PigStun

Developing non-aversive stunning methods for pigs

Description of the current stunning practices for pigs in high throughput slaughterhouses

Deliverable D1

March 2024

Work package: 1

Nature: Deliverable

Code:

DOCUMENT CHANGE RECORD			
Version	Date	Notes / Change	Author
V1.0	30/09/2023		T1.1: DMRI T1.2: AU T1.3: AU
V.2.0	23/11/2023	The deliverable was revised according to comments received from Hadea	T1.1: DMRI T1.2: AU T1.3: AU

V.3.0	20/3/2024	The deliverable was revised according to comments received from Hadea	T1.1: DMRI T1.2: AU T1.3: AU

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1. Description of the current stunning practices for pigs in high throughput slaughterhouses

Today, two common stunning methods for pigs are applied in EU slaughterhouses: electrical stunning and high concentration carbon dioxide (CO_2) stunning. CO_2 stunning at high concentration is authorized and defined by the EU legislation (Regulation (EC) No 1099/2009) as a direct or progressive exposure of conscious animals to a gas mixture containing more than 40% CO_2. There is a gap in knowledge on which stunning systems are most prevalent in practice, and what makes Food Business Operators decide to use a particular system. We need to understand the logic that drives decision makers to choose one stunning method against another one and the conditions that could encourage them to change for an alternative method of stunning. These logics will be further explored in Work Package 4, where key persons from case slaughterhouses are interviewed about their views on the suggested alternatives and an online stakeholder meeting will be held.

The specific objectives of the descriptive work in Work Package 1 were:

- To describe stunning practices for pigs in high throughput slaughterhouses in the EU
- To identify the main drivers that influence the choice of slaughterhouse operators for a stunning practice

These objectives will provide the background to the work on alternatives in the PigStun project

The work was conducted in three tasks:

- Macro-economic data: current status of stunning practices in the EU (T1.1)
- Micro-economic data: economic and technical data in high throughput slaughterhouses with different stunning practices and other relevant data based on case studies (T1.2)
- Identification of main drivers that influence slaughterhouse operators on choice of pig stunning methods (T1.3).

The report is structured accordingly into three sections, which are all finalised by a sum up with elaborations on results. Finally, overall conclusions referring to the two specific objectives of the Work Package are listed.

2. Task T1.1: Macro-economic data: Current status of stunning practices applied in the EU.

Introduction

The aim of T1.1 was to obtain information quantitative information on slaughterhouses and pig stunning methods in the EU.

These data were collected and presented in Table 1. As there is no single publication that summarises these data on number of slaughterhouses, several sources were identified and reviewed, and a number of stakeholders were contacted to collect additional information.

The complexity of data collection was further increased, because:

- The number of slaughtered pigs in the EU is currently declining and conditions are changing.
- There is a relatively high number of large slaughterhouses in some of the relevant countries. However, the smaller slaughterhouses of which less is known in public data, also have an impact on the statistics.
- The definition of an approved slaughterhouse does not seem to be equal in every Member State.
- There is a certain reluctance to share data and information regarding stunning methods, as well as economic data of slaughterhouses.

Status of stunning methods used at pig Slaughterhouses in the EU.

Table 1 shows the stunning methods used at pig slaughterhouses in the largest pig producing countries, representing 92% of the total production in the EU. In addition to the four countries represented by partners in the consortium (Netherlands, Denmark, Germany and Spain) the following eight were added to the table: Belgium, Italy, France, Finland, Poland, Portugal, Austria and Hungary. The smallest one in terms of pig production presented in the table (Finland) which accounts for approximately 0.8% of EU production. The sources of information are indicated by superscripts, and the source reference can be found in the reference list below. The number of slaughterhouses was acquired from the lists of approved slaughter establishments provided by the relevant Ministry of the chosen country. These lists are continuously updated, and therefore the numbers can vary over time. The numbers presented in the table were collected in September 2023. As an example, one of the five large slaughter plants in The Netherlands will convert from electrical to high concentration CO_2 stunning from 2024.

The number of slaughtered pigs per country was sourced from EUROSTAT and is presented as the total of slaughtered pigs over a 12-month period from July 2022 to June 2023 (both months included). In the 12-month period a total of 226,224,550 pigs were slaughtered in the 27 member countries of EU[1]. The countries listed in Table 1 cover 92.1% of the total slaughtering in the EU. The remaining 15 EU countries which are not listed in Table 1 each contribute less than 1.5% of the total slaughtering in EU (see Table 2). For this reason, they were not included in the further collection and analyses of the data.

Poland and Hungary are the only eastern European presented in Table 1. The United Nations define the following EU Member States countries as part of Eastern Europe: Bulgaria, Czechia, Hungary, Poland, Romania and Slovakia[20]. Of these six Member States, Poland and Hungary contribute 10.2% of the total slaughtering in the EU. The remaining four Eastern countries jointly contribute only 3%[1]. Therefore, Poland and Hungary were the only eastern European countries included in Table 1.

Table 1: Information on abattoirs and stunning methods in the EU

Country	No. of pig abattoirs May 2023	Total No. of Pigs Slaughtered in July-2022 to June-2023[1]	Percentage of total slaughtering in EU	EST. Number of Pigs stunned by CO_2	EST. % of Pigs Stunned by CO_2	EST. Number of Pigs Stunned by Electricity	EST. % of Pigs stunned by Electricity	Largest slaughterhouse groups		
								Name	Stunning method	Throughput/ Capacity*
Spain	288[18]	54,217,870	24.0%	40,663,403	75%[8]	13,554,468	25%[8]	Norfrisa/Batalle	CO_2[5]	650 pigs/hour, capacity[43], ≈ 2.2 mio. pigs/year[47]
								Litera Meat/ Pini Group	CO_2[5]	≈ 8.3 mio. pigs /year[42]
								Vall Companys Group	CO_2[19]	4 slaughterhouses, total, 4.3 mio pigs/ year[44]
Germany	3376[12]	44,912,660	19.9%	33,684,495	75%[8]	11,228,165	25%[8]	Tönnies	CO_2[5]	16 mio pigs/year[33]
								Westfleisch	Unknown	7.3 mio pigs/year[33]
								Vion	CO_2[5]	7.0 mio pigs/year[33]
								Danish Crown	CO_2[5]	2.9 mio pigs/year[33]
France	103[10]	22,362,690	9.9%	6,932,434	31%[11]	15,430,256	69%[11]	Cooperl	CO_2 & Electrical[11]	Electrical; 2 slaughterhouses, total ≈ 2.5 mio. pigs/year[11] CO_2:1 slaughterhouse ≈ 1.7 mio. pigs/year[11]
								Bigard	Mainly Electrical[11]	Electrical; 7 slaughterhouses, total ≈4.3 mio. pigs/ year[11] CO_2, 1 slaughterhouse, 1.3 mio. pigs/year[11]
								SVA	Unknown	2 slaughterhouses ≈ 2.4 mio. pigs/ year total[11]
Poland	480[17]	18,606,180	8.2%	13,954,635	75%[5]	4,651,545	25%[5]	Skiba	CO_2[5]	300 pigs/ hour[45] capacity
								Animex	Mainly CO_2[5]	2 slaughterhouses, total ≈ 3.7 mio. pigs/year[5]
								Gobarto	Unknown	Unknown
								Goodvally	CO_2[5]	Unknown
Denmark	66[7]	16,042,100	7.1%	15,721,258	98%[8]	320,842	2%[8]	Danish Crown	CO_2[5]	13.2 mio. pigs/year[47]
								Tican	CO_2[5]	3.8 mio pigs/year[46]
								Danepork	CO_2[5]	0.8-1.0 mio pigs/year[28]
Netherlands	7[15]	15,774,800	7.0%	11,831,100	75%[8]	3,943,700	25%[8]	Vion	CO_2	Unknown
								Vion	CO_2	Unknown
								Vion	Electrical	Unknown
								Compaxo Meat	Electrical	650 pigs/hour capacity[39], ≈1.65 mio. pigs/year[47]
								Westfort Meat	CO_2	725 pigs/ hour[40] capacity, ≈2.7 mio. pig/year[47]
								Paligroup	Electrical	Unknown
								Van Rooi Meat	CO_2[16]	unknown
Italy	220[13]	10,212,800	4.5%	5,106,400	50%[8]	5,106,400	50%[8]	Opas	Unknown	480 pigs/hour capacity[37]
								Zema Srl	Electrical[14]	Unknown
								Pini	CO_2	32,000 pigs/day capacity[38]
Belgium	22[2]	9,844,020	4.4%	8,583,985	87%[3]	1,260,035	13%[3]	NordVlees Group/ Grep Vanden Avenne	CO_2[4]	1.3 mio/ year[25]
								Belgian Pork Group	Mainly CO_2, but Electrical at Westvlees[5]	Comeco: 1.2 mio/year Lovenfosse: 0.6 mio/year Westvlees: 1.4 mio pigs/year[26]
								DebraGroup NV/ Tielt Export Slaughterhou	CO_2[6]	1.4 mio pigs/year[27]

Portugal	43[21]	5,303,250	2.3%	Unknown	Unknown	Unknown	Unknown	AGP Meat	CO_2[32]	300 pigs/ hour capacity[32]
								Matadouro Central de Entre Douro e Minho S.A	Unknown	Unknown
Austria	2325[22]	4,789,900	2.1 %	2,394,950	50%[33]	2,394,950	50%[33]	Dachsberger	Unknown	364,000 pigs/year[36]
								Grossfurtner	Electricity[34]	468,000 pigs/year[36]
								Fleischhof Raabtal	Unknown	468,000 pigs/year[36]
								Steirerfleisch	Unknown	1,040,000 pigs/year[36]
Hungary	Unclear[23]	4,477,030	2.0%	NA	NA	NA	NA	Hungary Meat Ltd.	Unknown	500 pigs/hour[24] capacity
								MSC Slaughterhouse Ltd.	CO_2[30]	166,400 pigs/year[29]
Finland	35[9]	1,768,890	0.8%	1,592,001	90%[5]	176,889	10%[5]	HK-scan	CO_2[5]	Unknown
								Atria	CO_2[5]	Unknown
								Snellman	CO_2[5]	Unknown
Total		208,312,190	92.1%	140,464,660	67%	58,067,249	28%			

*Unfortunately, the majority of sources do not indicate whether the number represents a total capacity or the actual throughput rate. Therefore, these should be regarded as indicative. When numbers were provided in pigs/week in the given reference, the number per year was calculated to make it easier to compare (by multiplying with 52 weeks).

Table 2: Slaughterings per member state in the EU		
Country	Total No. of Pigs Slaughtered in July-2022 to June-2023[1]	Percentage of total slaughterings in EU
Spain	54,211,230	24.0%
Germany	44,912,660	19.9%
France	22,362,690	9.9%
Poland	18,606,180	8.2%
Denmark	16,042,100	7.1%
Netherlands	15,774,800	7.0%
Italy	10,212,800	4.5%
Belgium	9,844,020	4.4%
Portugal	5,303,250	2.3%
Austria	4,789,900	2.1%
Hungary	4,477,030	2.0%
Ireland	3,439,450	1.5%
Romania	3,013,490	1.3%
Sweden	2,645,810	1.2%
Czechia	2,192,450	1.0%
Finland	1,768,890	0.8%
Greece	1,211,510	0.5%
Bulgaria	1,148,160	0.5%
Croatia	1,107,400	0.5%
Lithuania	789,820	0.3%
Cyprus	543,150	0.2%
Slovakia	518,000	0.2%
Estonia	490,070	0.2%
Latvia	409,510	0.2%
Slovenia	220,650	0.1%
Luxembourg	140,880	0.1%
Malta	48,780	0.0%
Total	226.224.550	100.0 %

The number of pigs stunned by either CO_2 in high concentration or by electrical stunning is based on estimated percentages suggested by various sources (see reference list). The estimated proportion of CO_2 and electrical stunning is further described in Fig. 1.

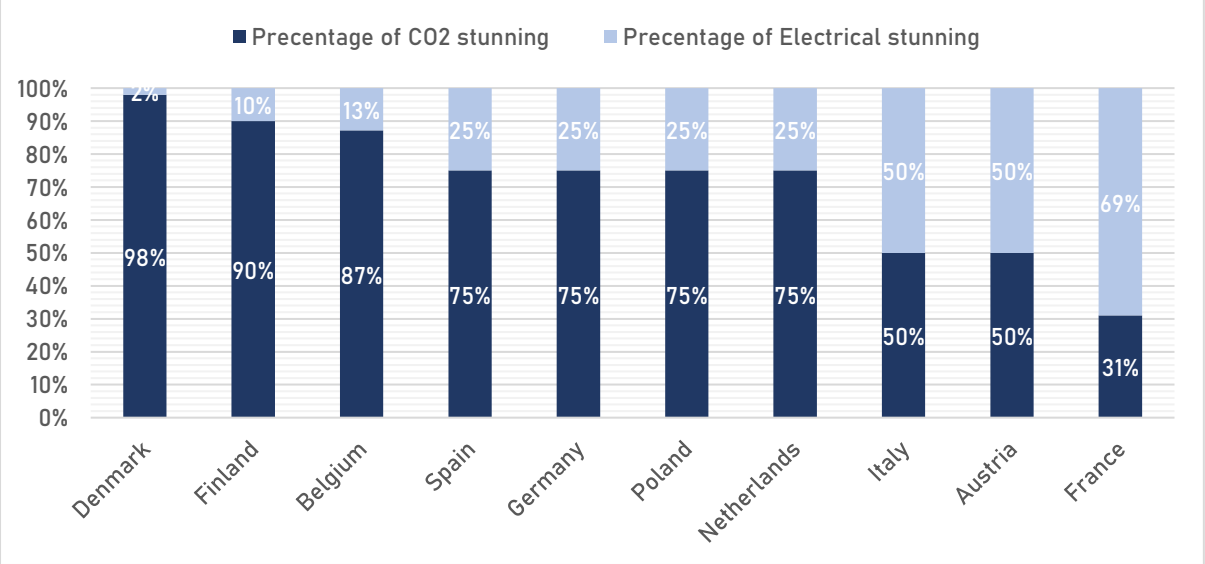

Fig 1. Estimated proportion of CO_2 and electrical stunning for ten EU Member States (based on data from Table 1)

Sum up

From Table 1 it can be concluded that the majority of pigs slaughtered in the EU are stunned by CO_2 in high Controlledconcentration. It is estimated that approximately 67% of pigs slaughtered in EU are stunned by CO_2 and approximately 28% by electrical stunning. For the remaining 5% the method could not be determined. In case of high throughput slaughter-plants it appears that the vast majority of these slaughterhouses use CO_2 stunning.

For Portugal and Hungary it was not possible to get data on (or estimates) of the ratio of stunning methods. However, for Hungary at least five facilities have acquired CO_2 stunning equipment in the period 1995-2014. Portugal did not acquire CO_2 stunning equipment from Marel in this given period.[5]

It was not possible to obtain information about the throughput in each specific slaughterhouse. In countries such as Germany there are a lot of slaughterhouses, making it virtually impossible to obtain a complete overview. Furthermore, not all slaughterhouses are providing this information upon our request.

There can be multiple reasons for a choice of stunning methods in each country - animal welfare, meat quality, investment costs etc. Also, demands from major retailers can be one of the reasons of choosing a certain stunning method. For example the Hungarian slaughterhouse MSC Slaughterhouse Ltd. chose CO_2-stunning to comply demands from Tesco[30]. Tesco favours and promotes the use Controlled-Atmosphere Stunning (CAS) system due to irreversibility of the stunning[31].

Looking at the countries slaughtering the highest number of pigs, there is a positive correlation between the total number of slaughtered pigs and the preferred stunning method. The CO_2-stunning/electrical-stunning ratio for Belgium, Germany, Denmark, Netherland, Poland and Spain is between 75-98% CO_2 vs. 2-25% electrical. However, in France 31% use CO_2-stunning and 69% use electrical-stunning. In Italy the distribution is fifty-fifty.

A calculation of the average number of pigs slaughtered per slaughterhouse for each country does not give a clear pattern in relation to preferred method. However, it suggests that the countries slaughtering a large number of pigs use CO_2 to a higher extent. Please note: there is a degree of uncertainty to these estimates, as the definitions used by different Member States regarding the classification of slaughterhouses is not always uniformly applied.

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3. Task T1.2: Micro-economic data: Economic and technical data in high throughput slaughterhouses with different stunning practices

Introduction

We collected economical and technical data on current practices from single facilities in five case slaughterhouses in Europe. Four of the facilities used CO_2 and one used head-to-body electrical stunning. The cases are used to provide a broad description of current common practices and highlight some of the key differences between using CO_2 stunners and electrical stunners, not to exemplify practices of specific operators. Due to the low number of cases, and the fact that there only is one slaughterhouse that uses electrical stunners, the conclusions on the differences between CO_2- and electrical stunners should be interpreted with caution.

All the information in the report is based on self-reporting. Data was collected by a written questionnaire which was shared with relevant professionals at each facility. The questionnaire used for collection of information is shown in Appendix 1.

The team made a lot of effort obtaining this information. Some answers to the questionnaires were incomplete or unclear in the first round of questioning, some questions needed to be answered by other people and were left unanswered, and some questions were unanswered for unknown reasons. These incomplete and missing answers were followed up via e-mails via a document including all the remaining unclear and missing answers for each case slaughterhouse. This provided more and better answers. In the third and final step, the interview rounds of T1.3 were used to ask the case slaughterhouses again about missing information.

Part of the reason that some answers are missing is that the data simply is not measured. Some examples are the ammonia levels in lairage, which are only measured by one case slaughterhouse and occurrence of Pale-Soft-Exudative (PSE) meat and blood spots in meat which are not registered in all case slaughterhouses.

The four slaughterhouses with CO_2 stunners are specified in the tables throughout this report as CO_2-1 to CO_2-4, and the slaughterhouse using electrical stunning is specified as Electrical-1. All slaughterhouses using CO_2 use high concentration CO_2 in air (>85% CO_2).

The results in T1.2 are descriptive for the different case slaughterhouse processes and their specific situations. Thus, the results do not allow extrapolation to the systems level. However, the information can be used as relevant case information towards the overall conclusions.

Basic Information

Table 3 contains some basic information on the capacity of the slaughterhouses.

Table 3: Capacity of the Five Facilities

	CO_2-1	CO_2-2	CO_2-3	CO_2-4	Electrical-1
Number of pigs slaughtered per year	4 mio	2.5 mio	2 mio	1.5 mio	1.5 mio
Number of pigs slaughtered per day	20,000	10,800	9,500	4,900	6,500
Number of pigs slaughtered per hour	1.200*	700	600	400	700**
Average slaughter weight in kg	88	92	88	95	98

* Max capacity. In this facility 2 lines are available

** In this facility there are 4 electrical stunners available

Unloading and Time in Lairage

At arrival to the slaughterhouse, pigs are unloaded either inside or in roofed outdoor areas. The average time between the arrival of the trucks and unloading in each slaughterhouse is around 30 minutes. One case reported an average of 3.5 hours. Some trucks wait for up to 6 hours before the pigs are moved to lairage. The length of the route to lairage varies from 3 to 60 meters. Pigs were stimulated to move from truck to lairage by using plastic bags (most common), peddles, flags, hands and voice. Only in one case, pigs are moved to lairage without the use of such stimulation means.

In lairage, the pigs stay in their transport groups except in some cases, where single pigs are separated from others if special attention is required. Size and occupancy of the pens in lairage are shown in Table 4. The pigs are most often kept in lairage for 1-2 hours, but in some facilities, they are typically kept in lairage for up to 5-6 hours. In four of five cases, almost all pigs (90-100%) are reported to lay down for at least half of the time in lairage. In one facility, this is the case for only 50% of the pigs.

No specific differences are seen between slaughterhouses using CO_2 and slaughter houses using electrical stunners on unloading and time in lairage. Most of the variation between cases is between different slaughterhouses using CO_2 stunners.

Table 4: Information on Size and Occupancy of the Pens in Lairage

	CO_2-1	CO_2-2	CO_2-3	CO_2-4	Electrical-1
Size of pens in m^2	9	8,1	9.24 or 18.48	18	NA*
Number of pigs per pen	15	16	14 or 28	25	18/36
m^2 per pig	0.60	0.51	0.66	0.72	NA*

*: Pens can be adjusted to various sizes

Indoor Environment

Room temperature in lairage varies from7 to 25 degrees Celsius according to time of year and facility. Details are given in Table 5.

Table 5: Room temperature in lairage at pigs' level in °C

	CO_2-1	CO_2-2	CO_2-3	CO_2-4	Electrical-1
Spring	23	18 to 20	18	15 to 18	25
Summer	25	20 to 24	25	20 to 30	25
Autumn	23	18 to 20	13	15 to 22	25
Winter	20	18 to 20	7	10 to 15	25

Room humidity in lairage is only measured in two of the slaughterhouses (85-90% all year round). Room ammonia levels is only measured in one slaughterhouse (0.5-0.7 ppm, highest in summer). All five slaughterhouses have alarm functions to ensure adequate ventilation.

As noted from Table 5, the temperature in lairage in some cases vary very much and also in some cases temperatures go above and below the thermoneutral zone of slaughter pigs, which is 15-21°C. It appears from Table 5, that the temperature in lairage in the facility using electrical stunning is constant throughout the seasons, which is not the cases in the CO_2 stunning facilities. This may be explained by the fact that the facility with electrical stunning has been newly renovated with air-conditioning systems in lairage. Normally, there should be no association between stunning system and the temperature in lairage.

Facilities and Handling in Lairage

All five slaughterhouses have shower/misting facilities for the pigs in lairage. These facilities are typically either used for predetermined intervals (more often during summer) or misting at arrival and departure from lairage. In one case, shower facilities were always on when pigs are in lairage. Intermittent sprinkling is in some cases used as a preventive measure against fighting (if room temperature allows). Other preventive measures against fighting include having sufficient drinking and feeding points, materials for enrichment and calm handling.

Nipple or bowl drinkers are provided with ad libitum access to water – one for every seven to sixteen pigs. In two cases there is one drinker per pen, in the remaining three other cases there are two or more drinkers per pen. When circumstances require that pigs remain in lairage for longer durations, they are generally provided with feed after 12 hours, though in one of the cases they are provided with feed after six hours in lairage.

Other measures applied with the aim of ensuring comfort in lairage in the different facilities include keeping the pigs in small groups, keeping human contact to a minimum, apply floor heating, provide music, bedding (straw/sawdust) and enrichment materials such as balls, chains and bags.

Different strategies are used to stop pigs fighting. In some cases, employees manually stop the fighting, e.g., by waving a plastic bag or spraying with no-bite spray (a spray that smells and tastes bad), and in severe cases the incompatible pigs are separated in different pens. In other cases, the shower/misting installation is used to distract the pigs from fighting. In some cases, pigs who require special attention are separated in pens with ad libitum feed. Sending pigs with a tendency to fight directly to the slaughter line is also done sometimes.

No specific differences are noted between slaughterhouses using CO_2 and electrical stunners on the facilities and handling in lairage.

Movement from lairage to stunner

In the slaughterhouses using CO_2, pigs are moved from lairage to the stunner in groups of 10 to 16 pigs, in some cases splitting into two groups just before the stunner. In some cases, automatic push gates are used to move the pigs throughout the raceway towards the CO_2 stunner. In other cases, push gates are only used at the entrance of the stunner. Human interaction with rattle sticks, flags or plastic bags are used at different levels depending on the system.

Figure 1: Raceway towards CO_2 stunner. Automatic push gates push the pigs forward with a maximum pressure of 100 kg (Copyright PigStun)

Figure 2: Entrance to CO_2 stunner. Automatic push gates ensure minimum handling by humans. (Copyright PigStun)

In the electrical stunning system, pigs are moved to the stunners in groups of either 6-7 or 12-14 pigs depending on the distance from the specific lairage pens to the stunners, and approximately 8-9 meters before the stunner given the option to choose which raceway to walk into. Brushes and plastic boards are generally used to motivate the pigs to move. In exceptional cases, when necessary, an electrical stimulator is used in the raceway just in front of the stunners. The use of electrical stimulation is monitored by video.

There are some differences between slaughterhouses in the design of the raceway towards the stunner. In most cases, the raceway ends in an incline, but otherwise the design is customized according to the experiences and possibilities given in the specific settings. Examples of raceway designs towards CO_2 stunners are given in Figures 1-4 and towards electrical stunning systems in Figures 5-7.

Figure 2: In this example, the raceway has a bend to encourage the pigs to move forward. The blue coloured light is used to calm the pigs (Copyright: PigStun)

Figure 1: Green coloured light is used to calm the pigs. In this case, push gates are only used at the entrance to the stunner (Copyright PigStun)

Figure 5: Group of male pigs walking towards the raceway in an electrical stunning system (Copyright: PigStun)

Figure 6: In the raceway the pigs are divided into two single lines in an electrical stunning system (Copyright: PigStun)

Figure 7: Entrance to an electrical stunner (Copyright: PigStun)

CO_2 Stunning

Two main CO_2 gas stunning systems are used, the dip-lift system and the paternoster system. Dip-lift designs have only one gondola that goes down and up in the system per pit. In the dip-lift system the gondola goes straight to the bottom of the pit without in between stops. The paternoster designs have a number of gondolas, rotating in a deep pit. The paternoster system stops at various intervals for loading of conscious pigs on one side and unloading unconscious pigs on the other side for sticking. CO_2 levels are monitored at two to four levels within the gondolas, dependent on the facility. In all cases, one of the monitors is placed in the bottom of stunner to monitor the maximum level reached. Details of the CO_2 stunning processes in the four facilities using this method are given in Table 6.

Table 6: Overall description of systems

	CO_2-1	CO_2-2	CO_2-3	CO_2-4
CO_2 Stunning System	Paternoster	Dip-lift	Paternoster	Paternoster
Number of pigs in each gondola	7 or 8	8	6	4 or 5
Size of the gondolas (m^2)	3.43	4	2.75	2.45

The available space per pig in each gondola (m^2)	0.43 or 0.49	0.5	0.46	0.49 or 0.61
Time to arrive at the first stop (sec)*	20	5	10	13
Time of cycle (sec)**	250	145	180	210
Percentage of CO_2 at the first stop	90%	98%	88%	92%
Max percentage of CO_2 at the bottom	90%	98%	90%	92%

*: In case of dip-lift system 'first stop' is the bottom. **: time from the pigs get in the stunner and till they are removed from the stunner.

In some cases video cameras are used to assess the pigs in waiting areas, as well as the entrance and the exit of the stunners. Video cameras are not installed within the stunners, but in some cases, pigs can be monitored visually from the top of the stunner during stunning. When asked what percentage of pigs shows excitation before loss of posture, two slaughterhouses answered that they don't know as they have no visual access or video cameras covering that part of the process. In the remaining cases, the answer was 75% and 100%.

Average time from exit of the stunner to sticking was 45 to 95 seconds in all facilities. For the last pig in each group, the time varied from 80 to 95 seconds.

Electrical stunning

The facility using electrical stunning has four stunners available. The stunning parameters are as follows: The minimum current to the head is 0.8 A, the minimum voltage to the chest is 75 V. The stunner uses a maximum frequency of 60 Hz, and each slaughter pig is exposed to electricity for a minimum of three seconds.

Assessment of stunning efficiency

Correct sticking is assessed by blood weight (3 of 5 case slaughterhouses), human assessment (4 of 5 case slaughterhouses) or camera (3 of 5 case slaughterhouses). In one case, AI-assisted cameras are being tested. In the slaughterhouse using electrical stunners, correct sticking is assessed by human assessment and camera.

The state of consciousness is sometimes assessed at the exit of the stunner in case slaughterhouses using CO_2 stunners and assessed in all case slaughterhouses before shackling, during sticking and during bleeding.

The indicators used to assess state of consciousness before shackling, before sticking and during bleeding, and how many facilities use the different indicators, are shown in Table 7.

Table 7: Number of case slaughterhouses using each of the animal based indicators to assess the state of consciousness before shackling, before sticking and during bleeding.

	Righting reflex	Presence of breathing	Corneal/palpebral reflex	Presence of vocalisations	Response to nose prick/ear pinch	Presence of voluntary movement*
Before shackling	4*	5*	4*	4	1	2
Before sticking	3*	5*	4*	3	0	2
During bleeding	2	5*	3	3	0	2

*: Including the case slaughterhouse using electric stunners.

All slaughterhouses reported a high efficiency of their stunning process. Thus, the facilities using CO_2 reported that between 0% and 0.05% were inefficiently stunned and the facility using electrical stunning reported that 0.8% were inefficiently stunned. Thus, the efficiency of stunning tend to be lower in the electrical stunning system compared to the CO_2 stunning systems. No specific differences are seen between slaughterhouses using CO_2 and slaughterhouses using electrical stunners in terms of how they assess the state of consciousness after stunning.

Work Environment

Workdays comprise between 7.4 and 10 hours. Task rotations several times a day are the rule but with different schemes and traditions between facilities. One facility did not answer the question on working rotations.

The maximum noise levels in the slaughterhouses reach 79-105 decibel. The exact level of noise and the place experiencing the highest level of noise differs a lot between facilities. In two cases (one using CO_2 and one using electrical stunning) very high levels of noise are experienced in lairage (105 and 79 decibel, respectively). In other cases, the highest levels of noise are reached in the raceway (79 decibel in electrical system and 100 decibel in a CO_2-system, respectively) or at the entrance or exit of the stunner (80-87 decibel in CO_2-systems). In all cases, workers use hearing protection. Methods to limit the noise include physical design to limit noise, small groups of pigs, and using other tools than paddles to move the pigs.

Injuries occur incidentally from both animals and equipment. Fall- and pinch injuries by the gates are also seen. However, injuries are not seen as a major concern.

The protection requirements for workers include mandatory boots with a steel toe in all the slaughterhouses. Protective clothing and monitors for CO_2 levels are also in some case a requirement.

Workers receive animal welfare training as well as instruction in safety and machinery and in the work positions. In some cases, the welfare training is formalized with refresher courses at regular intervals, either every three years or more often. In some cases, written, oral and practical exams instituted by external authorities are a part of the training program.

The only slaughterhouse not reporting any injuries from either animals or equipment was the slaughterhouse using electrical stunning. This may partly reflect that it is the newest of the case slaughterhouses. Apart from this, we do not find any specific differences in work environment in facilities using CO_2 vs. facilities using electrical stunning. No specific differences are noted between slaughterhouses using CO_2 and electrical stunners on the protection requirements for workers and the animal welfare training they receive. One of the slaughterhouses using CO_2 stunners chose not to give a statement on questions regarding the length of the workday and number of incidental injuries.

Meat quality

The proportion of carcasses diagnosed with PSE/light coloured meat is generally below 5%, however, one facility using CO_2 experiences it in more than 10% of the carcasses. Two of the facilities specified the exact proportion – in these cases the proportions were 0.005% (in CO_2 system) and 0.3% (in electrical system). One facility did not register cases of PSE. The case slaughterhouse with a high proportion of carcasses with PSE also report a long reloading time and a low winter temperature in lairage.

The proportion of carcasses with haemorrhages is not routinely registered in all facilities. It is generally estimated to be seen only rarely in both CO_2 and electrical systems ("almost zero economic losses"), and two facilities could not answer since they did not have enough data. In one facility using CO_2, haemorrhages are seen in 5-10% of carcasses, which leads to an economic loss of 750.000 euros annually.

The facility using CO_2 which has the highest economic loss due to PSE and haemorrhages, also has veining defects in 25% of their hams, resulting in an annual economic loss of 4 million euros.

From the obtained data it is difficult to identify specific differences between systems using CO_2 and systems using electrical stunning on meat quality.

Environment and Sustainability

It was not possible to obtain estimates on the total CO_2 emission from any of the facilities. Three slaughterhouses using CO_2 have delivered data on CO_2 emission specifically from the stunning process. These facilities emit on average 327 grammes per pig and 807 tonnes per year, with facilities emitting less per pig and more per year the higher the throughput. The emission from the stunning process itself, is not expected to contribute significantly to the total emission.

The CO_2 stunners are cleaned with water and disinfectants. In some cases, they are also cleaned with detergents or degreasers, or in some cases using a clean-in-place (CIP) procedure.

The stunners in the electrical stunning system are cleaned three times a day with a rinse, a degrease treatment, a rinse, a disinfection treatment, and a final rinse.

One facility did not answer the questions on treatment of wastewater, and another answered that they have no statement. The three that did answer, have treatment facilities for the wastewater, of which two provide pretreatment before they let the water out into the public sewage system. In the last case the water is filtered and reused after treatment.

Investments and costs of high concentration CO_2 stunning and electrical stunning

It appears from Table 1, that two different stunning methods are currently used for stunning slaughter pigs in Europe: High contraction CO_2 stunning and electrical stunning. In this section we will compare and discuss costs of electrical stunning and high concentration CO_2 stunning.

It is complicated to compare different stunning systems as installation costs will depend on case-to-case situations. Existing buildings may affect costs for new installations. Installation and running costs will further depend on throughput. Furthermore, costs may vary considerably across EU. Also, national regulations on environments, labour and construction may affect the costs.

To investigate the costs influencing the costs of stunning we have developed a cost model. The cost model focuses only on costs, not revenues and it focuses only on costs, which may be affected by choice of stunning system.

The parameters included in the cost model are described in Table 8.

Table 8. Parameters included in the cost model

Cost factor	Description
Installation costs €	The costs of installing the stunner alone for a pig slaughterhouse
Maintenance €/year	Annual maintenance costs of the stunner
Labour related to pre-stunning and stunning, hours/day	Number of staff hours per day required for prestunning, stunning, bleeding and shackling
Throughput pigs/hour	Average number of pigs slaughtered per hour
Working hours per day	Average hours of slaughter per working day
Working days per year	Average days at work during a year
Water for stunning m^3/day	1000 liters of water required per day for cleaning stunner and raceway
Electricity for stunning, kWatt/day	Kilowatt hours of electricity used for stunning per day (stunner and raceway)
Gas for stunning, tonnes/day	Tonnes of gas (CO_2) required per day for stunning
Costs per discarded pig, €	Avg. price for a pig paid to the farmer
Labour €/hour	Avg. cost per hour for staff working with pre-stunning, stunning and bleeding
Gas price € per tonnes	Avg. price per tonnes of CO_2 for stunning
Electricity €/kWatt	Avg. price per kWatt used for stunning
Water €/m^3	Avg. price per 1000 litres of water used for cleaning stunner and raceway

We collected costs of stunning from five case slaughter plants in four countries (Denmark Germany, the Netherlands and Spain). We asked for their technical and price parameters valid for 2023. Based on this input typical costs were calculated (high, low and mean costs for CO_2-based on four cases) and for electrical stunning.

Typical technical and price parameters are provided in Table 9. Based on the cost and technical parameters, we calculated cost per pig as shown in Table 10.

Table 9 Technical and price parameters obtained from five case slaughterhouses

	CO_2 stunning		Electrical stunning
Cost factor	Minimum value	Maximum value	One case
Installation costs €	700,000	1,700,000	550,000
Maintenance per year % of installation costs	8	13	1.8
Labour related to pre-stunning stunning and bleeding, hours/day	62	140	60
Throughput pigs/hour	435	860	680
Working hours per day	12.4	17	10
Working days per year	240	252	281
Water for stunning m^3/day	3	65	50[1]
Electricity for stunning, kWatt/day	115	641	144[1]
Gas for stunning, tonnes/day	2.12	7.47	0
Labour €/hour	20	38	30
Gas price € per tonnes	136	350	
Electricity €/kWatt	0.11	0.24	0.21
Water €/m^3	1.25	4.5	4.5

Table 10. Costs for stunning a pig in high concentration CO_2 stunning and electrical stunning

	CO_2 stunning			Electrical stunning
Cost factor cents/pig	Minimum value	Maximum value	Mean value	One case
Installation costs (depreciated over 10 year)	2.54	12.51	5.80	2.88
Maintenance	2.84	9.56	5.18	0.52
Labour	22.19	44.19	31.25	31.25
Water	0.04	5.37	1.91	3.31
Electricity	0.12	2.85	0.87	0.87
Gas for stunning,	5.32	12.13	9.86	0
Total	39.59	63.89	54.38	33.61

It appeared that gas use differs for CO_2 stunning system depending on the stunning system. Dip lift systems use more gas than paternoster systems.

The use of labour for moving pigs through the raceway as well as for stunning, shackling and bleeding vary between slaughterhouses. The typical labour use was 2 people for the pre-stunning process, 2 people for bleeding and shackling and 1-2 people for quality control per stunner. As labour is a major cost in all systems the average salary per hour play an important role for the costs for stunning a pig. The labour costs as a proportion of the total costs for stunning varied between 36 and 71% across the four CO_2 stunning cases. The costs of gas varied between 14 and 23% of the total costs. Depreciation of installation costs and maintenance costs varied between 11-35% between the four CO_2 cases.

For the electrical stunning case labour covers 79% and installation and maintenance costs cover 10%

In a comparison between CO_2 stunning (mean of four cases) and our electrical case the electrical stunning was 32% cheaper than CO_2 stunning. However, the CO_2 case with the lowest costs had only marginal higher costs than the electrical stunning case. The costs per pig in the electrical stunning systems after improvement (using four stunners instead on one with a similar throughput) would be 19% more expensive than the average cost for the CO_2 stunning system.

[1] Figures taken from the improved stunning system

The costs calculations are sensitive to the salary level and the price of gas. If we increase the salary costs by 20%, the electrical stunning case is 51% lower than the mean CO_2 stunning cost. If we increase the gas price by 20% the electrical stunning is 60% less costly than the mean cost for CO_2 stunning.

Sum up

From the data obtained by questionnaires in five case slaughterhouses, we can draw the following conclusions:

- A large variation is seen between different slaughterhouses in relation to unloading and time in lairage, but these differences do not seem to be explained by the stunning system. Raceways towards stunners are designed differently in each case slaughterhouse, especially in relation to how much human interaction vs. pushing with automatic push gates is used. In all cases with CO_2-stunning, pigs are moved in groups, which takes into account their normal social behaviour. In the electrical stunning system, the pigs are in a single file line for the last 8 meters of the raceway. Sometimes an electrical stimulator is used to move the pigs whenthey are in the raceway, though many measures are taken to limit its use.
- All slaughterhouses report a high efficiency of their stunning process, though the case slaughterhouse with an electrical stunner reports 0.8% inefficiently stunned pigs compared to between 0% and 0.05% in the facilities using CO_2.
- The level of noise is an important concern in relation to work environment, with a reported maximum level between 79 and 105 decibels. The highest levels of noise are seen in lairage. The noise level was not different in the electrical stunning case compared to the CO_2 stunning cases
- Fall and pinch injuries by automatic gates are reported to occur, but in no case seen as serious problems. The electrical stunning facility does not report to experience injuries to the personnel.
- Meat quality problems are generally at a low level, with PSE/light coloured meat seen in less than 5% of carcasses in most of the CO_2 and electrical stunning systems. However, one facility using CO_2 reported PSE in more than 10% of carcasses as well as higher economic losses due to haemorrhages and veining defects than the other facilities. This facility also reported a long reloading time and a low winter temperature in lairage, which may explain some of the difference.
- The proportion of carcasses with haemorrhages is not routinely registered in all facilities, and generally not seen as a problem. One facility using CO_2, however, experiences haemorrhages in 5-10% of carcasses, which leads to an economic loss of 750,000 euros annually.
- The facility using CO_2 which has the highest economic loss due to PSE and haemorrhages, also has veining defects in 25% of their hams, and thereby has an annual economic loss of 4 million euros due to meat quality issues.
- In a comparison between CO_2 stunning (mean of four cases) and our electrical stunning case the electrical stunning was 32% cheaper than CO_2 stunning. However, the CO_2 case with the lowest costs had only marginal higher costs than the electrical stunning case. The costs per pig in the electrical stunning systems after improvement (using four stunners instead on one with a similar throughput) would be 19% more expensive than the average cost for the CO_2 stunning system.
- The costs calculations are sensitive to the salary level and the price of gas. If we increase the salary costs by 20%, the electrical stunning case is 51% lower than the mean CO_2 stunning cost. If we increase the gas price by 20% the electrical stunning is 60% less costly than the mean cost for CO_2 stunning.

4. Task T1.3: Identification of main drivers that influence slaughterhouse operators on the choice of stunning methods for pigs

Introduction

To better understand the drivers that influence the choice for the applied stunning method and how key employees in different slaughterhouses evaluate their current practices and conditions for change of stunning methods, focus group interviews in four different slaughter facilities across Europe were performed (T1.3). By nature, interview studies report what participants express and how they reflect. Reflections given in interviews are coloured by personal experiences and opinions, and it is the idea of this report to describe the views and opinions of the participants.

Between May and September 2023 four separate focus group interviews were conducted with employees from three CO_2 stunning slaughterhouses (paternoster or dip-lift system) and one electrical stunning slaughterhouse. The interviews included between three and eight persons. Seven of these participated via an online connection. They were selected based on their position in the organisation (managers and decision makers) and their knowledge in different areas of the slaughter process. The job titles of the interviewees were as follows: Managing directors (n=3), Animal Welfare officers (n=4), Managers of Quality Assurance programme (n=4), Floor managers (persons responsible for the whole slaughter process on the floor from arrival to cooling (n=2)), Managers of technical departments (n=2), Managers of sustainability (environmental issues/CSR/ work environment and safety) (n=2) and Manager of housing and handling in lairage facility (n=1). The affiliation of the persons participation in the interviews are described in Table 11.

Table 11 Information on affiliation of persons participating in the group interview

	CO_2-1	CO_2-2	CO_2-4	Electrical
Operation manager/managing director		1	1	1
Director, meat quality	1			
Floor manager/head of controlling		1	1	
Director, product standards	1			
Manager, technical department	1		1	
Manager, sustainability (the environment and work safety)	2		1	
Manager of lairage facility and handling	1			
Animal welfare responsible	1	2	0.5*	1
Manager quality assurance	1	1	0.5*	1

*: The same person has two different functions.

Due to the majority of slaughterhouses being CO_2-based, fewer of the interviewees had experience with electrical stunning. In cases where interviewees at CO_2 stunning slaughterhouses had experience with electrical stunning, it was mainly gained many years back.

Below are given nine headlines extracted from the interviews, which give an understanding of the main drivers in relation to choice of stunning method as well as conditions for change of method as expressed by the interviewees.

The main aim was to clarify what the managers and decision makers of slaughterhouses consider as main drivers for choice of stunning system and conditions for change. To support this ambition, and scale it up to the level of company management, after the focus group interviews, the higher managements (CEO's/directors) in the five case slaughterhouses plus slaughterhouses in Poland and France were contacted by phone. These CEOs and directors were

asked to prioritize and motivate the drivers for choice of stunning system in their situation. In addition, they were asked to elaborate on which conditions would encourage them to change to an alternative stunning method and the economic benefits of their current stunning method.

Proper design and management pre-stunning ensure calm pigs and a better stunning process

Having a stunning system causing as little stress and discomfort as possible was essential for all participants, and all participants placed a great deal of emphasis on keeping the pigs as calm as possible and avoiding stress. Throughout the previous years, all slaughterhouses had put effort in improving animal welfare during the process, and especially the pre-stunning phase was described as essential to ensure a calm and efficient stunning process leading to improved animal welfare as well as improved meat quality.

It was emphasized, that minimizing stress prior to stunning, during the whole process from arriving at the slaughterhouse to the stunning itself, was imperative to ensure the stunning process being as quick and calm as possible. It was pointed out how for example noise and rough handling would affect the level of stress experienced by the pigs. Optimizing handling throughout the whole process from unloading, through lairage, to moving pigs to the stunner, was in all slaughterhouses seen as a very important focus point. Optimal handling was described as having well instructed personnel with calm attitudes and no unnecessary use of devices to motivate the pigs to move. Some of the participants highlighted how personal handling and moving of animals was monitored with video cameras to ensure qualified handling of the animals and to give specific feedback. In some cases, this would result in workers being moved to tasks not involving live animals.

One way to optimize the handling of live animals by humans was investment in the continuous training of personnel. The training included formal education, attending congresses and consulting with veterinarians, but also work meetings to discuss procedures and potential improvements in handling. In some cases, when batches of pigs were very difficult to handle, slaughterhouses communicated with the farm of origin to give feedback and attempt to improve conditions in the future.

The interviewees emphasized that indoor unloading, plenty of room in lairage to ensure quick unloading for all pigs and efficient regulation of temperature in lairage were all important elements in ensuring calm pigs and therefore, improving the whole stunning process.

All facilities had a system (design and equipment) in place where the pigs were moved in groups to the raceway. At the electrical stunning slaughterhouse, they were subsequently moved into a single file line some meters before the stunner. When participants from CO_2 based facilities discussed the use of electrical stunning, the individual stunning process was highlighted very negatively, as it necessitates pigs moving into the stunner in a single line, which is against their natural behaviour and therefore stressful. Some of the participants mentioned that in electrical systems a lot of human interaction was necessary to motivate the pigs to move into the stunner, and that the pigs were therefore stressed.

When some of the participants from CO_2 based slaughterhouses compared moving of pigs in groups with previous systems, where pigs were moved into the stunner in a single file, they described it as “a world of difference”. In the previous system, use of electric prods had been unavoidable to have the pigs moving in the right direction. The interviewees had experienced high levels of stress in the animals as indicated by a very high level of noise in the raceway and many cases of Pale, Soft and Exudative (PSE) meat. When moved in groups, it was described that the pigs were generally calm and vocalized very little. In group-moving-systems, “Stop-and-go” situations were described as the main challenge. In such cases, when e.g. for technical reasons, the flow was interrupted and the pigs had the time to sit or lay down, they could be very reluctant to start moving again.

Some of the participants explained how they were always looking for ways to make it easier to move the pigs towards the stunners, and took a lot of factors such as temperature, humidity, lighting, airflow, the slope of the floor and more into account when continually improving the designs. They had divergent opinions on whether more or less human contact was beneficial to keep the pigs calm. Some of them explained that having additional workers assigned to the raceway or having people instead of automatic push gates at certain points of the raceway, made the flow smoother and minimized problems. Some indicated having bad experiences with automatic push gates that would push pigs being less able to walk too hard, and thus cause harm. Others had made an intense effort in designing the lairage and raceway facilities in such a way that minimum handling by humans was required. In these cases, it was argued, that

often the pigs were not used to handling by humans and therefore were fearful towards people. To minimize the need for human-animal interaction, in some cases all moving from lairage to the stunner was carried out by an automatic system and almost no human interaction. In these facilities, the gates were allowed to maximally push with a weight of 100 kg. Only if technical problems arose, e.g. if technical problems were encountered or the security system would stop moving due to exceeding 100 kg push, a person would step in and stimulate the pigs to move. Moving of pigs from lairage to and into the stunner was conducted at least partially by an automatic system in all facilities with a CO_2 stunner. In one facility this was only the case for the last push into the gondola. In the electrical stunning slaughterhouse automatic gates were not used. Participants from the electrical stunning slaughterhouse agreed that moving pigs in single file lines was an issue in relation to animal welfare, but in their situation did not consider it a significant problem. They explained how the easiness of handling of the pigs in single lines depends on multiple factors, such as breed, gender, temperature, individual character of the pig etc, but also very much on the mentality of the workers. Thus, how workers behave towards the animals has a major influence in this system with very close human animal contact. In the current facility, the pigs were allowed to move as a group to the raceway, after which the raceway design ensured that only one pig could enter at a time and then choose to walk towards one of the two stunners situated to the left or right. In the participants' experience, many pigs willingly went in, and when the first pig entered the other pigs usually followed without hesitation. An electrical prod was, however, occasionally used in the raceway to the electrical stunner. The electrical prods had been changed from ones using high voltage to ones using low voltage, designed by the company itself. The managers at the facility using electrical stunning put a lot of effort in minimizing the use of electrical prods by supervising workers, giving them other options and placing the electrical prod in a hard-to-reach area. Cameras on the raceway were used to register each use of the electric prod, to keep track of the use and to give feedback on the process to personnel.

To sum up, both in gas- and electrical systems, a calm pre-stunning phase from unloading to entering the stunner was considered essential to ensure a good stunning process. Thus, the possibility for designing pre-stunning facilities (transport, unloading, lairage and raceways) in such a way that stressful handling can be reduced to a minimum was identified as an important driver for choice of system.

Having a system to ensure a constant flow of moving pigs and a minimum of stressful handling of pigs was identified as a main driver for choice of stunning system. Whether systems with minimum handling by humans was seen as an advantage differed between interviewees.

Meat quality is a sensitive and debated area

The quality of the meat is by nature the main focus of slaughterhouses. The participants often emphasized how animal welfare and meat quality went hand-in-hand. They explained for example, that rough handling by truck-drivers would be visible in the meat quality. Improvements in animal welfare during lairage and moving of pigs had been seen to have a positive effect on the pH in the meat.

Participants in CO_2 stunning facilities who had experience with electrical stunning from years back, explained how significant a change they had experienced in relation to blood spots and PSE when changing to CO_2. Back in time, when electrical stunning was used, and the pigs were extremely stressed prior to stunning, losses from PSE and blood spots were significant. Nowadays, losses due to PSE were considered neglectable. In some cases, facilities did not even register blood spots with a code, as they considered problems to be insignificant. They explained that butchers working with their meat never reported to experience problems with blood spots. It was clear from the interviews that meat quality in electrical systems was – and for many years had been - a much debated area. Participants working with electrical systems expressed how the 'gas-stunning lobby' tended to draw forward experiences from the past when electrical stunning systems had big challenges with blood spots in meat. As they saw it, the debate on meat quality was characterized by fixed opinions based on knowledge from the past. Their own experience was, however, that by decreasing the throughput, they simultaneously were able to decrease the voltage and the time the electrodes made contact with the pigs, they had thereby overcome previous problems with meat quality. They told how they were providing meat to a lot of consumers and did not receive any negative feedback. The effect on meat colour was identified as a possible drawback of electrical stunning in relation to consumers. Thus, participants from the electrical stunning facility explained that 'it is said that gas gives a better colour in the meat than electrical stunning'. They appeared not to have noticed this themselves and not to have received complaints from customers on this.

To sum up, being able to ensure a good meat quality was identified as a main driver for choice of system in both electrical- and CO_2-stunning slaughterhouses. The risk of PSE, blood spots and discoloration of meat in electrical

stunning systems seems to be a driver to prefer gas stunning methods, although users of electrical stunning systems claim that these potential drawbacks are not relevant anymore in modern facilities.

The familiar stunning system is the preferred stunning system

Participants from CO_2-using facilities considered CO_2 a fast, efficient and safe stunning method with a low rate of necessary re-stuns. Some of them expressed how they thought it was unfair that animal rights organisations and others were so much against the use of CO_2 stunning. They saw it as the most welfare-friendly method available in high throughput slaughterhouses, with a need for high capacity. They based their judgement on its reliability to stun effectively and to keep the pigs unconscious for a sufficient period after exiting the stunner to ensure that none of them would wake up again. Therefore, they also questioned whether EU's negative judgement of the use of CO_2 for stunning was fair and sufficiently based on scientific evidence.

In practice, participants from all facilities expressed that they had only very few or no incidences of pigs being ineffectively stunned. One of the CO_2 slaughterhouses had been informed by the supplier of the stunner that 95% of pigs would be dead at exiting the stunner. This reassured them that they should not fear problems with inefficiently stunned animals, and they also experienced this in practice. The stressful induction phase in CO_2 systems was described as unavoidable and in the end bearable, considering the positive elements in this type of stunning. However, some stressed that they were on the lookout for methods that further reduce the aversiveness of the induction phase, but for now did not see a better solution than their current system.

The lack of space in the gondolas in a CO_2 stunning system was mentioned to sometimes negatively affect animal welfare. In some cases, when loading 7-8 animals in the same gondola the pigs would arrange themselves in a way that did not make space for all of them, and thus creating a fuss. The participant recognized that this could be solved with fewer animals per gondola, but this would affect the capacity of the system. It was also mentioned that a benefit of the CO_2 stunning process was the ability to easily adjust the loading of the gondola. Thus, the same system could be used for pigs of different sizes in different numbers.

The company using electrical stunning had been using that method for decades. In their most recently re-built slaughter facility, they had chosen to install four electrical stunners instead of just one. Because of the availability of four stunners, they had been able to adjust the stunners over a period of several months by prolonging the time spent in the stunner and reducing the number of pigs entering each stunner per hour. The facility now used 15 seconds per pig in the stunner, rather than 5-5.5 seconds as in the beginning. The lower throughput had resulted in calmness and less stress for the pigs, as well as fewer skin lesions and less blood spots in the meat. As the interview participants saw it, the lower throughput also eased the placement of electrodes on each pig.

When asked why they decided to stay with electrical stunning, the participants from this company all firmly agreed on the fact that they preferred to stun pigs electrically due to the efficiency. They described how pigs stunned in electrical systems lose consciousness in milliseconds, after which they are unloaded and bled, and described the method as 'using a bullet' rather than using a prolonged method as with CO_2. They very much questioned that changing to gas would be an animal welfare improvement, due to the significant stress induced during the first phase of stunning when using CO_2. However, if given the option to use an alternative gas that would cause the pigs to fall asleep without any stress, they could see gas stunning as a proper alternative.

Participants working at CO_2-based facilities generally assumed electrical stunning to have a negative effect on animal welfare, though some of them recognized how a faster stunning process could be beneficial. Their concerns related to changing to electrical systems included an increased need for re-stunning due to challenges with placing the electrodes and fear about possibly giving the pigs a painful shock if the electrodes were placed incorrectly. They described the process of placement of the electrodes as less 'foolproof' than using gas and suspected that it was hard to ensure optimal placement on all pigs. When some of these participants visited slaughterhouses using electrical stunning, they had experienced a lot of human interaction with the pigs to motivate them to move into the stunner and more stressed pigs than in their own system. Furthermore, they found the unconscious muscle and leg movements of the stunned pigs unpleasant to see, even knowing that the where unconscious at that time.

To sum up, many interviewees saw the speed of stunning as a main driver for choice of stunning system, and especially the participants working with electrical stunning systems considered the loss of consciousness in milliseconds imperative. Participants working in CO_2 based facilities emphasized how an easy to apply 'fool-proof' system was extremely important in order to always ensure that no pigs would wake up again and to ensure sufficient time between exit from stunner and bleeding.

Main concerns in relation to alternative gas-stunning systems were expected shorter time-intervals between exit of stunner and recovery and thus very short time to initiate bleeding of the animals.

An important condition identified for considering a change of system to alternative gases was scientific evidence showing that the pigs stunned with alternative gases would lose consciousness with no feeling of stress and pain and would not recover consciousness again before proper bleeding. Furthermore, the appearance of the stunned pigs (that they seem calm and relaxed e.g. without involuntary muscle contractions) was identified as a consideration, as the appearance of the process mentally affects the people working in the systems, even when assured that the pigs do not feel anything.

Human safety is an everyday concern in gas-based systems

Participants working in CO_2-based facilities recognized human safety as a serious consideration, but generally did not express great concerns in this relation. To ensure that the system was not leaking and to handle any technical issues arising, the facilities had service-contracts with their supplier of stunner and thereby had regular services of the equipment. Participants further described that checking the equipment was a part of the daily quality assurance system.

Always ensuring high enough levels of CO_2 for efficient stunning and at the same time a safe work environments was pointed out as a dilemma. This was exemplified by a situation in one of the facilities where they experienced problems with too high levels of CO_2 in the work environment. They explained how their alarm system for ensuring that the CO_2-level would stay below recommended levels had had to be turned off, because the alarm tended to go off again and again. They had deemed the system too sensitive and managed without. In another example of a practical dilemma, participants explained how their system had a ventilation system which was originally installed beneath the stunner to draw out excess of CO_2. After some time, the ventilation system was de-installed, as it was not compatible with keeping a high enough level of CO_2 within the stunner. Equipment to stick on clothes for measuring CO_2-level was available but not routinely used by the workers, perhaps indicating that they did not feel a notable risk.

The very low need for human interaction in some of the facilities with both the animals and the stunner itself was seen as an advantage regarding work safety. Those using automatic gates only partially, had the gates close to the stunner, and thereby there was no need for humans to be close to the stunners. Some of the participants stressed that the CO_2 stunners mostly would 'run on their own' with little required action from workers. This would reduce the potential for human errors and injury. Methods like manual electrical stunning (which is only done in emergency situations) was mentioned by participants as an alternative with increased risks from inadequate handling of the stunning equipment by the workers, including the risk of humans getting electrical shocks.

Participants who had experienced a shift from moving pigs to the stunner in a single line to moving them as a group, described a great change in the work situation at the raceway and how the job satisfaction of workers seemed to have improved a lot. They described that prior to the change, when electrical prods were in use and it took a lot of effort to move the pigs in the right direction, personnel "took on a stoneface" during workhours. Nowadays, they seemed much more relaxed, and the work environment was less stressful. With respect to recruitment of personnel to work with the live animals, it was still described as quite difficult.

In some cases people did work in close proximity with CO_2 stunners, and in these cases some worries in relation to occupational safety were expressed. Some of them explained that it was quite complicated to clean the systems properly. Inefficient cleaning of the gondolas sometimes resulted in manure blocking the flow of gas, and thereby the desired percentage of CO_2 could be difficult to reach, and the stunning process would be compromised. Cleaning and maintenance of pits was also mentioned as a challenge for work safety reasons. Before workers are allowed to work in the pit for cleaning purposes, it must be ensured with special gas measuring devices that, in addition to CO_2, other harmful gases (e.g., ammonia) are no longer detectable. Due to the high sensitivity of the equipment to the harmful gases and the associated alarms, several labour-intensive and time-consuming rounds of evacuating the pit and measuring are necessary before workers are lowered into the pit. These procedures are necessary to meet requirements regarding occupational health and safety. The descent into the pit also poses a risk of accidents due to the slippery surfaces. Some of the facilities paid for a specialized company to clean the equipment instead of asking their own employees.

Other critical elements that were pointed out in relation to CO_2 stunners were a proneness to mechanical failures and sometimes a tendency to cause bad air quality (CO_2 or ammonia). It was mentioned that newer stunning devices may already alleviate some of these concerns. Important drivers identified for choice of stunning system in relation to human safety were having systems that 'run on their own' with minimal need for human interference. Having systems

that on the same time efficiently stun the pigs and do not harm the working environment for humans was identified as a dilemma in current CO_2-based systems.

An important consideration in relation to change of system was identified as the ease of cleaning and keeping free from manure and dust during the workday so that emptying the system from gas would not be necessary. As current CO_2-based systems were seen as quite complicated to run and maintain without breaks in workflow and potential safety issues for the personnel, alternative systems with improved conditions for cleaning and maintenance would be appreciated.

Security of supplies and climate footprint are important points to consider

The CO_2 used in the current gas stunning systems is produced as a by-product of the fertilizer industry at only a few factories. In the last few years participants had experienced the CO_2 supply being under threat due to many unforeseen circumstances in the form of factories shutting down for service and repair at the same time, or due to reduced fertilizer production because of the Corona pandemic and the war in Ukraine. Other minor events could also have an effect, such as a potential accident for the gas delivery vehicles, or if the facility has not ordered enough gas on time. These events had not yet directly affected the production in the case facilities, but they were close enough for participants to realize that it could be a serious issue. Solutions for this problem mentioned in the interviews included finding more suppliers for CO_2 and finding a way to use more than one type of gas in the CO_2 stunning system.

Using an electrical stunning system would also solve this problem, as electricity is readily available in the necessary amounts at all facilities. Low costs and constantly available supplies were highlighted as important benefits in systems using electrical stunning.

The security of supply of alternative gasses was mentioned as an important issue by participants. They expressed concerns about which processes the gases would be derived from and in which countries the alternative gasses could be extracted. In this relation, they saw a limited number of gas suppliers in a limited number of countries as a major concern. The problematic supply of helium from Russia was given as an example, as currently trade with Russia is restricted due to the war in Ukraine Also, while there are not many suppliers, CO_2 is known to be readily available as a byproduct from many processes. It was stressed that this was not likely to be the case for alternative gasses.

When discussing the climate footprint of slaughterhouses, it was pointed out that the CO_2 used in the stunning process would normally derive as a by-product from industrial processes and thereby as such would not further add to the climate footprint. The total climate footprint would then rather depend on the energy use in transport of the gas and in the facility. It was mentioned by some, that they had been looking into possibilities for extracting CO_2 from the chimney of their facility, but the idea had been dismissed due to high costs. Extraction of gas from the processes involved in production of biogas was mentioned as a probable future climate-friendly way of achieving CO_2. Electrical stunning systems were seen as positive with respect to climate footprint, as electricity can be produced climate friendly and because no transportation by vehicles is involved.

It was highlighted that when assessing the climate footprint of using alternative gasses, it would be necessary to investigate the entire process of producing the gasses. For some alternative gasses, processes involved in the extraction of the gasses might be very energy-intensive and thus (in contrast to CO_2 and electricity) add significantly to the climate footprint of the facilities as well as the costs of using the gas. Therefore, in relation to the green agenda there was a fear that alternatives could deteriorate the situation.

Low costs, constant supply, a large range of suppliers and a low climate footprint were all mentioned as important drivers for choice of stunning system. The Corona pandemic and the war in Ukraine had highlighted the importance of being self-supplied with essential materials and therefore some of the interviewees were very sceptical about in the future being dependent of the supply of alternative gases from countries like Russia.

A condition for change to alternative gases was that it would be possible to shift between gas-types and thereby ensure some flexibility for the slaughterhouses instead of dependency on very few suppliers. Significant concerns in relation to climate footprints of the entire process of using alternative gases compared to current systems was identified as a lock-in for change.

Significant practical challenges and costs of converting to alternatives

Main concerns for using alternatives to current systems regarded slaughter capacity, meat quality and economic viability with regard to both implementation and running costs. The possibility of mobile slaughter units as an alternative that would reduce stress pre-stunning was considered unsuitable to achieve the necessary slaughter capacity. Furthermore, the participants had some concerns related to inspection by the competent authorities with a decentralized system with a multitude of small mobile slaughter facilities.

Concerns were expressed about the potential costs of having to convert to an alternative system. The participants explained how everything – place of unloading, pens in lairage, automatic systems to move pigs from pens to the raceway and through the raceway - was designed to fit the current system. The challenge of fitting new equipment into existing buildings was often highlighted as extremely big as many conditions were interdependent. Especially, when no planning permissions for expansion of the facility were given, the task of implementing a different system could be very difficult and expensive. Altogether, the message from the participants was that changes in stunning systems would be extremely costly. They only would find it worthwhile making such investments if they were assured that investments and improvements in animal welfare were somehow proportionate.

Replacing CO_2 with alternative gases in the future or stunning with high pressure penetrative waterjets were discussed, but neither of them considered economically feasible. Alternative gases to CO_2 were considered to be still experimental, but with the potential to reduce aversiveness. Some participants noted that they had heard about positive stunning results with helium, but they did not see as achievable to use helium in the daily use due to extremely high prices compared to CO_2. It was also pointed out that in case the gas to be implemented would be lighter than air, it would not be possible to reuse most of the design of a CO_2 stunner as it would be necessary to make the gondolas go upwards instead of downwards.

In changing from an electrical stunning system, it would also be very costly to change to a system using any kind of gas, as the stunner would also need to be entirely replaced. In addition, the permits necessary to use gas, e.g. permits to install the relevant infrastructure and environment permits, would be a new issue for the facility.
In the current CO_2 based systems, costs for maintenance were pointed out as a drawback. This included regular inspection of the equipment by the manufacturer, and the training of personnel required to maintain and clean the equipment. It was mentioned by some, that a downside of alternative gas stunning systems was that maintenance costs would remain high, as the new system would also contain many movable parts.

In terms of running costs, it was pointed out that the time required to stun was an important parameter. If the alternative system would not be able to reach the same capacity as the current system, the slaughter capacity and the economic viability of the system would be very significantly affected.

Using other types of gas than CO_2 was also expected to necessitate a shorter timespan from exit of the stunner to bleeding, which means both the required number of staff and design of the exit would need rethinking and increased expenses should be expected. Possible engineering adjustments that would achieve an increase in slaughter capacity at the existing slaughterhouse to compensate for the increased cycle times for alternative gases, if necessary, included the installation of additional gondolas or the construction of a second parallel operating stunning device. The viability of this would depend on whether the increased investment effort would be worthwhile. The lower capacity of the electrical stunning system when compared to a gas stunning system was also mentioned by participants from CO_2 stunning slaughterhouses as an issue that made using an electrical stunning system unfeasible.

To sum up, though it was recognized that alternative gases had the potential to reduce aversiveness, none were currently seen as economically viable. Especially, the huge investment costs related to change of stunning system were highlighted, as not only the stunner itself but often the whole facility as such would be affected by the design of the stunner. A main driver expressed for choice of stunner was the throughput capacity, and there was a concern about alternative gases requiring a lower throughput per stunner. Huge investments in new systems were only considered worthwhile if animal welfare benefits by change of systems were documented.

Slaughterhouse managers' replies

The management of four slaughterhouses (CO_2-1, CO_2-2, CO_2-3 and Electrical-1) ranked the following potential drivers for choice of stunning system: Animal welfare, Market opportunities (requirements for labels or concepts), Operating costs or Permits/Legislation. All of them ranked animal welfare as the most or next-most important driver. Meat

quality was ranked in top-2 by 3 of the slaughterhouse managers, but in the slaughterhouse using electrical stunning, market opportunities were ranked higher. The motivations for ranking of drivers to choose for specific stunning systems are outlined in Table 12. It should be noted that the Electrical-1 facility had already implemented an improved method for electrical stunning with lower throughput per stunner than traditionally. Economic benefits of the different systems as seen by the management are outlined in Table 13.

When asked about conditions that would encourage them to change to an alternative stunning method, animal welfare and meat quality issues were once again highlighted. Only the management of the slaughterhouse using electrical stunning could not point to any conditions that would motivate change (presumable due to the fact that they already made a change from classic electrical stunning to an improved electrical stunning approach). In Table 14, the answers from management in relation to conditions for change are given.

The answers from top-management align well with the results of focus group interviews, as animal welfare and meat quality are prioritized as the main drivers for choice of system. The fact that market opportunities also play a significant role is stressed more clearly by the answers from management and highlights how labels such as 'Better Life' and NGO's play a role in the decision-systems.

Table 12: Motivations (direct quotes) for ranking animal welfare, meat quality and market opportunities as main drivers for choice of stunning system				
	CO_2-1	CO_2-2	CO_2-3	Electrical-1
Animal welfare	'The CO_2 stunning system used in all our plants was chosen due to its low stress handling and efficient stunning. In our opinion, electrical stunning or captive bolt stunning is prone to misfires and requires more stressful interaction with the animals.'	'Pigs are group- oriented animals, therefore, to guide a group of pigs to a stunner is the most animal friendly way without pressure or manual interference.'		'We have always preferred (and used) electrical stunning over CO2 stunning. Purely because of the effect on the animals.'
Meat quality/ Market opportunities*	'The absence of DFD and PSE in meat from pigs stunned with CO_2 is in our opinion evidence of the low stress nature of the stunning method.'	'Less stress during the pre-stun phase (group based & within a short period in the stunner) results in better pH values after stunning/before chilling. CO_2 stunning has no negative meat quality results as blood spots. The convulsions after 'loss of posture' are low. Convulsions have a bad impact on meat quality and beside that the sight of convulsions is unwanted. CO_2 stunning results in an enhanced pH decrease (H+ ions). The percentage of re-stun is very low, minimal negative meat quality results by manual electric stunning therefore.'	'Meat quality was the main reason to choose CO_2 at that time. Both lack of animal welfare during electrical stunning and inferior meat quality were the principal drivers. Costs were not involved in the decision.'	'Because of the Better Life Label requirements, we had to actually consider CO_2 stunning for a period of time. We need this label from business continuity perspectives in the Netherlands. Luckily, we were able to contact the Dutch Society for the Protection of Animals (owner of the Better Life Label) and come to an contractual agreement with them (and NGO Eyes on Animals) on improved electrical stunning and adjusted requirements in return.'

*: The slaughterhouse using electrical stunning ranked market opportunities higher than meat quality – the others ranked meat quality higher.

Table 13: How management explained the economic benefits of their current stunning method (direct quotes)			
CO_2-1	CO_2-2	CO_2-3	Electrical-1
'The economic benefit of CO_2 stunning is the absence of DFD and PSE issues, miscolouring etc. The investment in CO_2 is considerably higher than electrical stunning but as the longevity of the equipment and stability is good, the actual operational costs are acceptable.'	'Quality of the meat (meat colour, pH progress, less drip losses, better shelf life). Less rejects due to better meat quality (less blood spots etc). The higher investment and higher operation costs of CO_2 stunning are for certain more than worthwhile the positive effect of animal group handling in the pre-stun phase and the positive effect of meat quality which has a positive economic impact on the valorizing of the meat (better meat gives access to better markets, less blood spots / fractures means lower % depreciation / food waste, better water binding capacity gives better yield, longer shelf life is less food waste).'	'Meat quality and cost are well known in the CO_2 systems.'	'The economic benefits are business stability/continuity. From a financial perspective our stunning method is more expensive than CO_2 stunning or 'regular' electrical stunning. We do have an advantage when it comes to reducing downtime because of technical issues, but most important, we believe that from a (European/Dutch) laws and regulations standpoint, we are future-proof. And, we have reasons to believe that the meat quality is better when the stunning method is electrical.'

Table 14: Conditions that would encourage slaughterhouse management to change to an alternative stunning method (direct quotes).			
CO_2-1	CO_2-2	CO_2-3	Electrical-1
'A stunning method that could demonstrate an even lower level of stress would be ideal, provided of course it could be practically implemented. The stunning itself should be seen in combination with ways of driving the pigs to the stunning chamber itself.'	'A group stunning system with all positive points of the CO_2 group stunning without the irritating effect of CO_2 on the animals in the first part of the stunning period.'	'Adequate meat quality with no effects on welfare and full compliance with legislation.'	'We believe electrical stunning is the only right method and can be very well suitable also on industrial scale.'

Sum up on the focus group interviews

Focus group interviews with key employees and direct questions to the top-management of European slaughterhouses provided significant insights regarding drivers for their choice of stunning system, and for the conditions that are required for a potential change of system.

We identified the following reasons for choosing current systems:

- Independent on which system the interviewees were working with, they all saw very good reasons for their own system and expressed reluctance to change. Thus, the tendency to 'stick with what you know' was very pronounced. This may be explained by the fact that the act of killing animals is always unpleasant and to some extent associated with stress and discomfort. Therefore, a conservative approach perhaps feels more secure, and people tend to bear with the constraints given by their current systems – 'You know what you have – not what you'll get'.
- Ensuring a high meat quality was imperative to all, and meat quality was described to reflect animal welfare conditions during the pre-stunning and stunning processes to a high degree.
- Though it was recognized that alternative gases had the potential to reduce aversiveness, none were currently seen as economically viable. Especially, the huge investment costs related to change of stunning system were highlighted, as not only the stunner itself but often the whole facility as such would be affected by the design of the stunner. There was a concern about alternative gases requiring a lower throughput per stunner, reducing the throughput capacity of the slaughter facilities.
- Many practical and economic reasons for sticking with the already implemented system were given. The slaughterhouses had invested large amount of time and money in designing their facilities to fit their stunning systems over the years. Thus, all details in the facilities were customized to fit the conditions for stunning in terms of design, capacity and speed. It was stressed that changing stunning method therefore included much more than changing the stunning equipment. In some cases, the participants feared very high investments costs and running costs (due to an expected reduced capacity) in relation to a change in stunning method.

Reasons specifically relevant for <u>choosing high CO_2 stunning systems</u>:

- The pre-stunning phase in gas stunning systems with movement of pigs in groups all the way into the stunner was emphasized as a good way to ensure calm and stress-free conditions for the animals prior to stunning and thereby also a high quality of meat. The moving in groups was also highlighted by top-management as a priority for ensuring animal welfare.
- CO_2 was drawn forward as a reliable method to ensure unconsciousness (or even death in many cases) for a long enough period for the workers to have sufficient time for bleeding. Therefore, CO_2 was seen as 'foolproof' to use.
- Alternative gases to CO_2 were not seen as 'foolproof', because the time to regain consciousness compared to CO_2 was expected to be shorter. This would be a constrain on the workers, as they would have to work faster to ensure that no pigs would wake up again before bleeding.
- Currently, only two alternatives exist for stunning in high throughput slaughterhouses, electrical and CO_2-based systems. Thus, as a logical consequence, only electrical stunning was considered a possible alternative to the participants working in CO_2-based systems and vice versa. Concerns in relation to animal welfare (animals moved in single file against their nature sometimes with use of electrical prods), work safety (risk for persons to receive electric shocks) and meat quality (PSE, blood spots) in electrical systems were expressed by participants working with CO_2 systems, and these concerns seemed to be an overall reason for choosing CO_2. On the other hand, a longer and more stressful period for induction of unconsciousness in CO_2-systems was a main driver for choosing an electrical system.
- Some of the interviewees were sceptical about in the future being dependent of the supply of alternative gases from countries like e.g. Russia.

- Significant concerns in relation to climate footprints of the entire processes (extraction, transportation, storing etc.) of using alternative gases compared to current systems was identified as a lock-in for change, as in current systems, CO_2 and electricity used for stunning can have a very low climate footprint.

Reasons specifically relevant for choosing electrical stunning systems:

- The instantaneous nature of stunning in electrical systems was highlighted as positive and referred to as 'a bullet' – fast and painless. Top-management in the slaughterhouse using electrical stunning with lower throughput per stunner than traditionally, saw this as the most welfare friendly method of stunning. 'Eyes on Animals' and the 'Beter Life' label have approved this improved method of electrical stunning.

The following potential drivers for change to another system were identified:

- An important condition for a change of system to alternative gases was the availability of scientific evidence showing that the pigs would lose consciousness with no feeling of stress and pain and not recovering consciousness again to soon after exit of the stunner.

- Methods that result in calm and relaxed pigs (also including absence of involuntary muscle contractions after stunning) are preferred.

- An important driver for change would be that the new gas stunning method reduces or removes the danger for the humans working in the system.

- Some of the participants highlighted those systems that 'run on their own' with minimal need for human interference to be beneficial in relation to animal welfare. Therefore, systems that run smoothly without interruptions from technical problems, frequent need of cleaning etc. would be a big advantage.

- An important consideration in relation to change of system was identified as the ease of cleaning and keeping free from manure and dust during the workday so that emptying the system from gas would not be necessary. As current CO_2-based systems were seen as quite complicated to run and maintain without breaks in workflow and potential safety issues for the personnel, alternative systems with improved conditions for cleaning and maintenance would be appreciated.

- The ability in the future to have systems capable of shifting between gas-types and thereby ensure some flexibility for the slaughterhouses instead of dependency on very few suppliers was seen as a great opportunity.

- Top-management in slaughterhouses using CO_2 highlighted how they saw group movement into the stunners as the best / only way to ensure animal welfare. Thus, a main condition for change of system in their eyes is to be able to still handle an stun the animals in groups.

Consortium workshop on conclusions regarding current stunning practices for pigs in high throughput slaughterhouses in the EU

The Pigstun consortium includes a vast and diverse expertise and experience in current stunning practices for pigs in the EU. The consortium includes six research performing organizations, an international supplier of meat-processing equipment, a world leading gas supplier and five slaughterhouses. The consortium conducted on February 9th 2024, a workshop for evaluating and discussing the results obtained on current stunning practices for pigs and main drivers for choosing stunning system. The evaluation was conducted by 13 partners during a two-hour meeting: Compaxo, Danish Crown, Norfrisa, Westfort , Vion, Wageningen Livestock Research, Aarhus University, FLI, IRTA, MRI, DMRI, Marel and University of Gottingen. The participants included decision makers from five slaughter companies.

Macro-economic considerations

The macro-economic data obtained from the twelve largest pig producing countries in EU show that two third of the pigs in EU are stunned by CO_2 and one third of the pigs are electrically stunned. There is a tendency that large slaughter plants use CO_2. The general trend is that slaughter plants using electrical stunning convert to CO_2 stunning. Retailers

and/or welfare labels ask the slaughter plants to choose an irreversible stunning method (to choose CO_2 stunning) or to ban electrical prods for moving pigs to the stunner (which are currently used in electrical systems). The participants generally agreed that it is not possible to avoid the use of electrical prods in electrical stunning systems. The case using electrical stunning, however, indicated that it is possible to minimize the use of electrical prods in electrical systems. A potential ban on electrical prods, however, puts pressure on slaughter plants using electrical stunning. It was emphasized during the discussion that increased focus on the induction phase in gas stunning may put a negative focus on CO_2 stunning. In Spain as well as in Germany there may be regulations on the way enforcing video documentation of the entire stunning process including video recording from the induction phase.

Micro economic considerations

Electrical stunning has traditionally been linked to meat quality problems such as blood spots and PSE. The case using electrical stunning agreed that meat quality problems where previously a problem. However, these problems in their case have been solved by decreasing the throughput rate per stunner. It was confirmed by another case using electrical stunning in parallel with CO_2 stunning that meat quality problems in electrical stunning can be avoided. Solving the meat quality problem goes hand in hand with reducing the animal welfare issues related to electrical stunning. Putting pigs into single lines for electrical stunning can be less stressful for the pigs at a low throughput rate and well designed raceways.

Work environment and safety

The consortium did not find that work environment or safety risks differ between modern electrical and CO_2 stunning systems. Previously, there was more noise in electrical stunning systems due to pig vocalization and sounds from metal equipment.

5. Overall conclusions on current stunning practices for pigs in high throughput slaughterhouses

Controlled atmosphere stunning with high concentration CO_2 is a common practice in EU pig slaughterhouses. The gas is aversive and causes hyperventilation and irritation of the mucous membranes and elicits hyperventilation and gasping before loss of consciousness. For these reasons, high concentration CO_2 stunning has been criticized. The general objective of the PigStun project is to encourage EU pig slaughterhouses using high CO_2 concentration for stunning of pigs to convert to more animal welfare friendly systems, by developing technical specifications for promising alternatives.

As a basis for suggesting and implementing alternatives to high concentration CO_2 stunning we have:

- Described stunning practices for pigs in high throughput slaughterhouses in the EU.
- Identified the main drivers that influence the choice of slaughterhouse operators for a stunning practice.

We have come to the following overall conclusions:

- Approximately 67% of pigs slaughtered in EU are stunned by CO_2 and approximately 28% by electrical stunning, and for the remaining 5% the method could not be determined. It furthermore appears that the vast majority of high throughput slaughterhouses use CO_2 stunning and thus have facilities that support this method. There can be multiple reasons of choice of stunning methods in each country such as animal welfare, meat quality and investment costs. Also demands from major retailers came through as one of the reasons of choosing a certain stunning method.
- Independent on which system the interviewees and top-managers were working with, they all saw very good reasons for their own systems and expressed a reluctance towards other alternatives (especially the electrical system as an alternative to CO_2).
- The dominant main drivers for choice of stunning method were animal welfare and meat quality. Especially the movement in the raceway was highlighted as a critical phase.
- The main reason for staying with high CO_2 stunning was the fact that it allows pigs to be moved in groups the whole way to the stunner, which was seen as an efficient way to ensure animal welfare and good meat quality.
- The main reason for staying with electrical stunning was the 'bullet-like' and fast stunning process with no painful period before loss of consciousness in this system.
- The management in slaughterhouses using high concentration CO_2 stunning seem to be open for other types of gas stunning if a significant benefit for animal welfare is documented.
- The general trend is that slaughter plants using electrical stunning convert to CO_2 stunning. Retailers and/or welfare labels ask the slaughter plants to choose an irreversible stunning method (to choose CO_2 stunning) or to ban electrical prods for moving pigs to the stunner (which are currently used in electrical systems). It is not possible to avoid the use of electrical prods in conventional electrical stunning systems. A ban on electrical prods puts pressure on conversion towards electrical stunning.
- Increased focus on the induction phase in gas stunning may put a negative focus on CO_2 stunning. Mandatory video documentation of the entire slaughter process may be implemented in some Member states. Video recordings showing the induction phase in CO_2 stunning systems is the major driver for NGO's to call for alternatives and a ban on high concentration CO_2 stunning in pigs.

Appendix 1

The questionnaire used for collecting data from the slaughter plants. Differences between the questionnaire sent to slaughter plants using CO_2 stunners and electrical stunners are shown with red text in brackets throughout the questionnaire.

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Background information on this questionnaire

In EU pig slaughterhouses two stunning methods are commonly applied: Electrical stunning and carbon dioxide stunning at high concentrations. In 2004 and 2020, the European Food Safety Authority (EFSA) concluded for the gas stunning of pigs that at concentrations above 30% CO_2, the gas is aversive and causes hyperventilation and irritation of the mucous membranes. This is likely to be painful and elicits hyperventilation and gasping before loss of consciousness. For this reason, high concentration CO_2 stunning has been criticized. The general objective of the PigStun project[2] is to encourage EU pig slaughterhouses using high carbon dioxide concentration for stunning pigs to convert to more animal welfare friendly systems, by developing technical specifications for four promising alternatives. Three of these alternatives involve gas stunning, one of them aims at improving the electrical stunning process. In order to develop, compare and test these possible alternatives to CO_2 stunning, detailed knowledge of common practices is needed.

During the first part of the project, data on current practices will be collected in five case slaughterhouses in different countries. The gathering of information will be done in two phases: Phase 1. Facts on current technical, practical, and economic data are gathered by use of a questionnaire to be filled in by you and the local project partner; Phase 2. A focus group interview with key persons at the facility is conducted to gain knowledge on your main drivers for choosing the current and future systems (to be conducted in June 2023).

For Phase 1, please have a look at the attached questionnaire and please fill in as much as possible. We are aware that not all questions are self-explanatory, and therefore finalization of the questionnaire will be done together with your local partner in an online or physical meeting.

We have the following deadlines, that we hope you can align with:

Return of questionnaires with your preliminary answers: 30.4.2023 (to be adjusted by partners)

Online/ physical meeting to complete the answers: 10.5.2023 (to be adjusted by partners - AU would like to have questionnaires back no later than 15th of May)

Thanks a lot for your willingness to share information and experiences of your system with us.

[2] For information on the project, see: HaDEA signs a grant agreement with PigStun consortium for the development of non-aversive stunning methods for pigs (europa.eu)

General information

1. How many pigs were slaughtered per year?

2020	
2021	
2022	

Comments:

2. How many pigs are slaughtered per hour?

Comments:

3. What is the average slaughter weight of the pigs?

Comments:

Unloading and time in lairage

4. What is the average time between arrival of trucks and unloading of the pigs?

Comments:

5. How are the animals protected against weather conditions during unloading?

Unloaded inside	Unloaded outside with roof	Other way (please specify)

Comments:

6. How long is the route to lairage (in meters)?

Comments:

7. Which types of stimulating materials are used to move pigs from the trucks to lairage?

Flags	Peddles	Electric pods	Other (please specify)

Comments:

8. Do the animals stay within their transport groups in lairage?

Yes	No

Comments:

9. What is the size of pens and how many pigs per pen in lairage (note: if different sizes fill in more rows)?

Size (m^2)	Number of pigs

Comments:

10. If fighting is observed, how is this handled?

Please explain (include managemental and housing measures):

11. Which, measures are applied with the intention to ensure a comfortable stay in lairage Please explain (think broadly on design, management, feeding etc.):

12. How long are the animals usually kept in lairage?

<1 h	1h-2h	>2h

Comments:

13. Which percentage of animals do usually lay down for at least half of the time in lairage?

Comments:

14. What is the room temperature in lairage at pigs' level (please, note intervals for each season)?

Spring	Summer	Autumn	Winter

Comments:

15. What is the room humidity in lairage at pigs' level (please, note intervals for each season)?

Spring	Summer	Autumn	Winter

Comments:

16. What is the room ammonia level in lairage at pigs' level (please, note intervals for each season)?

Spring	Summer	Autumn	Winter

Comments:

17. Which control/ alarm functions do you have to ensure adequate ventilation in lairage?

Please explain:

18. How is the design of equipment for drinking water and how many animals per drinker?

Please explain:

19. Do you have shower facilities in the lairage? – When are they used and for how long periods and with which intervals?

Please explain:

20. Is feed available for the pigs in lairage and under which circumstances are the pigs fed?

Please explain:

CO_2 Stunning (only for participants with a CO2 stunner)

21. Which group-sizes are used when pigs are moved from lairage to stunning?

Comments:

22. How is the moving of pigs handled in the raceway towards the stunner?

Humans with rattle sticks	Machines doors pushing	Combination

Comments:

23. How is the design of the raceway towards the stunner?

Please explain (include descriptions of slope, path design etc.):

24. How many gondolas per line?

Comments:

25. What type of stunning equipment is used?

Paternoster	Dip lift

Comments:

26. How many pigs are in each gondola?

Comments:

27. What is the size of the gondolas?

M^2	M^3

Comments:

28. How many lines/ stunners are available?

Comments:

29. How many pigs per line per day?

Comments:

30. How long time does a cycle last (from the moment the pigs get in the stunner and till they are removed from the stunner)?

Comments:

31. Where is the CO_2 level monitored?

Entrance of the stunning equipment	On the top of gondolas	In the bottom of gondolas	Exit of the stunning equipment	Others

Comments (If more than one monitor, please state how many and where they are placed):

32. How long time does it take to get to the first stop?

Comments:

33. What is the percentage of CO_2 at the first stop?

Comments:

34. What is the max percentage of CO_2 at the bottom?

Comments:

35. How long does it take to arrive to the maximum concentration?

Comments:

36. Do you use video cameras to assess the stunning process?

Yes	No

Comments (Please, specify where the cameras are placed):

37. Which percentage of pigs shows excitation before loss of posture?

Comments:

38. How much time is there on average from pigs exiting the stunner till stick?

Comments:

39. How much time is there between exit of the stunner to stick for the last pig in the group?

Comments:

40. Where and how is the effectiveness of the stunning assessed?

	Righting reflex	Presence of breathing	Corneal or palpebral reflex	Presence of vocalizations	Presence of response to nose prick or ear pinch	Other way (please specify)
At exit of gondola						
Before shackling						
During chest sticking						
After bleeding						

Comments:

41. Which percentage of pigs is assessed for effective stunning by the animal welfare officer?

Comments:

42. Which percentage of pigs are inefficiently stunned?

Comments:

43. How is correct sticking assessed?

Blood weight	Camera	Humans	Other

Comments:

44. What are the indicators used to assess the state of consciousness before shackling?

Righting reflex	Presence of breathing	Corneal or palpebral reflex	Presence of vocalizations	Presence of response to nose prick or ear pinch	Other (please specify)

Comments:

45. What are the indicators used to assess the state of consciousness before sticking?

Righting reflex	Presence of breathing	Corneal or palpebral reflex	Presence of vocalizations	Presence of response to nose prick or ear pinch	Other (please specify)

Comments:

46. What are the indicators used to assess the state of consciousness during bleeding?

Righting reflex	Presence of breathing	Corneal or palpebral reflex	Presence of vocalizations	Other (please specify)

Comments:

Electrical stunning (only for participants with an electrical stunner)

47. Which group-sizes are used when pigs are moved from lairage to stunner?

Comments:

48. How is moving of the pigs handled in the raceway towards the stunner?

Humans with rattle sticks	Machines doors pushing	Combination

Comments:

49. How is the design of the raceway towards the stunner?

Please explain (include descriptions of slope, path design, how is the separation from the group handled etc.):

50. How many lines/stunners are available?

Comments:

51. How many pigs per line per day?

Comments:

52. What kind of stunning equipment is used?

Please describe:

53. How many stunners are used at the same time?

Comments:

54. What are the stunning parameters?

	Slaughterpigs	Sows
Minimum current (mA) head		
Minimum current (mA) chest		
Minimum voltage (V) head		
Minimum voltage (V) chest		
Maximum frequency (HZ)		
Minimum time of exposure (sec)		

Comments:

55. Which percentage of pigs is assessed for correct stunning by the animal welfare officer?

Comments:

56. Which percentage of pigs are inefficiently stunned?

Comments:

57. How is correct sticking assessed?

Blood weight	Camera	Humans	Other

Comments:

58. Where in the process are the pigs assessed for the state of consciousness?

Before shackling	During chest sticking	After bleeding	Other

Comments:

59. What are the indicators used to assess the state of consciousness before shackling?

Righting reflex	Presence of breathing	Corneal or palpebral reflex	Presence of vocalizations	Presence of response to nose prick or ear pinch	Other (please specify)

Comments:

60. What are the indicators used to assess the state of consciousness before sticking?

Righting reflex	Presence of breathing	Corneal or palpebral reflex	Presence of vocalizations	Presence of response to nose prick or ear pinch	Other (please specify)

Comments:

61. What are the indicators used to assess the state of consciousness after bleeding?

Righting reflex	Presence of breathing	Corneal or palpebral reflex	Presence of vocalizations	Other (please specify)

Comments:

Work environment

62. What is the maximum noise level at full capacity (db)?

Comments:

63. Where in the process do you have the highest level of noise?

Please explain:

64. Which measures are taken to protect workers from noise (hearing protection, maximum time in noisy areas etc.)?

Please explain:

65. How long is a normal workday?

Comments (please indicate if it differs between work tasks and how):

66. How is the working rotation?

Please explain:

67. Are limits established on number of hours of work, requirements for rotation, lifting or carrying?

Please explain:

68. What kind of injuries occur incidentally?

From Animals	From equipment	Both	Other types (please specify)

Comments:

69. Which kinds of protection requirements are there for the workers?

Mandatory boots with steal toe	Mandatory protective clothing	Mandatory hearing protection	Mandatory monitors for CO_2 level

Comments:

70. What kind of education in handling of animals and equipment do the workers have/get?

Please explain:

71. Are the workers tested for MRSA?

Yes – How often?	No

Comments - What is the consequence of positive tests?

Meat quality

72. Which percentage of carcasses are diagnosed with PSE?

0-5%	5%-10%	>10%	Others

Comments:

73. What are your economic losses (in euros per year) due to PSE?

Comments:

74. Which percentage of carcasses with haemorrhages in meat?

0-5%	5%-10%	>10%	Others

Comments

75. What are your economic losses (in euros per year) due to hemorrhages?

Comments:

76. Any other meat quality defects?

Please explain (types and economic losses caused by each)

Environment/ sustainability

77. What is the CO_2 emission from the stunning process per working day? (only on the questionnaire for participants with a CO_2 stunner)

Comments:

78. What is the total CO_2 emission from the plant per working day?

Comments:

79. How much water is used per day (include showers, drinkers, cleaning)?

Unloading area	Lairage	Raceway	Stunner (including exit of stunner)

Comments:

80. How is the stunning equipment cleaned?

Please explain (equipment, chemicals etc.):

81. How is the sewage water cleaned?

Please explain:

Investments and costs

82. What was the price of the stunner and in what year did you buy it?

Price (in euros)	Year

Comments:

83. What are the operational costs (in euros per year) of the stunner?

Comments:

84. What is the average salary (in euros) for workers in the stunning facility per year?

Comments:

85. What are the maintenance costs (in euros per year) of the stunner?

Comments:

86. How often is service done on the stunning equipment?

Once a year	Twice a year	More	Others

Comments:

87. What is the cost of each service (in euros)?

Comments:

88. What are the costs (in euros) of water for cleaning in lairage per year?

Comments:

89. What are the costs (in euros) for cleaning the stunning equipment per year?

Comments:

90. What are the costs (in euros) to get rid of the sewage water from the stunning facility per year?

Comments:

91. What are the costs (in euros) of electricity for the stunning facility per year?

Comments:

92. What are the costs (in euros) of chemicals to clean and disinfect the stunning facility per year?

Comments:

PigStun

Developing non-aversive stunning methods for pigs

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