Slurry volumes and estimated storage time of slurry in Danish livestock buildings

Report prepared for Biogas Taskforce, Danish Energy Agency

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INDHOLD

1. DANSK SAMMENDRAG

Danmark afrapporterer årligt emissionen af drivhusgasser til FN's klimapanel. Hidtil har data om emissionen fra stalde været mangelfulde, og derfor er der gennemført en række projekter i regi af Energistyrelsen med henblik på at forbedre datagrundlaget. I nærværende delprojekt har der været særlig fokus på emissionen fra husdyrproduktioner, som leverer husdyrgødning til biogasanlæg.

Den totale emission (E) af drivhusgasser fra afgasset gylle kan udregnes som:

$E_{total} = E_{stalde\ inkl.\ fortank} + E_{biogasanlæg} + E_{efter\ afgasning}$

Denne rapport har til formål at tilvejebringe data for del den af ligningen, som omfatter emissionerne fra stald og fortank. Målet med rapporten er specifikt at tilvejebringe data om mængden af gylle, som opbevares i stalde og fortanke. Derudover er gødningens opholdstid i stalden vurderet, da dette har betydning for emissionen af drivhusgasser. Til besvarelse af dette spørgsmål er den hydraulisk opholdstid (HRT) for gyllen under lagring i stald og fortank beregnet ud fra formlen:

$$\text{HRT (dage)} = \frac{\text{gyllemængde i stald og fortank (ton) x 365 (dage pr. år)}}{\text{årlig produktion af gylle ifølge danske normer (ton pr. år)}}$$

Der er gennemført et litteraturstudium af relevante undersøgelser, som belyser mængden af gylle, som opbevares i stalde, som vurderes at være sammenlignelige med danske stalde. I praksis blev litteraturstudiet afgrænset til danske undersøgelser, idet det blev vurderet, at udenlandske byggeskikke og driftsformer afviger så meget fra de tilsvarende danske, at en sammenligning reelt ikke er mulig. Der foreligger dog kun få undersøgelser, som har belyst dette spørgsmål. Data fra disse undersøgelser, som blev alle gennemført af SEGES, Videncenter for Svineproduktion er refereret i denne rapport, og resultaterne er inkluderet i fastlæggelsen af typiske data for danske stalde.

I alt opereres der i Danmark med 112 kombinationer af husdyrart og staldtype for kvæg og svin, og hvor husdyrgødningen håndteres helt eller delvist som gylle. Syv af kombinationerne repræsenterer mere end halvdelen af de rapporterede dyreenheder, som producerer gylle. Der er gennemført et feltstudium i 16 stalde hos 10 danske landmænd, som leverer gylle til biogasanlæggene Bånlev, Thorsø Biogas eller Horsens Biogas. De 16 stalde repræsenterer de syv mest udbredte kombinationer. De ti landmænd blev besøgt og interviewet om staldsystemet, antal dyr, gylleudpumpnings- og afhentningsrutiner mv. Ved besøget blev den aktuelle gyllemængde i stalden(e) opmålt ved at opmåle arealet af gylleoverflade og den gennemsnitlige gylledybde i stalden. De fleste stalde var sektionerede, hvorfor målingerne blev gennemført sektionsvis. I de besætninger, hvor der fandtes fortank, blev denne opmålt ved at måle gyllens overfladeareal og gylledybde. Den samlede gyllemængde blev beregnet som mængden pr. årsdyr.

I tabel 3 er anført resultaterne fra hver af de 16 undersøgte stalde i feltstudiet. Hovedresultaterne fra feltstudiet er samlet og grupperet med resultaterne fra litteraturstudiet i tabel 4. Resultaterne viser en vis variation selv mellem ellers sammenlignelige stalde. Denne variation er dels et udtryk for forskelligheden i staldindretning og drift og dels et udtryk for metodeusikkerheden. HRT-værdier beregnet på grundlag af besøgte stalde, der fik afhentet gylle hyppigt, dvs. flere gange ugentligt, og fra slagtesvinestalde med mange sektioner, vurderes som mest præcise. Mens der er relativ stor usikker knyttet til HRT-værdier for stalde med lav afhentningsfrekvens, og stalde med relativ ensartet dyresammensætning og få gyllekummer, fx ringkanalstalde til malkekøer.

I tabel 5 (og i tabel 1 i det danske sammendrag) er anført typiske værdier for alle 112 kombinationer af husdyrart og staldtype. Data i tabel 5 (og 1) er udtryk for en tolkning af data fra tabel 4. Dels er der data estimeret for husdyrarter og staldsystemer, som ikke har været genstand for opmåling i feltstudiet og dels er der, baseret på en faglig vurdering, kompenseret for forhold i de opmålte stalde, som har været vurderet for atypiske.

Tabel 1. *Husdyrart og staldtype. Typiske tal for danske staldsystemer. Data om antal stalde og dyreenheder er fra GHI (2011). Data fra feltstudiet er skrevet med fed tekst.*

Husdyrart	Staldtype	Antal stalde	Antal dyre-enheder	Gylle i stald + fortank, ton pr. dyr	Hydraulisk retentionstid (HRT), dage
Malkeko, stor race	Bindestald med riste	581	37.579	0,5	6
Malkeko, stor race	Dybstrøelse, lang ædeplads med fast gulv	70	4.144	0,1	0
Malkeko, stor race	Dybstrøelse, lang ædeplads med spalter, bagskyl	119	9.861	0,5	30
Malkeko, stor race	Dybstrøelse, lang ædeplads med spalter, linespil	105	6.562	0,1	0
Malkeko, stor race	Sengestald med fast gulv	522	103.851	0,1	0
Malkeko, stor race	Sengestald med spaltegulv, bagskyl	1.577	304.015	**2,5**	**40**
Malkeko, stor race	Sengestald med spaltegulv, ringkanal			**1,5**	**30**
Malkeko, stor race	engestald med spaltegulv, linespil	714	142.223	0,1	0
Malkeko, stor race	Sengestald, fast drænet gulv med skraber og ajleafløb	82	17.503	**0,3**	**4**
Malkeko, Jersey	Bindestald med riste	69	2.061	0,4	6
Malkeko, Jersey	Dybstrøelse, lang ædeplads med fast gulv	25	2.532	0,1	0
Malkeko, Jersey	Dybstrøelse, lang ædeplads med spalter, bagskyl	43	4.350	0,4	30
Malkeko, Jersey	Dybstrøelse, lang ædeplads med spalter, linespil	39	3.726	0,1	0
Malkeko, Jersey	Sengestald med fast gulv	105	13.464	0,1	0
Malkeko, Jersey	Sengestald med spaltegulv, bagskyl	281	31.278	2,0	40
Malkeko, Jersey	Sengestald med spaltegulv, ringkanal			1,3	30
Malkeko, Jersey	engestald med spaltegulv, linespil	108	11.939	0,1	0
Malkeko, Jersey	Sengestald, fast drænet gulv med skraber og ajleafløb	17	2.366	0,3	4
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Bindestald med riste	352	3.958	0,4	20
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Dybstrøelse, kort ædeplads med fast gulv	264	2.114	0,1	0
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Dybstrøelse, lang ædeplads med fast gulv	165	4.194	0,1	0
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Dybstrøelse, lang ædeplads med spalter, bagskyl	172	3.861	0,4	85
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Dybstrøelse, lang ædeplads med spalter, linespil	230	5.844	0,1	0
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Sengestald med fast gulv	458	15.449	0,1	0
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Sengestald med spaltegulv, bagskyl	1.177	42.969	**1,5**	**85**
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Sengestald med spaltegulv, ringkanal			1,0	50
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	engestald med spaltegulv, linespil	464	16.329	0,1	0
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Sengestald, fast drænet gulv med skraber og ajleafløb	56	2.211	0,2	10
Kvier, tung race, 6 mdr. til kælv. ved 27 mdr.	Spaltegulvbokse	3.090	71.977	1,0	50
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Bindestald med riste	32	194	0,3	20
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Dybstrøelse, kort ædeplads med fast gulv	24	189	0,1	0
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Dybstrøelse, lang ædeplads med fast gulv	27	441	0,1	0
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Dybstrøelse, lang ædeplads med spalter, bagskyl	35	804	0,3	85
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Dybstrøelse, lang ædeplads med spalter, linespil	36	864	0,1	0

Husdyrart	Staldtype	Antal stalde	Antal dyre-enheder	Gylle i stald + fortank, ton pr. dyr	Hydraulisk retentionstid (HRT), dage
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Sengestald med fast gulv	60	1.677	0,1	0
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Sengestald med spaltegulv, bagskyl	143	2.656	1,2	85
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Sengestald med spaltegulv, ringkanal			1,0	50
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	engestald med spaltegulv, linespil	51	941	0,1	0
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Sengestald, fast drænet gulv med skraber og ajleafløb	14	269	0,2	10
Kvier, Jersey, 6 mdr. til kælv. ved 25 mdr.	Spaltegulvbokse	295	3.707	0,8	50
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Bindestald med riste	165	525	0,4	20
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Dybstrøelse, kort ædeplads med fast gulv	243	2.134	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Dybstrøelse, lang ædeplads med fast gulv	53	575	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Dybstrøelse, lang ædeplads med spalter, bagskyl	80	734	0,4	85
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Dybstrøelse, lang ædeplads med spalter, linespil	88	1.060	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Sengestald med fast gulv	46	55	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Sengestald med spaltegulv, bagskyl	141	1.341	1,5	85
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Sengestald med spaltegulv, ringkanal			1,0	50
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Sengestald med spaltegulv, linespil	67	1.466	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Sengestald, fast drænet gulv med skraber og ajleafløb	21	224	0,2	10
Slagtekalv, 6 mdr. til slagtning ved 440 kg, stor race	Spaltegulvbokse	2.094	16.149	1,0	50
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Bindestald med riste	8	9	0,3	20
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Dybstrøelse, kort ædeplads med fast gulv	21	37	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Dybstrøelse, lang ædeplads med fast gulv	12	40	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Dybstrøelse, lang ædeplads med fast gulv	5	3	0,3	85
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Dybstrøelse, lang ædeplads med spalter, ringkanal	10	21	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Sengestald med fast gulv	5	4	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Sengestald med spaltegulv, bagskyl	15	19	1,2	85
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Sengestald med spaltegulv, ringkanal			1,0	50
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Sengestald med spaltegulv, linespil	7	2	0,1	0
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Sengestald, fast drænet gulv med skraber og ajleafløb	5	4	0,2	10
Slagtekalv, 6 mdr. til slagtning ved 328 kg, Jersey	Spaltegulvbokse	186	341	0,8	50
Avlstyr, stor race, over 440 kg	Bindestald med riste	11	6	0,4	20
Avlstyr, stor race, over 440 kg	Dybstrøelse, kort ædeplads med fast gulv	22	10	0,1	0
Avlstyr, stor race, over 440 kg	Dybstrøelse, lang ædeplads med fast gulv	6	4	0,1	0
Avlstyr, stor race, over 440 kg	Dybstrøelse, lang ædeplads med spalter, bagskyl	5	2	0,4	85
Avlstyr, stor race, over 440 kg	Dybstrøelse, lang ædeplads med spalter, ringkanal	4	2	0,3	40
Avlstyr, stor race, over 440 kg	Sengestald med fast gulv	7	4	0,1	0
Avlstyr, stor race, over 440 kg	Sengestald med spaltegulv, bagskyl	3	2	1,5	85
Avlstyr, stor race, over 440 kg	Sengestald med spaltegulv, ringkanal			1,0	50
Avlstyr, stor race, over 440 kg	Sengestald med spaltegulv, linespil	6	3	0,1	0

Husdyrart	Staldtype	Antal stalde	Antal dyre-enheder	Gylle i stald + fortank, ton pr. dyr	Hydraulisk retentionstid (HRT), dage
Avlstyr, stor race, over 440 kg	Sengestald, fast drænet gulv med skraber og ajleafløb	1	0	0,2	10
Avlstyr, stor race, over 440 kg	Spaltegulvbokse	18	10	1,0	50
Avlstyr, Jersey, over 328 kg	Dybstrøelse, lang ædeplads med spalter, bagskyl	1	0	0,3	85
Avlstyr, Jersey, over 328 kg	Dybstrøelse, lang ædeplads med spalter, ringkanal			0,3	40
Avlstyr, Jersey, over 328 kg	Sengestald med spalter	1	0	0,1	0
Avlstyr, Jersey, over 328 kg	Spaltegulvbokse	1	0	0,8	50
Ammeko uden kalve, (400-600 kg)	Bindestald med riste	263	1.659	0,5	15
Ammeko uden kalve, (400-600 kg)	Dybstrøelse, kort ædeplads med fast gulv	92	660	0,1	0
Ammeko uden kalve, (400-600 kg)	Dybstrøelse, lang ædeplads med fast gulv	22	246	0,1	0
Ammeko uden kalve, (400-600 kg)	Dybstrøelse, lang ædeplads med spalter, bagskyl	44	337	0,5	60
Ammeko uden kalve, (400-600 kg)	Dybstrøelse, lang ædeplads med spalter, linespil	45	433	0,1	0
Ammeko uden kalve, (over 600 kg)	Bindestald med riste	492	4.513	0,5	15
Ammeko uden kalve, (over 600 kg)	Dybstrøelse, kort ædeplads med fast gulv	135	1.283	0,1	0
Ammeko uden kalve, (over 600 kg)	Dybstrøelse, lang ædeplads med fast gulv	49	581	0,1	0
Ammeko uden kalve, (over 600 kg)	Dybstrøelse, lang ædeplads med spalter, bagskyl	73	874	0,5	60
Ammeko uden kalve, (over 600 kg)	Dybstrøelse, lang ædeplads med spalter, linespil	91	1.088	0,1	0
Ammeko uden kalve, (under 400 kg)	Bindestald med riste	15	29	0,5	15
Ammeko uden kalve, (under 400 kg)	Dybstrøelse, kort ædeplads med fast gulv	6	10	0,1	0
Ammeko uden kalve, (under 400 kg)	Dybstrøelse, lang ædeplads med fast gulv	2	5	0,1	0
Ammeko uden kalve, (under 400 kg)	Dybstrøelse, lang ædeplads med spalter, bagskyl	3	30	0,5	60
Ammeko uden kalve, (under 400 kg)	Dybstrøelse, lang ædeplads med spalter, linespil	8	33	0,1	0

Husdyrart	Staldtype	Antal stalde	Antal dyre-enheder	Gylle i stald + fortank, ton pr. dyr	Hydraulisk retentionstid (HRT), dage
Søer med smågrise til 7,4 kg, farestald	Delvis spaltegulv	2.084	59.297	**0,5**	**50**
Søer med smågrise til 7,4 kg, farestald	Fuldspaltegulv	423	14.797	**0,7**	**160**
Søer med smågrise til 7,4 kg, løbe-drægtighedsstald	Delvis spaltegulv, individuel	1.703	118.766	0,04	6
Søer med smågrise til 7,4 kg, løbe-drægtighedsstald	Fuldspaltegulv	223	16.996	**0,05**	**6**
Søer med smågrise til 7,4 kg, løbe-drægtighedsstald	Delvis spaltegulv, grupper	237	18.884	0,04	6
Søer med smågrise til 7,4 kg, løbe-drægtighedsstald	Dybstrøelse og fast gulv	139	2.210	0,01	0
Søer med smågrise til 7,4 kg, løbe-drægtighedsstald	Dybstrøelse og spaltegulv	291	15.220	**0,3**	**50**
Smågrise, 7,4-30 kg	Drænet gulv + spalter (50/50)	277	10.574	0,06	30
Smågrise, 7,4-30 kg	Fuldspaltegulv	737	27.508	**0,06**	**30**
Smågrise, 7,4-30 kg	Delvis spaltegulv	2.129	96.133	**0,02**	**10**
Slagtesvin, 30-107 kg	Delvis spaltegulv, 25-49% fast gulv	2.390	157.576	**0,07**	**15**
Slagtesvin, 30-107 kg	Delvis spaltegulv, 50-75 % fast gulv	728	42.925	0,05	10
Slagtesvin, 30-107 kg	Drænet gulv + spalter (33/67)	473	46.663	0,1	20
Slagtesvin, 30-107 kg	Dybstrøelse, opdelt lejeareal	51	2.579	0,05	20
Slagtesvin, 30-107 kg	Fuldspaltegulv	3.586	307.643	**0,1**	**20**
Slagtesvin, 7,4-107 kg (FRATS)	Delvis spaltegulv, 25-49% fast gulv	19	2.131	0,07	15
Slagtesvin, 7,4-107 kg (FRATS)	Delvis spaltegulv, 50-75 % fast gulv	47	6.559	0,05	10
Slagtesvin, 7,4-107 kg (FRATS)	Drænet gulv + spalter (33/67)	5	1.019	0,1	20
Slagtesvin, 7,4-107 kg (FRATS)	Dybstrøelse, opdelt lejeareal	3	140	0,05	20
Slagtesvin, 7,4-107 kg (FRATS)	Fuldspaltegulv	26	4.369	0,1	20
I alt, kvæg og svin på gyllesystemer		31.871	1.866.663	-	-
Danmark i alt		107.737	2.353.425	-	-

2. INTRODUCTION

Denmark reports annually the emissions of greenhouse gasses from agriculture to the UN. So far, the data for calculation of emission of methane from animal houses have been poor, and a project to establish sufficient data was formulated by the Danish Energy Agency. Especially from systems including biogas plants and digested biomass the data have been insufficient.

The total emission from digested slurry can be calculated as:

$E_{total} = E_{livestock\ building\ and\ Pre\text{-}tank} + E_{biogas\ plant} + E_{after\ digestion}$

This report is part of the project, and the purpose is to supply data for the $E_{livestock\ building\ and\ Pre\text{-}tank}$ part of the equation. The main purpose of this part of the project was to supply data about the average amount of slurry stored in the livestock building at any time. Furthermore, the average retention time in the building is calculated.

3. METHODOLOGY / APPROACH

The results given in this report are based on a literature study, interviews with key persons and a field study and measurement in a number of livestock buildings for pigs and cattle.

3.1. Desk top literature study

Danish and international literature was studied in order to identify research and development studies, in which the amount of slurry in the livestock building was examined. In the study, focus was put on building systems comparable to Danish conditions. Therefor most international literature was omitted. In e.g. the Netherlands many livestock production conditions are comparable to Danish conditions. However in the Netherlands the slurry traditional is stored in deeper slurry pits under the building for a longer period than in Denmark. Therefore Dutch studies have minor value for this project.

Especially one Danish study carried out by Danish Pig Research Centre (Videncenter for Svineproduktion) provided valuable information. In the study, different housing types for pigs were visited numerous times, and, as part of the study, the surface area of the slurry pits and the depth of slurry under the slats was measured numerous times providing valuable information of the common layout of Danish pig houses and the production taking place in them.

3.2. Field study

Based on the information of number of animals and production system for each farmer in Denmark in the database "Gødnings- og husdyrindberetning" from NaturErhvervstyrelsen, GHI, a table of the livestock building system was formed including the total number of animals and animal units[1] in Denmark for each system. According to the database almost 32,000 buildings housed cattle or pigs with slurry systems (see table 1). The actual number of houses is lower, because some buildings housed more than one animal type. In total 104 combinations of animal type and housing system was identified.

For sows, finishers, dairy cattle and heifers the dominating housing systems were identified, and six combinations of animal type and housing system were selected for the field study. The systems and number of animal units for each system is shown in table 2. The six selected combinations of animal

[1] A Danish animal unit (AU) is the number animals required to produce an amount of manure containing 100 kg nitrogen in the manure including losses of nitrogen associated with the storage of manure in house and ex house.

type and housing system accounted for 48 % of all buildings and 57 % of all animal units housed in slurry based systems.

***Table 2**. Six dominating housing systems for sows, finishers, dairy cattle and heifers in Denmark according to the GHI database (Gødnings- og Husdyrindberetning).*

Animal type	Housing system	Number of buildings	Number of animal units
Dairy cows, heavy breed*)	Recirculation ring channel	1,577	304,015
	Back flush		
Heifers, heavy breed	Fully slatted boxes	3,090	71,977
Sows	Partly slatted	3,787	178,063
Finishers	Partly slatted	3,118	200,501
	Fully slatted	3,586	307,643
Dominating in total (slurry systems only)		15,158	1,062,201
Denmark in total (slurry systems only)		31,871	1,866,663
Dominating in total in % of Denmark in total		48	57

*) In the GHI-database the two housing systems are not separated.

For each of the six selected combinations of animal type and housing system two farms were selected for further inspection and measurements. In order to focus on farms which delivered slurry to a biogas plant, the selection of farms was carried out in collaboration with staff of the three centralized biogas plants Bånlev (near Aarhus), Thorsø, and Horsens. Technical staff of AgroTech visited the farms. Some of the farms had more than one combination of animal type and housing system, so the actual number of farms visited was lower than twelve.

On each farm the surface area of slurry pits was measured for each section with a commercial laser measure (Bosch DLE 70 Professional). In each of the barn sections, the slurry depth was measured at a minimum three locations using a standard folding rule. The depth in each section was calculated as a simple average of the three or more measurements.

The amount of slurry in the pre-tank was calculated by multiplication of the measured slurry surface and the slurry depth.

Data on number of animals, production system, feeding system, slurry collection frequency etc. was noted based on the interview with the farmer.

The total amount of slurry stored in the building under the slats and in the Pre-tank was calculated, and the stored amount was calculated per produced piglet or finisher pig, or per cow, heifer, or sow.

The average storage time of the slurry under the slats and in the Pre-tank was calculated as the hydraulic retention time (HRT) using the equation:

$$\text{HRT (days)} = \frac{\text{total measured amount of slurry stored in the building under the slats and in the Pre} - \text{tank (ton) x 365 (days per year)}}{\text{annual production of slurry according to standard figures (ton per year)}}$$

4. LITTERATURE STUDY

4.1. Cattle barns

Tie-stalls

Tie-stalls are a barn type where the cattle are housed in individual stalls using a tether which does not allow for the animals to walk freely. Often the cows are maintained in the stalls where they are fed and milked. Tethering the cattle in individual stalls allow for a narrow slurry channel covered by slats or grates (Figure 1), or an open shallow gutter in the floor (Figure 2). By law, it is not allowed to build new tie-stalls in Denmark, and all tie-stalls are forbidden from 2022 (Anonymous, 2015).

Figure 1. Tie-stall with tethered cows and a narrow slurry channel covered with slats behind the cows.

Figure 2. Tie-stall with tethered cows and a shallow gutter with scrapers behind the cows (Photo: Landbrugsinfo.dk).

Cubicle barns

Cubicle barns are free stalls allowing the cattle to move freely within a larger enclosure inside the barn. The cubicle is the resting place where the cow ruminates. The floor between rows of cubicles, in connecting pathways, and in front of the feeding place is the walking alleys which may be concrete slatted floor (Figure 3) or solid drained concrete floor (Figure 4).

Figure 3. Cubicle barn with slatted floor in the walking alleys. (Photo: Maskinbladet.dk)

Figure 4. Cubicle barn with precast concrete solid drained floor in the walking alleys. (Photo: Perstrup A/S).

Cubicle barns with slatted floor and interconnected slurry channels for frequent recirculation of the slurry (ring channel system)

The barn have concrete slatted floor in the walking alleys, and in case milking is carried out in a milking parlour typically also in the collecting area next to the milking parlour. Under the slats, the manure is collected in slurry channels which are connected, thus the popular name *ring channel barn*. Situated

outside the barn is a pumping well which allows for the liquid manure (slurry) to be stirred to prevent stratification of the slurry.

The depth of the interconnected slurry channels is normally 1.20 m, which is the maximum allowable depth of slurry channels according to Danish law (At.-anvisning nr. 2.6.1.1., August 1996). In order for the ring channel system to function properly, the minimum depth of slurry is 0.40 m (Landbrugets byggeblade, 2004). The maximum allowed slurry depth is 0.40 m below the underside of the slatted floor; i.e. the maximum slurry depth is 0.80 m for a 1.20 m deep slurry channel. Provided that the capacity of the slurry channels is fully utilized before emptying the channels, the average slurry depth is estimated ((0.8–0.4)/2) = 0.60 m.

Cubicle barn with slatted floor with manure pit with back-flush
This type of cubicle barn have concrete slatted floor in the walking alleys and in case milking is carried out in a milking parlour typically also in the collecting area next to the milking parlour. Under the slats, the manure is collected in manure pits which are emptied to a pump well. Due to prolonged collection of high dry matter slurry, emptying of the manure pits may be challenged because of stratification of the slurry, i.e. formation of sediment and floating layer. Stirred slurry from the pump well may be recirculated to the manure pit via a pipe situated in manure pit opposite to the slurry outlet providing manure flushing and mechanical mixing.

The depth of the manure pit is normally 1.20 m, which is the maximum allowable depth of slurry channels according to Danish law (At.-anvisning nr. 2.6.1.1., August 1996). It is possible to utilize the full capacity of the manure pits. However, by law recirculation of slurry requires a minimum of 0.50 m free space between the slurry surface and the slatted floor (At.-anvisning nr. 2.6.1.1., August 1996).

Cubicle barn with slatted floor with a manure channel and mechanical scraper system
This type of cubicle barn have concrete slatted floor in the walking alleys under which there is a manure channel equipped with a mechanical scraper allowing for frequent removal of the manure from the barn. The manure is scraped to a collection channel at the end of the scraper channel. From the collection channel the manure is transferred to a pump well by use of another scraper or by gravity, and from the pump well to the slurry store.

The manure is normally removed 4 times day^{-1} to external slurry store, i.e. the average amount of manure present in the barn equals daily amount of manure produced divided by 8 plus the amount of manure leftover in collecting cross channels.

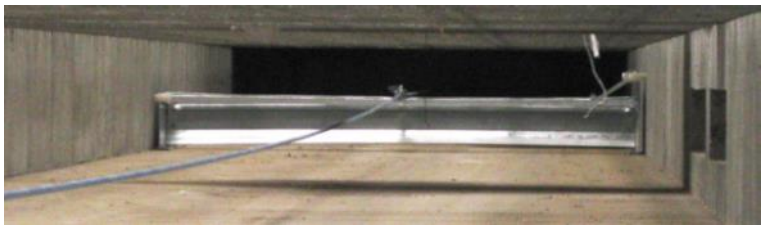

Figure 5. Mechanical scraper in manure channel under the slatted floor of a dairy barn. (Photo: Lind Jensens Maskinfabrik A/S).

Cubicle barn with solid drained floor
The dairy barn has solid floor in the walking alleys, which permits continuous drainage of the urine to a channel situated underneath the floor, and the solid manure is removed by scraping using a mechanical scraper, typically 12 times per day, i.e. the average amount of manure present in the barn equals daily amount of manure produced divided by 24 plus the amount of manure leftover in collecting channels.

Figure 6. Dairy cubicle barns with solid drained floor in the walking alleys. Left: Precast concrete solid floor with grooves and urine drainage holes (Photo: Perstrup A/S). Right: In situ cast concrete floor with 2-3% slope towards a manure channel in the middle of the walking alley' longitudinal direction (Photo: www.landbrugsinfo.dk).

Deep litter barn with long eating space

Dairy barn where the cows are loose housed in groups. The barn contains a deep litter area and a long eating space. Assumingly 60 % of manure is excreted in the deep litter and the remaining 40 % is excreted in the eating space. "Long eating space" means that the area in front of the eating space is wide enough to allow other cows to pass behind eating cows. The floor in the eating space may be slatted or solid floor (Figure 7).

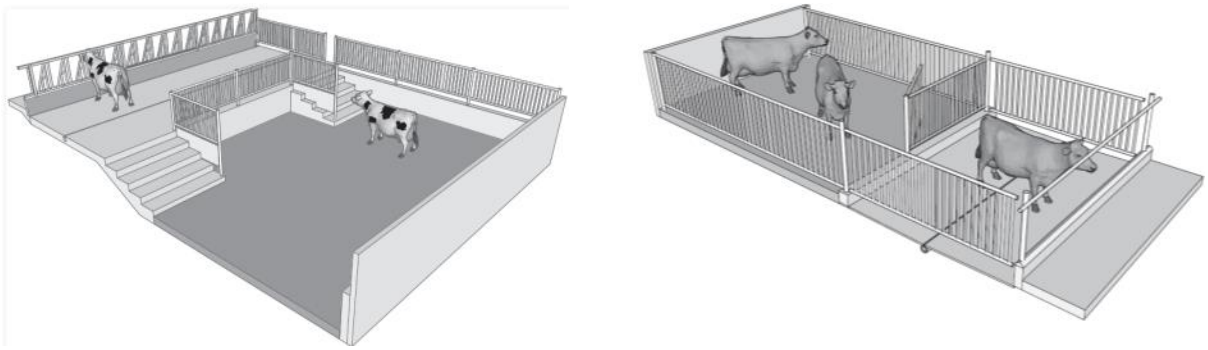

Figure 7. Deep litter barns with "long eating space". The floor in the eating space may be solid floor, solid drained floor with mechanical removal of the manure (pictures), or slatted floor combined with a ring channel system or back-flush manure pit (Drawing: Anonymous (2010)).

Deep litter barn with long eating space - slatted floor, ring channel system

The floor and associated manure collection in the eating space is previously described. The amount of liquid manure inside the barn is estimated 40 % of the estimated average amount of manure in the cubicle barn type with slatted floor and ring channel manure system.

Deep litter pen with long eating space - slatted floor, manure pit with back-flush manure pit

The floor and associated manure collection in the eating space is previously described. The amount of liquid manure inside the barn is estimated 40 % of the estimated average amount of manure estimated in the cubicle barn type with slatted floor and back-flush manure pit.

Deep litter pen with long eating space – solid floor

The floor and associated manure collection in the eating space is previously described. The amount of liquid manure inside the barn is estimated 40 % of the estimated average amount of manure estimated in the cubicle barn type with solid floor.

Deep litter pen with long eating space – solid drained floor, scraper
The floor and associated manure collection in the eating space is previously described. The amount of liquid manure inside the barn is estimated 40 % of the estimated average amount of manure estimated in the cubicle barn type with solid drained floor.

Slatted floor boxes
The pen type is equipped with fully slatted floor under which there is a slurry pit with back-flush or ring channel system. The pen type is used for housing heifers (6 months to calving) and bulls (6 months to approx. 440 kg LW). It is no longer legal to establish slatted floor boxes. Existing boxes are gradually phased out by 2024.

4.2. Pig houses

Pregnant and dry sows

Individual housing in crates with partly slatted floor
In this system the sows are housed individually in crates on a partly slatted floor. The manure is collected in slurry pits under the slatted floor which may extent to the walking alley between two rows of crates (Figure 8). The manure is collected as slurry and the slurry pit is defined as a pull-plug system (aka vacuum system), where the slurry is evacuated from the slurry pit by gravity to an external pump well via 250 or 310 mm piping.

Riis (2006) and Riis (2008) surveyed four commercial pig production farms with dry and pregnant sows housed in crates with partly slatted floor (Figure 8). All farms collected the excreta in slurry pits with pull-plug function. The average depth of the manure pits were 0.50 m (range: 0.43-0.53 m). The slurry surface averaged 1.0 m^2 per sow (range: 0.9-1.2 m^2) including the inspection path. The median depth of slurry observed was 0.15 m (95 % interval of confidence: 0.07-0.37 m; n=24) and 0.22 m (95 % interval of confidence: 0.07-0.50 m; n=24) measured at visits carried out during the summer and winter campaigns, respectively.

Group-housed pregnant sows in pens with partly slatted floor
Loose sows are housed in groups in pens with concrete solid floor in the lying area and in the optional feeding crates. There is partly slatted floor in the dunging area of the pens (Figure 9). The manure may be collected in slurry pits with pull-plug function or in manure channels equipped with mechanical scrapers. Due to the use of straw/bedding new facilities are often constructed with a mechanical manure system.

Riis (2006) and Riis (2008) surveyed four commercial pig production farms with dry and pregnant sows housed in groups in pens with partly slatted floor. Figure 9 depicts an example of a pig house with pens for group-housed sows. The excreta was collected in manure pits with pull-plug function (n = 1) or in shallow manure channels with a mechanical scraper (n=3). The average depth of the manure pits was 0.50 m (range: 0.43-0.53 m). The slurry surface in the single herd with vacuum operated manure pit was 1.5 m^2 per sow including the inspection path, while in the three herds with manure channels and mechanical scraper the average slurry surface was 0.7 m^2 per sow (range: 0.6-0.9 m). The median depth of slurry of all herds observed was 0.02 m (95 % interval of confidence: 0.02-0.35 m; n=18) and 0.05 m (95 % interval of confidence: 0.05-0.29 m; n=18) measured at visits carried out during the summer and winter campaigns, respectively.

Figure 8. Individual crates with partly slatted floor for dry sows and pregnant sows. (Photo: SEGES, Danish Pig Research Centre).

Figure 9. "T-pen" for group housing of pregnant sows. (Photo: SA Christiansen A/S).

Farrowing sows

Farrowing crates with partly slatted floor

In this housing system the farrowing sows and piglets are kept in individual crates equipped with partly slatted floor. The manure is collected as liquid manure in shallow pull-plug type slurry pits (Figure 10).

Riis (2006) and Riis (2008) surveyed four commercial pig production farms with farrowing sows housed in crates with partly slatted floor. All farms collected the excreta in shallow manure pits with pull-plug function (aka vacuum system). The depth of the manure pits were on average 0.50 m (range: 0.45-0.57 m). The slurry surface averaged 1.7 m^2 per sow (range: 1.5-2.2 m^2) including the inspection path. The median depth of slurry observed was 0.26 m (95 % interval of confidence: 0.04-0.44 m; n=24) and 0.21 m (95 % interval of confidence: 0.07-0.32 m; n=24) measuring at visits carried out during the summer and winter campaigns, respectively.

Farrowing pens with fully slatted floor

In this housing system the farrowing sows and the piglets are kept in individual crates equipped with fully slatted floor. The manure is collected as liquid manure in shallow pull-plug type slurry pits (Figure 11). Riis (2006) surveyed four commercial pig production farms with farrowing sows housed in crates with fully slatted floor. All farms collected the excreta in shallow manure pits with pull-plug function (aka vacuum system). The depth of the manure pits were on average 0.55 m (range: 0.50-0.60 m). The slurry surface averaged 4.7 m^2 per sow (range: 3.9-5.6 m^2) including the inspection path. Note that the heating plate provided for the piglets is integrated in the slatted floor and so does not extend to the floor of the manure pit, meaning that heating plate area is not excluded in the calculation of the manure surface area per sow. The median depth of slurry observed during 16 visits was 0.15 m (95 % interval of confidence: 0.11-0.33 m).

Figure 10. Farrowing crate with partly slatted floor (Photo: SEGES, Danish Pig Research Centre).

Figure 11. Farrowing crate with fully slatted floor. (Photo: SEGES, Danish Pig Research Centre).

Weaners

Two-climate pens with partly slatted floor

In this housing system the weaned pigs are kept in pens equipped with partly slatted floor in the dunging area. The resting area typically has an adjustable cover which provides the weaners an optimal temperature when they are resting. The manure is collected in shallow pull-plug type slurry pits (Figure 12).

Riis (2006) and Riis (2008) surveyed four commercial pig production farms with weaned pigs (approx. 7.5 to 32 kg) housed in pens with partly slatted floor. All farms collected the excreta in shallow manure pits with pull-plug function (a.k.a. vacuum system). The depth of the manure pits were on average 0.5 m (range: 0.40-0.57 m). The slurry surface averaged 0.12 m^2 per pig (range: 0.10-0.15 m^2) including the inspection path. The median depth of slurry was 0.22 m (95 % interval of confidence: 0.11-0.41 m; n=24) and 0.25 m (95 % interval of confidence: 0.10-0.39 m; n=24) measuring at visits carried out during the summer and winter campaigns, respectively.

Pens with 50 % drained floor and 50 % slatted floor

In this housing system the weaned pigs are kept in groups in pens with fully drained floor. By law, minimum 50 % of the floor allowance must be solid or drained floor defined as max 10 % opening area. The rest may be slatted or grated floor. The manure is collected in pull-plug type slurry pits. Also the inspection path may have slats, effectively increasing the slurry surface area per animal place. The manure is collected in shallow pull-plug type slurry pits (Figure 13).

Riis (2006) surveyed four commercial pig production farms with weaned pigs (approx. 7.5 to 32 kg) housed in pens with fully slatted floor. All weaned pig rooms collected the excreta in shallow manure pits with pull-plug function (aka vacuum system). The slurry surface was on average 0.36 (range: 0.34-0.39) m^2 per pig including the inspection path. The depth of the manure channels were on average 0.5 m (range: 0.41-0.77 m). The pig farms were visited on six occasions and the median depth of slurry was 0.16 m (95 % interval of confidence: 0.05-0.44 m).

Figure 12.Two-climate pens with partly slatted floor and covered lying area for weaners (Photo: SEGES, Danish Pig Research Centre).

Figure 13.Pens with fully slatted floor (Photo: SEGES, Danish Pig Research Centre).

Growing/finishing pigs

Pens with 1/3 drained floor and 2/3 slatted floor

In this housing system, the growing finishing pigs are kept in groups in pens where the floor is drained in 33 % of the area and the remaining 67 % is concrete slatted floor which is the minimum requirement according to the law. There is a manure pit under the entire pen area. Typically, the slurry pit extents underneath the inspection path which has slatted floor to improve the hygiene, thus effectively increasing the slurry surface area per animal place (Figure 15).

Riis (2006) surveyed four commercial pig production farms with growing-finishing pigs (approx. 32 kg to slaughter) housed in pens with fully slatted floor and combined drained floor and slatted floor, re-

spectively. All farms collected the excreta in shallow manure pits with pull-plug function. The depth of the manure pits were on average 0.65 m (range: 0.53-0.76 m). The slurry surface averaged 0.75 m^2 per pig (range: 0.70-0.80 m^2) including the inspection path. Today, traditional fully slatted floor is no longer allowed for growing-finishing pigs. Instead, a minimum of 33 % of the space allowance shall be solid or drained[2] floor. However, the manure system underneath the floor has not changed. The pig farms were visited on six occasions and the median depth of slurry was 0.31 m (95 % interval of confidence: 0.06-0.52 m) for pens with fully slatted floor, while the median slurry depth in pens with 1/3 drained floor was 0.27 m (95 % interval of confidence: 0.18-0.35 m).

Two other Danish studies involving growing-finishing pigs housed in pens with fully slatted floor and combined drained and slatted floor revealed that the average slurry depth was 5-6 cm measured on day one following emptying the slurry pits (Jonassen, 2011; Jonassen, 2013). In the study by Jonassen (2011) each pen measured 2.40 x 4.80 m (11.5 m^2) and housed 17 pigs equal to a gross space allowance of 0.67 m^2 per pig. Since the floor elements rests on two concrete walls, the effective width of the manure pit was estimated 2.26 m, which equals a manure surface of 10.85 m^2 manure surface per pen or 0.64 m^2 per pig.

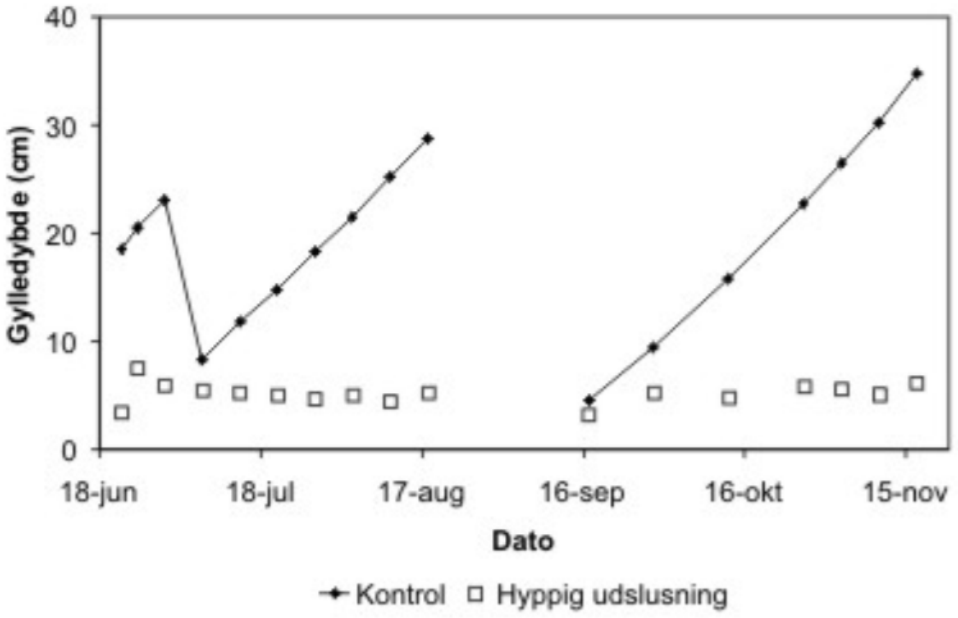

Figure 14. Depth of slurry in two growing-finishing pig houses with fully slatted floor and shallow manure pits. In the control unit slurry was collected over a period of 6 weeks before emptying the shallow manure pit (solid diamonds). In the test unit, the shallow manure pit was emptied once per week (open squares) (Jonassen, 2011).

Pens with partly slatted floor

In this housing system, the growing finishing pigs are kept in groups in pens where the floor is partly slatted. According to the law a minimum of 33 % of the space allowance must be solid or drained (se previous) resulting in up to 67 % slatted area. However, as much as approx. 67 % may be solid floor leaving only 33 % slatted floor (Figure 15). There is a manure pit under the slatted area.

[2] Maximum area of openings is 10 % of the floor allowance.

Figure 15. Typical Danish pen for growing/finishing pigs with drained floor in the lying area and concrete slatted floor in the rest. The pen has a shallow manure pit under the entire pen area (Photo: SEGES, Danish Pig Research Centre).

Figure 16. Growing-finishing pig pen with partly slatted floor (photo: SEGES, Danish Pig Research Centre).

Riis (2006) surveyed four commercial pig production farms with growing-finishing pigs (approx. 32 kg to slaughter) housed in pens with partly slatted floor. All farms collected the excreta in shallow manure pits with pull-plug function. The average depth of the manure pits were 0.50 m (range: 0.40-0.60 m). The average slurry surface was 0.29 m^2 per pig (range: 0.15-0.44 m^2) including the inspection path. Often the manure pit under growing-finishing pig pens with partly slatted floor does not extent underneath the inspection path, thus limiting the surface of the manure to approximately the same area as the slatted area. The median depth of slurry was 0.37 m (95 % interval of confidence: 0.12-0.53 m; N=10).

5. SURVEY

10 farms with dairy cows, heifers, sows, piglets and finishers housed in slurry based systems were visited during December 2014 to March 2015. The farmers were interviewed, and the amount of slurry in the slurry pits under the slats and in the pre-tank was measured. Basic results of the interviews, and the results of the measurements are shown in tables 3.1 – 3.16.

Table 3. *Summary of the results from the survey.*

No. 1								
Farmers name and place					Jacob Kviesgaard, Fårvang			
Deliver to biogas plant					Thorsø Biogas			
Delivery frequency					Every week day			
Animal type					Dairy cows, heavy breed			
Barn type					Cubicle barn with drained concrete floor			
Animal number (heads)					288			
Norm slurry production per animal and in total, m^3					26.6/7,650			
Pre-tank capacity, m^3					No Pre-tank			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Slurry per animal place, m^3	Slurry production, m^3/day	HRT, days
1	49	0	0.32	20	-			
2	42	0	0.38	15	-			
3	57	0	0.33	17	-			
4	57	0	0.31	15	-			
5	48	0	0.32	17	-			
In total	253	0		83	-	0.29	21	4

No. 2								
Farmers name and place					Jens Erik Østergaard, Langå			
Deliver to biogas plant					Thorsø Biogas			
Delivery frequency					Three times a week (Mon., Wed., 2 x Fri.)			
Animal type					Dairy cows, heavy breed			
Barn type					Cubicle barn with slatted floor and ring channel slurry pits			
Animal number (heads)					160			
Norm slurry production per animal/in total, m^3 $year^{-1}$					26.6/4,250			
Pre-tank capacity, m^3					20 m^3			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	239	0	0.59	141				
2	48	0	0.59	28				
In total				169	20	1.18	12	16

No. 3								
Farmers name and place					Rene Rasmussen, Thorsø			
Deliver to biogas plant					Thorsø Biogas			
Delivery frequency					Three times a week (Mon., Wed., Fri.)			
Animal type					Dairy cows, heavy breed			
Barn type					Cubicle barn with slatted floor and ring channel slurry pits			
Animal number (heads)					215			
Norm slurry production per animal/in total, m^3 $year^{-1}$					26.6/5,715			
Pre-tank capacity, m^3					No pre-tank			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	272	0	0.94	256				
2	410	0	0.93	378				
In total				634	0	2.95	16	40

No. 4								
Farmers name and place					Thyge Glismann, Gjern			
Deliver to biogas plant					Thorsø Biogas			
Delivery frequency					Twice a week (Mon., Thurs.)			
Animal type					Dairy cows			
Barn type					Cubicle barn with slatted floor, slurry pits with back-flush			
Animal number (heads)					100			
Norm slurry production per animal/in total, m^3 $year^{-1}$					26.6/2,660			
Pre-tank capacity, m^3					23 m^3			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	109	0	0.66	71				
2	140	0	0.52	73				
3	35	0	0.55	19				
4	91	0	0.55	50				
5	20	0	0.44	9				
In total				222	23	2.45	7	34

No. 5								
Farmers name and place					Eskild Gramkow Olesen, Horsens			
Deliver to biogas plant					Horsens			
Delivery frequency					Every two weeks			
Animal type					Dairy cows, heavy breed			
Barn type					Cubicle barn with slatted floor, slurry pits with back-flush			
Animal number (heads)					144			
Norm slurry production per animal/in total, m^3 $year^{-1}$					26.6/3,830			
Pre-tank capacity, m^3					50 m^3			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	30	0	0.55	16				
2	48	0	0.83	40				
3	48	0	0.74	35				
4	23	0	0.53	12				
5	7	0	0.76	5				
6	20	0	0.74	15				
7	77	0	0.73	56				
8	77	0	0.86	52				
In total				232	50	2.0	10	27

No. 6								
Farmers name and place					Hans Versteegen, Brædstrup			
Deliver to biogas plant					Horsens			
Delivery frequency					Every two weeks			
Animal type					Dairy cows, heavy breed			
Barn type					Cubicle barn with slatted floor, slurry pits with back-flush			
Animal number (heads)					120			
Norm slurry production per animal/in total, m^3 $year^{-1}$					26.6/3,190			
Pre-tank capacity, m^3					26 m^3 (shared by two barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	152	0	0.92	140				
2	152	0	0.91	139				
3	51	0	0.88	45				
4	15	0	0.91	13				
5	15	0	0.92	14				
7	56	0	0.55	31				
8	17	0	0.53	9				
9	7	0	0.55	4				
10	46	0	0.63	29				
In total				423	26	3.75	9	51

No. 7								
Farmers name and place					Hans Versteegen, Brædstrup			
Deliver to biogas plant					Horsens			
Delivery frequency					Every two weeks			
Animal type					Heifers, heavy breed			
Barn type					Cubicle barn with slatted floor, slurry pits with back-flush			
Animal number (heads)					75			
Norm slurry production per animal/in total, m^3 $year^{-1}$					5.85/439			
Pre-tank capacity, m^3					4 m^3 (shared by two barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
6	180	0	0.55	98				
In total				98	4	1.36	1	85

No. 8								
Farmers name and place					Ole Pedersen, Langå			
Deliver to biogas plant					Thorsø Biogas			
Delivery frequency					Weekly (every Friday)			
Animal type					Growing/finishing pigs			
Pen type					Partly slatted floor			
Animal production $year^{-1}$					1,500			
Norm slurry production per animal/in total, m^3 $year^{-1}$					0.44/660			
Pre-tank capacity, m^3					48 m^3 (shared by three barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	65	28	0.40	26				
2	79	34	0.37	29				
In total	145	62	0,38	55	14	0.17	1.8	38

No. 9								
Farmers name and place					Keld Jensen, Spørring			
Deliver to biogas plant					Bånlev			
Delivery frequency					Weekly (every Friday)			
Animal type					Growing/finishing pigs			
Pen type					Fully slatted floor			
Animal production $year^{-1}$					3,350			
Norm slurry production per animal and in total, m^3					0.44/1,474			
Pre-tank capacity, m^3					21 m^3 (shared by three barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	646	17	0.26	171	10	0.20	4.0	45

No. 10								
Farmers name and place					Keld Jensen, Spørring			
Deliver to biogas plant					Bånlev			
Delivery frequency					Weekly (every Friday)			
Animal type					Growing/finishing pigs			
Pen type					Fully slatted			
Animal production year^{-1}					775			
Norm slurry production per animal/in total, m^3 year^{-1}					0.44/341			
Pre-tank capacity, m^3					21 m^3 (shared by three barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	153	0	0.22	34	2	0.17	0.9	39

No. 11								
Farmers name and place					Keld Jensen, Spørring			
Deliver to biogas plant					Bånlev			
Delivery frequency					Weekly (every Friday)			
Animal type					Growing/finishing pigs			
Pen type					Partly slatted floor			
Animal production year^{-1}					2,900			
Norm slurry production per animal/in total, m^3 year^{-1}					0.44/1,275			
Pre-tank capacity, m^3					21 m^3 (shared by three barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	428	10	0.17	74	9	0.11	3.4	24

No. 12								
Farmers name and place					Ole Pedersen, Langå			
Deliver to biogas plant					Thorsø Biogas			
Delivery frequency					Weekly (every Friday)			
Animal type					Weaners			
Pen type					Partly slatted floor			
Animal production year^{-1}					6,250			
Norm slurry production per animal/ in total, m^3 year^{-1}					0.12/756			
Pre-tank capacity, m^3					48 m^3 (shared by three barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	35	0	0.53	19				
2	35	0	0.27	10				
3	35	0	0.23	8				
4	35	0	0.17	6				
In total	140	0	0,30	42	16	0.054	2.1	28

No. 13								
Farmers name and place					Knud W. Thomsen, Langå			
Deliver to biogas plant					Thorsø Biogas			
Delivery frequency					Three times weekly (Mon., Wednes., Thurs)			
Animal type					Growing/finishing pigs			
Pen type					Fully slatted floor			
Animal production year^{-1}					6,000			
Norm slurry production per animal/in total, m^3 year^{-1}					0.44/2,620			
Pre-tank capacity, m^3					400 (shared by weaner and growing/finishing pig houses, respectively)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	129	10	0.20	28				
2	129	10	0.28	39				
3	129	10	0.11	15				
4	129	10	0.20	28				
5	129	10	0.27	37				
6	129	10	0.13	19				
7	129	10	0.17	23				
8	129	10	0.24	33				
9	284	56	0.20	67				
In total	1316	136	0,20	289	146	0.21	7	61

No. 14								
Farmers name and place					Ole Pedersen, Langå			
Deliver to biogas plant					Thorsø Biogas			
Delivery frequency					Weekly (every Friday)			
Animal type					Sows, pregnant			
Pen type					Partly slatted floor			
Animal number (heads)					235			
Norm slurry production per animal/ in total, m^3 year^{-1}					3.68/865			
Pre-tank capacity					48 m^3 (shared by three barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal place, m^3	Slurry production, m^3/day	HRT, days
1	54	0	0.17	9				
2	688	0	0.38	261				
In total	742	0	0,28	270	18	1.23	2.4	122

No. 15								
Farmers name and place					Flemming Larsen, Horsens			
Deliver to biogas plant					Horsens			
Delivery frequency					Every two weeks			
Animal type					Sows, farrowing			
Pen type					Partly slatted floor			
Animal number (heads)					185			
Norm slurry production per animal/ in total, m^3 $year^{-1}$					1.56/1,095			
Pre-tank capacity					15 m^3 (shared by three barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal, m^3	Slurry production, m^3/day	HRT, days
1-3	166	0	0.43	71				
4	60	0	0.45	27				
5	62	0	0.37	23				
6-7	41	0	0.37	15				
In total	329	0	0,41	136	10	0.79	3.0	49

No. 16								
Farmers name and place					Flemming Larsen, Horsens			
Deliver to biogas plant					Horsens			
Delivery frequency					Every two weeks			
Animal type					Sows, pregnant			
Pen type					Partly deep litter and slatted floor			
Animal number (heads)					515			
Norm slurry production per animal/in total, m^3 $year^{-1}$					2.02/1,410			
Pre-tank capacity					15 m^3 (shared by three barns)			
Section	Pit area, pens, m^2	Pit area, path, m^2	Average slurry depth, m	Slurry volume, barn, m^3	Slurry volume, pre-tank, m^3	Volume per animal, m^3	Slurry production, m^3/day	HRT, days
1	54	0	0.29	16				
2	26	0	0.24	6				
3	54	0	0.09	5				
4	26	0	0.26	7				
5	88	0	0.02	2				
6	62	0	0.02	1				
7	61	0	0.03	2				
8	89	0	0.03	2				
9	88	0	0.17	15				
10	62	0	0.07	4				
11	61	0	0.08	5				
12	89	0	0.04	4				
In total	760	0	0,11	68	5	0.13	4	19

6. DISCUSSION

In table 4 a summary of the results of the literature study and the survey is given. Only key figures from chapter 4 and from table 3.1 to 3.16 are given. The figures are grouped by animal type and housing system to make comparison between survey and literature study easier.

Data for the same animal type and housing system varies, which illustrates the variation in management in practice. Another reason for the variation is that, in the survey we assumed that the amount of slurry in the barn on the day for the visit was representative for the amount of slurry at any day, and this is not quite true. In reality the amount of slurry varies, e.g. the amount will be higher just before delivering to the biogas plant than following delivery. That influences both the calculated amount of slurry and the calculated HRT. It is expected that values of manure HRT calculated based on data collected from farms that frequently empty the manure pits, and farms with many units containing animals of different age, e.g. growing/finishing pigs, are relatively precise. HRTs obtained from farms that empty the manure pits less frequently, or farms with few manure pits, e.g. ring channel barns for dairy cows are less precise. Also, the lower the pit surface area per animal, the higher the uncertainty, because the depth of slurry in the pit varies more from day to day, e.g. pens with partly slatted floor compared with fully slatted floor.

In table 5 typical data for Danish livestock production systems are given. The number of buildings and animal units are based on data from GHI. In the GHI database the barn type slats and a back flush pit and the barn type with slats and ring channels for cattle are grouped even though the barn systems are distinct. In table 5 the only one figure for number of animal and animal units are given for each type of animal.

The amount of slurry and the hydraulic retention time is generally based on data from table 4 (marked in bold text). The data from table 3 may have been adjusted before entered in table 5. The adjustment was based on knowledge of a typical design or management of the barns from the survey.

Data on animal type and housing systems not covered by neither the survey nor the literature study are extrapolated from the covered housings based on expert judgment. In generating the data, the following assumptions are made:

- The lower the pit surface area per animal, the lower the amount of manure stored in the barn.
- The lower the pit surface area per animal and the higher the annual manure production, the lower the HRT.
- In housing systems with scraper systems, the estimated amount of manure is very low, and it is assumed that the HRTs are assumed 0 days, because the manure is removed from the barns on a daily basis.
- The HRTs of Jersey and heavy breeds are assumed to be identical. The amount of in-house stored slurry from Jersey cattle is a little lower per animal than from heavy breeds, however, the stocking density is a little higher.
- Housing systems for heifers and bulls are assumed to have identical HRTs.

Table 4. *Summary of results of literature study and survey*

Animal type	Barn type	Source	Surface area of pit incl. path area, m^2 per animal place	Average slurry depth in pits, m	Amount of slurry in barn incl. pre-tank, m^3 per animal place	Hydraulic retention time, HRT, days
Dairy cows	Drained floor	Jacob Kvistgaard	0.88	0.33	0.29	4
Dairy cows	Ring channel	Jens Erik Østergaard	1.79	0.59	1.18	16
	Ring channel	Rene Rasmussen	3.17	0.94	2.95	40
Dairy cows	Back flush	Thyge Glismann	3.94	0.54	2.45	34
	Back flush	Eskild G. Olsen	2.29	0.71	1.96	27
	Back flush	Hans Versteegen	4.26	0.75	3.75	51
Heifers	Back flush	Hans Versteegen	2.40	0.55	1.36	85
Pigs, Finishers	Partly slatted	Ole Pedersen	0.55	0.38	0.17	38
	Partly slatted	Keld Jensen	0.54	0.17	0.11	24
	Partly slatted	VSP	0.29	0.37	0.12**)	22
Pigs, Finishers	Fully slatted	Keld Jensen	0.70	0.26	0.20	45
	Fully slatted	Keld Jensen	0.70	0.22	0.17	39
	Fully slatted	Knud W. Thomsen	0.82	0.20	0.21	61
	Fully slatted	VSP	0.75	0.29	0.20*)**)	45
Pigs, Weaners	Partly slatted	Ole Pedersen	0.15	0.30	0.054	28
	Partly slatted	VSP	0.12	0.23	0.025*)**)	13
Pigs, Weaners	Fully slatted	VSP	0.36	0.16	0.052*)**)	27
Sows, pregnant	Partly slatted	Ole Pedersen	3,16	0.28	1,23	122
Sows, pregnant	Partly deep litter, slatted floor	Flemming Larsen	1.48	0.11	0.13	19
Sows, farrowing	Partly slatted	Flemming Larsen	1.78	0.41	0.79	49
	Partly slatted	VSP	1.70	0.21	0.36**)	84
Sows, farrowing	Fully slatted	VSP	4.7	0.15	0.71**)	166

*) The amount of slurry per produced pig was calculated as the amount per pig place divided by 3.7 for finishers and 5.8 for weaners (3,7 batches per year for finishers and 5.8 batches per year for weaners).

**) Figures do not include amount of slurry in pre-tanks.

***Table 5**. Typical data for Danish livestock production systems grouped by animal type and barn type. The number of buildings and animal units are bases on data from GHI. Data from survey and literature study marked in bold text.*

Animal type	Barn type	Number of buildings according to GHI	Number of Animal Units*) according to GHI	Estimated amount of slurry in barn + pre-tank per animal, tonnes	Estimated hydraulic retention time (HRT), days
Dairy cow, heavy breed	Tie-stall with iron slats	581	37,579	0.5	6
Dairy cow, heavy breed	Partly deep litter, long feeding area, solid floor	70	4,144	0.1	0
Dairy cow, heavy breed	Partly deep litter, long feeding area, back flush	119	9,861	0.5	30
Dairy cow, heavy breed	Partly deep litter, long feeding area, scrapers	105	6,562	0.1	0
Dairy cow, heavy breed	Cubicle barn with solid floor	522	103,851	0.1	0
Dairy cow, heavy breed	Cubicle barn with slats, channels with back flush	1,577	304,015	**2.5**	**40**
Dairy cow, heavy breed	Cubicle barn with slats, channels with circulation ring channel			**1.5**	**30**
Dairy cow, heavy breed	Cubicle barn with slats, channels with mechanical scrapers	714	142,223	0.1	0
Dairy cow, heavy breed	Cubicle barn with solid drained floor with scrapers	82	17,503	**0.3**	**4**
Dairy cow, Jersey	Tie-stall with iron slats	69	2,061	0.4	6
Dairy cow, Jersey	Partly deep litter, long feeding area, solid floor	25	2,532	0.1	0
Dairy cow, Jersey	Partly deep litter, long feeding area, back flush	43	4,350	0.4	30
Dairy cow, Jersey	Partly deep litter, long feeding area, scrapers	39	3,726	0.1	0
Dairy cow, Jersey	Cubicle barn with solid floor	105	13,464	0.1	0
Dairy cow, Jersey	Cubicle barn with slats, channels with back flush	281	31,278	2.0	40
Dairy cow, Jersey	Cubicle barn with slats, channels with circulation ring channel			1.3	30
Dairy cow, Jersey	Cubicle barn with slats, channels with mechanical scrapers	108	11,939	0.1	0
Dairy cow, Jersey	Cubicle barn with solid drained floor with scrapers	17	2,366	0.3	4
Heifer, 6 months to calving at 27 months, heavy breed	Tie-stall with iron slats	352	3,958	0.4	20
Heifer, 6 months to calving at 27 months, heavy breed	Partly deep litter, short feeding area, solid floor	264	2,114	0.1	0
Heifer, 6 months to calving at 27 months, heavy breed	Partly deep litter, long feeding area, solid floor	165	4,194	0.1	0
Heifer, 6 months to calving at 27 months, heavy breed	Partly deep litter, long feeding area, back flush	172	3,861	0.4	85
Heifer, 6 months to calving at 27 months, heavy breed	Partly deep litter, long feeding area, scrapers	230	5,844	0.1	0
Heifer, 6 months to calving at 27 months, heavy breed	Cubicle barn with solid floor	458	15,449	0.1	0
Heifer, 6 months to calving at 27 months, heavy breed	Cubicle barn with slats, channels with back flush	1,177	42,969	**1.5**	**85**
Heifer, 6 months to calving at 27 months, heavy breed	Cubicle barn with slats, channels with circulation ring channel			1.0	50
Heifer, 6 months to calving at 27 months, heavy breed	Cubicle barn with slats, channels with mechanical scrapers	464	16,329	0.1	0
Heifer, 6 months to calving at 27 months, heavy breed	Cubicle barn with solid drained floor with scrapers	56	2,211	0.2	10
Heifer, 6 months to calving at 27 months, heavy breed	Fully slatted boxes	3,090	71,977	1.0	50
Heifer, 6 months to calving at 25 months, Jersey	Tie-stall with iron slats	32	194	0.3	20
Heifer, 6 months to calving at 25 months, Jersey	Partly deep litter, short feeding area, solid floor	24	189	0.1	0
Heifer, 6 months to calving at 25 months, Jersey	Partly deep litter, long feeding area, solid floor	27	441	0.1	0
Heifer, 6 months to calving at 25 months, Jersey	Partly deep litter, long feeding area, back flush	35	804	0.3	85

Animal type	Barn type	Number of buildings according to GHI	Number of Animal Units*) according to GHI	Estimated amount of slurry in barn + pre-tank per animal, tonnes	Estimated hydraulic retention time (HRT), days
Heifer, 6 months to calving at 25 months, Jersey	Partly deep litter, long feeding area, scrapers	36	864	0.1	0
Heifer, 6 months to calving at 25 months, Jersey	Cubicle barn with solid floor	60	1,677	0.1	0
Heifer, 6 months to calving at 25 months, Jersey	Cubicle barn with slats, channels with back flush	143	2,656	1.2	85
Heifer, 6 months to calving at 25 months, Jersey	Cubicle barn with slats, channels with circulation ring channel			1.0	50
Heifer, 6 months to calving at 25 months, Jersey	Cubicle barn with slats, channels with mechanical scrapers	51	941	0.1	0
Heifer, 6 months to calving at 25 months, Jersey	Cubicle barn with solid drained floor with scrapers	14	269	0.2	10
Heifer, 6 months to calving at 25 months, Jersey	Fully slatted boxes	295	3,707	0.8	50
Bull, 6 month to slaughter at 440 kg, heavy breed	Tie-stall with iron slats	165	525	0.4	20
Bull, 6 month to slaughter at 440 kg, heavy breed	Partly deep litter, short feeding area, solid floor	243	2,134	0.1	0
Bull, 6 month to slaughter at 440 kg, heavy breed	Partly deep litter, long feeding area, solid floor	53	575	0.1	0
Bull, 6 month to slaughter at 440 kg, heavy breed	Partly deep litter, long feeding area, back flush	80	734	0.4	85
Bull, 6 month to slaughter at 440 kg, heavy breed	Partly deep litter, long feeding area, circulation ring channel	88	1,060	0.1	0
Bull, 6 month to slaughter at 440 kg, heavy breed	Cubicle barn with solid floor	46	55	0.1	0
Bull, 6 month to slaughter at 440 kg, heavy breed	Cubicle barn with slats, channels with back flush	141	1,341	1.5	85
Bull, 6 month to slaughter at 440 kg, heavy breed	Cubicle barn with slats, channels with circulation ring channel			1.0	50
Bull, 6 month to slaughter at 440 kg, heavy breed	Cubicle barn with slats, channels with mechanical scrapers	67	1,466	0.1	0
Bull, 6 month to slaughter at 440 kg, heavy breed	Cubicle barn with solid drained floor with scrapers	21	224	0.2	10
Bull, 6 month to slaughter at 440 kg, heavy breed	Fully slatted boxes	2,094	16,149	1.0	50
Bull, 6 month to slaughter at 328 kg, Jersey	Tie-stall with iron slats	8	9	0.3	20
Bull, 6 month to slaughter at 328 kg, Jersey	Partly deep litter, short feeding area, solid floor	21	37	0.1	0
Bull, 6 month to slaughter at 328 kg, Jersey	Partly deep litter, long feeding area, solid floor	12	40	0.1	0
Bull, 6 month to slaughter at 328 kg, Jersey	Partly deep litter, long feeding area, back flush	5	3	0.3	85
Bull, 6 month to slaughter at 328 kg, Jersey	Partly deep litter, long feeding area, circulation ring channel	10	21	0.1	0
Bull, 6 month to slaughter at 328 kg, Jersey	Cubicle barn with solid floor	5	4	0.1	0
Bull, 6 month to slaughter at 328 kg, Jersey	Cubicle barn with slats, channels with back flush	15	19	1.2	85
Bull, 6 month to slaughter at 328 kg, Jersey	Cubicle barn with slats, channels with circulation ring channel			1.0	50
Bull, 6 month to slaughter at 328 kg, Jersey	Cubicle barn with slats, channels with mechanical scrapers	7	2	0.1	0
Bull, 6 month to slaughter at 328 kg, Jersey	Cubicle barn with solid drained floor with scrapers	5	4	0.2	10
Bull, 6 month to slaughter at 328 kg, Jersey	Fully slatted boxes	186	341	0.8	50
Breeding bull, heavy breed, over 440 kg	Tie-stall with iron slats	11	6	0.4	20
Breeding bull, heavy breed, over 440 kg	Partly deep litter, short feeding area, solid floor	22	10	0.1	0
Breeding bull, heavy breed, over 440 kg	Partly deep litter, long feeding area, solid floor	6	4	0.1	0
Breeding bull, heavy breed, over 440 kg	Partly deep litter, long feeding area, back flush	5	2	0.4	85
Breeding bull, heavy breed, over 440 kg	Partly deep litter, long feeding area, circulation ring channel	4	2	0.3	40
Breeding bull, heavy breed, over 440 kg	Cubicle barn with solid floor	7	4	0.1	0

Animal type	Barn type	Number of buildings according to GHI	Number of Animal Units*) according to GHI	Estimated amount of slurry in barn + pre-tank per animal, tonnes	Estimated hydraulic retention time (HRT), days
Breeding bull, heavy breed, over 440 kg	Cubicle barn with slats, channels with back flush	3	2	1.5	85
Breeding bull, heavy breed, over 440 kg	Cubicle barn with slats, channels with circulation ring channel			1.0	50
Breeding bull, heavy breed, over 440 kg	Cubicle barn with slats, channels with mechanical scrapers	6	3	0.1	0
Breeding bull, heavy breed, over 440 kg	Cubicle barn with solid drained floor with scrapers	1	0	0.2	10
Breeding bull, heavy breed, over 440 kg	Fully slatted boxes	18	10	1.0	50
Breeding bull, Jersey, over 328 kg	Partly deep litter, long feeding area, back flush	1	0	0.3	85
Breeding bull, Jersey, over 328 kg	Partly deep litter, long feeding area, circulation ring channel			0.3	40
Breeding bull, Jersey, over 328 kg	Cubicle barn with slats, channels with mechanical scrapers	1	0	0.1	0
Breeding bull, Jersey, over 328 kg	Fully slatted boxes	1	0	0.8	50
Sucking cow without calves, (400-600 kg)	Tie-stall with iron slats	263	1,659	0.5	15
Sucking cow without calves, (400-600 kg)	Partly deep litter, short feeding area, solid floor	92	660	0.1	0
Sucking cow without calves, (400-600 kg)	Partly deep litter, long feeding area, solid floor	22	246	0.1	0
Sucking cow without calves, (400-600 kg)	Partly deep litter, long feeding area, back flush	44	337	0.5	60
Sucking cow without calves, (400-600 kg)	Partly deep litter, long feeding area, scrapers	45	433	0.1	0
Sucking cow without calves, (over 600 kg)	Tie-stall with iron slats	492	4,513	0.5	15
Sucking cow without calves, (over 600 kg)	Partly deep litter, short feeding area, solid floor	135	1,283	0.1	0
Sucking cow without calves, (over 600 kg)	Partly deep litter, long feeding area, solid floor	49	581	0.1	0
Sucking cow without calves, (over 600 kg)	Partly deep litter, long feeding area, back flush	73	874	0.5	60
Sucking cow without calves, (over 600 kg)	Partly deep litter, long feeding area, scrapers	91	1,088	0.1	0
Sucking cow without calves, (under 400 kg)	Tie-stall with iron slats	15	29	0.5	15
Sucking cow without calves, (under 400 kg)	Partly deep litter, short feeding area, solid floor	6	10	0.1	0
Sucking cow without calves, (under 400 kg)	Partly deep litter, long feeding area, solid floor	2	5	0.1	0
Sucking cow without calves, (under 400 kg)	Partly deep litter, long feeding area, back flush	3	30	0.5	60
Sucking cow without calves, (under 400 kg)	Partly deep litter, long feeding area, scrapers	8	33	0.1	0

Animal type	Barn type	Number of buildings according to GHI	Number of Animal Units*) according to GHI	Estimated amount of slurry in barn + pre-tank per animal, tonnes	Estimated hydraulic retention time (HRT), days
Sow with piglets to 7,4 kg, farrowing barn	Partly slatted floor	2,084	59,297	**0.50**	**50**
Sow with piglets to 7,4 kg, farrowing barn	Fully slatted floor	423	14,797	**0.70**	**100**
Sow with piglets to 7,4 kg, barn for pregnant sows	Partly slatted floor, individual	1,703	118,766	0.04	6
Sow with piglets to 7,4 kg, barn for pregnant sows	Fully slatted floor	223	16,996	**0.05**	**6**
Sow with piglets to 7,4 kg, barn for pregnant sows	Partly slatted floor, group	237	18,884	0.04	6
Sow with piglets to 7,4 kg, barn for pregnant sows	Partly deep litter, solid floor	139	2,210	0.01	0
Sow with piglets to 7,4 kg, barn for pregnant sows	Partly deep litter, slatted floor	291	15,220	**0.30**	**50**
Weaners, 7,4-30 kg	Drained floor and slats (50/50 %)	277	10,574	0.06	30
Weaners, 7,4-30 kg	Fully slatted floor	737	27,508	**0.06**	**30**
Weaners, 7,4-30 kg	Partly slatted floor	2,129	96,133	**0.02**	**10**
Finishers, from 30-107 kg	Partly slatted floor, 25-49% solid floor	2,390	157,576	**0,075**	**15**
Finishers, from 30-107 kg	Partly slatted floor, 50-75 % solid floor	728	42,925	0,05	10
Finishers, from 30-107 kg	Drained floor and slats (33/67 %)	473	46,663	0,1	20
Finishers, from 30-107 kg	Partly deep litter, slats	51	2,579	0,05	20
Finishers, from 30-107 kg	Fully slatted floor	3,586	307,643	**0,1**	**20**
Finishers, from 7,4-107 kg (FRATS)	Partly slatted floor, 25-49% solid floor	19	2,131	**0,075**	**15**
Finishers, from 7,4-107 kg (FRATS)	Partly slatted floor, 50-75 % solid floor	47	6,559	0,05	10
Finishers, from 7,4-107 kg (FRATS)	Drained floor and slats (33/67 %)	5	1,019	0,1	20
Finishers, from 7,4-107 kg (FRATS)	Partly deep litter, slats	3	140	0,05	20
Finishers, from 7,4-107 kg (FRATS)	Fully slatted floor	26	4,369	**0,1**	**20**
In total, cattle and pigs in slurry systems		31,871	1,866,663	-	-
In Denmark in total		107,737	2,353,425	-	-

*) 1 Animal Unit is equal to the number of animals whose total manure production contains 100 kg nitrogen at the end of the storage period, i.e. losses of nitrogen during storage inside the animal house and outside the animal house is deducted.

7. LITERATURE

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