RE-DiAPER

Get your bums in the cycle!

1 cloth diaper can be used 50 times - while disposable only once!

FLOW

Flow of disposable diapers and incontinence material from young children and elderly

CHALLENGE

Reduction of post-consumer waste through the elimination of single-use plastics

THE CIRCULAR DIAPER SERVICE

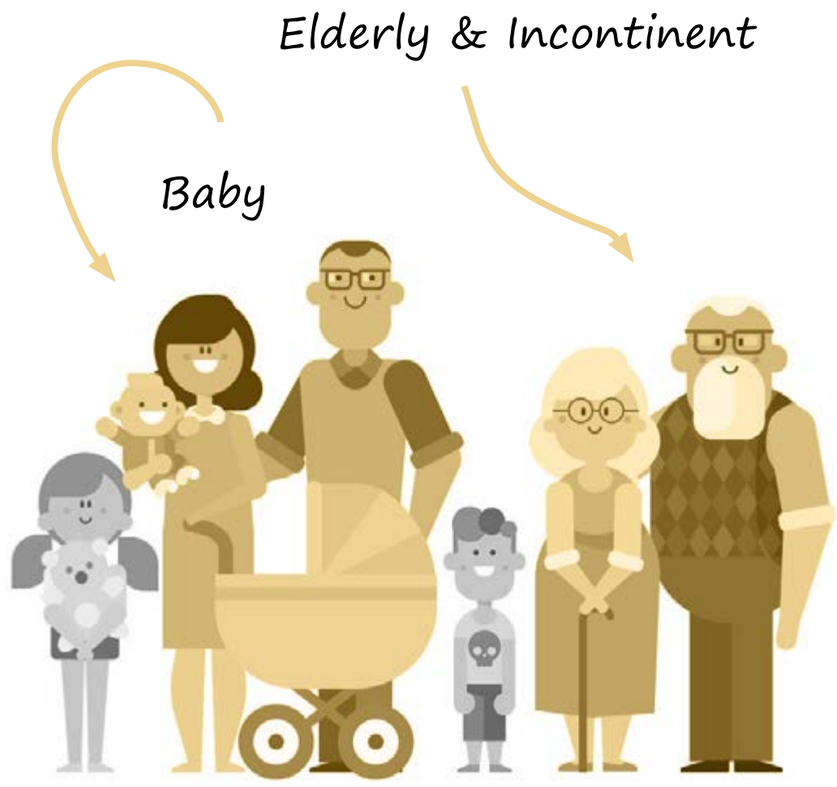
RE-DiAPER is an all-inclusive service aimed at reducing the residual waste from disposable diapers by choosing a more circular approach. By offering reusable cloth diapers, pick-up and delivery, as well as a diaper washing service, it seeks to make the transition to this more durable type of diapers and the way of use as smooth as possible. The service focuses on two target groups: baby (and their parents) and incontinent elderly (and their caregivers).

CONTEXT & SYSTEM

Currently there is a lack of alternatives for sustainable diaper waste treatment in the province of South-Holland. In the Netherlands at large, only one factory exists which recycles disposable diapers, located in the East of the country. In order to process the diaper waste of the entire province, approximately 14 additional industrial installations such as this will be needed. The solution of composting is not ideal either, since it does not reduce the magnitude of resource exploitation.

In this project, we argue that a use-oriented service-system is favourable for diapers. First, it will address the problem upstream by replacing the plastic by a bio-based, more durable material. Second, it will reduce the volume of diaper waste that needs to be processed downstream massively (Ng et al., 2013).

A system is needed that offers diapers as a service, taking away the hassle from parents and caregivers and reducing their costs simultaneously. The province of South-Holland has the largest share of babies, children and elderly of the entire country. In 2018, there were a total of 120k, children between 0 and 3 years old - about 23% of the total of 700k in the whole country (Central Bureau for Statistics, CBS, 2019). Therefore a programme as such is expected to make a large-scale impact.



Target groups

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Q4 2019-2020 | AR0074 Geo-design for a Circular Economy in Urban Regions

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2 | REPRESENTATION MODEL

70 Million Kg

of diaper waste is generated in South-Holland annually

9,425

are used on average per person, throughout his or her lifetime. The vast majority is disposable

5,063 €

is spent on average per person on diapers, throughout his or her lifetime

~500 Years

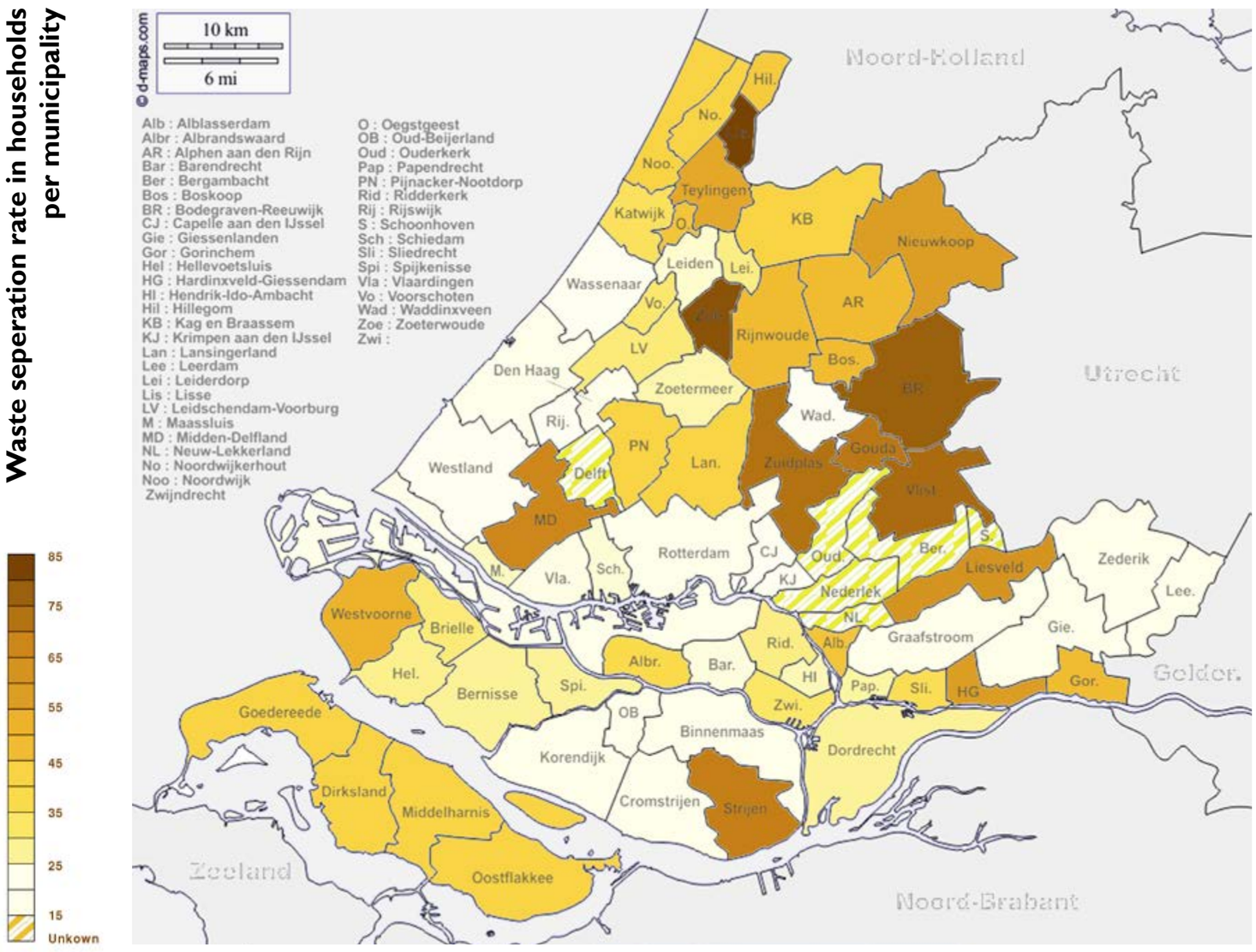
is how long it takes for a disposable diaper to decompose. Imagine: had king Henry VIII worn disposables, they'd still be around today

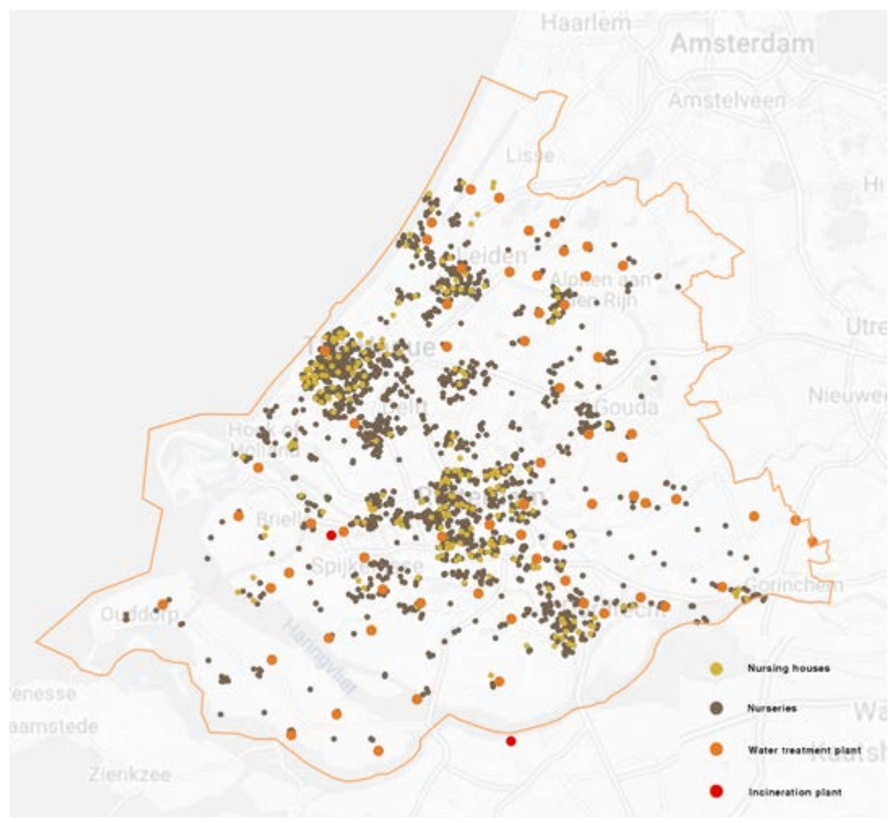
40,489 Tonnes

of CO2-eq. is emitted along the life cycle of diapers consumed in South-Holland annually

95,333 People

currently use incontinence material in South-Holland, among them are 80% of elderly homes residents





PROBLEM STATEMENT

Large amounts of diapers waste are generated on an annual basis from children and elderly, of which current waste treatment technologies do not allow for circular end-of-life treatment.

WASTE SEPARATION RATES

The map on the left-hand side represents the household waste separation rates across South-Holland. It appears that each municipality has its own policy when it comes to waste separation. Whereas in small municipalities (oftentimes in rural areas) rates can be up to 85%, some urban areas - characterized by highrise and a lack of space - a rate of merely 15% is common. In the latter case, municipalities opt for post-consumer separation, to reach a higher level or purity which benefits recycling. However, when it comes to diapers, no separation takes place at household level yet (Rijkswaterstaat, 2019).

WASTE TREATMENT INFRASTRUCTURE

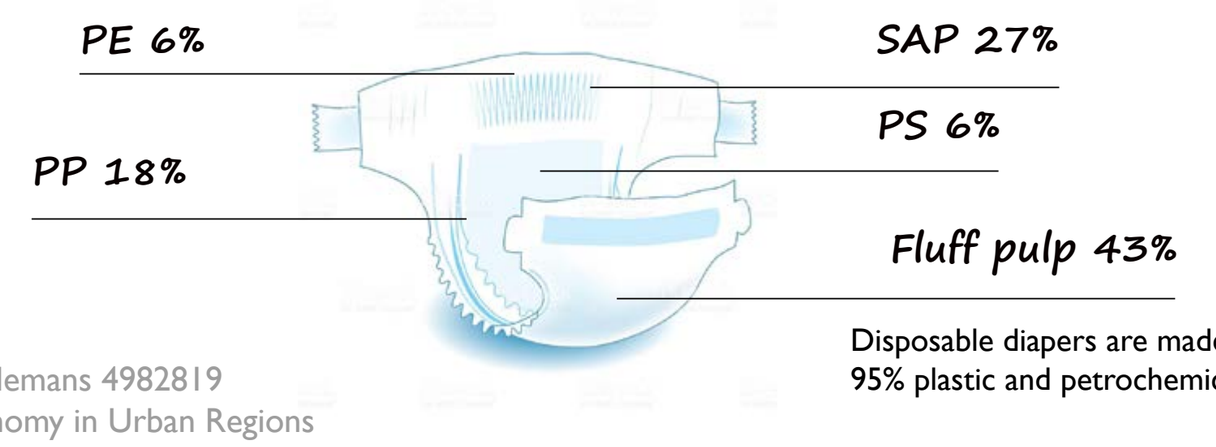
Currently, the most dominant residual waste treatment method applied in the Netherlands is incineration. In the province of South-Holland, there are three waste incineration plants (WIPs), where disposable diaper waste is transported via a vast network of roads and waterways.

The WIPs and wastewater treatment plants (WWTP) are mostly located in the margin of the cities, in industrial zones that are hidden from the public eye. At this moment, the sewage water arriving from households does not include faecal matter and urine from diapers and incontinence material. This means that valuable nutrients (i.e. phosphates, or P, and nitrogens, or N) and other substances that may potentially be recovered from diapers are inevitably lost. Moreover, the total capacity of the WWTPs should be sufficient to process an additional flow of wastewater from washed diapers from the adjacent city, because centralized wastewater treatment is more efficient than local treatment (Stichting Nederlandse Watersector, n.d.).

DISPERSION OF ELDERLY HOMES AND NURSERIES

The map on the right side also shows 233 elderly homes and 1,874 nurseries in South-Holland, which means a large number of diapers are generated every day (Overheid.nl, n.d.; Zorgkiezer, n.d.). When looking into the location of all the nurseries and elderly homes, most of them are gathered in big cities like Den Haag, Rotterdam, Dordrecht, and Leiden. It is assumed that many of the children and elderly are concentrated in the surroundings of nurseries and elderly homes. The higher density of the care facilities, the more efficient the circular diaper service is expected to be, due to short transportation distances.

Weekly average consumption of disposable baby diapers



Disposable diapers are made up of between 75% and 95% plastic and petrochemical materials

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3 | PROCESS MODEL

PROCESS

On the right, the processes of the conventional diaper production and consumption system are visualized by means of diagrams and a corresponding system section, adding a spatial dimension. On top of that, the relevant stakeholders in the examined context will be represented schematically with the aim to gain insight into potential supporting and conflicting parties.

FROM CRADLE-TO-GATE

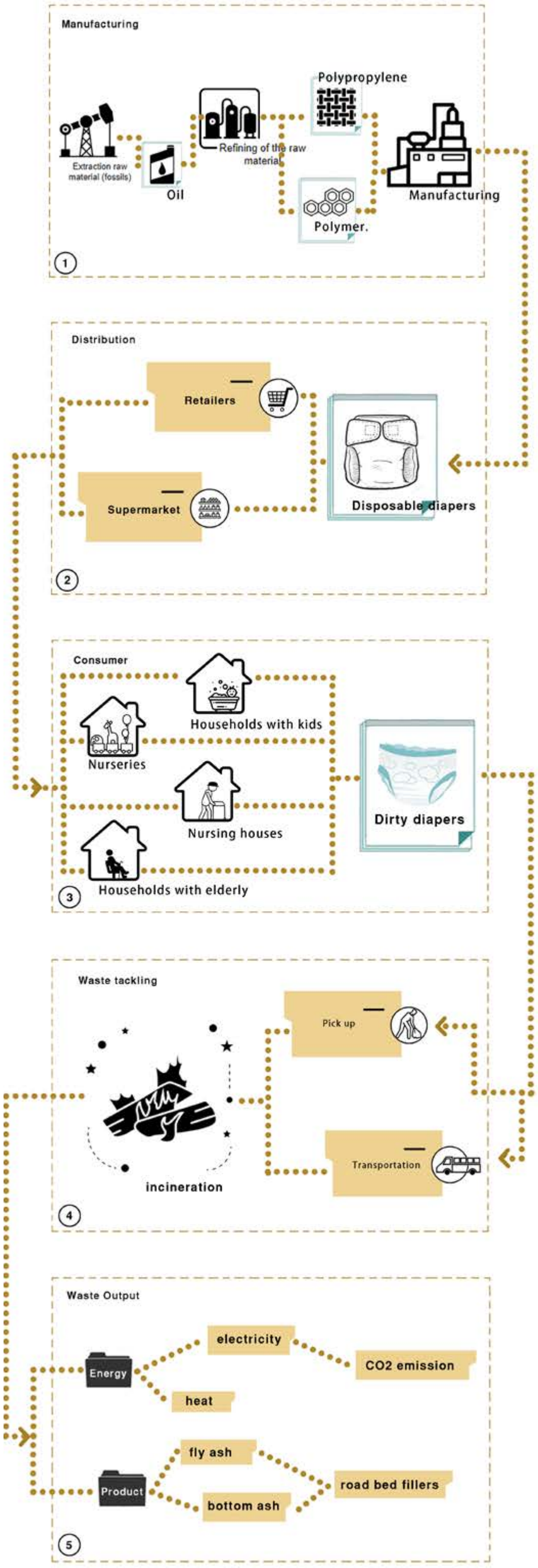
In the process diagram (block 1 and 2), the upstream processes needed for the production of disposable diapers are shown. The value chain commences with the extraction of vast amounts of raw materials, oftentimes heavy crude oil, from underground reserves. Next, the oil is distilled in a refinery and used for diaper manufacturing. Up until here, the processes lay outside of the system boundaries, meaning that the province of South-Holland heavily relies on imported goods, oftentimes transported over long distances. Diapers generally are a private consumer good, part of a product-oriented business model. Therefore, these are typically sold by retailers, supermarkets and drugstores to households and find their way into the nurseries and elderly homes (Mendoza et al., 2019).

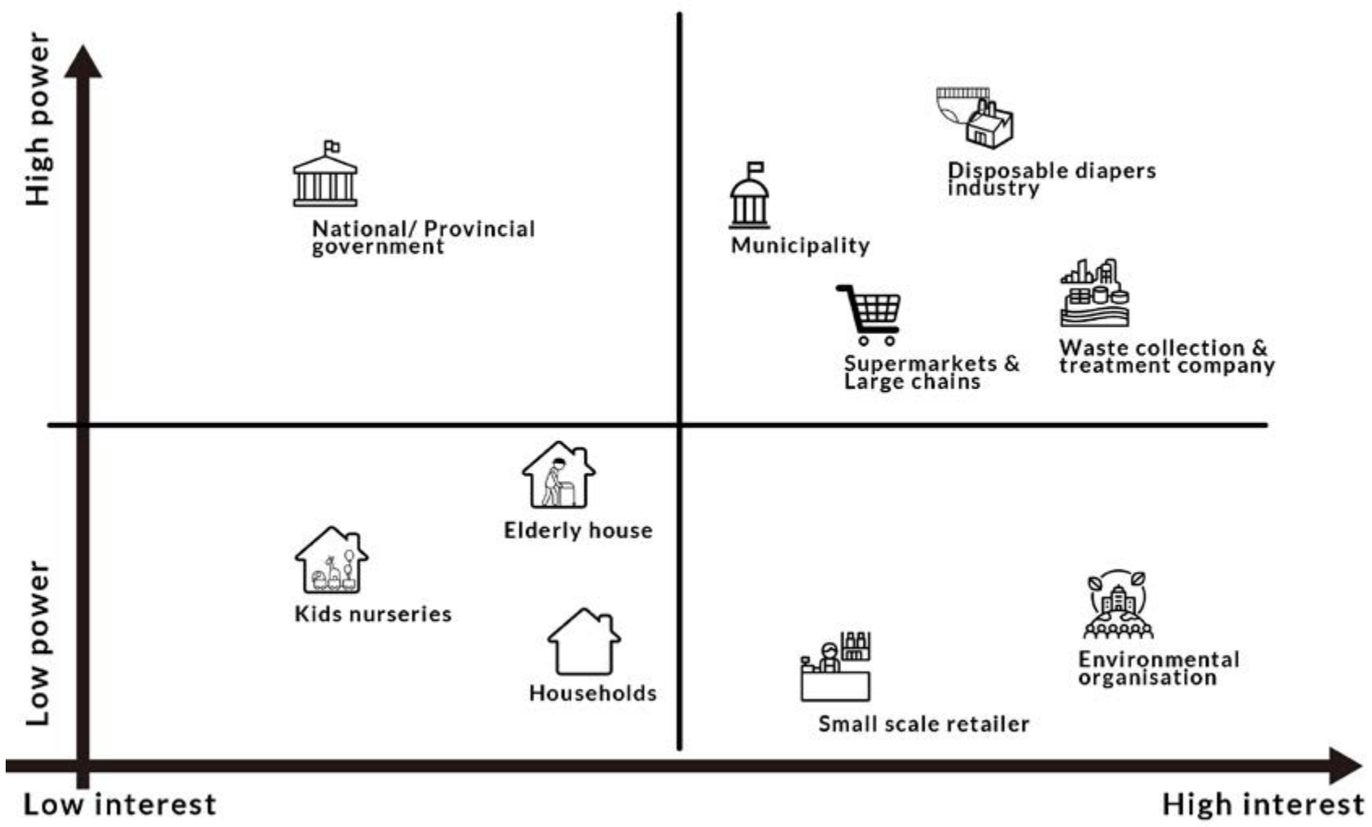
FROM GATE-TO-GRAVE

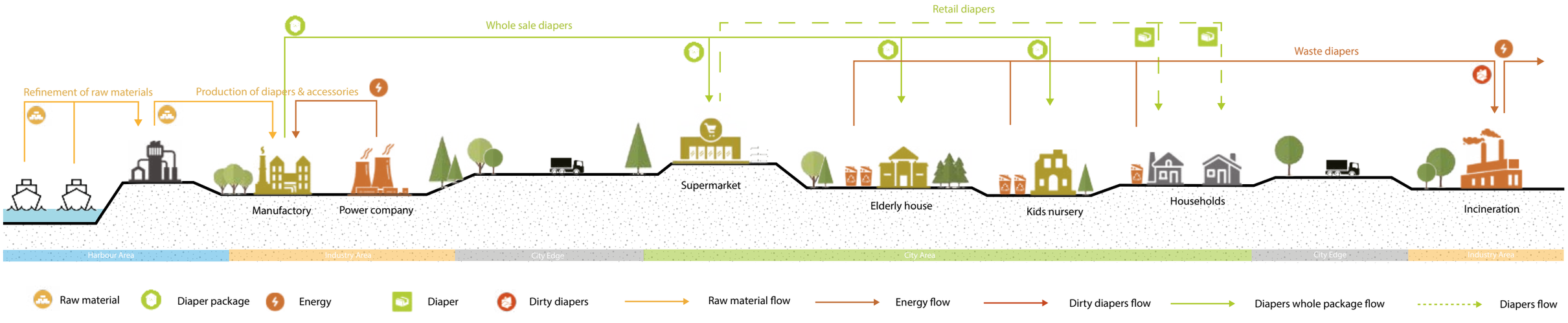
The lower part of the diagram (block 3 to 5) demonstrates the downstream elements of the value chain, starting at household consumption. Once the diaper has been used by the child or incontinent adult, it is disposed of in the residual garbage bin. A waste collection company, in South-Holland usually Renewi, is responsible for collecting the garbage from the streets. The diaper waste is transported to the WIP where incineration occurs. The main by-products of incineration are electricity and heat, commonly fed back into the grid or employed in greenhouses or urban districts, and fly- and bottom-ash, a resource for concrete or cement production in the construction material industry (Rijksoverheid, 2018). Incineration is generally regarded as undesirable in the light of environmental sustainability, as the value of the materials cannot be recovered, thereby maintaining the linear economic make-take-dispose model (Planning Bureau for the Living Environment, 2018).

STAKEHOLDER DIAGRAM

A power-interest matrix provides a simplified overview of the major stakeholders involved in a predefined system. In this case, several players were identified that significantly impact or are impacted by the diaper value chain. To begin with, commercial actors (like the diaper production industry and supermarkets), tend to have a high degree of power and interest in protecting the traditional diaper markets and therefore are key players. Worldwide, the disposable children diaper market alone was estimated to be worth $48 billion (equal to €43 billion euros) in 2017, with a projected 60% increase in value up until 2025. For elderly, this growth will probably be even higher, considering the longer lifespan of the global population (Dawande, 2018). Switching to reusable, cloth diapers, would drastically reduce the turnover of companies specialised in single-use hygiene products. Policymakers (like the national and provincial governments) are best characterized as context setters due to their ability to implement financial or legislative instruments, but have many other priorities, hence the slightly lower interest. Societal players (like households and environmental organizations) can be counted as the crowd or subjects, whose voices are only occasionally heard because of the relatively low power and varying level of interest. It is derived that all players are to be taken into consideration in finding a circular alternative for disposable diapers. Especially getting the diaper industry on board will be a challenge because of their conflicting vested interests and likely unwillingness to change.







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4 | EVALUATION MODEL

PEOPLE engaged

The total number of people from South-Holland, actively involved in a service-oriented cloth diaper system, either as a caretgiver (i.e. customer) or as an employee with distance to the labour market, on an annual basis.

0 persons **0 persons**

Social

COSTS per year

The expenses pay per year on diapers for one child or elderly incl. the costs made along the value chain of diapers, coverage of upfront investments and profit margin.

€436/ €1,820

Economical

WASTE to be incinerated

The amount of solid (i.e. plastics) and liquid (i.e. excrements) waste from diapers, consumed in South-Holland, incinerated by WtE-plants on an annual basis.

70 million Kg

Environmental

WATER used in process

The quantity of water needed for the of diapers by one child or elderly for a year, along the whole value chain, and with or without a washing service.

14,905L/29,815L

Environmental

INDICATORS

Social participation

Social participation can be defined as "involvement in a life situation through the execution of a task or action by an individual" (Piskur et al., 2014, p. 212). It perceives bodily functions as embedded in overarching, societal structures, influenced by environmental and personal factors. A service-oriented diaper system requires households and care institutes (i.e. elderly homes and nurseries) to change everyday behavioural patterns related to the physical needs of children and elderly - including diaper changing and waste disposal practices. Over the past decade, some (product-oriented) pilot projects were launched across the Netherlands to encourage the integration of cloth diapers in households which, however, never gained ground. Hence, their impact was negligible. (Milieu Centraal, n.d.). Besides, as the disposable diaper industry typically has its production facilities overseas, in countries like China and the United States of America (USA), there is barely room for the local employment of people with distance to the labour market. One of the goals of the Dutch government is to create 30k social workspaces for people with a distance to the labour market by 2050, which the present diaper supply system does not contribute to (Rijksoverheid, 2019).

Costs

Across Europe, households spend a sizable amount of money on disposable diapers, both for children and, increasingly, adults. To begin with, it was estimated that on average, the price of a diaper for a child is about €0.24/piece and for an adult about €1/piece (Babybytes, 2016; Tena Webshop, n.d.). With the consumption of 5 diapers per day, one arrives at a cost of €436.8/year per child and €1,820/year per adult (O'Brien et al., 2009). Remarkably, disposable incontinence material is significantly more expensive, to be partly explained by higher production and transport costs. Also, it was found that especially upstream processes (i.e. resource extraction and fabrication) contribute significantly (over 80%) to the total costs of the disposable diaper value chain, followed by transport (±10%), waste treatment and manufacturing (both ±5%) (Mendoza et al., 2019). The remaining costs (±€0.09/diaper) cover the upfront investments, and the profit margin amounts to ±20% (Fernandez, 2017). Particularly for households with a low(er-middle) income, the costs of throw-away diapers is a substantial expense that may severely constrict their remaining disposable budget. From a survey among Dutch parents of newborns, it appears that 80% wait until diapers are on discount, and then stock up a large pile at once, which suggests the need for a standard, cheaper solution (Babybytes, 2016).

Waste

In the Netherlands, in total about 300 million kg of diaper waste is generated annually (ChemistryNL, 2019). To calculate the relative contribution of South-Holland, the percentage of children up until 3 years (±120k) and elderly using incontinence material 75 (±286k) living in the province was looked up (Central Bureau for Statistics, CBS, 2019; Staat van Zuid-Holland, 2020). It was estimated that about one-third of the elderly face incontinence issues, equal to about 95k individuals (De Tijd, 2017). Next, it was assumed that the amount of diapers consumed in South-Holland is proportional to the amount of young children and elderly who reside there, which appeared to be 23% of the total domestic diaper waste. This means that an enormous impact in terms of waste generation can be made by addressing disposable diaper consumption in this particularly densely populated province.

Water

Disposable diapers do not have to be washed, yet the involved production process does involve sizable quantities of water. From an LCA study, it appears that on average, over the entire value chain of one child's diaper, ±8.19L of water is consumed. Most of it (±99%) is tapped during the production processes, including the water-intensive bleaching procedure (Aumônier, 2008). Since a piece of adult incontinence material commonly is twice the weight of a child's diaper, it was assumed to demand double the amount of water as well (±16.38L) (Itsubo, 2020). For one child or adult, with an average use of 5 diapers per day, this boils down to a total annual water consumption of 14,905.8L and 29,815.24L respectively. In the decision model poster, these results of these indicators will be compared with a future situation marked by the large-scale implementation of the RE-DiAPER project.

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5 | CHANGE MODEL

60% less

synthetic material is present in reusable diapers compared to disposable diapers. Only the absorbent core and some details contain plastic

12.75Kg

of bio-plastics can be produced from the faeces and urine, present in diapers used by one person, throughout his or her lifetime. That is enough to manufacture 232 naturally compostable bags

189 diapers

are used on average per person, throughout his or her lifetime, all of them being reusable

0.5 Year

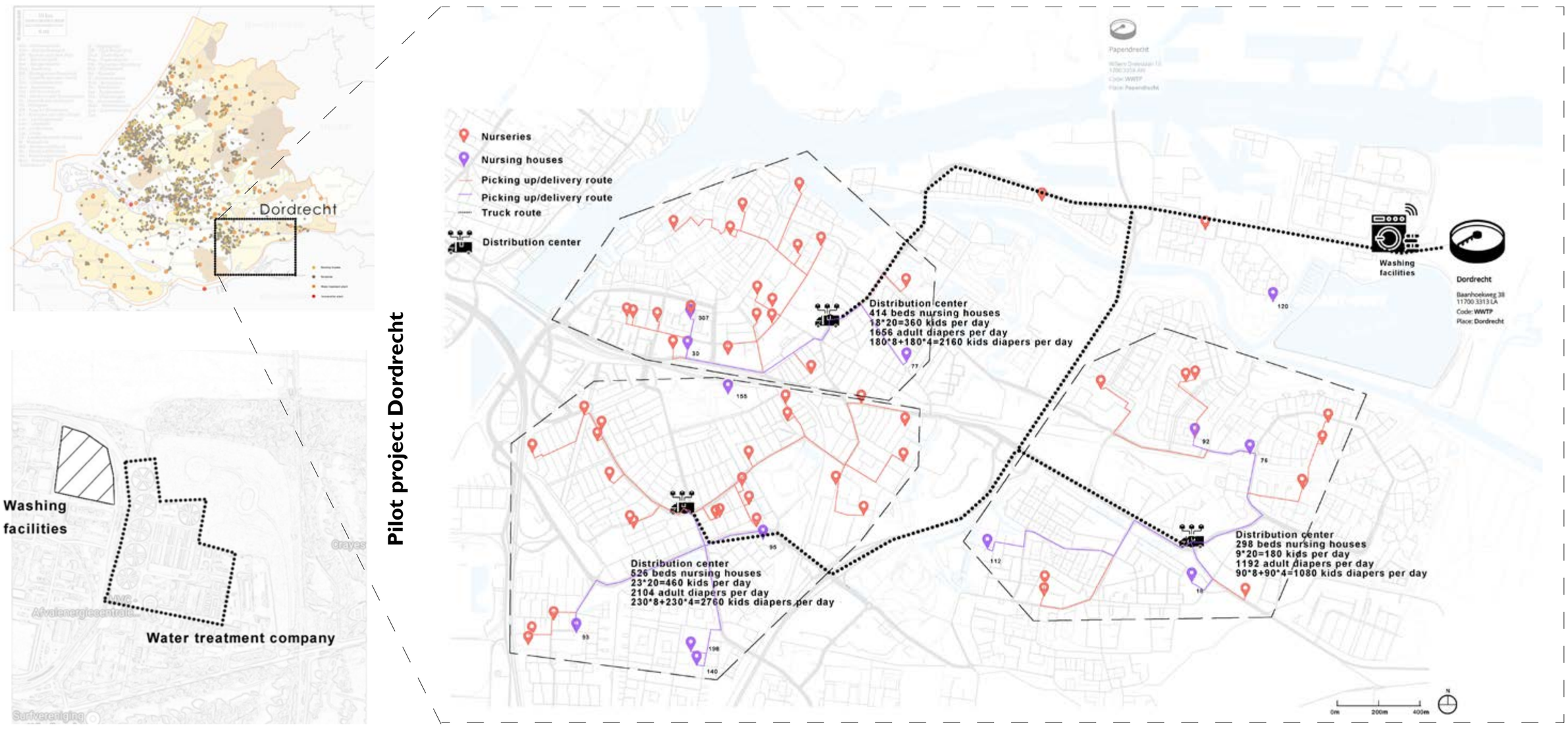
on average is a child potty trained quicker when using cloth diapers instead of disposable diapers

13.85Kg

of the valuable nutrients nitrogen (N) and phosphor (P) can be recovered from the diapers used by one person, throughout his or her lifetime. This can be used as an organic fertiliser to grow local fruits and vegetables

10-30% of costs

can be saved on average per person on diapers, throughout his or her lifetime, by using reusable diaper

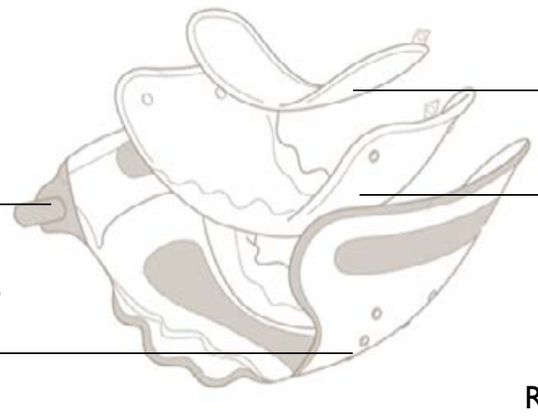


SPATIAL IMPLEMENTATION

On this poster, the changes resulting from the intervention are shown. The map zooms in on the city of Dordrecht, to give an impression of what the spatial implementation of the project will look like in the urban environment. The red and purple landmarks represent the locations of the nurseries and elderly homes across the city. Lines mark the (fastest) route to the closest diaper distribution point, to minimise transportation distances. In the first phase of implementation, some nurseries and elderly homes in remote locations will not have access to the diaper service yet. An electric vehicle (such as the Goupil G4) delivers clean diapers and picks up the dirty ones (Ecomobiliteit BV, n.d.). Once arriving at a central distribution point, the diapers are weighed for administration purposes and transported to the laundry facility by truck.

INDUSTRIAL SYMBIOSIS

The laundry facility is situated outside of the center, with potential locations depicted by a laundry machine icon. A vacant spot in proximity to a municipal WTTP was chosen, as to enable an efficient exchange of resources. The WWTP will be in charge of cleansing the effluent water from the laundry facility, and generate the valuable resources present in the activated sludge. Their role is to obtain the raw material of polyhydroxyalkanoate (PHA): biodegradable polyesters synthesized by bacteria (Morgan-Sagastume et al., 2014; Valentino et al., 2019). These plastics will be utilised for the production of compostable bags for customers to store the dirty diapers in until these are picked up. Moreover, the nutrients (N and P) will be recovered through struvite, with magnesium, and sold to local farmers as an extra source of income (Rose et al., 2015). Finally, clean water will be delivered straight back to the laundry facility, to be cycled into the washing process again. In this way, our company aims to close its loops as much as it can, to thereby reduce its negative environmental impacts.



Reusable cloth diapers are made from natural fibers (cotton, hemp, bamboo) or synthetic fibers (micto fibers or fleece), wool, polyaster and PUL.

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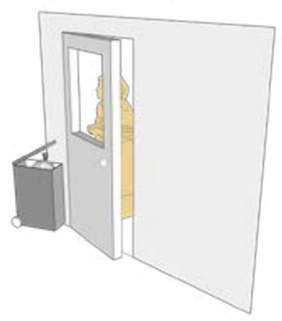
5 | CHANGE MODEL

Wet bag for transport 40*70*120 cm

Outdoor container 40*70*120 cm **pick-up point**

2-3 containers for a nursery (20 kids) with pick-up twice a week

Mini-outdoor container 25*50*70 cm



Home container 20*30*40 cm

PHA Bag ~20*30*40 cm

THE USER'S ROUTINE

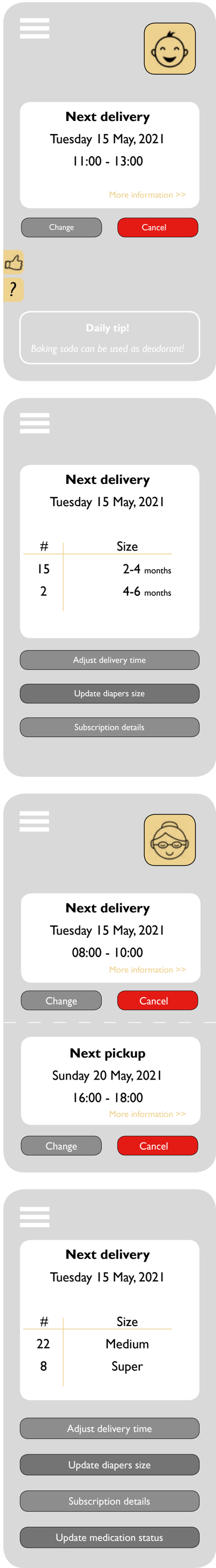
Nurseries and elderly homes are at the core of the RE-DiAPER service. These care institutes can register via the website. Initially, an appointment is made to discuss the number of diapers (and containers for hygienic disposal) needed, and the time slots for delivery and pick-up. Besides these care institutes, individual households are also welcome to take a subscription. Such a customer either receives the order at the nursery (in the case of a child) or at home (in the case of an independently living elderly and babies under 6 months). Fresh diapers arrive in a biodegradable PHA bag made from the diapers waste. After every use, the dirty diapers are thrown into the odor-proof container, which the customer rents from RE-DiAPER as long as his or her subscription lasts, together with a reusable wet bag. Once the bin is full - for a baby after 20 diapers or 3-4 days and for an elderly after 15 diapers or 2-3 days - the bag can be put into the wet bag. Parents can easily use this bag in combination with bike panniers (in Dutch: "fietstassen",) as illustrated. For the elderly, the containers, which have various sizes for indoor and outdoor use, can be used for pick-up and delivery.

USER EXPERIENCE

Once registered, care institutes and households will have access to an app, facilitating quick contact with the RE-DiAPER company. The app will enable them to adjust the subscription, including the diaper size and the quantity of diapers received weekly. Also, it contains instructions about the delivery date and approximate time slot, as well as on handling the cloth diapers (e.g. certain skincare products are harmful for the material, and cannot be used). Finally, caregivers can ask questions to the customer service, and give advice on (sustainable) user practices with others. For large families, comprising multiple children, it is possible to subscribe to a larger package of diapers with a discount. For instance, a household with two children gets 5% off, and one with three children 10%. In this way, RE-DiAPER seeks to include lower-income households, who experience the financial burden of disposable diaper expenses, in its service as well.

STAKEHOLDER ENGAGEMENT

Before, it was noted that particularly commercial actors (e.g. diaper manufacturers and supermarket chains) take a strong interest in maintaining the status quo of the linear diaper consumption model. Transitioning to a model where longer-lasting, cloth diapers prevail, potentially opposes their business model. Depending on the price against which the RE-DiAPER service can be provided, certain forms of governmental support are perceived as beneficial. In the pilot phase, for instance, the provincial or municipal authorities may offer a premium on top of the price to cover any losses, or residual waste tax discount to incentivize participation among households and care institutes. Consequently, policymakers would transform from context setters into key players, moving to the right upper corner in the power-interest diagram. At the same time, implementing a service-oriented diaper programme would aid in meeting the provincial target of reducing waste from diapers and incontinence material, which is advantageous in the light of its circular economy ambitions (Province South-Holland, 2018). Once RE-DiAPER has managed to expand to a wider customer base, and a level playing field with the disposable diaper industries (which now are no longer key players) is established, the government could withdraw its support. Finally, the societal players (like households and care institutes) turn from a passive crowd into active participants, embedded in an overarching network of citizens who feel empowered to diminish their share in the residual waste creation.



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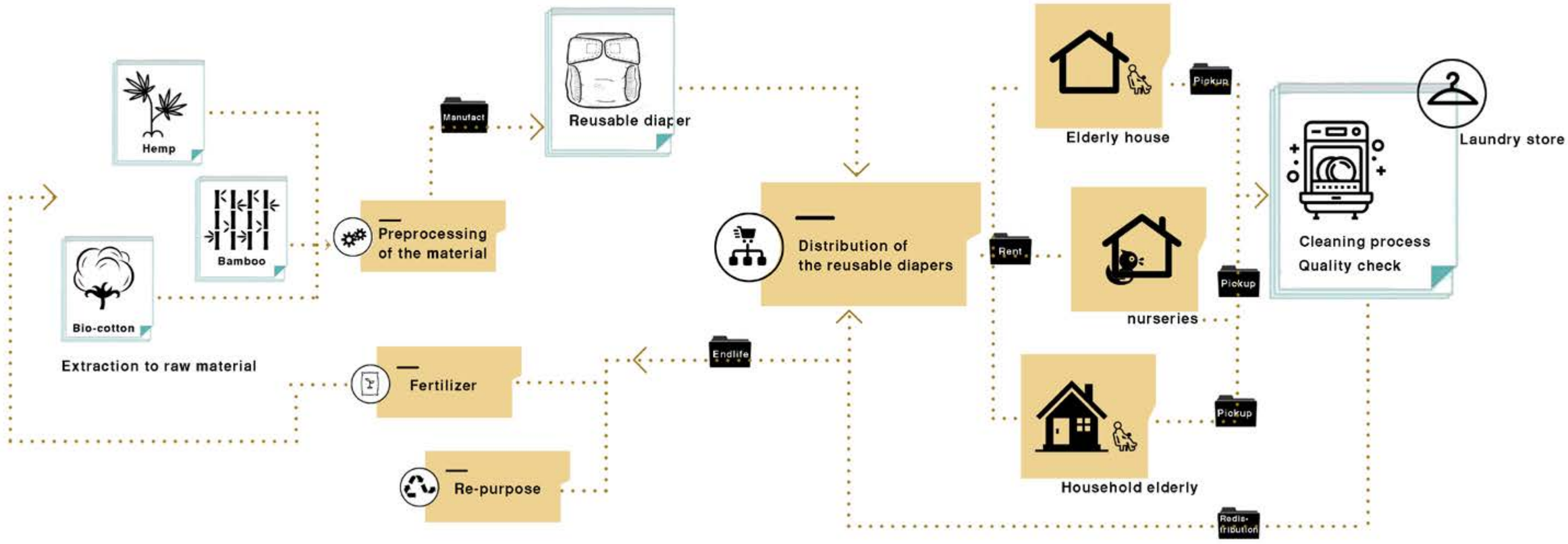
6 | IMPACT MODEL



CHANGED SYSTEM FLOWS

The reusable diapers in the circular diaper service will be mainly produced by bamboo and cotton which is available within Europe. The new diaper would be soft, anti-allergic, and durable. After the manufacturing process in the industrial zone is completed, the diapers are transported to the distribution center in the urban area, situated in the heart of a service cluster. From there, bulk packages of clean diapers will be delivered to the nurseries and elderly homes, and small packages to the households with elderly and babies under six months (since these are too young to attend nursery). After usage, the dirty diapers are picked up from the customers and sent to the washing facilities, simultaneously organised as a workspace for people with a distance to the labour market, in the margin of the urbanized area. The nutrients from the washing water are collected by the WWTP and used by local, organic farmers. Cleaned and checked diapers are returned to the distribution center and packed up again; the cycle now repeats itself. At the end-of-life of the reusable diapers, the bio-based materials are either composted, or repurposed as an insulation material in neighborhoods where the phenomenon of energy-poverty is pervasive.

PILOT PROJECT DORDRECHT

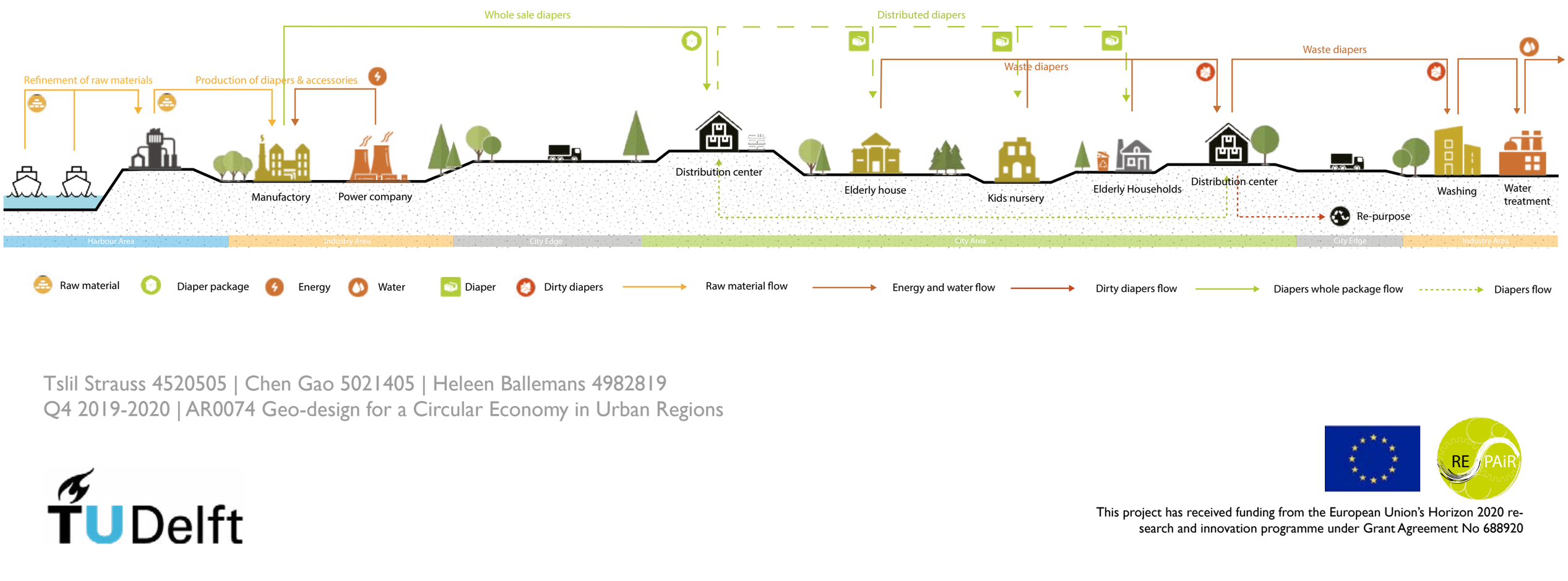
For several reasons, it was decided to set up the first pilot project of the RE-DiAPER business model in Dordrecht. First of all, the map showing nurseries and elderly homes across the province, reveals that the city has a high number of care institutes: 97 in total (Overheid.nl, 2020; Zorgkiezer, n.d.). This implies that the transportation distances to be covered in the distribution network are relatively short, and thereby efficient. Besides, when it comes to waste separation rates, the municipality of Dordrecht scores far better than the other dense cities in South-Holland. In fact, 37% of household and commercial waste is separated at the source in Dordrecht, compared to merely 15% in Rotterdam and The Hague (Rijkswaterstaat, 2019). Hence, it is assumed that separate waste collection is ingrained in the habits of the residents of Dordrecht, which may reduce resistance against an isolated diaper waste management system. On top of this, the vacant space around the WWTP of Dordrecht allows for the placement of the laundry facility, which needs to be in close proximity for the exchange of resources. Since Dordrecht comprises ±5% of the nurseries and elderly homes in South-Holland, it is assumed that the amount of diaper waste generated here is also ±5% (Overheid.nl, 2020; Zorgkiezer, n.d.).

SCALING UP THE MODEL

After the pilot project in Dordrecht has proven successful, the aim is to extend the spatial coverage of the RE-DiAPER model by offering the services elsewhere in the province. In order to meet the province-wide target to reach 50% circularity by 2030 and 100% by 2050, a certain number of distribution clusters needs to be established (Province South-Holland, 2018). On average, one cluster consists of ±2 elderly homes and ±16 nurseries. The table below shows that in 2021, only three distribution clusters are active (in Dordrecht). By 2030, however, about 58 clusters - with a total of 937 nurseries and 117 elderly homes - have to be running to diminish the diaper waste output by 50% of the current amount (Overheid.nl, 2020; Zorgkiezer, n.d.). On average, one cluster covers about 3.760 caretakers, including private households with elderly and babies. Looking even further into the future, to the year 2050, this number will be doubled to >116 clusters. Possibly, the "more than"-sign is added here, as the less densely populated areas that the RE-DiAPER service will extend to at a later stage, may require more small clusters to be set up. It should be noted that this table cannot be interpreted as a prediction of the future, but rather as a desirable outlook on the number of involved people and clusters, based on rough estimations.

PROJECT LONG-TERM PLAN

Indicator	2021	2026	2030	2050
% diaper waste incinerated	95	73	50	0
# caretakers involved	11282	114696	218110	>436220
# clusters	3	31	58	>116



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7 | DECISION MODEL

PEOPLE engaged

The total number of people from South-Holland, actively involved in a service-oriented cloth diaper system, either as a caretgiver (i.e. customer) or as an employee with distance to the labour market, on an annual basis.

218,110 persons

220 persons

Social

COSTS per year

The expenses pay per year on diapers for one child or elderly incl. the costs made along the value chain of diapers, coverage of upfront investments and profit margin.

€338/ €800

Economical

WASTE to be incinerated

The amount of solid (i.e. plastics) and liquid (i.e. excrements) waste from diapers, consumed in South-Holland, incinerated by WtE-plants on an annual basis.

35 million Kg

Environmental

WATER used in process

The quantity of water needed for the of diapers by one child or elderly for a year, along the whole value chain, and with or without a washing service.

17,278L/31,151L

Environmental

DECISION

All in all, the service-oriented business model for cloth diapers, proposed by RE-DiAPER, offers many opportunities from the social, economic and environmental perspective. The province of South-Holland, responsible for generating nearly a quarter of all diaper waste in the Netherlands, is recommended to consider supporting the implementation of such a model, based on the insight of this and solid follow-up studies.

INDICATORS

Social participation

It is assumed that a 50% reduction in diaper waste by 2030 can only be achieved if about half of the 233 elderly homes (35,322 staff members) and 1,874 nurseries (4,585 staff members), as well as half of the households, commit to using cloth diapers (CBS, 2020a, 2020c; CPB, 2011; Overheid.nl, 2020; Zorgkiezer, n.d.). Across the province ±58k incontinent elderly live outside of care homes and ±120k children under 3 years old are being raised (CBS, 2019; Staat van Zuid-Holland, 2020). If half of them participate, with an average of two caretakers each, almost 180k additional individuals get engaged. These institutes and households will become part of a close-knit network of cloth diaper users, connected through the central pick-up/drop-off points. At the same time, the project will be sufficiently large to offer ±220 protected workspaces, both in the laundry facility and the distribution centers. In this way, it contributes to the nationwide ambition to employ many individuals with a distance to the labour market, who currently receive social benefits (Rijksoverheid, 2019).

Costs

Here, the core assumption was that a cloth diaper can be reused 50 times before it no longer meets the strict quality standards on hygiene and comfort (O'Brien, 2009). From the life cycle calculation, it became clear that ±65% of the costs are made during the washing process. Mainly the costs for electricity, and water, as well as the labour (for washing, checking the quality and packing) added up to this (Evides, 2019; Rijksoverheid, n.d.; Pricewise, 2020). Besides the washing process, the transport makes up another 25% of the service-oriented system. Regarding distribution, an electric vehicle (i.e. the Goupil G4) with a load carrying capacity of 1.2t, was assumed, saving high fuel taxes (Ecomobiliteit BV, n.d.). The upfront investment costs were kept the same as for disposables, but a 10% profit was assumed enough to remain a viable business. Based on this, the costs on an annual basis were calculated (Washcot, n.d.). Interestingly, the costs are lower compared to the status quo due to a lower raw material demand, making the RE-DiAPER service attractive for many.

Waste

A 50% reduction in diaper waste will drastically affect the region's waste management systems. Instead of 70 mln kg of waste, by 2030 only 35 mln kg will be generated. As a result, an overcapacity of WIP arises. Also, it will diminish the amount of fuel-intensive trucks for residual waste transportation, supposedly leading to a reduction in noise, smell and particulate matter pollution (Zannin et al., 2018). This will enhance the liveability in cities, especially in the dense urban areas. Further calculations are needed to determine what the precise effect on, for example, NO2 and CO2 emissions are necessary.

Water

The proposed diapers predominantly consist of bamboo (±40%) and cotton (±40%), while the remaining details and absorbent core contain polyester (±20%). For the production of these materials, large amounts of water are needed, mainly for irrigation of the crops as input for the bio-based materials (Khor & Feike, 2017). In total, the raw material production and manufacturing of one child's diaper equates to ±378.8 L of water, assuming the materials are not organic. Yet, since it can be reused 50 times, the amount of water per cycle is ±7.57, plus ±3.64 L per diaper for the washing process in a very efficient A+, industrial laundry machine (Aumônier, 2008). In total, this comes down to about 11.22L/ child's diaper, which is 17.29 m3/ year (correcting for the earlier potty trained child) (Washcot, n.d.). For elderly, 17.12L/diaper is consumed, equal to 31,15 m3/year. In both cases, the water consumption for cloth diapers is higher than for disposables. Switching to the use of organic bio-based materials would increase the water demand, while reducing the use of fertilisers and toxic substances present in pesticides and insecticides (Khor & Feike, 2017). Hence, this is a trade-off that needs to be considered carefully.

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