A Guide to Expert Testimony for Climate Scientists

by
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I wrote this Guide especially for the purposes of the Expert Witness Training Academy ("EWTA"); it is divided into three parts. Part I provides concise summary—everything a well-educated scientist should know about the use of expert witnesses in legal and legislative situations, and everything you need to play your role in the EWTA, whether as an expert witness or as a lawyer. Part II-A contains a concise description of the leading standards for scientific expert testimony. Thus, pages 1-16, with bullet points to help you prepare efficiently, is the only required reading in this Guide.

Part II-B, which is optional reading, digs a bit deeper, to provide additional context about the most important modern issues and controversies about the use of experts, especially in the context of scientific evidence. Part III includes the most important legal authority (rules of evidence and case law) pertaining to experts. Where I have provided a citation to legal authority, you will find that legal authority in Part III.

To summarize, Part I will help orient you, guide you, and provide a quick review when you need it. Part II will provide greater depth so that you understand what is at stake for the lawyers, judges, and other decision-makers who will use your research and testimony in controversial legal settings. Part III provides the primary legal authorities for you should you wish to explore them.

Part I: Nuts and Bolts of Expert Evidence Law

When Does the Legal System Rely on Expert Witnesses?

The American legal system often relies on expert witnesses to help those persons designated by the law, or by other authority, as "finders of fact." The paradigm of the "finder of fact" is the American jury. In contrast, judges are generally limited to making legal rulings and instructing the jury on the law. There are times, however, when a judge serves as a "finder of fact"—when, for example, the parties do not have a right to a jury trial or when they waive that right.

Expert testimony is not automatically allowed in all legal contexts. In the courtroom, and frequently in other legal situations, the key requirement is whether the scientific, technical, or other specialized knowledge will assist a non-expert "finder of fact" in determining disputed factual issues, or public policy issues resting on disputed facts. Fed. R. Evid. 702. The idea behind this rule is that where the subject of the testimony is something an ordinary juror could

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understand, we do not want an expert's opinions to replace or impinge on the exercise of the common sense of the typical juror.

The most common setting for expert testimony is in a courtroom at a trial, in which a jury or a judge (when the judge is serving as "the trier of fact," which is a legal term of art) makes the factual decision. But an expert may also be called to testify at an arbitration, in which the parties have agreed to have one or more designated individuals—who may or may not be lawyers or judges—decide the dispute. Or, an expert may be asked to testify in an administrative proceeding (such as an environmental agency hearing) or at a legislative hearing. The common denominator for all of these situations is that one or more individuals must make a decision about the facts under conditions of uncertainty—and need an expert's knowledge, research, and opinions to help inform their judgment.

In a courtroom, experts may be asked to testify by one party. When that party presents its expert's testimony, it does so through "direct examination," a question-and-answer style of presentation familiar to anyone who watches television or movies! The "direct examination" of an expert witness will be followed by the "cross-examination" (more Q and A) by the opposing party, in which the opposing lawyer tries to show that the expert is not worthy of belief because of weaknesses in the expert's credentials, omissions in the expert's data, errors in the expert's research techniques, or any other problem with the expert's testimony. The main difference in direct examination and cross-examination, from an expert witness's point-of-view, is that cross-examination questions will be leading questions—questions framed so that they suggest their own answer, and the witness is forced to answer only "yes" or "no."

What are the Purposes of Expert Testimony?

Expert testimony can serve several purposes, whether presented at an administrative or legislative hearing, arbitration, pre-trial hearing, or trial. Experts may do one or more of the following:

- Provide the decision-maker (legislator, arbitrator, judge, or jury) with factual information and background to provide the decision-maker with an adequate context for the decision.
- Apply expert knowledge to the facts of a case and render an opinion about the facts, such as whether certain conditions actually caused an effect.
- Explain scientific principles and theories to the decision-maker.
- Explain testing procedures used as a basis for the expert's opinion.
- Extrapolate from the actual facts or hypothetical facts and rendering an opinion regarding the likelihood of an event or occurrence. Experts may speculate on events or occurrences because of their special knowledge or training.
- Provide an opinion that contradicts or undermines the opinions or conclusions of an expert who testified for the opposing party.

Who Does the Law Consider to Be Expert?

A person who has specialized knowledge gained by education, research, training, experience, or skill may be qualified as an expert. Fed. R. Evid. 702. In a trial context, the judge decides—as a preliminary issue, outside the hearing of the jury—whether an individual is sufficiently qualified to provide expert testimony. If a judge decides that an individual is not sufficiently qualified to render an expert opinion in a case, or if the judge decides that the individual might be an expert, but that the expert's testimony will not be based on sufficiently reliable data or methods, the judge can refuse to allow the expert to testify. As discussed more in Part Two of this Guide, the trial judge has extremely broad power in making this decision—it is rare that an appellate court will reverse this decision. So if expert testimony is challenged, the parties must make their best arguments—and the expert must make the best case for his or her work—in front of the trial judge.

If a judge decides to allow the expert to testify, or the parties agree (or "stipulate") that the person is an expert, the expert's qualifications and experience continue to be important information for the "trier of fact" to use in evaluating the expert's credibility, especially when there are conflicting expert opinions about the issue in dispute.

Thus, even though the expert's credentials may be extensively examined and tested in front of a judge in a pretrial evidentiary hearing (called a "*Daubert* hearing" in federal court, and a "motion *in limine*" in state court—these are discussed further below and in Part II), the parties will present those impressive expert credentials again during direct-examination—and those credentials will be challenged (again) on cross-examination. Put another way, the judge must decide, as a matter of evidence law, whether the expert can testify to a particular opinion. However, even if the judge allows the expert testimony, it is up to the trier of fact (the jury or, sometimes the judge) to weigh the pros and cons of the testimony, and decide whether to believe and use the expert's opinion as a basis for decision.

What are the Legally Permissible Bases of an Expert Opinion or Conclusion?

This question captures the special status of an expert witness in contrast to ordinary witnesses. In general, non-expert witnesses may only testify on facts or matters within their first-hand knowledge: what the witness saw, heard, smelled, touched, or tasted. Fed. R. Evid. 701. A non-expert witness (sometimes called a "lay" witness) can only testify in the form of an opinion or conclusion if the testimony is based on that first-hand knowledge and cannot be described in a more precise way. Fed. R. Evid. 701. For example, a lay witness may want to testify that she heard a "loud" noise. That statement that the noise was "loud" is technically a conclusion or opinion. However, where the party offering the testimony can show that (1) the witness was in a position to hear a noise, and (2) the witness cannot communicate in any more precise way (such as how many decibels the noise registered), the witness may be permitted to testify in the form of her conclusion that the noise was "loud." Fed. R. Evid. 701.

Expert witnesses may also use first-hand or personal knowledge of the facts acquired before or at the hearing, as a basis for their testimony. However, unlike lay witnesses, experts may use much wider range of information as the basis for their testimony, including:

- Information obtained from other experts, documents, records, files, witnesses, and other sources, prior to or during the hearing or trial;
- Evidence, including testimony, heard by or reported to the expert during the case;
- Evidence that otherwise satisfies the legal standards of the jurisdiction (more about this below).

However, experts may be limited in what they can tell the decision-maker about the basis of their opinion or conclusion. Sometimes, in forming an opinion, an expert researches and evaluates materials other than those produced by the expert him or herself, such as the research of other experts in the relevant field. Under some evidence rules, the expert may not be allowed, initially, to tell the jury about this extra research, because its original source is not on the witness stand, subject to cross-examination (so the expert's outside research would be called "hearsay"). Fed. R. Evid. 703.

If you think about it, this evidence rule makes some sense—if one courtroom expert can just echo the research of other experts who are not present, the party presenting the one courtroom expert can save a lot of money in expert witness fees! But if the opposing party's attorney starts to question (on cross-examination) the grounds for the in-court expert's opinion or conclusions, then the expert can defend his or her opinion by talking about the other research relied upon. This is why attorneys must pay close attention to the questions they ask their experts on "direct" examination as well as the questions they ask opposing experts on "cross-examination." You may be asked to help the attorney craft the right questions at the right time to bring out the strength of your opinions and conclusions, and to help show the problems in a different expert's testimony.

What is the Controlling Law Regarding the Use of Expert Witnesses?

The law of expert witnesses depends on where the legal dispute is to be resolved. As a preliminary matter, is the dispute in federal court or a state court? If the dispute being heard in a state court, which one of the 50 states? Each of the 50 states and the federal system are separate legal jurisdictions, with their own specific rules of evidence and body of judicial rulings regulating the qualifications of experts and limitations on expert testimony.

Fortunately, over half of the states tend to pattern their own evidence rules after those followed by the federal courts—the Federal Rules of Evidence—so one can group the different approaches into a few different "schools" or approaches to scientific expert testimony. These different approaches are discussed in more detail in Part Two of this manual.

How Does an Attorney Prepare to Question an Expert Witness?

There are several ways to prepare to examine an expert witness, depending on whether the expert will testify on behalf of an attorney's client, or is an opposing expert witness. If the attorney has hired an expert witness to testify on behalf of a client, the attorney may work with that expert to develop his or her testimony into the question and answer format of direct

examination. However, the attorney might also hire an expert who is not going to testify at the trial to help the attorney prepare for trial. This attorney does this because the non-testifying expert can work confidentially along with the attorney and the client—the client's opposition generally cannot question this non-testifying expert, so the attorney and client can be more candid with the non-testifying expert about the strengths and weaknesses of the case without worrying that the other side will discover this information.

The expert who is going to testify at a civil trial must generally prepare an "expert report" as part of the pretrial discovery process. The exact content of the expert's report depends on the rules of the jurisdiction, but in general, this expert report will contain information about the expert's credentials and experience, as well as a summary of the opinions and conclusions of the expert along with the bases of those opinions and conclusions. For this EWTA exercise, you have been provided with the experts' reports, as well as their C.V.s—these will be the main materials you will use to prepare to question the experts (in the role of an attorney) and to play the role of the experts.

An attorney would also likely depose the other side's expert witnesses in an attempt to get more detail about whether the expert is truly qualified to testify at trial, and to prepare to cross-examine the expert if the expert is permitted to testify at trial. If an attorney can show that the expert is not qualified to testify, or has used unreliable methods or has unreliable conclusions, the attorney may want to bring a pretrial motion to prevent the expert from testifying at all. In a deposition, the attorney will try to be exhaustive—pinning down all the bases and supporting materials for the experts' opinions so that if the expert changes his or her testimony at trial, the attorney can confront the expert with his or her inconsistency. Finally, in the deposition, the attorney has a chance to challenge the expert and see how credible and calm the expert can be under the pressure of questioning.

If I am Assigned the Role of an Attorney During the EWTA Exercise, What Should I Ask the Expert Witness about During a Deposition or a Direct Examination? (And, if I am Assigned the Role of the Expert Witness in a Deposition or Direct Examination, What Should I Be Prepared to Answer?)

We will discuss this more in briefings on the topics of depositions and direct examinations, but in general, the "attorney" taking a deposition or doing the direct examination should be prepared to ask the following kinds of questions (and the "expert" should be prepared to answer them):

- The qualifications and experience of the expert.
- The opinions and conclusions of the expert.
- Explanation of each opinions and conclusion.
- The bases of each opinion and conclusion of the expert (such as the general theories or principles as well as facts that support an opinion or conclusion).
- The sources of information relied upon by the expert.
- Standard tests or routine procedures used to generate the opinion or conclusion.
- Special tests or procedures used to generate the opinion or conclusion.

The main difference between the questions asked during a deposition and the questions asked on direct examination is that the questions asked on direct examination are structured carefully in advance so that the party can communicate its expert's story in a compelling way. In a deposition, the opposing side has prepared questions for the expert in advance, but asks the questions in a more free-flowing manner, trying to discover what the expert really knows, and what the weak points may be in the expert's conclusions or underlying sources, methods or data.

If I am Assigned the Role of an Opposing Attorney During the EWTA Exercise, What Should I Ask the Expert About During Cross-Examination? (And, if I am Assigned the Role of the Expert Witness, What Should I be Ready to Discuss?)

In a pre-trial evidentiary hearing (such as a *Daubert* motion), an arbitration, or a trial, the side opposing the expert witness is given a chance to question the expert to test whether the expert is truly qualified, and can provide reliable opinions and conclusions. This process of "testing" or "challenging" the expert witness is generally called "cross-examination."

If you are assigned to cross-examine an expert, you should prepare questions that test and challenge the witness on the following subjects (if you play the expert, you should be ready to answer questions on these topics):

- Lack of proper qualifications, credentials, or experience for the subject of the testimony;
- Whether the expert is a "professional expert," who makes a substantial part of his or her living from testifying as an expert instead of doing non-litigation research.
- Existence of a financial interest in the subject of the testimony or the testing procedures that lead to the opinions or conclusions;
- Other biases or prejudices (is the expert a friend, a disgruntled past or current employee, or past business associate of a party?);
- Unreliable sources of information;
- Insufficient facts or data;
- Lack of thoroughness in investigating the facts or data;
- Insufficient testing of the facts or data;
- Lack of validity and reliability in testing of facts or data;
- Existence of other causes or explanations for conclusions or outcomes;
- Show differences of opinion among experts;
- Ask for different outcomes or opinions if the facts or assumptions are those of the opposing side, rather than the facts or assumptions the expert's lawyer gave the expert.

In the EWTA, we will spend a fair amount of time showing you how attorneys craft questions for cross-examination, because these questions are sometimes difficult to create, which may require attorneys to consult with their experts to draft them. Moreover, cross-examination questions can be difficult or frustrating for the expert to answer because they often call for only a "yes" or "no" answer, limiting the expert's ability to control the response.

What is the Biggest Challenge for an Expert in Testifying in Legal Proceedings?

Law and science: they exist on the same planet, but are different worlds. The fields of law and science (and their subfields) have their own languages, cultures, and values. Add to this the complexity of the individuals who use law and science—the parties, the lawyers, the judges, the legislators, the arbitrators, and the scientists. It is no surprise that they have a hard time communicating with each other.

Part of the problem is the goal of different systems. In legal disputes, the parties seek a defined, final outcome. Science does not—it remains open to discovery—revisiting old theories and assumptions. Thus, law often pushes scientific experts for more definitive opinions than scientists may feel are warranted. And the craft of the lawyer is to do this pushing—both for one side and against another.

One important legal concept to understand is "the burden of proof." The most widely known (but seldom understood) burden of proof is the standard the government must meet in criminal cases: the government must prove that an individual defendant is guilty of a crime "beyond a reasonable doubt." In civil cases, the standard of proof is lower, but is still a significant hurdle for plaintiffs. The most common standard of proof in civil cases is "preponderance of the evidence." Put another way, a civil plaintiff must provide enough evidence to persuade a jury that each element of the plaintiff's legal claim "more likely than not" exists.

For example, in our EWTA negligence case, the plaintiffs must prove the defendants: (1) owed them a duty of care: (2) breached that duty of care (that the defendants acted unreasonably under the circumstances); (3) that this breach was a cause of this harm (even though there might have been other causes too); and (4) that the plaintiffs suffered damage as a result. For our case, the jury must be convinced that each of these statements or elements is "more likely than not" true.

Scientists work with different concepts of evidence and standards of proof—which are far more demanding than asking that a fact be proved "more likely than not"—which is why scientists can be reluctant to testify definitively about one variable "caused" an effect. But legal participants need to use scientific expert testimony to prove—or disprove—facts in particular cases. And thus, the tug of war between law and science continues.

What are the Ethical Obligations of the Scientific Expert Witness?

Like all other witnesses at a trial, and often at other legal proceedings (a deposition, a legislative hearing, an arbitration), the expert witness takes an oath before giving testimony; the expert must swear to tell "the truth, the whole truth, and nothing but the truth."

As the previous question suggested, however, science and the law frequently have different understandings of "truth," which sets up doctrinal and ethical conflict. Moreover, some scientists and lawyers will readily agree that no expert—or indeed scientific expert testimony—is perfectly "objective" or "neutral," in the sense of immune from the influence of human values.

Here are some of the common ethical problems of experts. Experts tend to be highly accomplished, successful individuals. They get to their distinguished positions in part because of their driven, competitive nature. The legal system, which is largely adversarial, can bring out the competitive qualities in people who might otherwise be more temperate. In other words, who doesn't want to be on the "winning" side?

The adversarial, competitive quality of legal contexts may lead some expert witnesses to give more definitive testimony than the data or research might warrant. Or, a scientist may, even unintentionally, ignore data that does not fit the explanation offered by "her" side. There are additional problems in some areas of science, where research is funded by parties who may have strong preferences for particular outcomes—such as where the testing involves their product or potential liability. As we all know, scientists are not immune from conflicts of interest.

The adversarial structure of legal communication does not always allow scientists opportunities for "full disclosure" that would mitigate some of these ethical problems. The lawyers craft questions for direct and cross-examination that aim at presenting the sharpest version of each side's story so the jury or judge will be persuaded that their side is "more likely than not" true. The lawyers have the bulk of control over what gets communicated in the courtroom. That can be ethically troubling for a scientist.

Trial judges, however, are charged with supervising the adversarial excesses. Sometimes, when the other side objects, a trial judge will step in to allow an expert to provide a more nuanced or full explanation to a question. However, many judges will not intervene on their own initiative. So if a lawyer who is offering an expert's testimony is not listening carefully as the witness is cross-examined, or the lawyer and his or her expert do not communicate with each other well, the lawyer may miss opportunities to object to the way the cross-examiner is pushing the scientist's testimony to the point of distortion. And the expert witness will sit in the witness box, fuming. The way to prevent these problems is for the expert witness and the sponsoring lawyer to work with each other to carefully prepare for both the expert's direct testimony and cross-examination.

Part II, which follows, describe attempts to winnow out unreliable scientific testimony before it even is heard by a jury.

Part II: Controversy Regarding Scientific Experts

Expert witnesses need to understand that expert testimony is the subject of much debate in American courtrooms. The use of expert testimony on scientific issues is often fiercely contested because there is so much at stake—in the case of complex civil cases, large monetary awards, and in the case of criminal prosecutions, an individual's liberty. Attitudes toward expert testimony have changed. In the past thirty years, both federal and state courts have changed their evidentiary rules for the use of scientific expert witnesses, as they attempt to balance the desire for more reliable expert testimony with the cultural demand for and constitutional requirements of the American jury trial.[2] Part of this Guide provides expert witnesses an overview of the debate and the development of case law and rules, particularly on the federal level, aimed at tightening the standards for expert testimony—especially expert opinions resting on scientific principles and data. The cases cited in this section may be found in Part III of the Guide, if you wish to read them.

In general, U.S. state and federal courts do not have separate rules of evidence for criminal and civil cases, although a few individual evidence rules may sometimes contain separate provisions for criminal and civil cases. The rules regarding expert testimony, however, treat civil and criminal cases alike—at least in theory.

The contemporary movement for the reform of expert testimony in the U.S. began in the context of complex civil litigation, especially toxic tort and products liability cases, which could ultimately be decided by a lay jury. One cannot over-emphasize the significance of this special context. Of course, jurors are not the only decision-makers who struggle with the relationship between law and science in the courtroom.[3] However, one cannot separate the issue of expert testimony reform from the topic of tort law reform, and more specifically, judicial control over jury verdicts.[4] Behind the veneer of the search for more accurate decision-making in the adversary system is strong financial motivation—a growing concern for the high cost of trying complex cases that had the potential to result in unpredictable and substantial jury verdicts.

A. The Development of Expert Testimony Rules in the United States

Sharp criticism of the use of experts in American courtrooms can be traced back to the end of the nineteenth century.[5] However, the current American rules for the admissibility of expert testimony stem from the early twentieth century, when the dominant standard for allowing expert evidence was set forth in *Frye v United States*.[6] *Frye* was a criminal case, in which the District of Columbia Circuit Court of Appeal affirmed a trial court's decision to exclude expert testimony regarding a lie detector test based on changes in systolic blood pressure. Specifically,

[2] The Sixth Amendment to the U.S .Constitution provides a right to jury trial in criminal cases. The Seventh Amendment provides a limited right to a jury trial in civil cases, stating in relevant part, that "In suits at common law . . . the right of trial by jury shall be preserved."
[3] D. Dwyer, *The Judicial Assessment of Expert Evidence*, (Cambridge: Cambridge Univ. Press 2008).
[4] M.A. Berger, "Upsetting the Balance between Adverse Interests: The Impact of the Supreme Court's Trilogy on Toxic Tort Litigation" (2001) 64 Law and Contemp. Prob. 289.
[5] T. Golan, Laws of Men and Laws of Nature: The History of Scientific Expert Testimony in England and America, (Cambridge, MA: Harvard Univ. Press, 2004) 255-256.
[6] 293 F. 1013, 1014 (D.C. Cir. 1923)

the appellate court ruled that scientific findings must "be sufficiently established to have gained general acceptance in the particular field in which it belongs."[7] The court rejected the expert's testimony because the lie detector test "ha[d] not yet gained such standing and scientific recognition among physiological and psychological authorities."[8]

Historian Tal Golan suggests that *Frye* was the first American case to separate the qualifications of an expert from the reliability of the expert's opinion. In doing so, Golan argues, the *Frye* court resurrected a much earlier debate. In 1782, a barrister of the Middle Temple, George Hardinge, argued that the court should exclude the testimony of John Smeaton, for although the witness qualified as an expert, the theory to which he proposed to testify was not established in science. Lord Mansfield, chief justice of the King's Bench, was not persuaded—he decided that once qualified as an expert, a witness could testify in the form of an opinion. If there were faults with the expert's opinion, it was up to the opposing side to expose those problems to the jury through cross-examination.[9]

Hardinge's argument, however, ultimately prevailed in America. *Frye* severed the question of the admissibility of expert testimony into two parts: (1) is the witness qualified as an expert by training, education or other experience?; and (2) is the scientific method or theory on which the expert's opinion relied adequate, so that the jury may hear testimony about it and consider it in its decision-making? As we will see further on in this section, the second question has become particularly controversial, but both questions are at the heart of any conflict about expert testimony, no matter which evidentiary "test" of legal sufficiency is used.

Frye quickly became the majority rule on the admissibility of scientific or novel expert testimony in both federal and state courts. But *Frye* did have its critics, who charged that the "general acceptance test" was overly protective, keeping relevant and reliable evidence away from the jury. Frye's critics pointed out that a new or novel theory is not inherently unreliable or irrelevant. Moreover, it was difficult to determine "general acceptance." Was a majority of scholars or scientists in a particular field required to demonstrate "general acceptance"? Or would just a substantial number who adhere to a theory be sufficient? And how was the relevant scientific or technical "field" to be defined in an era of ever-growing scientific and technical sub-specialties?[10]

In 1975, a new approach to expert testimony surfaced when Congress codified the Federal Rules of Evidence. The original version of Federal Rule of Evidence 702 set forth the basic standard for the admissibility of expert testimony:

> If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education may testify thereto in the form of an opinion or otherwise.[11]

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[7] Ibid.
[8] Ibid.
[9] Golan, note 5, 258-259.
[10] P.C. Giannelli, `The Admissibility of Novel Scientific Evidence: Frye v. United States, A Half Century Later' (1980) 80 Colum.L.Rev. 1197, 1208-1228.
[11] Fed. R. Evid. 702 (1975), superseded by amendment, 2000.

However, there was no reference to *Frye* in the text of this rule or its legislative history. In the absence of any authoritative declaration that *Frye* was dead, many federal courts continued to follow *Frye* in evaluating scientific evidence.[12] Other federal courts, however, looked to the text of Federal Rule of Evidence 702, specifically its requirement that expert testimony should "assist the trier of fact" to be admissible. This language, the courts reasoned, required the trial judge who was deciding whether to admit expert testimony resting on scientific methods to apply a flexible test of reliability that differed significantly from the "nose-counting" of acceptance by a scientific or expert community that marked the *Frye* test.[13]

The essence of this "reliability," or "relevance" test was a common sense notion: unreliable evidence cannot prove a material issue in the case. Thus, if it the evidence could not prove an issue in the case, it would not "assist the trier of fact," especially a jury. Nor would evidence that is unduly overwhelming, confusing or misleading. The relevancy test allowed a trial judge to consider the acceptance of the proffered theory or scientific method by experts in the field, but imposed an independent obligation to consider other factors as circumstantial evidence of the reliability of the evidence, such as the degree to which the method or theory has been "exposed to critical scientific scrutiny" or the non-forensic uses to which the scientific technique has been put, among other factors.[14]

Almost twenty years after the adoption of the Federal Rules of Evidence, the U.S. Supreme Court finally decided whether the *Frye* test survived the codification of the Federal Rules. In *Daubert v Merrell Dow Pharmaceuticals, Inc*.,[15] the Supreme Court responded with a resounding no—and yes. The plaintiffs Jason Daubert and Eric Schuller and their parents sued Merrell Dow Pharmaceuticals (Merrell Dow) in California state court, alleging that the children's birth defects had been caused by the mothers' ingestion of the defendant's product Bendectin, a drug prescribed to ameliorate nausea for about 17.5 million pregnant women in the United States between 1957 and 1982.[16] At the time, California was known as a jurisdiction where the court system favored jury trials,[17] and jury trials meant, at least in the rhetoric of corporate defendants, outlandish damage awards.[18] Defendant Merrell Dow responded to the plaintiffs' claims by using a procedural tool that allowed defendants with a ground of federal jurisdiction to remove the case from the state court to the federal court system.[19]

The Supreme Court held that the Federal Rules of Evidence superseded *Frye*; *Frye* was neither included in the text of the rules nor part of their legislative history.[20] But no sooner had the Supreme Court interred *Frye*'s "general acceptance" standard than it resurrected it,

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[12] EK. Cheng & AH Yoon, `Does Frye or Daubert Matter? A Study of Scientific Admissibility Standards' (2005) 91 Va. L. Rev. 471.

[13]The leading case for the "relevancy" approach is United States v Downing, 753 F.2d 1224, 1238 (3d Cir. 1985), written by Judge Edward Becker, a former trial judge who was well-regarded for his expertise in evidence law.

[14] Ibid, 1239.

[15] 509 US 579 (1993). The Daubert family pronounces its name "DOW-bert."

[16] 509 US at 587.

[17] G.S. Koppel 'The California Supreme Court Speaks Out on Summary Judgment in its Own 'Trilogy' of Decisions: Has the Celotex Era Arrived?' (2002) 42 Santa Clara L. Rev. 483, 495

[18] Ibid, 501

[19] 28 USC § 1441 (2010)

[20] 509 US 579, 587 (1993).

transfigured as one of several factors for evaluating the reliability of scientific evidence. The other factors mentioned were testability (falsification of the theory), peer review, and error rates.[21] The Supreme Court was quite clear that these four factors were neither an exhaustive list of considerations nor a checklist of items that needed to be ticked off one by one.[22] Nonetheless, post-*Daubert*, lower courts frequently treated the *Daubert* "factors" as essential ingredients for admissible expert testimony.[23]

At this point in the description of admissibility standards, it might be difficult to distinguish *Daubert*'s approach from the relevancy approach, but there is a significant difference. The Supreme Court's decision in *Daubert* was far more explicit in demanding that scientific expert testimony meet scientific standards. Specifically, the Court stated that the trial court must make a preliminary determination of "whether the reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue."[24]

The Court's reference to the concepts of scientific validity, reliability, falsifiability and error rates drew fire from Chief Justice Rehnquist, who objected to the Court roving well beyond deciding the precise question before it (whether *Frye*'s "general acceptance" test survived the codification of the Federal Rules of Evidence) to charge federal judges with the obligation to become, in his words, "amateur scientists."[25] Nonetheless, the most lasting point from *Daubert*, on which all of the Justices agreed, was its dominant metaphor: the trial judge must be a responsible "gatekeeper," keeping the jury sheltered from expert testimony by charlatans peddling "junk science."[26]

In the U.S., the *Daubert* decision is more commonly discussed as the "*Daubert* trilogy," because two significant U.S. Supreme Court cases followed the initial *Daubert* ruling, adding crucial dimensions to the *Daubert* doctrine on expert testimony. The second chapter of the *Daubert* trilogy came in *General Electric Company v. Joiner*,[27] when an electrician, who suffered from lung cancer, sued the manufacturer of polychlorinated biphenyls (PCBs) and manufacturers of electrical transformers and dielectric fluid, alleging strict liability, negligence, fraud, and battery. The trial court excluded the testimony of the electrician's experts and granted the defendants' motion for summary judgment, dismissing the case without a jury trial as a matter of law because of a lack of admissible evidence on the issue of causation. The Court of Appeals for the Eleventh Circuit reversed, holding that "[b]ecause the Federal Rules of Evidence

[21] Ibid, 593-594.
[22] Ibid, 592.
[23] D. M. Risinger, Goodbye to All That, or A Fool's Errand, by One of the Fools: How I Stopped Worrying About Court Responses to Handwriting Identification (and "Forensic Science" in General) and Learned To Love Misinterpretations of Kumho Tire v. Carmichael' 43 Tulsa L. Rev. 447, 460 (2007)(despite Daubert's direction that the four factors were illustrations, not a checklist , 'many lower courts have tried to make a code of regulations out of a caricature version of the "Daubert factors"').
[24] Daubert at 592-593.
[25] Ibid, 600-601 (Rehnquist, C.J. and Stevens, J. concurring in part and dissenting in part).
[26] Ibid, 592-593, 600 (Rehnquist, C.J. and Stevens, J. concurring in part and dissenting in part). P. W. Huber, *Galileo's Revenge: Junk Science in the Courtroom* (Basic Books, 1991) 206-09.
[27] 522 U.S.136 (1997).

governing expert testimony display a preference for admissibility, we apply a. particularly stringent standard of review to the trial judge's exclusion of expert testimony."[28]

The Supreme Court reinstated the trial court's ruling, excluding the expert opinions. The Court held that a trial judge's determinations regarding the admissibility of expert testimony should be reviewed for error by appellate courts using the "abuse of discretion" standard of appellate review.[29] The abuse of discretion standard of review is extremely deferential to the trial court's decisions, making it unlikely that an appellate court would find error in a trial court's decision to admit or reject expert opinion. The abuse of discretion standard of review is used for virtually all evidentiary rulings. Applying this standard, the appellate court will not find error unless the trial court's decision is "manifestly erroneous."[30] Put in more colloquial terms, it is not enough for a trial court to simply make a mistake—the trial court's decision must rise to the level of "abuse" of its analytical powers. It is very rare for an appellate court to reverse a trial court for "abuse of discretion." Thus, the decision of the trial court about whether to allow expert testimony opinion or whether to restrict it in some fashion is often a pivotal moment in criminal trials or civil litigation.

The final case in the *Daubert* trilogy is *Kumho Tire Company v Carmichael*,[31] in which the Supreme Court extended the trial court's gatekeeping role and the reliability standard set forth in *Daubert* to all types of expert testimony, scientific or otherwise.[32] The plaintiffs in *Kumho*, a family of eight, sued a tire manufacturer for products liability after the right rear tire of their mini-van failed, causing serious injury to all plaintiffs and the eventual death of one of the plaintiffs. The trial court rejected the proffered testimony of the plaintiffs' engineering expert that the particular tire failed due to manufacturing or design defect. As in *Daubert* and *Joiner*, the trial court also granted summary judgment against the plaintiffs, because of a lack of evidence of a product defect, an essential issue in the case. The Court of Appeals for the Eleventh Circuit reversed, holding that the trial court erred in applying the *Daubert* factors to an engineering, or technical expert.[33]

The Supreme Court reversed the Court of Appeals, holding that *Daubert*'s reliability requirement applied to all types of expert testimony. Looking to the language of Federal Rule of Evidence 702 on the admissibility of expert testimony, the Court emphasized that the rule extends 'its reliability standard to all "scientific," "technical," or "other specialized" matters within its scope', not distinguishing different kinds of expertise. The *Kumho* court also clarified an area that had confounded the lower courts since the *Daubert* decision, explaining the proper role of *Daubert*'s four-factor test: whether

(1) the theory has been or can be tested,

(2) the theory has been subjected to peer review,

(3) there are standards controlling the operation of the technique or theory, or a known or potential error rate, and

[28] 78 F.3d 524, 529 (11th Cir. 1996).
[29] 522 U.S. at 142.
[30] Ibid. at 141-142.
[31] 526 U.S.137 (1999).
[32] 526 U.S. at 141.
[33] 131 F.3d 1433 (11th Cir. 1997).

(4) general acceptance of the theory or technique.[34]

The *Kumho* court emphasized repeatedly that *Daubert*'s test was to be viewed as "flexible" and not as a definitive checklist of factors to apply in every case.[35] The Court was emphatic on this point:

> we can neither rule out, nor rule in, for all cases and for all time the applicability of the factors mentioned in *Daubert*, nor can we now do so for subsets of cases categorized by category of expert or by kind of evidence. Too much depends upon the particular circumstances of the particular case at issue.[36]

The Court observed that sometimes the *Daubert* factors might be helpful in determining reliability and sometimes not, depending on the issue at hand. To illustrate its point, the Court used an example of a trial judge analyzing an engineering expert's experience-based methodology to see if it has produced erroneous results, or enquiring whether such a method is generally accepted in the relevant engineering community. In such a case, the *Daubert* factors might be helpful to determine reliability. In contrast, the Court noted, it would not matter that an expert's work had been generally accepted by the relevant community if the discipline itself lacks reliability, such as astrology or necromancy.[37] The power, the Court declared, is in the hands of the trial court; "the trial judge must have considerable leeway in deciding in a particular case how to go about determining whether particular expert testimony is reliable."[38]

Following *Kumho*, Federal Rule of Evidence 702 was amended in 2000 to codify the *Daubert* trilogy. As amended, Rule 702 reads:

> If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.[39]

The most significant aspect of this amendment is what it did not contain. The drafters of the amendment deliberately chose not to codify the four *Daubert* reliability "factors," emphasizing, as the Supreme Court did in *Kumho*, that the factors of peer review, error rate, testability, existence and maintenance of standards and controls, and general acceptance were intended as examples of methods the courts could use to determine whether an expert's methodology and conclusions were reliable, but that these factors were not an exhaustive list, nor was it necessary that all kinds of expert testimony "pass" all four factors.[40]

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[34] Ibid. at 149.
[35] Ibid. at 150.
[36] Ibid.
[37] Ibid. at 151.
[38] Ibid.
[39] Fed. R. Evid. 702.
[40] Committee Note to Fed. R. Evid. 702.

Moreover, the drafters of the amendment pointed out that since *Daubert*, federal courts had found other factors, not mentioned in the *Daubert* trilogy, to be helpful in determining whether a particular expert's methodology and conclusions were reliable under the circumstances of the case at hand. These additional factors include: (1) whether the methodology, technique, or research was developed independent of the litigation or was developed for the purpose of providing expert testimony; (2) whether the scope of the expert's inferences are justified by the data or evidence; (3) whether the expert has considered and can explain why he or she rejects alternate explanations; (4) whether the expert is applying the same level of intellectual rigor to his or her testimony as would be the case in the expert's daily work; and (5) whether the field of expertise to which the expert belongs is known for reaching reliable conclusions.[41] The drafters of the 2000 amendment also clarified the burden of proof on the party offering expert testimony; the proponent of the expert evidence must persuade the trial judge that the expert evidence is more likely than not reliable, that is, by "a preponderance of the evidence."[42]

Finally, it is essential to stress that although this summary has focused on the development of expert testimony rules in the federal courts, each of the 50 states has its own evidence law, whether embodied in legislative statutes, rules, or case law. The Federal Rules of Evidence serve as a model code for a majority of the states, but many of them deviate from the federal rules in significant ways. For example, even though the state of Minnesota generally follows the federal rules in developing its own evidentiary rules, it may choose not to follow the Supreme Court cases interpreting the identical language in the federal rules, or may choose not to adopt the 2000 amendment codifying those cases. Indeed, Minnesota is one of several states (along with the District of Columbia, which is not a state) that still follows a variant of the *Frye v United States* "general acceptance" test.[43] These jurisdictions may be in the minority, but they include some of the most politically and economically important states, such as Arizona, California, Illinois, Maryland, New Jersey, New York, Pennsylvania, and Washington. Just over half of the states have adopted *Daubert* or a similar test, while six other states apply the *Daubert* factors with an emphasis on the "general acceptance" factor (coming from *Frye*), and the four remaining states have created their own tests, emphasizing relevancy and reliability.[44] Florida recently passed a bill to adopt the *Daubert* standard as the law governing expert witness testimony, which took effect on July 1, 2013.

See the end of this Guide for a map of the United States, showing a state-by-state comparison of *Daubert*/*Frye*/Other approaches to standards for scientific expert testimony.

Daubert/Federal Rule of Evidence 702/Motion in Limine Checklist on Scientific Expert Testimony

A lawyer who wants to challenge the admissibility of expert testimony based on scientific, technical or other source of expertise will generally bring a pretrial motion. A "motion" is a

[41] Ibid.
[42] Ibid. (quoting Bourjaily v United States, 483 U.S. 171 (1987)).
[43] A.B. Lustre, Annotation, `Post-Daubert Standards for Admissibility of Scientific and Other Expert Evidence in State Courts' (2001) 90 A.L.R. 5th 453, 454-455 .
[44] Ibid.

written presentation of evidence (which may come from the earlier deposition of the expert) and legal arguments and authorities. At the "*Daubert*" hearing (sometimes called a "motion in limine—or motion to exclude evidence), the judge will often allow direct testimony from the challenger's experts (on why the other expert is no expert or is likely to provide unreliable testimony). The lawyer representing the party whose expert is challenged will then have a chance to cross-examine the challenger's expert. Then, the challenged expert will likely give direct testimony, and be cross-examined by the challenger. The debate in these hearings is never witnessed by the jury. However, recall that sometimes the judge serves as a trier of fact—that means that the judge will decide whether he or she will consider the expert testimony in his or her own decision-making, rather than just whether a jury may hear the evidence and use it if they are persuaded by it.

Here are the factors that the parties will debate at the *Daubert* hearing or motion in limine:

- whether the theory, method, or technique has been or can be tested;
- whether the theory, method or technique has been subjected to peer review;
- whether there are standards controlling the operation of the theory, method, or technique (such as a known or potential error rate);
- whether the theory, method, or technique has been generally accepted in the relevant field (*Frye* issues);
    - How many experts subscribe to this theory, method, or technique?
    - By what kind of margin is it accepted? A supermajority (2/3 or more)? A significant consensus (40%?)? A bare majority? (51/49%)?
    - How credible are the experts that accept it? (A fringe, but large group of practitioners)?
    - Do other experts agree with this expert that the theory, method, or technique has been generally accepted? (Do you have experts to corroborate this expert's testimony that the theory, method, or technique has been generally accepted by the relevant field)?
- whether the theory, method, or technique was developed independent of the litigation or was developed for the purpose of providing expert testimony;
- whether the scope of the expert's inferences are justified by the data or evidence;
- whether the expert has considered and can explain why he or she rejects alternate explanations;
- whether the expert is applying the same level of intellectual rigor to his or her testimony as would be the case in the expert's daily work; and
- whether the field of expertise to which the expert belongs is known for reaching reliable conclusions.

B. Problems with the *Daubert* Trilogy

This subsection of the Guide digs a bit further to highlight the problems that have surfaced with the *Daubert* approach and its progeny, suggesting why some very significant states (e.g., New York, California) have rejected the *Daubert* test. The Guide outlines the broader problems with the *Daubert* approach and then explains more particular problems with expert testimony that have occurred in jurisdictions adopting *Daubert* or similar approaches. It is

important for an expert witness to understand these disputes, because the attitude of the trial judge toward *Daubert* may impact his or her willingness to allow scientific expert testimony.

The first sign of trouble following the Supreme Court's decision in *Daubert* was that both the plaintiffs and defendant claimed victory.[45] Ordinarily, this could be dismissed as a public relations strategy. However, there actually was something for both sides in the Court's opinion. The plaintiffs claimed victory, pointing to the Court's holding that Federal Rule of Evidence 702 did not codify the 'conservative' *Frye* test, which had led to the exclusion of their expert evidence at the trial court level.[46] In contrast, the defense focused on the Court's concern about 'junk science' and its direction to the trial judge to serve as 'gatekeeper' against the introduction of unreliable evidence.[47] The plaintiffs' hope that *Daubert* would prove to be a more liberal approach to the admissibility of expert testimony was soon dashed. On remand, the Court of Appeals for the Ninth Circuit, applying the new *Daubert* standard, held that the plaintiffs' evidence was inadmissible and upheld the summary judgment in favor of the defendant.[48]

The basic critique of *Daubert* is that it is unrealistic, especially given the abilities of legally-trained but not scientifically-trained judges. The argument is that trial judges are simply not equipped to apply the rigorous kind of analysis that the *Daubert* opinion envisions whenever expert testimony is at issue. The general refrain echoes Chief Justice Rehnquist's lament that federal judges are not equipped to become 'amateur scientists'.[49] According to one study of over 400 judges, the overwhelming majority of judges have no real understanding of two of the four *Daubert* criteria.[50] Specifically, while 88 percent of the judges reported that "falsifiability" is a useful guideline for assessing scientific evidence, 96% of these same judges lacked even a basic understanding of this core scientific concept.[51] Similarly, 91 percent of the judges reported that they found 'error rates' helpful, although when questioned, they had no real understanding of this basic scientific precept.[52] The "judicial incompetence" critique is not dispositive. There is no question that as the heightened responsibility to engage in 'gatekeeping' began to take root, judges in jurisdictions applying the *Daubert* factors were inundated with opportunities to 'enhance' their education in critical analysis of natural science and social science evidence. However, other critiques have had more durability.

One of the most difficult critiques is that the combination of the directive to become a "gatekeeper" of expert testimony has become an encroachment on the role of the jury. What was largely unnoticed in the immediate aftermath of the *Daubert* trilogy was the special procedural

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[45] D. L. Faigman, E. Porter & M. J. Saks. 'Check Your Crystal Ball at the Courthouse Door, Please: Exploring the Past, Understanding the Present, and Worrying About the Future of Scientific Evidence' (1994) 15 Cardozo L. Rev. 1799.1819.

[46] P.M. Barrett, 'Justices Rule Against Business in Evidence Case--Restrictive Standard for Use of Scientific Testimony in Trials Is Struck Down' Wall St. J., June 29, 1993, at p. A3 (describing it as a pro-plaintiff decision); K. Chesebro, 'Taking Daubert's "Focus" Seriously: The Methodology/Conclusion Distinction' (1994) 15 Cardozo L.Rev. 1745 (identifying himself in the author note as the lawyer for the plaintiffs the 'winning' party in Daubert).

[47] B. Black, F.J. Ayala, & C. Saffran-Brinks, 'Science and the Law in the Wake of Daubert: A New Search for Scientific Knowledge' (1994) 72 Texas L. Rev. 715.

[48] Daubert v. Merrell Dow Pharmaceuticals, Inc., 43 F.3d 1311 (9th Cir. 1995).

[49] Daubert at 600-601 (Rehnquist, C.J. and Stevens, J. concurring in part and dissenting in part).

[50] S.I. Gatowski et al., 'Asking the Gatekeepers: A National Survey of Judges on Judging Expert Evidence in a Post-Daubert World' (2001) 25 Law & Hum. Behav. 433, 443.

[51] Ibid. at 444-445.

[52] Ibid. at 445.

posture of these cases—the question of the admissibility of expert testimony was decided in the context of a motion for summary judgment (also called judgment as a matter of law), which, if granted by the trial judge, ends a civil case before it reaches a jury trial.[53] Americans are quite conflicted when it comes to the jury system. Americans treasure the jury system, so much so that the framers of the US Constitution put the right to jury trial in the document twice: once for criminal cases (in the Sixth Amendment) and once for the class of civil cases one would find " at common law" (in the Seventh Amendment). And yet, Americans commonly disparage juries, particularly in civil cases.[54]

There are studies that have suggesting that the particular standard (*Frye* or *Daubert*) chosen by a US jurisdiction is less important than the message that is sent by highlighting the need for a trial court to use its critical judgment when asked to admit expert testimony.[55] Two researchers opined that "[t]he results of this study are consistent with the theory that the power of the Supreme Court's *Daubert* decision was not so much in its formal doctrinal test, but rather in its ability to create greater awareness of the problems of junk science."[56] This might be true in terms of specific decisions about the admissibility of expert opinions—that is they would come out the same way, regardless of whether the trial court used *Frye* or *Daubert*. Nonetheless, when one considers the *Daubert* trilogy as a whole, along with other Supreme Court precedents, it is clear that the Supreme Court was signaling that it is permissible for federal courts to grant judgment as a matter of law in complex civil cases in which a dispositive issue rests on expert testimony, thus ensuring that the case would never be heard by a jury, with all the uncertainty that this might mean for the litigants.[57]

For many years it was conventional wisdom that summary judgment was inappropriate for complex civil cases. However, the willingness of federal courts to grant summary judgment changed dramatically in the late 1980s, as federal court caseloads began to grow. In 1986, the US Supreme Court responded to the concern about 'runaway juries' by reinterpreting Federal

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[53] Federal R. Civ. P. 12(b)(6), 12(c), 50, and 56 all provide a federal judge with the power to enter judgment as a matter of law. Recent scholarship has started to question the constitutionality of these procedural devices in light of the Seventh Amendment. S.A. Thomas, `The Unconstitutionality of Summary Judgment: A Status Report' (2008) 93 Iowa L. Rev. 1613; `Why Summary Judgment Is Unconstitutional' (2007) 93 Va. L. Rev. 139. In criminal cases, only the defendant may ask the court to take the case away from the jury because the prosecution has failed to provide sufficient evidence on the essential elements of a criminal charge. Fed. R. Crim. P. 29 (motion for judgment of acquittal).

[54] Huber, ibid.

[55] E.K. Cheng & A. H. Yoon, note 16, at 504 ('the findings [of our research] suggest that future attempts to improve the handling of scientific evidence in the courts could be more effective if advocates for rigorous use of scientific evidence shifted their focus away from tinkering with doctrinal tests and instead toward "softer" solutions that increase the judiciary's understanding of scientific concepts and processes. For example, reformers instead might pay greater attention to judicial education programs and help develop official literature such as the acclaimed Reference Manual on Scientific Evidence'.); P.J. Jensen, Note, 'Frye Versus Daubert: Practically the Same?' (2003) 87 Minn. L. Rev. 1579, 1581.

[56] E.K. Cheng & A.H. Yoon, note 16, at 503.

[57] Daubert has been used to take the case away from the jury, even after the jury has rendered a verdict. In Weisgram v Marley Co., 528 U.S. 440, 447-456 (2000), the Supreme Court held that Federal Rule of Civil Procedure 50 permits an appellate court to direct the entry of judgment as a matter of law if it determines that evidence was erroneously admitted at trial, and that the remaining, properly admitted evidence is insufficient to constitute a triable case. The appellate court, after Weisgram, does not have to remand the case to the trial court for a new trial; the appellate court can simply enter judgment for the defense, notwithstanding the jury verdict in the original trial.

Rule of Civil Procedure 56, the summary judgment rule, making it easier to resolve even complex cases as a matter of law, without the need for a trial.[58] However, even after the Supreme Court's substantial reform of the summary judgment rule, it was not possible to resolve many complex tort cases in cases where the issue of causation rested on conflicting expert opinion. To resolve these evidentiary conflicts as a matter of law, it would be necessary to conclude, for example, that the party with the burden of proof on the issue of causation in a tort case had failed to provide sufficient evidence that would entitle a reasonable jury to find in that party's favor. But this would require far deeper scrutiny of the expert's data, methods, and opinions than American judges had performed to date to determine whether the expert's testimony is "sufficiently reliable."

No one seriously questions that expert opinion testimony should be "sufficiently reliable" to put before a jury. Although the academic and popular literature are replete with colorful references to astrology, crystal balls, Ouija boards, phrenology and other 'junk' science, serious disputes about expert opinion testimony do not, for the most part, rest on such cartoonish methodology. In the vast majority of cases, the question whether expert testimony is sufficiently reliable to be admitted arises amidst a significant dispute about whether a particular scientific theory is sound or whether the application of that theory to the particular circumstances in the case is sound. Thus, the key part of the question is what does "sufficiently" reliable mean? As mentioned above, after the post-*Daubert* trilogy amendments to Federal Rule of Evidence 702, the answer is clear for US courts. The trial court decides the admissibility of all expert testimony under the terms of Federal Rule of Evidence Rule 104(a). Under that Rule, the proponent of the evidence has the burden of establishing that the pertinent admissibility requirements are met by a preponderance of the evidence.[59]

The problem with making the sufficient reliability of expert testimony a question solely for the judge under Rule 104(a) is that it makes easier for the judge to invade what would ordinarily be the province for the jury. One can illustrate how easy it is for the court to slide over the line—moving from its proper role in determining whether an expert's methodology, and application of that methodology, is sufficiently reliable to allow it to be used as evidence in the case at hand to the jury's role of deciding whether to find the expert's conclusions sufficiently persuasive. One example comes from the Supreme Court's decision in *General Electric Company v Joiner*.[60]

Recall that in this civil case, an electrician, who suffered from lung cancer, sued the manufacturer of polychlorinated biphenyls (PCBs) and manufacturers of electrical transformers and dielectric fluid, alleging strict liability, negligence, fraud, and battery, but the trial court excluded the plaintiff's expert testimony of the electrician's experts and granted the defendants' motion for summary judgment because of a lack of admissible evidence on the issue of

[58] Celotex Corp. v. Catrett, 477 U.S. 317 (1986); Anderson v. Liberty Lobby, Inc. 477 U.S. 242 (1986); Matsushita Electric Industrial Co. v. Zenith Radio Corp., 475 U.S. 574 (1986). Together, these cases are commonly referred to as the summary judgment 'trilogy'. Committee Note to Fed. R. Civ. P. 56 (2010).
[59] Daubert, ibid, at 592. (The question is resolved under Rule 104(a)). Bourjaily v. United States, 483 U.S. 171 (1987).
[60] 522 U.S.136 (1997).

causation. Applying a searching review of the trial court's ruling, the Court of Appeals for the Eleventh Circuit reversed:[61]

> the gatekeeping responsibility of the trial courts is not to weigh or choose between conflicting scientific opinions, or to analyze and study the science in question in order to reach its own scientific conclusions from the material in the field. Rather, it is to assure that an expert's opinions are based on relevant scientific methods, processes, and data, and not on mere speculation, and that they apply to the facts in issue. . . .
>
> Instead of viewing the bases of an expert's opinion as a whole to screen out mere speculation, the district court assessed only a portion of the studies relied upon by each of the Joiners' experts, and then excluded the testimony because it drew different conclusions from the research than did each of the experts. Ultimately, the court should satisfy itself as to the legal reliability of proffered expert testimony, leaving the jury to decide the correctness of competing expert opinions.[62]

In short, the Court of Appeals found that the trial court had "crossed the line"—usurping the role of the jury.

However, the "line" can be confusing when the ultimate procedural question is the one raised at the trial level in *Joiner*--whether the court should grant summary judgment-- judgment as a matter of law—or the case should continue to a jury trial. In the summary judgment context, where the central issue turns on the admissibility of expert opinion of causation or on some other essential issue, there are really two lines. The first consists of the trial judge's decision about whether evidence is sufficiently reliable under Daubert to be considered by the jury as a basis for its decision (i.e., admissible). Ordinarily, we think of this decision being made only at trial. However, the brilliance of *Daubert* (from a case management efficiency perspective) is that it made this a question solely for the judge under Rule 104(a),[63] meaning that it could be decided any time before trial—on paper affidavits and motions, rather than through live testimony, at the discretion of the trial judge. The second line for the judge to cross is the issue for summary judgment—whether there is enough evidence on an essential element of the plaintiffs' claim for the case to continue to trial (i.e., sufficient grounds to deny summary judgment). If the judge decides not to cross the first line--finding the evidence inadmissible because it is not sufficiently reliable—the case is likely over, because there is unlikely to be other admissible expert evidence. The trial judge can then easily cross the second line—deciding that there is insufficient evidence on an essential issue in the case (such as causation) to allow the jury to hear the case. Thus, we never reach the ultimate line: whether the jury believes the expert testimony is sufficiently credible that the plaintiffs have proved, for example, that the exposure to PCBs caused Mr. Joiner's cancer. This is why I have argued that the Daubert's greatest sin (from a US procedural constitutional perspective), especially when coupled with Joiner, is that it made it easier for the trial court to usurp the jury's role through judgment as a matter of law in a veiled and quiet manner.[64]

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[61] 78 F.3d 524, 529 (11th Cir. 1996).
[62] Ibid. at 530, 533.
[63] And codified in Fed. R. Evid. 702, as amended in 2000.
[64] E.A. Scallen & W.E. Wiethoff, 'The Ethos of Expert Witnesses: Confusing the Admissibility, Sufficiency and Credibility of Expert Testimony' (1998) 49 Hastings L.J. 1143.

If one can see how *Daubert* made the first step in this analysis possible, then one can see how Joiner (along with the summary judgment trilogy) created the second step to closing the courthouse doors to plaintiffs in complex civil cases. *Joiner* was an essential step, because it prevented appellate review of trial court summary judgment decisions resting on expert evidentiary rulings. The Court of Appeals in *Joiner* set forth the standard rules for appellate review of a summary judgment. A trial court can grant summary judgment 'when there is no genuine issue of material fact, and the moving party is entitled to judgment as a matter of law.' The party seeking summary judgment (here, the defense) 'bears the burden of showing that there is no issue of material fact'.[65] Finally, an appellate court reviews a trial court's decision to grant of summary judgment *de novo*.[66] As the name suggests, under the de novo standard, an appellate court is free to substitute its own judgment for that of the trial court. It might appear logical that where a trial judge's evidentiary ruling effectively terminates the case through summary judgment, the appellate court would have the ability to scrutinize the trial court's decision-making with at least the rigor that the trial court can give an expert's reasoning. Nonetheless, the Supreme Court in Joiner reversed the section of the Court of Appeals decision addressing the admissibility of the expert opinions in the case, holding that the appellate court should not have second-guessed the trial court's decision about the reliability of the expert's methodology and its "fit" to the conclusions drawn in a particular case.

Writing for the majority, Chief Justice Rehnquist `adjusted' the appellate court's standard of review 'glasses' so that they reflected the proper deference to the trial court's decision-making. He rejected the plaintiffs'

> claims that because the District Court's disagreement was with the conclusion that the experts drew from the studies, the District Court committed legal error and was properly reversed by the Court of Appeals. But conclusions and methodology are not entirely distinct from one another. Trained experts commonly extrapolate from existing data. But nothing in either *Daubert* or the Federal Rules of Evidence requires a district court to admit opinion evidence that is connected to existing data only by the *ipse dixit* of the expert.[67]

Watch carefully the sleight-of-hand in the final two sentences of this quotation. In the penultimate sentence, the Supreme Court concedes that the plaintiffs' expert methodology is normally acceptable for experts of this type. Then, however, the Court declares that there is no evidentiary principle that requires a trial court to accept the expert's conclusions if the trial court chooses not to accept the expert's inference linking the conclusions to the methodology and data; an inference made by an expert in an area in which the trial court is admittedly not an expert, becomes, according to the Supreme Court, nothing more than an '*ipse dixit.*'

Despite the Court of Appeals analysis demonstrating that there were plausible conclusions to be inferred from the Joiner experts' data and methodology,[68] the Supreme Court refused to allow the appellate court to second-guess the trial court's ruling on the reliability of

[65] Ibid. at 529 (quoting Celotex Corp. v Catrett, 477 U.S. 317, 325 (1986).
[66] Ibid. at 529 (citation omitted).
[67] 522 U.S. at 146.
[68] 78 F.3d at 532.

the expert testimony.[69] The Court of Appeals had applied the 'abuse of discretion' standard of review, but reasoned that because 'the Federal Rules of Evidence . . . display a preference for admissibility, we apply a particularly stringent standard of review to the trial judge's exclusion of expert testimony.'[70] Nonetheless, Supreme Court rejected both this argument and the plaintiffs' argument that a more searching 'abuse of discretion' standard of review should apply to the trial court's decision because the evidentiary ruling in the case was 'outcome-determinative' (i.e., without the expert testimony, the plaintiff had no other proof of causation and could not survive a summary judgment).

The Supreme Court responded that the issue of admissibility of expert testimony is the kind of issue the abuse of discretion standard was created—to give the trial court flexibility in deciding issues involving 'multifarious, fleeting, special, narrow facts that utterly resist generalization.'[71] One can criticize the Court's reasoning in *Joiner*, because the scientific validity of scientific methodologies is subject to the kind of 'generalization' the Court emphasized, even if particular questions of application may be unique to particular case. In Joiner, for example, the appellate court found that the experts' 'weight of the evidence' methodology was a 'scientifically acceptable' basis on which an expert could draw a conclusion, even if other experts had reached other conclusions based on the same data.[72]

The Supreme Court's reasoning in *Joiner* might make sense if the appellate court was reviewing a judgment entered after a trial, but where the evidentiary ruling becomes the determinative ruling of the case, it makes the notion of 'de novo' review of the summary judgment superfluous.[73] By holding that ordinarily deferential abuse of discretion standard applied, the Supreme Court quietly made the trial court's decision to grant summary judgment, based on the lack of expert evidence of causation, non-reviewable by an appellate court for all practical purposes. To put it more colloquially, one trial court judge's decision on whether to allow a jury to hear the expert's opinion decided the whole ball game.

In its opinion in *Joiner,* the Supreme Court did do a service to the legal and scientific communities by clarifying a poorly chosen phrase it had used in *Daubert*: the "focus, of course, must be solely on principles and methodology, not on the conclusions that they generate."[74] The Court retreated from this phrase in *Joiner*, stating that "conclusions and methodology are not entirely distinct from one another."[75]

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[69] 522 US at 142.
[70] 78 F.2d at 529 (citations omitted).
[71] Pierce v. Underwood, 487 US 552, 561-562 (1988)
[72] The Court of Appeals described this methodology, relied on by the plaintiff's experts in Joiner: 'Opinions of any kind are derived from individual pieces of evidence, each of which by itself might not be conclusive, but when viewed in their entirety are the building blocks of a perfectly reasonable conclusion, one reliable enough to be submitted to a jury along with the tests and criticisms cross-examination and contrary evidence would supply." 78 F.3d 524, 532 (11th Cir. 1996).
[73] The Supreme Court had other choices to resolve the problem of appellate review of expert testimony rulings. M.J. Saks, 'The Aftermath of Daubert: An Evolving Jurisprudence of Expert Evidence' (2000) 40 Jurimetrics J. 229, 234 ('Thus, appellate courts should review case-specific evidence rulings deferentially and trans-case scientific issues de novo, and lower courts should treat appellate decisions on trans-case scientific issues as they would holdings of law').
[74] Daubert, 509 U.S at 595.
[75] Joiner, 522 U.S. at 146.

In addition, the Joiners were a bit luckier than other the other plaintiffs in the *Daubert* trilogy. The Supreme Court noted that there was still an open factual question that needed to be "remanded" (or sent back to) the trial court, because case-specific facts need to be decided at the trial court level.[76] Thus, the Supreme Court and the Court of Appeals sent the case back to the trial court to determine "whether Joiner was exposed to furans and dioxins, and whether if there was such exposure, the opinions of Joiner's experts would then be admissible."[77] Because there are no further proceedings indicated after this, one may reasonably infer that this case settled.

The plaintiffs in *Daubert* and *Kumho* as well as many plaintiffs with cases following the *Daubert* trilogy did not fare as well at the Joiners. As noted above, after taking the case back from the Supreme Court on remand, the Court of Appeals for the Ninth Circuit applied *Daubert*'s reliability standard, held that the plaintiffs' evidence was not sufficiently reliable, and, without additional expert evidence to prove causation, upheld the trial court's decision to grant summary judgment against the plaintiffs.[78] The Supreme Court in *Kumho* also reversed the appellate court ruling, reinstating the trial court's summary judgment.[79]

In 2001, the RAND Institute for Civil Justice released a study analyzing the impact of *Daubert*.[80] The study confirmed what many court-observers suspected *Daubert* led to more evidence being challenged, more evidence being excluded, and more summary judgments being granted—especially against plaintiffs.[81] In particular, the study found that 'the frequency with which summary judgment was requested rose substantially after *Daubert*, as did the frequency with which summary judgment was granted.'[82] The vast majority of the requests for summary judgment were aimed at civil plaintiffs' evidence; only 10 percent of the requests were aimed at civil defendants' evidence.[83]

The critiques about the critical competence of judges and judicial preemption of the jury's job in weighing expert evidence are quite problematic. Even worse, however, is that with the *Daubert* trilogy, the Supreme Court created a 'no-win' situation for the trial judges. Trial judges may not rely on "general acceptance" to make their evidentiary decision-making more efficient. They must revisit the same issues time and time again. In other words, the Supreme Court tried to create a test with enough rigor to keep "junk science" away from the trier of fact and at the same time provide sufficient flexibility to capture the wide range of expert opinions offered in courtrooms across the US, it ultimately created a discretionary standard that invites unequal application even in similar circumstances—and thus unjust decisions.[84]

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[76] Joiner v. General Electric Comp., 522 U.S. at 147.
[77] Joiner v. General Electric Comp., 134 F.3d 1457 (11th Cir. 1998).
[78] Daubert v. Merrell Dow Pharmaceuticals, Inc., 43 F.3d 1311 (9th Cir. 1995).
[79] Kumho Tire Comp. v. Carmichael, 526 U.S. 137, 158 (1999).
[80] L. Dixon & B. Gill, RAND Inst. for Civil Justice, Changes in the Standards for Admitting Expert Evidence in Federal Civil Cases Since the Daubert Decision (2001), available at http://www.rand.org/publications/MR/MR1439/MR1439.pdf [hereinafter RAND Study].
[81] A. Kanner & M.R. Casey 'Daubert and the Disappearing Jury Trial' (2006) 69 U. Pitt. L. Rev. 281, 314-315.
[82] RAND Study at 56.
[83] Ibid.
[84] R.F. Pierce & J.M. DeTeso, 'A Lawyer's Lament: Unpredictability and Inconsistency in the Wake of the Daubert Trilogy' (2001) 2 Sedona Conf. J. 163.

One treatise on scientific evidence observes that the admissibility of expert testimony appears to be a function of not only the legal standard recognized in the jurisdiction (*Frye* or *Daubert*), but also the degree of "permissiveness" in the legal culture, where permissiveness is defined as the quantity of expert evidence that is likely to be put before the jury.[85] The degree of permissiveness is determined by the how the jurisdiction resolves

> the classic problem of defining the proper roles for judges and juries in the trial process. A high threshold indicates a relatively active judicial role in screening expert opinion for the jury. A low threshold leaves the weighing function to jurors—a task that might include, of course, the jury's according some expert evidence a weight of zero.[86]

The treatise goes on to identify 'four basic approaches to the judicial role regarding expert evidence: (1) Daubert-rigorous; (2) *Daubert*-permissive; (3) *Frye*-rigorous; and (4) *Frye*-permissive.'[87] The treatise notes that in applying this matrix, one is not only contrasting the culture of a particular community of courts (for example, federal courts versus state courts, Minnesota versus Florida, or even urban courts versus rural courts), but also may see variance within one particular jurisdiction and even within one particular courthouse.[88] In short, regardless of the standard used, there is the problem of the user—especially where the standard invites the user to exercise discretion, as the *Daubert* standard does.

The reaction to this range of approaches to the *Daubert* precedent has not been positive. As one slightly exasperated commentator put it, 'the result [of the *Daubert* trilogy] is a standardless standard'.[89] The most serious charge of inconsistency is that *Daubert* is unevenly applied in criminal cases compared to civil cases. Post-*Daubert*, commentators regularly pointed out that after *Daubert,* even courts that were willing to scrutinize and criticize scientific, social science, and technical experts in civil cases, turned a blind-eye to the problems with many forms of expert testimony resting on forensic science in criminal cases.[90] Although some inconsistency might be justifiable in the name of flexibility, the degree to which applications of *Daubert* have varied—between civil and criminal evidence, between 'hard science' and 'soft science', between 'syndrome experts' and 'pattern identification experts' creates the appearance of injustice when it surfaces in courts of law.

C. Scientific Expert Testimony Standards Applied to Climate Science

Unlike many areas of expert testimony frequently challenged under *Daubert* and other evidentiary standards, disputes centering on the admissibility and use of expert testimony about

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[85] D.L. Faigman, D.H. Kaye, M.J. Saks, & J. Sanders, 1 Modern Scientific Evidence: The Law and Science of Expert Testimony (Westlaw 2009), §1.1.

[86] Ibid. There is an interesting value judgment implicit in this assessment, for the 'low' threshold is assigned to the active role of the jury in evaluating evidence, while the 'high" threshold means the judge takes the most active role.

[87] Ibid.

[88] Ibid.

[89] M.D. Goodman, `A Hedgehog on the Witness Stand—What's the Big Idea?: The Challenges of Using Daubert to Assess Social Science and Nonscientific Evidence' (2010) 59 Am. U. L. Rev. 635, 651

[90] P.C. Giannelli, 'Daubert Revisited' (2005) 41 (No. 3) Crim. L. Bull. 5; J.A. Moreno, 'Eyes Wide Shut: Hidden Problems and Future Consequences of the Fact-Based Validity Standard' (2003) 34 Seton Hall L. Rev. 89; M.J. Saks, 'Banishing Ipse Dixit: The Impact of Kuhmo Tire on Forensic Identification Science' (2000) 57 Wash. & Lee L. Rev 879, 882 (2000).

climate change are relatively rare at this point. Of those cases dealing evidence of climate change, most of the court cases have been challenges to federal and state agency determinations (generally for failure to take action or follow regulations).[91] A smaller, but growing number of cases involve claims for money damages or injunctions against alleged contributors to environmental changes.[92] However very few of these cases

An analysis of the growing material on litigation involving issues of climate change is beyond the scope of this Guide, but if you wish to explore, we provide the following citations for additional reading:

a. K. Engel & J. Overpeck, *Adaptation and the Courtroom: Judging Climate Science*, Ariz. Legal Studies Discussion Paper No. 12-38, Apr. 16, 2013 (forthcoming *in Michigan Journal of Environmental & Administrative Law, 2013), available online at* *http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2185616 (*last accessed July 30, 2013).

Abstract*:* Climate science is becoming increasingly important in litigation and in agency proceedings. With the growing policy emphasis upon adaptation to climate change, the potential for disputes in which climate science will be relevant will only multiply. Judges play a critical role in evaluating scientific evidence, from decisions regarding whether the evidence is admissible in a trial to the weight that it should be accorded in determining particular facts. Judges, however, are not apt to be familiar with the basic methods of climate science and, in particular, how to evaluate the reliability and relevance of climate studies and expert testimony. This chapter is an effort to fill this gap. In doing so, we hope to help judges exercise their responsibility to ensure that litigation outcomes are informed by quality climate science and, at the same time, ensure that quality climate science receives due consideration in the courtroom.

b. *Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie*
508 F.Supp.2d 295 (D.Vt. 2007)

Summary: Automobile dealers, manufacturers and associations brought action seeking declaratory and injunctive relief from Vermont regulations adopting California's greenhouse gas (GHG) emissions standards for new automobiles.

Plaintiffs moved to exclude testimony from three of Defendants' experts:

(1) Dr. James Hansen, an expert in climatology, Director of the Goddard Institute for Space Studies, and Adjunct Professor in Earth and Environmental

[91] D. Markell and J.B. Ruhl, *An Empirical Assessment of Climate Change in the Courts: A New Jurisprudence or Business as Usual?*, 64 Fla. L. Rev. 15, 32 (2012)(analyzing climate change litigation matters filed through 2010), cited in K. Engel & J. Overpeck, Adaptation and the Courtroom: Judging Climate Science, Ariz. Legal Studies Discussion Paper No. 12-38 (forthcoming in *Michigan Journal of Environmental & Administrative Law, 2013), available online at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2185616 (last accessed July 30, 2013).*
[92] Ibid.

Sciences at Columbia University, where he teaches Introduction to Planetary Atmospheres and Climate Change and a graduate level class on Atmospheric Radiation;

(2) Dr. Barrett N. Rock, professor at the University of New Hampshire (UNH), a past director of the Complex Systems Research Center at the Institute for the Study of Earth, Oceans and Space at UNH, and a Ph.D. in botany, focusing on the comparative study of forest conditions; and

(3) Mr. K.G. Duleep, plaintiff's expert on fuel economy and emissions in the automobile industry.

To challenge Defendants' experts, the Plaintiffs used their own "rebuttal experts,"

With each of the Defendants' experts, there was no real issue about their qualifications. Instead, the Plaintiffs attacked each expert's proposed testimony as irrelevant and unreliable, using the *Daubert* test for the admissibility of scientific expert testimony.

After a very thorough discussion of *Daubert*, and application of the standard to each of the three Defendants' experts, the trial court denied all three of Plaintiffs' motions to exclude Defendants' experts.

In this case, the trial court served as the trier of fact, not a jury. Because of its *Daubert* rulings, the court was able to use the testimony from Defendants' experts in ultimately deciding to deny all of Plaintiffs' claims that federal law preempted Vermont state law. The trial court entered judgment for the Defendants. Only the parts of the lengthy trial court opinion dealing with the application of *Daubert* to climate science experts and the energy consultant are attached to this Guide under Part III. You need not read this material, but if you do, it may help you generate arguments for the *Daubert* motion (and the response) exercise in the EWTA case.

Part III: Legal Authority Regarding Expert Testimony

A. The Relevant Federal Rules of Evidence

Rule 701. Opinion Testimony by Lay Witnesses

If a witness is not testifying as an expert, testimony in the form of an opinion is limited to one that is:
(a) rationally based on the witness's perception;
(b) helpful to clearly understanding the witness's testimony or to determining a fact in issue; and
(c) not based on scientific, technical, or other specialized knowledge within the scope of Rule 702.

(Enacted by Pub. L. 93–595, §1, Jan. 2, 1975, 88 Stat. 1937. Amended Mar. 2, 1987, eff. Oct. 1, 1987; Apr. 17, 2000, eff. Dec. 1, 2000; Apr. 26, 2011, eff. Dec. 1, 2011).

Rule 702: Testimony by Expert Witnesses

A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:
(a) the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
(b) the testimony is based on sufficient facts or data;
(c) the testimony is the product of reliable principles and methods; and
(d) the expert has reliably applied the principles and methods to the facts of the case.

(Enacted by Pub.L. 93-595, § 1, Jan. 2, 1975, 88 Stat. 1937. Amended Apr. 17, 2000, eff. Dec. 1, 2000; Apr. 26, 2011, eff. Dec. 1, 2011).

Rule 703. Bases of an Expert's Opinion Testimony

An expert may base an opinion on facts or data in the case that the expert has been made aware of or personally observed. If experts in the particular field would reasonably rely on those kinds of facts or data in forming an opinion on the subject, they need not be admissible for the opinion to be admitted. But if the facts or data would otherwise be inadmissible, the proponent of the opinion may disclose them to the jury only if their probative value in helping the jury evaluate the opinion substantially outweighs their prejudicial effect.

(Enacted by Pub. L. 93–595, §1, Jan. 2, 1975, 88 Stat. 1937. Amended Mar. 2, 1987, eff. Oct. 1, 1987; Apr. 17, 2000, eff. Dec. 1, 2000; Apr. 26, 2011, eff. Dec. 1, 2011).

Rule 704. Opinion on an Ultimate Issue

(a) In General — Not Automatically Objectionable. An opinion is not objectionable just because it embraces an ultimate issue.
(b) Exception. In a criminal case, an expert witness must not state an opinion about whether the defendant did or did not have a mental state or condition that constitutes an element of the crime charged or of a defense. Those matters are for the trier of fact alone.

(Enacted by Pub. L. 93–595, §1, Jan. 2, 1975, 88 Stat. 1937. Amended through Pub. L. 98–473, title II, §406, Oct. 12, 1984, 98 Stat. 2067. Amended Apr. 26, 2011, eff. Dec. 1, 2011).

Rule 705: Disclosing the Facts or Data Underlying an Expert's Opinion

Unless the court orders otherwise, an expert may state an opinion — and give the reasons for it — without first testifying to the underlying facts or data. But the expert may be required to disclose those facts or data on cross-examination.

(Enacted by Pub. L. 93–595, §1, Jan. 2, 1975, 88 Stat. 1938. Amended Mar. 2, 1987, eff. Oct. 1, 1987; Apr. 22, 1993, eff. Dec. 1, 1993; Apr. 26, 2011, eff. Dec. 1, 2011).

Rule 706. Court-Appointed Expert Witnesses

(a) Appointment Process. On a party's motion or on its own, the court may order the parties to show cause why expert witnesses should not be appointed and may ask the parties to submit nominations. The court may appoint any expert that the parties agree on and any of its own choosing. But the court may only appoint someone who consents to act.
(b) Expert's Role**.** The court must inform the expert of the expert's duties. The court may do so in writing and have a copy filed with the clerk or may do so orally at a conference in which the parties have an opportunity to participate. The expert:
(1) must advise the parties of any findings the expert makes;
(2) may be deposed by any party;
(3) may be called to testify by the court or any party; and
(4) may be cross-examined by any party, including the party that called the expert.
(c) Compensation**.** The expert is entitled to a reasonable compensation, as set by the court. The compensation is payable as follows:
(1) in a criminal case or in a civil case involving just compensation under the Fifth Amendment, from any funds that are provided by law; and
(2) in any other civil case, by the parties in the proportion and at the time that the court directs — and the compensation is then charged like other costs.
(d) Disclosing the Appointment to the Jury**.** The court may authorize disclosure to the jury that the court appointed the expert.
(e) Parties' Choice of Their Own Experts**.** This rule does not limit a party in calling its own experts.

(Enacted by Pub. L. 93–595, §1, Jan. 2, 1975, 88 Stat. 1938. Amended Mar. 2, 1987, eff. Oct. 1, 1987; Apr. 26, 2011, eff. Dec. 1, 2011).

B. *Frye v. United States*, 293 F. 1013 (D.C. Cir. 1923)(edited).

No. 3968. Submitted November 7, 1923. Decided December 3, 1923.

Appeal from the Supreme Court of the District of Columbia., to the Court of Appeals of District of Columbia.

Opinion by: VAN ORSDEL, Associate Justice.

Appellant, defendant below, was convicted of the crime of murder in the second degree, and from the judgment prosecutes this appeal.

A single assignment of error is presented for our consideration. In the course of the trial counsel for defendant offered an expert witness to testify to the result of a deception test made upon defendant. The test is described as the systolic blood pressure deception test. It is asserted that blood pressure is influenced by change in the emotions of the witness, and that the systolic blood pressure rises are brought about by nervous impulses sent to the sympathetic branch of the autonomic nervous system. Scientific experiments, it is claimed, have demonstrated that fear, rage, and pain always produce a rise of systolic blood pressure, and that conscious deception or falsehood, concealment of facts, or guilt of crime, accompanied by fear of detection when the person is under examination, raises the systolic blood pressure in a curve, which corresponds exactly to the struggle going on in the subject's mind, between fear and attempted control of that fear, as the examination**1014 touches the vital points in respect of which he is attempting to deceive the examiner.

In other words, the theory seems to be that truth is spontaneous, and comes without conscious effort, while the utterance of a falsehood requires a conscious effort, which is reflected in the blood pressure. The rise thus produced is easily detected and distinguished from the rise produced by mere fear of the examination itself. In the former instance, the pressure rises higher than in the latter, and is more pronounced as the examination proceeds, while in the latter case, if the subject is telling the truth, the pressure registers highest at the beginning of the examination, and gradually diminishes as the examination proceeds.

Prior to the trial defendant was subjected to this deception test, and counsel offered the scientist who conducted the test as an expert to testify to the results obtained. The offer was objected to by counsel for the government, and the court sustained the objection. Counsel for defendant then offered to have the proffered witness conduct a test in the presence of the jury. This also was denied.

Counsel for defendant, in their able presentation of the novel question involved, correctly state in their brief that no cases directly in point have been found. The broad ground, however, upon which they plant their case, is succinctly stated in their brief as follows:

‘The rule is that the opinions of experts or skilled witnesses are admissible in evidence in those cases in which the matter of inquiry is such that inexperienced persons are unlikely to prove capable of forming a correct judgment upon it, for the reason that the subject-matter so far partakes of a science, art, or trade as to require a previous habit or experience or study in it, in order to acquire a knowledge of it. When the question involved does not lie within the range of common experience or common knowledge, but requires special experience or special knowledge, then the opinions of witnesses skilled in that particular science, art, or trade to which the question relates are admissible in evidence.‘

Numerous cases are cited in support of this rule. Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs.

We think the systolic blood pressure deception test has not yet gained such standing and scientific recognition among physiological and psychological authorities as would justify the courts in admitting expert testimony deduced from the discovery, development, and experiments thus far made.

The judgment is affirmed.

C. *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993)(edited).

No. 92–102. Argued March 30, 1993. Decided June 28, 1993.

BLACKMUN, J., delivered the opinion for a unanimous Court with respect to Parts I and II–A, and the opinion of the Court with respect to Parts II–B, II–C, III, and IV, in which WHITE, O'CONNOR, SCALIA, KENNEDY, SOUTER, and THOMAS, JJ., joined. REHNQUIST, C.J., filed an opinion concurring in part and dissenting in part, in which STEVENS, J., joined, *post,* p. ——.

*582. Justice BLACKMUN delivered the opinion of the Court.
In this case we are called upon to determine the standard for admitting expert scientific testimony in a federal trial.

I

Petitioners Jason Daubert and Eric Schuller are minor children born with serious birth defects. They and their parents sued respondent in California state court, alleging that the birth defects had been caused by the mothers' ingestion of Bendectin, a prescription antinausea drug marketed by respondent. Respondent removed the suits to federal court on diversity grounds.

After extensive discovery, respondent moved for summary judgment, contending that Bendectin does not cause birth defects in humans and that petitioners would be unable to come forward with any admissible evidence that it does. In support of its motion, respondent submitted an affidavit of Steven H. Lamm, physician and epidemiologist, who is a well-credentialed expert on the risks from exposure to various chemical substances.[93] Doctor Lamm stated that he had reviewed all the literature on Bendectin and human birth defects—more than 30 published studies involving over 130,000 patients. No study had found Bendectin to be a human teratogen (i.e., a substance capable of causing malformations in fetuses). On the basis of this review, Doctor Lamm concluded that maternal use of Bendectin during the first trimester of pregnancy has not been shown to be a risk factor for human birth defects.

*583 Petitioners did not (and do not) contest this characterization of the published record regarding Bendectin. Instead, they responded to respondent's motion with the testimony of eight experts of their own, each of whom also possessed impressive credentials.[94] These experts had

[93] Doctor Lamm received his master's and doctor of medicine degrees from the University of Southern California. He has served as a consultant in birth-defect epidemiology for the National Center for Health Statistics and has published numerous articles on the magnitude of risk from exposure to various chemical and biological substances. App. 34–44.

[94] For example, Shanna Helen Swan, who received a master's degree in biostatistics from Columbia University and a doctorate in statistics from the University of California at Berkeley, is chief of the section of the California Department of Health and Services that determines causes of birth defects and has served as a consultant to the World Health Organization, the Food and Drug Administration, and the National Institutes of Health. Id., at 113–114, 131–132. Stuart A. Newman, who received his bachelor's degree in chemistry from Columbia University and his master's and doctorate in chemistry from the University of Chicago, is a professor at New York Medical College and has spent over a decade studying the effect of chemicals on limb development. Id., at 54–56. The credentials of

concluded that Ben-dectin can cause birth defects. Their conclusions were based upon "in vitro" (test tube) and "in vivo" (live) animal studies that found a link between Bendectin and malformations; pharmacological studies of the chemical structure of Bendectin that purported to show similarities between the structure of the drug and that of other substances known to cause birth defects; and the "reanalysis" of previously published epidemiological (human statistical) studies.

The District Court granted respondent's motion for summary judgment. The court stated that scientific evidence is admissible only if the principle upon which it is based is " 'sufficiently established to have general acceptance in the field to which it belongs.' " 727 F.Supp. 570, 572 (S.D.Cal.1989), quoting United States v. Kilgus, 571 F.2d 508, 510 (CA9 1978). The court concluded that petitioners' evidence did not meet this standard. Given the vast body of epidemiological data concerning Bendectin, the court held, expert opinion which is not based on epidemiological evidence *584 is not admissible to establish causation. 727 F.Supp. at 575. Thus, the animal-cell studies, live-animal studies, and chemical-structure analyses on which petitioners had relied could not raise by themselves a reasonably disputable jury issue regarding causation. Ibid. Petitioners' epidemiological analyses, based as they were on recalculations of data in previously published studies that had found no causal link between the drug and birth defects, were ruled to be inadmissible because they had not been published or subjected to peer review. Ibid.

The United States Court of Appeals for the Ninth Circuit affirmed. 951 F.2d 1128 (1991). Citing Frye v. United States, 54 App.D.C. 46, 47, 293 F. 1013, 1014 (1923), the court stated that expert opinion based on a scientific technique is inadmissible unless the technique is "generally accepted" as reliable in the relevant scientific community. 951 F.2d, at 1129–1130. The court declared that expert opinion based on a methodology that diverges "significantly from the procedures accepted by recognized authorities in the field ... cannot be shown to be 'generally accepted as a reliable technique.' " Id., at 1130, quoting United States v. Solomon, 753 F.2d 1522, 1526 (CA9 1985).

The court emphasized that other Courts of Appeals considering the risks of Bendectin had refused to admit reanalyses of epidemiological studies that had been neither published nor subjected to peer review. 951 F.2d, at 1130–1131. Those courts had found unpublished reanalyses "particularly problematic in light of the massive weight of the original published studies supporting [respondent's] position, all of which had undergone full scrutiny from the scientific community." Id., at 1130. Contending that reanalysis is generally accepted by the scientific community only when it is subjected to verification and scrutiny by others in the field, the Court of Appeals rejected petitioners' reanalyses as "unpublished, not subjected to the normal peer review process and generated solely for use in litigation." Id., at 1131. The *585 court concluded that petitioners' evidence provided an insufficient foundation to allow admission of expert testimony that Bendectin caused their injuries and, accordingly, that petitioners could not satisfy their burden of proving causation at trial.

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the others are similarly impressive. See Id., at 61–66, 73–80, 148–153, 187–192, and Attachments 12, 20, 21, 26, 31, and 32 to Petitioners' Opposition to Summary Judgment in No. 84–2013–G(I) (SD Cal.).

We granted certiorari, 506 U.S. 914, 113 S.Ct. 320, 121 L.Ed.2d 240 (1992), in light of sharp divisions among the courts regarding the proper standard for the admission of expert testimony. . . .

II

A.

In the 70 years since its formulation in the Frye case, the "general acceptance" test has been the dominant standard for determining the admissibility of novel scientific evidence at trial. See E. Green & C. Nesson, Problems, Cases, and Materials on Evidence 649 (1983). Although under increasing attack of late, the rule continues to be followed by a majority of courts, including the Ninth Circuit.

The Frye test has its origin in a short and citation-free 1923 decision concerning the admissibility of evidence derived from a systolic blood pressure deception test, a crude precursor to the polygraph machine. In what has become a famous (perhaps infamous) passage, the then Court of Appeals for the District of Columbia described the device and its operation and declared:

> "Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages *586 is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs." 54 App.D.C., at 47, 293 F., at 1014 (emphasis added).

Because the deception test had "not yet gained such standing and scientific recognition among physiological and psychological authorities as would justify the courts in admitting expert testimony deduced from the discovery, development, and experiments thus far made," evidence of its results was ruled inadmissible. Ibid.

The merits of the Frye test have been much debated, and scholarship on its proper scope and application is legion. *587 Petitioners' primary attack, however, is not on the content but on the continuing authority of the rule. They contend that the Frye test was superseded by the adoption of the Federal Rules of Evidence. We agree.

We interpret the legislatively enacted Federal Rules of Evidence as we would any statute. Beech Aircraft Corp. v. Rainey, 488 U.S. 153, 163, 109 S.Ct. 439, 446, 102 L.Ed.2d 445 (1988). Rule 402 provides the baseline:

> "All relevant evidence is admissible, except as otherwise provided by the Constitution of the United States, by Act of Congress, **2794 by these rules, or by other rules prescribed by the Supreme Court pursuant to statutory authority. Evidence which is not relevant is not admissible."

"Relevant evidence" is defined as that which has "any tendency to make the existence of any fact that is of consequence to the determination of the action more probable or less probable than it would be without the evidence." Rule 401. The Rule's basic standard of relevance thus is a liberal one.

Frye, of course, predated the Rules by half a century. In United States v. Abel, 469 U.S. 45, 105 S.Ct. 465, 83 L.Ed.2d 450 (1984), we considered the pertinence of background common law in interpreting the Rules of Evidence. We noted that the Rules occupy the field, id., at 49, 105 S.Ct., at 467, but, quoting Professor Cleary, the Reporter,*588 explained that the common law nevertheless could serve as an aid to their application:

> " 'In principle, under the Federal Rules no common law of evidence remains. "All relevant evidence is admissible, except as otherwise provided...." In reality, of course, the body of common law knowledge continues to exist, though in the somewhat altered form of a source of guidance in the exercise of delegated powers.' " Id., at 51–52, 105 S.Ct., at 469.

We found the common-law precept at issue in the Abel case entirely consistent with Rule 402's general requirement of admissibility, and considered it un-likely that the drafters had intended to change the rule. Id., at 50–51, 105 S.Ct. at 468–469. In Bourjaily v. United States, 483 U.S. 171, 107 S.Ct. 2775, 97 L.Ed.2d 144 (1987), on the other hand, the Court was unable to find a particular common-law doctrine in the Rules, and so held it superseded.

Here there is a specific Rule that speaks to the contested issue. Rule 702, governing expert testimony, provides:

> "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise."

Nothing in the text of this Rule establishes "general acceptance" as an absolute prerequisite to admissibility. Nor does respondent present any clear indication that Rule 702 or the Rules as a whole were intended to incorporate a "general acceptance" standard. The drafting history makes no mention of Frye, and a rigid "general acceptance" requirement would be at odds with the "liberal thrust" of the Federal Rules and their "general approach of relaxing the traditional barriers to 'opinion' testimony." Beech Aircraft Corp. v. Rainey, 488 U.S., at 169, 109 S.Ct., at 450 (citing Rules 701 to 705). See also Weinstein, Rule 702 of the Federal Rules of Evidence is 589*589 Sound; It Should Not Be Amended, 138 F.R.D. 631 (1991) ("The Rules were designed to depend primarily upon lawyer-adversaries and sensible triers of fact to evaluate conflicts"). Given the Rules' permissive backdrop and their inclusion of a specific rule on expert testimony that does not mention "'general acceptance,' " the assertion that the Rules somehow assimilated Frye is unconvincing. Frye made "general acceptance" the exclusive test for admitting expert scientific testimony. That austere standard, absent from, and incompatible with, the Federal Rules of Evidence, should not be applied in federal trials.

B.

That the Frye test was displaced by the Rules of Evidence does not mean, however, that the Rules themselves place no limits on the admissibility of purportedly scientific evidence.[95] Nor is the trial judge disabled from screening such evidence. To the contrary, under the Rules the trial judge must ensure that any and all scientific testimony or evidence admitted is not only relevant, but reliable.

] The primary locus of this obligation is Rule 702, which clearly contemplates some degree of regulation of the subjects and theories about which an expert may testify. "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue" an expert "may testify thereto." (Emphasis added.) The subject of an expert's testimony must *590 be "scientific ... knowledge." The adjective " scientific" implies a grounding in the methods and procedures of science. Similarly, the word "knowledge" connotes more than subjective belief or unsupported speculation. The term "applies to any body of known facts or to any body of ideas inferred from such facts or accepted as truths on good grounds." Webster's Third New International Dictionary 1252 (1986). Of course, it would be unreasonable to conclude that the subject of scientific testimony must be "known" to a certainty; arguably, there are no certainties in science. See, e.g., Brief for Nicolaas Bloembergen et al. as Amici Curiae 9 ("Indeed, scientists do not assert that they know what is immutably 'true'—they are committed to searching for new, temporary, theories to explain, as best they can, phenomena"); Brief for American Association for the Advancement of Science et al. as Amici Curiae 7–8 ("Science is not an encyclopedic body of knowledge about the universe. Instead, it represents a process for proposing and refining theoretical explanations about the world that are subject to further testing and refinement" (emphasis in original)). But, in order to qualify as "scientific knowledge," an inference or assertion must be derived by the scientific method. Proposed testimony must be supported by appropriate validation—i.e., "good grounds," based on what is known. In short, the requirement that an expert's testimony pertain to " scientific knowledge" establishes a standard of evidentiary reliability.[96]

*591 Rule 702 further requires that the evidence or testimony "assist the trier of fact to understand the evidence or to determine a fact in issue." This condition goes primarily to relevance. " Expert testimony which does not relate to any issue in the case is not relevant and,

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[95] THE CHIEF JUSTICE "do[es] not doubt that Rule 702 confides to the judge some gatekeeping responsibility," post, at 2800, but would neither say how it does so nor explain what that role entails. We believe the better course is to note the nature and source of the duty.

[96] We note that scientists typically distinguish between "validity" (does the principle support what it purports to show?) and "reliability" (does application of the principle produce consistent results?). See Black, 56 Ford.L.Rev., at 599. Although "the difference between accuracy, validity, and reliability may be such that each is distinct from the other by no more than a hen's kick," Starrs, Frye v. United States Restructured and Revitalized: A Proposal to Amend Federal Evidence Rule 702, 26 Jurimetrics J. 249, 256 (1986), our reference here is to evidentiary reliability—that is, trustworthiness. Cf., e.g., Advisory Committee's Notes on Fed.Rule Evid. 602, 28 U.S.C.App., p. 755 (" '[T]he rule requiring that a witness who testifies to a fact which can be perceived by the senses must have had an opportunity to observe, and must have actually observed the fact' is a 'most pervasive manifestation' of the common law insistence upon 'the most reliable sources of information' " (citation omitted)); Advisory Committee's Notes on Art. VIII of Rules of Evidence, 28 U.S.C.App., p. 770 (hearsay exceptions will be recognized only "under circumstances supposed to furnish guarantees of trustworthiness"). In a case involving scientific evidence, evidentiary reliability will be based upon scientific validity.

ergo, non-helpful." 3 Weinstein & Berger ¶ 702[02], p. 702–18. See al-so United States v. Downing, 753 F.2d 1224, 1242 (CA3 1985) ("An additional consideration under Rule 702—and another aspect of relevancy—is whether expert testimony proffered in the case is sufficiently tied to the facts of the case that it will aid the jury in resolving a factual dispute"). The consideration has been aptly described by Judge Becker as one of "fit." Ibid. "Fit" is not always obvious, and scientific validity for one purpose is not necessarily scientific validity for other, unrelated purposes. See Starrs, Frye v. United States Restructured and Revitalized: A Proposal to Amend Federal Evidence Rule 702, 26 Jurimetrics J. 249, 258 (1986). The study of the phases of the moon, for example, may provide valid scientific "knowledge" about whether a certain night was dark, and if darkness is a fact in issue, the knowledge will assist the trier of fact. However (absent creditable grounds supporting such a link), evidence that the moon was full on a certain night will not assist the trier of fact in determining whether an individual was unusually likely to have behaved irrationally on that night. Rule 702's "helpfulness" *592 standard requires a valid scientific connection to the pertinent inquiry as a precondition to admissibility.

That these requirements are embodied in Rule 702 is not surprising. Unlike an ordinary witness, see Rule 701, an expert is permitted wide latitude to offer opinions, including those that are not based on firsthand knowledge or observation. See Rules 702 and 703. Presumably, this relaxation of the usual requirement of firsthand knowledge—a rule which represents "a 'most pervasive manifestation' of the common law insistence upon 'the most reliable sources of information,' " Advisory Committee's Notes on Fed. Rule Evid. 602, 28 U.S.C.App., p. 755 (citation omitted)—is premised on an assumption that the expert's opinion will have a reliable basis in the knowledge and experience of his discipline.

Faced with a proffer of expert scientific testimony, then, the trial judge must determine at the outset, pursuant to Rule 104(a),[97] whether the expert is proposing to testify to (1) scientific knowledge that (2) will assist the trier of fact to understand or determine a fact in issue.[98] This entails a preliminary assessment of whether the reasoning or methodology*593 underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue. We are confident that federal judges possess the capacity to undertake this review. Many factors will bear on the inquiry, and we do not presume to set out a definitive checklist or test. But some general observations are appropriate.

Ordinarily, a key question to be answered in determining whether a theory or technique is scientific knowledge that will assist the trier of fact will be whether it can be (and has been) tested. "Scientific methodology today is based on generating hypotheses and testing them to see if they can be falsified; indeed, this methodology is what distinguishes science from other fields

[97] Rule 104(a) provides:
"Preliminary questions concerning the qualification of a person to be a witness, the existence of a privilege, or the admissibility of evidence shall be determined by the court, subject to the provisions of sub-division (b) [pertaining to conditional ad-missions]. In making its determination it is not bound by the rules of evidence except those with respect to privileges." These matters should be established by a preponderance of proof. See Bourjaily v. United States, 483 U.S. 171, 175–176, 107 S.Ct. 2775, 2778–2779, 97 L.Ed.2d 144 (1987).

[98] Although the Frye decision itself focused exclusively on "novel" scientific techniques, we do not read the requirements of Rule 702 to apply specially or exclusively to unconventional evidence. Of course, well-established propositions are less likely to be challenged than those that are novel, and they are more handily defended. Indeed, theories that are so firmly established as to have attained the status of scientific law, such as the laws of thermodynamics, properly are subject to judicial notice under Federal Rule of Evidence 201.

of human inquiry." Green 645. See also C. Hempel, Philosophy of Natural Science 49 (1966) ("[T]he statements constituting a scientific explanation must be capable of empirical test"); K. Popper, Conjectures and Refutations: The Growth of Scientific Knowledge 37 (5th ed. 1989) ("[T]he criterion of the scientific status of a theory is its falsifiability, or refutability, or testability") (emphasis deleted).

Another pertinent consideration is whether the theory or technique has been subjected to peer review and publication. Publication (which is but one element of peer review) is not a sine qua non of admissibility; it does not necessarily correlate with reliability, see S. Jasanoff, The Fifth Branch: Science Advisors as Policymakers 61–76 (1990), and in some instances well-grounded but innovative theories will not have been published, see Horrobin, The Philosophical Basis of Peer Review and the Suppression of Innovation, 263 JAMA 1438 (1990). Some propositions, moreover, are too particular, too new, or of too limited interest to be published. But submission to the scrutiny of the scientific community is a component of "good science," in part because it increases the likelihood that substantive flaws in methodology will be detected. See J. Ziman, Reliable Knowledge: An Exploration *594 of the Grounds for Belief in Science 130–133 (1978); Relman & Angell, How Good Is Peer Review?, 321 New Eng.J.Med. 827 (1989). The fact of publication (or lack thereof) in a peer reviewed journal thus will be a relevant, though not dispositive, consideration in assessing the scientific validity of a particular technique or methodology on which an opinion is premised.

Additionally, in the case of a particular scientific technique, the court ordinarily should consider the known or potential rate of error, see, e.g., United States v. Smith, 869 F.2d 348, 353–354 (CA7 1989) (surveying studies of the error rate of spectrographic voice identification technique), and the existence and maintenance of standards controlling the technique's operation, see United States v. Williams, 583 F.2d 1194, 1198 (CA2 1978) (noting professional organization's standard governing spectrographic analysis), cert. denied, 439 U.S. 1117, 99 S.Ct. 1025, 59 L.Ed.2d 77 (1979).

Finally, "general acceptance" can yet have a bearing on the inquiry. A "reliability assessment does not require, although it does permit, explicit identification of a relevant scientific community and an express determination of a particular degree of acceptance within that community." United States v. Downing, 753 F.2d, at 1238. See also 3 Weinstein & Berger ¶ 702[03], pp. 702–41 to 702–42. Widespread acceptance can be an important factor in ruling particular evidence admissible, and "a known technique which has been able to attract only minimal support within the community," Downing, 753 F.2d, at 1238, may properly be viewed with skepticism.

The inquiry envisioned by Rule 702 is, we emphasize, a flexible one. Its overarching subject is the scientific validity *595 and thus the evidentiary relevance and reliability—of the principles that underlie a proposed submission. The focus, of course, must be solely on principles and methodology, not on the conclusions that they generate.

Throughout, a judge assessing a proffer of expert scientific testimony under Rule 702 should also be mindful of other applicable rules. Rule 703 provides that expert opinions based on otherwise inadmissible hearsay are to be admitted only if the facts or data are "of a type reasonably relied upon by experts in the particular field in forming opinions or inferences upon

the subject." Rule 706 allows the court at its discretion to procure the assistance of an expert of its own choosing. Finally, Rule 403 permits the exclusion of relevant evidence "if its probative value is substantially outweighed by the danger of unfair prejudice, confusion of the issues, or misleading the jury...." Judge Weinstein has explained: "Expert evidence can be both powerful and quite misleading because of the difficulty in evaluating it. Because of this risk, the judge in weighing possible prejudice against probative force under Rule 403 of the present rules exercises more control over experts than over lay witnesses." Weinstein, 138 F.R.D., at 632.

III

We conclude by briefly addressing what appear to be two underlying concerns of the parties and amici in this case. Respondent expresses apprehension that abandonment of "general acceptance" as the exclusive requirement for admission will result in a "free-for-all" in which befuddled juries are confounded by absurd and irrational pseudoscientific assertions.*596 In this regard respondent seems to us to be overly pessimistic about the capabilities of the jury and of the adversary system generally. Vigorous cross-examination, presentation of contrary evidence, and careful instruction on the burden of proof are the traditional and appropriate means of attacking shaky but admissible evidence. See Rock v. Arkansas, 483 U.S. 44, 61, 107 S.Ct. 2704, 2714, 97 L.Ed.2d 37 (1987). Additionally, in the event the trial court concludes that the scintilla of evidence presented sup-porting a position is insufficient to allow a reasonable juror to conclude that the position more likely than not is true, the court remains free to direct a judgment, Fed.Rule Civ.Proc. 50(a), and likewise to grant summary judgment, Fed.Rule Civ.Proc. 56. Cf., e.g., Turpin v. Merrell Dow Pharmaceuticals, Inc., 959 F.2d 1349 (CA6) (holding that scientific evidence that provided foundation for expert testimony, viewed in the light most favorable to plaintiffs, was not sufficient to allow a jury to find it more probable than not that defendant caused plaintiff's injury), cert. denied, 506 U.S. 826, 113 S.Ct. 84, 121 L.Ed.2d 47 (1992); Brock v. Merrell Dow Pharmaceuticals, Inc., 874 F.2d 307 (CA5 1989) (reversing judgment entered on jury verdict for plaintiffs because evidence regarding causation was insufficient), modified, 884 F.2d 166 (CA5 1989), cert. denied, 494 U.S. 1046, 110 S.Ct. 1511, 108 L.Ed.2d 646 (1990); Green 680–681. These conventional devices, rather than wholesale exclusion under an uncompromising "general acceptance" test, are the appropriate safeguards where the basis of scientific testimony meets the standards of Rule 702.

Petitioners and, to a greater extent, their amici exhibit a different concern. They suggest that recognition of a screening role for the judge that allows for the exclusion of "invalid" evidence will sanction a stifling and repressive scientific orthodoxy and will be inimical to the search for truth. See, e.g., Brief for Ronald Bayer et al. as Amici Curiae. It is true that open debate is an essential part of both legal and scientific analyses. Yet there are important differences between the quest for truth in the courtroom and the quest*597 for truth in the laboratory. Scientific conclusions are subject to perpetual revision. Law, on the other hand, must resolve disputes finally and quickly. The scientific project is advanced by broad and wide-ranging consideration of a multitude of hypotheses, for those that are incorrect will eventually be shown to be so, and that in itself is an advance. Conjectures that are probably wrong are of little use, however, in the project of reaching a quick, final, and binding legal judgment—often of great consequence—about a particular set of events in the past. We recognize that, in practice, a gatekeeping role for the judge, no matter how flexible, inevitably on occasion will prevent the jury from learning of authentic insights and innovations. That, nevertheless, is the balance that is

struck by Rules of Evidence designed not for the exhaustive search for cosmic understanding but for the particularized resolution of legal disputes.[99]

IV

To summarize: "General acceptance" is not a necessary precondition to the admissibility of scientific evidence under the Federal Rules of Evidence, but the Rules of Evidence—especially Rule 702—do assign to the trial judge the task of ensuring that an expert's testimony both rests on a reliable foundation and is relevant to the task at hand. Pertinent evidence based on scientifically valid principles will satisfy those demands.

The inquiries of the District Court and the Court of Appeals focused almost exclusively on "general acceptance," as gauged by publication and the decisions of other courts. Accordingly,*598 the judgment of the Court of Appeals is vacated, and the case is remanded for further proceedings consistent with this opinion.

It is so ordered.

Chief Justice REHNQUIST, with whom Justice STEVENS joins, concurring in part and dissenting in part.

The petition for certiorari in this case presents two questions: first, whether the rule of Frye v. United States, 54 App.D.C. 46, 293 F. 1013 (1923), remains good law after the enactment of the Federal Rules of Evidence; and second, if Frye remains valid, whether it requires expert scientific testimony to have been subjected to a peer review process in order to be admissible. The Court concludes, correctly in my view, that the Frye rule did not survive the enactment of the Federal Rules of Evidence, and I therefore join Parts I and II–A of its opinion. The second question presented in the petition for certiorari necessarily is mooted by this holding, but the Court nonetheless proceeds to construe Rules 702 and 703 very much in the abstract, and then offers some "general observations."

"General observations" by this Court customarily carry great weight with lower federal courts, but the ones offered here suffer from the flaw common to most such observations—they are not applied to deciding whether particular testimony was or was not admissible, and therefore they tend to be not only general, but vague and abstract. This is particularly unfortunate in a case such as this, where the ultimate legal question depends on an appreciation of one or more bodies of knowledge not judicially noticeable, and subject to different interpretations in the briefs of the parties and their amici. Twenty-two amicus briefs have been filed in the case, and indeed the Court's opinion contains no fewer than 37 citations to amicus briefs and other secondary sources.

*599 The various briefs filed in this case are markedly different from typical briefs, in that large parts of them do not deal with decided cases or statutory language—the sort of material we customarily interpret. Instead, they deal with definitions of scientific knowledge, scientific

[99] This is not to say that judicial interpretation, as opposed to adjudicative fact-finding, does not share basic characteristics of the scientific endeavor: "The work of a judge is in one sense enduring and in another ephemeral.... In the endless process of testing and retesting, there is a constant rejection of the dross and a constant retention of what-ever is pure and sound and fine." B. Cardozo, The Nature of the Judicial Process 178, 179 (1921).

method, scientific validity, and peer review—in short, matters far afield from the expertise of judges. This is not to say that such materials are not useful or even necessary in deciding how Rule 703 should be applied; but it is to say that the unusual subject matter should cause us to proceed with great caution in deciding more than we have to, because our reach can so easily exceed our grasp.

But even if it were desirable to make "general observations" not necessary to decide the questions presented, I cannot subscribe to some of the observations made by the Court. In Part II–B, the Court concludes that reliability and relevancy are the touchstones of the admissibility of expert testimony. Federal Rule of Evidence 402 provides, as the Court points out, that "[e]vidence which is not relevant is not admissible." But there is no similar reference in the Rule to "reliability." The Court constructs its argument by parsing the language "[i]f scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, ... an expert ... may testify thereto...." Fed.Rule Evid. 702. It stresses that the subject of the expert's testimony must be "scientific ... knowledge," and points out that "scientific" "implies a grounding in the methods and procedures of science" and that the word "knowledge" "connotes more than subjective belief or unsupported speculation." From this it concludes that "scientific knowledge" must be "derived by the scientific method." Proposed testimony, we are told, must be supported by "appropriate validation." Indeed, in footnote [96], the Court decides that "[i]n a case involving scientific evidence, evidentiary reliability will *600 be based upon scientific validity."

Questions arise simply from reading this part of the Court's opinion, and countless more questions will surely arise when hundreds of district judges try to apply its teaching to particular offers of expert testimony. Does all of this dicta apply to an expert seeking to testify on the basis of "technical or other specialized knowledge"—the other types of expert knowledge to which Rule 702 applies—or are the "general observations" limited only to "scientific knowledge"? What is the difference between scientific knowledge and technical knowledge; does Rule 702 actually contemplate that the phrase "scientific, technical, or other specialized knowledge" be broken down into numerous subspecies of expertise, or did its authors simply pick general descriptive language covering the sort of expert testimony which courts have customarily received? The Court speaks of its confidence that federal judges can make a "preliminary assessment of whether the reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue." The Court then states that a "key question" to be answered in deciding whether something is "scientific knowledge" "will be whether it can be (and has been) tested." Following this sentence are three quotations from treatises, which not only speak of empirical testing, but one of which states that the " 'criterion of the scientific status of a theory is its falsifiability, or refutability, or testability."

I defer to no one in my confidence in federal judges; but I am at a loss to know what is meant when it is said that the scientific status of a theory depends on its "falsifiability," and I suspect some of them will be, too.

I do not doubt that Rule 702 confides to the judge some gatekeeping responsibility in deciding questions of the admissibility of proffered expert testimony. But I do not think *601 it imposes on them either the obligation or the authority to become amateur scientists in order to

perform that role. I think the Court would be far better advised in this case to decide only the questions presented, and to leave the further development of this important area of the law to future cases.

D. *Green Mountain Chrysler Plymouth Dodge Jeep v. Crombie,* (D. Vt. 2007)(edited down to focus on the scientific expert testimony issues).

Nos. 2:05–CV–302, 2:05–CV–304. Sept. 12, 2007.

The District Court, Sessions, Chief Judge held that:

(1) defendants' experts' opinion testimony was reliable and relevant;
(2) exclusion of consultant's expert testimony regarding feasibility of compliance with challenged regulations was not warranted on basis of consultant's failure to disclose the sources for certain cells in his lumped parameter model and or his destruction of notes of his interviews with automakers;
(3) preemption doctrines did not apply to the interplay between Environmental Protection Agency's (EPA) authority to regulate greenhouse gases from new motor vehicles under Clean Air Act (CAA) and National Highway Traffic Safety Administration's (NHTSA) authority under Energy Policy and Conservation Act (EPCA) to promote energy efficiency by setting mileage standards; and
(4) Vermont regulations were not preempted.

Judgment for defendants.

Introduction

In these consolidated cases, Plaintiffs, a collection of new motor vehicle dealers, automobile manufacturers and associations of automobile manufacturers, seek declaratory and injunctive relief from regulations adopted by Vermont in the fall of 2005 that establish greenhouse gas ("GHG") emissions standards for new automobiles. The *301 brought six claims for declaratory and injunctive relief: express and implied preemption under the Energy Policy and Conservation Act of 1975, 49 U.S.C. §§ 32901–32919 ("EPCA") (Count I); preemption under the Clean Air Act as amended, 42 U.S.C. §§ 7401–7671q ("CAA") (Count II); violation of the CAA (Count III); foreign policy preemption (Count IV); violation of the dormant Commerce Clause (Count V); and violation of the Sherman Act (Count VI). On May 3, 2006, five non-profit environmental advocacy groups were permitted to intervene as defendants in the cases, and on July 27, 2006 the State of New York was also permitted to intervene as a defendant.

Section 502 of EPCA directs the Department of Transportation ("DOT") to set fuel economy standards for new passenger vehicles and light trucks. 49 U.S.C. § 32902. Section 509 of EPCA preempts any state laws or regulations related to fuel economy standards. 49 U.S.C. § 32919(a). Because there is a relationship between de-creasing carbon dioxide emission from the

tailpipe of a motor vehicle and increasing its fuel economy, Plaintiffs challenged Vermont's regulations as preempted by EPCA, among other contentions.

Recently, in Massachusetts v. EPA, 549 U.S. 497, 127 S.Ct. 1438, 167 L.Ed.2d 248 (2007), the United States Supreme Court confirmed that EPA has the authority to regulate GHG emissions from new motor vehicles under Section 202(a)(1) of the CAA. It commented: "that DOT sets mileage standards in no way licenses EPA to shirk its environmental responsibilities.... The two obligations may overlap, but there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency." 127 S.Ct. at 1462.

Given that automobile manufacturers require lead time in order to make design changes to their vehicles to attempt to comply with the regulations, and given that it has taken years to process waiver applications (although EPA has consistently granted California's applications for a waiver of preemption), the Court and the parties have proceeded with this case on the assumption that EPA will grant California's waiver application. If it does not, of course, Vermont's regulation is preempted by the CAA's section 209(a).

In this decision the Court addresses first the statutory background of the case, *303 and includes a summary of the decision in Massachusetts v. EPA, 549 U.S. 497, 127 S.Ct. 1438, 167 L.Ed.2d 248 (2007). The Court turns next to the question whether the opinions and testimony of Defendants' witnesses Duleep, Rock and Hansen must be excluded from consideration either as a sanction for discovery violations or as precluded by Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579, 113 S.Ct. 2786, 125 L.Ed.2d 469 (1993). Then, in the first section of the Findings and Conclusions, the Court outlines the context of the GHG regulation in California and Vermont, along with the concerns about global warming that led to the regulation's development, and details the GHG regulation itself. Next the Court discusses express and implied preemption, concluding first that this is not rightly a case about federal preemption, but about potential conflict between two federal statutes. Second, the Court concludes that EPCA does not expressly preempt Vermont's GHG regulations, nor are Vermont's GHG regulations precluded under principles of field or conflict preemption. Finally, the Court deals with the remaining legal challenge to the regulation, concluding that the regulation does not impermissibly intrude upon the foreign affairs prerogatives of the President and Congress of the United States.

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Evidentiary Issues

I. Daubert Challenges

The plaintiffs move under Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579, 113 S.Ct. 2786, 125 L.Ed.2d 469 (1993), to exclude the expert testimony of three witnesses called by Defendants: Dr. James Hansen, Dr. Barrett Rock and Mr. K.G. Duleep. There is no debate as to the adequacy of these experts' credentials; rather, the plaintiffs have moved to strike their testimony on the grounds that it is not reliable scientific evidence and does not assist the trier of fact.

The party proffering expert testimony has the burden of establishing its admissibility "by a preponderance of proof." Daubert, 509 U.S. at 592 n. 10, 113 S.Ct. 2786. Rule 702 of the Federal Rules of Evidence provides that:

> [i]f scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.

Fed.R.Evid. 702.

To be admissible as scientific knowledge under this rule, expert opinion testimony must meet a "standard of evidentiary reliability." That is, it must be "derived by the scientific method" and "supported by appropriate validation." Daubert, 509 U.S. at 590, 113 S.Ct. 2786. Proffered testimony must be based upon "sufficient facts or data." Fed.R.Evid. 702. This sufficiency analysis is quantitative rather than qualitative, and "facts or data" may include reliable opinions of other experts and hypothetical facts that are supported by the evidence. See id. advisory committee's note. The expert opinions offered must be the product of reliable principles and methods that have been reliably applied to the facts of the case. Fed.R.Evid. 702. While the testimony *311 must be reliable, its subject need not be " 'known' to a certainty; arguably, there are no certainties in science." Daubert, 509 U.S. at 590, 113 S.Ct. 2786. Experience alone, or experience combined with other knowledge, skill, training or education, may be the basis for expert testimony under the Rule. Fed.R.Evid. 702 advisory committee's note.

The focus under Daubert must be on principles and methodology, not on the conclusions that they generate. Daubert, 509 U.S. at 595, 113 S.Ct. 2786. However, a district court is not required to "admit opinion evidence that is connected to existing data only by the ipse dixit of the expert." Gen. Elec. Co. v. Joiner, 522 U.S. 136, 146, 118 S.Ct. 512, 139 L.Ed.2d 508 (1997).

In Daubert, the Supreme Court set forth a non-exclusive list of four considerations that may bear on whether a theory or technique has sufficient scientific validity to constitute reliable evidence: (1) "whether it can be (and has been) tested," Daubert, 509 U.S. at 593, 113 S.Ct. 2786; (2) "whether [it] has been subjected to peer review and publication," id.; (3) as to a scientific technique, its "known or potential rate of error, and the existence and maintenance of standards controlling the technique's operation," id. at 594, 113 S.Ct. 2786 (citation omitted); and (4) "widespread acceptance." Id.; see also Campbell v. Metro. Prop. & Cas. Ins. Co., 239 F.3d 179, 185 (2d Cir.2001). These factors are to be considered in addition to the three enumerated in the rule itself. While a theory's acceptance in the expert community is a factor to be considered, "general acceptance" is not an "absolute prerequisite" to admissibility under Rule 702. Daubert, 509 U.S. at 588, 113 S.Ct. 2786.

The inquiry into scientific validity is a flexible one, see id. at 594, 113 S.Ct. 2786, and courts applying Daubert have used the enumerated factors in a flexible manner, finding other factors pertinent or recognizing that the Daubert factors do not apply to all types of expert testimony. See, e.g., Blanchard v. Eli Lilly & Co., 207 F.Supp.2d 308, 315–16 (D.Vt.2002)

(citing cases). Kumho Tire Co. v. Carmichael, 526 U.S. 137, 141, 119 S.Ct. 1167, 143 L.Ed.2d 238 (1999), clarified that the specific factors mentioned in Daubert must be considered only when their consideration "will help determine that testimony's reliability." A district court enjoys "broad latitude when it decides how to determine reliability." Id. at 142, 119 S.Ct. 1167 (emphasis deleted); see also Wills v. Amerada Hess Corp., 379 F.3d 32, 41 (2d Cir.2004); Amorgianos v. Nat'l R.R. Passenger Corp., 303 F.3d 256, 265 (2d Cir.2002). Each stage of an expert's testimony "must be evaluated practically and flexibly without bright-line exclusionary (or inclusionary) rules." Heller v. Shaw Indus., Inc., 167 F.3d 146, 155 (3d Cir.1999).

Factors not listed in Daubert but found to be relevant by the Circuit courts include: (1) whether the expert pro-poses to testify about matters derived from research independent of the litigation, see Daubert v. Merrell Dow Pharms., Inc., 43 F.3d 1311, 1317 (9th Cir.1995); (2) whether the expert has adequately accounted for obvious alternative explanations, see Claar v. Burlington N.R.R., 29 F.3d 499 (9th Cir.1994); cf. Ambrosini v. Labarraque, 101 F.3d 129, 139–40 (D.C.Cir.1996) (the possibility of uneliminated causes goes to weight rather than admissibility, provided that the expert has considered and reasonably ruled out the most obvious); (3) whether the expert has employed the same level of intellectual rigor in the courtroom as in the relevant field of expertise, see Kumho Tire, 526 U.S. at 152, 119 S.Ct. 1167; (4) the non-judicial uses to which the method has been put, see *312 Elcock v. Kmart Corp., 233 F.3d 734, 746 (3d Cir.2000); (5) whether the expert's discipline itself lacks reliability, see Kumho Tire, 526 U.S. at 151, 119 S.Ct. 1167, and (6) whether the expert has unjustifiably extrapolated from an accepted premise to an unfounded conclusion. See Joiner, 522 U.S. at 146, 118 S.Ct. 512.

Overall, the Supreme Court has emphasized the "liberal thrust" of the Federal Rules of Evidence with regard to expert opinion testimony. Daubert, 509 U.S. at 588, 113 S.Ct. 2786. In ruling that an expert's testimony is reliable for the purposes of admission into evidence, a trial court does not indicate that contradictory expert testimony is unreliable or inadmissible. As the Advisory Committee Notes to the 2000 Amendments to Rule 702 explain, the Rule permits the introduction of "testimony that is the product of competing principles or methods in the same field of expertise." Fed.R.Evid. 702 advisory committee's note. The proponent of an expert's testimony need prove only that the opinions offered are reliable, not that they are correct. Id. (citing In re Paoli R.R. Yard PCB Litig., 35 F.3d 717, 744 (3d Cir.1994)); United States v. Vargas, 471 F.3d 255 (1st Cir.2006) (internal citations omitted). "Vigorous cross-examination, presentation of contrary evidence, and careful instruction on the burden of proof are the traditional and appropriate means of attacking shaky but admissible evidence." Daubert, 509 U.S. at 596, 113 S.Ct. 2786 (citing Rock v. Arkansas, 483 U.S. 44, 107 S.Ct. 2704, 97 L.Ed.2d 37 (1987)). In this case, both parties have availed themselves of opportunities for cross-examination and for the presentation of contrary evidence.

The Rules' liberal approach to the admission of expert testimony is particularly appropriate in a bench trial. Ex-pert testimony is likely to hold "unique weight" in the minds of a jury. See Nimely v. City of New York, 414 F.3d 381, 397 (2d Cir.2005). Here, by contrast, much of the testimony presented on each side was expert testimony, and the Court is accustomed to evaluating the strengths and weaknesses of such testimony. Therefore, the Court can weigh the evidence admitted without being unduly swayed by a witness's designation as an expert.

A. James Hansen, Ph.D.

The plaintiffs contend that Dr. Hansen's opinions are inadmissible as unreliable. They seek to exclude his testimony regarding the impact of the regulation, and more specifically his "tipping point" theory, including his testimony regarding ice sheet disintegration. They apparently do not seek to exclude his testimony regarding species extinction and regional effects of global warming, except insofar as these effects are presented as consequences of the Earth passing a "tipping point."

1. Hansen's Qualifications

There can be no dispute that Dr. Hansen is qualified "by knowledge, skill, experience, training, or education" as an expert in climatology. See Fed.R.Evid. 702. Dr. Hansen has had an illustrious scientific career. His work history includes positions as a Resident Research Associate at the NASA Goddard Institute for Space Studies, between 1967 and 1969; a position as an NSF Postdoctoral Fellow at the Leiden Observatory in the Netherlands; a three-year position as a Research Associate at Columbia University, and a long stint as a staff member and space scientist at the Goddard Institute, where he was also the Manager of the Institute's Planetary and Climate Programs, from 1972 until his appointment as the Institute's Director in 1981. Hansen Resume, Hansen Decl.App. A. Hansen continues to *313 hold his position as the Director of the Goddard Institute. Id.; Tr. vol. 13–A, 145:2–3 (Hansen, May 3, 2007). He is also an Adjunct Professor in Earth and Environmental Sciences at Columbia University, where he teaches Introduction to Planetary Atmospheres and Climate Change and a graduate level class on Atmospheric Radiation. Hansen Resume.

Hansen's impressive educational background includes an undergraduate degree in physics and mathematics, and a master's degree and doctorate in astronomy. Tr. vol. 13–A, 147:1–17. He has particular expertise in climatology and the science of global warming; he testified at trial that since the late 1970s, he has focused all of his time on trying to understand the climate of the Earth. Id. at 148:21–24. During the last thirty years, he has published more than 100 peer-reviewed articles on the general topic of climatology, and edited a book on the subject of climate change and the paleoclimate. Id. at 153:1–14.

Dr. Hansen's expertise has been honored on many occasions and in many settings. He is a member of the American Geophysical Union, the American Meteorological Society, and the National Academy of Sciences. Id. at 149:7–9. He has won awards including the Duke of Edinburgh Award from the World Wildlife Fund; the Rogen Ravel Medal from the American Geophysical Union; the Leo Szilard Lectureship Award from the American Physical Society; and the Heinz Environment Award. Id. at 151:6–152:4. Between 1977 and 2005 Hansen won eighteen awards for his scientific work, including winning the Goddard Institute's "Best Scientific Publication" award, determined by a peer vote, three times. Id. at 152:5–11; Hansen Resume. His testimony at trial revealed his extensive familiarity with research and data on climate history, climate change and its likely effects.

2. Hansen's Testimony

Hansen testified that human emissions of greenhouse gases, including carbon dioxide and methane, are climate "forcing" agents that can cause warming of the Earth's surface.[100] Tr. vol. 13–B, 12:7–8 (Hansen, May 3, 2007). Since pre-industrial times, there has been a drastic increase in atmospheric concentrations of such gases, due primarily to fossil fuel burning.[101] Id. at 13:8–14:3. On long term scales, the climate is very sensitive to even small forces, and human-made forces are now much larger than the changes that drove glacial to interglacial changes in the past. Id. at 30:22–31:1.

Hansen's "tipping point" theory posits that at a certain point the changes associated*314 with global warming will become dramatically more rapid and out of control. The "tipping point" is the point at which very little, if any, additional forcing is needed for substantial changes to occur. Id. at 50:18–23. Hansen testified that based on the historical temperature record, drastic consequences, including rapid sea level rise, extinctions, and other regional effects, would be inevitable with a two to three degrees Celsius warming expected if no limits are imposed and emissions continue at their current rate. Such changes could happen quickly once a tipping point is passed. On the other hand, Hansen theorizes that if GHG emissions are reduced, warming may remain within the upper limit of previous interglacial periods and might avoid the most drastic consequences of global warming. See id. at 48:7–49:1.

In the last one hundred years the temperature has in-creased to within less than one degree Celsius of the warmest interglacial period in the past 1.3 million years.[102] Id. at 37:15–38:2. Hansen testified that warming may be less dangerous as long as it stays within that range, and certainly it would have a less drastic effect than the warming that is expected if GHG emissions continue un-checked by regulation. He posits that an "alternative scenario" in which regulations are imposed to keep the temperature in that range is necessary. Id. at 38:4–13.[103]

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[100] A "forcing" is an imposed perturbation to the planet's energy balance, measured in watts per meter squared. Tr. vol. 13–B, 10:2–10 (Hansen, May 3, 2007). Greenhouse gases absorb heat radiation, so that an increase in the amount of these gases in the atmosphere is a mechanism for making the Earth's surface warmer. Such warming can be measured in the same way as other causes of temperature change, such as changes in the sun's brightness. Id. at 12:16–24.

[101] The concentration of carbon dioxide in the ambient atmosphere in the present time, averaged over the world, is about 383 parts per million, compared with 280 parts per million in the pre-industrial era. Id. at 13:8–13. This increase is due primarily to fossil fuel burning, which ac-counts for about eighty percent of the increase. To find carbon dioxide concentrations as high as current ones, it is necessary to look at a period two to five million years ago. Current annual increases in carbon dioxide emissions are two parts per million, up from one part per million when measurements began in 1958. They are predicted to rise to about four parts per million per year by the middle of the century under the business-as-usual scenarios. Id. at 58:15–59:3.

[102] This data is from the temperature as measured in ocean cores.

[103] Hansen supports this conclusion by looking at the historical record. In the middle Pliocene period 3–1/2 million years ago, the temperature was two to three degrees Celsius warmer than the present global temperature, approximately the level of global warming that Hansen predicts absent regulation of greenhouse gases. Sea level rose twenty-five meters. Id. at. 28:3–9. During the past 1.3 million years, while temperature fluctuations were less dramatic, sea level was at least a few meters higher than today's during some periods, but the rise was less drastic. Id. at 38:20–24.

Hansen testified that sea level rise is likely to take place in a nonlinear fashion because of multiple positive feedbacks.[104] Id. at 52:7–20. Once a certain point is reached, rather than melting at a consistent rate, ice sheets may rapidly disintegrate. Hansen pointed to evidence in the paleoclimate record for such abrupt climate changes.[105] Id. at 46:22–47:18. Huge changes, on the scale of one hundred meters of sea level rise, have frequently taken place over the course of only a few thousand years. There are multiple instances in which sea level has risen several meters per century, in response to smaller forcings than those currently underway. Id. at 51:8–21. Based on this record, Hansen's opinion is that the time scale of the response of an ice sheet depends on the time scale of a forcing. Id. at 51:12–15. The scale of the GHG forcing currently underway shows that it is virtually certain that such a large-scale rise will occur if *315 GHG emissions continue to increase. Id. at 52:7–20.

To support his testimony regarding ice loss, Hansen presented substantial data, including satellite observations and gravitational measurements from the GRACE satellite in Greenland and West Antarctica, showing patterns that suggest that ice sheets are both melting and becoming increasingly unstable.[106]

Hansen also testified regarding likely regional climate changes resulting from global warming. Climate history underscores the likelihood of species extinction resulting from climate change; in the history of the Earth there have been five or six global warming events comparable to or larger than that predicted for the end of the 21st Century, each resulting in the extinction of a majority of the species on the planet. Id. at 69:13–23.

As to regional effects, climate models agree on an intensification of the climatic patterns of rainfall belt in the tropics and dry subtropical regions on both sides, leading to more intense dry conditions in the western United States and Mediterranean and parts of Africa and Australia. Id. at 56:24–57:11.

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[104] Feedbacks magnify the effect of a forcing. Even a very small forcing may have a large effect because warming will cause the release of carbon dioxide from oceans, increasing the forcing, and decrease ice cover, increasing the amount of warmth that is absorbed by the Earth rather than reflected. These feedbacks will cause still more carbon dioxide release and melting of ice. Id. at 22:22–23–1.

[105] For example, in the transition from the last ice age to the current interglacial period, there was a period in which sea level increased twenty meters in four hundred years, or about one meter every twenty years, a phenomenon known as Meltwater Pulse 1A. That ice sheet was at a lower latitude than the Greenland or Antarctic ice sheets, but was subject to a much smaller forcing. Id. at 47:7–18.

[106] Satellite observations support Hansen's belief that the Earth is at risk from ice sheet disintegration. Satellites show increasing meltwater on the ice sheet in Greenland during the summers. Id. at 43:9–15. Icewater finds the lowest spot and burrows a hole through the base of the sheet, lubricating the base of the sheet and speeding the discharge of giant icebergs to the ocean. On the largest ice stream in Greenland, the flux of ice-bergs has doubled in the last five years. Id. at 43:25–44:2. The satellite GRACE, which measures the gravitational field of the Earth to show changes in ice sheet mass, shows that the ice sheet is melting faster than it is being increased by additional snowfall. Id. at 44:17–45:3. The frequency of earthquakes in Greenland has doubled between 1993 and 1999, and again between 1999 and 2005, a pattern consistent with a nonlinear process in which the ice sheet is becoming less stable. Id. at 45:11–46:4. The ice sheet of greatest concern is the West Antarctic Ice Sheet, which sits on bedrock, below sea level, in direct contact with the ocean. This ice sheet contains sufficient water that, if melted, could cause sea level to rise a total of seven meters. Its ice shelves are now melting several meters per year. Id. at 49:2–16.

Addressing these problems, according to Hansen, means addressing emissions of carbon dioxide, the most important greenhouse gas,[107] through an alternative scenario. Id. at 25:5–10. That scenario contemplates an initial slow decrease in carbon dioxide emissions followed by more rapid decreases later in the century as new technologies are developed. Id. at 59:6–63:1. The vehicle emissions reductions that the GHG regulation requires are consistent with the alternative scenario's conception of the necessary steps to check global climate change before the Earth reaches a tipping point leading to the disastrous results described above.[108]

*316 Hansen did not testify that GHG regulations such as Vermont's will solve the global warming problem. Id. at 71:24–72:4. Rather, he testified to his opinion that the Vermont regulations' emissions reductions are scientifically important, not because of their effects when taken alone, but because they are consistent with the rates of change necessary to avoid the most drastic consequences of global warming. Id. at 72:18–73:2. Hansen testified that it is hard to say what straw will break the camel's back in terms of tipping points. Id. at 73:6–12. In addition, he noted that the effects of the regulation may be magnified if its adoption encourages reductions in other parts of the country and the world. Id. at 73:16–21.

If the alternative scenario is to be achieved, action must be immediate. One more decade of business as usual—that is, another ten years of two percent increases in carbon dioxide emissions annually—would lead to emissions in 2015 that are thirty-five percent greater than those in 2000. It would then be virtually impossible to reduce emissions to the level necessary to meet the alternative scenario. Id. at 69:24–70:7.

3. Reliability of Hansen's Testimony

The plaintiffs assert that Hansen's testimony does not meet Rule 702's reliability requirements, arguing that his opinions "arise out of pure speculation." Pls.' Renewed Mot. to Exclude Test. of Hansen 1 (Doc. 485). As to the Daubert factors, they argue that Hansen's testimony "meets none of Daubert's criteria for reliability": his "technique certainly has no known error rate and his hypothesis has not been, and cannot be, tested; the scientific community has explicitly considered and rejected his view as lacking scientific support; and his projections

[107] Although methane is a far more powerful greenhouse gas, it is not released in the same large quantities and does not have the same lengthy lifetime. A century after carbon dioxide is released a third of the carbon dioxide will remain in the atmosphere. After five hundred years, a quarter will remain. Although some carbon dioxide is taken up by the ocean, carbon dioxide taken up by the ocean exerts a back pressure on the atmosphere, so a significant fraction will remain in the atmosphere until that previously taken up has been deposited in the sediments of the ocean, a process taking thousands of years. Id. at 29:10–30:12.

[108] Hansen and his students used the National Research Council report on vehicle efficiencies to determine how vehicle emissions reductions could fit in with such a scenario. By taking the improvements outlined in that report that would basically pay for themselves and forecasting a phase-in of those recommendations over a ten year period, they found that with the expected growth in vehicle numbers, those improvements actually cause a moderate decrease in total vehicle emissions, which continues for a few decades without further improvements. Id. at 63:2–64:1. That report used slightly weaker emissions requirements than those that the regulation imposes. Id. at 67:20–68:8.

regarding the tipping point and sea level rise find no objective support in the scientific literature."[109]

Hansen's testimony is based on sufficient facts and data and reliable methods, applied reliably to the facts. Hansen cited abundant data in support of his theories regarding climate change, including historical data gathered from a number of sources including measured temperatures, ice cores and ocean cores, as well as modeling results. He also cited substantial data regarding the likelihood of ice sheet disintegration, including satellite imagery and the GRACE satellite's gravitational field data showing recent losses of mass in Greenland and Antarctica, increases in ice quakes in Greenland, recent accelerations in ice streams flowing off Greenland, and historical data on sea level rise at other warm periods in paleoclimate history. As the '302 plaintiffs note in their motion to exclude Hansen's testimony, historical data is not a perfect predictor of what will happen in our current climate. Id. at 9. The unprecedented nature of current human-made*317 forcings means that history is not a perfect guide. However, that the situation is unprecedented does not mean that scientists may not testify reliably as to global warming's likely effects.

Plaintiffs' rebuttal expert, Dr. John Christy,[110] testified that Hansen's hypothesis regarding rapid sea level rise is unsupported by the scientific evidence. Christy critiqued the use of data from the GRACE satellite; while he agreed that the data was accurate, he noted that only a few years' worth of data are available. Tr. vol. 14–A, 109:5–14 (Christy, May 4, 2007). Since the GRACE data was only one of several sources supporting Hansen's conclusions, objections to that data are insufficient to render Hansen's testimony inadmissible. In addition, the Court, as the trier of fact, can take into account the short time period for which GRACE measurements exist. This limitation goes to the weight, rather than to the admissibility of Hansen's testimony.[111]

As to sea level rise, Hansen acknowledges that no existing mathematical or scientific model can predict the sea level rise that will result from ice sheet disintegration, when it will occur, or the exact sea level rise it will cause. Tr. vol. 13–B, 96:14–15; 122:5–123:1 (Hansen, May 3, 2007). Under these circumstances, Hansen's use of his expertise to make a prediction based on climate history is not an unreasonable choice of methodology. Hansen's predictions need not be certainties to be admissible under Rule 702, nor need his estimates of the timing and

[109] Plaintiffs did not produce any evidence to contradict Hansen's testimony on likely species extinctions and devastating regional impacts of global warming other than ice sheet disintegration. In addition, they do not address that testimony in their Motion. Therefore, the Court assumes that their motion seeks the exclusion of Hansen's testimony as to the concept of a "tipping point" and as to his predictions regarding ice sheet disintegration and sea level rise, but does not seek the exclusion of his testimony as to the effects of global warming on species extinction or regional impacts.

[110] Christy is the Alabama state climatologist. He is also a professor of atmospheric science and Director of the Earth Systems Science Center at the University of Alabama at Huntsville. Tr. vol. 14–A, 66:15–19 (Christy, May 4, 2007).

[111] Christy also suggested that some data shows that snowfall increases over ice sheets resulting from global climate change will make ice sheets larger, not smaller. Id. at 116:10–117:21. Hansen's response demonstrated his familiarity with the data that Christy referenced, and referenced additional data to support his position. These differences in the experts' interpretations of the available data are not grounds for the exclusion of Hansen's testimony. In addition, it appears that the bulk of scientific opinion opposes Christy's position. In recent testimony on the IPCC's findings to the U.S. House of Representatives Committee on Science and Technology, Dr. Richard Alley noted that "melting is now widespread," including in "the great ice sheets of Greenland and Antarctica, and we see it even when there is more snow falling. And so it's really hard to blame loss of ice and of snow if there is more snow in some places, and yet it is melting faster." PX 1238.

amount of sea level rise be exact to be admissible. The '302 plain-tiffs refer to an "absence of any objective evidence" to support Hansen's opinion, Pls.' Mot. 12, but Hansen did reference substantial supporting evidence in his testimony, including several examples from climate history. The lack of a model to address ice sheet disintegration does not mean that evidence on that point is de facto unreliable.

The plaintiffs repeatedly compare the IPCC's sea level rise predictions to Hansen's, arguing that Hansen's estimates are flawed because they are higher. The comparisons are misleading. The IPCC predicted a sea level rise of between eighteen and fifty-nine centimeters under a "business-as-usual" scenario. PX 1297 at 13. Although the IPCC takes into account runoff of snow and land-based ice from mountain glaciers, and continued ice sheet stream flow rates the same as those experienced from 1993–2003, in addition to thermal expansion, it does not address the possibility of ice sheet disintegration, which would cause much of the sea level rise that Hansen predicts. IPCC hearing transcript at 9:7–14; PX 1297 at 14. It is *318 common and acceptable for trained experts to extrapolate from existing data, as Hansen has done in making predictions from available information on the Earth's climate history. See Joiner, 522 U.S. at 146, 118 S.Ct. 512. Although a "court may conclude that there is simply too great an analytical gap between the data and the opinion proffered," id., there is no such gap here.

It is true that Hansen's predictions do not have a known error rate and cannot be tested, at least not in a laboratory. Daubert's factors are meant to be applied flexibly, see Blanchard, 207 F.Supp.2d at 315–16, and they by no means indicate that Hansen's testimony is inadmissible. Hansen's testimony is of a different nature from much of the expert testimony on which there is more extensive case law. Hansen presented a wide-reaching theory regarding the worldwide effects of unprecedented human-created climate change, not a theory about a drug's causation of birth defects, as in Daubert itself, or the likely credibility of witnesses, as in Nimely v. City of New York, 414 F.3d 381 (2d Cir.2005), or the likelihood that exposure to toxins was harmful, as in Wills, 379 F.3d at 46, and Amorgianos, 303 F.3d at 269–70. Although this theory must still be proven reliable, some Daubert factors may be less applicable here than in other cases involving expert testimony.

Hansen didn't testify to a screening test for a disease or genetic trait, which one would expect to have a particular error rate. Rather, he used various sources of evidence to make a prediction about the future of the Earth, a prediction which it is difficult to assign a defined error rate. As the conclusion which he reached is supported by evidence, the absence of a defined error rate does not render it in-admissible.

Plaintiffs argue at length that Hansen's theory is unreliable because it has not been tested by controlled scientific experimentation. It is difficult to imagine a conclusive test for any theory about the future climate effects of the world's current emissions of greenhouse gases. The appearance of Hansen's predicted large-scale impacts following a global temperature rise of two to three degrees Celsius would be the only entirely conclusive proof of his theories, but clearly it would be ridiculous to exclude his testimony on the grounds that this has not yet occurred. A prediction on this enormous scale must necessarily be tested by the extent to which it is confirmed by evidence such as the historical record and model results, rather than through testing. The same would be true of a theory on global warming offered by any expert. While the plaintiffs complain that the theory has not been tested, their motion does not describe what sort

of "controlled scientific experiment" they propose. Pls.' Mot. 8. The absence of controlled scientific testing does not undermine the reliability of Hansen's opinions given the nature of the predictions that he offers.

Plaintiffs argue that Hansen's theories are unreliable because they have not been subjected to peer review. Hansen published a paper in 2000 defining the "alternative scenario." See DX 2285. Hansen's views on the likelihood of rapid ice sheet disintegration have also been published; in 2005 he published an editorial essay projecting that two to three degrees Celsius warming would likely cause a sea-level rise of at least six meters within a century due to ice sheet disintegration. See James E. Hansen, A Slippery Slope: How Much Global Warming Constitutes "Dangerous Anthropogenic Interference"?, 68 Climatic Change 269 (2005). While not peer-reviewed, this publication did serve to place his views before the scientific community. *319 More recently, a paper regarding Hansen's sea level rise theory was published in a peer-reviewed journal. See James Hansen et al., Dangerous Human–Made Interference with Climate: A GISS Model E Study, 7 Atmos. Chem. Phys. 2287 (May 7, 2007).

Daubert notes that peer review is a relevant consideration in determining whether expert testimony is reliable because "submission to the scrutiny of the scientific community is a component of 'good science,' in part be-cause it increases the likelihood that substantive flaws in methodology will be detected." 509 U.S. at 593, 113 S.Ct. 2786. Although not extensively peer-reviewed, his publications demonstrate that Hansen's opinions have been thoroughly presented to the scientific community and are longstanding rather than framed for litigation purposes alone. See Daubert, 43 F.3d at 1317. In any case, this single factor is not determinative, and does not justify exclusion of his testimony under these circumstances, where his testimony is otherwise reliable.

There is widespread acceptance of the basic premises that underlie Hansen's testimony. Plaintiffs' own expert, Dr. Christy, agrees with the IPCC's assessment that in the light of new evidence and taking into account remaining uncertainties, most of the observed warming over the last fifty years is likely to have been due to the increase in GHG concentrations. Tr. vol. 14–A, 145:18–148:7 (Christy, May 4, 2007). Christy agrees that the increase in carbon dioxide is real and primarily due to the burning of fossil fuels, which changes the radiated balance of the atmosphere and has an impact on the planet's surface temperature toward a warming rate. Id. at 168:11–169:10. Christy also agreed that climate is a nonlinear system, that is, that its responses to forcings may be disproportionate, and rapid changes would be more difficult for human beings and other species to adapt to than more gradual changes. Id. at 175:2–174:11. He further agreed with Hansen that the regulation's effect on radiative forcing will be proportional to the amount of emissions reductions, and that any level of emissions reductions will have at least some effect on the radiative forcing of the climate. Id. at 174:16–23.

The plaintiffs contend that there is no support in the scientific community for Hansen's theories on sea level rise. Again, this is not accurate. At trial, Defendants introduced, in connection with Dr. Hansen's testimony, a peer-reviewed article by a group of scientists including Dr. Richard Alley, a top glaciologist, in which Dr. Alley and his coauthors conclude that "current knowledge cannot rule out a return to ... conditions [in which ice sheets have contributed meters above modern sea level in response to modest warming] in response to continued GHG emissions. Moreover, a threshold triggering many meters of sea-level rise could

be crossed well before the end of this century." DX 2287; see also DX 2292 (Antarctica is actually losing mass at a significant rate despite the increase in snowfall rate in the center of the ice sheet, contrary to previous beliefs).[112]

The plaintiffs further argue that Hansen's testimony is inadmissible due to lack of evidence that the regulation will avoid triggering a tipping point. Pls.' Renewed*320 Mot. 12. This objection to Dr. Hansen's testimony appears to rest on a misunderstanding of the opinion that he has offered.[113] Hansen does not argue that the change in GHG emissions that will result from the regulation challenged in this case will itself have the immense impact of preventing the Earth from reaching a "tipping point." Rather, he articulates a pressing need for the worldwide community to act in a comprehensive variety of arenas to reduce GHG emissions, as described in his "alternative scenario." He states that the reductions implied by the regulation at issue are consistent with that scenario. The fact that global warming will not be solved by changes in any one industry or by regulation of any one source of emissions in no way undercuts the vital nature of the problem or the validity of partial responses; rather, it points to the necessity of responses, however incomplete when viewed individually, on any number of fronts. See Massachusetts v. EPA, 127 S.Ct. at 1457 ("Agencies, like legislatures, do not generally resolve massive problems in one fell regulatory swoop. They instead whittle away at them over time.").

The Court finds that Hansen's opinions are reliable for purposes of their admission into evidence.

4. Relevance of Hansen's Testimony

Hansen's testimony provides the Court with important information on the nature and risks of global warming. As the regulation at issue was crafted in response to a recognition of these risks, understanding the nature of the regulation and its effects depends on an understanding of the science that underlies global warming. By explaining how such warming begins and grows, as well as how it may be addressed at this point in time, Hansen illuminated important background to the issues in this case. While Hansen does not, as noted above, argue that the regulation will in itself solve the global warming problem, his testimony provided valuable context for the Court's consideration of the Plaintiff's contentions that the regulation is essentially useless. Therefore, the Court finds that Hansen's opinions do assist the Court, as the trier of fact in this case.

The Renewed Motion to Exclude Testimony of James E. Hansen is denied.

[112] In addition, the National Academy of Science ("NAS") published a 2002 report in which it found that abrupt climate change is likely in the future, referencing the concept of "thresholds" or "tipping points." National Academy of Sciences, Abrupt Climate Change, Inevitable Surprises (2002) at page v, available at http:// books. nap. edu/ openbook. php? isbn= 0309074347.

[113] Plaintiffs' expert Dr. Christy estimated that implementing the regulations across the entire United States would reduce global temperature by about 1/100th (.01) of a degree by 2100. Hansen did not contradict that testimony.

B. Barrett N. Rock, Ph.D.

The plaintiffs move to exclude Dr. Rock's testimony on the grounds that his opinions are not relevant to this litigation and are methodologically flawed and unreliable.

1. Dr. Rock's Qualifications

Dr. Rock's qualifications are undisputed. He has been a professor at the University of New Hampshire ("UNH") for thirty-five years, and is the past director of the Complex Systems Research Center at the Institute for the Study of Earth, Oceans and Space at UNH. Tr. vol. 14–A, 7:20–8:4 (Rock, May 4, 2007). He has an undergraduate degree, a master's degree, and a Ph.D. in botany, focusing on the comparative study of forest conditions. Id. at 10:10–15. He has published peer-reviewed articles on those subjects and belongs to a variety of relevant professional associations. Id. at 10:20–11:3. Of particular relevance to this case, Rock has done substantial work on the impact of climate on forest health in the eastern United States and *321 elsewhere. Id. at 11:4–15. His peer-reviewed articles appeared in the New England Regional Assessment (the "regional assessment" or "NERA"), one of sixteen regional studies conducted as part of the U.S. Global Change Research Program's national assessment. Id. at 11:16–12:1; see also PX 2297, PX 2298. Rock was the lead author of the regional assessment. Tr. vol. 14–A, 13:10–11. Rock clearly is qualified to offer an expert opinion on the effects of climate change on Vermont's climate, forests, and associated industries.

3. Dr. Rock's Testimony

Dr. Rock testified that the past one hundred years have seen a warming trend in the New England region and the state of Vermont.[114] In the regional assessment, Rock used two climate models—the Hadley climate model and the Canadian climate model—which predicted six degrees Fahrenheit warming by 2100, and ten degrees Fahrenheit warming by 2100, respectively. Id. at 19:23–20:5. Rock testified that either level of warming would place at risk iconic elements of the Vermont experience and economy including fall foliage, maple syrup production, and the ski industry.

As to foliage, Rock testified that increased warming would result in very muted color displays, given that color changes in maples result from seasonal changes in temperature and day length. Id. at 18:16–24. In addition, climate change could cause the loss of maple trees in Vermont, as they are unable to tolerate a warmer climate. With the warming that either model predicts, there would eventually be no more maples in New England. Id. at 18:24–19:3, 20:6–12.

Warming will also lead to shorter and warmer winters in Vermont, according to Rock, which will mean less snow. Id. at 28:16–19. The regional assessment found that average snowfall for Vermont decreased by fifteen percent from 1953 to 1993. Id. at 28:22–29:9. The

[114] His data is from the National Climate Data Center's historic climate network, and is based on data from approximately 350 monitoring sites across the region. The data includes New York in the New England region. Tr. vol. 14–A, 15:23–16:6 (Rock, May 4, 2007). Overall warming in the region was 0.7 degrees Fahrenheit between 1895 and the present, while warming in Vermont was 1.6 degrees Fahrenheit. Id. at 15:12–20.

period during which snow is on the ground each year has decreased by about a week between 1953 and 1998. Id. at 29:10–30:4. Differences in snowfall are likely to affect the skiing industry.

Finally, Rock testified that warming will affect maple sugar production. Id. at 30:14–17. Syrup production re-quires specific conditions: freezing temperatures at night (below twenty-seven degrees Fahrenheit), and warming temperatures during the day (above thirty-two degrees and preferably between thirty-seven and thirty-eight degrees). These conditions cause bubbles to form in the sap that drive it up the tree to provide sugar to developing buds. The sap varies in sugar content based on conditions during what is known as the "cold recharge period," which normally takes place during parts of November, December, January, and beginning mid-to-late February. Id. at 30:20–31:21. The last few sugar seasons have been poor because December temperatures have been too high for an adequate cold recharge, which has affected both quality and quantity of syrup. Id. at 32:12–17. Lately, the sap season has become shorter and begun earlier in the season, which is a problem for sugar manufacturers who are accustomed to tap trees around President's*322 Day and miss the first sap run if it begins early.[115].

4. Reliability of Dr. Rock's Testimony

The plaintiffs attack specific portions of Rock's testimony on reliability grounds. Specifically, they argue that: (1) his testimony as to likely temperature in-creases in Vermont and New England relies on models which are methodologically flawed; (2) his testimony as to the impact of warmer temperatures on maple sugar production is flawed due to reliance on a study which references those same models; (3) his testimony regarding the impact of warmer regional temperatures on the ski industry is unreliable because it is based on a study of New Hampshire, rather than Vermont; and (4) his testimony as to the impact of warmer temperatures on fall foliage is unreliable because Rock has not shown that leaf color will actually change or tested his hypothesis to that effect. Pls.' Renewed Mot. to Exclude Test. of Rock (Doc. 479). The '302 plaintiffs have not attacked the science underlying Rock's testimony about how maple sugar is formed or about the conditions that favor maple syrup production or create fall foliage color.

Rock relied upon the National Climate Data Center's U.S. Historical Climate Station Network (the "Network") in his testimony regarding historical changes in Vermont's climate. Christy, testifying as a rebuttal witness to Rock, stated that the Network produces questionable results as to long-term variations. Tr. vol. 14–A, 120:7–15 (Christy, May 4, 2007). Christy has studied the accuracy of the Network in other regions and concluded that it has some bias toward showing too much warming over time. Id. at 120:16–25. Christy does not offer an alternate source of data. Christy's opinion that the data was flawed was drawn from his studies in other regions, not New England. In addition, the data that the Network produces does not result from the application of a model or formula; rather, it is a compilation of actual measurements from regional monitoring sites. Christy's only explanation for why the measurements might show inaccurate trends over long time periods is that stations move or other things happen to them. See id. at 120:16–21. However, a study updating the NERA report, published in 2005, used data only from stations with continuous records, excluding discontinuous or incomplete records, and still

[115] The first run is when the sap has the highest sugar content and lowest metabolic by-products, and makes the highest quality, Grade–A fancy syrup. Id. at 31:22–32:11.

found that Vermont was warming faster than the region overall. Tr. vol. 14–A, 17:3–18:5 (Rock, May 4, 2007).

Rock's testimony as to likely temperature increases in Vermont and New Hampshire is based on NERA's report, which uses the Hadley and Canadian models. The plaintiffs argue that his testimony on future climate change in the region is inadmissible due to the use of those models. Both are global models, which NERA downscaled for use at the regional level. They do not take into account regional environmental factors affecting regional climate, such as coastal orientation, grade change in elevation, latitude and position of the zone of westerlies. Id. at 44:4–14. Dr. Rock agreed that the models were not "ideal" and that regional models are needed; however, he nonetheless stated that the models were useful and standard in the scientific community. Id. at 43:21–44:3.

Christy criticized the Hadley and Canadian models, suggesting that they were extreme and were downscaled unreliably. Tr. vol. 14–A, 121:13–122:4 (Christy, May 4, 2007). Although Christy testified that *323 he had used climate models, however, he did not claim to be an expert on climate modeling. Id. at 78:20–79:3. In fact, his view of the reliability of climate models does not fall within the mainstream of climate scientists; his view is that models are, in general, "scientifically crude at best," although they are used regularly by most climate scientists and he himself used the compiled results of a variety of climate models in preparing his report and testimony in this case. Id. at 152:23–153:3; 155:12–156:18.

The Hadley and Canadian models were selected by the United States government for use in the U.S. Global Climate Change Research Project's assessment of regional global warming impacts. National Assessment Synthesis Team Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change (2000) at 16. Studies released after the regional assessment was complete confirm the results of those models.[116] See Tr. vol. 14–A, 60:11–61:5 (May 4, 2007). In that study, Katherine Hayhoe measured the likely increase in Northeast temperatures using a total of nine climate models using a more sophisticated form of downscaling, and found nearly the same results as those upon which Rock relied. Id. at 61:11–62:15. As an "ideal" model was not available to Rock, his failure to use one does not render other models unreliable, particularly since their results have been validated by other studies. Rock's methods are not unreliable, as he used models which other scientists at the U.S. Global Change Research Project had determined were reliable and which were later validated.

Next, the plaintiffs assert that Rock's testimony should be excluded as inadmissible under Rule 703, which states that "[t]he facts or data in the particular case upon which an expert bases an opinion or inference may be those perceived by or made known to the expert at or before the hearing." Fed.R.Evid. 703. The plaintiffs argue that Rock's reliance on global climate models

[116] See K. Hayhoe et al., Past and Future Changes in Climate and Hydrological Indicators in the U.S. Northeast, 28 Climate Dynamics 381, 404 (March 4, 2007) (models "are capable of re-producing the dominant influence on regional temperature-related climate indicators"); see also K. Hayhoe et al., Quantifying the Regional Impacts of Global Climate Change, in review at Bulletin of the American Meteorological Society. Another regional study reaching similar conclusions is a report of the Climate Change Research Center, at UNH. See Clean Air–Cool Planet and C.P. Wake, Indicators of Climate Change in the Northeast, 2005.

which he did not create and which he lacks the modeling expertise to fully evaluate violates Rule 703.

"Facts or data" on which an expert relies may include reliable opinions of other experts, or hypothetical facts. Fed.R.Evid. 702 advisory committee's note. Rock's use of the models essentially amounts to reliance on the experts who created and validated them; their primary function is to provide a scenario for him to use in describing the effects of the warmer temperatures that they predict, as the advisory committee expected that scientists would do with information that they gained from other experts.[117]See id.

The plaintiffs move for the exclusion of Rock's opinions regarding the likelihood that global warming will cause the *324 loss of maple trees in Vermont, arguing again that he improperly relies on a study performed by other scientists. First, they argue that the Iverson and Prasad study, on which Rock relied in concluding that warming would cause the loss of maple trees, is unreliable because it is based on the Hadley and Canadian studies. For the reasons noted above, the Court does not find the use of those models to be a source of unreliability.

Second, the plaintiffs argue that Rock has improperly used the study, which merely "indicat[es] ... the potential impact on species' distribution" to "forecast" the loss of maple trees in Vermont. The distinction between an "indication" and a "forecast" does not affect the admissibility of Rock's testimony. Rock has expertise regarding the effect of climate change on trees and forests independent of the study that underlies his opinion regarding loss of maple trees. As the study is only part of the basis for Rock's ultimate opinion regarding the effect of warming on Vermont's forests, Rock's conclusions need not perfectly track those of the study.

Finally, the plaintiffs argue that Rock is insufficiently informed as to the means by which Iverson and Prasad arrived at their conclusions. Again, however, it is legitimate for Rock to use information gained experts in other fields as data in support of his own conclusions. See Fed.R.Evid. 702 advisory committee's note. Rock testified that it is customary for scientists in his field to use the output of climate models—and projections generated by other experts—in generating their opinions. Tr. vol. 14–A 21:14–20. In addition, he testified that his conclusion as to the loss of maples is based on his "knowledge of tree physiology in terms of how sugar maples are adjusted to the current climate conditions, and what those changes would have to be under the climate scenarios provided." Id. at 21:22–22:2. Testimony from Rock's own knowledge and experience would be acceptable even in the absence of citation to a study confirming his conclusions. See Fed.R.Evid. 702 advisory committee's note ("Nothing in this amendment is intended to suggest that experience alone-or experience in conjunction with other knowledge, skill, training or education-may not provide a sufficient foundation for expert testimony.").

Rock's testimony regarding the impact of warmer regional temperatures on the ski industry is also admissible. The plaintiffs object to this testimony because Rock bases his conclusions on a study of the New Hampshire ski industry, rather than the Vermont industry. They argue that Rock did not perform a proper analysis to determine whether factors affecting

[117] The gist of Rock's testimony was not a prediction as to the exact level of warming that is likely to occur in Vermont. Rather, his testimony concerned the effects of such warming, which is also the area in which he has the most experience and knowledge. Therefore, that is the testimony to which the Court has given weight.

the success of the New Hampshire industry would have the same effects in Vermont. Rock's testimony on this point was relatively simple: he essentially used the New Hampshire study to support his conclusion that warmer temperatures were likely to lead to less snow and have an effect on Vermont's ski industry. This seems, as a proposition, unarguably true. The study's origin in a neighboring state rather than Vermont does not negate its applicability to the Vermont ski industry; the states are small and contiguous and have similar climates. Insofar as the Plaintiffs have articulated relevant differences between Vermont and New Hampshire ski conditions and industries, those differences affect the weight, not the admissibility of Rock's testimony.

Finally, the plaintiffs have attacked Rock's testimony as to the impact of warmer temperatures on Vermont's fall foliage. This testimony falls within Rock's core area of expertise. The plaintiffs object that Rock has not shown that warming will affect fall foliage color, but in fact, *325 Rock did present evidence that foliage color will diminish with warming. He has expertise on the issue of how fall colors are produced and the role that temperature and season play in that transformation, which he has properly applied to the temperature changes that he found are likely in Vermont. The plaintiffs note that Rock did not perform tests to demonstrate the truth of his opinions regarding temperature's effect on the amount of sugar in the leaf and resulting color. Given Rock's extensive expertise on this topic and coherent explanation of the mechanisms of foliar color change, the lack of such a test does not render his testimony on this point inadmissible.

The plaintiffs object to Rock's reliance on a graph of first frost data which dealt only with Burlington, Vermont. The fact that the data was only from Burlington and not the entire state does not entirely eliminate its usefulness as a marker of change in the state's climate. As noted above, minor limitations in some of the data on which Rock relied goes to the weight of Rock's testimony on this point, not its admissibility.

In light of the evidence presented by all of the parties, it is the Court's conclusion that Rock's testimony meets Rule 702's threshold reliability requirement.

5. Relevance of Rock's Testimony

Rock's testimony is relevant to this matter, and assists the Court, for the reasons given above concerning the relevance of Hansen's testimony. His testimony focused on effects on Vermont in particular, and demonstrated some reasons that avoiding global warming is of particular interest to this state. His testimony adds to Hansen's by providing local information which is useful to the Court's understanding of the regulation.

The Renewed Motion to Exclude the Testimony of Barrett N. Rock is denied.

C. Mr. K.G. Duleep

The plaintiffs move to exclude the testimony of Defendants' Expert Mr. K.G. Duleep on the grounds that it is unreliable due to his use of allegedly flawed methods.

1. Duleep's Qualifications

Duleep has extensive experience in the study of fuel economy and emissions in the automobile industry. He is a managing director at Energy and Environmental Analysis, Inc. ("EEA"), where he is responsible for directing all studies in the area of automotive emission control and fuel economy. Tr. vol. 12–A, 83:23–84:4 (Duleep, May 2, 2007). Major projects in that area include analysis of the technical feasibility of improving vehicle fuel economy up to 2025; estimation of automotive technology attributes such as costs, performance, and fuel economy benefit; strategic planning support to manufacturers in engine/emission control technology; and regulatory strategy definition and evaluation for state, local, and foreign governments to control mobile source emissions. DX 2687.

Duleep was a Senior Professional at EEA between 1979 and 1987. During that period he served as the company's lead engineering analyst on all mobile source emissions and fuel economy issues, and worked on projects including the development of emission factors for EPA's MOBILE3/4 models; estimates of 1990–1995 fuel economy potential for domestic auto manufacturers; an analysis of heavy duty truck emission standards in Canada in 1990; and analysis of alternative fuel vehicle technology development. Id. Prior to his employment with EEA, Duleep worked as a Senior Engineer in the Electronics *326 and Engine Control Systems Group at Bendix, where he was involved in a variety of design and development projects; as a research assistant at the University of Michigan's Department of Aerospace Engineering; and as a junior scientific officer at the Aeronautical Development Establishment. Id.

Duleep's educational background includes a 1972 Bachelor of Technology degree, specialized in Aerospace Engineering, from the Indian Institute of Technology; a 1975 Master's degree in Aerospace Engineering/Computer Information and Control Engineering from the University of Michigan; completed course-work as a doctoral candidate in aerospace engineering specializing in combustion at the University of Michigan; and a 1989 M.B.A. with a specialization in finance from the University of Pennsylvania's Wharton School. Id.; Tr. vol. 12–A, 86:25–87:6, 88:6–10.

Duleep has published more than ten articles in peer-reviewed journals and has authored about one hundred reports to clients. DX 2687; Tr. vol. 12–A, 102:15–24. His presentations, papers and articles produced in recent years include many on the topics of marketability and feasibility of new automotive technologies and the relationship between tires and energy consumption.[118] DX 2687.

[118] These articles include: Market Prospects for Alternative Hybrid Designs, presented at the SAR Hybrid Vehicle Technologies Symposium, San Diego CA, February 2006; Tires, Technology and Energy Consumption, presented at the International Energy Agency Workshop on Tire Rolling Resistance, Paris, France, November 2005; Prospects for Hybrid, Diesel and Hydrogen Vehicles, presented at Air Pollution as Climate Forcing: A Second Workshop, sponsored by NASA, Honolulu, HI, April 2005; Vehicle Energy Use and the Tire Contribution, presented at the Second Meeting of the Committee for National Tire Efficiency Study, National Academy of Sciences, Davis CA,

Duleep frequently consults for various governmental entities. He has done substantial work for the Department of Energy ("DOE") and NHTSA, including providing DOE with more than twenty reports on the fuel economy potential of light-duty vehicles. Id.; see Tr. vol. 12–A, 90:19–91:4. Duleep served as the principal consultant to a National Academy of Science ("NAS") committee on the future of CAFE standards in 2001 and 2002.[119] The NAS used Duleep's analysis of the technological feasibility and cost of improving fuel efficiency for light-duty vehicles in 2015 in its 2002 study. See DX 2007 at 1. In 2005, Duleep supported the NAS tire rolling resistance committee with technical information and analysis. Tr. vol. 12–A, 93:24–94:3. Duleep completed a joint report in May 2006 for DOE and the Department of Transportation ("DOT"), updating the 2002 NAS report's estimates of technology cost and attributes for use in developing new fuel economy standards and an evaluation of whether alternative methodologies should be used in future NAS reports. Id. *327 at 91:5–92:3.[120]

Duleep has testified three times before the United States Senate and three times before the House of Representatives. The bulk of his testimony in each chamber was on the subject of fuel economy technology. Id. at 100:5–102:12.

In addition to his clients in the United States government, Duleep works extensively outside the United States. He has worked for Natural Resource Canada, Transport Canada, Australia, Sweden, and the World Bank. Id. at 96:5–97:12. He also has private automakers and suppliers as clients in the areas of vehicle drive train technology planning and active safety technologies. Nearly half of his work is for these private clients. Id. at 98:11–99:25.

2. Duleep's Testimony

a. Methodology

Duleep examines whether the automobile industry as a whole can comply with the regulation, but does not speak to individual manufacturers' ability to comply or likely compliance strategies. Id. at 121:9–14. He explores path-ways to compliance for a set of representative vehicles, but these pathways are descriptive, not prescriptive. Id. at 134:24–135:3.

March 2005; and The Potential Market and Fuel Economy Impacts of Hybrid and Diesel Technologies (co-authored with Drs. Greene and McManus) presented at the 10th Diesel Engine Emission Reduction Conference, Coronado CA, August 2004. Duleep has also authored two encyclopedia articles: Auto-motive Engines—Efficiency, in Encyclopedia of Energy Technology and the Environment 379 (John Wiley 1995), and Internal Combustion Engine Vehicles, in Encyclopedia of Energy 497 (Elsevier 2004). See DX 2687.

[119] The NAS is an independent governmental body that responds to requests from the President's administration or Congress to study topics of interest. It is composed of leading scientists in various fields who are elected to membership. Tr. vol. 12–A, 92:14–21 (Duleep, May 2, 2007).

[120] Duleep's other work for U.S. government entities includes projects for the Congressional Office of Technology Assessment, for which he fulfilled a request in the mid–1990s to examine the potential for fuel economy of vehicles until the year 2020, and for the Energy Information Administration, which he has assisted in deter-mining how fuel economy can change in the future in response to the macroeconomic forces of fuel price, income, and other factors. Id. at 94:19–95:4, 97:17–98:4. During the 1980s and 1990s Duleep worked for EPA's Ann Arbor Motor Vehicle Emissions Laboratory on the development of new emissions standards. Id. at 95:20–96:2.

To determine whether the regulation is technologically feasible in the time frame provided, Duleep began by assembling a list of all available technological options that could be feasibly introduced during the relevant period.[121] Id. at 118:22–24. Second, he evaluated each technology based on the method by which it obtains fuel economy, its cost, and its potential fuel economy gain in various applications.[122] Id. at 119:6–11. Finally, Duleep adopted the cheapest technology relative to the benefit provided. He did this by assessing a cost-benefit ratio for each technology, then adding technologies in the order of cost effectiveness until the standard was met. Id. at 120:9–15. Duleep has used this basic methodology for twenty years. Id. at 121:2–3.

As a baseline Duleep divided vehicles into different classes based on size, then took a typical vehicle from each for the year 2005.[123] He then examined each vehicle to see whether there was sufficient technology available to allow it to meet the regulation's requirements. Id. at 122:18–123:1. To do so, he first listed the technologies already present in a specific vehicle *328 to avoid double-counting, then applied additional technologies based on cost-effectiveness and availability. Id. at 125:10–17.

After identifying the relevant technology set for each vehicle in his baseline analysis, Duleep outlined the average fuel economy benefit and cost of the technologies, and used a simple multiplicative model to provide an initial assessment of each technology combination. Id. at 127:22–128:3. The multiplicative model estimates how technologies will work when applied in combination to a vehicle. For example, if a technology improves fuel economy ten percent, then adding it to a car will reduce that car's fuel consumption to ninety percent of its starting level. If a second technology improves economy five percent, then adding it to the same car would reduce fuel economy by five percent, but from the ninety percent consumption, not from the car's original consumption, so that a diminishing amount of fuel is saved as additional technologies are added. Id. at 128:13–129:3.

In addition to these diminishing returns, some technologies have dys-synergies. If two technologies affect the same source of energy loss, then putting them both on a vehicle won't result in cumulative fuel savings. Id. at 129:13–20. Based on his experience, Duleep adjusted for dys-synergy loss by reducing the multiplicative model's estimate of fuel consumption reduction by nine to ten percent where these sorts of overlapping technologies were present; he referred to this step as the use of a dys-synergy factor. Id. at 129:21–130:7.

To determine whether manufacturers could comply with the regulation, Duleep calculated the percentage fuel consumption reduction necessary for each of the baseline vehicles that he used to achieve compliance. Duleep found that compliance was possible in each category, though some vehicles would require conversion of some of the fleet to hybrid vehicles. Id. at 132:5–24.

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[121] Due to his work for the DOE and other parties, Duleep's company has a list of such technologies and their likely availability, constantly updated based on current trade press technical journals. Id. at 118:24–119:5.

[122] Duleep gathered this more detailed information on specific technologies through Society of Automotive Engineers meetings, and by discussing the issues with tier one suppliers and auto manufacturers, as well as through his attendance at technical conventions. Id. at 119:12–25.

[123] Specifically, he used three representative vehicles in his PC/LDT1 category—a small compact/subcompact car, an intermediate/mid-sized car, and a large car—and three representative vehicles in his LDT2 category—the compact Ram, an intermediate sized SUV, and a large pickup. Id. at 123:9–124:4.

b. Validation of Results with the Lumped Parameter Model

After Duleep estimated potential GHG emissions reductions using the multiplicative method, he checked his work using a lumped parameter model. Id. at 130:21–25. The model categorizes the benefits of the various technologies according to the source of loss that they address. Id. at 131:6–15. Conventional technologies can improve the fuel economy of an engine or transmission in just a few ways: by increasing the engine's peak efficiency, by reducing pumping loss, or by reducing friction loss. Tr. vol. 12–B, 14:18–25. The purpose of the lumped parameter model is to keep track of how each technology affects each type of loss and to compute the cumulative effects of multiple technologies on pumping loss, friction loss, and peak efficiency. Id. at 15:5–13. In other words, the model outlines technology interactions when several technologies are applied to a single vehicle.

Duleep did not rely on the lumped parameter model as his primary mode of analysis in this case; rather, he formed an opinion using the simple multiplicative model, which he adjusted based on his experience and understanding of the technologies used to account for dys-synergies. The lumped parameter model is merely a way of confirming his initial conclusion, while ensuring that his application of multiple technologies didn't violate any fundamental principles of physics or engine operation. Id. at 16:21–17:15.

The lumped parameter model takes each technology and distributes its benefits among efficiency, pumping, and friction, using information derived from Duleep's external review of each technology, review of literature, and discussions with auto *329 manufacturers and suppliers to the auto industry. Id. at 17:22–18:2; 19:4–21. The model begins with a baseline vehicle whose characteristics, including EPA-measured fuel economy, are known. It uses that knowledge to estimate the energy required to move the vehicle over the entire EPA driving cycle. Id. at 20:14–21. Next, it determines how that energy is derived. It then determines how much of the energy that the engine puts out is lost in the drivetrain and how much is lost in the accessories, to come up with the engine's total energy output. Id. at 20:22–21:14. Finally, it calculates how much fuel has to go into the engine to result in that output. Id. at 21:15–19. These computations result in a determination, based on the actual measured fuel economy, of the pumping and friction loss for a particular vehicle. Id. at 21:20–23. Given that knowledge, Duleep can use the model to apply particular technologies to that vehicle, reducing the base values of loss in accord with each technology's known characteristics. See id. at 21:23–23:2. He goes through that process for each of the technologies that he applies to the vehicle, keeping track of pumping, friction and peak efficiency changes. The end result is a picture of the fuel economy that will result from the cumulative application of all of the technologies, taking into account the dys-synergies that result from multiple technologies affecting the same sources of loss. Id. at 15:4–13.

c. Duleep's Cost Analysis

Duleep arrived at an initial cost of compliance estimate based on the costs of technologies that he found necessary to apply to vehicles to reach required emissions levels. He adjusted that amount to reflect the effects of other regulations in effect in Vermont. He arrived at an estimated net cost of about $1500 per vehicle in the PC/LDT1 category and $1450 in the LDT2/MDPV category. Id. at 46:11–47:25.

3. Evaluating the Reliability of Duleep's Testimony

The plaintiffs assert as an initial matter that the boundaries of the subject matter of Duleep's testimony are in themselves a "flawed use of his chosen methodology" and a source of unreliability. Pls.' Renewed Mot. to Exclude Test. of Duleep 12–13 (Doc. 487). In fact, they describe his choice not to perform a manufacturer-specific compliance analysis as "egregious." Id. 13. To the contrary, the fact that Duleep's analysis is general rather than aimed at specific manufacturers' situations in no way diminishes its usefulness to the Court or its reliability. Duleep's testimony was perfectly transparent as to the boundaries of his analysis and the topics included in his testimony.

Thomas Austin is Plaintiffs' expert on manufacturers' ability to comply with the regulations.[124] Insofar as Austin and Duleep address different subjects, since Duleep modeled the compliance ability of the industry as a whole while Austin projected the likely compliance choices of individual manufacturers, both experts bring useful though diverse perspectives to the Court's attention. In this bench trial, the Court is capable of understanding the differing utilities of each model in conducting its review of the evidence, and it is useful to the *330 Court to see data that covers the industry as a whole.

The plaintiffs have focused their criticism of Duleep's testimony on his methodology. The multiplicative model appears to be a relatively straightforward method of applying technologies to a baseline to see their effects. The plaintiffs criticize Duleep's use of a dys-synergy factor to adjust for the effects of combining technologies that address the same sources of loss. They argue that the factor that Duleep chose is not replicable or reliable and is not widely accepted. However, it is undisputed that it is necessary to somehow account for dys-synergies between technologies applied to a vehicle.

Duleep developed his dys-synergy factor based on his substantial experience in the motor vehicle industry and detailed knowledge of technology and technology interactions. See Fed.R.Evid. 702 advisory committee's note (experts may testify based on experience alone). In addition, he validated that factor through the use of the lumped parameter model, which confirmed his results. The plaintiffs persistently frame their criticism of Duleep's methods as though the multiplicative method (including the use of the dys-synergy factor) and the lumped parameter method were operating in two entirely separate spheres; in fact, their confirmation of one another's results lends each credibility since they are both using the same data but applying entirely different methodologies.

Plaintiffs additionally criticize Duleep's use of the lumped parameter model (again, without acknowledging any interaction between the two models). They rely on testimony by

[124] Austin is a founding senior partner at Sierra Research, Inc. ("Sierra"), a research and consulting firm in California that specializes in research and regulatory matters relating to emissions control and fuel economy. Tr. vol. 6–B, 62:23–63:10 (Austin, Apr. 20, 2007). He is the former head of CARB's motor vehicle emission control program. Id. at 69:11–22; 70:15–71:15.

their own experts, Austin and Dr. Donald Patterson,[125] for arguments that the lumped parameter model's results are not replicable and, when replicated, yield results that overstate the fuel economy benefits of some technologies. However, this testimony is ultimately unconvincing in light of Duleep's and others' validation of that model's results.

The reliability of the lumped parameter model has been tested in two ways. First, Duleep used a vehicle from a year before certain technologies were applied as a baseline, then used the model to add to it technologies found in a later vehicle. The comparison between the estimate of the later vehicle's fuel economy resulting from the model and the actual measured fuel economy of that vehicle serves as a validation.[126] Tr. vol. 12–B, 26:5–21 (Duleep, May 2, 2007). Second, when Duleep consulted for NAS during their fuel economy study, in order to check his results' consistency with other commonly used models, both Duleep and Austin used the same set of inputs in their respective models (the lumped parameter model and VEHSIM). The results were very close, in all cases within four percent of one another, and neither model gave uniformly higher or lower results. Id. at 30:25–32:9. The rate of error of Duleep's methods, as illustrated in these tests, is relatively low.

*331 Patterson agreed that one way to evaluate a model is to compare its estimates to real-world vehicle attributes, but insisted that correlation between the model's results and the real-world measurements does not necessarily mean that the process used to get the estimates is correct. Tr. vol. 16–A, 17:23–18:2 (Patterson, May 8, 2007). Other experts in his field believe that reliability of a model is normally assessed in this manner. Dr. John Heywood[127] has submitted a declaration to the Court in which he states that in his field, "the reliability of a model's results is typically assessed by comparing the model's results to the measured results from existing vehicles, such as the EPA Test Car List." Heywood Decl. ¶ 10. Dr. Marc Ross,[128] in a similar declaration, states that he also validates results from models "by comparing them to measured fuel economy values on EPA's Test Car List-in other words, to known data from actual vehicles." Ross Decl. ¶ 9. Therefore, it appears that Duleep has undertaken to validate his model, with results suggesting that the model can successfully predict real-world results of the use of various technologies. He has performed what appear to be standard checks on his methodology, and has used multiple methodologies to validate his results.

There is wide or moderate acceptance of both of Duleep's primary methods of analysis. The simple multiplicative model is widely accepted in the community of experts on fuel

[125] Dr. Patterson is a professor emeritus in mechanical engineering at the University of Michigan. Tr. vol. 16–A, 6:20–24 (Patterson, May 8, 2007).

[126] Duleep started with the Ford Focus and compared it to the 2005 Honda Civic, which incorporated a subset of the technologies that Duleep modeled for the small car for his report in this case. He arrived at an estimated fuel economy very slightly lower than the Civic's actual fuel economy, but within the margin of error. Tr. vol. 12–B, 28:9–30:11 (Duleep, May 2, 2007). He has performed similar validations in each size class that he modeled, and in each case found that he was able to predict the fuel economy of various vehicles using his model. Id. at 30:12–22; 33:4–35:1.

[127] Heywood is the Sun Jae Professor of Mechanical Engineering at the Massachusetts Institute of Technology where he has taught and researched since 1968. Heywood Decl. ¶ 1. Patterson testified that he knows Professor Heywood, has used Heywood's textbook in his own teaching, and considers Heywood one of the leading mechanical engineers in the country. Tr. vol. 16–A 23:11–24:24

[128] Ross is a professor emeritus in the Physics Department at the University of Michigan, where he has taught and performed research since 1963 in the area of environmental physics, with a focus on "energy use, its impacts, and how to reduce those impacts through efficiency and conservation." Ross Decl. ¶ 1.

economy. The simple multiplicative model was used in the NAS report, and is currently used by DOT and NHTSA in setting standards. Tr. vol. 12–B, 41:3–12 (Duleep, May 2, 2007). Canada largely bases its standards on the United States' standards, but has used the results of the lumped parameter model for some purposes. Id. at 41:17–23. Japan does not use a vehicle simulation method in setting its standards. See id. at 41:24–42:6.

Patterson testified that a second-by-second vehicle simulation model, such as Austin's VEHSIM, is the only reliable method of modeling, such that both the multiplicative and lumped parameter models are by definition unreliable. Tr. vol. 16–A, 31:8–13; 32:3–8 (Patterson, May 8, 2007). He was unaware of the methodologies used by NHTSA, Japan, and Canada in setting fuel economy standards, but stated that he would consider those methods unreliable if they did not use a second-by-second model. Id. at 23:15–24; 37:7–38:8.

It is clear that Patterson's view does not express a consensus within the relevant scientific community. See Daubert, 509 U.S. at 594, 113 S.Ct. 2786. Heywood states that he has used aggregated parameter engine models, simpler models than VEHSIM, like the lumped parameter method. He and other colleagues used these models in a 2000 study assessing technologies that could reduce GHG emissions from passenger cars by the year 2020, and he believes that "well-formulated aggregated parameter models can reasonably accurately simulate fleet-wide vehicle characteristics." Heywood Decl. ¶¶ 6–9 *332 (referencing Malcolm A. Weiss, John B. Heywood et al., On the Road in 2020: A Life–Cycle Analysis of New Automobile Technologies) (MIT Energy Laboratory October 2000). Ross explains that VEHSIM and similar models, and Duleep's lumped parameter models, all operate by "solv[ing] the equations that describe a vehicle's fuel consumption," at "different levels of disaggregation and complexity." Ross Decl. ¶ 5. Ross uses a model which, like Duleep's, uses about ten to twelve parameters and is in-tended to model the entire light-duty fleet. Ross's research has led him to the conclusion that, "when simulating fleetwide vehicle characteristics, a model with a dozen parameters is just as accurate as a model with two hundred parameters for the large majority of vehicles." Id. ¶ 6.[129]

The plaintiffs also cite the testimony of Kenneth Patton, an engineering group manager in the GM power train advanced engineering group, who testified that he has never worked on the design or development of an engine without employing vehicle simulation methods. Tr. vol. 10–B, 30:8–23 (Patton, Apr. 30, 2007). However, as Duleep was not engaged in actually designing an engine for production but in estimating the effects of the addition of a large number of technologies to current vehicles, his methods need not be the same as those used internally by automakers in creating new engines. Patton's testimony does not address the reliability of Duleep's methods.

[129] Ross also details recent research by one of his students which supports this conclusion. One of his graduate students used his model to calculate the fuel economy of approximately 1300 vehicles using only four parameters, and found that the results were accurate to within five to ten percent of the fuel economy values on the EPA Test Car List for about ninety percent of the vehicles, while many results were much closer. Ross Decl. ¶ 7. The vehicles falling outside of the five to ten percent range did so because they were "hybrids or flexible fuel vehicles whose fuel economy cannot be accurately modeled on a model designed for conventional gasoline engines," or were "very high performance European sports cars" which are driven differently and would require adjustments to the model. Id. ¶ 8. The light-duty vehicles that Duleep modeled are in neither category.

The opinions of experts such as Heywood and Ross demonstrate that Duleep's methods are generally accepted for purposes of Daubert and Rule 702. Daubert requires general, not universal acceptance; even "substantial criticism as to one theory or procedure will not be enough to find that the theory/procedure is not generally accepted." United States v. Bonds, 12 F.3d 540, 562 (6th Cir.1993).

For the most part, Duleep's work has not been published. Duleep is not an academic, but a professional consultant, whose work is typically performed for government entities or private clients rather than for publication. Publication is "not a sine qua non of admissibility" and "does not necessarily correlate with reliability." Daubert, 509 U.S. at 593, 113 S.Ct. 2786. The Daubert court noted, in particular, that some theories may not have been published because they are "well-grounded but innovative" or "too particular, too new, or of too limited interest" for publication. Id. Duleep need not back his testimony with published studies that unequivocally support his conclusions. See Amorgianos, 303 F.3d at 266.

In any case, Duleep's work has been subjected to the extensive scrutiny of the relevant community of experts. In his work for governmental clients, Duleep's work is often checked by others. In the thirty years that he has worked for DOE, Duleep has submitted about twenty reports to the agency, many regarding automotive technologies and effects on fuel *333 economy. Tr. vol. 12–B, 37:3–7 (Duleep, May 2, 2007). DOE routinely checks the results of his work by asking scientists at Oak Ridge National Lab and Argonne National Lab to review it; in periods of high interest they have also sent his reports for external review by leading academics, and in a few instances he was asked to defend his work to auto makers. Id. at 37:18–38:19. This extensive review, while not taking place through the publication mechanism, fully serves the purpose of testing the validity of his methods and increases the likelihood that significant flaws in his methods would have been exposed during the lengthy period in which he has used those methods.

In light of all of the evidence, the Court finds that Duleep's testimony is reliable. Objections to his methods go to the weight, not the admissibility, of his opinions.

5. Relevance of Duleep's Testimony

There is no debate as to the relevance of Duleep's testimony. Like that of Austin and several of the witnesses who testified on behalf of the auto manufacturer plaintiffs, his testimony addresses the ability of the auto industry to comply with the regulations adopted by Vermont.

The Motion to Exclude the Testimony of K.G. Duleep (Doc. 487) is denied.

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[The trial court ultimately held that that the experts did not violate the rules of discovery and that Vermont regulations establishing greenhouse gas emission standards were not expressly preempted by the federal Energy Policy and Conservation Act and dismissed the Plaintiffs remaining claims, entering judgment for Defendants].

State-by State Comparison of Standards for Admissibility of Scientific Expert Testimony