

The Results of Web-based Questionnaires in Support of the Joint Fire Science Program Smoke Science Plan

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Abstract: From October 2009 through September 2010 we conducted a series of short web-based questionnaires in support of the Joint Fire Sciences Program Smoke Science Plan. There were in all five questionnaires. The first was a general questionnaire on wildland fire smoke issues and research priorities that was answered by 554 people. From the responses to this survey, personal interviews about smoke research priorities done in October 2009, reviews of past smoke research needs assessments, and our personal knowledge of smoke research needs we developed four provisional themes for the Smoke Science Plan; 1. *Smoke emissions inventory research*, 2. *Fire and smoke model validation*, 3. *Smoke and populations*, and, 4. *Climate change and smoke*. Due to success of the first questionnaire, we decided to use follow-up questionnaires focussing on each of the four themes to determine how well supported the chosen themes might be in the Smoke Science Plan. Each of the four follow-on questionnaires, which were released sequentially, was completed by at least 100 people, often many more. The responses validated the four themes but also added focus. An example of this is that although many see regulatory restrictions increasingly impacting the ability to apply prescribed fire (as has been a common perception since perhaps the late 1970's), there are also new concerns that people's perceptions of fire may also increase limitations. Also, it was clear that the four chosen themes had resonance with the reviewers, but, we were surprised to see the theme dealing with peoples' perceptions of smoke receiving the smallest response. Finally, the questionnaires results and written comments highlighted a continuing perceived fundamental tension between the need for fire for ecosystem health and air quality regulations to protect the public.

Introduction: Since the 1977 Clean Air Act Amendments, and perhaps before, there has been concern that air quality regulations and forest fire smoke could disastrously collide over conflicting legal requirements, vested interests, overly bureaucratic interpretations of regulations, lack of appreciation for ecosystems or public health, and fumbled communication. Although there has been friction over the issue, air quality and forest management have avoided a national show-down. Although there may be a number of reasons for this happy circumstance, it can be rightfully said that the fire community's support of smoke research resulted in tools being created that ameliorated the conflict. The Joint Fire Science Program (JFSP) has been very supportive of fire smoke research and has funded over 34 studies on the topic, much of its funding based on results from needs assessments. In 2007 JFSP conducted, through the services of a contractor, two workshops to determine what new smoke research needs might be arising. The meetings, one held in the eastern and one in the western

USA, were purposed to uncover needs and develop specific recommendations to support both regional and national needs. Eleven recommendations resulted. Some were clearly within the research scope of JFSP and others were technology or procedural needs. It was determined in 2009 that JFSP needed something more than the eleven recommendations to guide future smoke research investments. As a result JFSP commissioned in late 2009 the development of a smoke science plan, a framework to focus smoke investments for the next five years. As a foundation for this a web-based brief questionnaire was employed to gain insight on current perceptions of wildland fire smoke as an issue, what research topics are perceived as of highest needs, and what value people placed on the eleven recommendations of the JFSP smoke roundtables.

The results of this first questionnaire were striking in that so many people responded. The number that responded (554), in our opinion, was a reflection not of the good design of the questionnaire or a popularity of web-based approaches, but rather it was a strong indication that people are concerned about smoke issues. We also believe that objectively from the responses there was general support for four themes we had been considering as a device to construct a meaningful science plan for the Joint Fire Science Program. The themes are; 1. *Emissions inventory research*, 2. *Fire and smoke model validation*, 3. *Smoke and populations*, and 4. *Climate change and smoke*. Naturally these themes are not the only possible themes which might be chosen to organize smoke research across agencies. So we decided to test their robustness and how well they might be accepted, by asking people who had responded in the first questionnaire that they would be willing to provide more opinions on the plan as it was developed (about 250 people responded positively.) Therefore, we asked them to complete focused questionnaires on each theme. These four focus questionnaires were released sequentially over five months, being completed just before the first complete draft of the Smoke Science Plan was sent to JFSP. About 100 people completed each of the questionnaires, some being a core group of responders who completed all the questionnaires offered while some only completed one or two of the focus questionnaires. In total, we received a little more than 1000 responses to all five questionnaires. As a note for those interested, all the questionnaires used a program named Survey Monkey (see: www.surveymonkey.com); a rather powerful and very flexible program that in the opinion of the authors may suffer a potential lack of professional credibility from its rather silly name.

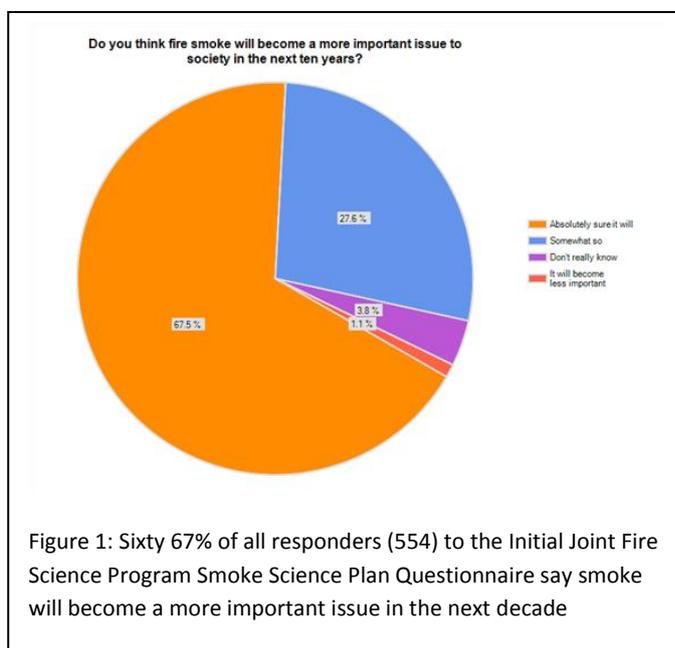
Background of the Questionnaires: The use of a web-based questionnaire is not unique to the process of developing the JFSP smoke science plan. It was the second such approach employed by the authors for understanding smoke science needs. An earlier web-based questionnaire was used by the authors to complete a smoke research needs assessment for the Joint Fire Science Program (Riebau and Fox, *TASET*, 1999). As mentioned earlier, the questionnaire was brief (12 questions) and took only about 10 or 15 minutes to complete. A link to the questionnaire was distributed by email to about 150 individuals beginning in early October 2009. Those sent the email were asked to complete the questionnaire themselves but to also send the link on to others they knew who might have useful input. Although at first response was light, consecutive email reminders allowed the survey to gain momentum with 554 people responding before the web-link was deactivated at the end of February 2010. Many more people completed the questionnaire than were emailed, over double the numbers sent emails; this itself may have meaning in that the importance of fire smoke as an issue is perhaps compelling enough that a grass-roots interest in the future actions of the JFSP on the topic was developed. We also believe this same phenomena occurred in the four follow-on theme focus questionnaires albeit a bit differently. Although not everyone sent the link to the questionnaires followed it and completed the questions, each of the questionnaires were answered by at least a few people who had received the link information from a colleague.

A detracting factor for these final four theme focus questionnaires could be that because they were spread so widely around, perhaps too many of the wrong types of people answered the questionnaires and thus this 'overly populist-type response' has biased, inappropriately, the results. To answer this simply, each respondent was asked in each questionnaire to identify who they worked for and what were their job responsibilities. There was also a free-form field available to add answers beyond the choices we gave; we did not have anyone identify themselves as being in a job/work duties category other than which could be categorized under the broad categories of natural resources management and natural sciences. However, the largest response population for each of the five questionnaires was composed of individuals who identified themselves as 'operational' rather than 'research.' Most expressed that they had relevant experience in the subject area of the particular questionnaire for at least five years (generally about 40% or more in each questionnaire). It can, we think, be rightly said that the responses we received are more indicative of the ideas of fire and smoke research users than researchers themselves, and that these users had a reasonable self-reported level of knowledge and experience. This fact, if considered a weakness, is somewhat mitigated by the ability to sort the results by responder community, thus making it possible to put in relief what people doing one type of work function over those doing another might have responded. What the responses show, for any who might have such concerns, were that the differences between viewpoints which differing groups held were not very great (e.g., generally 10% or below, which is a surprising result in itself). Finally, one could also ask if we got the right people to respond, wondering if perhaps we missed who really should have responded but got responses from a large group of people who would be less desirable for input. From our knowledge of the smoke community and review of the email addresses (looking for individuals we knew should respond and individuals representing agencies which are stakeholders in smoke issues), we think that the more than 1000 total responses provide a good representation. So, we believe that the five questionnaires provide more useable information on what smoke stakeholders believe should compose a JFSP national smoke agenda than any other effort to date. This opinion is, we admit unashamedly, subjective.

Readers should be warned, however, that the questionnaire was not designed as tool to meet social sciences academic standards. Naturally, a rigorous social sciences survey would be different than this approach of a series web-based questionnaires. First, it might structure questions differently. Our questions were meant to be as simple and straight-forward as possible, worded so that they would result in answers that were unambiguous. Additionally, the 'sampling taking' had no statistical design or pre-arranged target population as a well-designed social sciences study would but was rather just sent as a request for voluntary answers from organizations, groups, and even individuals we knew to have a vested interest in smoke. Social science professionals might thus see flaws in the questionnaires, but we also believe that they will surely see much they will like as the questionnaires and their results could perhaps inform future, more rigorous, social science studies on smoke. We do believe strongly that the five questionnaires have met our purposes for informing our development of and providing a foundation for the Joint Fire Sciences Smoke Science Plan. The results and conclusions from the questionnaire we draw are merely understandings we have gained from informed peoples expressed opinions on smoke as they apply to the development of JFSP smoke science plan. Due to the size of the response we received for the questionnaires, we are of the firm conviction that knowledge of the questionnaires' responses should be recorded and shared with the JFSP.

Who responded to the questionnaire: The first two questions asked on all the questionnaires were for whom does the responder work and what is their primary job function. In the initial questionnaire twenty-six people responded from outside of the USA, while the remaining 528 were from within.

The greatest numbers of respondents work for US federal government agencies, with USDA Forest Service leading. Responders to the questionnaire were offered 31 choices to identify their employer and 12 choices to describe their job category. These job categories and employer choices were developed from our personal experience in fire smoke (over 50 years between the authors) and our understanding of the audience for the Joint Fire Science Program. As the questionnaires were voluntary (not required by employers as a condition of continued employment, for example), it was not possible to set targets for a required number of responses from specific employer or specific job category. However, there were so many people who did respond that there was some representation from most USDA and USDOJ agencies that are significant clients for JFSP research products. There were also responders representing different job categories we believe most appropriate to answer the questionnaire from personal knowledge and experience. Table 1 presents this balance which, although might be faulty from the standpoint of a scientifically designed controlled survey, we deem as very useful for the purposes of the questionnaire. It is, in our experience, the largest and most representative response to a wildland fire smoke questionnaire to date.



Joint Fire Science Program Smoke Roundtables and The Initial Questionnaire Results:

The smoke roundtables produced eleven recommendations from invited specialists at two workshops held in 2007 (SRA International, 2007). The recommendations were not all strictly smoke research topics as some, such as holding annual summits to share information and names of responsible people in agencies concerning smoke, might best be approached as topics for government agency policy-making or operations. Only about 14% of respondents to the questionnaire stated that they were fully aware of the roundtables and their results. Forty nine percent stated that they had no knowledge of the roundtables whatsoever.

Responders to the questionnaire were asked to rate the eleven roundtable recommendations as high, medium or low based on usefulness or need, with an option to also say the recommendation wasn't at all useful or was impossible to understand. Fire managers who responded are supportive of a campaign to educate school children about the need for fire (54% of them ranked this as high) but ranked climate change issues and fire as low (climate change regulations 44% as low, greenhouse gases 42% as low, and climate change regulation effect on fire management prognostication 37% low). Air quality managers (who said they work for USDA Forest Service, EPA, state, and local governments) rank the roundtable recommendation for a national emissions inventory for fire smoke as high (61%), a campaign for school education as medium (41%), and climate change regulation as the roundtable recommendation receiving the most ticks for a low ranking (48%). Researchers and scientists who responded also ranked fire emissions inventory their numerically highest choice of the roundtable recommendations (49%) but more of them ranked the campaign for school education about fires as low than any other choice (37%). International responders to the questionnaire ranked the two

emissions inventory roundtable recommendations (for general pollutants and greenhouse gases) as high (61 and 39%) but considered the campaign for school education about fire as equal in usefulness to a greenhouse gas inventory (also about 39%); the roundtable recommendation with lowest international responder ranking was that of holding local 'summits' to exchange information about fire smoke (39% ticking low and 12% as not useful at all). Interestingly, of the eleven recommendations the two which directly mentioned climate change and fire got the most marks for being of low or no usefulness by the entire group of responders. The roundtable recommendations were presented cryptically in the questionnaire due to limitations of space on the questionnaire itself, nevertheless very few responders checked a box indicating they could make no sense of the recommendations (on average about 2%) or didn't think the recommendations on average were useful at all (about 6% of responders). As smoke research topics the responses to the questionnaire concerning the roundtable recommendations support (1) fire emissions inventory, (2) fire smoke impacts to health of populations, (3) a field experiment(s) for smoke model performance evaluation, and (4) climate change smoke issues. Such topics for smoke research investments have been identified by others (Bytnerowicz et. al, 2009) and thus have some confirmations outside of the smoke roundtables or the questionnaire itself.

Table 1: Employers and Job Functions of Respondents to the Joint Fire Science Program Smoke Science Plan General Development Activity Web-Based Questionnaire

Employer	Scientist (researcher)	Fire Manager or Fire Fighter	Air Manager or Specialist	Quality	Natural Resources Manager
USDA Forest Service	22	94	16		8
UDOI Fish and Wildlife Service	0	34	0		3
USDOJ Park Service	2	16	1		5
USDOJ Bureau of Land Management	0	21	0		0
US Federal EPA	4	0	2		0
NASA and NOAA	3	0	0		0
US State and Local Agencies	2	18	20		18
International Responders	12	4	1		2
USA Universities	22	1	0		1
Other	5	20	3		20

Note: This table does not include all the job categories of the questionnaire nor all the employer categories the initial questionnaire included, thus the number of responders it contains does not total to 554.

The importance of wildland fire smoke: The question 'how important is wildland fire smoke', has been discussed in published literature, conference proceedings, and in unpublished internal government documents. For the initial questionnaire, respondents widely agreed that smoke is important now and will become more important in the next decade (out of 554 people, only 6 stated that smoke would become a less important issue in the next decade). When asked, on a scale of 1 to 10 (ten being 'critical') to rate smoke as a general issue, 111 people rated smoke as 10, 85 people rated smoke as 9, 139 people rated smoke as 8, and only 6 people rated smoke as 1 (safe to ignore). Thus 60 percent of respondents see smoke as one of the top three issues relating to natural resources or environmental concerns. Sixty-nine percent of responders stated the reason for this being increasing regulatory pressure by both federal and state government, while forty-seven percent felt that smoke will adversely impact public health. When asked what might make smoke less important (or

ameliorate smoke concerns), 72% of responders said that increased public awareness about smoke might do so. Respondents were allowed space for short written comments within the questionnaire. Two opinion threads about the importance of smoke were contained in a number of comments (although many comments conveyed a wide array of thoughts); smoke impacts public health and no amount of public education about smoke would make people accept serious health threats from smoke, and conversely, if the public understood the reasons for prescribed fire (in particular) they would accept smoke without hesitation.

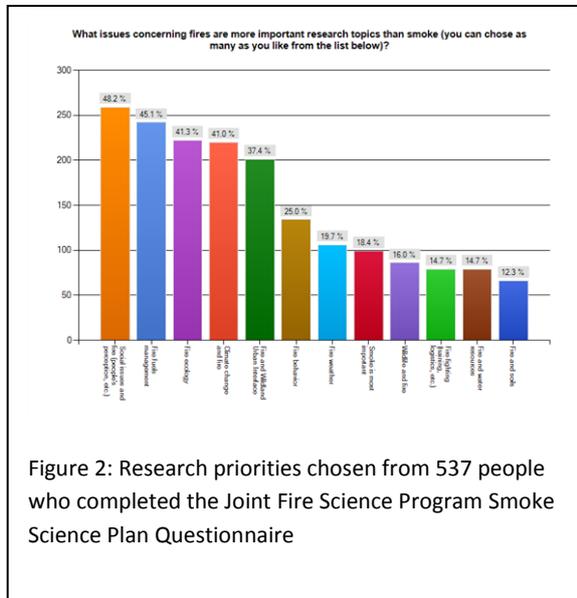


Figure 2: Research priorities chosen from 537 people who completed the Joint Fire Science Program Smoke Science Plan Questionnaire

Smoke research priority: One important question in developing a JFSP smoke science plan is the priority of smoke research. Eighty-four percent (450) of the responders to the initial questionnaire stated that more research should be done on smoke in the USA by universities, governments, and non-government agencies (NGOs). When asked how much of a \$100,000 research budget they would spend on smoke, 30% of the 550 people who answered the question stated they would spend half or more of the budget on smoke research with 21% stating that they would spend a quarter of the budget. Less than 12% stated that they would not spend any of the \$100,000 on smoke research with only 6% stating they would spend it all on smoke. Since the respondents did not recommend spending all the available \$100,000 on smoke, what other wildland

fire research topics had higher priority for research in their opinion (Figure 2). The two most important research issues identified from the twelve choices given were social issues and fire (48% or 259 people) and fire fuels management (45% or 242 people). Running a close third place to these two topics, were fire ecology and climate change and fire tied at 41% each (or 220 people ticking their boxes on the questionnaire). Interestingly, 99 respondents still listed smoke as most important and 17 of the responders chose to skip the question. Respondents were given opportunity to write short comments to this question and the comments left supported the tabular results. There was an interesting feature to the responses in that fire managers were most supportive of social research concerning fire (61% of the fire managers and fire fighters who responded), research scientists put most emphasis on climate change fire research (51%), and air quality managers rated climate change and then smoke research as highest priority (45% for climate change, 42% for smoke).

Two important viewpoints expressed in written comments to the initial questionnaire: Many written comments were received but are difficult to summarize in a short paper. There were only two comments (less than 0.4%) suggesting the questionnaire was poorly designed or had errors in spelling or grammar; this may be an indication the questionnaire overall was understandable and worthwhile. An interesting pattern emerged in the written comments. In general, fire and natural resources managers (especially those from US federal agencies) believe that education on the need for fire as an ecosystem process will lower the concerns of the public about smoke. Researchers and air quality managers in general (from the comments they wrote) disagree and state that it is unlikely the public could be educated or informed in a manner which would make them accept adverse impacts to their health from smoke. Some comments on either side of this fence were almost vehement; it may be that

a new dialogue is needed between those who advocate education/social sciences investigations about fire and those who advocate air quality/ health science concerned with fire smoke. A simplistic way to harmonize these two views maybe to balance the health of ecosystems and the health of human populations in an as yet undiscovered, universally satisfying, manner.

Reported Value of the Four Themes to Smoke Management in the United States: The design as the Smoke Science Plan is based on thematic research lines. The themes employed are critical to the plan's success. Although, as stated earlier, we believed we had chosen four robust themes that were supported by both our personal knowledge and input from others knowledgeable of wildland fire smoke issues, we still also believed that our chosen themes needed more validation. We designed and executed four focus questionnaires, one for each of the SSP research themes. The web-link to each of the questionnaires was sent to about 250 individuals who were on our list of contacts. Each of the questionnaires was opened for response for about 30 days. On average 115 people answered each questionnaire with a range of 86 responses for the *Smoke and Populations* theme to 139 responses for the *Climate Change and Smoke* theme (Table 2). It is perhaps not surprising that USDA Forest Service was the dominant employer of our focus questionnaire responders, but, it is somewhat surprising that the second most numerous group of responders identified themselves as being employed by state and local governments. Regrettably, very few responders work for the Federal EPA. In the questionnaires we also queried responders as to their job duties. In all cases fire management professionals made up the greatest number of responders but there were what we consider to be good level of responses in other duty categories; on average for the four focus questionnaires fire managers were 34%, air quality managers were 9%, and research scientists were 11% of the responders. In the total number of responses, the spread of responses for each questionnaire, the spread of employers for the responders, and the job duties of responders was, we think, reasonable for our purposes.

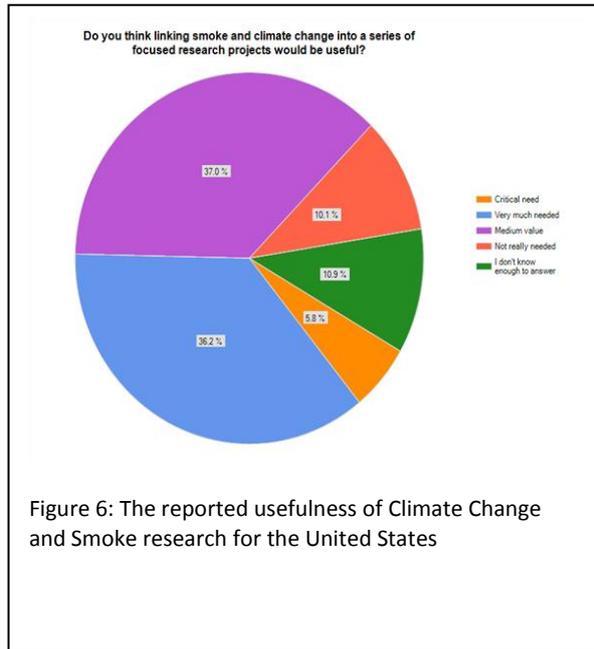
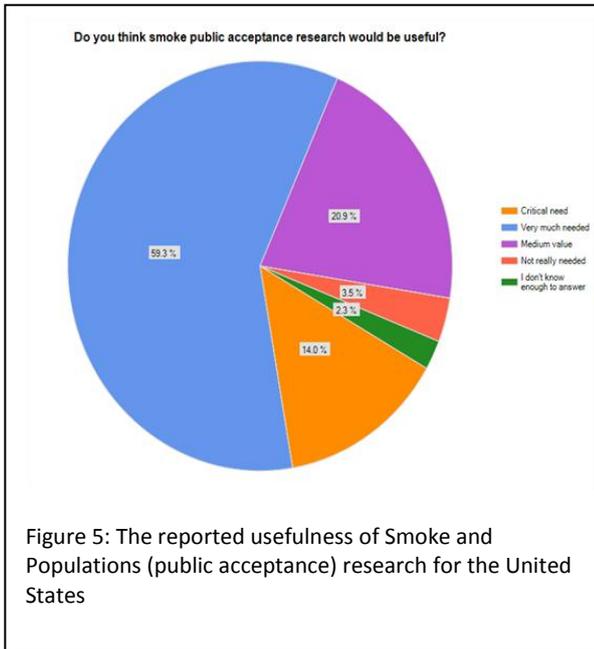
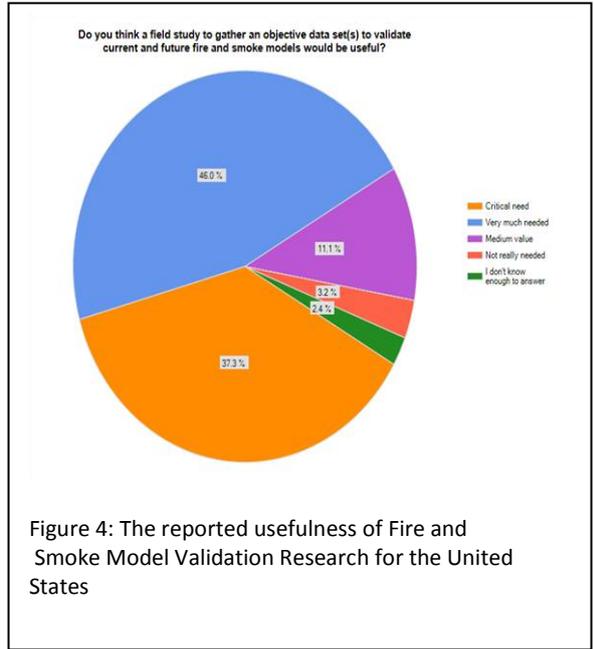
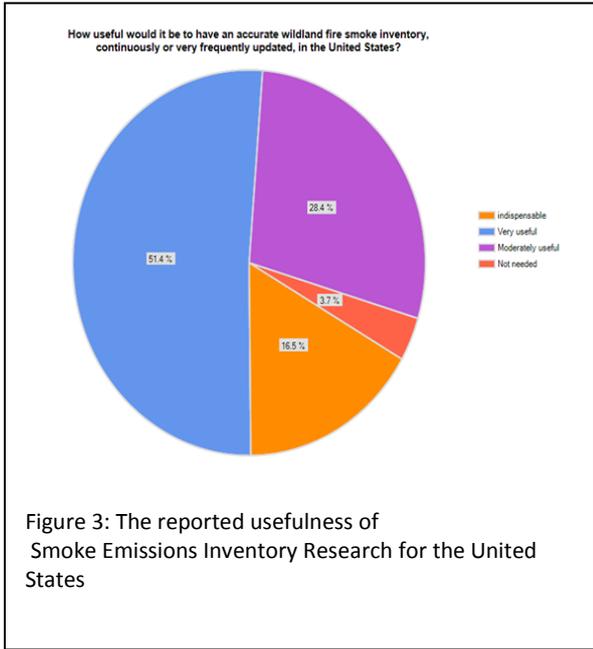
From the responses to the four focus questionnaires there is clear support for the four themes. There was very little 'push back' on any theme. In fact, although *Climate Change and Smoke* received the most responses it was ranked as the lowest in priority of the four themes (e.g., about 10% saying it wasn't necessarily needed). The majority of responders, from their written comments and questionnaire choices made it clear however, that it was an important issue that should not be dropped from the SSP. The theme with the least number of responses, *Smoke and Populations*, was not seen as the theme with the lowest research priority or that it could be omitted from the plan.

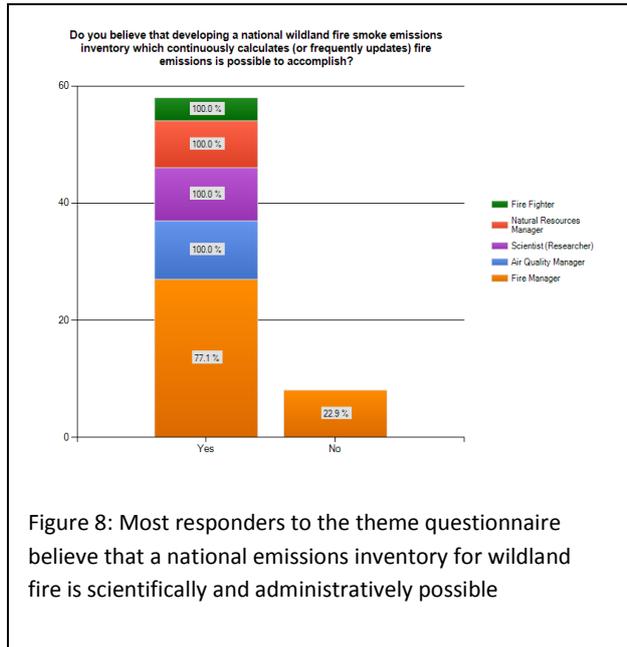
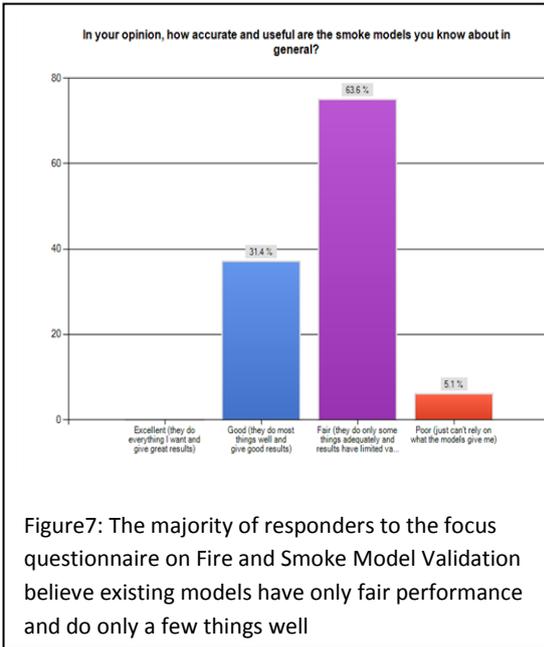
Perhaps the most challenging (esoteric or requiring the most detailed knowledge of smoke regulatory management) of the four themes is *Fire and Smoke Model Validation*. There was very strong support for this theme. Especially, and perhaps surprisingly, much support for this theme was received from fire professionals. Research scientists also saw this as a high-priority need. Additionally, research scientists also support the *Emissions Inventory Research* theme strongly as do air quality managers, but, fire managers also understand this as a priority. If we were to list the themes in order of priority, as expressed by the responders to the four focus questionnaires (Figures 3, 4, 5, & 6), the list would be: 1) *Fire and Smoke Model Validation*, 2) *Emissions Inventory Research*, 3) *Smoke and Populations*, and, 4) *Climate Change and Smoke*.

Table 2: Employers of Respondents to the Joint Fire Science Program Smoke Science Plan Development Activity Web-Based Theme Focus Questionnaires

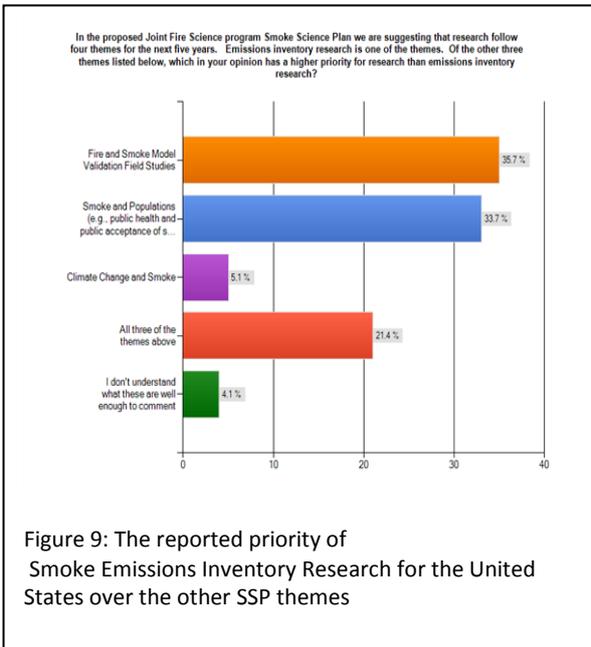
Employer	Emissions Inventory Research	Fire and Smoke Model Validation Research	Smoke and Populations Research	Climate Change and Smoke Research
USDA Forest Service	25	40	24	36
UDOI Fish and Wildlife Service	4	10	3	10
USDOI Park Service	4	9	3	10
USDOI Bureau of Land Management	14	9	5	12
US Federal EPA	2	2	0	0
NASA and NOAA	14	3	5	11
US State and Local Agencies	22	23	13	23
International Responders	6	5	6	5
USA Universities	5	6	7	6
Other	13	19	20	26
TOTAL	109	126	86	139

Note: This table does not include the entire employer categories offered as choices in the questionnaires; the number of people who completed the four theme focus questionnaires total to 460. A total 1014 responses were recorded for all the web-based questionnaires (e.g., the initial and the four focus questionnaires) used in developing the Smoke Science Plan.





It would be fair to ask if perhaps the support for the four themes shown in responses to questionnaires was just an artefact of the questionnaire design or even just that these themes were the ones proposed rather than some others. This, although not outside of the realm of possibility, is not as likely as it might sound. We state this on the strength of written comments left by responders under each theme that supported the themes and questions specifically asking for responders to state other, better alternatives; none were proposed. So we conclude that the themes, admittedly with perhaps some weaknesses, are supported by the SSP audience. They will stand then, we believe with good community of interest support, as the organizational principal for the next five years of smoke research for the JFSP under the SSP.



The Importance of the Fire Emissions Inventory Research Theme:

Fire Emissions Inventory Research is almost universally ranked as a useful line of research for the JFSP by our responders (67% as critical or very useful research, Figure 3) but with only 21% of responders stating that it was the lowest priority of the themes (Figure 9). It is significant, that 16.5% of the people who responded see this line of research as indispensable and over half saw it as 'very

useful.' Indeed, when the Smoke Science Plan itself was reviewed, all four reviewers of the plan also ranked this theme as very much needed with one suggesting that perhaps most of the JFSP funding for smoke research should be applied to this theme alone. Interestingly, people appeared to understand that there was a clear delineation between the research and science needed to develop an emissions inventory and an emissions inventory. Also, our responders almost all believe that a national fire emissions inventory that can be updated at least monthly is technically possible (Figure 8). As part of that understanding there was strong support for JFSP leading science in this area, with caveats that such research needed strong coordination with the Federal EPA. Responders also saw that smoke *Emissions inventory research* ranked about evenly with the theme for *Smoke and Populations* as a critical issue (17% and 14% respectively) but far below *Fire and Smoke Model Validation* (37%), and was a higher priority than *Climate Change and Smoke* (6%, from Figures 3-6), although this ranking across the theme questionnaires may be stretching the meaning of the responses. Finally from written comments, there was a strong signal that a fire smoke emissions inventory should be at both regional and national scales and that purely software development activities (e.g., the programming of a database system for smoke emissions) should not necessarily be a JFSP responsibility.

The Importance of the Fire and Smoke Model Validation Research Theme:

If there were any surprises for the JFSP resulting from the four theme focus questionnaires, perhaps one is that so many people responded that Fire and Smoke Model Validation Research is a 'critical need' (e.g., 37.3%, Figure 4). We had thought that this theme might only be supported so strongly by researchers and perhaps air quality managers who have experience with models. There was very strong support for this among fire managers also, 75% of whom saw this as critical or very much needed. The idea for this theme came directly from the Smoke Roundtables, but, that such a high percentage of responders saw this as high priority is perhaps indicative that years of smoke model development have not convinced the fire management community that the models are actually skilful at simulating smoke in the real world under all conditions (Figure 7). There is strong support for the development of a large-scale interagency effort in this area, but little support for the JFSP doing this by itself or being the major intellectual lead in this line of research. However, people recognise that JFSP is a very good candidate for coalescing an interagency effort to have fire and smoke model validation 'done right.' One other point of note, there is very strong support that fire behaviour model and smoke model validation must be done together and cannot be two separate activities. We would recommend that JFSP fund both types of validation together.

Regardless of whether or not you think research on wildland fire smoke and populations would be useful (even if you think it wouldn't be), should the following topics of study be considered under such a program of research (please rank from most important to least important, or something not to study) in your opinion?

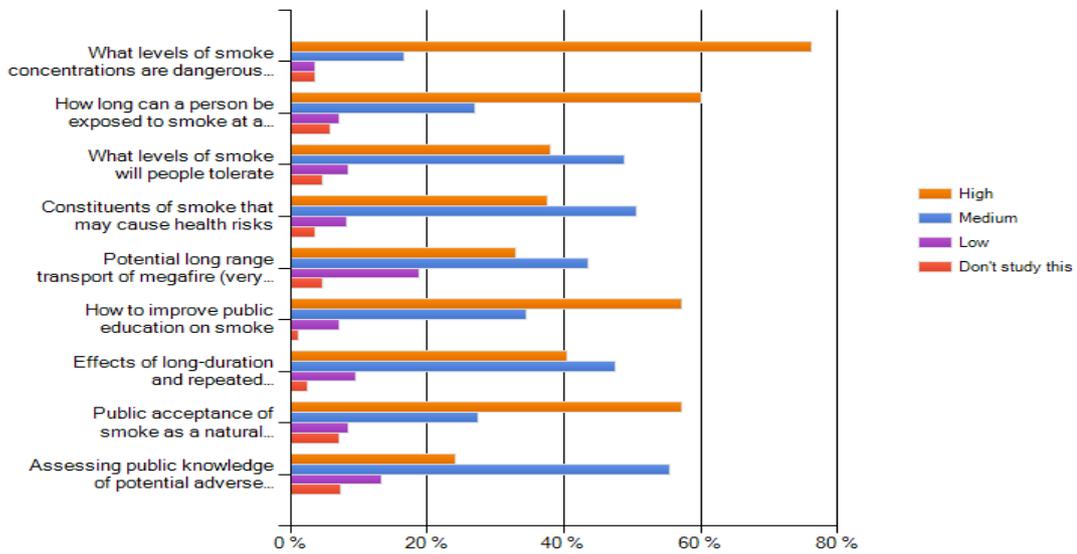


Figure 10: Issues ranked in research priority by responders to the Smoke and Populations focus questionnaire

Regardless of whether or not you think research on smoke and climate change would be useful (even if you think it wouldn't be), what types of studies might be considered under such a program of research?

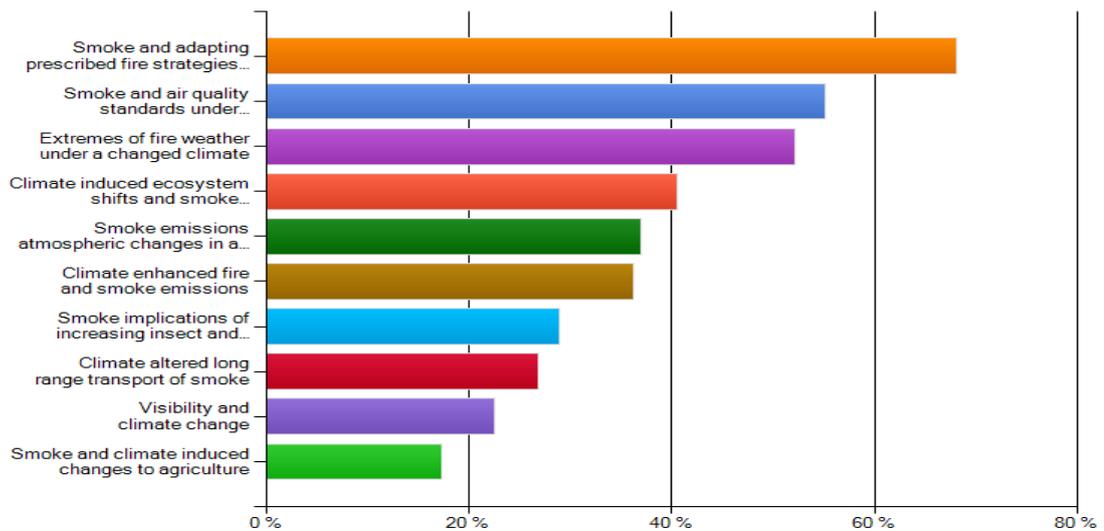


Figure 11: Issues ranked in research priority by responders to the Climate Change and Smoke focus questionnaire

The Importance of the Smoke and Populations Theme:

This theme focus questionnaire, to our surprise, had the least number of individuals who completed it of the four focus questionnaires. However, there was in the first general questionnaire and in this theme focus questionnaire both a strong indication that public perceptions of fire need to be better understood and, although it is perhaps a statement that some will take umbrage at, 'managed' so that fire as an ecosystem management tool will not be lost. When we attempted to break the theme down into topical issues, there was strong support for both public health and public awareness research (Figure 10). There was not, though, complete consensus on smoke public health research; a few responders stated in written comments that this had a potential for being a topic that might be best left unexplored as it was likely unsolvable by JFSP efforts. Other responders in written comments, however, were opposed to this view and saw JFSP as having an appropriate role in smoke/public health research and saw it as important.

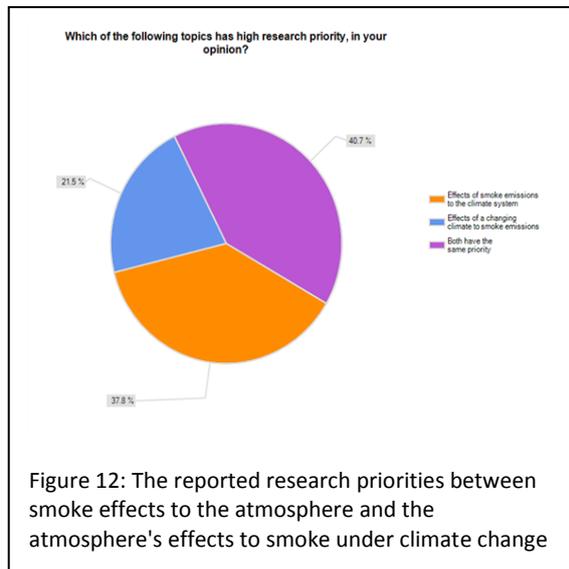


Figure 12: The reported research priorities between smoke effects to the atmosphere and the atmosphere's effects to smoke under climate change

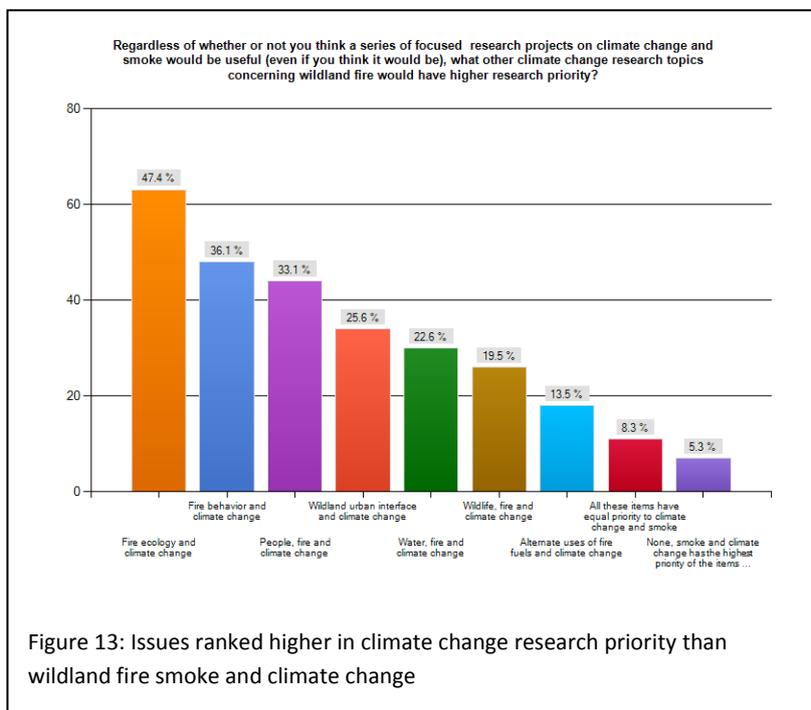


Figure 13: Issues ranked higher in climate change research priority than wildland fire smoke and climate change

The Importance of the Climate Change and Smoke Theme:

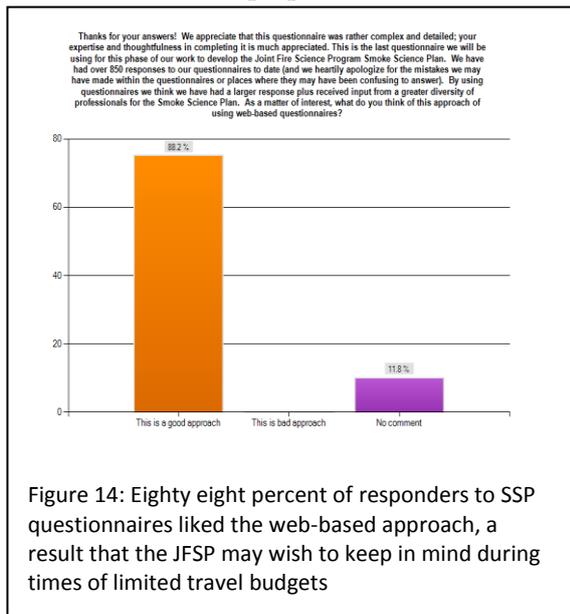
This theme focus questionnaire received 139 responses, again predominately from fire professionals (34%) but with also reasonable response from air quality professionals (8%). Of the people who responded that this was a critical or much needed line of research, the reasoning was that greenhouse gas regulations would adversely affect the freedom of action needed to manage fire in ecosystems. Almost 50% of responders saw this line of research as a

lesser priority than the other theme areas of research (Figure 6), with the highest percentage of responders to any of the focus questionnaires stating that they just feel that they don't know enough about fire climate change issues to assess what priority such a line of research should have. Ninety eight percent of responders stated that they had less than 5 years experience working with climate change issues but almost 50% stated that they had over 10 years experience in fire issues.

Clearly climate change and prescribed fire is an area of concern among our responders (Figure 11) as are smoke atmospheric relationships (e.g., balance of fire emissions effects to the atmosphere and a changing atmosphere's effect of fire emissions, Figure 12). As we saw in our first questionnaire, fire ecology under a changing climate is reported as a higher research priority than smoke as are fire behaviour and social issues (Figure 13). The responses to this theme were somewhat contradictory between individuals, some seeing it as a high priority while others did not support the view; only one person, however, suggested the theme should be dropped stating that 'climate change was not real.'

Other viewpoints expressed in written comments in the focus questionnaires:

In each of the four theme focus questionnaires there was opportunity for written comments on research issues relating to each theme. Overall, there were 114 written comments suggesting new research issues or advising how the suggested research issues might be implemented; of this only 4 responses were negative (two of these in response to the *Smoke and Populations* theme) and suggested that JFSP should not exist or that smoke research was a waste of money. Naturally, the written comments from the theme questionnaires are a resource but at the same time are very difficult to summarize. We propose that all of the comments should be organized in a word document and



used during the implementation of the SSP as their greatest value will perhaps be in informing yearly RFA development. To provide some summary here, a very course interpretation of the comments is presented with the two most reported issues reported for each SSP theme. For *Emissions Inventory Research* two comments voiced issues we highlight here; 1) Plume dynamics and fire behaviour need to be better understood to calculate emissions fate correctly and 2) emissions inventory must be improved to protect public health. For the theme *Fire and Smoke Model Validation* (for which there was extremely strong support with 48 people providing specific research comments) the two issues we report are; 1) fire behaviour linked with fuels characteristics should be validated along with all aspects of fire smoke trajectories, and 2) validate smoke trade-offs between prescribed and wildfires. For the theme *Smoke and Populations* (for which only 16 comments were left) the two issues we report are; 1) long-term and short-term effects smoke has on fire fighters, and 2) how can issues such as smoke warnings/evacuations be decided if we already have health impairment concentration levels embodied in the national ambient air quality standards. Finally, for the theme *Climate Change and Smoke*, the following two issues are

reported; 1) long-term smoke trade-offs between prescribed and wildfires and, 2) the potential feedbacks between climate driven changes in ecosystems and smoke at varying spatial scales.

Conclusions: That the questionnaires drew so many people to respond, and also that the questionnaires were forwarded by so many individuals to their colleagues was both gratifying and perhaps even a bit surprising. A conclusion we draw from this fact is that smoke is clearly an important issue which many responders said would surely become more important in the next decade (Figure 2). Many also see the JFSP work as important and the JFSP effort to develop a smoke science plan worth taking advantage of opportunities for input. A majority of the initial questionnaire responders also voted that the USA should spend more research funds for smoke and a majority indicated that about 25% of fire research funding should address smoke (the four focus questionnaires also supported this as a general range of expenditure). The JFSP smoke roundtable recommendations were not well-known to the initial questionnaire responders, but there were a significant number of responders expressing that the recommendations had value, although to varying degrees depending much on responders work duties. Fire managers who responded indicated that education of the public about the ecological and emergency response needs for fire management would ultimately lessen controversy about wildland fire. Air quality managers didn't necessarily agree that this was so. Almost all responders indicate that there will be increasing air quality regulatory pressure on smoke as a pollutant, with some written responses very gloomy about the future of prescribed fire in the light of perceived more stringent regulations. There was also a clear division between responders on the balance between the need for fire in ecosystems and the protection of the public from unhealthy smoke concentrations. Some extremes in expressed views were that the public should just accept smoke or be educated enough to accept that burning to improve ecosystem health should trump concerns for their own health. Another extreme was that fire and resulting smoke must be stopped at whatever cost if there was danger to public health from smoke intrusions.

It is clear that conflicts between smoke and air quality regulations are still seen as threatening the application of prescribed fire, just as they have in earlier decades. Of course, an often expressed anxiety by responders is whether or not climate change regulations will be developed that will somehow preclude all burning, favouring (as expressed by some responders) the requirement to turn all excess fire fuels in all US forest ecosystems into boiler fuels or biofuels. Although such a concern may at first appear novel, climate change regulations and fire smoke concerns have been discussed since the 1980s or perhaps earlier. That such dire prognostications have not occurred in our estimation demonstrates the usefulness of past smoke science, modelling and models, collegial relations between all parties, and continuing thoughtful attention to the issue.

The development of the JFSP Smoke Science Plan was a large and complex task. The intellectual model we chose was that themes would be devised in response to social drivers and that the themes would be used to pursue lines of research to achieve linked thematic objectives in a five year period. This approach was strongly validated through the four focus questionnaires. The four themes chosen were also strongly supported.

Finally a note about the web-based questionnaire approach we used. As can be seen from Figure 14, nearly 90% of responders when asked liked this approach. It was surely very cost effective, as attempting to get such broad input through meetings would have been prohibitively expensive in travel costs and also hugely time consuming. Although there were many very positive comments,

there were some valid negative points. A few did not like the way questions were worded and also that there were so many questionnaires. Some few questioned whether the results of the questionnaires had any validity because they were designed by 'scientists.' We have learned four general lessons from this work about the use of on-line questionnaires. First, they are effective but must be kept short and questions should be unambiguous. Second, one or two questionnaires in series are enough. Third, keep free form answers (e.g., comment fields) to a minimum. Fourth, careful proof-reading and design must go into the questionnaire as readers will catch you out. To close, we believe that these questionnaires, not having been designed by survey professionals, only apply directly to the SSP and issues immediately surrounding it. Larger implications, such as how the questionnaire responses might apply to other parts of the JFSP research portfolio, science endeavours by other entities, and the public's view of smoke should perhaps not be taken from the questionnaire responses. All this being said, however, over 1000 responses to the SSP series of questionnaires should not be ignored by JFSP as a source of supplemental information in regard to its smoke, climate change, and social sciences research portfolios.

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