



HAL
open science

Preferences for climate change policies: the role of co-benefits

Jens Abildtrup, Jette Bredahl Jacobsen, Suzanne Elizabeth Vedel, Udo Mantau, Robert Mavsar, Davide Pettenella, Irina Prokofieva, Florian Schubert, Anne Stenger, Elsa Varela, et al.

► To cite this version:

Jens Abildtrup, Jette Bredahl Jacobsen, Suzanne Elizabeth Vedel, Udo Mantau, Robert Mavsar, et al.. Preferences for climate change policies: the role of co-benefits. *Journal of Environmental Economics and Policy*, In press, 213, pp.1-19. 10.1080/21606544.2023.2223182 . hal-04132398

HAL Id: hal-04132398

<https://hal.science/hal-04132398>

Submitted on 6 Jul 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 **Manuscript submitted Journal of Environmental Economics and Policy**

2 **14/05/2023, published 18/06/2023: <https://doi.org/10.1080/21606544.2023.2223182>**

3

4 **Title: Preferences for climate change policies: the role of co-benefits**

5 Abildtrup, Jens^{1,†}

6 Jacobsen, Jette Bredahl^{2,3}

7 Vedel, Suzanne Elizabeth⁴

8 Mantau, Udo⁵

9 Mavsar, Robert⁶

10 Pettenella, Davide⁷

11 Prokofieva, Irina⁸

12 Schubert, Florian⁹

13 Stenger, Anne¹⁰

14 Varela, Elsa⁸

15 Vidale, E.⁷

16 Thorsen, Bo Jellesmark^{2,3}

17

18

19 **Affiliations**

20 ¹ Université de Lorraine, Université de Strasbourg, AgroParisTech, CNRS, INRAE, BETA, 54000 Nancy, France

21

22 ² Department of Food and Resource Economics, University of Copenhagen, Rolighedsvej 23, 1958 Frb C, Denmark.

23

24 ³ Centre for Macroecology, Evolution and Climate, University of Copenhagen, Rolighedsvej 23, 1958 Frb C,
25 Denmark.

26

27 ⁴ Department of Analytics, The Technical and Environmental administration, City of Copenhagen, Njalsgade 13,
28 DK-2300, Denmark.

29

30 ⁵ INFRO-Informationssysteme für Rohstoffe, An der Lachte 13, 29223 Celle, Germany.

31

32 ⁶ European Forest Institute, Yliopistokatu 6, 80100 Joensuu, Finland

33

34 ⁷ Department of Land, Environment, Agriculture and Forestry, University of Padova, Vale Università 16, 35020
35 Legnaro PD, Italy

36

37 ⁸ Forest Science and Technology Centre of Catalonia, Ctra. St. Llorenç de Morunys km 2, 25280 Solsona (Lleida),
38 Spain.

39

40 ⁹ INTEND Geoinformatik GmbH, Johanna-Waescher-Straße 5, 34212 Kassel

41

42 ¹⁰ Université de Strasbourg, Université de Lorraine, AgroParisTech, CNRS, INRAE, BETA, 67000, Strasbourg
43 France

44

† Corresponding author

45

46 **Acknowledgement**

47 This research was funded by the European Union under EU FP7 (Grant no.: 243950 NEWFOREX).

48 Disclosure statement: The authors report there are no competing interests to declar

49 **Preferences for climate change policies: the role of co-benefit**

50 **Abstract:**

51 Policies mitigating climate change provide a global public good but are also likely to imply local co-benefits where implemented.
52 This may affect citizens' preferences for what policy to implement as well as where to implement it. This aspect remains
53 understudied despite its relevance for international climate negotiations, national policies, and the development of voluntary
54 carbon credit markets. The results of a discrete choice experiment show that citizens in five countries (Denmark, France,
55 Germany, Italy and Spain) have quite similar mean willingness to pay for carbon emission reductions and agree on the ranking of
56 policies targeting different sectors. Specifically, policies targeting renewable energy use, are preferred over policies targeting
57 industrial energy efficiency or carbon sequestration and biomass production in forests. Applying follow-up questions shows that
58 concerns over co-benefits, notably air pollution, is linked to preferences for implementation in the home country. In the absence
59 of co-benefits, citizens are indifferent or prefer policies implemented in other countries.

60 **Key policy insights**

- 61 - Citizens in five European countries share preferences for climate change mitigation
62 policies, though significant intra-national heterogeneity in preferences exist
- 63 - Policies targeting increased use of renewables are preferred over policies targeting
64 improved energy efficiency in the industry.
- 65 - Citizens express preferences for policies implemented in their own country. This is
66 associated with their perception of co-benefits. In particular, consideration of reduced air
67 pollution as a side effect of investing in renewable energy and in energy efficiency in the
68 industry are important determinants of preferences for national implementation of
69 policies.
- 70 - Preferences for national co-benefits may both enhance policy acceptance and reduce
71 willingness to support policies implemented in other countries. The latter aspect may
72 reduce cost-effectiveness across countries but ease effort-sharing negotiations.

73 **Keywords:** Carbon emissions, co-benefits, willingness to pay, choice experiment, cross-country study, policy
74 acceptability

75 **1. Introduction**

76 Reaching international agreements on climate change mitigation remains high on the agenda of
77 governments and intergovernmental institutions (Vasconcelos, Santos, and Pacheco 2013). As
78 greenhouse gases distribute globally in the atmosphere, reducing emissions is a global public
79 good as no exclusion or rivalry is possible with regard to the climate benefits from carbon
80 emission reductions. Therefore, the international policy debate has focused on instruments that
81 could promote cost-effective policies and reduce emissions at the lowest marginal costs across
82 countries (Hepburn and Stern 2008; Kriegler et al. 2014, Stiglitz 2019).

83 While a global agreement on carbon emission reductions in Paris 2015 (COP21) was reached,
84 international agreements on concrete actions have lagged behind (Wagner and Zeckhauser 2012;
85 Vasconcelos et al. 2013), and explanations for this include the sheer complexity of multiparty
86 negotiations (Wagner and Zeckhauser 2012; Smead et al. 2014). The pursuit of cost-
87 effectiveness in some cases clashes with views on justice (or distributional and historical
88 fairness) (Grubb 1995; Gardiner 2004; Adger et al. 2009; Wei et al. 2012; Anderson and
89 Bernauer 2016; Ščasný et al. 2017; Jagers et al. 2021). People in different countries often differ
90 in their perceptions of climate change and in their support for mitigation policies (Leiserowitz
91 2006; Reiner et al. 2006; Adger et al. 2009; Ščasný et al. 2017; Kàcha, VINTR, and Brick 2022).
92 They also differ in their trust in the ability of (foreign) governments and institutions to undertake
93 effective mitigation actions (Akter, Bennett, and Ward 2012), or their perception of burden-
94 sharing design (Carlsson et al. 2013; Ščasný et al. 2017). Finally, while mitigation is a global
95 public good, any specific mitigation policy is likely to have side effects in the form of co-
96 benefits or collateral damages that are often predominantly local, for example changes in local
97 air pollution, visual disamenities, traffic risk, etc. (Pearce 2000; IPPC 2001 chapter 8; Bollen,
98 Jamet, and Corfee-Morlot 2009; West et al. 2013; Sovacool et al. 2020). The not-in-my-

99 backyard (NIMBY) effect is also a well-known example of local disamenities, well-studied
100 within renewable energy (Batel, 2020). However, much less emphasis has been given to co-
101 benefits. Yet, both may affect public policy preferences (Pittel and Ruebbelke 2008; Svenningsen
102 and Thorsen 2020), and thereby policy choices at a larger scale.

103 If we look at current policies, public perceptions play a large role. The European Union's Council
104 recently decided Fit-for-55 plan of reducing emissions by 55% in 2030 relative to 2005, and details
105 are currently being negotiated and adopted¹. It is interesting in this perspective as the plan contains
106 both a common goal and national aggregate targets (yet to be distributed) but also sector-specific
107 targets. It is a part of the Green Deal, which contains multiple objectives, not only emission
108 reductions. For example a just transition, climate adaptation, and ambitions of increased welfare.
109 If we look at instruments, we see both a cross-national instrument: a quota trading scheme for
110 certain sectors, but also areas where national regulation is by large decided independently from the
111 common EU policies. In addition, we see fast-growing voluntary carbon credit markets (Kreibich
112 and Hermwille 2021). This complexity of goals and instruments can be interpreted as a result of
113 political reality, and therefore, it is of relevance to investigate the general public's perception, as
114 they are ultimately the ones choosing the politicians.

115

116 How much the public is willing to pay for carbon emission reductions has been investigated in
117 the economic literature on climate change (Alló and Loureiro 2014; Drews and van den Bergh
118 2015) and an overview of studies can be found in Alberini et al. (2018). Studies have
119 predominantly focused on carbon emission reductions from a single policy measure targeting
120 specific sectors, e.g. addressing transport choices (Brouwer, Brander, Van Beukering 2008;

¹ EU's fit-for-55 plan: <https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/>

121 Achtenicht 2012), energy choices (Ek 2005; Longo, Markandya, Petrucci 2008; Solomon and
122 Johnson 2009; Scarpa and Willis 2010; Akter and Bennett 2011; Adaman et al. 2011; Hanemann,
123 Labandeira, and Loureiro 2011; O’Keeffe 2014; energy efficiency (Longo, Hoyos, and
124 Markandya 2012), household reduction measures (Faure et al. 2022), or more loosely defined
125 policies (Carlsson et al. 2012; Ščasný et al. 2017). Thus, policies targeting alternative sectors are
126 rarely evaluated against each other. This is unfortunate as different sectors may face different
127 opportunity costs of emissions, and different policies are likely to come with different co-
128 benefits, costs and potentially negative externalities. The willingness to pay (WTP) for co-
129 benefits and other ancillary effects of mitigation measures and carbon offset programs has been
130 investigated (MacKerron et al. 2009; Kotchen, Boyle, and Leiserowitz 2013; Rodriguez-Entrena,
131 Espinosa-Goded, and Barreiro-Hurle 2014; Torres et al. 2015; Baranzini, Borzykowski, and
132 Carattini 2018), but not across different policies and countries. Furthermore, few studies have
133 elicited comparable WTP for carbon reductions across different countries (Carlsson et al. 2012;
134 Ščasný et al. 2017; Faure et al. 2022). Some studies have reported that citizens think mitigation
135 policies should be implemented in their own country rather than in other countries (Carlsson et
136 al. 2012; Buntaine and Prather 2018; Svenningsen and Thorsen 2020), while other studies
137 (Diederich and Goeschl 2017; Baranzini, Borzykowski, and Carattini 2018) have found no
138 significant preferences for mitigation locally (European) over mitigation in developing countries.
139 However, to the best of our knowledge, the perceived role of co-benefits for the preferences for
140 an action to be undertaken in peoples’ home country relative to alternative countries has not been
141 analyzed in detail before. Anderson and Bernauer (2016) suggest for future research, based on a
142 study analyzing factors determining preferences for carbon offsetting in the US, that ‘...it would
143 *be interesting to examine how various types of co-benefits influence preferences for domestic*

144 *versus international offsetting. Examples of such co-benefits are green technology innovation,*
145 *local air quality improvement, and biodiversity protection*'. Torres et al. (2015) find a decreasing
146 WTP for forest carbon services with the distance to the site of implementation but only
147 considering mitigation projects within Mexico.

148
149 This paper applies a discrete choice preferences elicitation technique (Train 2003) to estimate the
150 WTP for various carbon emission reduction policies. As in Ščasný et al. (2017) and Faure et al.
151 (2022), the estimated WTP is used as an indicator of the policy acceptance. Therefore, the focus
152 is not to estimate the size of the marginal WTP for carbon emission reductions per se, but to test
153 the following three hypotheses: The first null hypothesis is that the WTP for carbon reduction
154 policies does not vary between policies. Three policies (types of measures) are considered:
155 investment in energy-saving production technologies in the industry, investment in renewable
156 energy and investment in forest management and wood use to increase CO₂-sequestration. These
157 three groups do not cover all potential mitigation options, but represent important options
158 (Kriegler et al. 2014) that differ substantially in how mitigation takes place, i.e. energy
159 efficiency, energy production and carbon sequestration, respectively. We have no a priori
160 expectations about the relative preferences for the three policies. The second null hypothesis is
161 that the WTP for implementing measures in the home country is identical to implementing it in
162 other countries (Carlsson et al. 2012; Buntaine and Prather 2018). In other words, respondents
163 will not give up cost-effectiveness to ensure local implementation even if they are reminded that
164 the impact is independent of the location of the mitigation measures. The empirical literature
165 does not show a clear tendency regarding the impact of location, e.g. Diederich and Goeschl
166 (2017) did not find a positive preference for local reductions in emissions. The third null

167 hypothesis is that the WTP for local implementation of a measure does not depend significantly
168 on the respondents' perception of co-benefits associated with the measure. However, according
169 to other findings in the literature the a priori expectation is, that local implementation matters for
170 some measures. If the co-benefits are perceived to be positive and considered important, the
171 WTP is higher and if considered negative and important the WTP is lower (Torres et al. 2015,
172 Longo, Hoyos, and Markandya 2012). Considering side effects of forest measures on recreation
173 possibilities and biodiversity (the use value of local nature protection) protection are expected to
174 strengthen the preferences for local implementation (Elbakidze and McCarl 2007; Glenk and
175 Colombo 2011; Torres et al. 2015; Bakhtiari et al. 2018). Similarly, we expect a positive impact
176 on preferences for local implementation of renewable energy and industry efficiency measures if
177 the respondents consider reduction of air pollution a positive side effect (Nemet, Holloway, and
178 Meier 2010; West et al. 2014). On the other hand, we would expect that the WTP is lower for
179 these reduction measures if the respondents consider negative local employment effects resulting
180 from these measures (Krupnick, Burtraw, and Markandya 2000; O'Keeffe 2014; Bernauer and
181 Gampher 2015). If any of these assumptions holds, we must reject the null hypothesis. However,
182 again the existing empirical evidence is not clear. For example, Baranzini, Borzykowski, and
183 Carattini (2018) find, in an experiment with students in Geneva, no significant positive effect on
184 preferences for local implementation with an information treatment emphasizing local co-
185 benefit².

186

187 These hypotheses are tested among representative samples of the citizens of five European
188 countries (Denmark, France, Germany, Italy and Spain). The following section presents the data

² The fact that Baranzini, Borzykowski, and Carattini (2018) did not find an effect of an information treatment emphasizing local co-benefits, is not the same as rejecting that respondents consider co-benefits.

189 collection and econometric analysis. Section 3 presents the results followed by a discussion,
190 concluding remarks and perspectives.

191

192 **Material and Methods**

193 *Survey design and data collection*

194 A first version of the questionnaire was developed in English in co-operation between national
195 teams of researchers. This allowed a common and careful deliberation of each component of the
196 questionnaire and ensured a rigid translation process. Following this, the questionnaire was
197 translated into the five languages of the five countries participating in the survey and was tested
198 on the local populations. Based on results and feedback from these pilot tests, the English
199 language common questionnaire was revised and translated again.

200 The final questionnaire (see supplementary material) had the following structure: First, a part
201 with general questions on knowledge and attitudes towards climate change was presented,
202 followed by the introduction of a choice experiment (see e.g. Mariel et al. 2021) which was used
203 to elicit the preferences for carbon reduction policies among citizens of the five European
204 countries. After the choice experiment, followed a section, which gathered information on the
205 respondents' attitude towards and consideration of co-benefits.




206 Respondents were given a careful introduction to the different policy aspects included in the
207 choice experiment. They were informed that the EU member states have already committed
208 themselves to carbon emission reductions and that they were now to consider the choice among
209 policies relevant to achieve this goal. They were also informed that while their responses were
210 entirely anonymous, the results of the survey would eventually be communicated to policy
211 makers and could influence future policy developments. This to ensure consequentiality (Mariel

212 et al. 2021). Respondents were then asked to consider that, should further policies be
213 implemented along the lines suggested from the results of the experiment, the financing of these
214 policies would come from the member states and their citizens. More precisely, the costs of the
215 policies would be financed by an additional tax levied on all European households' electricity
216 bill³, and in each alternative they were asked to consider the stated specific costs to their
217 household. Respondents were also reminded that the proposed policies do not solve the problem
218 of CO₂ in the atmosphere entirely, but are only some policy initiatives among others, which will
219 contribute to the reduction of the total CO₂ emissions by the EU countries. Thereby we stressed
220 the marginal aspect. They were also informed about the global public good nature of carbon
221 emission reductions, including that CO₂ emissions distribute in the atmosphere, and therefore it
222 does not matter for the climate where emissions are reduced. To provide an intuition about the
223 scale of the CO₂ emission reductions, this information was presented in terms of annual
224 emissions from the corresponding number of average European households.

225 Next, the different aspects (attributes) of the policies were explained, including the levels these
226 could take. In the choice sets the attribute levels were described with text and icons (see Figure 1
227 for an example). The policy alternatives would target effects in one of three sectors: Either
228 increased energy efficiency in the industry *or* investing more in renewable energy technology, *or*
229 changes in forest management to increase carbon sequestration and use of wood. The policy
230 alternatives were briefly explained in general terms without reference to potential co-benefits
231 (Figure 2). As our purpose was to assess the preferences for different main sectors where
232 reductions could take place, the descriptions did not detail the specific potential technologies, but

³ The electricity bill as payment vehicle is also used in Aldy, Kotchen, and Leiserowitz (2012) to reveal WTP for climate mitigation policies. As no common EU level taxation scheme exists, this was considered the most coherent payment vehicle across countries - even though energy also comes from other sources than electricity. The payment vehicle was also accepted as realistic among participants in the focus groups.

233 were kept in generic terms. For example, the measure “forest management and wood use” may
 234 reflect reduced harvest to increase carbon stock, changes in tree species to increase sequestration,
 235 or a change in wood use, either to increase sequestration of carbon in wood products or to
 236 increase substitution of fossil fuel-based products. The policy would be implemented in only one
 237 of the five countries, and which one was shown in a separate line. The policy differed also in the
 238 amount of carbon emission reductions it produced and finally also in the cost to the household.

	Policy 1	Policy 2	Policy 3	No policy
Sector targeted	Forest management and use of wood 	Industry 	Renewable energy 	None of them
Country where measure is implemented	Denmark	Spain	France	-
Annual reduction of CO ₂ in million of tonnes (Mt)	4 Mt CO₂ (1 million households' emission)	10 Mt CO₂ (2.5 million households' emission)	8 Mt CO₂ (2 million households' emission)	0
Extra annual cost of energy for your household for the next 5 years	€ 8	€ 2	€ 60	€ 0
TICK here →	↓ <input type="checkbox"/>	↓ <input type="checkbox"/>	↓ <input type="checkbox"/>	↓ <input type="checkbox"/>

239 **Figure 1.** A presentation of a choice set. Each respondent was asked to indicate their preferred policy among three
 240 different policies and a ‘No policy’ alternative. Note the cost to the household being explicitly stated and tied to
 241 each alternative. Attribute levels vary between alternatives and choice sets. Each respondent answered eight such
 242 choice sets.



Industry

This includes investments in energy-saving production technologies to improve the effectiveness of raw material consumption, and to improve transport modes and logistic systems to decrease fuel consumptions.



Renewable energy

This includes investments in renewable energy technology, for example, establishing windmill parks, solar energy projects and the enhanced use of biomass-based energy.



Forest management and the use of wood

Trees and other plants bind CO₂ when they grow. Therefore, we can reduce CO₂ in the atmosphere by e.g. increasing forest stock or by changes in wood use.

243

244 Figure 2. The information given to the respondents about the reduction strategies in the questionnaire

245

246 The design of the choice experiment involved four different attributes each with three to 10
247 different levels, all explained to the respondents. These are outlined in Table 1. In each choice
248 task the respondent had the option to pick either of three alternative policies or no additional
249 policy, a status quo option. A d-efficient design was generated using the software Ngene for a
250 multinomial logit model with zero priors for main effects.

251

252 **Table 1** Attributes and attribute levels used to describe the policy alternatives, see the questionnaire extract above
 253 for details of the presentation to respondents.

Attribute	Policy attribute levels	Status quo (no policy)
Sector targeted	-Forest management and use of wood -Industry -Renewable energy	No measure
Country where measure is implemented	-Denmark -Germany -France -Italy -Spain	-
Annual CO ₂ reduction, million tonnes (Mt)	4, 6, 8, 10, 12	0
<i>Extra annual</i> cost of energy for <i>your</i> household for the next 5 years	€0.5, €1, €2, €4, €8, €15, €30, €60, €130 ^a	€0 (status quo)

254 ^a In Denmark these units were converted into DKK (€1=7.5 DKK) and rounded to the levels 3, 7, 15, 30, 60, 100,
 255 200, 500, 1000

256
 257
 258 The survey data were collected through an online survey platform using samples of the
 259 population in Denmark, France, Germany, Italy, and Spain, where representativeness was
 260 targeted with regard to gender and age. A sample size of around 400 was targeted and achieved
 261 in all countries, cf. Table 2 below. The survey was carried out using the SurveyXact software
 262 and distributed by local polling agencies in the different countries during April 2013. The sample
 263 is representative with regards to gender. There are some national deviations on other socio-
 264 demographics, e.g. in Denmark, Germany, and Spain the samples are slightly underrepresented
 265 with regard to young people (< 25 years old) and relatively overrepresented with older people
 266 (>65 years old). In France and Italy samples are relatively underrepresented with respondents in
 267 the oldest age class. While Table 2 reveal the representativeness with respect to socio-
 268 demographic characteristics we are not able to evaluate to which degree, the respondents are
 269 representative with respect to knowledge and preferences for climate mitigation policies.
 270 However, we have no reason to believe that the probability of membership of the panels of the
 271 polling agencies is dependent on their attitude to climate mitigation policies. Furthermore, when
 272 respondents were invited to answer the questionnaire they were not told that the questionnaire

273 was about climate policy and therefore it is less likely that respondents self-selected into the
 274 questionnaire.

275 **Table 2** Age and gender distribution in the samples compared to the distributions in each country (2013) for the age
 276 range 18-70 targeted in survey (%)

	Age class	Denmark	Germany	France	Italy	Spain	Average
Population	18-24	13.2	11.5	12.8	10.4	10.2	11.6
Sample	18-24	5.0	2.4	11.9	10.0	8.4	7.5
Population	25-34	17.0	17.8	18.6	17.0	20.1	18.1
Sample	25-34	8.8	18.9	27.0	24.1	23.5	20.4
Population	35-44	19.9	19.0	20.2	22.6	24.2	21.2
Sample	35-44	13.8	18.4	22.7	29.1	21.0	21.0
Population	45-54	21.0	24.2	20.6	22.3	21.2	21.9
Sample	45-54	23.0	22.9	19.7	22.6	11.3	19.9
Population	55-64	18.2	18.9	19.2	18.2	16.2	18.1
Sample	55-64	32.3	22.9	14.6	13.0	19.7	20.5
Population	65-70	10.7	8.5	8.6	9.4	8.1	9.1
Sample	65-70	17.3	14.6	4.0	1.3	16.2	10.7
Population	Female	50.4	50.8	51.5	51.6	50.7	51.0
Sample	Female	49.8	49.6	50.9	50.6	49.8	50.1

277 Source Eurostat appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_pjan&lang=fr Table : Population on 1
 278 January by age and sex Code : demo_pjan

279
 280
 281
 282 A total of 2208 completed questionnaires were gathered (DK: 402, D: 429, F: 419, I: 470, E:
 283 488). 78 observations were excluded, because respondents had reported an age outside the
 284 targeted interval of 18-70 years. Respondents who had chosen the answer “no policy” in all
 285 choice sets were asked a follow-up question. If they replied “I do not want to pay more in taxes
 286 and I think the government should finance it from currently collected taxes” or “I think the large
 287 polluters (industries) should pay as they are polluting the most” they were excluded as their
 288 answers indicate that they did not make a deliberate trade-off between the choice alternatives.
 289 This was the case for only 30 respondents distributed over all countries.

290

291 *Measures of co-benefit concern*

292 The survey design was prepared for an analysis of the importance of co-benefits, which was
293 formulated to the respondents as ‘side effects’ in their local language as ‘co-benefits’ was
294 considered technical jargon. Specifically, respondents were asked follow-up questions after the
295 choice experiment about to what degree they considered a set of different side effects, when
296 making the policy choices they just made. Respondents rated the consideration they assigned to
297 each type of co-benefit on a four-point Likert scale with the intervals “Not at all”, “Hardly”, “A
298 little” to “A lot”. The side effects considered was an outcome of statements from respondents
299 during the pre-testing phase of the questionnaire. Thus, it reflects effects that respondents expect
300 – not necessarily the actual effects. As our aim was to investigate co-benefits, we emphasized
301 positive such. There are obviously other externalities, depending on which specific technology is
302 considered within each sector. Our aim with the co-benefit concerns was to investigate their
303 correlation to the prior stated WTP. Thus, to avoid too lengthy a survey, we opted for a single
304 statement for each co-benefit (rather than e.g. formulate opposing statements with both a positive
305 and a negative effect).

306

307 *Econometric models and analyses*

308 The choice experiment relies on Lancaster’s consumption theory (Lancaster 1966), stating that
309 the utility of a good, in the present case an alternative policy, is derived from the attributes of
310 that alternative good. Further, this is combined with random utility theory (McFadden 1974,
311 Train 2003), where it is assumed that each individual choose the alternative among a set of
312 alternatives that maximize expected utility.

313 Specifying the utility function in preference-space, the respondents are indexed by n , their chosen
 314 policy by i , the household cost of the policy alternative by p_i and the attributes of the alternative
 315 are all included in the vector x_i . Thus, the utility, U , of choosing a particular alternative may be
 316 described as:

317

$$318 \quad U_{ni} = asc + \alpha p_i + \beta' x_{ni} + \varepsilon_{ni} \quad (1)$$

319

320 Here, α , and β are parameters to be estimated and ε_{ni} is the unobserved component of utility.

321 $asc = 1$ if the “Policy 1”, “Policy 2” or “Policy 3” are chosen; otherwise zero. ε_{ni} is assumed
 322 to be a stochastic, *iid* extreme value distributed error term.

323 To enable an easy comparison across country specific models in the analyses, equation (1) is
 324 reformulated to obtain a representation of the respondents’ preferences in so-called willingness
 325 to pay (WTP) space (Train and Weeks 2005):

326

$$327 \quad U_{ni} = \alpha(\overline{asc} + p_i + \mathbf{c}' x_{ni}) + \varepsilon_{ni} \quad (2)$$

328

329 Here $\mathbf{c} = \beta/\alpha$ and $\overline{asc} = asc_i/\alpha$ where \mathbf{c}' is a vector of marginal WTP estimates, each related
 330 to an attribute of the policy alternative in question. Notice that this implies that the WTP is
 331 estimated directly thereby avoiding the problem of unstable marginal WTP estimates based on
 332 ratios of parameters estimated in preference-space models (Thiene and Scarpa 2009).

333 To account for heterogeneity in preferences and hence WTP for the different aspects of policies
 334 across the respondents in each country, for each country specific data set a mixed logit
 335 specification was applied. This is a flexible and computationally practical econometric model,
 336 which in principle may be used to approximate any discrete choice model derived from random

337 utility maximization (Train 2003; Train and Weeks 2005). It allows for heterogeneity across
 338 respondents by specifying random variation in the coefficients \mathbf{c} of equation (2). The distributions
 339 of the random coefficients are defined as $f(\mathbf{c}|\boldsymbol{\omega})$ where $\boldsymbol{\omega}$ denotes a matrix of parameters of these
 340 distributions. This allows writing the unconditional choice probability of a sequence of the T
 341 choices $y_n = \{i_{1n}, i_{2n}, \dots, i_{Tn}\}$ made by respondent n as:

$$342 \quad P(y_n) = \int \prod_t^T \frac{e^{\alpha(\overline{asc} + p_t + \mathbf{c}'\mathbf{x}_{nt})}}{\sum_j e^{\alpha(\overline{asc} + p_j + \mathbf{c}'\mathbf{x}_{nj})}} f(\mathbf{c}|\boldsymbol{\omega}) d(\mathbf{c}) \quad (3)$$

343 Continuous distributions for the WTP of the policy attributes are assumed normal.
 344 The test of the third hypothesis that co-benefit concerns are of no concern for local
 345 implementation of reduction measures is undertaken by including the replies to the question on
 346 co-benefit concern in the econometric model (Longo, Hoyos, and Markandya 2012). More
 347 specifically interaction terms, z_{kn} , between the various co-benefit concerns and the dummies
 348 representing the different policy sectors (renewable energy, industry, and forest management) are
 349 created and included in (2):

$$350 \quad U_{ni} = \alpha(\overline{asc} + p_i + \mathbf{c}'\mathbf{x}_{ni} + \gamma_1 z_{1n} h_{ni} + \dots + \gamma_6 z_{6n} h_{ni}) + \varepsilon_{ni}$$

352 (4)

353 where z_{kn} takes on a value of one if the respondent n has replied “*a lot*” or “*a little*” for combination,
 354 k , of side effect concern and policy measure as defined in table 3; otherwise zero. h_{ni} takes the
 355 value of one if the policy measure is implemented in the country where the respondent is living;
 356 otherwise 0.

357 Table 3 Definition of the interaction terms z_{kn} by side effect concern question and policy
 358 measure.

	Forest management and use of wood	Industry	Renewable energy
Side effect concern “A little” or “A lot”			
Forest management’s impact on biodiversity	$z_{1n}=1$		
Forest management’s impact on recreational opportunities	$z_{2n}=1$		
That reducing CO ₂ -emissions from industry will give cleaner air locally		$z_{3n}=1$	
That reducing CO ₂ -emissions by increased use of renewable energy will give cleaner air locally			$z_{4n}=1$
That implementing reduction measures may have a negative impact on local employment		$z_{5n}=1$	$z_{6n}=1$

359

360 **Results**

361 *The main effects across countries*

362 The main results for the choice model are shown in Table 4. Note that the country where the
363 policies are implemented and the different policies enter as 0-1 dummy variables in each of the
364 estimations. Therefore, one country variable and one policy variable are omitted for the
365 estimation to be feasible. In each country’s regression, the home country is omitted and the forest
366 management policy is omitted. These are confounded with the constant of the regression; the
367 ASC. Thus, the estimated parameters show if people on average prefer implementation in other
368 countries more or less than in their own country, and if they on average prefer a policy targeting
369 energy efficiency in the industry or investments in renewable energy more or less than policies
370 targeting forest management and use of wood. For each attribute the rows show the estimated
371 mean WTP in the countries populations and the standard deviation (SD) of the WTP distribution.

372

373 **Table 4:** Mean annual willingness to pay (WTP) for policy attributes, measured in EURO (2012 PPP EU27;
374 EUROSTAT ESA95 aggregated) per household per year for the next five years. For the sector and country of
375 implementation attributes, we have used “forest management and wood use” and home country as reference
376 variable, respectively. S.D. is the estimated standard deviation of the WTP distribution. Standard errors of estimated
377 parameters (WTP means and standard deviations) are reported in parentheses. Bold figures are significantly different
378 from zero at the 5% level and italics at 10% level.

Policy	Respondents in:									
	Denmark		France		Germany		Italy		Spain	
CO ₂ (Mt/year)	WTP	6.78 (1.11)	7.22 (0.80)	6.93 (0.88)	8.29 (1.26)	11.6 (1.49)				
	S.D.	15.67 (1.47)	9.5.2 (0.87)	11.73 (1.00)	15.8 (1.66)	20.3 (1.83)				
Target industry	WTP	-7.08 (5.59)	-20.36 (4.65)	-11.00 (4.97)	2.94 (7.88)	<i>-14.42</i> (8.45)				
	S.D.	54.02 (7.30)	38.33 (6.29)	47.41 (6.67)	87.22 (11.03)	94.98 (10.95)				
Target renewable energy	WTP	28.54 (4.91)	21.80 (3.75)	33.62 (4.50)	66.20 (8.04)	48.19 (7.42)				
	S.D.	55.01 (6.20)	39.00 (5.30)	49.32 (5.31)	82.88 (9.97)	85.91 (9.60)				
Implementation in Denmark	WTP		-42.87 (6.41)	-65.14 (8.30)	-52.82 (12.17)	-89.82 (12.61)				
	S.D.		52.21 (7.63)	48.33 (8.18)	108.88 (15.22)	113.19 (14.01)				
Implementation in France	WTP	-29.08 (4.89)		-44.59 (5.40)	-22.85 (8.11)	-52.66 (7.86)				
	S.D.	1.32 (12.99)		1.31 (9.35)	4.24 (18.20)	1.01 (13.67)				
Implementation in Germany	WTP	-26.87 (6.59)	-15.04 (5.26)							
	S.D.	0.46 (11.15)	31.53 (10.82)							
Implementation in Italy	WTP	-44.84 (6.27)	-42.84 (5.52)	-71.86 (7.72)						
	S.D.	12.16 (21.13)	1.98 (13.06)	8.23 (40.68)						
Implementation in Spain	WTP	-22.56 (5.07)	-23.43 (4.21)	-50.54 (5.82)	-9.41 (8.34)					
	S.D.	26.60 (10.66)	0.46 (11.18)	1.04 (11.21)	0.90 (45.06)					
Technical constant (ASC)	WTP	86.0 (9.92)	106.8 (9.88)	114.90 (10.59)	204 (21.2)	182.2 (18.23)				
Number of respondents		391 (1955)	422 (2110)	384 (1920)	462 (2310)	441 (2205)				
Log Likelihood		-2027.6	-2062.5	-1895.8	-2375.5	-2225.3				
McFadden pseudo R ²		0.252	0.295	0.288	0.258	0.272				

379
380 It is noted that in several cases there is considerable heterogeneity in the preferences among
381 respondents in the different countries. This is indicated by the significant standard deviations of
382 the preference distributions; cf. equation (3). While the respondents in different countries have a
383 very similar mean WTP for carbon reductions there is considerable heterogeneity in the
384 population with respect to this attribute in all the countries. The opposite is the case for e.g. the
385 “Implementation in Italy” attribute, where the estimated standard deviations of the parameters
386 are not significant in any of the four countries. The overall model fit as indicated by the
387 McFadden pseudo R² between 0.252 and 0.295 across the models.

388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410

A first finding is the large similarity across countries in the mean marginal value per Mt for reduced CO₂ emissions. It is almost identical for households from Denmark, Germany and France but higher for Italy, and in particular higher for Spain. However, the difference in WTP is only statistically significant between Spain and Denmark, Germany and France, applying a two-sided t-test and a 5% level of significance.

The first hypothesis, that the WTP is the same for all three groups of policies is rejected.

Households in all countries on average significantly prefer policies targeting investment in renewable energy use to policies targeting either of the other sectors. Policies targeting energy efficiency in the industrial sector are not preferred over policies targeting the forest sector; for France and Germany, they are even preferred less. It should be noted here that these results do not compare specific forest management or wood use measures with specific measures in the renewable energy or industry sectors, but only how the population overall consider measures in these sectors.

Households in most countries on average agree that policy implementation in their home country is preferable to implementation elsewhere, and thereby we reject the second hypothesis that WTP for reduction abroad is the same as for reductions in the home country. Only Italy is marginally indifferent to implementation in Germany, Spain or at home. Implementation in Italy or Denmark is the least preferred by other countries.

Another finding of interest is evident from the regression constant. The constant can be interpreted as the willingness to support any mitigating actions above the status quo (irrespective of place, sector and impact), plus a correction for the confounded baseline variables for a policy targeting forest management in the respondent's home country. The citizens of the

411 Mediterranean countries, Spain and Italy, have a significantly higher tendency to support any
412 alternatives to the status quo, compared to the three other countries and the citizens in France
413 have a significant higher tendency to support measures than in Denmark (5% level).

414

415 *Accounting for co-benefit concerns*

416 Co-benefits were, generally, considered important (Table 5). Especially, the impacts on air
417 quality were considered important. On average over the five countries, 80% of the respondents
418 did consider the positive impact of increased use of renewable energy on the local air quality “a
419 lot” or “a little”, while only 20% did “not at all” or “hardly” consider these co-benefits in their
420 choice of policy. Similarly, 77% of the respondents did consider the impact of reducing industry
421 emission on local air quality “a lot” or “a little”. The impacts of policy measures on employment
422 were, on average considered the least important.

423

424 **Table 5.** Share of respondents replying “a lot” or “a little” on the question “To what extent did you take the
 425 following side effects into account when choosing between the policies above?” The alternative answers were
 426 “hardly” and “not at all”.

	Denmark	Germany	France	Italy	Spain	Average
Forest management’s impact on biodiversity	0.54	0.58	0.76	0.75	0.78	0.68
Forest management’s impact on recreational opportunities	0.54	0.63	0.65	0.87	0.69	0.67
That reducing CO2-emissions from industry will give cleaner air locally	0.62	0.70	0.75	0.89	0.89	0.77
That reducing CO2-emissions by increased use of renewable energy will give cleaner air locally	0.68	0.70	0.78	0.91	0.91	0.80
That implementing reduction measures may have a negative impact on local employment	0.44	0.32	0.44	0.59	0.56	0.47
Average	0.56	0.59	0.68	0.80	0.77	0.68

427

428

429 A model for the preferences elicited in the choice sets, was estimated taking into account this
 430 source of preference heterogeneity using interaction terms between the home country variable,
 431 and the variable for associated policy-specific co-benefit concern cf. equation (4) and Table 3.
 432 The results are reported in Table 6.

433 **Table 6** Households' annual willingness to pay for policy attributes in Euros (PPP EU27) per household the next five years taking into account concerns about co-benefits.
 434 The base reference category is a policy targeting "forest management and wood use" for respondents not considering recreation and biodiversity co-benefits. Bold figures
 435 are significantly different from zero at the 5% level and italics on a 10% level. S.D. is the estimated standard deviation of the estimated WTP. Standard errors are in
 436 parentheses.

Policy attribute			Denmark		France		Germany		Italy		Spain		
CO₂ (Mt/year)	Row	WTP	6.85	(1.10)	6.29	(0.72)	6.97	(0.89)	7.87	(1.26)	10.83	(1.42)	
		S.D.	15.4	(1.46)	8.63	(0.79)	11.6	(1.02)	15.8	(1.66)	19.0	(1.69)	
The base reference category "Forest management and wood use" implemented in home country <u>and</u> not concerned about biodiversity and recreation co-benefits.		(0)											
"Forest management and wood use" with biodiversity concern <u>and</u> implementation in home country ($z_{1n}=1, h=1$) vs reference (0)		(1)	WTP										
"Forest management and wood use" with recreation concern <u>and</u> implementation in home country ($z_{2n}=1, h=1$) vs reference (0)		(2)	WTP	2.52	(7.95)	13.05	(5.90)	11.53	(7.09)	-12.16	(15.50)	11.15	(9.73)
"Industry" not implemented in home country and/or without concerns for air pollution and employment effect vs reference (0)		(3)	WTP	30.27	(8.08)	5.98	(5.99)	18.60	(7.01)	42.97	(16.09)	-4.92	(9.23)
"Industry" with air pollution concern <u>and</u> implementation in home country ($z_{3n}=1, h=1$) vs reference (3)		(4)	WTP	-1.47	(5.98)	-14.15	(4.67)	-8.86	(5.49)	5.59	(8.67)	-24.34	(9.13)
"Industry" with employment concern <u>and</u> implementation in home country ($z_{5n}=1, h=1$) vs reference (3)		(5)	WTP	54.28	(7.27)	35.38	(5.66)	44.98	(6.81)	88.70	(10.96)	91.67	(10.27)
"Renewable energy" not implemented in home country and/or without concerns for air pollution and employment effect vs reference (0)		(6)	WTP	22.73	(8.54)	9.96	(4.22)	24.77	(5.09)	<i>16.52</i>	(9.95)	26.09	(10.42)
"Renewable energy" air pollution concern <u>and</u> implementation in home country ($z_{4n}=1, h=1$) vs reference (6)		(7)	WTP	-3.42	(9.95)	-1.90	(4.64)	2.60	(5.67)	17.32	(8.17)	-12.77	(11.48)
"Renewable energy" Employment concern <u>and</u> implementation in home country ($z_{6n}=1, h=1$) vs reference (6)		(8)	WTP	31.46	(5.54)	30.17	(3.95)	37.50	(5.21)	60.67	(8.18)	32.84	(8.25)
			S.D.	53.62	(6.15)	36.71	(4.81)	46.27	(5.35)	86.08	(10.25)	82.83	(9.04)
Implementation in Denmark relative to implementation in home country for respondents not considering local co-benefits		(9)	WTP										
			S.D.			-12.32	(11.56)	13.41	(15.23)	<i>60.13</i>	(34.83)	-39.11	(25.94)
Implementation in France relative to implementation in home country for respondents not considering local co-benefits		(10)	WTP	47.03	(13.71)			48.34	(8.16)	110.4	(15.58)	108.11	(12.95)
			S.D.	2.28	(14.68)			1.20	(8.97)	2.05	(17.29)	0.74	(13.09)
Implementation in Germany relative to implementation in home country for respondents not considering local co-benefits		(11)	WTP	48.24	(14.35)	16.68	(11.11)			103.00	(34.99)	-3.42	(25.11)
			S.D.	0.46	(11.15)	28.30	(10.30)			6.16	(27.04)	4.51	(23.05)
Implementation in Italy relative to implementation in home country for respondents not considering local co-benefits		(12)	WTP	30.51	(13.79)	-9.25	(11.26)	5.57	(14.98)			-42.85	(25.36)
			S.D.	9.29	(22.24)	2.94	(14.41)	17.78	(15.78)			2.29	(16.75)
Implementation in Spain relative to implementation in home country for respondents not considering local co-benefits		(13)	WTP	54.70	(14.04)	7.59	(10.78)	28.40	(14.67)	100.11	(34.87)		
			S.D.	25.46	(10.67)	1.31	(12.68)	1.25	(10.80)	4.04	(38.07)		
Technical constant (ASC)			WTP	6.10	(15.25)	67.21	(13.22)	35.02	(15.89)	99.47	(37.13)	133.6	(28.28)
Number of respondents (choices)				391	(1955)	422	(2110)	384	(1920)	462	(2310)	441	(2205)
Loglikelihood					-1998.1		-2039.2		-1873.3		-2361.1		-2216.8
McFadden pseudo R ²					0.263		0.303		0.296		0.263		0.275

437

438 The parameters for the main effects of sector and country variables are estimated as random and
439 normally distributed in this model. The interaction variables between the ‘co-benefit concern’
440 measures and the relevant sector targeted and the presence of ‘own country’ in the alternatives
441 chosen are not, the reason being that these variables themselves are explaining heterogeneity in
442 choices made. As was the case in the model of Table 4, there is also considerable preference
443 heterogeneity remaining in this more developed model. In particular, there is heterogeneity in the
444 preferences related to the different policy sectors and the actual mitigation measure. In this
445 model, preferences are generally more homogenous when it comes to the country of
446 implementation, and mainly finding considerable heterogeneity for implementation in Denmark.
447 The model extension increased the model fit somewhat, though not dramatically.

448
449 The third hypothesis, that the perception of co-benefit has no impact on WTP can be rejected.
450 Accounting for concerns for local co-benefits eliminates or even reverses the preferences for
451 country of implementation. Note that row (9) to (13) in Table 6 show that the marginal WTP of
452 implementing a policy abroad is now relative to implementing at home for citizens not
453 considering co-benefits⁴. Thus, preferences for implementation at home are driven by a
454 substantial group of citizens concerned with co-benefits. When the reference is citizens not
455 concerned with co-benefits Danes and Italians tend to favor implementation abroad, while
456 German, French and Spanish residents are largely indifferent. It is also noted that the estimated
457 average WTP in the population for the reduced carbon emissions are largely unaffected in size
458 from this model extension. Similarly, after having controlled for local implementation for
459 citizens considering co-benefits, the variables for the sectors still show that investments in

⁴ The change in reference category between Table 4 and Table 6 explain the differences in the WTP of the ASC.

460 renewable energy is systematically preferred over the alternatives, whereas citizens in three of
461 the countries are indifferent between policies targeting the two other sectors. France and Spain
462 have a small but significant preference for policies targeting forest management and use of wood
463 over policies targeting energy efficiency in industry (row (3)). The small sensitivity of these
464 variables to the model extension shows that the covariance between co-benefit concern variables
465 and the remaining model is centered on the country of implementation variables.
466 The coefficients on the interaction terms show that preference for reduced air pollution is the
467 main reason to prefer implementation at home of the ‘Renewable energy’ policy and the
468 ‘Industry efficiency’ policy. Furthermore, positive or negative impacts on employment rarely
469 affects preferences, with Italians’ concern with industry jobs being the only exception. For
470 Italians, concern for employment effects influence unexpectedly positively the preferences for
471 energy efficiency measures implemented locally. Finally, people in Denmark, Germany and
472 Spain concerned with local recreation effects of a policy targeting forest management will pay a
473 premium for implementing forest policies at home, for example to benefit from increased forest
474 areas or similar. Concern for biodiversity effects of a forest sector targeted policy does not spill
475 over to WTP except to a small extent in France.

476

477 **Discussion**

478 The present study analyzed the acceptance of different emission reduction policies in Europe,
479 applying a discrete choice experiment. While this approach allows us to estimate the
480 determinants of the WTP for alternative policies, it was not the objective to provide an estimate
481 of the social value of CO₂ emission reductions.

482 The study design allows evaluating how citizens in different countries view climate mitigation
483 policies targeting different sectors and the tradeoffs they see herein, and this is largely new to the
484 literature. The finding that the citizens across countries on average share a very similar idea
485 about how the different policies rank relative to each other is of considerable policy interest as it
486 sheds new light on the popular undercurrent reflected in the national and international policy
487 agendas on renewable energies. In this way, the study contributes significantly to a literature
488 where earlier studies have predominantly focused on carbon emission reductions from a single
489 policy measure targeting specific sectors, e.g. addressing transport choices (Brouwer, Brander,
490 and Van Beukering 2008; Achtnicht 2012), energy choices (Akter and Bennett 2011; Hanemann,
491 Labandeira, and Loureiro 2011), or more loosely defined policies (Carlsson et al. 2012). An
492 exception is Longo, Hoyos, and Markandya (2012) who also find that WTP for a policy
493 promoting renewable energy is higher than for promoting energy efficiency⁵. The drawback of
494 considering a larger number of alternative policy targets is that it is not possible to make
495 respondents relate to more specific details of how each policy might be designed for the different
496 sectors. Therefore, respondents may vary considerably in how they imagine and believe each
497 policy to be designed. This variation will be embedded and captured in the preference
498 heterogeneity found across all countries in the models used in this paper. One of the sectors in
499 our study was defined rather loosely as “Forest management and wood use”. One could argue
500 that this could cover a wide range of different measures and strategies which may be mutually
501 exclusive; reducing harvesting, increasing the carbon stock in the forest, harvesting more to
502 stock carbon in wood products, or substituting fossil-intensive products. These different
503 measures may have different co-benefits and the preference for this measure may therefore

⁵ The policies considered had different scope, i.e. the WTP per ton of reduction were highest for a policy promoting energy efficiency.

504 depend on how the respondents perceived the measure. To investigate if lack of detailed
505 information on the definition of the reduction measures may have influenced choices in the
506 choice experiment we analyzed the answers to an open-ended question which in the
507 questionnaire was given to respondents who said they never choose the sector “Forest
508 management and wood use” in the five choice tasks. We asked them to explain why they have
509 not been choosing this measure. Out of 319 answers, only 65 indicated that they have not chosen
510 this measure due to lack of knowledge or not believing in the measure. Thus, this ambiguity does
511 not seem to have caused concerns for most respondents. Nevertheless, to shed light on
512 preferences for specific forest management and wood use options, we suggest that future studies
513 should explore different forest measures, the importance of information provision and
514 respondents’ perceptions.

515

516 The same limitation of using a generic sector description applies to reduction measures targeting
517 renewable energy sector, where different measures (e.g. windmills, solar panels, and biomass
518 use) may have different co-benefit and the preferences will therefore depend on which measure
519 considered by the respondent. For example, in our questionnaire it was assumed that the effect of
520 measures in the renewable energy sector would have a positive effect on air pollution, However,
521 this may not be the case if the renewable energy measure was burning biomass for energy. In this
522 sense, our phrasing of the co-benefit follow-up questions could be criticized for being
523 suggestive⁶. For all the co-benefits, we only included single statements of co-benefits to which
524 people could state agree or disagree on a five point Lickert scale, not reversed formulations.

525 While this is indeed a limitation if the study was focused on analyzing these statements alone, it

⁶ A point raised by a reviewer

526 is of minor importance here, where our focus is on evaluating the correlation between the answer
527 to this question and the WTP elicited in the prior choice experiment, which is unaffected by the
528 formulations. Possible other side effects that respondent find relevant will be captured in the
529 sector specific variable.

530 One possible consideration is that the payment vehicle is linked to electricity consumption. It
531 may seem less clear why reductions in industry or by carbon sequestration in forests, should
532 affect the electricity bill. However, in reality they are linked to some extent as the grid costs are
533 shared and paid for, not only depending on consumption. Likewise, carbon compensation
534 mechanisms cause carbon sequestration to be included as well. Therefore, and because we did
535 not find evidence for such concerns in focus groups, we do not see it likely that this drives the
536 results.

537 The majority of earlier studies of policies with positive local externalities have reported people to
538 prefer policies implemented in their home country rather than abroad (Carlsson et al. 2012;
539 Buntaine and Prather 2018) and to be concerned about local co-benefits (Longo, Hoyos, and
540 Markandya 2012; Torres et al. 2015). The present results provide a much stronger basis for these
541 findings as the topics are combined in one cross-country experiment. On average, people will
542 prefer a policy implemented at home, and this preference has a significant size in the sense that
543 people may be willing to trade their preferred choice of sector target for a policy that targets their
544 second or even third choice of sector, but is implemented in their home country. This pattern
545 appears particularly strong for Germany and Spain, but the preference for implementation at
546 home is another general preference, which is shared across all five countries. Interestingly, there
547 is much less heterogeneity on this part of the preference set. It is only for implementation in
548 Denmark (which together with Italy are the on average least preferred two countries by the four

549 other countries to have a policy implemented in) that there is significant heterogeneity in
550 preferences. For all the other countries most heterogeneity estimates are not significant. Thus,
551 these preferences are more stable and generally shared not only across, but also within,
552 populations.

553 Importantly, results show that preferences for implementation at home may reflect concerns over
554 local co-benefits. When accounting for the shared commonalities in choices made by people who
555 have expressed strong concerns for the potential co-benefits, the only parameters that change
556 significantly are those related to the preferred country of implementation. Thus, when controlled
557 for co-benefit concerns, respondents who did not consider co-benefits in their choices are much
558 less likely to prefer implementation at home. In fact, we find that not only do a lot of the
559 parameters on target countries become insignificant, but many in fact change sign and become
560 significantly positive. This is true for all countries, but in particular for citizens in Denmark and
561 Italy. This result has important implications for the choice of regulations for emission reductions.

562 While international and inter-sectoral transferal quotas are normally preferred as they are
563 considered cost-efficient, sector and national dependent ancillary effects may create externalities
564 on the carbon reduction market. Therefore, it may be relevant to consider a tariff system when
565 trading carbon credits between different sectors or countries (Lutter and Shogren 2002).

566 Understanding the population's preferences for carbon mitigation measures and their location
567 should also guide the development of business models for voluntary carbon credit markets
568 (Anderson and Bernauer 2016).

569 The results show that citizens of the Mediterranean countries have a higher WTP, than citizens in
570 northern countries, which may indicate that WTP may also vary with local expected impacts. In
571 Europe, the Mediterranean countries are among those expected to feel climate change impact the

572 most, with higher temperatures and in particular potentially severe problems with draught
573 periods (Giorgi and Lionello 2008a). Evidence from studies of resource owners and citizens
574 suggest that personal experiences with climate anomalies and extremes is a key driver in both
575 beliefs about and actions in relation to climate change (Owen et al. 2012), and studies have also
576 found indications of a similar North-South gradient related to personal experience (Blennow and
577 Persson 2009; Blennow et al. 2012). The citizens samples in the present sample are likely to vary
578 considerably in the way they look upon all these different aspects and in their experiences and
579 this will lead to preference heterogeneity. In the econometric model, this heterogeneity is
580 captured explicitly and it is significant. Thus, while the mean estimates suggest that most are
581 willing to contribute towards mitigation, the standard deviations also show that some are willing
582 to contribute a lot more than the mean, whereas as others are not willing to contribute.
583 Nevertheless, the similarity of preferences and willingness to support policies suggests a strong
584 popular basis for the joint European Union policies on climate change mitigation.

585
586 In this study, we have had emphasis on co-benefits and country of implementation, but other
587 factors may matter for preferences for where to implement mitigation policies. Negative (local)
588 externalities (e.g. NIMBY aspects) may be an issue, but probably more at a local scale than a
589 national one. Given the results of preference for home country location for policy
590 implementation, other issues important for the respondents have outweighed any concerns for
591 local negative externalities in our results. Another possible reason could be a question of trust in
592 institutions. If people have higher trust in their national governments than in other countries
593 governments, it may drive the results. Finally, there may ethical considerations of burden sharing
594 (see e.g. van den Berg et al, 2020) which may also affect the results. We leave it for future

595 studies to investigate the interplay between these factors. While choice experiments are a useful
596 method for assessing the determinants of policy acceptability (Ščasný et al 2017; Faure et al.
597 2022), carrying out complementary studies, applying, for example, qualitative interviews, could
598 improve the understanding of the underlying perceptions and knowledge for the choices made in
599 the choice experiment.

600

601 **Concluding remarks and perspectives**

602 This study has undertaken cross-country analysis of citizens' preferences for climate mitigation
603 policies that vary in their degree of mitigation in the form of carbon emission reductions, in what
604 sector they target, and in which of the countries included, the policies would be implemented.

605 Such a study requires that it is credible that policy implementations in one country can
606 potentially affect the income of citizens in other countries. The European Union represents a
607 credible institutional framework for such a study. The EU has a joint budget to which all
608 countries and hence tax paying citizens contribute, and it has a joint climate mitigation policy
609 ambition and has already implemented significant, mandatory and judicially binding largescale
610 policy instruments across and within countries, most notably the ETS. Thus, targeting citizens in
611 the five European Union member states Denmark, France, Germany, Italy and Spain, the
612 research questions set forth could be addressed.

613 Overall there is considerable support and willingness to pay (WTP) for significant climate
614 mitigation policies, though there is also considerable variation in the support and degree of
615 willingness to pay – and more so within each country than between them.

616 A substantial part of the WTP relates directly to the public good of carbon emission reductions,
617 which in all countries and models remains a stable and dominant component of citizens average

618 WTP. The mean WTP per unit of carbon emission reductions are surprisingly similar across
619 countries, though it tends to be higher in the Mediterranean countries.

620 Three other elements, however, are also of importance to people and their support for climate
621 mitigation policies: namely which sector is targeted by the policy and in which country of the
622 five, the policy will be implemented. Again, the citizens in all countries share a similar pattern of
623 preferences. First of all, in all countries, citizens on average prefer policies targeting investment
624 in renewable energy over policies targeting either energy efficiency in the industry sector or
625 forest management and the use of wood. Secondly, in all countries, citizens prefer policies
626 implemented at home *ceteris paribus*, and this is a preference where homogeneity is strong
627 within countries as well as between. Thirdly, it is shown that the citizens' concern for potential
628 co-benefits, notably reductions in air pollution from measures targeting renewables energy or the
629 industry sector, is the driver of preferences for implementation in the home country. Correcting
630 for this, and in the absence of co-benefits or co-benefit concerns, people are indifferent to where
631 a policy is implemented or may even prefer it elsewhere.

632 These results are important and raise three immediate points of relevance for international and
633 national policy debates. First, they suggest that it is likely easier to pursue and obtain public
634 support for cost-effectiveness goals across borders, when the policy instrument selected has no
635 co-benefits of concern to people. Secondly, national policies on the other hand, might benefit
636 from taking into account the role of co-benefits in their design, making policies more robust
637 (Bernauer and Gampher 2015). Articulation and quantification of co-benefit aspects of climate
638 mitigation actions implemented domestically may increase popular support for policies. Together
639 and thirdly, however, these policy implications could also spell trouble for international climate
640 policy negotiations as the most cost-effective policies could potentially also come with

641 significant co-benefits. In such cases, national governments might tend to focus these policies on
642 a national implementation, which may violate an overall cost-effective implementation.

643

644

645 **Acknowledgements:**

646 **[excluded in review version]**

647

648 **6. References**

- 649 Achtnicht M., 2012. German car buyers' willingness to pay to reduce CO2 emissions. *Climatic*
650 *Change*, 113:679-697.
- 651 Adaman, F., Karalı, N, Kumbaroğlu, G., Or, İ., Özkaynak, B., and Zenginobuz, Ü. 2011. What
652 determines urban households' willingness to pay for CO2 emission reductions in Turkey:
653 A contingent valuation survey. *Energy Policy*, 39(2):689–698.
- 654 Adger W.N., Dessai S., Goulden M., Hulme M., Lorenzoni I., Nelson D.R., Naess L.O., Wolf J.,
655 and Wreford A. 2009. Are there social limits to adaptation to climate change? *Climatic*
656 *Change*, 93:335-354.
- 657 Akter S., Bennett J., and Ward M.B. 2012. Climate change scepticism and public support for
658 mitigation: Evidence from an Australian choice experiment. *Global Environmental*
659 *Change-Human and Policy Dimensions*, 22:736-745.
- 660 Akter S. and Bennett J., 2011. Household perceptions of climate change and preferences for
661 mitigation action: the case of the Carbon Pollution Reduction Scheme in Australia.
662 *Climatic Change*, 109: 417-436.
- 663 Alberini, A., Bigano, A., Ščasný, M., and Zvěřinová, I. 2018. Preferences for Energy Efficiency
664 vs. Renewables: What Is the Willingness to Pay to Reduce CO2 Emissions? *Ecological*
665 *Economics*, 144: 171–185.
- 666 Aldy, J. E., Kotchen, M. J., and Leiserowitz, A. A. 2012. Willingness to Pay and Political
667 Support for a U.S. National Clean Energy Standard. *Nature Climate Change* 2(5)
- 668 Alló, M. and Loureiro, M.L. 2014. The Role of Social Norms on Preferences towards Climate
669 Change Policies: A Meta-Analysis. *Energy Policy* 73: 563–574.

670 Anderson, B. and Bernauer, T. 2016. How much carbon offsetting and where ? Implications of
671 efficiency, effectiveness, and ethicality considerations for public opinion. *Energy Policy*,
672 94:387–395.

673 Anthoff D. and Tol R.S.J. 2010. On international equity weights and national decision making on
674 climate change. *Journal of Environmental Economics and Management*, 60:14-20.

675 Anthoff D., Hepburn C., and Tol R.S.J. 2009a. Equity weighting and the marginal damage costs
676 of climate change RID A-2105-2009 RID D-5245-2011. *Ecological Economics*, 68:836-
677 849.

678 Anthoff D., Tol R.S.J., and Yohe G.W. 2009b. Risk aversion, time preference, and the social cost
679 of carbon. *Environmental Research Letters*, 4:024002.

680 Bakhtiari, F., Jacobsen, J.B., Thorsen, B.J., Lundhede, T.H., Strange, N., and Boman, M. 2018.
681 Disentangling distance and country effects on the value of conservation across national
682 borders. *Ecological Economics* 147, 11-20.

683 Baranzini, A., Borzykowski, N., and Carattini, S. 2018. Carbon offsets out of the woods?
684 Acceptability of domestic vs. international reforestation programmes in the lab. *Journal*
685 *of Forest Economics*, 32:1–12.

686 Batel, S., 2020. Research on the social acceptance of renewable energy technologies: Past,
687 present and future. *Energy Research and Social Science*, 68: 101544.

688 Bernauer, T. and Gampfer, R. 2015. How robust is public support for unilateral climate policy?
689 *Environmental Science and Policy*, 54, 316–330

690 Blennow K., Persson J., Tome M. and Hanewinkel M., 2012. Climate Change: Believing and
691 Seeing Implies Adapting. *Plos One*, 7:e50182.

692 Blennow K. and Persson J., 2009. Climate change: Motivation for taking measure to adapt.
693 Global Environmental Change-Human and Policy Dimensions, 19:100-104.

694 Bollen, J. C., Jamet, S., and Corfee-morlot, J. 2009. Co-Benefits of Climate Change Mitigation
695 Policies: Literature review and new results. OECD, Economics Department Working
696 Paper Series No. 693.

697 Brouwer R., Brander L., and Van Beukering P. 2008. "A convenient truth": air travel passengers'
698 willingness to pay to offset their CO₂ emissions. Climatic Change, 90:299-313.

699 Buntaine, M. T. and Prather, L. 2018. Preferences for Domestic Action Over International
700 Transfers in Global Climate Policy. Journal of Experimental Political Science, 5(2), 73–
701 87

702 Carlsson F. and Martinsson P., 2001. Do hypothetical and actual marginal willingness to pay
703 differ in choice experiments? Application to the valuation of the environment. Journal of
704 Environmental Economics and Management, 41:179-192.

705 Carlsson F., Kataria M., Krupnick A., Lampi E., Lofgren A., Qin P., and Sterner T., 2013. A fair
706 share: Burden-sharing preferences in the United States and China. Resource and Energy
707 Economics, 35:1-17.

708 Carlsson F., Kataria M., Krupnick A., Lampi E., Lofgren A., Qin P., Chung S., and Sterner T.
709 2012. Paying for Mitigation: A Multiple Country Study. Land Economics, 88:326-340.

710 Carson R.T. and Groves T. 2007. Incentive and informational properties of preference questions.
711 Environmental & Resource Economics, 37:181-210.

712 Diederich, J. and Goeschl, T. (2017). Does Mitigation Begin At Home? Discussion Paper Series
713 634, Department of Economics, Heidelberg University, Heidelberg pp26.

714 Drews, S. and van den Bergh, J. C.J.M. 2015. What Explains Public Support for Climate
715 Policies? A Review of Empirical and Experimental Studies, *Climate Policy* 3062: 1–22.

716 Elbakidze, L., and McCarl, B. A. (2007). Sequestration Offsets versus Direct Emission
717 Reductions : Consideration of Environmental co-effects. *Ecological Economics*, 60, 564–
718 571.

719 Ek, K. 2005. Public and private attitudes towards “green” electricity: The case of Swedish wind
720 power. *Energy Policy*, 33(13):1677–1689.

721 Faure, C., Guetlein, M. C., Schleich, J., Tu, G., Whitmarsh, L., and Whittle, C. 2022. Household
722 acceptability of energy efficiency policies in the European Union: Policy characteristics
723 trade-offs and the role of trust in government and environmental identity. *Ecological*
724 *Economics*, 192

725 Gardiner S. 2004. Ethics and global climate change. *Ethics*, 114:555-600.

726 Giorgi F. and Lionello P. 2008a. Climate change projections for the Mediterranean region.
727 *Global and Planetary Change*, 63:90-104.

728 Giorgi F. and Lionello P. 2008b. Climate change projections for the Mediterranean region.
729 *Global and Planetary Change*, 63:90-104.

730 Glenk, K., Colombo, S. 2011. Designing policies to mitigate the agricultural contribution to
731 climate change : an assessment of soil based carbon sequestration and its ancillary effects.
732 *Climatic Change*, 43–66.

733 Grubb M., 1995. Seeking Fair Weather - Ethics and the International Debate on Climate-Change.
734 *International Affairs*, 71:463-496.

735 Hanemann M., Labandeira X., and Loureiro M.L. 2011. Climate change, energy and social
736 preferences on policies: exploratory evidence for Spain. *Climate Research*, 48:343-348.

737 Hepburn C. and Stern N., 2008. A new global deal on climate change. *Oxford Review of*
738 *Economic Policy*, 24:259-279.

739 IPCC 2001. *Mitigation of Climate Change. Contribution of Working Group III to the Third*
740 *Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge
741 University Press, Cambridge.

742 Jagers, S. C., Lachapelle, E., Martinsson, J., and Matti, S. 2021. Bridging the ideological gap?
743 How fairness perceptions mediate the effect of revenue recycling on public support for
744 carbon taxes in the United States, Canada and Germany. *Review of Policy Research*,
745 38(5): 529–554.

746 Kácha, O., Vintř, J., and Brick, C. 2022. Four Europes: Climate change beliefs and attitudes
747 predict behavior and policy preferences using a latent class analysis on 23 countries.
748 *Journal of Environmental Psychology*, 81(june).

749 Kotchen M.J., Boyle K.J., and Leiserowitz A.A. 2013. Willingness-to-pay and policy-instrument
750 choice for climate-change policy in the United States. *Energy Policy*, 55:617-625.

751 Kriegler, E., Weyant, J.P., Blanford, G. J., Krey, V., Clarke, L., Edmonds, J., Fawcett, A.,
752 Luderer, G., Riahi, K., Richels, R., Rose, S.K., Tavoni, M., and Vuuren, D. P. Van. 2014.
753 The role of technology for achieving climate policy objectives : overview of the EMF 27
754 study on global technology and climate policy strategies. *Climatic Change*, 123: 353–
755 367.

756 Kreibich, N. and Hermwille, L. 2021. Caught in between: credibility and feasibility of the
757 voluntary carbon market post-2020. *Climate Policy*, 21(7): 939-957.

758 Krupnick, A., Burtraw, D., and Markandya, A. (2000). The Ancillary Benefits and Costs of
759 Climate Change Mitigation. In OECD (Ed.), *Assessing the Ancillary Benefits and Costs*
760 *of Greenhouse Gas Mitigation* (pp. 517–560). OECD Publishing.

761 Lancaster K.J., 1966. New Approach to Consumer Theory. *Journal of Political Economy*,
762 74:132-157.

763 Leiserowitz A., 2006. Climate change risk perception and policy preferences: The role of affect,
764 imagery, and values. *Climatic Change*, 77:45-72.

765 List J. and Gallet C. 2001. What experimental protocol influence disparities between actual and
766 hypothetical stated values? *Environmental & Resource Economics*, 20:241-254.

767 Longo A., Hoyos D., and Markandya A. 2012. Willingness to Pay for Ancillary Benefits of
768 Climate Change Mitigation. *Environmental & Resource Economics*, 51:119-140.

769 Longo, A., Markandya, A., and Petrucci, M. 2008. The internalization of externalities in the
770 production of electricity: Willingness to pay for the attributes of a policy for renewable
771 energy. *Ecological Economics*, 67(1):140–152.

772 Lutter, R., and Shogren, J. F. 2002. Tradable Permit Tariffs: How Local Air Pollution Affects
773 Carbon Emissions Permit Trading. *Land Economics*, 78(2):159–170.

774 Mariel, P., Hoyos, D., Meyerhoff, J., Czajkowski, M., Dekker, T., Glenk, K., Jacobsen, J.B.,
775 Liebe, U., Olsen, S.B., Sagebiel, J., and Thiene, M. 2021. *Environmental Valuation with*
776 *Discrete Choice Experiments, Guidance on Design, Implementation and Data Analysis.*
777 *Springer Briefs in Economics*, Springer International Publishing, 129 pp.

778 MacKerron G.J., Egerton C., Gaskell C., Parpia A., and Mourato S. 2009. Willingness to pay for
779 carbon offset certification and co-benefits among (high-)flying young adults in the UK.
780 *Energy Policy*, 37:1372-1381.

781 McFadden D., 1974. Conditional logit analysis of qualitative choice behaviour. In: P. Zarembka
782 (Editor), *Frontiers in Econometrics*. Academic Press, New York, pp. 105-142.

783 Murphy J., Allen P., Stevens T., and Weatherhead D., 2005. A meta-analysis of hypothetical bias
784 in stated preference valuation. *Environmental & Resource Economics*, 30:313-325.

785 O’Keeffe, L. 2014. A Choice Experiment Survey Analysis of Public Preferences for Renewable
786 Energy in the United States. *Journal of Environmental and Resource Economics at Colby*,
787 1(1).

788 Nemet, G. F., Holloway, T., and Meier, P. (2010). Implications of incorporating air-quality co-
789 benefits into climate change policymaking. *Environmental Research Letters*, 5(1):

790 Owen, A., Conover, L. E., Videras, J., and Wu. S. 2012. Heat Waves, Droughts, and Preferences
791 for Environmental Policy. *Journal of policy analysis and management* 31(3): 556–77.

792 Pearce, D. 2000. Policy frameworks for the ancillary benefits of climate change. In OECD (Ed.),
793 *Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation* (pp. 517–560).
794 OECD Publishing.

795 Pittel K. and Ruebbelke D.T.G., 2008. Climate policy and ancillary benefits: A survey and
796 integration into the modelling of international negotiations on climate change. *Ecological*
797 *Economics*, 68:210-220.

798 Reiner D., Curry T., De Figueiredo M., Herzog H., Ansolabehere S., Itaoka K., Johnsson F., and
799 Odenberger M. 2006. American exceptionalism? Similarities and differences in national
800 attitudes toward energy policy and global warming. *Environmental science & technology*,
801 40:2093-2098.

802 Rodríguez-Entrena, M., Espinosa-Goded, M., and Barreiro-Hurlé, J. 2014. The Role of Ancillary
803 Benefits on the Value of Agricultural Soils Carbon Sequestration Programmes: Evidence

804 from a Latent Class Approach to Andalusian Olive Groves. *Ecological Economics* 99:
805 63–73.

806 Scarpa, R. and Willis, K. G. 2010. Willingness-to-pay for renewable energy: Primary and
807 discretionary choice of British households' for micro-generation technologies. *Energy*
808 *Economics*, 32(1), 129–136

809 Ščasný M., Zvěřinová, I., Czajkowski, M., Kyselá, E., and Zagórska, K. 2017. Public
810 acceptability of climate change mitigation policies: a discrete choice experiment, *Climate*
811 *Policy* 17: S11-S130.

812 Smead R., Sandler R.L., Forber P., and Basl J. 2014. A bargaining game analysis of international
813 climate negotiations. *Nature Climate Change*, 4:442-445.

814 Solomon, B. D. and Johnson, N. H. 2009. Valuing climate protection through willingness to pay
815 for biomass ethanol. *Ecological Economics*, 68(7), 2137–2144

816 Sovacool, B. K., Martiskainen, M., Hook, A., Baker, L. 2020. Beyond cost and carbon : The
817 multidimensional co-benefits of low carbon transitions in Europe. *Ecological Economics*,
818 169(November 2019)

819 Stiglitz, J.E. 2019. Addressing climate change through price and non-price interventions.
820 *European Economic Review*, 119: 594-612.

821 Svenningsen. L.S. and Thorsen, B. J. 2020. Preferences for distributional impacts of climate
822 policy. *Environmental and Resource Economics*, 75: 1-24

823 Thiene M. and Scarpa R. 2009. Deriving and Testing Efficient Estimates of WTP Distributions
824 in Destination Choice Models. *Environmental & Resource Economics*, 44:379-395.

825 Torres, A. B., MacMillan, D. C., Skutsch, M., and Lovett, J. C. 2015. ‘Yes-in-My-Backyard’:
826 Spatial Differences in the Valuation of Forest Services and Local Co-Benefits for Carbon
827 Markets in México. *Ecological Economics* 109: 130–41.

828 Train K. and Weeks M. 2005. Discrete choice models in preference space and willingness-to-pay
829 space. In: R. Scarpa and A. Alberini (Editors), *Applications of simulation methods in
830 environmental and resource economics*, Springer Publisher, Dordrecht, The Netherlands,
831 pp. 1-16.

832 Train K.E. 2003. *Discrete Choice Methods with Simulation*. Cambridge University Press,
833 Cambridge, Cambridge, 334 pp.

834 van den Berg, N.J., van Soest, H.L., Hof, A.F., den Elzen, M.G.J., van Vuuren, D.P., Chen, W.,
835 Drouet, L., Emmerling, J., Fujimori, S., Höhne, N., Köberle, A.C., McCollum, D.,
836 Schaeffer, R., Shekhar, S., Vishwanathan, S.S., Vrontisi, Z., Blok, K., 2020. Implications
837 of various effort-sharing approaches for national carbon budgets and emission pathways.
838 *Climatic Change* 162: 1805–1822.

839 Vasconcelos V.V., Santos F.C., and Pacheco J.M. 2013. A bottom-up institutional approach to
840 cooperative governance of risky commons. *Nature Climate Change*, 3:797-801.

841 Wagner G. and Zeckhauser R.J. 2012. Climate policy: hard problem, soft thinking. *Climatic
842 Change*, 110:507-521.

843 Wei T., Yang S., Moore J.C., Shi P., Cui X., Duan Q., Xu B., Dai Y., Yuan W., Wei X., Yang Z.,
844 Wen T., Teng F., Gao Y., Chou J., Yan X., Wei Z., Guo Y., Jiang Y., Gao X., Wang K.,
845 Zheng X., Reng F., Lv S., Yu Y., Liu B., Luo Y., Li W., Ji D., Feng J., Wu Q., Cheng H.,
846 He J., Fu C., Ye D., Xu G., and Dong W. 2012. Developed and developing world

847 responsibilities for historical climate change and CO2 mitigation. Proceedings of the
848 National Academy of Sciences of the United States of America, 109:12911-12915.
849 West, J. J., Smith, S. J., Silva, R. A., Naik, V., Zhang, Y., Adelman, Z., Fry, M.M., Anenberg, S.,
850 Horowitz, L.W., and Lamarque, J.-F. 2014. Co-benefits of Global Greenhouse Gas
851 Mitigation for Future Air Quality and Human Health. Nature Climate Change, 3(10):
852 885–889.
853
854