

Supplementary Material S2: DELPHI QUESTIONNAIRE

CIRCULAR ECONOMY: APPLICATION TO EGG PRODUCTION IN CANADA **QUESTIONNAIRES FOR VALIDATION OF INDICATORS**

QUESTIONNAIRE 1

We would like to have your opinion on the importance of Decision Variables (DVs) for each of the four (4) Categories of Economic Circularity Assessment (CECA), for measuring CE in egg production (**Figure 1 above**).

CECA1: WASTE REDUCTION & CIRCULAR ACTIVITIES

Based on your knowledge, how important are each of these decision variables to improve the economic circularity of egg production?

(**1** = *unimportant*, **2** = *Somewhat unimportant*, **3** = *Somewhat important*, **4** = *Important*, **5** = *Very important*)

Reduction of and disposition of mortalities	1	2	3	4	5
Reduction and disposition of downgraded eggs	1	2	3	4	5
Spent hens disposition	1	2	3	4	5
Manure production and management	1	2	3	4	5

CECA2: RESOURCE USE EFFICIENCY

Based on your knowledge, how important do you think each of the following decision variables are to improve resource efficiency for egg production?

(**1** = *unimportant*, **2** = *Somewhat unimportant*, **3** = *Somewhat important*, **4** = *Important*, **5** = *Very important*)

Hens' productivity	1	2	3	4	5
Feed utilization	1	2	3	4	5
Water use/consumption	1	2	3	4	5
Use of production equipment and other disposables	1	2	3	4	5
Energy use	1	2	3	4	5

CECA3: ENVIRONMENT (ENERGY & EMISSIONS)

Based on your knowledge, how important are each of the following decision variables to improve environmental objectives of Circular Economy?

(**1** = *unimportant*, **2** = *Somewhat unimportant*, **3** = *Somewhat important*, **4** = *Important*, **5** = *Very important*)

Use of renewable energy	1	2	3	4	5
Greenhouse gas emissions	1	2	3	4	5

CECA4: COMPLEMENTARY INDICATORS (SOCIAL & BIODIVERSITY)

Based on your knowledge, how important are each of the following decision variables to improve social and biodiversity aspects?

(1 = unimportant, 2 = Somewhat unimportant, 3 = Somewhat important, 4 = Important, 5 = Very important)

Occupational health and safety	1	2	3	4	5
Local employment and wealth	1	2	3	4	5
Animal welfare	1	2	3	4	5

Comments & suggestions on decision variables

1.1. Prioritization of Categories of Economic Circularity Assessment (CECA)

The decision variables (DVs) evaluated above are organized according to the categories of evaluation of circularity (CECA). Now, we would like to get your opinion on the importance of these categories in improving economic circularity for the specific case of egg production.

⇒ In **Table S1**, please give each CECA a rank ranging from 1 to 4 (4 being the best rank) expressing the relative importance of the category in improving economic circularity in the egg production sector.

Table S1. Prioritization of Categories of Economic Circularity Assessment (CECA)

CECA (In alphabetical order)	Rank	Motivation of the ranking (2 to 3 sentences)
COMPLEMENTARY INDICATORS (SOCIAL & BIODIVERSITY)		
ENVIRONMENT (ENERGY & EMISSIONS)		
RESOURCE USE EFFICIENCY		
WASTE REDUCTION & CIRCULAR ACTIVITIES		

Comments & suggestions (You can make general comments on prioritization of Categories of Economic Circularity Assessment_(CECA)

QUESTIONNAIRE 2:

The following questions are asked to help make trade-offs between different options or best practices for improving economic circularity.

Q1: Trade-off between use of hen mortalities

Mortalities are hens that die throughout the production lifecycle and do not include spent hens which are hens at the end of the production cycle. Possible uses for mortalities include composting, landfilling, rendering and incineration.

Which option for mortalities use do you think is the best from CE perspective?

⇒ In **table S2**, please rank these options (listed in alphabetical order) by assigning each option a rank ranging 1 to 4 (1 being the best option).

Table S2 : Ranking for mortalities use options

Valorisation Options	Rank	Motivation of the ranking (2 to 3 sentences)
Composting		
Incineration		
Landfilling		
Rendering		
<u>Others (if you know other options)</u>		

Q2: Trade-off between options for use of spent hens

Options for spent hens' (living hens at the end of production cycle) include composting, human consumption, landfilling, rendering and incineration.

Which option for use of spent hens do you think is the best from CE perspective?

⇒ In **table S3**, please rank these uses (listed in alphabetical order) by assigning each option a rank ranging 1 to 5 (1 being the best option).

Table S3 : Ranking for spent hens use options

Valorisation Options	Rank	Motivation of the ranking (2 to 3 sentences)
Composting		
Human Consumption		
Incineration		
Landfilling		

Valorisation Options	Rank	Motivation of the ranking (2 to 3 sentences)
Rendering		
Others (if you know other options)		

Q3: Manure options

Manure produced on farm can be used by composting, soil fertilization, anaerobic digestion for energy production (biogas) and drying, cubing and bagging for sale.

Assessed from the perspective of improving the circularity of an egg production company, which of these manure options is the best?

⇒ *In **table S4**, please rank these options (listed in alphabetical order) by assigning each option a rank ranging 1 to 4 (1 being the best option).*

Table S4 : Ranking of manure options

Valorisation Options	Rank	Motivation of the ranking (2 to 3 sentences)
Anaerobic digestion for energy production: biogas		
Composting for fertilization		
Cubing and bagging for sale		
Fresh manure for soil fertilization		
Others (if you know other options)		

Q4: Extending the duration of the production cycle

In general, for all egg production companies, the production cycle lasts 51 weeks or 358 days (exactly 12 months minus one week).

⇒ *Do you think that increasing the duration of the production cycle is a relevant intervention to improve the circularity of production in the egg sector? Please justify your answer.*

Write your answer in this box

Q5: Trade-off between animal welfare and human well-being

With respect to animal welfare, hen housings can be provided with accessories that can allow hens to exhibit natural behaviors to varying degrees. *Conventional cage* systems are made of cages housing 6 hens. The approximate space per hen is 80 square inches (in²). In *enriched colony housing* systems, 60 hens are housed in larger and more open cages that provide 116 in² of space per hen. The colony housing is equipped with perches, nesting areas and materials that facilitate scratching. In *free run* systems, hens can move freely within the barn have access to the same equipment as the enriched colony. The approximate space per hen is 144 in². The *organic* system is like free run, but the hens have access to an outdoor section and receive foods of certified organic origin. Thus, conditions inside the building are similar to those described for the free-run systems but space per hens is slightly higher.

- ⇒ We ask you to rank hen housing systems taking into consideration specific criteria of human well-being in the first table and animal welfare in second table. In the third table, we ask you to rank hen housing systems while considering both human and animal welfare.

HUMAN WELFARE

- Please rank hen housing systems (Columns 2 to 5) by assigning each system a rank ranging from 1 to 4 (1 being the highest level of well-being) with respect to criteria of the well-being of each row. N.B. A same rank can be attributed to more than system if you think they are equal.

Welfare (WF) criteria	Hen housing systems (columns 2 to 5)			
Human WF criteria	Conventional cages	Enriched colonies	Free run	Organic
Employee exposure to particulate matter (PM) concentrations and endotoxin				
Risk to human health associated with egg contamination				
Risk of back and/or repetitive movements problems for workers				

ANIMAL WELFARE

- Please rank hen housing systems (Columns 2 to 5) by assigning each system a rank ranging from 1 to 4 (1 being the highest level of welfare) with respect to hens' expression of their natural behaviors. N.B. A same rank can be attributed to more than one system if you think they are equal.

Welfare (WF) criteria	Hen housing systems (columns 2 to 5)			
Human WF criteria	Conventional cages	Enriched colonies	Free run	Organic
To what extent can hens express their natural behaviors				

HUMAN + ANIMAL WELFARE

- Please rank hen housing systems (Columns 2 to 5) by assigning each system a rank ranging from 1 to 4 (1 being the highest level of well-being) with respect to both human and animal well-being. N.B. A same rank can be attributed to more than one system if you think they are equal.

Welfare (WF) criteria	Hen housing systems (columns 2 to 5)			
Human WF criteria	Conventional cages	Enriched colonies	Free run	Organic
To what extent combined criteria for human and animal welfare are minimized/enabled in the concerned hen housing system?				

Q6: Trade-off between sources of the used energy

Our interviews (focus group and farm visits) revealed various sources of energy used on egg farms. These sources are propane, natural gas, geothermal energy, biomass, biogas, hydroelectricity, coal-based electricity, solar, wind and electricity from other sources.

In your opinion, which types (sources) of energy better meet the logic of the circular economy?

- ⇒ In **table S6**, please rank these sources of energy (listed in alphabetical order) by assigning each option a rank ranging 1 to 10 (1 being the best option and 10 the worst). **N.B.** A same rank can be attributed to many systems in case you think they are equal.

Table S6: Ranking of energy sources

	1	2	3	4	5	6	7	8	9	10
Natural gas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Propane	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Geothermal energy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Biogaz	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Biomass	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hydroelectricity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Coal based electricity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Solar	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Wind	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Electricity from other sources	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- Others (if you know other sources of energy used on egg farm)

Comments: In few words, please motivate your ranking of the above sources of energy