OREGON DOUGLAS FIR AND SUSTAINABLE WOOD CHOICE IN SOLID BODY ELECTRIC GUITARS

by

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This thesis explores alternative wood choice in solid body electric guitar manufacturing, with the focus being in long term resource sustainability, and how the choice of the wood affects the sound and manufacturing. Gibson Guitars is primary company of comparison because of its reliance on the tropical hardwood mahogany. Douglas fir is the sustainable wood choice because of prominence in Oregon and because of Oregon direct place in Gibson's timber supply chain. Douglas Fir is faster growing, and protected more heavily than mahogany, and can be acquired from the country in which the guitars are built. Douglas Fir is comparable to mahogany in specific gravity, and the role of the guitar body in electric guitars has significantly less effect on the sound than in an acoustic instrument, and the final guitars sounds comparable to similar instruments made from other woods. The evidence is a fully functioning electric guitar with a body built from Douglas fir.

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Introduction / Chapter 1: Design Brief

The purpose of this thesis is to explore alternative wood choice in solid body electric guitar manufacturing. Specifically, this thesis explores the use of Douglas fir as an alternative to mahogany for use in Gibson USA guitars. This written thesis corresponds to the creation of a physical guitar as the experimental and creative portion of the thesis research. Beyond the creation of the guitar concept, the written portion of the work studies the impact of wood in the creation of guitars both from a structural and environmental perspective. The ultimate aim of this project is to explore to potential benefits of a theoretical recommendation to Gibson to consider this guitar concept for production, with a focus on Oregon regionalism. A Douglas fir guitar would allow Gibson to offer a sustainable guitar option, reduce its reliance on tropical hardwoods, and support the Pacific Northwest's lumber economy.

The initial inspiration for this thesis came from the Okala Impact assessment. Okala is a curriculum and design tool developed by the Industrial Design Student Association to help designers have a measure with which they can assess the environmental impact of their designs. This guide shows the relative of carbon impact that materials and manufacturing processes have on designs.[1] The Okala impact assessment analyzes raw materials, modes of production, and disposal of a product. The Okala impact assessment points are based on many factors including human toxicity, carbon footprint, fossil fuel depletion, ozone depletion among other factors.[2] The Okala practitioner was created to provide these tools to designers, in conjunction with the US

[1] *Okala Practitioner: Intergrating Ecological Design*
[2] White, *Okala Practitioner*

Environmental Protection Agency. Due to differences in growth time of different trees, and harvesting processes, different woods have different Okala impact factors. The low Okala impact rating of pine, compared to hardwoods helped to catalyze the concept of using a softwood to build a guitar that was locally sourced and less environmentally impactful. Of the three most popular guitar models: The Fender Telecaster, the Fender Stratocaster, and the Gibson Les Paul, none are made from a softwood, or wood from coniferous tree.[3] The Fender models are made from either ash or alder, and the Gibson Les Paul is made from mahogany and maple. The original concept for this product was a guitar that featured pine as the alternative wood choice. It is similar in density to the hardwoods used in guitar and is prevalent in Oregon. Since some of the early Telecaster prototypes were made from pine, it was an option that had some historical precedence. Douglas fir, however, as opposed to pine, offers a greater representation of the majority in the timber harvest in Oregon, and thus a potentially beneficial connection to local Oregon identity.[4][5] Oregon identity strengthens the "Made in America" branding already found in Gibson.

[3] Dumoulin and Gauzente, *Guitar in the Digital Era*
[4] Brandt et al., *Industry and Timber Harvest, 2003*
[5] Gale, et al., *Industry and Timber Harvest, 2008*

Chapter 2: Electric Guitar History

Electric guitars are undoubtedly a cultural phenomenon, constituting half of all instrument sales in the USA. The electric guitar is essential to rock music and all of its various genres and at 39 percent of players, the guitar is the most played instrument in the US.[6] The modern six string guitar replaced the early five paired string version. The newer 6 string instrument was tuned in fourths and featured one string per note, as opposed to the earlier paired string version. The guitar would eventually become one the primary instruments in popular music. Orville Gibson, who founded Gibson, was one of the people to utilize steel strings, a string type not found on all guitars in the late nineteenth century.[7] Other guitars at the time still used traditional gut strings Some guitar features, like a bolt-on neck come from guitars built by Christian Frederick Martin, and would later be adopted by Leo Fender in his Telecaster guitar. Orville Gibson was also responsible for carved top acoustic design that would become popular in jazz combos and eventually would become the template for hollow body electric guitars, the first type of electric guitar Another important invention was the truss rod. The truss rod was invented by a Gibson employee, Thaddeus Mugh, in 1921. A truss rod is a metal rod that sits in a channel under the fingerboard of a guitar. By adjusting the bow of the rod, one can adjust the neck to assure it stays straight under the pressure of the strings. The truss rod allows the guitars neck to be compensated for changes in string tension and humidity, and guitars with truss rods were able to be adjusted so they always played consistently. . In 1931, Rickenbacker introduced the electric Hawaiian

[6] Dumoulin and Gauzente, *Guitar in the Digital Era*
[7] Martin, *Development of the Guitar*

style (or slide) guitar. It was called the Frying Pan, and the innovations that the instrument made were paramount to the evolution of other electrified guitars. In 1937, Gibson introduced their electric guitar, a jazz archtop with a pick-up to help amplify the instrument in loud band settings. This innovation transformed the guitar into an instrument that could be a solo instrument, as well as a rhythm instrument. The electric guitar presented a different tone structure and sound than the acoustic guitars due to its magnetic based pickups, which transferred vibration differently than the body of an acoustic instrument would. As Paté et al said, "The solid body electric guitar is the first musical instrument in history to have been originally designed for a mass-production: even if numerous craftsmen have gained a solid reputation among the guitar player community, the solid body electric guitar market has been dominated by the industry for over sixty years."[8] Solid body electric guitars have their rich industrial design potential and history because of how their existence as commercial products shaped their design. The first commercial solid body electric guitar was produced by Leo Fender at Fender Guitars. Initially called the Broadcaster, the Telecaster debuted in 1950 (see Figure 1). Earlier electric guitars had been acoustic instruments with pickups fitted onto them but the solid body electric guitar was designed for use with an amplifier rather than on its own. Without the crucial role of the amplifier, this project would have not been possible. The solid body electric guitar (referred as the electric guitar hereafter) utilized a body made from a slab of wood, with, in the case of the Telecaster, a neck that was bolted on. Some Telecaster prototypes were made from pine, although the production models did not feature the softwood. The electric guitar is the start of the guitar as a

[8] Paté et al., *Variability in industrial electric guitar making*

commercial product. “The solid body electric guitar is the first musical instrument in history to have been originally designed for a mass-production: even if numerous craftsmen have gained a solid reputation among the guitar player community, the solid body electric guitar market has been dominated by the industry for over sixty years.[9]” Gibson introduced the Les Paul model in 1952, which became their flagship model (see Figure 2). The Les Paul was endorsed, although not designed by the recording artist of the same name. The Les Paul, like some of Gibson’s acoustic guitars featured a carved top.[10] The guitar also featured a set or glue in neck as opposed to a bolt on neck. In 1954 Gibson debuted the Les Paul Special which like the Telecaster featured a slab, not carved body. The Special was priced between the higher end Les Paul Standard and the cheaper Les Paul Jr, the student model. In 1958 the shape of the Les Paul Special was changed to include another cutaway, for better access to the higher frets (see Figure 3).[11]The guitar built for this thesis is designed based on the 1958 Les Paul Special as well as the Fender Telecaster. These two guitar model families, with the addition of the Fender Stratocaster have become the three most iconic guitar designs, spawning numerous variations and imitation, as well as creating the initial design vernacular for other electric guitars to follow.[12]

[9] Paté et al., *Variability in industrial electric guitar making*
[10] Martin, *Development of the Guitar*
[11] *Gibson Guitars*
[12] Dumoulin and Gauzente, *Guitar in the Digital Era*

Chapter 3: Design Inspiration

The design of this guitar was inspired by the simplicity of lower-price models in the 1950's like the Les Paul Special and Jr., as well as the minimal design of Leo Fender's Telecaster. The Telecaster's body features no carving or shaping of the guitars thickness. The profile of the shape is cut and the edges are rounded but there is no binding. All of the controls are loaded on to the control plate and suspended over the control cavity. The neck is attached to the body with screws. The thesis guitar design particularly emphasizes these two features. The '58 Les Paul Special lends its profile to the design, as well as pickup choice and neck. The Les Paul Specials had slab bodies without binding or contouring as opposed to the Les Paul Standards. They also lacked the maple cap of the Standards, and featured a solid mahogany body.[13] What is appealing aesthetically about the Telecaster and the Les Paul Special is the way they abstract the shape of historical guitars and distill them to their most essential form language. There is no elevation change on the body, just a flat outline with the necessary hardware. The bodies help balance the guitar visually and when worn standing up, and the curves help the guitars rest easily for playing while sitting down. The radius around the top prevents the guitar from digging into the forearm of the players, like a guitar with binding would. Bindings are brought to the electric guitar from the acoustic guitar. In acoustics and hollow body guitars, electric binding help seal the top and prevent moisture from getting into the wood. On a solid body the choice is

[13] *Gibson Guitars*

purely aesthetic. Because of the time that adding binding to a guitar takes, some players see it as valuable, while some prefer the feel of a guitar top with a chamfer or radius.

The Fender Telecaster provided the inspiration for the control plate. The design choice of the Telecaster control plate was closely tied with the usability if the instrument. The drop in plate allows for convenient access to the electronics for modification and repair, since the plate can be un-screwed and pulled off of the guitar. The Telecaster control plate features the pick-up selector closest to the picking area, followed by the volume and tone controls. The plate for this guitar is in this order so that the most used control, the volume knob is closest to the picking area, followed by the selector, the tone knob, and the output jack. This allows for quick volume and pickup changes, while leaving the less used tone control farther away from the hands. This layout could modulate depending on the player, but for guitar models like the Stratocaster or the Les Paul Jr., the volume knob is usually placed near the picking area.

In addition to the control plate, the neck construction of the thesis guitar also deviated from the Les Paul Special model. The bolt on neck was more beneficial to this project. The advantage over bolt-on neck as opposed to the glued in necks it that they can easily be replaced, in case of repair or the desire to switch to a different neck. The other advantage was that bolt on necks are more readily available for guitar builds than glue in necks, because of their modular nature

Chapter 4: Wood Choice

For this guitar and thesis, I am specifically focusing on alternative wood choices for mahogany in Gibson guitars. The primary reason to use Gibson as the example of a new Douglas fir sustainable guitar is because of the predominant use of mahogany in their existing line of guitars. Fender guitars use alder and ash for their American instruments, which can be sourced from the United States. The mahogany in Gibson guitars is imported from Central America.[14] Thus, Gibson provides a clear example of which to make a meaningful comparison. The other reason to examine Gibson is the design of the guitar is based off of the Gibson Les Paul Special model. However, the prototype could be taken into production with any company that makes solid body guitars, with similar outcomes. Douglas fir has different properties and is different to work with than mahogany or alder from a craftsmanship perspective, and it is important to consider that this product is not intended to be a significant replacement of Gibson's mahogany based guitar production. This project is intended to both explore environmental and political issues around wood choice, and to present an option that would be able to offset a portion of those guitars with ones made of Douglas fir, or to provide consumers with the option of Douglas fir guitars.

Pseudotsuga menziesii, or Douglas fir, is a conifer that grows from British Columbia down the West Coast into Mexico, extending west towards Alberta and down through New Mexico into Western Texas. The Douglas fir that grows to the west of the Cascades in Oregon is some of the higher quality Douglas fir in its range, along with

[14] Martinez-Reyes, *Mahogany intertwined*

British Columbia and Washington. It can grow to over 200 feet high, with branches starting over one third of the way up, leaving over a third of the wood clear of knots when cut. Douglas firs can range from a light yellow to pinkish red. Douglas fir has a high strength to weight ratio, which allows it to be heavily used in construction.[15] Douglas fir comprised of 77 percent of Oregon's timber harvest in 2008. All of the Douglas fir harvest accounted for 2548.7 million board feet out of the total 3616.8 million board feet from the 2008 timber harvest. Of the Douglas fir, 2056.6 million of the board feet was used for saw logs. All hardwood harvest in the same year only amounted for a total of 129.7 million board feet, or less than ten percent of Douglas fir harvest. In Oregon, the volume of timber available for Douglas fir is much greater than hardwoods.[16] It is worth noting that not every piece of Douglas fir is ideal for guitar making. Clear grained pieces with close earlywood and latewood[17], free of knots and of proper size are what required for standard manufacturing and quality guitars in general. Because of where the branches of the Douglas grow on the bottom third of the tree is suitable for knot free stock.[18]

It is possible to make Douglas fir guitars out of wood that does not meet those specifications anyway. Models like The Fender 2011 Telecaster Closet Classic Pro exemplify the use of imperfect and found woods incorporated into the aesthetic of the guitar (see Figure 4). It is made from reclaimed 100-year-old Pine, and comes with a four-piece body made from boards reclaimed form a building. Other companies use

[15] Schoonover, *American Woods*
[16] Gale, *Industry and Timber Harvest, 2008*
[17] Earlywood is defined as the softer part of the grain, from when the tree was growing quickly, while latewood is the harder part of the grain, from when the tree was growing more slowly.
[18] Schoonover, *American Woods*

reclaimed or wood with knots and defects, wood that is not used in large scale commercial guitar runs. While it is another approach to the question of alternative wood choices, and was part of the original conception of this thesis, the guitar portion of this thesis is built with virgin material. The reason to use virgin clear grain fir, as opposed as using reclaimed lumber is foremost for the ability to manufacture the guitar using standard production methods. By using virgin material there is a consistent supply of materials for bodies, like in other standard guitar production runs. Using reclaimed material has its own benefits and challenges, and ultimately is a larger departure from those production techniques. This is because of the extra labor required to find reclaimed lumber of desirable size, and in checking the integrity of the individual wood pieces, some of which that have already had a history of use. If guitar companies were to proceed with that approach, Douglas fir's prevalent use as a building material means that there is often wood to be reclaimed from buildings. Larger, nonresidential buildings hold the greatest potential as a source due to the size and volume of the lumber used, versus single residence homes. Due to the aging infrastructure in the US, some of these building are being torn down, presenting the option of a new lumber source.[19] The process of guitar building could be applied to sufficient quality of lumber as mentioned before, with no modification required once the wood is sized, cut and glued. The drawback is that it is hard to scale to larger production runs that require a consistent supply that can be replenished.

The idea and potential market benefits of a sustainable guitar production are not unexplored in the guitar industry. Several companies already design and market with

[19] Falk et al., *Engineering Properties of Douglas-fir*

material sustainability, defying conventions in materials and construction techniques. Major brands like Gibson have sustainability focuses, but for purposes of this thesis I have chosen to examine two smaller guitar companies who are using unique guitar materials. One such brand is a guitar company founded by 23-year-old Nick Pourfard. His company, Prisma Guitars, makes guitars exclusively out of broken or old skateboard decks. Prisma Guitars takes the old decks and laminates them together to form the wood that is used to make the guitars (see figure 5). The already dyed skate board decks give the guitars a whirl of different colors. Prisma Guitars makes the guitar bodies, necks and the control knobs from raw materials in-house. By only using the laminated maple reclaimed from skateboard decks, the impact of a Prisma guitar is environmentally less than using virgin materials. The materials recycled by Prisma Guitars are not conventional, but is the material that provide the guitars with their unique look and appeal. Additionally, Prisma guitars keeps all of those skateboard decks out of the landfill and forms them into a product that has a much longer product life, an electric guitar[20].

Flaxwood guitars utilize an even more experimental material, composed of European spruce bound with a polymer (see figure 6). This material can be injection molded instead of carved and is fully recyclable, according to their website. The advantage of having a formable material is that creating the body is no longer a destructive process, a process that requires the removal of material. Traditionally, guitar making involves taking away wood to get the final body shape but Flaxwood Guitars eliminate that waste. Every inch of wood that they bring in is theoretically used, which

[20] *Prisma Guitars*

makes their manufacturing process that much less impactful. The builders at Flaxwood can melt down a guitar body with defects and reuse the material immediately to produce a new instrument. Lastly they only use celluloid inlays, not mother-of-pearl or other material that can be harmful to marine ecosystems.[21] In regards to those companies, the purpose of this guitar is different, in that it is not seeking to rethinking the process of how guitars are made, but to reconsider the material that they are made from.

One consideration that is important in the choice of Douglas fir and the specific piece for this guitar was how it would function as a guitar body. It needed to have regular grain as not to warp, and to make sure the CNC[22] process left clean cuts. Any structural compromises had to be able to be easily and cleanly repaired. As previously stated, Gibson guitars use mahogany for most of their models, including the Les Paul Special Double Cutaway. As a coniferous tree, Douglas fir is a classified as a softwood. Mahogany is a tropical hardwood native to the Americas. While the names may confuse consumers who do not want a "softwood" guitar, the specific gravities of Honduran mahogany and Coastal Douglas fir are comparable, being 0.54 and 0.53 respectively, meaning the density of both woods as a whole is similar. Furthermore, due to the natural variance in wood, particularly dense and close grain Douglas fir stock can be selected as to avoid the problems associated with softer pieces, such as denting and tear-outs.

Mahogany is a wood that has a cost greater than its price. Big Leaf mahogany, the kind variety used by Gibson for their guitars, is listed as endangered, and has

[21] *Flaxwood Guitars*

[22] Computer numerical controlled router.

restrictions from the Convention on International Trade in Endangered Species of Wild Fauna and Flora(CITES).[23] It grows from Southern Mexico through South America. In Chetum, Mexico, mahogany guitar blanks go for $5-$7, to be turned into Gibson USA guitars like the Les Paul Special.[24] Honduran or Big Leaf mahogany is part of a family of trees all listed under the same CITES studies. They are all slow-growing, taking 200 years to reach 6 feet in diameter and due to their growth rate are not viable as a commercial wood source.

> Extraction of old-growth stocks eliminates mahogany's ability to fulfill its ecological role in the forest as a canopy species, serving as habitat and a food source for a diverse array of animals and insects. Also, because logging roads opened to exploit mahogany in previously inaccessible regions provide access to less valuable commercial timber species, the removal of mahogany leads to extensive forest degradation.[25]

This declining supply is something that Gibson has already had to cope with, and could pose future problems to their guitar lines. With 700 guitars made per day that utilize mahogany, offsetting some of those guitars could prolong their sourcing decline. Even with the CITES restrictions, illegal logging of mahogany is a dire problem, especially in Peru and other mahogany supplying countries. The restrictions placed on Big Leaf mahogany do not apply in places where it is not native, and has led Gibson to source some of that mahogany from these alternative sources including plantations in Fiji.[26] In Fiji, during 2006, a military coup overthrew the government under the leadership of Commodore Voreque Bainimarama. The newly elected government supported an export group called Sustainable Mahogany Industry with which Gibson is now involved.

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[23] *Current CITES Listings of Tree Species*
[24] Martinez-Reyes, *Mahogany intertwined*
[25] Youatt and Cmar, *Fight for Red Gold*
[26] Martinez-Reyes, *Mahogany intertwined*

Commodore Voreque Bainimarama received a Gibson Les Paul made from Fijian mahogany as a gift from the company. Gibson has stated they are committed to fair and legal wood sourcing, but their implicit support of a coup leader suggests the need to further address their ethical as well as environmental policies.[27] The problematic relation between Gibson and its wood sources are not isolated to mahogany. In 2009, federal officials raided the Gibson factory, seizing what Gibson estimates at $500,000 dollars of Brazilian Rosewood, wood that is used for fingerboards. The wood was seized under the accusations of illegal harvesting under the Lacey Act.[28] The updating of the Lacey Act to include raw wood was partly a reaction to illegal Mahogany trade. Gibson was raided again in 2011, this time under accusation of illegally procured Madagascar Ebony.[29] All of these raids and wood sources illustrate Gibson's growing problem with their wood sources, and point to why a local, sustainable alternative like Douglas fir could be valuable to the company.

On the broadest level, global forests have been shrinking since the growth of industrialization in the nineteenth century, but currently, the future of forests in the US runs counter to the reality of this trend. In the Western United States the amount of forestland is the highest it has been since 1920. Douglas fir's long term sustainability is much higher than the slow-growing mahogany both generally and in regard to guitar manufacturing. First, Douglas fir's journey from Oregon to Tennessee, where the Gibson USA Factory resides, is much shorter than the journey from Central American or Fiji to Tennessee. Some of the imported mahogany that Gibson uses is exported to

[27] Martinez-Reyes, *Mahogany intertwined*
[28] Blenford, *Are Gibson guitars killing the rainforest?*
[29] Havighurst, *Why Gibson Guitar Was Raided by the Justice Department*

Oregon or Washington first, so the supply chain already passes through where the wood for the Fir guitars would be sourced.[30] Transport alone could be a case for the sustainability of Fir. For mahogany, over harvesting has caused the species to be placed on the endangered species list, as mentioned before, whereas Douglas fir harvests, specifically in Oregon has a more secure future. While mahogany is not viable for extensive commercial harvest, Douglas fir is the source of millions of board feet of lumber a year.[31] In 2003, the growth to harvest ratio for Douglas fir was 1.7:1.[32] This net growth was even higher for other trees in Oregon. Harvest levels have decreased since the early 2000's, post-recession, and the current growth to harvest level for Douglas fir could be even higher.

Sustainability does reach farther than mere growth to harvest ratios. Mahogany is a tropical hardwood. When harvesting mahogany, the effect is greater than just the tree. Loss of tropical forests directly result in loss of habitat for other species in the ecosystems. Douglas fir has different role in its habitat, and different protections than mahogany. The management of Douglas fir forests has undergone many changes since the early twentieth century. Changes in forest management, economies of logging, and protection of species within those forests, have affected Douglas fir as a timber source. Douglas fir is a tree species that still has large amounts of old growth in the US. As with mahogany, the protection of Douglas fir as a whole, and specifically as old growth is necessary for the health of those respective species. Old growth forests are important to biodiversity, and successful old growth forest require more than a lack of harvesting to

[30] Martinez-Reyes, *Mahogany intertwined*
[31] Gale et al., *Industry and Timber Harvest, 2008*
[32] Brandt et al., *Industry and Timber Harvest, 2003*

develop.[33] Human involvement has shaped forests in a way that letting parts of them grow unchecked also poses problems. Biodiversity is an important metric in old growth forests and monocultures of Douglas fir do not reflect natural old growth.[34] In Oregon most of the old growth forest is on Federal lands. In 2008, 82 percent of the timber harvest was from private lands. From the perspective of sustainability, the areas Douglas fir is harvested from are not the same place that also sustains old growth forest, meaning that harvest poses less of a threat to the health of old growth forests than if it was logged from the same lands. Part of the shift towards harvest on private lands was spurred by protection of habitat for the northern spotted owl, the marbled murrelet, and other species staring in 1990. The concepts on what forest conservation means have evolved in this timeframe too. Early forest conservation was focused on timber as a cash crop, with the trees alone being the sole focus of the conservation.[35] Both the government and industry helped to shape early timber policy. Fires were seen as a threat to property and not part of a healthy forest, as timber reigned as a source of income for much of the state. In contrast, current conservation policies tend to reflect a more holistic approach, as illustrated by the change in timber use with the listing of threatened species. One cannot protect endangered animals without protecting their ecosystem.[36]

In addition to the benefits in sustainability with Douglas fir as a guitar source, there are economic problems that could be addressed by the use of Douglas fir in

[33] Hansen, *Alternative Silvicultural Regimes*
[34] Montgomery and Latta and Adams, *Cost of Achieving Old-Growth Forest Structure*
[35] Robbins, *Good Fight*
[36] Franklin et al., *Disturbances and Structural Development*

guitars. First, the timber sales in Oregon have declined since the recession following the Housing Crisis in the mid-2000s. In 2008 the Oregon Timber industry employed 51,000 workers, down from 65,700 in 2003. Timber and paper sales value fell from roughly 9 billion in 2005 to 5 billion in 2010 in Oregon. The harvest in 2008 was the lowest since the Great Depression, with the recent decline fueled by the collapse of the housing market. The industry used only half of its capacity for production in 2010, and as utilization of capacity stays below peak levels, mills and processing center are forced to shut down. The high point of use of capacity in comparison was 80 percent.[37] One run of Douglas fir guitars will not solely return jobs or account for an additional 3 billion dollars of sales value, but there is the capacity for Oregon to be able to supply large amounts of timber. Sourcing wood from Oregon also eases the restrictions and possibly some of the legal problems that Gibson faces. It is easier to insure that the wood is harvested legally and the workers harvesting are paid a fair wage. Foreign certifications and restrictions would be absent from these Douglas fir guitars. Offsetting tropical and endangered hardwood with the non-threatened Douglas fir could reduce the wood that could be seized in raids of the Gibson factory, such as the raid in 2011. Even if the wood that is confiscated is legally acquired, it costs Gibson to have it unable for use, and it costs them to pay the associated fines. When some of the confiscated rosewood fingerboard seized in a raid were returned to Gibson, Gibson made a special line of guitars and named them the Government series in honor of the raid, a fitting tribute to the complicated legal relationship that Gibson has with their lumber sources and the US government.

[37] Gale et al., *Industry and Timber Harvest, 2008*

Chapter 5: The Sound of the Electric Guitar

Considering the complicated nature of using tropical hardwoods, Gibson still has their reasons for continuing to use it. The reason for using mahogany in guitars are more than aesthetic considerations. Mahogany is a tonewood, and is used because of the sound it imparts on the guitar.[38] This consideration of the sound is especially important in the case in acoustic guitars, where the guitar itself acoustically amplifies the string vibrations. The same logic is applied in the theory of tonewood in electric guitar. Thus, the case can be made that a Gibson electric made out of Fir and not mahogany would not sound like a Gibson. However due to the nature of the electric guitar as an instrument, the difference in wood does not contribute to the overall sound of the instrument in the same degree that it would in an acoustic guitar. Part of this thesis is to prove that the use of Douglas fir would not alter the sound in a way that would depart at great lengths from a traditional mahogany instrument.

The way electric guitar functions as an instrument departs from the way an acoustic guitar functions as an instrument. According to Arthur Paté , Jean-Loïc Le Carrou, and Benoît Fabre, "The sound of the solid body electric guitar comes from the string velocity signal which is captured by the electromagnetic pickup, and sent through an electro-acoustical chain basically made of signal processing devices (effect pedals), an amplifier, and a loudspeaker for the sound radiation."[39]The object of the electric guitar is merely part of the instrument as a whole. The electronics and interaction with

[38] Dumoulin and Gauzente, *Guitar in the Digital Era*
[39] Paté et al., *Variability in industrial electric guitar making*

signal processors and amp create the sound of the electric guitar. Considering the place of the guitar body in the entire instrument of the electric guitar, the role of tonewood is not as vital as in and acoustic guitar. Helmut Fleischer contests that "… the electric guitar does not radiate the sound itself and consequently there is no intrinsic need for energy transfer from the strings to the instrument body.[40]" The sound of the guitar comes primarily through the inductance of the pick-ups, and the player themselves. Guitar pick-ups are composed of copper wire wrapped multiple times around magnets. These pick-ups generate a magnetic field that is disturbed when the player moves the nickel or streel strings. The wood in the guitar does interact with the string vibration, but not in the same ways as an acoustic guitar. Unlike and acoustic, there is very little vibrational transference from the strings to a guitar bridge. Indeed, there is more transference of vibrational energy in the neck of the guitar than in the bridge.[41] A. Paté et al. 's research seems to strengthen the idea of the body being minimal in the vibration of the guitar. They write that "Heavier (resp. lighter) guitars could be expected to have lower (resp. higher) modal frequencies. Nonetheless no such link between the mass of an individual instrument and its modal frequencies was observed on the two guitar sets."[42] In their examination, a factor like density that would alter the sound of an acoustic instrument, had no link to the sound of an electric guitar.

[40] Fleischer, *Mechanical Vibrations of Electric Guitars*
[41] Indib.
[42] Paté et al., *Variability in industrial electric guitar making*

Chapter 6: Building the Guitar

The purpose of building the guitar is twofold. The first reason is to prove the viability of a Douglas fir electric guitar. The second purpose is to utilized learned skills like wood working, metal working, digital modeling, prototyping, electronics, and painting and finishing in a comprehensive and challenging project. Since the purpose is to prove the viability of Douglas fir as a tonewood for electric guitars in general, this thesis utilizes a Fir guitar as proof of this[43]. Guitar necks could also be made from Fir, but the challenges and processes are equally applicable to the body as well as the neck. Many guitars utilize a different wood in the neck, and there is a greater variety of woods found in guitar bodies than in necks. Furthermore, guitar necks are a more complicated build than guitar bodies, requiring more time and specialized tools to complete. For this guitar, the neck came from an Epiphone Les Paul Special. The scale length is 24 ¾" and the neck is maple with a rosewood fretboard. It came with a thick black poly urethane finish that was stripped with a heat gun and a scraper. The remained finish was sanded off so it could be finished with the rest of the guitar.

The modern electric guitar is built with a combination of automated and hand work. Gibson guitars start with the blanks, which are glued then rough sized with band saw by hand. The sized blanks are then routed in batches with a CNC router. This guitar utilized the same process of CNC routing and then handwork to finish. The CNC routing allows for precise shaping of the body, which is essential to having and instrument that plays correctly. Hand finishing is required for the rest of the build

[43] See Appendix B for process and guitar photos. Used for reference in the remainder of this section and throughout.

because of how the components have to interact in such a precise way. The guitar body was modeled in Autodesk's Fusion 360, and the CAM file was generated first in the same program, with the final CAM being made in Rhino.

There are three ways to attach the guitar neck to the body. The first method, which is widely prevalent on budget guitars and Fender guitars as a whole, is the bolt-on method. This is where the neck is attached to the body through four screws that go through a metal plate, the body and then into the neck. The plate distributes the force of the screws over its surface area and assures a tight coupling between the respective parts. The second method is to glue or "set" the neck into the body. This guitar uses the first method of neck joinery but is based off a model that uses the second method. In my CAD model the original Gibson design had to be modified so it would be compatible with the bolt-on neck joint. This meant modifying the heel so that it would accommodate the neck and the correct screw spacing. The pocket for the neck pickup was situated against the neck joint. In the original guitar the tenon goes under the neck pick-up. Since this design utilized screws and not a glued in tenon, the neck pick-up pocket was moved away from the neck to ensure the integrity of the joint. Even the original set neck models had trouble, and on later models the neck pocket was shifted into the guitar to provide better neck stability. The other major change from the commercial model is the control layout. The controls on a commercial Gibson Les Paul Special are back routed, meaning that the body blank is turned over during the CNC process and the control cavity is routed from the back. This guitar features a top routed cavity and a control plate. This allowed for the guitar to be routed in one pass, but also allows for quick access to the controls for repair and modification. The control plate is

also an aesthetic reference to Leo Fender and the Fender telecaster. The early models of the Telecaster were made from another coniferous wood, pine, and the plate is a reference to that material and design history.

Part of the design process is knowledge of how the process of crafting shapes the design. In designing anything for manufacturing part tolerances are an important consideration. The guitar was designed to be accurate within one thousandth of a millimeter. Typically, one would leave tolerance so that all the parts fit but for a guitar the nature of the preciseness of the instrument no tolerances were left in the design. Due to the variable nature of wood and the CNC process leaving no tolerances meant that the guitars could be hand finished so all the parts to have a press fit.

The piece of fir that makes of the body is a piece of straight grain nearly quarter sawn (probably rift sawn) old growth that was at least 50 years old. With the guitar body being approximately 14 inches wide this guitar used one 8 in wide 8/4 stock piece that was cut in half and glued to get the required width. There was a crack that went through the whole board so the final stock split in two places. Neither of the places were structurally important, and the break was clean, which allowed for the repair to be clean, and it did not compromise the instrument. The only problem that arose was the break on the right side went through the wall of the control cavity, which slightly altered the width in the actual guitar. The design is meant to utilize Fender Telecaster sized control plate with custom holes for a Gibson style switch and an output jack. In the production model the standard Telecaster sized plate can be used but for this guitar a custom plate out of aluminum was made so it would fit properly to the cavity. The first

plate that was made was too small. A plastic version was made and once the proper fit was achieved it was used as a template to make the final aluminum version.

An important consideration for guitar makers using Douglas fir is the growth rings. Due the distinct difference between the earlywood and latewood, the grain tear-out can be a problem. On the sides of the guitar where the grain was the shortest, there were several blow-outs from the CNC router and the manual router. Making a production run of Douglas fir would require makes to use sharp tools, and to proceed with more caution than they may have to with other types of wood. Router feed rate and other factors can also help to prevent problems like grain tear-out

After the remaining outline was routed, the edges were then cut with a .25 inch radius router bit to round the edges. Chisels and a rasp were used to shape the undercut in the neck pocket. The neck of the guitar interfaces with the body at a 3-degree slope and the CNC machine that cut the body was a 3 axis machine, so the undercut had to be done by hand. The pick-up cavities were slightly too small on the actual guitar body so they were made bigger with a chisel and sandpaper so that the pick-ups would fit. The parts that could not be routed with the .25 inch round-over bit were shaped using a rasp. The finish for the instrument is a water based polyurethane. The whole body was sanded and cleaned for finishing. The neck was finished with a water based Poly-acrylic transparent finish. Before the finish was applied, the neck was painted in off-white with acrylic based spray paint. The finish was left to dry and then sanded before all the components were placed. Once the finish was sanded the final soldering was completed. After stringing the guitar, the bridge height and neck relief were adjusted to ensure playability of the instrument.

Conclusion

Douglas fir does make a suitable wood for guitar building. It requires sharp tools and special attention but yields quality instruments. Its grain and natural color variance also lends itself to transparent finishes as well as opaque ones. In building the guitar, there are several things that could be done differently in newer builds. Making a neck from Douglas fir would be another useful exploration of the material, and cutting the neck pocket manually with a router would lead to a better neck fit and a cleaner neck joint. When plugged in the guitar sounds comparable to a new Gibson Les Paul Jr, and the biggest sound differences can likely be attributed to the pickups and electronics more so than the wood. The guitar tone has body and chime, and the instrument is lively even unplugged. The guitar feels similar other guitars in regards to weight, and the way the grain pattern interacts with the shape of the instrument is visually striking. To further test the findings in this thesis, guitars from both Douglas fir and mahogany could be constructed from the same pattern as to provide a more thorough comparison. Besides the material challenges discussed in this thesis, another challenge in making a commercial run of Douglas fir guitars, would be how to market a Douglas fir guitar to a company's customer base. Such marketing plan would have to overcome assumptions about the durability of a softwood guitar, and how Douglas fir behaves as a tone wood. With the world's supply of tropical hardwoods dwindling, sustainable wood choices might become more and more economically viable to companies, regardless of the differences or advantages of current wood choices.

Figures

Figure 1: Fender Telecaster, 1950. Image Source <http://farm4.static.flickr.com/3584/3459899455_27f98aee6d_o.jpg>

Figure 2: Gibson Les Paul, 1952. Image source <http://cdn.mos.musicradar.com/images/artist-news/les-paul/lpgoldtop-body-630-80.jpg>

Figure 3: 1959 Les Paul Special. Image Source <https://upload.wikimedia.org/wikipedia/commons/c/c8/1960_Les_Paul_Special_Doublecut.jpg>

Figure 4: Fender Telecaster Closet Classic. Image Source < http://medias.audiofanzine.com/images/normal/fender-custom-shop-63-telecaster-closet-classic-490314.jpg>

Figure 5: Prisma Guitars. Image Source <prismaguitars.com>

Figure 6: Flaxwood Guitar. Image Source < http://www.flaxwood.com/models/290-h+290-t+liekki/>

Appendix A: Process Photos

Douglas Fir glued and on the CNC table.

Guitar blank after the CNC cut.

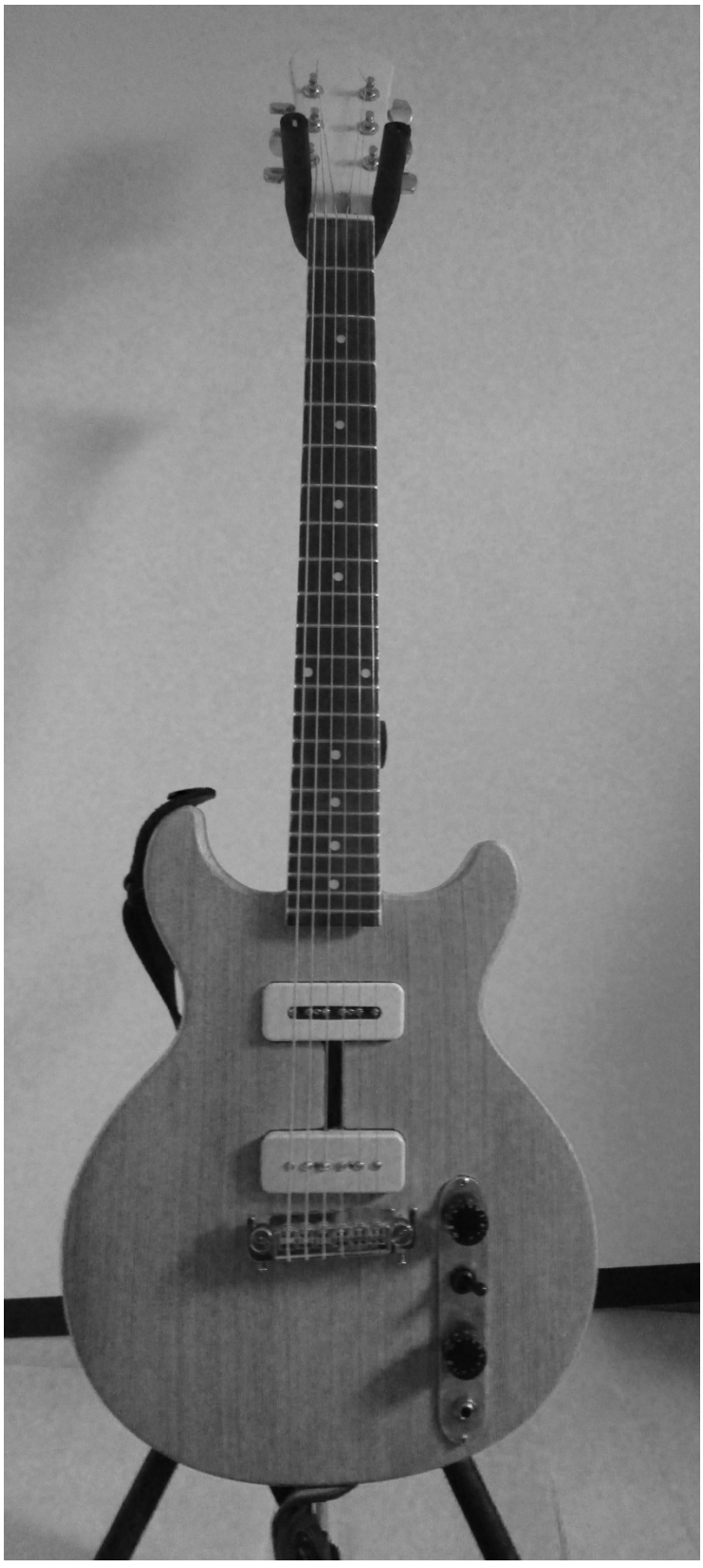
Post CNC Shaping.

Testing the Neck Fit.

Painting Neck

Finishing the Body

Appendix B: Final Guitar



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