Enerkem Rotterdam

A case study

31 May 2019

Innovation:	**Chemical recycling of hydrocarbon wastes (e.g. plastics, biomass)**
Intervention:	**Enerkem – Waste-to-Chemicals project Rotterdam**
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Methodology:	5 interviews: Securing interviews with stakeholders from the private sector was rather difficult. Especially details on the technological aspects of the process are not disclosed publicly. Site visits were not possible as the Rotterdam facility is still in the planning stage and the only existing facility is located in Edmonton/Canada.
Case Study Overview	
Sector(s):	Plastics, Cross-Sectoral
Value Chain Stage(s):	Resource & Production, Consumption & Waste
Type of Intervention:	Technical and Economic
Date & Duration:	2000 (Founding Enerkem Inc. in Canada) - on-going
Location:	Edmonton (Alberta, Canada); potentially Rotterdam, The Netherlands
Initiating Actors:	Enerkem
Actor Constellation:	Financing (Canada): Braemar Energy Ventures, Cycle Capital Management, Fondaction CSN, Fonds de solidarité FTQ, Investissement Québec, National Bank of Canada, Rho Capital Partners, Waste Management of Canada, Westly Group, Valero Energy, Blackrock, Sinobioway (and since April 2019: Suncor) Governance (Canada): Enerkem together with Gov't of Canada (subsidy through WINN program), City of Edmonton Regulation (Canada): U.S. Environmental Protection Agency, Gov't of British Columbia (certification of bio-ethanol as renewable fuel) Rotterdam plant partners: Enerkem, Nouryon (formerly AkzoNobel), Air Liquide, Shell, Port of Rotterdam Rotterdam plant governance: Gov't of Netherlands; Province of Zuid Holland, City of Rotterdam (subsidies)
Short Description of Intervention:	Enerkem (Canada) has developed a (fluidised bed) gasification technology to produce syngas from (hydro)carbon wastes (e.g. biomass, mixed municipal solid waste/MSW, plastics). The technology was patented in 2009. One commercial plant has been in operation in Edmonton (Alberta) since 2015. Since the 1990s various projects have looked at gasification of biomass and wastes to produce syngas (e.g. in the U.S., Europe). In the Enerkem process, the syngas is converted to methanol. Methanol is used as a platform to make ethanol or produce other (intermediate) chemicals. A consortium of Air Liquide, Nouryon (formerly AkzoNobel Specialty Chemicals), Shell, Enerkem and the Port of Rotterdam will build a waste treatment/recycling facility in the Botlek area of the Port of Rotterdam. The project is still in the planning phase.
Research Theme Summaries	
1. Innovation History & Dynamics:	The Enerkem process uses proprietary technology to gasify RDF (Refuse Derived Fuel) to produce synthesis gas, which is converted to methanol after gas clean up. It builds on previous experience with RDF and waste gasification and uses a so-called bubbling fluidised bed reactor. The process is scalable, as it is based on a standardised design of the chemical reactors (train) with a processing capacity of 100,000 tonnes/year. Hence, the capacity can be increased by adding additional trains. The technology was originally developed by Dr. Esteban Chornet at Université de Sherbrooke (Quebec, Canada). He co-founded Enerkem in 2000 with Vincent Chornet (his son). After successfully employing the technology at a pilot plant in Sherbrooke and a demo plant in Westbury, the first methanol at the commercial facility in Edmonton was produced in 2015. Enerkem has also developed a new process to convert methanol to ethanol that has been applied in Edmonton since 2017. The Canadian project had been considerably delayed and became much more expensive than originally planned. This was related to a high level of sophistication inherent in building the first commercial-sized trash-to-ethanol facility in the world. As a result, Enerkem achieved its full capacity of converting about 100,000 tonnes of pre-treated MSW into methanol only in 2018.

	The first plant outside Canada is considered to be built in Rotterdam, The Netherlands. Although initial operation had been planned for 2020, due to delays the final investment decision has been postponed to the second half of 2019. The facility is expected to produce methanol that can be used as feedstock for chemicals (by adjacent sites of Nouryon and Shell). Furthermore, methanol can be blended in transport fuels, thus fulfilling EU requirements on the share of bio-based fuels in transport fuels. Hence, future business of the W2C plant depends on policy developments on EU level as well as regarding the implementation of EU law in the different member states. It could be negatively affected by policy variability as well as uncertainty over future policymaking. This is true for biofuel legislation but also mandatory recycling and MSW reduction rates, which could decrease the availability of MSW as a resource for methanol production.
2. Governance Arrangements & Agents of Change:	In Rotterdam, multiple stakeholders from different sectors are collaborating to implement the Enerkem process of chemical recycling of hydrocarbon wastes. Within the consortium, Enerkem acts as technology provider, lead contractor and equity partner. The Port of Rotterdam provides state-of-the-art infrastructure. In addition, about 2 million tons of municipal solid waste (MSW) are already being shipped to Rotterdam, facilitating the feedstock supply through agreements with waste management companies. Air Liquide acts as a supplier of oxygen and hydrogen and Nouryon participates as a supplier of hydrogen (a by-product of its chlorine production) and a customer of methanol. Shell plans to buy the facility's product, (bio-)methanol. Among the public bodies, the Province of Zuid-Holland and the City of Rotterdam provide financial support. The Dutch Ministry of Economic Affairs and Climate Policy has additionally agreed to develop instruments that help scale up the technology. However, in the decision for the Rotterdam location, public funding played a significantly minor role compared to the availability of private equity capital. Overall, funding the W2C project in Rotterdam appears to be a challenge even though various global players are involved. As in the case of other new technology developments, the risk for financial investors is considered high and thus finding investors turns out to be difficult. As social demand for low-carbon solutions increases, also many companies recognise the need for low-carbon societies and engage in low-carbon innovations to secure their future competitiveness. Thereby, they also prepare for potential future regulation demanding strong climate protection efforts and thus avoid being caught off guard by stringent legislation. A successful commercial application of an innovation could also make the company a frontrunner in the supply of low-carbon technologies. Public institutions supporting innovative projects similarly recognise the need for climate protection measures and are also interested in a prospering local economy including job creation and preservation. Moreover, the use of waste as feedstock counters the (potential) problem of scarcity of landfilling space and fulfils society's desire for increased waste diversion. An Enerkem representative attributed the creation of the W2C project in Rotterdam to policy developments, namely progressive waste policy in particular but also general policy objectives on different levels (EU, national, local). Hence, regulatory developments linked to European and Dutch decarbonisation pathways play a prominent role, but also other drivers such as market trends influenced the decision in favour of the particular project. Those market drivers include e.g. that waste is the most inexpensive feedstock which is abundantly and readily available in all regions (urban and rural) and already collected. On the demand side, there is a consumer pull for renewable and bio-based products, i.e. methanol for fuel use as well as intermediate for "greener" variants of glues, paints, cosmetics etc. Compared to the Enerkem project in Canada, W2C is mainly financed by the joint venture partners' equity capital as well as public grants. The Enerkem-owned Edmonton project also receives public funding. There are, however, many more investors involved, among them venture capitalists, who do not participate in the operational business. The governance model of the Rotterdam project thus appears exceptional in the participation of a rather large variety of stakeholders, which are not only investors, but mostly industrial players. Partly, this arises from location-specific aspects, mainly the fact that the companies participating in the operation of the project are already clustered within the Port of Rotterdam. On a more aggregate level, the interlinkage of value chains in the framework of the W2C cooperation could represent a first step towards more industrial symbioses, i.e. the use by one company or sector of by-products, including energy, water, logistics and materials, from another. In the Rotterdam W2C case, the definition mainly applies to Nouryon acting as a supplier of hydrogen, a by-product of its chlorine

	production. This kind of industrial cooperation holds large emission mitigation potentials and is considered a key measure for the decarbonisation of the energy intensive industry. So far, however, few cooperation projects became reality as different kinds of barriers prevail, such as geographical distance and a lack of trust and knowledge.
3. Transformative Capacities:	So far, the W2C consortium appears successful in generating the skills, knowledge and resources for the implementation of the project. An important step for addressing inertia in this field has been taken by Enerkem with the development of their proprietary technology, which will be transferred to Rotterdam. Furthermore, by bringing together Enerkem, the Port of Rotterdam, Air Liquide, Nouryon and Shell, actors with expertise on different parts of the W2C value chain have been united for this project. While securing funding proves rather difficult, the consortium appears to be capable of generating sufficient financial resources for project implementation. Since the W2C facility in Rotterdam so far only exists on paper, making its decarbonisation potential legible is still rather difficult, especially as it will depend on the composition of the MSW processed at the facility. Consequently, to date the project participants mainly engage in storytelling. The W2C consortium draws the picture of a project which represents a step towards a circular economy where waste becomes the feedstock for everyday products. Enerkem Canada and its collaborating companies also try to highlight concrete cases showing how the general public benefits from its business activity. This comprises the reduction of greenhouse gas emissions, the generation of biofuels used as an alternative to fossil fuels as well as building a sustainable bio-economy. The way in which the W2C partners seek to generate authority and legitimacy for the initiative is closely linked to the vision of a future where waste will be a useful feedstock which can even replace fossil fuels. Towards that goal, the W2C project positions itself as a sole frontrunner being able to actually provide and implement a ground-breaking low-carbon measure. Although potential drawbacks exist, the promise of an applicable solution seems to generate a high level of legitimacy for the initiative. Due to the participation of important multinational corporations and the technological credibility built up by Enerkem in Canada, the generation of authority will probably be successful as well. In Canada, Enerkem further aims at having its facility's 'low-carbon' qualities recognised and assessed by other, possibly impartial institutions. This is realised by product certifications, evaluations of the production process as well as assessments of the company's business model and management in general. Overall, Enerkem Canada appears successful in giving value to its ‚low-carbon' qualities. The awards the company is receiving from industry and its peers show that Enerkem is recognised the way it aims to be.
4. Assessment & Evaluation:	The W2C project is still in the planning phase and public assistance or partnering in the project is limited. Hence, little information is publicly available on the technical, economic and environmental assessment of the Rotterdam plant. The project's economics are strongly influenced by the availability of sufficient MSW, as well as the value of the methanol produced. The delay in the permitting and construction of the facility means that the W2C facility needs to comply with stronger CO_2 emission reduction requirements to be recognised as a bio-fuel (i.e. at least 65% reduction). Since also the composition of the waste will affect the level of CO_2 emissions, it is infeasible to fully evaluate the economics of the project at this time. While the plant in Edmonton complies with Canadian air quality standards, and the produced ethanol is recognised as bio-ethanol by U.S. regulators, the Rotterdam facility is not yet operational. Hence, the technology cannot yet be assessed under European regulatory circumstances. Similarly, the W2C plant's potential impact on the climate cannot be assessed at this moment, as this will strongly depend on the composition of the MSW used as input into the plant, as well as on the alternative use of the MSW replaced by the Enerkem plant. Until now, the W2C project has not been publicly or externally evaluated. Yet, in its initial support for the project the Province of Zuid Holland demanded that the Rotterdam facility contributes to at least a reduction of CO_2 emissions by 200 $ktCO_2$/year while producing at least 180 kt methanol/year. At least 30% of the MSW should come from The Netherlands, which would otherwise be incinerated. Recyclables should have been removed from the MSW before processing, so that the facility would only process post-separation residual waste. To foster innovation, it was expected that the plant should be operational within 24 months, and if this was delayed to over 36 months require sufficient explanation.

	For the products to be recognised as bio-fuel, European regulation requires that the project achieves a reduction in CO_2 emissions of at least 65%. Similar guidelines do not yet exist for chemical feedstocks. If the methanol would be used to manufacture MTBE (a fuel additive), it should be expected to comply with the same standards. As outlined above, this would require detailed monitoring of both the waste flow, the process, as well as the uses of the produced methanol. The Canadian plant has been evaluated since the start of operations. It was criticised as its operating costs have increased since 2012 but the total waste was constant. Moreover, instead of increasing total waste diverted from landfills has declined. At the same time, Enerkem said that its Alberta Biofuels facility has been meeting the highest quality standards set by the International Methanol Producers and Consumers Association (IMPCA) for the production and sale of methanol.
5. Uptake & Consequences:	As the W2C project itself is still in the planning phase, its operational and commercial feasibility still has to be proven. However, the participating companies are optimistic and believe that the W2C facility in Rotterdam can serve as an example to be imitated worldwide in the near future. Currently, further facilities are being planned in Spain, North America as well as China. When developing the Edmonton site, Enerkem already worked to ensure the potential for expansion. They decided to use a modular manufacturing approach when designing the facility in order to allow for rapid building of new such biorefineries. In case of cooperation, Enerkem provides partners with fabricated modular equipment and handles assembly on site. Additionally, Enerkem licenses its technology to partners. The main criteria for partnerships are the design of public policies, the level of tipping fees and population as well as proximity to petrochemical infrastructure. If its commercial success endures, the Enerkem technology could form the basis for the development of a future economy in which waste serves as a feedstock for different kinds of chemical products and fuels. With regard to the W2C project Rotterdam, due to its forward-looking nature no consequences of its operation could have been identified yet.
Conclusion & Outlook	
Key Learnings:	The Enerkem plant in Rotterdam would convert MSW to methanol, which would be used as feedstock for chemicals or as fuel (additive). Although gasification of MSW is not new and has been studied since the 1970s, few technologies have been successful. If the Enerkem process is successful, the technology would be the first to be so at large scale. While the technology has been licensed for export to e.g. China, the Edmonton plant is still the only operating facility worldwide. The Rotterdam facility would be the second commercial plant to be built worldwide. The initial development and the Edmonton facility were supported by both public and private investments from a variety of backgrounds (e.g. waste management, fuels, equity funding). The Province of Quebec has invested considerably over the whole period (estimated at over C$ 40 million) in the technology. The key driver for the technology is the diversion of MSW from landfilling to produce (bio-)fuels. The Rotterdam plant is primarily funded by private investment (e.g. Nouryon, Shell, Air Liquide). Although its availability is considered limited, public funding is also involved in the initial stages. The main driver for the Rotterdam plant is the trend towards a circular economy (also in policy making) and the search for low-carbon chemical feedstocks as part of the energy transition of the chemical industry. This has brought together (semi-)public and private parties, which all see strategic opportunities relating to their core business. The project would lead to new relationships across supply chains. It proves that public policy can be an important driver for low-carbon innovation. Simultaneously, such projects could be negatively affected by policy variability as well as uncertainty over future policymaking.
Open Questions & Further Research Requirements:	It is hard to evaluate the impacts on GHG emissions and its contribution to deep decarbonisation, as the actual impact is determined by a variety of factors. On the input side these are mainly the composition and origin of the MSW residual to be processed, the alternative ways to process (parts of) the MSW, and the efficiency of the process to convert the MSW. On the output side it depends on the actual use of the product and the feedstocks substituted. Given EU regulation and the delay in construction of the plant, the produced methanol can only be recognised as biofuel if the CO_2 emission reduction exceeds 65%. This will only be achievable if the MSW would primarily consist of biogenic material (e.g. organic waste, paper). As the plant will operate on at least 30% domestic

	waste and up to 70% imported (unsorted) waste, it is unclear if the EU regulatory standard can be achieved. If the methanol will be used as chemical feedstock, EU regulation would not apply, and lower reductions of GHG emissions may be sufficient for the project partners. As competing technologies in the fields of MSW separation and recovery as well as (chemical) recycling arise, it is difficult to evaluate the systemic impacts of the Enerkem process in the European context on technology development, the shift towards a circular economy, and (deep) reductions of GHG emissions.

For Europe to achieve its long-term climate objectives, carbon-intensive industries have to reduce their emissions.

REINVENT focuses on plastics, steel, paper and meat & dairy – industrial sectors that are key to our daily lives, but where low-carbon transitions are still relatively unexplored.

To gain a broader understanding of the possibilities of transition, entire value chains of the industries are studied. This includes non-technical factors such as supply chains, financing, trade, and social and economic impacts. Together with forward-looking industry leaders and policy-makers, we explore potentials and capabilities for making transitions in these resource-intensive industries.

PARTICIPANTS & FUNDING

REINVENT is supported by the European Union's Horizon 2020 Research and Innovation Programme (2016-2020). It involves five world renowned research institutions from four countries: Lund University (Sweden), Durham University (United Kingdom), Wuppertal Institute (Germany), PBL Netherlands Environmental Assessment Agency (the Netherlands) and Utrecht University (the Netherlands).

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