Assessment of biomethane production from maritime common reed

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Aim

1. To perform an energy balance of the system

2. Quantify GHG emissions in comparison with a fossil reference system

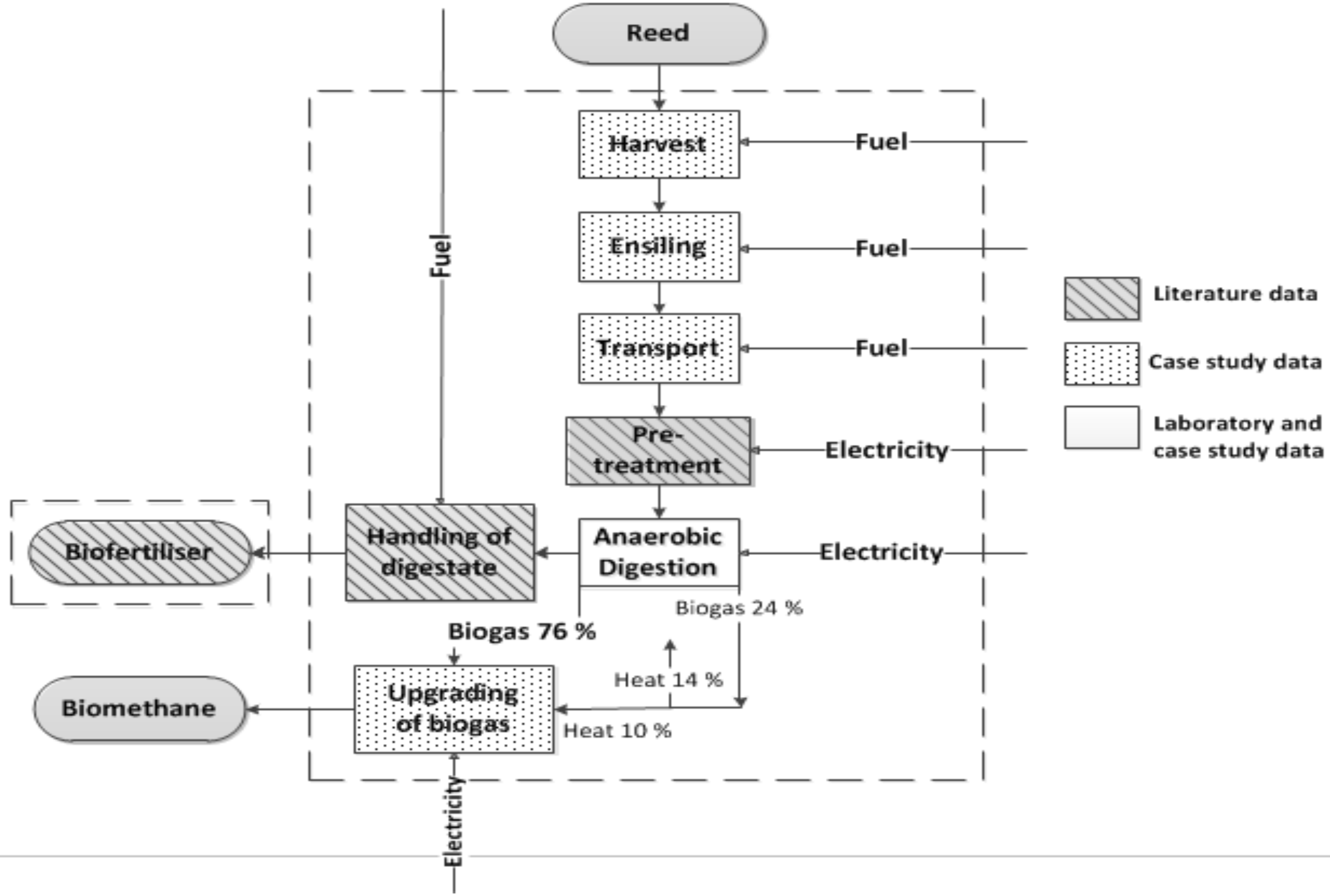
3. Estimate net nutrient recirculation potential

Case study Kalmar

Risén, Gregeby, Tatarchenko, Blidberg, Malmström, Welander, Gröndahl

Harvesting

System description

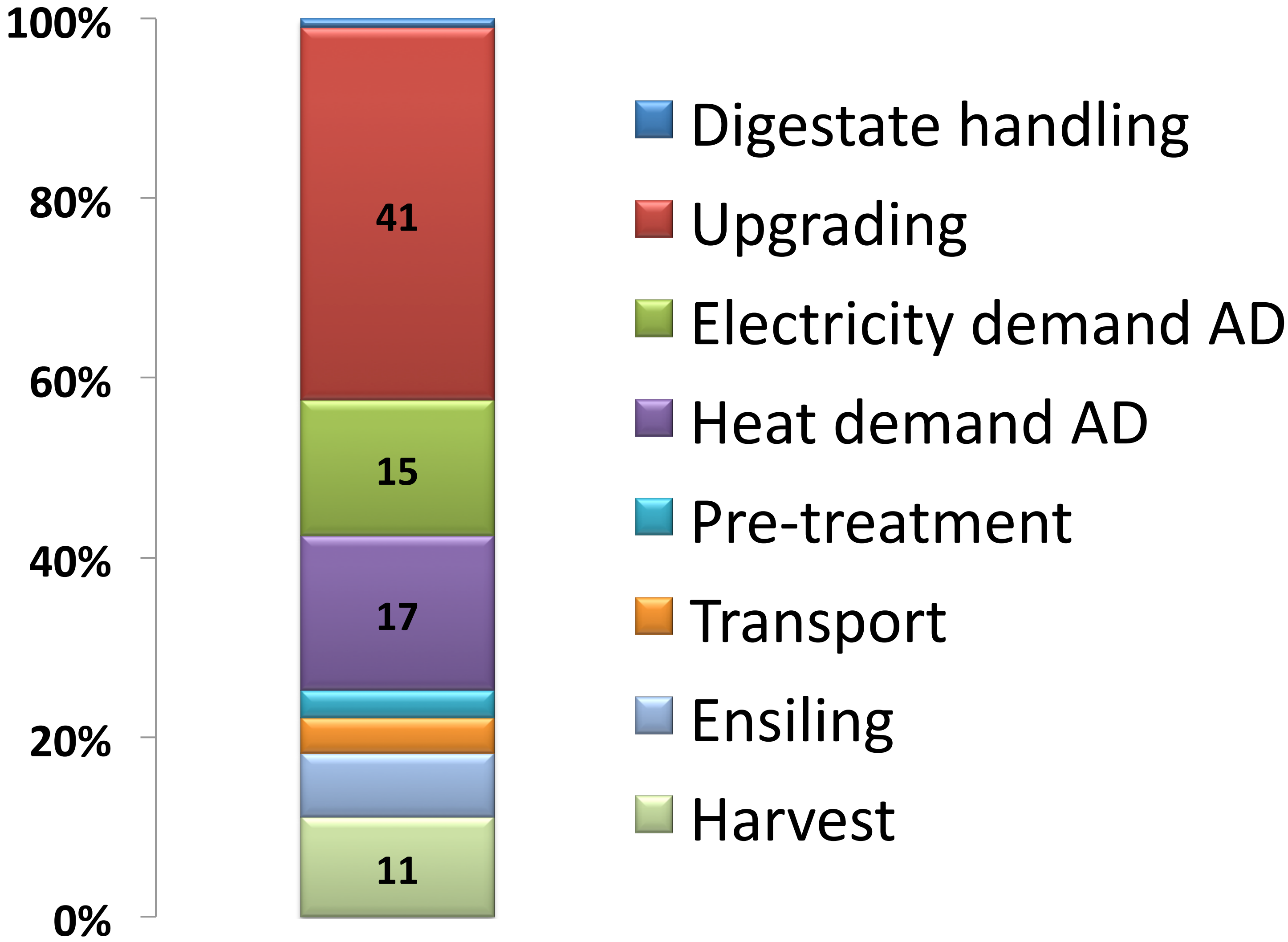


Risén, Gregeby, Tatarchenko, Blidberg, Malmström, Welander, Gröndahl

System analysis

1. Energy analysis
   - Energy input
   - Methane yield
   - Net production
2. Greenhouse gas emissions
3. Nutrient retrieval

Results energy input



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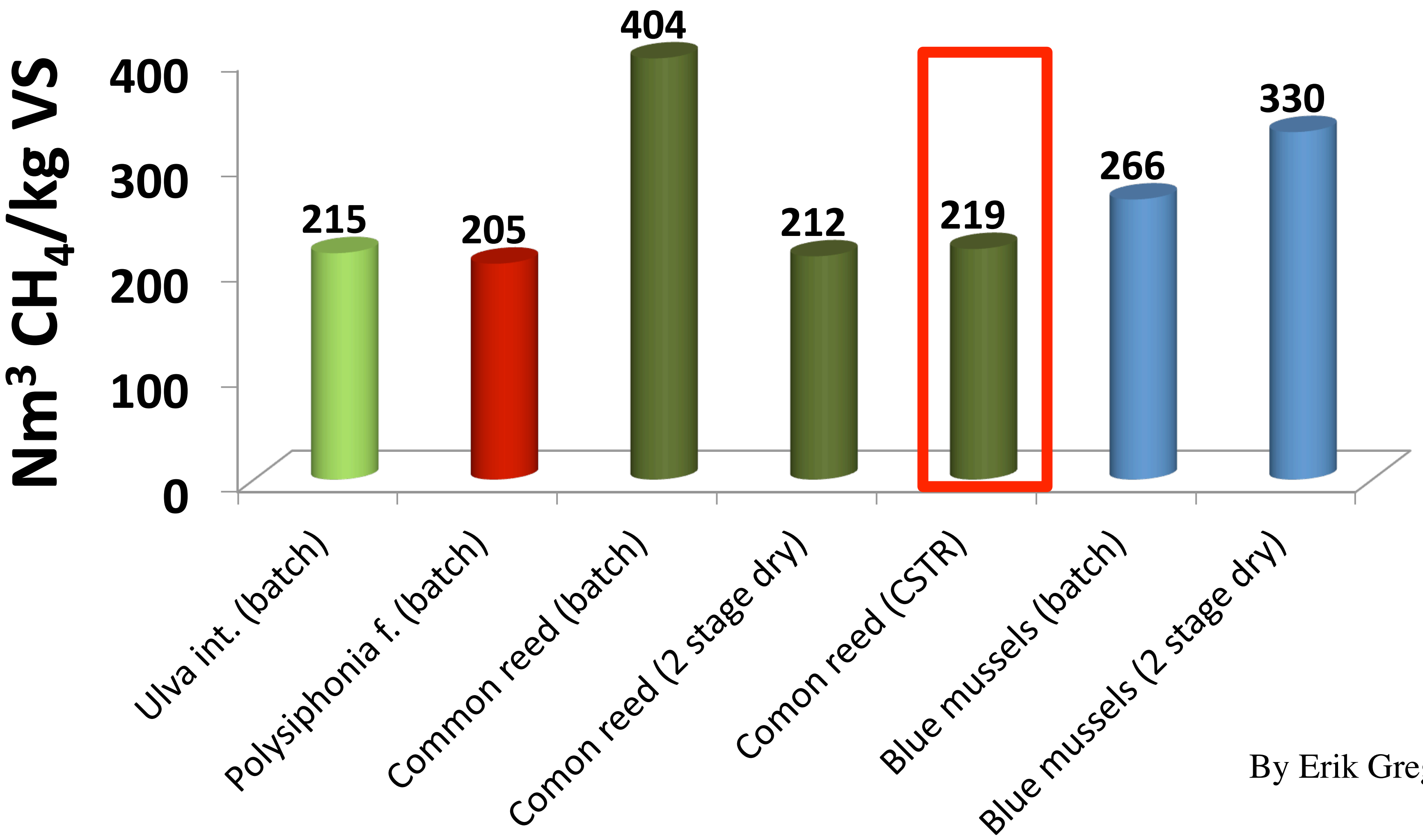
Submariner 5/9/2013

Results methane yield



By Erik Gregeby

Results Energy analysis

- The energy demand of the system corresponds to 40% of the biomethane produced
- Net production is approximately 40 L gasoline-equivalents per t of reed
- About 50% of support energy is from renewable resources
- A hypothetical harvest of all reed in the Kalmar Municipality (180 ha) corresponds to less than 1% of the total energy utilisation of the transport sector

Results GHG emissions

- A reduction of 80% in comparison with a fossil reference system is possible

Results Net nutrient flows

- Almost all of the retrieved P can be recirculated to farm land

- Approximately 60% of the retrieved N can be recirculated to farm land

Results Net nutrient flows

- A hypothetical harvest of the total reed area in Kalmar County (ca. 530 ha) corresponds to:

- 1 % of annual N leackage from farm land
- 20 % of annual P leackage form farm land

Summary 1

- Positive energy balance
- Satisfactory reduction of GHG emissions
- Possibility to recirculate nutrients
- System design and system boundaries are key factors for our results

Summary 2

Further studies are necessary

- Socio-economic aspects of biomass retrieval
- Ecological risks with large scale harvest

Thank you for listening!

Thank you for paying!

KTH
VETENSKAP OCH KONST

formas
Forskningsrådet Formas
Formas främjar framstående forskning för hållbar utveckling

Linnéuniversitetet Kalmar Växjö

biogas
nya substrat från havet
En investering för framtiden
EUROPEISKA UNIONEN
Europeiska regionala utvecklingsfonden

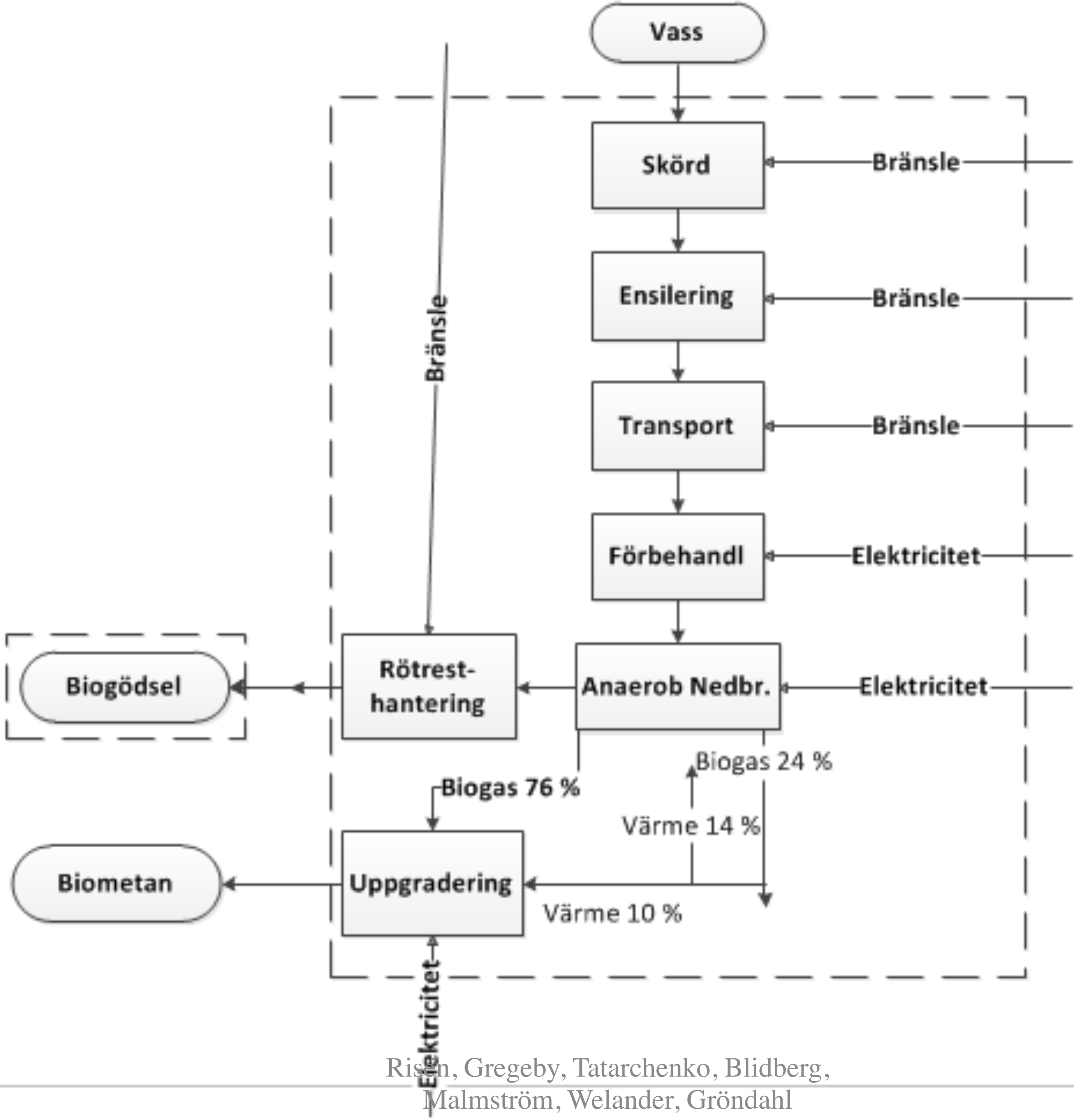
Energy analysis

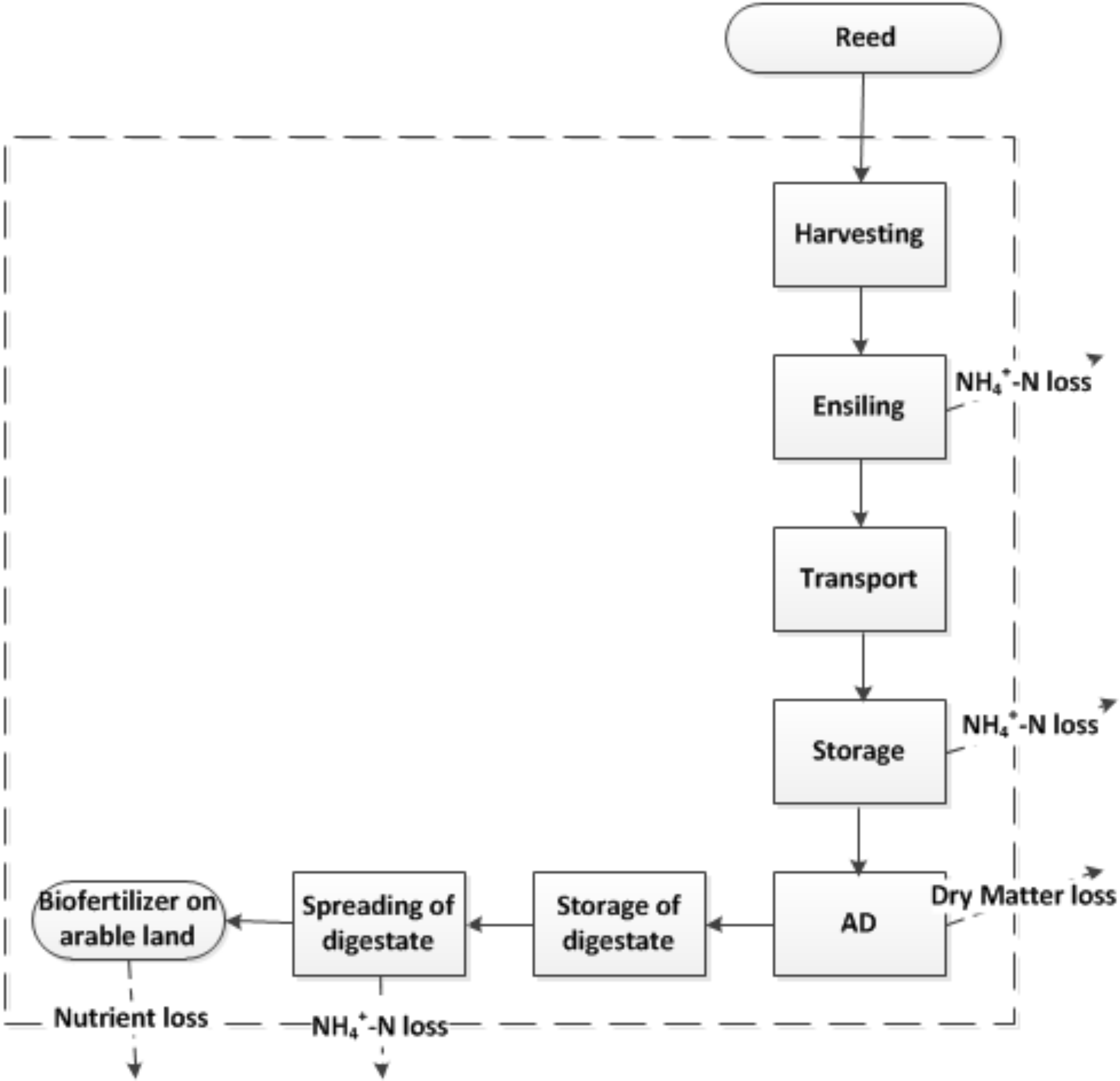
- Primary energy
- Several indicators e.g. Input/Output

Net nutrient flows

Reed composition

Reed composition	Average (% of DM)
DM	44.6 (% of dwt)
VS	93.8
TKN	1.5
P	0.14
K	1.2


Vass
Skörd
Bränsle
Ensilering
Bränsle
Transport
Bränsle
Förbehandl
Elektricitet
Bränsle
Rötrest-
hantering
Anaerob Nedbr.
Elektricitet
Biogödsel
Biogas 24 %
Biogas 76 %
Värme 14 %
Biometan
Uppgradering
Värme 10 %
Elektricitet


Reed
Harvesting
Ensiling
NH4+-N loss
Transport
Storage
NH4+-N loss
AD
Dry Matter loss
Storage of digestate
Spreading of digestate
Biofertilizer on arable land
Nutrient loss
NH4+-N loss

Energibalans

$$IOR = \frac{(E_{tot\ in} - E_{subst})}{E_{tot\ out}}$$

$$NEV = E_{tot\ out} + E_{subst} - E_{tot\ in}$$

$$\mathrm{ERenEF} = \frac{\mathrm{E_{tot\ out} - E_{nrin}}}{\mathrm{E_{tot\ out}}}$$

Table 3.1 Primary energy input into harvesting, ensiling, pre-treatment, transportation and spreading of digestate.

Process step	Reed		Straw		
	This study	Hansson and Fredriksson, 2004	Pöschl et al., 2010	Berglund and Börjesson, 2006	Börjesson and Berglund, 2006
Harvesting (MJ/tonne dwt)	559		n.a.	280[A]	230[B]
Ensiling (MJ/tonne dwt)	332		140[C]	n.a.	n.a.
Transportation (MJ/tonne dwt, km) (tractor/truck/digestate tank truck)	8.5/12.8/ 4.2	4.4/n.a./ n.a.	6.9/n.a./ 2.5	n.a./3.5[D]/ n.a.	n.a./3.5[D]/ n.a.
Pre-treatment (MJ/tonne dwt)	150		n.a.	n.a.	33
Spreading of digestate (MJ/tonne dwt)	150	400[E]	202[E]	170[E]	250[E]

[A] Straw recovery and transport from field to storage

[B] Diesel consumption by machinery + manufacture of transport machinery

[C] Fuel consumption during baling operations

[D] Calculated from 2.0 MJ/t wwt with an DM content of 82 %

[E] Calculated from an DM content of 10 % in the digestate

Table 3.2
Primary energy input biogas plant operation and biogas upgrading

Process step	**Biogas plant operation and biogas upgrading**		
	This study	**Berglund and Börjesson, 2006**	**Beil, 2009**
Biogas plant heat (MJ/m^3 substrate, 10 % DM)	285[A]	110[B]	n.a.
Biogas plant electricity (MJ/m^3 substrate, 10 % DM)	151	66	n.a.
Biogas upgrading heat (MJ/Nm^3 biogas)[C]	4.2 (764*)	n.a.	2.1
Biogas upgrading electricity (MJ/Nm^3 biogas)	0.8 (137*)	n.a.	0.9

[A] Large-scale biogas plant (CSTR, thermophilic process temperature)
[B] Large-scale biogas plant (CSTR, mesophilic process temperature)
[C] Chemical (amine) absorption
* MJ/m^3 substrate, based on the biogas production from 1 tonne wwt of reed (1 tonne wwt = 1 m^3 substrate)
n.a.-Not Available

Table 2.2 Energy indicators

Indicator	Acronym	Equation	Measure	Previous use
Input output ratio	IOR	$IOR = \frac{(E_{tot\,in} - E_{subst})}{E_{tot\,out}}$	Energy efficiency of a system IOR ratio < 1 positive	(Berglund and Börjesson, 2006; Börjesson et al., 2010; Pöschl et al., 2010)
Net energy value	NEV	$NEV = E_{tot\,out} + E_{subst} - E_{tot\,in}$	Net energy output from the system NEV>0 positive	(Hansson and Fredriksson, 2004; Varadharajan et al., 2008)
Net renewable energy value	NREV	$NREV = E_{tot\,out} + E_{subst} - E_{Nrin}$	Amount of avoided non renewable energy usage NREV>0 positive	(Graboski, 2002; von Blottnitz H. and Curran, 2007; Varadharajan et al., 2008)
Non renewable input ratio	NRIR	$NRIR^{A} = \frac{E_{Nrin}}{E_{tot\,in}} * 100$	Percentage of total energy input of non renewable origin	Not previously used
Energy Renewability Efficiency	ERenEF	$ERenEF = \frac{E_{tot\,out} - E_{nrin}}{E_{tot\,out}} * 100$	Renewability Efficiency	(Malca and Freire, 2006)

^{A} Heating of the plant with biogas was considered as an external energy input in NRIR in order to assess all energy utilised.

Results energy indicators

Table 3.5 Input Output Ratio, Net Energy Value, Net Renewable Energy Value, Net Renewable Input Ratio and Energy Renewability Efficiency applied to the case study system. Criteria for indicators to be positive are shown in brackets.

IOR (<1)	NEV [MJ/ t wwt] (>0)	NREV [MJ/ t wwt] (>0)	NRIR [%]	ERenEF
0.39	1 644	1 891	53 %	68 %

Växthusgasindikator

$$\Gamma = \frac{CO_{2\ eq\ tot\ g} - CO_{2\ eq\ tot}}{CO_{2\ eq\ tot\ g}} * 100$$

Koldioxid
Metan
Dikväveoxid

Energiinsats, biogasanläggning (inkl. uppgradering)

	Biogas plant operation and biogas upgrading		
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Biogas plant electricity (MJ/m^3 substrate, 10 % DM)	151	66	n.a.
Biogas upgrading heat (MJ/Nm^3 biogas) [C]	4.2 (764[*])	n.a.	2.1
Biogas upgrading electricity (MJ/Nm^3 biogas)	0.8 (137[*])	n.a.	0.9

[A] Large-scale biogas plant (CSTR, thermophilic process temperature)

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[C] Chemical (amine) absorbtion

[*] MJ/m^3 substrate, based on the biogas production from 1 tonne wwt of reed (1 tonne wwt = 1 m^3 substrate)