

MAYOR AND CITY COUNCIL
OF BALTIMORE

Plaintiff,

v.

BP P.L.C., *et al.*

Defendants.

* IN THE
* CIRCUIT COURT
* FOR BALTIMORE CITY
* Case No. 24-C-18-004219
* Specially Assigned to the
* Hon. Videtta A. Brown
*

* * * * *

**PLAINTIFF MAYOR AND CITY COUNCIL OF BALTIMORE'S
MEMORANDUM OF LAW IN OPPOSITION TO
DEFENDANT CNX RESOURCES CORPORATION'S INDIVIDUAL MOTION TO
DISMISS FOR FAILURE TO STATE A CLAIM**

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TABLE OF CONTENTS

I.	The City Alleges Actionable Misrepresentations Attributable to CNX.....	1
	A. The City’s Allegations Link CNX to Many Misrepresentations.	1
	B. The City Permissibly Relies on Collective Allegations, or “Group Pleading.”	5
	C. CNX Misrepresents Particularity Pleading, Which the City Satisfies Anyway.	7
	1. Only a Subset of the City’s MCPA Claim Is Subject to a Particularity Pleading Requirement.....	7
	2. Particularity Pleading Is Met for the City’s § 13-301(9) MCPA Claim.	8
II.	CNX’s Superior Knowledge of Its Products’ Dangers Gave Rise to a Duty to Warn.....	9

TABLE OF AUTHORITIES

	Page(s)
Cases	
<i>Bank of Am., N.A. v. Knight</i> , 725 F.3d 815 (7th Cir. 2013)	4
<i>Bell Atl. Corp. v. Twombly</i> , 550 U.S. 544 (2007).....	6
<i>CASA de Md., Inc. v. Arbor Realty Tr., Inc.</i> , 2022 WL 4080320 (D. Md. Sept. 6, 2022)	6
<i>Chevron U.S.A. Inc. v. Apex Oil Co.</i> , 113 F. Supp. 3d 807 (D. Md. 2015).....	6
<i>Compass, Inc. v. Real Estate Bd. of N.Y., Inc.</i> , 2022 WL 992628 (S.D.N.Y. Mar. 31, 2022)	4
<i>Consumer Prot. Div. v. Morgan</i> , 387 Md. 125 (2005)	1, 2, 3
<i>Copiers Typewriters Calculators, Inc. v. Toshiba Corp.</i> , 576 F. Supp. 312 (D. Md. 1983).....	3
<i>Cozzarelli v. Inspire Pharms. Inc.</i> , 549 F.3d 618 (4th Cir. 2008)	7
<i>Crowe v. Coleman</i> , 113 F.3d 1536 (11th Cir. 1997)	6
<i>Dashiell v. Meeks</i> , 396 Md. 149 (2006)	2
<i>Figgie Int'l, Inc., Snorkel-Econ. Div. v. Tognocchi</i> , 96 Md. App. 228 (1993)	10
<i>Frazier v. U.S. Bank, N.A.</i> , 2013 WL 1337263 (N.D. Ill. Mar. 29, 2013).....	6
<i>Grasso Enters., LLC v. Express Scripts, Inc.</i> , 2017 WL 365434 (E.D. Mo. Jan. 25, 2017)	4
<i>Green v. H & R Block, Inc.</i> , 355 Md. 488 (1999)	3
<i>Haley v. Corcoran</i> , 659 F. Supp. 2d 714 (D. Md. 2009).....	5
<i>Heritage Harbour, L.L.C. v. John J. Reynolds, Inc.</i> , 143 Md. App. 698 (2002)	5

<i>In re Asbestos Litig.</i> , 509 A.2d 1116 (Del. Super. Ct. 1986)	4
<i>In re Turkey Antitrust Litig.</i> , 642 F. Supp. 3d 711 (N.D. Ill. 2022)	4
<i>Lackey v. MWR Investigations, Inc.</i> , 2015 WL 132613 (D. Md. Jan. 8, 2015)	6
<i>Ledvinka v. Ledvinka</i> , 154 Md. App. 420 (2003)	6
<i>Lloyd v. General Motors Corp.</i> , 397 Md. 108 (2007)	8
<i>Mack Trucks, Inc. v. Coates</i> , 2018 WL 2175932 (Md. App. 2018)	10
<i>Mazda Motor of Am., Inc. v. Rogowski</i> , 105 Md. App. 318 (1995)	10
<i>McCormick v. Medtronic, Inc.</i> , 219 Md. App. 485 (2014)	7, 8
<i>N.A.A.C.P. v. Claiborne Hardware Co.</i> , 458 U.S. 886 (1982)	4
<i>P. Flanigan & Sons, Inc. v. Childs</i> , 251 Md. 646 (1968)	3
<i>Purdum v. Edwards</i> , 155 Md. 178 (1928)	1
<i>Robertson v. Sea Pines Real Estate Cos., Inc.</i> , 679 F.3d 278 (4th Cir. 2012)	6
<i>Rojas v. Delta Airlines, Inc.</i> , 425 F. Supp. 3d 524 (D. Md. 2019)	4
<i>Spangler v. Sprosty Bag Co.</i> , 183 Md. 166 (1944)	7
<i>State v. Exxon Mobil Corp.</i> , 406 F. Supp. 3d 420 (D. Md. 2019)	6
<i>Tavakoli-Nouri v. State</i> , 139 Md. App. 716 (2001)	8
<i>Thomas v. Nadel</i> , 427 Md. 441 (2012)	7
<i>U.S. Gypsum Co. v. Mayor & City Council of Baltimore</i> , 336 Md. 145 (1994)	10

<i>United States v. United Healthcare Ins. Co.</i> , 848 F.3d 1161 (9th Cir. 2016)	6
<i>Vantone Grp. Liab. Co. v. Yangpu NGT Indus. Co.</i> , 2015 WL 4040882 (S.D.N.Y. July 2, 2015)	6
<i>Virgil v. Kash N' Karry Serv. Corp.</i> , 61 Md. App. 23 (1984)	10
<i>Wells v. State</i> , 100 Md. App. 693 (1994)	5
Statutes	
Md. Code Ann., Com. Law § 13-301	7, 8
Rules	
Federal Rule of Civil Procedure 8	6
Federal Rule of Civil Procedure 9(b)	6, 7
Maryland Rule 1-104(a)	10
Maryland Rule 2-303(b)	5
Maryland Rule 2-341	10
Maryland Rule 5-201	2
Other Authorities	
William Prosser, <i>Joint Torts and Several Liability</i> , 25 Calif. L. Rev. 413 (1936)	2
Restatement (Second) of Torts § 876	2

The Mayor and City Council of Baltimore (the “City”) amply states claims against CNX Resources Corporation (“CNX”), as explained in the City’s opposition to Defendants’ joint motion to dismiss for failure to state a claim (“Opposition”), which the City incorporates by reference here. *See Opp.* at Part IV.D.1–IV.D.5.

CNX’s additional arguments in its separate memorandum (“Motion”) change nothing. *First*, the City alleges actionable misrepresentations that are attributable to CNX under a concert-of-action theory. *Cf.* Mot. at 6–9. CNX’s counterarguments conflate concert-of-action with agency, conspiracy, and aiding-and-abetting theories, which the City also satisfies in any event. Then, CNX seeks to avoid the City’s allegations by trying to elevate the pleading standard. CNX asserts the Court should disregard the Complaint’s allegations that refer collectively to CNX and other Defendants. But Maryland courts have not proscribed such collective allegations, which comport with basic pleading principles. Also, CNX posits that all of the City’s claims are subject to a particularity pleading requirement, but only the subset of the City’s MCPA claim that sounds in fraud must be pleaded with particularity, which it is. *Second*, CNX tries to sidestep the City’s theories of liability based on CNX’s concealment and failure to warn (as opposed to its misrepresentations) by asserting that CNX lacked a duty to warn. But the City amply alleges CNX’s superior knowledge about its products’ risks that gave rise to its duty to warn.

The Court should deny CNX’s Motion or, in the alternative, grant the City leave to amend.

I. The City Alleges Actionable Misrepresentations Attributable to CNX.

A. The City’s Allegations Link CNX to Many Misrepresentations.

CNX asserts that the Complaint does not describe any actionable misrepresentations by CNX. Mot. at 5–9. But the City’s allegations link CNX to many such misrepresentations under a concert-of-action theory. That theory “recognize[s] joint and several liability for ‘true’ joint tortfeasors” that “act in concert,” *Consumer Prot. Div. v. Morgan*, 387 Md. 125, 177 (2005),

including when persons “concur[] in making [a tortious] misrepresentation,” *Purdum v. Edwards*, 155 Md. 178 (1928). To define concert-of-action, the Maryland Supreme Court “repeatedly” has cited William Prosser’s scholarship, including for the rule that “[t]hose who actively participate in the wrongful act, by cooperation or request, or who lend aid, encouragement or countenance to the wrongdoer, or approval to his acts done for their benefit, are equally liable with him.” *Morgan*, 387 Md. at 178 (quoting Prosser, *Joint Torts and Several Liability*, 25 Calif. L. Rev. 413, 429–30 (1936)). “Express agreement is not necessary; all that is required is that there shall be a common design or understanding.” *Id.* (quoting Prosser, 25 Calif. L. Rev. at 430). The Court also has relied on Restatement (Second) of Torts (“Rest.”) § 876, which includes within concert-of-action instances where a defendant “does a tortious act in concert with the other or pursuant to a common design with him” or “knows that the other’s conduct constitutes a breach of duty and gives substantial assistance or encouragement” nonetheless. *Morgan*, 387 Md. at 184.

The City ties CNX to misrepresentations under a concert-of-action theory. CNX and other Defendants engaged in a “concerted public relations campaign to cast doubt on the science connecting climate change to fossil fuel products,” including by advancing “climate change denialist” front groups. Compl. ¶¶ 1–7, 147. CNX and its collaborators had a common design: using the early warning they received about the climate change crisis, *e.g.*, *id.* ¶¶ 111, 115, 137, they together “discredit[ed] and/or misrepresent[ed] information that tended to support restricting consumption of . . . [their] products,” *id.* ¶ 146; *see id.* ¶¶ 141–70. Even more, CNX’s predecessor Consolidation Coal Company was a member of the Global Climate Coalition (“GCC”).¹ GCC’s

¹ The Complaint does not allege this fact, but it is judicially noticeable because it is “capable of accurate and ready determination by resort to sources whose accuracy cannot reasonably be questioned.” Md. Rule 5-201; *see Dashiell v. Meeks*, 396 Md. 149, 175 & n.6 (2006). CNX’s relationship to Consolidation Coal Company is verifiable from CNX’s Securities and Exchange Commission submissions. CNX, *SEC Form 10-K*, at 6 (Feb. 7, 2018) (attached as Ex. 1) (CNX used to be known as CONSOL Energy, Inc., which was incorporated in 1991, and CNX/CONSOL Energy, Inc.’s “predecessors had been mining coal . . . since 1864”), <https://perma.cc/5F6S-AXNE>; CONSOL Energy, Inc., *SEC Form 10-K*, at *5 (Feb. 7, 2012) (attached as Ex. 2) (“CONSOL Energy was incorporated in Delaware in

purpose was to widely disseminate false and misleading information about climate change and fossil fuel products that its members knew to be false and misleading, including by funding an array of efforts to knowingly promote inaccurate climate change science. *Id.* ¶ 161. Publicly available documents make clear that GCC's membership reviewed and approved its publications. *See id.* ¶ 161 n.185.² So, CNX acted in concert with other Defendants and front groups by funding, encouraging, ratifying, and aiding their widespread false and misleading conduct.

CNX tries to avoid concert-of-action liability by asserting the City must allege the elements of “agency,” “conspiracy,” or “aiding and abetting” to show such liability. Mot. at 7–8. Maryland courts have not used those terms to limit concert-of-action liability and have instead defined concerted action as a broader concept than agency, conspiracy, or aiding-and-abetting. *See Morgan*, 387 Md. at 184–85. And even if CNX were correct that the City must allege agency, conspiracy, or aiding-and-abetting to attribute others' misrepresentations to CNX, the City alleges each theory. “[A]n agency relationship can be . . . infer[red] from the acts of the agent and principal,” and the existence of such a relationship “is ordinarily a question of fact.” *Green v. H & R Block, Inc.*, 355 Md. 488, 50304 (1999) (cleaned up). Questions about the existence of an agency relationship are ill-suited for resolution on the pleadings and are typically reserved “for the trier of fact.” *See Copiers Typewriters Calculators, Inc. v. Toshiba Corp.*, 576 F. Supp. 312, 324 (D. Md. 1983) (citing *P. Flanigan & Sons, Inc. v. Childs*, 251 Md. 646, 652 (1968)). The City has not only

1991. Our coal operations began in 1864. CONSOL Energy's beginnings as the 'Consolidation Coal Company' in Western Maryland led to growth and expansion . . .”), <https://perma.cc/JU7X-ZFMQ>. Consolidation Coal Company's relationship with GCC is verifiable from a submission by GCC to Congress that was incorporated in a congressional hearing record. *Global Env't: A Nat'l Energy Strategy: Hearing on H.R. 5521 Before the Subcomm. on Energy and Power of the Comm. on Energy and Com.*, Serial No. 101-217 at 181 (U.S. Gov't Printing Off. 1991) (attached as Ex. 3), <https://hdl.handle.net/2027/pst.000017880244>. At minimum, these materials reinforce that the Court should grant the City leave to amend the Complaint if CNX's Motion is granted.

² GCC's 1996 “Primer on Climate Science” cited in the Complaint, *see* Compl. ¶ 161 n.185, is labeled “Approval Draft” and is accompanied by a cover letter directing the document to GCC's membership and noting that the document will be discussed at an upcoming GCC committee meeting, *see* Ex. 4 at AIAM-050775.

alleged the elements of agency, Compl. ¶ 32, but also—as discussed—provided a mosaic of facts supporting an inference that Defendants including CNX engaged in a coordinated disinformation campaign where they acted as each other’s agents.

As for conspiracy, CNX cites cases for the unremarkable proposition that a defendant’s mere membership in a lawful trade organization does not prove their participation in a conspiracy. Mot. at 8. If anything, those factually different cases only underscore that CNX’s membership in a group *can* give rise to liability if CNX and the group intended and acted to undertake unlawful conduct.³ Here, the City does not cite CNX’s membership in trade organizations as bare evidence of a conspiratorial agreement; rather, the City alleges that the very purpose and nature of these organizations was to advance the shared goal of spreading deception.⁴ CNX’s membership and participation in organizations substantially dedicated to pursuing a specific unlawful agenda is evidence of sharing in that agenda, and is sufficient to allege conspiracy.

CNX’s argument that the criteria for aiding-and-abetting liability are not satisfied, Mot. at

³ See *In re Asbestos Litig.*, 509 A.2d 1116, 1120 (Del. Super. Ct. 1986) (holding that “proof of non-membership alone does not preclude the possibility of [defendant’s] participation in its own conspiracy with the members of the association,” and observing in dicta that “*mere membership* in a trade association . . . is not *sufficient* to give rise to an inference of conspiracy” (emphasis added)); *Rojas v. Delta Airlines, Inc.*, 425 F. Supp. 3d 524, 543 (D. Md. 2019) (in a RICO suit, holding that defendant airlines’ mere membership in CANAERO, a trade association that had entered the “CANAERO Contract” with the Mexican government to collect certain taxes on its behalf, did not support the view that the airlines had entered a conspiracy to collect excessive taxes *in violation of* the CANAERO Contract); see also *Bank of Am., N.A. v. Knight*, 725 F.3d 815, 818 (7th Cir. 2013) (in a case that did not involve a trade association or similar group, noting in passing that “it remains essential to show that a particular defendant joined the conspiracy and knew of its scope”).

⁴ Cf. *N.A.A.C.P. v. Claiborne Hardware Co.*, 458 U.S. 886, 920 (1982) (even in the context of a Jim Crow-era lawsuit in a rural Mississippi county against the NAACP by white merchants, noting in dicta that civil liability might be imposed on an individual based on their NAACP membership if “the group itself possessed unlawful goals and that the individual held a specific intent to further those illegal aims”); *In re Turkey Antitrust Litig.*, 642 F. Supp. 3d 711, 727 (N.D. Ill. 2022) (“Although opportunities to cooperate in trade associations are not ipso facto evidence of a conspiracy, when one considers them in the broader context, evidence of these opportunities plausibly helps to fill-out the picture of an alleged conspiracy.” (cleaned up)); *Compass, Inc. v. Real Estate Bd. of N.Y., Inc.*, 2022 WL 992628, at *3 (S.D.N.Y. Mar. 31, 2022) (in the antitrust context, applying the Second Circuit’s rule that “there is no conceptual difficulty in treating trade associations as continuing conspiracies when they regulate areas where their members are in competition” (quotations omitted)); *Grasso Enters., LLC v. Express Scripts, Inc.*, 2017 WL 365434, at *4 (E.D. Mo. Jan. 25, 2017) (finding that “[i]n combination with . . . [various] circumstantial elements, Defendants’ and their co-conspirators’ joint involvement in a trade association supports an inference of a conspiracy,” and noting that “[m]embership and participation in a trade group . . . provides opportunities to conspire” (quotations omitted)).

8, ignores that the threshold for aiding-and-abetting is even lower than for conspiracy: if two people “participate in a riot” and one, “although throwing no rocks himself, encourages [the other] to throw rocks,” both are liable to a third party who is struck and injured. Rest. § 876(b) Illus. 4. At minimum, the City alleges that CNX gave substantial assistance or encouragement to other Defendants and front groups in spreading disinformation they all knew to be false.

B. The City Permissibly Relies on Collective Allegations, or “Group Pleading.”

Instead of showing that the City does not satisfy the ordinary pleading standard, CNX tries to elevate the standard. CNX suggests that Maryland law does not allow the City to use collective allegations that refer to CNX and other Defendants together and state that they acted in the same way. Mot. at 3–4, 6. CNX is wrong because there is no such Maryland case law, whether under an ordinary or heightened pleading standard.⁵ And the City’s use of collective allegations is benign indeed. The City’s use of the term “Defendants” is unremarkable because Defendants acted in concert and in similar ways. The City’s use of the term “CONSOL” to refer to CNX, CONSOL Energy Inc., and its subsidiary CONSOL Marine Terminals is natural because CONSOL Energy was part of CNX until it and CONSOL Marine were spun off in 2017. Compl. ¶ 29(a).

Moreover, the Court should credit the Complaint’s collective allegations because they comport with Maryland pleading principles. The Maryland Supreme Court has rejected technical pleading and required that “a pleading shall be simple, concise, and direct” and “shall contain only such statements of fact as may be necessary to show the pleader’s entitlement to relief.” Md. Rule

⁵ None of CNX’s cited cases proscribe group pleading. Mot. at 6 (citing *Heritage Harbour, L.L.C. v. John J. Reynolds, Inc.*, 143 Md. App. 698, 711 (2002) (dismissal upheld where complaint lacked “any mention of” eight of twenty defendants, and the only allegation that could pertain to those eight defendants was that all twenty “we[re] developers, architects and/or contractors who participated in the design, construction, evaluation and/or repair of” defective buildings); *Wells v. State*, 100 Md. App. 693, 703–04 (1994) (to assess whether the plaintiff pleaded a wanton or willful state of mind for multiple defendants, “examin[ing] what each is charged with doing or failing to do,” and finding the thin allegations insufficient); *Haley v. Corcoran*, 659 F. Supp. 2d 714, 724 (D. Md. 2009) (under federal particularity pleading standard, noting a plaintiff must “specify each defendant’s participation in the alleged fraud”)).

2-303(b). A pleading has four purposes, the first of which is most important: “(1) it provides notice to the parties as to the nature of the claim or defense; (2) it states the facts upon which the claim or defense allegedly exists; (3) it defines the boundaries of litigation; and (4) it provides for the speedy resolution of frivolous claims and defenses.” *Ledvinka v. Ledvinka*, 154 Md. App. 420, 429 (2003). Here, the City’s allegations give CNX ample notice about the claims, underlying facts, and the bounds of the litigation, assuring the Court that the City’s claims are meritorious.⁶ So, the City’s use of collective allegations promotes brevity while satisfying the purposes of pleading.

Consonantly, federal courts in Maryland and elsewhere often have embraced collective allegations.⁷ In fact, Maryland federal courts have been especially receptive of collective allegations where the alleged wrongful conduct is such that the plaintiff has only limited “available information” without discovery, *CASA of Md., Inc. v. Arbor Realty Tr., Inc.*, 2022 WL 4080320, at *4 (D. Md. Sept. 6, 2022) (quotations omitted),⁸ as is the case here given Defendants’ concealment of their deception, *see* Compl. ¶¶ 31, 166–67. In fact, federal courts have recognized that group pleading can satisfy even heightened pleading requirements like Federal Rule of Civil

⁶ *See Frazier v. U.S. Bank, N.A.*, 2013 WL 1337263, at *3 (N.D. Ill. Mar. 29, 2013) (“Although Plaintiff refers to [defendants] collectively, Plaintiff has provided sufficient factual detail about the nature of his allegations and about each defendant to provide fair notice of his claims.”).

⁷ *E.g., Crowe v. Coleman*, 113 F.3d 1536, 1539 (11th Cir. 1997) (“When multiple defendants are named in a complaint, the allegations can be and usually are to be read in such a way that each defendant is having the allegation made about him individually.”); *State v. Exxon Mobil Corp.*, 406 F. Supp. 3d 420, 476 (D. Md. 2019) (rejecting defendants’ argument that “group pleading” was “improper” and holding that collective allegations “provide[d] defendants with ‘fair notice’ of the claims against them ‘and the grounds upon which [they] rest’” (quoting *Bell Atl. Corp. v. Twombly*, 550 U.S. 544, 555 (2007))); *Chevron U.S.A. Inc. v. Apex Oil Co.*, 113 F. Supp. 3d 807, 815 n.1 (D. Md. 2015) (collecting cases to show that “[n]othing in [Federal Rule of Civil Procedure] 8,” the rule setting forth general pleading requirements, “prohibits collectively referring to multiple defendants where the complaint alerts defendants that identical claims are asserted against each defendant” (quoting *Vantone Grp. Liab. Co. v. Yangpu NGT Indus. Co.*, 2015 WL 4040882, at *3 (S.D.N.Y. July 2, 2015))); *Lackey v. MWR Investigations, Inc.*, 2015 WL 132613, at *2, *3 (D. Md. Jan. 8, 2015) (explaining the “presum[ption] that all allegations made against the defendants collectively applied equally to the individual defendant” and noting that “[o]n numerous occasions . . . this Court has found [] collective allegations . . . sufficient”) (collecting cases)).

⁸ *See also, e.g., Robertson v. Sea Pines Real Estate Cos., Inc.*, 679 F.3d 278, 291 (4th Cir. 2012) (“The requirement of nonconclusory factual detail at the pleading stage is tempered by the recognition that a plaintiff may only have so much information at his disposal at the outset.”).

Procedure 9(b). *See United States v. United Healthcare Ins. Co.*, 848 F.3d 1161, 1184 (9th Cir. 2016). Collective allegations are proper as long as a plaintiff meets the otherwise applicable pleading standard.

C. CNX Misrepresents Particularity Pleading, Which the City Satisfies Anyway.

CNX next tries to elevate the pleading standard with another tactic: it argues the City does not plead fraud with the required particularity and implies that this purported shortcoming requires dismissal of *all* the City's claims. *See* Mot. at 7. CNX is wrong.

1. Only a Subset of the City's MCPA Claim Is Subject to a Particularity Pleading Requirement.

Maryland's particularity pleading requirement for fraud is a "judge-made gloss on the general rules of pleading." *See McCormick v. Medtronic, Inc.*, 219 Md. App. 485, 528 (2014). It applies only where a plaintiff seeks "relief on the ground of fraud," *see Thomas v. Nadel*, 427 Md. 441, 453 (2012) (quotations omitted), meaning fraud is "[t]he basis of . . . the relief sought," *Spangler v. Sprosty Bag Co.*, 183 Md. 166, 173 (1944).⁹

CNX is wrong to assert that particularity pleading applies to the City's nuisance, trespass, design defect, and failure-to-warn claims, which do not include fraud as an element. Mot. at 5. In addition to these tort claims, the City also brings an MCPA claim. Maryland courts have applied particularity pleading to MCPA claims *only* to the extent they "replicate[] common-law fraud." *See McCormick*, 219 Md. App. at 529. Here, the City alleges *non-fraudulent* MCPA violations under Md. Code Ann., Com. Law § 13-301(1) and (3) based on CNX's statements, representations, and omissions that had the effect, capacity, or tendency to deceive, as well as fraudulent violations under § 13-301(9) based on CNX's deception with the *specific intent* to induce consumer

⁹ Maryland's judge-made particularity pleading requirement thus differs from Federal Rule of Civil Procedure 9(b)'s particularity pleading requirement, which some courts have interpreted as extending beyond claims that require showing fraud as an element. *See, e.g., Cozzarelli v. Inspire Pharms. Inc.*, 549 F.3d 618, 629 (4th Cir. 2008).

reliance.¹⁰ Under controlling precedent, *McCormick*, 219 Md. App. at 529, only the subset of the City's MCPA claim based on § 13-301(9) is even arguably subject to particularity pleading.

2. Particularity Pleading Is Met for the City's § 13-301(9) MCPA Claim.

The City amply pleads its MCPA claim based on § 13-301(9) by exhaustively describing the multi-decade deception and concealment campaign in which CNX participated. *Lloyd v. General Motors Corp.*, 397 Md. 108, 150–54 (2007), similarly involved an MCPA claim alleging automakers' multi-decade effort to fraudulently conceal a product danger. The Maryland Supreme Court found particularity pleading satisfied because plaintiffs alleged that defendants "ha[d] known the risk of injury," provided "facts that support that assertion," and alleged that defendants had "engaged in a 30-year cover-up." *Id.* at 153 & n.21. The court did not require greater precision. The City's allegations here are more robust than those in *Lloyd*.

CNX's reliance on the Appellate Court's decision in *McCormick*, 219 Md. App. 485, fails for at least two key reasons. *First*, *McCormick* involved only allegations of a fraudulent, affirmative misrepresentation. *Id.* at 528 (defendants' statements "intended to induce physicians . . . to rely on [certain] alleged misrepresentations"). By contrast, the City—as the plaintiffs did in *Lloyd*, 397 Md. at 153–54—also alleges omissions like failure to warn and concealment. Compl. ¶¶ 295–96; *see also id.* ¶¶ 141–70. *McCormick*'s requirement to specify "who made what false statement, when, and in what manner," 219 Md. App. at 528, does not fit the City's case, which places weight on CNX's omissions.

Second, the City's allegations here are far more detailed than those in *McCormick*, where

¹⁰ Although the Complaint expressly refers only to §§ 13-301(1) and 13-301(9), *see* Compl. ¶ 292, the Complaint also states a violation of § 13-301(3). Specifically, the City alleges that the climatic risks of fossil fuel products are material to Maryland consumers, *see id.* ¶¶ 295–96, and that CNX and other Defendants failed to warn of their products' climatic risks while marketing and selling those products, *see id.* ¶¶ 141–70, 241, 274, which has deceived consumers, *id.* ¶ 170. These allegations state a § 13-301(3) claim against CNX. *See Tavakoli-Nouri v. State*, 139 Md. App. 716, 730 (2001) ("The critical inquiry is not whether the complaint specifically identifies a recognized theory of recovery, but whether it alleges specific facts that . . . would justify recovery under any established theory.").

the complaint only “vague[ly] reference[d]” misrepresentations. *See id.* The City shows “who made what false statement, when, and in what manner . . . ; why the statement is false; and why a finder of fact would have reason to conclude that the defendant acted with scienter . . . and with the intention to [induce reliance].” *See id.* Along with other Defendants, CNX deployed a sophisticated deception campaign that promoted unrestricted use of their fossil fuel products without warning of their risks, while spreading disinformation about the scientific consensus regarding climate change. Compl. ¶¶ 141–70. CNX relied in large part on front groups—many identified in the Complaint—to disseminate disinformation on its behalf. *Id.* ¶¶ 30–31, 150–68.

In sum, the City amply alleges affirmative misrepresentations, failure to warn, concealment, and omissions attributable to CNX.¹¹

II. CNX’s Superior Knowledge of Its Products’ Dangers Gave Rise to a Duty to Warn.

The City’s case rests on not only misrepresentations, but also concealment and failure to warn. CNX insists the City’s allegations of such omissions are insufficient because CNX lacked “special” knowledge about its products’ dangers and thus had no duty to warn. Mot. at 9–10. CNX’s argument ignores the City’s allegations and seeks to wrest factual questions from the jury.

The City alleges that Defendants, including CNX, had special knowledge that using their fossil fuel products as intended would cause myriad climate-related hazards that the City now faces. Compl. ¶¶ 106–40. CNX knew or should have known of these product hazards based on information shared by, among others, Defendants’ own research divisions, trade associations, and industry groups. *E.g., id.* ¶¶ 111, 115, 137. CNX thus owed a duty to warn the City and others foreseeably harmed by its products’ intended use, *id.* ¶¶ 238, 271, which it breached by failing to warn and concealing its knowledge, *see id.* ¶¶ 141–70; Opp. § IV.D.3. In arguing otherwise, CNX

¹¹ The other cases CNX cites in its particularity pleading argument change nothing; the City’s allegations are much more robust than the allegations in those factually distinct cases. Mot. at 6; *see supra* n.5 (addressing those cases).

reiterates its flawed argument against collective allegations and ignores the rule that CNX is “held responsible for knowing what was generally known in the scientific or expert community about [its] product[s]’ hazards,” including “by scientists or experts employed by other manufacturers,” *U.S. Gypsum Co. v. Mayor & City Council of Baltimore*, 336 Md. 145, 165 (1994). The sole case CNX properly cites is unhelpful because it involved review of a directed verdict based on a complete lack of *record evidence* that the defendants knew or should have known of the product’s danger.¹²

Although CNX suggests the dangers of its products were obvious or widely recognized, *see* Mot. at 9, the City alleges that Defendants including CNX waged sophisticated deception campaigns that “prevented reasonable consumers from recognizing the risk that fossil fuel products would cause grave climate dangers.” Compl. ¶¶ 141–70, 242, 275, 295; Opp. § IV.D.3.b. It is “for [a] jury to decide” the disputed factual question of whether the dangers CNX and other Defendants themselves spent decades concealing were obvious. *See Figgie Int’l, Inc., Snorkel-Econ. Div. v. Tognocchi*, 96 Md. App. 228, 240 (1993); *Mazda Motor of Am., Inc. v. Rogowski*, 105 Md. App. 318, 329 (1995) (obviousness typically “a jury issue because reasonable minds could differ on it” (quotation omitted)); *see also* Opp. § IV.D.3.b. The Court should credit the City’s allegations that CNX knew about the non-obvious hazards of its products, giving rise to a duty to warn.

CNX’s Motion should be denied. If the Court finds the allegations deficient in any regard, the City respectfully requests leave to amend. *See* Md. Rule 2-341.

¹² Mot. at 9 (citing *Virgil v. Kash N’ Karry Serv. Corp.*, 61 Md. App. 23, 33–34 (1984), and improperly citing an unreported decision in violation of Md. Rule 1-104(a), *Mack Trucks, Inc. v. Coates*, 2018 WL 2175932, at *7 (Md. App. 2018) (unpublished)).

Dated: December 12, 2023

Respectfully submitted,

EBONY M. THOMPSON
(CPF No. 1312190231)
Acting City Solicitor

/s/ Sara Gross *Sara Gross up 12/12/23*
Sara Gross (CPF No. 412140305)
Chief, Affirmative Litigation Division
BALTIMORE CITY LAW DEPT.
100 N. Holliday Street, Suite 109
Baltimore, MD 21202
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Victor M. Sher (*pro hac vice*)
Matthew K. Edling (*pro hac vice*)
Corrie J. Yackulic (*pro hac vice*)
Stephanie D. Biehl (*pro hac vice*)
Martin D. Quiñones (*pro hac vice*)
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*Attorneys for Plaintiff the Mayor and City Council
of Baltimore*

CERTIFICATE OF SERVICE

I hereby certify that on this 12th day of December 2023, a copy of the *Mayor and City Council of Baltimore's Memorandum of Law in Opposition to Defendant CNX Resources Corporation's Individual Motion to Dismiss for Failure to State a Claim* was served upon all counsel of record via email (by agreement of the parties).

/s/ Matthew K. Edling

Matthew K. Edling

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CIVIL DIVISION

EXHIBIT 1

10-K 1 cnx-123117x10k.htm 10-K

**UNITED STATES
SECURITIES AND EXCHANGE COMMISSION**
Washington, D.C. 20549

FORM 10-K

(Mark One)

☒ **ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934.**

For the fiscal year ended December 31, 2017
OR

☐ **TRANSITION REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934**

For the transition period from _____ to _____
Commission file number: 001-14901

CNX Resources Corporation

(Exact name of registrant as specified in its charter)

Delaware

(State or other jurisdiction of
incorporation or organization)

51-0337383
(I.R.S. Employer
Identification No.)

CNX Center
1000 CONSOL Energy Drive Suite 400
Canonsburg, PA 15317-6506
(724) 485-4000

(Address, including zip code, and telephone number, including area code, of registrant's principal executive offices)

Securities registered pursuant to Section 12(b) of the Act:

Title of each class

Common Stock (\$.01 par value)

Preferred Share Purchase Rights

Name of exchange on which registered

New York Stock Exchange

New York Stock Exchange

Securities registered pursuant to Section 12(g) of the Act: None

Indicate by check mark if the registrant is a well-known seasoned issuer, as defined in Rule 405 of the Securities Act. Yes ☒ No ☐

Indicate by check mark if the registrant is not required to file reports pursuant to Section 13 or Section 15(d) of the Act. Yes ☐ No ☒

Indicate by check mark whether the registrant: (1) has filed all reports required to be filed by Section 13 or 15(d) of the Securities Exchange Act of 1934 during the preceding 12 months (or for such shorter period that the registrant was required to file such reports), and (2) has been subject to such filing requirements for the past 90 days. Yes ☒ No ☐

Indicate by check mark whether the registrant has submitted electronically and posted on its corporate Web site, if any, every Interactive Data File required to be submitted and posted pursuant to Rule 405 of Regulation S-T (§232.405 of this chapter) during the preceding 12 months (or for such shorter period that the registrant was required to submit and post such files). Yes ☒ No ☐

Indicate by check mark if disclosure of delinquent filers pursuant to Item 405 of Regulation S-K (§229.405) is not contained herein, and will not be contained, to the best of registrant's knowledge, in definitive proxy or information statements incorporated by reference in Part III of this Form 10-K or any amendment to this Form 10-K. ☐

Indicate by check mark whether the registrant is a large accelerated filer, an accelerated filer, a non-accelerated filer, or a smaller reporting company. See the definitions of "large accelerated filer," "accelerated filer" and "smaller reporting company" in Rule 12b-2 of the Exchange Act. (Check one):

Large accelerated filer ☒ Accelerated filer ☐ Non-accelerated filer ☐ Smaller Reporting Company ☐

Emerging Growth Company ☐ If an emerging growth company, indicate by check mark if the registrant has elected not to use the extended transition period for complying with any new or revised financial accounting standards provided pursuant to Section 13(a) of the Exchange Act. ☐

Indicate by check mark whether the registrant is a shell company (as defined in Rule 12b-2 of the Exchange Act). Yes ☐ No ☒

The aggregate market value of voting stock held by nonaffiliates of the registrant as of June 30, 2017, the last business day of the registrant's most recently completed second fiscal quarter, based on the closing price of the common stock on the New York Stock Exchange on such date was \$1,685,654,421.

The number of shares outstanding of the registrant's common stock as of January 22, 2018 is 223,758,284 shares.

DOCUMENTS INCORPORATED BY REFERENCE:

Portions of CNX's Proxy Statement for the Annual Meeting of Shareholders to be held on May 9, 2018, are incorporated by reference in Items 10, 11, 12, 13 and 14 of Part III.

TABLE OF CONTENTS

	Page
PART I	
ITEM 1. Business	<u>6</u>
ITEM 1A. Risk Factors	<u>20</u>
ITEM 1B. Unresolved Staff Comments	<u>35</u>
ITEM 2. Properties	<u>35</u>
ITEM 3. Legal Proceedings	<u>35</u>
ITEM 4. Mine Safety and Health Administration Safety Data	<u>35</u>
PART II	
ITEM 5. Market for Registrant's Common Equity and Related Stockholder Matters and Issuer Purchases of Equity Securities	<u>36</u>
ITEM 6. Selected Financial Data	<u>38</u>
ITEM 7. Management's Discussion and Analysis of Financial Condition and Results of Operations	<u>39</u>
ITEM 7A. Quantitative and Qualitative Disclosures About Market Risk	<u>71</u>
ITEM 8. Financial Statements and Supplementary Data	<u>73</u>
ITEM 9. Changes in and Disagreements with Accountants on Accounting and Financial Disclosures	<u>123</u>
ITEM 9A. Controls and Procedures	<u>123</u>
ITEM 9B. Other Information	<u>125</u>
PART III	
ITEM 10. Directors and Executive Officers of the Registrant	<u>125</u>
ITEM 11. Executive Compensation	<u>126</u>
ITEM 12. Security Ownership of Certain Beneficial Owners and Management and Related Stockholder Matters	<u>126</u>
ITEM 13. Certain Relationships and Related Transactions and Director Independence	<u>126</u>
ITEM 14. Principal Accounting Fees and Services	<u>126</u>
PART IV	
ITEM 15. Exhibits and Financial Statement Schedules	<u>127</u>
ITEM 16. Form 10-K Summary	<u>133</u>
SIGNATURES	<u>134</u>

PART I

ITEM 1. Business

General

CNX Resources Corporation, (CNX or the Company) is one of the largest independent oil and natural gas companies in the United States and is focused on the exploration, development, production, gathering, processing and acquisition of natural gas properties in the Appalachian Basin. Our operations are centered on unconventional shale formations, primarily the Marcellus Shale and Utica Shale.

CNX was incorporated in Delaware in 1991 under the name CONSOL Energy Inc. (CONSOL Energy), but its predecessors had been mining coal, primarily in the Appalachian Basin, since 1864. CNX entered the natural gas business in the 1980s initially to increase the safety and efficiency of its Virginia coal mines by capturing methane from coal seams prior to mining, which makes the mining process safer and more efficient. The natural gas business grew from the coalbed methane production in Virginia into other unconventional production, including hydraulic fracturing in the Marcellus Shale and Utica Shale in the Appalachian Basin. This growth was accelerated with the 2010 asset acquisition of the Appalachian Exploration & Production business of Dominion Resources, Inc.

On November 28, 2017, CNX completed the tax-free spin-off of its coal business resulting in two independent, publicly traded companies: CONSOL Energy, a coal company, formerly known as CONSOL Mining Corporation; and CNX, a natural gas exploration and production company. As a result of the separation of the two companies, CONSOL Energy and its subsidiaries now hold the coal assets previously held by CNX, including its Pennsylvania Mining Complex, Baltimore Marine Terminal, its direct and indirect ownership interest in CONSOL Coal Resources LP, formerly known as CNXC Coal Resources LP, and other related coal assets previously held by CNX. To effect the separation, CNX's shareholders received one share of CONSOL Energy common stock for every eight shares of CNX's common stock held as of the close of business on November 15, 2017, the record date for the separation and distribution. The coal company, previously reported as the Company's Pennsylvania Mining Operations division, has been reclassified in the Audited Consolidated Financial Statements in Item 8 of this Annual Report on Form 10-K (the Form 10-K) to discontinued operations for all periods presented.

CNX operates, develops and explores for natural gas primarily in Appalachia (Pennsylvania, West Virginia, Ohio, and Virginia). Our primary focus is the continued development of our Marcellus Shale acreage and delineation and development of our unique Utica Shale acreage and stacked pay opportunity set. We believe that our concentrated operating area, our legacy surface acreage position, our regional operating expertise, our extensive data set from development, as well as from non-operated participation wells and our held-by-production acreage position provides us a significant operating advantage over our competitors. Over the past ten years, CNX's natural gas business has grown by approximately 625% to produce a total of 407.2 net Bcfe in 2017.

Our land holdings in the Marcellus Shale and Utica Shale plays cover large areas, provide multi-year drilling opportunities and, collectively, have sustainable lower risk growth profiles. We currently control approximately 530,000 net acres in the Marcellus Shale and approximately 652,000 net acres that have Utica Shale potential in Ohio, West Virginia, and Pennsylvania. We also have approximately 2.2 million net acres in our coalbed methane play.

Highlights of our 2017 production include the following:

- Total average production of 1,115,523 Mcfe per day;
- 90% Natural Gas, 10% Liquids; and
- 59% Marcellus, 20% Utica, 16% coalbed methane, and 5% other.

At December 31, 2017, our proved natural gas, NGL, condensate and oil reserves (collectively, "natural gas reserves") had the following characteristics:

- 7.6 Tcfe of proved reserves;
- 93.9% natural gas;
- 58.2% proved developed;
- 95.5% operated; and

EXHIBIT 2

10-K | cnx-123111x10k.htm FORM 10-K

**UNITED STATES
SECURITIES AND EXCHANGE COMMISSION**
Washington, D.C. 20549

FORM 10-K

(Mark One)

☒ **ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934.**

For the fiscal year ended December 31, 2011

OR

☐ **TRANSITION REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934**

For the transition period from _____ to _____

Commission file number: 001-14901

CONSOL Energy Inc.

(Exact name of registrant as specified in its charter)

Delaware

(State or other jurisdiction of
incorporation or organization)51-0337383
(I.R.S. Employer
Identification No.)1000 CONSOL Energy Drive
Canonsburg, PA 15317-6506
(724) 485-4000

(Address, including zip code, and telephone number, including area code, of registrant's principal executive offices)

Securities registered pursuant to Section 12(b) of the Act:

Title of each class

Common Stock (\$.01 par value)

Preferred Share Purchase Rights

Name of exchange on which registered

New York Stock Exchange

New York Stock Exchange

Securities registered pursuant to Section 12(g) of the Act: None

Indicate by check mark if the registrant is a well-known seasoned issuer, as defined in Rule 405 of the Securities Act. Yes ☒ No ☐Indicate by check mark if the registrant is not required to file reports pursuant to Section 13 or Section 15(d) of the Act. Yes ☐ No ☒Indicate by check mark whether the registrant: (1) has filed all reports required to be filed by Section 13 or 15(d) of the Securities Exchange Act of 1934 during the preceding 12 months (or for such shorter period that the registrant was required to file such reports), and (2) has been subject to such filing requirements for the past 90 days. Yes ☒ No ☐

Indicate by check mark whether the registrant has submitted electronically and posted on its corporate Web site, if any, every Interactive Data File required to be submitted and posted pursuant to Rule 405 of Regulation S-T (§232.405 of this chapter) during the preceding 12 months (or for such shorter period that the registrant was required to submit and post such files). Yes ☒ No ☐

Indicate by check mark if disclosure of delinquent filers pursuant to Item 405 of Regulation S-K (§229.405) is not contained herein, and will not be contained, to the best of registrant's knowledge, in definitive proxy or information statements incorporated by reference in Part III of this Form 10-K or any amendment to this Form 10-K. ☒

Indicate by check mark whether the registrant is a large accelerated filer, an accelerated filer, a non-accelerated filer, or a smaller reporting company. See the definitions of "large accelerated filer," "accelerated filer" and "smaller reporting company" in Rule 12b-2 of the Exchange Act. (Check one):

Large accelerated filer ☒ Accelerated filer ☐ Non-accelerated filer ☐ Smaller Reporting Company ☐

Indicate by check mark whether the registrant is a shell company (as defined in Rule 12b-2 of the Exchange Act). Yes ☐ No ☒

The aggregate market value of voting stock held by nonaffiliates of the registrant as of June 30, 2011, the last business day of the registrant's most recently completed second fiscal quarter, based on the closing price of the common stock on the New York Stock Exchange on such date was \$10,963,933,121.

The number of shares outstanding of the registrant's common stock as of January 25, 2012 is 227,093,353 shares.

DOCUMENTS INCORPORATED BY REFERENCE:

Portions of CONSOL Energy's Proxy Statement for the Annual Meeting of Shareholders to be held on May 1, 2012, are incorporated by reference in Items 10, 11, 12, 13 and 14 of Part III.

TABLE OF CONTENTS

	Page
PART I	
ITEM 1. Business	4
ITEM 1A. Risk Factors	37
ITEM 1B. Unresolved Staff Comments	52
ITEM 2. Properties	52
ITEM 3. Legal Proceedings	52
ITEM 4. Mine Safety and Health Administration Safety Data	52
PART II	
ITEM 5. Market for Registrant's Common Equity and Related Stockholder Matters and Issuer Purchases of Equity Securities	53
ITEM 6. Selected Financial Data	54
ITEM 7. Management's Discussion and Analysis of Financial Condition and Results of Operations	58
ITEM 7A. Quantitative and Qualitative Disclosures About Market Risk	108
ITEM 8. Financial Statements and Supplementary Data	110
ITEM 9. Changes in and Disagreements with Accountants on Accounting and Financial Disclosures	179
ITEM 9A. Controls and Procedures	179
ITEM 9B. Other Information	181

PART III

ITEM 10.	Directors and Executive Officers of the Registrant	<u>181</u>
ITEM 11.	Executive Compensation	<u>182</u>
ITEM 12.	Security Ownership of Certain Beneficial Owners and Management and Related Stockholder Matters	<u>182</u>
ITEM 13.	Certain Relationships and Related Transactions and Director Independence	<u>182</u>
ITEM 14.	Principal Accounting Fees and Services	<u>182</u>

PART IV

ITEM 15.	Exhibits and Financial Statement Schedules	<u>183</u>
SIGNATURES		<u>190</u>

FORWARD-LOOKING STATEMENTS

We are including the following cautionary statement in this Annual Report on Form 10-K to make applicable and take advantage of the safe harbor provisions of the Private Securities Litigation Reform Act of 1995 for any forward-looking statements made by, or on behalf of us. With the exception of historical matters, the matters discussed in this Annual Report on Form 10-K are forward-looking statements (as defined in Section 21E of the Exchange Act) that involve risks and uncertainties that could cause actual results to differ materially from projected results. Accordingly, investors should not place undue reliance on forward-looking statements as a prediction of actual results. The forward-looking statements may include projections and estimates concerning the timing and success of specific projects and our future production, revenues, income and capital spending. When we use the words "believe," "intend," "expect," "may," "should," "anticipate," "could," "estimate," "plan," "predict," "project," or their negatives, or other similar expressions, the statements which include those words are usually forward-looking statements. When we describe strategy that involves risks or uncertainties, we are making forward-looking statements. The forward-looking statements in this Annual Report on Form 10-K speak only as of the date of this Annual Report on Form 10-K; we disclaim any obligation to update these statements unless required by securities law, and we caution you not to rely on them unduly. We have based these forward-looking statements on our current expectations and assumptions about future events. While our management considers these expectations and assumptions to be reasonable, they are inherently subject to significant business, economic, competitive, regulatory and other risks, contingencies and uncertainties, most of which are difficult to predict and many of which are beyond our control. These risks, contingencies and uncertainties relate to, among other matters, the following:

- deterioration in global economic conditions in any of the industries in which our customers operate, or sustained uncertainty in financial markets cause conditions we cannot predict;
- a significant or extended decline in prices we receive for our coal and natural gas affecting our operating results and cash flows;
- our customers extending existing contracts or entering into new long-term contracts for coal;
- our reliance on major customers;
- our inability to collect payments from customers if their creditworthiness declines;
- the disruption of rail, barge, gathering, processing and transportation facilities and other systems that deliver our coal and natural gas to market;

- or produce anticipated proceeds;
- the terms of our existing joint ventures restrict our flexibility and actions taken by the other party in our gas joint ventures may impact our financial position;
- the anti-takeover effects of our rights plan could prevent a change of control;
- risks associated with our debt;
- replacing our natural gas reserves, which if not replaced, will cause our gas reserves and gas production to decline;
- our hedging activities may prevent us from benefiting from price increases and may expose us to other risks;
- other factors discussed in this 2011 Form 10-K under "Risk Factors," as updated by any subsequent Form 10-Qs, which are on file at the Securities and Exchange Commission.

PART I

ITEM 1. Business

CONSOL Energy's Business Introduction

CONSOL Energy safely and responsibly produces coal and natural gas for global energy and raw material markets, which include the electric power generation industry and the steelmaking industry. During the year ended December 31, 2011, we produced 62.6 million tons of high-British thermal unit (Btu) bituminous coal from 12 mining complexes in the United States. During this same period, our natural gas production totaled 153.5 net billion cubic feet equivalent (Bcfe) from approximately 15,000 gross natural gas wells primarily in Appalachia.

Additionally, we provide energy services, including river and dock services, terminal services, industrial supply services, water services and land resource management services.

CONSOL Energy's History

CONSOL Energy was incorporated in Delaware in 1991. Our coal operations began in 1864. CONSOL Energy's beginnings as the "Consolidation Coal Company" in Western Maryland led to growth and expansion through all major coal producing regions in the United States. CONSOL Energy entered the natural gas business in the 1980s to increase the safety and efficiency of our coal mines by capturing methane from coal seams prior to mining, which makes the mining process safer and more efficient. Over the past five years, CONSOL Energy's natural gas business has grown by over 164% to produce 153.5 net Bcfe in 2011. This business has grown from coalbed methane production in Virginia into other unconventional production, such as Marcellus Shale, in the Appalachian basin. This growth was accelerated with the 2010 asset acquisition of the Appalachian E&P business of Dominion Resources, Inc. (Dominion Acquisition). Subsequently, in August and September

EXHIBIT 3

4, EN 2/3:101-217

GLOBAL ENVIRONMENT: A NATIONAL ENERGY STRATEGY

HEARING BEFORE THE SUBCOMMITTEE ON ENERGY AND POWER OF THE COMMITTEE ON ENERGY AND COMMERCE HOUSE OF REPRESENTATIVES ONE HUNDRED FIRST CONGRESS

SECOND SESSION

ON

H.R. 5521

A BILL TO ESTABLISH A NATIONAL ENERGY STRATEGY THAT REFLECTS CONCERN FOR THE GLOBAL ENVIRONMENTAL CONSEQUENCES OF CURRENT TRENDS IN ATMOSPHERIC CONCENTRATIONS OF GREENHOUSE GASES

SEPTEMBER 13, 1990

Serial No. 101-217

Printed for the use of the Committee on Energy and Commerce
PENNYSYLVANIA STATE UNIVERSITY

MAY 17 1991



DOCUMENTS COLLECTION
U.S. Depository Copy

U.S. GOVERNMENT PRINTING OFFICE

41-503-7

WASHINGTON : 1991

For sale by the Superintendent of Documents, Congressional Sales Office
U.S. Government Printing Office, Washington, DC 20402

COMMITTEE ON ENERGY AND COMMERCE

JOHN D. DINGELL, Michigan, *Chairman*

JAMES H. SCHEUER, New York
HENRY A. WAXMAN, California
PHILIP R. SHARP, Indiana
EDWARD J. MARKEY, Massachusetts
THOMAS A. LUKE, Ohio
DOUG WALGREN, Pennsylvania
AL SWIFT, Washington
CARLIS COLLINS, Illinois
MIKE SYNAR, Oklahoma
W.J. "BILLY" TAUZIN, Louisiana
RON WYDEN, Oregon
RALPH M. HALL, Texas
DENNIS E. ECKART, Ohio
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JIM SLATTERY, Kansas
GERRY SIKORSKI, Minnesota
JOHN BRYANT, Texas
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RICK BOUCHER, Virginia
JIM COOPER, Tennessee
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THOMAS J. MANTON, New York
EDOLPHUS TOWNS, New York
C. THOMAS McMILLEN, Maryland

NORMAN F. LENT, New York
EDWARD R. MADIGAN, Illinois
CARLOS J. MOORHEAD, California
MATTHEW J. RINALDO, New Jersey
WILLIAM E. DANNEMEYER, California
BOB WHITTAKER, Kansas
THOMAS J. TAUKE, Iowa
DON RITTER, Pennsylvania
THOMAS J. BLILEY, Jr., Virginia
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MICHAEL G. OXLEY, Ohio
HOWARD C. NIELSON, Utah
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DAN SCHAEFER, Colorado
JOE BARTON, Texas
SONNY CALLAHAN, Alabama
ALEX McMILLAN, North Carolina

JOHN S. ORLANDO, *Chief of Staff*

JOHN M. CLOUGH, Jr., *Staff Director*

MARGARET A. DUBBIN, *Minority Chief Counsel/Staff Director*

SUBCOMMITTEE ON ENERGY AND POWER

PHILIP R. SHARP, Indiana, *Chairman*

W.J. "BILLY" TAUZIN, Louisiana
JOHN BRYANT, Texas
JIM BATES, California
JIM COOPER, Tennessee
TERRY L. BRUCE, Illinois
EDOLPHUS TOWNS, New York
EDWARD J. MARKEY, Massachusetts
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DOUG WALGREN, Pennsylvania
AL SWIFT, Washington
MIKE SYNAR, Oklahoma
RALPH M. HALL, Texas
JOHN D. DINGELL, Michigan
(*Ex Officio*)

CARLOS J. MOORHEAD, California
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MICHAEL BILIRAKIS, Florida
JOE BARTON, Texas
SONNY CALLAHAN, Alabama
NORMAN F. LENT, New York
(*Ex Officio*)

JOHN A. RIGGS, *Staff Director*

RICHARD H. COUNTEAN, *Counsel*

JESSICA LAVERTY, *Minority Counsel*

(11)

CONTENTS

	Page
Text of H.R. 5521.....	5
Testimony of:	
Brown, Hon. George E., Jr., a Representative in Congress from the State of California.....	82
Craig, James, industrial commercial marketing manager, Knauf Fiber Glass Co., on behalf of Mineral Insulation Manufacturers Association....	163
Jasinowski, Jerry, president, National Association of Manufacturers, on behalf of the Global Climate Coalition.....	173
Lashof, Daniel A., senior scientist, Natural Resources Defense Council.....	182
Schneider, Hon. Claudine, a Representative in Congress from the State of Rhode Island.....	84
Stuntz, Linda G., Deputy Under Secretary, Policy, Planning and Analysis, Department of Energy.....	104
Wolf, James L., executive director, Alliance to Save Energy	152
Material submitted for the record by:	
Alliance for Fair Competition, statement by Walter M. "Pete" Reckinger, III, chairman	223
Alliance To Save Energy: Meeting summary	159
American Gas Association, statement.....	228
American Public Power Association, statement	233
Electric Transportation Coalition, statement	236
Energy Department:	
Administration's Medium Term Energy Measures.....	127
Responses to subcommittee questions	130
Energy and Power Subcommittee: Letter from Hon. Claudine Schneider to Chairman Sharp dated September 13, 1990	88
Global Climate Coalition, statement	177
Natural Resources Defense Council and the Pacific Gas & Electric Co., joint statement.....	193
Sheet Metal and Air Conditioning Contractors National Association, Inc.: Letter to Chairman Sharp, dated September 11, 1990	255
Sheet Metal Contractors Association of Central Indiana, Inc.: Letter to Chairman Sharp, dated September 6, 1990	253
U.S. Chamber of Commerce: Letter to Chairman Sharp, from Donald J. Kroes, Vice President, Legislative and Public Affairs, September 26, 1990	256

(III)

GLOBAL ENVIRONMENT: A NATIONAL ENERGY STRATEGY

THURSDAY, SEPTEMBER 13, 1990

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ENERGY AND COMMERCE,
SUBCOMMITTEE ON ENERGY AND POWER,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:03 a.m., in room 2322, Rayburn House Office Building, Hon. Philip R. Sharp (chairman) presiding.

Mr. SHARP. The subcommittee will come to order. Today, the Subcommittee on Energy and Power is holding a hearing on the National Energy Policy Act of 1990. This legislation is intended to stake a first cut at reducing the emission of so-called greenhouse gases which threaten to increase the average temperature of our planet.

It's purpose is not to undertake drastic crash programs which may or may not be warranted by the scientific information. Rather, this bill is to start us to take steps doing those that will be helpful in reducing greenhouse gas emissions.

Specifically, this bill promotes energy efficiency and research and development on clean energy technologies. Last year, the subcommittee held two hearings on the scientific understanding of and agreement on global warming. We still know far less than we would like to, but some general consensus appears to have formed over the past year.

The Intergovernmental Panel on Climate Change [IPCC], an international group of scientists and government officials, convened under the auspices of the United Nations with the active support and participation of the United States, recently released a set of reports in Stockholm. One of their conclusions is that there is not a great deal of certainty, but they are certain that emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases and that these increases will enhance the greenhouse effect, resulting, on average, in a gradual warming of the Earth's surface.

Their estimate is that the global mean temperature will increase 1.8°F by the year 2025, and 5.4° by the end of the 21st century, unless mitigating steps are taken. They also identified measures that can help resist global warming in the short term.

The first item was improved energy efficiency. They listed a number of steps which governments should undertake now in order to prepare for more intensive action in the longer run. One of these

(1)

should be undertaken through a multilateral approach. We should emphasize flexibility in our energy, agricultural, foreign assistance, and research policies so that we can adjust our programs and our investments as our understanding of the global climate change phenomenon increases and as our multilateral discussions mature.

The Coalition urges the Subcommittee to support these principles and work to ensure that any legislation does as well. We look forward to working with you and your staff as this legislation progresses.

Thank you.

Global Climate Coalition Membership

Aluminum Association
American Electric Power Service Corporation
American Gas Association
American Iron & Steel Institute
American Mining Congress
American Nuclear Energy Council
American Paper Institute
American Petroleum Institute
Amoco Corporation
ARCO
Armco, Inc.
Arizona Public Service Company
Association of Home Appliance Manufacturers
AT&T
Automobile Importers of America
Baltimore Gas and Electric Company
BHP - Utah Minerals International, Inc.
Business Roundtable
Carolina Power and Light Company
Champion International
Chemical Manufacturers Association
Chevron U.S.A., Inc.
Chrysler Corporation
Coalition Opposed to Energy Taxes
Consolidation Coal Company
Consumers Power Company
Council of Industrial Boiler Owners
Dow Chemical Company
Duke Power
E.I. DuPont de Nemours & Company, Inc.
Eastman Kodak
Edison Electric Institute
Electricity Consumers Resource Council
Entergy Corporation
Ford Motor Company
Fusion Power Associates
General Motors Corporation
Georgia Pacific Corporation
Hercules Incorporated

Illinois Power Company
Int'l Business-Government Counsellors, Inc.
Jefferson Energy Foundation
Kaiser Aluminum & Chemical Corporation
Maytag Corporation
Monsanto Company
Motor Vehicle Manufacturers Association
National Association of Manufacturers
National Coal Association
National Steel Corporation
Northern States Power
Occidental Chemical Corporation
Pacific Gas & Electric Company
Peabody Holding Company, Inc.
Pennsylvania Power & Light Company
Petrochemical Energy Group
Petroleum Marketers Association of America
Phillips Petroleum Company
Portland Cement Association
PPG Industries
Process Gas Consumers Group
Public Service Indiana
Rockwell International
Rubber Manufacturers Association
Shell Oil Company
Society of the Plastics Industry, Inc.
Southern Company Services, Inc.
Texaco, Inc.
Union Carbide Corporation
UNOCAL Corporation
U.S. Chamber of Commerce
U.S. Council for Energy Awareness
U.S. Council for International Business

August 20, 1990

EXHIBIT 4



Chairman
F. SCHWAB
Porsche
1st Vice Chairman
D. MAZZA
Hyundai
2nd Vice Chairman
D. SMITH
Toyota
Secretary
D. HELPMAN
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Treasurer
J. AMESTOY
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Honda
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Isuzu
Kia
Land Rover
Mazda
Mitsubishi
Nissan
Peugeot
Porsche
Renault
Rolls-Royce
Saab
Subaru
Suzuki
Toyota
Volkswagen
Volvo

President
P. HUTCHINSON

TECH-96-29
1/18/96

TO: AIAM Technical Committee

FROM: Gregory J. Dana
Vice President and Technical Director

RE: GLOBAL CLIMATE COALITION (GCC) - Primer on
Climate Change Science - Final Draft

Enclosed is a primer on global climate change science developed by the GCC. If any members have any comments on this or other GCC documents that are mailed out, please provide me with your comments to forward to the GCC.

GJD:ljf

Mobil Oil Corporation

ENVIRONMENTAL HEALTH
AND SAFETY DEPARTMENT
P.O. BOX 1031
PRINCETON, NEW JERSEY 08543-1031

December 21, 1995

To: Members of GCC-STAC

Attached is what I hope is the final draft of the primer on global climate change science we have been working on for the past few months. It has been revised to more directly address recent statements from IPCC Working Group I and to reflect comments from John Kinsman and Howard Feldman.

We will be discussing this draft at the January 18th STAC meeting. If you are coming to that meeting, please bring any additional comments on the draft with you. If you have comments but are unable to attend the meeting, please fax them to Eric Holdsworth at the GCC office. His fax number is (202) 638-1043 or (202) 638-1032. I will be out of the office for essentially all of the time between now and the next STAC meeting.

Best wishes for the Holiday Season,



L. S. Bernstein

AIAM-050773

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Predicting Future Climate Change: A Primer

In its recently approved Summary for Policymakers for its contribution to the IPCC's Second Assessment Report, Working Group I stated:

...the balance of evidence suggests that there is a discernable human influence on global climate.

The Global Climate Coalition's Science and Technical Advisory Committee believes that the IPCC statement goes beyond what can be justified by current scientific knowledge.

This paper presents an assessment of those issues in the science of climate change which relate to the ability to predict whether human emissions of greenhouse gases have had an effect on current climate or will have a significant impact on future climate. It is a primer on these issues, not an exhaustive analysis. Complex issues have been simplified, hopefully without any loss of accuracy. Also, since it is a primer, it uses the terminology which has become popular in the climate change debate, even in those cases where the popular terminology is not technically accurate.

Introduction and Summary

Since the beginning of the industrial revolution, human activities have increased the atmospheric concentration of CO₂ by more than 25%. Atmospheric concentrations of other greenhouse gases have also risen. Over the past 120 years, global average temperature has risen by 0.3 - 0.6°C. Since the Greenhouse Effect can be used to relate atmospheric concentration of greenhouse gases to global average temperature, claims have been made that at least part of the temperature rise experienced to date is due to human activities, and that the projected future increases in atmospheric concentrations of greenhouse gases (as the result of human activities) will lead to even larger increases in future temperature. Additionally, it is claimed that these increases in temperature will lead to an array of climate changes (rainfall patterns, storm frequency and intensity, etc.) that could have severe environmental and economic impacts.

This primer addresses the following questions concerning climate change:

- 1) Can human activities affect climate?

The scientific basis for the Greenhouse Effect and the potential impact of human emissions of greenhouse gases such as CO₂ on climate is well established and cannot be denied.

- 2) Can future climate be accurately predicted?

The climate models which are being used to predict the increases in temperature which might occur with increased atmospheric concentrations of greenhouse gases are limited at present both by incomplete scientific understanding of the factors which affect climate and

APPROVAL DRAFT

by inadequate computational power. Improvements in both are likely, and in the next decade it may be possible to make fairly accurate statements about the impact that increased greenhouse gas concentrations could have on climate. However, these improvements may still not translate into an ability to predict future climate for at least two reasons:

- limited understanding of the natural variability of climate, and
- inability to predict future atmospheric concentrations of greenhouse gases.

The smaller the geographic area considered, the poorer the quality of climate prediction. This is a critical limitation in our ability to predict the impacts of climate change, most of which would result from changes in a local or regional area.

- 3) Have human activities over the last 120 years affected climate, i.e. has the change been greater than natural variability?

Given the limitations of climate models and other information on this question, current claims that a human impact on climate has already been detected, are unjustified. However, assessment of whether human activities have already affected climate may be possible when improved climate models are available. Alternatively, a large, short term change in climate consistent with model predictions could be taken as proof of a human component of climate change.

- 4) Are there alternate explanations for the climate change which has occurred over the last 120 years?

Explanations based on solar variability, anomalies in the temperature record, etc. are valid to the extent they are used to argue against a conclusion that we understand current climate or can detect a human component in the change in climate that has occurred over the past 120 years. However, these alternative hypotheses do not address what would happen if atmospheric concentrations of greenhouse gases continue to rise at projected rates.

Can Human Activities Affect Climate?

The Sun warms the Earth and is the source of energy for the climate system. However, as shown in Figure 1, the process by which this occurs is complicated. Only about half of the incoming radiation from the Sun is absorbed by the Earth's surface. About a quarter is absorbed by the atmosphere, and the remainder is reflected back into space by clouds, dust and other particulates without being absorbed, either by the surface or atmosphere.

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The energy absorbed by the Earth's surface is reradiated to space as longwave radiation. A fraction of this reradiated energy is absorbed by greenhouse gases, a phenomenon known as the Greenhouse Effect. Greenhouse gases are trace gases - such as water vapor, CO₂, methane, etc. - which have the ability to absorb longwave radiation. When a greenhouse gas molecule absorbs longwave energy, it heats up, then radiates energy in all directions, including back down to the Earth's surface. The energy radiated back to the Earth's surface by greenhouse gas molecules is the Greenhouse Effect that further warms the surface. The warmer the surface of the Earth, the more energy it reradiates. The higher the concentration of greenhouse gases, the more energy they will absorb, and the more they will warm the Earth. The average temperature of the Earth depends on the balance between these two phenomena. Naturally occurring greenhouse gases, predominantly water vapor, account for 95-97% of the current Greenhouse Effect. They raise the average temperature of Earth's surface by about 30°C. Without this natural Greenhouse Effect, the Earth would probably be uninhabitable. The science of the Greenhouse Effect is well established and can be demonstrated in the laboratory.

Human activities can affect the energy balance at the Earth's surface in three ways:

- combustion, agriculture and other human activities emit greenhouse gases and can raise their concentration in the atmosphere, which would directionally lead to warming;
- combustion emits particulates, and gases such as sulfur dioxide which form particulate matter in the atmosphere, which would directionally lead to cooling; and
- changes in land-use, such as removing forests, can change the amount of energy absorbed by the Earth's surface, the rate of water evaporation, and other parameters involved in the climate system, which could result in either warming or cooling.

These three factors create the potential for a human impact on climate. The potential for a human impact on climate is based on well-established scientific fact, and should not be denied. While, in theory, human activities have the potential to result in net cooling, a concern about 25 years ago, the current balance between greenhouse gas emissions and the emissions of particulates and particulate-formers is such that essentially all of today's concern is about net warming. However, as will be discussed below, it is still not possible to accurately predict the magnitude (if any), timing or impact of climate change as a result of the increase in greenhouse gas concentrations. Also, because of the complex, possibly chaotic, nature of the climate system, it may never be possible to accurately predict future climate or to estimate the impact of increased greenhouse gas concentrations.

The usual approach to discussing the impact of the increased atmospheric concentrations of greenhouse gases on climate is to convert them to an equivalent amount of CO₂, then discuss

APPROVAL DRAFT

the effect of some fixed increase in equivalent CO_2 . Most of the discussion is about doubled equivalent CO_2 . The conversion to equivalent CO_2 introduces a number of errors, because the effects of some greenhouse gases depend on their location in the atmosphere, but since the convention is well established, it will be used in this discussion. A more accurate approach is to refer to increased radiative forcing, which is the increase in energy radiated to the Earth's surface, taking into account all of the complexities in the physics of greenhouse gases.

Can Future Climate Be Accurately Predicted?

Climate models, called General Circulation Models (GCMs), are used to predict the change in temperature, rainfall, cloud cover and other climate parameters that would result from a change in equivalent CO_2 and sometimes aerosols. The estimates of climate parameters are then used to predict impacts of climate change, such as frequency and severity of tropical storms, effects on agriculture and biodiversity, etc. While most discussions of models focus on their predictions of changes in average temperature, factors such as changes in maximum and minimum temperature, soil moisture content, and prevalence of conditions which favor the formation of tropical storms are far more important in determining potential climate change impacts.

GCMs are three-dimensional grid models which cover the whole Earth, the atmosphere to a sufficient height to include all climate processes, and the oceans in multiple depth layers. GCMs are also referred to as coupled atmosphere-ocean climate models. Most of the debate about the prediction of climate change centers around the quality of both the models and the input data they use, and the degree to which both can be improved. The concerns about these models can be grouped into five categories:

- (1) limits in scientific understanding of climate processes,
- (2) how they model "feedbacks,"
- (3) how they describe the initial conditions, i.e., the current state of the climate,
- (4) how well we understand the natural variability of climate, including the possibility that the climate system is chaotic, and
- (5) the computational power required to accurately model climate.

A sixth concern, not directly related to GCMs, but important to the question of whether future climate can be accurately predicted, is whether future atmospheric concentrations of greenhouse gases can be accurately predicted. The problem has two components, economic and scientific. The economic question is whether we can accurately predict both the future

APPROVAL DRAFT

level of global economic activity and the technology which will be employed. Past predictions in both areas have been highly inaccurate. The scientific question is whether we understand the fate of greenhouse gases well enough to accurately predict the effect their emissions will have on atmospheric concentrations. For example, only about half of the CO₂ emitted from human activities ends up in the atmosphere. The remainder is believed to be absorbed by increased plant growth or in the oceans. Estimates of the amount of CO₂ absorbed by these two sinks are highly uncertain. There is also a great deal of scientific debate on what, if any, impact higher temperatures and related climate change will have on the rate of CO₂ absorption by plants and the ocean.

Limited Scientific Understanding of Climate Processes

Quantifying what we don't know about climate processes is an impossible task. However, the huge volume of important new findings about the processes that are critical to climate generated over the past few years make it obvious that there is a great deal more to be learned about the basic science of climate. For example, in 1995, Prof. Cess and his co-workers at the State University of New York published a paper on the energy balance around clouds which indicated that the values being used in climate models were incorrect by 25%. Cess *et al.* were unable to identify the physical processes which led to this different estimate of energy absorption. Since clouds are a critical part of the climate system, a correct characterization of their properties is essential. Other recent studies indicate that vegetation may be absorbing much more CO₂ than previously believed, allowing less of it to accumulate in the atmosphere.

Feedbacks

Climate models predict that the direct effect of doubling equivalent CO₂ from pre-industrial levels is relatively small. Global average temperature would rise by 0.5 - 1°C, an amount which is not generally considered to represent a problem. However, even that rise in temperature would cause a variety of changes, some of which would act to further increase temperature, others of which would act to decrease temperature. These secondary changes are called "feedbacks." The popular usage is that a positive feedback is one which acts to further increase temperature, and a negative feedback is one which acts to decrease temperature. The technical definition is that a positive feedback is one which exaggerates the initial perturbation, which could either increase or decrease temperature, and a negative feedback is one which decreases the initial perturbation. Since the popular usage is so common, it will be used in this paper.

The most important positive feedback is the impact which rising temperatures will have on the amount of water vapor in the atmosphere. Water vapor is the most important natural greenhouse gas in the atmosphere, accounting for the majority of the natural Greenhouse

APPROVAL DRAFT

Effect. As temperature increases, more water evaporates, the concentration of water vapor in the atmosphere rises, the Greenhouse Effect is enhanced, and temperatures rises further. An example of a negative feedback is that more evaporation of water results in the formation of more clouds. Low level clouds reflect sunlight, preventing its energy from reaching the Earth's surface, thus providing a cooling effect. As noted below, high level clouds provide a positive feedback.

Modeling feedbacks is one the major challenges in developing accurate climate models. The role of clouds is a particularly difficult modeling task. Low level clouds reflect sunlight and therefore are a negative feedback. However, clouds are made up of water vapor and therefore also absorb radiation. For high level clouds the absorption of radiation is more important than the reflection of radiation; they provide a positive feedback. Better estimates of the energy balance around clouds are becoming available, and preliminary modeling results indicate that the use of these better estimates improves the ability of GCM's to match current conditions.

Prediction of Current Conditions

GCMs are supposed to be theory-based models, not empirical models. As such they should be able to match current climate conditions using only the independent variables that determine climate (solar radiation, greenhouse gas concentrations, the current temperature of the oceans, etc.) as inputs. GCMs fail this test because they do not accurately predict the transfer of energy from the oceans to the atmosphere, a critical climate parameter. To correct this error, most GCMs are adjusted with "flux corrections," that on a point-by-point basis adjust the amount of heat being transferred from the oceans to the atmosphere to match actual conditions. The "flux corrections" can be quite large, as much as 10 - 20 times the effect of doubling equivalent CO₂. Having to make this large a correction to obtain model results which provide a reasonable description of the baseline is a cause for serious concern.

Flux corrections are correcting for one of two possible errors: missing climate processes, or errors in the description of the climate processes used in the model. New data, such as a better description of the energy balance around clouds, should lead to improvements in models and a reduction in the flux corrections.

Whether modeling capability will improve to the point where the flux corrections can be eliminated or reduced to a more reasonable level is an open question. To eliminate the flux corrections it is necessary to accurately model all climate processes and have an accurate description of initial conditions. Distribution of heat in the oceans is poorly understood, and the cost of collecting the necessary data makes it unlikely that a better understanding will be developed anytime soon.

Natural Variability and the Possibility that Climate is Chaotic

APPROVAL DRAFT

Thus far, GCMs have been described as relatively mechanical models - plug in the right processes and initial conditions and the model will describe climate. However, climate has natural variability, on both long and short time scales. The existence of Ice Ages and the warm periods between them is proof of climate's natural variability on very long time scales. But climate is also naturally variable on shorter time scales. For example, the milder temperatures in the North Atlantic at about 1000 AD allowed the Vikings to settle Iceland and Greenland, and explore the North American coast. The colder temperatures of the Little Ice Age after 1400 wiped out the Viking settlement in Greenland and nearly did the same to Iceland. This was climate variability on a time scale of several centuries. To accurately model future climate, we need an good estimate of the natural variability of climate on still shorter periods, decades to a century, which is currently unavailable.

Understanding the natural variability of climate on a decadal time scale and its causes would greatly improve our understanding of current climate data. Reasonable temperature records exist for only the last 120 years. Data on factors which could be causes for the variability of climate, such as changes in ocean circulation, is either non-existent or available for much shorter time periods. Until we have a better understanding of natural variability, it will be impossible to determine whether a part of the rise in average temperature experienced over the past century is due to human activities.

In addition, climate may be a chaotic system, which is extremely sensitive to very small changes in initial conditions. Weather is known to be chaotic, and since climate is the long-term average of weather, it, too, may be chaotic. In discussing the ability of GCMs to simulate climate, IPCC WG I, in section 6.2.6 of its Second Assessment Report, does not use the term chaotic, but states

The models produce a high level of internal variability, as observed (Chapter 5), leading to a spread of possible outcomes for a given scenario, especially at the regional level.

This is a functional definition of chaotic behavior. The reference to Chapter 5 is to a discussion of the ability of models to describe observed climate over the last 120 years. If climate is chaotic, our ability to predict future climate or the effect of anthropogenic changes such as the increase in greenhouse gas emissions will be limited.

Computational Limits

GCMs are huge models which require supercomputers to run in any reasonable time. Computational limitations require that they use large grid sizes, typically 500 km. on a side. These cells are larger than many of the important physical features in the system they are trying to model, for example, the width of the Gulf Stream. Computational limits also mean

APPROVAL DRAFT

that some critical factors, such as the atmospheric interactions between greenhouse gases and the chemistry of aerosol formation, are not included in the model. The rapid increase in computational power may make it possible to overcome these limitations in the future, but at present they severely limit the quality of GCM predictions.

Capabilities of GCMs

Even with flux corrections, GCMs still cannot describe climate features on a 1000 mile scale which are critical to any discussion of the impacts of climate change. Also, there is considerable concern about the ability of GCMs to predict future climate because the flux correction is constant with changing equivalent CO₂. There is no reason to assume that the flux correction should remain the same if climate changes in response to increased CO₂. As a result, statements such as: "Doubling CO₂ will lead to x°C. increase in temperature." do not seem justified.

While climate models currently are incapable of accurate predictions of future climate, rapid improvement in their capability is possible. Better understanding of climate processes, such as the role of clouds, could significantly improve the models as could the ever increasing power of computers. Whether we can ever accurately predict future climate is still uncertain because of two problems. First, as mentioned above, climate may be chaotic. Second, even if climate is not chaotic, a model's predictions are only as good as the input data used. Our ability to predict future greenhouse gas emission rates depends on being able to predict the future level of global economic activity and the technology which will be used to generate that activity. Past predictions in both areas have been highly inaccurate.

A critical problem in climate modeling is the prediction of regional climate change. Most of the impacts of climate change will be felt on the regional or local level. The change in global average temperature and rainfall will not help predict the effect of climate change on farmers in the mid-West. The ability to predict regional climate change is poorer than the ability to predict global climate change. The IPCC sums up the situation as follows:

Confidence is higher in hemispheric-to-continental scale projections of coupled atmospheric-ocean models than in the regional projections, where confidence remains low.

Have Human Activities Over the Last 120 Years Affected Climate?

As part of its contribution to the IPCC (Intergovernmental Panel on Climate Change, the UN body charged with assessing the peer-reviewed literature on the science, impacts and economics of climate change) Second Assessment Report, WG I (Working Group I, the sub-group assessing science), after considering the uncertainties in the scientific information,

APPROVAL DRAFT

concluded:

Nevertheless, the balance of evidence suggests that there is a discernable human influence on global climate.

This statement is stronger than those which appeared in the draft of the underlying report, where the authors stated:

Any claims of positive detection and attribution of significant climate change are likely to remain controversial until uncertainties in the total natural variability of (the) total climate system are reduced.

As used by the IPCC,

"Detection of change" is the process of demonstrating that an observed change in climate is highly unusual in a statistical sense, but does not provide a reason for the change. "Attribution" is the process of establishing cause and effect relations, including the testing of competing hypotheses.

At the conclusion of the WG I Plenary Session that approved the statement on a human impact on climate, the authors of the underlying report were instructed to modify their report to bring it into agreement with the summary statement. This process is the reverse of what is called for by the IPCC rules of procedure and normal scientific practice.

WG I considered four types of information in evaluating whether the observed change in climate was in fact "highly unusual in a statistical sense," and whether it could be attributed to human influences. A discussion of each type of information follows. Specific scientific studies are mentioned in three cases; they are the studies which have received the most publicity, but are not the only studies in the category.

- 1) Model-based estimates of natural variability - The Max Planck Institute (MPI), a German government laboratory and developer of one of the GCMs, ran their model for 1000 years into the future with only random perturbations to assess "natural" variability of temperature. They then determined, with 95% confidence, that the changes in temperature observed over the last 100 years could not be explained by their measure of "natural" variability. German politicians and press have reported this result as meaning that there is 95% confidence that the temperature changes of the last 100 years have been caused by human emissions of greenhouse gases, a significant overstatement of the scientific finding.

The MPI finding does not prove that the temperature changes of the last 100 years are

APPROVAL DRAFT

due to human greenhouse gas emissions for two reasons:

- o Models are simplifications and therefore less variable than the real world. Actual "natural" variability of temperature is almost certain to be larger than the estimate from the MPI computer study.
- o The temperature change of the past 100 years may be due to natural changes in climate. Changes of this magnitude have occurred naturally in the past without any human influence. Section 3.6.3 of IPCC WG I's contribution to the Second Assessment Report states:

"The warming of the late 20th century appears to be rapid, when viewed in the context of the last millennium. But have similar, rapid changes occurred in the past? That is, are such changes a part of the natural climate variability? Large and rapid changes did occur during the last ice age and in the transition toward the present Holocene period which started about 10,000 years ago. Those changes may have occurred on the time scale of a human life or less, at least in the North Atlantic, where they are best documented. Many climate variables were affected: atmospheric temperature and circ, precipitin patterns and hydrological cycle, temperature and circulation of the ocean."

- 2) Pattern-based studies - The Hadley Centre, a U.K. government laboratory and the developer of another GCM, has added sulfate aerosol effects to its model and calculated temperature from 1860 to 2050. The addition of aerosol effects provides an improved, but still relatively poor, match for observed temperature from 1860 to the present, and addresses one of the key concerns about climate models, their inability to "backcast" the temperature record. The study ties the increase in temperature over the past 100 years to emissions of greenhouse gases and aerosols.

There are two concerns about the Hadley Centre's work:

- o They considered only the direct effect of sulfate aerosols, i.e., their scattering of incoming sunlight. They did not consider the indirect effects of the aerosols - their impact on cloud formation - which could have an equally large impact on temperature.
- o Adding historical sulfate aerosol effects to the model requires a large number of assumptions about fuel usage rates and emission factors which cannot be tested. The validity of this approach is suspect.

APPROVAL DRAFT

The draft IPCC report discussed the Hadley Centre study and similar work and concluded:

While some of the pattern-based studies discussed here have claimed detection of a significant climate change, no study to date has positively attributed all or part of that change to anthropogenic causes. Nor has any study quantified the magnitude of a greenhouse gas effect or aerosol effect in the observed data ...

This statement may also change as a result of the instructions given to authors to bring their report into agreement with the summary statement.

- 3) Studies of the vertical temperature profile of the atmosphere - Climate models predict that an increase in greenhouse gases should lead to a warmer troposphere but a cooler lower stratosphere. The fact that this pattern has been observed is being used to argue for the fundamental correctness of climate models and for the validity of their predictions that human emissions of greenhouse gases will cause changes in climate. However, the effect may be due to stratospheric ozone depletion rather than to the buildup of greenhouse gases in the troposphere. IPCC WG I's part of the Second Assessment Report (Section 8.4.2.1) cites two studies which could be interpreted as supporting this conclusion. If stratospheric ozone depletion is the cause it is "a human forcing of climate" but a different one from the buildup of greenhouse gases in the troposphere. Model agreement with the stratospheric ozone effect does not "prove" that the model is correct in predicting the effects of greenhouse gases in the troposphere.
- 4) Statistical models fitted to observations - T. R. Karl and three other researchers at National Climatic Data Center (NCDC) evaluated U.S. climate data since 1910 using an index of specific weather events which included: above normal minimum temperatures, above normal precipitation from October to April, below normal precipitation from May to September, and a greater than normal proportion of precipitation coming from heavy rainfalls. These are the types of climate "signature" that many scientists believe will be the first indication of climate change. Karl *et al.* concluded that there is a 90 - 95% probability that climate in the U.S. since 1976 has been affected by the increase in greenhouse gases in the atmosphere.

MIT researchers question the choice of factors included in the NCDC index, since the index is strictly empirical and has not been developed from basic principles. However, the parameters in the index are variables which other researchers have claimed could change as the result of climate change. As in the case of the other studies claiming to show that there has already been a human impact on climate, one can question whether the observed changes are the result of greenhouse gases or other climate influences.

APPROVAL DRAFT

The limitations which prevent climate models from accurately predicting future climate also limit their ability to assess whether a human impact on climate has already occurred. Claims that human activities have already impacted climate are currently unjustified. However, the improvements in climate models could make an assessment of human impacts on climate possible. Alternatively, a sufficiently large, short term change in climate consistent with model predictions could be used as proof of a human impact on climate.

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Are There Alternate Explanations for the Climate Change Which Has Occurred Over the Last 120 Years?

Several arguments have been put forward attempting to challenge the conventional view of greenhouse gas-induced climate change. These are generally referred to as "contrarian" theories. This section summarizes these theories and the counter-arguments presented against them.

Solar Variability

Contrarian Theory

Solar radiation is the driver for the climate system. Any change in the intensity of the solar radiation reaching the Earth will affect temperature and other climate parameters. Dr Robert Jastrow, Director of the Mt. Wilson Observatory, and others have shown a close correlation between various sun spot parameters, which they believe are a measure of solar intensity, and global average temperature for the past 120 years, the period for which reasonable quality data exist for both sun spots and global average temperature. The correlation has been pushed back to about 1700 using less accurate data for both temperature and sun spots. In addition, observations of Sun-like stars indicate that they show the amount of variability in radiation intensity needed to account for recent changes in the Earth's climate.

More recently, Tinsley and Heelis at the Univ. of Texas have proposed a mechanism by which changes in solar activity can impact on climate in by a mechanism other than the direct change in the intensity of solar radiation impacting on the Earth's atmosphere.

Counter-arguments

Direct measures of the intensity of solar radiation over the past 15 years indicate a maximum variability of less than 0.1%, sufficient to account for no more than 0.1°C temperature change. This period of direct measurement included one complete 11 year sun spot cycle, which allowed the development of a correlation between solar intensity and the fraction of the Sun's surface covered by sun spots. Applying this correlation to sun spot data for the past 120 years indicates a maximum variability on solar intensity of 0.1%, corresponding to a maximum temperature change of 0.1°C, one-fifth of the temperature change observed during that period.

If solar variability has accounted for 0.1°C temperature increase in the last 120 years, it is an interesting finding, but it does not allay concerns about future warming which could result from greenhouse gas emissions. Whatever contribution solar variability makes to climate change should be additive to the effect of greenhouse gas emissions.

The Tinsley and Heelis proposed mechanism may revive the debate about the role of solar variability. To date it has not entered the climate change debate.

APPROVAL DRAFT

Role of Water Vapor

Contrarian Theory

In 1990, Prof. Richard Lindzen of MIT argued that the models which were being used to predict greenhouse warming were incorrect because they predicted an increase in water vapor at all levels of the troposphere. Since water vapor is a greenhouse gas, the models predict warming at all levels of the troposphere. However, warming should create convective turbulence, which would lead to more condensation of water vapor (i.e. more rain) and both drying and cooling of the troposphere above 5 km. This negative feedback would act as a "thermostat" keeping temperatures from rising significantly.

Counter-arguments

Lindzen's 1990 theory predicted that warmer conditions at the surface would lead to cooler, drier conditions at the top of the troposphere. Studies of the behavior of the troposphere in the tropics fail to find the cooling and drying Lindzen predicted. More recent publications have indicated the possibility that Lindzen's hypothesis may be correct, but the evidence is still weak. While Lindzen remains a critic of climate modeling efforts, his latest publications do not include the convective turbulence argument.

APPROVAL DRAFT

Anomalies in the Temperature Record

Contrarian Argument

The temperature record of the last 120 years cannot be explained by greenhouse gas emissions, which rose steadily through that period. If greenhouse gases were the explanation for recent climate, one would have expected temperature also to have risen steadily through the period. However, temperature rose from 1870 to 1930, then leveled off to 1940, dropped between 1940 and 1970, and has been rising since 1970.

Satellite measurements covering over 98% of the globe indicate that global average temperature has decreased slightly over the past 15 years, during a time when land-based temperature measurements indicated a series of record high temperatures.

Counter-arguments

While atmospheric concentrations of greenhouse gases have risen steadily since 1870, their total increase has been too small for greenhouse warming to be distinguishable above the cooling effect of aerosols and the variability caused by all of the other factors which affect climate (volcanic eruptions, solar variability, random variability possibly due to the chaotic nature of climate, etc.). This does not mean that a further increase in greenhouse gas concentrations will not add to measurable warming.

Satellites measure the average temperature of a column of air from the surface to about 6 km. above the surface, while the land-based measurements are surface measurements. Also, the land-based measurements are for land only. The oceans, which cover 70% of the Earth's surface, are not included. The oceans would be expected to warm more slowly than the land surface, lowering global average temperature.

While raw data from the satellite measurements indicate a cooling of $0.06^{\circ}\text{C}/\text{decade}$, correcting the raw data for known effects (volcanos and periodic warming of the Eastern tropical Pacific Ocean as part of the El Nino cycle), yields $0.09^{\circ}\text{C}/\text{decade}$ warming. The corrected satellite measurements still do not agree with the land-based temperature record, but they both show warming.

APPROVAL DRAFT

Detailed temperature records do not agree with predictions about greenhouse warming. Prof. Patrick Michaels of the University of Virginia presented a series of hypotheses about how greenhouse warming should affect temperature. Only two will be discussed in detail.

First, if greenhouse gases were responsible for the increase in global average temperature, one would expect daytime maximum temperatures to increase. What is actually happening is that daytime maximum temperatures are staying constant, while nighttime temperatures are increasing. Michaels argues that the increase in nighttime temperatures is due to the urban heat island effect.

Second, one would also expect Northern Hemisphere temperatures to have increased more than Southern Hemisphere temperatures, since greenhouse gas concentrations are higher in the Northern Hemisphere. However, Southern Hemisphere temperatures have increased more than Northern Hemisphere temperatures. Michaels argues that the smaller increase in the Northern Hemisphere is due to cooling by aerosols, a position which is now becoming generally accepted.

While some scientist argue that greenhouse warming has already occurred, most say that it cannot be separated from all of the other factors affecting climate, including the urban heat island effect and aerosol cooling. Thus, the fact that the recent temperature record does not agree in detail with a greenhouse gas warming scenario does not diminish the potential threat from substantially higher atmospheric concentrations of greenhouse gases.

Conclusions about the Contrarian Theories

The contrarian theories raise interesting questions about our total understanding of climate processes, but they do not offer convincing arguments against the conventional model of greenhouse gas emission-induced climate change. Jastrow's hypothesis about the role of solar variability and Michaels' questions about the temperature record are not convincing arguments against any conclusion that we are currently experiencing warming as the result of greenhouse gas emissions. However, neither solar variability nor anomalies in the temperature record offer a mechanism for off-setting the much larger rise in temperature which might occur if the

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atmospheric concentration of greenhouse gases were to double or quadruple.

Lindzen's hypothesis that any warming would create more rain which would cool and dry the upper troposphere did offer a mechanism for balancing the effect of increased greenhouse gases. However, the data supporting this hypothesis is weak, and even Lindzen has stopped presenting it as an alternative to the conventional model of climate change.

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