The Nelson A. Rockefeller Center at Dartmouth College
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FIFTH GENERATION (5G) WIRELESS TECHNOLOGY IN THE STATE OF VERMONT

The Economic and Health Implications

Presented to Rep. Tim Briglin, Chair, Vermont House Committee on Energy and Technology

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report addresses the health, economic, and legislative implications of 5G rollout in the state of Vermont. A review of recent scientific literature suggests that exposure to radio frequency radiation could have adverse effects on human health. Many state, municipal, and international governments have taken health-related legislative action, and many of these actions could be replicable in Vermont. Economically, there are numerous benefits to expanding earlier generations of cell service prior to the establishment of 5G technology. Vermont and other states command limited control over telecommunications companies, but they retain the ability to take regulatory action. Most domestic regulation involves the imposition of fees and siting restrictions, while international regulation tends to invite local control. Domestic and international governing bodies have organized task forces to streamline 5G development. Much of this legislation has aspects that could be adapted for use by the Vermont Legislature.

INTRODUCTION

Fifth-generation wireless technology (5G) is the newest generation of cellular telephone networks. This new technology will speed up the rate of data transfer by 100 times or more, greatly reduce the time between signal reception and response and will allow cellular networks to manage more wireless devices than presently possible. [1] Regarding infrastructure, the higher-frequency radio waves of 5G technology can only function via small cell wireless facilities (SWF) placed every few hundred meters.[2] Thus, access to 5G technology is currently limited to areas where the funds and labor necessary for developing such infrastructure exist. As of October 2019, 5G technology is offered by four cell carriers across 21 U.S. cities.[3] Industry experts predict that 5G technology will become available for large scale use at the consumer level by 2021, though availability will, of course, differ regionally.[4]

The process of implementing 5G technology rollout in localities across the country is driven largely by service providers and regulated by the Federal Communications Commission (FCC). [5] However, state and local governments do have the capacity to influence the establishment of 5G technology. As of now, twenty state legislatures have enacted bills to streamline 5G deployment in their jurisdictions. While some lawmakers set stringent requirements, others have developed loose legislative frameworks to guide local governments and agencies.[6] In many of these states, efforts to establish 5G technology are opposed to some degree by constituent groups with concerns about the health, environmental, and economic implications of the new technology.

1. HEALTH-RELATED IMPLICATIONS OF 5G TECHNOLOGY

While 5G technology holds promise of faster download speeds, interconnected cities, and improved access to broadband, it will utilize higher frequency radiation and more densely positioned broadcast sites (small cells) than earlier generations of service. These changes have led some to question the biological safety of 5G technology. Scientists, medical doctors, legislators, and grassroots community organizations are among the groups that have expressed concern.[7] The FDA writes that existing regulations "are adequate to protect the general public" based upon a "review of the recently published rodent study from the National Toxicology Program," as well as a recently published "Review of Published Literature between 2008 and 2018 of Relevance to Radiofrequency Radiation and Cancer."[8] [9] [10] However, this review primarily examines connections between 5G and cancer; some scientists warn that the FDA neglects to investigate a different type of harm: "the non-thermal effects" of radiation. These scientists support their claim by explaining that the agency relies upon an assumption about radiation absorption (referred to as thermal avoidance) that recent scientific evidence has rendered "no longer valid."[11] [12]

In short, the February 2020 FDA review addresses a subset of biological concerns (carcinogenicity) related to 5G technology. This review examines the existing literature specifically as it relates to connections between cancer and 5G technology. Our report accounts for a wide range of scientific literature related to the biological effects of 5G, including but not limited to the investigation of carcinogenic potential conducted by the FDA. Following this study of the existing literature, our team finds that there is not sufficient scientific evidence to prove unequivocally that exposure to RF radiation is entirely safe, nor is there sufficient evidence to prove unequivocally that exposure causes adverse health effects. Because data indicate the possibility of non-thermal health effects, many scientists emphasize that further research is critical in assessing the safety of the technology. [13] [14] [15] [16]

In Section 1.1 of this paper, a concise review is performed of the most recent scientific literature pertaining to the biological effects of non-ionizing radiation. The review reveals that exposure to radio frequency radiation (RFR) can result in adverse health effects related to the thermal (external) effect of radiation, but that exposure limits set by the FCC are largely adequate in protecting everyday consumers against these thermal health risks.[17] However, the FCC regulations account only for thermal effects of RFR exposure, and there is some limited scientific evidence (detailed in Section 1.1) for the potential existence of non-thermal health effects. In Section 1.2, an outline and analysis of health-related 5G legislation in United States. states finds that four states have passed health-related 5G legislation since the 2018 FCC order that limits state and municipal control of 5G deployment. Most of this legislation involves the commission of a study or the formation

of an investigative task force. Some states have also passed legislation that widens the regulatory ability of municipalities, which might limit construction of small cells in areas where constituents harbor health concerns. A small number of states have proposed legislation that would facilitate the sending of declaratory letters to the FCC or require that small cells are routinely monitored and registered for public access, though no such bills have passed into law. Finally, Section 1.3 includes a summary of recent health-related opposition to 5G. In the United States, grassroots organizations are growing—some contingency of 5G opposition has a base in every state. These groups have filed lawsuits against the FCC, prepared sample legislation for states and municipalities, and worked with state legislators to develop informational fact sheets. Municipal opposition has inhibited small cell deployment in a few instances, but health-related opposition to 5G poses a much more significant barrier to deployment in a number of European countries.

1.1 A Review of Scientific Literature

Data from two of the largest global scientific databases, PubMed and ScienceDirect (with collective coverage of over 46 million articles), show that more than 45,000 peer-reviewed research studies on the health effects of non-ionizing radiation have been published in the past five years. This non-ionizing radiation is the type of radio frequency radiation emitted by all cellular networks, including 5G. In general, these studies investigate one of two types of potential health effects from exposure to non-ionizing radiation: non-thermal (internal) effects and thermal (external) effects. This divide comes from a lack of scientific consensus regarding the penetrative capabilities of non-ionizing radiation. On the electromagnetic spectrum, non-ionizing radiation is a type of low-energy radiation that does not have enough energy to remove an electron from an atom or molecule. Most prominent governing bodies, including the FCC and the World Health Organization (WHO), maintain the position that there is no convincing scientific evidence for any internal effects of this non-ionizing radiation. All cellular networks, including the higher frequency bands that will be utilized in some 5G networks, are classified as non-ionizing forms of radiation.[18]

Figure 1 is a graph showing the current allocation of wavelengths for 5G networks. These wavelengths each occupy a different "lane" in the wireless world, and telecommunications companies cannot utilize a band of operation until that band is allocated or licensed to them by the FCC. While all 5G networks will operate using frequencies that have been used in preceding network generations, some networks—particularly those in densely-populated regions—will also utilize especially high frequencies known as "mmWave." These frequencies, shown in the top-third of the figure, are defined as any frequency above 24 GHz. Importantly, these higher-frequency mmWaves still fall far below the 100 GHz-threshold for ionizing radiation.[19]

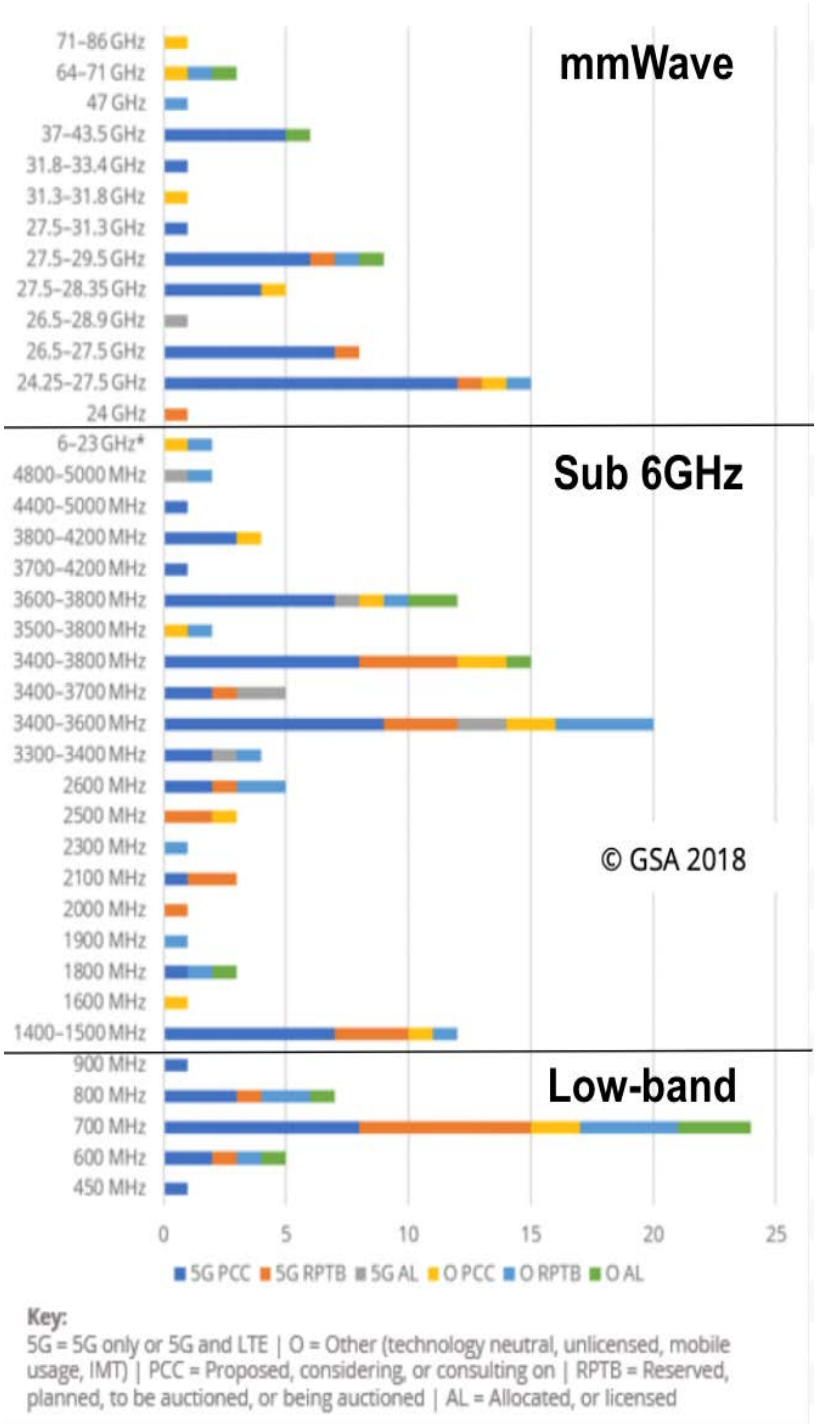


Figure 1. 5G Licensing Status by Frequency[20]

The distribution of 5G frequencies displayed in Figure 1 offers important context for the following literature review for two reasons. Primarily, the distribution demonstrates that all cellular networks—including the novel "mmWave" bands upon which some 5G networks will operate—are well below the threshold for ionizing radiation (hence the focus on non-ionizing radiation, despite a wide pool of biological research on neighboring frequencies).

It must also be noted that the wide distribution of wavelengths in Figure 1 exemplifies the necessity of gathering health-related data on *all* non-ionizing frequencies, including those utilized by earlier cell service generations, even when 5G technology is the primary concern; even though the new mmWave bands have become the face of 5G, less than one-third of 5G technology (at least within the next few years) is expected to utilize this mmWave range—and such utilization will take place primarily in large urban centers.[21] In the state of Vermont, the same middle- and low-band frequencies that have been utilized in 3G and 4G technology will comprise much of the 5G service. For this reason, as well due to the low number of health-related publications pertaining specifically to 5G, the following literature review includes studies pertaining to electromagnetic radiation at all non-ionizing frequencies, and not simply those utilized by the new mmWave 5G bands.

1.1.1 Thermal Effects

As can be observed in Figure 1, the high frequency radio waves upon which 5G and preceding network generations function are all below 100 GHz in frequency. This means that all cellular radio frequency radiation is classified as "non-ionizing." These radio waves are incapable of separating intracellular ions from other particles, which is why microwaves and visible light are markedly less harmful than ionizing x-rays and gamma rays. However, non-ionizing radiation (like sunlight) is known to have biological effects on the order of heating, burns, and shocks. The regulatory activity of the FCC addresses only these thermal (heat-related) effects of non-ionizing radiation—despite a growing body of evidence suggesting that these non-ionizing wavelengths could possibly have deeper, non-thermal biological effects.

In a human, the degree of temperature change in skin varies proportionally to the intensity of the radiation given off by a wireless device. This relationship has enabled scientists and industry regulators to develop a standardized "safe limit" for the amounts of radiation that smartphones marketed in the U.S. can legally emit. The limit requires that no wireless technology causes any harmful increase in the temperature of human skin during regular use. Compliance with this limit is mandatory for all cellular devices sold in the U.S.[22]

The intensity of human exposure to radiation is described in terms of Specific Absorbance Rate, or SAR.[23] Different cellular devices emit radiation with slightly different SARs, but the FCC requires that all cellular devices marketed in the U.S. must emit radiation with an SAR below 1.6 watts of energy per kilogram of mass. During compliance testing, cellular devices are activated at maximum power for each of their possible frequency bands. The device is placed in a number of common positions around the head and body of a human-simulating model, where a robotic probe then records data from the model's electric fields. The highest SAR values for each frequency band are incorporated into a final determination of SAR value for the device. In most circumstances, cellular devices operate far below the maximum power levels used in testing. Even still, cellular devices that exhibit maximum SARs at or below the threshold of 1.6 W/kg do not emit anywhere near enough energy to have any thermal effect on the human body.[24]

The preceding information is provided to offer Representative Briglin and the Vermont Committee on Energy and Technology a detailed depiction of the type of RFR safety testing that is commissioned by the FCC. This depiction is provided in the hope that it will both inform Committee members generally and that it might offer a starting point in addressing constituent concerns regarding the adverse health effects of RFR exposure from 5G networks.

A review by Wu et. al., published just after the initial unveiling of 5G mmWave technology, consulted a wide body of research on the thermal effects of RF radiation. The review focused on the new mmWave technology that would be utilized in 5G networks. While some argue that the higher mmWave frequencies could have worse thermal effects than lower frequencies, the review by Wu, as well as reports by International Electrotechnical Commission and a research-backed database from the Foundation for Research on Information Technologies in Society, suggest that this is not the case; the thermal effects of mmWave frequencies do not differ significantly enough from lower bands to warrant new thermal safety standards from the FCC.[25]

Figure 2 shows a graph from the Wu review of studies regarding the penetrative effects of mmWaves. Six different models (shown in the top-right) were developed in separate studies, yet they appear to corroborate one another in their predictions of an inverse relationship between wave frequency and the relative permittivity of human skin. Likewise, Figure 3 displays similar results pertaining to the heating of tissue.

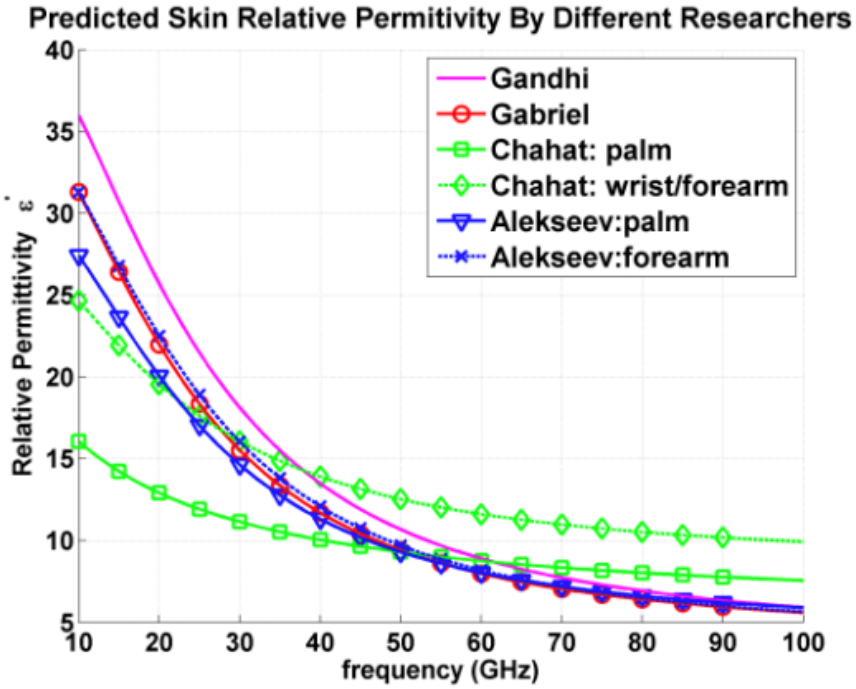


Figure 2: Predicted Skin Permittivity by Radio Frequency Radiation Across Studies[26]

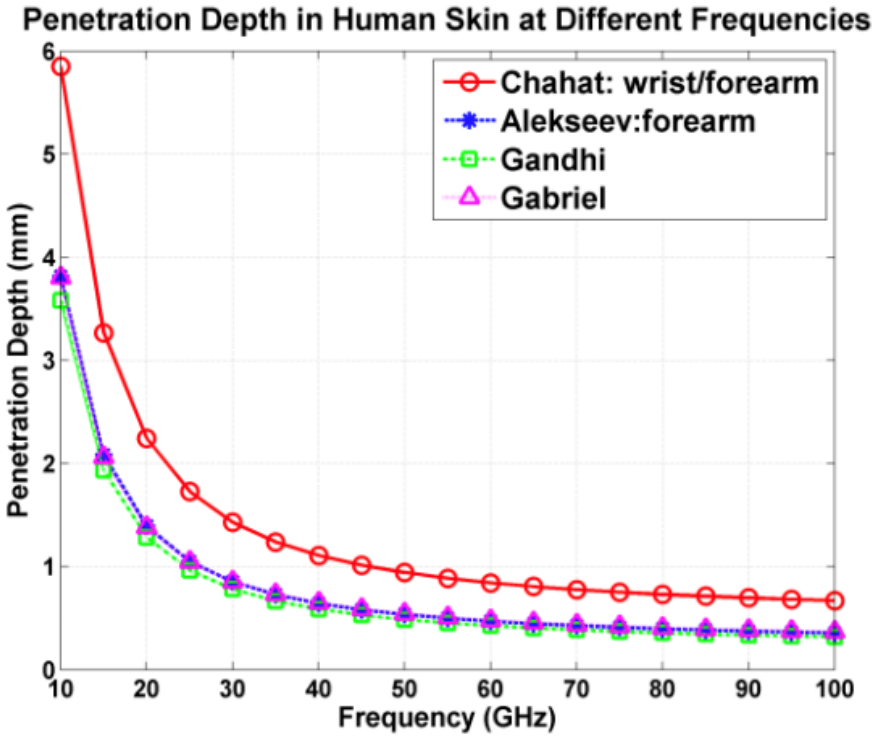


Figure 3: Penetration Depth of Different Radio Frequencies Across Studies[27]

In short, recent scientific literature suggests that the FCC and their contracted testing facilities screen cellular technology quite adequately for any potential thermal (external) health effects. Claims regarding adverse health effects that arise as a result of heating, such as temporary decreases in sperm count or heat-initiated cataract development, are scientifically unfounded. However, justifiable uncertainty does remain on the question of whether FCC regulations are sufficient in protecting consumers from any potential non-thermal effects of 5G radiation. The potential non-thermal effects under investigation include carcinogenic characteristics, neurological harm, and damage to the immune system, among other concerns. A broad review of the recent scientific literature regarding these non-thermal effects follows.

1.1.2 Non-Thermal Effects

Since the advent of preliminary 5G technology in 2015, numerous peer-reviewed studies have been published regarding the biological implications of non-ionizing RFR (the form of radiation utilized in 5G and in preceding generations of cell service). Areas of investigation include the effects of RFR on the reproductive system, immune system,

central nervous system, and on cognitive processes. Research has also been conducted to evaluate the carcinogenicity of RFR radiation. Many of the reviewed studies are limited in their reliability by the methodological difficulties of measuring and modeling RFR dosage in animal subjects, the ambiguous applicability of animal studies to human populations, and inconsistencies or bias in the self-reporting that epidemiological studies depend on.[28] For this reason, no definitive causal relationship can be established between RFR exposure and adverse biological effects. Some scientists, like Paul Ben Ishai of the Ariel University physics department in Israel, suggest that the denial of non-thermal biological effects by the FCC "flies in the face of the massive scientific evidence that has accumulated."[29] Others conclude that the available findings (detailed below) give "weak evidence" for association between RFR and cancer, but "justify continued epidemiologic monitoring of possible hazards."[30]

The following review examines results from fifty of the most widely cited studies investigating the biological effects of 5G and non-ionizing radiation. Studies published prior to the year 2000 are not included, given the recency of developments in cellular technology. Articles have been selected by using the PubMed bibliographic database with keywords "electromagnetic fields"; "cellular phone"; "mobile phone"; "base station"; "RF-EMF"; "radiofrequency"; "millimeter waves"; "wi-fi"; "MMW"; "5G"; and "cellular networks," coupled with keywords from each area of health effect (i.e., "carcinogenic" or "reproductive").

Carcinogenic Effects:
Cancerous implications have been some of the most widely studied with regard to cellular and wireless radiation. One of the largest RFR studies to date, the 2018 National Toxicology Program report commissioned by the FDA, found "clear evidence" for an association between radiation exposure and the development of tumors in the hearts of male rats.[31] The study also found "clear evidence" of an increase in DNA damage associated with RF radiation exposure. However, the researchers stress that heart cancer was "only seen in 5–6 percent of rats exposed to a higher power level—four times higher than the maximum human exposure," and that the study "should not be directly extrapolated to human cell phone usage." The purpose of the study was to provide future researchers with an idea of the bodily regions that might be particularly affected by RFR. Still, the researchers urge adherence to the FDA guidelines on cautionary reduction to cell phone exposure.[32]

In 2018, the Ramazzini Institute in Italy conducted the largest long-term study ever performed in rats on the health effects of RF radiation. The results aligned with those of the NTP study; both found evidence for increased tumors in exposed rats, and the tumors were similar to those observed in some human epidemiological studies. While this data

cannot be extrapolated to humans, the researchers conclude that the results merit re-evaluation of IARC conclusions regarding the carcinogenic potential of RF radiation in humans.[33]

The NTP and Ramazzini Institute studies are two of the most recent publications on carcinogenicity, and they are prominently referred to in current policy decisions. However, prior to their release, a host of related literature was published. Many of these earlier studies found modest association between cancers and RFR exposure.[34] [35] [36] [37] Some scientists maintain that small sample sizes, biases, or experimental errors inhibit a causal interpretation of this data. A number of case-control studies, especially those investigating the association between prior cellular telephone use and malignant tumors in cancer patients, found no significant increases in the risk of cancer for individuals who reported higher-than-average use of their cellular telephone.[38] [39] [40] [41]

Importantly, in February 2020, the FDA published "A Review of Published Literature between 2008 and 2018 of Relevance to Radiofrequency Radiation and Cancer." The report acknowledges the limited reliability of existing studies, and it concludes that "there is insufficient evidence to support a causal association between RFR exposure and tumorigenesis." [42] Studies into the relation between RFR exposure and cancer will continue, and the FDA concludes that it "will continue to monitor the available information."[43] However, the results of the review indicate that concerns regarding the carcinogenicity of non-ionizing radiation are unlikely to slow the rollout of 5G technology.

Reproductive Effects:

As with carcinogenicity, recent literature regarding effects of RFR on the reproductive system varies in its conclusions. No literature could be identified relating mmWave technology to reproductive health. However, a 2019 review examines the effect of 2.45 GHz RFR (within the frequency range for low- and middle-band 5G service) on reproductive health. In the review, 13 reproductive studies from 2015 and later are found to report some form of adverse effect of RFR on the reproductive system. Among these adverse effects are decreases in sperm count, sperm motility, and in levels of testosterone.[44] Yet the review finds a lack of evidence for any effect of RFR on other aspects of reproductive health, including sperm vitality and DNA structure.[45]

The methods of RFR exposure, including intensity, duration, and source, vary between studies. Some reproductive studies investigate consenting men in fertility clinics, while others draw data from rats or mice. Understandably, variation in conclusions is common. However, a lack of consensus does not necessarily mean a lack of harm—nor, of course, do the studies prove the existence of adverse health effects. What the scientific literature

does show is that there are biological mechanisms for RFR interaction with the reproductive system past mere heating of the tissue.[46] Tissue heating (thermal effects) are the only health effects that are accounted for by the FCC maximum exposure limits and compliance testing.

Cognitive Effects:
The effects of RFR exposure on cognitive function have proven particularly ambiguous. A broad 2017 meta-analysis of radio frequency exposure and cognitive function found no significant association between the two.[47] Recent animal model studies tend to reflect this lack of association.[48] [49] However, animal model exposure in a prenatal environment is linked to cognitive deficiencies—in concurrence with the theory that pregnant women and fetuses are particularly vulnerable to RFR exposure. [50] [51] [52] Such results make up part of a wider call for legislation that protects particularly vulnerable populations from 5G and RFR radiation through setback requirements near daycares and residencies.

A number of peer-reviewed studies published within the last three years suggest adverse effects of RFR exposure on long-term memory and spatial reasoning, as well as increased hyperactivity, headaches, and fatigue.[53] [54] [55] [56] However, when it comes to the assessment of subjective symptoms like hyperactivity, headaches, and fatigue, confounding variables (such as cell phone usage among adolescent study participants, in one example) tend to lessen the validity of these associations.[57] Though these cognition-related studies do prove particularly vulnerable to confounding evidence, scientists tend to conclude that preliminary evidence for adverse health effects warrants caution and further investigation.

Millimeter-Wave Technology:
The preceding categories of analysis investigate exposure to all types of non-ionizing (cellular) radiation, because the new 5G networks will also utilize these existing wireless bands. An initially small and urban-centric proportion of 5G service will utilize higher frequency millimeter waves. The specific health implications associated with these mmWaves in recent scientific literature are as follows.

Though high frequency mmWaves do not penetrate human skin, a wide variety of systemic effects arising from wave-skin interaction have been reported. Five studies since 2008 have reported altered gene expression as a result of mmWave exposure,[58] [59] [60] [61] [62] while five more report mmWave-influenced changes in the function of neuro-muscular systems and the endoplasmic reticulum.[63] [64] [65] [66] [67] A 2016 study presents evidence to suggest that even in the absence of deep penetration, surface-level effects on glycolysis lead to changes in the expression of intracellular genes.[68] In a 2014 study that found 665 altered genes as a result of mmWave exposure, the researchers concluded that current exposure limits

(informed by the International Committee on Non-Ionizing Radiation Protection, or ICNIRP) are likely "too permissive to prevent biological response."[69]

When presented with a summary of health-related scientific literature on 5G and RFR, the Chairman of the FCC released a statement affirming the present safety standards as recommended by the ICNIRP and other international governing bodies.[70] The ICNIRP guidelines, established in 1998 and reaffirmed in 2009, are based primarily upon research from reviews published by the WHO (2007), the United Kingdom Health Protection Agency (2006, 2008), and by ICNIRP themselves (2003).[71] The FCC has not updated their maximum safe exposure threshold since the 2015 advent of mmWaves and 5G technology.

There is not sufficient scientific evidence to prove unequivocally that exposure to RF radiation is entirely safe, nor is there sufficient evidence to prove unequivocally that exposure causes adverse health effects. In response to the ambiguity, some state and local legislators have proposed legislation that would mandate further study of health effects or urge Congress to do so.[72] Legislative approaches to 5G rollout differ between states and are limited by federal preemption, but the following section offers a summary and analysis of health-related 5G legislation around the country. A broader analysis of state and local 5G legislation, including both health-related and other forms of 5G legislation, can be found in Section 3 of this report.

1.2 Health-Related 5G Legislation

Regarding specific legislation on the placement of 5G small cells and the construction of new cell towers, state governments are bound by national preemption and FCC regulations. Section 3 of this report addresses a broader range of legislative implications as they relate to 5G. Here, legislation as it pertains specifically to the potential health effects of 5G is reviewed.

According to the National Conference of State Legislatures (NCSL) "Mobile 5G and Small Cell Legislation" webpage, legislators from 44 U.S. states have proposed legislation pertaining to the development of 5G since 2017.[73] In most of the remaining six, legislation is currently being drafted, and many municipalities have passed or proposed their own legislation. Of the states where legislation has been passed, four states (Louisiana, Hawaii, Vermont, and New Hampshire) have enacted legislation that pertains in some part to the potential health effects of 5G technology.[74] In Tennessee, the governor signed into law the "Competitive Wireless Broadband Investment, Deployment, and Safety Act of 2018," cited by NCSL as pertaining to 5G. Despite the term "safety" in the title of the act, potential health effects of 5G do not appear to be referenced in the act; for this reason Tennessee is not included in the list of states that have enacted health-related legislation regarding 5G.[75]

In each of the four states referenced, the legislation directs some committee or other body to conduct a report or study on the potential health effects of 5G. One of these reports, commissioned by the New Hampshire state legislature, asks particularly relevant health-related questions.[76]

The language of Act 522 in New Hampshire includes research questions such as: "Why have 1,000s of peer-reviewed studies, including the recently published U.S. Toxicology Program 16-year $30 million study, that are showing a wide-range of statistically significant DNA damage, brain and heart tumors, infertility, and so many other ailments, being ignored by the Federal Communication Commission (FCC)?" and "Why are the FCC-sanctioned guidelines for public exposure to wireless radiation based only on the thermal effect on the temperature of the skin and do not account for the non- thermal, non-ionizing, biological effects of wireless radiation?" The Commission has released one interim report and is expected to release a final report in the coming months.[77]

While health-related 5G legislation has only passed in four states and consists entirely of requested or commissioned reports on the health effects of 5G technology, health-related legislation has been *proposed* in a number of states.[78] Some of this legislation remains under consideration. Even those bills that have died or been referred to committee will be briefly addressed here, in the hope that knowledge of their language or intent might prove beneficial.

According to NCSL data, there are eight proposed bills from five states related to the health effects of 5G. Three of these bills come from Massachusetts. There, SB 1272 would register wireless facilities to allow for monitoring of small cells and to ease public access to contact information. The bill was presented by constituent request and has been referred to the legislature's public health committee. SB 1273, presented under the same circumstances and also referred, would "ban especially dangerous wireless facilities, emissions, and products." Finally, HB 2885, similar to much of the enacted legislation, would establish a special commission to study the environmental and health effects of 5G. This bill has been referred to its Committee on Telecommunications, Utilities, and Energy.[79]

Of the remaining proposed legislation, one bill (HB 469 from Montana) would restrict small cell citing near schools. HJR 13, also from Montana, "urges Congress to amend the federal Telecommunications Act to account for health effects of siting small cell network equipment in residential areas."[80] The former "missed the deadline for general bill transmittal," and the latter passed in the House but died in standing senate committee. The proposed health-related legislation in New Jersey was a commissioned study on the implications of 5G technology, health being one of the subjects investigated. HB 3375 in Oregon is a similar bill and is currently under consideration. SB 3046 in New York would

require the notification of residents living within a designated distance of new 5G cell sites. It advanced to third reading and was referred to the Senate Committee on Energy and Telecommunications in January 2020.[81]

Figure 4 shows a nationwide distribution of this legislation, constructed from data available on the NCSL page "Mobile 5G and Small Cell Legislation."[82]

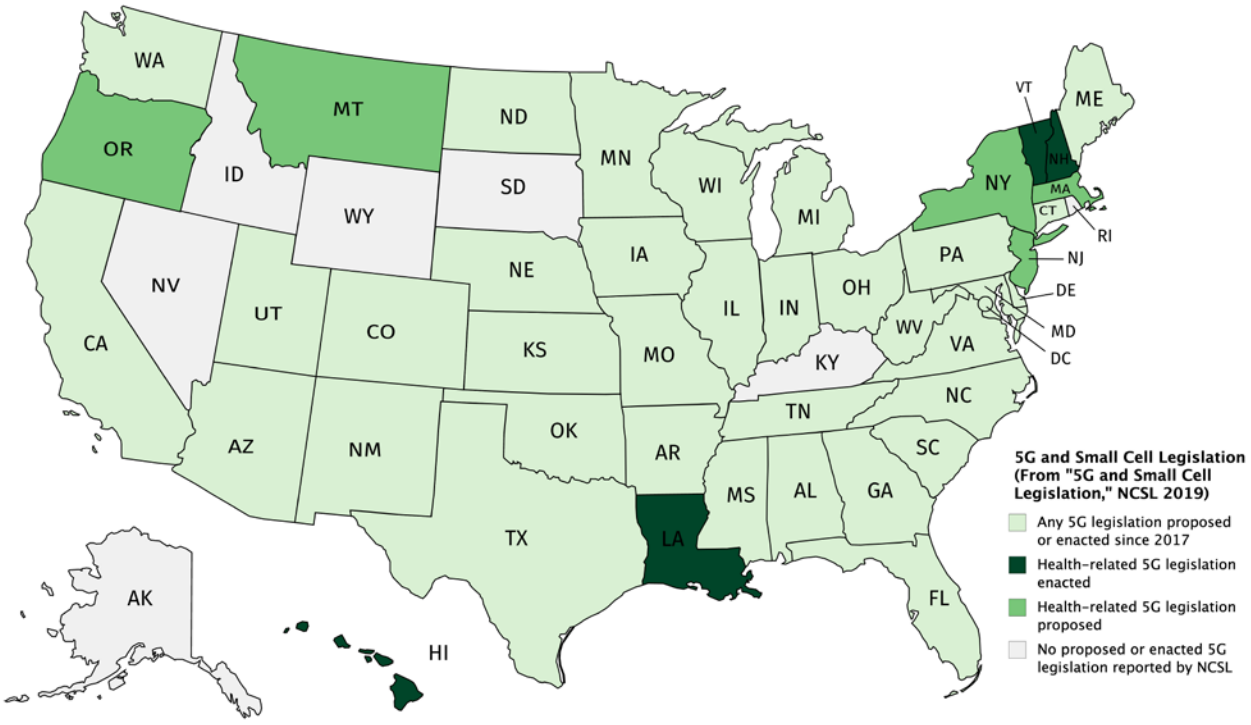


Figure 4. Health-Related Small Cell and 5G Legislation[83]

Health-related legislation on 5G technology is clearly still nascent across state legislatures. Massachusetts is perhaps the current leader in the introduction of such legislation (by measure of volume of proposed legislation), and committee referral has been the most prominent bill destination. Proposed legislation that targets the legitimacy of federal rulings or that directly restricts the construction of wireless facilities appears to have had little success. Among health-related legislation, bills that invite municipalities to the regulatory scene appear to pass into law slightly more often than the other forms of health-

related legislation addressed above. However, it must be noted that statewide conformity orders intended to facilitate smoother 5G rollout are significantly more prevalent than municipality-engaging legislation. Such orders lack relation to health and are accordingly addressed more directly in Section 3: Federal Implementation and State and Local Regulations.

Of the 44 U.S. states that have proposed 5G legislation since 2017, five include language associated with increased municipal regulatory control. In many of these cases, local authorities are able to exert limited control of small cell citing by exercising their ability to "regulate the placement, construction, and aesthetics of wireless telecommunications facilities."[84] [85]Some municipal legal counsels have identified the preceding language as "compliant with the 2018 FCC Order."[86] In a September 2018 Declaratory Ruling, the FCC itself protects "state and local consideration of aesthetic concerns in the deployment of Small Wireless Facilities, recognizing that certain reasonable aesthetic considerations do not run afoul of Sections 253 and 332."[87] Figure 5 is a map showing the distribution of this municipality-engaging legislation, including both proposed bills and enacted laws, created from NCSL data.[88]

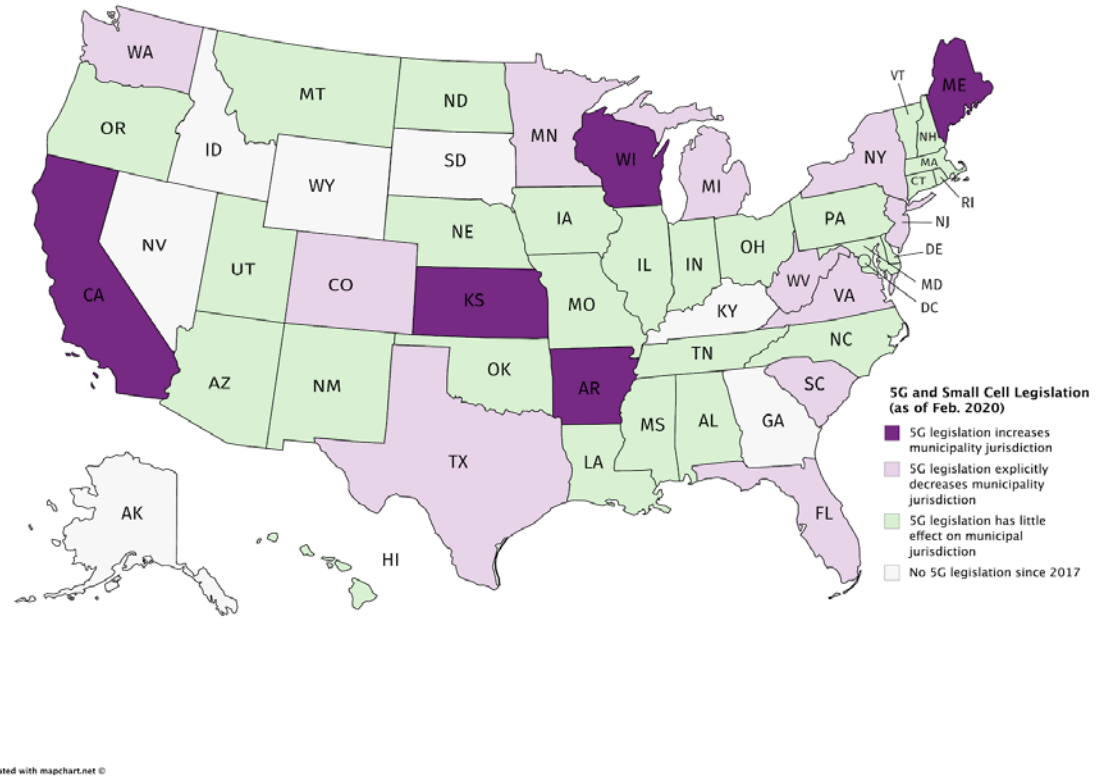


Figure 5. Proposed and Enacted 5G Legislation and Municipality Jurisdiction[89]

The five states highlighted in Figure 5 (California, Kansas, Arkansas, Wisconsin, and Maine) are those states where proposed or enacted 5G legislation would explicitly grant increased power to municipal governments; local-level legislation is concentrated in, but not limited to, these states. California municipalities have been some of the most active. In Berkeley, the 2018 "Right to Know" ordinance requires cellular retailers to inform consumers that cell phones emit radiation and that "if you carry or use your phone in a pants or shirt pocket or tucked into a bra when the phone is ON and connected to a wireless network, you may exceed the federal guidelines for exposure to RF radiation."[90] The ordinance was challenged and upheld in a July court case, with the panel explaining that the public health issues at hand were "substantial" and that the "text of the Berkeley notice was literally true," and "uncontroversial."[91] As the 5G rollout gathers speed, an ordinance like the Berkeley one could serve as a lawmaking route for state and/or local governing bodies that hope to provide consumers with as much information as possible about the new technology, especially as FCC orders limit their ability to control the establishment of the network.

In Los Altos, California, citing guidelines for the construction of small cells assuage some health concerns by mandating that cells are constructed at least 500 feet from schools and at least 1500 feet from one another. Installation of small cells on public utility easements in residential neighborhoods is prohibited, and a 500-foot setback is imposed near multi-family residences in commercial districts.[92] In San Diego and Marin County, CA, recent draft ordinances require that small cells are not located within 1,000 feet of schools, child care centers, hospitals, or churches.[93] Petaluma, CA has passed an ordinance with similar setback requirements, and it also requires that an encroachment permit is obtained for any work in the public right-of-way.[94]

Of particular relevance to Vermont, a Warren, CT ordinance distinguishes between rural and urban levels of adequate coverage and exposure levels, as well as limits the total number of towers in the area.[95] While the Warren ordinance has been successful, a Burlington, MA, attempt to charge cellular companies annual recertification fees simply deterred the cell provider in question from pursuing small cell development in Burlington.[96] A Little Silver, NJ ordinance requires notification of residents within 500 feet of construction sites and mandates that telecommunications companies show that existing wireless infrastructure does not accommodate regional needs.[97]

Local-level ordinances that mandate fees or extend an application process have found limited success in slowing the construction of 5G small cells. In some cases, telecommunication companies eager to establish the new technology have chosen simply to switch targets rather than comply with fees or work through cumbersome application processes—but, importantly, this has not been the case everywhere.[98] Some cities have

been sued by telecom companies for their adoption of non-compliant ordinances.[99] Rochester was successfully sued by Verizon in 2018 for its adoption of a non-compliant order, but the court decided in favor of San Francisco in a similar suit later that year, determining that the FCC Ordinance "allows the City to condition approval of a particular Wireless Permit on aesthetic considerations" and that construction of any wireless structure that generates "inconvenience, discomfort, and disturbance beyond mere blockage" could be legally denied by the city.[100]

State-level legislation pertaining to an increase in municipal control is also one of the most widely called-for legislative movements among health and safety advocates.[101] Further legislative requests and recommendations from concerned constituents, both in the U.S. and internationally, are addressed in the following section.

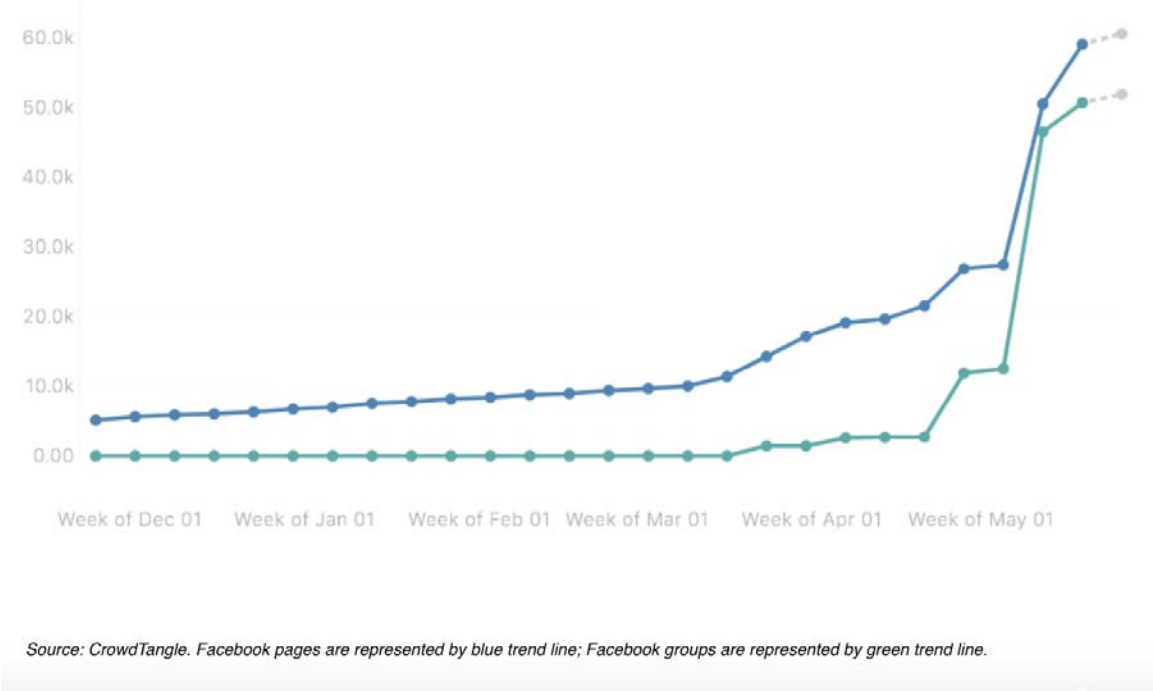
1.3 Domestic and International Opposition to 5G and Legislative Responses

Constituent concerns surrounding 5G technology are growing across the nation. Importantly, though some of these concerns refer to valid scientific literature, a scan of internet search results associated with "5G health" suggests the existence of disinformation and harmful conspiracy theories surrounding 5G technology. A recent 5G-related health concern pertains to fear of a nonexistent association between 5G small cells and the coronavirus pandemic.[102] Arsonists have set 5G towers on fire in the United Kingdom, apparently due to concerns about association between 5G and COVID-19.[103] The World Health Organization and the scientific community at large forcefully deny any such links. There is no scientifically valid mechanism through which 5G technology could cause, spread, or otherwise facilitate a coronavirus infection.[104]

Unfortunately, disinformation surrounding 5G technology did not arise with the emergence of coronavirus. Groups like the Children's Defense Fund, also known to have supported anti-vaccination agendas, are among those speaking out against 5G. Some claim that 5G technology kills insects and birds or could act as a non-lethal "crowd dispersal" weapon.[105] These claims are rebuked by existing scientific evidence.[106] However, due to the nascence of the technology and lack of long-term epidemiological (human) studies into the biological effects of 5G, not all health-related claims are simple to discredit. In the following section, blatantly unscientific or categorically false positions will be highlighted as such. Inclusion of the following positions and groups in this briefing is not an endorsement of their scientific validity. Rather, the research team intends to provide an overview of domestic and international health-related opposition to 5G in an effort to familiarize readers with various forms of 5G opposition—and the corresponding legislative responses.

Concerns about the safety of 5G, unrelated to COVID-19, have existed for years. Claire Edwards, a retired editor on the United Nations staff, has put together a chronology of prominent 5G push-back around the world and in the United States.[107] Her list, as well as an interview with RF-EMF health advocate, grassroots organizer, and former tech-writer Cecelia Ducaine of Wireless Education Massachusetts, are among the sources that inform this section.

At a local level, constituent phone calls and attendance at town meetings regarding 5G establishment are increasingly regular occurrences. Online, social networking pages dedicated to the issue of 5G and its health effects have also grown immensely in the past year.[108] The substantial proliferation of anti-5G Facebook pages and groups is shown in Figure 6. (The graph tracks 5G Facebook activity from December 2018 through May 2019. The blue line shows Facebook pages, while the green shows Facebook groups.)



Source: CrowdTangle. Facebook pages are represented by blue trend line; Facebook groups are represented by green trend line.

Figure 6: Increases in Online Popularity of Anti-5G Campaigns[109]

These Facebook groups, mirrored by a rise in related Twitter hashtags and Instagram pages, help mark the existence of numerous grassroots movements in opposition to 5G.[110] In the legal realm, the groups tend to call for three courses of action from state governments: a moratorium on 5G development, a transfer of regulatory control to municipalities, and a public information campaign. No state government has declared a moratorium on 5G rollout; the 2018 FCC order prohibits such action. Since 2018, a number of states have

considered or enacted legislation that would widen local jurisdiction over 5G development. The Massachusetts legislature published an RF-EMF Safety factsheet in 2016 for public reference, but the sheet has since been removed from their website.[111] Many states have enacted legislation to centralize and streamline 5G regulation at the state level.

Some grassroots organizations, such as the Americans for Responsible Technology, have published online templates for legislation that would allow legislators at both the state and local level to mitigate any potential health effects of 5G technology.[112] The nonprofit organization Wireless Education has also built a half-hour Schools and Families educational course, as well as a Corporate course, both of which are resources intended to spread awareness of the health effects that may accompany 5G technology.[113]

Online campaigns, however, are only the beginning of public pushback to 5G technology. In March of 2019, 62 entities and municipalities across the United States filed a class action lawsuit against the FCC, aiming to vacate the declaratory ruling by the FCC that would streamline the deployment of wireless facilities.[114] Lawsuits like these are a common course of action among concerned parties; in September of 2019, a class action lawsuit was brought against Apple and Samsung on the basis of overexposure to RFR.[115] Numerous lawsuits against the FCC and ADA are underway, including lawsuits filed as recently as February of 2020 by the Children's Defense Fund and by Dr. Debra Davis, Nobel co-laureate on climate change and founder of the Environmental Health Trust.[116] Some of these citizen groups, like the Children's Defense Fund, are also involved in anti-vaccination campaigns. (Vaccinations have been routinely proven entirely safe and effective, as stated by the Immunization Safety Office at the CDC.[117] Other groups, however—like the one led by Dr. Davis—are comprised of reputable scientists and doctors from organizations like the National Institute of Environmental Health Sciences (NIEHS), the National Toxicology Program (NTP), and the International Agency for Research on Cancer, to name a few.[118] As of yet, no prominent citizen lawsuit on 5G technology has been filed against a state government. These lawsuits mainly target the FCC in an effort to mediate the near-solitary control that Ajit Pai and the agency exercise in 5G regulation.

On an international level, one of the broadest appeals against the establishment of 5G technology takes the form of a letter sent to the EU in 2017 and signed by more than 260 scientists and medical doctors. The signees request for a moratorium on the deployment of 5G until the associated health risks are fully investigated by industry-independent scientists. The appeal and four rebuttals to the EU over a period of more than two years have garnered no legislative action. Many suggest that the reason for this is the reliance of international government on regulatory bodies like the ICNIRP and the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), both of which employ senior members with personal ties to the cellular technology industry.[119] Much

recent work of grassroots opposition groups has centered around investigating these ties between regulatory agencies and the industry. The results of such investigation, as well as a record of lobbying action and evidence in support of monetary industry-agency relations, are detailed in a 2014 report by Harvard professor Norm Alster.[120]

Internationally, additional pushback has come from the Planetary Association for Clean Energy (PACE), which submitted a statement to the UN in February of 2019 declaring that allowable international "radiation limits will have to be increased by 30 to 40 percent" to make 5G deployment technologically feasible. The association calls 5G "an experiment on humanity that constitutes cruel, inhuman and degrading treatment" in violation of more than 15 international treaties and agreements. The UN has received many such complaints, but it maintains a pro-development position on the grounds of ICNIRP recommendations and states that "the primary responsibility for protecting the public from potential harmful effects of electromagnetic fields remains with the Member States."[121] Importantly, when U.S. regulatory agencies refer to EU actions in defense of limited regulation on 5G, it must be taken into account that the EU does not regard it as their role to account for any potentially harmful effects of 5G technology.

In many European nations, legislators are responding to constituent concerns by adopting legislation that slows or suspends the rollout of 5G technology until more definitive scientific conclusions are reached. In March of 2019, the Belgian Environment Minister announced the halt of a planned 5G pilot project, stating that "the people of Brussels are not guinea pigs whose health I can sell at a profit."[122] In April, the Geneva government adopted a motion for a moratorium on 5G and called on the WHO to monitor independent scientific studies to determine the harmful effects of 5G.[123] Many European municipalities, including the city of Glastonbury in England, the Swiss canton of Vaud, and the cities of Cuneo and Casarta in Italy, have adopted motions opposing 5G on the basis of health effects.[124]

Unlike the United States, where the 2018 FCC order prohibits a moratorium, public opposition to 5G development in Europe has disrupted the activity of multiple large telecom companies. Europe's biggest carrier, Deutsche Telekom AG, as well as mobile operator Orange Belgium and Swiss carrier Sunrise Communications AG, report having to modify their 5G development in response to health concerns that have manifested in public protests and strict municipal-level emissions standards.[125]

Often, parties in opposition to 5G reference prominent WHO and EU guidelines for legislation on ambiguous health issues. In 1999, the European Union adopted the Precautionary Principle (PP). The PP states that governing bodies should "take prudent action when there is sufficient scientific evidence (but not necessarily absolute proof) that

inaction could lead to harm."[126] Another widely referenced guide is the ALARA principle. ALARA is an acronym for "as low as (is) reasonably achievable," and urges governing bodies to make every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as is practical.[127] Many concerned parties centralize their arguments upon these principles, maintaining that regulatory and governing bodies should adhere to them more closely. A graphic (Figure 7) from Dr. Leeka Kheifets of the WHO presents a number of guiding regulatory principles as they relate to the levels of knowledge and potential for harm surrounding RF-EMF exposure.[128]

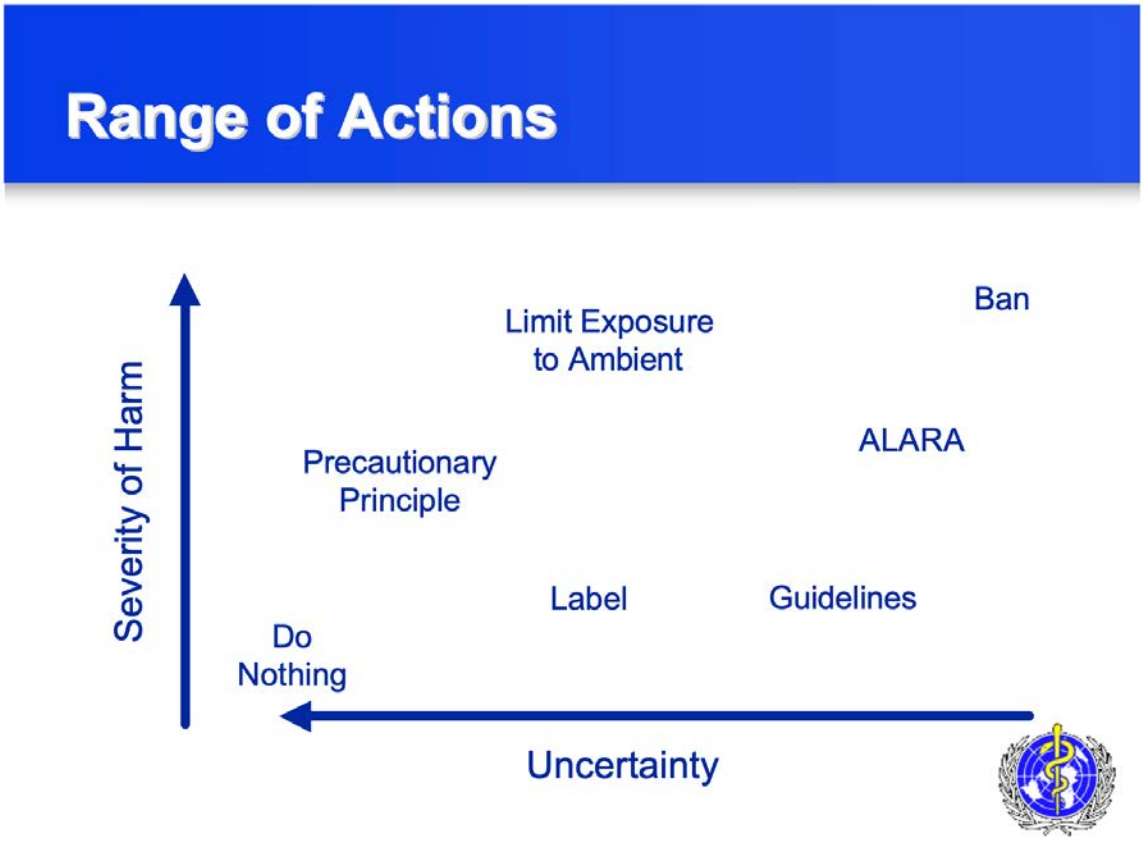


Figure 7: WHO Guiding Regulatory Principles[129]

The WHO, in conjunction with the CDC and other international bodies, maintains that the Precautionary Principle and related guidelines (pictured in Figure 7) should be adhered to in the development of new drugs, technologies, or clinical practices that have the potential to generate adverse health effects. The Precautionary Principle, often referred to by concerned constituent groups, could help to guide health-related policy decisions as they pertain to 5G technology.

Precautionary measures include, but are not limited to: a public information campaign to educate consumers on the potential health effects of 5G, mandates for recurring demonstration of small cell safety and compliance when installed in the public right-of-way, considerations of wired fiber optic networks (especially in rural areas), a legislative petition to the FCC with a request for their response to recent scientific literature, and/or a temporary halt on any current legislation enabling expedited establishment of 5G small cells.

2. ECONOMIC IMPLICATIONS OF 5G IMPLEMENTATION

5G has generated significant debate and controversy regarding its potential health effects, but the new technology has garnered equally as much attention regarding its potential economic implications. Therefore, it is important to consider the economic implications of 5G implementation given the immense financial capital that will be required to implement 5G, as well as the potential of the new technology to generate significant income.

2.1 Background Information

When evaluating the economic implications of 5G, it is important to consider the economic backing necessary to support the current 4G-reliant industry. For reference, we currently rely on 4G, a mobile communications standard intended to supplement 3G, allowing wireless internet access at a much higher speed. Currently, over 200,000 cell towers (which mainly rely on 4G) make up the existing cellular network in the U.S., which initially cost over 200 billion dollars to build.[130]

However, the Global System for Mobile Communications (commonly referred to as the GSM Association), which represents 800 of the largest mobile operators in the world, reports that companies will likely need to spend an additional 500 billion dollars within the next two years to establish nationwide 5G coverage.[131] This estimate factors in the additional 300,000 towers that AT&T believes will be necessary in the establishment of functional 5G services.[132]

The construction of cell towers, however, is only the beginning of 5G implementation.[133] Currently, there are a very limited number of phones, computers, and modems that are 5G-compatible. Thus, in order for consumers to benefit from this technology, it will be necessary for them to purchase devices that are able to rely on this type of wireless technology.

This obviously presents significant economic potential for a number of network providers and device makers. In fact, T-Mobile, Verizon, and Apple are already scrambling to secure

access to its products so they can participate in the 5G revolution, as it is bound to serve as an industry that will revolutionize many different parts of our current living standards. It is predicted that nearly real-time speeds will drive world-changing tech, like self-driving cars and remote surgery, as is illustrated in Figure 8.

Figure 8: The Potential That Lies Within "Smart Cities," All Powered By 5G[134]

Although the industry clearly has potential from an international and national perspective, it is important to consider the economic feasibility on a more local level, especially for the state of Vermont.[135]

2.2 Challenges with 5G Implementation

Although there are a variety of potential benefits associated with 5G implementation, it is important to equally consider the difficulties that come about with its implementation, both from a physical and economic perspective.

Since 5G technology will operate on higher-frequency, lower-amplitude waves than preceding networks, the new network is sometimes referred to as "millimeter wave technology."[136] However, because the wavelength of 5G is so short, on average, a 5G signal can only travel one kilometer from its base station, which is equivalent to a radius

of approximately four city blocks. This distance is 70 times smaller than the capabilities of a 4G signal, as 4G signals can travel distances up to 70 kilometers long.[137] Although there are a variety of explanations for this difference, the main takeaway is that 5G networks will require hundreds of thousands of smaller towers, placed in close proximity, while 4G networks require significantly fewer cell towers).

A number of Mobile Network Operators (wireless service providers, commonly referred to as MNOs), are aware of this fact, and are trying to factor in the necessary costs and infrastructure in order to spread this technology. A key distinction, however, is that unlike 4G cell towers, which can reach a height of 200 feet, 5G cell towers are significantly smaller, and are roughly equal to the size of a trash can.[138]

Although 5G relies on different cell towers, it is possible for 5G to coexist with the existing 4G framework. Pursuant to Brian Lavallée, the Senior Director of Portfolio Marketing with Global Responsibility for telecommunications company Ciena, the 5G backbone will not be physically or virtually separate from the 4G backbone. He states that "if, for example, a service provider has a 4G cell tower and wants to add 5G radios to that macro tower, they would likely end up sharing the aggregation and core network back to the data center, perhaps over different wavelengths or different parts of the network. Rolling out completely separate networks for both would become cost prohibitive quickly and much harder to get to ROI [return on investment]. Some parts of the network will be only for 5G, and some shared.[139]

However, it is also important to note that for 5G to function within society, the underlying wireline architecture that currently supports 4G mobile backhaul will need to slightly change. Today, Mobile Networking Operators (wireless service providers) typically feed a 1 GB/s (Gigabit per second) Ethernet line to 4G cell sites, with roughly 200-300 Mb/s being used on average. With 5G, that same marco tower may need tens to hundreds of GB/s (10-100 times the speed for 4G cell cities), which will require enormous capacity upgrades to those towers.[140]

The extensive cost of rewiring these 5G networks means that expense is the most substantial barrier to 5G establishment. However, 5G networks will also bring economic gain for a number of sectors, as can be illustrated in Figure 9.[141]

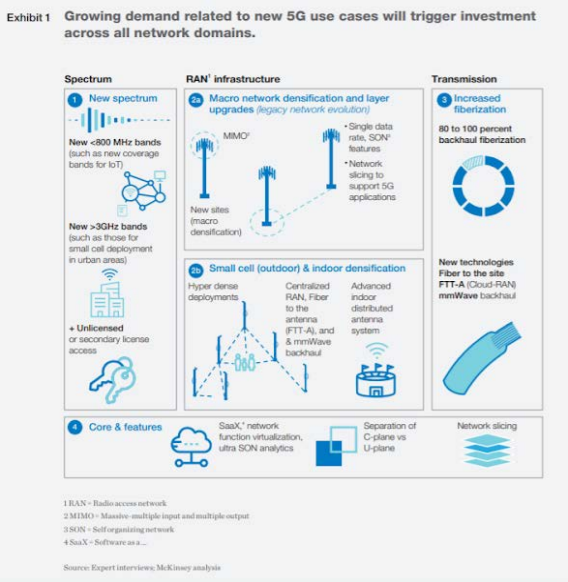


Figure 9: Growing demand related to new 5G use cases will trigger investment across all domains.[142]

2.3 Different Types of 5G

Although it is true that on average, the wavelength of 5G is shorter, and the frequency is higher than that of 4G (and other cellular networks), 5G differs from prior cell phone standards in having a much wider radio dial than before, meaning that it is capable of tuning into multiple types of different frequencies, resulting in different signal types. For 5G, specifically, three different types of signals exist: low, medium and high bands.[143]

These bands of 5G differ from one another in a number of ways, and these differences allow for a wider range of function than was demonstrated by earlier cellular networks. Generally, each of the three bands (low, medium, and high) differ from one another in the speed at which they deliver internet connection, and in the spatial range that they can cover. These differences are summarized in Figure 10.

Type of 5G	Frequency (in GHz)	Speed (in Gbps)	Radius of Signal
Low Band 5G Will Have …	Shorter Frequency, Longer Wavelength	Slower Speeds	Longer Transmission
Low Band	.600-.700	.030 to .250	Hundreds of Miles
Medium Band	2.5-3.5	.100 to .900	Several-Mile Radius
High Band	24-39	1-3	One-Mile or Lower Radius
High Band 5G Will Have …	Higher Frequency, Shorter Wavelength	Faster Speeds	Shorter Transmission

Figure 10: The different characteristics of the different types of 5G[144]

An important caveat regarding Figure 10, above, is that each of the tiers (low, medium, high) will improve in performance over time; the data above only provides a temporary metric for the current developments that have been established for this specific wireless technology.

Regardless of the developments that occur with these types of 5G, however, it is important to recognize that unlike prior generations of wireless networks (including 4G, 3G, etc.), which relied solely on low-band spectrum, 5G will enable utilization of the complementary relationships between the low-, mid-, and high-band spectrums to cover many regions of the United States. Each band of 5G will need to be used in order to create an efficient networking system for all.[145] Although there are clear differences among a variety of characteristics between low, middle, and high band 5G, it is important to understand what role those differences play on a bigger level.

2.3.1 Low Band 5G

Far into the future, it is hoped that low-band 5G will become the cost-effective "baseline" for internet connectivity for the nation. It will provide a base, standard level for 5G. Even though low band 5G does not present service as quick as other forms of 5G, this type of 5G is effective in covering larger geographic areas, because it is significantly cheaper, and because its range spans a vast area. This enables coverage in the most far-flung and rural locations.[146]

In terms of speed, the low band 5G provided by T-Mobile peaks at somewhere in the neighborhood of 225 megabits per second (MBps), which is six to seven times faster than common 4G speeds in the United States today.[147]

However, this quick speed is largely dependent on location. Pursuant to some testing carried out by Jeremy Horowitz, a writer for VentureBeat in Apple, AI, and tech news, in all of the locations that he tested with his 5G phone, the connection speed was usually between 20 percent and 100 percent higher than results at the same times and places on a 4G phone.[148]

It is essential to dive slightly deeper into the economic implications of low band 5G, as it is likely that if 5G were to be implemented in Vermont, the majority (if not almost the entirety) of the state would use low-band 5G.

Based on previous research, David W. Sosa, Ph.D. and Greg Rafert, Ph.D., members of the Analysis Group—an organization with devoted economic, financial and strategy Consultants—predict that low-band 5G infrastructure-related capital spending will be split into four industry categories:

- 47 percent wireless communications equipment
- 29 percent construction
- 15 percent wireline communications equipment
- 10 percent wire and cable

These calculations do not only confirm the notion that 5G deployment will require substantial investment into backhaul fiber, but a significant amount of additional small cells and towers as well. Sosa and Rafert then continue to explain that given this investment, 5G will result in three different types of economic activity: direct, indirect, and induced. Within their paper, they define the three terms as follows:

- **Direct Effects**
  - Effects as a result of increased GDP and employment directly resulting from the new spending on goods and services to deploy the 5G infrastructure itself.
- **Indirect Effects**
  - Effects as a result of changes to sales and employment in sectors supplying goods to the industries which create the infrastructure.
- **Induced Effects**
  - Effects as a result of increased sales and employment driven by greater household spending due to higher incomes driven by the initial spending.

Although it is unclear as to what the exact financial impact of 5G rollout will be on the state of Vermont, it is expected that approximately 80 percent of it will be attributed to direct and indirect activity, and the remaining 20 percent will be attributed to induced activity, as is illustrated in Figure 11. It is important to remember that these financial impacts will be occurring in addition to the job growth that is projected to accompany 5G expansion.[149]

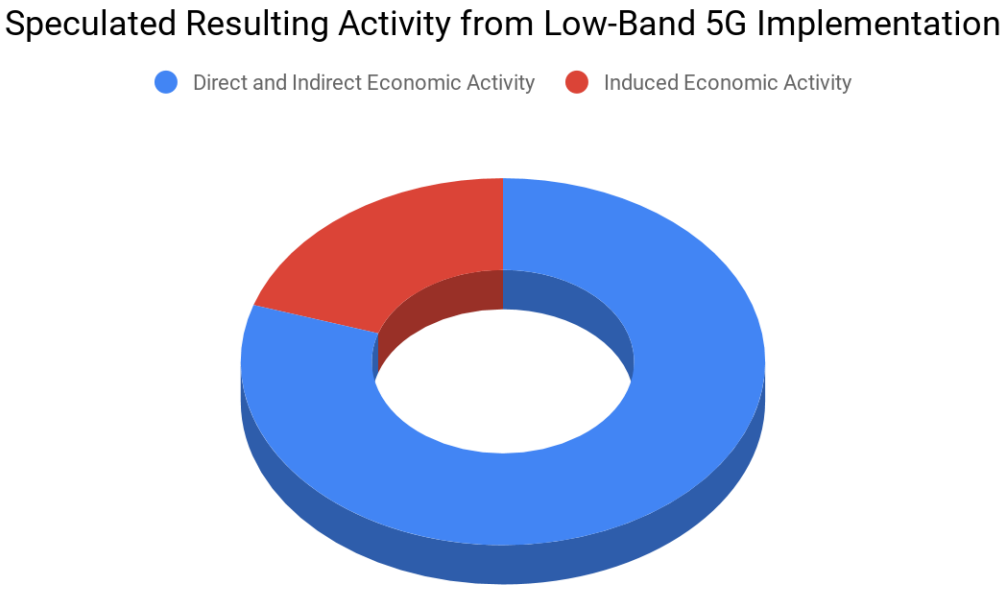


Figure 11: Potential Economic Activity Based on Low-Band 5G Implementation

2.3.2 Middle Band 5G

As implied by its name, this type of band serves as the middle ground between low-band and high-band 5G, and is likely going to become available in many of the "metro" areas of the United States across every major carrier in 2020. For other countries, this flavor of 5G may constitute the minimum 5G performance tier in some countries. Even in the United States, for example, it is likely that some carriers will skip low-band 5G altogether.[150]

Domestically, one carrier (Sprint) is already offering mid band 5G using 2.5 GHz frequencies. In other countries, mid-band 5G is generally slower (3.5-3.7 GHz frequencies). However, mid-band (commonly referred to as "sub-6GHz") generally includes radio frequencies from two GHz to six GHz, all of which have similar speed and

distance characteristics. Towers built with mid band radios can offer service within several-mile radiuses, which is a shorter range than low band, but a wider range than high band.[151]

With middle band 5G, data speeds are markedly higher as compared to low band, but are fairly similar. Jeremy Horowitz found that, on average, middle band speeds are as fast as low band 5G, but that 5G middle band is significantly different in the fact that the fastest speed it can reach is significantly high at 600-700 Mbps (Megabytes per second), which is roughly eighteen to twenty times faster.[152]

Middle band 5G is developing slightly differently in different countries, but everyone in the cellular industry can agree on one thing: mid band 5G will soon be the sweet spot for 5G distance and performance, assuming you live within a couple of miles of a tower.[153]

2.3.3 High Band 5G

High band 5G, on the other side of the spectrum, utilizes high band (high frequency) millimeter waves. These waves offer the highest-speed wireless available, but their range is the shortest of all existing bands. This means that high band 5G will likely be deployed in "dense urban" environments and public gathering places that frequently serve large numbers of people, including sporting and concert stadiums, convention centers, and the like.[154]

In addition to the low range of millimeter-wave 5G, these high frequency bands are also particularly susceptible to environmental interference. For example, depending on the construction materials within a building, such as the type of glass that is used for windows, the distance that the 5G can travel can significantly decrease. In some cases, obstacles like walls and trees restrict the passage of 5G altogether.[155]

If you happen to be near one of these towers, however, you will see peak cellular speeds beyond your wildest dreams: real world numbers between one and three Gbps, which is in the neighborhood of 30-80 times faster than the typical 4G connection available today across the country. Qualcomm and Samsung are raising the stakes even higher, convincing industry experts that their latest 5G modems can peak at over 7Gbps.

However, in Vermont, such high frequency bands of 5G are not likely to be deployed at all—at least for the next few years. The 40,000-person population of Burlington does not quite exceed the 50,000-person minimum for high band 5G.

2.4 Cost of 5G Implementation

Since 5G is in its first stages of implementation, the general cost of implementation is still speculative. However, the International Telecommunications Union has listed out several mock scenarios in their paper, "Setting the Scene for 5G: Opportunities and Challenges," and they have calculated the estimated capital expenditure (commonly abbreviated as capex) for each rollout scenario. They present one scenario for a large, dense city, and another scenario for a small, medium-density city.[156]

For these scenarios, in addition to assuming that the city benefits from 4G coverage and that 5G implementation is commercially attractive, McKinsey operated under the following assumptions for capital expenditure scenarios for the two scenarios:

Small cell distance	Scenario 1	Scenario 2
RAN equipment (antenna, street cabinet, base station electronics, battery backup and network maintenance modules)	25%	24%
Implementation costs (design and planning costs, site upgrade costs, permit costs and civils costs to lay street cabinets)	50%	46%
Fibre (provision of 144 fibre along the route of activated street assets)	25%	30%
MER (single rack and termination equipment)	<0.1%	<0.1%

Figure 12: McKinsey's Speculation as to the Contribution to CAPEX for each Scenario[157]

Additionally, for each scenario, the following: assumptions were made:

Scenario 1 (largely densely populated city)	**Scenario 2 (small medium density city)**
• Proposed urban coverage area: 15 sq km • Population density of coverage area: 12,000 people per sq km • Inter-site small cell distance: 150 m	• Proposed urban coverage area: 3 sq km • Population density of coverage area: 3,298 people per sq km • Inter-site small cell distance: 200m

Figure 13: Assumptions for each scenario[158]

Based on these assumptions, the following values were obtained for the capital expenditure of 5G rollout in each city.

Scenario 1 - large dense city	
Item	**Value**
Total CAPEX (USD millions)	**55.5**
Number of small cell sites	1,027
Cost per square km (USD millions)	3.7
CAPEX per site (USD thousands)	54.1

Scenario 2 - small less dense city	
Item	**Value**
Total CAPEX (USD millions)	6.8
Number of small cell sites	116
Cost per square km (USD millions)	2.3
CAPEX per site (USD thousands)	58.6

Figure 14: Total CAPEX (and other information) for both scenarios[159]

Now, similar techniques can guide an estimation of potential capital expenditure for 5G implementation in the state of Vermont.

For example, one can evaluate the potential cost of 5G rollout in Burlington, Vermont, through the process outlined below. First, geographic and demographic characteristics of the city must be considered:

Facts about Burlington, VT

		Population	42,899 (as of 2019)		
Total Area (in mi^2)		15.48	**Total Area (in km^2)**		40.093016
Land Area (in mi^2)		10.31	**Land Area (in km^2)**		26.69
Population (people/mi^2)	**Density**	4,160.91	**Population (people/km^2)**	**Density**	1607.31

Figure 15: Statistics About City of Burlington, Vermont

Based upon these facts and the McKinsey projection method, one can assume the following (if we were to cover the most populated parts of Burlington):

Scenario 3 - Burlington, Vermont
• Proposed urban coverage area: 3 sq km • Population density of coverage area: 1,607 people per sq km • Inter-site small cell distance: 200 m.

Figure 16: Underlying Assumptions When Considering 5G Rollout in Burlington, Vermont

We will also operate under additional assumptions laid out by Scenario 2, and assume the following for the Burlington Scenario:

Small cell distance	Burlington
RAN equipment (antenna, street cabinet, base station electronics, battery backup and network maintenance modules)	24%
Implementation costs (design and planning costs, site upgrade costs, permit costs and civils costs to lay street cabinets)	46%
Fibre (provision of 144 fibre along the route of activated street assets)	30%
MER (single rack and termination equipment)	<0.1%

Figure 17: Contribution to CAPEX

After using the same approach used by McKinsey, we come to the conclusion that to implement 5G for three square kilometers of Burlington (note that this does not cover the entire city), it is likely going to cost $3.45 million.

Scenario 3 - Burlington, Vermont	
Item	**Value**
Total CAPEX (USD millions)	3.45
Number of small cell sites	58
Cost per square km (USD millions)	1.15
CAPEX per site (USD thousands)	58.6

Figure 18: Potential cost for covering part of Burlington Vermont with 5G.

Granted, these numbers are simply estimates. However, the estimates provide a starting point from which to understand the economic implications of 5G implementation in some of the most populous regions of Vermont. Although these costs will be incurred by the cell companies, it is critical to recognize how much this infrastructure will cost as a whole.

2.5 Potential Financial Impact for Consumers

Although it is important to consider the economic cost for the infrastructure behind 5G, it is also important to consider how 5G implementation will affect the average consumer.

Admittedly, there are a number of benefits that come about with the implementation of 5G (especially those concerning faster speeds). However, a significant detriment of 5G implementation is the increased consumer cost.

As stated by David Goldman, a reporter for CNN, "with great speed comes great cost." According to Netflix (in 2014), a typical standard-definition streaming video that you watch on your phone uses up to 0.7 GB of data per hour, whereas an hour of a 4K video (videos with high-definition (HD) resolution that has four times the resolution of 1080p HD video) uses seven GB of data per hour. The fact that so much data is used within such a short time frame should indicate that wireless bills will likely be extremely high.[160]

However, as was predicted in 2015 by many wireless analysts, cell carriers have tried to lower cell phone costs in order to make 5G affordable for the average consumer.[161] For example, Verizon is only charging an additional $10 a month (per smartphone) for subscribers who want to utilize 5G, assuming that their devices are 5G-compatible.[162]

Although there might be additional costs higher than $10 associated with 5G plans, it appears as if 5G implementation will not impose a significant increase in the cost of current cell plans (although this relies on many current assumptions).[163]

However, we also must not ignore the fact that with higher wireless speeds, consumer data usage is going to increase. Because this is going to generate more traffic on the grid, this, in turn, could potentially result in slightly higher cell phone bills than we would initially expect.[164]

2.6 Alternatives to 5G Implementation

Although 5G does seem to be a favorable option for the state of Vermont in numerous regards, the state ultimately has a variety of options. Clearly, Vermont has the option to prioritize 5G investments to accelerate commercial prospects (although this would limit parts of the state to still operate under 2G, 3G, and 4G networks).

However, some telecommunications officials suggest that service providers focus on the establishment of state-wide 4G prior to the rollout of nascent 5G service; many municipalities still rely on 2G and 3G service alone. Brian Lavallée, the Senior Director of Portfolio Marketing with global responsibility for Ciena (a telecommunications company), explains that 5G will undergo a number of changes, upgrades, and modifications in the time during which the country is brought up to 4G-speed, and that states are likely to save time and money by slowing 5G implementation.[165]

Importantly, a temporary halt on the establishment of 5G technology does not necessarily mean that Vermont would be abandoning 5G-related development entirely. Since 5G small cells can be implemented as additions to pre-existing 3G and 4G infrastructure, the statewide development of these earlier-generation cell networks will simultaneously serve as groundwork for the eventual installation of 5G .For example, the development of additional fibrous connections will be necessary for statewide 4G coverage, and such action will also ease eventual 5G implementation—especially in rural regions, where fiber connections are viewed as the best mechanism for making that "final leap" in service from small cells along roadways to widely dispersed rural residencies. Macro-cells, too, will be beneficial in both the establishment of wider 4G coverage and eventual 5G service.[166]

Even though 5G relies on different cell towers, it is possible for 5G to coexist with the 4G framework, since 4G and 5G share many of the aggregation and core network back to the data center (even if they operate on different wavelengths or different parts of the network), and it is important that cell companies utilize this overlap in function to their advantage, as rolling out completely separate networks for both would add unnecessary costs—costs that

could be transferred to consumers.[167] As stated by McKinsey in their paper, "The Road to 5G: The Inevitable Growth of Infrastructure Cost," the "evolutionary approach [building up 4G coverage prior to establishing 5G service] will be the natural path for most operators, allowing them to minimize investments while the incremental revenue potential of 5G remains certain."[168]

Ultimately, it will be up to cell providers, and (in a limited fashion) the state, to determine what path Vermont should take. Both options provide certain benefits that are inherently associated with them, but both obviously come with certain drawbacks (physical limitations, financial concerns, etc.). However, as research into 5G increases and more developments are made regarding the feasibility of 5G rollout, it will be important to stay up-to-date on this research in order to determine what true economic implications it will have.

3. FEDERAL IMPLEMENTATION REGULATION AND OTHER STATE AND COUNTRY COMPARISONS

States must work around the federal preemption on telecommunication issues. Within the federal legal and regulatory outline, states fill in the specifics of 5G rollout. There is very limited room to work, but it is important to know the leeway states and municipalities have on certain issues. It seems that the goal of the federal government is to avoid a quilt work of state regulation while also allowing some local decision making.

3.1 FCC's 5G Rollout Plan

The Facilitate America's Superiority in 5G Technology Plan is the FCC strategy to regulate the rollout of 5G technology. It has three parts. The first is "pushing more spectrum into the marketplace" which the FCC has done by auctioning off high-band spectrum for 5G services a priority which is the fastest speed but has the shortest range.[169] The second is "updating infrastructure policy" through new rules attempting to reduce regulation for deployment of small cell infrastructure and update old regulation to accommodate small cells applications in states and municipalities.[170] The final part is through "modernizing outdated regulations to support the wired backbone of 5G networks."[171]

3.1.1 Federal Preemption

Federal preemption on telecommunications is defined in the Telecommunications Act (TCA) of 1996 which modified the original TCA of 1934. Section 253 allows the FCC, "after notice and an opportunity for public comment," to preempt the enforcement of a state or municipal regulation if one of two conditions are met.[172] The first is if a state or

local statute or regulation "prohibit[s] or have the effect of prohibiting the ability of any entity to provide any interstate or intrastate telecommunications service."[173] The second is if the state does not impose "on a competitively neutral…, requirements necessary to preserve and advance universal service, protect the public safety and welfare, ensure the continued quality of telecommunications services, and safeguard the rights of consumers."[174] However, a state or local government may "require fair and reasonable compensation from telecommunications providers, on a competitively neutral and nondiscriminatory basis, for use of public rights-of-way on a nondiscriminatory basis, if the compensation required is publicly disclosed by such government."[175]

Section 332(c)(7) states that "regarding the placement, construction, and modification of personal wireless service facilities," state and local governments cannot discriminate between providers of similar services or prohibit the delivery of services.[176] They must act on request for authorization in a reasonable time period and submit written evidence justifying a denial of an authorization.[177] State or local governments cannot "regulate the placement, construction, and modification of personal wireless service facilities on the basis of the environmental effects of radio frequency emissions to the extent that such facilities comply with the Commission's regulations concerning such emissions."[178] In the case of a party being negatively affected by inaction from a state or local government may pursue action in any court within thirty days.[179]

3.1.2 2018 Declaratory Ruling and Order

The main federal regulation pertaining to states and municipalities for the current deployment of 5G technology is the Declaratory Ruling and Order issued by the FCC on wireless infrastructure deployment.[180] It was published to remove regulatory barriers the hindered the creation of infrastructure needed for 5G and advanced wireless services.[181] The Declaratory Ruling and Order builds off of the framework of the TCAs by applying them to the new deployment of 5G technology.

Deployments of 5G technology are also known as small wireless facilities (SWF) and are primarily located on existing poles, structures, and infrastructure in the public right-of-way (ROW).[182] The first thing that the Declaratory Ruling and Order does is uphold the criteria from the 1997 FCC *California Payphone* decision stating that state or local regulation pertaining to fees and aesthetic requirements violate Sections 253 and 332 of the TCA if "the ordinance materially inhibits or limits the ability of any competitor or potential competitor to compete in a fair and balanced legal and regulatory environment."[183] It limits fees that state and local governments charge to be only those that "are nondiscriminatory and represent a reasonable approximation of the local government's objectively reasonable costs."[184] Additionally, fees in compliance with Section 253 or 332(c)(7) may be no more

than "$500 for non-recurring fees, including a single up-front application that includes up to five Small Wireless Facilities, with an additional $100 for each Small Wireless Facility beyond five, or $1,000 for non-recurring fees for a new pole (i.e., not a collocation) intended to support one or more Small Wireless Facilities." The second type of fees in compliance with the TCA may be no more than "$270 per Small Wireless Facility per year for all recurring fees, including any possible ROW access fee or fee for attachment to municipally-owned structures in the ROW."

The Declaratory Ruling and Order sets certain non-fee requirements. Regarding aesthetics, states and local governments may enact regulation if it is "(1) reasonable, (2) no more burdensome than those applied to other types of infrastructure deployments, and (3) objective and published in advance."[185] The same criteria pertain to undergrounding requirements of SWFs as long as it does not amount to "an effective prohibition of the service," however, this would be likely given the effect to propagation characteristics of wireless signals underground.[186] The aesthetics criteria are also applied to minimum spacing requirements of SWFs.

Finally, the last effect is the establishment of two new "shot clocks" for SWFs. A shot clock is the amount of time that may pass between the submission of an application for the installation of a SWF and the response to that application. The complete shot clock is shown in Figure 19. The failure of a state or local government to act within the shot clock would constitute a presumptive prohibition on the provision of services which could be addressed in court.[187]

FCC Review Shot Clock Types and Times	
Type of Review	**Shot Clock**
Franchise	120 days
Right-of-way Permit	30 days
Collocation of small wireless facilities (**new**)	60 days
Construction of new small wireless facilities	90 days
Construction of new facilities other than small wireless (**new**)	150 days
Eligible Facilities Requests (6409(a))	60 days
Eligible Facilities Requests Application Review	60 days (deemed granted if not acted upon)

Figure 19: FCC Review of Shot Clocks [188]

3.2 Other State Comparisons

The body of state regulations on 5G rollout has been careful to work within the stated FCC limits. States are primarily concerned with setting fees, specific shot clocks, and specifying physical constraints. The only legislation that has not pertained to setting more specific standards has been the few health-related bills introduced. Some states have highlighted the unknown health consequences of 5G technology. There is not much variety within new state regulation because of FCC preemption.

3.2.1 Connecticut

InConnecticut, the "Accelerating the Deployment of 5G Wireless Facilities" Act sets out physical regulations SWFs and develop fee structures to comply with FCC regulation.[189] Its first task is to create a Council on 5G Technology that will review wireless carriers proposals to install SWFs on state-owned real property and determine which state owned property may made available for the installation of SWFs.[190] The state lays out how it will determine its own fee structure and shot clock through state committees and departments.[191]Additionally, the state will work with municipalities to create a streamlined process for installing SWFs on municipal property.[192]

3.2.2 Wisconsin

In 2019, Wisconsin passed Act 14, creating limits for the state and municipalities to regulate wireless facilities and imposes setback requirements for SWFs. It first off deals with setting specific fees and contractual agreements for telecommunication companies to use public ROWs, which are in line with FCC regulation.[193] Then it lists the rules for utility poles and a specific shot clock for applications.[194] Act 14 goes on to describe the permissible aesthetic requirements, safety requirements, and other applicable physical regulations such as instillation in a historic district or an underground district.[195] It addresses when approval is and is not needed for maintenance work on SWFs.[196] Wisconsin reaffirms the preemptive position that federal law has on the topic.[197]

3.2.3 Maine

Maine does little to change its existing regulation. Half of the Act to Facilitate the Deployment of Small Wireless Facilities in Maine simply defines wireless facility and SWF. A SWF is defined as "a wireless facility each antenna of which could fit within an enclosure of no more than three cubic feet and of which all associated wireless equipment other than antennas, electric meters and concealment elements has a cumulative volume of

no more than 28 cubic feet."[198] The last part states that a SWF "must be a permitted use within the public right-of-way" as long as it meets the proper permits and nondiscriminatory conditions consistent with state and federal law.[199]

4. CONCLUSION

The rollout of 5G technology in the state of Vermont has a number of implications Economically, the state will rely largely upon low-band 5G networks that will be built upon existing 3G and 4G infrastructure. Thus, investing in the continued development of these earlier generations is both favorable for rural residents and economically advantageous. With regard to health effects, there is not sufficient scientific evidence to prove unequivocally that exposure to RF radiation is entirely safe, nor is there sufficient evidence to prove unequivocally that exposure causes adverse health effects. In response to this ambiguity, some state and local legislators have proposed legislation that would mandate further study of 5G-related health effects or urge Congress to do so.[200] Legislative approaches to 5G rollout differ between states and are limited by federal preemption, but the entirety of enacted legislation as it pertains to potential adverse health effects of 5G takes the form of commissioned studies or reports. Some states have passed legislation that offers local and municipal governments the opportunity to legislate on small cell regulation. While FCC regulations limit the vast majority of state and local legislation, the Order does not bar states and municipalities from taking some minor forms of regulatory action, specifically when related to the aesthetics of small cell sites. Some municipalities in the U.S. have taken such action, though the emergence of lawsuits associated with a small proportion of these decisions suggest that they should be made with careful legal counsel. Many states have passed legislation that is intended to facilitate a smooth 5G rollout process. Nationwide, much 5G-related legislation has been proposed over the past two years. The state and local legislative bodies of neighboring regions could serve as a valuable source of information and guidance as new legislative propositions continue to emerge. Also consistently emerging are studies on the biological effects of 5G technology. Given the nascence of 5G technology and its anticipated far-reaching effects, these studies should be monitored and legislative decisions regarding 5G should, to the extent possible, take into account the still-developing body scientific literature.

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