\mathbf{Q} = [\widetilde{\mathbf{B}} \quad \mathbf{B}'] \begin{bmatrix} \widetilde{\mathbf{A}} & -\mathbf{C}^{d} \\ -\mathbf{C}^{u} & \mathbf{I} - \mathbf{A}' \end{bmatrix}^{-1} \begin{bmatrix} \tilde{\mathbf{f}} \\ \mathbf{f} \end{bmatrix} = \overline{\mathbf{B}}\overline{\mathbf{A}}^{-\mathbf{1}}\overline{\mathbf{y}}\,, \quad \mathbf{(9)}$$

where the bar indicates integrated hybrid matrices and vectors, and where **Q** is the total factor inventory (or the amount of environmental intervention as called in (Suh 2004; Suh 2004; Suh and Huppes 2005; Suh and Huppes 2005) and used in this work, refer to Eq. **(6)**), the **B** matrices are the factor intensities (or environmental interventions), $\widetilde{\mathbf{A}}$ is the process-based technology coefficient matrix (in physical units), **A'** is the commodity-by-commodity input-output technology coefficients matrix (in monetary units), $\tilde{\mathbf{f}}$ (in physical units) and **f** (in monetary units) represents final demand from process and input-output systems respectively, while $\mathbf{C}^{u}$ and $\mathbf{C}^{d}$ are the so-called upstream and downstream cut-off matrices expressed in mixed units. The *upstream cut-off by processes* matrix $\mathbf{C}^{u}$ holds the inputs into the processes that are not covered by the process database, expressed in monetary units per physical unit while the *downstream cut-off by functional flow* matrix $\mathbf{C}^{d}$ holds the deliveries of process outputs to input-output sectors, expressed in physical units per monetary unit. The former is derived by dividing the total bill of goods for the inputs that are not covered by processes in a process based system during the period of steady-state approximation by the total unit operation time of each process while the latter is derived by dividing the annual sales of functional flows by the production of each total commodity. In other words, $\mathbf{C}^{u}_{ij}$ represents the amount of cut-off of input-output commodity *i* to process *j* during the unit operation time in monetary terms while $\mathbf{C}^{d}_{ij}$ shows the amount of cut-off flows of functional flow *i* to input-output commodity *j* per unit of monetary value of its output, in relevant physical units. The presence of these two cut-offs matrices in the system depicted in Eq. **(9)** clearly illustrates the interaction in both directions between the functional flow-based system and the commodity-based system. Note that, computationally, integrated Hybrid LCA is a functional generalisation of both input-output-based and tiered hybrid LCA since setting $\mathbf{C}^{d}$to 0 transforms $\overline{\mathbf{A}}$ into a lower triangular matrix (i.e.: no feedback from the foreground to the background system).

2.4.4. Double counting incidents in hybrid LCA

By combining both life-cycle and input-output analysis within the same framework to describe a given system, a process may be instigated in both the IO and LCI data. As a consequence, double-counting incidents may arise distorting and biasing the final results of a study. Yet, in IO-based hybrid LCA, detailed process-specific data can be fully resorted to without spawning any double counting incident (Joshi 1999). However this is not as straightforward for both the integrated and tiered hybrid LCA frameworks. Besides, the way those incidents are dealt with for these latter is relevant for the *PXCH method*. Consequently it will be presented in the following.

2.4.4.1. Tiered hybrid LCA

To deal with double counting incidents that occur when

a) a part of demand from the foreground system is decoupled from the input-output background system and coupled to the process background system, and
b) the sectors under demand in the process and input-output system have intersecting coverage.

(Strømman, Peters et al. 2009) developed a method which underlying algorithm allows to remove double counted monetary flows in the input-output system by using an SPA (refer to section 2.5) based on the criterion that the sets of input-output paths to be removed should leave the same monetary value as the process system flows that it overlaps with. Unlike Suh (Suh 2004), (Strømman, Peters et al. 2009) do not thus correct the input-output matrix by subtracting the coverage of processes (refer to next section), but instead allow their process and input-output matrices to contain intersecting data. Their main focus is then to remove double-counting from the input-output system during the performance of the LCA, using SPA and adjustment techniques.

However, because of this allowed intersecting coverage, decision must be taken regarding which entries to keep and which corresponding paths to remove. Because environmental LCA data are more precise than input-output ones and that the underlying aim of the study is to describe environmental impacts, (Strømman, Peters et al. 2009) prefer keeping entries in $\mathbf{A}^{pf}$ (rather than in $\mathbf{A}^{nf}$) and subsequently removing paths originating from $\mathbf{A}^{nf}$ that corresponds to entries in $\mathbf{A}^{pf}$ to avoid double counting incidents. This being possible only if definition of input-output sectors in $\mathbf{A}^{nf}$ at least covers that of the process sectors since the latter will be subtracted out from the monetary inputs. The algorithm then first indentifies double counting incidents before adjusting for them according to the following seven main steps:

a) identifying at which tier and with what magnitude each foreground process instigates activity across the foreground system frontier and storing it in an *output of foreground processes by tier* matrix $\breve{\mathbf{x}}$;
b) establishing the monetary values $\mathbf{q}$ (not to be confused with a production factors matrix $\mathbf{q}$; Eq. **(5)**) of each items of the foreground system demand $\breve{\mathbf{x}}$ from the process system;

c) since all the processes in the set p can be assigned to a commodity group within the input-output data thanks to a correspondence matrix $\mathbf{H}^{np}$, establishing the binary concordance of input-output sector(s) $\mathbf{b}(\mathbf{k}) = \mathbf{H}^{np}(\mathbf{k})$ that correspond to the process sectors $\mathbf{k} \in p$ under demand;
d) carrying out an SPA for the sectors $\mathbf{b} \in n$ of the input-output $[\mathbf{A}^{nf}\ \mathbf{A}^{nn}]$ subsystem (refer to section 2.4.2.);

Since the SPA algorithm returns a sorted and ranked list of all the input paths identified in the input-output system for each given double counting incident (Z^{all}), paths identified in Z^{all} represent more paths than needed for cancelling out the double counting incidents, therefore the algorithm goes on by:

e) selecting a set of paths Z^{req}, in the top-ranking input paths returned by the SPA algorithm, until the sum *psum* over all paths equals the monetary value $\mathbf{q}$ of the item covered by the process analysis; these paths will have lengths $\mathbf{t} = t_i$ and end-points $\mathbf{b}(\mathbf{k})$;

At that stage, the algorithm has now revealed all the double counting incidents in $\mathbf{A}^{nf}$ and $\mathbf{A}^{nn}$ for every non-negative entry in $\mathbf{A}^{pf}$. It continues to adjust for them by:

f) Distributing and accumulating the double-counted flow, that is the values of paths in Z^{req}, into tiers t of adjustment vectors $\tilde{\mathbf{x}}_t = \{\tilde{x}_{b(k),t_i}\}$; note that the double-counted flows is non-zero only for commodities $\mathbf{b}(\mathbf{k})$, so that in the input-output system are adjusted only purchases of commodities that correspond to the process sectors $\mathbf{k} \in p$ under demand;
g) Undertaking a tier-wise expansion and correction of $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y}$ which entails subtracting the double-counting flows $\tilde{\mathbf{x}}_t$ from the flows obtained from the adjustment in the previous tier according to $\mathbf{x}_t = \mathbf{A}\mathbf{x}_{t-1} - \tilde{\mathbf{x}}_t$.

Since the tiered method is applied whilst carrying out the LCA, the above procedures are specific to the final demand appraised in that particular LCA.

2.4.4.2. Integrated hybrid LCA

This hybridization technique enables a consistent allocation method throughout the hybrid system and especially avoids double counting incidents by subtracting the commodity flows in a process-based system from the input-output system. Indeed, while the inputs added in the upstream cut-off matrix are already missing from the process database and are added in order to complete the input bill, the downstream cut-offs are in principle contained in a complete input-output database. Therefore those inputs by processes have to be subtracted from the monetary inputs of the input-output sectors. In other words, in order to avoid double counting, the coverage of the process system has to be taken out of the input-output system.

A detailed method is presented in Appendix A of (Suh 2004) to correct for the monetary *make* ($\mathbf{V}$) and *use* ($\mathbf{U}$) matrices for process flows double-counted by $\mathbf{C}^u$ and $\mathbf{C}^d$. This correction requires:

a) Extracting out of the *functional flow record* matrix, a sub-matrix ($\widetilde{\boldsymbol{Z}}_{*}^{\boldsymbol{\pi}}$) to only deal with functional flows leading to a double counting incidents. This occurs when a functional flow between two processes within a process-based system involves monetary transaction and both of these processes belong to industries in the intermediate part of an input-output table.
b) Since the input-output framework used for this integrated hybrid model is based on a *commodity-by-commodity* coefficients matrix, subtracting double counted portions is done by transforming this extracted *functional flow record* sub matrix into supply-use form by separating produced and used functional flows according to their signs (see Eqs. (A1) and (A2) in (Suh 2004) such that

$$\widetilde{\mathbf{Z}}_{*}^{\boldsymbol{\pi}} = (\mathbf{V}_{*}^{\boldsymbol{\pi}})^{\mathbf{T}} - \mathbf{U}_{*}^{\boldsymbol{\pi}}, \qquad \textbf{(10)}$$

c) Reclassifying use and supply matrices into input-output classification with the help of a functional flow permutation matrix and a process permutation matrix.
d) Adjusting the re-classified process use and supply matrices with price vectors, and
e) Subtracting the resulting matrices from the supply and use input-output tables.

Resorting to the industry-technology model or the commodity technology model to derive the commodity-by-commodity technology coefficient matrix out of the reduced Make and Use matrices (see Eqs. (A6) and (A7) in (Suh 2004)) obtained with the above procedure yields the commodity flows relations, excluding those *already* covered in the process-based system. Note that with this framework, the environmental intervention-by-commodity matrix $\mathbf{B}'$ also needs to be adjusted (adjustment done by subtracting the environmental interventions by processes that were represented in the input-output accounts).

2.4.5. Drawbacks and limitations of current hybrid LCA techniques

2.4.5.1. Input-output based LCA

This method describes the process part and the input-output part in a consistent framework and avoids double counting incident under certain circumstances (Joshi 1999) but recurring flows between the main system and use and end-of-life phase (externally added to the main system) are not properly described and yield misleading results if the national economy relies heavily upon imports (ISO 1997).

2.4.5.2. Tiered hybrid LCA

This method allows for a simple upgrade or improvement of a conventional LCA by simply introducing an extra background economy which aim is to cover purchases of commodities from the input-output system that are missed out in the process-based LCI data. Besides, literatures databases and case-studies are well documented. But on the other hand recurring flows are not properly described by process-flow diagram approach and misspecifications through double counting arise when sectors under demand in the process and input-output system have intersecting coverage (ISO 1997).

Even if (Strømman, Peters et al. 2009) developed an algorithm that combines partially overlapping physical and monetary data and as such limit downsides inherent to this technique, their algorithm simply loops through the ranked list of paths until the double counted value **q** is covered. The top-ranking paths returned by the SPA algorithms that match the economical value **q** are then removed. Nonetheless this may not be exactly those top-ranking paths that actually correspond to the processes in $\mathbf{A}^{pp}$ (purchased by the system through $\mathbf{A}^{pf}$) and that are thus responsible for double counting incidents. However, (Strømman, Peters et al. 2009) let the door open to other strategies for picking double counting paths (refer to (Strømman, Peters et al. 2009), section 6). Furthermore, due to differences between the value assumed for the price of a good in a transaction between the foreground and the process system on the one hand and prices inherent to the input-output system on the other, it may be impossible to cover the entire economic value **q** of the quantity to be accounted for (Lenzen 2009). In other words, the price π_k valuing the double-counted foreground-process transaction $\mathbf{A}_{kl}^{pf}$ may be quite different from the average price of a basket of commodities covered by the corresponding foreground/input-output transaction $\mathbf{A}_{b(k)l}^{nf}$. Finally this method does not allow for a modelling of feedback loops from the process-based to the input-output-based system since $\mathbf{A}^{fn}$=$\mathbf{A}^{pn} = \mathbf{A}^{fp}$ =0, whereas it is important to understand that the relationship between the process-based system and the input-output based system, representing the microstructure of the commodity flows web and the wider, embedding economy, respectively, is interactive, and that an integrated model is thus required to model this interactive relation.

2.4.5.3. Integrated Hybrid LCA

Whereas this technique does not suffer from double counting incidents peculiar to the tiered hybrid method and the whole life-cycle is dealt with in a consistent mathematical framework upon which analytical tools (e.g.: SPA) are easy to apply, it remains relatively complex to use and implies high data and time requirements, especially when it comes to the compilation of the downstream cut-off matrix. Indeed, Peters and Hertwich (Peters and Hertwich 2006) while examining Suh (Suh 2004) with respect to the downstream cut-off matrix $\mathbf{C}^{d}$, concluded that, unless LCA process sectors form a significant part of the economy, the contribution of $\mathbf{C}^{d}$ to the inputs contained in the input-output table will be negligible and as consequence, doubt whether the compilation of sales of processes to the economy, followed by their subtraction from the monetary input-output data, is worth the effort.

In his reply, Suh (Suh 2004) argues that the fact that the downstream cut-off contribution is generally small is no reason to automatically set this term to zero. Further, he makes the point that $\mathbf{C}^{d}$ is constructed by the LCA practitioner by consecutively adding upstream and downstream process components to the process tree, and that $\mathbf{C}^{d}$ does not require an LCA of all economic sectors. However, Suh concedes that in practice, few practitioners would have access to an integrated hybrid database, and that this would likely form the task of database providers. All said and done, the contribution of $\mathbf{C}^{d}$ will vary depending on the magnitude of the sales of the products on which the LCA is performed into the embedding economy.

2.5. Structural path analysis

The use of matrices to represent an input-output system not only bestows a straightforward mathematical solution (see Eqs. **(3)**, **(4)**, **(5)**, and **(6)**), it also allows for a very useful algebraic decomposition that offers even deeper insights than multipliers would otherwise provide into the round-by-round or tier-by-tier behaviour of a system (Waugh 1950). This breakdown, holding inasmuch as the Leontief inverse exists (see (Suh and Heijungs 2007) for necessary and sufficient conditions) and referred to as power series expansion (Peters 2007), allows rewriting the Leontief inverse in a sum of powers of the *coefficients* matrix **A** according to the following formula:

$$(\mathbf{I}-\mathbf{A})^{-1}=\sum_{k=0}^{\infty}\mathbf{A}^{\mathrm{k}} \qquad \mathbf{(11)}$$

Structural path analysis (Crama, Defourny et al. 1984; Defourny and Thorbecke 1984) builds upon this decomposition and Eq. **(5)** to break down a particular multiplier into contributions from all input paths as in Eq. **(12)** (Waugh 1950; Lenzen 2002; Peters 2007; Suh and Heijungs 2007):

$$\mathbf{m}_{ij}=\sum_{\mathrm{k}=1}^{\mathrm{N}}\mathbf{q}_{ik}\left(\boldsymbol{\delta}_{kj}+\mathbf{A}_{kj}+\sum_{\mathrm{l}=1}^{\mathrm{N}}\mathbf{A}_{kl}\mathbf{A}_{lj}+\sum_{\mathrm{l}=1}^{\mathrm{N}}\sum_{\mathrm{m}=1}^{\mathrm{N}}\mathbf{A}_{kl}\mathbf{A}_{lm}\mathbf{A}_{mj}+\cdots\right) \qquad \mathbf{(12)}$$

where $\mathbf{m}_{ij}$ denotes a particular multiplier of production factor *i*, while *k, l, m,* and *j* denote industries, and $\boldsymbol{\delta}_{kj}$ represents Kronecker's delta. $\mathbf{m}_{ij}$ is thus a sum over a direct factor input $\mathbf{q}_{ij}$, occurring in industry *i* itself, and higher order input paths. A first order input path for the production factor *i* from industry *k* to industry *j* will have a shape $\mathbf{q}_{ik}\mathbf{A}_{kj}$ while a second order input path from industry *k* to industry *j* via industry *l* will have a shape $\mathbf{q}_{ik}\mathbf{A}_{kl}\mathbf{A}_{lj}$; so on and so forth.

This decomposition thus allows disentangling the intricate network of relationships of a complex system by unravelling all the input paths contained in the corresponding **A** matrix at each order (N^n input paths at the n$^{\mathrm{th}}$ order) and consequently offers a detailed insight on the structure of this system. However the value of input paths usually decreases with path lengths since the contents of far-upstream inputs are generally smaller than that of near-upstream inputs. Consequently the SPA algorithm loops through all those paths only up to a specified maximum order that *per se* reflects a desired degree of completeness. It then extracts and ranks the most significant ones in terms of their contribution to a given total factor multiplier. For each of the extracted paths, the algorithm returns the path sequence (succession of nodes the path skirts on its way through the layers of production to its final destination) and the value of the path (for application see (Lenzen 2007). With this ranking SPA thus provides the practitioner with substantial insights for directions into which further data collection efforts should be made. Logically the *PXCH method* which underlying objective is to swap process-based data for equivalently matching input-output data among the top-ranking input paths in order to refine the granularity of the study relies on that tool (refer to the next section).

2.6. Path exchange method

2.6.1. Rationale

Referring to section 2.4., the aim of Hybrid LCA techniques is to reconcile the advantages of both IOA and LCA while overcoming their respective drawbacks. But despite the substantial improvements proffered by hybrid LCA techniques some downsides still hold. Integrated hybrid analysis (Suh 2004) remains data- and time-intensive while tiered hybrid analysis may suffer from double-counting incidents when the same process is instigated in both the IO and LCI data (Strømman, Peters et al. 2009).

Besides, in current hybrid LCA techniques, when a direct input-output coefficient is changed (respectively set to 0) at the matrix level, it alters (respectively eliminates) all the particular paths from the Leontief inverse data that relate directly or indirectly to the corresponding node (Treloar 1997). In order to not permanently change the input-structure of a transaction and therefore erroneously alter all the paths containing the corresponding node, the adjustment should thus be done without a coefficient change (i.e.: not be dealt with at the matrix level).

To avert both those aforementioned drawbacks and this irremediable system disturbance, another approach for the hybridisation of a system has thus been developed. This hybridization technique does not anymore operate at the matrix level but instead at the structural path level which is the finest level of detail possible for the disaggregation of the Leontief inverse. It is designed to modify the characteristics of only a fraction of a path relating to only a particular purchase whereas in previous hybrid method, once a path is re-routed from the input-output system into the process system, all further upstream coefficients remain in the process system. This method called *PXCH method* is exposed, detailed and exemplified hereafter.

2.6.2. Methodology

2.6.2.1. Principle

The core idea behind the *PXCH method* is to adjust the total factor inventory **Q** (refer to Eq. **(6)**) for a final demand bill by operating at the path level by swapping process-based data for equivalently matching input-output data (Treloar 1997; Lenzen 2009). Doing so, the hybridisation of the life cycle inventory takes place at the highest level of detail.

The starting point is a conventional input-output analysis upon which a structural path analysis (SPA) has been conducted. Once performed the PXCH practitioner determines whether relevant process data points from in-house engineering knowledge and supplier information can be found to replace corresponding input-output data in any of the top-ranking input paths returned by the SPA algorithm. Once all the modifications the practitioner was willing to accomplish are performed, the correction of the entire life-cycle inventory requires running a regular input-output analysis on the monetary activity vector $\boldsymbol{y}$ and then looping through all the modifications (Lenzen 2009).

2.6.2.2. Mathematical framework

This method enables transaction coefficients, indicators and multipliers (**A, q,** or **m**) modifications at the structural path level. For indicators and transaction coefficients, these modifications can either concern the whole path or a fraction of it while for a multiplier it involves changing the whole sub-tree upstream of the node where the change has taken place.

This is the nature (**A, q,** or **m**) of the process data point to be replaced that determines how adjustments are performed (Lenzen 2009). Those adjustments along with their underlying consequences on the system behaviour are explained in depth in the following sections.

However whatever the nature of the process data point, before swapping it for corresponding input-output data, it is imperative to determine to which extent it applies to the current **A, q,** or **m** by establishing its coverage (i.e.: the matching between process and input-output data). This is because input-output sectors are often more aggregated than process sectors (compare (Strømman, Peters et al. 2009), Section 2.3). Therefore, the practitioner needs to estimate the proportion σ of **q, m** or **A** to which the process data point *P* applies so as to correct only the fraction of the path that is concerned by *P*.

At last, two different objects are distinguished in the *PXCH method*, the path and the sub-tree. A path S stretching from *m* --> … --> *i*, is broken down into its intensity **q**, its purchase **y**, and its node coefficients so that $S = \mathbf{q}_i \mathbf{A}_{ij} \mathbf{A}_{jk} \dots \mathbf{A}_{lm} \mathbf{y}_m$ while the sub-tree upstream from node *i* is broken down into its total multiplier **m**, its purchase **y**, and its node coefficients so that T= $\mathbf{m}_i \mathbf{A}_{ij} \mathbf{A}_{jk} \dots \mathbf{A}_{lm} \mathbf{y}_m$. Note that here and in the following *M* is set to 1 (refer to Eq. **(5)**) to simplify notations and ease the reading. However it is straightforward to generalize for *M* > 1. S represents a unique course from *i* to *m*, of length *m-i+1*, via the nodes *j,k,…,l* while the sub-tree T encompasses all the paths that dovetails path S at node *i* in addition to the path S *per se*. The former is used to deal with coefficients and indicators exchanges, while the latter is resorted to for multiplier exchanges. At last, a superscript is used in the following to denote the type of modification (1 stands for an intensity change, 2 for a transaction coefficient change and 3 for a multiplier change).

2.6.2.2.1. Indicator intensity change

If an indicator intensity is changed from $\mathbf{q}_i$ to $P^{(1)}$, then from the entire life-cycle inventory **Q**, and from the appropriate tiers of a Production Layer Decomposition (refer to Eq. **(12)**), the quantity $\sigma^{(1)} S^{(1)} = \sigma^{(1)} \mathbf{q}_i^{(1)} \mathbf{A}_{ij}^{(1)} \mathbf{A}_{jk}^{(1)} \dots \mathbf{A}_{lm}^{(1)} \mathbf{y}_m^{(1)}$ (old value) is subtracted from the user's overall results and the quantity $S'^{(1)} = P^{(1)} \mathbf{A}_{ij}^{(1)} \mathbf{A}_{jk}^{(1)} \dots \mathbf{A}_{lm}^{(1)} \mathbf{y}_m^{(1)}$ (new value) is added *loco parentis*. The quantity σ reflects the fraction of the path to be affected by the adjustment.

However, an intensity change may lead to *cross-influence* issues depending on the nature of the *indicator suite* (set of sub-, sub-sub- and head-indicators) chosen to be reported upon by the practitioner.

Indeed a level *n* indicator can directly influence another level *n* indicator whilst the reverse is not necessarily true (e.g.: *Energy consumption* directly influences *GHG emissions* while the reverse is false). Second, level *n* head-indicators are weighted average of level *n-1* sub-indicators themselves weighted average of level *n-2* sub-sub-indicators. As a matter of fact an update can only be performed from lower levels to higher levels. Last, some indicators can be sub-indicators to several head-indicators (e.g.: *CO_2 from fuel combustion* is a sub-indicator of both *Energy consumption* and *GHG emissions*). Consequently, updating a head-indicator via sub- and/or sub-sub-indicators will also update the other head-indicators that are made up of those latter.

As a direct consequence of these three facts, a *cross-influence issue* arises when a head-indicator that directly influences another head-indicator is adjusted at the highest level without any information on its sub- and sub-sub-indicators being entered. Updating a head-indicator at the highest level is of course not an issue in itself since what is relevant to the practitioner is the very value of the head-indicator he/she chose to report on and not the values of the sub- and/or sub-sub-indicators making up this head-indicator. Rather the issue arises because this head-indicator influences another head-indicator. Since adjustments can only be performed upward no adjustments can be done on the lower-level indicators that compose the directly updated head-indicator. Yet some of these non-updated lower-level indicators are common to both head-indicators. Consequently adjustments cannot ripple up to the other head-indicator. This is the very sole scenario where a *cross-influence* issue arises, that is a comprehensive update across all the head-indicators cannot be performed.

This is therefore the (entwined) nature of the *indicator suite* chosen to be reported on that may lead to cross-influence problems or not. Consequently, in order to avoid any such cross-influence issues, the practitioner must take into account the intrinsic relationships in between the head-indicators composing his/her *indicator suite* before directly updating a head-indicator. The below figure illustrates an entwined *indicator suite* (made up of *Pre's Eco-indicator* and *GHG emissions* head-indicators) that can lead to a *cross-influence* issue under certain circumstances. Indeed *GHG emissions* influences *Pre's Eco-indicator* and they have sub-indicators in common.

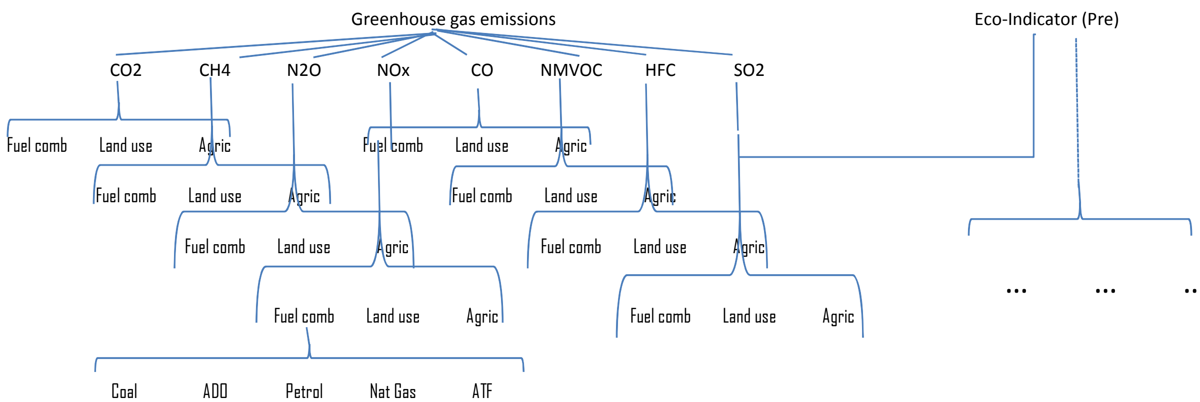

Figure 1: Instance of an *indicator suite* made up of the two head-indicators *GHG emissions* and *Eco-Indicator* that leads to *cross-influence* issues under certain circumstances.

2.6.2.2.2. Transaction coefficient change

If a transaction coefficient is changed from $A_{jk}^{(2)}$ to $P^{(2)}$, then from the entire life-cycle inventory **Q**, and from the appropriate tiers of a Production Layer Decomposition (refer to Eq. **(12)**), the quantity $\sigma^{(2)}S^{(2)} = \sigma^{(2)}\mathbf{q}_j^{(2)}\mathbf{A}_{jk}^{(2)} \dots \mathbf{A}_{lm}^{(2)}\mathbf{y}_m^{(2)}$ is subtracted from the user's overall results and the quantity $S'^{(2)} = q_j^{(2)}P^{(2)} \dots \mathbf{A}_{lm}^{(2)}\mathbf{y}_m^{(2)}$is added *loco parentis*. Likewise the quantity σ reflects the fraction of the path to be affected by the adjustment.

However when a coefficient in a particular supply chain is modified, this has consequences for all longer paths that at least *contain* the path originating from the very same consumer node up to the two nodes in-between which the change occurred – irrespective of the indicator. In other words, regardless what path S containing the node about to be changed is chosen to perform the coefficient modification, all the paths stretching from the very same consumer node as S up to at least the two nodes in between which the modification is to occur (i.e.: all the paths containing at least S), will also *integrate* this change.

To account for this *flow-on* effect assume that the practitioner downwards-adjusts 75% of the transaction coefficient *Black coal → Electricity* (coefficient change 1 on the figure below) along the third-order path *Black coal → Electricity → User* first because 75% of the user's electricity use comes from one particular power plant (i.e.: $\sigma^{(2)}$ = 75%) and second because the practitioner has found out that this power plant uses coal more efficiently than other economy-wide-average power plants because of a new pulverization technology. Obviously, anything that the coal mine uses to operate, and in turn to supply the power plant that supplies the user, *must* go through the already changed downstream path: *<input xyz> → Black coal → Electricity → User*. Therefore, if the user's power plant uses less coal per unit of electricity, then it also uses indirectly less mining machinery per unit of coal per unit of electricity, less explosives per unit of coal per unit of electricity, and so on. In other words, this coefficient change *must* affect all longer paths that originate from the same consumer node and that feature at least the two nodes in-between which the change occurred, that is the entire sub-tree upstream of the changed node.

However assume further that a subsequent second coefficient change along the fourth-order path *Mining machinery → Black coal → Electricity → User* is carried out at the node *Mining machinery → Black coal* (coefficient change 2 on the figure below). As a corollary this change thus affects a supply-chain sub-tree (blue) of the bigger supply-chain sub-tree (red) affected by the first coefficient change (*Black coal → Electricity*), which in turn is a sub-tree of the entire supply-chain tree originating from the user (black tree).

Therefore modifying the node-2 coefficient again (coefficient change 1 on the figure below) will in turn affect all other previous changes made on paths that at least contain the current path from the node about to be changed, down to the consumer node (for instance paths making up the blue sub-tree just previously modified).

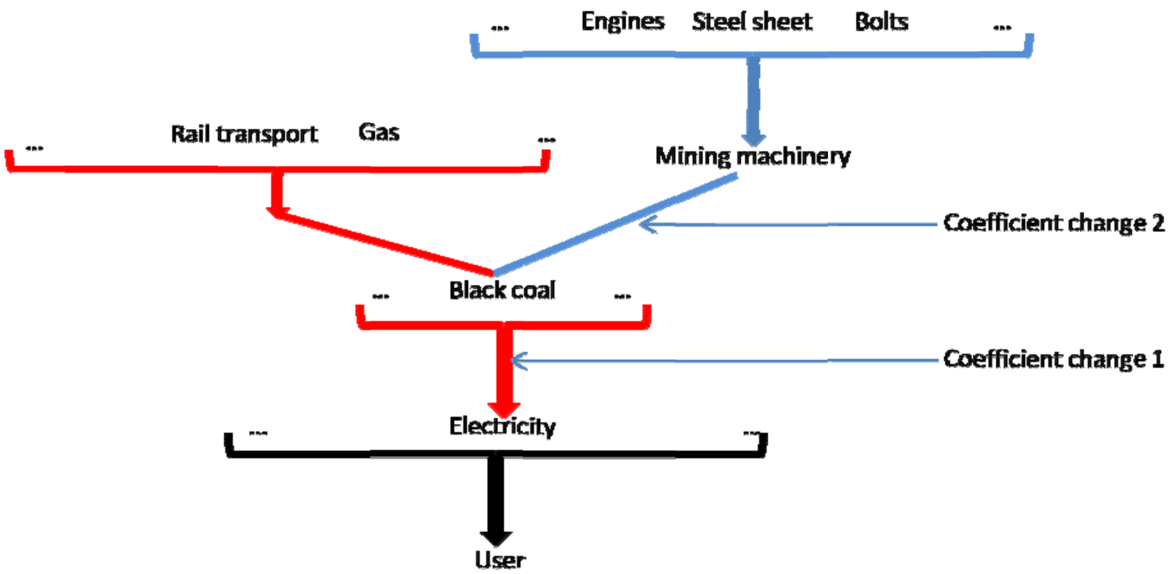

Figure 2: Supply-chain tree illustrating the *flow-on* effect and the necessity to proceed to changes in a given order. Thick vertical or slanting arrows represent flows occurring in-between nodes while horizontal ones represent performed changes. Dashes represent the multitude of paths converging towards one node and not represented for sake of clarity. Colors reflect the paths hierarchal arborescence.

All said and done, since changing a transaction coefficient in a particular supply chain entails consequences for all longer paths that at least *contain* the path stretching from the very same consumer node up to the two nodes in-between which the change occurred no matter what the indicator nature of its intensity term is, an order to operate modifications from lower-order nodes to higher-order ones prevails.

2.6.2.2.3. Multiplier exchange

If a multiplier is changed from $m_i^{(3)}$ to $P^{(3)}$, then from the entire life-cycle inventory $\mathbf{Q}$, the partial sub-tree $\sigma^{(3)}T^{(3)} = \sigma^{(3)}\mathbf{m}_i^{(3)}\mathbf{A}_{ij}^{(3)}\mathbf{A}_{jk}^{(3)} \ldots \mathbf{A}_{lm}^{(3)}\mathbf{y}_m^{(3)}$ is subtracted and the partial sub-tree $T'^{(3)} = P^{(3)}\mathbf{A}_{ij}^{(3)}\mathbf{A}_{jk}^{(3)} \ldots \mathbf{A}_{lm}^{(3)}\mathbf{y}_m^{(3)}$ is added *loco parentis*. Likewise the quantity σ reflects the fraction of the tree to be affected by the adjustment.

However when a sub-tree $T = m_i\ \mathbf{A}_{ij}\mathbf{A}_{jk} \ldots \mathbf{A}_{lm}\mathbf{y}_m$ upstream of a particular supply chain $\mathbf{A}_{ij}\mathbf{A}_{jk} \ldots \mathbf{A}_{lm}\mathbf{y}_m$ is changed, this entails consequences for previous and further changes of paths that are part of the changed sub-tree.

First, if prior to changing the sub-tree *T*, any path *S* with at least the nodes $\mathbf{A}_{ij}\mathbf{A}_{jk} \ldots \mathbf{A}_{lm}\mathbf{y}_m$ has been changed, then changing the sub-tree would either need to override the prior path change, or if not then the change would be impermissible. Second, if after changing the sub-tree *T*, any path *S* with at least the nodes $\mathbf{A}_{ij}\mathbf{A}_{jk} \ldots \mathbf{A}_{lm}\mathbf{y}_m$ is to be changed, then changing the path would either need to override the prior sub-tree change, or if not then the change would be impermissible. This is because when using a process data point for a multiplier, one does usually not know about particular components of that multiplier, or at least, if such components were known for example from an integrated hybrid LCA database, they would not all be stored in the change register. Hence, there would usually be no path reference for a path inside a process sub-tree, and hence no reference for a path change preceding or following a sub-tree change. Hence, the characteristics of the path exchange method with regard to multiplier exchanges are the same as those of the integrated hybrid method (refer to section 2.4.3.). Once a multiplier exchange is made, the characteristics upstream from that change are fixed by the content of the process database used for the change.

Second the information collected from a (non-integrated) process database on total embodiments may be subject to a *truncation error* (Lenzen and Dey 2000; Lenzen 2001)). In this case, modifying a sub-tree would introduce the truncation error into the hybrid LCA. This truncation issue does not arise if sub-trees are taken from an integrated hybrid LCA database.

At last, a tier-wise correction cannot be made to the Production Layer Decomposition, because it is not known how the new multiplier is distributed across input-output tiers.

2.6.3. Double counting

The *PXCH method* starts with a conventional input-output analysis upon which a SPA is performed. At that point there cannot be any double counting incident yet as only input-output data are resorted to. In other words, it is not yet a hybrid LCA but only an IOA coupled with an SPA. It only becomes a hybridization technique when the practitioner begins swapping process-based data for equivalently matching input-output data to refine the granularity of the study. As a matter of fact, only at that point does the hybridisation process start and so does consequently the risk of double counting.

However, the double counting incidents occurring in other hybridisation techniques result from the combination of both life-cycle and input-output analysis within the same framework to describe a given system which in turn may lead a process to be instigated in both the IO and LCI data. By contrast and in essence, the *PXCH method* does not combine process and input-output data but instead swap process data for equivalently matching input-output data.

In other words, a process is never instigated in both the IO and LCI data as can be the case in other hybridisation techniques. Instead a process is either described with IO data *or* LCI data. Consequently, the *PXCH method* solves problems associated with ambiguous overlap between process and input-output databases by

- managing overlap at the path level rather than at the sector-level at the process-input-output frontier and
- allowing the user to *replace* only a fraction of a path that relates to a particular purchase.

As a matter of fact, each of these *replacements* performed *by definition* (Lenzen 2009) cannot create any double-counting incident *à la* Strømman (Strømman, Peters et al. 2009).

2.6.4. Concluding remarks

The mathematical background and theoretical framework of the *PXCH method* being presented, the next two sections will be devoted to its demonstration and interpretation. But before that, some words of caution are necessary.

First, PXCH practitioners should bear in mind that the substitution of process data for input-output-based paths that are not top-rankings may in fact lead to a significant upward correction. As such these input paths should not be neglected even though they appear as insignificant in the ranking returned by the SPA algorithm. Moreover, both SPA and the *PXCH method* must be rerun in case a new monetary activity vector $\boldsymbol{y}$ is introduced. Finally, multipliers exchanges give birth to some issues. First, once a multiplier exchange is made, the properties upstream from that change are fixed by the content of the process database used for the exchange. Second, truncation errors may be introduced into the hybrid LCA due to multipliers data coming from a (non-integrated) process database. At last, since one does not *a priori* know how a newly exchanged multiplier is allocated across input-output tiers, a tier-wise correction cannot be undertaken onto the Production Layer Decomposition.

Consequently, the following demonstration of the *PXCH method* operability will only deal with the capability of modifying transaction coefficients and indicators' intensities.

3. Case-study

3.1. Description and objectives

To demonstrate the capabilities offered by the *PXCH method*, an in-depth environmental input-output analysis (EIOA) upon the University of Sydney has been carried out. This was possible first thanks to detailed financial data regarding the running of the university and second thanks to comprehensive on-site data regarding surface area, electricity, natural gas and water consumption. With the help of an internal database censing all the buildings and their corresponding belonging to a particular faculty or administrative service those on-site data were then allocated. In turn it was possible to cross-compare the thirteen faculties of the University of Sydney, allowing us to also dwell on the economic interpretation of the *PXCH method* from an input-output perspective.

In a first phase we will work at the structural path level to refine the granularity of the input-output analysis carried out upon the University of Sydney and hence build up the capabilities bestowed by the *PXCH method*. Then, once the effective demonstration of the operability of the method will have been performed, a cross-comparison amongst the University of Sydney's thirteen faculties will be carried out. The *indicator suite* chosen to be reported on for that cross-comparison is made up of the *GHG emissions*, *Water* and *Land use*, *Energy consumption* and *Material flow* head-indicators. It encompasses altogether 52 level *n-1* sub-indicators and 647 level *n-2* sub-sub-indicators. Finally, it is worth mentioning that such a cross-comparison is not to be found in the literature.

3.2. Collection of financial and environmental data

The economic input-output data were constructed from a range of sources published by the Australian Bureau of Statistics (Australian Bureau of Statistics 2008). The published data distinguished at most some 106 sectors; however these were disaggregated to 344 sectors (which list is to be found in appendix 1) through unpublished purchasing data (Statistics 2008).

Monetary and financial data pertaining to the running of the University of Sydney were extracted from the *2009 USyd General Ledger* (USyd is an acronym standing for University of Sydney and used in the following); collected among the *USyd financial department*. This General Ledger classification contains 80 faculty-level entities, themselves split into 9 sub-entities (accounts) each (see appendix 2 and 3). For each of these 720 *responsibility centres* (RC), financial accounts were broken down into revenues and expenditures via *class codes* (CC) numbering 1033 (610 for expenditures and 423 for revenues).

On-site data for water, natural gas and electricity were extracted from the 2008 USyd water, natural gas and electricity meters *UiS* (Utility Information System) database; sourced from the *USyd utilities procurement department*. Surface area on-site data were extracted from the 2008

USyd *Archbus* database; a persistently updated database that censes all the buildings of the University of Sydney along with their corresponding belonging to a particular faculty or administrative service in terms of surface area. It was also collected among the *USyd utilities procurement department*. Those on-site data are gathered in appendix 4.

Production factors matrix **q** (refer to Eq. **(5)**) relating to both *Energy consumption* and *Material flow*, *GHG emissions* and *Water use* were respectively sourced from energy statistics (Economics 1997), the National Greenhouse Gas Inventory (Committee 1998), and water accounts (Statistics 2000). Further sectoral disaggregation was achieved by using supplementary reports (Wilkenfeld and Associates Pty Ltd 1998) and unpublished estimates on these factors (Economics 1997; Statistics 2000). However, no comprehensive data exists for Australian land use, let alone land disturbance, so that a range of disparate sources had to be appraised for the *Land Use* indicator (Lenzen and Murray 2001).

3.3. Data processing protocol

3.3.1. Construction of the USyd's four-quadrant input-output table template

Five main steps were required to process the sheer volume of financial data collected (1033 x 720 entries). First the raw accounts sourced from the *2009 USyd General Ledger* were split into expenditures and revenues. By convention a negative revenue was considered an expenditure and vice versa. The expenditure account was denoted $\mathbf{X}_{ji}$ while the revenue account $\mathbf{R}_{ji}$, where *j* denotes the CC (class code) and *i* the RC (responsibility centre or university unit).

The second step was to construct the concordance matrices, say allocating each of the expenses and revenues items previously set up to the appropriate sector(s) in the National Accounts and internally. For each revenue CC, a decision was thus made regarding where the revenue came from (internally and externally). Where a CC *i* corresponds to a university unit or an Australian Bureau of Statistics economy sector *j,* a 1 was placed into element (*i,j*) for the revenue concordance matrix $\mathbf{C}^R$. The revenue concordance matrix has thus two parts: one internal concordance matrix mapping CCs for internal revenues to their internal origins in USyd (e.g.: Central accounts) and one external concordance matrix mapping CCs for external revenues to their external origins in the Australian economy (e.g.: the local, federal, or state government). Seemingly, for each expenditure CC, a decision was made concerning what was bought (internally and externally). Where a CC *i* corresponds to the output of a university unit or an ABS economy sector *j*, a 1 was placed into element (*i,j*) for the expenditure concordance matrix $\mathbf{C}^X$. As for the revenue concordance matrix, the expenditure concordance matrix has two parts. An internal one that maps CCs for internal expenditures to their internal destinations in the USyd (e.g.: faculties) and one external that maps CCs for external expenditures to their external destinations (commodities) in the Australian economy (e.g.: stationery or equipment). Then distribution matrices for both revenue and expenditure ($\mathbf{D}^R$ and $\mathbf{D}^X$ respectively) were built by normalizing the concordance matrices so that the row sum for each CC equals 1.

Thirdly internal transfers had to be established. It entailed first matching up CCs j of internal revenue and expenditure items. Secondly it implied extracting rows of revenue $\mathbf{R}_{ji}$ and rows of expenditure $\mathbf{X}_{jk}$ across each university unit (*i,k*) for each of the previously matched CCs j. Thirdly it entailed transposing the revenue rows $\mathbf{R}_{ji}$ into columns $\mathbf{R}_{ij} = \mathbf{R}_{ji}^{T}$. The superscript (^{T}) transforms a matrix into its transpose, such that whatever $(i,j) \in [1,n]^2$, $\mathbf{X}_{ji} = \mathbf{X}_{ij}^{T}$. Fourthly it implied calculating expenditure shares $\frac{\mathbf{X}_{jk}}{\sum_k \mathbf{X}_{jk}}$ for each of the matched CC j. And finally it required confronting and reconciling revenue $\mathbf{R}_{ji}$ by university unit i and expenditure $\mathbf{X}_{jk}$ by university unit k for each matched CC j. Then an internal transfer matrix $\mathbf{t}_{ik}$was calculated by distributing (transposing) internal revenue $\mathbf{R}_{ij}$ according to internal expenditure shares $\frac{\mathbf{X}_{jk}}{\sum_k \mathbf{X}_{jk}}$ so that $\mathbf{t}_{ik} = \frac{\sum_j \mathbf{R}_{ij}\mathbf{X}_{jk}}{\sum_k \mathbf{X}_{jk}}$. In other words, revenue received internally was distributed across the business unit which paid these revenues according to percentages calculated from internal charges paid by these business units.

The fourth step was to construct a gross University input-output account. That implied reclassifying and transposing the entire external revenue account from the CC classification R_{ji} into the ABS classification $\mathbf{R}_{ij}^{*}$ according to $\mathbf{R}^{*} = \mathbf{R}^{T}\mathbf{D}^{R}$ as well as reclassifying the entire external expenditure account from the CC classification $\mathbf{X}_{ji}$ into the ABS classification $\mathbf{X}_{ji}^{*}$ according to $\mathbf{X}^{*} = (\mathbf{D}^{X})^{T}\mathbf{X}$. After that, a four-quadrant input-output table template was constructed wherein the internal transfer matrix **t** was placed into the upper left quadrant and the reclassified external revenue matrix $\mathbf{R}^{*}$ and the reclassified external expenditure matrix $\mathbf{X}^{*}$were placed in the upper right and lower left quadrant respectively.

The last step was to integrate the university and economy input-output accounts. That entailed placing the 344 sectors input-output matrix of the Australian economy into the lower right quadrant of the four quadrant template of the gross university account previously constructed. The size of the four-quadrant template then reached a staggering (720+344+7) x (720+344+7).

3.3.2. Scanning algorithm

Eq. **(12)** was evaluated for each of the indicators making up the *indicator suite* chosen to be reported upon in this work by sequential backwards scanning of the production chain tree from final demand to the various locations of production factor usage as described by Mateti and Deo (Mateti and Deo 1976). Since the value of input paths decreases with path length, the scanning only proceeded up to the eighth order (arbitrary choice though). Furthermore, branches of the tree were ‘pruned’ when the respective path value became lower than a specified threshold chosen to be about one-thousandth of the non-weighted average of multiplier values over all sectors (Treloar 1997). At last only the top twenty input paths for each of the indicators were calculated (and thus returned).

3.4. Output

In addition to this faculty- and indicator-specific input paths ranking returned by the SPA algorithm, the computational structure developed also provides for each of the thirteen faculties and each of the indicators:

- *Commodity breakdown* tables*,*
- *Cumulative impact-by-layer* area-graphs*,*
- *Total-intensities* graphs*,*
- *Total-impacts* graphs.

However due to the resulting sheer volume of listings, rankings and graphs required to perform this cross-comparison on the one hand and the limited space available on the other, some of those outputs are only partly reproduced in this work. Thereby, only the top-ten inputs (*commodity breakdown* tables) for each of the faculties and each of the environmental indicators are displayed in appendix 5 whereas the computational structure allows listing the impacts of each of the 344 ABS sectors for each of the indicators and each of the faculties. Seemingly, while the algorithm developed allows determining the top-twenty structural input paths only the top-fifteen ones are listed in appendix 6 for each of the faculties and each of the indicators. In contrast, all the *impact-by-layer* area-graphs are appended for each of the faculties and each of the indicators (appendix 7). At last, the *total-intensities* and *total-impacts* graphs are directly included in the main text.

This choice of outputs is not neutral and lines up with the top-down approach of a hybridization technique: from a *macro* level of detail given by the *total-impacts* and *total-intensities* graphs to a *micro* level of detail bestowed by the *ranked structural paths* tables via the *meso* level of detail proffered by both the *commodity breakdown* tables and *impact-by-layer* area-graphs.

Indeed a *commodity breakdown* table for a given indicator shows the first level of breakdown of the total macro figures that are lumped in the *total-impacts* and *total-intensities* graphs. It unveils more specific details of the system's performance by displaying which inputs to the system carry the greatest impact for each of the indicators selected. There is *a priori* no reason for the ranking to remain the same from one indicator to the other. Likewise *impact-by-layer* area-graphs also yield a *meso* level of detail since it shows where up the supply chain impacts occur.

Once the inputs carrying the greatest impact along with the corresponding production layers they reside in have been identified with the help of the *commodity breakdown* tables and *impact-by-layer* area-graphs respectively**,** the r*anked structural path* tables are resorted to to determine which structural paths carry the highest impacts. In other words, it provides information broken down into single supply chains, which constitutes the most detailed output for identifying leverage points for abatement actions. It also tells how far removed they are in the supply chain and therefore the likelihood to influence production.

4. Discussion

In section 2, the mathematical and theoretical backgrounds of the *PXCH method* were elaborated along with the necessary tools required. In the previous section, the case-study upon which this new hybridisation technique will be tested against was introduced in addition to the way data were collected and processed. This upcoming section will now be used to first operate the practical demonstration of its capabilities in term of system hybridisation and to then dwell on its interpretation from an input-output vantage point.

4.1. Demonstration of the operability of the *PXCH method*

Multiplier exchanges will not be dealt with and only the following modifications will be carried out (refer to section 2.6.4.):

- Coefficient changes along a given path; concerning either the whole path or a fraction of it.
- Indicator intensity changes along a given path; concerning either the whole path or a fraction of it.

Furthermore for sake of clarity and conciseness, only one instance of each of the modifications enabled by this method will be presented and commented upon. Moreover it is important to set back into the *PXCH method* context: after both the IOA and the SPA are run the practitioner is provided with an indicator-specific top-ranking input paths listing. The *PXCH method* starts at this point, by choosing under which indicator and along which structural path changes will be performed. Finally the upcoming numbers have been disguised to ensure the confidentiality of all the protagonists' business data. Still orders of magnitude are preserved.

4.1.1. Indicator intensity change

Echoing the *indicator intensity changes* section the practitioner must always pay attention to the eventuality that *cross-influence* issues arise as a result of an *indicator suite* made up of an entwined set of sub- and sub-sub-indicators forming the head-indicators (refer to section 2.6.2).

To account for the potential *cross-influence* issues once for all in addition to present all the possibilities offered by this hybridisation technique regarding indicator intensity changes, a detailed example encompassing all the four possible scenarios is set up in the following. While the first two changes will occur under the *GHG emission* head-indicator, the last two ones will occur under the *Energy consumption* one. To account for this choice of indicators we already remind here that *GHG emissions* are a direct consequence of *Energy consumption* while the reverse is false. Furthermore we were able to obtain in-house engineering knowledge and supplier information only from *Energy Australia Contract*, University of Sydney's electricity main supplier. Consequently, the path along which indicator intensity changes will be carried out is the second-order path *electricity->USyd, faculty of science*. The choice of the faculty of science is random though.

We thereby found out that the coal-fuelled power utility that supplies electricity to the University of Sydney and *a fortiori* the faculty of science has a leakage from pipes. By dividing the total value of the leakage by the gross $ output of the power utility, the *fugitive fuel* intensity was estimated to be 10g/$. Furthermore, within its *green policy framework*, this power utility emits 15% less GHG than economy-wide-average power utilities, essentially because of a new coal pulverization technology (further details regarding this process data point will be unveiled in the upcoming section).

We change first the value of the *fugitive fuel* sub-sub-indicator. This indicator has no sub-indicator but is itself a sub-sub-indicator of the two following head indicators that are *GHG emissions* and *Energy consumption*. However the former does not affect the latter. Consequently, on the one hand, no update is required for the top indicator *Energy consumption* while on the other hand, there is no problem updating the values of the *GHG emissions* indicator as the adjustment is made from bottom (*fugitive fuel* sub-sub-indicator) to top (*GHG emissions* head-indicator).

This is echoed in the below table. The first two rows were included only to represent the initial state of the second-order path *electricity->USyd, faculty of science* from the vantage point of the two head-indicators before the *fugitive fuel* sub-sub-indicator intensity is modified. Changing this latter entailed an increase of 119 t CO_2-e along this path. As planned this change did not affect the *Energy consumption* head-indicator (fourth row) but affected the *GHG emissions* one (fifth row, increase in GHG emissions from 5341 to 5460 t CO_2-e along the path).

Table 1: Consequences of an intensity change of a sub-sub-indicator (*fugitive fuel*) to two head-indicators (*Energy consumption* and *GHG emissions)* under a head-indicator (*GHG emissions*) not influencing the other (*Energy* consumption).

Indicator	Path changed	Node changed	Old value	New value	Old path	New path	% of path ch'gd
Energy consumption	Electricity supply > Sydney University, Faculty of Science	Energy consumption - Intensity of Electricity supply	106,551 kJ/$		60,525 GJ		
Greenhouse gas emissions	Electricity supply > Sydney University, Faculty of Science	Greenhouse gas emissions - Intensity of Electricity supply	9,403 g CO2-e/$		5,341 t CO2-e		
Fugitive fuel	Electricity supply > Sydney University, Faculty of Science	Fugitive fuel - Intensity of Electricity supply	0.00 g/$	10.0 g/$	0.00 t	119 t	100.00%
Energy consumption	Electricity supply > Sydney University, Faculty of Science	Energy consumption - Intensity of Electricity supply	106,551 kJ/$	106,551 kJ/$	60,525 GJ	60,525 GJ	100.00%
Greenhouse gas emissions	Electricity supply > Sydney University, Faculty of Science	Greenhouse gas emissions - Intensity of Electricity supply	9,403 g CO2-e/$	9,562 g CO2-e/$	5,341 t CO2-e	5,460 t CO2-e	100.00%

We now proceed to the second intensity change under the *GHG emissions* head indicator which is made up of sub-indicators that in turn are also making up the *Energy consumption* head indicator we chose to report on.

Therefore, if no information is entered at the sub- or sub-sub-indicator level but only at the head-indicator level adjustments cannot be calculated for the other head-indicators (in this case *Energy consumption*). However, in that case, this is not an issue since the *GHG emissions* indicator does not affect the *Energy consumption* one. In addition the fact that no adjustments are made upon the *GHG emissions'* sub- and sub-sub-indicators is not an issue *per se* as what is of prime importance to the practitioner is the value of the head-indicators making up his/her *indicator suite* and not the sub-level indicators values. In the below table, one can observe that the *Energy consumption* indicator is not affected. The initial state (row 1) remains unchanged in the final state (row 3). In contrast, *GHG emissions* has been downward-adjusted along the path from 5341 to 4645 t CO_2-e due to the 15% GHG emissions reduction enabled by the power utility's *green policy framework.*

Table 2: Consequences of an intensity change of a head-indicator (*GHG emissions)* that does not directly affect another head-indicator (*Energy consumption*).

Indicator	Path changed	Node changed	Old value	New value	Old path	New path	% of path ch'gd
Energy consumption	Electricity supply > Sydney University, Faculty of Science	Energy consumption - Intensity of Electricity supply	106,551 kJ/$		60,525 GJ		
Greenhouse gas emissions	Electricity supply > Sydney University, Faculty of Science	Greenhouse gas emissions - Intensity of Electricity supply	9,403 g CO2-e/$	8,177 g CO2-e/$	5,341 t CO2-e	4,645 t CO2-e	100.00%
Energy consumption	Electricity supply > Sydney University, Faculty of Science	Energy consumption - Intensity of Electricity supply	106,551 kJ/$	106,551 kJ/$	60,525 GJ	60,525 GJ	100.00%

What is more, the recent *energy saving* framework established within the premises of the University of Sydney since 2008 has lead to a renewal of the main electrical appliances along with an improvement of their maintenance. Thanks to this ambitious policy, the efficiency of USyd's boilers is 7.5% better than equivalent economy-wide-average ones while the University of Sydney's overall energy intensity is 6% better than equivalent economy-wide-average ones.

Upon entering the new value of the sub-sub-indicator *Boilers* under the *Energy consumption* head indicator, we keep in mind that this indicator has no sub-indicators but is itself a sub-indicator of two head-indicators (*GHG emissions* and *Energy consumption*) and that *GHG emissions* are a direct consequence of *Energy consumption*. However there is no problem updating the values of these two head-indicators as the adjustments are made from bottom to top.

In the below table exemplifying the above scenario, the first two rows once again show the initial state of the second-order path *electricity->USyd, faculty of science* from the vantage point of the two head-indicators before the *boiler* sub-sub-indicator intensity is modified. Once this change is carried out, the two head-indicators are updated resulting in a 177 t CO_2-e and a 2022 GJ decrease in GHG emissions and energy consumption respectively.

Table 3: Consequences of an intensity change of a sub-sub-indicator (*boilers*) to two head-indicators (*Energy consumption* and *GHG emissions)* under a head-indicator (*Energy consumption*) influencing the other (*GHG emissions*).

Indicator	Path changed	Node changed	Old value	New value	Old path	New path	% of path ch'gd
Energy consumption	Electricity supply > Sydney University, Faculty of Science	Energy consumption - Intensity of Electricity supply	106,551 kJ/$		60,525 GJ		
Greenhouse gas emissions	Electricity supply > Sydney University, Faculty of Science	Greenhouse gas emissions - Intensity of Electricity supply	9,403 g CO2-e/$		5,341 t CO2-e		
Boilers	Electricity supply > Sydney University, Faculty of Science	Boilers - Intensity of Electricity supply	51,030 kJ/$	47,470 kJ/$	28,987 GJ	26,965 GJ	100.00%
Energy consumption	Electricity supply > Sydney University, Faculty of Science	Energy consumption - Intensity of Electricity supply	106,551 kJ/$	102,960 kJ/$	60,525 GJ	58,503 GJ	100.00%
Greenhouse gas emissions	Electricity supply > Sydney University, Faculty of Science	Greenhouse gas emissions - Intensity of Electricity supply	9,403 g CO2-e/$	9,090 g CO2-e/$	5,341 t CO2-e	5,164 t CO2-e	100.00%

To proceed to the fourth intensity change scenario, we now have to directly modify the value of the *Energy consumption* head-indicator. But this (head-)indicator is made up of sub-indicators which in turn also affect GHG emissions. Therefore, if one enters a new *Energy consumption* intensity value, no information on those sub-indicators is entered. Consequently no adjustment to the *GHG emissions* and *Energy consumption* sub- and sub-sub-indicators can be calculated.

While for the latter this is not an issue as the interesting quantity is the *Energy consumption* head indicator value *per se*, for the former however, a cross-influence issue arises. Indeed, since on the one hand *Energy consumption* affects GHG emissions and since on the other hand sub- and sub-sub-indicators cannot be adjusted, *GHG emissions* head-indicator cannot be updated.

This is the very sole configuration where such a *cross-influence* issue arises, that is to say a comprehensive update across all the head-indicator cannot be made. In the below table one can observe that first and last row are identical. That means that the change carried out under the *Energy consumption* indicator (that entailed a 3642 GJ decrease; row 2) has not affected the initial value of the path under the *GHG emissions* indicator; whereas it should have.

Table 4: Consequences of an intensity change of a head-indicator (*Energy consumption)* that directly affects another head-indicator (*GHG emissions*).

Indicator	Path changed	Node changed	Old value	New value	Old path	New path	% of path ch'gd
Greenhouse gas emissions	Electricity supply > Sydney University, Faculty of Science	Greenhouse gas emissions - Intensity of Electricity supply	9,403 g CO2-e/$		5,341 t CO2-e		
Energy consumption	Electricity supply > Sydney University, Faculty of Science	Energy consumption - Intensity of Electricity supply	106,551 kJ/$	100,040 kJ/$	60,525 GJ	56,827 GJ	100.00%
Greenhouse gas emissions	Electricity supply > Sydney University, Faculty of Science	Greenhouse gas emissions - Intensity of Electricity supply	9,403 g CO2-e/$	9,403 g CO2-e/$	5,341 t CO2-e	5,341 t CO2-e	100.00%

There are actually other scenarios possible but it always remains a corollary of the previous four instances. For example if the *indicator suite* does not comprise head-indicators with entwined sub- and/or sub-sub-indicators (e.g.: *land use* and *water use* are not correlated in any respect in the *indicator suite* chosen) no cross-influence issue will ever arise. Another instance could be the update of a sub-indicator that has at least one sub-indicator and is a sub-indicator of at least two head indicator. In that case no matter what are the relationship between the head indicators, since update are performed from bottom to top, there will never be any cross-influence issues with respect to the head-indicators. So on and so forth.

4.1.2. Transaction coefficient change

A second sinewy feature enabled by the *PXCH method* is to modify the value of a transaction coefficient along a given path. This advantage is obviously substantial with respect to previous hybridisation techniques for which such a change can only be performed at the matrix level and consequently entails irremediable system disturbance (refer to section 2.6.). However, echoing the theoretical *transaction coefficient change* section, when a coefficient in a particular supply chain is modified, this has consequences for all longer paths that at least *contain* the path originating from the very same consumer node up to the two nodes in-between which the change occurred – irrespective of the indicator (refer to section 2.6.2.2.2.).

To account for this upstream influence we resort to the *GHG emissions* indicator and to the third-order path *black coal-> electricity supply -> USyd, faculty of science*. This choice stems once again from the availability of extra process data points. However, in turn it also emphasizes that such changes can take place along any path of any length. In the previous section we explained that within their *green policy framework*, the coal-fuelled power utility that supplies electricity to the University of Sydney emits 15% less GHG than economy-wide-average power utilities, essentially because of a more efficient use of coal itself stemming from a new coal pulverization technology. More precisely their coal input path is 10.96 c/$ while the economy-wide-average path shows a coal input of 12.63 c/$. However before modifying the node 2 value of the third-order path *black coal-> electricity supply -> USyd, faculty of science* thanks to the above extra process data point, the fourth-order path *Railway freight transport services -> Black coal -> Electricity supply -> Sydney University, Faculty of Science* along which no change is carried out and consequently along which no adjustment is made (old path value equals new path value, say 1.17 t CO_2-e) is first brought up. Then the third-order path *coal-> electricity supply -> USyd, faculty of science* upon which the above extra process data point is applied at node 2 is brought up. Due to the decrease in the coal input, the (GHG emissions) value of the new path is downward-adjusted from 66.5 to 57.7 t CO_2-e. But most importantly when the fourth-order path *Railway freight transport services -> Black coal -> Electricity supply -> Sydney University, Faculty of Science* is brought up again, the old node 2 value is not anymore 12.63% as was the case when it was first brought up but *already* 10.96% which is the node 2 value entered along the third-order path *Black coal -> Electricity supply -> Sydney University, Faculty of Science* (see table below). In addition not only the coefficient value was updated but also the path value from 1.17 t CO_2-e to 1.01 t CO_2-e.

In other words, since the node 2 coefficient in the particular *Black coal -> Electricity supply -> Sydney University, Faculty of Science* supply chain has been modified, this will have consequences for all longer paths that at least *contain* the path originating from the very same consumer node (*Sydney University, Faculty of Science*) up to the two nodes in-between which the change occurred (*Black coal -> Electricity supply*) – irrespective of the indicator. This is indeed verified with the instance of the fourth-order path *Railway freight transport services -> Black coal -> Electricity supply -> Sydney University, Faculty of Science*.

Table 5: Consequences of a coefficient change (*Node 2 Black coal -> Electricity supply*) along a given path (*Black coal > Electricity supply > Sydney University, Faculty of Science*) and under a given indicator (*GHG emissions*) for a longer path (*Railway freight transport services > Black coal > Electricity supply > Sydney University, Faculty of Science*) that contains the modified path.

Indicator	Path changed	Node changed	Old value	New value	Old path	New path	% of path ch'gd
Greenhouse gas emissions	Railway freight transport services > Black coal > Electricity supply > Sydney University, Faculty of Science	Node 2 Black coal -> Electricity supply	12.63%		1.17 t CO2-e		
Greenhouse gas emissions	Black coal > Electricity supply > Sydney University, Faculty of Science	Node 2 Black coal -> Electricity supply	12.63%	10.96%	66.5 t CO2-e	57.7 t CO2-e	100.00%
Greenhouse gas emissions	Railway freight transport services > Black coal > Electricity supply > Sydney University, Faculty of Science	Node 2 Black coal -> Electricity supply	10.96%	10.96%	1.01 t CO2-e	1.01 t CO2-e	100.00%

To account for the fact that this *flow-on* effect occurs irrespective of the indicator we carried out exactly the same modifications but under the indicator *Energy consumption*. The same remarks made in the previous paragraphs still apply.

Table 6: Consequences of a coefficient change (*Node 2 Black coal -> Electricity supply*) along a given path (*Black coal > Electricity supply > Sydney University, Faculty of Science*) and under a given indicator (*Energy consumption*) for a longer path (*Railway freight transport services > Black coal > Electricity supply > Sydney University, Faculty of Science*) that contains the modified path.

Indicator	Path changed	Node changed	Old value	New value	Old path	New path	% of path ch'gd
Energy consumption	Railway freight transport services > Black coal > Electricity supply > Sydney University, Faculty of Science	Node 2 Black coal -> Electricity supply	12.63%		18.5 GJ		
Energy consumption	Black coal > Electricity supply > Sydney University, Faculty of Science	Node 2 Black coal -> Electricity supply	12.63%	10.96%	70.3 GJ	61.0 GJ	100.00%
Energy consumption	Railway freight transport services > Black coal > Electricity supply > Sydney University, Faculty of Science	Node 2 Black coal -> Electricity supply	10.96%	10.96%	16.1 GJ	16.1 GJ	100.00%

4.1.3. Change applied with a split

In every previous instance changes were affecting the whole path. However the *PXCH method* also enables applying a change to only a fraction of a path (or with a split of x %). In the following the possibility to apply a change to only a fraction of a path, be it for a coefficient or an indicator intensity, is demonstrated.

4.1.3.1. Intensity change with a split

The next milestone of USyd's *energy saving* framework is to source one tenth of its electricity from renewable from 2010 onwards. To estimate the GHG abatement due to this measure, the second-order top-ranking input path *electricity supply -> USyd, faculty of science* is brought up.

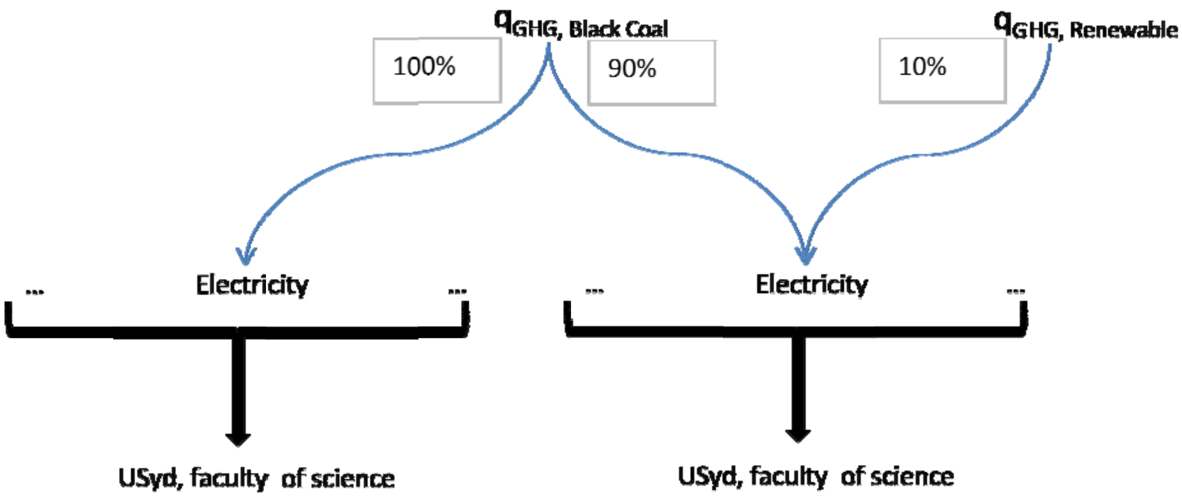

Figure 3: instance of a second-order path (*electricity supply -> USyd, faculty of science*) along which an indicator intensity is changed with a split: from a 100% *black coal* intensity (left hand side) to a 10% *renewable* and 90% *black coal* intensity (right hand side) split under the head-indicator *GHG emissions*. Boxes aside blue curved arrows represent allocated indicators intensity splits. Blue thin arrows represent the application of a particular intensity onto a given path (here *electricity supply -> USyd, faculty of science*). Remaining symbols bear the same meaning as in figure 2.

On the left hand side of the above figure electricity is solely sourced from black coal whereas, in pursuance of the USyd's *energy saving* framework (right hand side) 10% of the electricity comes from renewable, the remaining being sourced as usual. In the below table the yet unaffected path *electricity supply -> USyd, faculty of science* is listed first to show the initial state. The intensity of the sub-indicator *CO_2 from fuel combustion* is 9364 g/$ which being given the quantity of electricity required by the faculty of science and its financial turnover generates 5319 t CO_2-e. However, as prescribed by the USyd's *energy saving* framework, 10% of renewable will be resorted to to power the faculty of science in 2010. Yet it was not possible to know what equipment type and fuels will be involved in operating the renewable power plant. The value of the *CO_2 from fuel combustion* indicator, applied only to 10% of the path, was thus determined knowing that renewable plants operate on about 5% the fossil fuel input of conventional power plants, say 470 g/$.

In other words, *CO_2 from fuel combustion* intensity has been locally modified along the second-order path *electricity supply -> USyd, faculty of science* from 9364 g/$ to, on the one hand a value of 470g/$ for 10% of the path, and on the other hand, an identical value for the remaining 90% of the path. That is a new GHG emissions value for the (now split) path of $0.1 * 267 + 0.9 * 5319 = 4813.8$ t CO_2-e.

Table 7: Consequences of an indicator intensity change (*fuel combustion*) along a given path (*Electricity supply > Sydney University, Faculty of Science*) with a 10/90% split.

Indicator	Path changed	Node changed	Old value	New value	Old path	New path	% of path ch'gd
Fuel combustion	Electricity supply > Sydney University, Faculty of Science	Fuel combustion - Intensity of Electricity supply	9,364 g/$		5,319 t		100.00%
Fuel combustion	Electricity supply > Sydney University, Faculty of Science	Fuel combustion - Intensity of Electricity supply	9,364 g/$		5,319 t		90.00%
Fuel combustion	Electricity supply > Sydney University, Faculty of Science	Fuel combustion - Intensity of Electricity supply	9,364 g/$	470 g/$	5,319 t	267 t	10.00%

Note that it would have been possible to further break down the 10% renewable split into *exempli gratia* wind, solar and geothermal power (the case-study being based on an Australian facility) according to their respective share in the 10% renewable split had a more precise estimate of the renewable energy mix been known. In other words, it is theoretically possible to split *ad infinitum*.

4.1.3.2. Coefficient change with a split

Modifying a transaction coefficient upon only a fraction of a path is similar. Suppose that the University of Sydney only sources 75% of its electricity from the power utility that is engaged into the *green policy framework* described in the previous subsection. Consequently, the change (from an economy-wide-average coal input path of 12.63 c/$ to a locally coal input-path of 10.96 c/$) along the third-order path *coal-> electricity supply -> USyd, faculty of science* made in the previous section with a 100% split (first row in the below table) should have been applied to only 75% of the path (see figure below).

Table 8: Consequences of a transaction coefficient change (*Node 2 Black coal -> Electricity supply*) along a given path (*Black coal > Electricity supply > Sydney University, Faculty of Science*) under a given head-indicator (*GHG* emissions) with a 25/75%.

Indicator	Path changed	Node changed	Old value	New value	Old path	New path	% of path ch'gd
Greenhouse gas emissions	Black coal > Electricity supply > Sydney University, Faculty of Science	Node 2 Black coal -> Electricity supply	12.63%	10.96%	66.5 t CO2-e	57.7 t CO2-e	100.00%
Greenhouse gas emissions	Black coal > Electricity supply > Sydney University, Faculty of Science	Node 2 Black coal -> Electricity supply	12.63%	10.96%	66.5 t CO2-e	57.7 t CO2-e	75.00%

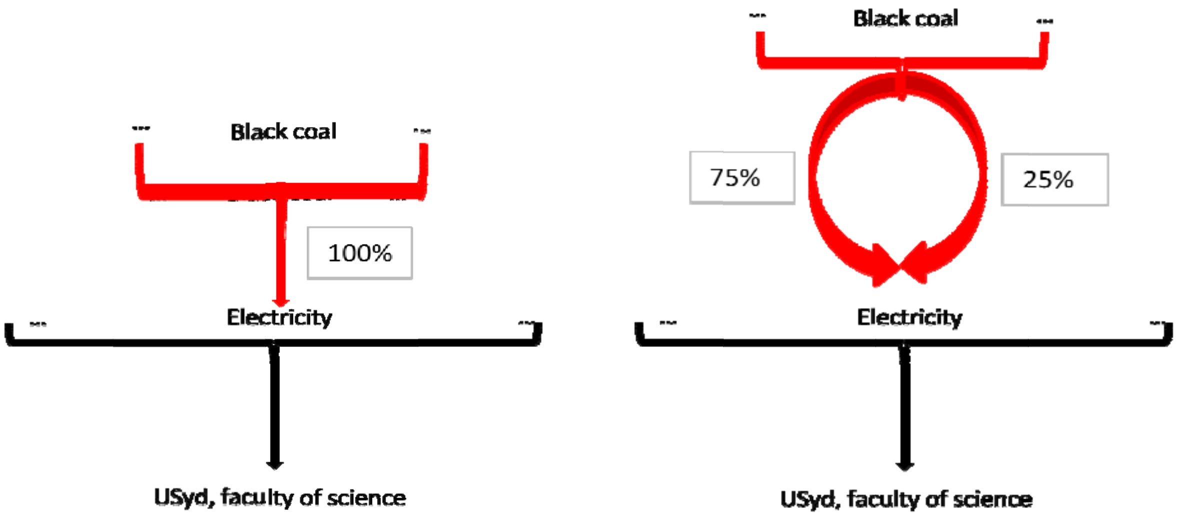

Figure 4: instance of a third-order path (*Black coal > Electricity supply > Sydney University, Faculty of Science*) along which a transaction coefficient is changed with a 25/75% split under the head-indicator *GHG emissions*. Boxes aside flows represent allocated transaction coefficient splits. Remaining symbols bear the same meaning as in figure 2.

Therefore, the practitioner enters exactly the same 10.96 c/$ value but applied with only a 75% split (second row of the below table). The new GHG emissions third-order *coal-> electricity supply -> USyd, faculty of science* path value is now $0.75 * 57.7 + 0.25 * 66.5 = 59.9$ t CO_2-e.

4.1.4. Concluding remarks

The screening of all the practicalities proffered by the *PXCH method* is now achieved. It was possible to observe the effects on the system under study of a change of an indicator intensity (along with its underlying risk to create a *cross-influence* issue), of a transaction coefficient (along with its *flow-on* effect) and finally of those two changes when applied with a split. While tables (from 1 to 8) were included to reflect the *analytical* modifications occurring at the *path* level, figures (from 3 to 4) were included to highlight the *physical* modifications occurring at the *supply-chain* level.

4.2. Interpretation of the *PXCH method* from an input-output perspective

The demonstration of the operability and capabilities of the *PXCH method* being done for transaction coefficient and indicator intensity changes, we will now linger on its interpretation from an input-output vantage point by performing an assessment of the thirteen faculties of the University of Sydney under the *indicator* suite we chose to report on (refer to section 3). The discussion will rely on the below *total-impacts* and *total-intensities* graphs in addition to tables, rankings and graphs (*commodity breakdown* tables*, ranked structural paths* tables, and *impact-by-layer* area-graphs by indicators and by faculties) to be found in appendices 5, 6 and 7 but not included here because of their sheer number.

Only bulk figures will be commented upon in the following sections whereas both bulk and intensity figures are reported on the below graphs. However if the reader wants to make his/her point from an intensity perspective instead of a bulk vantage point, he/she can resort to the *total-intensities* graphs which values simply stem from the ratio of a faculty's total embodiment (in terms of a given indicator) against its final demand (to be found in appendix 4) – rounding mistakes apart. Moreover, all the extra process data points collected in the course of that work have been included in order to refine as much as possible the granularity of the study. Besides, the rationale for interpreting the results first for the *Material flow* indicator, second for both the *Water* and *Land use* indicators, then for the *Energy consumption* indicator and finally for the *GHG emissions* indicator stems from the intricate links between the sub- and sub-sub-indicators of the aforementioned head-indicators making up the *indicator suite*. For instance *GHG emissions* are obviously a consequence of *Land use* and *Energy consumption*.

At last, and before beginning with the faculties cross-comparison *per se* we remind here that the objective of the upcoming discussion is not to compare the results of a hybrid analysis performed on the one hand with the *PXCH method* and on the other hand with standard hybridisation techniques but only to dwell on the interpretation of the former from an input-output perspective. Indeed this comparison between hybridisation techniques has already been performed by Crawford (Crawford 2008).

4.2.1. Material Flow

First of all, another rationale for commenting first upon this indicator is to double-check the allocation procedure. Indeed, that would be surprising to find *exempli gratia* some *animal food* commodities among the faculty of arts' top-ranking input-commodities or some *chemicals* among the faculty of laws' top-ranking input-commodities. Without entering into force detail, a quick glimpse to the *Material Flow commodity breakdown* tables confirms that the allocation procedure was done satisfactorily as every faculty's main input commodities are consistent with its teaching and educational purposes. For instance, some of the main commodities used by the faculty of science are *industrial machinery and equipment, electronic equipment, electrical equipment* while on the other hand the faculty of law mainly resorts to *printing and stationery, books, maps and magazines, and electronic equipment*.

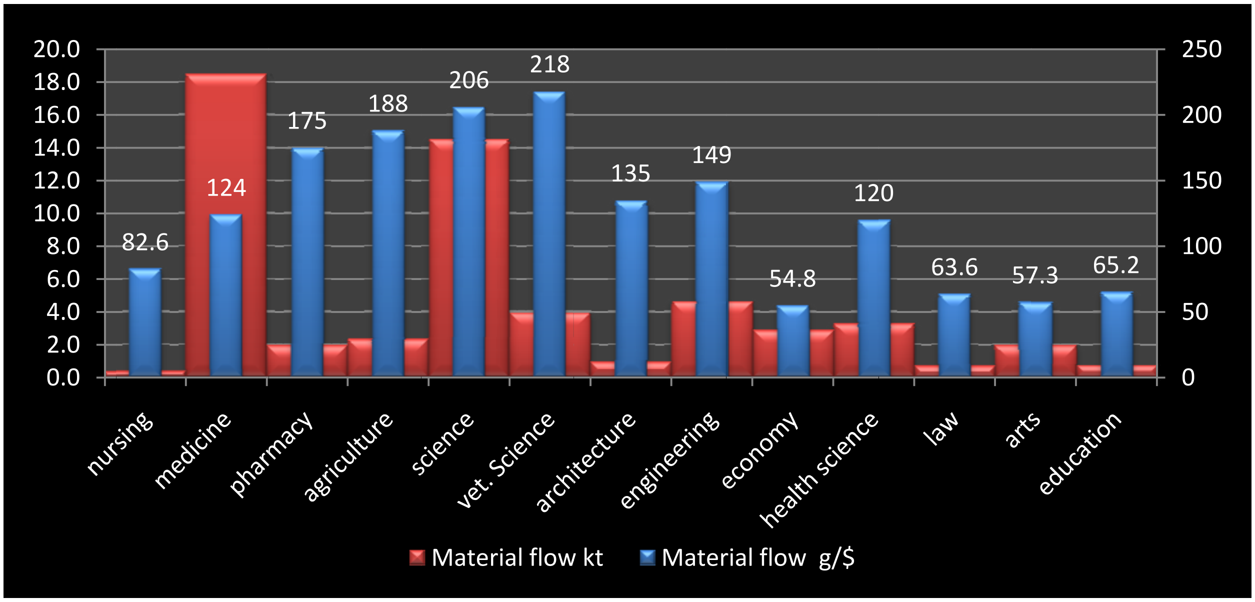

Figure 5: Faculties cross-comparison in terms of Material Flow (kt) and Material Flow Intensity (g/$)

That being said, *Material flow* which describes the mass of resources and other biomass extracted from the natural environment in order to produce industrial output (agricultural products, timber, seafood, mining products, manufactured products…) ranges from 0.4 kt/yr for the faculty of nursing to 18.5 kt/yr for the faculty of medicine, with an average value of 4.4 kt/yr across all the faculties. Only the faculties of science and engineering have higher values with 14.5 and 4.7 kt/yr respectively (see figure above).

Across all the faculties and among all the commodities consumed (refer to the *Material flow commodity breakdown* tables), *electricity* always ranks first except for the faculties of science, economy, pharmacy and medicine (for which it ranks either second or third) while *printing and stationery* is always listed among the top-ten commodities except for the faculties of medicine, engineering and science (respectively 11, 12 and 12th). In other words, the use of *electricity* and *printing and stationery* is common to every faculty and represents the bulk of their material flow, except for the faculties of medicine, science and engineering which patterns are different. This stems from the significant use of *plastic*, *glass* and *chemical products* as well as material-intensive *machineries and equipment* - commodities which are not used for teaching purposes in other faculties – in addition to the use of electricity and paper-based commodities.

The *Material flow ranked structural paths* tables logically reveals that the top-ranking input paths always begin with either *brown* or *black coal* or *soft* or *hardwoods*. Coal accounts for the *electricity* consumption (in Australia 83% of the electricity is coal-based) while woods account for the use of *paper* – the two commodities used across all the faculties. However, more than one third of the faculty of science material flow is due to coal whereas *softwoods* and *hardwoods* are not even listed among the top-twenty input paths (impact less than 0.5%) while for the faculty of economy the gap is not as substantial (23.7% for *coal* against 2.7% for *woods*).

This again reflects the intrinsic difference across faculties: apart from *electricity*, some faculties require mostly paper-based commodities (economy, arts, laws, and architecture for instances) while some others require in addition material- and energy-intensive commodities (science, medicine, agriculture, and veterinary science for instances).

Consequently, faculties resorting mainly to paper-based commodities will have proportionally a bigger material flow stemming from forestry products (paths beginning with *soft* and *hardwoods*) than would otherwise be the case for faculties that require other commodities in substantial amount. For those latter most of the top-ranking *material flow* paths will originate from mining products (paths beginning with *brown* and *black coal*). These patterns are echoed by all the faculties' *Material flow cumulative impact-by-layer* area-graphs. Indeed, most of the *Material flow* falls under the *mining* category (which includes *electricity*) and the *forestry* category (which includes *softwoods* and *hardwoods*). Furthermore, the more a faculty requires commodities other than *paper* (science, medicine and engineering for instances) the more the area pertaining to the mining category outclasses the area pertaining to the forestry category; corroborating the above.

All said and done, *material flow* across faculties is thus consistent at the meso-level (faculties' main commodities usage) and at the micro-level (faculties' main input paths) with respect to their teaching objectives.

4.2.2. Water use

Water use denotes the consumption of self-extracted and in-stream water (from rivers, lakes and aquifers, mainly extracted by farmers for irrigation) as well as mains water. Collected rainfall such as in livestock dams on grazing properties is not included. Water use across faculties ranges from 12.2 ML/yr for the faculty of nursing to 575 ML/yr for the faculty of medicine. The average value is 135 ML/yr and only the faculties of science and veterinary science along with the faculty of medicine have higher values (see figure below). There is no correlation in between the on-site water use and the overall water use. The faculty of agriculture with the biggest on-site water consumption (60 ML/yr) ranks only sixth in terms of overall water usage (102 ML/yr) while the faculties of science, veterinary science and medicine on-site water usage is at least half lower (respectively 30.2, 17.4, and 7.4 ML/yr) for an overall water consumption at least twice bigger.

Recalling what was observed in the *Material flow* section, *electricity* and *papers* are required by every faculty and for particular faculties, namely medicine, science and veterinary science and engineering, extra energy- and material-intensive commodities are also required. Referring to the *Water usage commodity breakdown* tables, water usage due to *electricity* always ranks within the top-three input commodities. Seemingly, water usage due to paper-based commodities (*printing and stationery*) is always listed among the top-ten input commodities except for the faculties of science, veterinary science and medicine (respectively 14, 16 and 20th). Besides those three faculties have the biggest water usage. Consequently water is embodied in substantial amount in the other commodities these three faculties require.

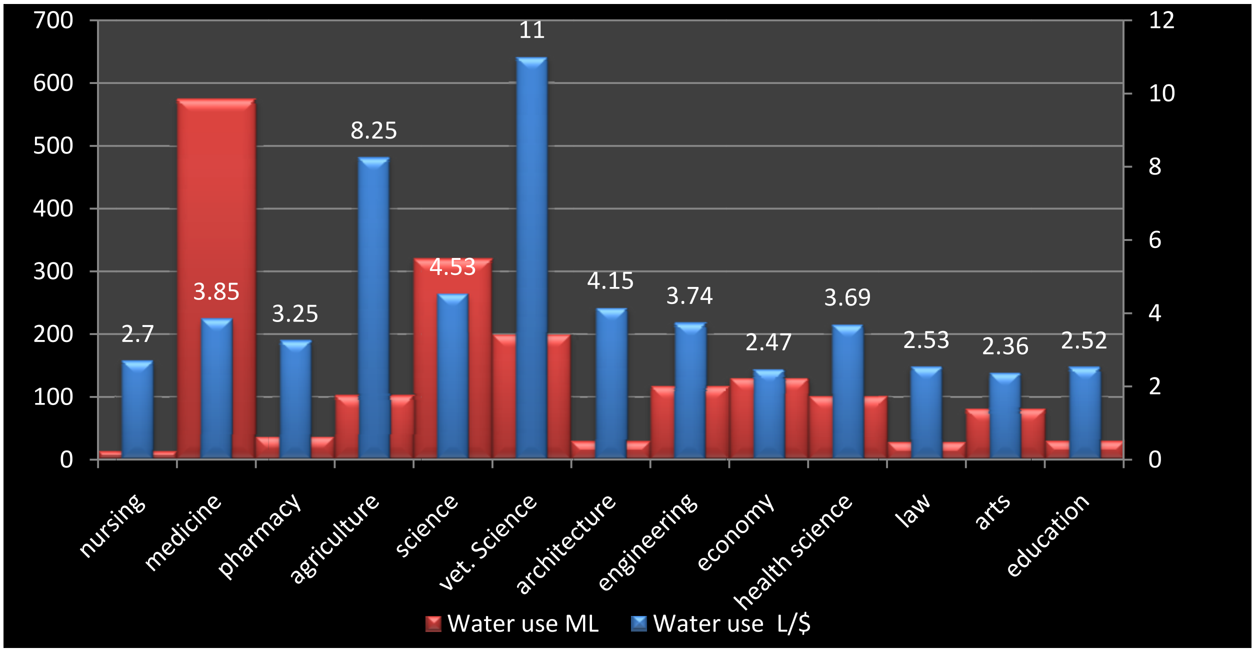

Figure 6: Faculties cross-comparison in terms of Water Use (ML) and Water Use Intensity (L/$)

For instance, half of the faculty of veterinary science total water usage is related to *agricultural*, *farm* and *animal products* (e.g.: 42.9 and 35.1 ML for respectively *hay* and *animal breeding*). For both the faculties of science and engineering, on-site water usage plus the amount of water embodied into electricity and paper-based commodities only account for a quarter of the total water requirement, entailing that 75% of their water usage is embodied into the remaining top-ranking commodities which are mainly *industrial machineries and equipment* (14.8 and 8.7 ML/yr respectively) and *electronic equipment* (11.1 and 3.7 ML/yr respectively). In contrast more than 60% of the faculty of agriculture total water usage is due to on-site water plus electricity requirement (ca 50% + 10%) implying that only ca 40% of the water usage of this faculty is embodied into other commodities.

From a micro-level of detail (refer to *Water use ranked structural paths* tables), one can observe that the on-site water usage path (first-order input-path) is always comprised in between the second and fifth top-ranking input path except for the faculty of agriculture (first top-ranking input path, 49.3% of total impact) and veterinary science (sixth top-ranking input path, 9.2% of total impact). Moreover, across the faculties, the water usage due to electricity consumption (second-order path) always ranks first except for the faculties of agriculture (second, 9.4% of total impact) and veterinary (third, 2.5% of total impact). This confirms that for the faculty of agriculture only 41.3% of the water usage is embodied into commodities while for the faculty of veterinary science this amounts to 88.3%; corroborating the above.

A look at the faculties' *Water use impact-by-layer* area-graphs confirms that in the case of the faculty of veterinary science most of the impact occurs at tier 2 (indirect impact) and stabilizes after tier 6 while for the faculty of agriculture, most of the impact occurs at tier 1 (on-site or direct impact) and stabilizes after tier 4. This corroborates the fact that for the faculty of agriculture most of the impact are on-site and near-upstream and that only a small share of its total water usage is embodied into the commodities it requires (early asymptote at tier 4 of the area-graph which entails that no substantial amount of water is used after that tier) while for the faculty of veterinary science, most of the impact are indirect (at least second order) and that a significant share of its total water usage is embodied into the commodities it requires (late asymptote, which entails that a significant amount of water is still used up to tier 6).

To conclude on the *Water usage* indicator, on-site usage is indeed a *sine qua none* condition for the overall water consumption but not a sufficient one. The faculty of agriculture is one such example. Rather this is the quantity of commodities and their underlying embodied amount of water that determine to which extent a faculty will have a substantial total water consumption. The faculty of veterinary science, with more than 88% of its water consumption embodied into the commodities it requires, is one such example. Nonetheless, its low material flow (4 kt/yr) compared to the faculties of science and medicine (14.5 and 18.5 kt/yr respectively) for a more or less equivalent share of water embodied (75% and 92% respectively) explains why these two latter faculties cap the ranking. In other words again, this is thus the quantity of the commodities required (material flow) along with the intrinsic quantity of water embodied into them that account for the variations across faculties.

4.2.3. Land Use

This indicator reflects the amount of land used because of pressure from domestic consumption and exports. It includes conservation and natural environments, production from relatively natural environments, production from dryland agriculture and plantations, production from irrigated agriculture and plantations, intensive uses, water, plus 48 sub-categories. *Land use* varies from 138 hectares for the faculty of nursing to 9600 hectares for the faculty of medicine with an average value across the faculties of 2000 hectares. Only the faculties of economy and science along with the faculty of medicine have a higher value (see figure below). On-site land usage is not correlated with the overall land usage. For instance, the faculty of science is responsible for the biggest on-site land use, yet it only accounts for half of the faculty of medicine's overall land use. Besides, whatever the faculty is, on-site land usage never exceeds more than 4% of the total land impact (refer to the *Land use ranked structural paths* tables) while on-site water usage reached 50% of the total water usage of the faculty of agriculture. Logically, it implies that at least 96% of the land usage is embodied into the commodities required by the different faculties (e.g.: to manufacture a paper-based commodity, a forest is needed in the first place). This is thus the quantity of these commodities (material flow) along with their intrinsic quantity of land embodied into it that will account for the variations amongst faculties.

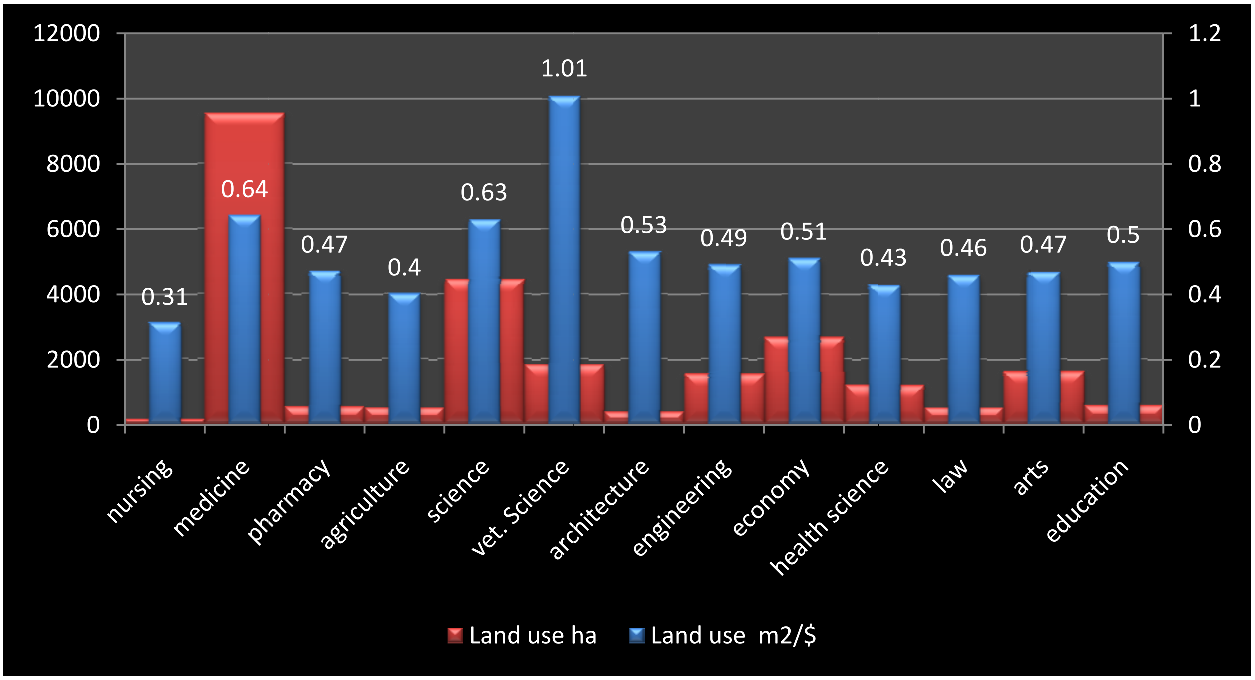

Figure 7: Faculties cross-comparison in terms of Land Use (ha) and Land Use Intensity (m2/$)

A meso-level look to the *Land use commodity breakdown* tables tells us that across all the faculties the top-two commodities are *hotels, clubs, restaurants and cafes* and *printing and stationery*. The former reflects the recreational installations offered to the members of a faculty while the latter accounts for the use of papers for teaching purposes.

Moreover, for that particular indicator, extra commodities required by some faculties for their peculiar teaching and educational purposes such as *industrial machineries and equipment* do not accentuate the differences across the faculties as they are not responsible for a significant land use. For instance, the land used by *electronic equipment* never exceeds the value of the land used for *printing and stationery;* whatever the faculty is.

Consequently, this is mainly the material flow itself rather than the commodities themselves that account for the variations across the faculties. Therefore, the pattern observed on the above graph has to be very similar to the *Material flow* indicator one; which is the case. Faculties of medicine and science top the lead while nursing brings up the rear. In between the two extremes, even if the ranking is slightly different, orders of magnitude are preserved.

A look at the faculties' *Land use cumulative impact-by-layer* area-graphs reveals that for almost every faculty, land use impact occurs mostly in between tier 3 and 4. For the faculty of science, veterinary science and medicine a substantial land use impact also occurs in between tier 3 and 4, but it is preceded by a significant one in between tier 1 and 2. This observation corroborates the *Land use ranked structural paths* tables.

Indeed, for all the faculties except these three latter ones, the top-five paths are at least fourth-order ones and begin with *beef cattle, sheep and lambs,* and *soft and hardwoods* to meet the need of the *hotels, clubs, restaurants and cafes* and *printing and stationery* commodities (which are the top-two commodities across the faculties in terms of land use; see above). For the remaining faculties, two second-order paths within the top-five input paths account for the steep impact increase from the first to the second tier. For instance, the faculty of veterinary science has two second-order paths beginning with *beef cattle* and *sheep and lamb.*

Moreover, since all these paths either begin with *beef cattle, sheep and lambs,* and *soft and hardwoods,* one expects to have *Land use cumulative impact-by-layer* area-graphs mainly covered with forestry (*hardwoods* and *softwoods* for *printing and stationery* mainly) and agriculture products (*beef cattle* and *sheep and lambs* for *hotels, clubs, restaurants and cafes*); which is the case whatever the faculty is.

All said and done, the pattern of this indicator is highly similar to the *Material flow* one. The reasons are threefold. First, top-ranking input commodities for this indicator are more or less the same across faculties (e.g.: *printing and stationery* and *hotels, clubs, restaurants and cafes* are always listed among the first top-two commodities). Second extra commodities (e.g.: *industrial machineries and equipment*) required by some faculties do not account for a significant quantity of land usage. Last on-site land use is two orders of magnitude lower than total impact (ca 1% across all the faculties).

4.2.4. Energy consumption

This indicator includes more than 480 separate components (black coal, brown coal, coke, coal byproducts, brown coal briquettes, refinery feedstock, LPG, auto gasoline-leaded, auto gasoline-unleaded, aviation gasoline, aviation turbine fuel, lighting kerosene, power kerosene, heating oil, fuel oil, petroleum products, solvents, lubricants and greases, bitumen, natural gas, town gas, solar energy, electricity…) aggregated into 28 categories that can be accounted for either at the top level (*Energy consumption*), aggregate level (e.g. *black coal*) or individual component level (e.g. *black coal, used in boilers*) if necessary. This indicator reflects the combustion of non-renewable fossil fuels. This definition covers fuels such as coal, natural gas, fuel petrol, diesel and kerosene. Items such as crude oil for refinery feedstock and wood are not included, since they are either not combusted or renewable. As a measure of non-renewable fossil fuels this indicator is crucial to an understanding of resource depletion.

Overall energy consumption varies from 7.4 TJ/yr for the faculty of nursing to 256 TJ/yr for the faculty of medicine with an average value across faculties of 68 TJ/yr. Only the faculties of engineering and science along with the faculty of medicine have a higher value. However the gap between both the faculties of medicine and science and the remaining ones is substantial; at least three times higher (see figure below).

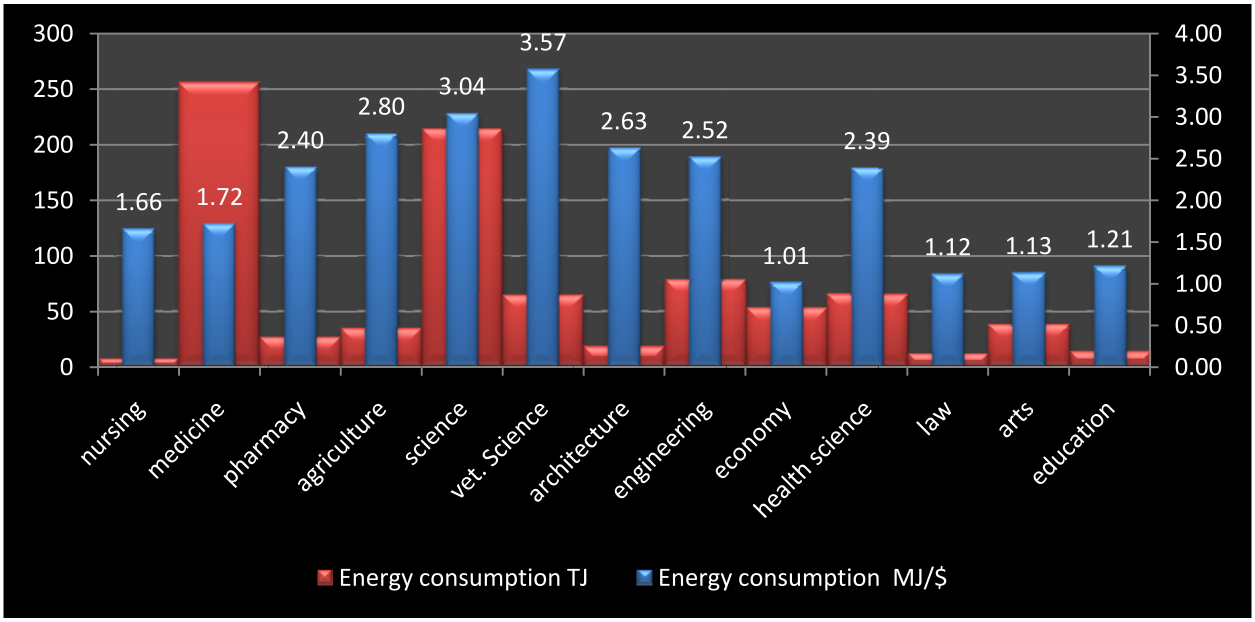

Figure 8: Faculties cross-comparison in terms of Energy Consumption (TJ) and Energy Consumption Intensity (MJ/$)

The faculty of science has the biggest on-site electricity consumption as well as the biggest on-site natural gas consumption (respectively 33.7 and 7.4 TJ/yr). For other faculties the pattern is less obvious to discern. Some faculties proportionally resort more to natural gas than to electricity (e.g.: the faculty of veterinary science consumes electricity only twice as much as natural gas) or vice versa (e.g.: the faculty of medicine consumes seven times more electricity than natural gas a year). However the main on-site electricity and natural gas consumers are the faculties of science, medicine, veterinary science and health science with respectively 41.1, 24.1, 21.9 and 16.7 TJ/yr (electricity and natural gas aggregated). Nonetheless on the above graph one can observe that these are the faculties of medicine, science and engineering that have the biggest total energy consumption. To account for the difference in between the on-site ranking and the total ranking it entails that a significant quantity of energy is embodied into the commodities required by those faculties. For instance the faculty of science with both the highest on-site natural gas and electricity consumption only ranks second on an overall basis behind medicine.

Looking at the *Energy consumption commodity breakdown* tables, *electricity* always ranks first while *printing and stationery* is always listed among the top-seven commodities except for the faculties of science and engineering (rank 16th), medicine (ranks 15th) and agriculture and pharmacy (ranks 14th and 12th). In other words, whatever the faculty is, *electricity* and *printing and stationery* account for a significant share of the overall energy consumption. But while on the one hand there are faculties which main inputs are only those (for instances architecture, law, art, education and economy) there are, on the other hand, faculties that also resort to other commodities in addition to those (for instances medicine, science and engineering require material- and energy-intensive equipments).

Consequently most of the energy used by the first category of faculties is devoted to the powering of on-site facilities and the manufacturing of paper-based commodities for teaching purposes while for the other category it only represents a share; the remaining being used to power energy-intensive equipments and/or is embodied into the extra energy-intensive commodities required (e.g.: the faculty of science consumes respectively 10.2 and 9.3 TJ a year to power *industrial machineries and equipment* and *electronic equipment* while the faculty of medicine consumes respectively 27.3, 16.4 and 15.3 TJ/yr due to energy embodied into *basic chemicals, plastics and gases*). Note that those three products the faculty of medicine requires are responsible for a bigger energy consumption than that of all the faculties but the top three ones. And this is again the material flow that accounts for the substantial gap in between the faculties of medicine and science on the one hand and the faculty of engineering on the other hand. Indeed, those three faculties all require more or less the same energy-intensive equipments and commodities. The gap can thus only stem from the difference in terms of quantity. Consequently this is the amount of energy embodied into commodities in addition to their quantity and the amount of energy used to power facilities that account for the two distinctive patterns mentioned above.

Looking at the *Energy consumption ranked structural paths* tables supplies micro details on the energy consumption across faculties. A first interesting observation is that within the top-fifteen paths returned by the SPA algorithm and across all the faculties only one is a fourth-order path (ranking 13th for the faculty of law and dealing with the supply of *electricity* to *printing and stationery* via *pulp*, *paper*, *and paperboards*). This means that most of the impact due to energy consumption occurs before tier 4 which is corroborated by every faculty's *impact-by-layer* area-graph for after this fourth tier, an asymptote springs. Moreover, whatever the faculty is, the first path is always a second-order one that deals with the direct supply of electricity to the different faculties. The percentage of impact of this particular path ranges from 14.9% for the faculty of medicine to almost 50% for the faculty of architecture, backing up the split into two groups of faculties previously evoked. The first group being the faculties that resort to energy almost entirely for powering on-site facilities and manufacturing paper-based commodities (architecture for instance, with its 50% impact only due to direct electricity supply) and the second group which requires in addition energy-intensive commodities (e.g.: medicine, with its low 14.9% impact due to direct electricity supply). This in turn confirms that the first group of faculties have a smaller share of their energy consumption embodied into the commodities they require (for instance less than 50% for the faculty of architecture) than the second group of faculties (for instance at least 85% for the faculty of medicine). In other words, the commodities required by the first group of faculties are less embodied with energy than is the case of the commodities required by the second group of faculties. These facts are also echoed by the *impact-by-layer* area-graphs; after the first tier of the faculty of architecture's *impact-by-layer* area-graph, all the area is occupied by *utilities* (i.e.: consuming directly energy). In contrast, the faculty of medicine's area-graph is covered both by direct energy consumption (*utilities*) and energy-intensive commodities such as *chemicals*, *minerals* and *metals*.

4.2.5. Greenhouse gases emissions

The combined effect of all greenhouse gases in the atmosphere is expressed in terms of the equivalent amount of carbon dioxide which would produce the same effect. The units in accordance with guidelines set out by the Intergovernmental Panel on Climate Change (IPCC 2009), greenhouse gas emissions are thus expressed in tonnes of CO_2-equivalents (CO_2-e) and calculated as a weighted sum of nominal emissions of various gas species using gas-specific global warming potentials (e.g.: 21 for (CH_4), 310 for (N_2O), 6500 for (CF_4), and 9200 for (C_2F_6)). This indicator encompasses among others CO_2, CH_4, N_2O, CO, NMVOC, PFC, SF_6, and HFC.

The bigger are the energy consumption, the land use and the material flow, the bigger are the GHG emissions. This is echoed by the *cumulative impact-by-layer* area-graphs as there is always a layer for forestry products and a layer for fuels and utilities. Likewise, the more a commodity embodied with GHG is used, the more GHG.

As a consequence one can expect to observe the same pattern for the *GHG emissions* indicator as for the *Land use*, *Energy consumption* and *Material Flow* ones; which is the case (see graph below). Indeed, GHG emissions range from 0.7 kt CO_2-e a year for the faculty of nursing to 26.5 kt CO_2-e/yr for the faculty of medicine with an average value of 7 kt CO_2-e a year across faculties. And apart from the faculties of science (20.1 kt CO_2-e a year) and medicine, emissions of the remaining faculties are under this average value.

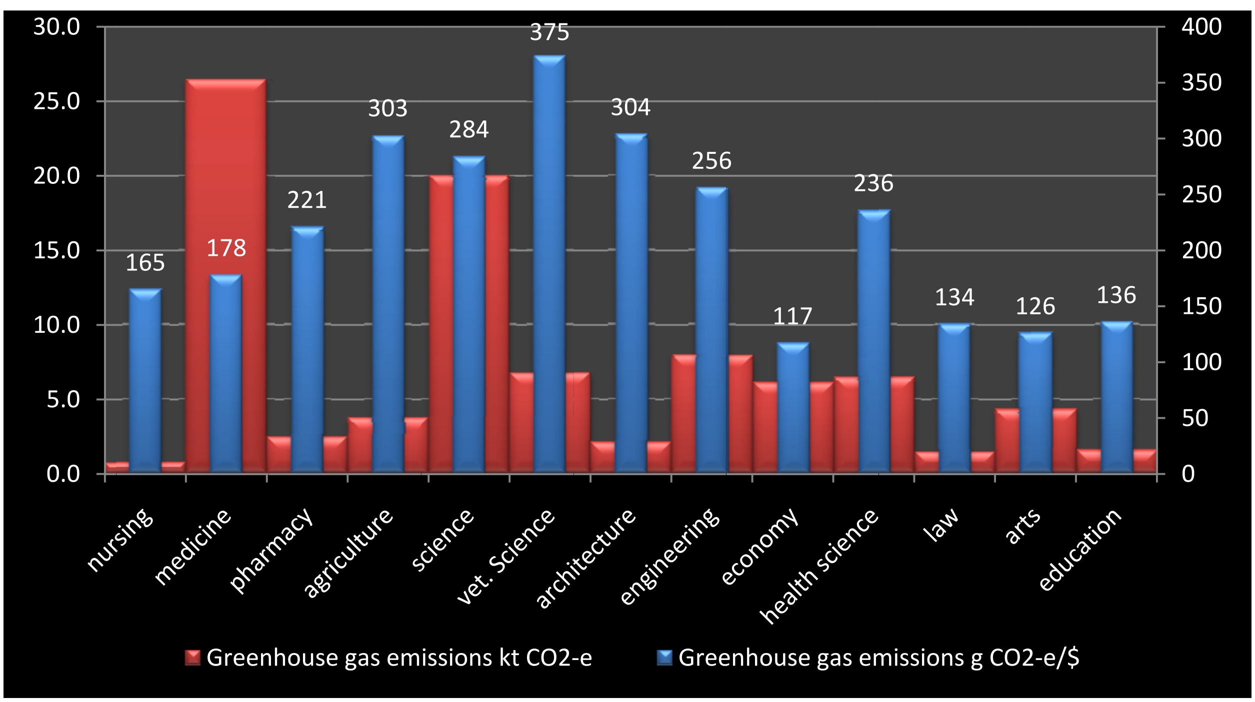

Figure 9: Faculties cross-comparison in terms of GHG emissions (kt CO_2-e) and GHG emissions Intensity (g CO_2-e/$)

Across all the faculties and among all the commodities consumed (refer to the *GHG emissions commodity breakdown* tables), *electricity* always ranks first except for the faculty of economy (for which it ranks second) while *printing and stationery* is always listed among the top-five commodities except for the faculties of science (for which it ranks seventh). In other words, *electricity* is the main GHG emitters across all the faculties. For instance, the faculty of science emits 6.3 kt CO_2-e a year just because of electricity consumption way ahead of the faculty of medicine with its 3.8 kt CO_2-e a year. This by the way confirms that the faculty of science is the biggest consumer of electricity across all the faculties.

The fact that electricity always ranks first is also backed up by the *GHG emissions ranked structural paths* tables which indicate that whatever the faculty is, the most important path is the second-order *electricity supply* path toward the faculty itself with a percentage of impact ranging from 12.2% for the faculty of medicine to 41.5% for the faculty of health science. This wide range of impact in turn tells us that like the other indicators previously commented upon a substantial share of GHG emission are embodied into commodities other than *electricity*. For instance, *glass*, *plastic* and *chemical products* consumed by the faculty of medicine are responsible for 1.2, 1.3 and 1.5 kt CO_2-e a year; which combined outclasses the GHG emissions of every faculty's electricity consumption but science (and even the GHG emissions due to electricity consumption of the faculty of medicine *per se*). Therefore, as for the previous indicators, two groups of faculties emerge. On the one hand faculties that mainly resort to *electricity* and paper-based commodities and on the other hand faculties that require in addition energy-consuming and material-intensive commodities and equipments. The latter having obviously higher bulk GHG emissions (e.g.: science and medicine). Furthermore, for the latter group, the top-ranking structural paths are third-order paths or lower (e.g.: second-order *basic chemicals* path for the faculty of medicine) indicating that the bulk of their GHG impact occurs near-upstream. In contrast, the former group of faculties often encompasses fourth- and even fifth-order paths in their top-ranking input paths; most of them beginning either with *soft* and *hardwoods* towards *printing and stationery* or with *electricity supply*. In turn it also confirms that their GHG emissions are mainly due to the use of electricity and paper-based commodities.

Looking at the *impact-by-layer* area-graphs yields the same observations. There are faculties for which GHG emissions due to electricity are proportionally more important. Obviously faculties that require mostly *electricity* and paper-based commodities and no energy-intensive and energy-consuming commodities are linked to this pattern. For instance and in contrast, the faculty of medicine area-graph is filled with many different layers (accounting for the many different commodities it requires in addition to just *electricity* and *paper*). Consequently the area occupied by electricity is proportionally smaller than would be the case for instance for the faculty of architecture which area-graph is overwhelmed by utilities (*electricity*). At last we also find the confirmation that impact due to electricity is substantial and occurs near-upstream (second-order path) since whatever the faculty is, the area occupied by electricity is at least one order of magnitude bigger than other commodities and start as soon as the first tier.

4.2.6. Concluding remarks

As explained in preamble the objective of this cross-comparison was not to validate the *PXCH method* comparing it with standard hybridisation techniques – which was already performed by Crawford (Crawford 2008) - but only to dwell on its economic interpretation from an input-output perspective.

Assessing these faculties against multi-criteria decision-tools in the optic to rank them is also beyond the scope of that work. However a ranking of the thirteen faculties for each of the indicators commented upon and this, both on an intensity and a bulk basis, can be found in appendix 8.

It is nevertheless interesting to give some conclusions. The faculty of economics (along with the faculties of arts, law, health science, nursing, pharmacy, architecture and education) only requires a small amount of energy to power out its on-site facilities and most of its teaching materials are paper-based commodities. Consequently its environmental impact remains low compared to the faculties of medicine, science, veterinary science and agriculture which require, in addition and among others, extra energy- and material-intensive commodities (e.g.: *plastics*, *chemicals*, *gases* and *machineries* and *industrial equipments*). It is thus not surprising to observe that the faculty of science (with all its equipments, machineries and sheds), the faculty of medicine (with all its laboratories and chemicals requirements), the faculty of veterinary science and agriculture (with their important on-site energy and water needs and substantial land usage) are the biggest consumers of energy, water, land and material and the biggest emitters of GHG.

At last, even if no comment were made upon the intensities figures in the main text (however their interpretation is achieved exactly the same way by dividing for a given faculty its total embodiment (in terms of a given indicator) by its final demand to be found in appendix 4) the best performing faculty from an intensity vantage point is the faculty of economics first because of a good overall environmental performance across all the indicators and second because of a substantial final demand in comparison with other faculties (arts, law, health science, nursing, pharmacy, architecture and education) that are indeed performing well on environmental grounds but have a lower final demand and thus a higher intensity. It is also interesting to note that the faculties of science and medicine hampered in the first place with a significant bulk environmental load but helped with a substantial final demand score average on an intensity basis. This is not the case for the faculty of veterinary science which suffers from both a high environmental load and a low final demand; making it the worst performing faculty within the campus of the University of Sydney on an intensity basis and this across all the indicators.

5. Conclusions

Now that the methodological and theoretical backgrounds of the *PXCH method* have been formulated, the demonstration of its operations proven and an interpretation from an input-output perspective given conclusions regarding the improvements bestowed by this hybridization method in comparison with existing ones will be presented. To do so the two current state-of-the-art hybrid LCA techniques main drawbacks and limitations from a theory and practice standpoint will briefly be reminded to highlight the culmination reached by the *PXCH method*.

Tiered hybrid LCA may suffer from double-counting incidents when the same process is instigated in both the IO and LCI data. If Strømman et al., 2009 indeed developed an algorithm that allows removing those potential double-counted incidents great care has to be taken first to avoid negative values, which could result during the netting of the input-output system in cases where the process system yields higher gross output that the input-output system (compare (Strømman, Peters et al. 2009), section 6) and second to match the prices of process and input-output commodities in order not to over- or under-adjust the input-output system. In addition the construction of the embedded database is relatively labor- and data-intensive. At last this method does not allow for a modelling of feedback loops from the process-based to the input-output-based system whereas it is important to understand that the relationship between the process-based system and the input-output based system, representing the microstructure of the commodity flows web and the wider, embedding economy, respectively, is interactive, and that an integrated model is thus required to model this interactive relation.

In contrast integrated hybrid LCA is able to capture feedback loops between the process and the input-output system thanks to the process database and its cut-off links to the economic system and does not suffer from double-counted flows. However these feedback loops are not covered at great detail in the input-output system. Likewise undertaking an hybridization with this method comes at a price of high labor and data intensity (compare Tab. 1 in (Suh and Huppes 2005)). In addition it is not straightforward, if not impossible, to couple the process-part of the integrated hybrid method directly to corporate financial accounting systems. Furthermore, in order to fully integrate a process database into an input-output table one has to estimate the sheer number of transaction coefficients between all the processes and all the input-output sectors. First, this represents a considerable and hardly automatable workload. Second, the practitioner may have very specific data on only one specific – important – input/transaction. Third, many of the coefficients to be compiled have to be estimated based on prorating. Such prorating procedures would yield the same result as economy-wide-average paths, and as such unnecessarily increase the computational and storage burden. At last, in an integrated hybrid system, the practitioner's choice is limited to what is contained in the process system, in the sense that once the practitioner chooses a purchase at the process frontier, further upstream technical coefficients and intensities cannot be altered, because they are prescribed by the process database.

And finally, from a mathematical vantage point, for both methods, an adjustment must be made without a coefficient change at the matrix level in order to not permanently change the input structure of the transaction in question, and therefore erroneously alter *all* the paths containing the respective node (Treloar 1997).

To avert those aforementioned drawbacks the *PXCH method* is designed to operate at the structural path level allowing modifying the characteristics of only a fraction of a path relating to only a particular purchase. Consequently it does not affect the global upstream characteristics whereas in a common hybrid method once a path is re-routed from the input-output system into the process system all further upstream coefficients remain in the process system. To achieve this hybridization that takes place at the highest level of detail possible for the disaggregation of the Leontief inverse the *PXCH method* relies on the top-ranking input paths listing returned by an SPA algorithm performed upon a conventional input-output analysis. Then, like the tiered hybrid adjustment method, the *PXCH method* uses this ranking to adjust the total factor inventory **Q** for a final demand bill **y**. But in contrast and in essence, whilst the tiered hybrid adjustment method operates by comparing sectors at the foreground-to-process and foreground-to-input-output frontiers and using paths only to correct overlap, the *PXCH method* operates by comparing paths at the detailed SPA level and by swapping process-based data for equivalently matching (non-overlapping) input-output data. In other words, the *PXCH method* works by replacing an economy-wide-average path with a practitioner-specific path, based on the practitioner's in-house data.

In addition to carrying out an hybridization at the highest level of detail possible and as a consequence, the *PXCH method* has the advantage that only highly-ranked, important contributions to a user's impact are followed up, and resources are not spent on unimportant items. Besides, at this level of detail (structural path) the implications of the proportionality assumption (refer to section 2.1.) can be directly assessed (Treloar 1997). Furthermore, since the practitioner is in principle able to replace any economy-wide-average path with any information whatsoever, he/she is not restricted to what process databases offer. At last, the *PXCH method* solves problems associated with ambiguous overlap between process and input-output databases and consequently avoids the need to re-distribute any double-counting towards other purchases or paths. This is achieved by managing overlap at the path level, rather than at the sector-level at the process-input-output frontier and by allowing the practitioner to replace only a fraction of a path that relates to a particular purchase.

But every cloud has its silver lining. First multipliers exchanges give birth to some issues. Second, substitution of process data for input-output-based paths that are not top-ranking may lead to a significant upward correction. Third and last cross-influence issues may arise under certain circumstances. However further research should win through the first issue, experienced practitioners through the second and third ones.

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7. Appendices

7.1. Appendix 1: Australian sector classification (ABS IOPC)

Sheep and lambs
Shorn wool
Oats, sorghum and other cereal grains
Wheat
Barley
Rice
Oilseeds
Legumes
Beef cattle
Untreated milk
Dairy cattle
Pigs
Poultry
Eggs
Vegetables
Fruit
Plant nurseries
Flowers
Grapes for wine
Horses
Deer
Animal breeding
Sugar cane
Unginned cotton
Hops
Grass seed
Hay
Natural rubber
Skins and other agricultural services
Ginned cotton
Cotton seed
Sheep shearing
Aerial agriculture
Forest products
Forestry
Softwoods
Hardwoods
Services to fishing and squid jigging
Rock lobsters
Prawns
Raw fish
Shellfish
Aquaculture
Black coal
Brown coal
Crude oil
Natural gas
LPG, LNG
Coal, oil and gas extraction
Iron ores
Non-ferrous ores
Bauxite
Copper concentrates and ores
Gold
Ilmenite and Leucoxene
Rutile
Mineral sands
Nickel ores
Lead ores
Silver and zinc ores
Tin ores
Uranium ores
Manganese ores
Gemstones, gypsum, silica
Gravel
Sand
Dimension stone
Construction materials
Limestone
Clays
Salt
Phosphate rock
Services to mining
Meat products
Fresh meat
Offal, hides, skins, blood meal
Poultry, slaughtered
Dairy products
Treated milk
Cheese
Butter oil
Butter
Vegetable products
Fruit products
Oils and fats
Rice products
Plain flour
Fodder and feed
Flour mill products
Gluten
Breakfast foods
Self-raising flour
Cakes
Pasta
Pies, cakes, biscuits
Bread and bread rolls
Confectionery
Food products
Raw sugar
Refined sugar
Fish
Lobster
Processed seafoods
Animal food
Soft drinks
Beer and malt
Spirits
Wine
Tobacco
Wool scouring
Human-made fibres
Cotton fabrics
Wool fabrics
Textile finishing
Textile products
Textile and canvas bags
Knitting mill products
Clothing
Footwear
Leather products
Sawmill products
Undressed sawn timber
Softwood woodchips
Undressed resawn timber
Hardwood woodchips
Pulp, paper and paperboard
Manufactured wood
Joinery products
Paper containers
Paper products
Printing and stationery
Trade advertising
Recorded media and publishing
Newspaper advertising
Newspapers
Periodicals
Books, maps, magazines
Petroleum and coal products
Petrol and diesel
Kerosene
Gas oil or fuel oil
Bitumen
Refinery LPG
Basic chemicals
Gases
Paints
Pesticides, insecticides and medicinal goods
Pharmaceutical goods for human use
Soap and other detergents
Cosmetics and toiletry preparations
Chemical products
Explosives and matches
Munitions
Inks
Glue
Rubber products
Tyres
Retreading strips
Plastic products
Superphosphate
Mixed fertilisers
Chemical fertilisers
Glass products
Ceramic products
Cement, lime
Ready-mixed concrete
Concrete products
Plaster boards and plaster
Non-metallic mineral products
Worked monumental or building stone
Glass fibre and glass wool products
Ground minerals
Iron and steel semi-manufactures
Non-ferrous non-aluminium semi-manufactures
Copper, silver, lead, zinc
Alumina
Aluminium
Nickel
Precious metals
Aluminium semi-manufactures
Aluminium foil
Structural metal products
Fabricated construction steel
Reinforcing rods
Aluminium doors
Architectural aluminium
Structural metal products repairing
Sheet metal products
Fabricated metal products
Firearms
Fabricated metal products repairing
Motor vehicle parts
Finished cars
Trucks
Motor vehicle repairing
Ships and boats
Ships and boat repairing
Railway equipment
Railway equipment repairing
Aircraft
Aircraft repairing
Photographic and scientific equipment
Surgical and medical
Spectacles and sunglasses
Electronic equipment
Gaming and vending machines
Household appliances
Space heaters, gas
Space heaters, electric
Domestic refrigerators
Room air conditioning
Commercial refrigerators
Clothes washing machines
Water heater, solar
Water heater, non-electric
Water heater, electric
Electrical equipment
Construction machinery
Hoists, cranes, lifting and loading machinery
Machinery for crushing, grinding, mixing
Mining or drilling machinery and parts
Elevators and escalators
Industrial machinery and equipment
Pumps
Air conditioning
Lawn mowers
Tillage, seeding, planting and fertilising equipment
Harvesting, haymaking and silage making equipment
Agricultural tractors
Irrigation equipment
Agricultural machinery and parts
Prefabricated buildings
Furniture
Wooden furniture
Sheet metal furniture
Mattresses
Miscellaneous manufacturing
Jewellerey
Advertising signs
Electricity supply
Gas supply
Water supply; sewerage and drainage services
Residential building repair and maintenance
Residential building construction
Non-residential building construction
Non-residential building repair and maintenance
Roads and bridges
Non-building construction
Non-building repair
Wholesale trade
Retail trade
Motor vehicle and lawn mower repairs
Industrial machinery repairs
Business machines and equipment repairing and services
Wholesale repair and servicing
Household electrical applicances repair and service
Retail repair and service
Hotels, clubs, restaurants and cafes
Accommodation
Road freight
Bus and tramway
Taxi and hire car
Railway freight transport services
Railway passenger transport services
Pipeline transport
Transport services
Water transport
Air and space transport
Parking services
Services to road transport
Services to water transport
Services to air transport
Travel and tourist agency services
Road freight forwarding
Forwarding agencies
Customs agencies
Storage
Overseas communication services and Pay TV
Postal services
Courier services
Domestic telecommunication services
Banking
Non-bank finance
Insurance
Life insurance
Health insurance
Public liability
Security broking and dealing
Services to finance and investment
Services to insurance
Ownership of dwellings
Property services
Property operator and developer services
Real estate agent services
Motor vehicle hire
Plant leasing, hiring and renting services
Computer and technical services
Research and meteorology services
Architectural services
Surveying services
Technical services
Data processing services
Legal services
Accounting services
Advertising services
Market research and other business management services
Employment placement
Typing, copying and mailing
Security and investigation
Pest control
Cleaning
Packing
Collecting and credit reporting
Business services
Judicial services
Federal government
State government
Local government
Defence
Education
GPs, dentists, optometrists, ambulance
Hospitals and nursing homes
Community health centres
Veterinary services
Motion pictures
Radio and television stations
Library, museum and art gallery services
Parks, botanical gardens and zoos
Music and theatre production
Creative arts
News reporting
Entertainment
Lottery
Gambling
TAB agencies
Sport and recreation services (incl horse and dog racing, sports grounds, services)
Personal services
Photographic film processing
Community services and religious organisations
Interest groups and community organisations
Police
Corrective centres
Fire brigade
Sanitary and garbage disposal
Wages and salaries
Gross operating surplus
Taxes on products
Taxes on production
Decreases in inventories
Competing Imports

7.2.Appendix 2: Faculty-level classification (80 entities)

Office of Provost(51000_OFFICE_PROVOST)
Faculty of Dentistry(E0000_DENTISTRY)
Faculty of Nursing(G0000_NURSING)
Faculty of Medicine(K0000_MEDICINE)
Faculty of Pharmacy(Q0000_PHARMACY)
Faculty of Agriculture(B0000_AGRICULTURE)
Faculty of Science(L0000_SCIENCE)
Faculty of Vet Science(N0000_VET_SCIENCE)
Faculty of Architecture(C0000_ARCHITECTURE)
Faculty of Engineering(H0000_ENGINEERING)
Conservatorium(Y0000_CONSERVATORIUM)
Faculty of Economics(F0000_ECONOMICS)
Graduate School of Business(W0000_GSB)
Faculty of Health Sciences(S0000_HEALTH_SCIENCE)
Cumberland Campus(S4000_CUMB_CAMPUS)
Faculty of Law(J0000_LAW)
Faculty of Arts(D0000_ARTS)
College of Arts(V0000_COLLEGE_ARTS)
Faculty of Edu & Social Work(X0000_EDUCATION)
Centres(54000_CENTRES)
DVC International Office(61100_DVC_INTNTL_OFF)
International Institute(61200_INT_INST)
International Networks(61300_INT_NTWKS)
International Services(61400_INT_SERVS)
Inactive International(42000_INACT_INT)
International Uni Wide Costs(61500_DVC_INT_UWC)
The Private College(71000_PRIVATE_COLL)
Senior Staff Development(72000_SEN_STF_DEV)
Quality Assurance(73000_QUALITY_ASSUR)
Office DVC CEO Uni College Syd(74000_OFF_DVC_CEO_UC)
Uni College Business Units(75000_DVC_CEO_UN_BU)
Ctre for Continuing Education(43300_CTRE_CONT_EDU)
Central Accounts(CENTRAL_ACCOUNTS)
Office of DVC and COO(24000_OFF_OF_DVC_COO)
Audit, Risk Mgt and Assurance(20100_AUDIT_RISK_MGT)
Sydnovate(44200_SYDNOVATE)
Campus Property and Services(27000_CPS)
Chief Financial Officer(24010_CFO)
ICT Inform & Comms Technology(65000_ICT_INF_CM_TCH)
Procurement Shared Services(29000_PROC_SHRD_SERV)
Strategy Implem Sustain Plan(23000_STRAT_SUST_PLN)
Sydney Talent Inc Uni RC(10060_SYDTAL_INC_UNI)
DVC Infrastrcture 2006 & Prior(10010_DVC_INF_EX)
VC and Senior Exec(28000_VC_&_SE)
Office of General Counsel(25000_GEN_COUNSEL)
Human Resources(69000_HR)
Director Goverment Relations(28040_DIR_GOVT_REL)
Director of Planning(28050_DIR_PLANNING)
Media Manager(28060_VC_MEDIA)
Secretary to the Senate(28070_SECR_SENATE)
Office of DVC Community(30100_OFF_DVC_COMM)
Marketing & Communication(32000_MRKT_COMM)
Alumni & Community Engagement(34000_ALUM_COMM_ENG)
Philanthropy and Development(35000_PHILANTH_DEVEL)
Museums & Cultural Engagement(36000_MUS_CULT_ENGN)
UWC CPT Holding(39000_UWC_CPT_HLD)
Community Foundations(37000_COMM_FNDNS)
Ex Community(39900_EX_COMM)
DVC Research Allocation(44800_DVC_RSCH_ALLOC)
Funding for Distribution(44020_FND_FOR_DIST)
Research Operating(44030_RSCH_OP)
Cross Faculty Departments(44040_CROSS_FAC_DEPT)
Microscopy Unit(44050_MICROSC_UNIT)
External Research Scholarships(44060_EXT_RSCH_SCHIP)
Institutes(44600_INSTITUTES)
Rsch & Innovation Operating(44000_RES_INNOV_OPER)
University Library(68000_UNI_LIBRARY)
Learning and Teaching(62000_LEARN_TEACH)
Voluntary Students Union(31000_VSU)
Scholarships Unit(62100_AWARDS_SSHIPS)
Student Admnistratn & Support(33000_SAS)
Student Markting & Recruitment(32200_STUD_MRKT_RECR)
Equity Support(39100_EQUITY_SUPPORT)
Dean of Graduate Studies(44500_DEAN_GRAD_STUD)
DVC Education Uni Wide Costs(20500_DVCE_UWC)
Indigenous Education(20600_INDIGENOUS_ED)
DVC Education Foundations(20700_DVCE_FNDNS)
ARMS & Secretariat(64000_ARMS_&_SECRETA)
Loans, Scholarships, Bursaries(20800_LOANS_SS_BURS)

7.3. Appendix 3: Account-level classification (9 entities)

DEPT_OP_PJ
SPECIFIC_OPERATING_PJ
CAPITAL_PLANS_PJ
RSCH_&_INNOV_PJ
EARMARKED_GTS_SSHIPS_PJ
COMMER_&_INVEST_PJ
CONSULT_OUTSIDE_EARN_PJ
DON_BEQ_CPT_PZ_SSHIP_PJ
22222_P_PJ

7.4. Appendix 4: 2008 faculties' on-site environmental data, total revenues and expenditures and final demand

	Electricity (GWh)	Electricity (TJ)	Natural Gas (TJ)	Water (ML)	Land Use (ha)	Total expenditure (M$)	Total revenue (M$)	final demand (M$)
Faculty of Nursing	0.40	1.45	0.47	2.07	0.48	7.61	2.79	2.07
Faculty of Medicine	5.85	21.08	2.96	17.37	3.66	278.64	223.81	146.28
Faculty of Pharmacy	0.84	3.04	0.13	0.02	0.53	19.83	14.44	9.94
Faculty of Agriculture	1.53	5.49	0.34	60.32	1.58	23.70	17.75	11.34
Faculty of Science	9.36	33.71	7.40	30.55	4.38	125.45	77.05	52.64
Faculty of Vet Science	4.09	14.72	7.18	7.29	2.68	41.21	30.33	15.98
Faculty of Architecture	1.16	4.16	0.00	1.92	0.05	11.37	5.71	4.25
Faculty of Engineering	3.97	14.30	2.25	9.62	2.64	62.30	39.30	5.41
Faculty of Economics	1.50	5.39	0.59	5.11	1.30	88.01	69.29	52.02
Faculty of Health Sciences	3.66	13.18	3.48	11.86	2.35	49.34	27.50	18.91
Faculty of Law	0.39	1.41	0.00	2.24	0.30	17.96	12.02	9.15
Faculty of Arts	1.21	4.37	0.42	2.86	1.07	63.05	27.71	18.86
Faculty of Education	0.72	2.60	0.05	0.84	0.70	20.35	7.63	5.41

Note that financial data are given in Australian dollar.

7.5. Appendix 5: *Commodity Breakdown* tables by faculties and by indicators

7.5.1. Commodity Breakdown across faculties for the Material Flow Indicator

Material Flow	Education and social work		Arts		Law		Health science		Economy		Engineering		Architecture	
Rank	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Electricity supply	240 t	Electricity supply	401 t	Electricity supply	150 t	Electricity supply	1,485 t	Hotels, clubs, restaurants and cafes	594 t	Electricity supply	1,178 t	Electricity supply	437 t
2	Hotels, clubs, restaurants and cafes	125 t	Hotels, clubs, restaurants and cafes	348 t	Accommodation	109 t	Printing and stationery	218 t	Electricity supply	532 t	Electronic equipment	319 t	Printing and stationery	64.4 t
3	Printing and stationery	64.7 t	Accommodation	195 t	Printing and stationery	97.8 t	Hotels, clubs, restaurants and cafes	178 t	Accommodation	244 t	Industrial machinery and equipment	318 t	Hotels, clubs, restaurants and cafes	62.5 t
4	Accommodation	63.3 t	Air and space transport	162 t	Hotels, clubs, restaurants and cafes	96.9 t	Accommodation	157 t	Printing and stationery	222 t	Gases	307 t	Electronic equipment	40.7 t
5	Air and space transport	35.5 t	Printing and stationery	118 t	Air and space transport	39.4 t	Electronic equipment	99.9 t	Air and space transport	177 t	Hotels, clubs, restaurants and cafes	247 t	Plant leasing, hiring and renting services	39.6 t
6	Plant leasing, hiring and renting services	26.7 t	Electronic equipment	95.2 t	Electronic equipment	28.2 t	Industrial machinery and equipment	88.6 t	Electronic equipment	121 t	Fabricated construction steel	193 t	Computer and technical services	32.4 t
7	Electronic equipment	17.1 t	Books, maps, magazines	67.3 t	Property services	25.3 t	Basic chemicals	82.2 t	Advertising services	116 t	Electrical equipment	179 t	Accommodation	28.2 t
8	Education	16.3 t	Bus and tramway	47.0 t	Books, maps, magazines	22.5 t	Air and space transport	79.9 t	Computer and technical services	112 t	Basic chemicals	155 t	Air and space transport	25.9 t
9	Petroleum and coal products	13.3 t	State government	38.4 t	Petroleum and coal products	17.6 t	Petroleum and coal products	67.7 t	Plant leasing, hiring and renting services	66.8 t	Accommodation	137 t	Plastic products	14.9 t
10	State government	12.8 t	Advertising services	33.7 t	Advertising services	13.0 t	Plastic products	65.1 t	Books, maps, magazines	56.1 t	Wholesale trade	131 t	Basic chemicals	14.8 t

Material Flow	**Veterinary science**		**Science**		**Agriculture**		**Pharmacy**		**Medicine**		**Nursing**	
Rank	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Electricity supply	1,034 t	Glass products	3,199 t	Electricity supply	539 t	Glass products	354 t	Glass products	2,314 t	Electricity supply	149 t
2	Basic chemicals	376 t	Electricity supply	2,946 t	Petroleum and coal products	209 t	Electricity supply	284 t	Basic chemicals	2,142 t	Printing and stationery	33.8 t
3	Petroleum and coal products	272 t	Gases	957 t	Glass products	199 t	Industrial machinery and equipment	200 t	Electricity supply	1,788 t	Accommodation	20.0 t
4	Plastic products	256 t	Industrial machinery and equipment	946 t	Industrial machinery and equipment	131 t	Basic chemicals	177 t	Plastic products	1,455 t	Plant leasing, hiring and renting services	19.3 t
5	Gases	191 t	Basic chemicals	713 t	Basic chemicals	83.6 t	Plastic products	124 t	Industrial machinery and equipment	1,186 t	Hotels, clubs, restaurants and cafes	18.6 t
6	Animal food	182 t	Hotels, clubs, restaurants and cafes	596 t	Plastic products	70.4 t	Gases	113 t	Hotels, clubs, restaurants and cafes	724 t	Air and space transport	16.9 t
7	Hotels, clubs, restaurants and cafes	123 t	Electronic equipment	541 t	Electrical equipment	68.1 t	Electrical equipment	94.9 t	Electrical equipment	594 t	Petroleum and coal products	15.6 t
8	Wholesale trade	123 t	Plastic products	513 t	Accommodation	67.1 t	Hotels, clubs, restaurants and cafes	62.6 t	Non-residential building repair and maintenance	592 t	Basic chemicals	14.7 t
9	Printing and stationery	111 t	Electrical equipment	489 t	Printing and stationery	63.4 t	Printing and stationery	54.0 t	Community health centres	546 t	Advertising services	13.1 t
10	Plant leasing, hiring and renting services	102 t	Petroleum and coal products	402 t	Industrial machinery repairs	56.0 t	Wholesale trade	52.3 t	Electronic equipment	546 t	Electronic equipment	3.7 t

7.5.2. Commodity Breakdown across faculties for the Water Use Indicator

Water use	Education and social work		Arts		Law		Health science		Economy		Engineering	
Rank	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Hotels, clubs, restaurants and cafes	11.1 ML	Hotels, clubs, restaurants and cafes	31.0 ML	Hotels, clubs, restaurants and cafes	8.63 ML	Electricity supply	30.6 ML	Hotels, clubs, restaurants and cafes	52.9 ML	Electricity supply	24.3 ML
2	Electricity supply	4.96 ML	Electricity supply	8.27 ML	Accommodation	4.08 ML	Hotels, clubs, restaurants and cafes	15.9 ML	Electricity supply	11.0 ML	Hotels, clubs, restaurants and cafes	22.0 ML
3	Accommodation	2.38 ML	Accommodation	7.31 ML	Electricity supply	3.10 ML	Sydney University, Faculty of Health Sciences	10.7 ML	Accommodation	9.18 ML	Electronic equipment	8.71 ML
4	Printing and stationery	1.33 ML	Air and space transport	2.89 ML	Sydney University, Faculty of Law	2.23 ML	Accommodation	5.91 ML	Advertising services	6.52 ML	Sydney University, Faculty of Engineering	7.68 ML
5	Plant leasing, hiring and renting services	1.25 ML	Electronic equipment	2.60 ML	Printing and stationery	2.01 ML	Printing and stationery	4.49 ML	Computer and technical services	5.89 ML	Accommodation	5.13 ML
6	Sydney University, Faculty of Edu & Social Work	0.78 ML	Sydney University, Faculty of Arts	2.55 ML	Property services	1.16 ML	Computer and technical services	2.98 ML	Sydney University, Faculty of Economics	5.02 ML	Education	4.82 ML
7	Education	0.73 ML	Printing and stationery	2.42 ML	Electronic equipment	0.77 ML	Electronic equipment	2.73 ML	Printing and stationery	4.56 ML	Wholesale trade	3.77 ML
8	Air and space transport	0.63 ML	Advertising services	1.89 ML	Advertising services	0.73 ML	Education	2.63 ML	Interest groups and community organisations	3.69 ML	Industrial machinery and equipment	3.72 ML
9	Water supply; sewerage and drainage services	0.60 ML	Books, maps, magazines	1.74 ML	Air and space transport	0.70 ML	Plant leasing, hiring and renting services	1.96 ML	Electronic equipment	3.30 ML	Printing and stationery	2.61 ML
10	State government	0.49 ML	Computer and technical services	1.59 ML	Books, maps, magazines	0.58 ML	Advertising services	1.77 ML	Air and space transport	3.15 ML	Electrical equipment	2.41 ML

Water use	Architecture		Veterinary science		Science		Agriculture		Pharmacy		Medicine		Nursing	
Rank	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Electricity supply	9.01 ML	Hay	42.9 ML	Electricity supply	60.8 ML	Sydney University, Faculty of Agriculture	50.4 ML	Electricity supply	5.87 ML	Hotels, clubs, restaurants and cafes	64.5 ML	Electricity supply	3.08 ML
2	Hotels, clubs, restaurants and cafes	5.56 ML	Animal breeding	35.1 ML	Hotels, clubs, restaurants and cafes	53.0 ML	Electricity supply	11.1 ML	Hotels, clubs, restaurants and cafes	5.58 ML	Animal breeding	40.1 ML	Sydney University, Faculty of Nursing	2.01 ML
3	Sydney University, Faculty of Architecture	1.87 ML	Electricity supply	21.3 ML	Sydney University, Faculty of Science	27.3 ML	Grass seed	5.30 ML	Industrial machinery and equipment	2.34 ML	Electricity supply	36.9 ML	Hotels, clubs, restaurants and cafes	1.66 ML
4	Plant leasing, hiring and renting services	1.85 ML	Hotels, clubs, restaurants and cafes	11.0 ML	Electronic equipment	14.8 ML	Hotels, clubs, restaurants and cafes	4.60 ML	Plastic products	1.76 ML	Deer	35.4 ML	Plant leasing, hiring and renting services	0.90 ML
5	Computer and technical services	1.70 ML	Animal food	7.82 ML	Education	12.3 ML	Animal breeding	3.66 ML	Wholesale trade	1.50 ML	Dairy cattle	31.3 ML	Accommodation	0.75 ML
6	Printing and stationery	1.33 ML	Dairy cattle	6.58 ML	Glass products	11.2 ML	Accommodation	2.52 ML	Electrical equipment	1.28 ML	Hospitals and nursing homes	21.1 ML	Advertising services	0.74 ML
7	Electronic equipment	1.11 ML	Deer	5.56 ML	Industrial machinery and equipment	11.1 ML	Water supply; sewerage and drainage services	1.79 ML	Education	1.26 ML	Plastic products	20.7 ML	Printing and stationery	0.69 ML
8	Accommodation	1.06 ML	Plant nurseries	5.15 ML	Accommodation	10.6 ML	Industrial machinery and equipment	1.53 ML	Glass products	1.24 ML	Community health centres	18.5 ML	Electronic equipment	0.32 ML
9	Air and space transport	0.46 ML	Sydney University, Faculty of Vet Science	5.02 ML	Wholesale trade	9.10 ML	Electronic equipment	1.45 ML	Accommodation	1.20 ML	Pigs	17.8 ML	Air and space transport	0.30 ML
10	Wholesale trade	0.36 ML	Plant leasing, hiring and renting services	4.75 ML	Plastic products	7.31 ML	Printing and stationery	1.30 ML	Printing and stationery	1.11 ML	Horses	16.7 ML	Computer and technical services	0.19 ML

7.5.3. Commodity Breakdown across faculties for the Land Use Indicator

Land use	Education and social work		Arts		Law		Health science		Economy		Engineering	
Rank	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Hotels, clubs, restaurants and cafes	399 ha	Hotels, clubs, restaurants and cafes	1,109 ha	Hotels, clubs, restaurants and cafes	309 ha	Hotels, clubs, restaurants and cafes	568 ha	Hotels, clubs, restaurants and cafes	1,896 ha	Hotels, clubs, restaurants and cafes	787 ha
2	Printing and stationery	46.6 ha	Printing and stationery	84.8 ha	Printing and stationery	70.4 ha	Printing and stationery	157 ha	Printing and stationery	160 ha	Printing and stationery	91.4 ha
3	Accommodation	15.6 ha	Books, maps, magazines	59.9 ha	Accommodation	26.8 ha	Accommodation	38.8 ha	Advertising services	89.0 ha	Retail trade	62.4 ha
4	Plant leasing, hiring and renting services	9.47 ha	Accommodation	48.0 ha	Books, maps, magazines	20.0 ha	Beef cattle	35.4 ha	Computer and technical services	69.8 ha	Electronic equipment	54.9 ha
5	Books, maps, magazines	8.81 ha	Advertising services	25.8 ha	Advertising services	9.96 ha	Computer and technical services	35.3 ha	Accommodation	60.3 ha	Wholesale trade	53.6 ha
6	Parks, botanical gardens and zoos	8.56 ha	Air and space transport	25.3 ha	Property services	9.09 ha	Education	24.2 ha	Books, maps, magazines	49.9 ha	Education	44.4 ha
7	Education	6.74 ha	Computer and technical services	18.8 ha	Recorded media and publishing	6.52 ha	Advertising services	24.1 ha	Interest groups and community organisations	36.0 ha	Accommodation	33.7 ha
8	State government	5.59 ha	State government	16.7 ha	Air and space transport	6.14 ha	Wholesale trade	20.5 ha	Air and space transport	27.6 ha	Parks, botanical gardens and zoos	27.5 ha
9	Air and space transport	5.52 ha	Electronic equipment	16.4 ha	Sydney University, Faculty of Law	5.28 ha	Retail trade	19.3 ha	Plant leasing, hiring and renting services	23.6 ha	Computer and technical services	26.5 ha
10	Sydney University, Faculty of Edu & Social Work	5.29 ha	Accounting services	14.9 ha	Electronic equipment	4.86 ha	Electronic equipment	17.2 ha	Electronic equipment	20.8 ha	Industrial machinery and equipment	20.1 ha

Land use	Architecture		Veterinary science		Science		Agriculture		Pharmacy		Medicine		Nursing	
Rank	Commodity	impa ct	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Hotels, clubs, restaurants and cafes	199 ha	Beef cattle	400 ha	Hotels, clubs, restaurants and cafes	1,900 ha	Hotels, clubs, restaurants and cafes	165 ha	Hotels, clubs, restaurants and cafes	200 ha	Beef cattle	2,549 ha	Hotels, clubs, restaurants and cafes	59.4 ha
2	Printing and stationery	46.4 ha	Hotels, clubs, restaurants and cafes	393 ha	Beef cattle	522 ha	Printing and stationery	45.6 ha	Printing and stationery	38.9 ha	Hotels, clubs, restaurants and cafes	2,310 ha	Printing and stationery	24.3 ha
3	Computer and technical services	20.1 ha	Sheep and lambs	194 ha	Sheep and lambs	253 ha	Retail trade	23.5 ha	Retail trade	31.2 ha	Sheep and lambs	1,236 ha	Advertising services	10.0 ha
4	Plant leasing, hiring and renting services	14.0 ha	Animal food	135 ha	Printing and stationery	207 ha	Wholesale trade	18.1 ha	Beef cattle	22.3 ha	Printing and stationery	365 ha	Plant leasing, hiring and renting services	6.83 ha
5	Electronic equipment	7.02 ha	Printing and stationery	79.8 ha	Retail trade	164 ha	Accommodation	16.6 ha	Wholesale trade	21.3 ha	Plastic products	214 ha	Sydney University, Faculty of Nursing	5.31 ha
6	Accommodation	6.97 ha	Wholesale trade	50.3 ha	Wholesale trade	129 ha	Parks, botanical gardens and zoos	10.5 ha	Plastic products	18.2 ha	Retail trade	200 ha	Accommodation	4.94 ha
7	Wholesale trade	5.06 ha	Animal breeding	44.4 ha	Education	113 ha	Plastic products	10.4 ha	Basic chemicals	16.4 ha	Basic chemicals	199 ha	Air and space transport	2.63 ha
8	Sydney University, Faculty of Architecture	4.92 ha	Plastic products	37.6 ha	Electronic equipment	93.2 ha	Advertising services	9.16 ha	Industrial machinery and equipment	12.6 ha	Wholesale trade	191 ha	Computer and technical services	2.26 ha
9	Advertising services	4.23 ha	Plant leasing, hiring and renting services	36.0 ha	Animal food	91.0 ha	Electronic equipment	9.15 ha	Education	11.6 ha	Community health centres	134 ha	Electronic equipment	2.02 ha
10	Paper products	4.13 ha	Basic chemicals	34.9 ha	Plastic products	75.4 ha	Plant leasing, hiring and renting services	8.97 ha	Sheep and lambs	10.8 ha	Hospitals and nursing homes	132 ha	Wholesale trade	3.79 a

7.5.4. Commodity Breakdown across faculties for the Energy Consumption Indicator

Energy Consumption	Education and social work		Arts		Law		Health science		Economy		Engineering	
Rank	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Electricity supply	5,587 GJ	Electricity supply	9,323 GJ	Electricity supply	3,493 GJ	Electricity supply	34,544 GJ	Electricity supply	12,372 GJ	Electricity supply	27,415 GJ
2	Air and space transport	1,603 GJ	Air and space transport	7,339 GJ	Air and space transport	1,783 GJ	Air and space transport	3,612 GJ	Air and space transport	8,007 GJ	Electronic equipment	5,452 GJ
3	Hotels, clubs, restaurants and cafes	1,440 GJ	Hotels, clubs, restaurants and cafes	3,999 GJ	Accommodation	1,466 GJ	Sydney University, Faculty of Health Sciences	3,437 GJ	Hotels, clubs, restaurants and cafes	6,835 GJ	Air and space transport	4,195 GJ
4	Accommodation	854 GJ	Accommodation	2,626 GJ	Hotels, clubs, restaurants and cafes	1,114 GJ	Printing and stationery	2,473 GJ	Accommodation	3,298 GJ	Industrial machinery and equipment	3,436 GJ
5	Printing and stationery	734 GJ	Bus and tramway	2,433 GJ	Printing and stationery	1,109 GJ	Accommodation	2,123 GJ	Printing and stationery	2,513 GJ	Wholesale trade	3,222 GJ
6	Bus and tramway	482 GJ	Electronic equipment	1,629 GJ	Electronic equipment	483 GJ	Hotels, clubs, restaurants and cafes	2,048 GJ	Electronic equipment	2,064 GJ	Gases	3,182 GJ
7	Plant leasing, hiring and renting services	348 GJ	Printing and stationery	1,335 GJ	Property services	338 GJ	Electronic equipment	1,709 GJ	Bus and tramway	2,043 GJ	Hotels, clubs, restaurants and cafes	2,839 GJ
8	Education	334 GJ	Road freight	1,076 GJ	Books, maps, magazines	244 GJ	Wholesale trade	1,229 GJ	Advertising services	1,744 GJ	Sydney University, Faculty of Engineering	2,336 GJ
9	Electronic equipment	293 GJ	Books, maps, magazines	730 GJ	Bus and tramway	217 GJ	Education	1,202 GJ	Computer and technical services	1,626 GJ	Education	2,200 GJ
10	Wholesale trade	207 GJ	Taxi and hire car	665 GJ	Wholesale trade	211 GJ	Basic chemicals	1,048 GJ	Taxi and hire car	1,330 GJ	Electrical equipment	2,061 GJ

Energy Consumption	Architecture		Veterinary science		Science		Agriculture		Pharmacy		Medicine		Nursing	
Rank	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Electricity supply	10,158 GJ	Electricity supply	24,054 GJ	Electricity supply	68,552 GJ	Electricity supply	12,541 GJ	Electricity supply	6,616 GJ	Electricity supply	41,598 GJ	Electricity supply	3,469 GJ
2	Air and space transport	1,171 GJ	Sydney University, Faculty of Vet Science	6,200 GJ	Glass products	21,129 GJ	Air and space transport	1,820 GJ	Glass products	2,336 GJ	Basic chemicals	27,299 GJ	Air and space transport	763 GJ
3	Printing and stationery	731 GJ	Basic chemicals	4,793 GJ	Air and space transport	11,968 GJ	Bus and tramway	1,698 GJ	Basic chemicals	2,251 GJ	Plastic products	16,443 GJ	Sydney University, Faculty of Nursing	523 GJ
4	Hotels, clubs, restaurants and cafes	719 GJ	Wholesale trade	3,022 GJ	Industrial machinery and equipment	10,208 GJ	Industrial machinery and equipment	1,410 GJ	Industrial machinery and equipment	2,165 GJ	Glass products	15,284 GJ	Printing and stationery	383 GJ
5	Electronic equipment	697 GJ	Plastic products	2,891 GJ	Gases	9,928 GJ	Glass products	1,314 GJ	Plastic products	1,401 GJ	Air and space transport	14,376 GJ	Accommodation	270 GJ
6	Plant leasing, hiring and renting services	515 GJ	Gases	1,981 GJ	Electronic equipment	9,250 GJ	Sydney University, Faculty of Agriculture	1,240 GJ	Wholesale trade	1,283 GJ	Industrial machinery and equipment	12,808 GJ	Plant leasing, hiring and renting services	251 GJ
7	Computer and technical services	469 GJ	Air and space transport	1,891 GJ	Basic chemicals	9,087 GJ	Wholesale trade	1,087 GJ	Gases	1,173 GJ	Wholesale trade	11,485 GJ	Hotels, clubs, restaurants and cafes	214 GJ
8	Bus and tramway	387 GJ	Hotels, clubs, restaurants and cafes	1,417 GJ	Sydney University, Faculty of Science	8,456 GJ	Basic chemicals	1,065 GJ	Electrical equipment	1,093 GJ	Electronic equipment	9,340 GJ	Electronic equipment	200 GJ
9	Accommodation	381 GJ	Plant leasing, hiring and renting services	1,321 GJ	Wholesale trade	7,779 GJ	Industrial machinery repairs	971 GJ	Air and space transport	766 GJ	Hospitals and nursing homes	8,916 GJ	Advertising services	197 GJ
10	Wholesale trade	304 GJ	Printing and stationery	1,257 GJ	Hotels, clubs, restaurants and cafes	6,852 GJ	Electronic equipment	909 GJ	Hotels, clubs, restaurants and cafes	720 GJ	Community health centres	8,837 GJ	Basic chemicals	188 GJ

7.5.5. Commodity Breakdown across faculties for the GHG Emissions Indicator

GHG emissions	Education and social work		Arts		Law		Health science		Economy		Engineering	
Rank	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Electricity supply	512 t CO2-e	Electricity supply	854 t CO2-e	Electricity supply	320 t CO2-e	Electricity supply	3,163 t CO2-e	Hotels, clubs, restaurants and cafes	1,361 t CO2-e	Electricity supply	2,510 t CO2-e
2	Hotels, clubs, restaurants and cafes	287 t CO2-e	Hotels, clubs, restaurants and cafes	796 t CO2-e	Printing and stationery	261 t CO2-e	Printing and stationery	581 t CO2-e	Electricity supply	1,133 t CO2-e	Sanitary and garbage disposal	570 t CO2-e
3	Printing and stationery	172 t CO2-e	Air and space transport	530 t CO2-e	Hotels, clubs, restaurants and cafes	222 t CO2-e	Hotels, clubs, restaurants and cafes	408 t CO2-e	Printing and stationery	591 t CO2-e	Hotels, clubs, restaurants and cafes	565 t CO2-e
4	Air and space transport	116 t CO2-e	Printing and stationery	314 t CO2-e	Accommodation	147 t CO2-e	Air and space transport	261 t CO2-e	Air and space transport	578 t CO2-e	Electronic equipment	534 t CO2-e
5	Accommodation	85.6 t CO2-e	Accommodation	263 t CO2-e	Air and space transport	129 t CO2-e	Accommodation	213 t CO2-e	Accommodation	331 t CO2-e	Printing and stationery	338 t CO2-e
6	Bus and tramway	38.6 t CO2-e	Books, maps, magazines	205 t CO2-e	Books, maps, magazines	68.5 t CO2-e	Sydney University, Faculty of Health Sciences	182 t CO2-e	Advertising services	207 t CO2-e	Air and space transport	303 t CO2-e
7	Plant leasing, hiring and renting services	37.6 t CO2-e	Bus and tramway	195 t CO2-e	Electronic equipment	47.3 t CO2-e	Electronic equipment	167 t CO2-e	Electronic equipment	202 t CO2-e	Wholesale trade	297 t CO2-e
8	Education	33.4 t CO2-e	Electronic equipment	159 t CO2-e	Property services	36.0 t CO2-e	Education	120 t CO2-e	Computer and technical services	189 t CO2-e	Industrial machinery and equipment	282 t CO2-e
9	Books, maps, magazines	30.1 t CO2-e	Road freight	82.7 t CO2-e	Advertising services	23.2 t CO2-e	Wholesale trade	113 t CO2-e	Books, maps, magazines	171 t CO2-e	Education	220 t CO2-e
10	Sydney University, Faculty of Edu & Social Work	2.39 t CO2-e	Newspapers	6.43 t CO2-e	Fabricated construction steel	0.75 t CO2-e	Joinery products	13.7 t CO2-e	Plastic products	4.47 t CO2-e	Joinery products	27.8 t CO2-e

GHG emissions	**Architecture**		**Veterinary science**		**Science**		**Agriculture**		**Pharmacy**		**Medicine**		**Nursing**	
Rank	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact	Commodity	impact
1	Electricity supply	930 t CO2-e	Electricity supply	2,202 t CO2-e	Electricity supply	6,277 t CO2-e	Electricity supply	1,148 t CO2-e	Electricity supply	606 t CO2-e	Electricity supply	3,809 t CO2-e	Electricity supply	318 t CO2-e
2	Sanitary and garbage disposal	249 t CO2-e	Hay	522 t CO2-e	Glass products	1,676 t CO2-e	Sanitary and garbage disposal	470 t CO2-e	Glass products	185 t CO2-e	Hotels, clubs, restaurants and cafes	1,658 t CO2-e	Printing and stationery	89.9 t CO2-e
3	Printing and stationery	172 t CO2-e	Sydney University, Faculty of Vet Science	339 t CO2-e	Hotels, clubs, restaurants and cafes	1,364 t CO2-e	Printing and stationery	169 t CO2-e	Industrial machinery and equipment	177 t CO2-e	Basic chemicals	1,479 t CO2-e	Air and space transport	55.1 t CO2-e
4	Hotels, clubs, restaurants and cafes	143 t CO2-e	Printing and stationery	295 t CO2-e	Electronic equipment	906 t CO2-e	Bus and tramway	136 t CO2-e	Printing and stationery	144 t CO2-e	Printing and stationery	1,350 t CO2-e	Hotels, clubs, restaurants and cafes	42.6 t CO2-e
5	Air and space transport	84.5 t CO2-e	Hotels, clubs, restaurants and cafes	282 t CO2-e	Air and space transport	864 t CO2-e	Air and space transport	131 t CO2-e	Hotels, clubs, restaurants and cafes	143 t CO2-e	Plastic products	1,278 t CO2-e	Sydney University, Faculty of Nursing	28.0 t CO2-e
6	Electronic equipment	68.2 t CO2-e	Wholesale trade	279 t CO2-e	Industrial machinery and equipment	837 t CO2-e	Hotels, clubs, restaurants and cafes	118 t CO2-e	Basic chemicals	122 t CO2-e	Glass products	1,212 t CO2-e	Plant leasing, hiring and renting services	27.1 t CO2-e
7	Plant leasing, hiring and renting services	55.7 t CO2-e	Basic chemicals	260 t CO2-e	Printing and stationery	766 t CO2-e	Industrial machinery and equipment	116 t CO2-e	Wholesale trade	118 t CO2-e	Wholesale trade	1,060 t CO2-e	Accommodation	27.0 t CO2-e
8	Computer and technical services	54.4 t CO2-e	Plastic products	225 t CO2-e	Wholesale trade	718 t CO2-e	Glass products	104 t CO2-e	Plastic products	109 t CO2-e	Industrial machinery and equipment	1,050 t CO2-e	Advertising services	23.4 t CO2-e
9	Accommodation	38.2 t CO2-e	Beef cattle	153 t CO2-e	Education	563 t CO2-e	Wholesale trade	100 t CO2-e	Electrical equipment	89.5 t CO2-e	Air and space transport	1,037 t CO2-e	Electronic equipment	19.6 t CO2-e
10	Bus and tramway	31.0 t CO2-e	Plant leasing, hiring and renting services	143 t CO2-e	Basic chemicals	492 t CO2-e	Accommodation	90.8 t CO2-e	Electronic equipment	66.1 t CO2-e	Beef cattle	978 t CO2-e	Basic chemicals	10.2 t CO2-e

7.6.Appendix 6: *Ranked Structural Paths* tables by faculties and by indicators

7.6.3. Ranked structural paths across faculties for the Material Flow indicator

Material Flow	Education				Arts			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Black coal > Electricity supply > Sydney University, Faculty of Edu & Social Work	138 t	3	18.5%	Black coal > Electricity supply > Sydney University, Faculty of Arts	230 t	3	11.8%
2	Brown coal > Electricity supply > Sydney University, Faculty of Edu & Social Work	56.6 t	3	7.6%	Brown coal > Electricity supply > Sydney University, Faculty of Arts	94.4 t	3	4.8%
3	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Edu & Social Work	16.9 t	4	2.3%	Black coal > Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	44.8 t	4	2.3%
4	Black coal > Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	16.1 t	4	2.2%	Crude oil > Petrol and diesel > Air and space transport > Sydney University, Faculty of Arts	44.0 t	4	2.3%
5	Natural gas > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	12.3 t	3	1.7%	Black coal > Electricity supply > Accommodation > Sydney University, Faculty of Arts	36.1 t	4	1.8%
6	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Edu & Social Work	12.2 t	4	1.6%	Natural gas > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	34.3 t	3	1.8%
7	Black coal > Electricity supply > Accommodation > Sydney University, Faculty of Edu & Social Work	11.7 t	4	1.6%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Arts	30.8 t	4	1.6%
8	Brown coal > Petroleum and coal products > Sydney University, Faculty of Edu & Social Work	11.0 t	3	1.5%	Natural gas > Accommodation > Sydney University, Faculty of Arts	27.5 t	3	1.4%
9	Crude oil > Petrol and diesel > Air and space transport > Sydney University, Faculty of Edu & Social Work	9.61 t	4	1.3%	Black coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Arts	24.9 t	4	1.3%
10	Natural gas > Accommodation > Sydney University, Faculty of Edu & Social Work	8.94 t	3	1.2%	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Arts	21.8 t	4	1.1%
11	Natural gas > Electricity supply > Sydney University, Faculty of Edu & Social Work	7.24 t	3	1.0%	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Arts	20.3 t	4	1.0%
12	Brown coal > Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	6.60 t	4	0.9%	Brown coal > Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	18.3 t	4	0.9%
13	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Edu & Social Work	5.86 t	4	0.8%	Crude oil > Kerosene > Air and space transport > Sydney University, Faculty of Arts	15.6 t	4	0.8%
14	Black coal > Electricity supply > Education > Sydney University, Faculty of Edu & Social Work	5.59 t	4	0.8%	Brown coal > Electricity supply > Accommodation > Sydney University, Faculty of Arts	14.8 t	4	0.8%
15	LPG, LNG > Electricity supply > Sydney University, Faculty of Edu & Social Work	5.23 t	3	0.7%	Construction materials > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	14.1 t	3	0.7%

Material Flow	Law				Health Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Black coal > Electricity supply > Sydney University, Faculty of Law	86.3 t	3	12.5%	Black coal > Electricity supply > Sydney University, Faculty of Health Sciences	854 t	3	26.0%
2	Brown coal > Electricity supply > Sydney University, Faculty of Law	35.4 t	3	5.1%	Brown coal > Electricity supply > Sydney University, Faculty of Health Sciences	350 t	3	10.6%
3	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Law	25.6 t	4	3.7%	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Health Sciences	75.2 t	4	2.3%
4	Black coal > Electricity supply > Accommodation > Sydney University, Faculty of Law	20.2 t	4	2.9%	Brown coal > Basic chemicals > Sydney University, Faculty of Health Sciences	58.9 t	3	1.8%
5	Natural gas > Accommodation > Sydney University, Faculty of Law	15.3 t	3	2.2%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Health Sciences	57.0 t	4	1.7%
6	Brown coal > Petroleum and coal products > Sydney University, Faculty of Law	14.5 t	3	2.1%	Brown coal > Petroleum and coal products > Sydney University, Faculty of Health Sciences	56.1 t	3	1.7%
7	Black coal > Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	12.5 t	4	1.8%	Natural gas > Electricity supply > Sydney University, Faculty of Health Sciences	44.7 t	3	1.4%
8	Crude oil > Petrol and diesel > Air and space transport > Sydney University, Faculty of Law	10.7 t	4	1.5%	Brown coal > Gases > Sydney University, Faculty of Health Sciences	44.3 t	3	1.4%
9	Natural gas > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	9.56 t	3	1.4%	LPG, LNG > Electricity supply > Sydney University, Faculty of Health Sciences	32.3 t	3	1.0%
10	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Law	8.86 t	4	1.3%	Brown coal > Electricity supply > Electricity supply > Sydney University, Faculty of Health Sciences	30.8 t	4	0.9%
11	Brown coal > Electricity supply > Accommodation > Sydney University, Faculty of Law	8.25 t	4	1.2%	Black coal > Electricity supply > Accommodation > Sydney University, Faculty of Health Sciences	29.2 t	4	0.9%
12	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Law	7.60 t	4	1.1%	Black coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Health Sciences	26.1 t	4	0.8%
13	Black coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Law	7.38 t	4	1.1%	Black coal > Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	22.9 t	4	0.7%
14	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Law	7.30 t	4	1.1%	Natural gas > Accommodation > Sydney University, Faculty of Health Sciences	22.2 t	3	0.7%
15	Construction materials > Accommodation > Sydney University, Faculty of Law	6.46 t	3	0.9%	Crude oil > Petrol and diesel > Air and space transport > Sydney University, Faculty of Health Sciences	21.7 t	4	0.7%

Material Flow	Economy				Engineering			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Black coal > Electricity supply > Sydney University, Faculty of Economics	306 t	3	10.6%	Black coal > Electricity supply > Sydney University, Faculty of Engineering	678 t	3	14.6%
2	Brown coal > Electricity supply > Sydney University, Faculty of Economics	125 t	3	4.4%	Brown coal > Gases > Sydney University, Faculty of Engineering	283 t	3	6.1%
3	Black coal > Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	76.5 t	4	2.7%	Brown coal > Electricity supply > Sydney University, Faculty of Engineering	278 t	3	6.0%
4	Natural gas > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	58.6 t	3	2.0%	Brown coal > Basic chemicals > Sydney University, Faculty of Engineering	111 t	3	2.4%
5	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Economics	57.9 t	4	2.0%	Brown coal > Petroleum and coal products > Sydney University, Faculty of Engineering	97.1 t	3	2.1%
6	Crude oil > Petrol and diesel > Air and space transport > Sydney University, Faculty of Economics	48.0 t	4	1.7%	Black coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Engineering	83.3 t	4	1.8%
7	Black coal > Electricity supply > Accommodation > Sydney University, Faculty of Economics	45.3 t	4	1.6%	Iron ores > Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Engineering	71.0 t	4	1.5%
8	Natural gas > Accommodation > Sydney University, Faculty of Economics	34.5 t	3	1.2%	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Engineering	59.7 t	4	1.3%
9	Black coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Economics	31.5 t	4	1.1%	Iron ores > Iron and steel semi-manufactures > Fabricated construction steel > Sydney University, Faculty of Engineering	46.3 t	4	1.0%
10	Brown coal > Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	31.3 t	4	1.1%	Brown coal > Basic chemicals > Plastic products > Sydney University, Faculty of Engineering	40.2 t	4	0.9%
11	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Economics	26.9 t	4	0.9%	Black coal > Electricity supply > Education > Sydney University, Faculty of Engineering	36.8 t	4	0.8%
12	Construction materials > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	24.2 t	3	0.8%	Limestone > Glass products > Sydney University, Faculty of Engineering	35.7 t	3	0.8%
13	Brown coal > Petroleum and coal products > Sydney University, Faculty of Economics	20.1 t	3	0.7%	Natural gas > Electricity supply > Sydney University, Faculty of Engineering	35.5 t	3	0.8%
14	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Economics	20.1 t	4	0.7%	Brown coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Engineering	34.1 t	4	0.7%
15	Brown coal > Electricity supply > Accommodation > Sydney University, Faculty of Economics	18.6 t	4	0.6%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Engineering	33.2 t	4	0.7%

Material Flow	Architecture				Veterinary Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Black coal > Electricity supply > Sydney University, Faculty of Architecture	251 t	3	26.8%	Black coal > Electricity supply > Sydney University, Faculty of Vet Science	595 t	3	15.0%
2	Brown coal > Electricity supply > Sydney University, Faculty of Architecture	103 t	3	11.0%	Brown coal > Basic chemicals > Sydney University, Faculty of Vet Science	269 t	3	6.8%
3	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Architecture	22.1 t	4	2.4%	Brown coal > Electricity supply > Sydney University, Faculty of Vet Science	244 t	3	6.2%
4	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	16.8 t	4	1.8%	Brown coal > Petroleum and coal products > Sydney University, Faculty of Vet Science	226 t	3	5.7%
5	Natural gas > Electricity supply > Sydney University, Faculty of Architecture	13.2 t	3	1.4%	Brown coal > Gases > Sydney University, Faculty of Vet Science	176 t	3	4.5%
6	Black coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Architecture	10.6 t	4	1.1%	Sugar cane > Raw sugar > Animal food > Sydney University, Faculty of Vet Science	91.2 t	4	2.3%
7	Brown coal > Basic chemicals > Sydney University, Faculty of Architecture	10.6 t	3	1.1%	Brown coal > Basic chemicals > Plastic products > Sydney University, Faculty of Vet Science	80.5 t	4	2.0%
8	LPG, LNG > Electricity supply > Sydney University, Faculty of Architecture	9.51 t	3	1.0%	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Vet Science	52.3 t	4	1.3%
9	Brown coal > Electricity supply > Electricity supply > Sydney University, Faculty of Architecture	9.05 t	4	1.0%	Brown coal > Chemical fertilisers > Plastic products > Sydney University, Faculty of Vet Science	39.4 t	4	1.0%
10	Construction materials > Sanitary and garbage disposal > Sydney University, Faculty of Architecture	8.90 t	3	1.0%	Limestone > Glass products > Sydney University, Faculty of Vet Science	34.2 t	3	0.9%
11	Black coal > Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	8.04 t	4	0.9%	Crude oil > Petroleum and coal products > Sydney University, Faculty of Vet Science	31.3 t	3	0.8%
12	Crude oil > Petrol and diesel > Air and space transport > Sydney University, Faculty of Architecture	7.02 t	4	0.8%	Natural gas > Electricity supply > Sydney University, Faculty of Vet Science	31.2 t	3	0.8%
13	Natural gas > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	6.16 t	3	0.7%	Brown coal > Basic chemicals > Basic chemicals > Sydney University, Faculty of Vet Science	30.2 t	4	0.8%
14	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	5.84 t	4	0.6%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Vet Science	29.0 t	4	0.7%
15	Black coal > Black coal > Electricity supply > Sydney University, Faculty of Architecture	5.42 t	4	0.6%	Crude oil > Petrol and diesel > Sydney University, Faculty of Vet Science	28.2 t	3	0.7%

Material Flow	Science				Agriculture			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Black coal > Electricity supply > Sydney University, Faculty of Science	1,695 t	3	11.7%	Black coal > Electricity supply > Sydney University, Faculty of Agriculture	310 t	3	13.3%
2	Limestone > Glass products > Sydney University, Faculty of Science	1,079 t	3	7.4%	Brown coal > Petroleum and coal products > Sydney University, Faculty of Agriculture	173 t	3	7.4%
3	Brown coal > Gases > Sydney University, Faculty of Science	881 t	3	6.1%	Brown coal > Electricity supply > Sydney University, Faculty of Agriculture	127 t	3	5.5%
4	Brown coal > Electricity supply > Sydney University, Faculty of Science	694 t	3	4.8%	Limestone > Glass products > Sydney University, Faculty of Agriculture	67.1 t	3	2.9%
5	Construction materials > Glass products > Sydney University, Faculty of Science	615 t	3	4.2%	Brown coal > Basic chemicals > Sydney University, Faculty of Agriculture	59.9 t	3	2.6%
6	Brown coal > Basic chemicals > Sydney University, Faculty of Science	511 t	3	3.5%	Brown coal > Gases > Sydney University, Faculty of Agriculture	47.9 t	3	2.1%
7	Natural gas > Glass products > Sydney University, Faculty of Science	448 t	3	3.1%	Construction materials > Glass products > Sydney University, Faculty of Agriculture	38.3 t	3	1.6%
8	Brown coal > Petroleum and coal products > Sydney University, Faculty of Science	333 t	3	2.3%	Brown coal > Chemical fertilisers > Sydney University, Faculty of Agriculture	29.6 t	3	1.3%
9	Sand > Glass products > Sydney University, Faculty of Science	331 t	3	2.3%	Iron ores > Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Agriculture	29.1 t	4	1.3%
10	Iron ores > Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Science	211 t	4	1.5%	Natural gas > Glass products > Sydney University, Faculty of Agriculture	27.8 t	3	1.2%
11	Brown coal > Basic chemicals > Plastic products > Sydney University, Faculty of Science	161 t	4	1.1%	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Agriculture	27.3 t	4	1.2%
12	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Science	149 t	4	1.0%	Crude oil > Petroleum and coal products > Sydney University, Faculty of Agriculture	24.0 t	3	1.0%
13	Black coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Science	141 t	4	1.0%	Brown coal > Basic chemicals > Plastic products > Sydney University, Faculty of Agriculture	22.2 t	4	1.0%
14	Black coal > Electricity supply > Glass products > Sydney University, Faculty of Science	96.4 t	4	0.7%	Crude oil > Petrol and diesel > Sydney University, Faculty of Agriculture	21.6 t	3	0.9%
15	Black coal > Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Science	96.1 t	4	0.7%	Sand > Glass products > Sydney University, Faculty of Agriculture	20.6 t	3	0.9%

Material Flow	Pharmacy				Medicine			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Black coal > Electricity supply > Sydney University, Faculty of Pharmacy	164 t	3	8.4%	Brown coal > Basic chemicals > Sydney University, Faculty of Medicine	1,534 t	3	8.3%
2	Brown coal > Basic chemicals > Sydney University, Faculty of Pharmacy	126 t	3	6.5%	Black coal > Electricity supply > Sydney University, Faculty of Medicine	1,028 t	3	5.6%
3	Limestone > Glass products > Sydney University, Faculty of Pharmacy	119 t	3	6.1%	Limestone > Glass products > Sydney University, Faculty of Medicine	780 t	3	4.2%
4	Brown coal > Gases > Sydney University, Faculty of Pharmacy	104 t	3	5.3%	Brown coal > Basic chemicals > Plastic products > Sydney University, Faculty of Medicine	458 t	4	2.5%
5	Construction materials > Glass products > Sydney University, Faculty of Pharmacy	68.0 t	3	3.5%	Construction materials > Glass products > Sydney University, Faculty of Medicine	445 t	3	2.4%
6	Brown coal > Electricity supply > Sydney University, Faculty of Pharmacy	67.0 t	3	3.4%	Brown coal > Electricity supply > Sydney University, Faculty of Medicine	421 t	3	2.3%
7	Natural gas > Glass products > Sydney University, Faculty of Pharmacy	49.5 t	3	2.5%	Natural gas > Glass products > Sydney University, Faculty of Medicine	324 t	3	1.8%
8	Iron ores > Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Pharmacy	44.7 t	4	2.3%	Brown coal > Petroleum and coal products > Sydney University, Faculty of Medicine	266 t	3	1.4%
9	Brown coal > Basic chemicals > Plastic products > Sydney University, Faculty of Pharmacy	39.0 t	4	2.0%	Iron ores > Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Medicine	264 t	4	1.4%
10	Sand > Glass products > Sydney University, Faculty of Pharmacy	36.6 t	3	1.9%	Brown coal > Gases > Sydney University, Faculty of Medicine	258 t	3	1.4%
11	Black coal > Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Pharmacy	20.4 t	4	1.1%	Sand > Glass products > Sydney University, Faculty of Medicine	239 t	3	1.3%
12	Brown coal > Chemical fertilisers > Plastic products > Sydney University, Faculty of Pharmacy	19.1 t	4	1.0%	Brown coal > Chemical fertilisers > Plastic products > Sydney University, Faculty of Medicine	224 t	4	1.2%
13	Sand > Electrical equipment > Sydney University, Faculty of Pharmacy	15.1 t	3	0.8%	Brown coal > Basic chemicals > Basic chemicals > Sydney University, Faculty of Medicine	172 t	4	0.9%
14	Construction materials > Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Pharmacy	14.8 t	4	0.8%	Salt > Basic chemicals > Sydney University, Faculty of Medicine	150 t	3	0.8%
15	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Pharmacy	14.4 t	4	0.7%	Black coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Medicine	143 t	4	0.8%

Material Flow	**Nursing**			
Rank	Path description	Path value	Path order	Percentage in total impact
1	Black coal > Electricity supply > Sydney University, Faculty of Nursing	85.8 t	3	23.0%
2	Brown coal > Electricity supply > Sydney University, Faculty of Nursing	35.1 t	3	9.4%
3	Brown coal > Petroleum and coal products > Sydney University, Faculty of Nursing	12.9 t	3	3.5%
4	Brown coal > Basic chemicals > Sydney University, Faculty of Nursing	10.5 t	3	2.8%
5	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Nursing	8.82 t	4	2.4%
6	Black coal > Electricity supply > Electricity supply > Sydney University, Faculty of Nursing	7.55 t	4	2.0%
7	Crude oil > Petrol and diesel > Air and space transport > Sydney University, Faculty of Nursing	4.57 t	4	1.2%
8	Natural gas > Electricity supply > Sydney University, Faculty of Nursing	4.49 t	3	1.2%
9	Black coal > Electricity supply > Accommodation > Sydney University, Faculty of Nursing	3.71 t	4	1.0%
10	LPG, LNG > Electricity supply > Sydney University, Faculty of Nursing	3.25 t	3	0.9%
11	Brown coal > Electricity supply > Electricity supply > Sydney University, Faculty of Nursing	3.09 t	4	0.8%
12	Brown coal > Basic chemicals > Plastic products > Sydney University, Faculty of Nursing	3.07 t	4	0.8%
13	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Nursing	3.06 t	4	0.8%
14	Black coal > Electricity supply > Electronic equipment > Sydney University, Faculty of Nursing	3.06 t	4	0.8%
15	Natural gas > Accommodation > Sydney University, Faculty of Nursing	2.83 t	3	0.8%

7.6.2. Ranked structural paths across faculties for the Water Use indicator

Water Use	Education				Arts			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Edu & Social Work	4.27 ML	2	14.7%	Electricity supply > Sydney University, Faculty of Arts	7.12 ML	2	8.8%
2	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	2.35 ML	4	8.1%	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	6.53 ML	4	8.1%
3	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	1.05 ML	4	3.6%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	2.91 ML	4	3.6%
4	Sydney University, Faculty of Edu & Social Work	0.78 ML	1	2.7%	Sydney University, Faculty of Arts	2.55 ML	1	3.2%
5	Water supply; sewerage and drainage services > Sydney University, Faculty of Edu & Social Work	0.56 ML	2	1.9%	Untreated milk > Dairy products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	1.51 ML	4	1.9%
6	Untreated milk > Dairy products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	0.54 ML	4	1.9%	Untreated milk > Cheese > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	1.46 ML	4	1.8%
7	Untreated milk > Cheese > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	0.53 ML	4	1.8%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	1.38 ML	3	1.7%
8	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	0.50 ML	3	1.7%	Electricity supply > Accommodation > Sydney University, Faculty of Arts	1.12 ML	3	1.4%
9	Printing and stationery > Sydney University, Faculty of Edu & Social Work	0.38 ML	2	1.3%	Vegetables > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	1.02 ML	3	1.3%
10	Electricity supply > Electricity supply > Sydney University, Faculty of Edu & Social Work	0.38 ML	3	1.3%	Accommodation > Sydney University, Faculty of Arts	1.02 ML	2	1.3%
11	Vegetables > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	0.37 ML	3	1.3%	Poultry > Poultry, slaughtered > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	0.98 ML	4	1.2%
12	Electricity supply > Accommodation > Sydney University, Faculty of Edu & Social Work	0.36 ML	3	1.3%	Fruit > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	0.94 ML	3	1.2%
13	Poultry > Poultry, slaughtered > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	0.35 ML	4	1.2%	Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	0.91 ML	2	1.1%
14	Fruit > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	0.34 ML	3	1.2%	Vegetables > Accommodation > Sydney University, Faculty of Arts	0.82 ML	3	1.0%
15	Accommodation > Sydney University, Faculty of Edu & Social Work	0.33 ML	2	1.1%	Water supply; sewerage and drainage services > Sydney University, Faculty of Arts	0.79 ML	2	1.0%

Water Use	Law				Health Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Law	2.67 ML	2	9.7%	Electricity supply > Sydney University, Faculty of Health Sciences	26.4 ML	2	26.1%
2	Sydney University, Faculty of Law	2.23 ML	1	8.1%	Sydney University, Faculty of Health Sciences	10.7 ML	1	10.5%
3	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	1.82 ML	4	6.6%	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	3.34 ML	4	3.3%
4	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	0.81 ML	4	2.9%	Electricity supply > Electricity supply > Sydney University, Faculty of Health Sciences	2.32 ML	3	2.3%
5	Electricity supply > Accommodation > Sydney University, Faculty of Law	0.62 ML	3	2.3%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	1.49 ML	4	1.5%
6	Printing and stationery > Sydney University, Faculty of Law	0.57 ML	2	2.1%	Printing and stationery > Sydney University, Faculty of Health Sciences	1.27 ML	2	1.3%
7	Accommodation > Sydney University, Faculty of Law	0.57 ML	2	2.1%	Water supply; sewerage and drainage services > Sydney University, Faculty of Health Sciences	0.91 ML	2	0.9%
8	Vegetables > Accommodation > Sydney University, Faculty of Law	0.46 ML	3	1.7%	Electricity supply > Accommodation > Sydney University, Faculty of Health Sciences	0.90 ML	3	0.9%
9	Fruit > Accommodation > Sydney University, Faculty of Law	0.42 ML	3	1.5%	Education > Sydney University, Faculty of Health Sciences	0.89 ML	2	0.9%
10	Untreated milk > Dairy products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	0.42 ML	4	1.5%	Accommodation > Sydney University, Faculty of Health Sciences	0.82 ML	2	0.8%
11	Untreated milk > Cheese > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	0.41 ML	4	1.5%	Electricity supply > Electronic equipment > Sydney University, Faculty of Health Sciences	0.81 ML	3	0.8%
12	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	0.39 ML	3	1.4%	Water supply; sewerage and drainage services > Computer and technical services > Sydney University, Faculty of Health Sciences	0.79 ML	3	0.8%
13	Entertainment > Sydney University, Faculty of Law	0.37 ML	2	1.3%	Untreated milk > Dairy products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	0.77 ML	4	0.8%
14	Water supply; sewerage and drainage services > Accommodation > Sydney University, Faculty of Law	0.30 ML	3	1.1%	Untreated milk > Cheese > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	0.75 ML	4	0.7%
15	Vegetables > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	0.28 ML	3	1.0%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	0.71 ML	3	0.7%

Water Use	Economy				Engineering			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	11.2 ML	4	8.6%	Electricity supply > Sydney University, Faculty of Engineering	20.9 ML	2	17.9%
2	Electricity supply > Sydney University, Faculty of Economics	9.45 ML	2	7.3%	Sydney University, Faculty of Engineering	7.68 ML	1	6.6%
3	Sydney University, Faculty of Economics	5.02 ML	1	3.9%	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	4.63 ML	4	4.0%
4	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	4.97 ML	4	3.8%	Electricity supply > Electronic equipment > Sydney University, Faculty of Engineering	2.57 ML	3	2.2%
5	Untreated milk > Dairy products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	2.58 ML	4	2.0%	Electronic equipment > Sydney University, Faculty of Engineering	2.23 ML	2	1.9%
6	Untreated milk > Cheese > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	2.50 ML	4	1.9%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	2.07 ML	4	1.8%
7	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	2.36 ML	3	1.8%	Electricity supply > Electricity supply > Sydney University, Faculty of Engineering	1.84 ML	3	1.6%
8	Entertainment > Sydney University, Faculty of Economics	1.96 ML	2	1.5%	Water supply; sewerage and drainage services > Sydney University, Faculty of Engineering	1.80 ML	2	1.5%
9	Interest groups and community organisations > Sydney University, Faculty of Economics	1.85 ML	2	1.4%	Education > Sydney University, Faculty of Engineering	1.62 ML	2	1.4%
10	Vegetables > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	1.74 ML	3	1.3%	Electricity supply > Education > Sydney University, Faculty of Engineering	1.14 ML	3	1.0%
11	Poultry > Poultry, slaughtered > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	1.67 ML	4	1.3%	Industrial machinery and equipment > Sydney University, Faculty of Engineering	1.09 ML	2	0.9%
12	Fruit > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	1.60 ML	3	1.2%	Untreated milk > Dairy products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	1.07 ML	4	0.9%
13	Water supply; sewerage and drainage services > Computer and technical services > Sydney University, Faculty of Economics	1.56 ML	3	1.2%	Untreated milk > Cheese > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	1.04 ML	4	0.9%
14	Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	1.56 ML	2	1.2%	Entertainment > Sydney University, Faculty of Engineering	1.02 ML	2	0.9%
15	Electricity supply > Accommodation > Sydney University, Faculty of Economics	1.40 ML	3	1.1%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	0.98 ML	3	0.8%

Water Use	Architecture				Veterinary Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Architecture	7.76 ML	2	27.0%	Hay > Sydney University, Faculty of Vet Science	35.1 ML	2	17.7%
2	Sydney University, Faculty of Architecture	1.87 ML	1	6.5%	Animal breeding > Sydney University, Faculty of Vet Science	29.5 ML	2	14.8%
3	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	1.17 ML	4	4.1%	Electricity supply > Sydney University, Faculty of Vet Science	18.4 ML	2	9.2%
4	Electricity supply > Electricity supply > Sydney University, Faculty of Architecture	0.68 ML	3	2.4%	Unginned cotton > Cotton seed > Hay > Sydney University, Faculty of Vet Science	6.29 ML	4	3.2%
5	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	0.52 ML	4	1.8%	Dairy cattle > Sydney University, Faculty of Vet Science	6.13 ML	2	3.1%
6	Water supply; sewerage and drainage services > Computer and technical services > Sydney University, Faculty of Architecture	0.45 ML	3	1.6%	Sydney University, Faculty of Vet Science	5.02 ML	1	2.5%
7	Water supply; sewerage and drainage services > Plant leasing, hiring and renting services > Sydney University, Faculty of Architecture	0.43 ML	3	1.5%	Plant nurseries > Sydney University, Faculty of Vet Science	4.41 ML	2	2.2%
8	Printing and stationery > Sydney University, Faculty of Architecture	0.37 ML	2	1.3%	Deer > Sydney University, Faculty of Vet Science	3.79 ML	2	1.9%
9	Electricity supply > Electronic equipment > Sydney University, Faculty of Architecture	0.33 ML	3	1.2%	Sugar cane > Raw sugar > Animal food > Sydney University, Faculty of Vet Science	2.98 ML	4	1.5%
10	Electronic equipment > Sydney University, Faculty of Architecture	0.28 ML	2	1.0%	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Vet Science	2.31 ML	4	1.2%
11	Untreated milk > Dairy products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	0.27 ML	4	0.9%	Pigs > Sydney University, Faculty of Vet Science	2.30 ML	2	1.2%
12	Untreated milk > Cheese > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	0.26 ML	4	0.9%	Horses > Sydney University, Faculty of Vet Science	1.90 ML	2	1.0%
13	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	0.25 ML	3	0.9%	Sheep and lambs > Sydney University, Faculty of Vet Science	1.84 ML	2	0.9%
14	Entertainment > Sydney University, Faculty of Architecture	0.19 ML	2	0.7%	Animal breeding > Animal breeding > Sydney University, Faculty of Vet Science	1.69 ML	3	0.9%
15	Vegetables > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	0.18 ML	3	0.6%	Beef cattle > Sydney University, Faculty of Vet Science	1.63 ML	2	0.8%

Water Use	Science				Agriculture			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Science	52.4 ML	2	16.4%	Sydney University, Faculty of Agriculture	50.4 ML	1	49.3%
2	Sydney University, Faculty of Science	27.3 ML	1	8.5%	Electricity supply > Sydney University, Faculty of Agriculture	9.58 ML	2	9.4%
3	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	11.2 ML	4	3.5%	Grass seed > Sydney University, Faculty of Agriculture	4.00 ML	2	3.9%
4	Dairy cattle > Sydney University, Faculty of Science	5.98 ML	2	1.9%	Animal breeding > Sydney University, Faculty of Agriculture	3.07 ML	2	3.0%
5	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	4.99 ML	4	1.6%	Water supply; sewerage and drainage services > Sydney University, Faculty of Agriculture	1.66 ML	2	1.6%
6	Deer > Sydney University, Faculty of Science	4.95 ML	2	1.6%	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Agriculture	0.97 ML	4	1.0%
7	Electricity supply > Electricity supply > Sydney University, Faculty of Science	4.61 ML	3	1.4%	Electricity supply > Electricity supply > Sydney University, Faculty of Agriculture	0.84 ML	3	0.8%
8	Electricity supply > Electronic equipment > Sydney University, Faculty of Science	4.36 ML	3	1.4%	Grass seed > Grass seed > Sydney University, Faculty of Agriculture	0.71 ML	3	0.7%
9	Education > Sydney University, Faculty of Science	4.16 ML	2	1.3%	Industrial machinery and equipment > Sydney University, Faculty of Agriculture	0.45 ML	2	0.4%
10	Electronic equipment > Sydney University, Faculty of Science	3.78 ML	2	1.2%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Agriculture	0.43 ML	4	0.4%
11	Industrial machinery and equipment > Sydney University, Faculty of Science	3.23 ML	2	1.0%	Electricity supply > Electronic equipment > Sydney University, Faculty of Agriculture	0.43 ML	3	0.4%
12	Pigs > Sydney University, Faculty of Science	3.00 ML	2	0.9%	Electricity supply > Accommodation > Sydney University, Faculty of Agriculture	0.38 ML	3	0.4%
13	Electricity supply > Glass products > Sydney University, Faculty of Science	2.98 ML	3	0.9%	Electronic equipment > Sydney University, Faculty of Agriculture	0.37 ML	2	0.4%
14	Electricity supply > Education > Sydney University, Faculty of Science	2.91 ML	3	0.9%	Printing and stationery > Sydney University, Faculty of Agriculture	0.37 ML	2	0.4%
15	Untreated milk > Dairy products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	2.58 ML	4	0.8%	Accommodation > Sydney University, Faculty of Agriculture	0.35 ML	2	0.3%

Water Use	Pharmacy				Medicine			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Pharmacy	5.05 ML	2	14.0%	Animal breeding > Sydney University, Faculty of Medicine	33.7 ML	2	5.9%
2	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	1.18 ML	4	3.3%	Electricity supply > Sydney University, Faculty of Medicine	31.8 ML	2	5.5%
3	Industrial machinery and equipment > Sydney University, Faculty of Pharmacy	0.68 ML	2	1.9%	Dairy cattle > Sydney University, Faculty of Medicine	29.2 ML	2	5.1%
4	Entertainment > Sydney University, Faculty of Pharmacy	0.61 ML	2	1.7%	Deer > Sydney University, Faculty of Medicine	24.2 ML	2	4.2%
5	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	0.52 ML	4	1.5%	Sydney University, Faculty of Medicine	14.8 ML	1	2.6%
6	Electricity supply > Electricity supply > Sydney University, Faculty of Pharmacy	0.44 ML	3	1.2%	Pigs > Sydney University, Faculty of Medicine	14.7 ML	2	2.6%
7	Education > Sydney University, Faculty of Pharmacy	0.42 ML	2	1.2%	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	13.6 ML	4	2.4%
8	Plastic products > Sydney University, Faculty of Pharmacy	0.36 ML	2	1.0%	Horses > Sydney University, Faculty of Medicine	12.1 ML	2	2.1%
9	Electrical equipment > Sydney University, Faculty of Pharmacy	0.33 ML	2	0.9%	Sheep and lambs > Sydney University, Faculty of Medicine	11.8 ML	2	2.1%
10	Electricity supply > Glass products > Sydney University, Faculty of Pharmacy	0.33 ML	3	0.9%	Beef cattle > Sydney University, Faculty of Medicine	10.4 ML	2	1.8%
11	Electricity supply > Electronic equipment > Sydney University, Faculty of Pharmacy	0.32 ML	3	0.9%	Poultry > Sydney University, Faculty of Medicine	10.1 ML	2	1.8%
12	Printing and stationery > Sydney University, Faculty of Pharmacy	0.31 ML	2	0.9%	Hospitals and nursing homes > Sydney University, Faculty of Medicine	6.86 ML	2	1.2%
13	Water supply; sewerage and drainage services > Sydney University, Faculty of Pharmacy	0.30 ML	2	0.8%	Water supply; sewerage and drainage services > Sydney University, Faculty of Medicine	6.58 ML	2	1.2%
14	Electricity supply > Education > Sydney University, Faculty of Pharmacy	0.30 ML	3	0.8%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	6.06 ML	4	1.1%
15	Glass products > Sydney University, Faculty of Pharmacy	0.28 ML	2	0.8%	Plant nurseries > Sydney University, Faculty of Medicine	5.23 ML	2	0.9%

Water Use Rank	Nursing			
Rank	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Nursing	2.65 ML	2	21.8%
2	Sydney University, Faculty of Nursing	2.01 ML	1	16.5%
3	Grapes for wine > Wine > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	0.35 ML	4	2.9%
4	Electricity supply > Electricity supply > Sydney University, Faculty of Nursing	0.23 ML	3	1.9%
5	Water supply; sewerage and drainage services > Plant leasing, hiring and renting services > Sydney University, Faculty of Nursing	0.21 ML	3	1.7%
6	Printing and stationery > Sydney University, Faculty of Nursing	0.20 ML	2	1.6%
7	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	0.16 ML	4	1.3%
8	Water supply; sewerage and drainage services > Advertising services > Sydney University, Faculty of Nursing	0.12 ML	3	1.0%
9	Electricity supply > Accommodation > Sydney University, Faculty of Nursing	0.11 ML	3	0.9%
10	Accommodation > Sydney University, Faculty of Nursing	0.10 ML	2	0.9%
11	Electricity supply > Electronic equipment > Sydney University, Faculty of Nursing	0.09 ML	3	0.8%
12	Horses > Advertising services > Sydney University, Faculty of Nursing	0.09 ML	3	0.8%
13	Vegetables > Accommodation > Sydney University, Faculty of Nursing	0.08 ML	3	0.7%
14	Electronic equipment > Sydney University, Faculty of Nursing	0.08 ML	2	0.7%
15	Untreated milk > Dairy products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	0.08 ML	4	0.7%

7.6.3. Ranked structural paths across faculties for the Land Use indicator

Land Use	Education				Arts			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Edu & Social Work	30.5 ha	4	36.7%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Arts	55.6 ha	4	28.8%
2	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Edu & Social Work	5.80 ha	4	7.0%	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Arts	39.5 ha	4	20.5%
3	Sydney University, Faculty of Edu & Social Work	5.29 ha	1	6.4%	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Arts	8.86 ha	4	4.6%
4	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Edu & Social Work	4.87 ha	4	5.9%	Softwoods > Pulp, paper and paperboard > Recorded media and publishing > Sydney University, Faculty of Arts	6.84 ha	4	3.6%
5	Beef cattle > Fresh meat > Sydney University, Faculty of Edu & Social Work	3.36 ha	3	4.0%	Hardwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Arts	6.29 ha	4	3.3%
6	Beef cattle > Meat products > Sydney University, Faculty of Edu & Social Work	3.11 ha	3	3.7%	Sydney University, Faculty of Arts	5.40 ha	1	2.8%
7	Softwoods > Pulp, paper and paperboard > Paper products > Sydney University, Faculty of Edu & Social Work	2.11 ha	4	2.5%	Beef cattle > Fresh meat > Sydney University, Faculty of Arts	4.86 ha	3	2.5%
8	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Printing and stationery > Sydney University, Faculty of Edu & Social Work	1.45 ha	5	1.8%	Beef cattle > Meat products > Sydney University, Faculty of Arts	4.51 ha	3	2.3%
9	Beef cattle > Fresh meat > Pies, cakes, biscuits > Sydney University, Faculty of Edu & Social Work	1.23 ha	4	1.5%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Books, maps, magazines > Sydney University, Faculty of Arts	2.70 ha	5	1.4%
10	Hardwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Edu & Social Work	0.92 ha	4	1.1%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Printing and stationery > Sydney University, Faculty of Arts	2.64 ha	5	1.4%
11	Softwoods > Pulp, paper and paperboard > Newspapers > Sydney University, Faculty of Edu & Social Work	0.86 ha	4	1.0%	Beef cattle > Fresh meat > Pies, cakes, biscuits > Sydney University, Faculty of Arts	1.78 ha	4	0.9%
12	Softwoods > Joinery products > Sydney University, Faculty of Edu & Social Work	0.83 ha	3	1.0%	Softwoods > Pulp, paper and paperboard > Periodicals > Sydney University, Faculty of Arts	1.41 ha	4	0.7%
13	Hardwoods > Paper products > Sydney University, Faculty of Edu & Social Work	0.82 ha	3	1.0%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Printing and stationery > Sydney University, Faculty of Arts	1.36 ha	5	0.7%
14	Softwoods > Pulp, paper and paperboard > Printing and stationery > Printing and stationery > Sydney University, Faculty of Edu & Social Work	0.75 ha	5	0.9%	Softwoods > Pulp, paper and paperboard > Paper products > Sydney University, Faculty of Arts	1.34 ha	4	0.7%
15	Shorn wool > Wool scouring > Printing and stationery > Sydney University, Faculty of Edu & Social Work	0.49 ha	4	0.6%	Softwoods > Pulp, paper and paperboard > Newspapers > Sydney University, Faculty of Arts	1.24 ha	4	0.6%

Land Use	Law				Health Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	199 ha	4	39.3%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	365 ha	4	30.6%
2	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Law	46.2 ha	4	9.1%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Health Sciences	103 ha	4	8.6%
3	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	42.4 ha	4	8.4%	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	77.9 ha	4	6.5%
4	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	16.7 ha	4	3.3%	Beef cattle > Sydney University, Faculty of Health Sciences	35.2 ha	2	3.0%
5	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Law	13.2 ha	4	2.6%	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	30.7 ha	4	2.6%
6	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	9.14 ha	5	1.8%	Sheep and lambs > Sydney University, Faculty of Health Sciences	17.1 ha	2	1.4%
7	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Law	7.36 ha	4	1.5%	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	16.8 ha	5	1.4%
8	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	5.95 ha	5	1.2%	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Health Sciences	16.4 ha	4	1.4%
9	Sydney University, Faculty of Law	5.28 ha	1	1.0%	Parks, botanical gardens and zoos > Sydney University, Faculty of Health Sciences	14.8 ha	2	1.2%
10	Softwoods > Pulp, paper and paperboard > Recorded media and publishing > Sydney University, Faculty of Law	4.28 ha	4	0.9%	Beef cattle > Fresh meat > Retail trade > Sydney University, Faculty of Health Sciences	11.7 ha	4	1.0%
11	Sheep and lambs > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	3.57 ha	4	0.7%	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	10.9 ha	5	0.9%
12	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Advertising services > Sydney University, Faculty of Law	3.55 ha	5	0.7%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Advertising services > Sydney University, Faculty of Health Sciences	8.60 ha	5	0.7%
13	Shorn wool > Wool scouring > Accommodation > Sydney University, Faculty of Law	3.48 ha	4	0.7%	Sydney University, Faculty of Health Sciences	6.61 ha	1	0.6%
14	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Printing and stationery > Sydney University, Faculty of Law	2.19 ha	5	0.4%	Sheep and lambs > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	6.56 ha	4	0.6%
15	Shorn wool > Wool scouring > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	2.13 ha	4	0.4%	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Health Sciences	6.19 ha	4	0.5%

Land Use	Economy				Engineering			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	1,218 ha	4	45.7%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	506 ha	4	33.0%
2	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	260 ha	4	9.8%	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	108 ha	4	7.0%
3	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Economics	105 ha	4	3.9%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Engineering	60.0 ha	4	3.9%
4	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	103 ha	4	3.9%	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	42.6 ha	4	2.8%
5	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	56.1 ha	5	2.1%	Beef cattle > Fresh meat > Retail trade > Sydney University, Faculty of Engineering	37.6 ha	4	2.5%
6	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	36.5 ha	5	1.4%	Parks, botanical gardens and zoos > Sydney University, Faculty of Engineering	27.3 ha	2	1.8%
7	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Economics	32.9 ha	4	1.2%	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	23.3 ha	5	1.5%
8	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Advertising services > Sydney University, Faculty of Economics	31.7 ha	5	1.2%	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	15.2 ha	5	1.0%
9	Sheep and lambs > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	21.9 ha	4	0.8%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Electronic equipment > Sydney University, Faculty of Engineering	10.8 ha	5	0.7%
10	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Economics	16.7 ha	4	0.6%	Beef cattle > Fresh meat > Sydney University, Faculty of Engineering	10.8 ha	3	0.7%
11	Shorn wool > Wool scouring > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	13.1 ha	4	0.5%	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Engineering	10.5 ha	4	0.7%
12	Beef cattle > Meat products > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	12.4 ha	5	0.5%	Beef cattle > Meat products > Sydney University, Faculty of Engineering	10.0 ha	3	0.7%
13	Beef cattle > Fresh meat > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	12.0 ha	5	0.5%	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Engineering	9.56 ha	4	0.6%
14	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Computer and technical services > Sydney University, Faculty of Economics	11.6 ha	5	0.4%	Sheep and lambs > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	9.09 ha	4	0.6%
15	Beef cattle > Meat products > Interest groups and community organisations > Sydney University, Faculty of Economics	8.90 ha	4	0.3%	Shorn wool > Wool scouring > Clothing > Sydney University, Faculty of Engineering	8.96 ha	4	0.6%

Land Use	Architecture				Veterinary Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	128 ha	4	34.8%	Beef cattle > Sydney University, Faculty of Vet Science	399 ha	2	21.8%
2	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	30.4 ha	4	8.3%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Vet Science	253 ha	4	13.8%
3	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	27.3 ha	4	7.4%	Sheep and lambs > Sydney University, Faculty of Vet Science	193 ha	2	10.6%
4	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	10.8 ha	4	2.9%	Beef cattle > Offal, hides, skins, blood meal > Animal food > Sydney University, Faculty of Vet Science	58.0 ha	4	3.2%
5	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	5.89 ha	5	1.6%	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Vet Science	53.9 ha	4	3.0%
6	Sydney University, Faculty of Architecture	4.92 ha	1	1.3%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Vet Science	52.3 ha	4	2.9%
7	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	4.85 ha	4	1.3%	Beef cattle > Fresh meat > Animal food > Sydney University, Faculty of Vet Science	42.6 ha	4	2.3%
8	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	3.84 ha	5	1.0%	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Vet Science	21.3 ha	4	1.2%
9	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Computer and technical services > Sydney University, Faculty of Architecture	3.34 ha	5	0.9%	Hay > Sydney University, Faculty of Vet Science	17.0 ha	2	0.9%
10	Parks, botanical gardens and zoos > Sydney University, Faculty of Architecture	2.74 ha	2	0.7%	Beef cattle > Offal, hides, skins, blood meal > Animal food > Animal breeding > Sydney University, Faculty of Vet Science	13.4 ha	5	0.7%
11	Softwoods > Pulp, paper and paperboard > Recorded media and publishing > Sydney University, Faculty of Architecture	2.59 ha	4	0.7%	Parks, botanical gardens and zoos > Sydney University, Faculty of Vet Science	12.4 ha	2	0.7%
12	Sheep and lambs > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	2.30 ha	4	0.6%	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Vet Science	11.6 ha	5	0.6%
13	Beef cattle > Fresh meat > Retail trade > Sydney University, Faculty of Architecture	2.21 ha	4	0.6%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Advertising services > Sydney University, Faculty of Vet Science	11.1 ha	5	0.6%
14	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Architecture	2.11 ha	4	0.6%	Deer > Sydney University, Faculty of Vet Science	10.7 ha	2	0.6%
15	Beef cattle > Meat products > Computer and technical services > Sydney University, Faculty of Architecture	2.09 ha	4	0.6%	Beef cattle > Meat products > Basic chemicals > Sydney University, Faculty of Vet Science	10.6 ha	4	0.6%

Land Use	Science				Agriculture			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	1,221 ha	4	27.4%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Agriculture	106 ha	4	21.5%
2	Beef cattle > Sydney University, Faculty of Science	520 ha	2	11.7%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Agriculture	29.9 ha	4	6.1%
3	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	261 ha	4	5.9%	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Agriculture	22.6 ha	4	4.6%
4	Sheep and lambs > Sydney University, Faculty of Science	252 ha	2	5.7%	Beef cattle > Fresh meat > Retail trade > Sydney University, Faculty of Agriculture	14.2 ha	4	2.9%
5	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Science	136 ha	4	3.1%	Parks, botanical gardens and zoos > Sydney University, Faculty of Agriculture	10.4 ha	2	2.1%
6	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	103 ha	4	2.3%	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Agriculture	8.92 ha	4	1.8%
7	Beef cattle > Fresh meat > Retail trade > Sydney University, Faculty of Science	99.1 ha	4	2.2%	Sydney University, Faculty of Agriculture	5.50 ha	1	1.1%
8	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	56.2 ha	5	1.3%	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Agriculture	4.88 ha	5	1.0%
9	Beef cattle > Offal, hides, skins, blood meal > Animal food > Sydney University, Faculty of Science	39.2 ha	4	0.9%	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Agriculture	4.77 ha	4	1.0%
10	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	36.6 ha	5	0.8%	Beef cattle > Fresh meat > Sydney University, Faculty of Agriculture	4.12 ha	3	0.8%
11	Parks, botanical gardens and zoos > Sydney University, Faculty of Science	33.1 ha	2	0.7%	Beef cattle > Meat products > Sydney University, Faculty of Agriculture	3.82 ha	3	0.8%
12	Beef cattle > Fresh meat > Animal food > Sydney University, Faculty of Science	28.8 ha	4	0.7%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Advertising services > Sydney University, Faculty of Agriculture	3.27 ha	5	0.7%
13	Sheep and lambs > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	21.9 ha	4	0.5%	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Agriculture	3.25 ha	4	0.7%
14	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Science	21.7 ha	4	0.5%	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Agriculture	3.17 ha	5	0.6%
15	Education > Sydney University, Faculty of Science	20.7 ha	2	0.5%	Shorn wool > Wool scouring > Clothing > Sydney University, Faculty of Agriculture	2.83 ha	4	0.6%

Land Use	Pharmacy				Medicine			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	128 ha	4	24.5%	Beef cattle > Sydney University, Faculty of Medicine	2,540 ha	2	26.6%
2	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	27.4 ha	4	5.2%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	1,485 ha	4	15.5%
3	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Pharmacy	25.5 ha	4	4.9%	Sheep and lambs > Sydney University, Faculty of Medicine	1,230 ha	2	12.9%
4	Beef cattle > Sydney University, Faculty of Pharmacy	22.2 ha	2	4.2%	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	317 ha	4	3.3%
5	Beef cattle > Fresh meat > Retail trade > Sydney University, Faculty of Pharmacy	18.8 ha	4	3.6%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Medicine	239 ha	4	2.5%
6	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	10.8 ha	4	2.1%	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	125 ha	4	1.3%
7	Sheep and lambs > Sydney University, Faculty of Pharmacy	10.7 ha	2	2.1%	Beef cattle > Fresh meat > Retail trade > Sydney University, Faculty of Medicine	121 ha	4	1.3%
8	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	5.91 ha	5	1.1%	Parks, botanical gardens and zoos > Sydney University, Faculty of Medicine	70.5 ha	2	0.7%
9	Sydney University, Faculty of Pharmacy	4.98 ha	1	1.0%	Deer > Sydney University, Faculty of Medicine	68.5 ha	2	0.7%
10	Beef cattle > Meat products > Basic chemicals > Sydney University, Faculty of Pharmacy	4.97 ha	4	1.0%	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	68.3 ha	5	0.7%
11	Beef cattle > Offal, hides, skins, blood meal > Basic chemicals > Sydney University, Faculty of Pharmacy	4.66 ha	4	0.9%	Beef cattle > Meat products > Basic chemicals > Sydney University, Faculty of Medicine	60.2 ha	4	0.6%
12	Parks, botanical gardens and zoos > Sydney University, Faculty of Pharmacy	4.63 ha	2	0.9%	Beef cattle > Offal, hides, skins, blood meal > Basic chemicals > Sydney University, Faculty of Medicine	56.5 ha	4	0.6%
13	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Pharmacy	4.06 ha	4	0.8%	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	44.5 ha	5	0.5%
14	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	3.85 ha	5	0.7%	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Medicine	38.1 ha	4	0.4%
15	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Advertising services > Sydney University, Faculty of Pharmacy	3.54 ha	5	0.7%	Horses > Sydney University, Faculty of Medicine	36.9 ha	2	0.4%

Land Use	Nursing			
Rank	Path description	Path value	Path order	Percentage in total impact
1	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	38.1 ha	4	27.7%
2	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Nursing	15.9 ha	4	11.6%
3	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	8.15 ha	4	5.9%
4	Sydney University, Faculty of Nursing	5.31 ha	1	3.9%
5	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Advertising services > Sydney University, Faculty of Nursing	3.58 ha	5	2.6%
6	Sheep and lambs > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	3.21 ha	4	2.3%
7	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Nursing	2.54 ha	4	1.8%
8	Beef cattle > Fresh meat > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	1.76 ha	5	1.3%
9	Beef cattle > Fresh meat > Pies, cakes, biscuits > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	1.14 ha	5	0.8%
10	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Nursing	0.89 ha	4	0.6%
11	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Advertising services > Sydney University, Faculty of Nursing	0.76 ha	5	0.6%
12	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Printing and stationery > Sydney University, Faculty of Nursing	0.76 ha	5	0.6%
13	Sheep and lambs > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	0.69 ha	4	0.5%
14	Beef cattle > Meat products > Advertising services > Sydney University, Faculty of Nursing	0.65 ha	4	0.5%
15	Beef cattle > Fresh meat > Retail trade > Sydney University, Faculty of Nursing	0.64 ha	4	0.5%

7.6.4. Ranked structural paths across faculties for the Energy consumption indicator

Energy Consumption	Education				Arts			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Edu & Social Work	4,933 GJ	2	35.5%	Electricity supply > Sydney University, Faculty of Arts	8,232 GJ	2	21.3%
2	Air and space transport > Sydney University, Faculty of Edu & Social Work	1,044 GJ	2	7.5%	Air and space transport > Sydney University, Faculty of Arts	4,782 GJ	2	12.4%
3	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	576 GJ	3	4.2%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	1,599 GJ	3	4.1%
4	Electricity supply > Electricity supply > Sydney University, Faculty of Edu & Social Work	434 GJ	3	3.1%	Bus and tramway > Sydney University, Faculty of Arts	1,446 GJ	2	3.8%
5	Electricity supply > Accommodation > Sydney University, Faculty of Edu & Social Work	419 GJ	3	3.0%	Electricity supply > Accommodation > Sydney University, Faculty of Arts	1,290 GJ	3	3.3%
6	Bus and tramway > Sydney University, Faculty of Edu & Social Work	286 GJ	2	2.1%	Electricity supply > Electronic equipment > Sydney University, Faculty of Arts	888 GJ	3	2.3%
7	Electricity supply > Education > Sydney University, Faculty of Edu & Social Work	200 GJ	3	1.4%	Road freight > Sydney University, Faculty of Arts	763 GJ	2	2.0%
8	Electricity supply > Electronic equipment > Sydney University, Faculty of Edu & Social Work	160 GJ	3	1.2%	Electricity supply > Electricity supply > Sydney University, Faculty of Arts	725 GJ	3	1.9%
9	Petrol and diesel > Air and space transport > Sydney University, Faculty of Edu & Social Work	124 GJ	3	0.9%	Petrol and diesel > Air and space transport > Sydney University, Faculty of Arts	568 GJ	3	1.5%
10	Electricity supply > Printing and stationery > Sydney University, Faculty of Edu & Social Work	124 GJ	3	0.9%	Taxi and hire car > Sydney University, Faculty of Arts	452 GJ	2	1.2%
11	Taxi and hire car > Sydney University, Faculty of Edu & Social Work	116 GJ	2	0.8%	Electricity supply > Bus and tramway > Sydney University, Faculty of Arts	449 GJ	3	1.2%
12	Sydney University, Faculty of Edu & Social Work	108 GJ	1	0.8%	Sydney University, Faculty of Arts	406 GJ	1	1.1%
13	Electricity supply > Plant leasing, hiring and renting services > Sydney University, Faculty of Edu & Social Work	93.6 GJ	3	0.7%	Electricity supply > Education > Sydney University, Faculty of Arts	323 GJ	3	0.8%
14	Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Edu & Social Work	92.3 GJ	3	0.7%	Wholesale trade > Sydney University, Faculty of Arts	273 GJ	2	0.7%
15	Electricity supply > Bus and tramway > Sydney University, Faculty of Edu & Social Work	88.9 GJ	3	0.6%	Electricity supply > Printing and stationery > Sydney University, Faculty of Arts	225 GJ	3	0.6%

Energy Consumption	Law				Health Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Law	3,084 GJ	2	25.4%	Electricity supply > Sydney University, Faculty of Health Sciences	30,499 GJ	2	46.5%
2	Air and space transport > Sydney University, Faculty of Law	1,162 GJ	2	9.6%	Sydney University, Faculty of Health Sciences	3,437 GJ	1	5.2%
3	Electricity supply > Accommodation > Sydney University, Faculty of Law	720 GJ	3	5.9%	Electricity supply > Electricity supply > Sydney University, Faculty of Health Sciences	2,685 GJ	3	4.1%
4	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	446 GJ	3	3.7%	Air and space transport > Sydney University, Faculty of Health Sciences	2,354 GJ	2	3.6%
5	Electricity supply > Electricity supply > Sydney University, Faculty of Law	272 GJ	3	2.2%	Electricity supply > Accommodation > Sydney University, Faculty of Health Sciences	1,043 GJ	3	1.6%
6	Electricity supply > Electronic equipment > Sydney University, Faculty of Law	263 GJ	3	2.2%	Electricity supply > Electronic equipment > Sydney University, Faculty of Health Sciences	932 GJ	3	1.4%
7	Electricity supply > Printing and stationery > Sydney University, Faculty of Law	187 GJ	3	1.5%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	819 GJ	3	1.3%
8	Taxi and hire car > Sydney University, Faculty of Law	142 GJ	2	1.2%	Basic chemicals > Sydney University, Faculty of Health Sciences	817 GJ	2	1.3%
9	Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Law	140 GJ	3	1.2%	Electricity supply > Education > Sydney University, Faculty of Health Sciences	718 GJ	3	1.1%
10	Petrol and diesel > Air and space transport > Sydney University, Faculty of Law	138 GJ	3	1.1%	Bus and tramway > Sydney University, Faculty of Health Sciences	556 GJ	2	0.9%
11	Bus and tramway > Sydney University, Faculty of Law	129 GJ	2	1.1%	Wholesale trade > Sydney University, Faculty of Health Sciences	514 GJ	2	0.8%
12	Road freight > Sydney University, Faculty of Law	125 GJ	2	1.0%	Taxi and hire car > Sydney University, Faculty of Health Sciences	457 GJ	2	0.7%
13	Electricity supply > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Law	118 GJ	4	1.0%	Gases > Sydney University, Faculty of Health Sciences	425 GJ	2	0.7%
14	Natural gas > Accommodation > Sydney University, Faculty of Law	89.1 GJ	3	0.7%	Electricity supply > Printing and stationery > Sydney University, Faculty of Health Sciences	418 GJ	3	0.6%
15	Wholesale trade > Sydney University, Faculty of Law	88.0 GJ	2	0.7%	Road freight > Sydney University, Faculty of Health Sciences	390 GJ	2	0.6%

Energy Consumption	Economy				Engineering			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Economics	10,923 GJ	2	20.6%	Electricity supply > Sydney University, Faculty of Engineering	24,205 GJ	2	30.8%
2	Air and space transport > Sydney University, Faculty of Economics	5,218 GJ	2	9.8%	Electricity supply > Electronic equipment > Sydney University, Faculty of Engineering	2,974 GJ	3	3.8%
3	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Economics	2,733 GJ	3	5.2%	Air and space transport > Sydney University, Faculty of Engineering	2,734 GJ	2	3.5%
4	Electricity supply > Accommodation > Sydney University, Faculty of Economics	1,620 GJ	3	3.1%	Gases > Sydney University, Faculty of Engineering	2,712 GJ	2	3.5%
5	Bus and tramway > Sydney University, Faculty of Economics	1,214 GJ	2	2.3%	Sydney University, Faculty of Engineering	2,336 GJ	1	3.0%
6	Electricity supply > Electronic equipment > Sydney University, Faculty of Economics	1,126 GJ	3	2.1%	Electricity supply > Electricity supply > Sydney University, Faculty of Engineering	2,131 GJ	3	2.7%
7	Electricity supply > Electricity supply > Sydney University, Faculty of Economics	962 GJ	3	1.8%	Basic chemicals > Sydney University, Faculty of Engineering	1,542 GJ	2	2.0%
8	Taxi and hire car > Sydney University, Faculty of Economics	904 GJ	2	1.7%	Wholesale trade > Sydney University, Faculty of Engineering	1,346 GJ	2	1.7%
9	Road freight > Sydney University, Faculty of Economics	702 GJ	2	1.3%	Electricity supply > Education > Sydney University, Faculty of Engineering	1,315 GJ	3	1.7%
10	Sydney University, Faculty of Economics	695 GJ	1	1.3%	Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Engineering	1,160 GJ	3	1.5%
11	Electricity supply > Advertising services > Sydney University, Faculty of Economics	631 GJ	3	1.2%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Engineering	1,135 GJ	3	1.4%
12	Petrol and diesel > Air and space transport > Sydney University, Faculty of Economics	620 GJ	3	1.2%	Road freight > Sydney University, Faculty of Engineering	1,073 GJ	2	1.4%
13	Electricity supply > Computer and technical services > Sydney University, Faculty of Economics	505 GJ	3	1.0%	Electricity supply > Accommodation > Sydney University, Faculty of Engineering	905 GJ	3	1.2%
14	Electricity supply > Printing and stationery > Sydney University, Faculty of Economics	424 GJ	3	0.8%	Iron and steel semi-manufactures > Fabricated construction steel > Sydney University, Faculty of Engineering	757 GJ	3	1.0%
15	Electricity supply > Bus and tramway > Sydney University, Faculty of Economics	377 GJ	3	0.7%	Bus and tramway > Sydney University, Faculty of Engineering	644 GJ	2	0.8%

Energy Consumption	Architecture				Veterinary Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Architecture	8,969 GJ	2	49.4%	Electricity supply > Sydney University, Faculty of Vet Science	21,237 GJ	2	32.9%
2	Electricity supply > Electricity supply > Sydney University, Faculty of Architecture	790 GJ	3	4.4%	Sydney University, Faculty of Vet Science	6,200 GJ	1	9.6%
3	Air and space transport > Sydney University, Faculty of Architecture	763 GJ	2	4.2%	Basic chemicals > Sydney University, Faculty of Vet Science	3,736 GJ	2	5.8%
4	Electricity supply > Electronic equipment > Sydney University, Faculty of Architecture	380 GJ	3	2.1%	Electricity supply > Electricity supply > Sydney University, Faculty of Vet Science	1,870 GJ	3	2.9%
5	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	287 GJ	3	1.6%	Gases > Sydney University, Faculty of Vet Science	1,688 GJ	2	2.6%
6	Bus and tramway > Sydney University, Faculty of Architecture	230 GJ	2	1.3%	Wholesale trade > Sydney University, Faculty of Vet Science	1,262 GJ	2	2.0%
7	Road freight > Sydney University, Faculty of Architecture	188 GJ	2	1.0%	Air and space transport > Sydney University, Faculty of Vet Science	1,232 GJ	2	1.9%
8	Electricity supply > Accommodation > Sydney University, Faculty of Architecture	187 GJ	3	1.0%	Basic chemicals > Plastic products > Sydney University, Faculty of Vet Science	1,117 GJ	3	1.7%
9	Basic chemicals > Sydney University, Faculty of Architecture	147 GJ	2	0.8%	Electricity supply > Electronic equipment > Sydney University, Faculty of Vet Science	613 GJ	3	1.0%
10	Electricity supply > Computer and technical services > Sydney University, Faculty of Architecture	145 GJ	3	0.8%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Vet Science	566 GJ	3	0.9%
11	Electricity supply > Plant leasing, hiring and renting services > Sydney University, Faculty of Architecture	139 GJ	3	0.8%	Electricity supply > Plastic products > Sydney University, Faculty of Vet Science	555 GJ	3	0.9%
12	Wholesale trade > Sydney University, Faculty of Architecture	127 GJ	2	0.7%	Animal food > Sydney University, Faculty of Vet Science	466 GJ	2	0.7%
13	Electricity supply > Printing and stationery > Sydney University, Faculty of Architecture	123 GJ	3	0.7%	Bus and tramway > Sydney University, Faculty of Vet Science	441 GJ	2	0.7%
14	Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	92.0 GJ	3	0.5%	Basic chemicals > Basic chemicals > Sydney University, Faculty of Vet Science	419 GJ	3	0.7%
15	Petrol and diesel > Air and space transport > Sydney University, Faculty of Architecture	90.7 GJ	3	0.5%	Road freight > Sydney University, Faculty of Vet Science	367 GJ	2	0.6%

Energy Consumption	Science				Agriculture			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Science	60,525 GJ	2	28.2%	Electricity supply > Sydney University, Faculty of Agriculture	11,072 GJ	2	31.9%
2	Glass products > Sydney University, Faculty of Science	9,805 GJ	2	4.6%	Sydney University, Faculty of Agriculture	1,240 GJ	1	3.6%
3	Gases > Sydney University, Faculty of Science	8,462 GJ	2	3.9%	Air and space transport > Sydney University, Faculty of Agriculture	1,186 GJ	2	3.4%
4	Sydney University, Faculty of Science	8,456 GJ	1	3.9%	Bus and tramway > Sydney University, Faculty of Agriculture	1,009 GJ	2	2.9%
5	Air and space transport > Sydney University, Faculty of Science	7,799 GJ	2	3.6%	Electricity supply > Electricity supply > Sydney University, Faculty of Agriculture	975 GJ	3	2.8%
6	Basic chemicals > Sydney University, Faculty of Science	7,084 GJ	2	3.3%	Basic chemicals > Sydney University, Faculty of Agriculture	831 GJ	2	2.4%
7	Electricity supply > Electricity supply > Sydney University, Faculty of Science	5,329 GJ	3	2.5%	Glass products > Sydney University, Faculty of Agriculture	610 GJ	2	1.8%
8	Electricity supply > Electronic equipment > Sydney University, Faculty of Science	5,046 GJ	3	2.4%	Electricity supply > Electronic equipment > Sydney University, Faculty of Agriculture	496 GJ	3	1.4%
9	Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Science	3,446 GJ	3	1.6%	Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Agriculture	476 GJ	3	1.4%
10	Electricity supply > Glass products > Sydney University, Faculty of Science	3,442 GJ	3	1.6%	Gases > Sydney University, Faculty of Agriculture	460 GJ	2	1.3%
11	Electricity supply > Education > Sydney University, Faculty of Science	3,364 GJ	3	1.6%	Wholesale trade > Sydney University, Faculty of Agriculture	454 GJ	2	1.3%
12	Wholesale trade > Sydney University, Faculty of Science	3,250 GJ	2	1.5%	Electricity supply > Accommodation > Sydney University, Faculty of Agriculture	445 GJ	3	1.3%
13	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	2,739 GJ	3	1.3%	Industrial machinery repairs > Sydney University, Faculty of Agriculture	325 GJ	2	0.9%
14	Natural gas > Glass products > Sydney University, Faculty of Science	2,599 GJ	3	1.2%	Electricity supply > Bus and tramway > Sydney University, Faculty of Agriculture	313 GJ	3	0.9%
15	Basic chemicals > Plastic products > Sydney University, Faculty of Science	2,240 GJ	3	1.0%	Basic chemicals > Plastic products > Sydney University, Faculty of Agriculture	307 GJ	3	0.9%

Energy Consumption	Pharmacy				Medicine			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Pharmacy	5,842 GJ	2	21.9%	Electricity supply > Sydney University, Faculty of Medicine	36,728 GJ	2	14.3%
2	Basic chemicals > Sydney University, Faculty of Pharmacy	1,755 GJ	2	6.6%	Basic chemicals > Sydney University, Faculty of Medicine	21,281 GJ	2	8.3%
3	Glass products > Sydney University, Faculty of Pharmacy	1,084 GJ	2	4.1%	Air and space transport > Sydney University, Faculty of Medicine	9,368 GJ	2	3.7%
4	Gases > Sydney University, Faculty of Pharmacy	1,000 GJ	2	3.7%	Glass products > Sydney University, Faculty of Medicine	7,093 GJ	2	2.8%
5	Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Pharmacy	731 GJ	3	2.7%	Basic chemicals > Plastic products > Sydney University, Faculty of Medicine	6,350 GJ	3	2.5%
6	Basic chemicals > Plastic products > Sydney University, Faculty of Pharmacy	541 GJ	3	2.0%	Electricity supply > Electronic equipment > Sydney University, Faculty of Medicine	5,095 GJ	3	2.0%
7	Wholesale trade > Sydney University, Faculty of Pharmacy	536 GJ	2	2.0%	Wholesale trade > Sydney University, Faculty of Medicine	4,798 GJ	2	1.9%
8	Electricity supply > Electricity supply > Sydney University, Faculty of Pharmacy	514 GJ	3	1.9%	Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Medicine	4,323 GJ	3	1.7%
9	Air and space transport > Sydney University, Faculty of Pharmacy	499 GJ	2	1.9%	Sydney University, Faculty of Medicine	4,006 GJ	1	1.6%
10	Electricity supply > Glass products > Sydney University, Faculty of Pharmacy	381 GJ	3	1.4%	Electricity supply > Education > Sydney University, Faculty of Medicine	3,902 GJ	3	1.5%
11	Electricity supply > Electronic equipment > Sydney University, Faculty of Pharmacy	368 GJ	3	1.4%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	3,330 GJ	3	1.3%
12	Bus and tramway > Sydney University, Faculty of Pharmacy	345 GJ	2	1.3%	Electricity supply > Electricity supply > Sydney University, Faculty of Medicine	3,234 GJ	3	1.3%
13	Electricity supply > Education > Sydney University, Faculty of Pharmacy	344 GJ	3	1.3%	Electricity supply > Plastic products > Sydney University, Faculty of Medicine	3,158 GJ	3	1.2%
14	Electricity supply > Industrial machinery and equipment > Sydney University, Faculty of Pharmacy	317 GJ	3	1.2%	Electricity supply > Accommodation > Sydney University, Faculty of Medicine	2,846 GJ	3	1.1%
15	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	288 GJ	3	1.1%	Electricity supply > Glass products > Sydney University, Faculty of Medicine	2,490 GJ	3	1.0%

Energy Consumption	Nursing			
Rank	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Nursing	3,063 GJ	2	41.1%
2	Sydney University, Faculty of Nursing	523 GJ	1	7.0%
3	Air and space transport > Sydney University, Faculty of Nursing	497 GJ	2	6.7%
4	Electricity supply > Electricity supply > Sydney University, Faculty of Nursing	270 GJ	3	3.6%
5	Basic chemicals > Sydney University, Faculty of Nursing	146 GJ	2	2.0%
6	Electricity supply > Accommodation > Sydney University, Faculty of Nursing	133 GJ	3	1.8%
7	Electricity supply > Electronic equipment > Sydney University, Faculty of Nursing	109 GJ	3	1.5%
8	Road freight > Sydney University, Faculty of Nursing	85.7 GJ	2	1.2%
9	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	85.6 GJ	3	1.2%
10	Electricity supply > Advertising services > Sydney University, Faculty of Nursing	71.2 GJ	3	1.0%
11	Electricity supply > Plant leasing, hiring and renting services > Sydney University, Faculty of Nursing	67.5 GJ	3	0.9%
12	Electricity supply > Printing and stationery > Sydney University, Faculty of Nursing	64.6 GJ	3	0.9%
13	Petrol and diesel > Air and space transport > Sydney University, Faculty of Nursing	59.1 GJ	3	0.8%
14	Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Nursing	48.2 GJ	3	0.7%
15	Wholesale trade > Sydney University, Faculty of Nursing	45.0 GJ	2	0.6%

7.6.5. Ranked structural path across faculties for the GHG emissions indicator

GHG	Education				Arts			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Edu & Social Work	435 t CO2-e	2	27.8%	Electricity supply > Sydney University, Faculty of Arts	726 t CO2-e	2	16.8%
2	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	97.1 t CO2-e	4	6.2%	Air and space transport > Sydney University, Faculty of Arts	309 t CO2-e	2	7.2%
3	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Edu & Social Work	91.9 t CO2-e	4	5.9%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	270 t CO2-e	4	6.3%
4	Air and space transport > Sydney University, Faculty of Edu & Social Work	67.4 t CO2-e	2	4.3%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Arts	167 t CO2-e	4	3.9%
5	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	50.8 t CO2-e	3	3.3%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	141 t CO2-e	3	3.3%
6	Electricity supply > Electricity supply > Sydney University, Faculty of Edu & Social Work	38.3 t CO2-e	3	2.5%	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Arts	119 t CO2-e	4	2.8%
7	Electricity supply > Accommodation > Sydney University, Faculty of Edu & Social Work	37.0 t CO2-e	3	2.4%	Electricity supply > Accommodation > Sydney University, Faculty of Arts	114 t CO2-e	3	2.6%
8	Bus and tramway > Sydney University, Faculty of Edu & Social Work	20.7 t CO2-e	2	1.3%	Bus and tramway > Sydney University, Faculty of Arts	105 t CO2-e	2	2.4%
9	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Edu & Social Work	20.7 t CO2-e	4	1.3%	Electricity supply > Electronic equipment > Sydney University, Faculty of Arts	78.4 t CO2-e	3	1.8%
10	Electricity supply > Education > Sydney University, Faculty of Edu & Social Work	17.6 t CO2-e	3	1.1%	Electricity supply > Electricity supply > Sydney University, Faculty of Arts	64.0 t CO2-e	3	1.5%
11	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Edu & Social Work	17.4 t CO2-e	4	1.1%	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Arts	57.6 t CO2-e	4	1.3%
12	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Edu & Social Work	14.6 t CO2-e	4	0.9%	Road freight > Sydney University, Faculty of Arts	54.0 t CO2-e	2	1.3%
13	Electricity supply > Electronic equipment > Sydney University, Faculty of Edu & Social Work	14.1 t CO2-e	3	0.9%	Sanitary and garbage disposal > Sydney University, Faculty of Arts	52.8 t CO2-e	2	1.2%
14	Electricity supply > Printing and stationery > Sydney University, Faculty of Edu & Social Work	10.9 t CO2-e	3	0.7%	Electricity supply > Bus and tramway > Sydney University, Faculty of Arts	39.6 t CO2-e	3	0.9%
15	Brown coal > Electricity supply > Sydney University, Faculty of Edu & Social Work	10.5 t CO2-e	3	0.7%	Petrol and diesel > Air and space transport > Sydney University, Faculty of Arts	34.6 t CO2-e	3	0.8%

GHG	Law				Health Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Law	272 t CO2-e	2	18.7%	Electricity supply > Sydney University, Faculty of Health Sciences	2,691 t CO2-e	2	41.5%
2	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Law	139 t CO2-e	4	9.5%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Health Sciences	310 t CO2-e	4	4.8%
3	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	75.1 t CO2-e	4	5.2%	Electricity supply > Electricity supply > Sydney University, Faculty of Health Sciences	237 t CO2-e	3	3.7%
4	Air and space transport > Sydney University, Faculty of Law	75.0 t CO2-e	2	5.1%	Sydney University, Faculty of Health Sciences	182 t CO2-e	1	2.8%
5	Electricity supply > Accommodation > Sydney University, Faculty of Law	63.5 t CO2-e	3	4.4%	Air and space transport > Sydney University, Faculty of Health Sciences	152 t CO2-e	2	2.3%
6	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Law	39.7 t CO2-e	4	2.7%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	138 t CO2-e	4	2.1%
7	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	39.3 t CO2-e	3	2.7%	Electricity supply > Accommodation > Sydney University, Faculty of Health Sciences	92.0 t CO2-e	3	1.4%
8	Electricity supply > Electricity supply > Sydney University, Faculty of Law	24.0 t CO2-e	3	1.6%	Electricity supply > Electronic equipment > Sydney University, Faculty of Health Sciences	82.3 t CO2-e	3	1.3%
9	Electricity supply > Electronic equipment > Sydney University, Faculty of Law	23.2 t CO2-e	3	1.6%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Health Sciences	72.2 t CO2-e	3	1.1%
10	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Law	22.0 t CO2-e	4	1.5%	Brown coal > Electricity supply > Sydney University, Faculty of Health Sciences	65.2 t CO2-e	3	1.0%
11	Electricity supply > Printing and stationery > Sydney University, Faculty of Law	16.5 t CO2-e	3	1.1%	Electricity supply > Education > Sydney University, Faculty of Health Sciences	63.4 t CO2-e	3	1.0%
12	Beef cattle > Meat products > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Law	16.0 t CO2-e	4	1.1%	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Health Sciences	49.1 t CO2-e	4	0.8%
13	Softwoods > Pulp, paper and paperboard > Recorded media and publishing > Sydney University, Faculty of Law	12.9 t CO2-e	4	0.9%	Bus and tramway > Sydney University, Faculty of Health Sciences	40.3 t CO2-e	2	0.6%
14	Natural gas > Accommodation > Sydney University, Faculty of Law	11.5 t CO2-e	3	0.8%	Electricity supply > Printing and stationery > Sydney University, Faculty of Health Sciences	36.8 t CO2-e	3	0.6%
15	Electricity supply > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Law	10.4 t CO2-e	4	0.7%	Wholesale trade > Sydney University, Faculty of Health Sciences	35.7 t CO2-e	2	0.6%

GHG	Economy				Engineering			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Architecture	791 t CO2-e	2	37.6%	Electricity supply > Sydney University, Faculty of Vet Science	1,874 t CO2-e	2	27.6%
2	Sanitary and garbage disposal > Sydney University, Faculty of Architecture	245 t CO2-e	2	11.6%	Hay > Sydney University, Faculty of Vet Science	479 t CO2-e	2	7.1%
3	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	91.5 t CO2-e	4	4.3%	Sydney University, Faculty of Vet Science	339 t CO2-e	1	5.0%
4	Electricity supply > Electricity supply > Sydney University, Faculty of Architecture	69.7 t CO2-e	3	3.3%	Electricity supply > Electricity supply > Sydney University, Faculty of Vet Science	165 t CO2-e	3	2.4%
5	Air and space transport > Sydney University, Faculty of Architecture	49.3 t CO2-e	2	2.3%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Vet Science	157 t CO2-e	4	2.3%
6	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	48.4 t CO2-e	4	2.3%	Beef cattle > Sydney University, Faculty of Vet Science	151 t CO2-e	2	2.2%
7	Electricity supply > Electronic equipment > Sydney University, Faculty of Architecture	33.5 t CO2-e	3	1.6%	Basic chemicals > Sydney University, Faculty of Vet Science	130 t CO2-e	2	1.9%
8	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Architecture	25.3 t CO2-e	3	1.2%	Sanitary and garbage disposal > Sydney University, Faculty of Vet Science	126 t CO2-e	2	1.9%
9	Brown coal > Electricity supply > Sydney University, Faculty of Architecture	19.2 t CO2-e	3	0.9%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Vet Science	95.5 t CO2-e	4	1.4%
10	Bus and tramway > Sydney University, Faculty of Architecture	16.6 t CO2-e	2	0.8%	Wholesale trade > Sydney University, Faculty of Vet Science	87.9 t CO2-e	2	1.3%
11	Electricity supply > Accommodation > Sydney University, Faculty of Architecture	16.5 t CO2-e	3	0.8%	Air and space transport > Sydney University, Faculty of Vet Science	79.6 t CO2-e	2	1.2%
12	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	14.5 t CO2-e	4	0.7%	Sheep and lambs > Sydney University, Faculty of Vet Science	57.1 t CO2-e	2	0.8%
13	Road freight > Sydney University, Faculty of Architecture	13.3 t CO2-e	2	0.6%	Electricity supply > Electronic equipment > Sydney University, Faculty of Vet Science	54.1 t CO2-e	3	0.8%
14	Electricity supply > Computer and technical services > Sydney University, Faculty of Architecture	12.8 t CO2-e	3	0.6%	Brown coal > Basic chemicals > Sydney University, Faculty of Vet Science	50.2 t CO2-e	3	0.7%
15	Electricity supply > Plant leasing, hiring and renting services > Sydney University, Faculty of Architecture	12.2 t CO2-e	3	0.6%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Vet Science	50.0 t CO2-e	3	0.7%

GHG	Architecture				Veterinary Science			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	91.5 t CO2-e	4	33.7%	Hay > Sydney University, Faculty of Vet Science	479 t CO2-e	2	17.5%
2	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	14.5 t CO2-e	4	5.4%	Sydney University, Faculty of Vet Science	254 t CO2-e	1	9.3%
3	Electricity supply > Printing and stationery > Sydney University, Faculty of Architecture	10.9 t CO2-e	3	4.0%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Vet Science	157 t CO2-e	4	5.8%
4	Softwoods > Pulp, paper and paperboard > Recorded media and publishing > Sydney University, Faculty of Architecture	7.80 t CO2-e	4	2.9%	Beef cattle > Sydney University, Faculty of Vet Science	151 t CO2-e	2	5.5%
5	Electricity supply > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	6.88 t CO2-e	4	2.5%	Basic chemicals > Sydney University, Faculty of Vet Science	130 t CO2-e	2	4.8%
6	Softwoods > Pulp, paper and paperboard > Books, maps, magazines > Sydney University, Faculty of Architecture	6.35 t CO2-e	4	2.3%	Sheep and lambs > Sydney University, Faculty of Vet Science	57.1 t CO2-e	2	2.1%
7	Softwoods > Pulp, paper and paperboard > Paper products > Sydney University, Faculty of Architecture	6.07 t CO2-e	4	2.2%	Wholesale trade > Sydney University, Faculty of Vet Science	51.4 t CO2-e	2	1.9%
8	Basic chemicals > Sydney University, Faculty of Architecture	5.11 t CO2-e	2	1.9%	Brown coal > Basic chemicals > Sydney University, Faculty of Vet Science	50.2 t CO2-e	3	1.8%
9	Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Architecture	3.37 t CO2-e	3	1.2%	Electricity supply > Plastic products > Sydney University, Faculty of Vet Science	49.0 t CO2-e	3	1.8%
10	Iron and steel semi-manufactures > Fabricated construction steel > Sydney University, Faculty of Architecture	3.22 t CO2-e	3	1.2%	Brown coal > Petroleum and coal products > Sydney University, Faculty of Vet Science	42.0 t CO2-e	3	1.5%
11	Electricity supply > Plastic products > Sydney University, Faculty of Architecture	2.85 t CO2-e	3	1.1%	Basic chemicals > Plastic products > Sydney University, Faculty of Vet Science	38.8 t CO2-e	3	1.4%
12	Paper products > Sydney University, Faculty of Architecture	2.73 t CO2-e	2	1.0%	Brown coal > Gases > Sydney University, Faculty of Vet Science	32.8 t CO2-e	3	1.2%
13	Wholesale trade > Sydney University, Faculty of Architecture	2.42 t CO2-e	2	0.9%	Gases > Sydney University, Faculty of Vet Science	31.3 t CO2-e	2	1.2%
14	Hardwoods > Paper products > Sydney University, Faculty of Architecture	2.34 t CO2-e	3	0.9%	Animal breeding > Sydney University, Faculty of Vet Science	28.4 t CO2-e	2	1.0%
15	Basic chemicals > Plastic products > Sydney University, Faculty of Architecture	2.25 t CO2-e	3	0.8%	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Vet Science	25.0 t CO2-e	4	0.9%

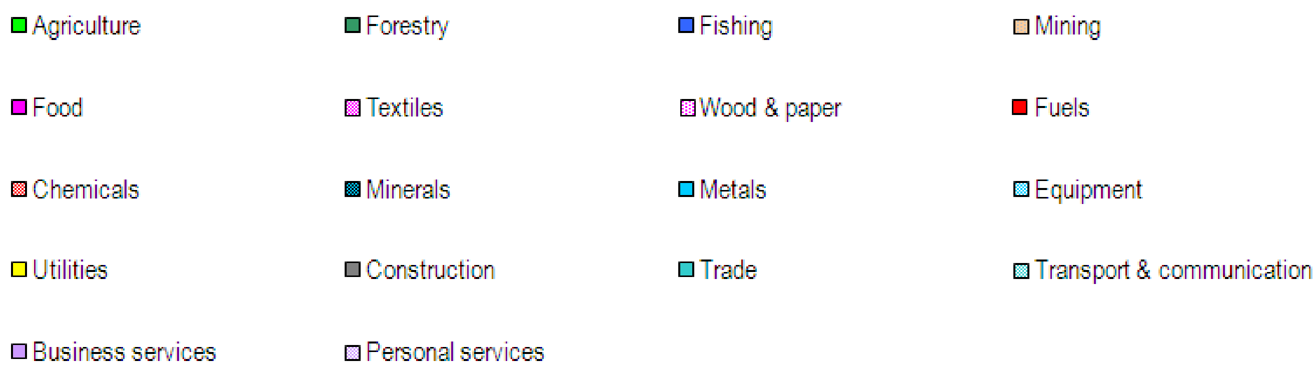
GHG	Science				Agriculture			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Science	5,341 t CO2-e	2	26.6%	Electricity supply > Sydney University, Faculty of Agriculture	977 t CO2-e	2	26.0%
2	Air and space transport > Sydney University, Faculty of Science	504 t CO2-e	2	2.5%	Sanitary and garbage disposal > Sydney University, Faculty of Agriculture	462 t CO2-e	2	12.3%
3	Glass products > Sydney University, Faculty of Science	499 t CO2-e	2	2.5%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Agriculture	90.0 t CO2-e	4	2.4%
4	Electricity supply > Electricity supply > Sydney University, Faculty of Science	470 t CO2-e	3	2.3%	Electricity supply > Electricity supply > Sydney University, Faculty of Agriculture	86.0 t CO2-e	3	2.3%
5	Sydney University, Faculty of Science	464 t CO2-e	1	2.3%	Sydney University, Faculty of Agriculture	79.2 t CO2-e	1	2.1%
6	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	462 t CO2-e	4	2.3%	Air and space transport > Sydney University, Faculty of Agriculture	76.6 t CO2-e	2	2.0%
7	Electricity supply > Electronic equipment > Sydney University, Faculty of Science	445 t CO2-e	3	2.2%	Bus and tramway > Sydney University, Faculty of Agriculture	73.1 t CO2-e	2	2.0%
8	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Science	408 t CO2-e	4	2.0%	Electricity supply > Electronic equipment > Sydney University, Faculty of Agriculture	43.7 t CO2-e	3	1.2%
9	Natural gas > Glass products > Sydney University, Faculty of Science	334 t CO2-e	3	1.7%	Grass seed > Sydney University, Faculty of Agriculture	43.5 t CO2-e	2	1.2%
10	Sanitary and garbage disposal > Sydney University, Faculty of Science	313 t CO2-e	2	1.6%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Agriculture	40.1 t CO2-e	4	1.1%
11	Electricity supply > Glass products > Sydney University, Faculty of Science	304 t CO2-e	3	1.5%	Electricity supply > Accommodation > Sydney University, Faculty of Agriculture	39.2 t CO2-e	3	1.0%
12	Electricity supply > Education > Sydney University, Faculty of Science	297 t CO2-e	3	1.5%	Brown coal > Petroleum and coal products > Sydney University, Faculty of Agriculture	32.2 t CO2-e	3	0.9%
13	Basic chemicals > Sydney University, Faculty of Science	246 t CO2-e	2	1.2%	Wholesale trade > Sydney University, Faculty of Agriculture	31.6 t CO2-e	2	0.8%
14	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Science	242 t CO2-e	3	1.2%	Glass products > Sydney University, Faculty of Agriculture	31.0 t CO2-e	2	0.8%
15	Wholesale trade > Sydney University, Faculty of Science	226 t CO2-e	2	1.1%	Basic chemicals > Sydney University, Faculty of Agriculture	28.8 t CO2-e	2	0.8%

GHG	Pharmacy				Medicine			
Rank	Path description	Path value	Path order	Percentage in total impact	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Pharmacy	516 t CO2-e	2	20.9%	Electricity supply > Sydney University, Faculty of Medicine	3,241 t CO2-e	2	12.2%
2	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Pharmacy	76.6 t CO2-e	4	3.1%	Beef cattle > Sydney University, Faculty of Medicine	961 t CO2-e	2	3.6%
3	Basic chemicals > Sydney University, Faculty of Pharmacy	60.9 t CO2-e	2	2.5%	Sanitary and garbage disposal > Sydney University, Faculty of Medicine	910 t CO2-e	2	3.4%
4	Glass products > Sydney University, Faculty of Pharmacy	55.2 t CO2-e	2	2.2%	Basic chemicals > Sydney University, Faculty of Medicine	739 t CO2-e	2	2.8%
5	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	48.6 t CO2-e	4	2.0%	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Medicine	719 t CO2-e	4	2.7%
6	Electricity supply > Electricity supply > Sydney University, Faculty of Pharmacy	45.4 t CO2-e	3	1.8%	Air and space transport > Sydney University, Faculty of Medicine	605 t CO2-e	2	2.3%
7	Iron and steel semi-manufactures > Industrial machinery and equipment > Sydney University, Faculty of Pharmacy	43.1 t CO2-e	3	1.8%	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	561 t CO2-e	4	2.1%
8	Wholesale trade > Sydney University, Faculty of Pharmacy	37.3 t CO2-e	2	1.5%	Electricity supply > Electronic equipment > Sydney University, Faculty of Medicine	450 t CO2-e	3	1.7%
9	Natural gas > Glass products > Sydney University, Faculty of Pharmacy	37.0 t CO2-e	3	1.5%	Sheep and lambs > Sydney University, Faculty of Medicine	364 t CO2-e	2	1.4%
10	Electricity supply > Glass products > Sydney University, Faculty of Pharmacy	33.6 t CO2-e	3	1.4%	Glass products > Sydney University, Faculty of Medicine	361 t CO2-e	2	1.4%
11	Electricity supply > Electronic equipment > Sydney University, Faculty of Pharmacy	32.5 t CO2-e	3	1.3%	Electricity supply > Education > Sydney University, Faculty of Medicine	344 t CO2-e	3	1.3%
12	Air and space transport > Sydney University, Faculty of Pharmacy	32.3 t CO2-e	2	1.3%	Wholesale trade > Sydney University, Faculty of Medicine	334 t CO2-e	2	1.3%
13	Electricity supply > Education > Sydney University, Faculty of Pharmacy	30.3 t CO2-e	3	1.2%	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Medicine	294 t CO2-e	3	1.1%
14	Electricity supply > Industrial machinery and equipment > Sydney University, Faculty of Pharmacy	28.0 t CO2-e	3	1.1%	Brown coal > Basic chemicals > Sydney University, Faculty of Medicine	286 t CO2-e	3	1.1%
15	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Pharmacy	25.4 t CO2-e	3	1.0%	Electricity supply > Electricity supply > Sydney University, Faculty of Medicine	285 t CO2-e	3	1.1%

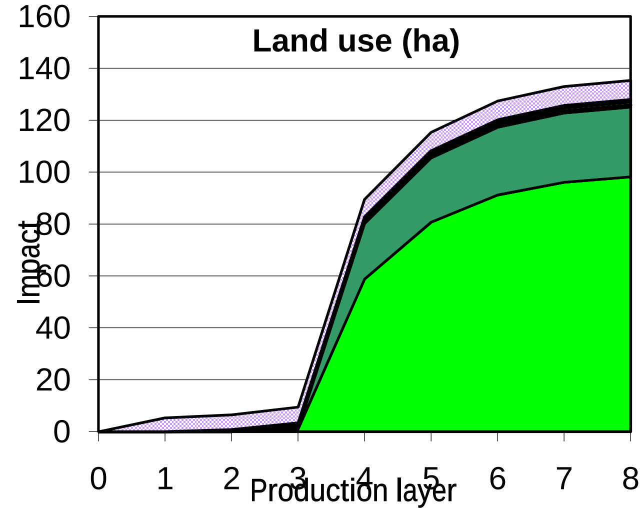
GHG	Nursing			
Rank	Path description	Path value	Path order	Percentage in total impact
1	Electricity supply > Sydney University, Faculty of Nursing	270 t CO2-e	2	36.3%
2	Softwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Nursing	47.9 t CO2-e	4	6.4%
3	Air and space transport > Sydney University, Faculty of Nursing	32.1 t CO2-e	2	4.3%
4	Sydney University, Faculty of Nursing	28.0 t CO2-e	1	3.8%
5	Electricity supply > Electricity supply > Sydney University, Faculty of Nursing	23.8 t CO2-e	3	3.2%
6	Beef cattle > Fresh meat > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	14.4 t CO2-e	4	1.9%
7	Electricity supply > Accommodation > Sydney University, Faculty of Nursing	11.7 t CO2-e	3	1.6%
8	Electricity supply > Electronic equipment > Sydney University, Faculty of Nursing	9.63 t CO2-e	3	1.3%
9	Hardwoods > Pulp, paper and paperboard > Printing and stationery > Sydney University, Faculty of Nursing	7.60 t CO2-e	4	1.0%
10	Electricity supply > Hotels, clubs, restaurants and cafes > Sydney University, Faculty of Nursing	7.55 t CO2-e	3	1.0%
11	Brown coal > Electricity supply > Sydney University, Faculty of Nursing	6.55 t CO2-e	3	0.9%
12	Electricity supply > Advertising services > Sydney University, Faculty of Nursing	6.28 t CO2-e	3	0.8%
13	Sanitary and garbage disposal > Sydney University, Faculty of Nursing	6.12 t CO2-e	2	0.8%
14	Road freight > Sydney University, Faculty of Nursing	6.06 t CO2-e	2	0.8%
15	Electricity supply > Plant leasing, hiring and renting services > Sydney University, Faculty of Nursing	5.96 t CO2-e	3	0.8%

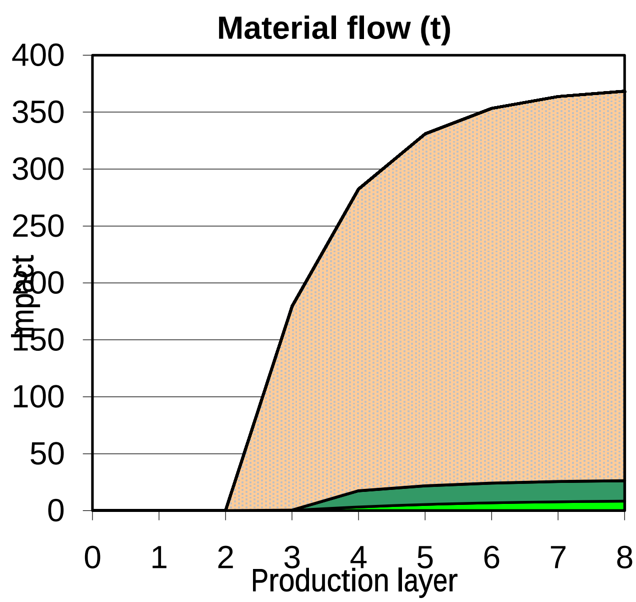
7.7. Appendix 7: Cumulative impact-by-layer area-graph by faculties and by indicator

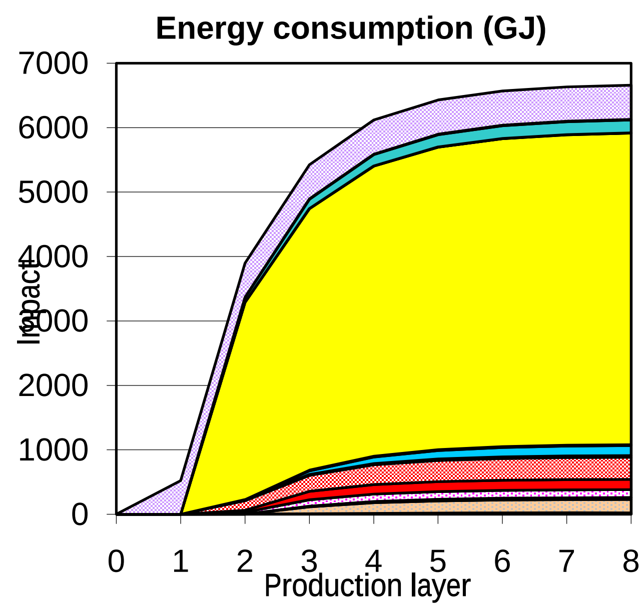
The same legend (represented below) applies to the next sixty-five area-graphs. In addition the 344 sectors have been reclassified into 18 groups (Agriculture, Forestry, Fishing, Mining, Food, Textiles, Wood & paper, Fuels, Chemicals, Minerals, Metals, Equipment, Utilities, Construction, Trade, Transport & communication, Business services, Personal services) for sake of clarity as it would clearly be impossible to show them all separately.

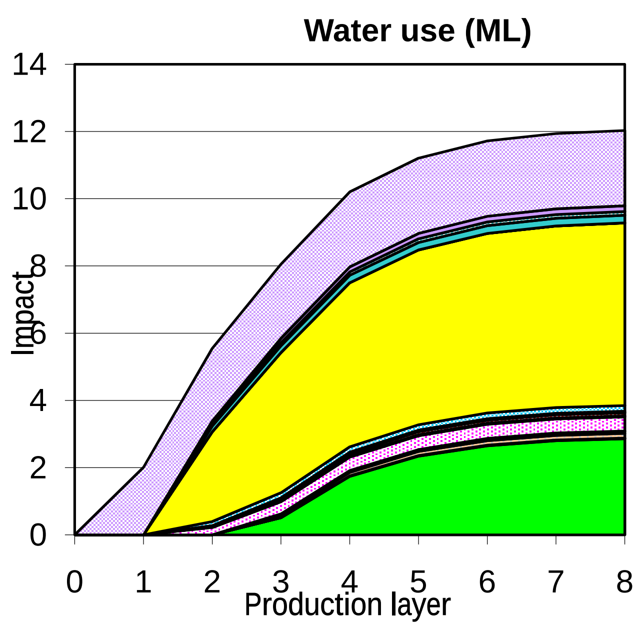


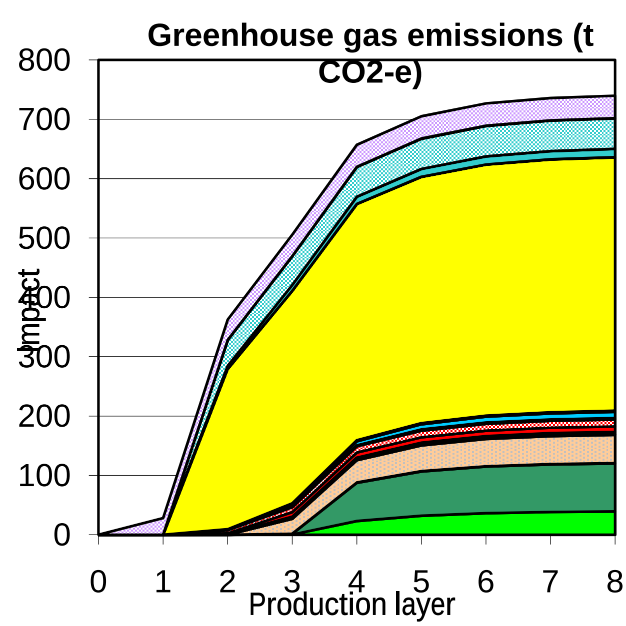
7.7.1. Faculty of Nursing



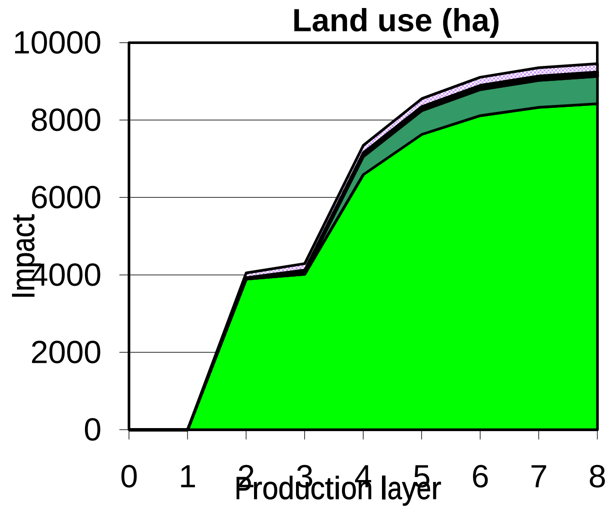


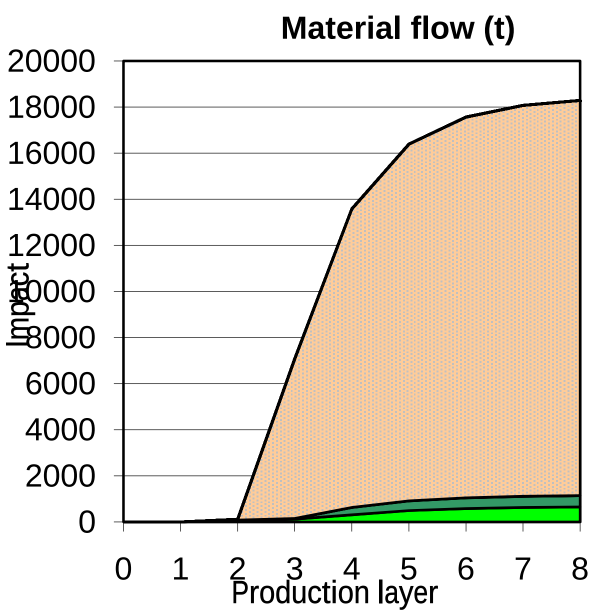


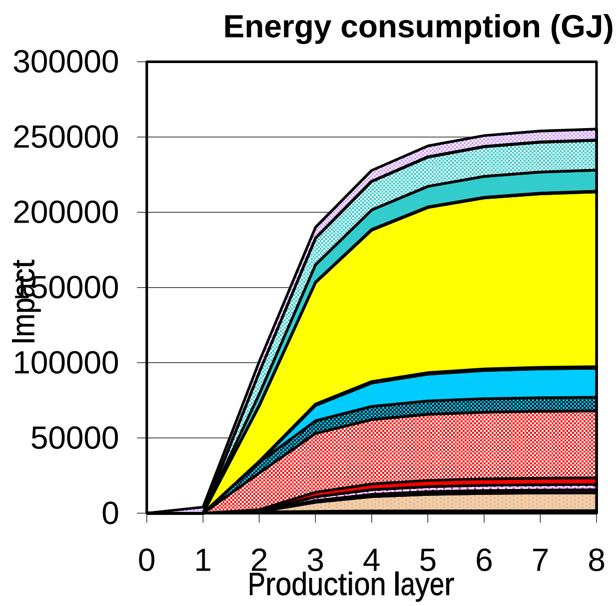


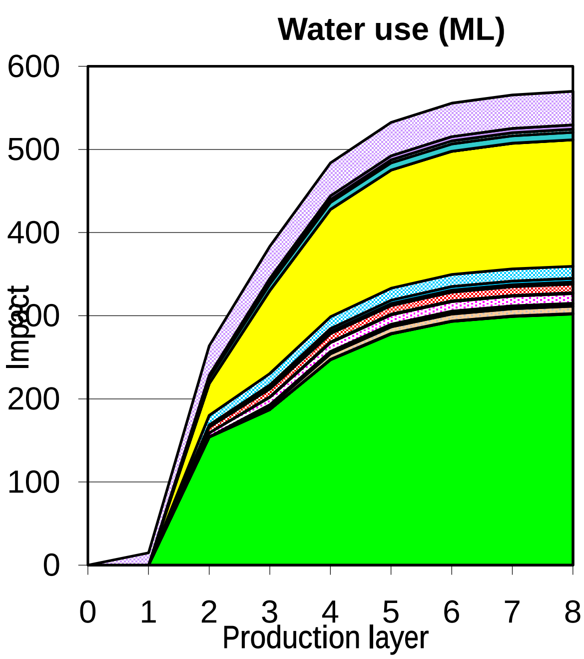


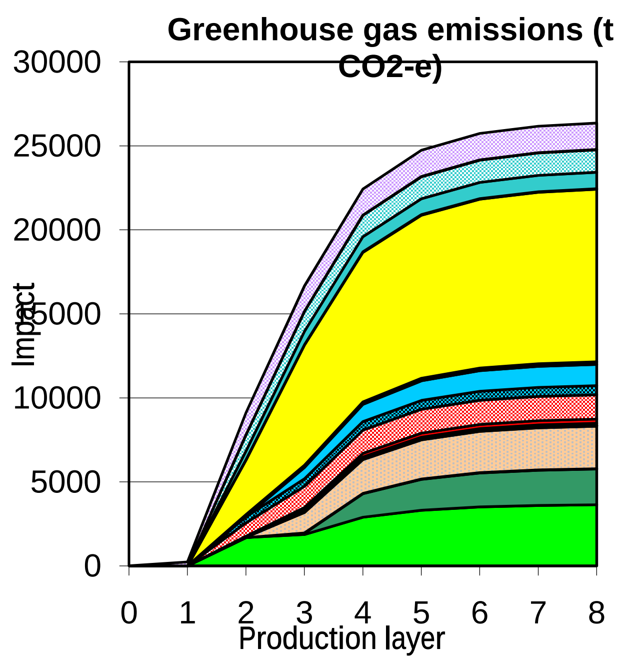
7.7.2. Faculty of Medicine



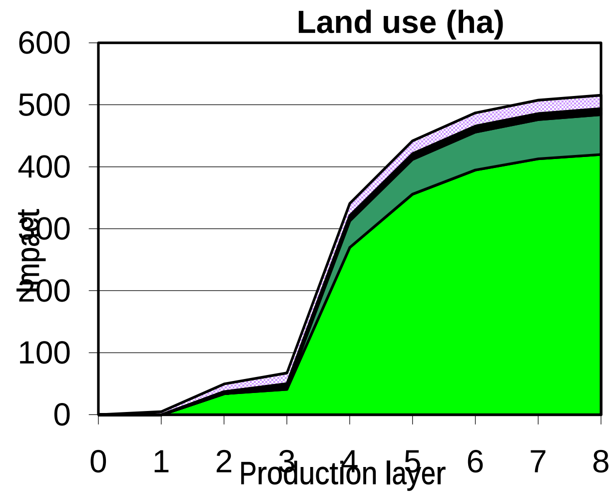


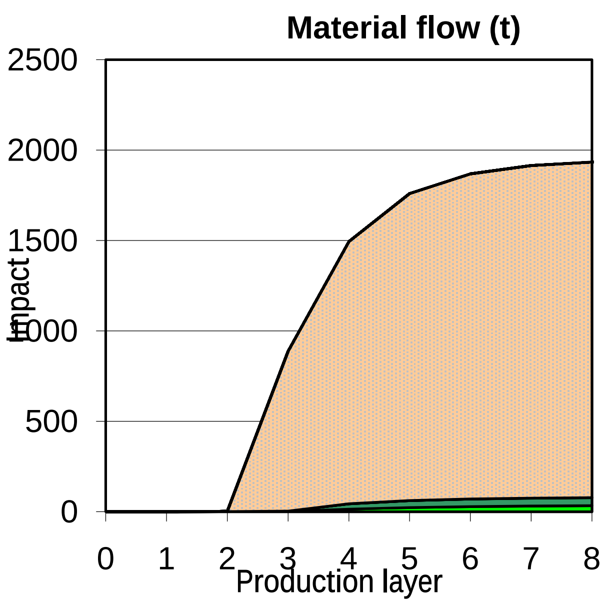


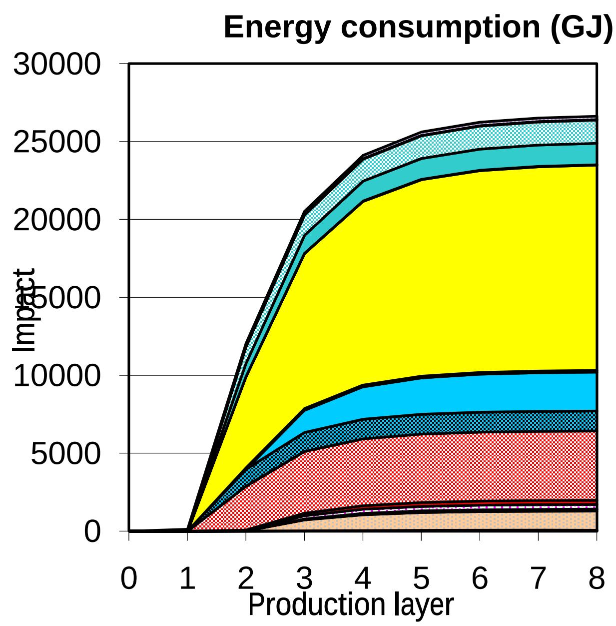


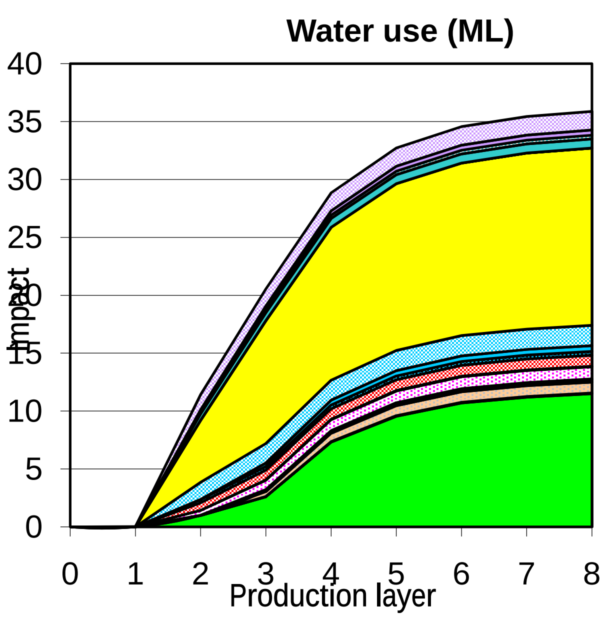


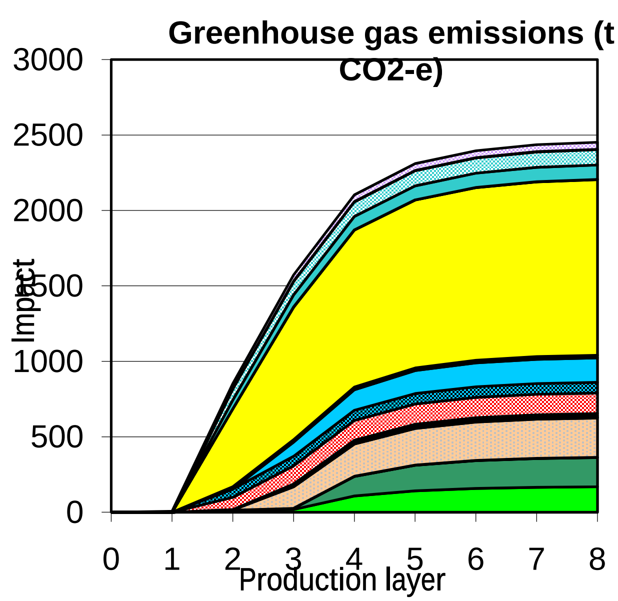
7.7.3. Faculty of Pharmacy



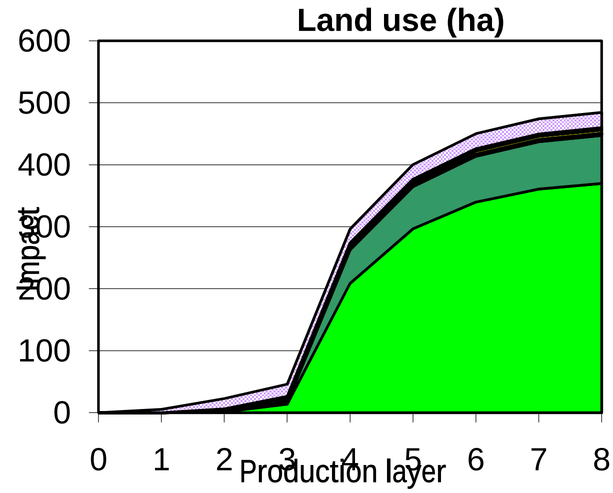


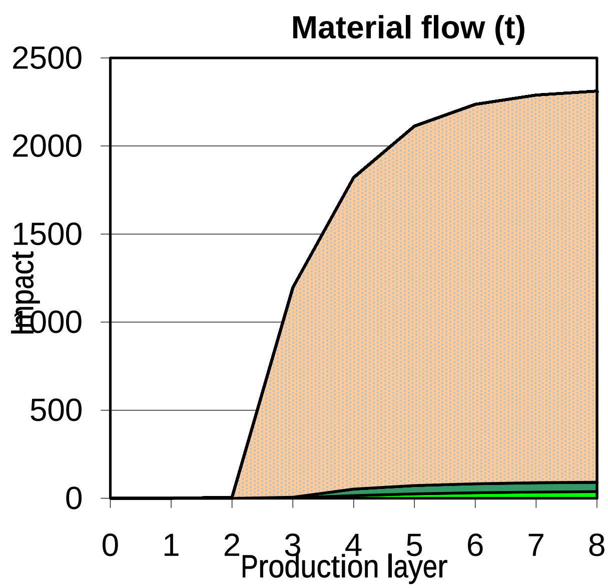


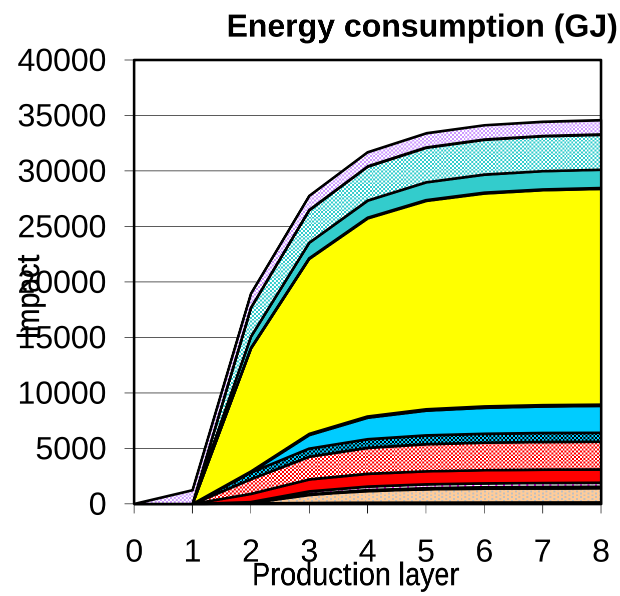


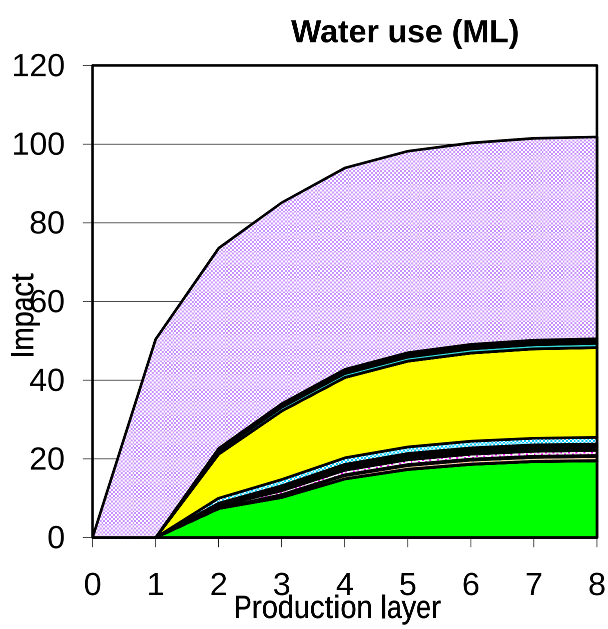


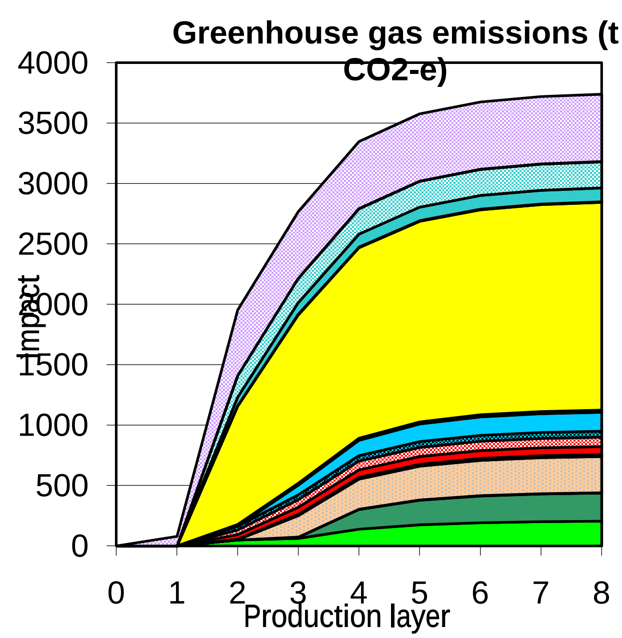
7.7.4. Faculty of Agriculture



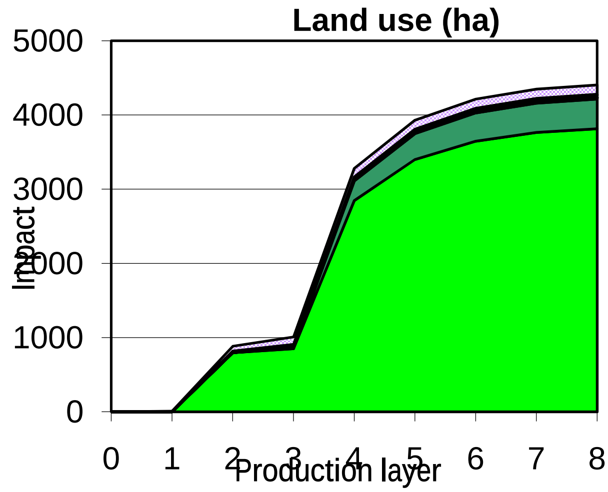


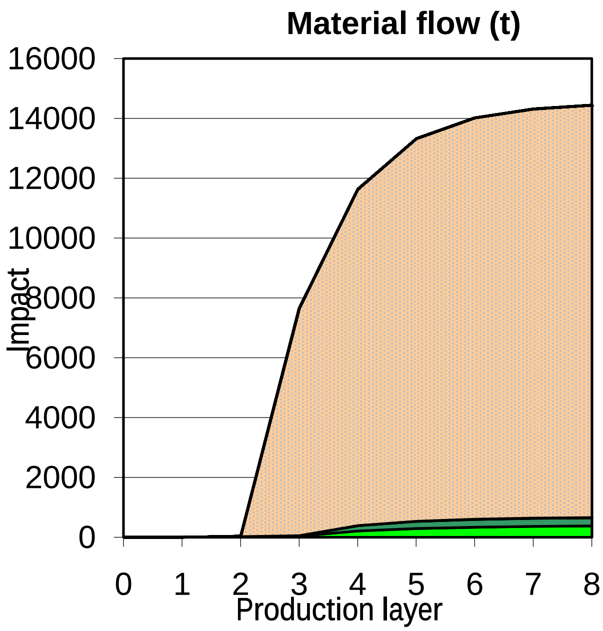


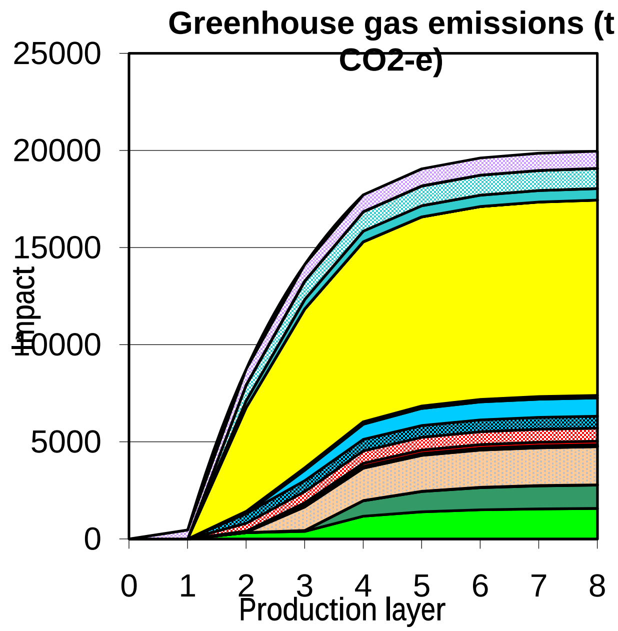


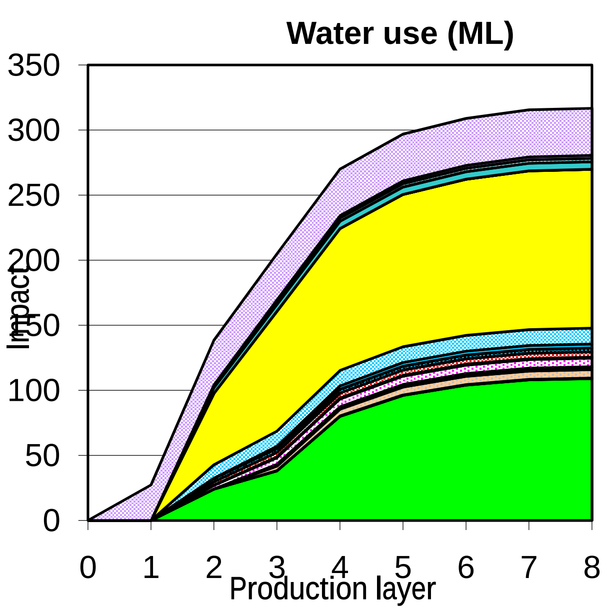


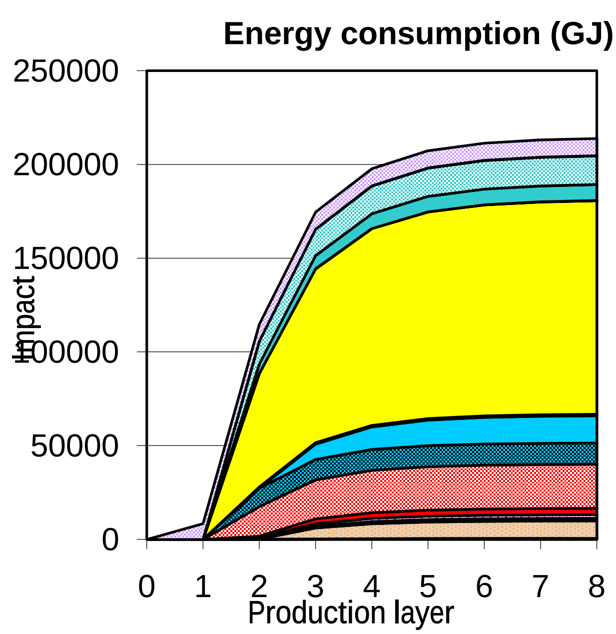
7.7.5. Faculty of Science



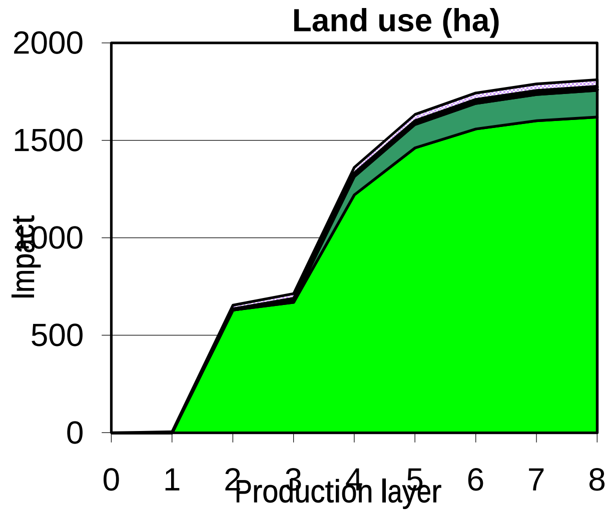


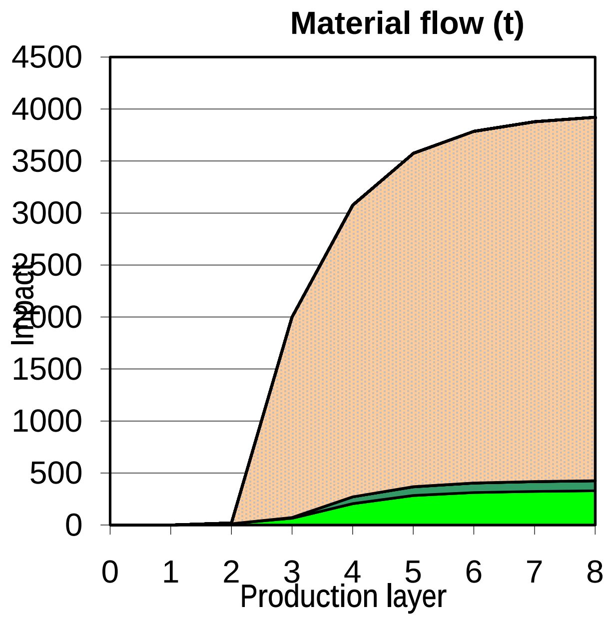


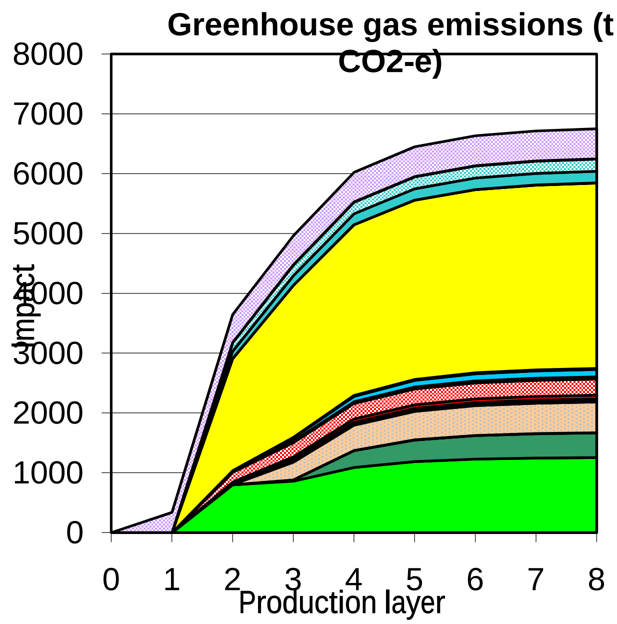


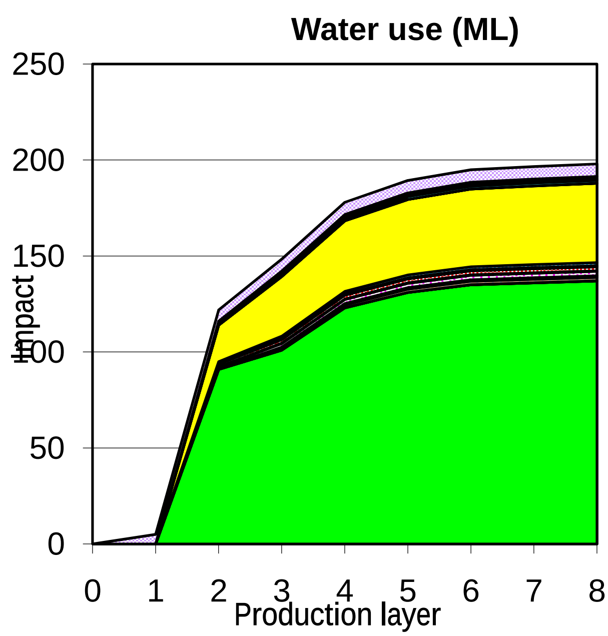


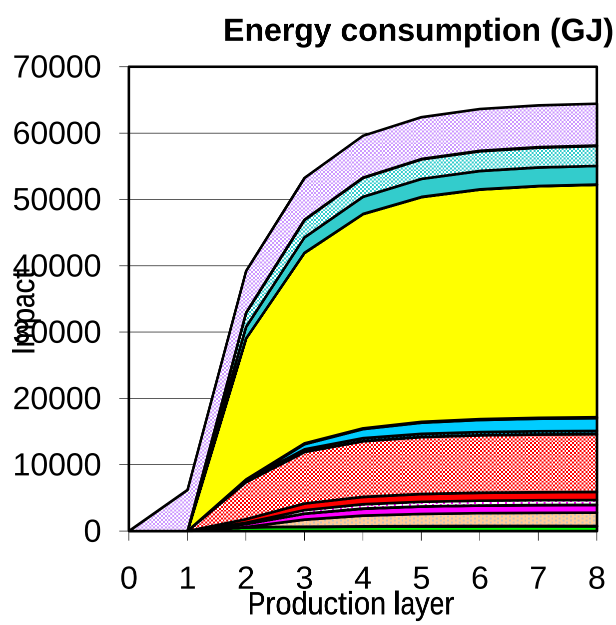
7.7.6. Faculty of veterinary science



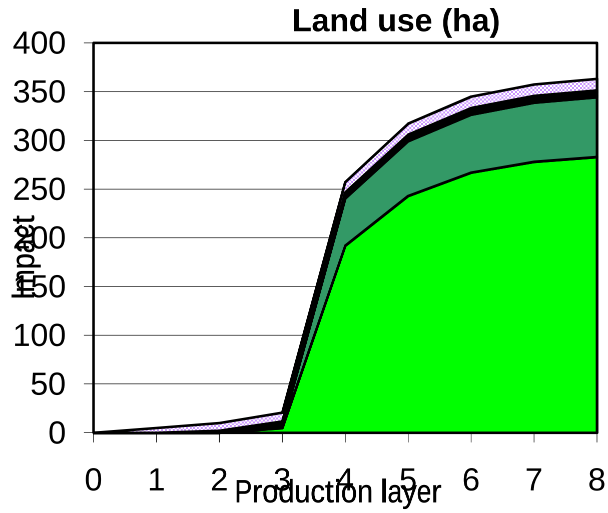


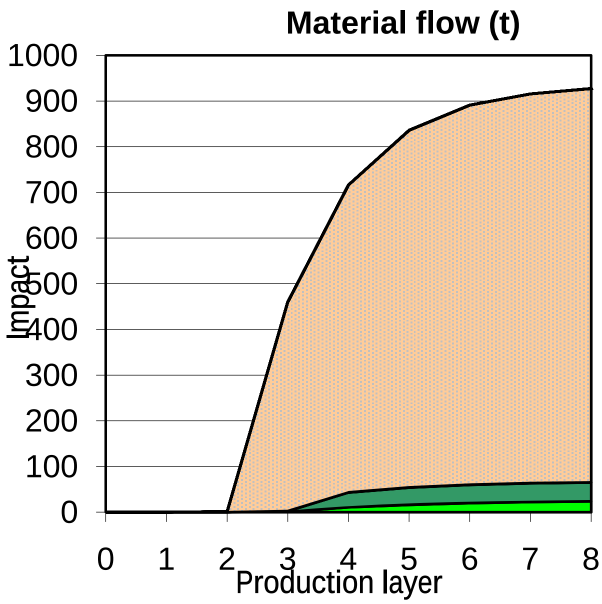


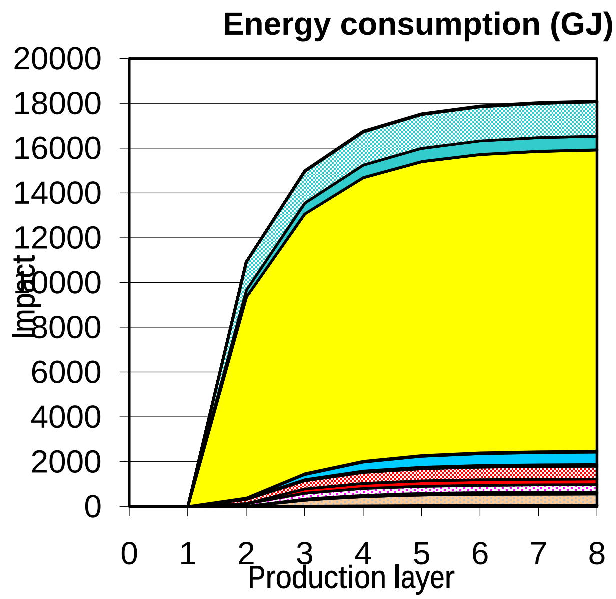


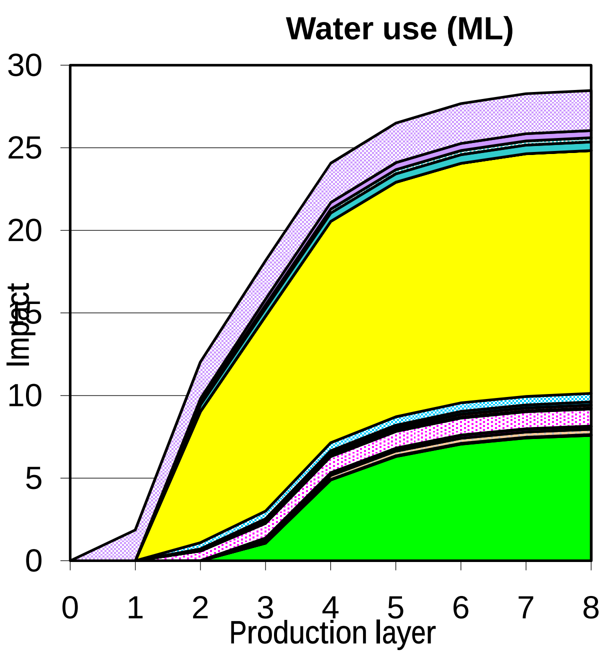


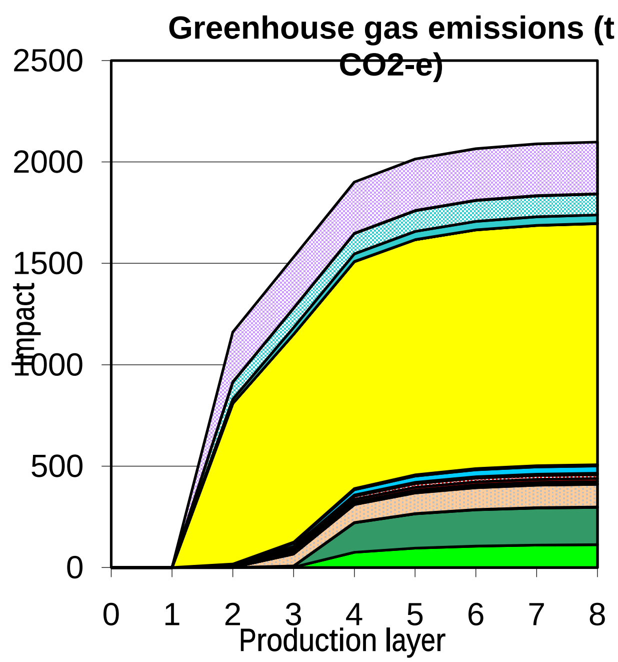
7.7.7. Faculty of Architecture



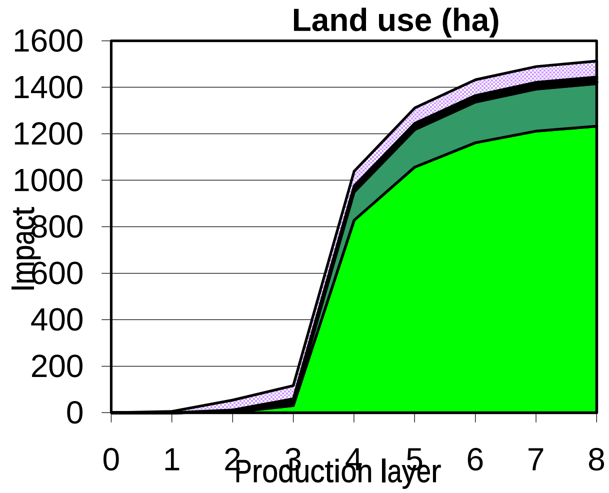


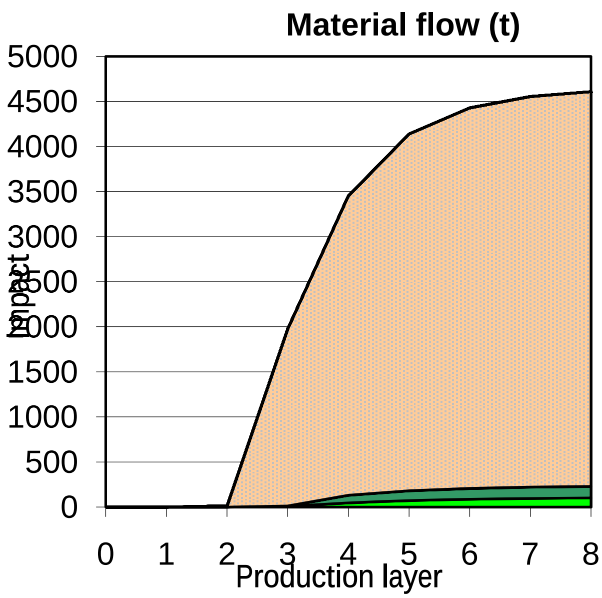


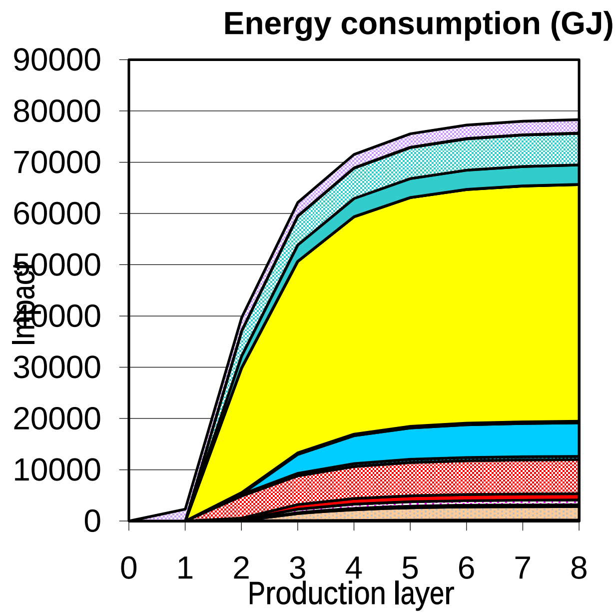


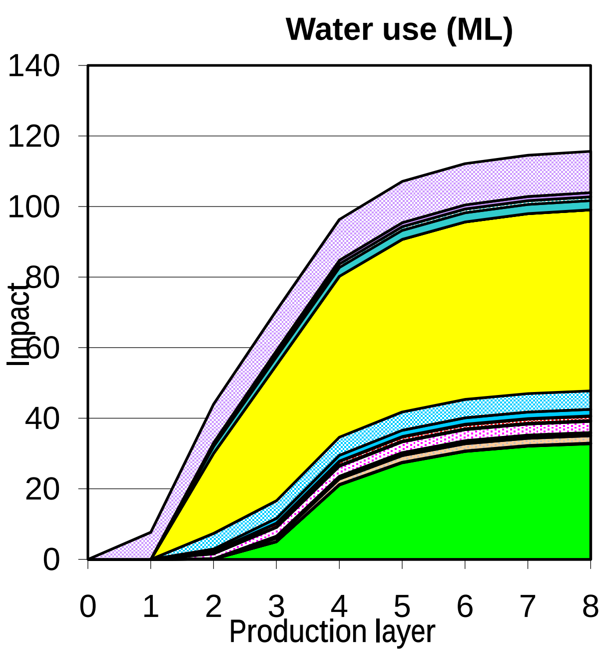


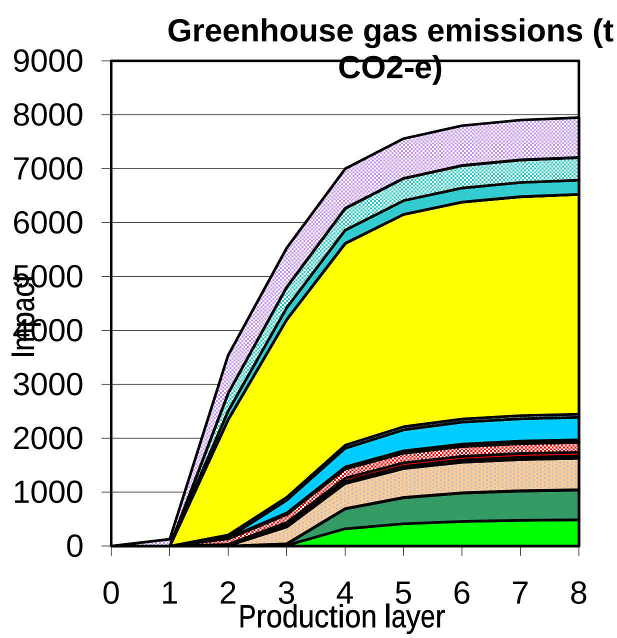
7.7.8. Faculty of Engineering



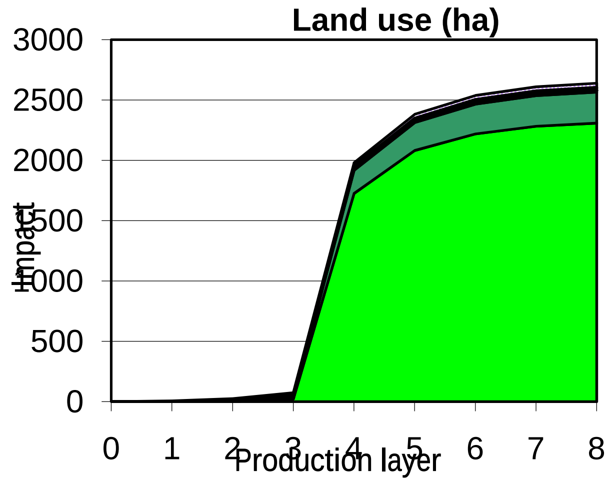


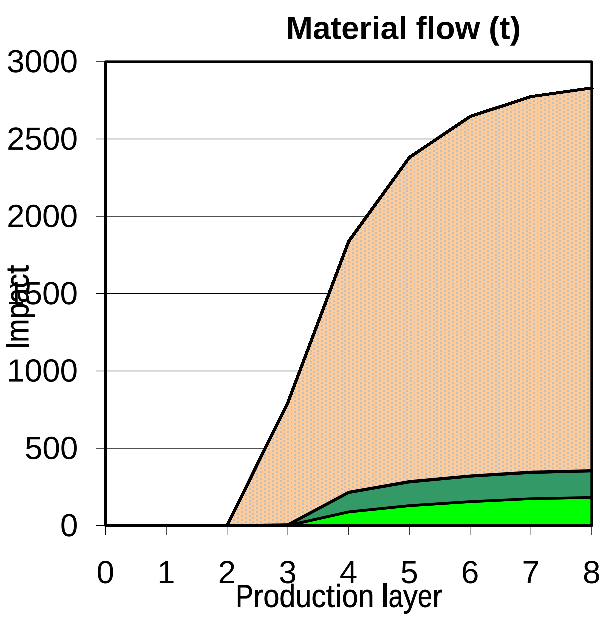


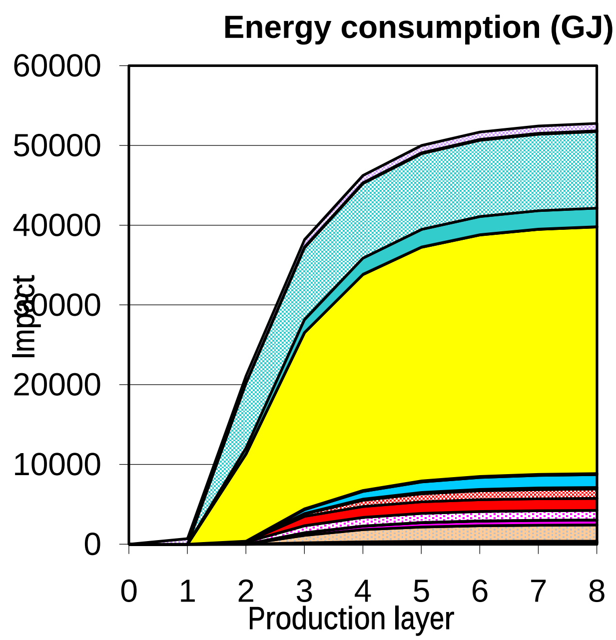


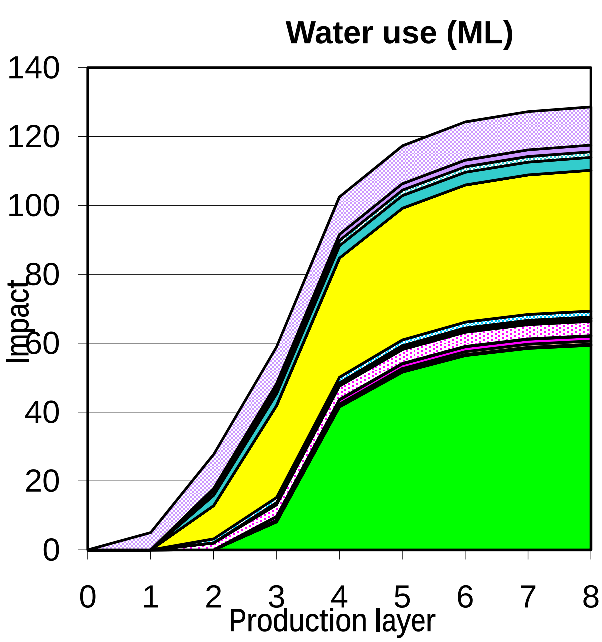


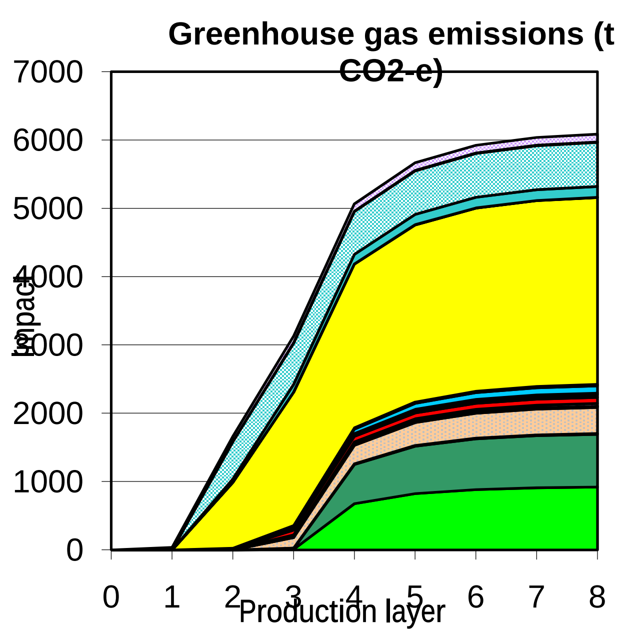
7.7.9. Faculty of Economy



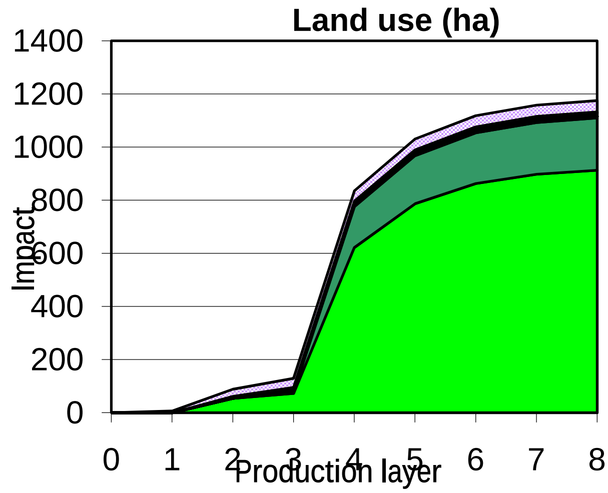


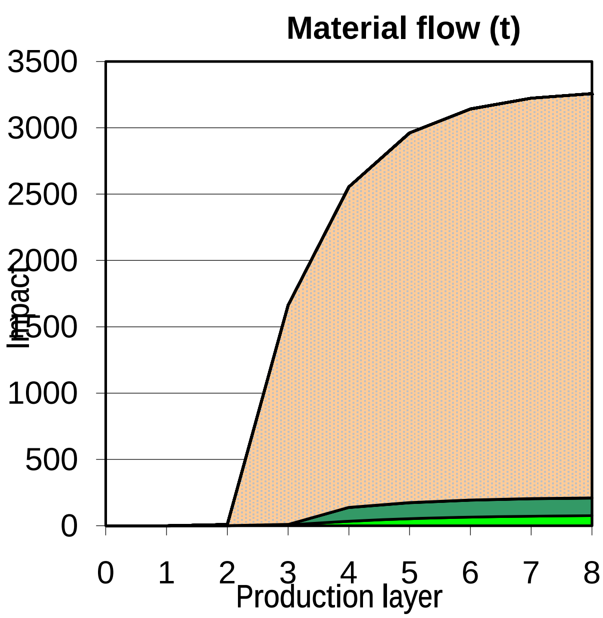


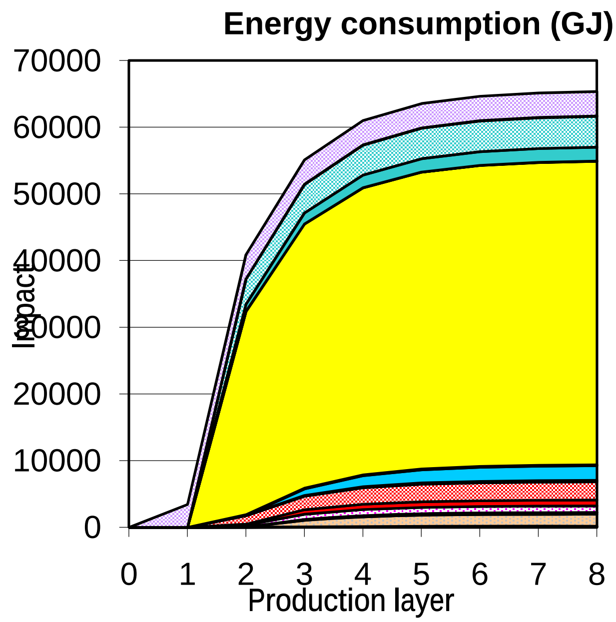


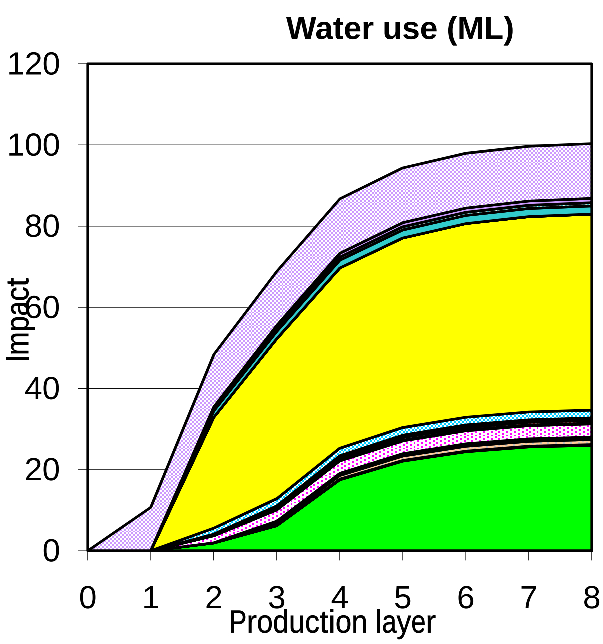


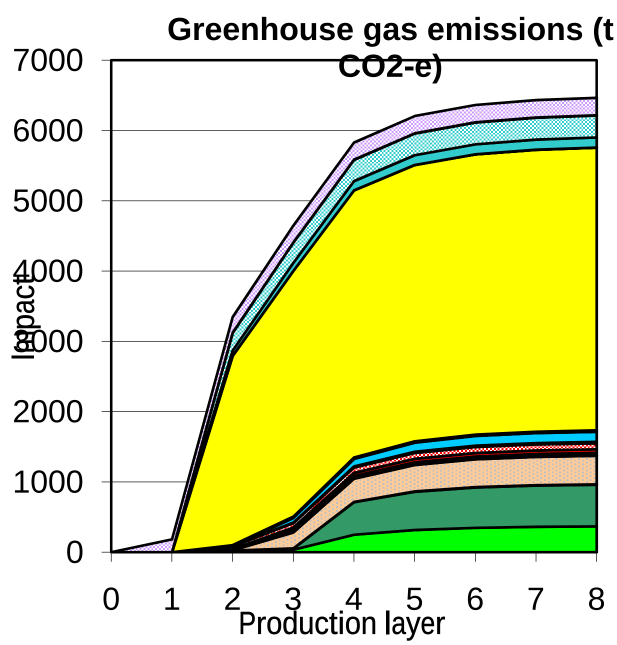
7.7.10. Faculty of Health Science



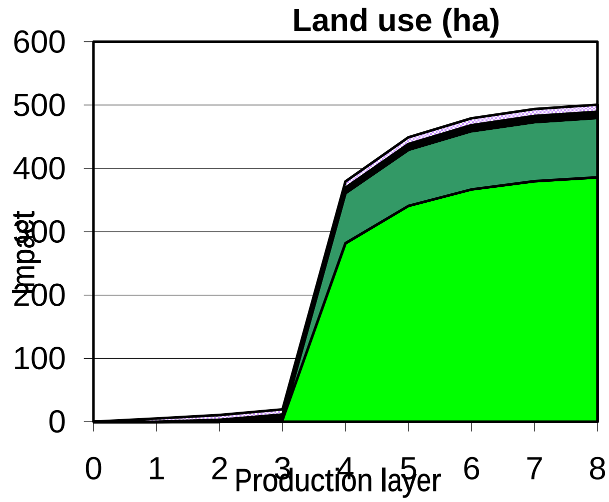


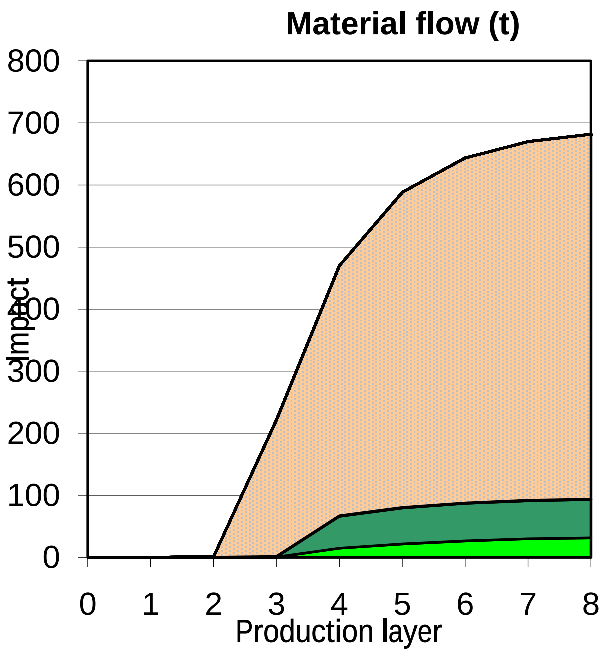


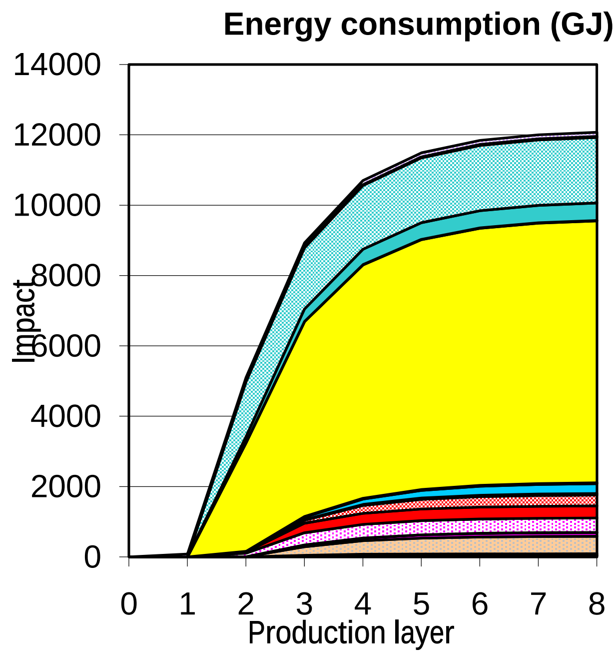


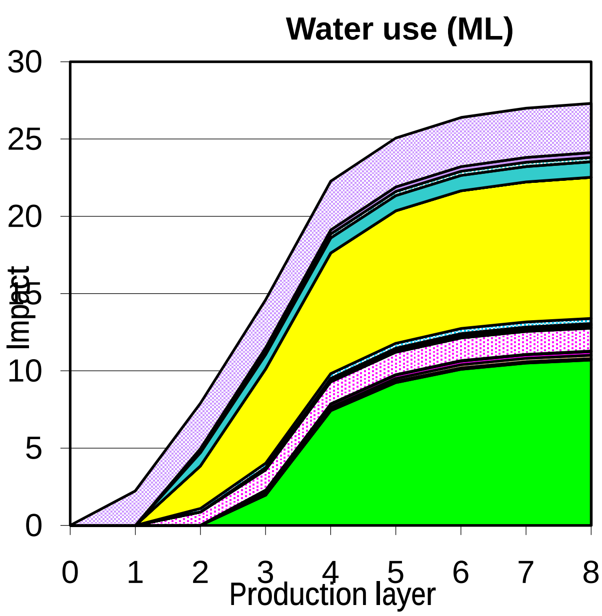


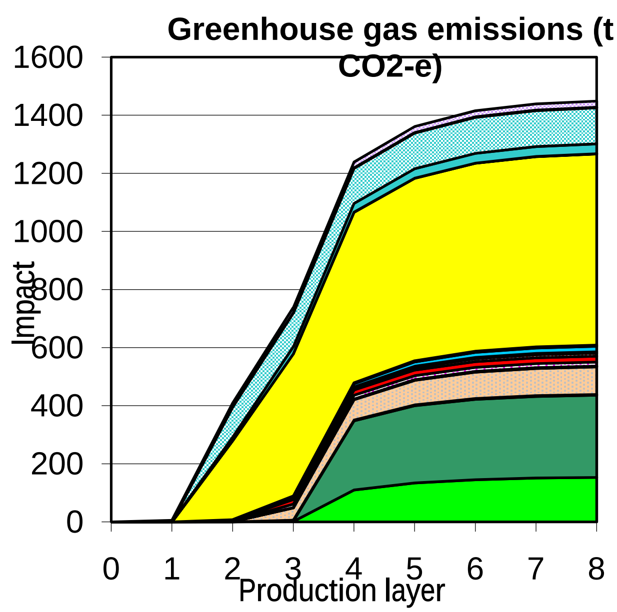
7.7.11. Faculty of Law



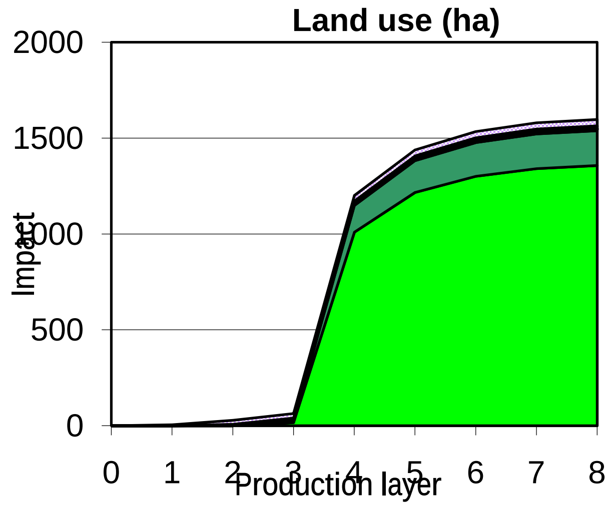


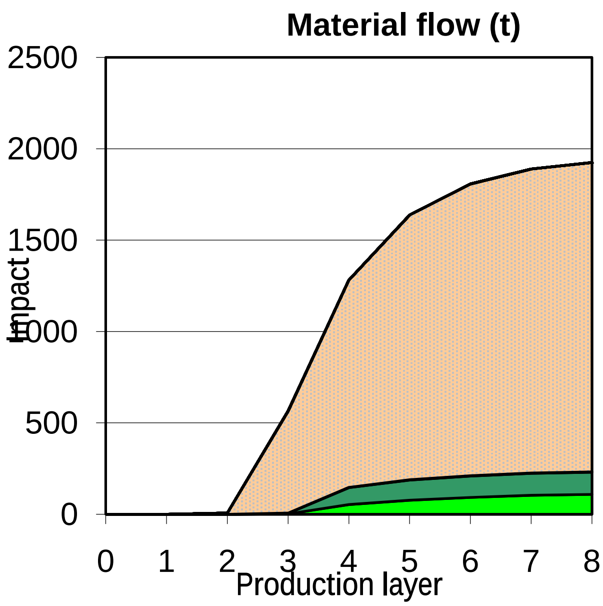


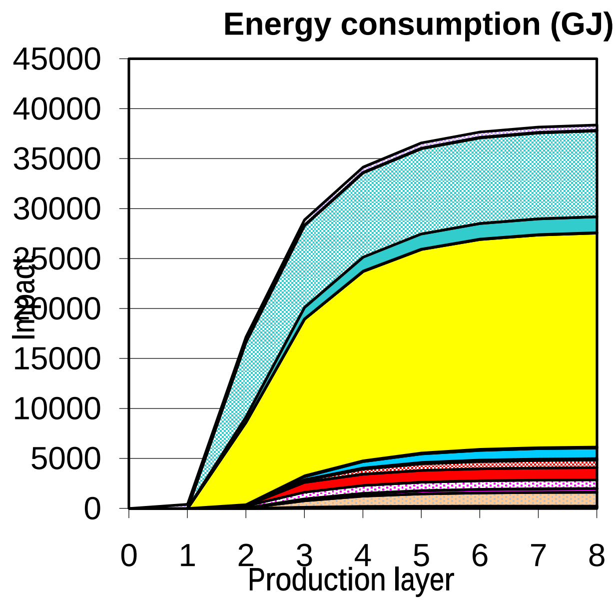


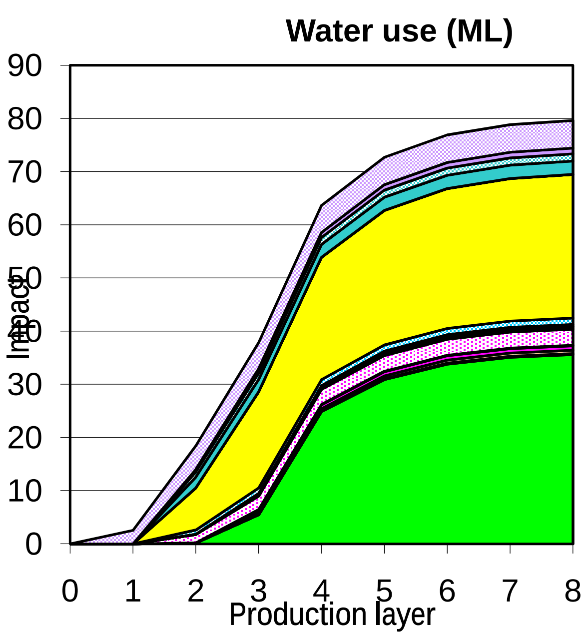


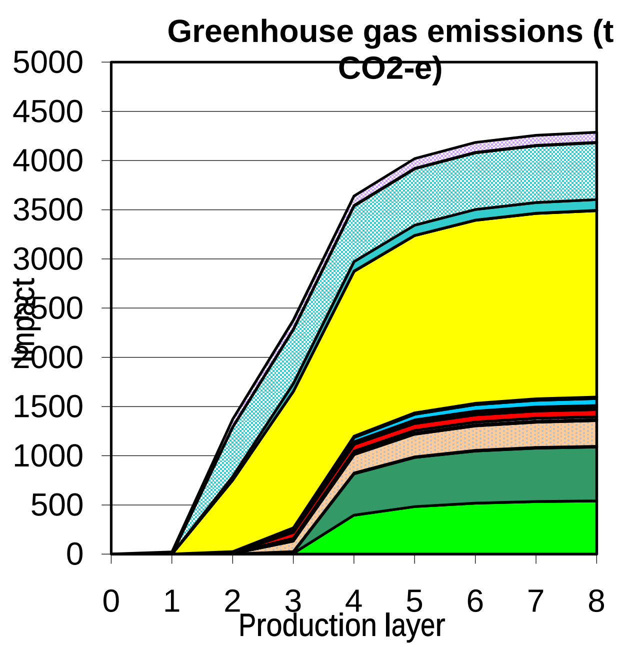
7.7.12. Faculty of Arts



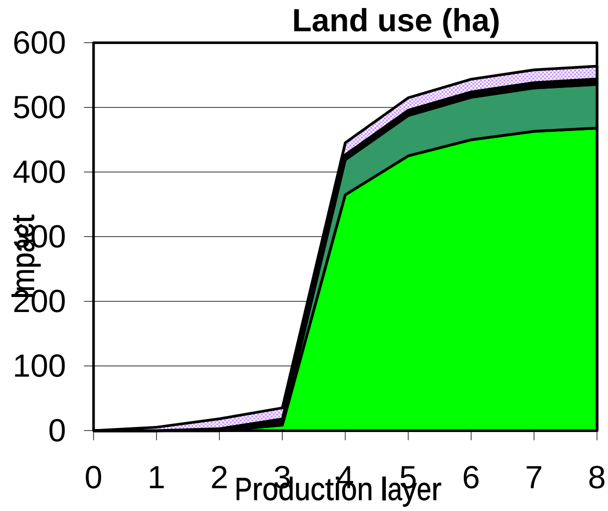


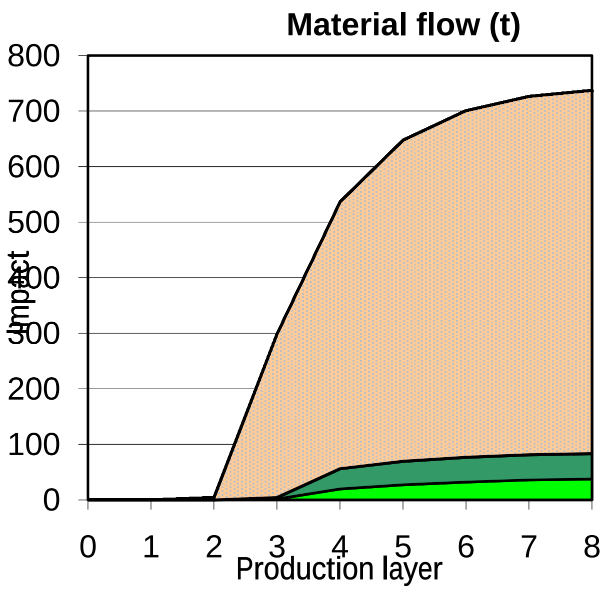


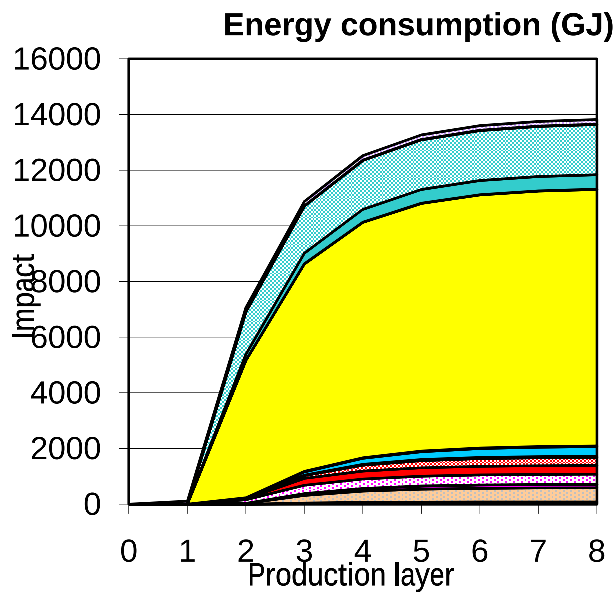


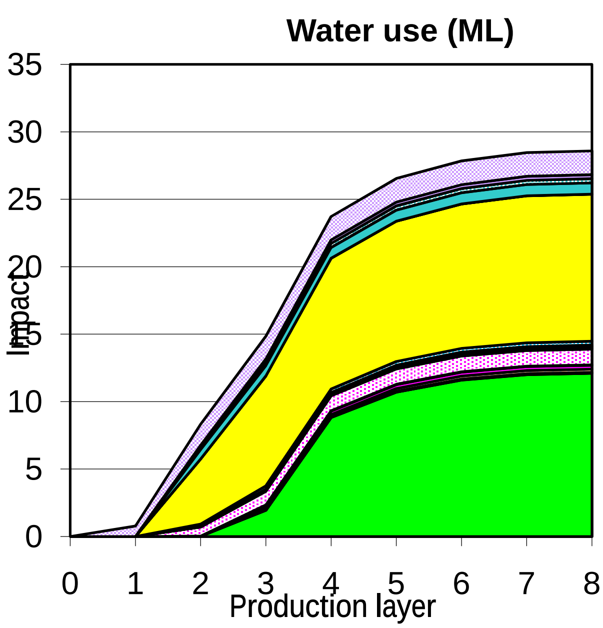


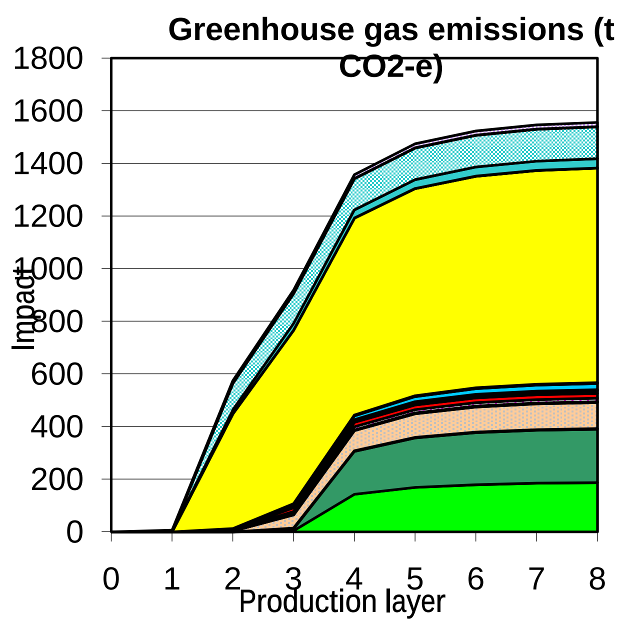
7.7.13. Faculty of Education











7.8. Appendix 8: Indicator-wise faculties ranking

Ranking on a bulk basis	material flow	energy consumption	water use	land use	GHG emissions
nursing	○ 1	○ 1	○ 1	○ 1	○ 1
medicine	● 13	● 13	● 13	● 13	● 13
pharmacy	◔ 5	◔ 5	◔ 5	◔ 5	◔ 5
agriculture	◑ 7	◑ 6	◑ 8	○ 3	◑ 6
science	● 12	● 12	● 12	● 12	● 12
vet. Science	◕ 10	◕ 9	● 11	◕ 10	◕ 10
architecture	◔ 4	◔ 4	○ 3	○ 2	◔ 4
engineering	● 11	● 11	◕ 9	◑ 8	● 11
economy	◑ 8	◑ 8	◕ 10	● 11	◑ 8
health science	◕ 9	◕ 10	◑ 7	◑ 7	◕ 9
law	○ 2	○ 2	○ 2	◔ 4	○ 2
arts	◑ 6	◑ 7	◑ 6	◕ 9	◑ 7
education	○ 3	○ 3	◔ 4	◑ 6	○ 3

Ranking on an intensiy basis	material flow	energy consumption	water use	land use	GHG emissions
nursing	◔ 5	◔ 5	◔ 5	○ 1	◔ 5
medicine	◑ 6	◑ 6	◕ 9	● 12	◑ 6
pharmacy	◑ 8	◑ 8	◑ 6	◔ 5	◑ 7
agriculture	● 11	● 11	● 12	○ 2	● 11
science	● 12	● 12	● 11	● 11	◕ 10
vet. Science	● 13	● 13	● 13	● 13	● 13
architecture	◕ 10	◕ 10	◕ 10	◕ 10	● 12
engineering	◕ 9	◕ 9	◑ 8	◑ 7	◕ 9
economy	○ 1	○ 1	○ 2	◕ 9	○ 1
health science	◑ 7	◑ 7	◑ 7	○ 3	◑ 8
law	○ 2	○ 2	◔ 4	◔ 4	○ 3
arts	○ 3	○ 3	○ 1	◔ 5	○ 2
education	◔ 4	◔ 4	○ 3	◑ 8	◔ 4