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The Coalition for Sustainable Egg Supply: A unique public–private partnership for conducting research on the sustainability of animal housing systems using a multistakeholder approach[1]

J. A. Mench,*[2] J. C. Swanson,† and C. Arnot‡

*Department of Animal Science and Center for Animal Welfare, University of California, Davis 95616; †Department of Animal Science, Michigan State University, East Lansing 48824; and ‡Center for Food Integrity, Gladstone, MO 64119

ABSTRACT: The growing emphasis on ensuring the sustainability of animal agriculture is providing an impetus for the adoption of new approaches to structuring and conducting research. Sustainability is a complex topic involving many considerations related to the economic, social, and environmental impacts of production systems. Successfully addressing this topic requires multidisciplinary research as well as a high degree of communication with food system stakeholders to ensure that the research results contribute to informed decision making. In this paper, we provide an overview of a public–private partnership, the Coalition for Sustainable Egg Supply (CSES), which was formed to support research evaluating the sustainability of laying hen housing systems. Because of increasing public concerns about the behavioral restriction imposed on laying hens housed in conventional cages, the U.S. egg industry is faced with a need to transition to alternative systems. However, before the CSES project, there was limited information available about how this transition might affect trade-offs related to the sustainability of egg production. The goal of the CSES project was to provide this information by conducting holistic research on a commercial farm that had 3 different hen housing systems. The CSES members represented a variety of stakeholders, including food retailers and distributors, egg producers, universities, and governmental (USDA ARS) and nongovernmental organizations. The CSES was facilitated by a not-for-profit intermediary, the Center for Food Integrity, which was also responsible for communicating the research results to food system stakeholders, including via quantitative and qualitative consumer research. In this paper, we describe the structural aspects of the CSES that were responsible for the successful completion and dissemination of the research as well as the insights that were gained regarding multidisciplinary and multi-institutional collaboration, conducting commercial-scale research, fostering and maintaining stakeholder interaction, and communicating research results. Although not without limitations, this project demonstrates that public–private partnerships can be effective strategies for addressing sustainability questions related to animal agriculture and, thus, serves as a useful model for the other animal industries.

Key words: coalition, multidisciplinary, public–private partnership, stakeholder, sustainability

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INTRODUCTION

There is a growing mandate for animal agriculture to be conducted sustainably, with consideration not only for the projected growth in global demand for foods of animal origin but also of the environmental and social impacts of intensified animal production practices. Food retailers increasingly consider sustainability to be a core element of their social responsibility programs and, therefore, a key driver of their purchasing decisions, including those for animal

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[2]Corresponding author: jamench@ucdavis.edu
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products. Retailer decisions about sustainable purchasing often involve input from nongovernmental organizations presumed to represent the views of the public. Therefore, sustainability-driven market and consumer considerations and preferences have the potential to have significant financial impacts on animal producers.

Although there is no single agreed-on definition of agricultural sustainability, many definitions include consideration of a variety of elements (e.g., Niles, 2013). A recent report from the National Academy of Science (NRC, 2015) on research needs to address the future sustainability of animal agriculture emphasized the importance of taking multidisciplinary research approaches that consider a range of sustainability indicators and involve input from multiple stakeholders. The report also emphasizes the importance of public–private partnerships in filling the gaps created by the decline in state and federal funding for animal agriculture research. We present information about a research project that used such an approach, focusing on sustainability of egg production in the United States. Our goal is to illustrate how this public–private partnership was organized and functioned to facilitate multistakeholder, multidisciplinary, and commercial-scale research as well as to discuss the advantages, limitations, and lessons learned. We begin our discussion by providing background about the recent sustainability concerns affecting the egg industry and how those created the impetus and framework for the project.

WHY EGG PRODUCTION?

Eggs are a primary source of animal protein in many countries. The United States is the third largest egg producing area in the world, after China and the European Union (the "EU-15": Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom), producing about 82 billion table eggs (nearly 5 million t) annually from more than 300 million hens (EIC, 2015; UEP, 2015). Almost all of these eggs are consumed domestically, with per-person consumption of 251 eggs per year in the form of shell eggs and egg products in 2014 (IEC, 2014). More than 94% of these eggs are produced from laying hens housed in conventional (battery) cages (Windhorst, 2015).

Commercial egg producers in the United States and other developed countries began widespread adoption of conventional cages in the 1950s. Before this time, hens had been kept mainly in small to medium-sized flocks in barn or free-range systems. Although these systems allowed the hens to perform a wide range of natural behaviors, they also exposed the hens to vector- and soilborne diseases and predation. In addition, hens often laid eggs outside of the designated nesting areas, and these eggs were dirtier than nest-laid eggs and potentially contaminated with bacteria, posing a food safety risk. Moving hens into cages greatly reduced these problems. It also facilitated the expansion and integration of the laying industry by allowing larger flock sizes and more automation of feeding, watering, and egg collection as well as by reducing the land needed to supply the consumer demand for eggs. This, in turn, reduced the cost of eggs for consumers.

Within a decade of the adoption of the conventional cage system, however, it began to be criticized in Europe because of the extent to which it restricted the behavior of the hens (Appleby, 2003; Mench et al., 2011). Not only were hens kept at very high stocking densities but the cages were small and bare wire enclosures that did not provide resources hens needed to perch, nest, or forage. This criticism was part of a larger and growing concern in Europe about the effects on animal health and welfare of the increasing intensification of livestock and poultry production. In 1976, the Council of Europe published a convention stating that farm animals should be given "space appropriate to their physiological and ethological [behavioral] needs." (CE, 1976, p.2) The European Union soon adopted minimum space standards for conventional cages but then, in 1999, decided to ban them entirely (CEC, 1999), with the ban to take effect in 2012.

A similar sentiment was growing in the United States. In 2008, California voters passed a referendum, Proposition 2 (Prevention of Farm Animal Cruelty Act, 2008) that, although ambiguously worded, effectively outlawed conventional cages for laying hens as of January 2015. Legislation that either outlawed or restricted the use of conventional cages was then passed in Michigan, Ohio, Washington, and Oregon during the following 2 yr (Rumley, 2015). These legislative efforts were led by animal welfare groups, mainly the Humane Society of the United States (**HSUS**). They eventually resulted in the egg industry, in concert with the HSUS, seeking federal legislation to ban conventional cages to create a "level playing field" for U.S. egg producers to prevent disruption of interstate commerce in eggs (Greene and Cowan, 2014). That effort was eventually abandoned due to strenuous opposition by several of the other key livestock industries, concerned that federal regulation of animal welfare in the egg industry would set a precedent for animal agriculture as a whole.

After the passage of their conventional cage ban, the European Union devoted considerable effort toward developing alternatives to conventional cage housing. The 2 major alternative types of systems now in use are noncage (cage-free) systems and furnished cages (which contain perches, a nesting area, and a scratch area and which are called enriched colony systems in North America).

Detailed descriptions of these systems and the current prevalence of their use globally can be found elsewhere (LayWel, 2009; Mench et al., 2011; Windhorst, 2015).

THE AMERICAN EGG BOARD PROJECT

As the European Union moved toward the implementation of the cage ban, it became apparent that there would be unanticipated or inadequately characterized effects of moving to alternative production systems, not only on hen welfare but also on other aspects of sustainability, such as the environment, egg safety and quality, economics, worker health and safety, and public values and attitudes. Because of the legislative initiatives to change hen housing systems in the United States, in 2008, the American Egg Board provided funding to Michigan State University and the University of California, Davis, to assemble teams of national and international experts from various sectors (mainly academia but also government, industry, and nongovernmental organizations) to review existing knowledge and highlight gaps (Swanson et al., 2011b).

The resulting papers were presented at the 2011 annual meeting of the Poultry Science Association and published in *Poultry Science*. These papers provided detailed reviews about the effects and risks associated with the different hen housing systems for each sustainability area (economics [Sumner et al., 2011], egg safety and quality [Holt et al., 2011], environment [Xin et al., 2011], hen welfare [Lay et al., 2011], and public attitudes and values [Thompson et al., 2011]); there was too little published information on worker health and safety for this area to be reviewed (Mench et al., 2011). Importantly, these papers also identified the knowledge gaps for each sustainability area that needed to be filled to make better-informed decisions going forward. An issue that spanned all sustainability areas was that most research had been performed in Europe and that there was a need to evaluate effects in the United States, given known and potential differences in public attitudes, economic and labor structures, and various aspects of hen management (e.g., hen genetics, egg safety and environmental regulations, building design). Also, much existing research had been conducted on an experimental rather than a commercial scale, potentially limiting its applicability.

THE COALITION FOR SUSTAINABLE EGG SUPPLY

The data gaps and approaches identified above were influential in informing the next stage in the process of evaluating the sustainability of egg production, which was the formation of the Coalition for Sustainable Egg Supply (**CSES**). The CSES was a multistakeholder group collaborating on a study of housing alternatives for egg-laying hens in the United States. Leadership for the project was provided by McDonald's (Oak Brook, IL); Cargill Kitchen Solutions (Monticello, MN); Michigan State University; University of California, Davis; and the American Humane Association (Washington, DC), with the American Veterinary Medical Association (Schaumburg, IL), the USDA ARS (Athens, GA), and the Environmental Defense Fund (New York, NY) serving as advisors.

The CSES had more than 30 members (http://www.sustainableeggcoalition.org/about; accessed March 1, 2015), which included research institutions, trade organizations, scientific societies, nongovernmental organizations, egg suppliers, food manufacturers, and restaurant–retail–food service companies. Retailers have assumed a central role in discussions about animal welfare and the sustainability of the food supply in general, because they have been increasingly subject to public activity (e.g., shareholders' resolutions, advertising campaigns) designed to influence their purchasing practices (Mench, 2008). The CSES was facilitated by the Center for Food Integrity (**CFI**), a not-for-profit organization dedicated to building consumer trust and confidence in the food system and whose members represent each segment of the food supply chain.

The goal of the CSES was to understand the magnitude of effects and the trade-offs in terms of hen welfare, worker health and safety, food affordability, environmental impacts, and egg safety and quality in different hen housing systems under U.S. conditions. Data were collected during 3 yr (over 2 full flock cycles) from a commercial farm in the Midwest that contained 3 types of housing: conventional cage, noncage aviary, and enriched colony (Zhao et al., 2015b). The research partners were Michigan State University; University of California, Davis; Iowa State University (Ames); and the USDA ARS. In addition, Cargill Kitchen Solutions provided specialized expertise on the assessment of worker ergonomics. There were 21 principal investigators across the 4 research institutions, and numerous graduate students, technicians, postdoctoral scholars, and other researchers at those institutions also contributed to the project. The specific effects and outcomes that were researched for comparison among the housing systems are listed in Table 1.

The CSES provided the funding for this multi-million dollar research effort, which also involved constructing the commercial houses necessary to achieve the research objectives. In addition, the CFI conducted parallel, independent qualitative and quantitative consumer research to better understand consumer attitudes toward hen housing systems and the sustainability of egg production as well as to determine

Table 1. Primary research topics addressed by the Coalition for Sustainable Egg Supply research project within 5 sustainability areas, with citations to the peer-reviewed papers currently published or in press for each area. More information about topics that are not covered in the peer-reviewed papers can be found in the final report posted on the Coalition for Sustainable Egg Supply website at http://www2.sustainableeggcoalition.org/final-results (accessed March 17, 2015)

Sustainability area	Specific research topics	Papers published
Hen health and well-being	Behavior, Space and resource use, Physiological indicators of stress, Physical condition, Health outcomes, and Bone quality and strength	Blatchford et al. (2015), Campbell et al. (2015a,b,c), Cotter (2015), and Regmi et al. (2015a,b)
Food safety and quality	Interior egg quality, Exterior egg quality, Egg shelf life, Microbial contamination of eggs, Microbial contamination of environment, and Immunological responses to Salmonella vaccine	Jones et al. (2015) and Karcher et al. (2015)
Environment	Indoor air quality, Indoor thermal conditions, Gaseous emissions (house/manure storage), Particulate matter emissions (house/manure storage), Resource use efficiency, Nitrogen mass balance, and Life cycle analysis	Li et al. (2015), Shepherd et al. (2015), and Zhao et al. (2015a)
Worker health and safety	Personnel exposure to gases, Personnel exposure to particulate matter, Respiratory health, Ergonomic stressors, and Musculoskeletal disorders	Arteaga et al. (2015) and Mitchell et al. (2015)
Food affordability	Operating costs, Capital costs, and Revenue (marketable output flows)	Matthews and Sumner, 2015

how those attitudes were influenced when consumers are provided with the information obtained from the CSES research project. Paid membership provided each member organization with first access to current research results through periodic updates and member meetings and direct contact with the researchers to address questions. Membership fees supported ongoing CSES communications initiatives, including media outreach and stakeholder materials development and coordinating and facilitating stakeholder briefings and hosting member meetings.

Members also had an opportunity to serve in leadership roles within the CSES. A multilayered governance and coordination structure was set up for the project, involving leadership, communications, research, and research administration committees (Fig. 1). A researcher at Michigan State University was designated as the overall project coordinator and was responsible for liaising between the researchers and the CSES committees as well as the researchers and the farm at which the research was conducted. The project coordinator regularly interacted with the scientific project coordinator at that commercial farm, who had been hired specifically to provide on-site support for the CSES researchers.

WHAT DID WE LEARN

About Conducting Multi-Institutional Multidisciplinary Research?

The complexity of dealing with multiuniversity research includes working through processes specific to each university, such as grant processing and procedures including the determination and negotiation of indirect costs. When conducting research under commercial conditions, which may carry on-site proprietary implications, the protection of research data becomes an important consideration. State and local mandates affecting the conduct and protection of research at public universities may vary. For example, the state of Michigan (1994) has a law protecting unpublished research data from disclosure, whereas the state of California does not have such a law. There is an additional layer of complexity involved in working with a U.S. government agency, because the protection of research and provisions for release of research data fall under strictly defined Federal Freedom of Information Act (FOIA, 2015) requirements.

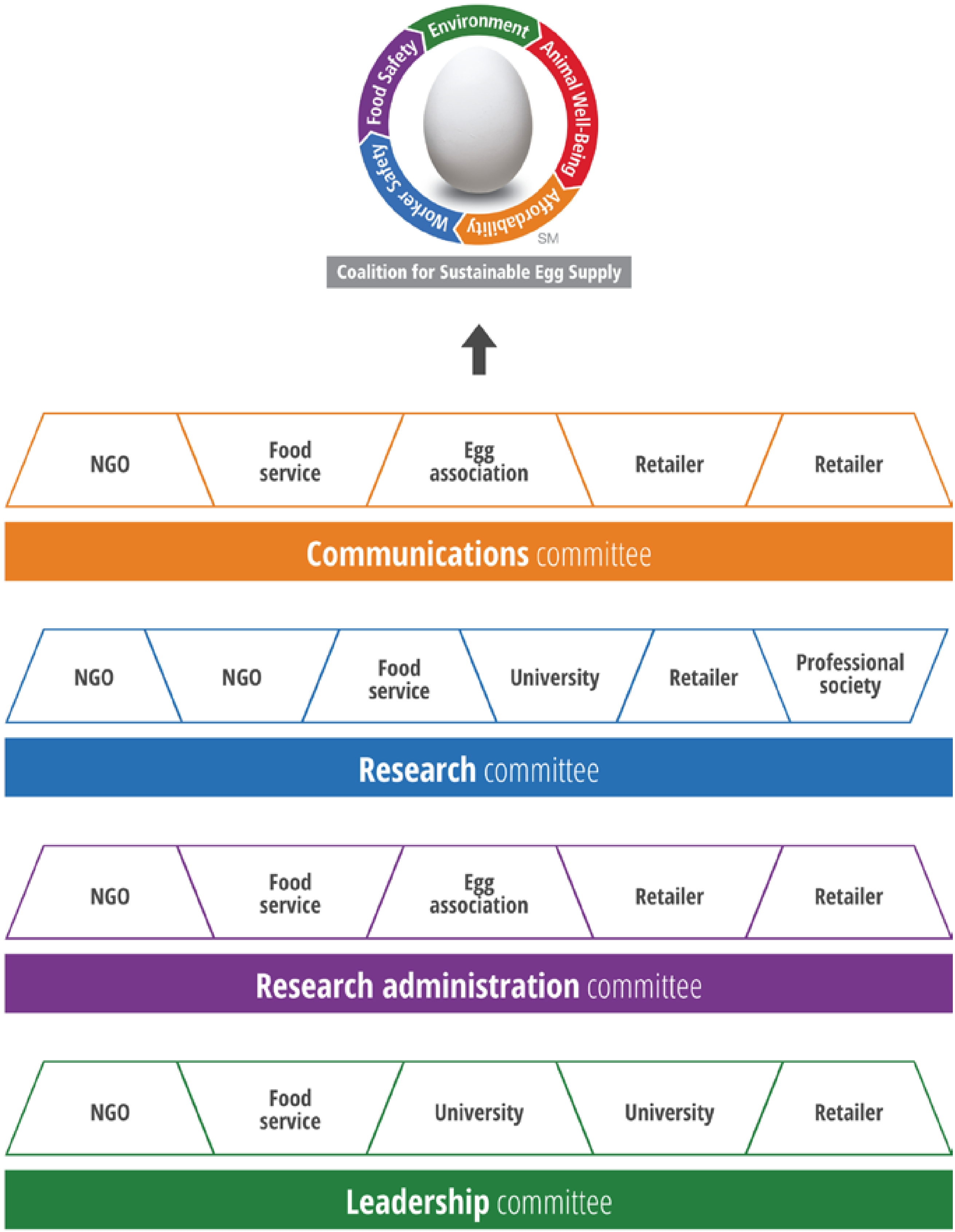

Figure 1. Organizational structure of the Coalition for Sustainable Egg Supply (CSES). Each committee had input from different types of stakeholder organizations, including nongovernmental organizations (NGO), as appropriate to the committee's function. The communications committee was responsible for providing input into and approval of the communications plan. The research committee was responsible for providing input into the initial research design and execution, and the research administration committee reviewed the quarterly research project reports and approved research invoices. The leadership committee had responsibility for general guidance of the CSES, including research timing, budget approval, and planning for coalition events. All committees reported to the CSES and were facilitated by the Center for Food Integrity.

Another challenge of the project was finding expertise in the manipulation and modeling of large data sets, especially in the context of a complex agricultural production system. The CSES scientists working on the different areas of sustainability shared data and, in some cases, cross-analyzed data where overlaps in data collection periods occurred. However, the formal integration of complex data, as alluded to above, requires expertise and computing capacity to handle large data sets and enable systems modeling beyond what was possible on this project. Although many universities and research institutions are building this capacity, at present, it is a rare commodity in agricultural research.

There were numerous challenges associated with the coordination of multi-institutional multidisciplinary teams of scientists. First, the scientific dialog and approach can be quite different among disciplines, which makes frequent communication and clarity of thought in common terms important (Eigenbrode et al., 2007). To accomplish an integrative research approach requires careful planning and identification of which data are unique and which can be commonly collected and shared and the time points that are most critical for data collection. It also involves discussion of criteria for validation of evidence and the values assumptions underlying integration of information across disciplines (Eigenbrode et al., 2007). The entire research team held face-to-face meetings before project initiation to lay out a detailed research plan and then at least annually to share research results and discuss coordination and information integration.

About Conducting Research on a Commercial Farm?

Establishing mechanisms for the on-site coordination of research activities and successfully interfacing with farm personnel was critical to the success of the project. An on-site project coordinator must be designated and trained to the expectations of the research project. Likewise, a designated scientific project director (or manager) is needed to interface between the on-site coordinator and the scientists to allow for the fluid communication and coordination of on-site activities. There are definite challenges for the commercial operation in that the research activities can be disruptive to normal farm operations, especially during periods of intense data collection. Careful development and identification of a priori questions must include consideration of not only research goals and outcomes but also on-site capabilities. Therefore, there are limits to the number of questions that can be asked under these conditions. Care must be taken not to introduce management problems that are difficult for on-site workers to resolve and create serious supply issues or customer challenges. Finally, there can be no expectation for on-site workers committed to the day-to-day operations of the farm to engage in the maintenance and upkeep of scientific equipment in use at the site.

About Integrating Food System Stakeholder Input?

The engagement of stakeholders in a project of this nature is essential. As part of the American Egg Board project described above, a group of stakeholders was assembled for a 1.5-d workshop exploring values affecting the future of egg production (Swanson et al., 2011a). Although this exercise provided important information about the diversity of viewpoints about egg production, more prolonged and intense stakeholder involvement is needed in making decisions about the sustainability of particular agricultural production systems. Connecting stakeholders via the development of a public–private partnership can be an effective method for obtaining this involvement, although as Benson et al. (2013) note, public–private partnerships must often contend with the issues of resource constraints, governance issues, and conflicts about mission and vision.

Suggestions about strategies to increase the potential for the success of public–private partnerships include engaging in problem definition and priority setting activities, carefully selecting stakeholders who are committed to the project and engaging them up front, identifying a facilitating agent to broker and manage the partnership, understanding partner motivations from the outset, engaging end users in preliminary discussions, fostering transparency about potential barriers (e.g., preexisting confidentiality agreements) and privacy issues, and paying adequate attention to monitoring, evaluating, and communicating results (NRC, 2009; Ferroni and Castle, 2011).

Involving stakeholders in a research project therefore carries both responsibilities and rewards. First, it is important to cultivate stakeholders that represent a variety of interests and are fully committed to the mission and goals of the project. Stakeholders requesting to join the CSES were fully apprised of the project mission and goals and formally asked to commit to them. The stakeholders who committed were invested in a project asking relevant questions about laying hen housing systems and the effects on egg production sustainability.

Ground rules were also established to address issues such as those related to confidentiality and integrity of the research. All CSES members had input into the research process in 2 ways: 1) they were able to suggest research topics and directions during the research development process (however, not all of these could be incorporated due to practical constraints related to funding availability or the commercial farm setting of the research) and 2) they provided comments about the results based on their own expertise at the annual meetings and during webinars. However, the ultimate decisions about research hypotheses, methodology, data interpretation and integration, and publication of results were made solely by the research team. Building cooperation and trust between the research team and stakeholders during this process was very important; some members of the research team had never before engaged in direct dialog with stakeholders. Fostering direct dialog increases sensitivity to issues that scientists may have never thought of before, and vice versa.

Equally important to success was setting up an organizational structure of the CSES that integrated stakeholder and research leadership. The committees included members of the scientific team as well as various stakeholders (Fig. 1). Stakeholder communication through email updates, CSES website postings, webinars, and regularly scheduled face-to-face meetings were essential to shaping the research agenda, staying informed about the project progression, gaining important feedback, and providing access to results as appropriate.

The expert facilitation of the CSES through an unbiased intermediary, in this case the CFI, kept scientists and stakeholders aligned with the mission and goals of the project. Aside from removing the burden of logistical issues associated with the project, the CFI kept a finger on the pulse of the CSES by detecting and averting potential problems or bringing new information to the floor for consideration.

The integration of stakeholder input greatly enhanced the value of information emerging from the CSES project. Stakeholders gained an inside view and understanding of what it takes to conduct a research project of this scale and scope, and scientists gained an understanding of how to escape their disciplinary box and conduct open dialog with stakeholders. Most importantly, scientists and stakeholders together developed a platform from which to build future partnerships.

About the Sustainability of Egg Production Systems?

Of course, the ultimate goal of this project was to provide scientifically based information about various aspects of the sustainability of egg production systems. The large amount of data collected by the research teams is being published in peer-reviewed scientific journals and was also made available in the form of an Executive Summary and detailed final report on the CSES website (http://www.sustainableeggcoalition.org/final-results; accessed March 17, 2015).

Overall, the research revealed the complexity of addressing sustainability problems, in that each housing system had negative and positive aspects (see Table 1 for the peer-reviewed references). For example, the cage-free aviary provided hens with the most freedom of movement and opportunity to perform natural behaviors (flight, foraging, and dust bathing) and was also associated with some hen health benefits (best leg and wing bone strength, good feather cover, and low overall incidence of foot problems), but it was also the most expensive in terms of egg production costs and had the greatest hen mortality, the worst indoor air quality (with consequently greater risks for worker respiratory health related issues due to inhalation of dust and endotoxins), the greatest dust emissions, the greatest feed usage and hence carbon footprint, the greatest nutrient losses, and the greatest potential for microbiological contamination (aerobic organisms and coliforms) of eggs. However, in many other ways, the systems were quite similar. For example, there were no marked housing systems differences in the quality aspects of fresh or stored eggs, *Salmonella* shedding or eggshell contamination with *Salmonella*, hen stress levels, egg production, house thermal environment, worker exposure to ammonia, or greenhouse gas emissions.

It should be noted that the goal of this project was to identify synergies and trade-offs, not to attempt to provide a formal integration of the data into a sustainability index that “ranked” the different housing systems. For this reason, the research teams generated a series of informational graphics representing the direction and the magnitude of the trade-offs for the various sustainability elements (Fig. 2). Each of the member stakeholders in the coalition can use the information obtained to make their own purchasing and supply decisions, based on their own organization’s values with respect to sustainability.

To make nationwide decisions about sustainable egg production systems, the development of strategies to better predict public behavior and policy decision making will be important, although these questions could not be addressed in detail within the particular constraints of the CSES project. Even if a production system achieves a high sustainability “rating” according to formal scientific models, the path to acceptance may be obstructed if that system ultimately is inconsistent with broader social values (Weary et al., 2015). For example, van Asselt et al. (2015) attempted a quantitative analysis of the sustainability of different egg production systems in the Netherlands. They found that enriched colony systems were the most sustainable when the social, economic, and environmental factors identified in their study were equally weighted. However, if the social factors were weighted more heavily, free-range production was the most sustainable. Various methods have been used to address the challenges associated with integrating sustainability indicators, including deliberative approaches, informal decision making, and quantitative analyses, but all of these have their limitations (Swanson et al., 2011a).

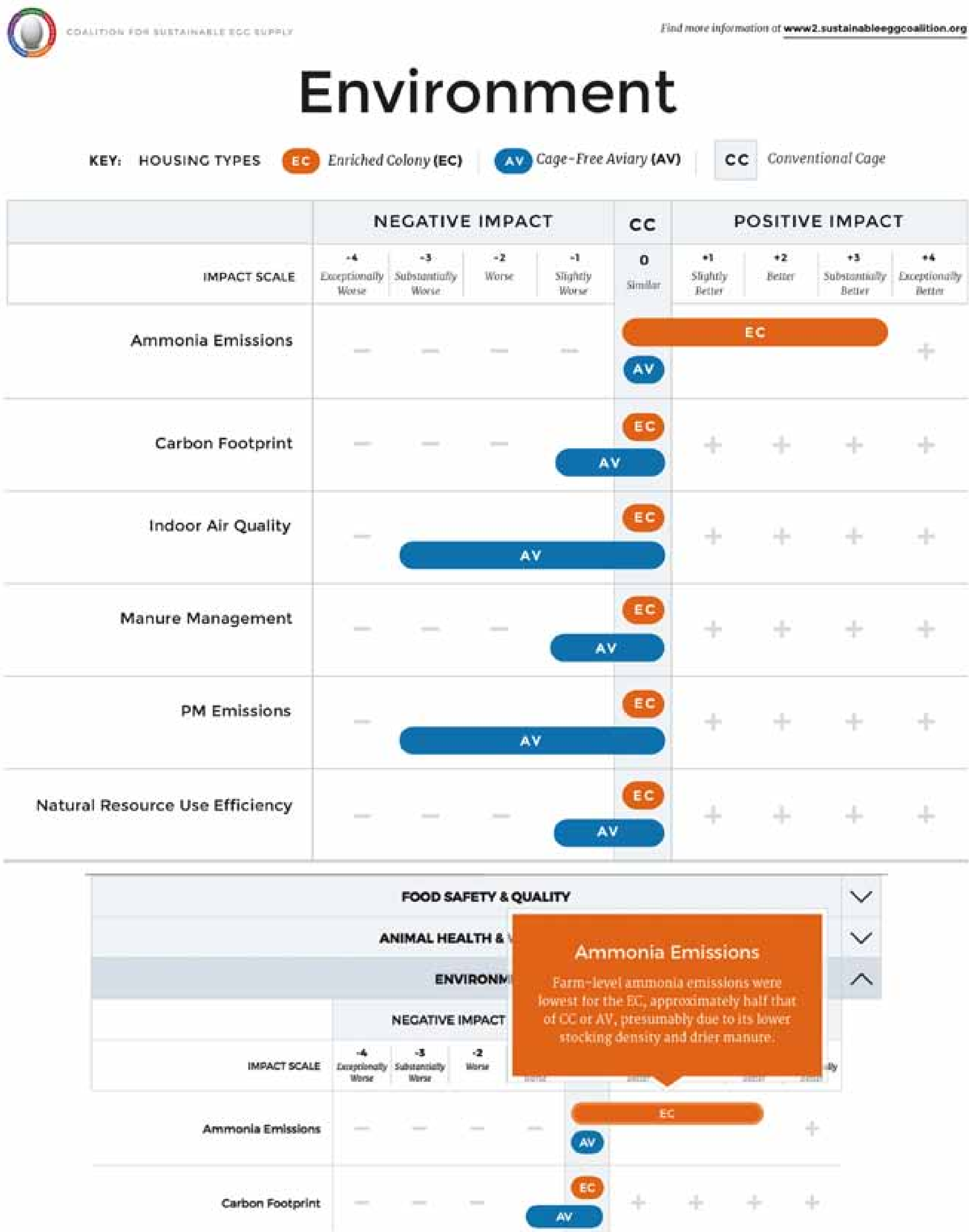

Figure 2. Representative infographic developed to communicate the trade-offs for each sustainability area, as identified by the Coalition for Sustainable Egg Supply research. The top panel shows the trade-offs for 6 aspects of environmental impact. In each case, the enriched colony system (EC) and cage-free aviary (AV) are compared with a conventional cage (CC) baseline. This graphic shows that research team judged EC to have a substantially positive impact compared with CC for ammonia emissions but to be essentially identical to CC in terms of carbon footprint, manure management, particulate matter emissions, indoor air quality, and natural resource use. The AV was substantially identical to CC in terms of ammonia emissions but was slightly worse in terms of carbon footprint, manure management, and natural resource use efficiency and significantly worse in terms of indoor air quality and particulate matter emissions. Pop-ups with additional information appear when the bars are rolled over; the lower panel shows the pop-up describing why the EC was considered positive with respect to ammonia emissions. This interactive graphic, with all associated pop-ups, can be found on the website of the Coalition for Sustainable Egg Supply, along with similar graphics for hen health and well-being, food affordability, and worker health and safety (http://www2.sustainableeggcoalition.org/research-results/; accessed Matthews and Sumner, 2015).

Decisions about every individual element of sustainability depend on reconciling competing value judgments (e.g., in the animal welfare area weighing behavioral freedom for hens against health considerations), and competing value judgments again come into play when weighing the importance of one area of sustainability against another when the information is conflicting. A sustained process of public engagement via participatory decision making will be needed to more broadly address these kinds of values conflicts (Swanson et al., 2011a).

About Communicating the Science?

An important aspect of the CSES project was the development and implementation of a communication plan for relaying the scientific findings. The diversity of stakeholders required a layered approach to information development and delivery. The primary venues for reaching scientists were peer-reviewed papers, special issues of *Poultry Science* highlighting CSES research results, presentations at key scientific meetings, and a special symposium held at the annual meeting of the Poultry Science Association. In contrast, scientific findings were reported to applied audiences, such as the members of the CSES, the media, egg producers, and others connected to egg production, in lay terminology with important data presented in formats that were easy to understand. These included annual research reports, an executive summary of the final report, press releases, and the informational trade-off graphics referred to earlier.

Public reporting about the project scope and its progress and scientific findings was also an important goal of the project. Communicating scientific findings to the public required translating concepts and methods into easy-to-understand terminology and use of informational graphics that conveyed important background information. Because recent CFI (2014) research indicates that the public increasingly goes online to obtain information about food, additional public-focused resources were made available on the CSES website, including short videos providing "walk-throughs" of the 3 housing systems and system schematics with pop-up information (Fig. 3), frequently asked questions, and information about CSES membership and the project background, scope, and goals.

Broad communication of research results is critical to provide a factual basis for addressing sustainability issues in animal agriculture. Animal agriculture currently functions mainly under a social license, which grants the privilege of operating with minimal formalized restrictions (i.e., regulation, legislation, or market-based mandates) based on maintaining public trust. Keeping this social license requires operating in a way that is consistent with the ethics, values, and expectations of stakeholders, including customers, employees, the local community, regulators, legislators, and the media.

If trust is lost, either through a single event or a series of events, social license is replaced with social control: regulation, legislation, litigation, or market action designed to compel a company or operation to perform to the expectations of its stakeholders. Operating with a high degree of social control increases costs, reduces operational flexibility, and increases bureaucratic compliance. For example, the accounting profession in the United States had a strong track record of building and maintaining public and government trust via an established and respected self-regulatory system. The Enron–Arthur Anderson violation of that public trust that occurred in 2001, however, was so striking that it led Congress to pass the Sarbanes–Oxley Act (Pub.L. 107–204, 116 Stat. 745, enacted July 30, 2002) in 2002, imposing stringent accounting and auditing requirements for publicly traded companies. Collectively, these companies were estimated to spend $2.5 billion to comply with the Sarbanes–Oxley Act in 2005 (Pasha, 2006). As this illustrates, the cost of violating public trust and losing social license can be significant.

The question then becomes, what can be done to maintain the public trust in the food system that grants the social license and protects freedom to operate? A nationwide consumer survey was conducted on behalf of the CFI to help answer this question (Sapp et al., 2009). It identified 3 primary elements that drive trust in the food system: confidence, competence, and influential others. Confidence is related to perceived shared values and ethics and a belief that an individual or group will do the right thing. Competence is about the skills, ability, and technical capacity of the individual or group sharing the information. Influential others include family and friends as well as respected, credentialed individuals such as doctors and veterinarians. In qualitative focus groups, respondents also frequently mentioned university scientists as highly trusted due to a perception that they possess technical expertise and are less influenced or motivated by profit than some other groups providing information. Survey participants were asked to rate their level of confidence, competence, and trust in various groups of influential others in the food system. The results of the survey were consistent and conclusive. Confidence, or shared values, was 3 to 5 times more important than competence for consumers in determining who they will trust in the food system. Historically, competence is where the agricultural community has focused communication about food under the assumption that consumers will make logical, data-based decisions if provided credible information. Clearly, meeting the challenge of building and maintaining trust cannot rely solely on science but must involve embracing new

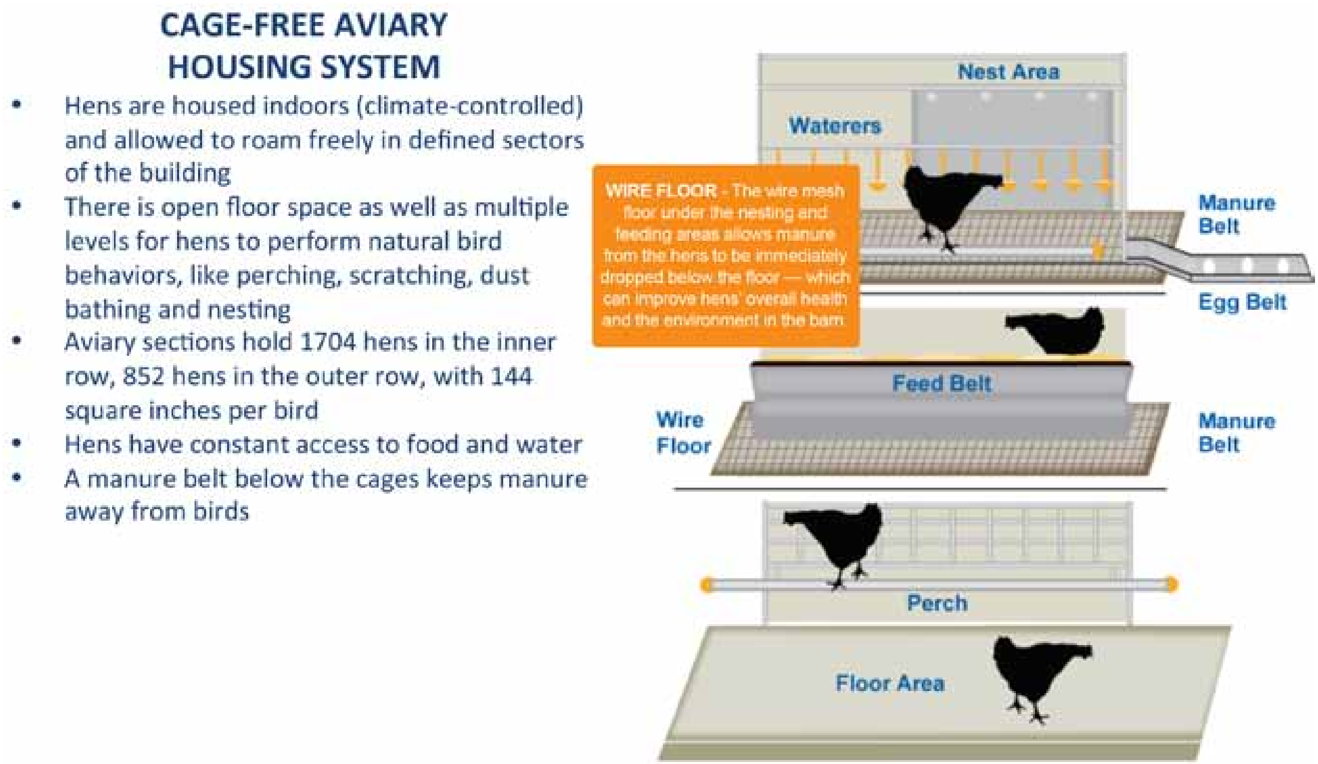

Figure 3. Representative graphic developed to provide consumers with information about the hen housing systems that were part of the research project. This graphic shows the cage-free aviary. Pop-ups with more detailed information appear when the text is rolled over. An example pop-up, for the wire floors in the aviary tiers, is shown. This interactive graphic, with all associated pop-ups, can be found on the website of the Coalition for Sustainable Egg Supply, as can similar graphics for the other housing systems (http://www2.sustainableeggcoalition.org/resources; accessed March 1, 2015).

models of public engagement that involve discussions of social and ethical considerations (Croney et al., 2012).

The CFI consumer research that was conducted specifically for CSES supports the conclusions from this earlier CFI work and provides a model for the kind of engagement that can be used to connect the 3 aspects of consumer trust to one another. Both qualitative and quantitative consumer research were completed to assess consumer understanding of hen housing and sustainability in egg production to 1) identify key message elements that resonate with consumers and align with their beliefs about sustainability in egg production; 2) evaluate trade-offs inherent in conventional, enriched colony, and cage-free aviary hen housing systems to gauge relative importance to consumers of different factors; and 3) determine language that consumers believe describes the advantages and disadvantages of those 3 housing systems. The qualitative research included 6 focus groups, 2 each in Illinois (Chicago), New York (White Plains), and California (Orange County). Focus groups included only female participants, because women are more likely than men to make food-purchasing decisions for their families. All of the participants were egg consumers and the primary egg shoppers in their home. Each 10 to 12 person focus group also contained one group of early adopters as defined by the Rogers model for adoption and diffusion of innovation (Rogers, 2003) and one group of non-early adopters in each city. Rogers' work indicates that early adopters are the opinion leaders in their social circles, and therefore, obtaining information about early adopter's views of particular issues is important for understanding how a broader social group will likely perceive those same issues. The quantitative research was an online survey of 406 early adopter women ages 25 to 65.

Participants in the qualitative focus groups initially perceived only 2 options for laying hen systems. The first perception was influenced by what they have seen in undercover videos, with hens in small, crowded cages. The other was a more idyllic setting where hens roam free outdoors. Consumers struggled to accept the complexity of hen housing systems and to embrace the concept of trade-offs. Once made aware that trade-offs do exist in hen housing, however, communicating shared values and fact-based information from university scientists, including information from the CSES study, helped to dispel myths and address their concerns. This supported informed decision making, including stated changes in egg purchasing intent.

Participants in the quantitative research were provided with a written description of each of the 3 housing systems evaluated in the CSES research. The descriptions were important in facilitating informed responses because most egg consumers have a very limited understanding of laying hen housing systems. They were then asked to rank trade-offs in hen housing systems, determining which they valued most and least. Respondents ranked food safety as the most important element of a sustainable egg supply followed by hen health and well-being. Worker health and safety, food affordability, and environmental impact had similar priority scores, below hen health and well-being. Effective messaging that addresses consumer concerns in the order they deem most important can help consumers more fully consider the trade-offs in laying hen housing systems and facilitate a more informed discussion.

The goal of this kind of communication should not be to win a scientific or social argument but to find more meaningful and relevant methods to introduce science in a way that encourages thoughtful consideration and informed decision making. How technical and scientific information is introduced is key to supporting informed decision making (Croney et al., 2012). A clear theme in the CFI's latest consumer survey results (CFI, 2014) is that food system experts can make a difference when they choose to engage by first establishing shared values and then providing factual, technical information that is relevant and meaningful. After confidence has been established, people are more willing to consider technical information in their decision-making process.

SUMMARY AND CONCLUSIONS

This is the first project ever performed that allowed simultaneous assessment of the magnitude of effects across all of the sustainability areas affecting an animal production system and on a commercial scale. As such, it allows interactions and trade-offs to be better understood than they could be by conducting independent studies. For example, information has been obtained about how hen housing system affects indoor air quality and what the ramifications of air quality differences are for hen and worker health, particulate matter emissions, and microbiological contamination of eggs (Arteaga et al., 2015; Blatchford et al., 2015; Jones et al., 2015; Mitchell et al., 2015; Zhao et al., 2015a).

The project was also unique in bringing together such a large group of invested and diverse stakeholders to share information, develop and directly fund research, and participate in evaluation and decision-making processes related to sustainability (NRC, 2015). The project structure that we outlined above addressed the key features of successful partnerships outlined in an Institute of Medicine summary of a workshop on public–private partnerships in food and nutrition (IOM, 2012): 1) a sense of authentic trust, 2) working toward a common goal with a high feasibility of achieving that goal, 3) joint planning, 4) clear procedural steps for risk mitigation, 5) establishing a project management process, and 6) contribution of unique but complimentary resources by the various partners. We do note that developing a public–private project of the size and scale of the CSES is often enabled through preexisting relationships with the relevant stakeholders. It is therefore important that junior scientists pay attention to building those relationships early in their careers.

As the Institute of Medicine workshop (IOM, 2012) also noted, all of the 4 sectors (academia, government, industry, and nongovernmental organizations) involved in these kinds of partnerships derive benefits related to their primary functions, although each partner is also exposed to some risks because of the limitations that public–private partnerships entail. As with other public–private partnerships, the CSES project was not without limitations. Many of these were due to the practical constraints (e.g., time, funding, research capability, need to balance research with commercial imperatives) associated with an undertaking of this particular type. For example, it was conducted on a single farm, with 1 genetic strain of hens, and in 1 geographical location in the United States. Although this potentially may have constrained its applicability to other regions of the United States and management practices, the research approach did provide an overall framework and methodology for assessment that can be used across contexts. In addition, the project had a carefully defined short-term goal, which is both a benefit and a downside. Although public–private partnerships that have "narrow targets" are often more successful in accomplishing their goals (IOM, 2012), they do not necessarily provide a framework for sustained funding. In this case, the CSES members decided to "sunset" the coalition after project completion because they considered that sufficient information had been obtained about trade-offs, meaning that the many additional research questions that were generated during the project will now need to be pursued using other funding and integration mechanisms. Regardless, the relationships that were built and strengthened during the CSES process will be valuable for these future efforts.

Although there is no single structure for public–private partnerships that is effective across all contexts (IOM, 2012; NRC, 2015), the CSES project demonstrated how such a partnership can be used to provide evidence-based information about sustainability questions related to animal agriculture that can serve as a model for the other animal industries.

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