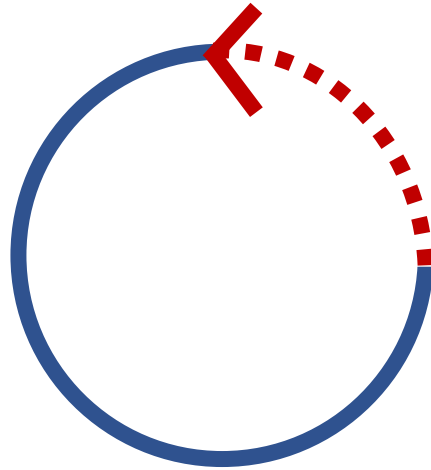
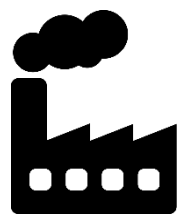
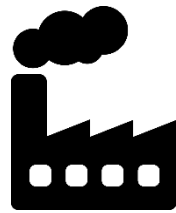


# How circular is Norway's BIOECONOMY ?



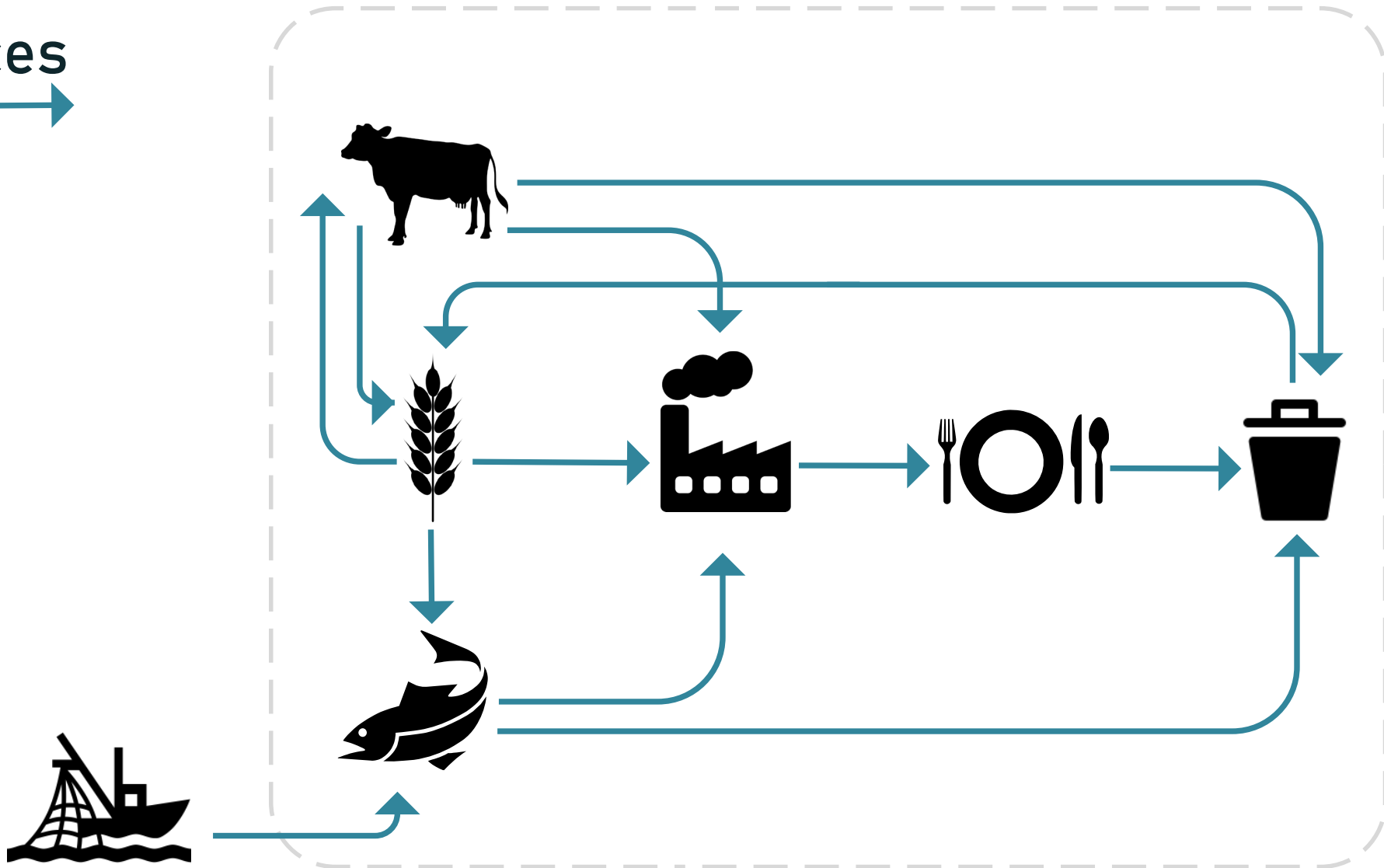




100%



Resources

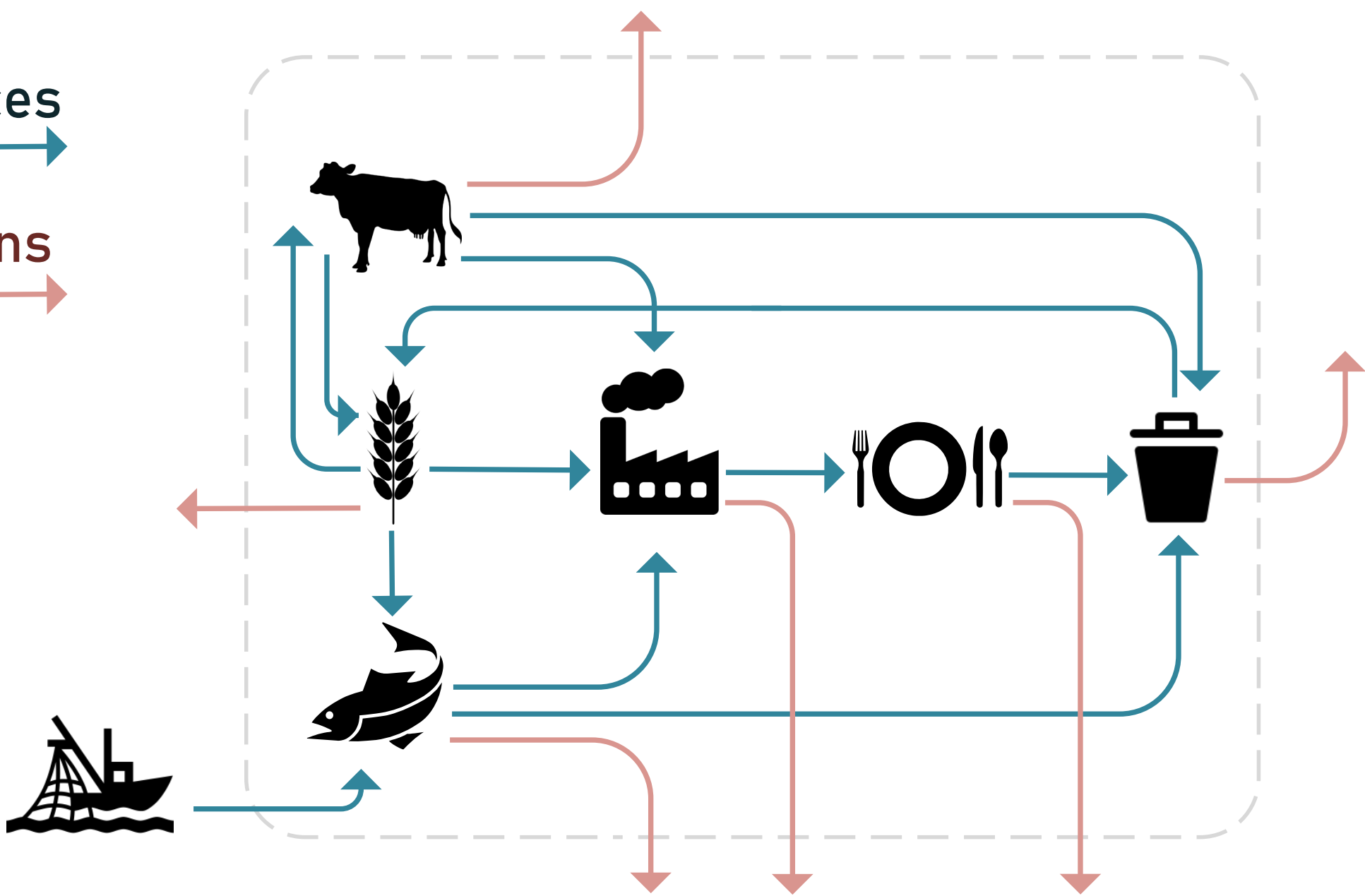




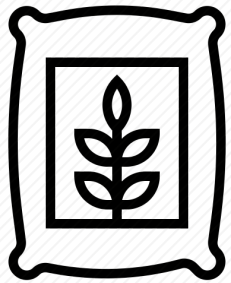
Resources



Emissions



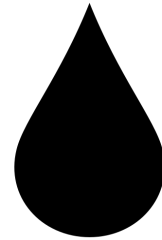
# Norwegian BIOECONOMY



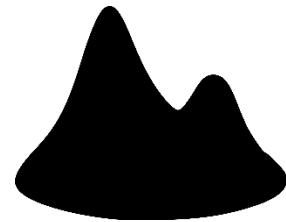
Nutrients



Energy



Water



Land

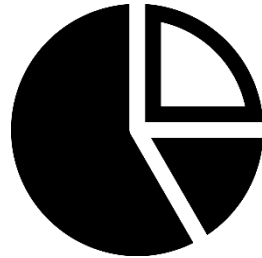
# Importance of Phosphorus



Critical  
Plant  
Nutrient

$P \neq N$

Irreplaceable



Limited



Underpins all  
food systems



Used  
Inefficiently

NO P = NO FOOD

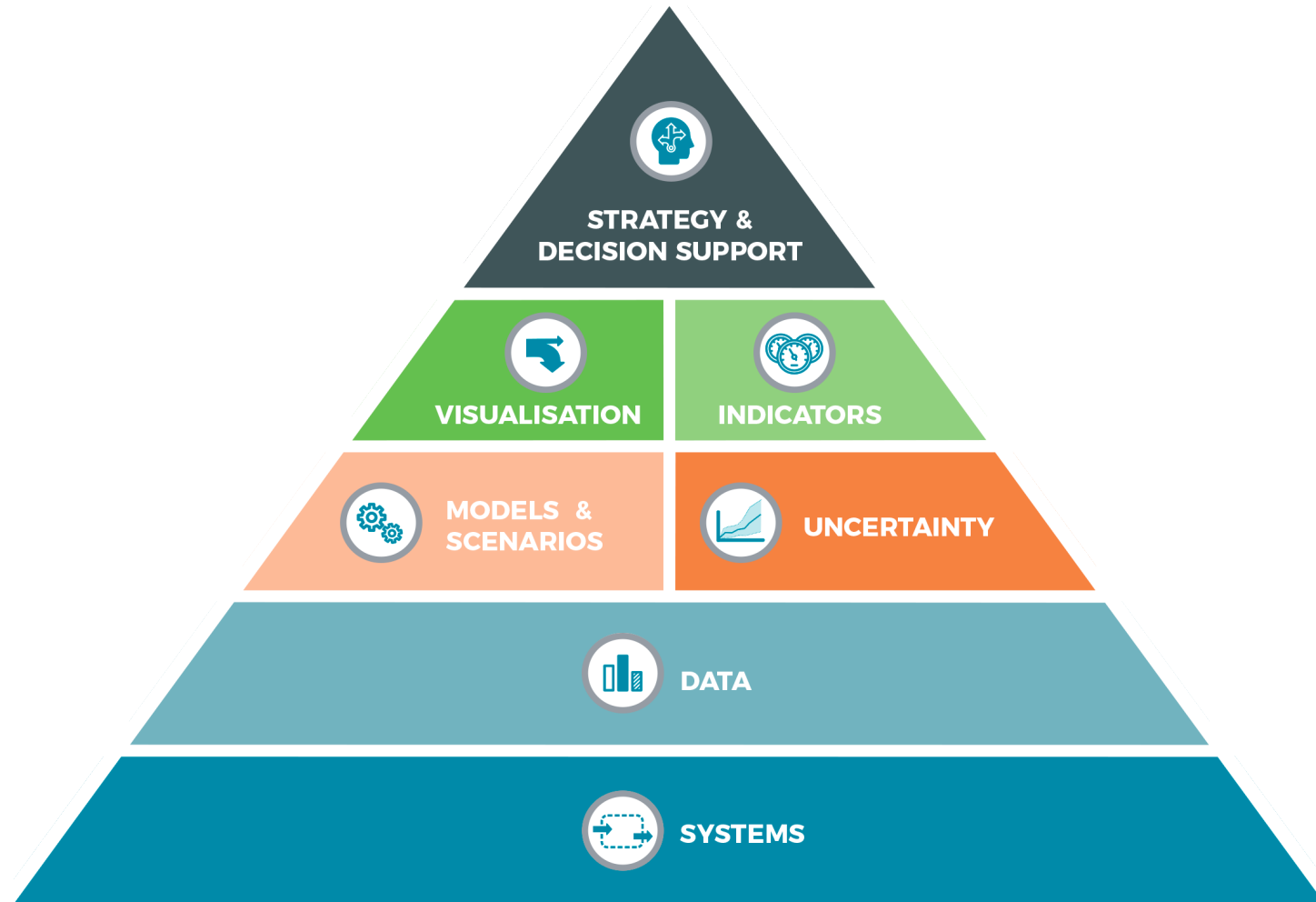
# Eutrophication



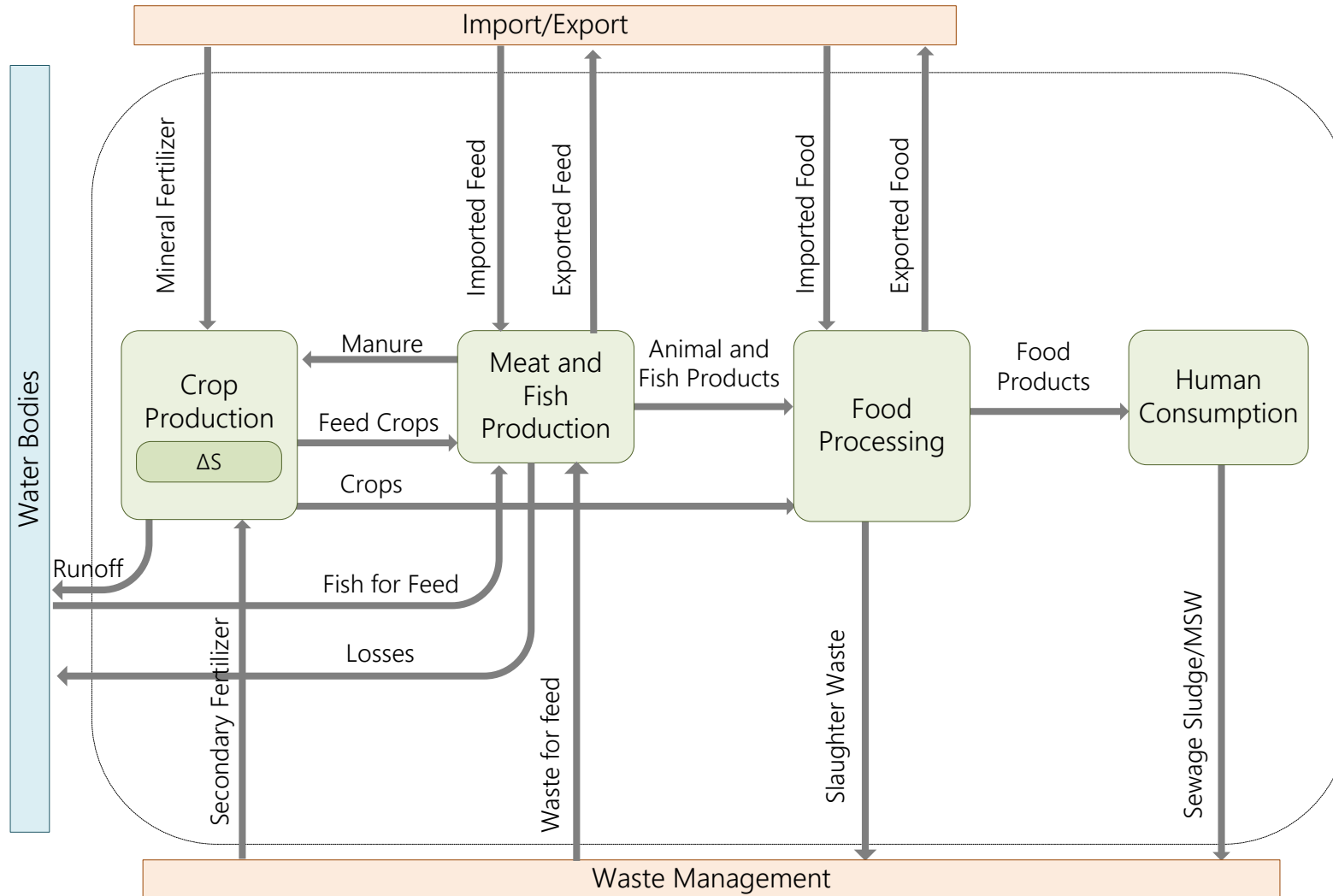
**Image Sources:** <https://serc.carleton.edu/microbelife/topics/deadzone/index.html> (top) <https://www.aftenposten.no/norge/i/K3G0M7/Havforskningsinstituttet--Oppdrett-har-ikke-skylden-for-algeoppblomstring> (bottom)



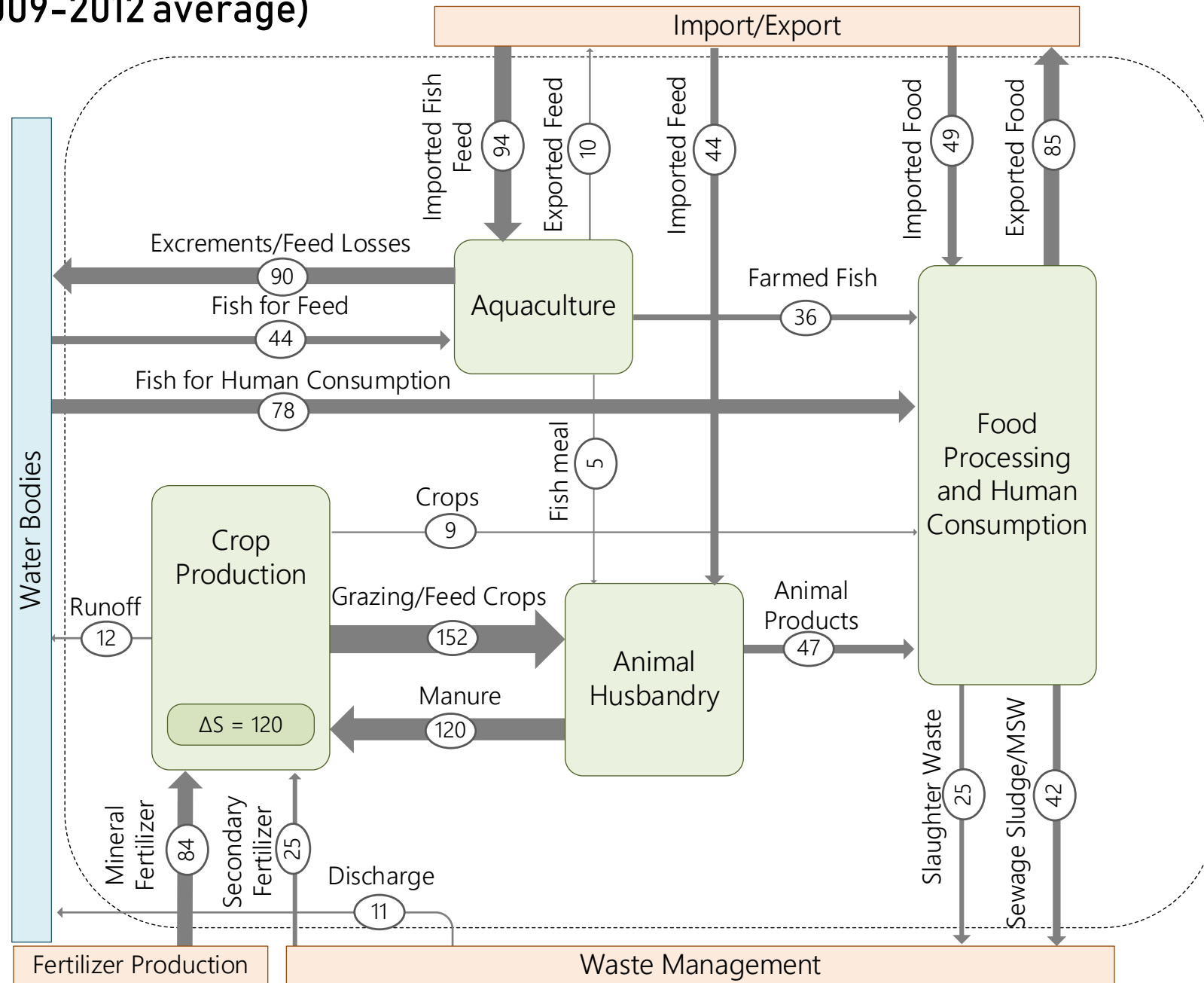
# Material Flow Analysis



# Norwegian Phosphorus Flow Analysis

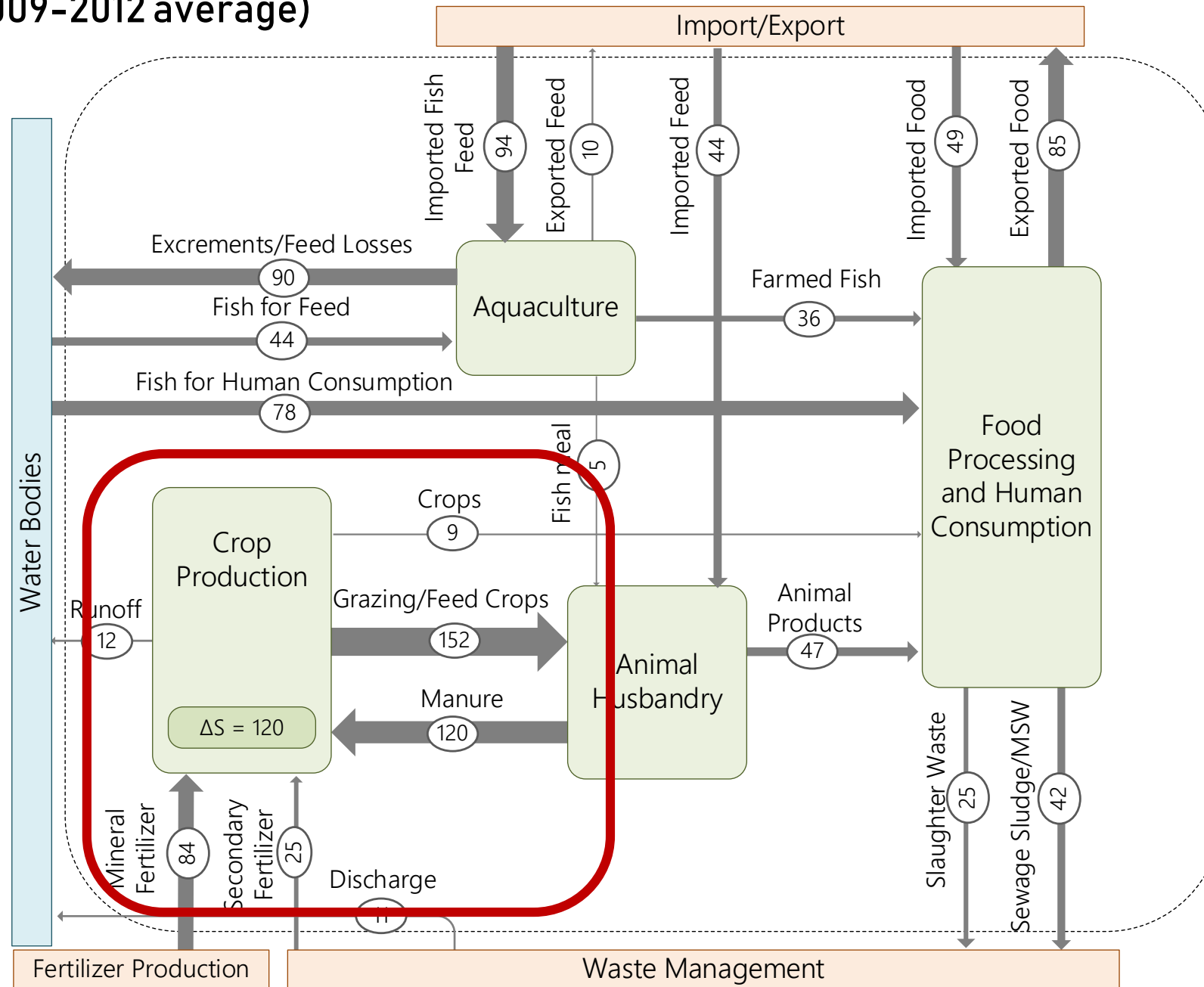


100 t P/yr (2009–2012 average)



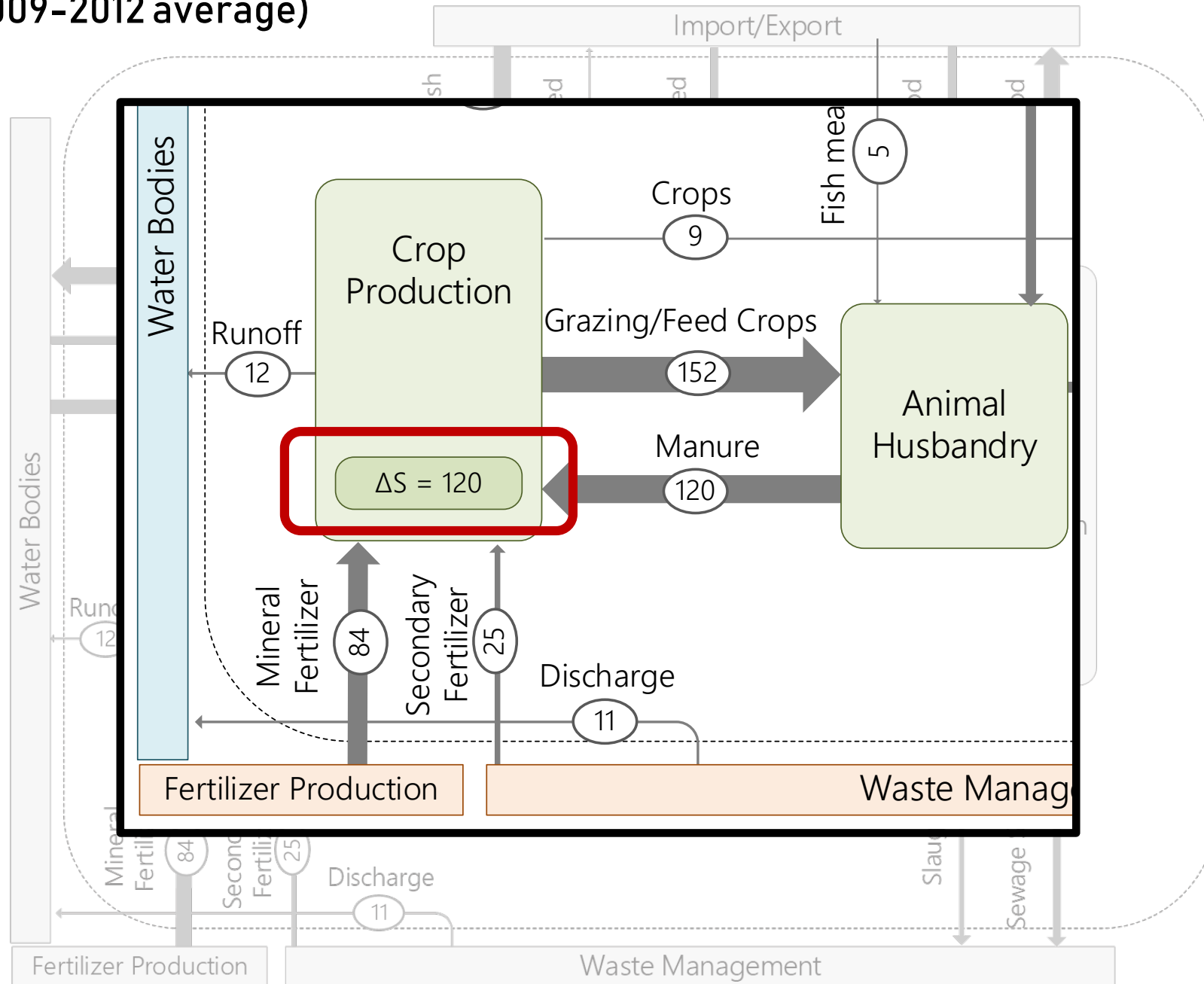
(Hamilton et al., 2016)

100 t P/yr (2009–2012 average)



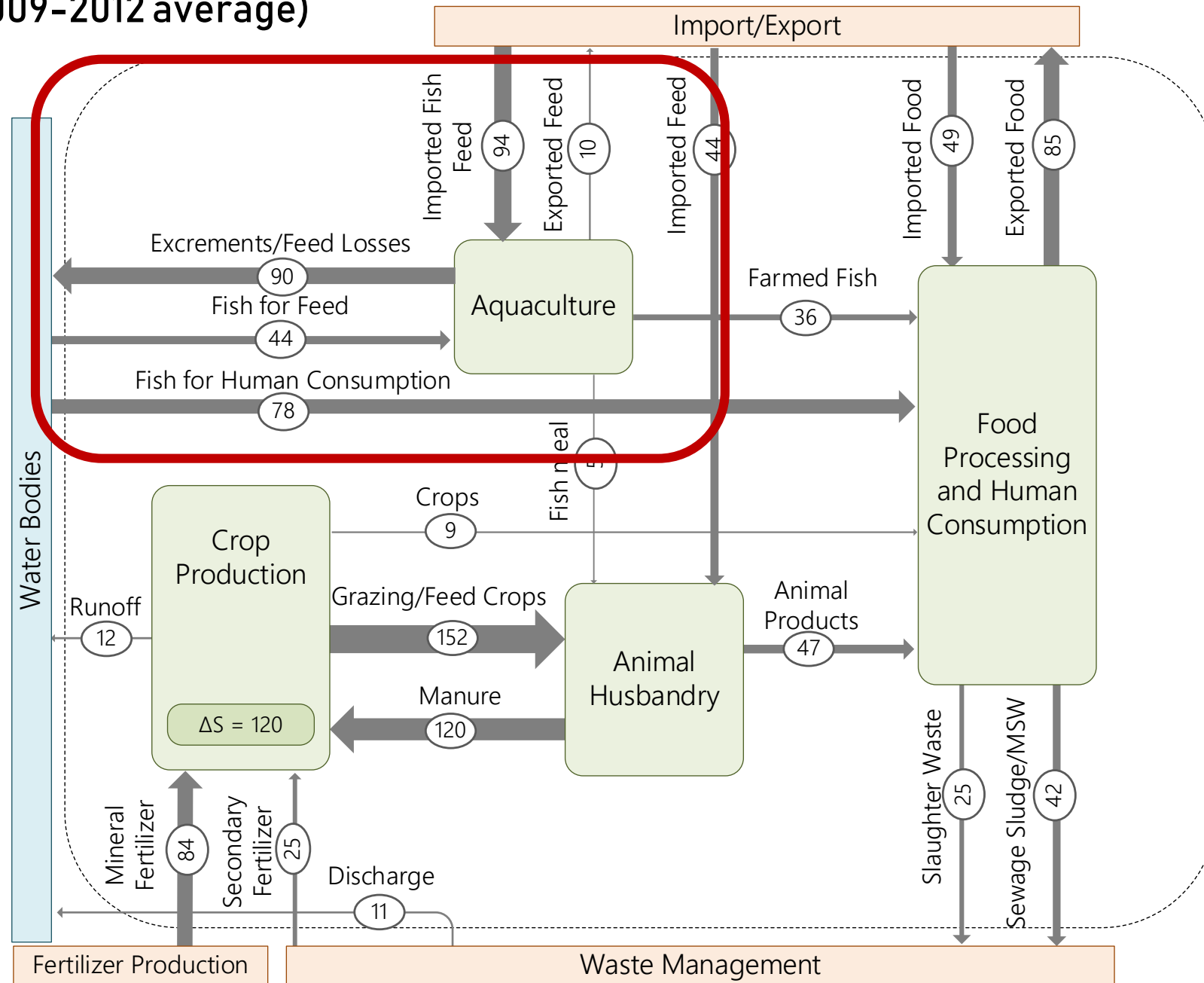
(Hamilton et al., 2016)

100 t P/yr (2009–2012 average)



(Hamilton et al., 2016)

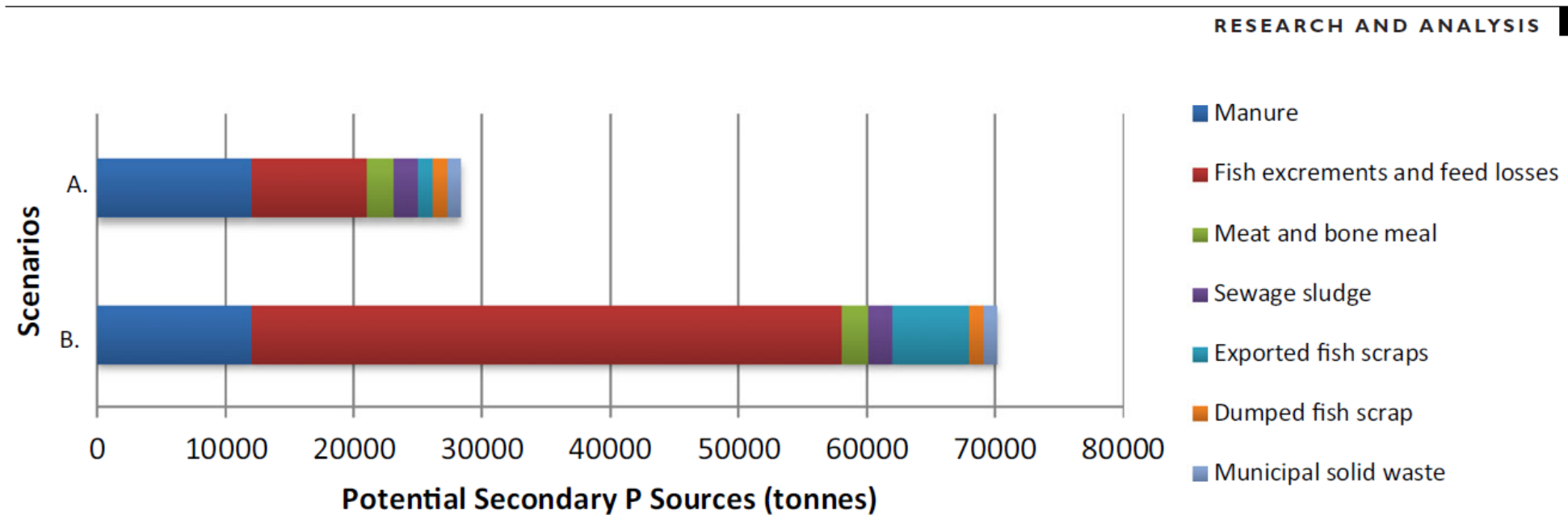
100 t P/yr (2009–2012 average)



2050?

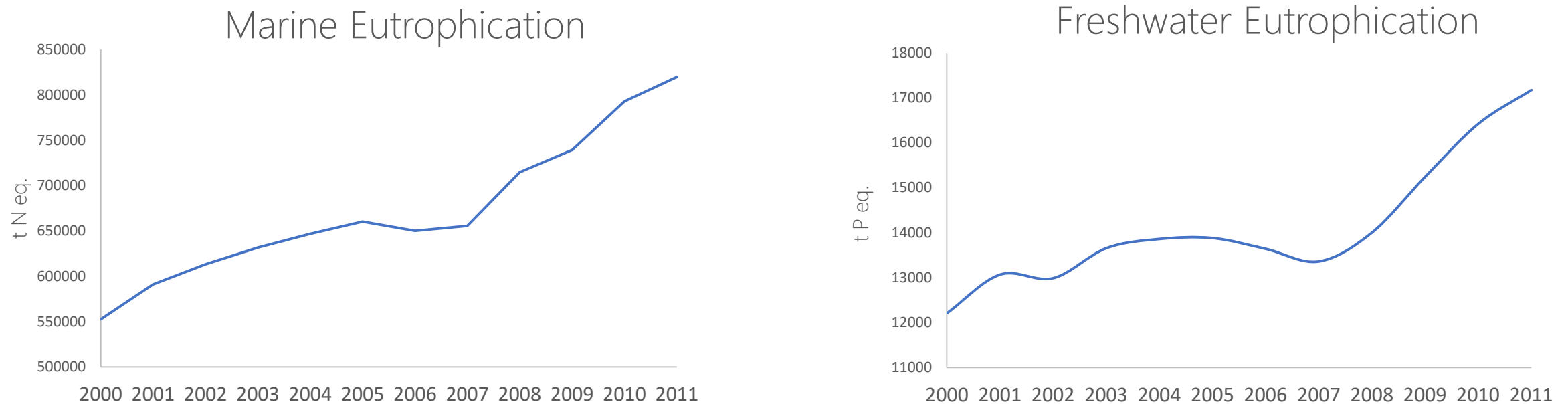
(Hamilton et al., 2016)

# Norwegian Secondary P Sources



**Figure 3** Potential secondary P sources for A. 2009–2011 and B. 2050 scenario in tonnes P.

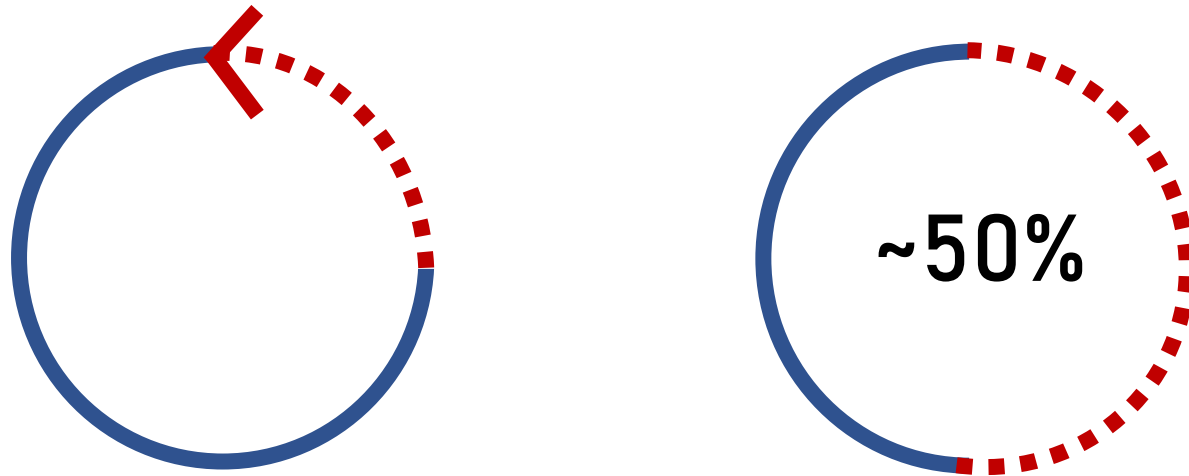
# Fisheries and Aquaculture Eutrophication Footprint



**Figure 1.** Global marine and freshwater eutrophication due to fisheries and aquaculture (Source: Hamilton et al., 2018, Nature Sustainability)

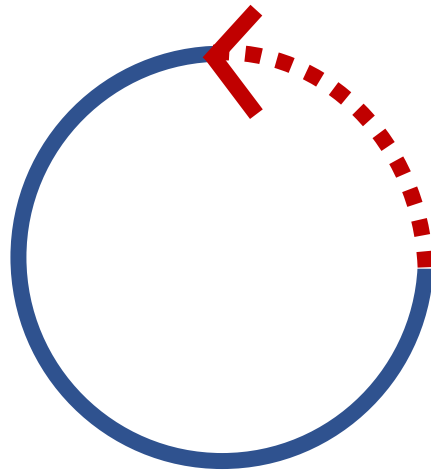


# How circular is Norway's BIOECONOMY ?



[in terms of phosphorus]

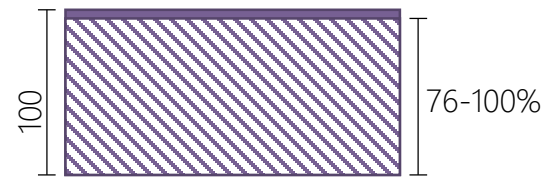
Is circular always better?





# Plant Availability

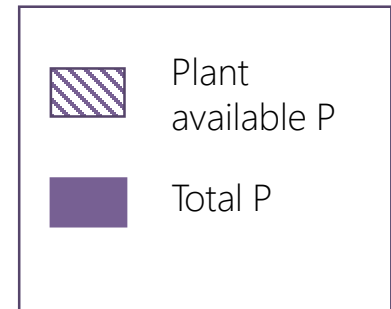
Manure



Fish Scrap



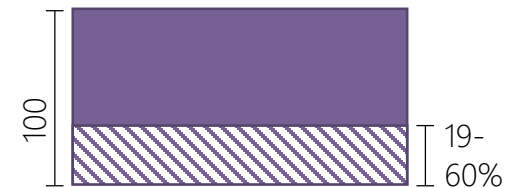
Sewage sludge



Fish excrements and feed losses



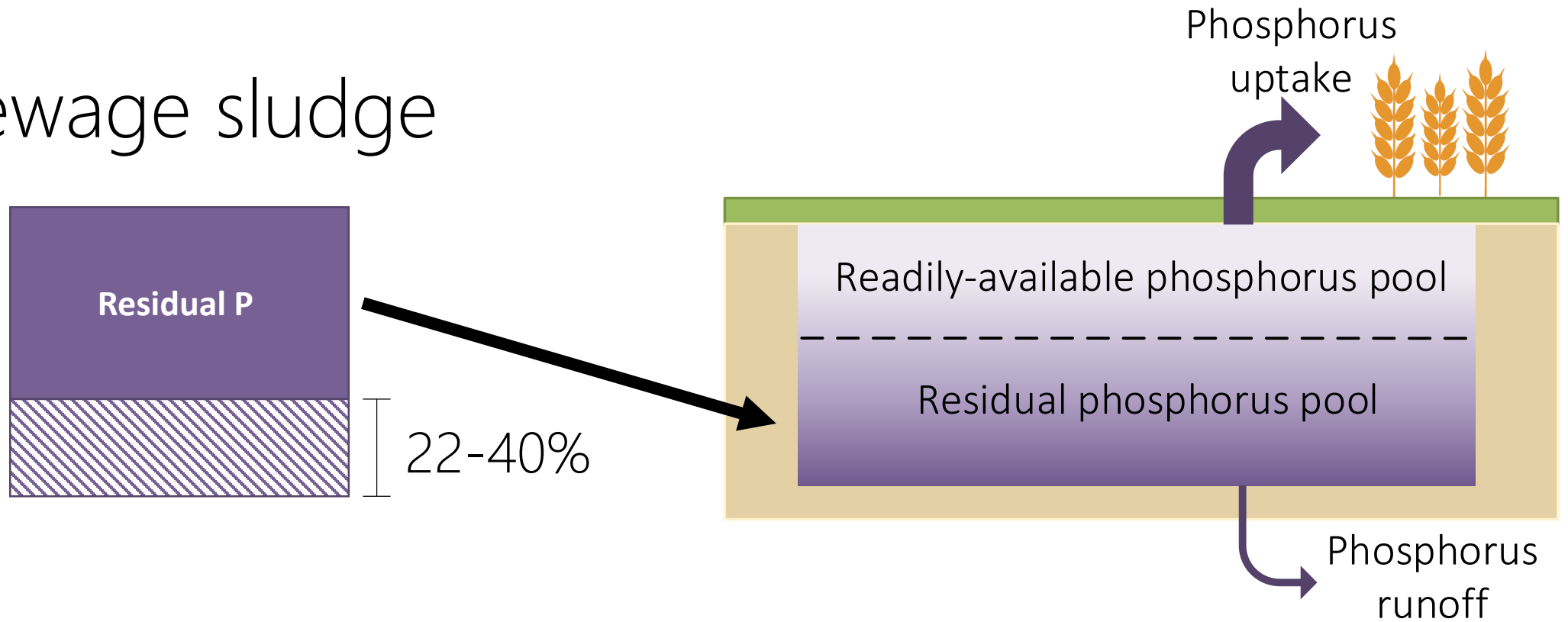
Meat bone meal



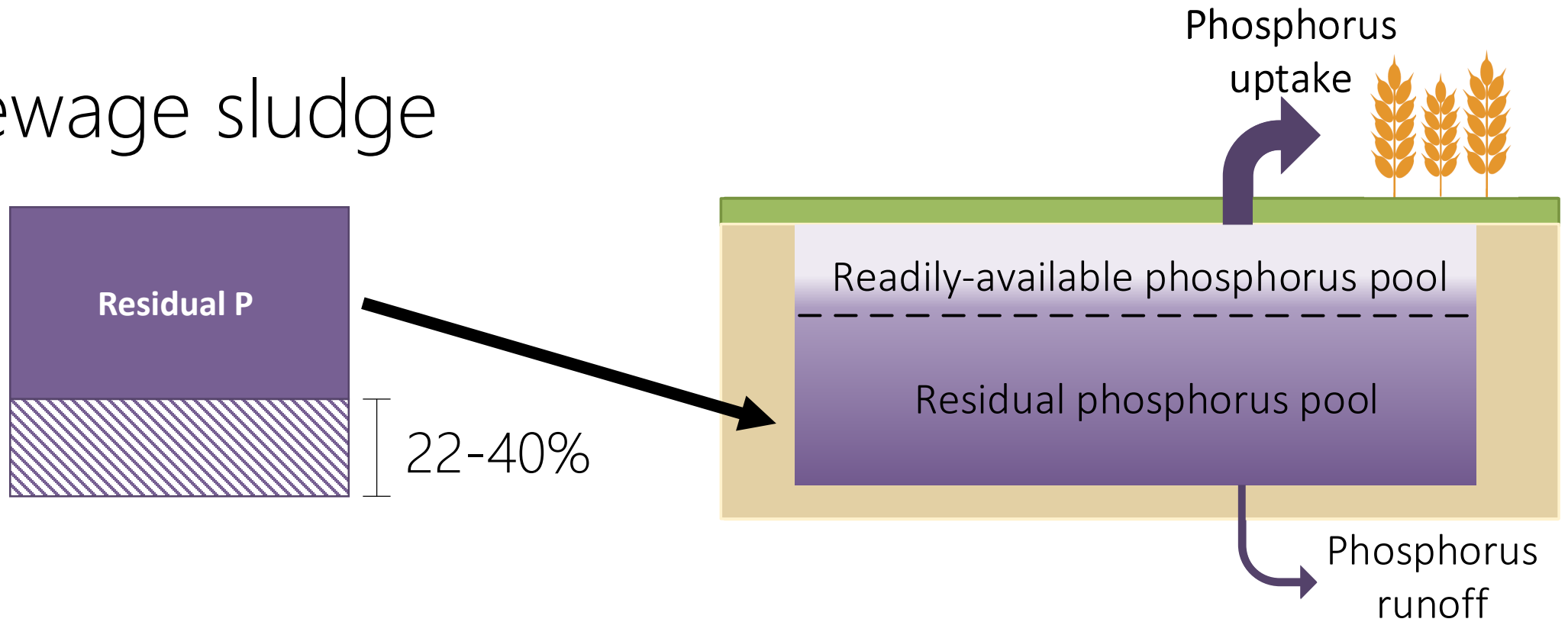
Food waste



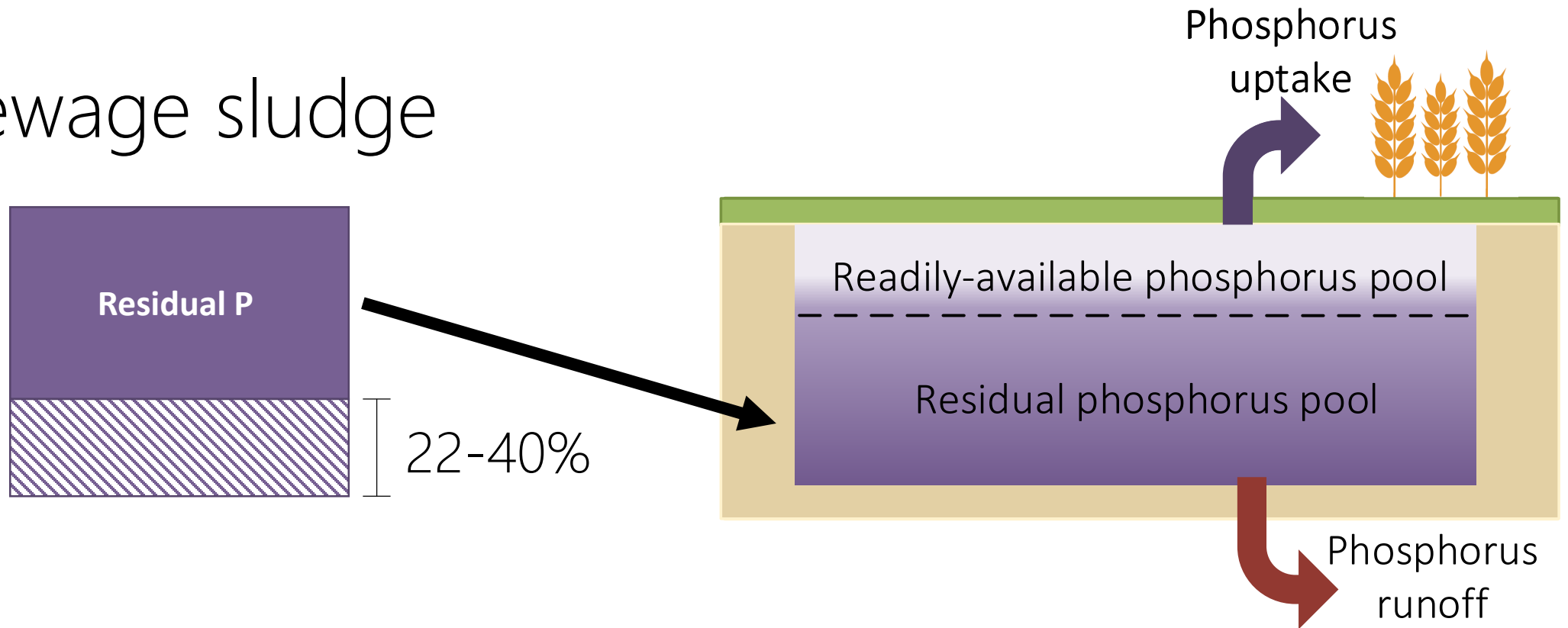
# Sewage sludge



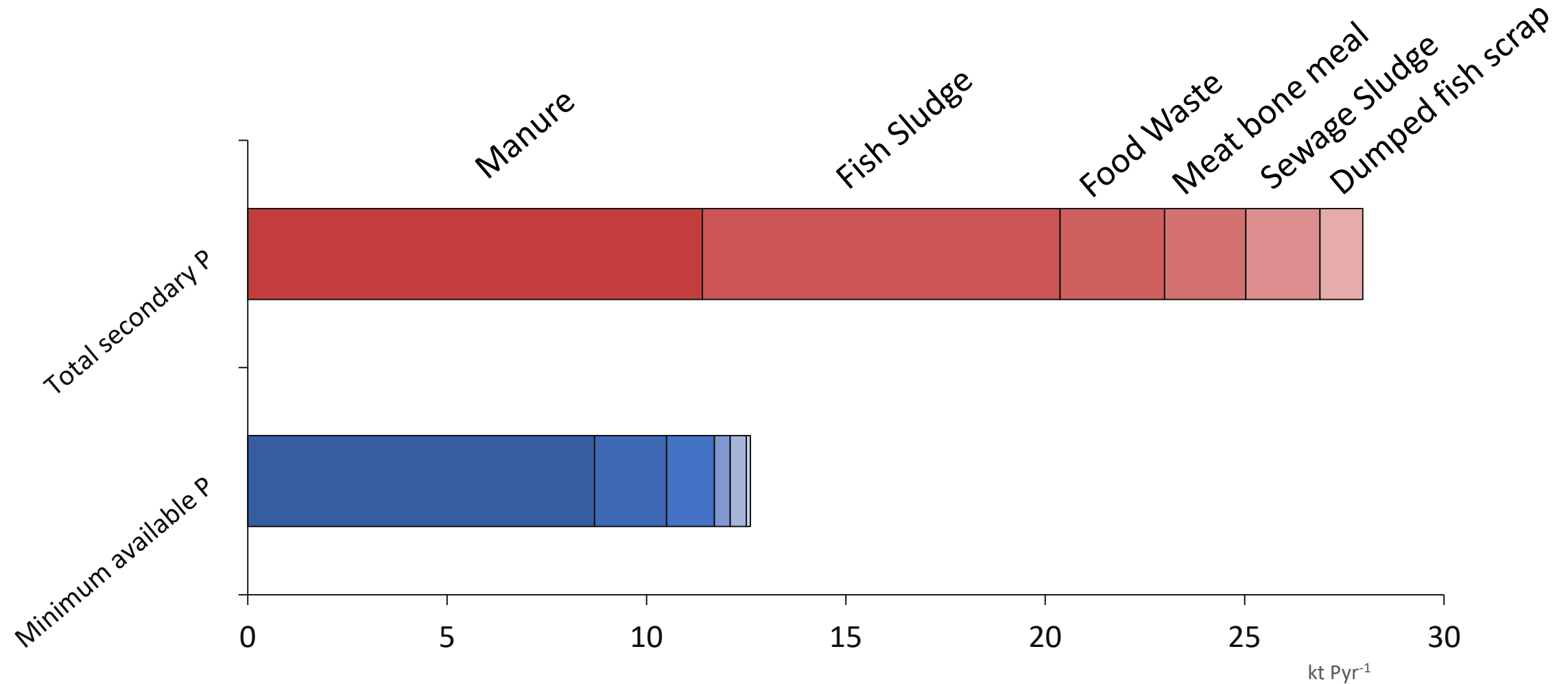
# Sewage sludge



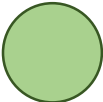

# Sewage sludge

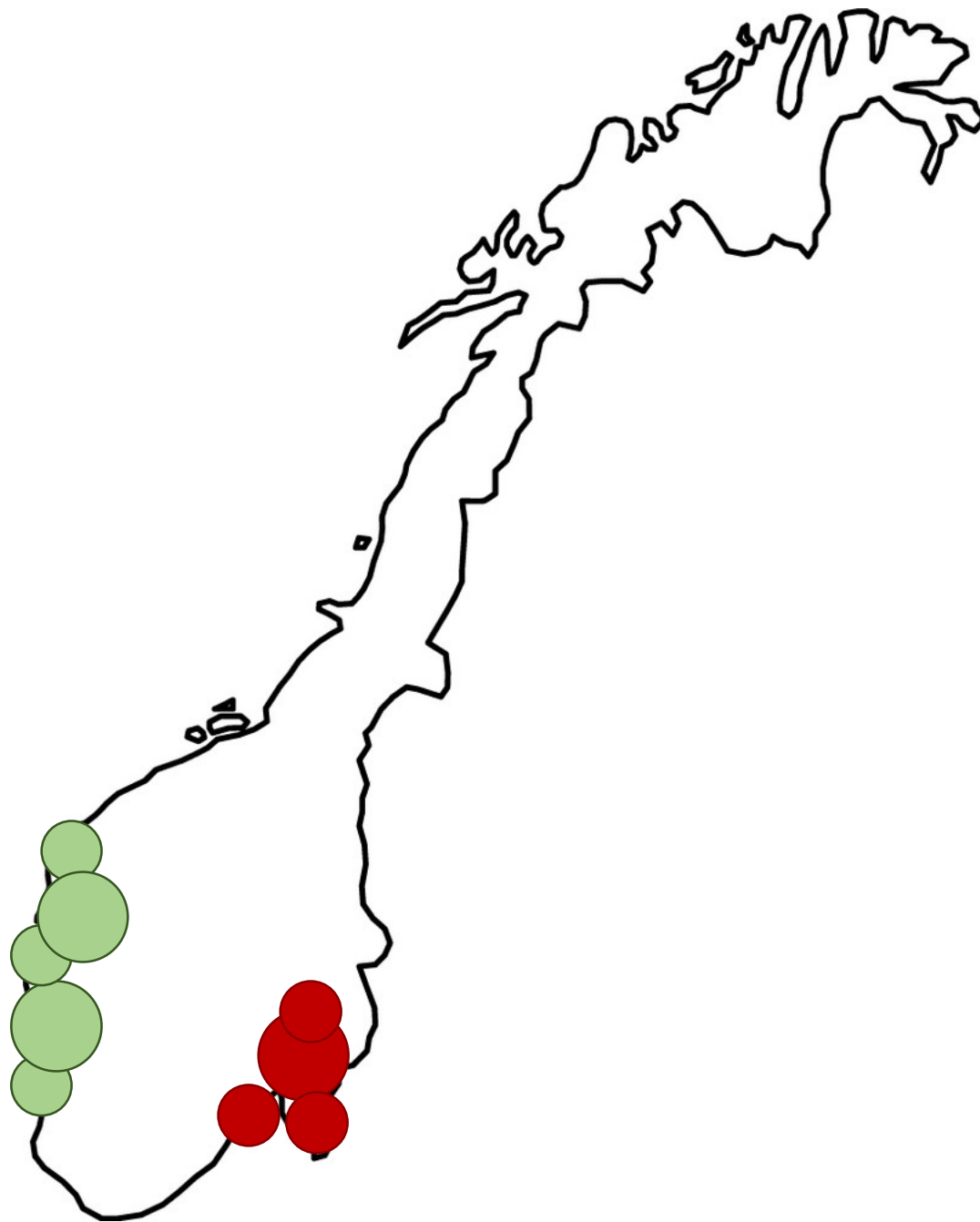


# Norway's Secondary P Potential



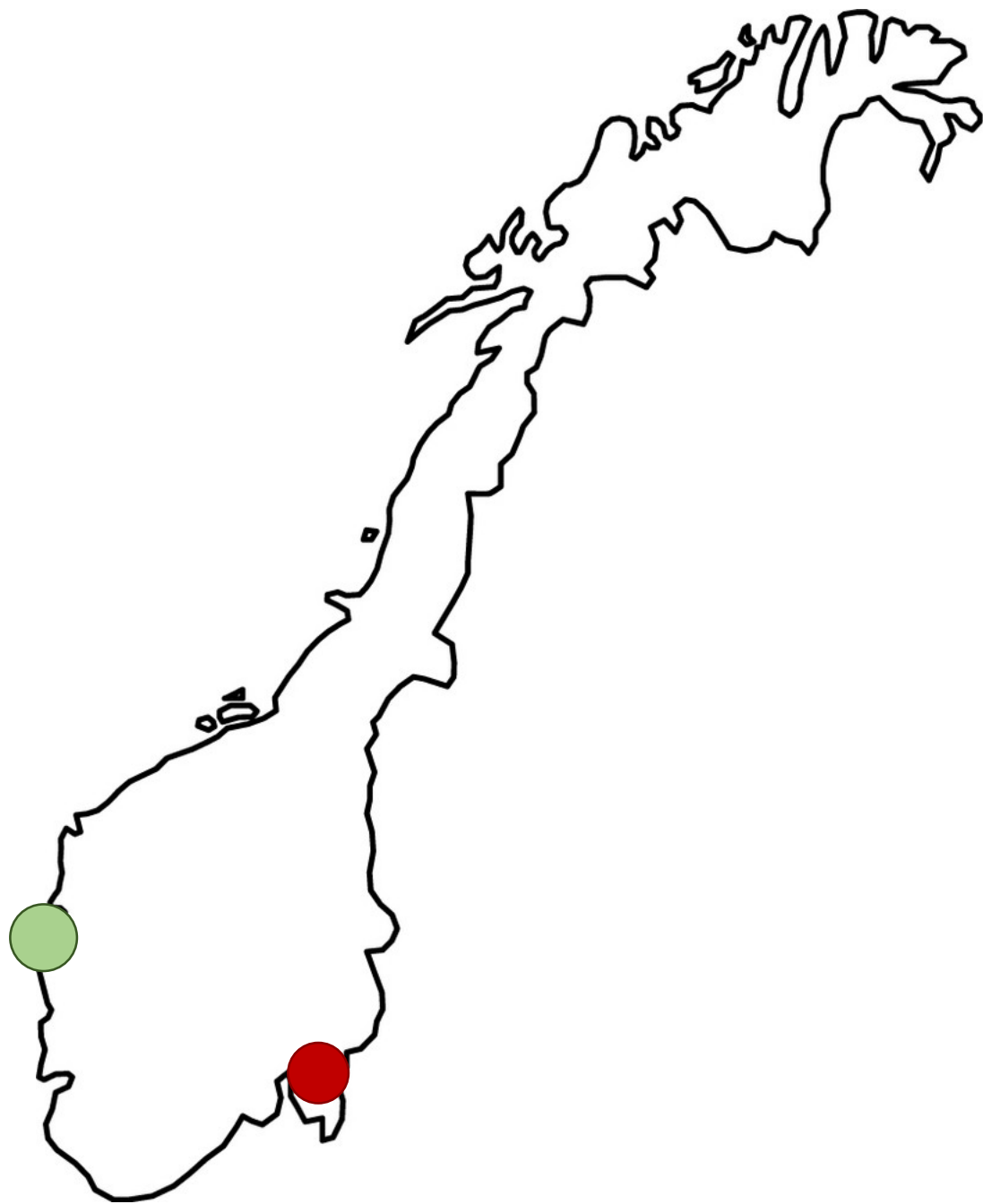
(Hamilton et al., 2017)

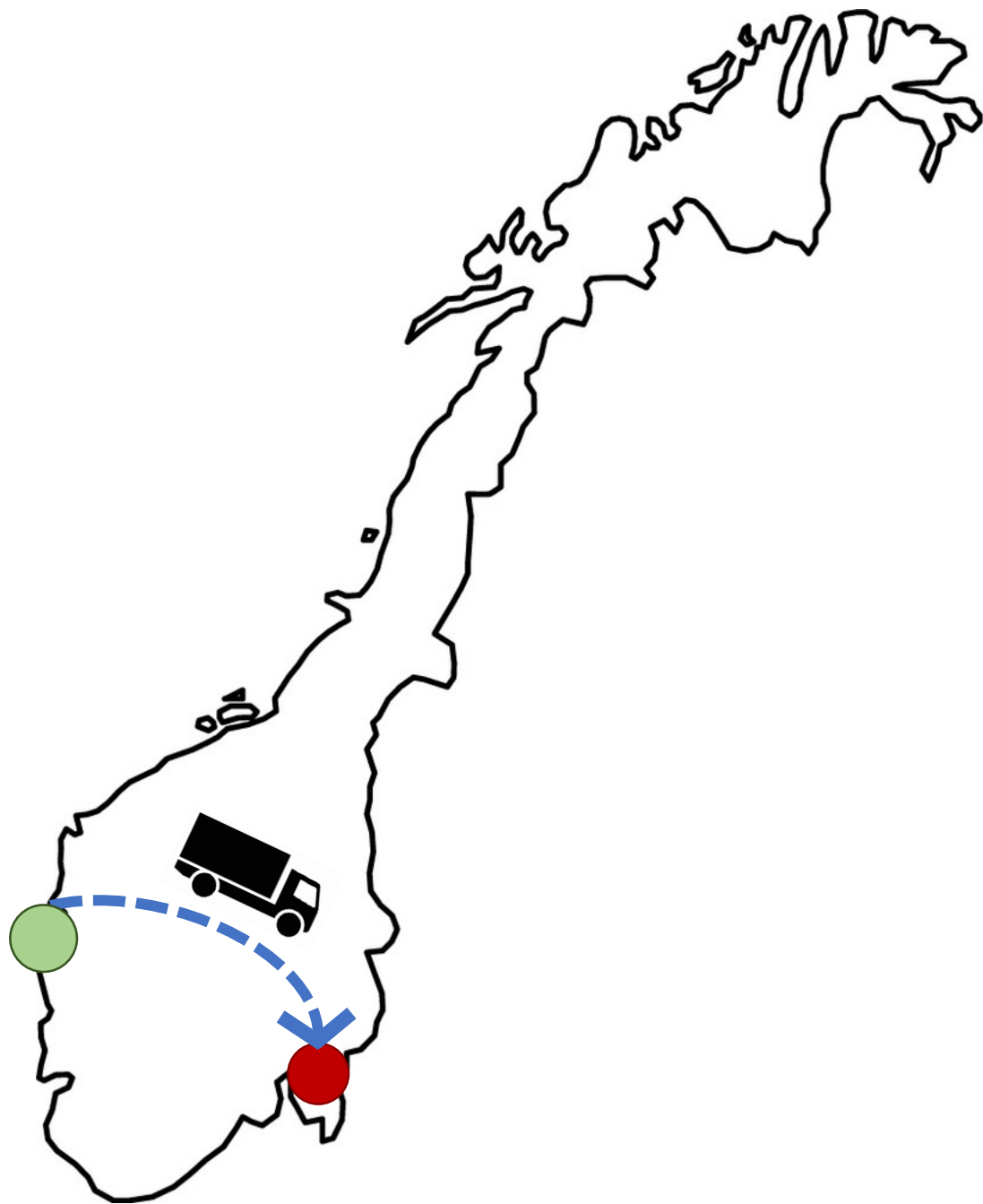
-  P Supply
-  P Demand

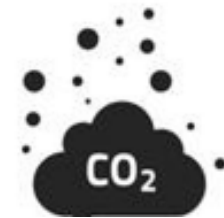
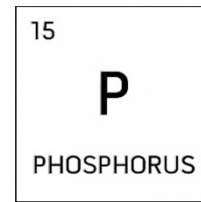
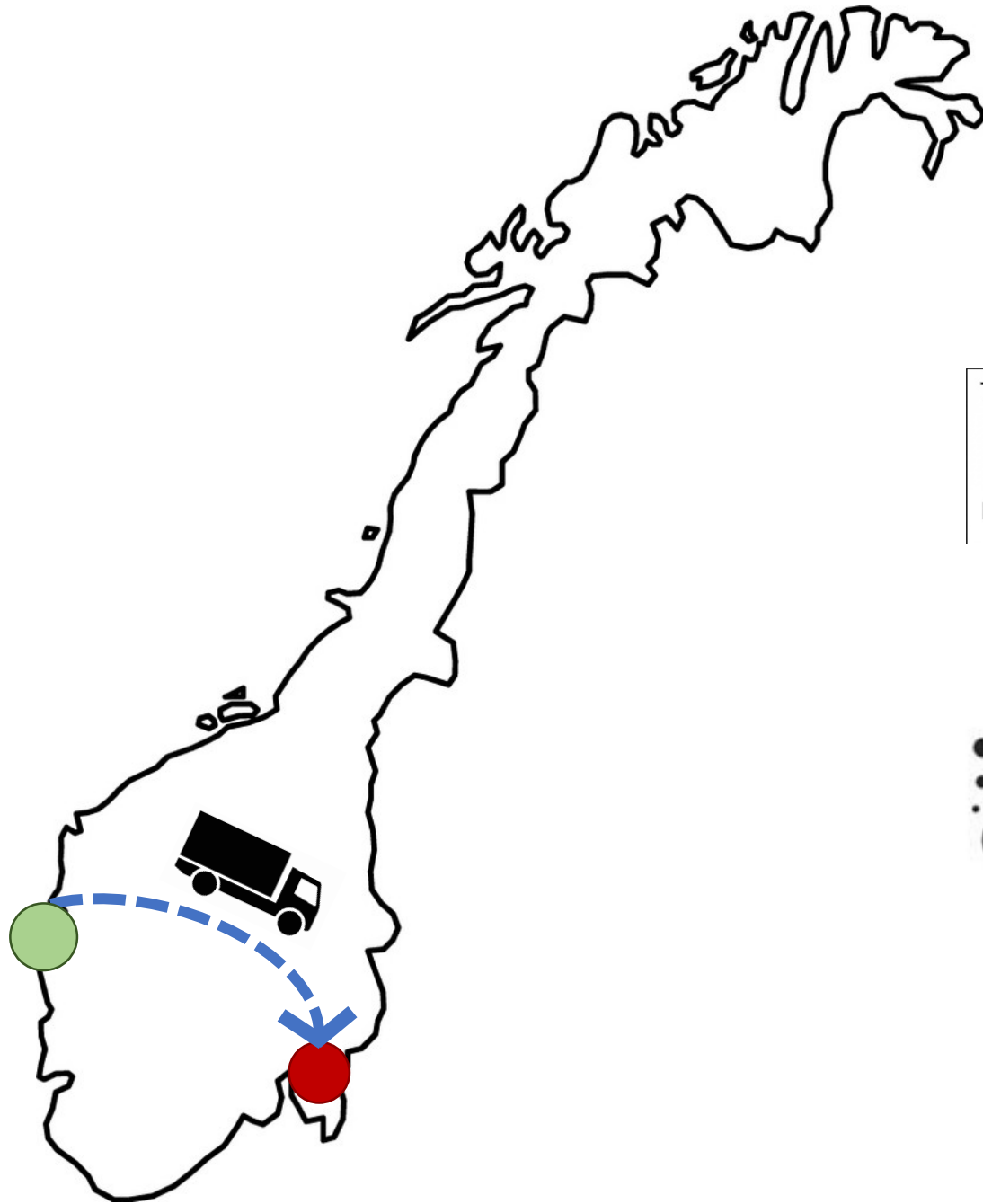


(Hansrud et al., 2015)



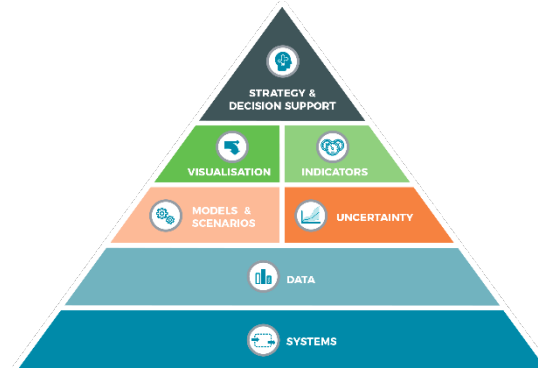
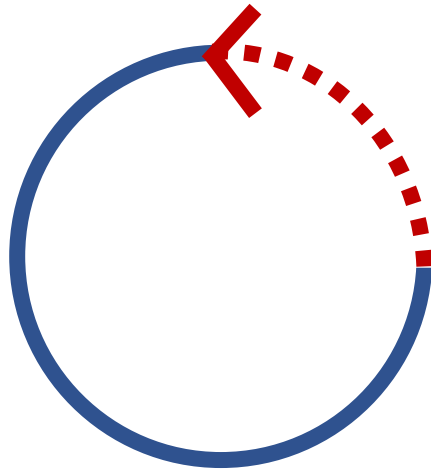








# Means to an end



 **SUSTAINABLE DEVELOPMENT GOALS**



# Thank you for your attention

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Industrial Ecology Programme

Norwegian University of Science and Technology

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NTNU Industrial Ecology

# Helen Ann Hamilton, Ph.D

## Sources:

**Hamilton, Helen Ann;** Ivanova, Diana; Stadler, Konstantin; Merciai, Stefano; Schmidt, Jannick; Van Zelm, Rosalie; Moran, Daniel; Wood, Richard. (2018) Trade and the role of non-food commodities for global eutrophication. *Nature Sustainability*. vol. 1 (6)

**Hamilton, Helen Ann;** Brod, Eva; Hanserud, Ola Stedje; Müller, Daniel Beat; Brattebø, Helge; Haraldsen, Trond. (2017) Recycling potential of secondary phosphorus resources as assessed by integrating substance flow analysis and plant-availability. *Science of the Total Environment*. vol. 575.

**Hamilton, Helen Ann;** Brod, Eva; Hanserud, Ola Stedje; Gracey, Erik Olav; Vestrum, Magnus Inderberg; Bøen, Anne; Steinhoff, Franciska Senta; Müller, Daniel Beat; Brattebø, Helge. (2016) Investigating cross-sectoral synergies through integrated aquaculture, fisheries and agriculture phosphorus assessments: A case study of Norway. *Journal of Industrial Ecology*. vol. 20 (4).

**Hamilton, Helen Ann;** Peverill, M. Samantha; Müller, Daniel Beat; Brattebø, Helge. (2015) Assessment of food waste prevention and recycling strategies using a multi-layer systems approach. *Environmental Science and Technology*. vol. 49.

Hanserud, Ola; E. Brod, A.F. Øgaard, D.B. Müller and H. Brattebø. (2016) A multi-regional soil phosphorus balance for exploring secondary fertilizer potential: the case of Norway. *Nutrient Cycling in Agroecosystems*. Vol 104.

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