

Basic value chain analysis for Etanolix® and Bionolix® bioethanol production by St1 in Finland

Nina Wessberg & Annele Eerola, VTT

(incl. information and comments provided by Juhani Laurikko, Tuula Mäkinen & Tiina Koljonen, VTT and Erja Hazley & Mika Anttonen, St1)

based on the value chain analysis template provided by *Simon Bolwig, DTU/Risö*

1. Description of concepts, processes and actors

1.1 Basic input/output structure of the value chain

The basic idea of St1 bioethanol production concept is to produce biofuel from waste near to the waste production: small-scale primary production plants are situated close to raw material feed to minimise transport of bulk. The primary production plants (primary processing plants: Etanolix and Bionolix plants) produce 85 % bioethanol, which is dehydrated in one central dehydration plant (secondary process) into 99,8 % bioethanol. This hard bioethanol is then stored in terminal and distributed to the fuel sites.

The transport of primary ethanol (85 %) is done with same trucks that distribute petrol to the distribution fuel sites; in that way an effective use of vehicle stock is achieved. The primary production units are high degree automated, in practice one person takes care of the production plant during day time; the plants are operated and monitored by a central unit (dehydration unit in Hamina, opened in 2008) during evenings and nights.

At the moment the feedstock of St1 biofuel production constitutes of sugar and starch containing biowaste and residues of food industry (**Etanolix® concept**) and municipal and industrial biowaste (**Bionolix® concept**). The feedstock consists of waste from:

- bakeries, e.g. dough
- shops, e.g. waste bread, and assorted bio waste
- households
- breweries and beverage industry
- sweetie industry
- potato industry
- other waste or residue starch, and sugar stock and masses.

In addition to bioethanol Etanolix production plant produces animal feed as by-product. Because of this, feedstock of Etanolix plant can not contain any meat products; regulation

forbids feeding animals with animal meat. In Bionolix plant, however, also meat products are allowed (no animal food as by-product). Bionolix plant produces electricity and district heat and fertilizer as by-product in addition to bio-ethanol.

There are in total, 4 Etanolix units in Finland so far:

- Hamina, integrated in the dehydration unit
- Vantaa, stand-alone unit
- Lahti, integrated next to the brewery (Hartwall Ltd) and
- Jokioinen 2011, integrated next to the enzyme plant (DuPont)

The production capacity Etanolix unit ranges from 1-2 Mio liters bioethanol per unit, except Jokioinen with the capacity of 9 Mio liters. Vantaa and Lahti units are able to use also packaged raw material. The feedstock has in practice been waste bread and dough collected from industry, small bakeries and food markets. The collection of waste bread is done in cooperation with Finnish waste collecting company called SITA (so called "Leipärinki" cooperation). 100 tons of waste bread means about 25 800 liters of high-blend ethanol for transportation use (about 318 000 km car driving), and produces about 100 000 kg of protein-feed, which is equivalent of annual protein need of 160 pigs.

The currently running demonstration plant based on the Bionolix concept was started in Hämeenlinna in 2010. The annual production capacity of this pilot plant is 1 Mio liters bio-ethanol. A biogas (biomethane) production unit is integrated part of Hämeenlinna Bionolix plant (integrated CHP boiler, opened in autumn 2012) producing district heat and electricity as by-product of the production process. Hämeenlinna plant is also able to utilize packaged biowaste. The biowaste collection is organised by waste company Kiertokapula Ltd. Also some other waste management companies deliver feedstock to St1 Etanolix and Bionolix plants.

Ethanol produced in Etanolix and Bionolix units is centrally dehydrated in St1 own Hamina dehydration plant. Annual capacity of this dehydration plant is 88 Mio liters of 99,8 % ethanol. At the dehydration plant site exists also the St1 bioethanol terminal (mixing with fossile fuels takes place there too). From the terminal the fuels are transported to be sold at St1, Shell and ABC service stations. The fuel grade ethanol is mainly used for (R)E85 production, and marginally to E10 or E5. In addition it is used produce RED95 to replace heavy duty diesel in captive fleets since June 2010

In the future St1 plans to widen its ethanol production with the Cellunolix concept in order to broaden the feedstock capacity into forestry sector using straw, saw dust, wood chips, waste wood and other waste from forest sector (lignocellulose).

The whole St1 concept is shown in the Figure 1.

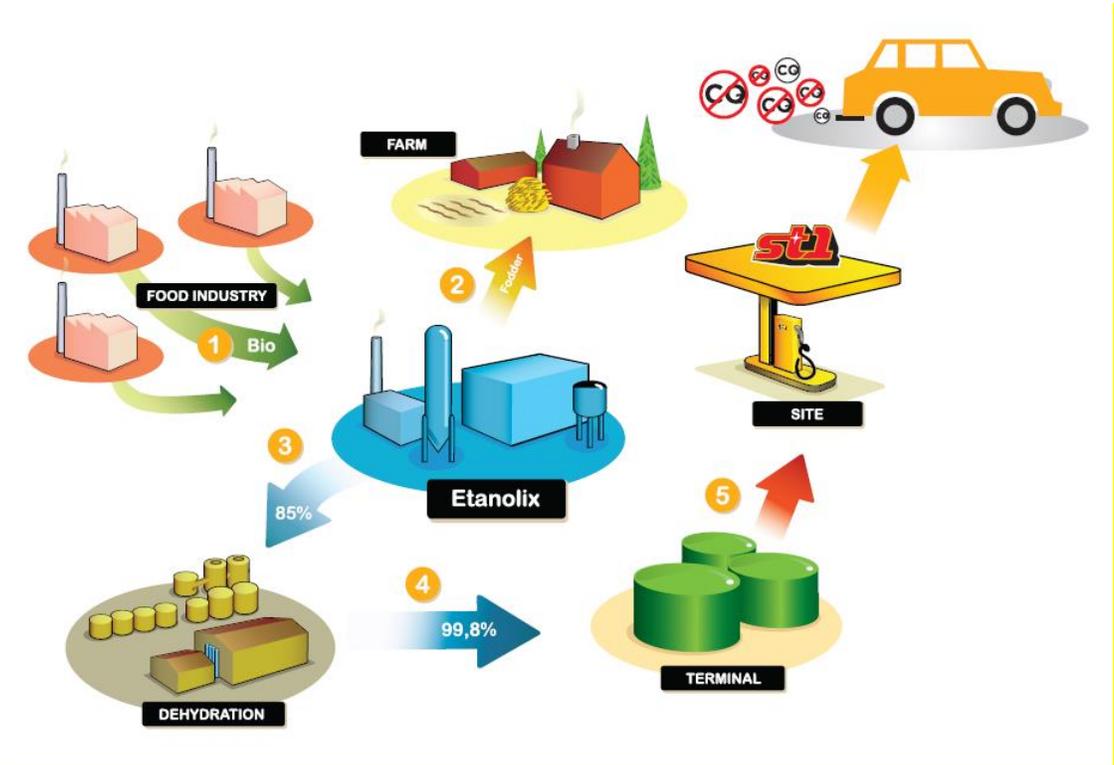


Figure 1. The St1 bio-ethanol production concept.

St1 Ethanolix and Bionolix processes utilize bio-waste as feedstock. The collection of waste bread for St1 Etanolix plants is done in co-operation with Finnish waste collecting companies. Primary processing plants are located close to important feedstock providers, being directly integrated with these in some cases. By-products of primary processing (animal feed & CHP) are sold to farms and local energy companies.

Primary processing (sugar fermentation) and secondary processing (dehydration) takes place in plants owned by St1 Biofuels (Etanolix & Bionolix plants + dehydration plant). Plant equipment is ordered from established manufacturers, but St1 Biofuels takes care of the project management and operations (has also built up competencies for the purpose). All the biofuels produced are sold to a trading company that is also responsible for oil mixing (St1 owns now almost half of the shares of the trading company). The transport of primary ethanol (85 %) to the dehydration plant is with the same trucks that distribute petrol to the distribution fuel sites.

1.2 Central actors of the value chain

Feedstock provisioning

Feedstock is provided by local food industry, bakeries, breweries, supermarkets and other instances producing bio-waste.. Waste management companies are operating the feedstock collecting. Companies working together with St1 in waste collecting are: SITA Ltd (collecting waste bread) and Kiertokapula Ltd. (collecting bio-waste). Some feedstock companies are directly integrated with St1 Etanolix units, e.g. Hartwall Ltd. and DuPont. St1 also actively searches for bio-wastes that are abundantly available but have no proper alternative uses (sawdust is considered such a feedstock for the planned new Cellunolix concept).

Processing (biorefinery)

The Etanolix and Bionolix plants – as well as the dehydration plant - are owned, operated and maintained by St1 Biofuels. St1 Biofuels Oy was established in 2006 and has now some 80 employees designing, building and operating bioethanol plants in Finland. The estimated turn-over in 2013 is 20 M€. Besides bio-ethanol the company delivers turnkey plants and life cycle services to other markets. The ultimate target is to develop waste-based biofuel concepts for global markets. The owners and management of St1 Group see this as a significant growing business in 10-20 years.

St1 Biofuels is part of St1 Group that is built around oil and fuel distribution business. The entire Group has 700 employees and its estimated annual turn-over in 2013 is around 7 billion/mrd (around 5 billion/mrd in 2012). More than 10 % of St1 Group employees thus work for St1 Biofuels, but its share of the annual turn-over is much less significant.

Distributing biofuel

The produced waste-based ethanol is distributed through the network of St1 fuelling stations. St1 owns and operates Shell branded sites under a license agreement in Finland and, Sweden, as it bought the business of Shell in Finland and in Sweden in 2010.

All the biofuel produced is, however, first sold to NEOT. NEOT is North European Oil Trade Ltd., a wholesale business selling oil and bio products company owned by SOK (51%) and St1 Ltd. (49 %). SOK is a Finnish customer owned business group concentrated on selling daily goods. NEOT employs around 60 oil and logistic experts. NEOT mixes St1 biofuel to E5, E10 and RE85 fuels and distributes mixed fossil and bio fuels to St1, Shell and ABC stations. ABC oil stations are owned and operated by SOK.

R&D investments

The designing of the St1 bio-ethanol concept originally started in state owned VTT with public funding. In 2006 a company called St1 Biofuels Ltd. was found as a spin-off company of VTT. Year after that VTT sold its share of the company to St1 Oy. After that St1 Biofuels has further developed its waste-based biofuel processes through internal R&D investment, but it has also received some public funding for the purpose, e.g. R&D funding from Tekes BioRefine Programme.

The St1 waste-based biofuel concept and technology is developed and patented in Finland. The St1 waste-based biofuel concept has also won various prizes: in 2008 innovation prize of Chemind, a silver medal in EEP European Environmental Innovation competition and the prize of the President of Finland INNOSUOMI 08, in 2009 St1 RE85 biofuel won the first prize in competition organised by the Association of Environmental Enterprises in Finland.

St1 Group has ambitious targets in developing waste-based biofuel concepts for global markets on turn-key basis: this is expected to become a significant growing business of St1 Group in 10-20 years. For the purpose the group invests in developing the concepts and required competencies, and in gathering early-phase experiences in the near-by markets. The owners and top-managers of St1 Group are very determined and committed to this target.

St1 is originally an oil distributing company, established in 1995, currently mainly distributing fossil fuel (over 1200 gasoline stations in Scandinavia, branded St1 and Shell). The company uses profits gained by selling fossil fuels for RD&D of the new biofuel concepts. Hence, the activities of the company are dependent on fossil oil markets and the success of the company when compared against other fossil oil and fuel companies. On the other hand, the owners and top-managers of the current St1 Group are committed to invest in the development of waste-based biofuel concepts. This enables long-term development of relevant competencies even in times when external funding is difficult to find.

Other

St1 is also active in wind power business, being a partner in TuuliWatti Ltd. developing and constructing on-shore wind power plants.

2. Key technologies: development stage and market characteristics

The Etanolix process consists of feedstock reception unit and the actual ethanol production unit. The feedstock unit is divided into extraction of plastic waste (e.g. of bread packages) and water addition into dough. The ethanol production unit consists of hydrolysis, fermentation, extraction of dry material, vaporization and distillation. Solid extract and forage are extracted in the process. From the fermentation process CO₂ is emitted into air.

The Bionolix process includes in addition to feedstock reception unit and fermentation process also a combined heat and power production unit producing electricity and district heat from biogas. Biogas (biomethane) is produced at the site from the solid extract extracted in the fermentation process.

Both Etanolix (4 plants operating, 8 more planned for 2020) and Bionolix (1 pilot plant operating, 1 more planned for 2016) concepts are emergent technologies. Although sugar fermentation itself is a well-known technology, the Etanolix and Bionolix processes are disruptive in the sense that the concept and production process are new using very low value raw materials (food waste). Etanolix concept is at the moment in a transfer process, transferring from nursing markets into bridging markets (can be considered as a mature technology already). Bionolix technology is in nursing stage.

St1 has been building a network of ethanol plants across Finland since 2007 with the goal to produce around 300 000 m³ ethanol for traffic fuel use from waste and side streams by 2020. St1 bioethanol is used as E85 fuel (St1's own RE85 fuel) and blended with fossil gasoline (maximum 10%). This mix is compatible with most modern cars. RE85 contains 80-85% waste based St1 bioethanol and is suitable for Flex-fuel vehicles (FFV), and cuts transport related fossil CO₂ emissions up to 80%. RED95 ethanol-diesel is meant to Scania Ethanol Engine Trucks and Buses and cuts transport related fossil CO₂ emissions up to 90 %.

St1 process owns high degree of integration and utilisation rate for raw materials/feedstocks.

3. Geographic scope of the present activities

St1 has over 1200 gasoline stations in Scandinavia (St1 branded: Finland 360, Sweden 200, Norway 40; Shell branded: Finland 225, Sweden 340). St1 Ethanolix units exist in Finland in Hamina, in Vantaa, in Lahti and in Jokioinen. Ethanol dehydration plant is located in Hamina, Finland. Geographical scope of the present operations is introduced in the Figure 2.

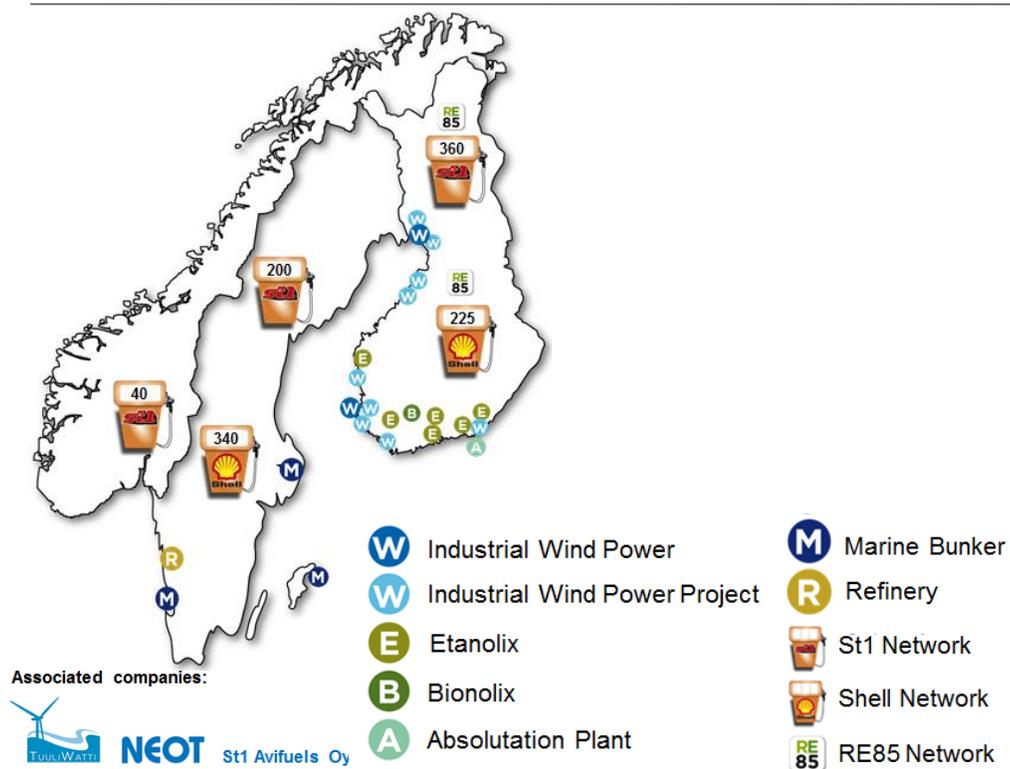


Figure 2. Geographical scope of St1 operations (situation in 2012-2013).

Each Etanolix unit produces in average 1-2 Mio liters bioethanol per unit per year, except Jokioinen produces 9 Mio liters; total amount equivalent of 13 Mio liters per year 99,8% bioethanol. The annual production capacity of the Hämeenlinna Bionolix pilot plant is 1 Mio liters bio-ethanol. Annual capacity of the Hamina dehydration plant is 88 Mio liters of 99.8 % ethanol. St1 headquarters are in Helsinki, Finland.

4. Governance structure of the value chain

St1 Group as a whole comes close to a vertically integrated firm model when biofuels are considered (see Figure 4 in summary chapter 6). The lead firms in this vertically integrated business are distribution networks (St1 & Shell) that must provide consumers fuels that fulfil the energy policy obligations. The St1-owned distribution networks are now vertically integrated with waste-based biofuel production plants, and in practice the St1 Group also controls the oil mix and logistics too. Overhead of St1 group (mainly from fossil fuel distribution business) is used for investments and competence building in waste-based biofuel production, supporting thus the long-term strategy of the company. Vertical integration also makes it possible to gather valuable early-phase experiences internally in nearby markets.

St1 Biofuels Ltd. is a private Finnish company who achieved in autumn 2012 a quality certificate (ISO9001:2008) encompassing the whole production area. The early-phase St1 bioethanol production concept is patented. The processes have, however, been further developed on the basis of real-world experiences in existing plants and nearby markets. This experience-based knowledge related to the complex processes of converting bio-waste into biofuels is difficult to copy. Because the required competencies cannot be found in any existing companies or university units, it is instead important to foster the competence building and experience gathering within the company. Vertical integration with St1 oil distribution business together with the current energy policy obligations makes the long-term development efforts possible even in this early phase of development (seen as a competitive advantage of St1 Biofuels).

5. Institutional context

The long-term strategy of St1 – investing in sustainable biofuels that decrease the global CO₂ emissions - is led from climate policy. The recent developments of European and national level energy policies have, however, provided the necessary framework for implementing the ambitious company strategy with regard to biofuels.

The EU's policy to increase the share of the use of renewables in transport by 2020 has created new markets for biofuels. Instead of the minimum 10% RE share in transport set by the EU, Finland has increased its RE target in transportation to 20% as a part of its National Renewable Energy Allocation Plan (NREAP). To increase the share of biofuels in transport and to decrease the greenhouse gas emission of the transport sector, a revision of transport fuel taxation was launched in 1.1.2011. The taxation of all fuels, including transport fuels, is now based on their energy content and carbon dioxide emissions. It has had a decisive role, because waste-based ethanol has the lowest level of excise, making it very competitive,

although St1 produced waste based ethanol also before this waste fuel beneficial taxation was launched. The national-level energy regulation thus functions as an enabler of long-term strategy implementation, making it possible to invest in the development of new concepts and competencies for waste-based biofuels and in gathering valuable early-phase experience in near-by markets. Better coordination of transport policies and energy policies would be appreciated, however, as some of the energy policy obligations are now impossible to reach with the existing vehicle fleet.

Feedstock supply is also dependent of waste regulations and environmental policies in large. Effective utilisation of waste-based feedstock can be facilitated by educational processes and actions too. The same holds for consumer education too: when people are aware of CO2 emissions of their choices the waste-based biofuels turn out as preferable alternatives. NGOs like Green Peace and WWF also contribute to this awareness and it is thus important to pay attention to their requests and viewpoints. St1 thus follows their communication and has also provided NGOs opportunities to visit the St1 plants. Continuous interaction with the important ministries, funding agencies and key people in the European Commission is needed as well.

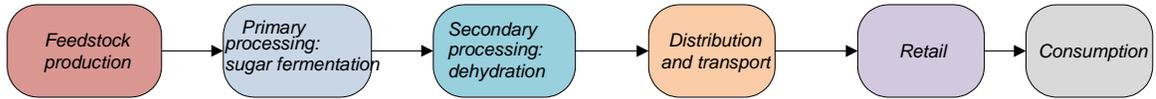
The central innovation policy actors (Tekes, VTT) have supported the St1 biofuel strategy implementation by providing partial funding and expertise for St1 biofuel R&D projects. This support was particularly important when developing the initial Etanolix concept and for the establishment of St1 Biofuels Ltd. Now much of the significant development work is done internally using the company's own resources, however. The company is currently also developing the required competencies internally as these competencies are not readily available from existing companies or university units. Development of the educational system would thus be appreciated to ensure conditions that support the long-term business development (the effects of educational renewals can, however, be seen just after years).

6. Summary of the value chain analysis

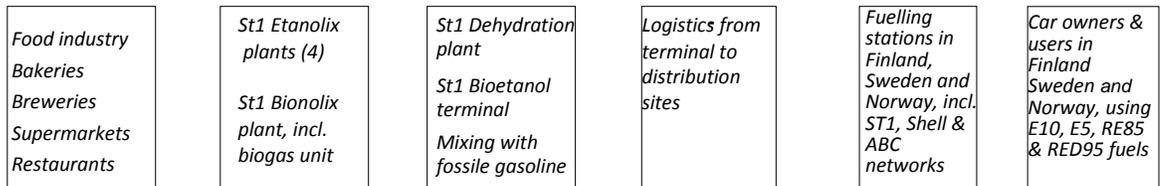
The value chain analysis of St1 Etanolix and Bionolix concept is summarized in Figure 3, followed by a concluding discussion on the governance structure of the value chain and the long-term targets of St1 Group (see the next pages).

Figure 3. Summary of St1 biofuel value chain analysis (Etanolix & Bionolix)

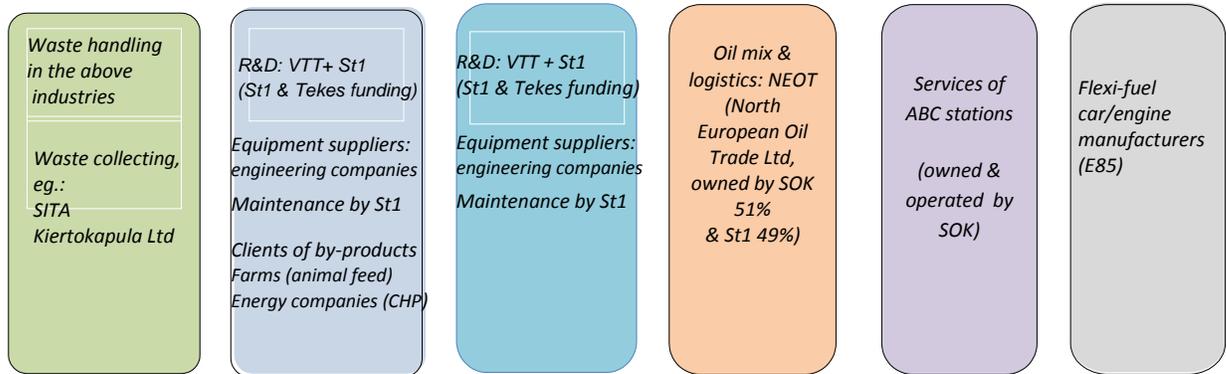
Value chain segments / activities: Flow of St1 biofuels process (Etanolix & Bionolix)



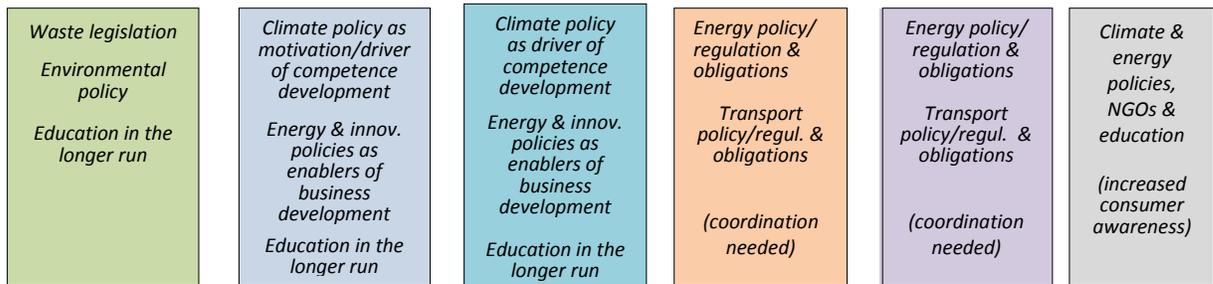
Value chain actors



Supporting activities

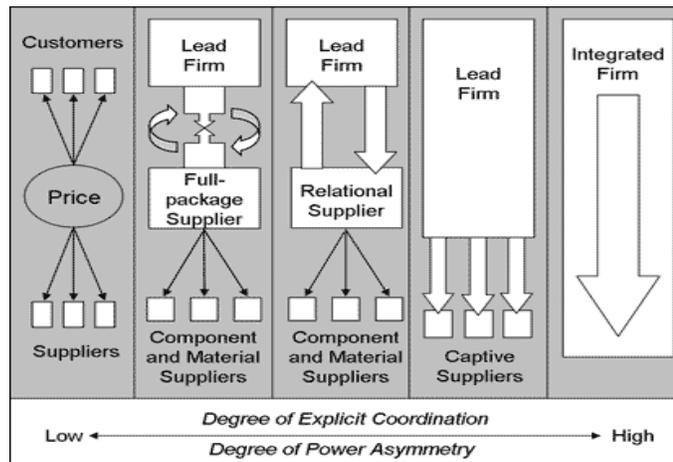


Policies and institutions



When thinking about the value chain governance structure, St1 Group as a whole comes close to a vertically integrated firm model (see Figure 4 below). The lead firms are distribution companies/networks (St1 & Shell) that are to provide consumers fuels that fulfil the energy policy obligations. The St1-owned distribution networks are now vertically integrated with waste-based biofuel production plants, and in practice St1 Group also controls the oil mix and logistics. Overhead of St1 group (mainly from fossil fuel distribution business) is used for investments and competence building in waste-based biofuel production - and other renewable energy technologies that enable significant reduction of CO2 emissions - making it possible to develop these new businesses even at times when external funding is difficult to find. Vertical integration also makes it possible to gather valuable experiences internally in nearby markets.

Figure 4. Typology of value chain governance structure
 (Source: Gereffi and Fernandez-Stark, 2011)



Market Modular Relational Captive Hierarchy

The ultimate target of St1 Group is, however, to develop waste-based biofuel concepts for global markets. The owners and management of St1 Group see this as their significant growing business in 10-20 years. The vertically integrated model ensures fluent early-phase development of waste-based biofuel concepts, incl. development of required competencies. EU and national-level energy regulation provides now favourable conditions for development of these waste-based biofuel concepts. The future depends on the development of the specific conditions and the speed of developing company's own competencies. If successful the St1 strategy will generate new profitable turn-key business and knowledge-based jobs for Finland while also decreasing the global CO2 emissions with the help of the new concepts provided. The nearby markets in the Nordic countries play an important role in gathering experience and further developing these biofuel concepts.

References

Gereffi, G. and Fernandez-Stark, K., 2011. Global Value Chain Analysis – A Primer. Center of Globalization, Governance & Competitiveness (CGGC), Duke University, Durham, North Carolina, USA.

Hazley, E. 2012. St1 Biofuels Oy. From Waste to Bioethanol. A presentation held in TOP-NEST annual seminar in Helsinki, October 12th 2012.

Mika Anttonen, Chair of Board, ST1 Group. Interview on May 24, 2013.

St1 website <http://www.st1.fi/>