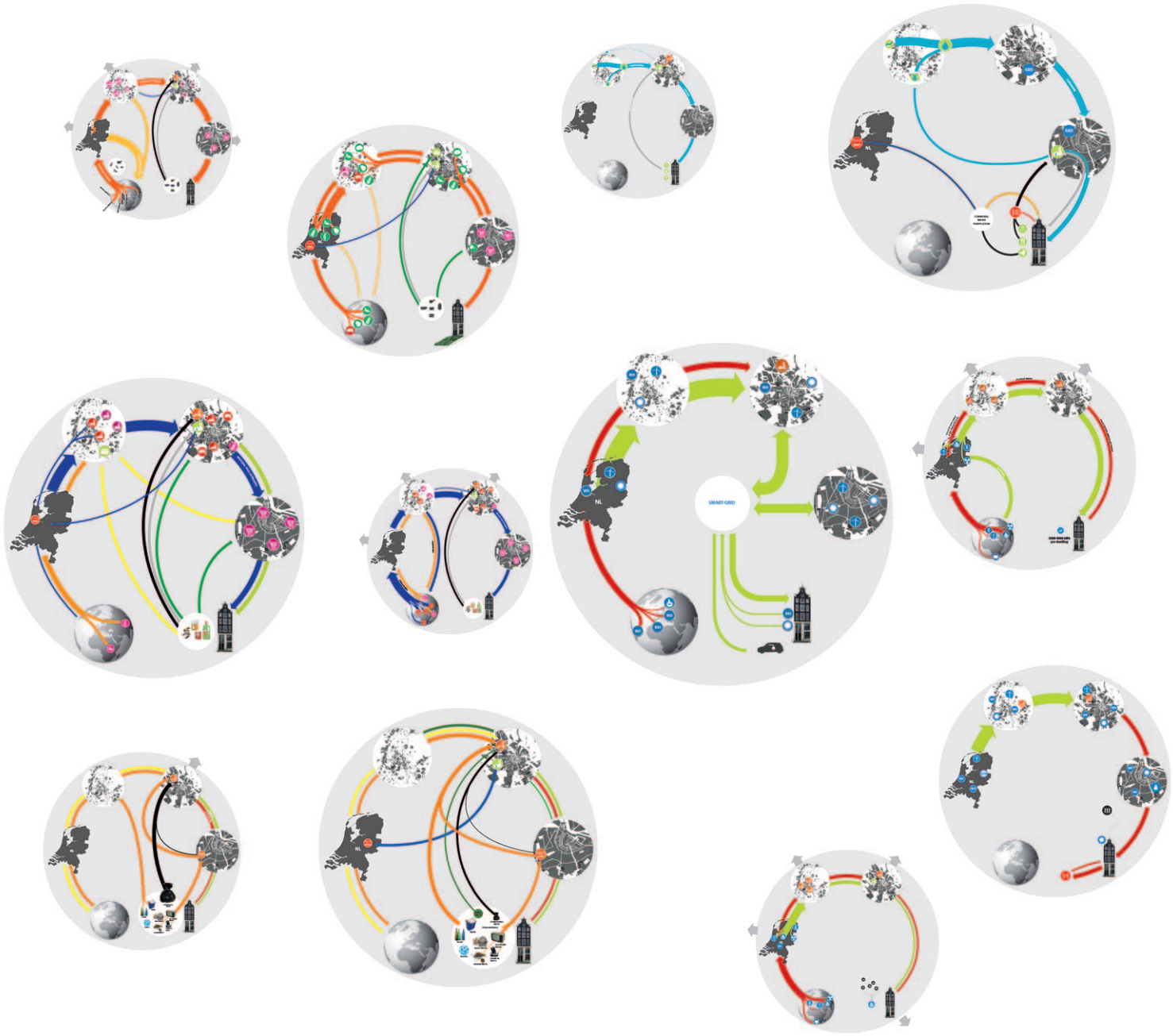


Towards the Amsterdam Circular Economy

Foreword

The booklet laid in front of you portrays the current and desirable future cycles for food, phosphate, waste, water, electricity and heat. It is the outcome of a collaborative project between the former City of Amsterdam's Environmental and Building Department (Dienst Milieu en Bouwtoezicht, or DMB), the Department of Physical Planning (Dienst Ruimtelijke Ordening, or DRO), Waternet and the Waste and Energy Company (Afval Energie Bedrijf, or AEB).

Effective use of raw materials is one of the spearheads in the city's first sustainability programme, 'Amsterdam Definitely Sustainable, 2011 – 2014' (Amsterdam Beslist Duurzaam 2011 – 2014), and this involves thinking in terms of cycles. Effective cycles contribute to an efficient use of materials and resources and thus to the reduction of our ecological footprint, the WWF writes in its Living Planet Report 2012. Which cycles do we find in the city? What do they look like now, but first and foremost how do we want them to look in the near future? Who do they affect and involve? What developments are we witnessing and how can we exploit them to make our city more sustainable, smarter and more liveable? To what extent can we take advantage of these cycles in district development, the use of urban space, and attracting new businesses? And are they able to motivate and influence city-dwellers and their behaviour?

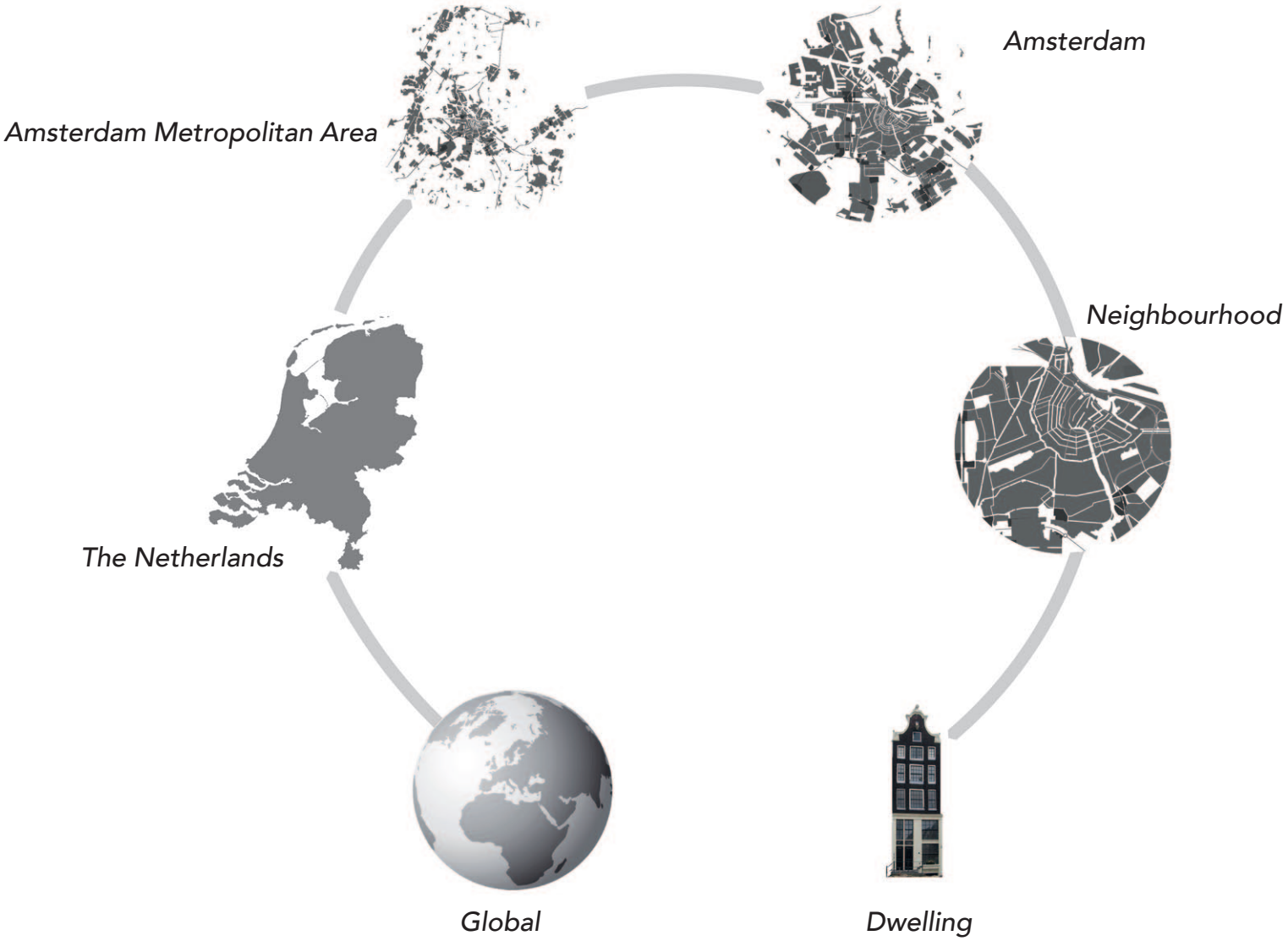
So why choose these cycles? The initiative was born in November 2010 from the Workforce Sustainability (Kerngroep Duurzamheid), an initiative of municipal departments within and outside the spatial sector to exchange information and share expertise. Moreover, it is an important theme within Amsterdam's sustainability policy. This working party ascertained a need to investigate how the various cycles are currently functioning in greater depth and to look beyond the Cradle-to-Cradle concept.

In the subsequent workshop everyone presented his or her own subject in a cycle that was best suited to the theme. There were of course many differences, but during discussions and looking from a broader perspective it nevertheless came to light that there are more similarities than was previously assumed. In addition, various cycles intersected or were interlinked. And in almost all the cycles there is evidence of a shifting of actors, of scales, and in certain areas of rapidly evolving insights and processes.

An important question in this context was the space requirements that these cycles would require in the future and to what extent this would serve as an invitation to adopt a more integrated approach. The results demonstrate the added value of sharing knowledge.

It was possible to depict the cycles for various resources and materials in an easily comparable manner, and thus establish a link with the most relevant scales . The cycles have therefore been depicted on a global scale, on the scale of the Netherlands, the Amsterdam Metropolitan Area, the city of Amsterdam, district and neighbourhood, all the way down to the scale of the residential block or individual dwelling. The current situation and the most desirable future scenario are presented for all the cycles. The texts explore in greater detail those steps that could or must be taken in the near future in order to achieve this.

The result speaks for itself. It is certainly not exhaustive, but as a cohesive whole it is intended to be informative and illustrative, to serve as inspiration and an invitation to continue thinking outside the box and beyond well-beaten paths. The illustrated and elucidated cycles do not offer ready-made solutions, but outlines developmental thrusts and a perspective, for which the initial steps have often already been undertaken, though they must above all be explored and elaborated further. We hope that this booklet inspires novel insights and contributes to new forms of cooperation.



Basis for the shared background of the various cycles. The key question for all the cycles was concerned with the path taken by the most important flows of resources and materials and the scale at which these have the greatest impact.

Content:

Food cycle
Present situation

Our food is produced in our own country, but also elsewhere around the world. It is imported and exported via multimodal 'mainports'. Processors and suppliers, primarily located in the Zaan Region and the Port of Amsterdam, as well as distribution centres are closely involved with this.

Storage and transhipment for city markets takes place in the urban regions and foodstuffs eventually reach the consumer via retailers and the food industry.

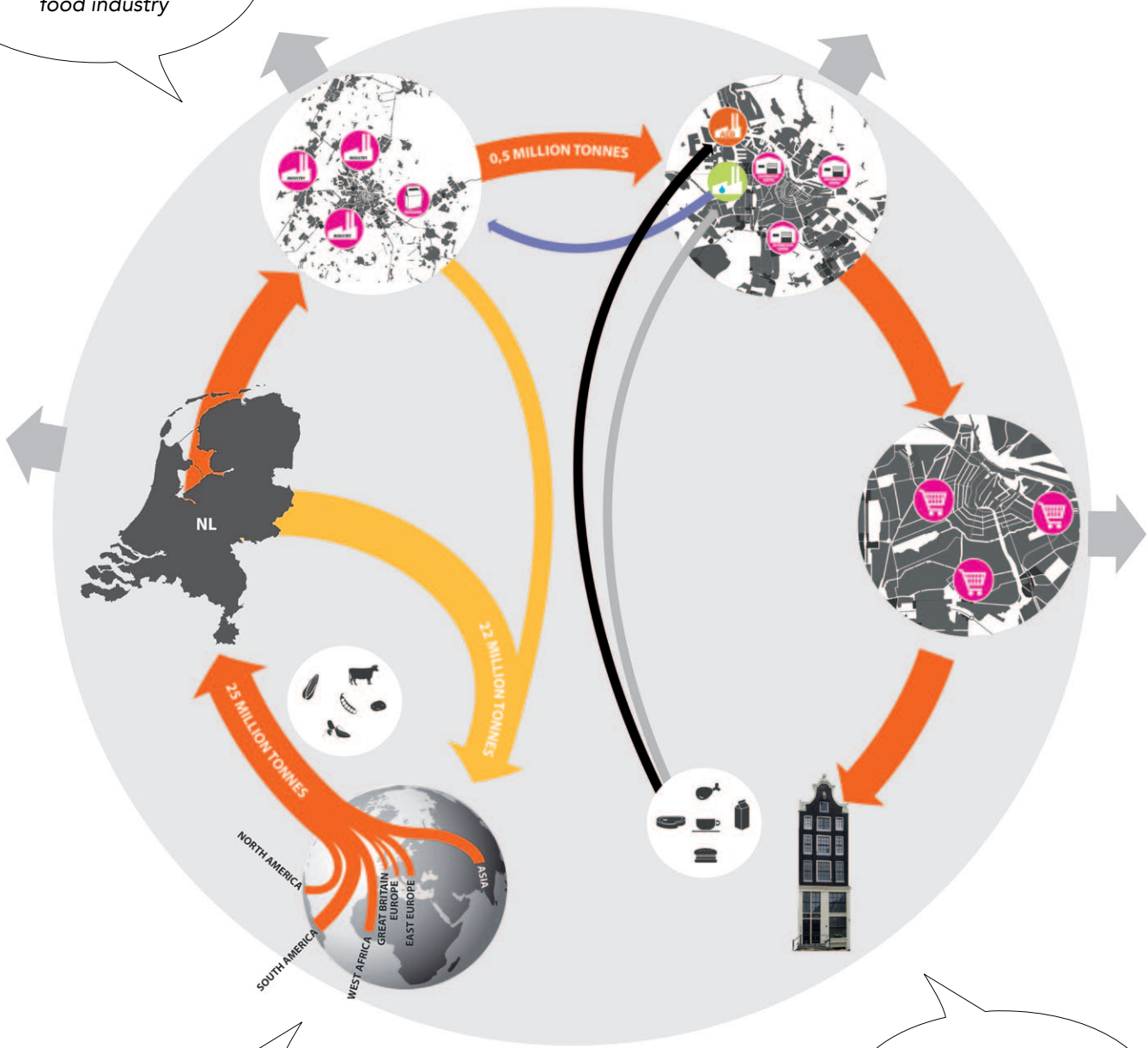
In Amsterdam, what remains after consumption – food waste – is hardly ever collected separately. It is processed by the Waste and Energy Company (Afval Energie Bedrijf, or AEB) along with other waste or it disappears into the sewers; just a small portion is composted. The food waste does not end up returning to the farmer, so the cycle is incomplete and the loop is still open.

Characteristics are

- Plenty of imports and exports, which requires transportation. An average meal of meat, potatoes and vegetables travels about 30,000 km before it arrives on our plates and the energy costs for a strawberry that is imported by air are 24 times higher than for a locally grown strawberry bought in June;
- A mere 20% of the retail price of food is determined by the primary, often large-scale producer; the remaining 80% is decided further along the chain (processing, storage, distribution, sales/marketing);
- The food industry and retail sector are dominated by a few major players;
- Almost 40% of CO_2 emissions are related to food. Meat and dairy are responsible for 18% of the global climate change caused by humankind (FAO, 2006);
- Packaging is responsible for about 80% of all CO_2 emissions in the food industry;
- There is plenty of wastage in the chain, especially because of packaging and the throwaway culture. Of the 600 kg of food that a Dutch person purchases each year (excluding 160 kg in packaging), about 8% is thrown away unused (12% if you include non-consumable mass). According to environmental agency Milieu Centraal, food wastage is responsible for more than 2% of the total greenhouse gas emissions of an average consumer;
- In Amsterdam most of the food waste is incinerated, which produces green energy. The food that is consumed disappears into the sewer and is carried off to the sewage treatment plant (RioolWaterZuiveringsInstallatie, or RWZI).

Food packaging is responsible for about 80% of all CO_2 emissions in the food industry

Most food waste is incinerated



Plenty of transportion as a result of the large amount of imports and exports

An average evening meal has travelled 30,000 km

Legend

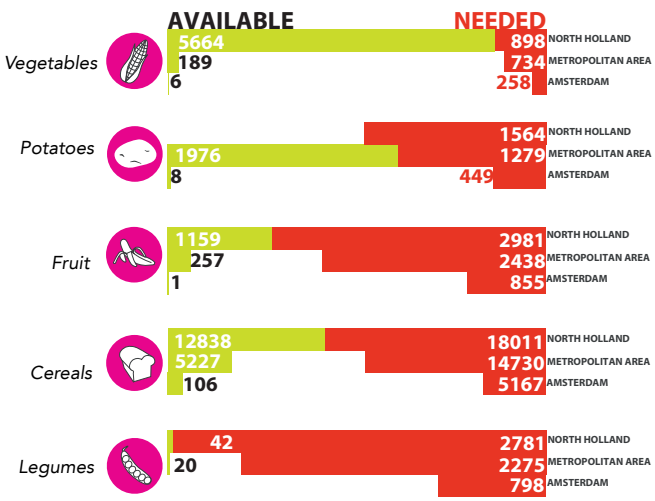
- Shops
- Industry
- Packaging
- Distribution centre
- Sewage treatment plant
- Energy Company (AEB)
- Food imports
- Food exports
- Cycle leak
- Waste
- Sewage
- Struvite

Foodproduction is currently large-scale, global and dependent on plenty of imports. The processing and retail trade in the Netherlands are dominated by a few major players.

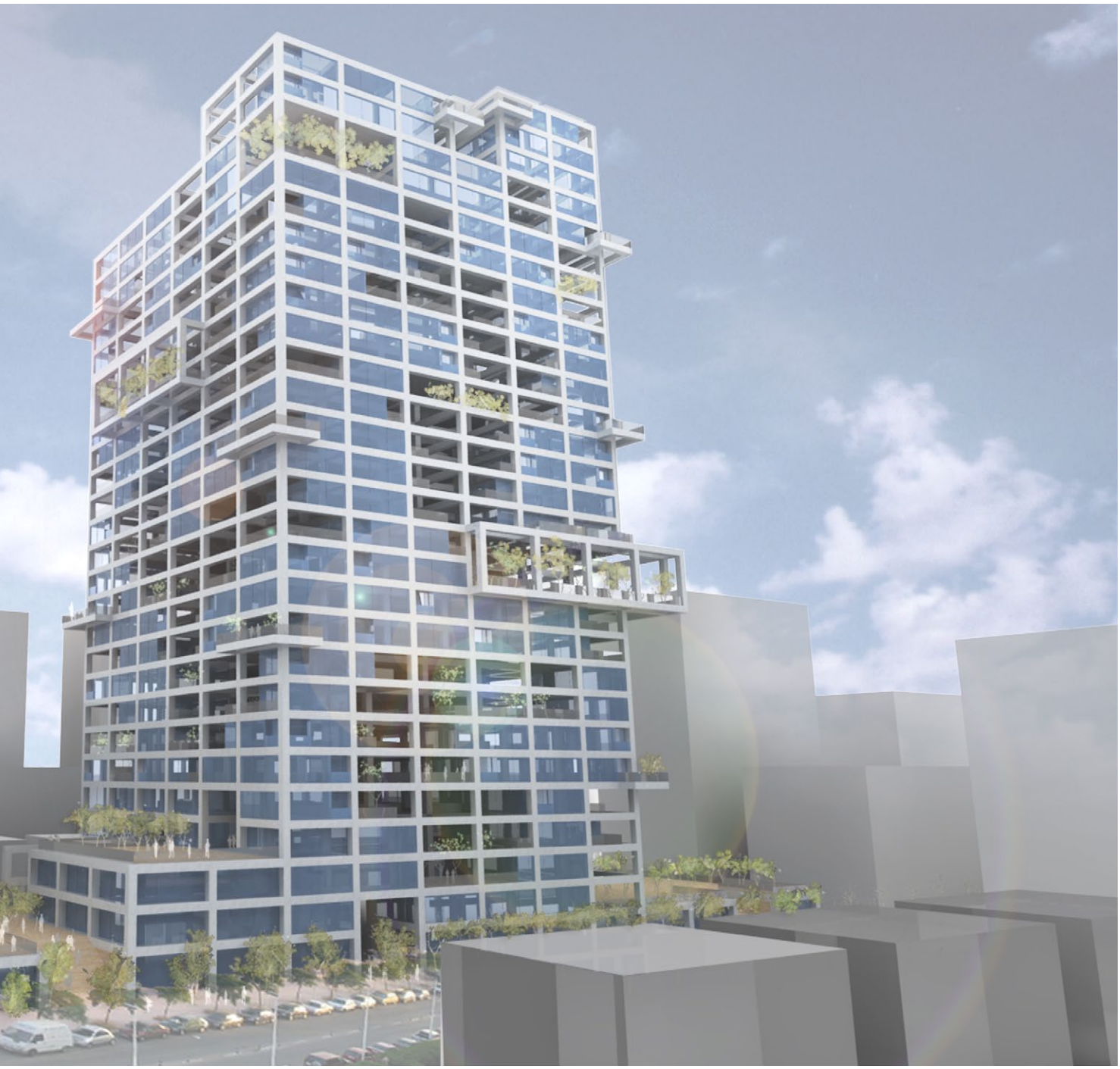
Some 75% of the total food-related energy use is indirect energy use, i.e. 19.7 GJ per person per annum. The estimated CO_2 emissions amount to 3,035 kg per person per annum (2000). This is about a third of the total greenhouse gas emissions of households.

Indirect energy use and GHG emissions from households (report number 1101a), BuildDesk, Delft 2011

AGRICULTURAL LAND (IN HECTARES)



Source: Department of Physical Planning, City of Amsterdam



Vertical urban horticulture. Source: NwA architecten

The challenge lies in the regional production of sufficient

food where the available land is scarce.

Food cycle
Future perspective

Dutch imports of food have been drastically reduced and exports have been minimised. Locally, i.e. in the Netherlands and specifically in the Amsterdam Metropolitan Area, the agricultural sector is focusing on sustainable and seasonal food production. Arable farmers are using crop rotation and employing fewer chemical herbicides and pesticides. The regional seasonal production requires less fossil fuel for the production of food, fewer food miles for transportation and less packaging, refrigeration and storage.

An efficient and environmentally friendly food distribution system transports the food into the city. Consumers produce their own food on a modest scale, throw away less (food) waste and consume less meat. Food waste is composted and the nutrients are reused in local agriculture and horticulture.

At the sewage treatment plant, and in the longer term possibly also at a decentralised sanitation system, phosphate is recovered on a large scale and sewage sludge is rendered suitable for use as manure, thus closing the loop of the food cycle.

Intermediate steps

The initial steps to encourage more local production and make Amsterdam's residents aware of the environmental impact of their consumer behaviour were taken with the 'Amsterdam the Experimental Garden' (Proeftuin Amsterdam') activities programme that ran from 2007 to 2010. This programme combined, interconnected and strengthened the initiatives of enterprises, organisations and other parties from the region that are active in the domain of sustainable and healthy food across the region. This prompted many parties to take action: for example, Rabobank has drawn up Food & Agribusiness Principles, and experiments with the production of local food are being conducted at several locations in the city.

In its purchasing policy the City Council takes sustainable production, transportation and waste into account. Organising an event such as the Floriade 2022 world horticultural expo, which will be focusing on the themes of city agriculture and sustainability, could give urban farming a substantial boost.

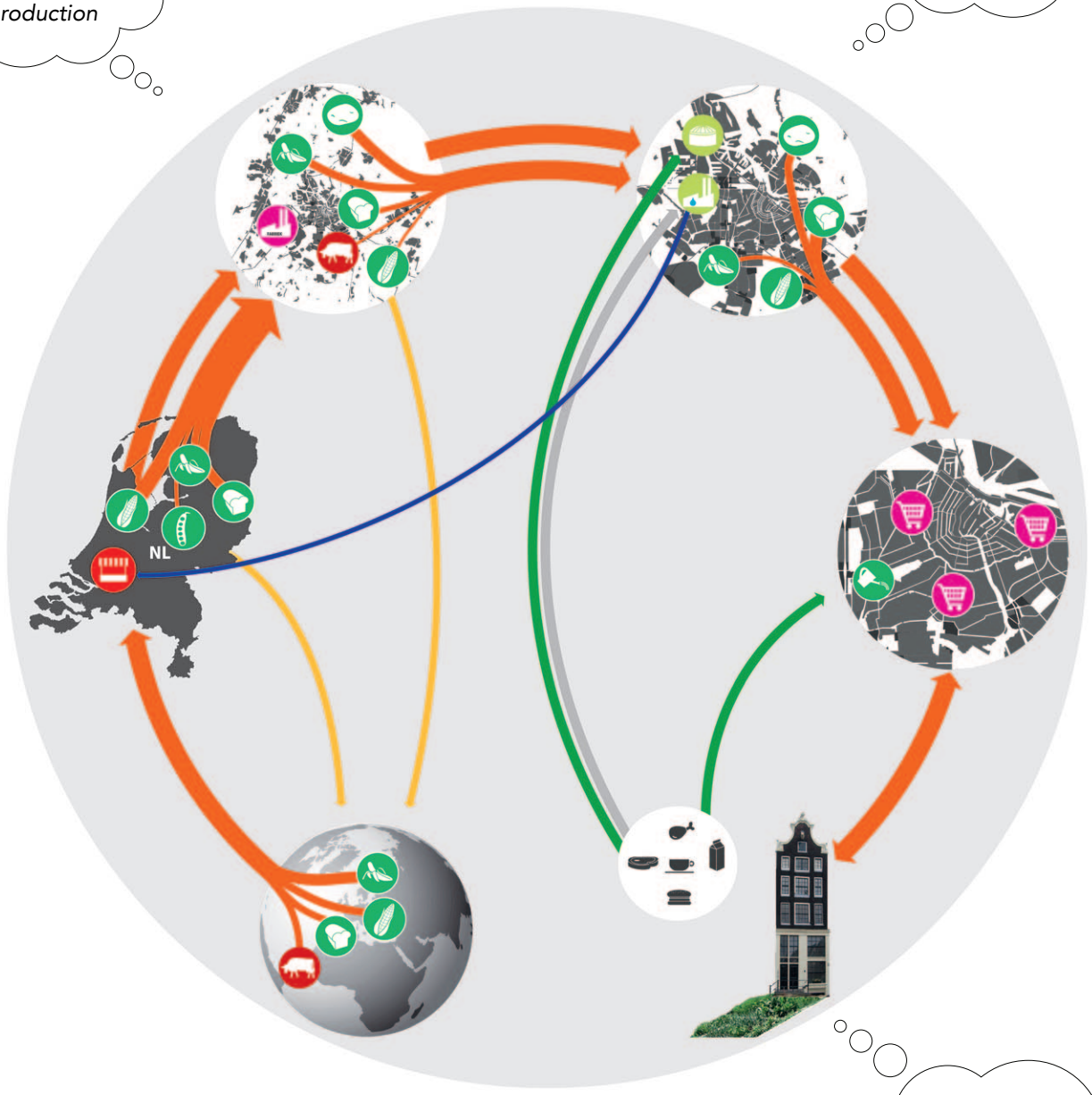
The challenge lies in the regional production of sufficient food where the available land is scarce:

- Where can we find sufficient space and/or land to provide for Amsterdam's food needs?
- Which locations could be used, such as the city's wedges of greenery, allotments, rooftop gardens and office buildings?
- What does regional food production mean for the ties between city and countryside?
- Who do we need for the realisation of food production that is more regional?

Pim Vermeulen, Department of Physical Planning (DRO)

Regional, seasonal production

Nutrients are recovered, waste recycled



Amsterdam's residents produce food at home and in the surrounding area

Legend

- Potatoes
- Maize
- Fruit
- Vegetables
- Cereals
- Gardens
- Sewage treatment plant
- Fermentation facility
- Industry
- Supermarket
- Phosphate market NL
- Meat
- Food imports
- Food exports
- Sewage
- Compost
- Phosphate

In the desirable scenario the food production is local, sustainable and seasonal, and waste is used more effectively.

Phosphate cycle
Present situation

The Netherlands imports phosphate (P_2O_5) in the form of mined phosphate ore, primarily from China, Israel, the Western Sahara and South Africa. Plenty of phosphate enters the country by way of imports of biomass (animal feed and food for human consumption) as well. Fertilizer manufacturers incorporate the phosphate ore into chemical manure and distribute it within the agricultural sector. Phosphate in organically fixed form is also supplied to the food-processing and agricultural industries. Via the retail trade it reaches consumers as food or another product.

In the agricultural industry phosphate exits the cycle because it accumulates in agricultural soil and is no longer available in the short term. Much of the phosphate in industrial and consumer waste is lost via the sewers and by incineration. The cycle is incomplete and the loop is still open.

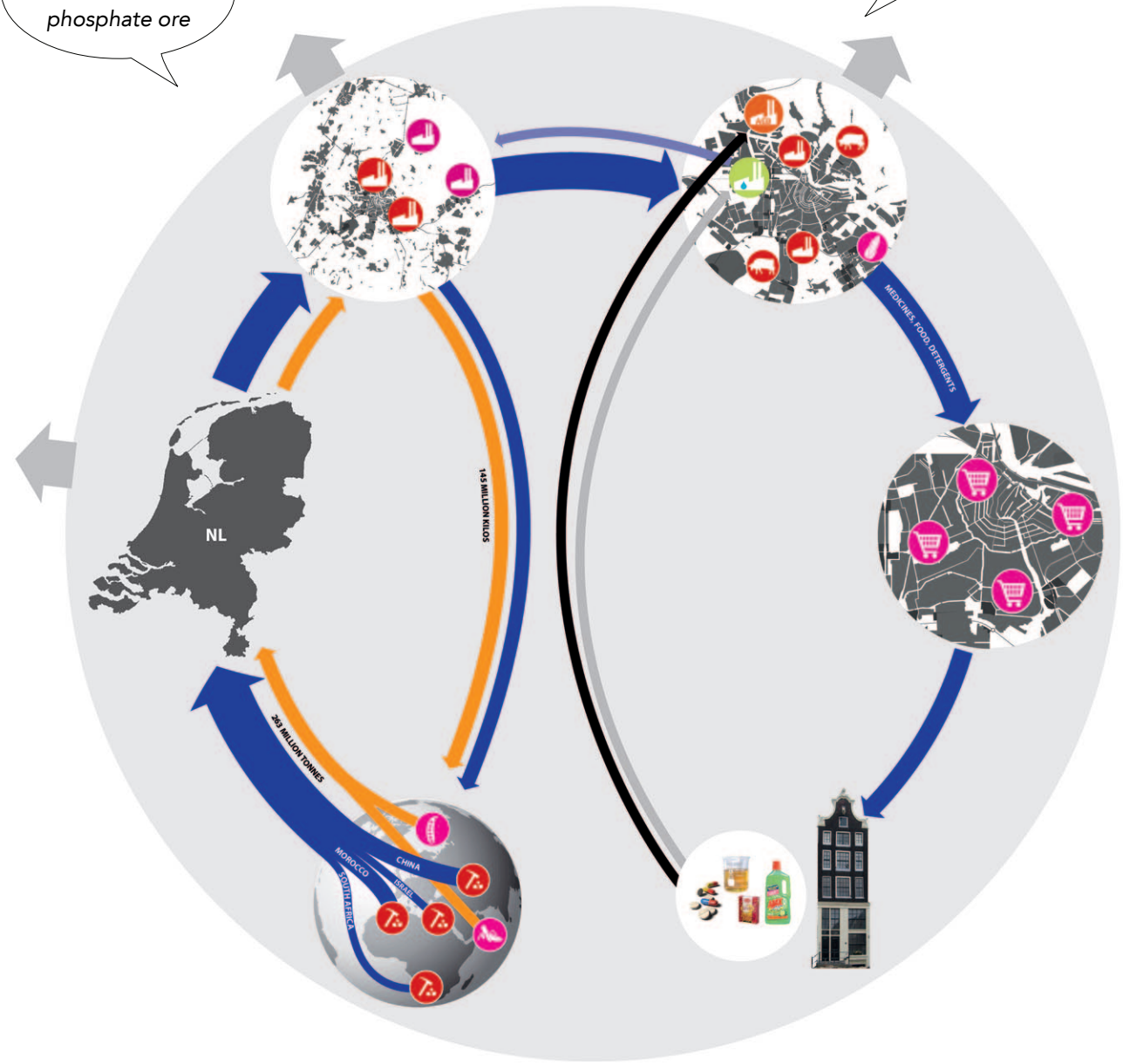
Characteristics

- The predictions about the period in which phosphate supplies will be exhausted range from 70 to 300 years. Phosphate is becoming scarcer, increasingly difficult to recover/mine and thus more expensive, while the quality is degenerating. In addition, Europe is dependent on the few countries that have large stocks at their disposal, which can also be a geopolitical risk;
- There is an imbalance in imports and exports of phosphate, resulting in a surplus situation in the Netherlands that places a burden on the environment. Elsewhere we are seeing shortages arise, which could result in scarcity of food. Between 2005 and 2008 the surplus shrank by 15%;
- Just 80% of the world's mined phosphate ends up on the plates of consumers as food. The remaining 20% is either lost or accumulates in agricultural land. Primarily because of soil erosion, plenty of phosphate ends up on the ocean floor (sedimentation). This phosphate cannot be recovered and must be regarded as lost, at least in the short term. The accumulation in farmland fell by 35% between 2005 and 2008;
- The washing away of an excess of fertilizers causes eutrophication, which can lead to a marked proliferation of certain types of algae, which often significantly reduces biodiversity. This leakage is being stemmed by increasingly stringent legislation;
- In Amsterdam domestic waste, biodegradable waste and sludge waste are incinerated, causing the wastage of lots of phosphate (i.e. rendering it 'ineffective'). For example, the bottom ash is used by the asphalt industry, so the phosphate it contains is no longer available. Consumed food disappears into the sewers and conveyed to the sewage treatment plant, where a portion of the phosphate is recovered in the form of struvite and reused in the chemical fertilizer industry. From 2005 to 2008 the quantity of phosphate that was rendered ineffective increased by 19%.

Water companies (Waternet), sludge processors and waste processors (e.g. the Amsterdam Waste and Energy Company or AEB) are deploying innovative technologies for the recovery of phosphate from waste with varying degrees of success.

There is lots of wastage due to the incineration of sludge from sewage treatment plants and the accumulation of phosphate in agricultural soil. Phosphate also escapes into the environment. Total wastage amounts to 118 million kg/year

Production based on phosphate ore



Phosphate is import-dependent, the mine reserves are finite

Legend

- Sewage treatment plant
- Food industry
- Farming
- Phosphate mines
- Power station/AEB
- Shops
- Fertilizer industry
- Animal feed
- Food
- Arable farming and horticulture
- Phosphate leak
- Food/biomass
- Phosphate
- Waste
- Sewers
- Struvite

In the current cycle the phosphate imports exceed exports. The result is a surplus situation that places a burden on the Dutch environment.

Phosphate is a nutrient extracted by mining: phosphate stocks are finite and there is no alternative source.

Phosphate mining in Togo

Phosphate production in the Netherlands. Source: ICL Fertilizers Europe C.V

Phosphate, which contains the phosphorus (P), is essential for all life on earth. It is needed by plants, animals and humans in order to grow, which means that phosphate is of direct importance for the food supply.

Phosphate cycle
Future perspective

The Netherlands no longer imports phosphate ore, though phosphate is still being imported in biomass. Where possible this phosphate is recovered by the food-processing industry before it is forwarded to the agricultural industry or retailers, to supply it as a secondary material to the phosphate market, where it is traded as a commodity. Fertilizer producers incorporate this secondary (i.e. recovered) phosphate into chemical manure.

The agricultural sector is increasingly efficient in its use of artificial fertilizer and animal manure, which is in part being collected and reused as a raw material for the production of secondary phosphate. Organic industrial and consumer waste is fermented or composted, producing biogas and a fertile soil improver, respectively. Sewage water and sludge are stripped of phosphate at the sewage treatment plant and/or local alternative facilities.The Waste and Energy Company recovers phosphate from residual waste and bottom ash.The phosphate cycle is closed, which has improved the quality of the water and increased biodiversity, ensuring high-quality food production.

Intermediate steps

An initial step towards a closed phosphate cycle was taken with the signing of the Green Deal Phosphate Recycling Chain Agreement (Green Deal Ketenakkoord Fosfaatkringloop) on 4 October 2011, by which no fewer than 20 parties expressed the ambition bring as much residual phosphate as possible (from sewage water, sludge and manure) back into the cycle in an environmentally responsible manner within two years and to export it, thus creating a new and sustainable market for secondary phosphates. The Phosphate Recycling Chain Agreement aims to turn an environmental problem into an economic opportunity. The participants include national government, the City of Amsterdam, the Association of Regional Water Authorities, Wageningen University and inorganic fertilizer manufacturer ICL Fertilizers, which is tapping into alternative local sources of phosphate in the Westpoort industrial zone in the Port of Amsterdam. The expectation is that agreements with several parties in the chain will generate knowledge and stimulate innovation. It is also important that the government is party to the Chain Agreement, so that it can critically examine legislation with the aim of fostering the use of secondary materials without compromising the requirements for a clean environment.

Waste is a base material in the Port of Amsterdam

Amsterdam is keen to contribute to the production of secondary phosphate and the creation of a phosphate market, in conjunction with the Port of Amsterdam, AEB, Waternet and companies such as ICL Fertilizers and Cargill. The municipal contribution is primarily as a facilitator, the provider of a framework and propagator.

The initial steps in achieving the shift from wasting to recycling phosphate or to a fully-fledged phosphate market have been taken. The crucial follow-up question is:

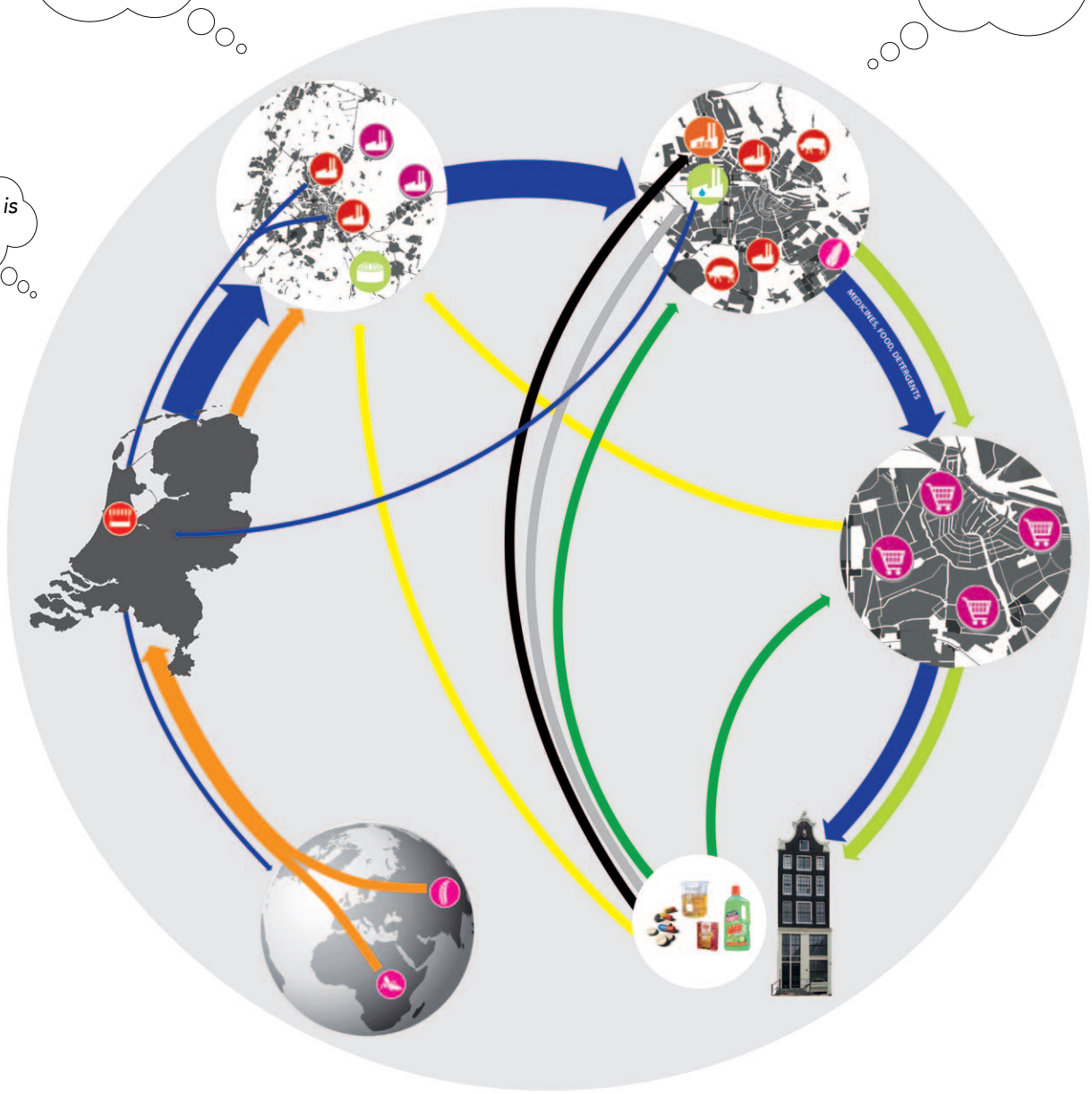
- Which of the technological innovations that contribute to the recovery of phosphates already exist or can be encouraged by us? For example, when it comes to the collection of manure from across the region or the possibilities of (local) sanitation systems?

Edgar Zonneveldt, Physical Planning Department (DRO)

Production based on the reuse of phosphate

Phosphate is recovered

Phosphate is trade



Phosphate imports (biomass) and exports are in balance

Legend

- Sewage treatment plant
- Food industry
- Farming
- Phosphate market in the Netherlands
- Power station/AEB
- Shops
- Fertilizer industry
- Animal feed
- Food
- Arable farming and horticulture
- Food imports
- Phosphate
- Waste
- Sewers
- Fermentation
- Compost
- Biogas
- Fermentation facility

In the desirable future the imports and exports of phosphate are in balance. The Netherlands imports phosphate via biomass and produces and exports secondary phosphate.

Waste cycle
Present situation

Some 30 percent of all Amsterdam's waste is collected separately, via shops (electrical equipment, batteries, light bulbs, etc.), the paper, glass and plastics container, in some city boroughs via the biodegradable waste container, and via six 'Wastepoints' (Afvalpunten) across the city for the disposal of bulk waste. The Wastepoints of the City of Amsterdam's Waste and Energy Company (Afval Energie Bedrijf, or AEB) are intended for waste that it is illegal to place in a bin bag or is oversized, including construction and demolition waste, broken furniture and chemical waste such as batteries and paint. This waste undergoes the processing method that results in the highest possible recycling yield. The Wastepoints therefore serve as an important link between the citizen and the recycling industry.

As suppliers of waste, citizens play a decisive role in its separated collection; private companies do that by recycling. The remaining 70 percent of the city's waste ends up at the AEB's waste-to-energy plants as residual waste (i.e. non-recyclable) via black bin bags. There it is incinerated and used for power and heat generation (electricity and district heating). Metals such as iron, copper and aluminium are recovered from the incombustible materials that are left behind, the 'bottom ash' or slag.

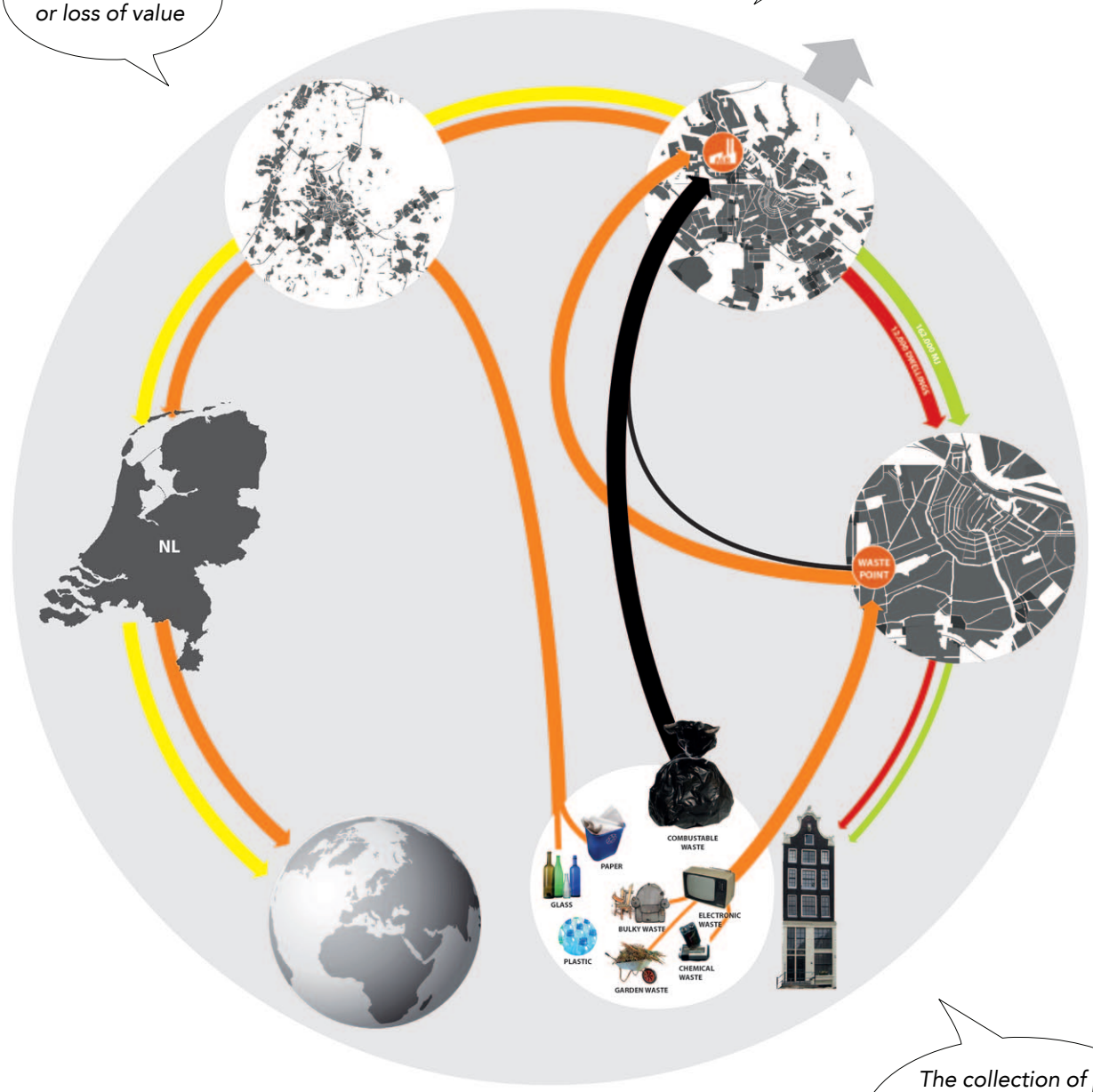
Characteristics:

- The waste that is collected separately is reused in its current form or recycled into another valuable or useful material. Re-cycling is often a case of down-cycling: the new products have a lower value than the original raw material; up-cycling, which results in the recycled material having a higher purity than that of the original, is still a rarity;
- Non-recyclable waste with a low value is incinerated and thus partially converted into energy that supplies a large number of Amsterdam's homes and businesses with electricity and heat;
- High-quality materials are recovered from the 'bottom ash' or slag that remains after incineration. These are chiefly ferrous (iron and iron-based alloys) and non-ferrous metals. The remaining low-value bottom ash is used as filling material in road-building, e.g. as a replacement for sand dredged from the ocean floor;
- Great technical efforts are undertaken to neutralise toxic substances and gases that are released during incineration, and where possible these are recycled as a raw material (e.g. gypsum and fly ash that is added to asphalt as a filling material).

The inhabitants of Amsterdam and the AEB are the most important links in this chain, alongside the consumers of raw materials and the recycling industry.

Incineration is key: materials are lost, electricity and heat are generated

Recycling is re-use or loss of value



The collection of pre-sorted waste requires consumers to take an active role

Legend

- AEB
- Waste collection points
- District heating network
- Ferrous / non-ferrous
- Waste
- Materials recycling
- Local energy
- Break in chain

In the current cycle the processing of waste is associated with value loss. Many raw materials are wasted.

City of Amsterdam Waste and Energy Plant

Non-recyclable waste with a low value is incinerated, partially transforming it into energy that provides a great many Amsterdam homes and businesses with electricity and heat.

Waste cycle

Future perspective

Waste is a raw material and energy. A life-cycle analysis for each product or waste flow is used to generate the maximum environmental efficiency and economic value. Innovative collection and sorting methods separate value materials from the non-recyclable waste and these are upcycled and recycled by businesses across the region. Cradle2Cradle (C2C) has really taken off, minimising the quantity of non-recyclable waste.

The separation of biodegradable waste has become the norm and phosphate is being recovered. The biodegradable waste is then used as a raw material for the production of biogas, which fuels the municipal rubbish trucks. Organic waste from the region's horticulture is also processed in this way. This involves an innovative synergy with Waternet's sewage treatment plant. In the case of downcycling a limited amount of material ultimately ends up in the residual waste phase, whereupon the energy value is recovered (electricity, heat and steam). Plenty of high-grade material can be recovered by improving the post-separation process after the incineration of waste. The remaining low-grade material is upcycled into building materials (including sand and granulates).

Amsterdam's inhabitants cooperate fully in the collection of pre-sorted waste. This is facilitated by the deployment of new collection methods and citizens are rewarded for their efforts (e.g. by lower municipal taxes or directly, on handing in their refuse).

Intermediate steps

Various forms of pre-sorted waste collection have now become the norm, such as the separate collection of paper and glass. The initial pilots for the separate collection of plastic are currently underway. In the field of recovering energy, since 2007 Amsterdam has boasted the most efficient power plant in the world.

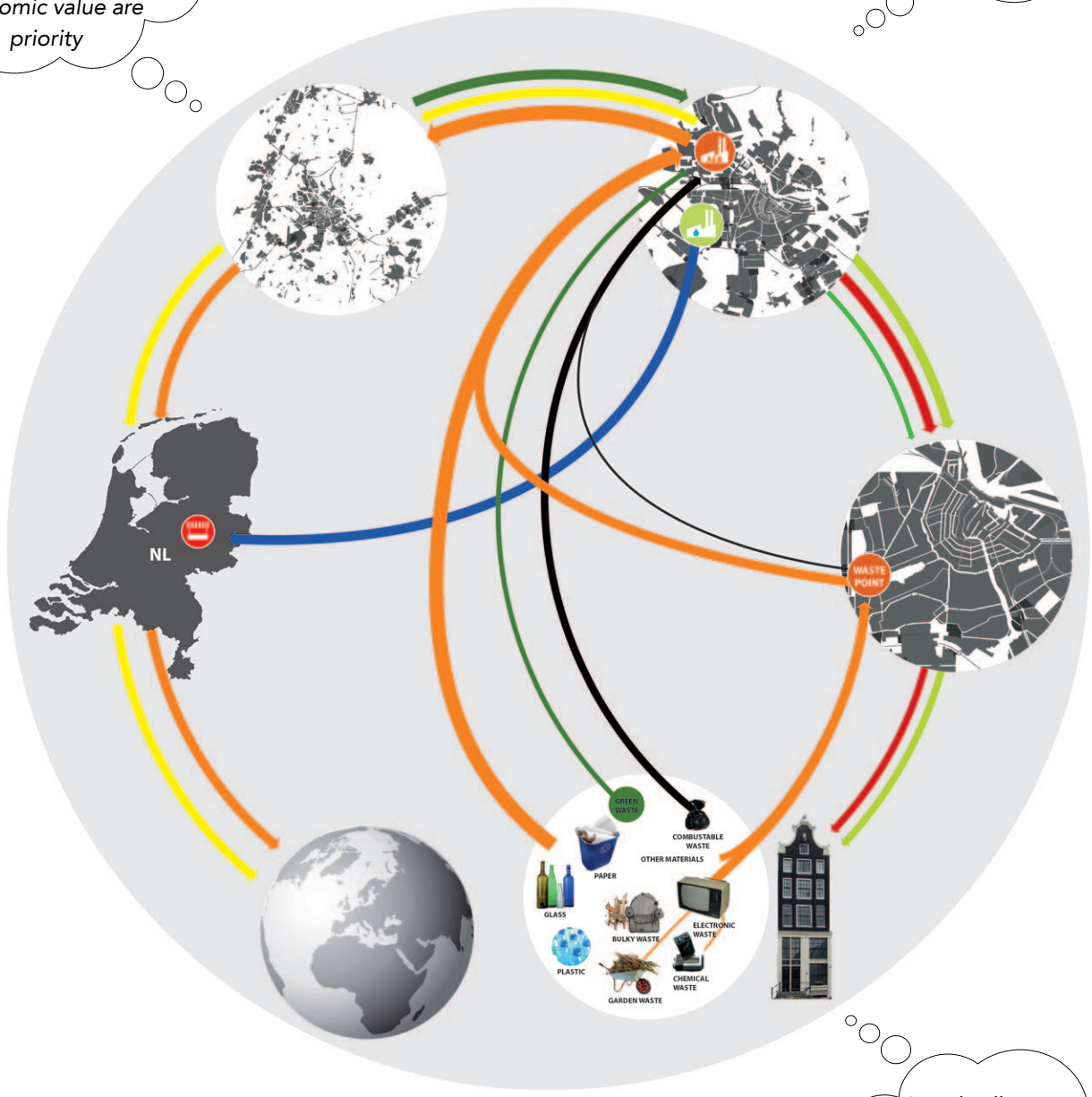
There are challenges and opportunities aplenty with regard to the sustainable processing of waste and the reduction of the stream of non-recyclable waste, which is an important mainstay of the city's sustainability index:

- How can the separation of waste by inhabitants be facilitated? The separate collection of biodegradable waste in the densely-built environment deserves particular attention in this regard. Besides contributing to the closure of the waste cycle, it also helps to close the phosphate cycle. In addition, biodegradable waste (and other biomass) can serve as a raw material for biogas, biofuel and/or bioplastics and thus contribute to the bio-based economy;
- Which technological innovations can contribute to the maximisation of environmental efficiency and economic value from (organic) waste?
- Can the packaging industry contribute to the better separation of materials? E.g. by using simple, uniform codes that translate into smart collection systems?
- How can the prevention of waste contribute to the closing of the waste cycle? E.g. by making products available 'on loan' and by propagating C2C thinking? And how can the private sector be challenged and stimulated to do this?

Sietse A. Agema, City of Amsterdam Waste and Energy Company (AEB)

Maximum environmental efficiency and economic value are priority

Production of raw materials is key issue



City-dwellers are assisted in pre-sorting their waste

Legend

- AEB
- Wastepoints
- Phosphate market (in NL)
- Biodegradable and organic waste
- Waste
- Materials recycling
- Local energy
- Phosphate
- District heating network
- Ferrous / non-ferrous
- Biogas (for AEB transportation)

In the desirable scenario the waste processing equates to the production of materials, with optimal environmental efficiency and economic value as the priority.

Water Cycle
Present situation

Amsterdam's drinking water has a natural source: river water and rainwater that is collected in the substratum of the protected Water Board Dunes near Zandvoort on the North Sea coast and seepage water from the Bethune Polder in the Vecht lakeland area to the southeast of the city. The water undergoes various purification processes, the colour and taste is improved and it is decalcified. After purification and improvement the water is stored in drinking water reservoirs. Distribution pumps and a mains system that is about 2,000 km in length carries this water to the consumer.

Wastewater, both black (toilet) and grey (household, minimally dirty), is conveyed via sewer conduits to the central sewage treatment plant (RioolWaterZuiveringsInstallatie, or RWZI) in the city's Western Harbour District for basic cleansing. The decontaminated water is then drained off into the North Sea Canal, while the residual sludge and biogas is put to good use by Amsterdam's Waste and Energy Company (Afval Energie Bedrijf, or AEB).

Most of the rainwater that falls on rooftops, streets and other paved surfaces in the city is collected via a system of rainwater drains and conveyed to the closest body of surface water. By exception, in the city centre the rainwater is mixed with wastewater and conveyed to the RWZI.

Characteristics:

- An efficient mains system results in very limited loss through leakages;
- High-quality water is supplied at a low price;
- Sludge and biogas from the central RWZI are transformed into heat and electricity in association with the AEB. The sludge is incinerated along with other waste in the AEB's ovens. The biogas that is released during sludge fermentation at the RWZI is also conveyed to the AEB for the generation of electricity and heat. The AEB subsequently supplies electricity and some of the heat generated by incineration back to the RWZI;
- No thermal energy is recovered;
- Phosphate and nitrogen are recovered at the RWZI. Innovations are being introduced to recover more base materials.

High-quality water is supplied cheaply

Some 2 million tonnes of human waste is discharged into the water system every day

Thermal energy is not recovered

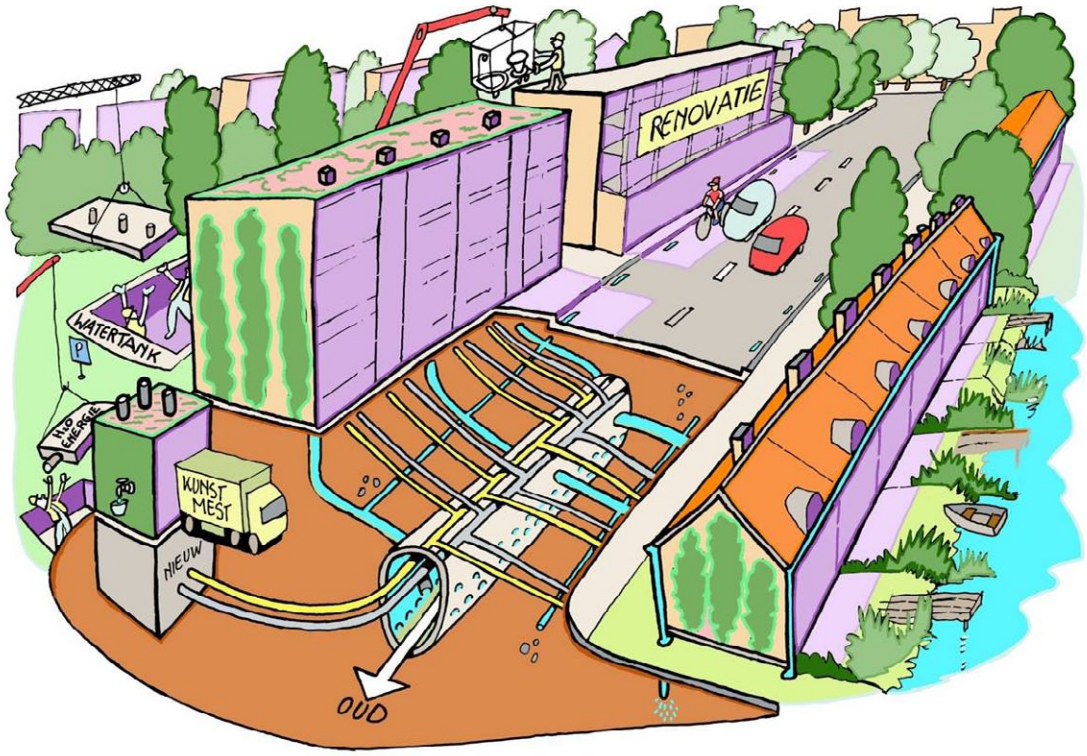
Legend

Water for:
- Toilet
- Sanitary
- Kitchen

- Waste and Energy Company (AEB)
- Groundwater
- River water
- Post-purification facility
- Sewage treatment plant

- Water
- Sewage
- Sludge
- Energy / heat
- Effluent into North Sea Canal

In the current cycle the water is collected, used, centrally purified and drained away. Raw materials and energy are lost.



Sewage pipes have become rainwater pipes

Renovated buildings in 2050

The sewage pipes have become rainwater pipes. New underground sewers have already been laid, with separate pipes for yellow (urine) and grey (bathroom and kitchen) water. Domestic wastewater is processed locally. Raw materials such as nitrogen, potassium and phosphate are recovered from the urine. Given that many neighbourhoods have no access to a local wastewater purification facility, the conventional sewage treatment plants for mixed wastewater are still in use. Modernisation means that the input/supply to the treatment plant is regulated much better than previously. Because the amount of mixed wastewater continues to decline, the expansion of conventional treatment plants is no longer necessary. There is more space for water in the streetscape, with larger gutters and a water reservoir that temporarily holds some of the rainwater. During extreme downpours the existing provisions for overflows come into operation. Because the pipes in the renovated districts contain only rainwater now, the overflows here no longer present a risk for the environment.

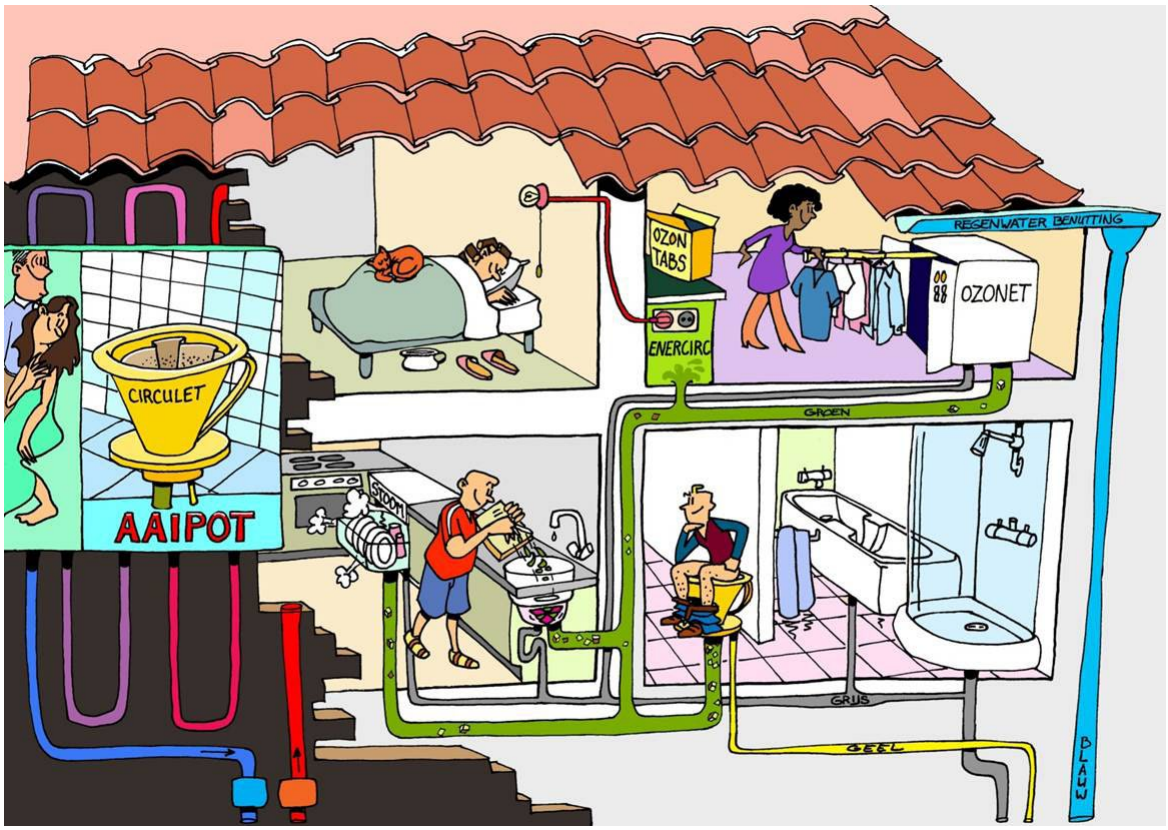
Flows of energy in the home in 2050

Water of drinking water quality flows from the tap, laundry is carried out using ozone and the dishwasher uses steam, thus reducing water consumption. Urine and faeces are separated in a no-mix toilet, the WC of the 21st century. Energy (green pipe) is produced from faeces and biodegradable waste. The urine (yellow pipe) is converted into fertilizer at a local facility, after traces of medicines have been removed. The bathroom and kitchen water (grey pipe) is also processed locally. There is underground geothermal storage.

Source: Verbindend Water – Lange termijn visie op de Waterketen. Een visie voor en door rijk, provincies, waterschappen, gemeenten en drinkwaterbedrijven (May 2009), a report about water as a connecting force and a long-term vision for the water cycle. Coordinated by the Core Team for the Water Cycle (Kernteam Waterketen). Illustrations: Carolien Feldbrugge and Peti Buchel, Beeldleveranciers.

Nowadays the laundry

is washed in ozone



Water cycle
Future perspective

Amsterdam's drinking water will be drawn from the same sources as in the current situation, and after purification it is supplied to the consumer.

In individual homes thermal energy will also be recovered from shower water and the thermal energy produced will be used by the consumer directly. Streams of grey and black water are separated at the source and treated in a local purification facility. Grey water is supplied back to the consumer after a simple purification and is used for flushing toilets (and perhaps in the long term, after a more elaborate cleansing, will be used for watering gardens as well). Black water is in large measure stripped of fertilizers such as phosphate and nitrate. The phosphate is processed into secondary phosphate and supplied to the phosphate market. The sludge is fermented and produces biogas, which is refined to serve as green gas for motor vehicles. Medicines are removed from the remnants. Base materials for bioplastics and the paper industry are produced as well.

Intermediate steps

A new long-term vision for the water cycle in the Netherlands was recently formulated. It envisages a future in which the users and the quality of their living environment are pivotal, rather than the system of mains and pipes. The way that might take shape in Amsterdam is outlined above.

In Amsterdam, with its efficient centralised sanitation system that deals with only small amounts of rainwater and the loss from leakages is very small, a complete transition to a decentralised system over the coming decades would not be cost-effective.

Small pilot projects are, however, set to be launched in the coming years, to gain experience and investigate whether the advantages of local systems also apply in our metropolitan context. At this point, alliance partners with whom the initial concrete steps can be undertaken are being sought.

There are several factors which mean that there is little urgency to close the water cycle: Water is available in abundance, there is an efficient system of water mains, water is cheap, and the requisite investments in a decentralised sanitation system are high. However, the closure of the water cycles rather seems to derive its urgency more from the contribution that it makes to the closure of other cycles: food, heat (geothermal), phosphate (and other materials) and waste.

Waternet is already cooperating intensively with the AEB to explore the opportunities to achieve synergies between water, energy and waste. The vision is to strive after closed water, energy and materials cycles at the metropolitan scale on the basis of the circular economy concept.

André Struker, Waternet

Decentralised purification of water, with base materials and heat being recovered and recycled

Legend

Water for:

- Toilet
- Sanitary
- Kitchen

- Groundwater
- River water
- Post-purification facility
- Sewage treatment plant

- Geothermal
- Phosphate market
- Heat recovery
- Water

- Wastewater
- Biogas
- Phosphate
- Grey water

In the desirable scenario the water is collected, used and purified locally, and base materials and thermal energy are recovered.

Electricity Cycle
Present situation

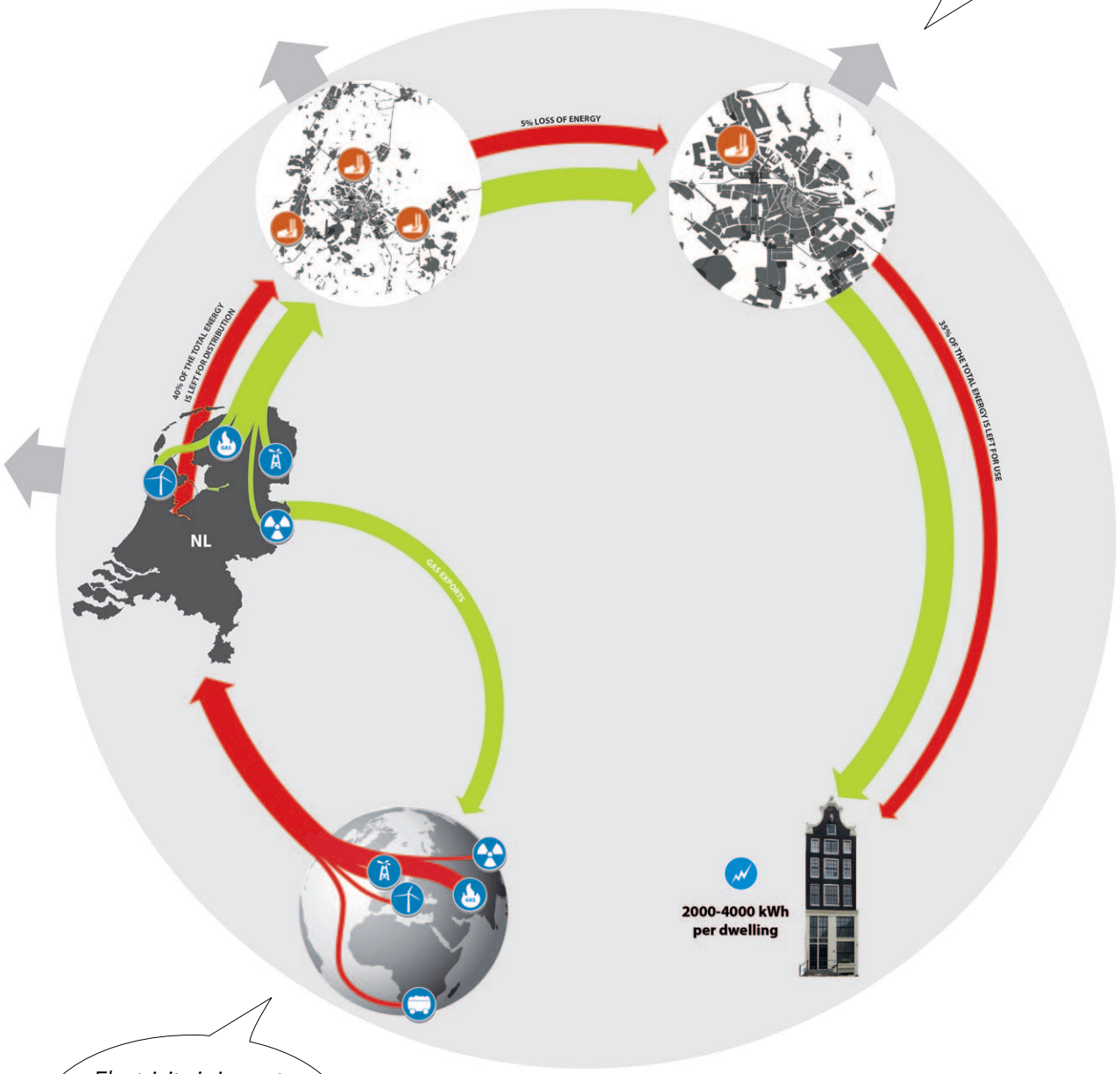
The current electricity supply is based on large, centralised fossil sources that produce power and heat. The fossil fuels are imported and/or mined and extracted in the Netherlands. Power stations in the region and the city itself produce electricity, releasing CO_2 and heat, which is not always used to the full. In Amsterdam a portion of the required electricity is supplied locally by means of waste incineration at the AEB.

Network operators are responsible for the conveyance of the electricity from power station to user. The path that energy travels from producer to consumer is a long one, and there is a small amount of energy loss in each phase. The cycle is incomplete and the loop is still open.

Characteristics:

- The most important criteria for the power supply are a reasonable price and reliability. These two criteria are efficiently organised by the current suppliers and the network operator;
- The power supply is dependent on fossil energy sources. The depletion of these sources and rising demand mean that these are becoming scarcer and therefore more expensive;
- For its electricity supply the Netherlands is dependent on imports of fossil fuels, which are produced by a limited number of major players and therefore represents a geopolitical risk;
- The use of fossil fuels in power stations results in the release of CO_2, which exacerbates the greenhouse gas effect;
- Electricity generation that fails to make use of residual heat is hardly efficient: there is considerable energy loss in the production process. There is also some loss that results from the distance over which electricity is conveyed.

Combustion of fossil fuels is the basis for the electricity supply



Electricity is import-dependent: the reserves and the number of producers are limited

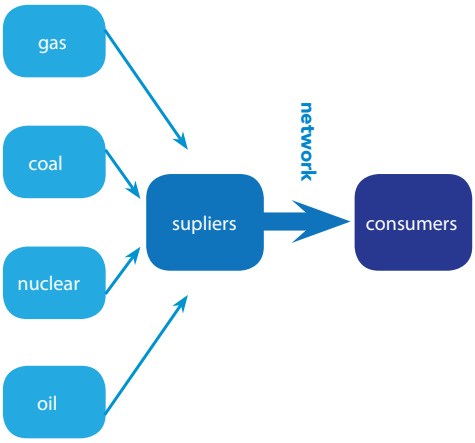
Considerable loss of energy during conveyance from producer to consumer

Legend

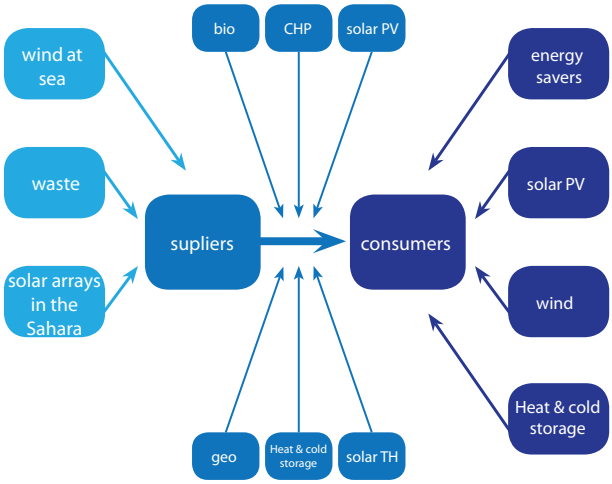
- Renewal energy
- Coal
- Oil / fossil fuels
- Gas
- Power station/AEB
- Energy consumption
- Nuclear energy
- Energy imports
- Local energy
- Greenhouse gas

In the current cycle the incineration of imported fossil fuels forms the basis for the electricity supply.

Amsterdam's energy requirements amount to 4,500 GWh/ year. Meeting this demand would require more than 200 wind turbines of 7.5 MW.



Centralised: Powerhouse



Decentralised: Smart Energy Cities

Electricity cycle
Future perspective

The Netherlands produces sustainable energy itself, supplemented by a limited amount of fossil fuel. There are many new sources in the Netherlands itself, such as wind, solar, biomass and possibly also tidal and algal energy, plugged in at various points in the network. The sources are diverse, from large to small and from predictable (fossil fuel/biomass) to less predictable sources (wind/solar).

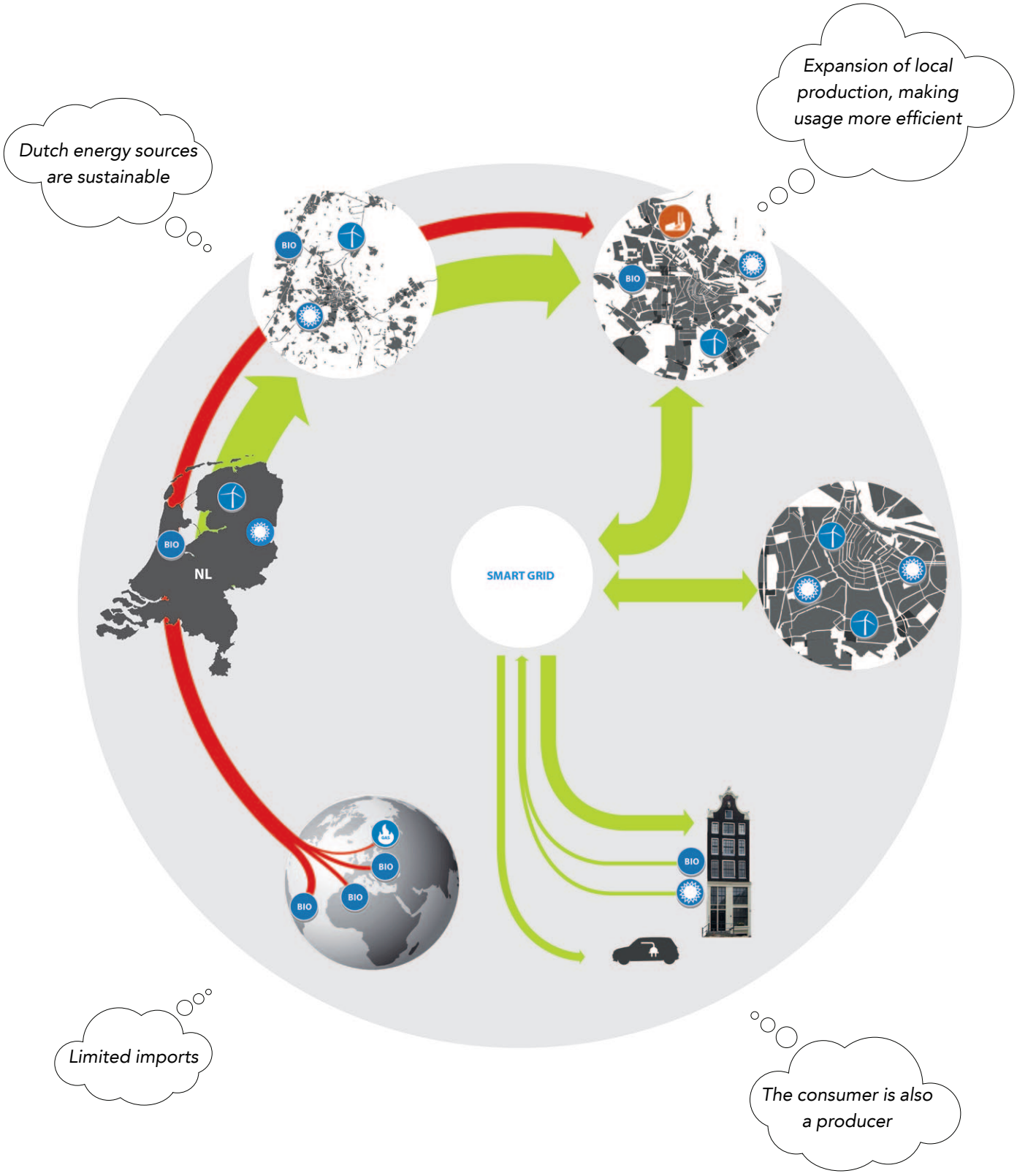
In addition, electricity from renewable sources is imported.The production of energy is partially decentralised: thanks to wind and sun the consumers are themselves producers. Demand for electricity has risen massively, because of electric vehicles, heat pumps and extra appliances, but with production being more local the consumption is much more efficient.The unpredictability of the electricity supply as a consequence of decentralised generation and sources such as wind and solar energy is held in balance by the deployment of smart grids: technologies such as smart meters, which regulate demand and supply on the network and thus facilitate the smart use of electricity at peak and off-peak hours. This smart use is underpinned by price differentiation: consumption at peak times is expensive. The charging of cars and cooling of fridges can also be schedules for periods when demand is low and supply is high, thus lowering peak demand and reducing costs.

Intermediate steps

The production of sustainable energy is high on Amsterdam City Council's agenda and is working on the expansion of Amsterdam's production of sustainable electricity to some 50% of the city's households in 2040. In collaboration with various internal and external parties, the City Council is devising a strategy aimed at trade and industry for the implementation of energy-saving measures by businesses.The requirement that from 2015 all new-build housing must be climate-neutral is underpinned by subsidies and the instruments provided by The Amsterdam Guide to Energetic Urban Planning (Leidraad Energetische Stedenbouw, or LES), which was devised for climate-neutral projects, and by the 'Menu for climate-neutral self-build by private individuals' (Menukaart Klimaatneutrale Zelfbouw door particulieren. The participation of residents and businesses is essential for the realisation of a closed electricity cycle. As a stimulus, in late 2011 Amsterdam City Council established an Investment Fund 'Climate, Sustainability, Air Quality'. The aims of this fund include supporting projects by citizens, enterprises and social organisations that are aimed at achieving energy savings, generating sustainable energy or making efficient use of residual heat. The investment in projects must be profitable, so that it can function as a revolving fund. One of the three selected projects is the 'Sun on Multi-owner Properties' (Zon op VvE) pilot scheme: solar panels on apartment blocks, rendering solar energy on communal roofs more cost-effective by virtually offsetting the energy generated against the consumption of all the dwellings under that particular roof. In 2013 the fund will continue seeking out new projects. Over the coming years, the grid operator Alliander will be making substantial investments in the Amsterdam network, in order to be able to provide the requisite capacity and 'smarten up' the network. In conclusion, there are many ongoing initiatives in the realm of the sustainable generation of electricity. Questions are:

- Is there sufficient land and/or space available to supply Amsterdam with sustainable electricity using wind turbines, solar panels and biogas?
- The transition to sustainable electricity is still expensive. Is the price of electricity high enough and the Amsterdam Investment Fund 'Climate, Sustainability, Air Quality' enough of an incentive to prompt Amsterdam's consumers and businesses to invest in the generation of sustainable energy and 'smartening up' the network?

Jannis van Zanten, Waternet



Legend

- Gas
- Solar energy
- Biomass
- Wind energy
- Power station/AEB
- Imported energy
- Local energy

In the desirable scenario the production of electricity is sustainable and partially decentralised. Smart grids regulate demand and supply on the network.

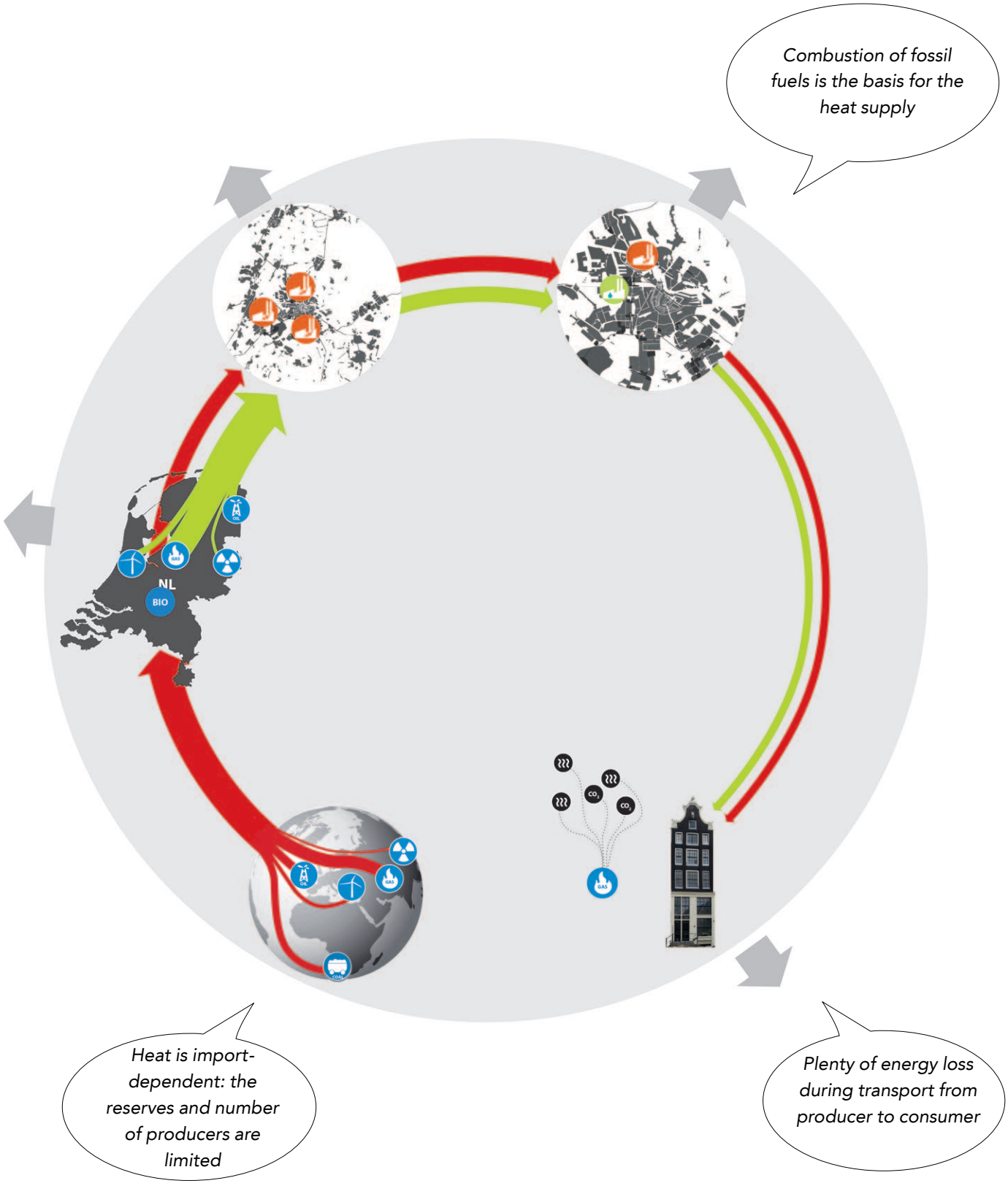
Heat cycle
Present situation

The current heat cycle is straightforward: fossil gas, the main source of heat, is imported and/or extracted in the Netherlands. Gas is transported to the end user via an extensive network of pipes. A central heating boiler provides homes with heat and warm water.

There are also buildings that are heated using district heating. The energy source is heat (mostly residual) from the power stations around Amsterdam and from waste incineration plants. This heat is distributed via an underground network of well-insulated pipes to the city districts, where it is then channelled to individual dwellings

Characteristics:

- Fossil gas is used as a heat source and on combustion CO_2 is released, so the cycle is incomplete;
- The heat supply is import-dependent. Expectations are that the Slochteren natural gas field in the province of Groningen will be exhausted by around 2030. This will lead to an increase in natural gas prices and a stronger dependence on foreign suppliers such as Russia and Iran. The production of biogas is being stimulated, but it is not expected to be able to meet current demand;
- The heat supply is not very efficient: there is plenty of energy loss between producer and consumer. A lot of heat is lost by consumers, too, from their individual dwellings;
- District heating via heat networks leads to energy savings, a reduction in CO_2 emissions of between 50 and 80% in built-up environments, and lower emissions of nitrogen dioxide.



Legend

- Renewable energy
- Biomass
- Coal
- Gas
- Oil / fossil fuels
- Nuclear energy
- CO_2 production
- Heat production
- Power station/AEB
- Sewage treatment plant
- Imported energy
- Local energy
- Greenhouse gas

In the current cycle the combustion of imported fossil fuels is the basis for the heat supply

Heat cycle

Future perspective

The Netherlands and Amsterdam are heated with heat from various (sustainable) sources. The Netherlands imports a certain amount of gas and biogas but primarily produces heat itself: at national, regional and municipal scales as well as at the level of individual dwellings. The sources are sustainable and diverse: residual heat that is released during large-scale electricity generation (waste, gas biomass, etc.), small-scale industrial residual heat, solar energy and new renewable sources that involve extracting energy from the earth: geothermal (drawing on the earth's heat at considerable subterranean depths) and geothermal pumps (for the storage and use of heat and cold in the substratum close to the earth's surface).

Amsterdam's district heating network lies in a continuous ring through the city. The power stations are connected to it and renewable sources feed into the heating network as well.The combination of the electricity and heat networks is energy-efficient, making it possible to achieve a fully sustainable energy supply in the densely built city, in combination with affordability and reliability for the user.For areas which cannot be connected to district heating network in the near future there are alternatives: biogas, which is a relatively simple option that is inadequate on a large scale, and individual heat pumps as components of the heat and cold storage network. The total demand for heat will increase as gas-heated dwellings are superseded by dwellings that produce and consume heat directly, leading to a decrease in demand for gas. The average heat demand per dwelling has also fallen, thanks to better home insulation and some homes being fitted with solar panels, and heat is even recovered from shower water.

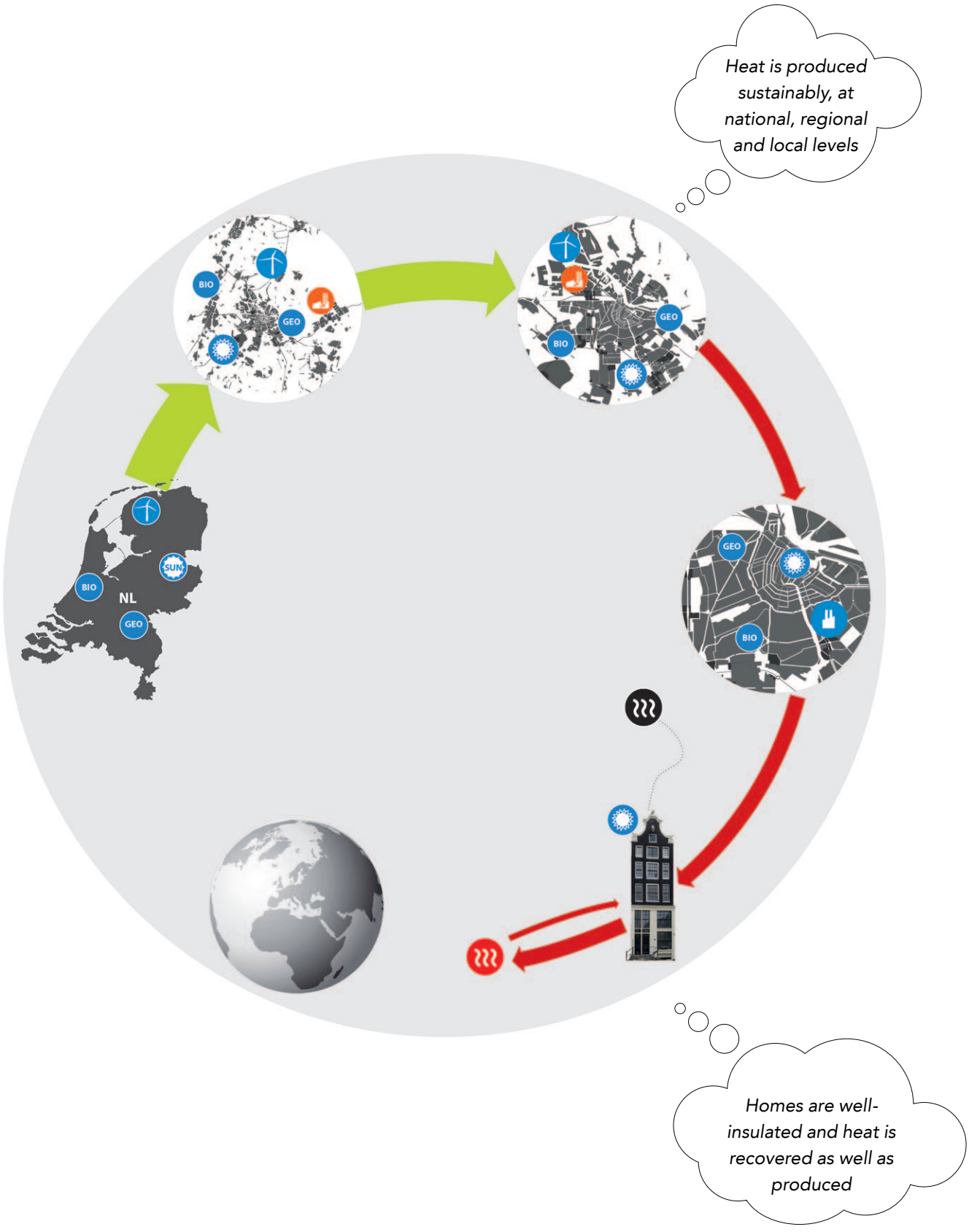
Intermediate steps

There are initiatives in the pipeline to realise a future city without fossil gas. The potential of renewable sources is being investigated broadly, and in the recently developed Overamstel and Houthavens districts there are projects underway to interconnect geothermal storage and district heating. Engineers are devising scenarios for the purpose of installing a district heating network and implementing the transformation agenda. This brings together all the future investments in the city's infrastructure and buildings, with the aim of organising the necessary energy transition 'smartly' and thus facilitating capital investments in collective provisions, at the same time preventing economic disinvestments and limiting the nuisance for the city during the realisation of the infrastructure.New earnings models and value chains are being formulated, as a basis for consumers and suppliers to enter into long-term agreements for the expansion of the district heating network throughout the existing city

Steps are being undertaken to prepare for the city without gas. The issues being investigated include:

- What is the potential capacity of Amsterdam's geothermal energy, heat and cold storage and other sources?
- How can the different production techniques with their distinctive characteristics (temperature, pressure, etc.) be interlinked in a single network?
- Is it possible to reduce the temperature of warm tap water without posing a risk to public health?
- Which parties are needed to implement the transformation agenda and to be able to install the district heating network?
- Heat has a monopolistic character. How can the interests of the various parties in the chain be safeguarded in the costly installation and the later operational management of heat networks?

Jannis van Zanten, Waternet



Legend

- Small-scale industry
- Solar energy
- Biomass
- Wind energy
- Geothermal, including heat and cold storage
- Heat
- Local energy
- Power station/AEB
- Heat production
- Heat recovery

In the desirable future, the Netherlands and Amsterdam produce heat themselves, from sources that are sustainable and diverse.

Concluding remarks

Each of the cycles outlines a distinctive transformation scenario, moving from the current situation to the future or desirable situation. When they are all set alongside each other there are a number of developments that stand.

From global to local

In almost all the cycles there is a discernable shift from global to local. The growing scarcity of inexpensive energy and raw materials will lead to ecosystem services manifesting themselves on a smaller scale. Processes that are still primarily international make a significant contribution to the delivery of materials, which entails expensive imports and transportation costs that will in future present the opportunity to shift to local production. Will this allow us to contribute to the reduction of our global footprint?!

From linear to circular

Many of the cycles are still primarily linear (e.g. water and energy), so materials are often destroyed or flushed away (phosphate) in the process. In future, forced by scarcity and rising prices, we will have to innovate and search for smarter and more efficient use of materials by bringing them back into the cycle. In a certain sense this also means rendering the chain more sustainable.

From centralised production to local sources

The role and significance of decentralised sources will increase in situations where there is still large-scale generation, for example of energy or heat, and to a certain degree that also applies for food and phosphate. The playing field will therefore become not only more diffuser but also more interesting because the number of local actors will increase. The question is to what extent the (primarily existing) city offers sufficient space to accommodate this, and not only in, on and beneath existing properties or plots of land but in the supply infrastructure as well. Will the infrastructure fit within or alongside the existing bundles of cables and mains, and to what extent can efficiencies be achieved here?

The role of the actors – Less city government, more citizen

All the above clearly foregrounds the growing significance of the role of consumers. In the near future they will also become producers of their own energy, phosphate, food and heat. To what extent will we succeed in breaking through the monopoly position of the current suppliers and, conversely, make the incentive sufficiently great to actually take that step?

"If we want things to stay as they are, things will have to change."

Giuseppe di Lampedusa (1896-1957), The Leopard

"The global effort for sustainability will be won, or lost, in the world's cities, where urban design may influence over 70 percent of people's Ecological Footprint. High-Footprint cities can reduce this demand on nature greatly with existing technology. Many of these savings also cut costs and make cities more livable".

Global Footprint Network, 2010

Key to the symbols (from top to bottom):
CO_2
Grazing land
Forest
Fishing grounds
Cropland
Built-up land

Source: WWF, Living Planet Report 2012

Synergy and overlaps between the cycles

Many cycles intersect, such as phosphate and food, but likewise waste and water in combination with electricity and heat. An obvious step is to look into how the innovation processes can influence each other more positively, such as the self-sufficient houseboat and the use of smart meters. This does, however, call for cooperation at various levels and bringing together all the parties concerned. The Amsterdam Guide to Energetic Urban Development (Leidraad Energetische Stedenbouw, or LES) and Amsterdam Smart City have already demonstrated how bringing together producers and consumers can lead to a more efficient use of raw materials and resources. In particular these processes show that besides needing knowledge and insight it also takes skill to get the right people involved in the right process and actually sitting down around the table.

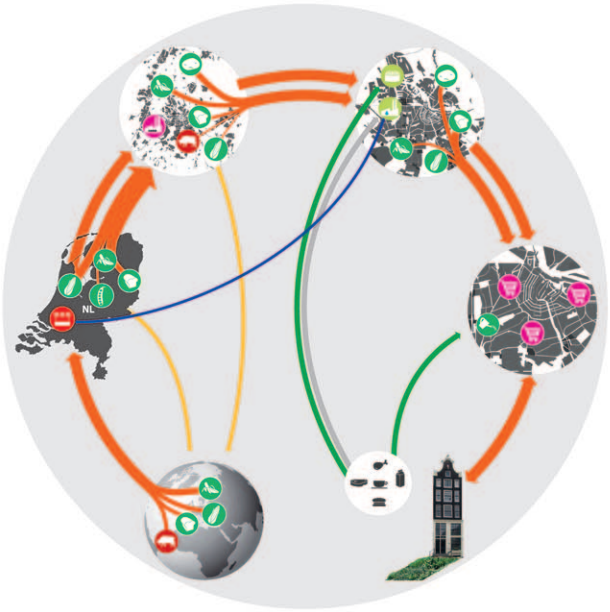
The challenge for the city – Towards a green economy

Over the next 20 years many of the outlined developments will be implemented or come into effect, whether rapidly or more gradually. This brings high expectations, but uncertainties as well. When is it cost-effective? Can I also tackle it with my neighbourhood? Which aspects should the government leave well alone? Have I gathered the right people around the table?

This period also allows the leeway to search for new solutions and challenges, to charge discussions with new inspiration and energy, and to search for connections between cycles and people who feel motivated to contribute to a better, healthier and above all more attractive city.

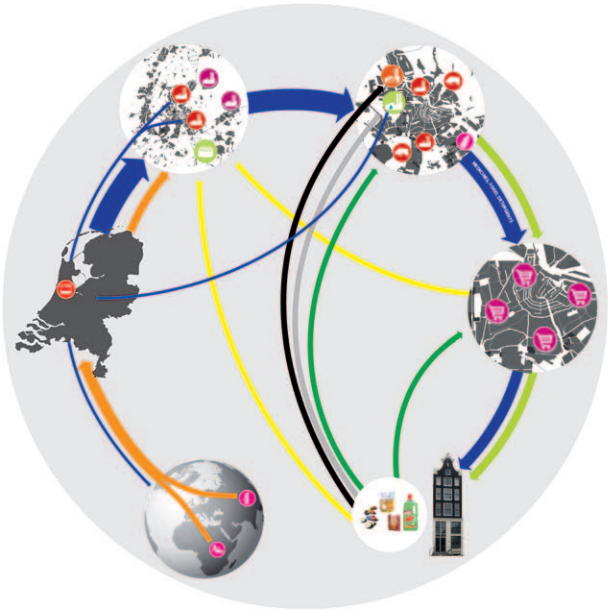
As the biggest producer of waste and emissions, the city bears a major responsibility. The city also offers the best opportunities for innovation, smarter use of space and the bundling of interests for a green economy: sustainable, reliable and affordable!

Food cycle - Present situation

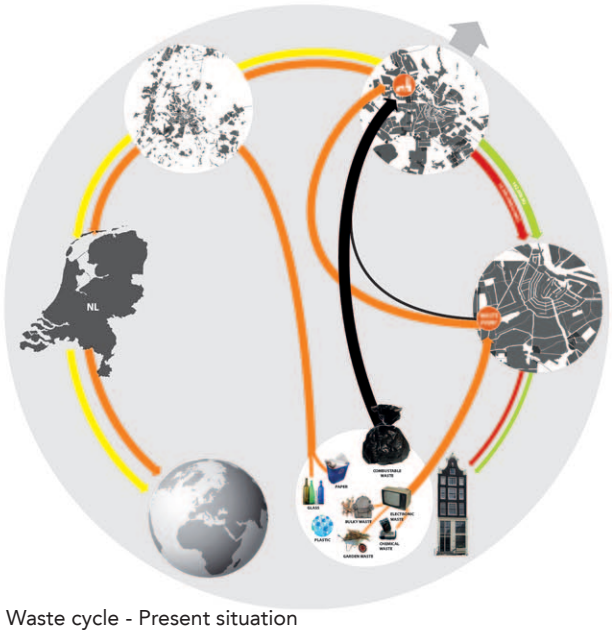


Food cycle - Future perspective

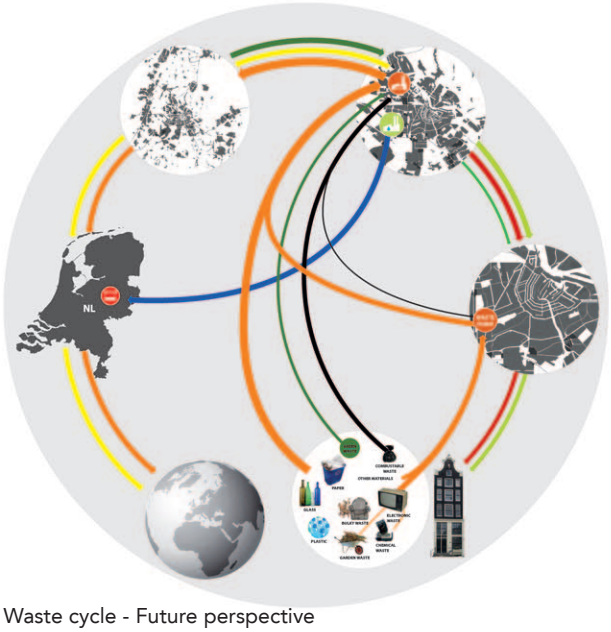
Phosphate cycle - Present situation



Phosphate cycle - Future perspective



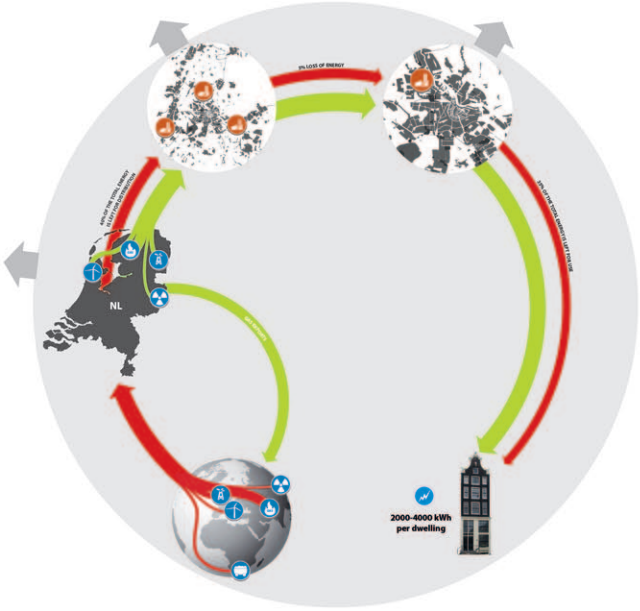
Waste cycle - Present situation



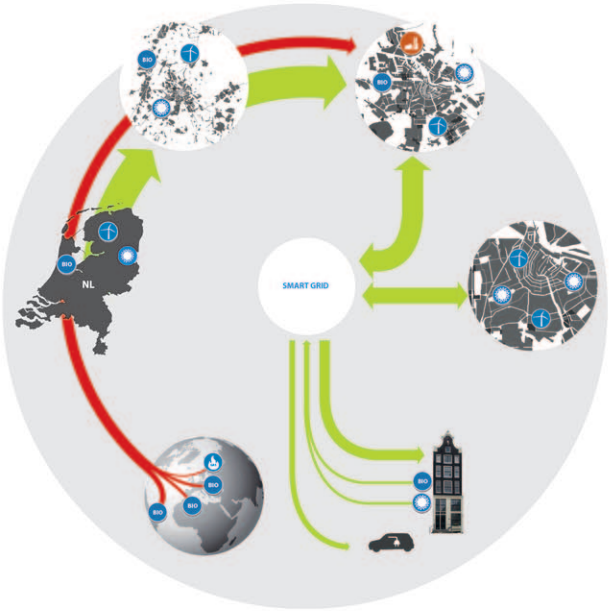
Waste cycle - Future perspective

Water cycle - Present situation

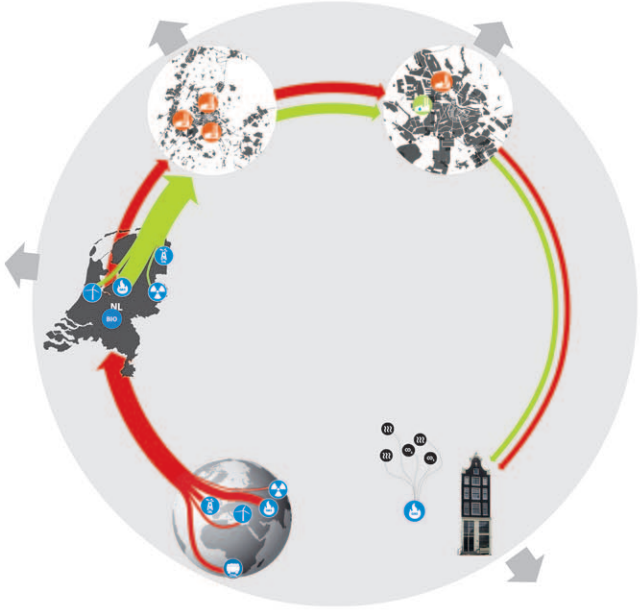
Water cycle- Future perspective



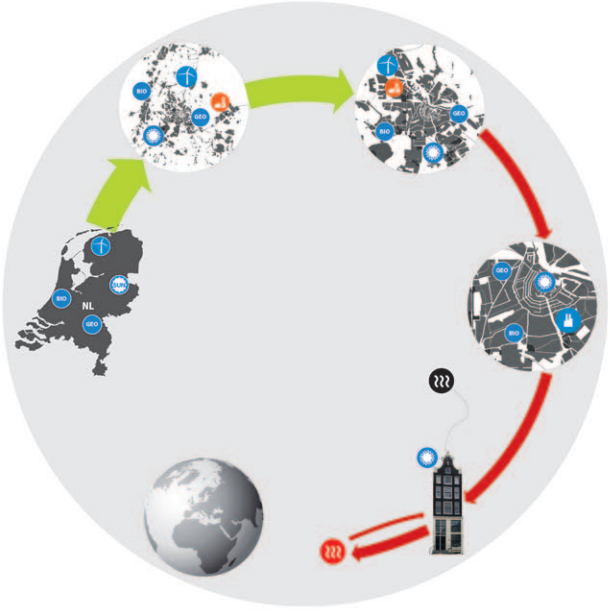
Electricity cycle - Present situation



Electricity cycle - Future perspective



Heat cycle - Present situation



Heat cycle - Future perspective

Background Information

Food

Contact: Pim Vermeulen, Physical Planning Department (DRO), P.Vermeulen@dro.amsterdam.nl
Further information:

- 'Voedsel, Schakel tussen stad en land / Food. The Link between City and Countryside' (with a summary in English), PLAN Amsterdam (September 2010): www.amsterdam.nl/publish/pages/417475/plan05-2010-05.pdf
- urban farming: www.farmingthecity.net; www.groentenuitamsterdam.nl
- sustainable consumption: www.youthfoodmovement.nl
- urban horticulture (Floriade 2022): http://www.zuidoostlob.nl/main.asp?wpl_id=55717
- food in the future: http://www.devoedingswijzer.nl/toekomst.html
- information about allotment gardens: http://www.bondvanvolkstuinders.nl/

Phosphate

Contact: Edgar Zonneveldt, Physical Planning Department (DRO) e.zonneveldt@dro.amsterdam.nl
Further information:

- http://www.rijksoverheid.nl/nieuws/2011/10/04/fosfaat-van-afvalstof-tot-exportproduct.html
- nutrientenplatform.org
- fosfaatrecycling.nl

Waste

Contact: Sietse A. Agema, Waste and Energy Company (AEB), agema@afvalenergiebedrijf.nl
Further information:

- AEB: http://www.afvalenergiebedrijf.nl/home.aspx
- Waste in Amsterdam: http://www.afval.amsterdam.nl/; http://www.amsterdam.nl/@369073/pagina/

Water

Contact: André Struker, Waternet, andre.struker@waternet.nl
Further information:

- www.samenwerkenaanwater.nl
- Long-term vision for the water cycle: http://www.samenwerkenaanwater.nl/bronnen/doc/verbindend_water_LT_Visie-LR.pdf
- The roadmap for innovation: http://www.samenwerkenaanwater.nl/bronnen/doc/verbindend_water_Routewijzer_LR.pdf

Electricity

Contact: Tjeerd Stam, Dienst Ruimtelijke Ordening, T.Stam@dro.amsterdam.nl
Further information:

- Wind energy: http://www.amsterdam.nl/wonen-leefomgeving/klimaat-energie/duurzame/windenergie-0/
- Climate-neutral construction: http://www.amsterdam.nl/wonen-leefomgeving/klimaat-energie/klimaatneutraal-0/
- The Amsterdam Guide to Energetic Urban Planning (LES): http://www.amsterdam.nl/gemeente/organisatie-diensten/dienst-ruimtelijke/les-leidraad/publicaties-les/publicaties/the-amsterdam-guide/
- Menu for climate-neutral self-build housing: http://www.amsterdam.nl/wonen-leefomgeving/klimaat-energie/klimaatneutraal/klimaatneutraal/ http://www.amsterdam.nl/wonen-leefomgeving/klimaat-energie/klimaatneutraal-0/bouw-huis/menukaart/
- The Amsterdam Energy and Climate Investment Fund: http://www.amsterdam.nl/@493320/pagina/

Heat

Contact: Jannis van Zanten, Waternet, jannis.van.zanten@waternet.nl
Further information:

Sustainable (geo)thermal resources:

- http://www.amsterdam.nl/wonen-leefomgeving/klimaat-energie/duurzame-verwarming/warmte-koude/
- http://www.amsterdam.nl/wonen-leefomgeving/klimaat-energie/duurzame/windenergie/
- Information about geothermal storage: http://www.agentschapnl.nl/nl/onderwerp/warmte-koude-opslag

District heating:

- http://www.amsterdam.nl/gemeente/organisatie-diensten/dmb/doet-dmb/advies_en_beleid/milieuadvies/projecten/luchtkwaliteit/actieplan/overzicht-acties/acties/stadsverwarming http://www.amsterdam.nl/gemeente/organisatie-diensten/dmb/doet-dmb/wat/advies-beleid/milieuadvies/projecten/luchtkwaliteit/actieplan/overzicht-acties/acties/stadsverwarming/

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Towards the Amsterdam Circular Economy

Effective use of raw materials is one of the spearheads in the city's first sustainability programme, 'Amsterdam Definitely Sustainable, 2011 – 2014' (Amsterdam Beslist Duurzaam 2011 – 2014), and this involves thinking in terms of cycles. Effective cycles contribute to an efficient use of materials and resources and thus to the reduction of our ecological footprint, the WWF writes in its Living Planet Report 2012. Which cycles do we find in the city? What do these look like now, but first and foremost how do we want them to look in the near future? Who do they affect and involve? What developments are we witnessing and how can we exploit them to make our city more sustainable, smarter and more liveable? To what extent can we take advantage of these cycles in district development, the use of urban space, and attracting new businesses? And are they able to motivate and influence city-dwellers and their behaviour?