ECTOS Methodology

An Approach To Socio – Economic & Environmental Studies Accompanying a Demonstration of a Public Transport System Using Fuel Cells and Hydrogen as a fuel and Running a Commercial Hydrogen Fuel Station 2001- 2005.

ECTOS Deliverables 1 & 2

EC supported project: Ecological City Transport System. Demonstration, Evaluation And Research Project Of Hydrogen Fuel Cell Bus Transportation System Of The Future. Contract: EVK4-CT-2000-00033

European Commission DG Research;

"City of Tomorrow and Cultural Heritage"

Fifth Framework For Research And Development

Icelandic New Energy

December 2002

Definitions of special ECTOS acronyms used in the paper. See also Attachment III:

CUTE, Clean Urban City Transport, a second bus demonstration within 9 European Cities.

EC, European Commission, specifically the technical administration, (DG research) for the Program on Energy and Environment

ECTOS, Ecological City TranspOrt System

EU, European Union or European Community

GUESS, Group Undertaking the Environ-mental, Socio-economic Study

IceTec, Technological Institute of Iceland

INE, Icelandic New Energy

LCA, Life Cycle Analysis

UNI, University of Iceland

VINNOVA, Swedish innovation systems

Well to Wheel, life cycle analysis focusing on energy use and green house gases

IKP, Institut für Kunststoffprüfung und Kunststoffkunde, Stuttgart, Germany

December 2002.

The ECTOS Methodology is only intended as a description of procedures within the implementation of a demonstration project. Descriptions and formulations of ideas are intentionally kept simple and explained with examples of practical procedures instead of complex terminology. Therefore it is not recommended as a reading within a philosophical discipline. It is foremost intended as a reference for working groups within a specific situation: A description of how studies can be implemented during a technical test of new types of vehicles, running on a new type of fuel. This Methodology is a description of the used theories, possibilities, approaches and applied methods as well as references to former sources rather than an explanation of an epistemology or a political strategy. Questions should be addressed to:

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Abstract

The goal of this document is to set a common ground for the cross-disciplinary studies that accompany ECTOS, a large demonstration project where hydrogen is used to fuel public fuel cell buses. Within the same project a hydrogen production, storage and filling station will also be operated on commercial terms. The hydrogen is produced via electrolysis from water, the hydrogen is stored under pressure on the location and storage cylinders on board the buses are filled diurnally and the fuel spent within the public transport system of Reykjavik, Iceland.

The studies cover social, economic and environmental aspects of the demonstration and are correlated with the technical performance of the equipment. According to the goals of ECTOS, comparative studies will be made with other fuel chains, environmental monitoring executed, social acceptance measured and Life Cycle Analyses carried out both for the vehicles and for the fuel. Information on the results and the process within the project will be given regularly to stakeholders and the public.

The role of the ECTOS methodology is to become a reference that partners and other stakeholders can use as a guide to the implementation of the project work, facilitate dialogue within the project and act as a handbook for similar work later on. A plan and description of approaches for the cross-disciplinary studies based on the Description of Work within ECTOS is introduced. The backbones of the paper are chapters collected from project partners about their intended studies on social factors, environmental aspects and cost-estimations. A theoretical background and comparable references is given and specific methods described which should fit each component of the project.

The emphasis of the applied methods is on analysing the processed data and goes further to act as action research. This implies that information will be disseminated from the project whilst it is going on and the response to the information analysed as well. This will provide a feedback into the project work, as well as acting as reflexive amendment tool to the described planned methodology.

Suggestions are stated about how the proposed methods can serve as a decision – aiding tool for similar transportation systems, particularly within the European Community.

1. Introduction

Ecological City Transport System (ECTOS 2001 - 2005) is the title of a demonstration project based in Reykjavik, Iceland and supported by the European Commission through the programme Environment, Energy and Research. The ECTOS project is a real scale demonstration that focuses on testing all the parts needed to run a public transport system using hydrogen as a fuel. The hydrogen is produced via electrolysis from water, using electricity available from the national grid. The electricity is solely derived from renewable energy sources, namely hydropower and geothermal power. The hydrogen will be stored under pressure on the production site and the buses filled up daily from a dispenser on the production site. Therefore transportation of hydrogen is minimized. Safety procedures in constructing the electrolyser and bus are in accordance to guidelines from the TÜV[1] South Germany. Norsk Hydro is the main deliverer of the fuel station and uses and cooperates closely with "Det norske Veritas", a similar institute on public health and safety measures in Scandinavia. The project keeps a record of all safety procedures and tests that the equipment undergoes.

Simplifying, the execution will be as follows: Preparation and construction of a hydrogen fuel station, the operation of three buses within a public transport system and the concurrent monitoring of the public acceptance of this operation, and the estimation of the environmental changes and costs.

Two main phases are planned during the project: 1) A forerunning organisation, planning and preparation phase and 2) A two year actual driving and technical test. Data will be collected during the entire project on social factors, environmental aspects and a cost study made which can be used to estimate the budged for establishing a hydrogen economy in Iceland.

Technical data will be collected on the equipment during the latter phase of the project.

1.1   Scope and Limitation for the methodology

The setting for the project is the city of Reykjavik, Iceland and the local conditions and administrative framework. Iceland is not a member of the EU but it is a member of the European Economic Area (EEA). Therefore it has particular agreements for participation within research and demonstration projects. Iceland's participation in the EEA also means that it is obliged to adapt the local legislation to the European legislation to a great extent. In most situations the same general rules and regulations apply for Reykjavik as within other cities in the European Community. Therefore references and reports used for comparison will mostly stem from the EU member states. These will be listed within the planned reports. A second demonstration project, the CUTE (Clean Urban Transport for Europe) will be run almost simultaneously in 9

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[1] The German Institute for safety and health protocol for the mobility sector

cities on the continent of Europe and close cooperation and data sharing will be kept between these two projects.

The ECTOS Methodology only deals with the socio – environmental and economic studies within the project, from this point referred to as "socio-eco-enviro studies" or the parallel research. Concurrently the technical data will be used as background reference and will therefore be reported alongside the results from the studies described here.
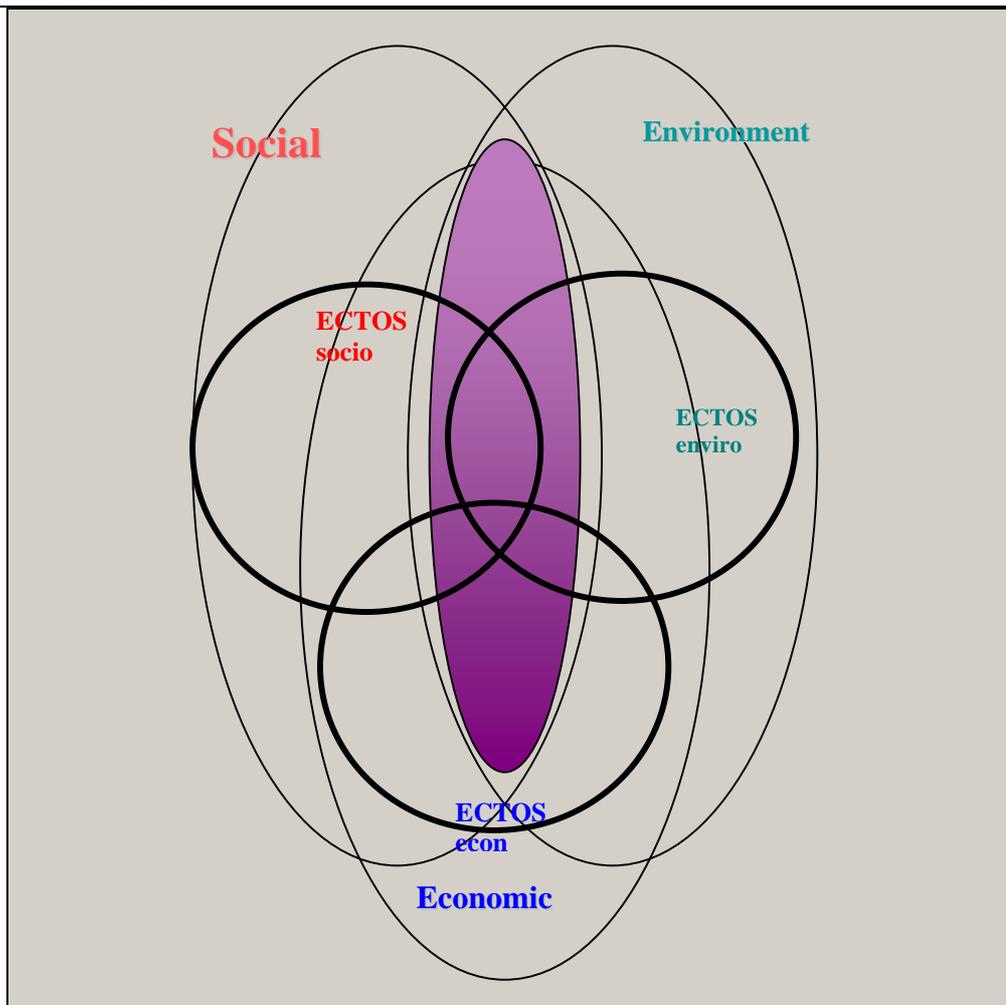
Figure 1: **Map of research areas The data collection will be on selected issues within Social, Environmental and Economic aspects. ECTOS studies are shown as smaller confined areas within the disciplines especially where these overlap. This indicates that the ECTOS studies only cover a small range of the theoretical possibilities within the area. The triple ring area of ECTOS is repeated in fig 2 and has the same implications in both figures.**

1.2   Goals

The participants within ECTOS have a preset vision: To overcome major problems so that Hydrogen can become an actual choice as a fuel in the future. Therefore the ECTOS is not set off as a passive observation but also as a means to an envisioned end.

The goals of the particular socio-eco-enviro studies will have to fit the whole context of the ECTOS project and the social and energy - political situation in Iceland. The government has stated the will to make use of the local renewable energy sources as a driving force for its transport system. Therefore the goals need to take into account the future energy scenario where both renewable energy and renewable fuel is to take over from the era of combustion engines and fossil fuels.

1.2.1   Prerequisites: the description of work within ECTOS

The objective by undertaking the ECTOS project is not only to test specified equipment. It should become a learning process in normative sense, an experience that can help to take further steps into using hydrogen as a fuel, at least within Icelandic conditions. A site dependent frame is therefore given for the socio-economic-enviro studies in ECTOS, whereas:

➢ The government of Iceland has officially promoted its policy to support a continued demonstration phase for using hydrogen as a fuel

➢ The outcome of ECTOS will be used to map drivers and barriers within the implementation of a future hydrogen economy and further political decisions

➢ Considerations of the transferability of the studies and outcomes will remain a central issue throughout the study period

Ergo, ECTOS is seen as a first step towards further "hydrogenisation" rather than an isolated pilot project.

1.2.2   Specific goals for the parallel studies

Within the socio-economic-enviro studies the aim is first and foremost to

Obtain knowledge on the implications of the new hydrogen technology.

Therefore the data processing will be kept open and justifiable. Below is the list of goals for the parallel studies. The goals are:

➢ *To assist the adaptation of a fuel technology that fits sustainable development.*
   The learning procedures should give rise to suggestions for future development or amendments to current transport systems as well as new ventures for research and social adaptation.

➢ *Map attitudes and awareness of the public.*
   Dissemination of the obtained knowledge will both be done in an organised way through media and published informative material as well as on request from varied interest groups. This is considered so important that an evaluation about the public reception will be carried out. Should there be indications of a failure to bring out the story the dissemination strategy must be reformulated. The information will hopefully generate public discourse. It is essential to map

the results of the information dissemination and the acceptance and preferences within the test municipality.

➢ *To set a frame for comparison between options of transportation technology.*
The impact assessment, Life Cycle Analysis of the equipment and fuel and the mapping of the costs and benefits of this test are important as information to the public and decision-makers for comparative measures anywhere. Therefore the data processing will have to be kept clear. This should facilitate the adoption of the ECTOS methodology.

➢ *To map drivers[2] and barriers for a shift to a hydrogen-based transport system.*
A profile of attitudes within the social and administrative framework of Reykjavik (key positions within the stakeholder group) should give insight into what are perceived to be obstacles and support for cleaner transport technology. The results are to be fed into the information dissemination.

➢ *To facilitate dialogue in society based on the obtained information.*
The information dissemination is intended to appear in major media sources (and indeed the of the project's homepage, www.newenergy.is) and so give rise to public discourse. Should that fail then the dissemination methods must be reformed according to the reflexive strategy. An independent company will assist in monitoring the coverage within the Icelandic media. A growing public understanding of the implications of the emerging hydrogen technology is considered a success criterion for the entire project. Therefore public surveys will help to follow up the awareness and acceptance of the technology.

➢ *To facilitate decision makers to gain insight*
into outcomes of tests like the one performed in ECTOS. Many tests have been carried out but often they are not comparable. The idea here is to present a simple information matrix on Urban Transportation Systems, their faults and benefits and how to obtain relevant information. The matrix should give a structured insight into various options for transportation systems. The matrix is not expected to be fully developed by the end of ECTOS yet the structure should be clear and hopefully readily useful for local governments.

➢ *To set a benchmark within the study of new fuels .*
The work in ECTOS should be ambitious enough to set a qualitative standard for further demonstrations. The work should provide essential information on most aspects of a single but complex core-case. These aspects are usually categorized within environmental, social and economic disciplines and are considered to influence impacts, amendments and continuum for the development of a new fuel technology. The work should become a benchmark for similar projects.

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[2] Within the ECTOS methodology text the connotation drivers and barriers refers to phenomena that either makes the adaptation to the hydrogen fuel cell transportation system easier (also facilitator) or that make it more difficult (also obstacles, or problems). Driver in this context should not be connected with bus conductors.

Yet it is not only these goals that set the criteria for measuring the success of the ECTOS project as a forerunner for further hydrogenisation in Iceland. Each stakeholder has his own reasons to participate in the process and his own evaluation criteria. Therefore the upcoming research will probably be valuable even as a study case in transition management but that view is out of the scope of ECTOS.

An overview of the scope and issues within the parallel studies is shown in Figure 1 and Figure 2, and the planned deliveries are listed in **Error! Not a valid bookmark self-reference.**.

Table 1: **Overview of studies and deliverables according to description of work within the ECTOS project.**

Title of study	Areas of research	Results will appear in Deliverable (title)	Section in ECTOS-methodology
Description of current situation, background	Social, economic, technical and environmental	Midterm Environmental study, final report,	2.1, 2.2
Questionnaires carried out by student groups	Social, environmental micro economics	Assessment and evaluation of socio-economic factors	2.1
In dept interviews	Environmental economic, social	Final report	2.1
Telephone surveys	Social	Assessment and evaluation of socio-economic factors	2.1
Air quality	Environmental	Midterm Environmental rep	2.2
Cost of fuel and infrastructure	Economic, social. Borrowed from Euro Hyport [3]proj.	Assessment and evaluation of socio-economic factors	Out of scope
Description of implemented technology	Current situation and description of the gear	Report on maintenance, structure and equipment	2.4
Background, technical performance	Data on maintenance, punctuality etc.	Technical report Mid term assessment report	Attachment II & appendices A and B
Well to wheel	Environmental	Environment	2.4

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[3] EC Accompanying measures, 5th framework, contract no ENK 6-CT-2001-80449, Euro-Hyport

Life c. Analyses	Environmental	Environm. costs	2.5

2. Proposed Methodology

> *…interpretation- free, theory neutral facts do not in principle exist.*
> *Data and facts,… are the constructions or results of interpretation: we have to do something with our sensory impressions if these are to be comprehensible and meaningful.*   **(Mats Alesson, Kaj Sköldberg, Reflexive Methodology p 1.)**

This chapter outlines some of the theoretical ideas behind the studies and which methods are to be applied to each of the subjects. Thereby the reader should become better informed of how the data will be collected and presented. The headings of sections, titles of each study and numbers and names of the deliverables appears correspond to the description of work within the ECTOS project.
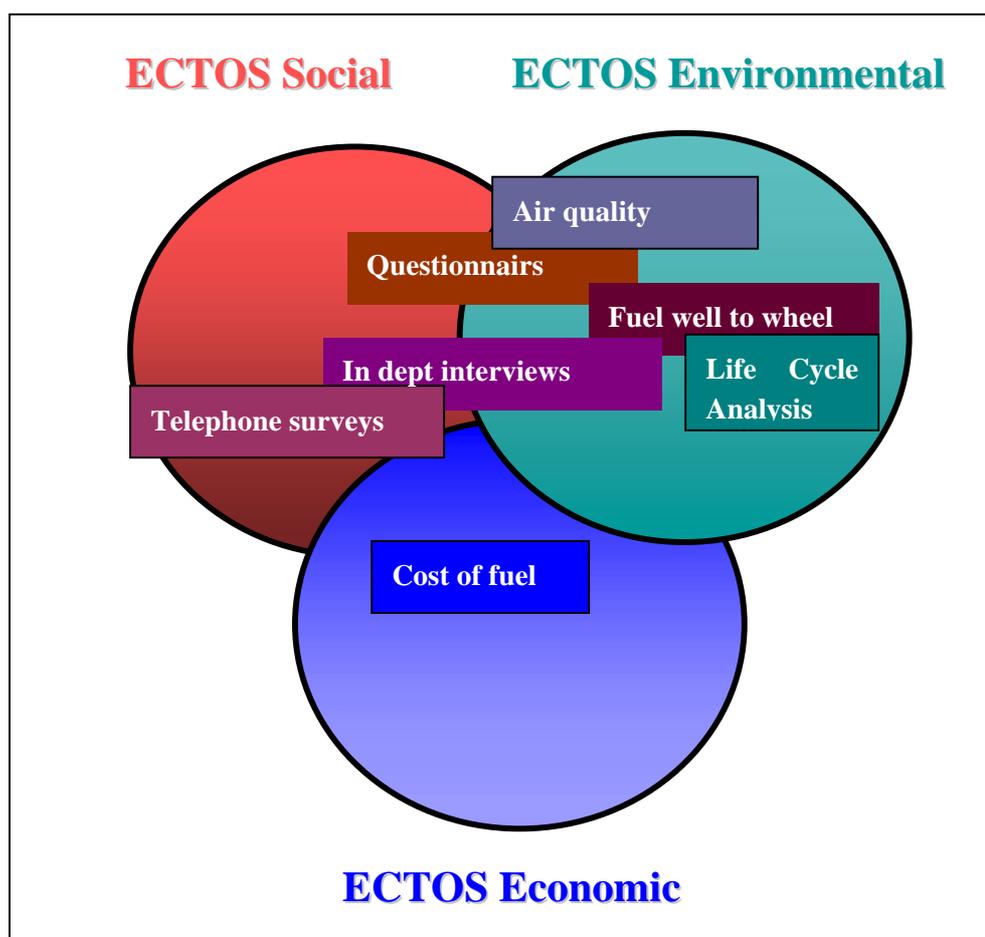
Figure 2:   **ECTOS study areas, procedures and titles of deliveries described in the ECTOS Methodology**

2.1   The Socio – Economic methods

For clarification purposes, an insight is given shortly for a general audience, on a few examples of socio-economic features and subsequently a description of ideas that specifically fit the frames of ECTOS.

2.1.1   A general introduction to social studies

Socio-economic and environmental issues can be a range of considerations related to humans in their environment, including population distributions, economic indicators of human welfare, aspects of health, educational issues or transportation networks. Other infrastructure concerns, such as water supply, waste management or policies on public services also fall under the category of social issues. They also include more intangible issues such as social values, community coherence, religion or cultural traditions.

What is about to be undertaken within the ECTOS parallel studies can be called a 'Social Impact Assessment' (SIA, as this kind of survey is called in the U.S.A., or using the European term: 'Socio-economic impact considerations'). SIA includes health impacts, recreational activities, aesthetic interests, land- and housing values, not only of economic pricing, job opportunities, community cohesion, lifestyles, governmental activities, psychological well-being and behavioural response on the part of individuals, groups, and communities[4]. An overall SIA approach would even overlap issues that are often included in an "Environmental Impact Assessment". Therefore the ECTOS parallel studies can be said to be an evaluation along a 'triple bottom line'[5].

The steps within the impact assessment are generally the following:

  ➢ Identification of potential socio-economic aspects

  ➢ Preparation of description of existing socio-economic conditions

  ➢ Listing of relevant standards, criteria or guidelines

  ➢ Impact prediction for without-project and with-project conditions

  ➢ Assessment of socio-economic impact significance

  ➢ Identification and incorporation of mitigation measures

The potential socio – economic aspects linked to changing the fuel chain and infrastructure of a public transportation system – and in the succession the elements for

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[4] Canter, Larry W (1996) Environmental Impact Assessment. Second edition, Erwin/McGraw – Hill, London, New York

[5] Using the concept triple bottom line draws, parallels to bookkeeping, where usually the success of a business is shown at the bottom line in terms of economic revenues. Triple bottom line bookkeeping would also show the results in environmental terms i.e. revenues in Euros / tons of CO2 emissions or revenues in Euros / new jobs created for the local community.

all mobility in an entire society – is overwhelming. They touch the individual's daily life and influence the national budget, tax policies etc[6].

Yet, if the topics are carefully chosen (according to relevance) within a smaller study, the results may prove to be as beneficial as those from a full-scale study. The potential issues have therefore been screened, the procedures are shown in fig 3. The first criteria used for the screening are listed within the Description of Work within the ECTOS contract.
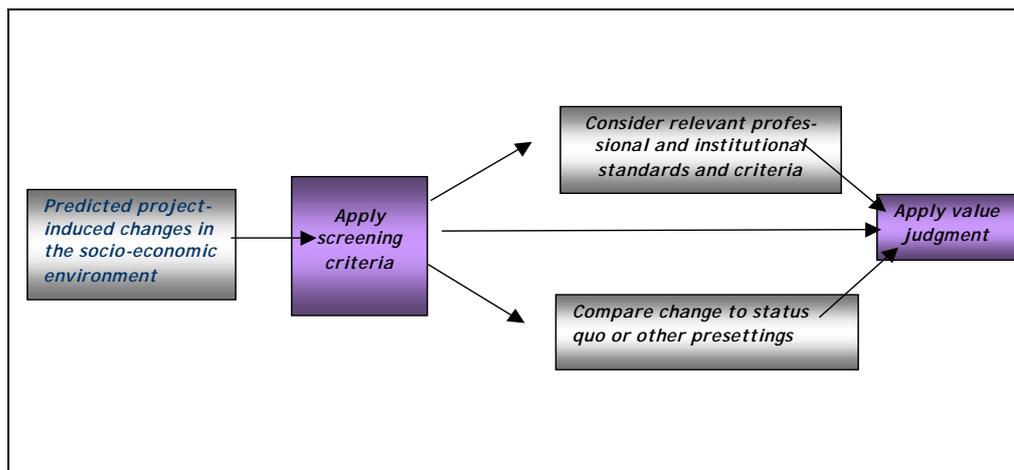
Figure 3:   Some important steps within the procedures in a socio-economic study[7]

The approaches or specific methods during the evaluation of the impacts within the various categories can differ for example in the following way:

➢ *Public services impacts*: A quantitative description based on unit-impact information (Example: how will the new technology effect the punctuality of buses and therefore impact the loss of working hours…)

➢ *Social impacts*: A quantitative description based on unit-impact information (Example: How many job opportunities would be lost / gained within the energy sector)

➢ *Fiscal impacts*: use quantitative description based on unit-impact information (Example: What would the infrastructure and distribution system cost for the entire society)

➢ *Quality of life (QOL) changes*: use qualitative description, quantitative description based on unit-impact information, and/or comparisons of the effects of alternatives (Example: What effects could the expected noise reduction have within the neighbourhood of bus routes)

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[6] SINTEF Energiforskning AS (Termisk avdelning) Techincal report 20th of May 2000: Title: Hydrogensamfunnet – en nasjonal mulighetstudie. Kvamsdal, A. M, (SINTEF) Energiforskning & Oeysten Ulleberg, IFE, Norge

[7] Canter, p.515

The results from the study should provide elementary information that can be used to construct a miniature model that can then be used to extrapolate and compose a map of a society that runs entirely on the tested equipment and infrastructure. The aim of the ECTOS project is to get information that can be used for forecasting towards larger implementation, under the same conditions where energy demand is based on forecasts for the year 2030[8].

2.1.2 Selected social issues for ECTOS

Most of the social issues within the study are difficult to quantify, and lately methods that involve qualified evaluation have gained respect within the field. However, researchers have to recognise that they cannot approach the subjects in a completely passive manner as only observers. For instance, even the choice of subjects within interviews or their interpretation will depend on the interviewers own background, culture, former experience and views. Therefore, it is essential to identify possible biases or assumptions before the studies; reflect on conditions of the study[9] and also to discuss the outcomes of the research within the partners' group and incorporate various views and interpretations. If outcomes of a study are used in a positive or negative feedback to reformulate or refine a following phase in the study the approach is said to be *reflexive*. **Action research** is a concept used to describe occasions when i.e. an interviewer introduces new ideas and follows up on the responses.[10]

The presumed most important issues and selected for further studies within the socio-economic context are indicated in bold text within Table 2 along with some of the issues that are deliberately left out. It is out of the scope of the ECTOS project to study all of these, but helpful to realise the possibilities. The process of collecting and processing the data is given in subsequent sections.

Table 2: **Examples of possible and addressed issues within the social aspects**

Socio-economic aspects on Private, individual and Corporative - level	Socio-economic aspects at Macro levels; the public, the state and administration:
Costs of fuel	Effects on fiscal balance due to expensive import within the H_2 technology or export of H_2-experience and – knowledge
Costs of (public) transport	
Reliability	
Punctuality	**Income from H_2-tourism**
Comfort	**The value of fuel independency and**

8 Orkustofnun (Icelandic Energy Authority) 2001, Eldsneytisspá 2001-2030 (Energy – forecast 2001 – 2030) Report no OS – 2001/040

9 ibit p 245

10 Alvesson,Mats, Kaj Sköldberg (2000) Reflexive Methodology, New Vistas for Qualitative Research, Sage Publications, London, UK

Costs of H2 vehicles	**fuel self – sufficiency,**
Optimisation of production / service chains	**Perception of the value of clean fuel image on marketing of Icelandic products and services**
Fuel price to consumers	
Impacts on electricity production/ distribution patterns	Effects on oil prices during transition phase; relevant if hydrogen is to be produced locally.
Changes in real-estate prices due to e.g. less noise at heavy traffic roads, closeness to hydrogen fuelling station, (hedonic prices) etc.	Possibility for increased establishment of CO2 emitting industry
	Changes in land values and planning
Rehabilitation opportunities for technicians and professional operators	**Losses of income from oil services**
Transition of oil/energy companies;	Tax and charges to compensate the state's loss of oil – taxes
Birth of hydrogen fuel companies, H2-technology (import /export) and job opportunities	**Savings because of less oil import**
Effects on retail of personal vehicles	Response of administration /government in making policies for hydrogen adaptation such as: Safe handling, economic incentives to facilitate the integration of the policy, economic instruments, dissemination of education
Availability of services and maintenance of fuel cell vehicles	
Acceptance of the bus demonstrations	
Identification of reasons or benefits and costs of hydrogen as a fuel	**Effects on establishment of CO2 emitting industry**
Availability of maintenance and services	**Public discourse about future choices within the energy sector**
Perception of safety	
Perception of health improvements due to decrease in pollution	**Stake- holders criteria of success**
Temporary disruptions in transport patterns until H_2 infrastructure is available	

2.1.3   Choice of methods and description of the execution

The list of topics can be extended or changed. But for every topic a suitable method for the data collection also has to be pinpointed. The quality of data may depend on *how* it is obtained. Therefore the design of the research is just as relevant as the choice of topics. To keep the focus the ECTOS research team will have to list beforehand: Issues

to be covered, the main goals by each study, the data collection methods and intended processing of the data and evaluation methods.

Table 3: **Overview of research approaches within the socio-economic aspects**

Topic	Goal	Method	Process	Intended internal evaluation
Public Surveys	Find out the awareness of the public, pinpoint the demand for information	Questionnaires via telephone surveys	The data is correlated with gender, age, education and income of the responders	Institute selected for its good reputation in doing neutral surveys based on reviewed methods. The students will be informed by the bus operator
Acceptance of customers and end-users	Map experience, and criteria of success. Find obstacles and issues for optimisation	Collected via questionnaires at bus stops and inside the demonstration buses;	As former surveys done by the bus company. Keep the outcomes comparable with former data	The questionnaires will be organised ac-cording to former and current surveys carried out on a continuous basis by the bus company. Standard methods according to strategic marketing theories.[11]
Drivers and barriers	Decision makers and future fuel scenarios. Opportunities of adjusting economy to new situations	Semi constr. interviews on international versus local energy solutions and fuel topics. SWOT analysis[12] and learning processes.	Expert eva-luated frame for interviews Results fed into public information. Discourse followed.	Questions will be kept open and specific issues that come up within interviews followed up in order to clarify the meaning of statements.

The   contents   of

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11 Þorhallur Örn Guðlaugsson, former marketing manager of the bus company, currently a lector on marketing at the
department of Economics, Univeristy of Iceland.

12 SWOT stands for Strengths, Weaknesses, Opportunities and Threats, a well known analytic process within Business,
Management and Administration. Many training sources available on the internet see e.g. www.swot-
analysis.com/links.htm

Table 3 is explained in the following paragraphs

2.1.3.1 Public surveys

The goal of public surveys is to gain insight into basic expectations and the public awareness of the hydrogen demonstrations. Simple surveys will be conducted via telephone questionnaires during the project implementation. The department of Sociology within the university of Iceland[13] has a long experience in carrying out surveys for companies and the authorities. Their working methods to select size of samples, select interviewees and processes are described in Appendix 4.

2.1.3.2 Acceptance of customers and end-users

Those who will be most exposed to the new types of buses and technology are probably the bus operators, bus conductors, maintenance staff and the daily customers of the bus line. Therefore their opinion and can indicate immediate acceptance or problems.

Student groups from two departments of the University will be trained to go through questionnaires with this target group during the bus demonstration and process the information. The students come from the institute of environmental studies and the institute of economics.

The public surveys are executed according to accepted international methods in collaboration with the bus company. The processing will be according to statistical calculations, similar to those measures, which the bus company is used to. The data will be compared to similar data collected in buses run on conventional fuels.

Example of the issues: Appearance of buses. Sounds / noise in buses, temperature, comfort, punctuality, views on the performance in general. Perception of safety. Also attitudes towards larger issues such as budget, value of environmental issues, costs and benefits, public transport and the system, municipality planning for sustainability, safety of oil handling, safety of fuel deliverance, expectations etc. Also people will be asked about information, what they have acquired as knowledge on the new technology, where it came form, and which information would be required according to their view.

2.1.3.3 Drivers and barriers

If the ECTOS project is to become only the first step into further hydrogenization of the Icelandic economy, then it is essential to map some of the issues that decision makers and key stake holders find relevant within the transition to hydrogen-rich energy systems. The specified method "Semi constructed interviews" will be used because of its reflexive nature. Specific topics need to be addressed, from the researches point of view, but using this method the interviewees can also bring in new

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[13] further information available online at: www.fel.hi.is/index-english.htm

issues they find important[14]. An interview of this kind can serve as an information exchange, the interviewee can inform the interviewed about the topic, or offer information from an external source, provide references or links to information and facilitate deeper insight into the topic and related issues. Most likely the selected stakeholders will be interviewed at least two times and later invited to look into the first outcomes of the interviews as a group.

The outcomes of the analysis can be fed into the stream of information for the public even during the demonstration phase. According to this description it is evident that the interviewers can influence the people they are interviewing and informing according to the type and contents of the information material they provide. – They become a part of the forces that act within the research, but cannot steer the influence to become in favour or against a specific outcome[15].

Yet, even during questionnaires or standardised interviews, it is impossible to construct 'neutral questions' and wait for neutral answers, the topic will always have social, political, environmental and fiscal aspects, which will emerge into public discourse during the demonstration tests. Therefore it is important to document well what material is used, the questions raised, what happens during interviews, which issues are taken up voluntarily, and indications of intonation, shown attitude or mood during interviews even body language. This material should be stored for later study and eventually a second interpretation.

2.1.4   Intended procedures:

Suggested topics for discussion with key stake holders are: The interviewee's view on the state of energy and fuels, both locally and world wide. General impression of externalities and their relevancy. Views on amendments to current energy systems; need for change; justifications for a change or reason for keeping status quo. Energy policies of the relevant companies or institute/ political movement or stakeholder group. Environmental policy of the company / institute / position. Personal energy policy? Foreseeable options for its realisation. Ideas for a communal or national policy on transportation, fuels or introduction strategy. Views on real costs and subsidies; their relevancy. Administrative facilitation of introducing new opportunities. Fuel independency and locally produced fuels, risk management and globalisation effects. Willingness to use economic/political tools, - economic incentives or law and regulations to facilitate a specific future scenario. Foreseeable spin-offs for forerunners?

The interviews will be conducted amongst key people within the municipality and national government, partners, planners, energy companies, research community,

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[14] Rubin, Herbert & Irene Rubin (1995) Qualitative interviewing. The art of hearing data, Sage publications, Thousand Oaks, London, UK.

[15] Sachs, Wolfgang, Reinhard Loske & Manfred Linz et al 98): Greeing the North; A post-industrial blueprint for ecology and equity, Zed Books, London,UK

economic authorities, consumers etc. Key people are considered those who can influence development within economy, social and environmental policies.

These interviews will then be analysed for key concepts and compared to find informing and guiding attitudes. The working groups will compose a map of common reasons and differences and learning on various levels. Priority criteria for support of fuel change and against the change. A *SWOT analyses* of the outcomes will then be shown to focus groups for further discussions and information dissemination.

2.1.4.1   Continuity -after the ECTOS-project

The analysed outcomes of the interviews may fit very well as an indicator of the status; the lack of information or the first perceived problems or barriers for further hydrogen implementations. The material would fit very well to shed light on how the society as a whole learns about Socio-technological experiments like the ECTOS[16] and interprets the results. Therefore it is likely that after the research period the collected material will be brought further to analyse the process of higher level learning within society. Not only the level of administration and political decision – makers needs to learn and get accurate information on the opportunities following the ECTOS undertakings, but the public in general. Recent experience from similar situations (Example: the IT integration in institutions., homes, schools etc.) has shown that transition - management has moved in many cases to governance-bodies which are dispersed throughout society. A good understanding of obstacles can help to overcome problems during the hydrogen demonstration or help decision makers to take appropriate actions according to a set policy – or to reframe a future policy.

Therefore at a later stage the plan is to feed the results into feed the outcomes int the public and administrative discourse and facilitate an exercise for future forecasting to a common energy vision for the most important stakeholders in Iceland. This would facilitate again back- casting from the vision to the current position and planning the foreseen preparations. These plans already constitute a PhD proposal for the person who oversees the methodology-formulation within the ECTOS, - but it is out of the scope of the 4 year implementation phase of the project.

2.2   The environmental studies

The environmental study is split into three subparts: The environmental impact assessment, well-to-wheel analysis and LCA study. These will inevitably have touching points and overlaps with each other, - as well as the social issues.

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[16] See for example the work in Texel, the Netherlands, on bounded socio technical experiments and also within the NOVEM project in Brabant province, the Netherlands. Verheaul, H & Vergragt, Ph.J 1995, social experiment in the Development of Environmental Technology: A bottom up Perspective, Technology Analysis & Strategic Management, Vol 7 No 3, 315 – 326

The environmental impact assessment is set up as an air quality study and will analyse the impact of fuel changes on the citizens. Direct measurements will be conducted and calculation based on them.

The well-to-wheel analysis is focused on the fuel chain. The aim is to evaluate the overall efficiency of the fuel, taken into account the use of fuel for its production, processing, filling, storing and transport. The release of CO_2 can then be estimated

LCA study is aimed at assessing the effects of hydrogen run fuel cell transport on global warming, acidification, eutrophication, toxic release, depletion of resources, biodiversity and other environmental impact categories. The bus conductors and maintenance staff need to fill out data sheets regularly in order to collect background information on daily performance. Examples of these are shown in *Appendix 5*.

2.2.1   Environmental monitoring and pollution modelling:

The main question put forth in the environmental monitoring and pollution modelling program is:

Which effect will it have on the air quality in Reykjavik City if the fuel for traffic is shifted to hydrogen?

The environment model. The model describing how and in what ways the city and its inhabitants are affected by the traffic and fuel handling. Includes aspects like local pollutants, noise, vibrations and visual appearance from different kinds of vehicles and in various locations. Also includes exposing the public for health risks and the biome for threats of decreasing biodiversity.

> ➤ *Pollution contribution model – direct exhaust measurements and data collection.*
> As a basis for the whole environmental pollution model the pollutants in vehicle exhaust will be measured directly and data collected from such existing studies. The measurements will be conducted on private cars using diesel and petrol, on trucks/lorries, cabs and on buses on specific parameters. From this a model of pollution contribution from different types of vehicles will be made. This can be done by using information on numbers of cars in Reykjavik, imported fuel etc. From this model an assessment of the proportional change in pollution levels resulting from an fuel exchange will be made. The national bookkeeping for greenhouse gases and other selected pollutants (NO_x, S) will be used, as well as air quality monitoring data in Reykjavik.

> ➤ *Comparison measurements*
> Measurement by passive samplers on buses, hydrogen and diesel respectively, placed on the rear of the buses. These measurements are intended to better enable us to assess directly the effect of the change of fuel on the public using the bus system. Parameters to measure are NO_x and SO_2

> ➤ *Reference measurements*
> Measuring stations at chosen locations in Reykjavik with passive samplers.

These measurements will be conducted before and after the introduction of the hydrogen buses, also intended as a reference for future measurements. Placement is dependent on location of hydrogen filling station and driving routes. Parameters to look at are SO_2, NO_x, CO and particulates

➢ *Categories of environmental aspects*

    i) Local pollutants; Examples of parameters to look at are SO_2, NO_x, CO and particulates. These are all affected by traffic related pollution. The exact list of parameters will be determined later. The measuring plan will take into account different seasonal conditions (e.g. summer, spring, autumn, winter). For the actual measuring period the targets will be hydrogen busses plus a typical diesel bus in current Reykjavik bus fleet (see page 5, Scope of evaluation)

    ii) Noise measurements can be conducted separately and preferably in the second part of the environmental monitoring study, i.e. after the arrival of the hydrogen busses. The noise from engine, fuel cell systems, tires and brakes needs to be evaluated, as well as other factors if applicable. As in part (i), seasonal conditions will be taken into account and comparison will be made to a typical diesel bus in current Reykjavik bus fleet.

    iii) A quick comparison (without any local analysis) with available literature and reports form other studies on health risks connected to traffic and transport will be made. The approach will be similar as to human impact assessment within an LCA, using references from accepted standards or tables. - The basis for such evaluation will be the predicted pollution, based on the outcome of the environmental monitoring programme paired with the known health effects from the different pollutants.

2.2.2 Stationary monitoring

Stationary monitoring means measurements at specific sites within the city. Mostly sites where heavy bus traffic is to be expected.

2.2.2.1 Reference measurements

The overall environmental impact of the change will probably be small, considering it is only bus traffic changing to hydrogen. Within the ECTOS demonstration only 3 buses will run on the streets, making the difference hardly noticeable. The available background measurements from the Institute of health and environment of City of Reykjavik on air quality are probably not sensitive enough to evaluate the difference nor has the placement of the measuring stations been aimed at bus traffic.

The measurements undertaken within ECTOS will be conducted before and after the introduction of the hydrogen buses and are also intended to become reference for future measurements.

2.2.2.2   Monitored factors

Particulates, carbon monoxide, carbon dioxide, sulphur dioxide, nitric oxides, VOC's or HC's, PAH (polyaromatic hydrocarbons) are parameters of importance in this regard. Their levels are all affected by traffic related pollution. The available equipment enables measurement of carbon monoxide, carbon dioxide, HC, SO_2 and NO_x and particulates on a continuous basis.

2.2.3   Selected sites and measuring plan

To assess the environmental impact of the change, measuring stations at the main bus terminals will be set up, i.e. where bus traffic is heavy. There are a few possible sites, Hlemmur, Ártún, Mjódd and Lækjartorg. Today the most likely site is at Hlemmur, the 'Down Town' bus central based on the foreseen route for the buses. A control site is chosen at Grensás where a Reykjvik city monitoring unit is placed. A more quiet site is chosen in Skeiðarvogur, a low traffic area. The measuring plan takes into account different seasonal conditions.

Table 4:   Stationary measurements, schemes

Sites >	Hlemmur	Skeiðarvogur	Control site
Year 2002			
Measure-ments	Number of Days	Number of Days	Number of Days
Autumn	4		4
Year 2003			
Winter	4	4	4
Spring	4		4
Summer	4	4	4
Autumn	4		4
Total	16	8	16
Year 2004			
Winter	4	4	4
Spring	4		4
Summer	4	4	4
Total	12	8	12

2.2.4   Monitoring of buses

These measurements are planned to take place on board buses in regular traffic.

2.2.4.1   Comparison measurements

For the actual measuring period the targets will be the hydrogen bus and a typical diesel bus in current Reykjavik bus fleet. Measurement will be carriee out by by sampling onboard buses, a hydrogen fuel cell - and diesel bus respectively. The measuring tools is placed at the front and rear end of the buses. Measured parameters are carbon monoxide, carbon dioxide, HC and SO_2. These measurements are intended to better enable us to assess directly the effect of the change of fuel on the public using the bus system. Reports on heath effects of pollution from transport from the EU will be kept close at hand for comparisons.

To further assess the environmental impact of change, diesel buses used on the same routes as the hydrogen buses will be monitored for oil consumption. Data on the fuel consumption and calculations from indices gives an internal reference to estimate the actual amount of measured parameters in the emissions.

It is preferable to monitor two routes with different driving cycles. The most likely driving route is the one no. 2. A second one will be chosen in cooperation with other partners and their preferences of routes. In 2002 and early 2003 measurements will be done on diesel busses but after the arrival of the hydrogen busses they will be monitored as well.

Table 5:   Bus monitoring plan

		Route 2	Route Y
Year 2002			
Measure-ments		Number of Days	Number of Days
Autumn		3	3
Year 2003			
Winter			
Spring		3	3
Summer		3 + 3	
Autumn		3 + 3	3 + 3
Total		15	9
Year 2004			
Winter		3 + 3	
Spring		3 + 3	3 + 3
Summer		3 + 3	
Total		18	6

2.2.5   Noise monitoring:

Noise measurements can be conducted separately and preferably in the second part of the environmental monitoring study, i.e. after the arrival of the hydrogen busses. The noise from engine, fuel cell systems, tires and brakes needs to be evaluated, as well as other factors if applicable. – Not particularly with quantitative tools, but as the perceived change. As in part (a), seasonal conditions will be taken into account and comparison will be made to a typical diesel bus in the current Reykjavik bus fleet.

2.3   Well to wheel – environmental analysis of the fuel chain

In the past several years some studies have been conducted to evaluate the Well-to-wheel (WTW) energy and emission impacts of different fuels[17]. The concept WTW is not well defined, in contrast with Life Cycle Assessment (LCA), which follows a well defined methodology, laid out in standards by the International Standards Organisation (ISO) and has been used for decades in various fields of research and industry.

2.3.1   General clarifications

A literature search on published WTW results, revealed several studies using the term. From these the following understanding of the concept is[18]:

> *WTW study is an accounting of energy use and greenhouse gas emissions over the entire fuel pathway, from primary resources to the actual moving of the vehicle through its drive cycle.*

For convenience the whole path is divided into two parts; Well-To-Tank (WTT) and Tank-To-Wheel (TTW). The first path, WTT, is an accounting from the primary energy source until the delivery of the fuel to the vehicle tank. The latter, TTW, includes the accounting during the moving of the vehicle through its drive cycle.

2.3.1.1   The boundaries

The boundaries for WTW studies differ from LCA in several important ways (see Figure 3). The aspects considered in a WTW analysis are a) energy use and b) Green House Gas (GHG) emissions where as in a LCA a range of environmental impacts are considered.

WTW does not include resources and emissions for construction of power plants, extraction of fuels or the building of vehicles, etc. The boundaries are set about looking only at the resources and emissions resulting from the production and transport of fuel and the operation of the vehicle.

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[17] Ludwik Bölkof Systemtechnik (2002); Ahlvik, et.al.; Wang, M. Q.

[18] L-B-systemtechnik GmbH

The level of detail of the data collected on energy use in the vehicle depends on the goal and scope of the study.

2.3.1.2 Presentation of units and outcomes

The outcome from a WTW study is generally presented as

➤ Energy use in MJ/km (Mega Joules / kilometre)

➤ Greenhouse gas emissions in g/km (grams of emission / kilometre)

➤ WTW efficiency (%) = output (MJ/km) / input (MJ/km)
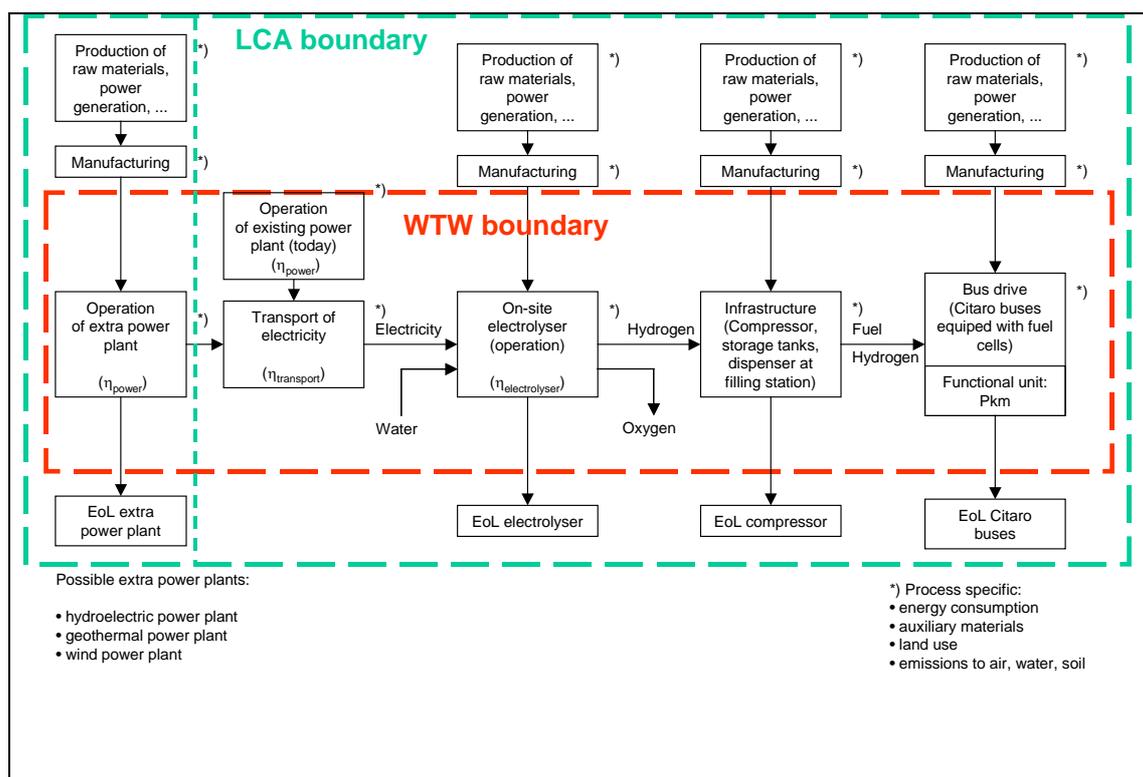
Figure 4:   LCA and WTW boundaries of ECTOS project

2.3.1.3 Functional Unit

The functional unit in WTW is generally *energy use* expressed in Mega Joules /kilometre or MJ/WTW efficiency. The functional unit in the LCA is place-km since it refers to the transport service provided by the bus system (see also chapter 4 and Appendix 5 on LCA). Therefore it is logical to also link the WTW energy use to km.

There are two ways to calculate the energy use, expressed in MJ/km.

Firstly the energy use for the latter part of the fuel pathway (the TTW) is calculated. The energy used to move the vehicle one km is based on the amount of fuel used and the energy content in that amount. Or in other words, the amount of energy that goes

into the system, times the Lower Heating Value (LHV)[19] equals the work that comes out of the driving system. The work is measured in MJ. This can be expressed and calculated according to equation [1] and called the TTW energy use;

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[1] $E_{in} * LHV = MJ_{out}$

where E_{in} is fuel consumption of the vehicle, given in litres/km

LHV[20] is the lower heating value of the fuel, given in MJ/l

MJ_{out} is the energy use per kilometre, given in MJ/km

Thereafter the energy-use for the former part of the fuel pathway (the WTT) is found. There are several ways to calculate this. It is possible to present the WTT energy use with a Sankey diagram as shown in Figure 5. The energy balance can be traced backwards, based on the outcome of TTW and then present the result as MJ_{in} (MJ/km).
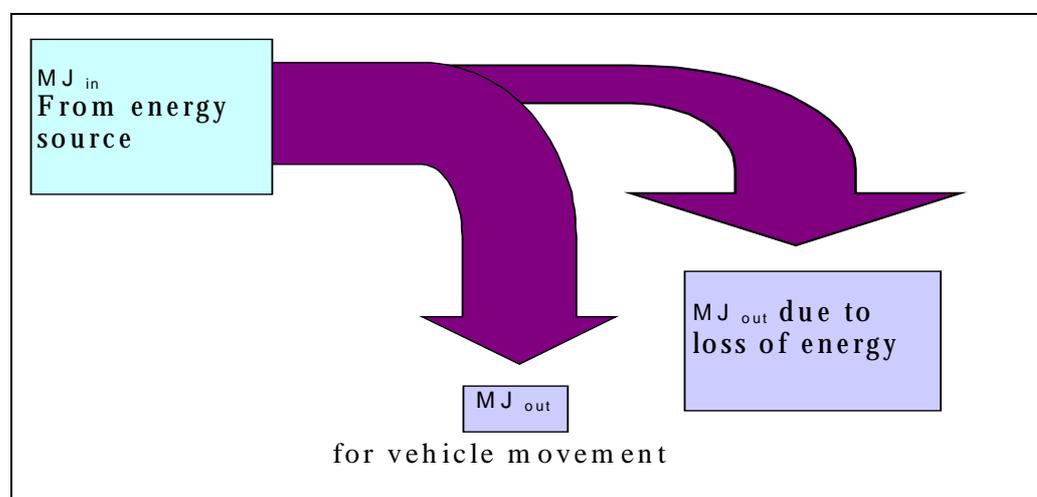
Figure 5: A potential Sankey diagram showing the energy path from Well To Tank.

Another method is to present the outcome from the WTT evaluation in MJ/volume of used fuel (for example MJ /litre). Then the whole calculation is based on the assumption that the outcome is correlated to 1 litre or another selected volume. To find the WTW energy use the two pathways, WTT and TTW are then combined by multiplying the energy used in WTT by the outcome from TTW; MJ_{in}/l fuel * l fuel used/km, giving the overall energy use in MJ/km (refer to equation [2]) .

WTW energy efficiency is calculated according to the following equation:

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[19] Lower heating value applies when the exhaust is given off in a gaseous form. If the heat is extracted and the emissions come out as a liquid it is called higher heating value.

$$[2] \qquad Efficiency \quad \eta_{WTW} = \frac{MJ_{out}}{MJ_{in}}$$

Where MJ_{in} is the energy input from power plant and MJ_{out} is the energy needed for moving the vehicle 1 km. For further expressing the energy-use a distinction will be made between renewable and non-renewable energy sources.

2.3.1.4   Greenhouse gas emissions

Analogous to energy use the green house gas emissions will be evaluated in g/vehicle km resp. g/place km. Greenhouse gases included in this study are CO_2, N_2O and CH_4 as that is the general approach in corresponding studies[21]. The effects from SF_6 emissions will be evaluated as well. The emissions will be weighted according to the impact potential, i.e. the multipliers recommended by the IPCC (Intergovernmental Panel on Climate Change (IPCC), see Table 6, listing the 100-year global warming potential (GWP)

Table 6:   Global Warming potential (GWP) of selected greenhouse gases (GHG)

GHG	GWP
CO_2	1
N_2O	310
CH_4	21
SF_6	23900

2.3.1.5   Goal

WTW studies have the prime objective of making possible a comparison between different alternatives of fuels and vehicles. The aim of the Well-To-Wheel study in this project is:

1. To compare the fuel efficiency of two vehicles, a bus run on hydrogen, run by a fuel cell and a conventional diesel bus with an internal combustion engine.

2. To evaluate the performance of the vehicles in different weather conditions, driving conditions, etc.

3. To make possible a comparison of hydrogen to other alternative fuels

2.3.1.6   Boundaries

The research groups within the ECTOS project chose to set the boundaries for the LCA and WTW studies together. Definition of Icelandic energy mix, choice of data collection method for production and transport of electricity, etc. are defined for both studies simultaneously. The WTW study does not include emissions from the natural

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[21] L-B-systemtechnik GmbH; Ahlvik, et.al.; Wang, M. Q.

resources and emissions from the construction phase of power plants, vehicles, etc. The boundaries are set as looking only at the resources and emissions resulting from the production, transportation of the fuel and its use in the vehicle. The WTW boundaries are illustrated in Figure 4 as of how it coincides with the boundaries of the LCA study. The fuel pathway of hydrogen is depicted in Figure 6.
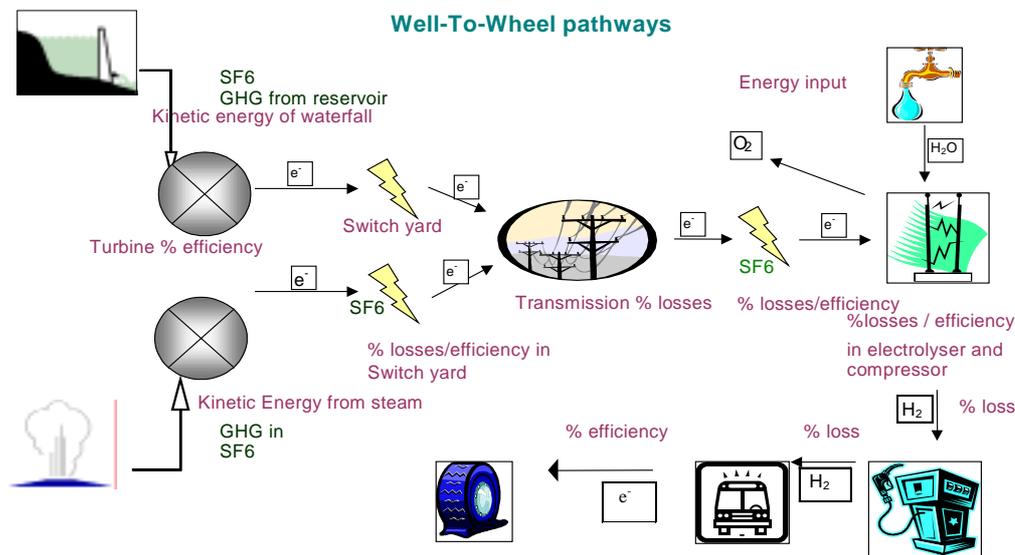
Figure 6: Well-to-wheel pathway for the ECTOS project. It consists of electricity production from hydro-power and geothermal-power, switch yard, distribution of electricity, electrolysis, compression and filling units and moving of vehicle.

The Icelandic electricity grid-mix consists only of electricity generated from renewable energy sources. The electricity

. Information on WTT for diesel fuel will be gathered from literature and LCA databases adjusted to Icelandic boundary-conditions.

production is described in Appendix 2, Section 4, but the share of each source in the grid mix is shown in
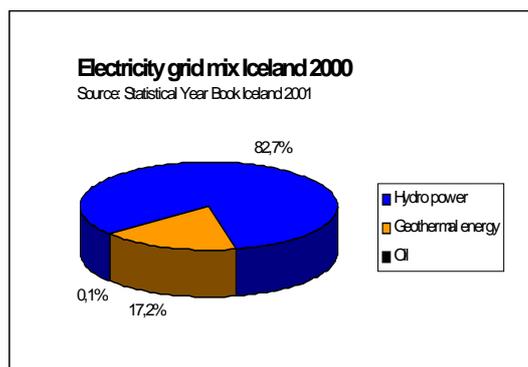
Figure 7: Electricity grid mix Iceland 2000

2.3.2 Data collection

In the following chapter the Well to Wheel is dealt with in two parts, Well to Tank (WTT) and Tank to Wheel (TTW). For convenience, the WTT is divided into two parts, electricity production and electrolysis of water.

2.3.2.1 Data collection on electricity production

Data collection for the electricity production is done simultaneously for the LCA and WTW. The data needed to establish the WTW is described in Table 7.

Table 7:   **Data needed on electricity production to establish WTW**

	Data energy use	**Data GHG**	**Source**
Hydro-power	Total efficiency Turbine efficiencies Energy generation MJ Hours per year Energy output, kWh	SF_6 CO_2, CH_4, N_2O	Landsvirkjun[22]; Power station Blanda is the primary source, but data is compared to an average local power plant where possible.
Geothermal power	Total efficiency Turbine efficiencies Energy generation MJ Hours per year Energy output, kWh	SF_6 CO_2 and CH_4 from geothermal gas	Nesjavellir[23] power station is the prime source of data but data is compared to average local geothermal power plant where applicable.
Transmission of energy	Losses in transmission lines Losses in switch yard	N_2O, SF_6	Primary source is Rarik[24]

2.3.2.2 Data collection for filling station equipment

The data for the filling stationr will be extracted from the LCA inventory. The filling station operated by Shell includes the production of hydrogen using an on-site electrolyser built by NorskHydro. The data needed for the entire WTW are according to

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[22] Landsvirkjun is the name of the National Power Company of Iceland home page in English: www.lv.is/EN/

[23] Orkuveita Reykjavíkur, Reykjavik Energy www.or.is/index_en.html

[24] Rafmagnsveitur ríkisins, the state energy distribution service Home page: www.rarik.is/english/index.cfm

34

Table 8.

Table 8:   Data needed on electrolysis to establish the WTW analysis

	Data energy	**Data GHG**	**Source**
Electrolyser	Input electricity Input water Output H_2 Efficiency Input other energy	Reports and experimental references	Norsk Hydro
Compressor	Input electricity Pressure in Pressure out Efficiency Input other energy	Reports and experimental references	Norsk Hydro
Water input	Energy requirement for water supply		Orkuveita Reykjavíkur[25]
Filling station	Input energy		NH, Shell

2.3.2.3 Sources of uncertainties

In the ECTOS project the source of information come from on-site measurements, from vehicles in actual service as public busses. Data collection of this kind differs from laboratory experiments and modelling calculations in terms of sources of uncertainty. Human and environmental impact, among other factors, can only be controlled to a certain extent, including the variables shown in Table 9:

Table 9:   Sources of uncertainties

Human effect from driving habits	Use of lights in and on bus
Road conditions; rain, snow, frost, asphalt	Opening of doors
Drive cycle; acceleration (negative and positive), hills, traffic, intersections, number of turns	Braking
	Tires; winter, summer, age
Load	Weather conditions; wind, moisture, wind direction light, etc.
Ventilation and heating in bus	

Collection of data will be aimed at information on the vehicle performance and on number of the above-mentioned variables as a background for comparison. The collected data will be an essential input to the LCA for the operation phase.

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[25] Orkuveita Reykjavíkur is the sole Energy and Water supply service of the City of Reykjavik.

2.4   LCA study

The following sections only give a brief and general introduction to Life Cycle Assessment (LCA). All the particular details which fit ECTOS and CUTE are given in ATTACHMENT II, page 55 – 166.

LCA is a system-tool used to analyse and assess the environmental impacts that are caused through production, use and disposal of products or product systems, processes or services for specific applications. LCA does not as a rule produce clear-cut straightforward assertions but gives diverse and complex results that need to be evaluated. An LCA can aid the process of decision-making by making complex implications transparent. The International standard (ISO 14040) defines an LCA as follows:

> *Life Cycle Analysis (LCA) is the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.*
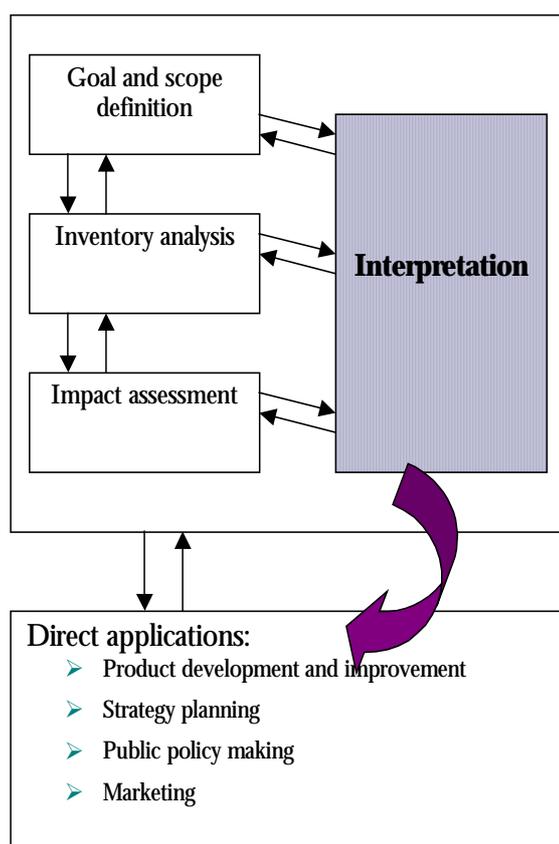
An overview of the procedures within an LCA is shown in Figure 8. At the start a functional unit is defined and the boundaries for the study is set. Detailed information is collected on the quantity of material, energy and other resources required for the production, use and disposal of the product. Then the impact from the whole process is evaluated: the impact assessment. Lastly an interpretation has to be carried out, the actual meaning of results laid out in common terms. The figure identifies the reciprocal influences of the individual phases. The application and the framework of the LCA have been purposely separated. An application is not automatically given through the results of an LCA study.

Figure 8:   Life Cycle Assessment framework (based on the ISO standard 14040)

2.4.1   Definition of goal and scope

Defining the goal of the study is of central importance and must be *the starting point* for any LCA, since the results are related to the respective research questions. Thus the related goal and scope are described comprehensively.

The following points must be documented in the goal definition:

> ➢ Intended application
>
> ➢ Reasons for carrying out the study
>
> ➢ Intended audience.

Following the requirements established in ISO 14040, the set goals for the ECTOS (and CUTE project) LCA are the following:

> ➢ The evaluation of environmental impacts of the whole system of hydrogen driven buses comprising the production, operation and end of life of bus itself as well as the fuel supply infrastructure
>
> ➢ Comparative assessment with diesel driven systems and other non conventional fuel driven systems
>
> ➢ Scaling-up and technology development scenarios
>
> ➢ Support to strategic decisions on future energy policy on a national and European political level (future fuel strategy),
>
> ➢ Definition of further research demand in order to improve the new technology

Defining the scope contains, in essence, the following points:

> ➢ A system description
>
> ➢ Fundamental procedures of data collection and processing
>
> ➢ Required quality

2.4.2   System description

A transparent presentation, usually in the form of flow charts, is used to explain which system is being addressed and how it is analysed. All the procedures and process description in use within ECTOS and CUTE are described in detail in Appendix 2. An important step in the system description is a definition of the functional unit. The functional unit specifies the function of the product-system and its efficiency calculated in reference to the specified unit. In another context an example of a functional unit would be: Various consumer packaging of 1 litre of milk. It serves as a reference unit for the environmental impacts. The spatial and temporal system-boundaries are then defined (the space and time under observation).

2.4.3 Fundamental procedures

Defining and documenting the fundamental procedures includes basic rules as well as specific issues. These could be, for example, the desired level of detail and depth or choice of impact categories within the study. The application of cut-off criteria (for input and output flows), which allow the exclusion of insignificant contributions, is to be described at this stage. If a system produces several products the input and output flows have to be allocated to each product. These allocation procedures must also be explained in context with the system under examination.
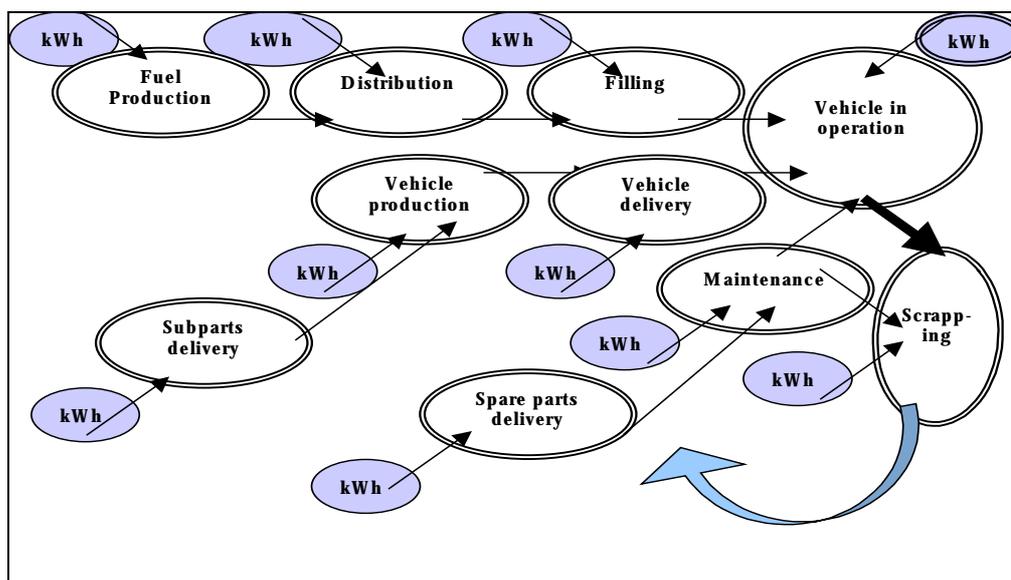
Figure 9: **An illustration a small part of the needed data to compose an inventory for on LCA**

2.4.4 Data requirements

The data quality has a significant influence on the LCA results and its accuracy. Depending on the goal, requirements on the quality of the collected data must be formulated (e.g. on its precision, completeness and relevance). In this context the sources of the data-base should be mentioned and used with reference to the pre-stages (e.g. energy provision, fabricated materials etc.) should be documented. Any assumptions, like estimations, should also be mentioned.

2.4.5 Life cycle inventory analysis

The main purpose of an inventory analysis in the context of data collection consists of identifying and quantifying the relevant input of energy and materials and output of waste and emissions over the whole life cycle of a product. The use of resources, use of land, raw materials, fabricated products, auxiliary materials, energy carriers and electricity used during the manufacturing must be counted as input. Emissions to air, water and land as well as waste and by-products (output) must also be recorded. By following the products whole life span it is ascertained that no environmental or social

burdens have been shifted from the user phase to other life phases and therefore left outs in the account[26].

Input that cannot be measures as taken from the earth's crust (e.g. electricity), must be connected with the respective pre-stages (see Figure 10). This means that all the necessary expenditure needed to provide for the input flows (e.g. in the production processes or transportation of electricity or oil) must also be taken into consideration when these facilitators enter the system.
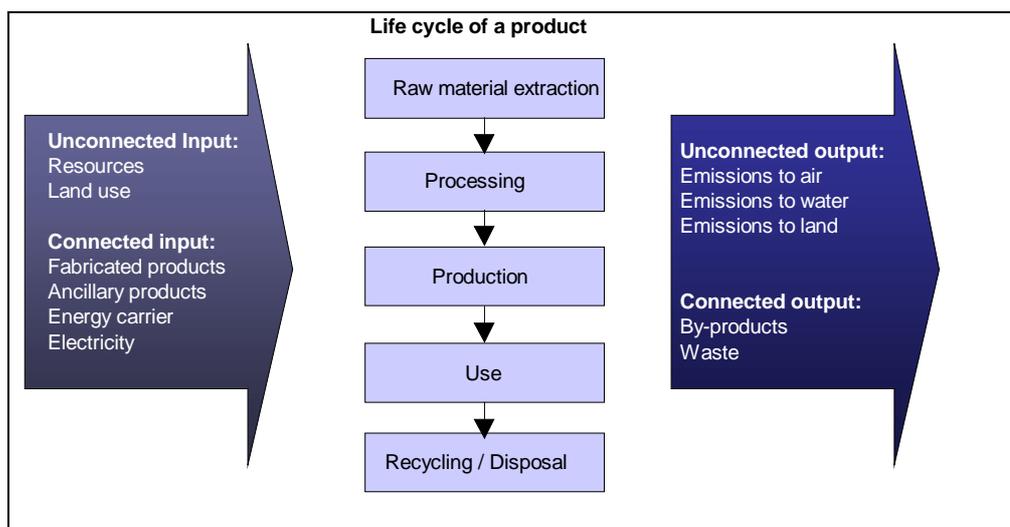

Figure 10:   General frame for the inventory of inputs and outputs during a products life cycle

Inventory analysis data are, as a rule, not suitable as a basis for direct comparative assertions. Therefore processing the data by various calculations is an important component of an inventory analysis. The question of allocation is of special importance. An allocation should always be carried out when dealing with systems involving multiple products (e.g. electricity and steam in a power plant). It is then important to define a method to allocate the environmental burdens of the production to the individual products according to their proportional effects

2.4.6   Life cycle impact assessment according to ISO 14042

The standard ISO 14042 divides the phases of the impact assessment into mandatory and optional elements. These are listed in table 8.

Table 10:   Elements to consider during impact assessments

	Mandatory elements	*Optional elements*

---

[26] An inverntory of an LCA incorporates a list of what is sometimes called external costs or externalities. It indicatrs costs that might not be reflected in the prices of the studied systems to the consumer. In stead they are moved on to the environment or future generations.

Procedures	choice of impact categories	normalisation
	classification	grouping
	characterisation.	weighting
		analysing the data quality

2.4.7   Life cycle interpretation according to ISO 14043

The final stages of an LCA is an interpretation and evaluation of the results from the impact assessment and the inventory analysis. Recommendations can be established on these as long as the quality of data is acknowledged and uncertainties made clear. A further aspect is the transparent presentation of the LCA results. The standard ISO 14043 comprises three interpretation elements:

➢ Identification of the significant issues;

➢ Evaluation which considers completeness, sensitivity and consistency checks;

➢ Conclusions, recommendations and reporting of the significant issues.

The research team has agreed that the outcomes of the LCA should be made understandable to laymen as well as specialists. This can mean that in stead of giving only indications by indices or numbers which might be compared to other reports then the results will be interpreted in words and compared to a few similar studies.

3. Further processing and use of outcomes

The parallel studies within ECTOS and the CUTE program give rise to speculations on how the obtained information could be put to use within the European Community. For example: will the boundaries for the ECTOS Well To Wheel study be applied to all the hydrogen production methods that are to be applied in CUTE or later studies or production methods. Beforehand it might be expected that the environmental burden would show to be smallest in Reykjavik whereas only renewable sources are used to produce the hydrogen fuel and no import or external transportation will be applied. These circumstances are rare in Europe. Yet it is highly likely that an optimal local solution could be quite comparable in the parameters that need to be evaluated for a WTW analysis.
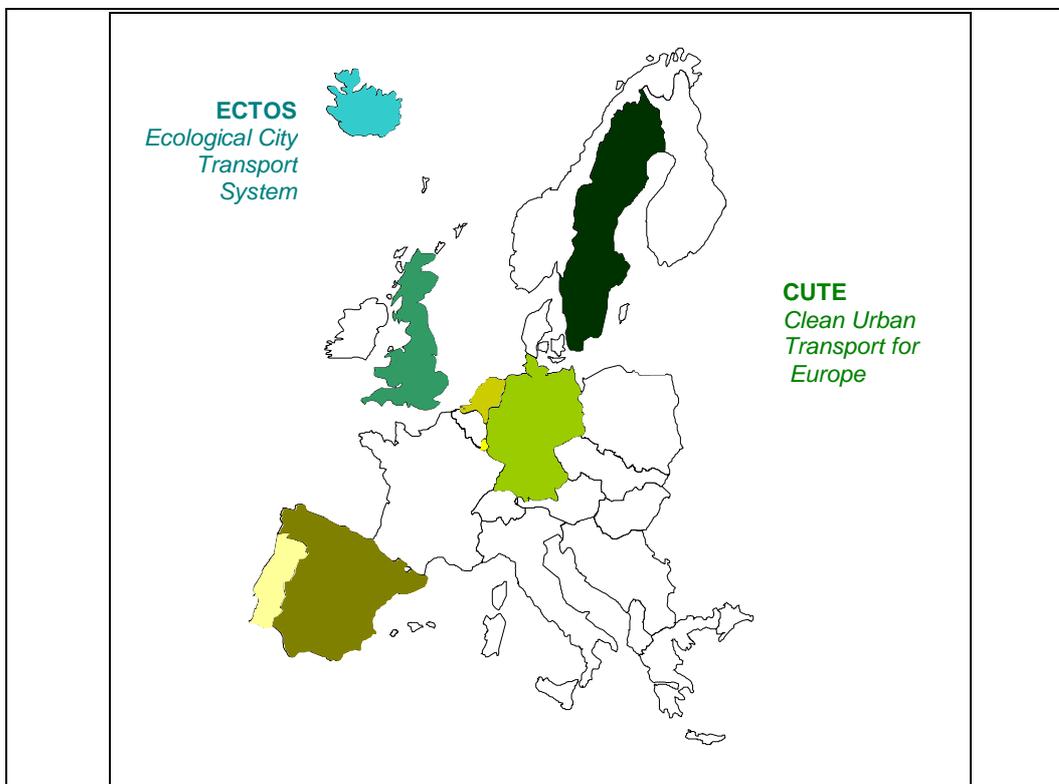

Figure 11:   The countries participating in ECTOS and CUTE using the same type of fuel cell buses

However, the comparative assessments will focus on finding environmental "hot spots" and differences between systems rather than a "full scale LCA" on each system. The reports and results give opportunities to discuss and evaluate possibilities for further use of hydrogen and the tested equipment.

At this point one cannot predict if general conclusions can be drawn from the results. What are the prerequisites for the Fuel Cell system in Iceland to be applicable in other European cities? How can a Fuel Cell bus, compete in environmental terms with the options that cities on the European continent can choose from, i.e., CNG, Biogas,

Ethanol, etc. How would the situation change with the scale, from 3 to 50, 500 or 5000 buses? Both Hydrogen production options and alternative fuel production systems will differ due to the production volume and the system boundaries can alter as well. This will not be possible if all systems were to be compared only according to the ISO outcomes of the plain study. Thus, the ECTOS LCAs must focus on possible comparison of different options in various geographical places and fuel production systems rather than focus on "in depth" analyses on all environmental effects as in a LCA according to ISO 14 040 Standards.

3.1   Added value to the results

As stated in the goals of ECTOS the demonstration is carried out in order to obtain knowledge. How can the results of the parallel studies within ECTOS be put to use? After all, the goal is to learn and get information that can be relevant for development within municipalities in Europe. A common understanding within the group undertaking the socio-eco-enviro studies in ECTOS-plan is to construct a simple decision assistance tool, the *Urban Transport Systems Model,* which is described in the following paragraphs.

3.1.1   Urban Transport System Model

An underlying assumption at this point is the following:

A model which facilitates discussion about priorities and helps to build understanding of the interwoven aspects of each public transport system, will prove to be more helpful to decision – makers than calculations based on a few digits; Indicators of weighted results from computerized decision models, which have been fed by graded socio – economic-enviro factors. One of the goals is to help to make decision procedures more transparent and give an insight into complex disciplines. It will still become the decision maker himself who decides what factors are most relevant to the situation the decision will still contain a subjective and political part.

The aspects covered within the aiding tool will be results from the ECTOS project as well as experiences and results from similar projects documented earlier[27]. One of the partners, Vinnova[28], has access to several research and pilot test projects that have been carried out with various fuels in recent years. The aim has been to develop models and forecasts within the transportation sector. These models have normally been developed for special purposes, e.g., vehicle emission forecasting, simulations of real life operating conditions, economic evaluation models, energy use by electric vehicles, etc. Still, a system model with a broader approach is lacking, where experiences from different research areas interact with each other, giving the user or decision-maker a

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[27] Johansson Bengt & Max Åhman, (2000) Koldioxid Neytrala Transportsystem. En studie av energieffektiva fordon och förnybar energi. KFB Rapport

[28] Vinnova stands for the Swedish Institute for Innovation systems, homepage: www.vinnova.se/index_en.htm. Last updated: Updated: 19 December 2002

holistic view. These underlying tests and demonstrations can have an added value to European conditions in a broader context. Decisions are often made on an intuitive basis using subjective criteria, but an Urban Transportation Systems Model (or "Urtra Symo") could present structured information, according to selected priorities and the prerequisites on the location.

3.1.2   Goal and usefulness

The aim with this task is to compile information from existing models, the findings from the ECTOS project and the experience that Vinnova has in the area to develop a descriptive Urban Transport Systems Model

The expected outcome is a structured descriptive model developed to enable comparisons of the functionalities, advantages and disadvantages of various systems. All relevant factors identified in the ECTOS project and from other experiments will be included and the lack of information and knowledge will be identified.

> *The developed Urban Transport Model will be set up as a simple pedagogic handbook for guiding other cities and regions that are considering an implementation of a transportation system where new technology and new fuels could confuse the picture. It will be reported as a "Simple Best Practice Handbook" with easy accessible Checklists, tables, matrixes, etc.*

3.2   Structure of the Urban Transport Systems Model

The model will be a useful tool in the ECTOS project primarily to facilitate the transference of technology and scientific evaluation methods to other cities and regions. The intention is to develop this model towards a framework for a decision model using scientific methods.

The model described below is a preliminary draft version. It will be developed during the project and shall be seen as a "skeleton" for further work. It will focus on fuel-cell systems but the structure of the model is to become usable for other systems as well, e.g., alternative fuels in traditional vehicles.

It should be "top-down" model, focused on usability, rather than an advanced computer processing. The ECTOS partners will define as many factors as possible that influence decisions within a transport system. This will include an unattractive pile of factors that has to be structured and weighted locally for importance. Nevertheless, it is relevant to underline the complexity of this kind of decisions.

There exist already several models that can help decision makers in a user-friendly way. So far, these models have been limited in scope focusing on only a few specific factors. Using these models in decision-making might give divertive results. Decisions must be based on several aspects of the subject and results from several scientific disciplines. The choices will still partly be based on subjective and intuitive decisions.

The structure of the model is for one part rooted in a "knowledge bank", where the information, scientific methods and models, experiences, references, etc. are compiled and structured. The second part is a "navigator" where the user is guided to sort out the relevant information for the particular needs and priorities.

3.2.1 Knowledge bank

The information within the knowledge bank is structured according to aspects or effects that influence the various components of a system. Examples of factors that influence the possibilities to implement a hydrogen/fuel-cell based system in a region are:

➢ Technical e.g.: In one city a FC bus with gas cylinders proved to be too heavy to pass an important bridge, if the number of passengers was not restricted

➢ Environmental; e.g.: Will the Hydrogen be produced from renewable energy or fossil fuels in the region? Will it be environmentally competitive to other transport systems and in all driving conditions?

➢ Costs e.g.: How much would the costs be inflicted by the scale of the system, - does a larger amount of buses and fuel change the total outcome?

➢ Reliability e.g.: Can we expect more system failures in a FC system compared to a traditional diesel system?

➢ Safety e.g.: Will the public accept a large number of hydrogen tanks in the society?

Table 11 shows an example on how the database can be presented. The information in the first and second columns is unanimous for all fuel- or transport systems. The 3rd and 4th columns can either be unanimous or specific for the different systems.

Table 11:　**Possible arrangement of information in the Urban Transport System Model**

Factors	Data inventory	Key references
Local vehicle emissions	Emission models, certified data,	Large motor test lab. and responsible national authorities
	On road measures	- " -
Regional vehicle emissions	Emission models, certified data	ECTOS environmental, Swedish research on Natural Gas
Global emissions	Fuel consumption/LCA	World watch reports
Production of raw materials	On site inventory/literature ref.	ECTOS , - LCA
Environmental data		
Distribution	How much emissions are linked to fuel transportation	EURO – HYPORT
Amount of raw material needed	Does the emission of the production of FC exceed production of a diesel engine	ECTOS – LCA
Public attitude towards environmental concerns	Interviews, Questionnaires	ECTOS – Social study
Local business interests	Interviews, Questionnaires	EURO – HYPEC
Public attitude towards the fuel	How do safety measures influence the acceptance	ECTOS – Social study
Job opportunities	Would the school system be ready to arrange rehabilitation of engineers?	
Behavioural change	What is the most popular type of vehicle?	Market studies by Strætó Iceland
Long term sustainability		LCA from CUTE
Technology		
Reliability	Experiences, statistics	CUTE – Stuttgart
Safety	Accident recordings	The ISO – standards
Range	Container sizes	Japanese techno reports
Prices and availability		
Fuel price, Cost of public transport	Market analyses/ production costs	
Investments in infrastructure	Experiences, offers	Joan Ogden[29]: Hydrogen Infrastructure, 1999
External costs	Environmental economy	
Cost of vehicles		Contact GM, Toyota, Honda
Impact on prices of raw materials	How is the availability of each fuel type? – Prognosis?	

The factors for each option for a transportation technology, including the fuel train, are presented in the knowledge bank. The following examples can be types of transport systems to choose from:

- ➢ Fuel cell bus with an on board reformer run on methanol produced from CNG

- ➢ Methane bus run on biogas from a municipal waste disposal

- ➢ Fuel cell bus run on hydrogen from electrolysis, using a local electricity mix

- ➢ Fuel cell bus run on hydrogen from a oil refinery

- ➢ Twin technology according to circumstances

3.2.2 The Navigator

In order to make it feasible for the user to work with the large amount of information an interactive guide helps to prioritise and exclude non-relevant factors. Figure 12 gives an overview of the reference procedures. The first thing a decision maker must do is to ask why there should be implemented a (new) transport system. The reasons can vary. It can be fuel hazards, environmental concerns; economic reasons, dependency on imported fuels or a combination of several factors.

The reasons or questions raised during a discussion on which options exist regulate what factors in the knowledge base will be used for the next steps. Some "frequently asked questions" will be pre-defined in the model to assist the decision maker with general understanding. These will originate from the work within the socio-enviro-economic study in ECTOS.

The outcome from the model will be a set of factors that decision makers have to consider and prioritise. Which of the factors in their opinion is the most important aspect? What are the prerequisites for the specific site? The user should define some physical limitations for the site, e.g., if the planning allows for all types of a fuel and technology, the amount of fuel needed, the economic frames, carrying capacity, public preferences, environmental goals within the municipality etc. By doing so several of the possible alternatives and other options can be ruled out and others found more relevant.
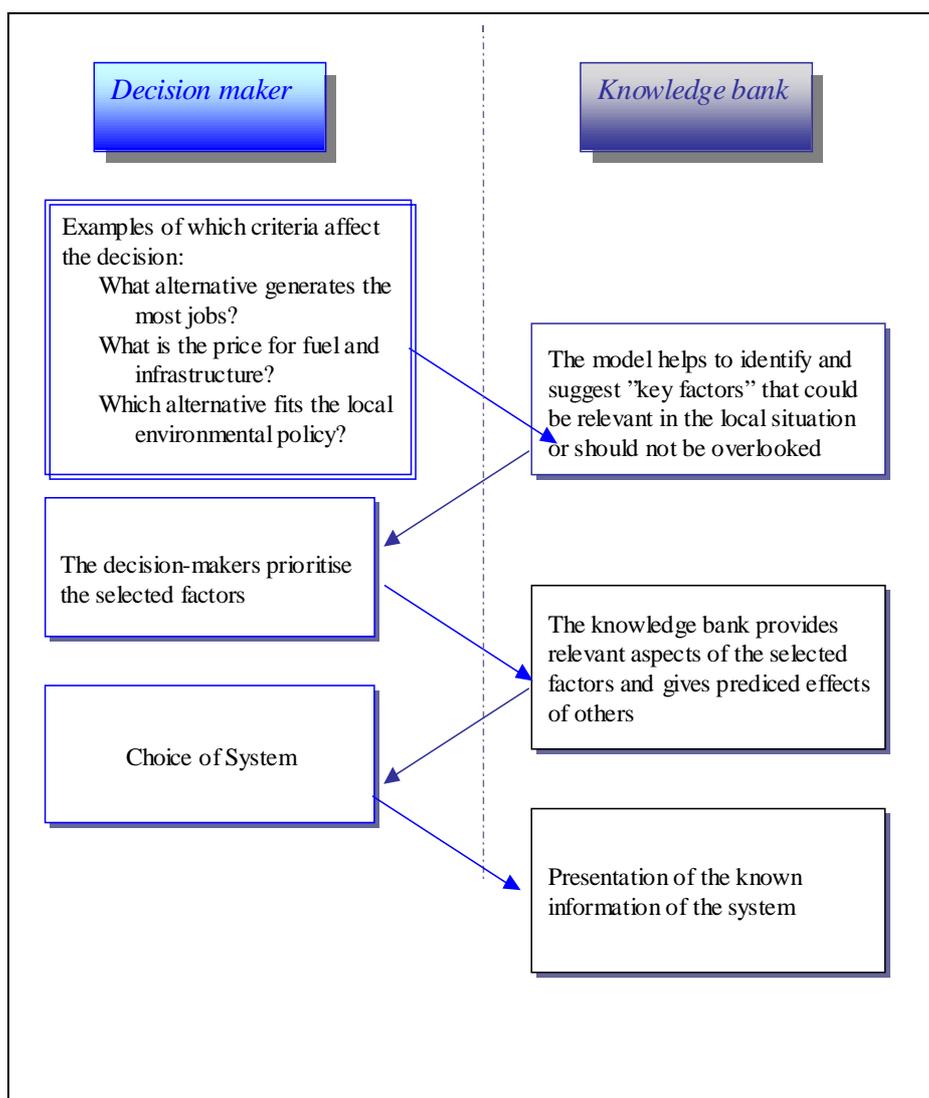
Figure 12:   **How the Urban Transport System Model is used**

Next step in the interactive process is that the model suggests a limited amount of possible solutions that meets the decision maker's priorities and site-specific prerequisites. The remaining factors are then analysed more thoroughly. For this phase the model gives recommendations of helpful methods.

When the decision has been taken the decision maker will need help in implementing the system. What barriers and problems can be expected? How shall the public and other interested parties be informed? Where are the risks and uncertainties? In this phase the experiences from similar projects would be of great help.

3.2.2.1 Using the model as a guide for implementation of a decided solution.

It will also be possible to use the knowledge bank from another angle. If a country, city or region already has decided to perform a test or to implement new technology, for

example a fuel-cell bus system, or to use a specific natural resource as a motor fuel in traditional vehicles then further steps can be simplified. The factors listed in the knowledge bank can in that case be used as a check-list for finding data and published references and to make sure that experiences from other sites and will be used in a guiding way. It is of great value to be prepared for possible obstacles that may show up in order to prevent problems.

3.3   Future refinements

Due to the restricted time and references sources, gaps in knowledge are to be expected in the first version of the model by the end of the ECTOS project. Identifying these gaps will be a part of the work process. If the model is to become useful in the future it must be updated and refined regularly. Each user can do this consecutively or research networks and co-operating organisations.

4. Dissemination strategy for this part of ECTOS

The partners within ECTOS have noticed a high interest for the Methodology and the outcomes of each sector of the research. Some of the approaches have been copied from similar projects but other parts have been adapted from theoretical basis and adapted to the specific conditions within the Icelandic context. Yet, the nature of some of the information is somewhat delicate and should be evaluated for disclosure as stated in the project description of ECTOS. The first ones to receive the results will be the partners, but as the information collection is supported by public EC funds an open communication about the results should be the main rule.

In general, methodology within socio – economic issues integrated with sustainable measures and technological integration is currently being reformulated within the academia. Therefore it is highly likely that some of the research staff can make further use of their specific qualifications and experience from the ECTOS research in their future work or new projects.

The international media has shown the plans and first steps to the hydrogen implementation in Reykjavik very high interest. This interest has been dealt with by open communication, presentations to news – agents, journalists and interest groups. Students are frequent guest already and this sort of dissemination about the working methods will be continued. The team will also present their Methods and results at conferences courses and meetings during the research period. A dissemination strategy has been set forth for the ECTOS describing how the channels will be selected for each target group. These procedures will be followed as planned and the homepage used for the first publications.

The results of the surveys and other outcomes for the socio-economic-enviro part of the ECTOS will evidently constitute part of the public discourse because they will be used to reform the research approach. If this discourse can also reach foreign discourse then one of the major targets with the implementation of the whole project has been reached.

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Attachment I

How the Methodology became

This section primarily shows the historical context of the how the ECTOS methodology was formulated.

The ECTOS project was launched 1st March 2001. During the launch, the representatives from all institutes involved in the socio-eco-enviro studies met. It became evident that several of the issues to be studied within each discipline would have overlaps both in terms of study methods and issues to be studied.

The group decided early to cooperate closely and maintain open communication during the time of the formulation of the methodology. In order to avoid overlaps, redundancy and repeated disturbance of some of the key people to information sources, the partners therefore put substantial effort into synergetic approaches to problems and synchronizing their work.

The participants collected their overall ideas, and established a so called "Primary methodology" (first composed draft). In this form it was presented and discussed at several occasions and within several review groups. The Primary Methodology was then sent to the EC as a forerunner of the ECTOS Methodology. Amendments and more precise description of all procedures were then made to the primary Methodology resulting in the current paper. Figs 1a and 1b show the procedures from the start, through the first stages until the document ECTOS - Methodology was completed. The formulation took 18 months. However, by that time some of the planned studies had already been carried out, that were necessary to establish a basis before the start of the demonstration.

Fig 1, see chapter 2 for explanations
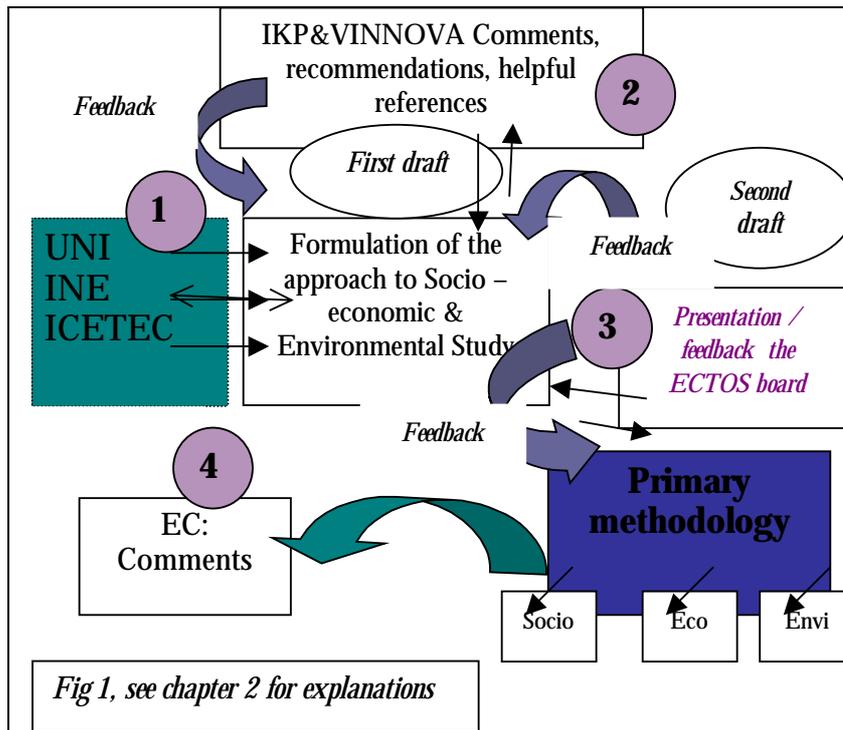
The annotation Primary methodology refers to the same document in both fig. 1 and 2, the Socio-Eco and Envi boxes to the specific details within each discipline.

Fig 2, The further formulation of details