THE DEMAND FOR CONSTRUCTION AGGREGATES IN ZEALAND, DENMARK: FORECAST 2012-2036

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Abstract

In the period from 1980 to 2011 Denmark produced annually between 36 and 69 million tonnes of aggregates.

In Denmark six regions are responsible for their mineral planning. The regions are required to designate aggregate land banks that should provide 24 years of mineral, and therefore the regions need to estimate the next 24 years of demand for minerals. This estimation can be undertaken using various methods and has caused an intense debate as to how the demand should be estimated.

One of the estimation methods is to calculate the demand for minerals based on the forecast for Gross Domestic Product (GDP) and changes in GDP. There is a relationship between the demand for construction aggregates and the economy described by GDP as well the changes in GDP, known as economic growth or economic recession. Based on these relationships a simple linear model for forecasting the demand for construction aggregates can be made and that modelling is the subject of this paper. The regional economic model for the future economy, 'SAM-K/LINE' has been used as a base for this economic forecast.

The forecast estimates a total production of construction aggregates on Zealand, for the period 2012-2024 of 164 million tonnes. This is 22% higher than in the previous 12 years (134 million tonnes). The consequences of failing to identify suitable land bank areas at the mineral planning stage are increasing transport distances and costs, which has been recorded on Zealand since the early 1990s. According to the forecast model, the trend of increasing transport distances seems to continue in the future.

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Introduction

In Denmark six regions are responsible for their own mineral planning, and the municipalities (which form the regions) approve and supervise the operation of individual gravel pits or quarries. The regions are required to designate aggregate land banks that should provide 24 years of mineral, and therefore the regions need to estimate the next 24 years of demand for minerals.

The consumption of aggregates has varied a lot during the last decade due to changes in the economy. This has caused an intense debate on how the future consumption of minerals should be estimated. This in turn affects the size of the land bank areas that the regions have to designate for mineral extraction. Environmentalists, local politicians and neighbours of proposed aggregate extraction sites have argued for a lower consumption of construction aggregates in the future.

Zealand is the most densely populated part of Denmark with the capital Copenhagen as the major growth center. Zealand is divided into two regions; The Capital Region of Denmark which covers Copenhagen and Northeast Zealand, and Region Zealand which covers the rest of Zealand as shown on Figure 1. The production of construction aggregates in the Capital Region is small; the majority of the aggregates are produced in Region Zealand. This causes a major export of aggregates from Region Zealand to the Capital Region and transport distances up to 70km are common.

The production of aggregates in Region Zealand is highly dependent on both the amount of aggregate production and the demand for aggregates in the Capital Region. Since the early 1990's an increased proportion of the aggregates produced on-land in Zealand has been from the Region Zealand, as shown on Figure 2. This is the consequence of a high consumption of aggregates and a lack of designated land bank areas for extraction in the Capital Region. This has led to increasing transportation of construction aggregates into the Capital Region. The high proportion of offshore production in Region Zealand in 1990 and 1991, shown on Figure 2, was due to large volumes of fill materials used in the construction of the Great Belt Bridge between Zealand and Funen.

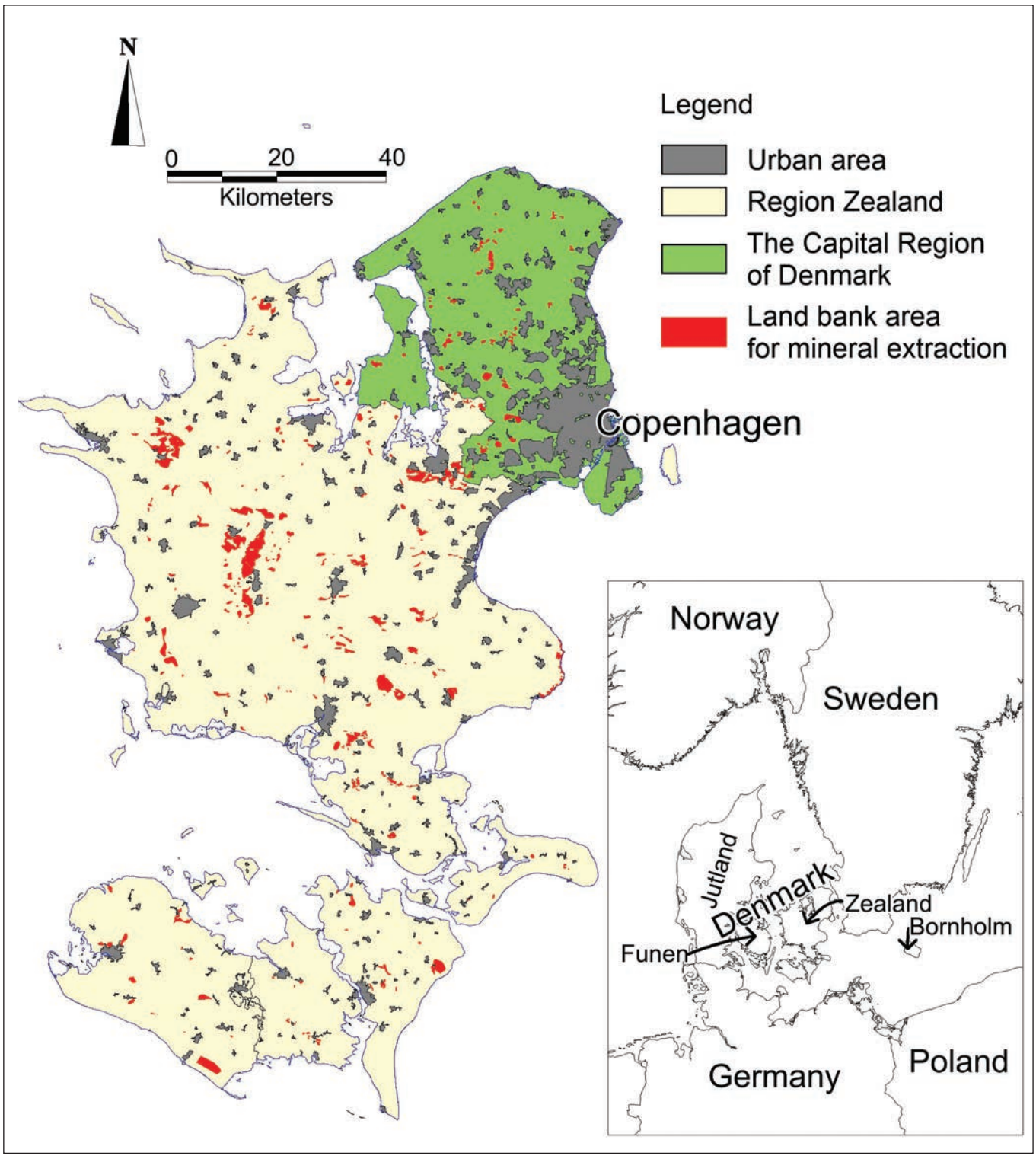

Figure 1. *Map of Zealand. The location of urban areas and land banks for mineral extraction in The Capital Region and Region Zealand.*

This paper gives a short introduction to the market for construction aggregates in Denmark and presents a simple forecast model based on linear regression for Region Zealand. Data for aggregate production, import and export and economy are collected from the Statistic Denmark's database (StatBank Denmark, 2012). Data for secondary and recycled aggregates are collected from Miljøstyrelsen (2011).

Aggregate Geology In Denmark

Quaternary deposits cover more than 99% of Denmark, with the landscape formed by the Weichselian and Saalian glaciers. Glacial meltwater sand or extramarginal meltwater sand as shown in Figure 3 cover more than 29% of the total land area.

The majority of aggregates produced on-land, in Denmark are from these glacial meltwater sands or from extramarginal meltwater sands. The best resources containing high contents of coarse materials are found in the higher parts of the outwash plains, just outside the

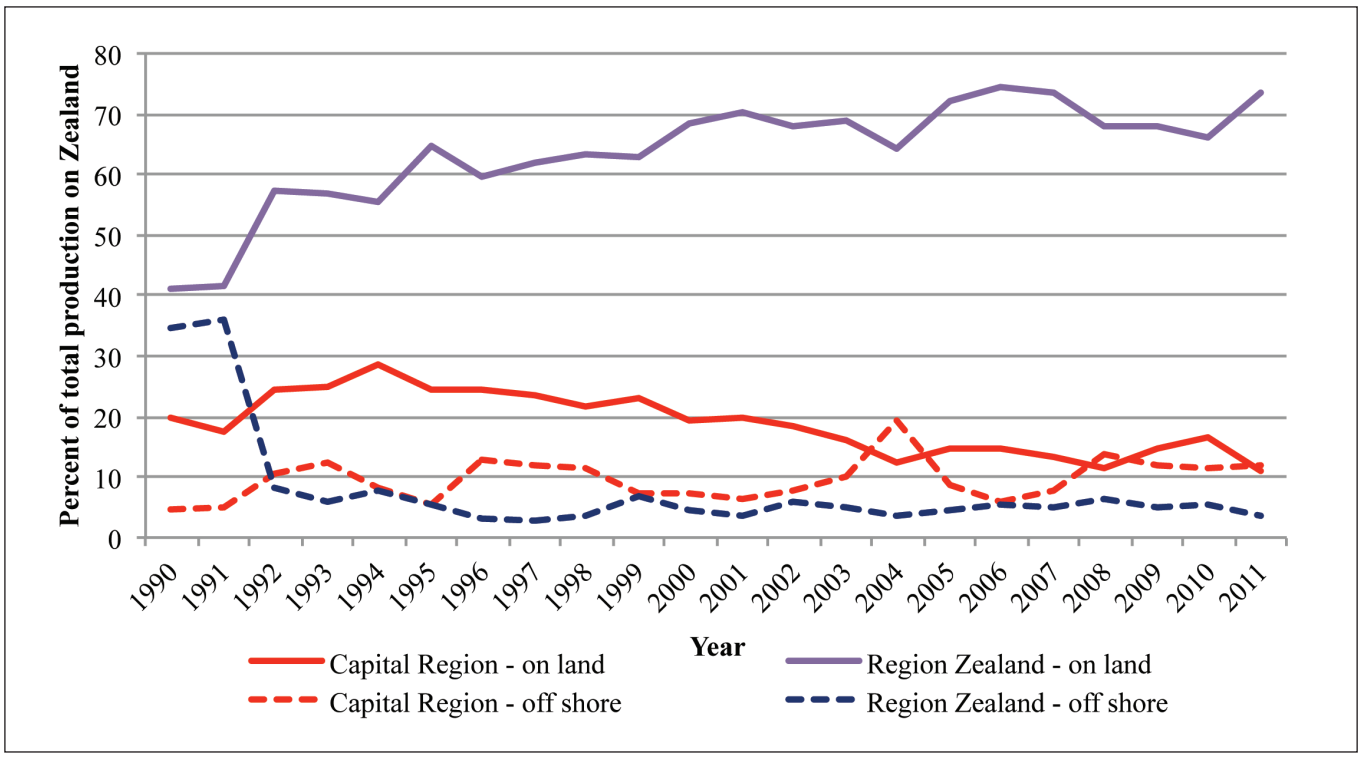

Figure 2. *Aggregate production, on-land and offshore, in The Capital Region and Region Zealand. Percentage of the total production in Zealand in the period 1990-2011. From StatBank Denmark (2012).*

major Late Weichselian end moraines. High quality deposits are also found in buried Middle Weichselian glaciofluvial deposits.

Offshore aggregates are dredged primarily from flooded Weichselian glaciofluvial deposits or Holocene flooded coastal sand and gravel deposits.

A significant amount of the aggregate deposits in Zealand have high contents of porous chert, especially on North and South Zealand, Funen and Eastern Jutland, due to chalk being near to the surface in eastern Denmark. In western Jutland, on the distal areas of the glacial outwash plains the glacial meltwater sand has a low content of coarse materials and is not suitable for construction aggregates. However, in parts of central and western Jutland the content of porous chert as fines, is low, and so high quality fine aggregates (particle sizes less than 4mm) for concrete can be produced. In central Jutland, Miocene sand is also used for high quality fine aggregates for concrete.

High quality coarse aggregates for concrete are only produced in limited volumes as crushed granite from the island of Bornholm in the Baltic Sea. The majority of coarse aggregates used in concrete are imported crushed rock from Norway.

Aggregate Supply And Consumption In Denmark

In the years from 1980 to 2011 Denmark produced on average 49.8 million tonnes of aggregates per year, mainly from gravel pits, though on average 20% of the production was dredged from offshore deposits. In some years the dredged aggregates accounted for a much higher proportion of the total, for example in the period 1989 to 1991 where large volumes of fill materials were used in the construction of the Great Belt Bridge between Zealand and Funen, and in 1999 and 2005 where large volumes of fill materials were used in Aarhus harbour (Skov- og Naturstyrelsen, 2001, 2006). In 1999 and 2005, 28% and 27% of the annual total production was from dredged aggregates, respectively.

On average, only 1.3% of the annual total production was crushed rock, from Bornholm.

As shown in Figure 4 the production of aggregates has varied from 36 to 69 million tonnes of aggregates per year with major peaks around 1987, 1999 and in 2006. The increase in production from 1981 to 1987 was due to high economic growth during this period. In 1986 and 1987 economic reforms were necessary due to a large balance of payments deficits. These reforms resulted in low economic growth and a decline in production of aggregates until 1993. New political reforms in 1993 stimulated the economy, which resulted in higher economic growth and an increased production of aggregates until 1999. The decreasing production of aggregates in the period from 2000 to 2003 was the result of a short, mild economic recession, mainly caused by the dot-com bubble bursting in 2000 and the terror attack on the World Trade Center in 2001. A continued decline of interest rates resulted in an increasing domestic demand, economic growth and in the production of aggregates from 2003 to 2006. In 2010 the total annual aggregates production in Denmark was nearly 40% lower than in 2006. The decrease was initiated by a downturn in the Danish economy in 2007 after a period with strong economic growth from 2003 to 2006. This downturn was continued by the global economic crisis in 2008, which led to a recession in the Danish economy.

During the last 20 years the import of aggregates has increased from 1 million tonnes to 3.5 million tonnes a

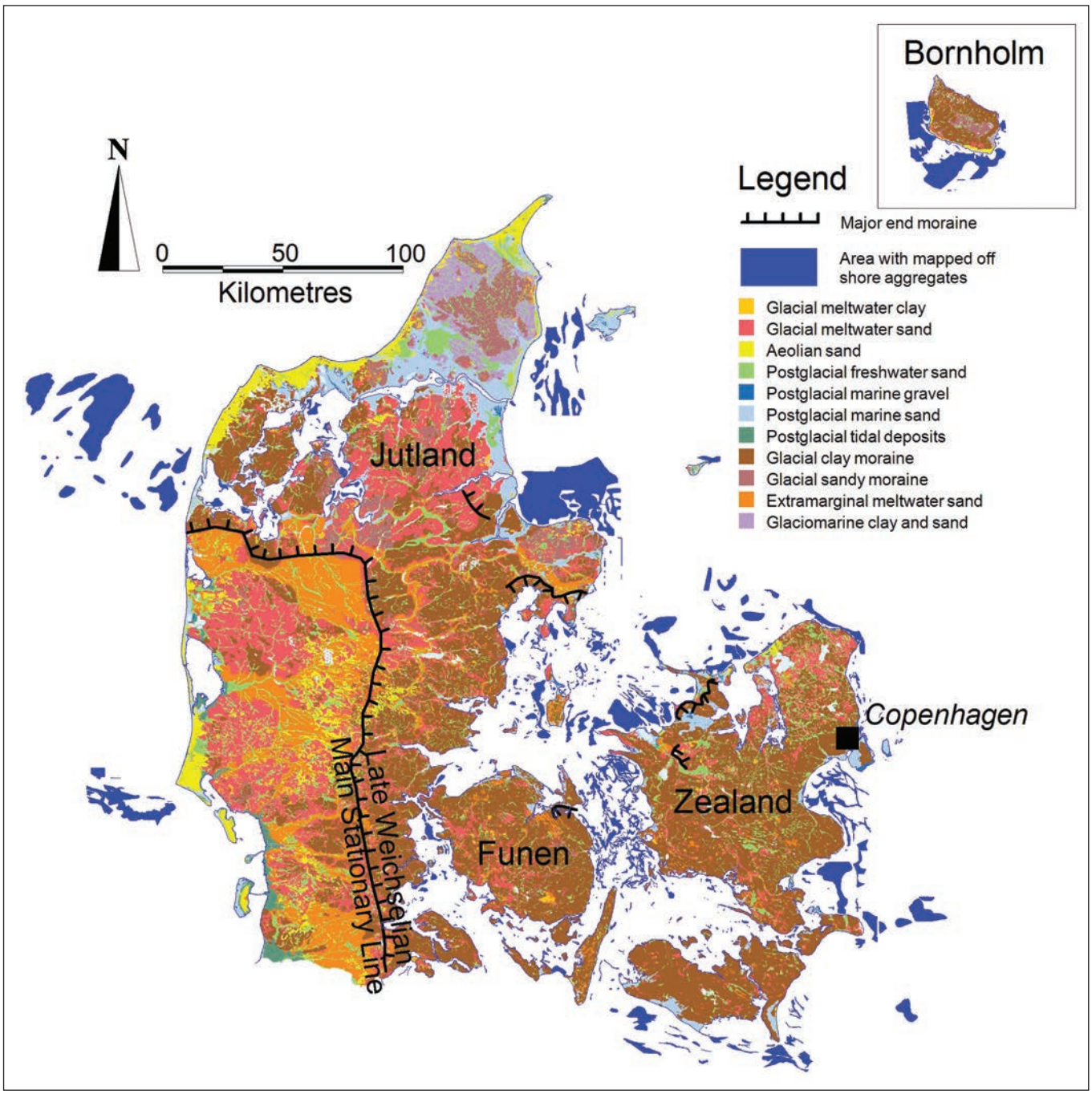

Figure 3. *Geological map of Denmark showing the surface cover at 1m depth. The major end moraines are illustrated. From GEUS (1989).*

year, as shown in Figure 5. In 2011, 6.4% of the annual consumption of aggregates in Denmark was from imports comprising mainly crushed rock from Norway. In the same period the export has remained stable at about 8% of the annual consumption of aggregates. The major part of the export is gravel and shingle to Germany and the UK.

During the last decade the use of recycled aggregates has increased significantly due to a political demand for sustainability. In particular, the use of recycled sand and gravel has increased due to a number of governmental objectives to minimize the need for landfilling. In 2009, 97% of the waste from the building and construction sector was recycled and 3% were landfilled (Miljøstyrelsen, 2011). Recycled aggregates now make up approximately 10% of the total consumption of construction aggregates, as shown on Figure 6.

The model for aggregate consumption in Denmark can be described as;

Total production on-land

\+ Total production offshore

\+ Use of secondary and recycled materials

\+ Net import

= Total consumption of aggregates, and

= Total demand for aggregates

The contribution that each of these aggregate sources makes to the total consumption is illustrated in Figure 7.

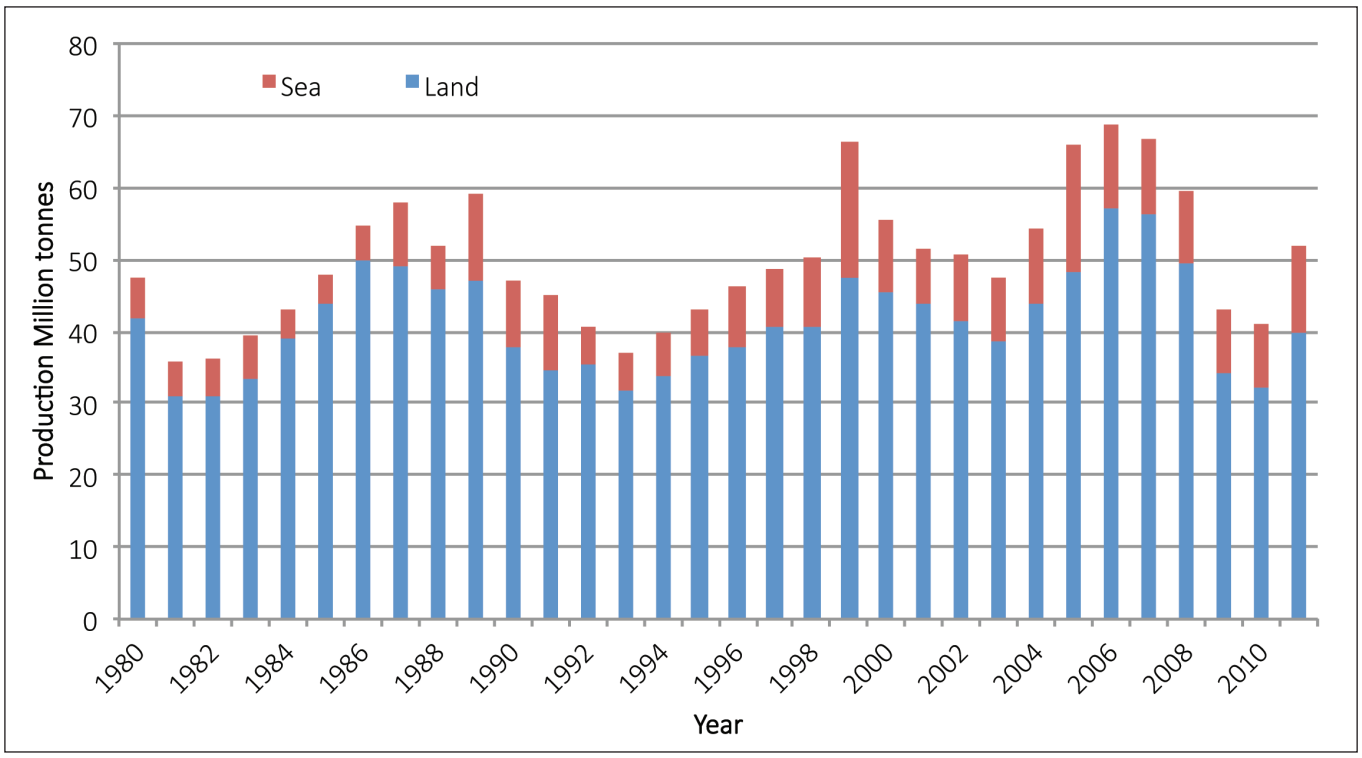

Figure 4. *Production of aggregates in Denmark during the period 1980-2011. From StatBank Denmark (2012).*

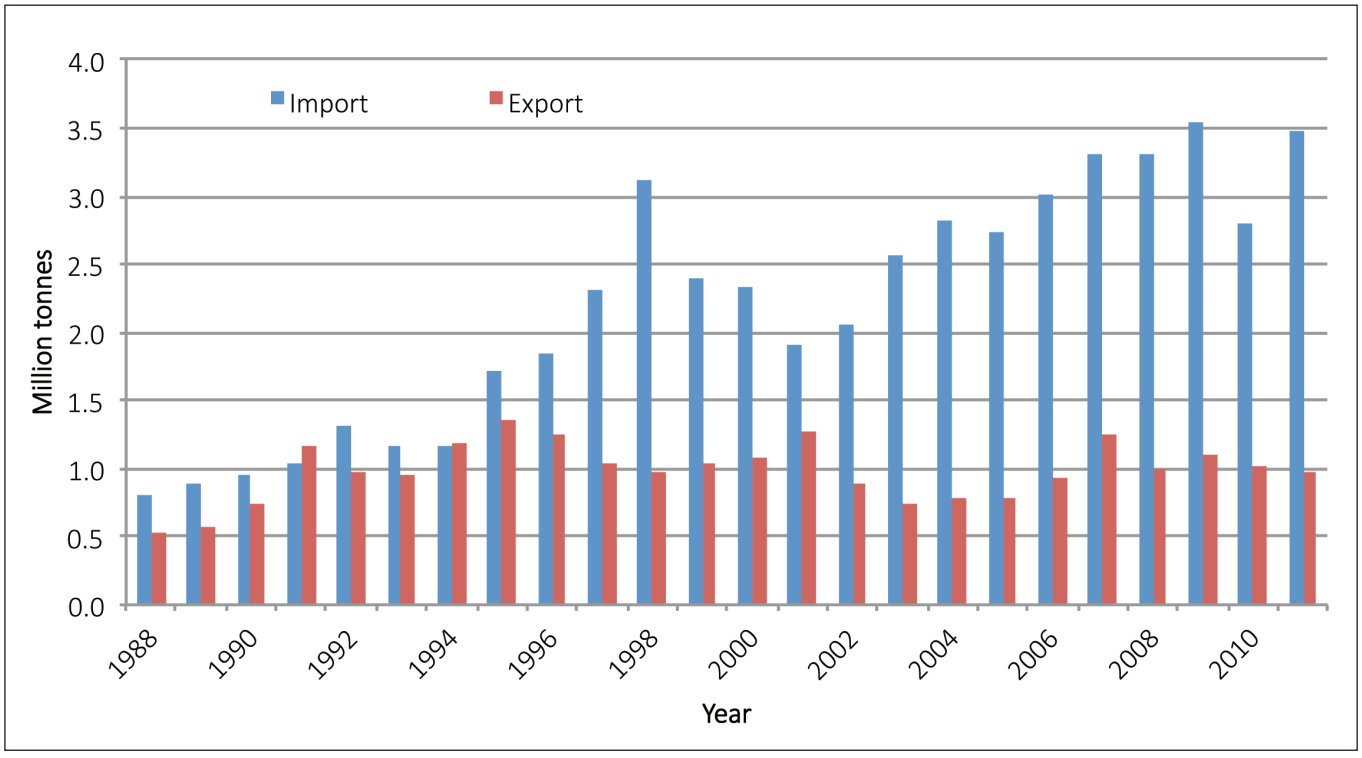

Figure 5. *Import and export of construction aggregates in the period 1988-2011. From StatBank Denmark (2012).*

Since the early 1980s, it has been a governmental objective to increase the proportion of total aggregate demand being met from offshore production. In the late 1980s, the proportion of aggregates produced offshore increased, as shown on Figure 8. One explanation for this is the increasing quality standards regarding aggregates for use in concrete. In large parts of Denmark the glaciofluvial deposits on-land have high contents of porous chert, causing alkali-silica reaction in the concrete. This resulted (in 1987) in the first Danish standard for aggregates for concrete; Basisbetonbeskrivelsen (Byggestyrelsen, 1987). Due to a lower content of porous chert in offshore aggregates, both in the coarse materials and in the sand, the offshore dredgers were faster than the aggregate producers on-land to meet the new demands.

In 1997 a new Raw Materials Act was approved by the government which limited the available offshore dredging areas and restricting the flexibility of the

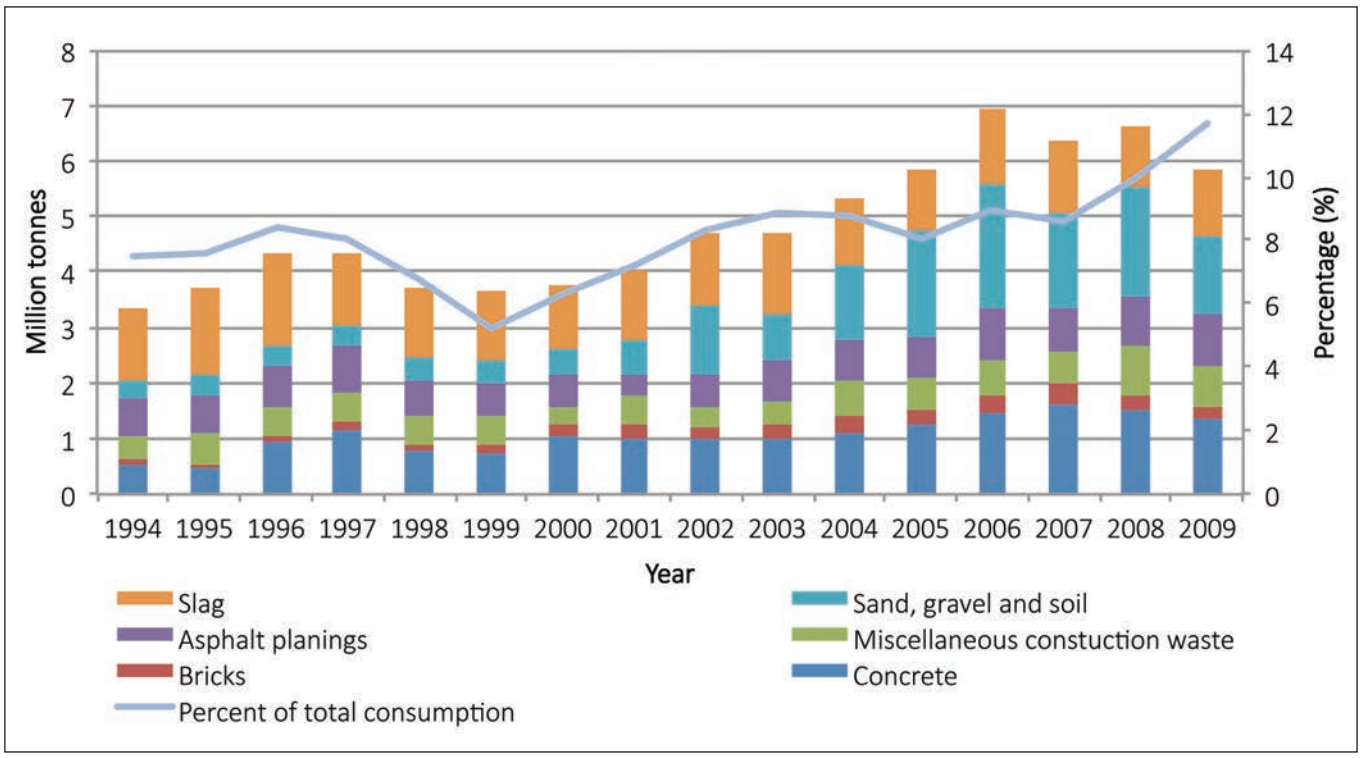

Figure 6. *Use of secondary and recycled materials in the period 1994-2009. From Miljøstyrelsen (2011).*

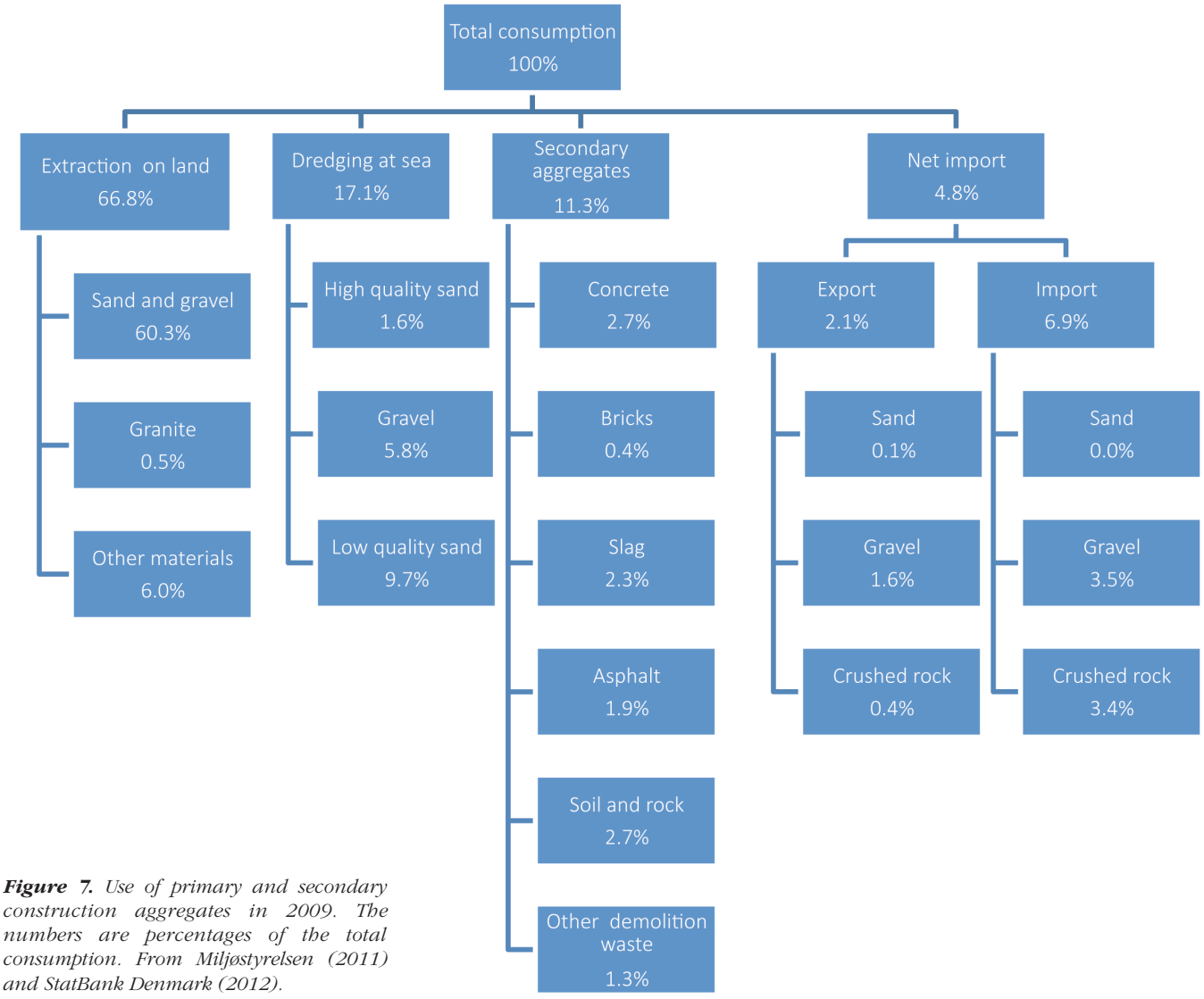

Figure 7. *Use of primary and secondary construction aggregates in 2009. The numbers are percentages of the total consumption. From Miljøstyrelsen (2011) and StatBank Denmark (2012).*

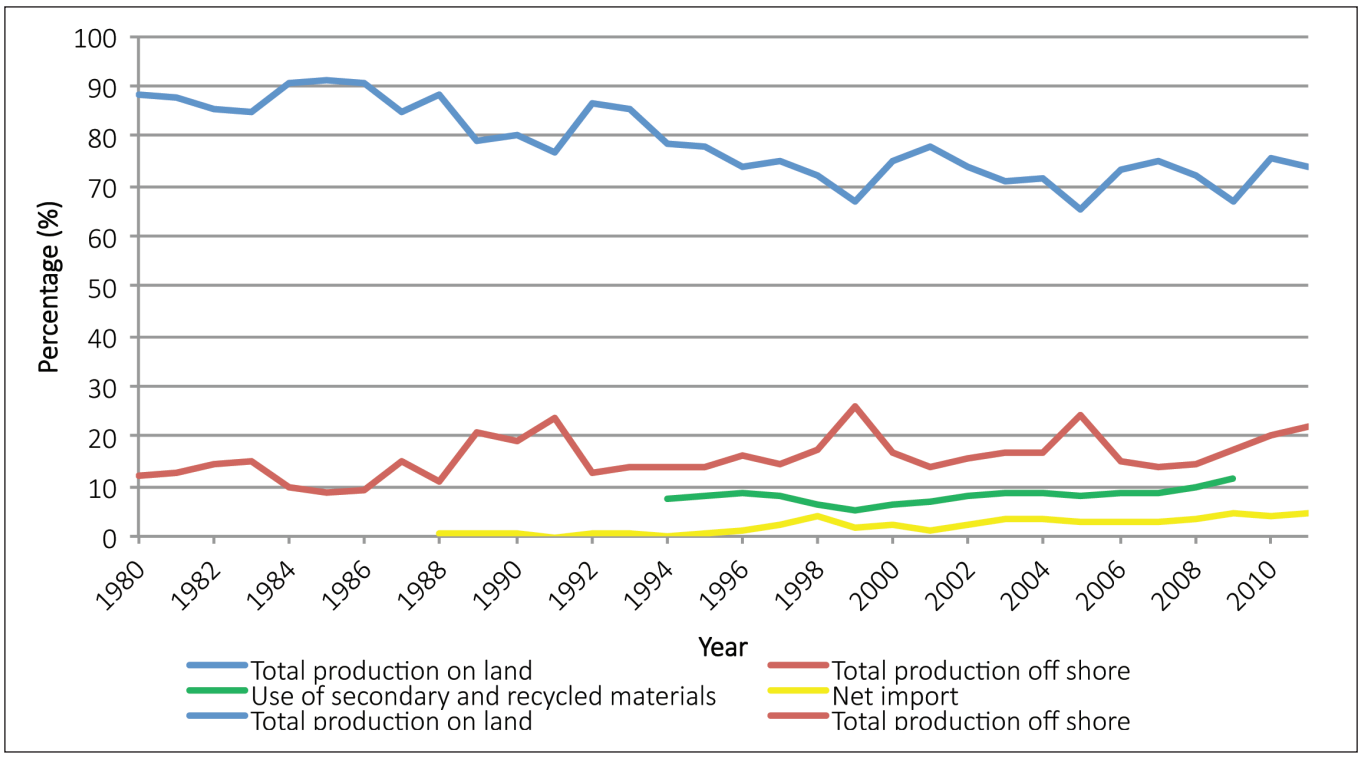

Figure 8. *The contribution of each source of aggregate to the total consumption of aggregates. Data for net import only is available in the period 1988-2011 and data for use of secondary and recycled materials only is available in the period 1994-2009. From Miljøstyrelsen (2011) and StatBank Denmark (2012).*

dredgers (Miljøministeriet, 1996). This act seems not to have influenced the proportion of the total production from offshore sources. Other restrictions on dredging have included the Natura-2000 network of protected sites (Miljøministeriet, 2007) and in addition, waterfront areas that have been developed for residential purposes which have limited the number of ports available for aggregate unloading. In 2010 a new Raw Materials Act was passed due to a governmental policy to increase the offshore production of aggregates. In this act a number of new initiatives were introduced including; changes to license fees payable to the government, exclusive rights to offshore areas and confidentiality in survey data. However an evaluation of the Raw Materials Act in 2012 indicated that competition offshore has not improved and so further initiatives have been suggested, including; increasing the period granted with exclusivity rights and removing of the maximum dredging volume limit. These have not yet been incorporated into the Raw Material Act.

Since registration of the use of secondary and recycled materials began in 1994 there has been a small reduction in the proportion of total aggregates demand met by on-land production (Figure 8). Though the proportion fluctuates from year to year, during the period 2005-2009 the average proportion of the on-land production was 71% of the total demand for aggregates, reduced from an average of 88% during the period 1980-1988.

Additional initiatives have been launched to reduce the use of aggregates, for example by using lime stabilised clay to build road beds and construction sites, instead of using sand.

In Denmark no measurable objectives have been set in relation to the contribution of each of the aggregate sources to the total consumption. However, there are now governmental policies to increase the proportion of the offshore production of aggregates and the use of secondary and recycled materials.

In future, the trend of slightly increasing offshore aggregate production will most likely continue. However, the production costs of offshore aggregates are far higher than the production costs for land produced aggregates. The use of, for example; lime stabilised clay, may decrease the use of virgin resources, in particular aggregates produced on-land, as the greater proportion of offshore aggregates are used in concrete and in offshore constructions, where lime stabilised clay cannot be used. One of the most important drivers (for reducing the use of aggregates) is undoubtedly a lack of designated land bank areas for extraction, on-land. In the Capital Region no new land bank areas (for mineral extraction) have been designated since 1985. Due to the difference in cost between aggregates produced on-land and offshore and the cost of their transportation, the lack of designated land bank areas in the Capital Region has led to an increased supply of land aggregates from Region Zealand and an increase in transport distance, instead of a substitution by offshore aggregates.

Relationship Between Consumption And Economy

The relationship between the consumption of construction aggregates and the economy has been described by Coriolis Consulting Corporation (1996), Jaeger (2006), Koziol, Kawalec and Kabzinski (2008) and, Menegaki and Kaliampakos (2010).

These studies have shown that the size of the economy and economic growth defined by gross

domestic product (GDP) and changes in GPD, are the main drivers in aggregate production, next to the size of the population and changes in size of population. Population density (urban and rural areas) also plays a major role in where construction aggregates are consumed.

In an economic assessment of construction aggregates the demand is expected to be inelastic, meaning that lower prices would not lead to higher consumption, as transportation costs are a major component of the total price of aggregates. This is observed in both Europe and North America (Jaeger, 2006; Bleischwitz and Bahn-Walkowiak, 2006). Construction aggregates are high volume, low price products. Further, the cost of aggregates only represents a small part of the total cost in the construction sector compared to e.g. wages, machinery and fuels.

The consumption of aggregates is highly dependent upon investments, especially investments in construction e.g. new houses, infrastructure, roads and railroads, as shown on Figure 9. Taking into account the years of exceptionally high production offshore i.e. 1989, 1999 and 2005 (Figure 8), the investment in construction is able to explain the consumption of aggregates statistically significant at a 95% confidence level. The linear correlation equation is as follows;

$$Consumption = \frac{0.4711 \times Investment\ in\ construction}{10009.7626}$$

Equation 1. *Linear correlation between aggregate use (in million tonnes) and investment in construction (in million Danish kroner). Data from 1989, 1999 and 2005 are excluded due to exceptionally high production offshore. R2(coefficient of determination)=0.946*

As described earlier, the Danish economy was in 2003-2007 in a period of economic boom. The economic growth resulted in capacity pressures on the economy. The high economic growth peaked in 2006 and the growth then declined. This led to a downturn in the Danish economy in 2007 which was exacerbated by the global economic slowdown in 2008.

One can consider the relationship between investment and consumption of aggregates to change over time, as changes in construction methods, the degree of urbanisation and costs in the construction sector are factors which affects the relationship. As the cost of aggregates only represents a small part of the total cost in the construction sector compared to for example; wages, machinery and fuels, then the changing price of aggregates will certainly not affect the relationship.

A country's investments in construction are dependent on several factors including; access to finance, changes in the size of population, the degree of urbanisation, tax issues, a willingness to invest in construction and previous investments in construction. The most important factors being the size of the economy (income) and economic growth, as shown on Figure 10.

In general, negative economic growth causes investments into construction to decrease while high economic growth increases the investment in construction. However, negative economic growth affects, to a higher degree the investment in construction than positive economic growth. A lower level of investment in construction is seen in the period following years with negative economic growth. This is the case in 1990 and 2010 where investments made are of the same magnitude, even though GDP in 2010 is much higher than in 1990. After the financial crisis in 2008 the willingness to invest in construction reached a historic low in Denmark as investors and banks were less willing to invest in construction.

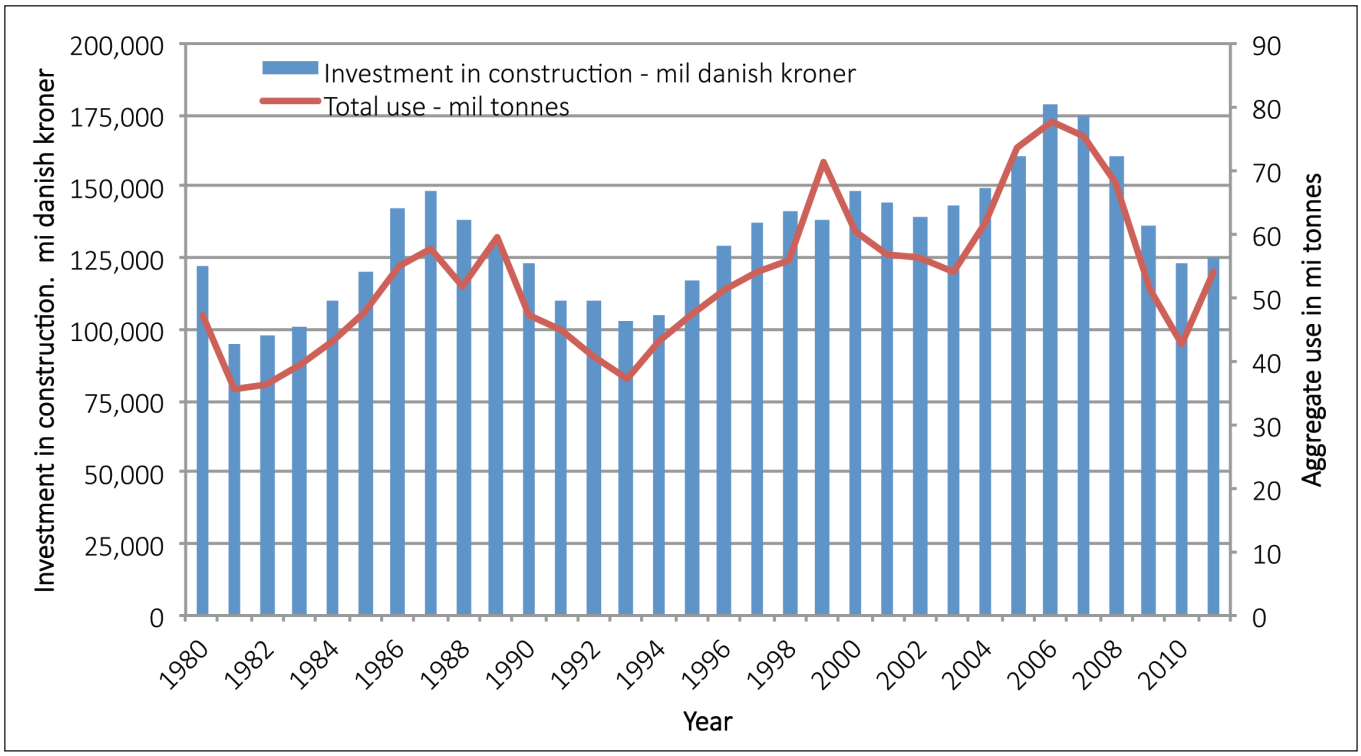

Figure 9. *Investment in construction and aggregate use in the period 1980-2011. From StatBank Denmark (2012).*

Figure 10. *Correlation between the level of investment in construction and GDP (in Denmark). Each bubble represents data from one year from the period 1990-2011. The blue bubbles represent economic growth and black bubbles represent negative growth. The size of the bubbles represent the amount of growth; the larger the bubble the greater the amount of economic growth, or negative growth. From StatBank Denmark (2012).*

Model For Consumption

Based upon the relationships between the economy and the demand for aggregate (as shown on Figure 9 and Figure 10), a simple model for forecasting the demand for construction aggregates has been established.

The input variables for the model are changes in GDP (economic growth or recession) and population. The population on Zealand is expected to increase from 2.5 million people in 2012 to approximately 2.8 million people in 2036 (Statistics Denmark, 2012).

Due to considerable uncertainty of the future economic growth, four scenarios for the economy have been considered.

- 0% growth in GDP
- 1% growth in GDP
- SAM-K/LINE growth in GDP
- 2% growth in GDP

The SAM-K/LINE is a regional economic model used by the regions to forecast the local economy. Changes in population size are included in the SAM-K/LINE model. The SAM-K/LINE model is based on the Danish Ministry of Finance economic model; ADAM and the Danish Governments 2020 plan for the future economy (CRT, 2010). The SAM-K/LINE model is expected to represent the best guess for the future economy.

Forecast And Perspective For Zealand

Using the four economic scenarios described, a forecast has been made for the demand of aggregates in the period 2012-2036; the period that regions are obliged to designate land bank areas for.

Based on the model, a total demand for aggregates on Zealand of between 388 and 670 million tonnes is expected in the period 2012-2036, equating to a yearly average of between 16.2 and 27.9 million tonnes, as shown on Table 1. In 2011 the actual demand for aggregates for Denmark was approximately 54.2 million tonnes. Of that, the amount of natural aggregate production on Zealand i.e. extraction from land and dredged aggregates was 12.4 million tonnes, nearly 23% of the total demand. The model calculated the demand for aggregates, including use of secondary aggregates and net import on Zealand in 2011, based on GDP at approximately 16.2 million tonnes.

The model assumes a continuously positive growth in the economy (except with the 0% growth scenario). The SAM-K/LINE scenario differs from the others by having lower economic growth and therefore lower aggregate demand in the last half of the period, whereas the 1% and 2% scenarios have constant economic growth.

On the basis of forecasted demand, shown in Table 1, and an evaluation of the proportion of the production on-land compared to the total demand, the expected production on-land has been forecast and is shown in Table 2. During the period 1994-2009 the average yearly proportion of total aggregate demand met by on-land production was 73%. However, due to increasing use of secondary and recycled materials, increasing net import and an increasing proportion of aggregate demand being met by offshore production, the yearly proportion of total aggregate demand met by on-land production has been decreasing and in 2009 the proportion was 66.8%. The year 2009 is the last year with data for use of secondary and recycled materials, as shown on Figure 8.

To calculate the expected production on-land in the

	Total demand 2012-36 (Millions of tonnes)	Yearly average demand 2012-36 (millions of tonnes)
0% growth	388	16.2
1% growth	518	21.6
SAM-K/LINE growth	595	24.8
2% growth	670	27.9

Table 1. *Demand for construction aggregates on Zealand in the period 2012-2036.*

	Total, on-land aggregate production forecast, 2012-36 (millions of tonnes)	Yearly average, on-land aggregate production forecast, 2012-36 (millions of tonnes)
0% growth	260	10.8
1% growth	347	14.5
SAM-K/LINE growth	399	16.6
2% growth	449	18.7

Table 2. *Forecast aggregate production from on-land sources on Zealand in the period 2012-2036.*

period 2012-2036 a proportion of 67% for the on-land production has been used. How this proportion will develop in the future is highly uncertain. The present day proportion has been used in the forecast, even it is logical that the proportion will not stay constant over time.

In the period 2012-2036 the total production of aggregates, on-land, is forecast between 260 and 449 million tonnes, which represents a yearly average of between 10.8 and 18.7 million tonnes, as shown in Table 2.The remainder of the production is estimated to be made up from the use of secondary and recycled materials (11%), net import (5%) and offshore production (17%) if the present day distribution continues on for the period 2012-2036.

If the SAM-K/LINE scenario is expected to represent the most qualified guess of the future economy, the production on-land on Zealand in the period 2012-24 is forecast to be 163.8 million tonnes. This is 22% higher than the previous 12 years (134.3 million tonnes).

Conclusion

The estimated increasing demand for aggregates might be met as follows:

- increase in land bank areas designated for aggregate extraction,
- increase in production from dredging offshore deposits,
- increase use of secondary and recycled materials and
- increase in import of aggregates.

Increase in production on-land to meet the increasing demand for aggregates, implies a requirement for an increase in land bank areas designated for aggregate extraction. This is likely to cause increasing resistance from various groups including local politicians and neighbours. Furthermore, the useful deposits closest to the large growth centers e.g. Copenhagen are already exhausted or are actively producing. The future land banks are likely to consist of deposits of lower quality and with higher overburden, located in areas with increasing environmental conflicts or further away from the construction sites. The increasing transport distances and costs of construction aggregates, which has been recorded on Zealand since the early 1990's is a natural development in the extractive industry. However, policy and willingness to designate land banks for aggregate extraction also has an influence. Since 1985 no new land banks for aggregate extraction has been designated in the Capital Region.

Since the early 1980s, it has been a governmental objective to increase the proportion of total aggregate demand met by offshore production. In this period the proportion of total aggregate demand met by offshore production has increased from 12% to 17%. Some initiatives have had positive effect on that figure, for example, the increased quality standards regarding aggregates for concrete, but other initiatives, like the introduction of license fees payable to the government in 2010 have had a less positive effect. Recent initiatives are again focused on increasing offshore production, for example, enhancing the competition offshore and this should lead to lower prices of offshore aggregates. Indirect initiatives however, such as higher environmental requirements for fuel oil for vessels which may be introduced in 2015, might lead to higher production costs. Today the production costs of offshore aggregates is far higher than production costs of land produced aggregates, and still too high to substitute land produced aggregates even when increasing transport costs are included.

Use of secondary and recycled materials has increased from 4.7% in 1994 to 9.6% in 2009, and in 2009, 97% of the waste from the building and construction sector was recycled. A series of initiatives such as using lime stabilized clay and cement stabilized sand will decrease

the use of virgin resources, and in particular aggregates produced on-land. However, due to increased precipitation and anticipated higher ground water levels due to climate change, more sand and gravel may be required to build foundation layers for roads.

The proportion of the total aggregate demand met by the net import of aggregates increased from 1% in 1988 to 2% in 2011. Behind these figures is a large increase in export and an even higher increase in import.

Taking this all into consideration, it is very difficult to forecast what proportion of each of these aggregate sources will contribute to the total consumption, in future. The most important factor is how the aggregate sources are able to compete in price and quality. Currently, the largest driver is the lack of designated land banks for aggregate production on-land, but the haulage distances have not yet reached a threshold where offshore produced aggregates are able to compete with on-land aggregate costs. As a consequence, the increasing trend in transport distances seems likely to continue in the future. However, increasing prices of transport by truck suggest that alternative transport options may need to be found, and adds to the attractiveness of increased dredging offshore, use of secondary and recycled materials or increased import, for example, from Norway.

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