



Mineral Fertiliser **IN**dependence
for **P**hosphorus in Norway

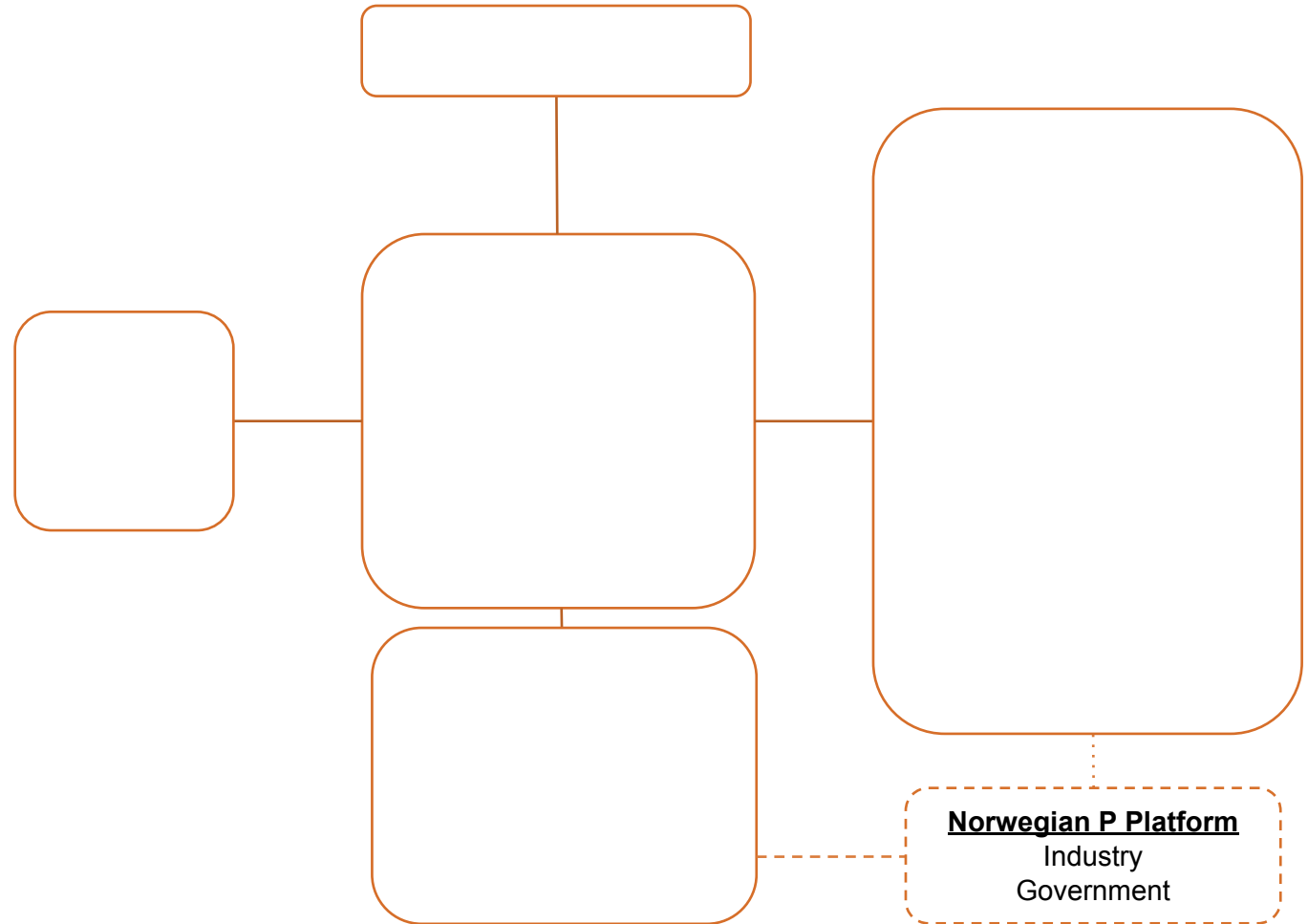
Kan Norge bli uavhengig av importert fosfor i 2030?

Daniel B. Müller and Helen Hamilton



MIND-P

- Finansiering: NFR - BIONÆR
- 9.9 million NOK
- Periode: 2007-2020



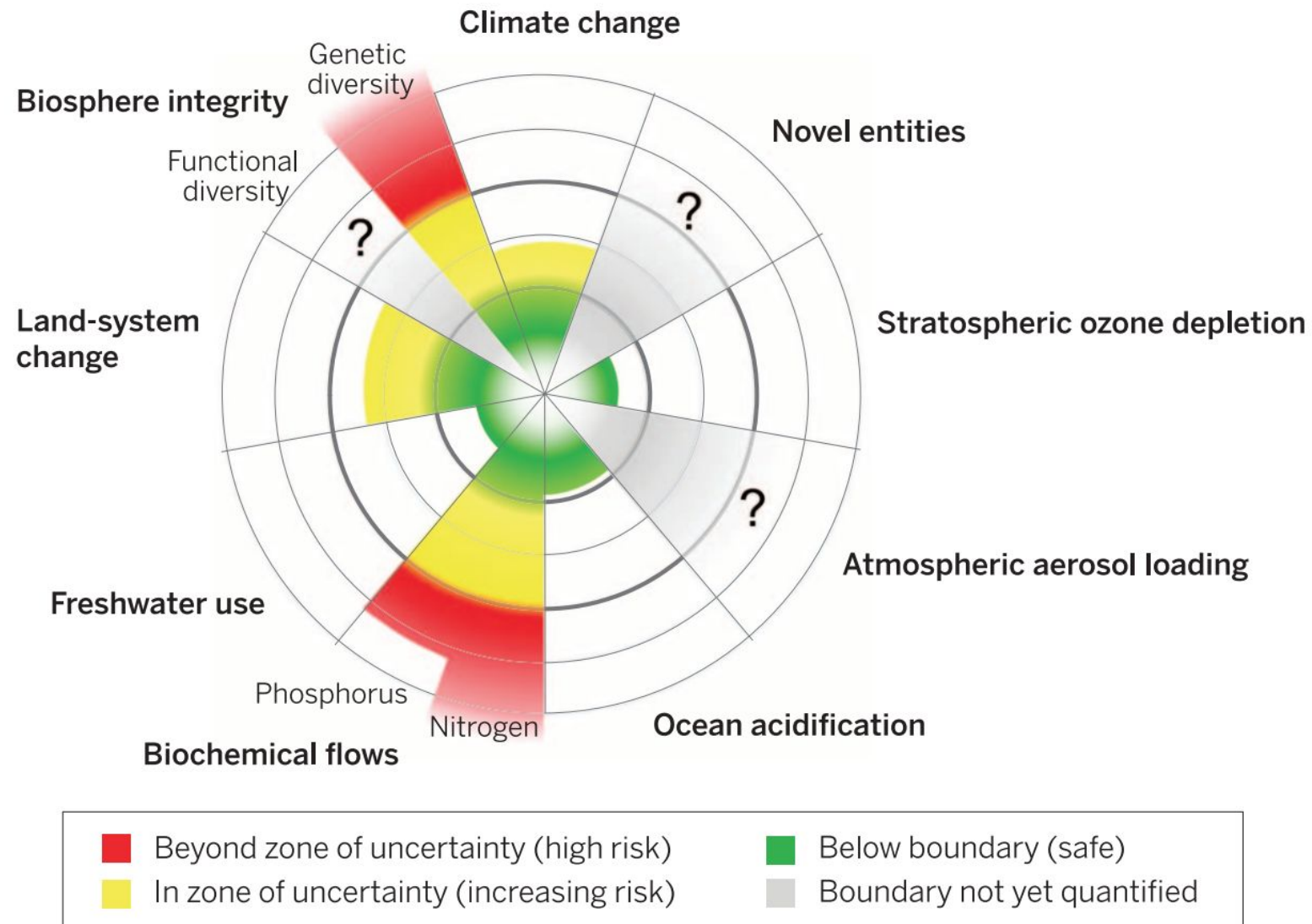
Relevans af fosfor 80 år siden



“I cannot overemphasize the importance of Phosphorus – not only to agriculture and soil conservation, but also to the physical health and economic security of the people of the nation.”

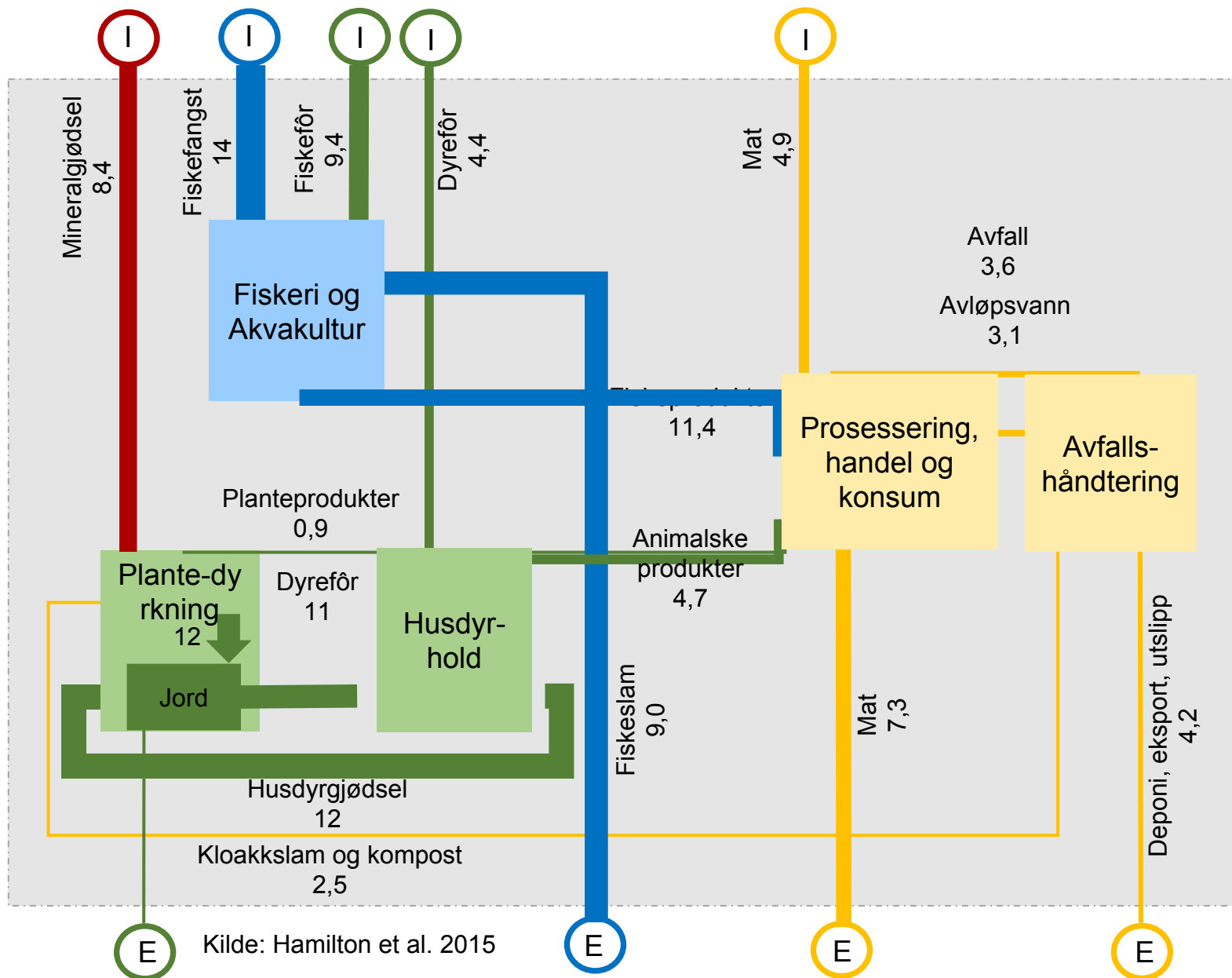
Franklin D. Roosevelt (1938)

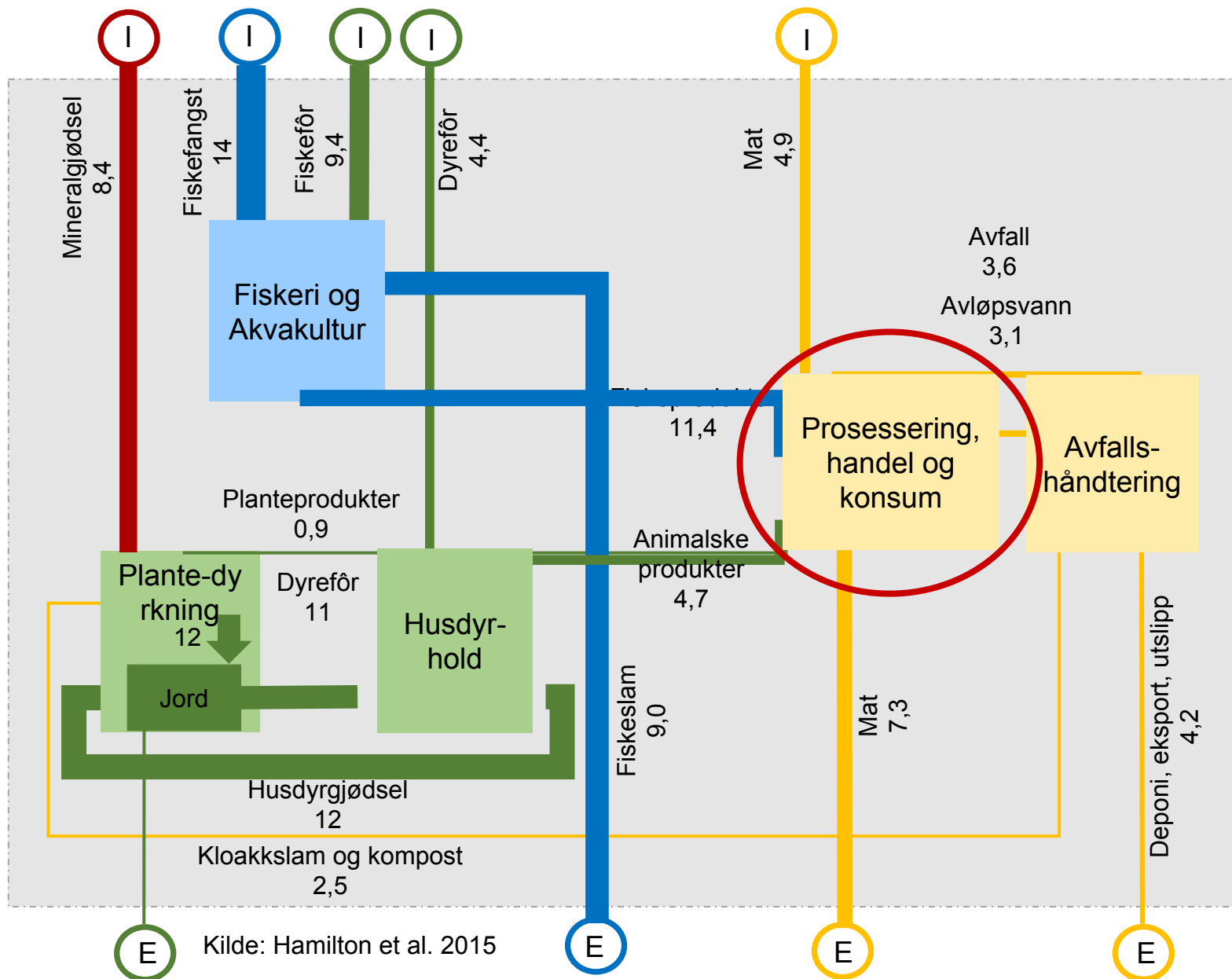
Relevans av fosfor i dag: Planetary boundaries



P-syklus i Norge

(kt/år, mellomsnitt 2009-2011)





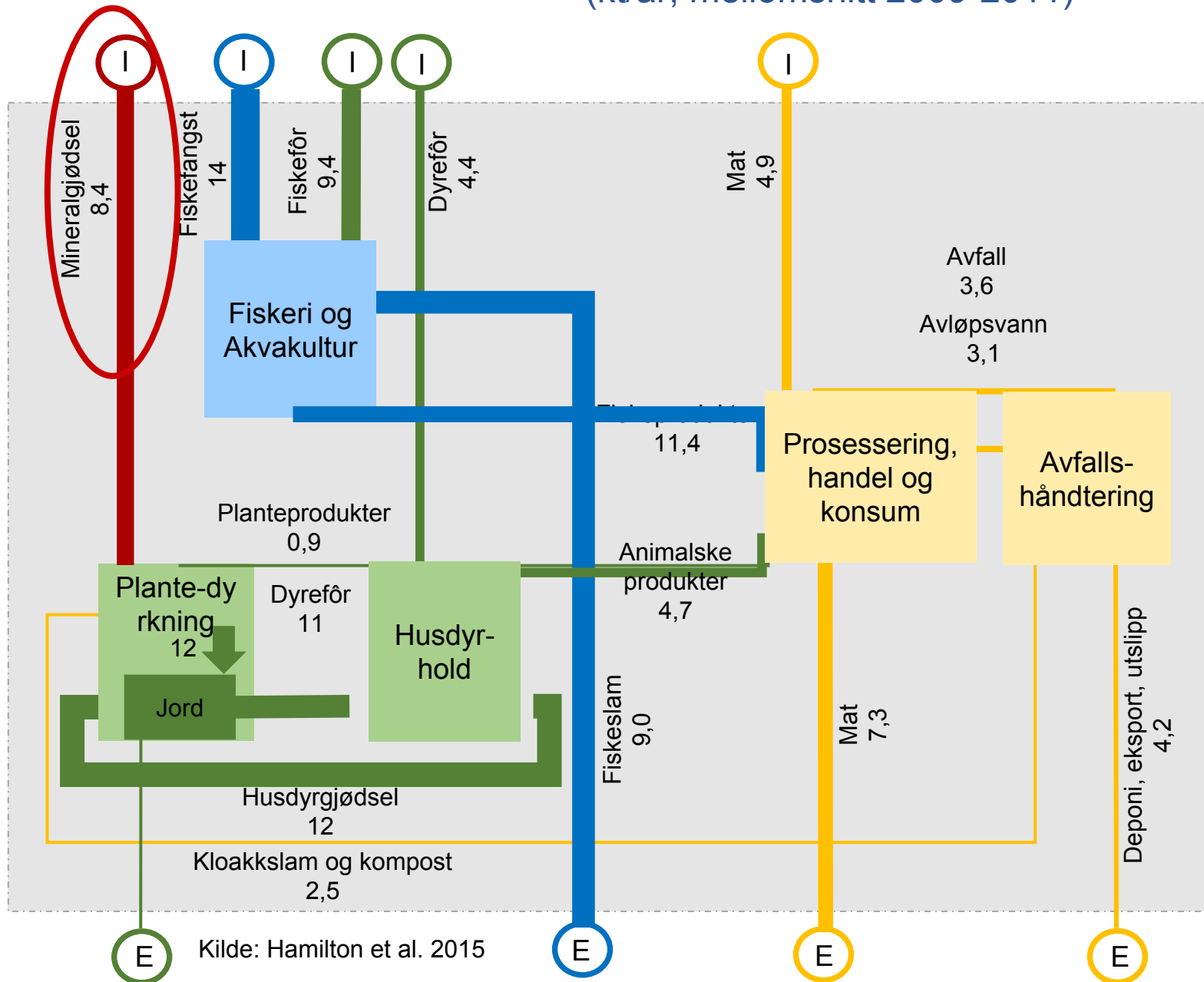
1. P er essensiell for livet
→ ingen erstatning!



- Genetisk kode (DNA)
- Energi (ATP)
- Tenner
- Bein
- ...

Utfordringer med P-syklus i Norge

(kt/år, mellomsnitt 2009-2011)

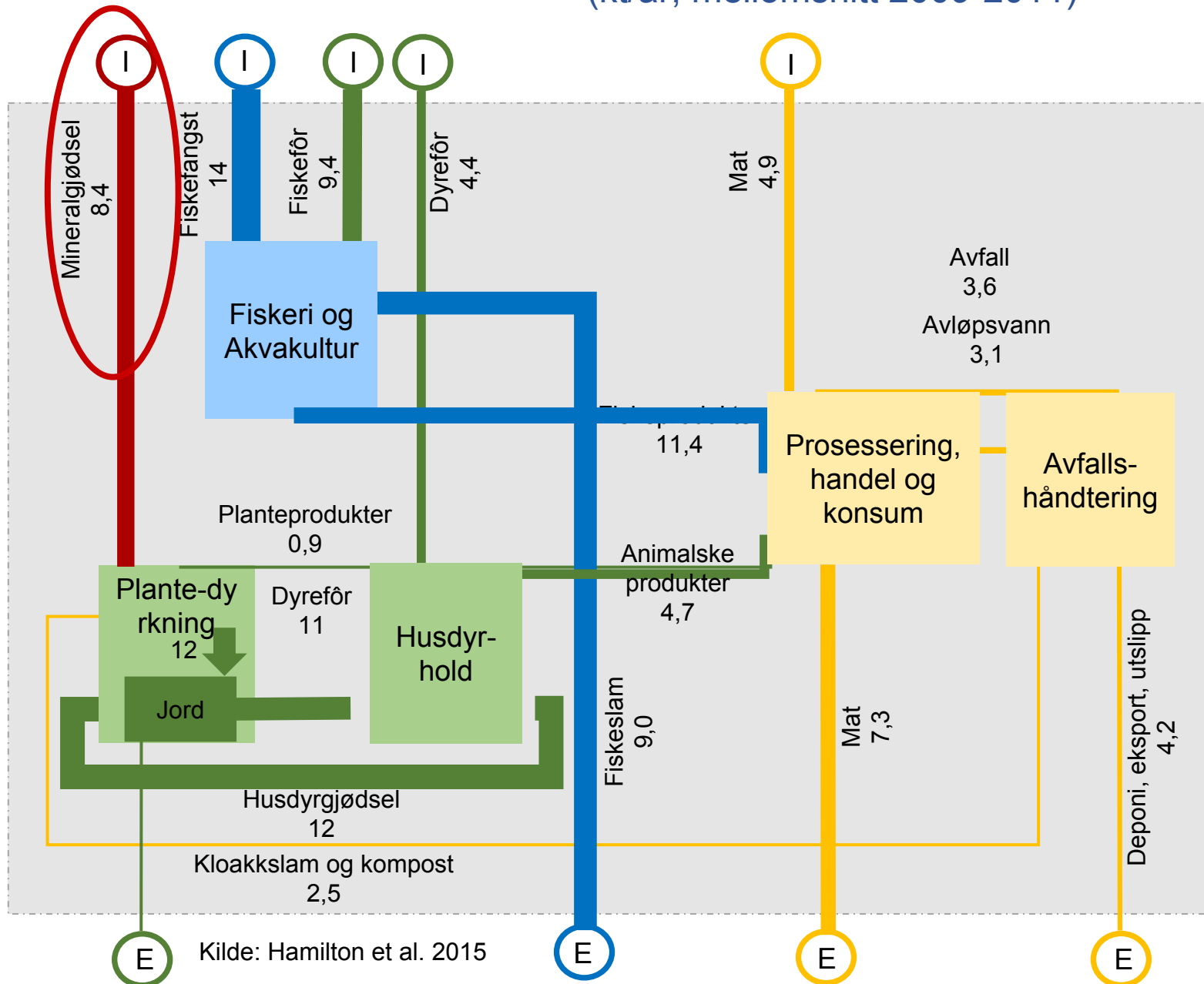


1. P er essensiell for livet
→ ingen erstatning!
2. Høy-kvalitet primære P kilder (fosfatstein) er begrenset

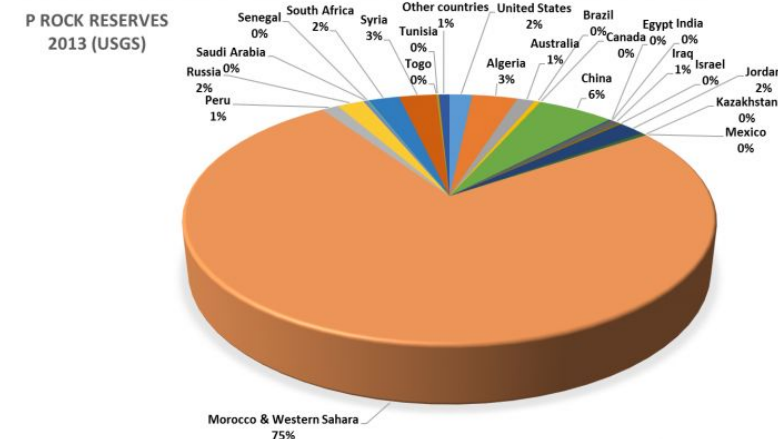


Utfordringer med P-syklus i Norge

(kt/år, mellomsnitt 2009-2011)



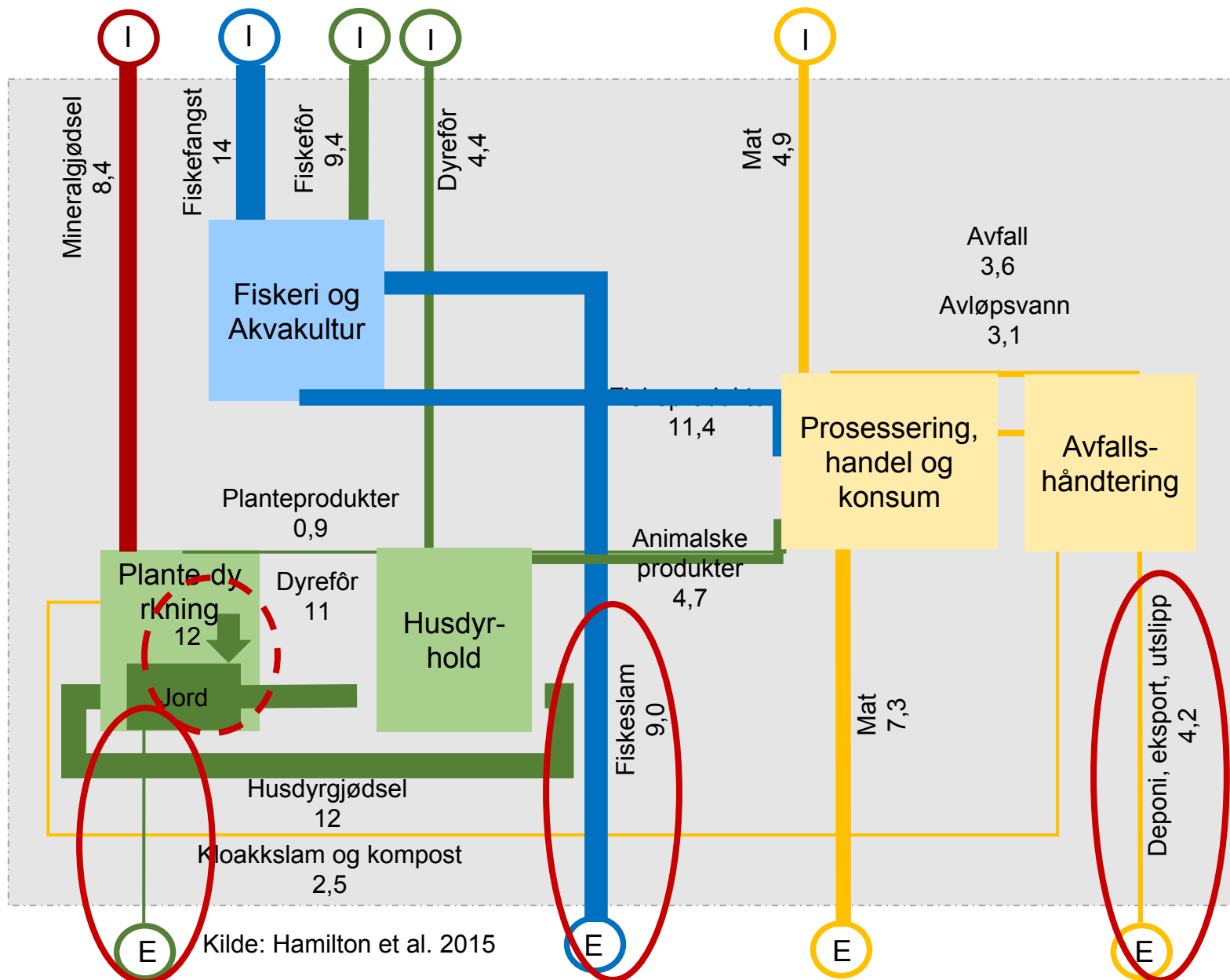
1. P er essensiell for livet
→ ingen erstatning!
2. Høy-kvalitet primære P kilder (fosfatstein) er begrenset
3. Globale fosfatsteinreserver er konsentrert i Marokko og Vest-Sahara (ca. 75%)
→ I dag: konflikt Saharawi
→ Fare: monopol / pris / hungersnød



Sammenligning:
OPEC består av 14 land som kontrollerer 81,5% av de globale oljereserver

Utfordringer med P-syklus i Norge

(kt/år, mellomsnitt 2009-2011)

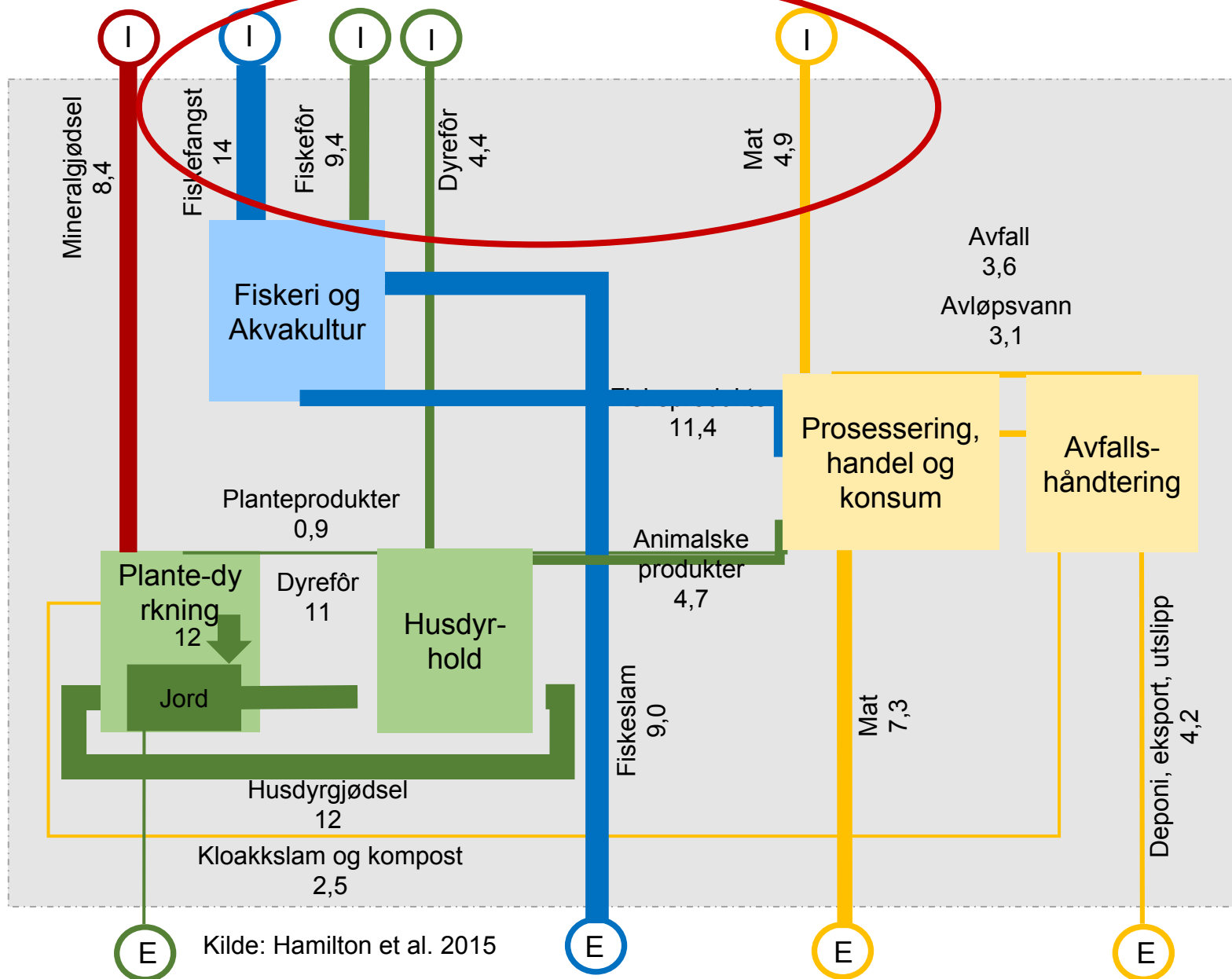


1. P er essensiell for livet
→ ingen erstatning!
2. Høy-kvalitet primære P kilder (fosfatstein) er begrenset
3. Globale fosfatsteinreserver er konsentrert i Marokko og Vest-Sahara (ca 75%)
→ I dag: konflikt Saharawi
→ Fare: monopol / pris / hungersnød
4. Forurensning av vann (eutrofiering)



Hva kan vi gjøre?

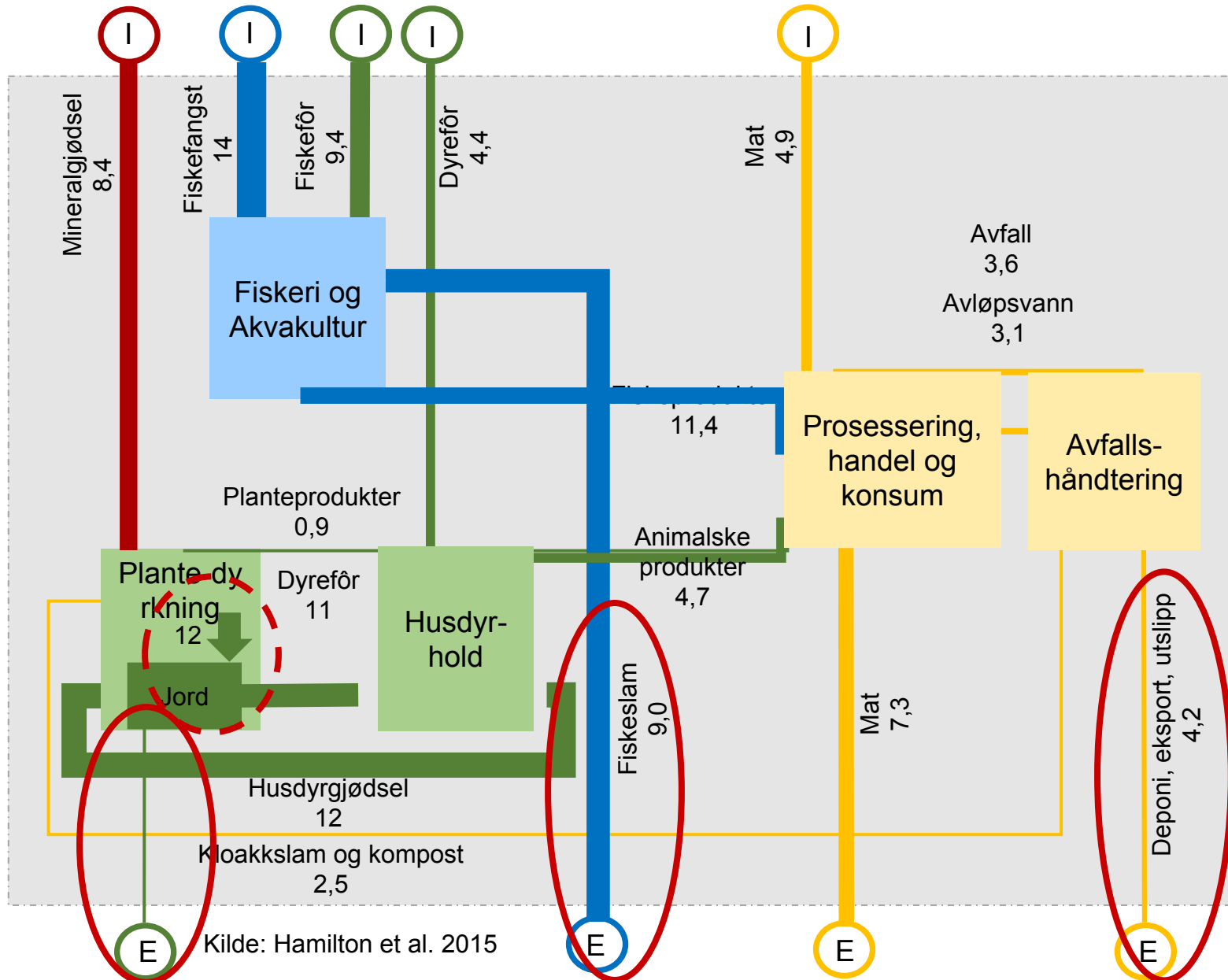
(kt/år, mellomsnitt 2009-2011)



1. Norge importerer store mengder P i form av fiskefangst, fôr (for fisk og husdyr), og mat

Hva kan vi gjøre?

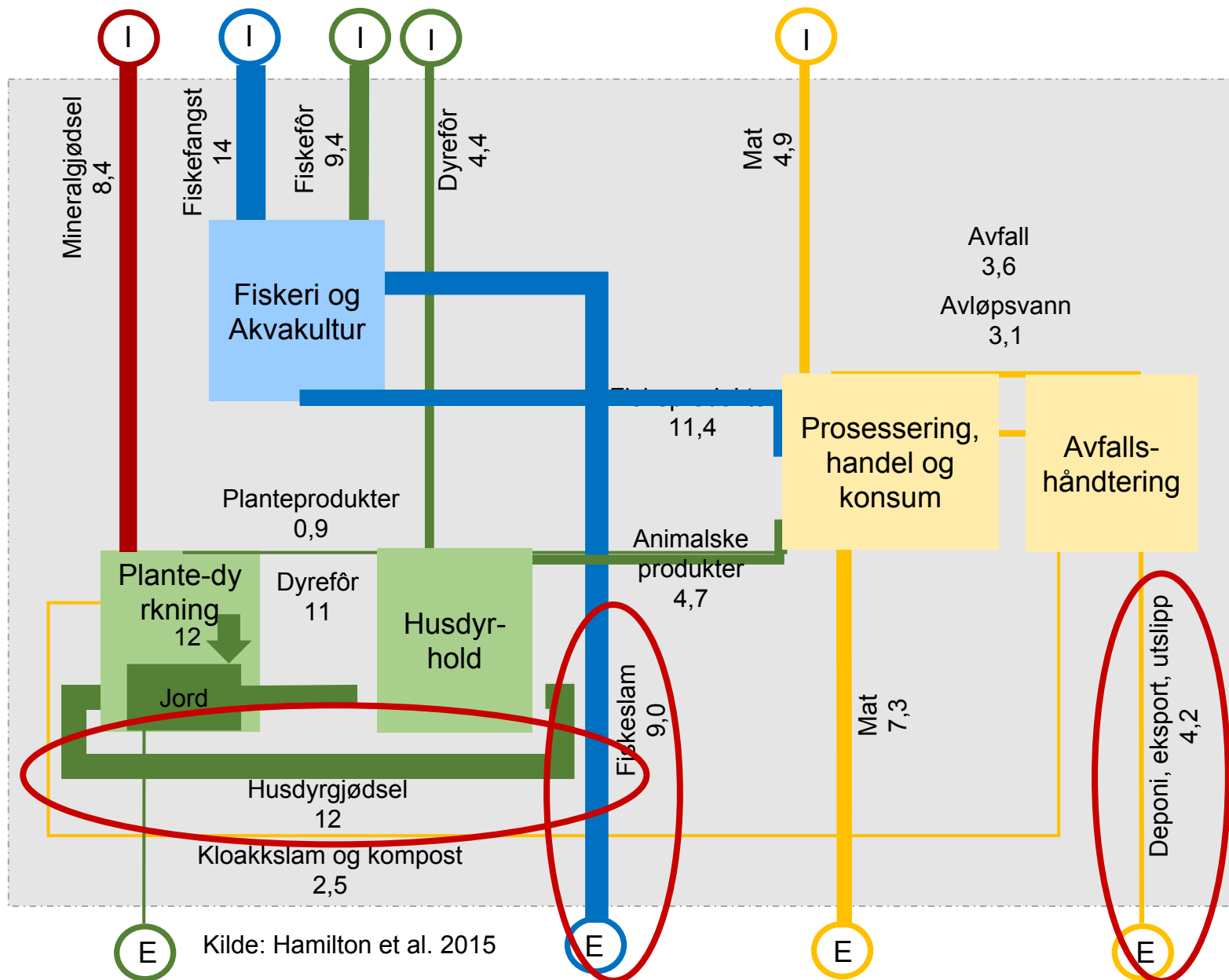
(kt/år, mellomsnitt 2009-2011)



1. Norge importerer store mengder P i form av fiskefangst, fôr for fisk og husdyr, og mat
2. P er brukt veldig ineffektivt
→ Akkumulering av P i jorda og i vannsystemer

Hva kan vi gjøre?

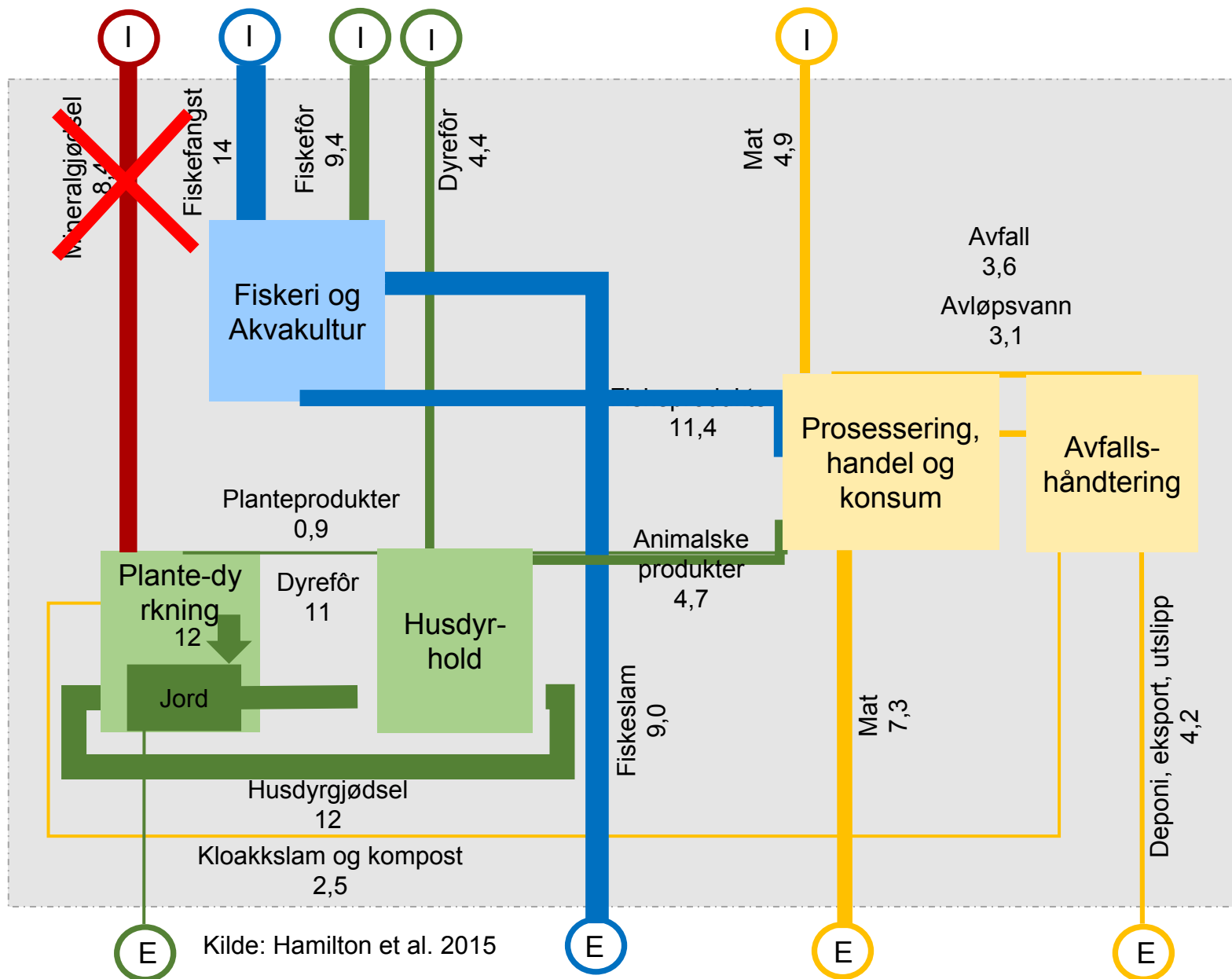
(kt/år, mellomsnitt 2009-2011)



1. Norge importerer store mengder P i form av fiskefangst, fôr for fisk og husdyr, og mat
2. P er brukt veldig ineffektivt
→ Akkumulering av P i jorda og i vannsystemer
3. Det er store mengder av ubrukte sekundære P-ressurser:
 - husdyrgjødsel
 - fiskeslam
 - avfall og kloakkslam

Hva kan vi gjøre?

(kt/år, mellomsnitt 2009-2011)

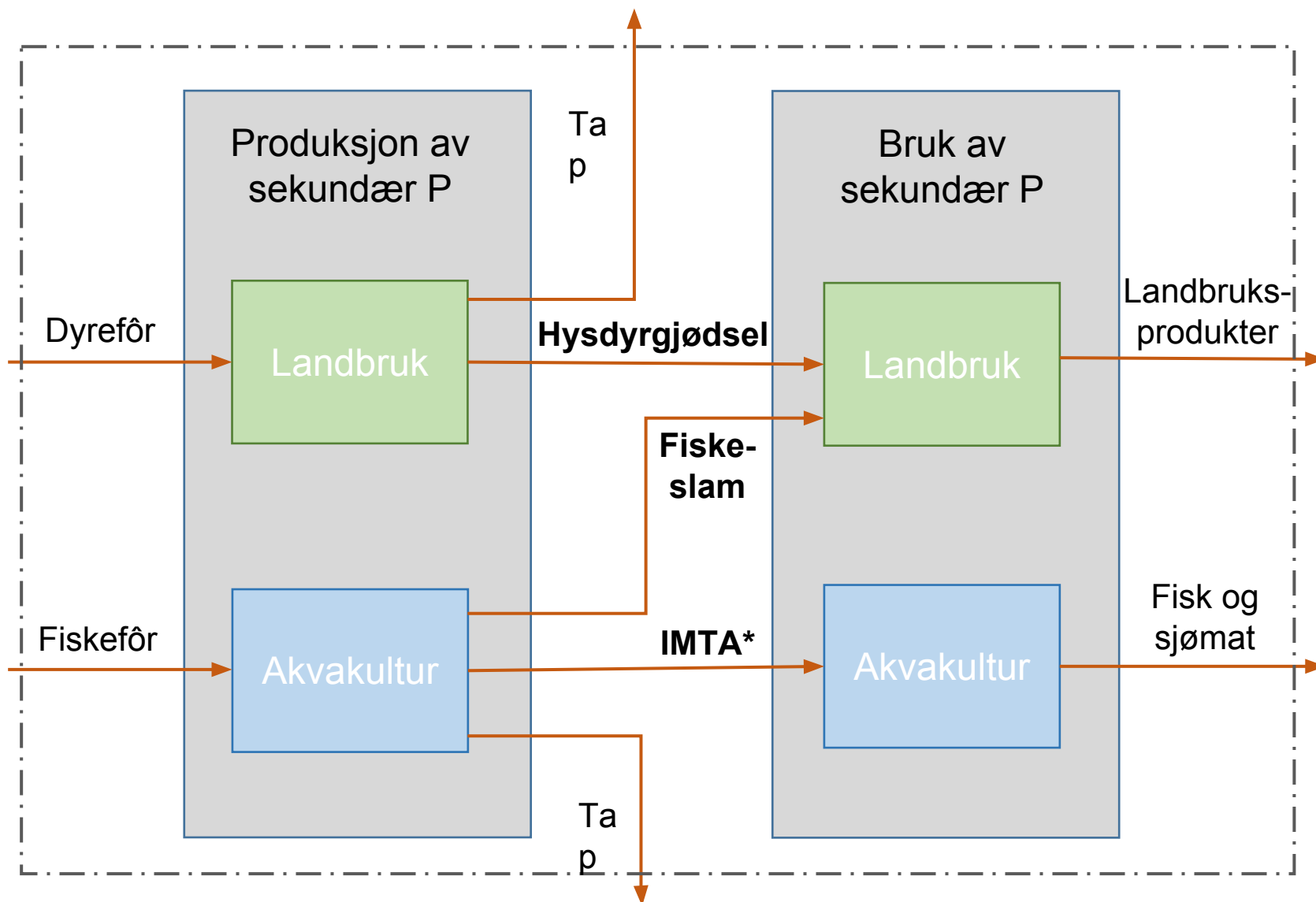


1. Norge importerer store mengder P i form av fiskefangst, fôr for fisk og husdyr, og mat
2. P er brukt veldig ineffektivt
→ Akkumulering av P i jorda og i vannsystemer
3. Det er store mengder av ubrukte sekundære P-ressurser:
 - husdyrgjødsel
 - fiskeslam
 - avfall og kloakkslam

Mål for MIND-P

Demonstrere løsningsveier til å gjøre Norge uavhengig av P mineralgjødsel til 2030 gjennom forbedret resirkulering av husdyrgjødsel og fiskeslam

Løsningsveier som analyseres



* IMTA: Integrert Multitrofisk Akvakultur

Egenskaper av sekundære P ressurser

	Manure	Fish Sludge	Sewage Sludge	MBM ¹	Fish Scrap	Food Waste ²	AD Food Waste ³
High Plant-Availability	✓	*	–	–	*	–	✓
High Transportability	–	–	✓	✓	✓	✓	–
Favorable N:P Ratio	–	–	–	–	–	–	✓
Large quantities	✓	✓	–	–	–	–	–
Accessible	✓	–	✓	✓	–	✓	✓

Kilde: Hamilton et al. 2017

- + products that exhibit the corresponding characteristic
- products that do not exhibit the corresponding characteristic
- products where the characteristic is uncertain/variable

¹ Meat bone meal

² Composted food waste

³ Anaerobically digested food waste

Work package structure

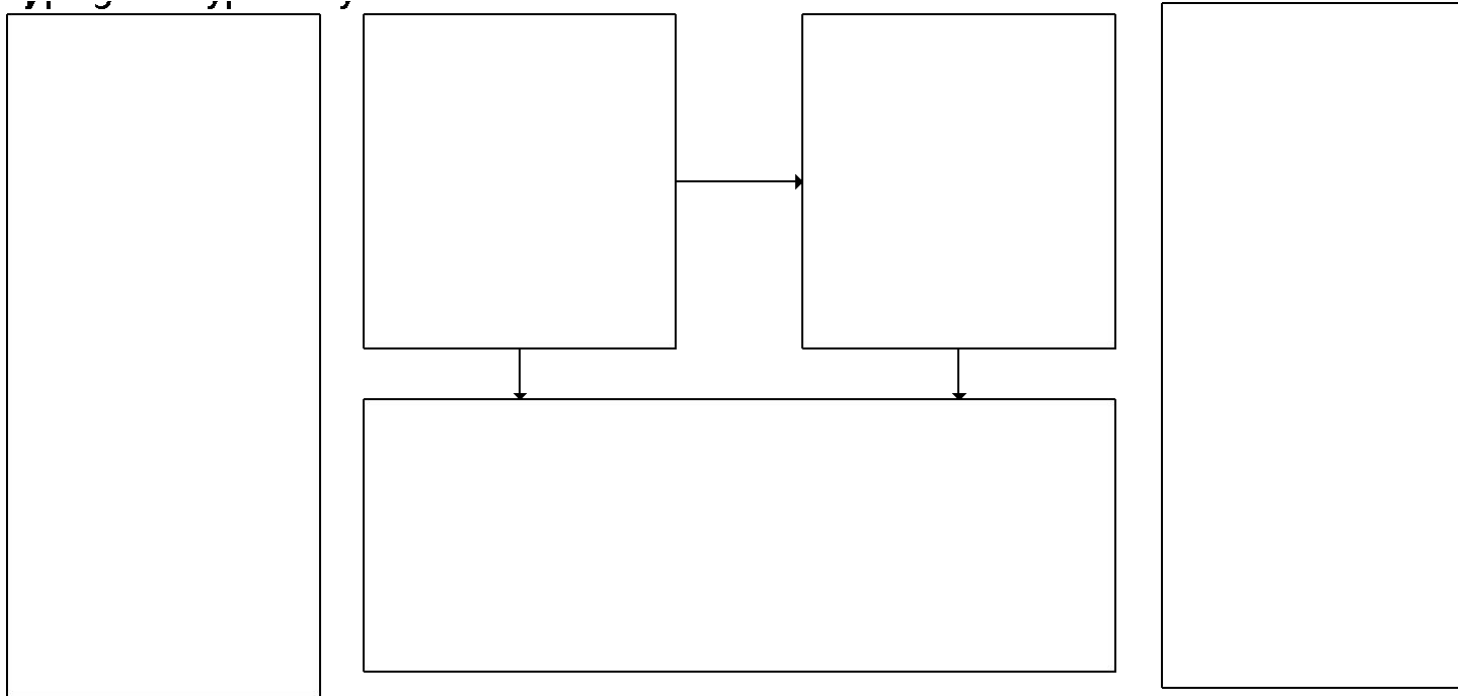
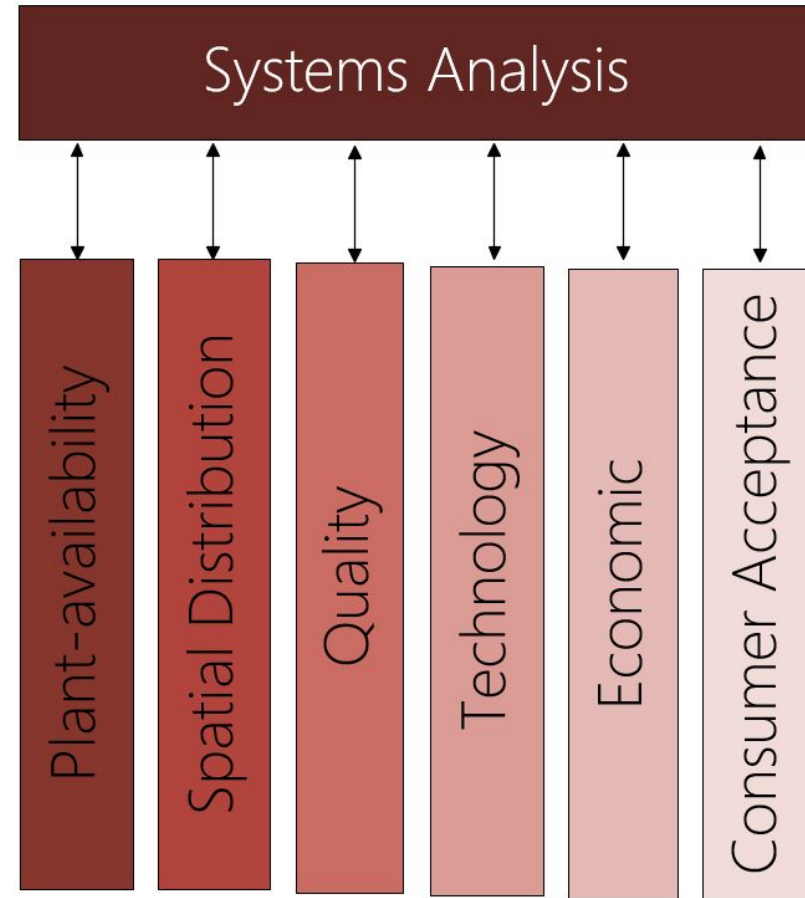


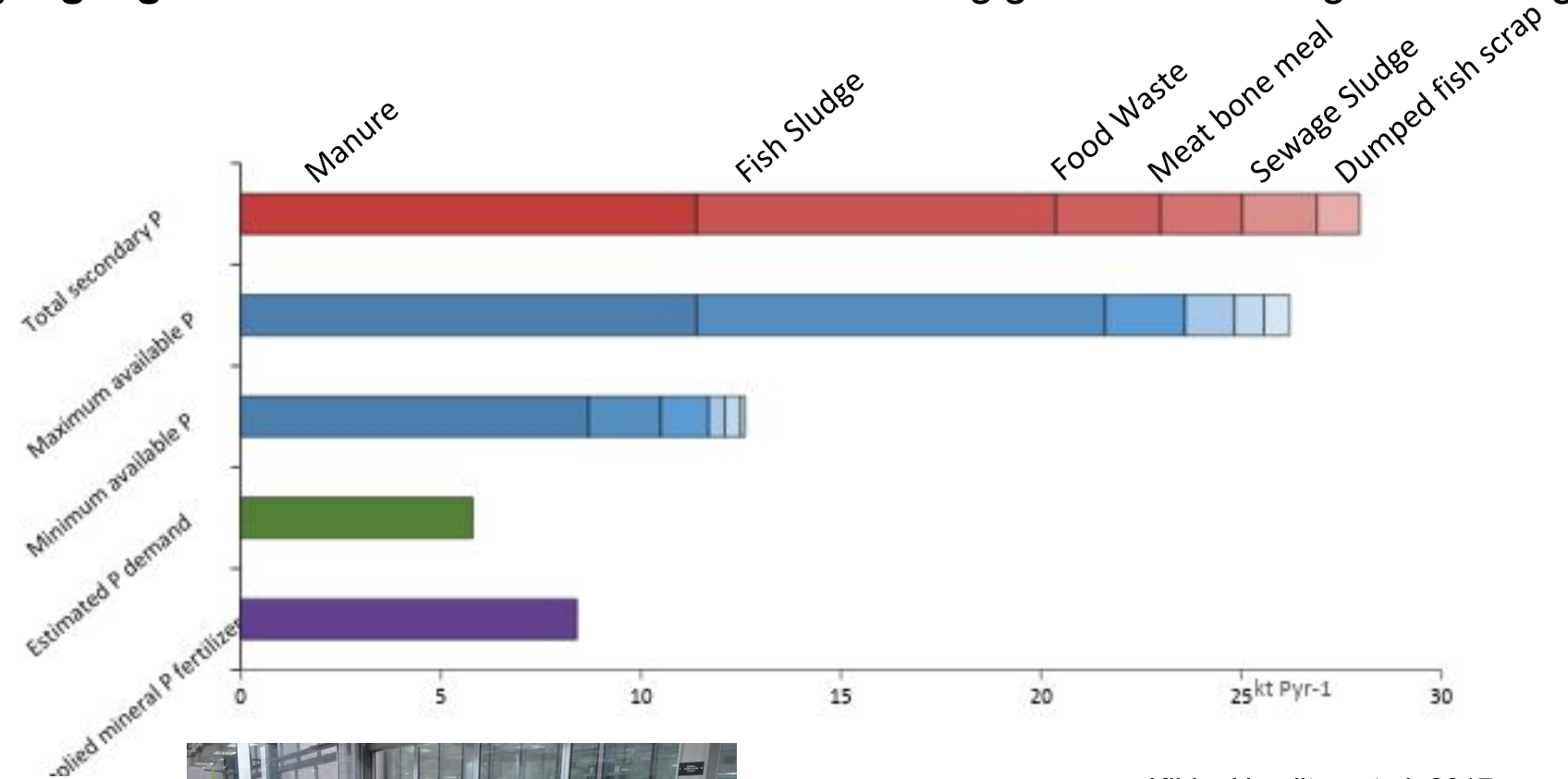
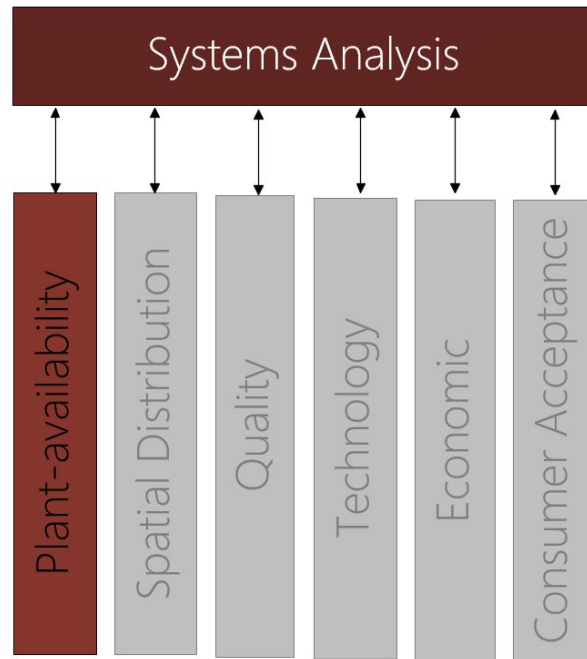
Figure 10. Work package structure illustration

Barrierer for effektivt P resirkulering

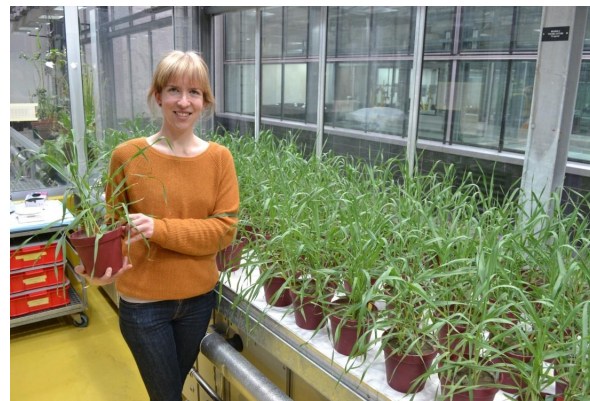


Barrierer for effektivt P resirkulering

Plantetilgjengelighet av P i sekundære ressurser er avhengig av ressurser og behandling



Kilde: Hamilton et al. 2017

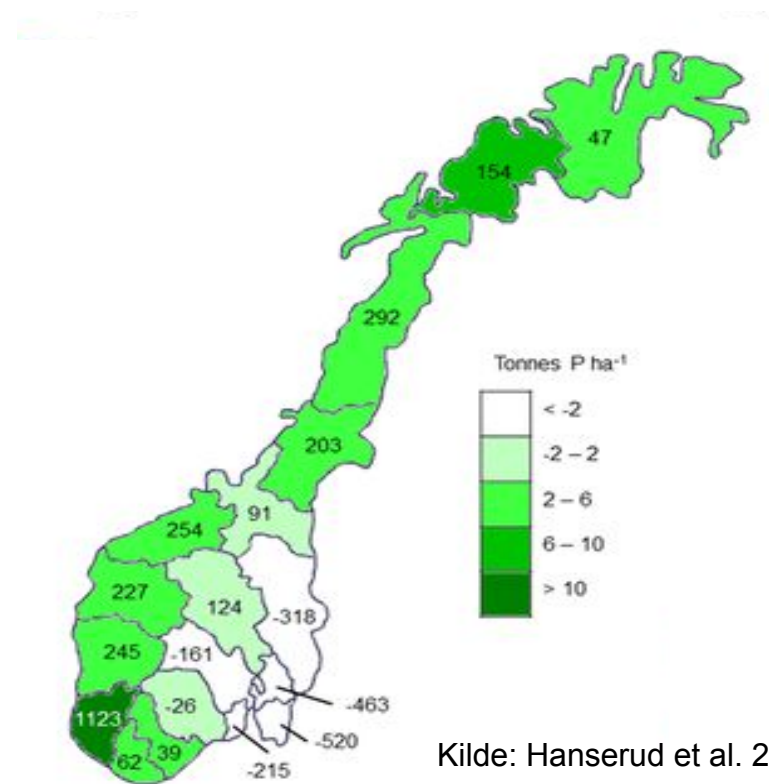
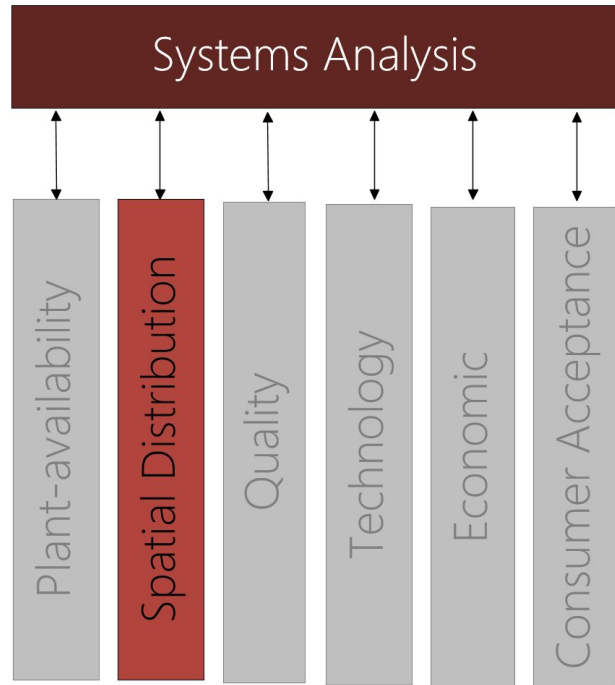


Eva Brod (NIBIO) gjennomfører potteksperimenter for å analysere effekten av gjødsling med forskjellige sekundære ressurser

Barrierer for effektivt P resirkulering

Husdyrgjødsel oppstår ikke hvor den trengs som gjødsel.

→ Romlig analyse av tilbud og etterspørsel av gjødsel



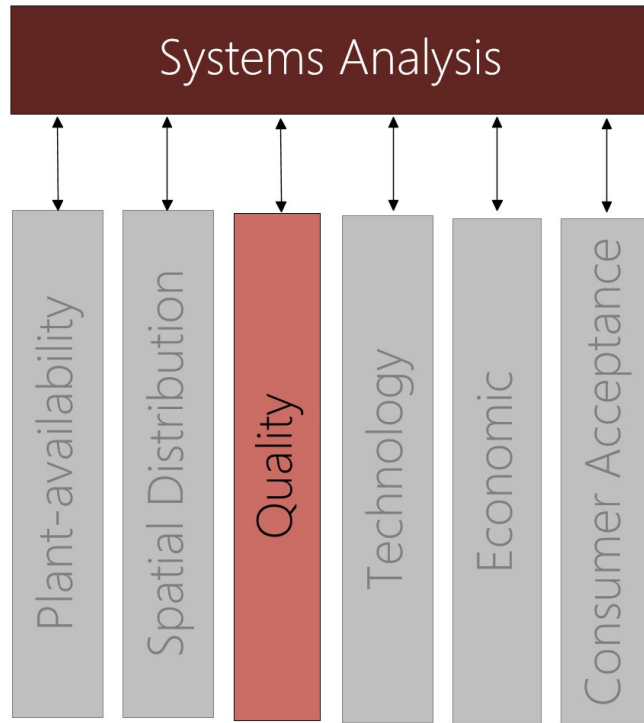
Kilde: Hanserud et al. 2014

Overskudd av P i jorda per fylke per år

Barrierer for effektivt P resirkulering

Sekundære P ressurser kan inneholde **giftige substanser**
(f.eks. tungmetaller)

→ Tungmetallbalanse i fiskeoppdrett



Products intended for animal feed	ML (mg kg ⁻¹)	N (2007–13)	Average (% of ML)	% > ML	Trend average (R ²)	RASFF (2007–13)	Priority
Complementary feed, with the exception of mineral feed and pet feed)	0.5	5	41	0	0 ^c	2	II
subset: complementary feed for ruminants	0.5	3	20	0	0 ^c	1	III
Complementary mineral feed	5	436	6	0	– (0.49)	1	III
subset: complementary mineral feed for ruminants	5	320	6	0	– (0.49) + ^{a,b} (0.67/0.43)	0	III
Complementary feed for pet animals	2	0	n.a.	n.a.	n.a.	0	III
Complete feed, with the exception of: complete feed for cattle (except calves), sheep (except lambs), goats (except kids) and fish	0.5	57	8	4	0 (0.05)	0	II
complete feed for pet animals	1	1	4	0	– (1.00)	0	III
Feed materials of marine origin	2	56	2	0	0 (0.00)	3	III
subset: fish meal	2	183	28	2	0 (0.01)	7	I
Feed materials of vegetable origin	2	139	34	2.9	+ ^b (0.74)	5	I
Feed materials of mineral origin, with the exception of phosphates	1	668	7	0	+ ^{a,b} (0.40)	1	II
subset: calcium carbonate	2	203	9	1	0 (0.07)	2	III
Phosphates	2	96	14	0	– (0.52)	1	III
Pre-mixtures	10	73	29	0	0 (0.00)	3	II
Feed additives belonging to the functional groups of binders and anti-caking agents	15	454	2	0	0 (0.01)	1	III
subset: sepiolite	2	204	10	0.5	0 (0.01)	0	III
Feed additives belonging to the functional group of compounds of trace elements with the exception of: cupric oxide, manganous oxide, zinc oxide and manganous sulphate monohydrate	2	116	13	1	0 (0.15)	0	III
Feed additives belonging to the functional group of vitamins and pro-vitamins	10	100	12	0	0 (0.22)	5	III
Other feed additives	30	41	3	0	0 (0.04)	3	III
	No ML	80	n.a.	n.a.	0 (0.05)	0	III
	No ML	66	n.a.	n.a.	0 (0.06)	0	III

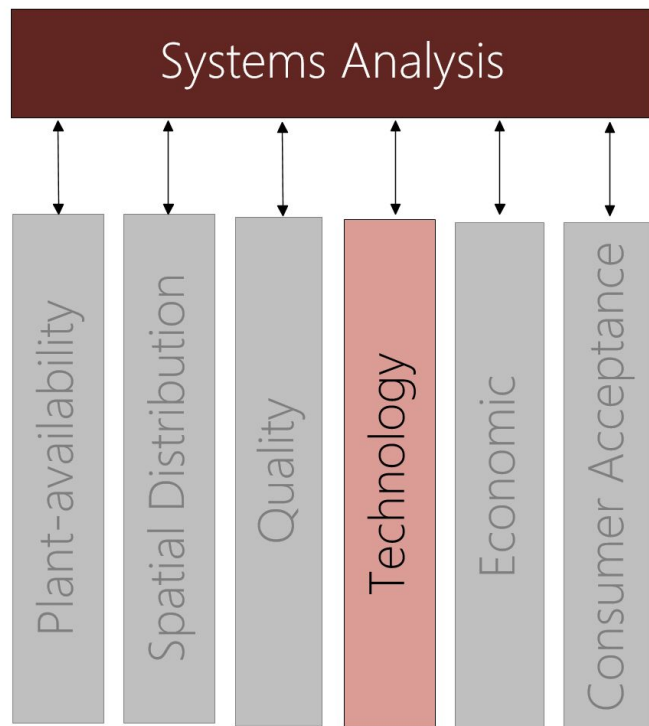
Notes: ^aMedian and/or ^bP90 increased significantly.

^cNot enough years for reliable trend analysis.

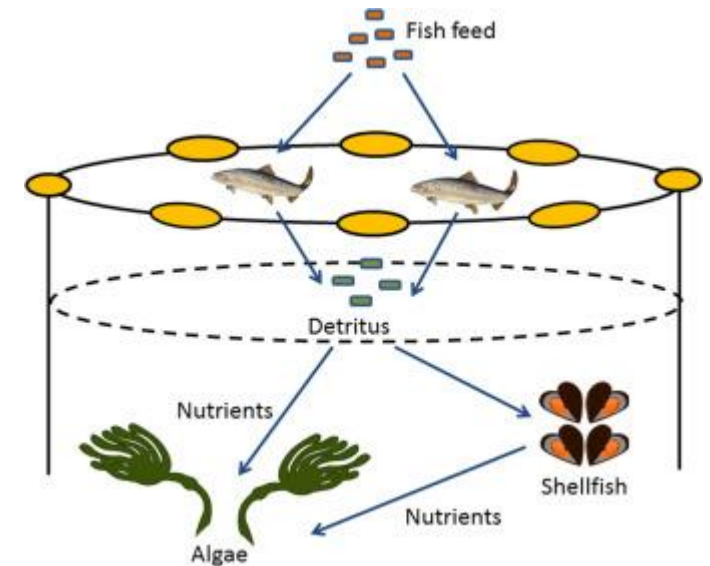
Evaluation of cadmium in animal feed and feed materials
between 2007 and 2013 (Adamse et al., 2017)

Barrierer for effektivt P resirkulering

Nye teknologier må utvikles for å få tak i og behandle sekundære P ressurser
→ Evaluering av forskjellige nye teknologier



Knut Vasdal (Foss Gård) utviklet en teknologi for å omdanne bløtgjødsel til granulat.

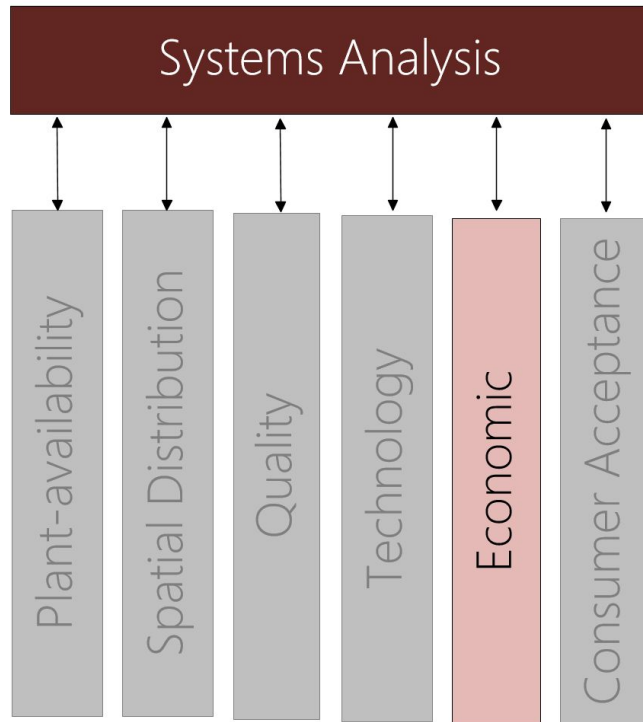


NTNU og DTY utvikler feltdt og laboratorieeksperimenter for å optimalisere IMTA design

Barrierer for effektivt P resirkulering

Kostnad av sekundære P ressurser skal være konkurransedyktig sammenlignet med mineralgjødning.

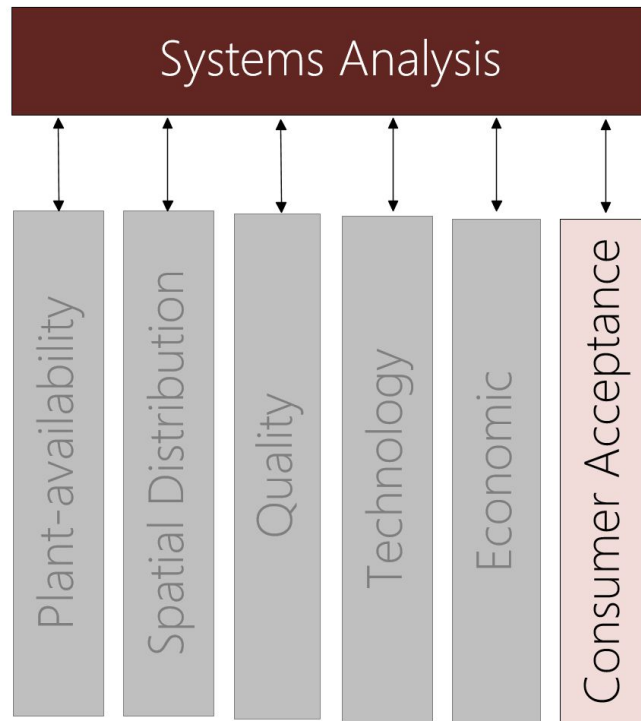
→ Cost-benefit analyse av forskjellige løsningsveier



Barrierer for effektivt P resirkulering

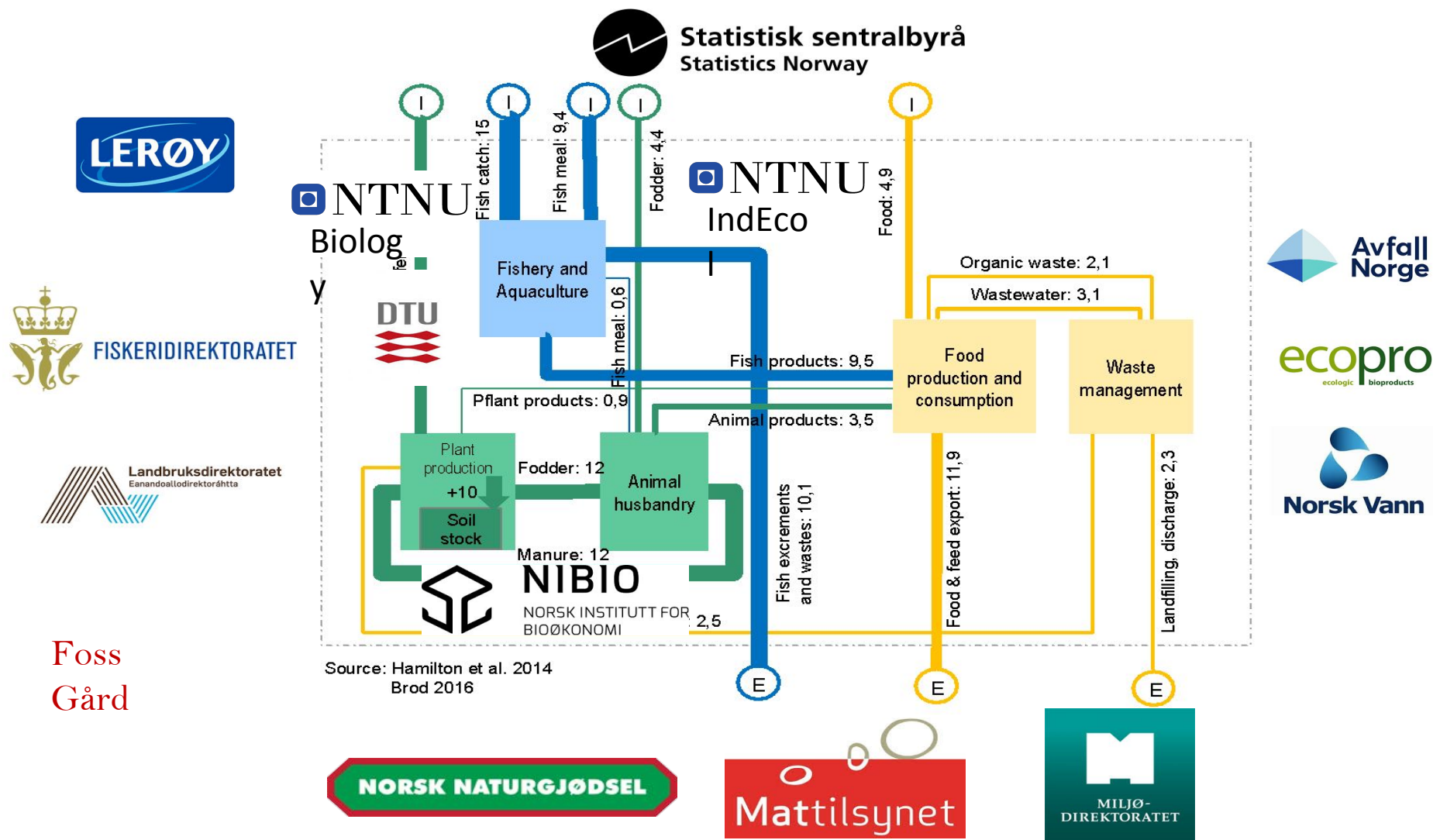
Forbrukerpreferanser er fundamental for å effektivisere fosforsyklusen.

→ Halvstrukturerte intervjuer med bonder og forbrukerorganisasjoner



Takk for oppmerksomheten!

Takk til partnere og referansegruppen av MIND-P



Barriers for efficient use of secondary P resources:

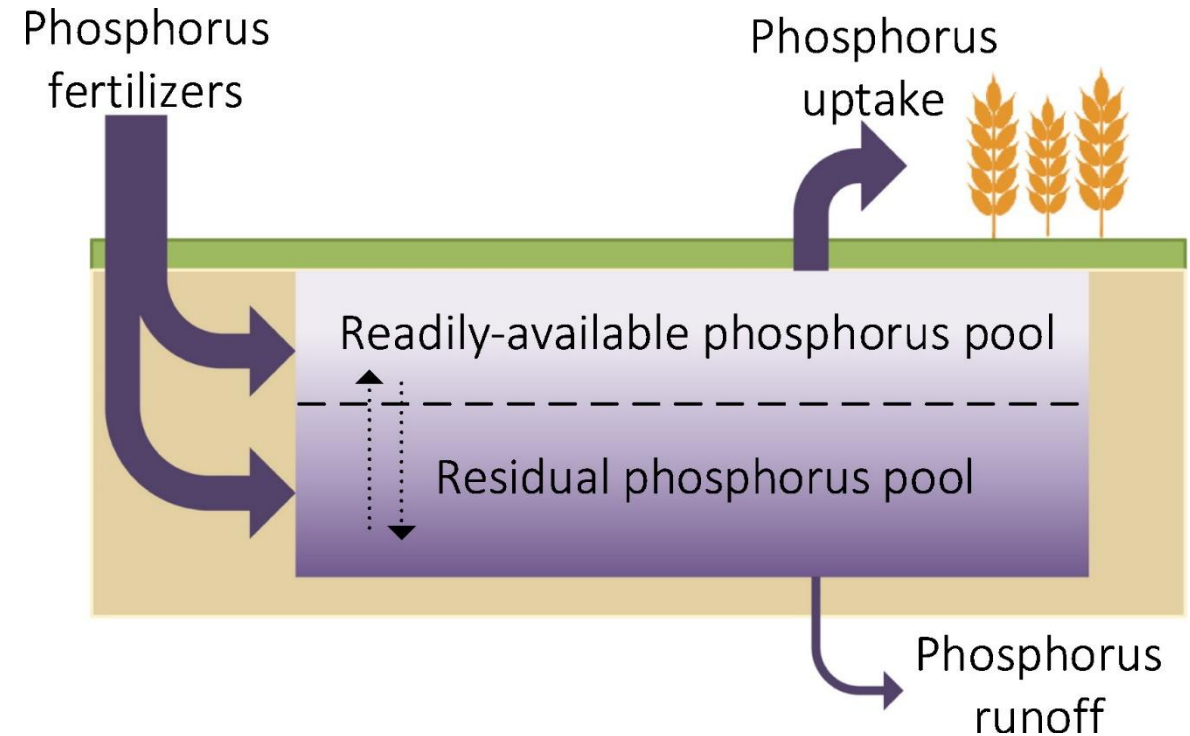
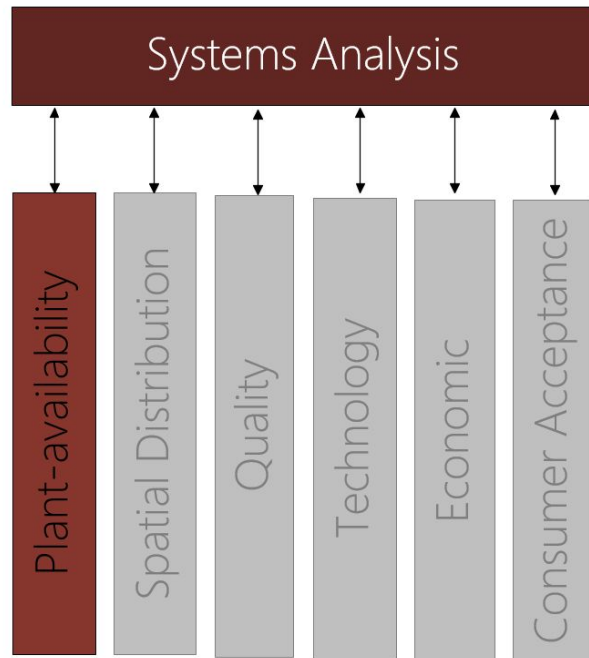
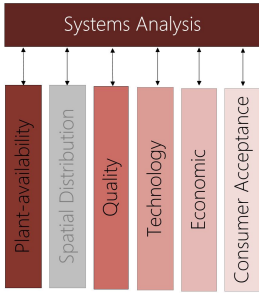


Figure 5. Partitioning of secondary products based on P plant availability (Hamilton et al., 2017)

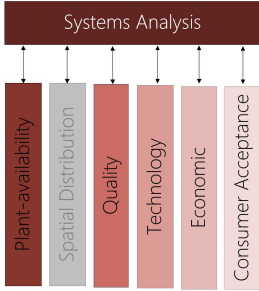
WP3: Agriculture Barriers and Opportunities (1)



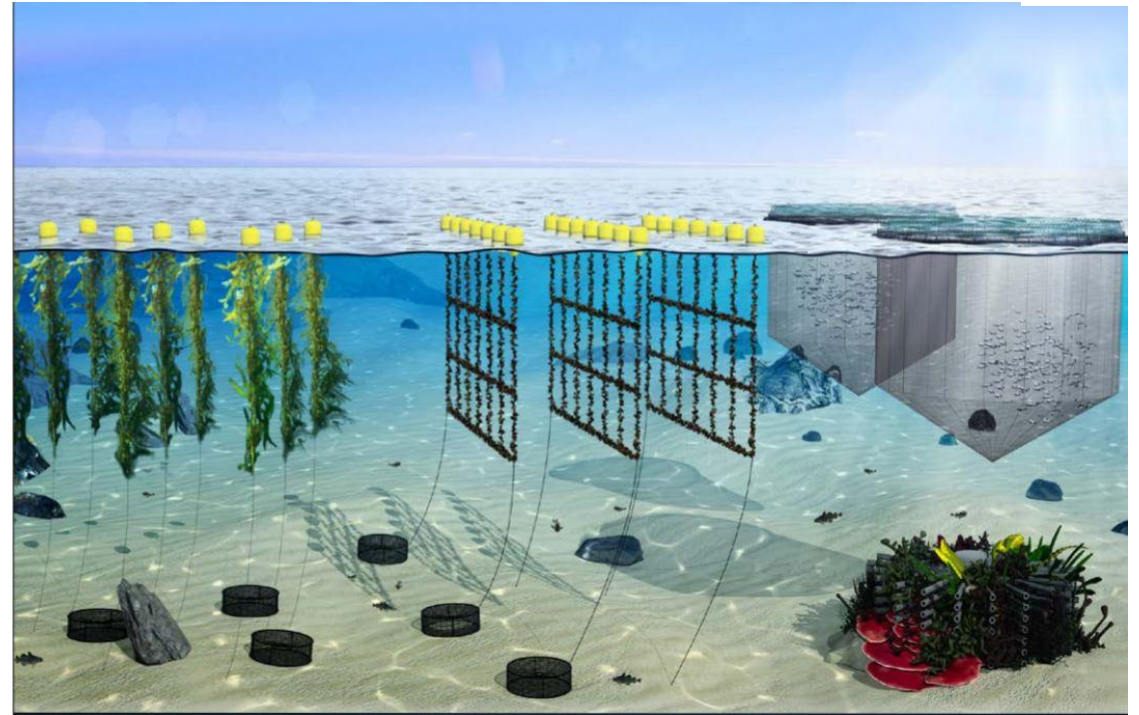
- Nutrient composition analysis of secondary P products
- Pot experiments to analyze the P fertilization effects of secondary resources



WP3: Aquaculture Barriers and Opportunities (2)



- Aquaculture nutrient and heavy metal balances
- Field and lab experiments to optimize IMTA design
- Applications for IMTA products



Bellona.org;

<http://bellona.org/news/renewable-energy/bioenergy/2017-10-the-great-blue-bellona-solutions-for-sustainable-aquaculture>

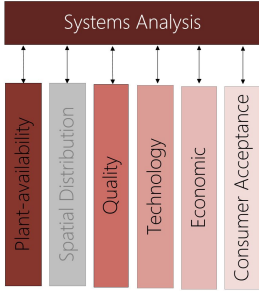
WP3: Economic Barriers and Opportunities (3)

- Cost-benefit analysis on (i) manure, (ii) fish sludge and (iii) IMTA products



Pixabay.com (creative commons)

WP3: Consumer Acceptance Barriers and Opportunities (4)



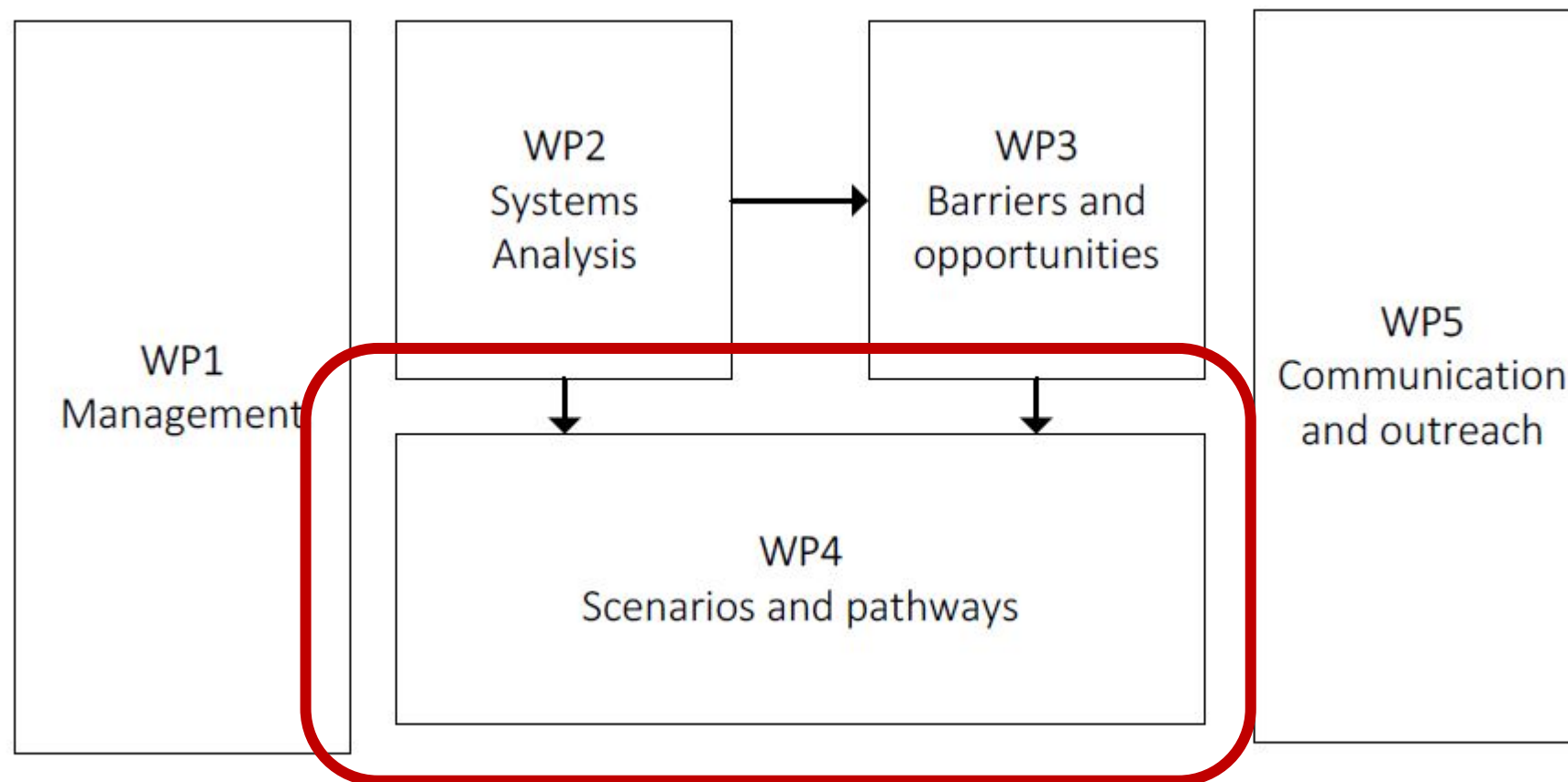
- Conduct interviews with stakeholders
- Preferred product quality and acceptable sources of fertilizer



<https://pixabay.com/en/interview-job-icon-job-interview-1018333/>

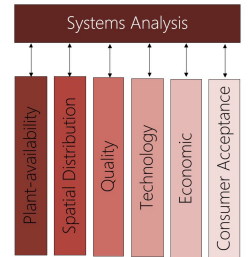
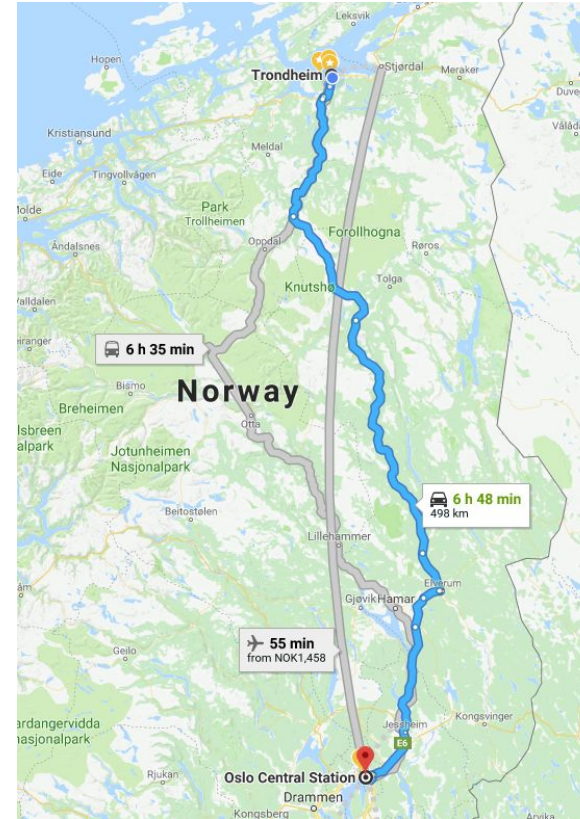


Work package structure

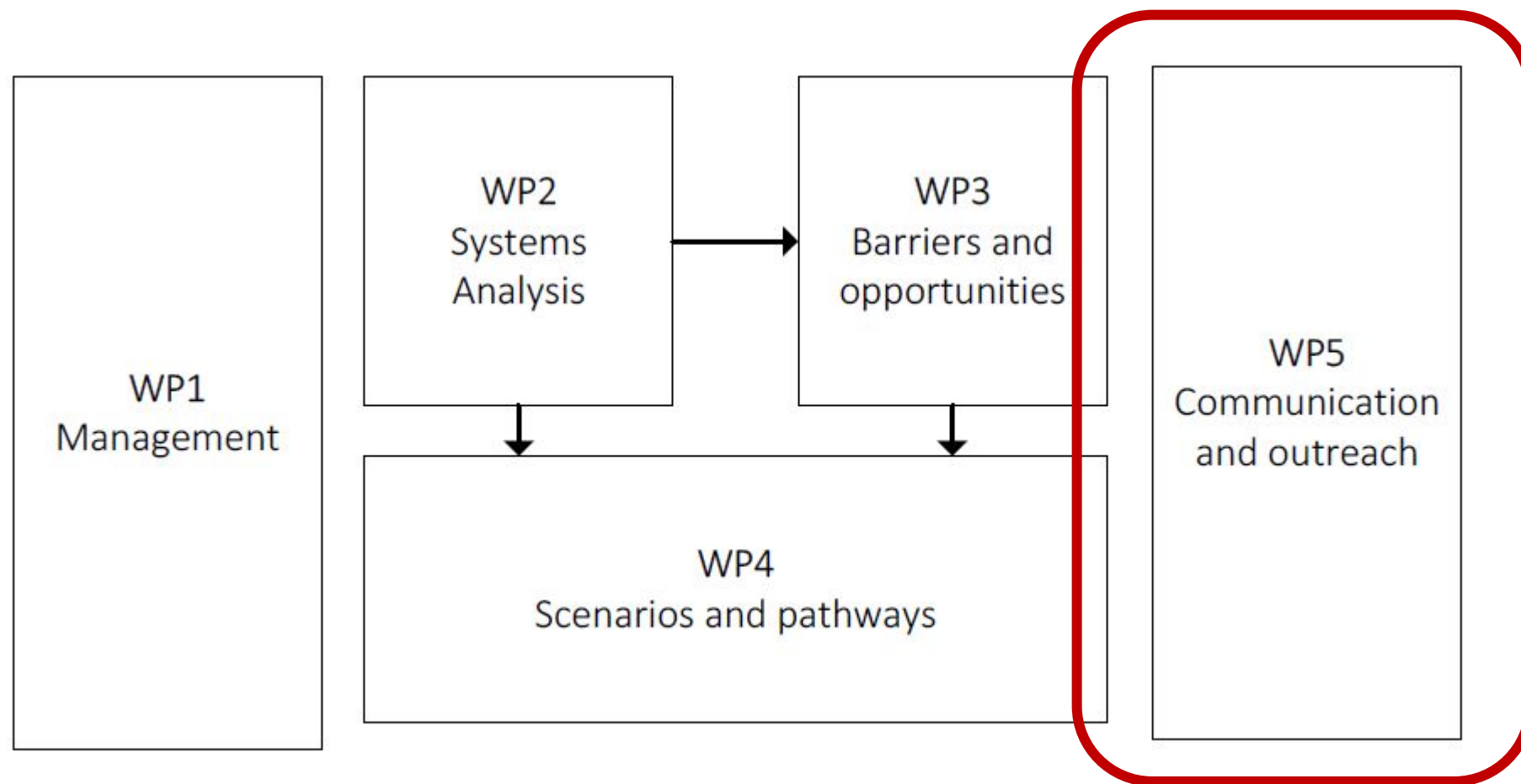


WP4: Scenarios and Pathways

- Integrate **key findings** from WP3 in **model**
- Scenario development
- **Pathways to mineral P independence**



Work package structure



WP5: Communication and Outreach

- Stakeholder workshops
- Roadmap with advisory board and stakeholders
- Popular media outreach and dissemination





Thank you for your attention

Helen Ann Hamilton

Daniel B. Müller

Department of Energy and Process Engineering

Industrial Ecology Programme

helen.a.hamilton@ntnu.no

