TN Department of Education | College, Career and Technical Education

Program of Study Justifications for Advanced Manufacturing

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TN Department of Education | College, Career and Technical Education

Electromechanical Technology

2017-18 Program of Study	Level 1	Level 2	Level 3	Level 4
Electromechanical Technology	Principles of Manufacturing (5922)	Introduction to Electromechanical (6091)	Advanced Electromechanical Technology (6090) -or- **Dual Enrollment** Electromechanical Technology (4061)	Manufacturing Practicum (5926) -or- **Dual Enrollment** Electromechanical Technology (4061)
	Industry Certification: Machining Level I - Measurement, Materials, and Safety Certification (NIMS			

Description

The *Electromechanical Technology* program of study is designed to provide students with the knowledge and skills to effectively perform basic industrial maintenance procedures in an advanced manufacturing facility. This program of study is designed for students that are interested in becoming: a general maintenance and repair worker, industrial machinery mechanic, master mechanic, electromechanical technician, mechanical engineer, or an electromechanical engineer. Course content focuses on the electromechanical domains, including: fundamental safety practices in electromechanical technology, shielded metal arc welding (SMAW), basic metal inert gas (MIG) welding, electrical systems, AC and DC motors, calibrating instruments, drive systems, pipe fabrication, hydraulic systems, pumps, digital electronics, programmable logic controllers (PLC), and troubleshooting procedures. Upon completion of this POS, proficient students will be prepared to pursue postsecondary electromechanical technology programs and entry-level industrial maintenance technology careers in the advanced manufacturing industry.

Job Outlook

Back in 2011, Governor Bill Haslam announced six target clusters for which Tennessee had a competitive advantage and would focus its recruitment efforts to bring more businesses to the state.[1] One of those target clusters was Advanced Manufacturing and Energy Technologies, and after several consecutive years of strong job gains, the demand for skilled workers shows no sign of slowing. Among these careers was Industrial Machinery Mechanics.[2] Industrial Mechanics fall under the manufacturing subcategory of Production.

Electromechanical Technology is the study of the combination of knowledge of mechanical technology systems with the knowledge of electronic circuits. Technologists will install, repair, and troubleshoot electronic and computer-controlled mechanical systems. Examples include working on robotic assembly machines, mobile robots and manipulator arms that operate on assembly lines.[3] In order for them to function properly, however, successful professionals in this field must be able to problem solve and troubleshoot by applying mathematics, design, and systems thinking, while also documenting highly technical processes in a manner that can be replicated by others.[4]

Compared to the national rate of 5.2 percent, job creation in Tennessee is soaring in manufacturing fields, accounting for $30.2 billion in manufactured goods exported every year and a 9% overall increase over the last four years.[5]

In 2015, Tennessee ranked first in the nation in automotive manufacturing strength.[6] With its attractive business climate and strategic location, Tennessee is home to a strong base of manufacturers representing many diverse industries, led by the state's automotive sector, which in recent years has converted into a regional and national powerhouse.[7] In industries such as these, employers like Alcoa, Eastman Chemical, and Bridgestone are in need of skilled technicians and engineers who can design, maintain, and operate complex production systems.

Moreover, the Tennessee Department of Labor and Workforce Development listed four manufacturing jobs on the list of Hot Careers in 2022. Among these careers were Machinists and

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[1] TN.gov, Newsroom & Media Center. Retrieved from: http://www.tn.gov/news/category/governor-haslam/P720
[2] Tennessee Department of Labor and Workforce Development. (2014). *Tennessee's Hot Careers to 2020,* on the Internet at https://www.tn.gov/assets/entities/labor/attachments/statewide_2020outlooks.pdf (visited May 2, 2017).
[3] Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook*. (2017) Retrieved from: http://www.bls.gov/ooh/architecture-and-engineering/electro-mechanical-technicians.htm#tab-2 (visited May 2, 2017).
[4] O*Net OnLine (2017). http://www.onetonline.org/link/summary/17-3024.00 (visited May2, 2017).
[5] Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tnecd.com/industries/advanced-manufacturing/. (visited May 2,2017).
[6] Tennessee Department of Economic & Community Development (2015). Retrieved from: http://www.tn.gov/ecd/news/16577 (visited May 2, 2017).
[7] Muro, M., Andes, S., Fikri, K., Ross, M., Lee, J., Ruiz, N., & Marchio, N. (2013). Drive! Moving Tennessee's Automotive Sector up the Value Chain. Brookings Institution. Retrieved from: http://www.brookings.edu/research/reports/2013/10/04-tennessee-automotive. (visited May 2, 2017).

Industrial Machinery Mechanics.[8] Maintenance and Repair Workers (general) and Industrial Machinery Mechanics fall under the manufacturing subcategory of Installation, Maintenance, and Repair. According to the National Bureau of Labor Statistics, Installation, Maintenance, and Repair occupations are expected to increase at a rate of 6.4 percent through the year 2024.[9]

Occupations in this program of study have bright outlooks nationally and statewide. **Figure 1 and Figure 2** outline the related career opportunities in Tennessee.

Figure 1. Tennessee long term employment projections for electromechanical-related occupations in Tennessee for the 2014-2024 projection period.[10][11]

Occupation	2014 Estimated Employment	2024 Projected Employment	Total 2014-2024 Employment Change	Total Percent Change	Median Salary
Electronics Engineering Technician	2,460	2,620	70	7.00%	$54,600
Electro-Mechanical Technician	270	310	10	17.00%	$50,920
Industrial Engineering Technician	1,610	1,680	40	5.00%	$43,530
Mechanical Engineering Technician	940	1,090	40	16.00%	$50,640

[8] Tennessee Department of Labor and Workforce Development. (2014). Tennessee's Hot Careers to 2022 on the Internet at http://www.tn.gov/assets/entities/labor/attachments/statewide_2020outlooks.pdf (visited May 2, 2017).
[9] Bureau of Labor Statistics, U.S. Department of Labor, *National Occupational Data*, *April 2017*, Table 1.1. (visited May 2, 2017)
[10] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj
[11] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wage Rates (OES)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Figure 2. State and national trends for electromechanical-related occupations with positive projections 2014-24[12][13][14][15]

United States	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Electronics Engineering Technician	139,400	136,600	-2%	3,410
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Electronics Engineering Technicians	2,460	2,620	+7%	70

United States	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Electro-Mechanical Technician	14,700	14,800	+1%	370
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Electro-Mechanical Technician	270	310	+17%	10

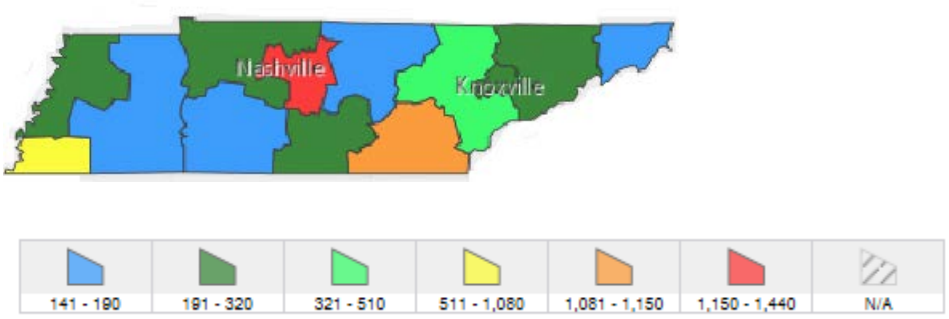
[12] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* http://www.onetonline.org/link/summary/17-3023.00
[13] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* https://www.onetonline.org/link/summary/17-3024.00
[14] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* https://www.onetonline.org/link/summary/17-3026.00
[15] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* https://www.onetonline.org/link/summary/17-3027.00

United States	Employment		Percent Change	Projected Annual Job Openings
	2014	2024		
Industrial Engineering Technician	66,500	63,500	-5%	1,630
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Industrial Engineering Technician	1,610	1,680	+5%	40

United States	Employment		Percent Change	Projected Annual Job Openings
	2014	2024		
Mechanical Engineering Technician	48,400	49,300	+2%	1,280
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Mechanical Engineering Technician	940	1,090	+16%	40

Job opportunities for industrial technicians are strongest in urban and surrounding areas in Tennessee. **Figure 3** shows that more industrial technician occupations in Tennessee are employed and needed in the Memphis, Nashville, and Chattanooga areas than in surrounding areas.

Figure 3. 2014 Estimated Employment[16]

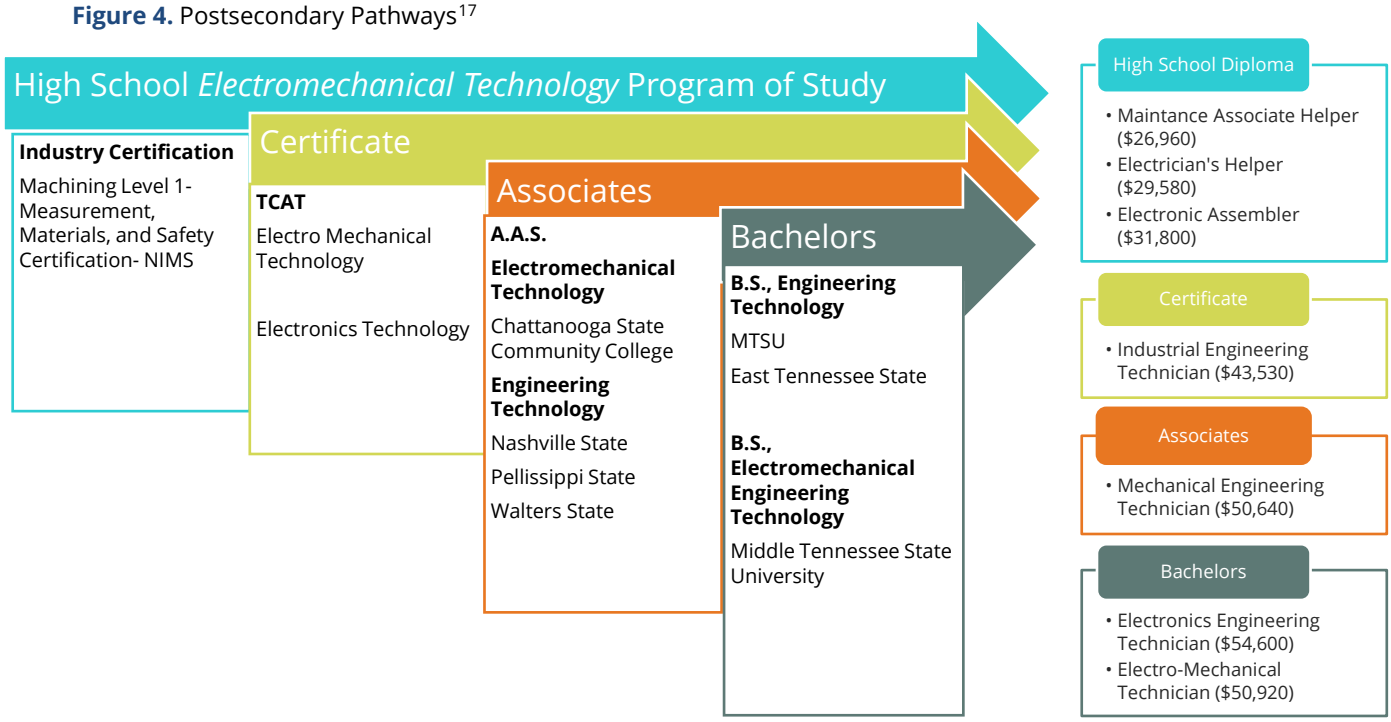


[16] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Postsecondary Pathways

What kinds of careers can students expect to pursue upon completion of the Electromechanical Technology POS in Tennessee? In many ways, Electromechanical represents a great example of the department's emphasis on creating pathways linked to local labor market needs, composed of stackable credentials at discrete levels of postsecondary. The figure below illustrates what one such pathway might look like for a student graduating from a Tennessee Electromechanical Technology program in high school.

Figure 4. Postsecondary Pathways[17]



Electromechanical technology pathways offer opportunities to funnel into careers at a variety of education levels. Pursuing just an additional year or two of study can yield great returns for students. Among Tennessee graduates from public two-year colleges who completed programs in Engineering Technology, median wages for their first year out of school was $50,640 which is higher than the state average for all Associate's holders. This, coupled with advanced training at the Bachelor's level, will open even more doors for students moving their employment prospects to the higher-wage engineering and production management occupations. As the following table demonstrates, compared to Associate's degree holders employed as electromechanical technicians, the payoff for earning a Bachelor's of Science in industrial or electrical engineering is complimented by the favorable ratio of available candidates to job openings. Due to this shift, the need to encourage more students to pursue early postsecondary opportunities at the high school level and

[17] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wages.* Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

ultimately complete certificate programs at the state's network of TCATs, in order to swiftly gain the credentials to compete for these openings is essential.[18]

Current Secondary Landscape

In the 2016-2017 school year, 19 schools in Tennessee responded to the demand to grow local talent in emerging manufacturing fields and instituted special programs of study in Electromechanical Technology. District data from SY 17-18 suggest that 23 schools will implement Electromechanical Technology at the beginning of the SY.[19] These figures demonstrate that there is an appetite among schools—and students—to explore machining technology at the high school level, which bodes well for the growing number of postsecondary institutions to offer machining-related programs.

Figure 5. Open Enrollment Analysis[20]

	Electromechanical Technology
2014-15	14
2015-16	25
2016-17	19
2017-18	23

Student Enrollment[21]

SY	Principles of Manufacturing	Introduction to Electromechanical	Advanced Electromechanical Technology	Manufacturing Practicum
2013-14	663	291	0	0
2014-15	793	147	51	175
2015-16	2910	229	177 *Includes DE	135

[18] Bureau of Labor Statistics, Employment Projections (2017). Retrieved from: http://www.bls.gov/emp/.
[19] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.
[20] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.
[21] Tennessee Department of Education. (2017). *Student Enrollment Data*. Retrieved from Author's calculation of student enrollment data.

Electromechanical Concentrators[22]

	Electromechanical Technology
2013-14	64
2014-15	22
2015-16	58

Recommendation

Through advisory council meetings and discussions with industry and postsecondary partners, it is the recommendation to add general standards to the Level 1: Principles of Manufacturing course that aligns workforce requirements addressing on overview of a manufacturing plant, and general manufacturing processes (forging, stamping, injection molds, and casting). It is also recommended that we add the Snap-on Precision Measurement Instruments Certification. These recommendations will add rigor and relevancy to the established courses already in place.

2018-19 Program of Study	Level 1	Level 2	Level 3	Level 4
Electromechanical Technology	Principles of Manufacturing (5922)	Introduction to Electromechanical (6091)	Advanced Electromechanical Technology (6090) -or- **Dual Enrollment** Electromechanical Technology (4061)	Manufacturing Practicum (5926) -or- **Dual Enrollment** Electromechanical Technology (4061)
	Industry Certification: Machining Level I - Measurement, Materials, and Safety Certification (NIMS)			
	Industry Certification: Snap-on Precision Measurement Instruments Certification			

[22] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.

References

Muro, M., Andes, S., Fikri, K., Ross, M., Lee, J., Ruiz, N., & Marchio, N. (2013). Drive! Moving Tennessee's Automotive Sector up the Value Chain. Brookings Institution. Retrieved from: http://www.brookings.edu/research/reports/2013/10/04-tennessee-automotive

O*Net OnLine (2017).http://www.onetonline.org/link/summary/17-3023.00

O*Net OnLine (2017). http://www.onetonline.org/link/summary/17-3024.00

O*Net OnLine (2017).http://www.onetonline.org/link/summary/17-3026.00

O*Net OnLine (2017). http://www.onetonline.org/link/summary/17-3027.00

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Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tn.gov/ecd/news/16577

Tennessee Department of Education. (2017). *Student Enrollment Data*. Retrieved from Author's calculation of student enrollment data.

Tennessee Department of Labor and Workforce Development. (2014). *Tennessee's Hot Careers to 2020.* Retrieved from https://www.tn.gov/assets/entities/labor/attachments/statewide_2020outlooks.pdf

Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wage Rates.* Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Tennessee Department of Labor and Workforce Development, Jobs4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

TN.gov, Newsroom & Media Center. Retrieved from http://www.tn.gov/news/category/governor-haslam/P720

United States Department of Labor, Bureau of Labor Statistics. (2017, May 2). *Occupational Outlook Handbook, 2016-17 Edition.* Retrieved from http://www.bls.gov/ooh/architecture-and-engineering/electro-mechanical-technicians.htm#tab-2

United States Department of Labor, Bureau of Labor Statistics. (2017, May 2). , National Occupational Data, April 2017, Table 1.1.

United States Department of Labor, Employment and Training Administration. (2017). *Career One Stop. Retrieved from* http://www.careeronestop.org/

Machining Technology

2017-18 Program of Study	Level 1	Level 2	Level 3	Level 4
Machining Technology	Principles of Manufacturing (5922)	Principles of Machining I (5929)	Principles of Machining II (5923) -or- **Dual Enrollment** Machining Technology (4060)	Manufacturing Practicum (5926) -or- **Dual Enrollment** Machining Technology (4060)
	Industry Certification: Machining Level I - Measurement, Materials, and Safety Certification (NIMS)	**Industry Certification:** Certified Production Technician (CPT) Safety Module	**Industry Certification:** Certified Production Technician (CPT) Quality Practices and Measurement Module	**Industry Certification:** Certified Production Technician (CPT) Manufacturing Processes and Production Module and Maintenance Awareness Module

Description

The *Machining Technology* program of study is designed for students interested in becoming a Computer-Controlled Machine Tool Operator, a CNC Machining Tool Programmer, or a Machinist. Course content focuses on safety practices concerning: machining technology; proper measurement and layout techniques; reading and interpreting specification drawings and blueprints; production design processes; quality control procedures; machine parts to specifications using both manual and computer-controlled machine tools; and measuring, examining, and testing completed products to check for defects and conformance to specifications. Upon completion of this POS, proficient students will be prepared to pursue industry certification at a technology college or more advanced coursework at a two-year or four-year postsecondary institution.

Job Outlook

Back in 2011, Governor Bill Haslam announced six target clusters for which Tennessee had a competitive advantage and would focus its recruitment efforts to bring more businesses to the state.[23] One of those target clusters was Advanced Manufacturing and Energy Technologies, and

[23] TN.gov, Newsroom & Media Center. Retrieved from: http://www.tn.gov/news/category/governor-haslam/P720

after several consecutive years of strong job gains, the demand for skilled workers shows no sign of slowing. Among these careers was Machinist.[24] Machinist fall under the manufacturing subcategory of Production. Compared to the national rate of 5.2 percent, job creation in Tennessee is soaring in manufacturing fields, accounting for $30.2 billion in manufactured goods exported every year and a 9% overall increase over the last four years.[25]

In 2015, Tennessee ranked first in the nation in automotive manufacturing strength.[26] With its attractive business climate and strategic location, Tennessee is home to a strong base of manufacturers representing many diverse industries, led by the state's automotive sector, which in recent years has converted into a regional and national powerhouse.[27] In industries such as these, employers like Alcoa, Eastman Chemical, and Bridgestone are in need of skilled technicians and engineers who can design, maintain, and operate complex production systems.

Machining Technology is the investigation of utilizing distinctive complex machining applications and procedures to help in more astute, more effective item plan and improvement. Engineers will set up and work a mixture of CNC controlled and mechanically-controlled machine apparatuses to deliver accurate metal parts, instruments, and devices. CNC machines control the cutting apparatus speed that intricately cut each section. The mechanic decides the cutting path, the velocity of the cut, and the feed rate by programming directions into the CNC machine. Mechanical engineers must have the capacity to utilize both manual and computer controlled apparatus in their occupations. [28]

Since the innovation of machining is evolving quickly, machinists must figure out how to work an extensive variety of machines. Some more up to date assembling procedures use lasers, water jets, electrical release machines (EDM), and energized wires. Albeit a portion of the computer controls are like those of other machine instruments, machinists must comprehend the one of a kind capacity of distinctive machines. As they create new sorts of machine devices, machinists must continuously learn new machining properties and systems.[29]

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[24] Tennessee Department of Labor and Workforce Development. (2017). *Tennessee's Hot Careers to 2020,* on the Internet at https://www.tn.gov/assets/entities/labor/attachments/statewide_2020outlooks.pdf (visited May 15, 2017)
[25] Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tnecd.com/industries/advanced-manufacturing/. (visited May 15, 2017)
[26] Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tn.gov/ecd/news/16577 (visited May 15, 2017)
[27] Muro, M., Andes, S., Fikri, K., Ross, M., Lee, J., Ruiz, N., & Marchio, N. (2013). Drive! Moving Tennessee's Automotive Sector up the Value Chain. Brookings Institution. Retrieved from: http://www.brookings.edu/research/reports/2013/10/04-tennessee-automotive. (visited May 17, 2017)
[28] Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2016-17 Edition*, Machinists and Tool and Die Makers, http://www.bls.gov/ooh/production/machinists-and-tool-and-die-makers.htm (visited May 15, 2017).
[29] Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2016-17 Edition*, Machinists and Tool and Die Makers, http://www.bls.gov/ooh/production/machinists-and-tool-and-die-makers.htm (visited May 15, 2017).

According to Jobs4TN.gov, the rate of employment is expected to grow in these occupations (See Figure 1 for details).[30] Although these occupations are all related to Machine Technology, they each have different roles and responsibilities. Machinists operate computer-controlled and mechanically-controlled machine tools to produce precision metal parts, instruments, and tools.[31] On the other hand, Computer Numerically controlled machine Tool Programmers (metal and plastic) develop the programs to control machining and processing of metal or plastic parts by automatic machine tools, equipment, or systems.[32] Finally, Computer-Controlled Machine Tool Operators (metal and plastic) operate computer-controlled machines or robots to perform one or more machine functions on metal or plastic work pieces.[33]

Occupations in this program of study have bright outlooks nationally and statewide. **Figure 1 and Figure 2** outline the related career opportunities in Tennessee.

Figure 1. Tennessee long term employment projections for machining-related occupations in Tennessee for the 2014-2024 projection period.[34][35]

Occupation	2014 Estimated Employment	2024 Projected Employment	Total 2014-2024 Employment Change	Total Percent Change	Median Salary
Machinists	8,470	9,960	15000	17.70%	$49,690
Computer Numerically Controlled Machine Tool Programmers, Metal and Plastic	500	660	160	31.70%	$57,930
Computer-Controlled Machine Tool Operators, Metal and Plastic	2,810	3,720	910	32.40%	$41,920

[30]Tennessee Department of Labor and Workforce Development. (2017). Supply and Demand Data: Occupation Employment and Projections (Long Term), on the Internet at www.jobs4tn.gov (visited May 15, 2017).
[31]Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2014-15 Edition*, Machinists and Tool and Die Makers, http://www.bls.gov/ooh/production/machinists-and-tool-and-die-makers.htm (visited May 15, 2017).
[32] O*Net Online, Computer Numerically Controlled Machine Tool Programmers (metal and plastic), on the Internet at http://www.onetonline.org/link/summary/51-4012.00 (visited May 15, 2017).
[33] O*Net Online, Computer-Controlled Machine Tool Operators (metal and plastic), on the Internet at http://www.onetonline.org/link/summary/51-4011.00 (visited May 15, 2017).
[34] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj
[35] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wage Rates (OES)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Figure 2. State and national trends for machining-related occupations with positive projections 2014-24[36][37][38]

United States	Employment		Percent Change	Projected Annual Job Openings
	2014	2024		
Machinists	399,700	438,900	+10%	15,470
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Machinists	8,470	9,960	+18%	340

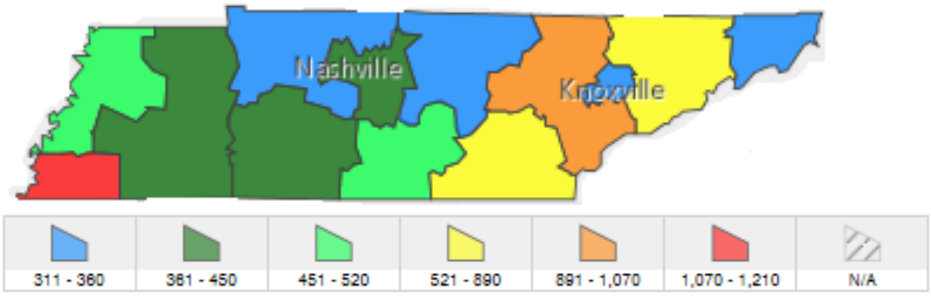
United States	Employment		Percent Change	Projected Annual Job Openings
	2014	2024		
Computer Numerically Controlled Machine Tool Programmers, Metal and Plastic	25,100	29,900	+19%	1,240
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Computer Numerically Controlled Machine Tool Programmers, Metal and Plastic	500	660	+32%	30

United States	Employment		Percent Change	Projected Annual Job Openings
	2014	2024		
Computer-Controlled Machine Tool Operators, Metal and Plastic	148,800	174,800	+18%	7,120
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Computer-Controlled Machine Tool Operators, Metal and Plastic	2,810	3,720	+32%	170

[36] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* http://www.onetonline.org/link/summary/51-4041.00
[37] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* https://www.onetonline.org/link/summary/51-4012.00
[38] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* https://www.onetonline.org/link/summary/51-4011.00

Job opportunities for machinists are strongest in urban and surrounding areas in Tennessee. **Figure 3** shows that more machining and engineering occupations in Tennessee are employed and needed in the Memphis areas than in surrounding areas.

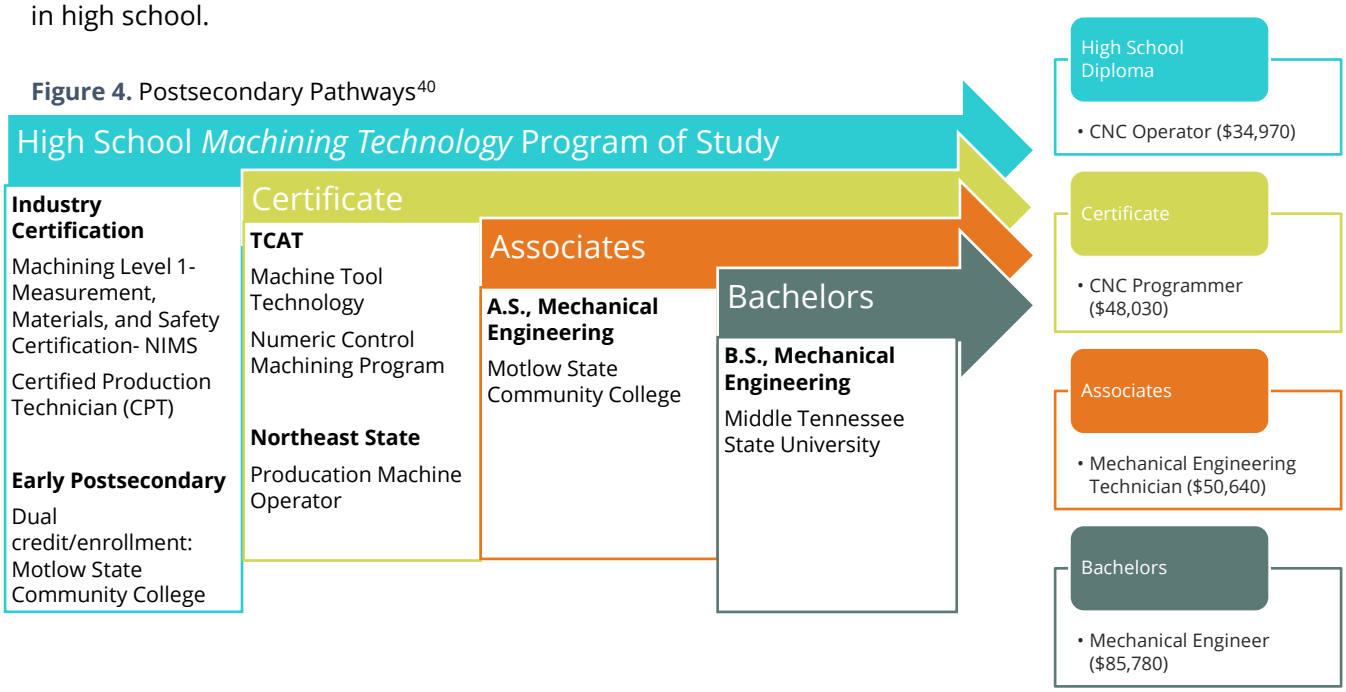
Figure 3. 2014 Estimated Employment[39]



Postsecondary Pathways

What kinds of careers can students expect to pursue upon completion of the Machining Technology POS in Tennessee? In many ways, Machining Technology represents one of the best examples of the department's emphasis on creating pathways linked to local labor market needs, composed of stackable credentials at discrete levels of postsecondary. The figure below illustrates what one such pathway might look like for a student graduating from a Tennessee Machining Technology program in high school.

Figure 4. Postsecondary Pathways[40]



[39] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

[40] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wages*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

As shown in the graphic above, machining technology pathways offer opportunities to funnel into careers at a variety of education levels. Moreover, demand is high for students who can complete with a certificate or related credential from a Tennessee College of Applied Technology (TCAT). The Tennessee Department of Labor and Workforce Development, in its statewide supply and demand analysis for the 16 national career clusters, forecasts that the Production Design, Precision Production, and Operations and Maintenance programs—all of which are aligned to advanced manufacturing-related careers—will produce shortages of qualified labor if the current rate of Tennessee postsecondary completers holds steady. Due to this shift, the need to encourage more students to pursue early postsecondary opportunities at the high school level and ultimately complete certificate programs at the state's network of TCATs, in order to swiftly gain the credentials to compete for these openings is essential.[41]

Current Secondary Landscape

In the 2016-2017 school year, 68 schools in Tennessee responded to the demand to grow local talent in emerging manufacturing fields and instituted special programs of study in Machining Technology. District data from SY 17-18 suggest that 84 schools will implement Machining Technology at the beginning of the SY.[42] These figures demonstrate that there is an appetite among schools—and students—to explore machining technology at the high school level, which bodes well for the growing number of postsecondary institutions to offer machining-related programs.

Figure 5. Open Enrollment Analysis[43]

	Machining Technology
2014-15	14
2015-16	25
2016-17	68
2017-18	84

[41] Bureau of Labor Statistics, Employment Projections (2017). Retrieved from: http://www.bls.gov/emp/.
[42] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.
[43]Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.

Student Enrollment[44]

SY	Principles of Manufacturing	Principles of Machining I	Principles of Machining II	Manufacturing Practicum
2013-14	663	603	489	0
2014-15	793	791	416	175
2015-16	2910	694	501* Includes DE	135

Machining Concentrators[45]

	Machining Technology
2013-14	0
2014-15	139
2015-16	321

Recommendation

Through advisory council meetings and discussions with industry and postsecondary partners, it is the recommendation to add general standards to the Level 1: Principles of Manufacturing course that aligns workforce requirements addressing on overview of a manufacturing plant, and general manufacturing processes (forging, stamping, injection molds, and casting). It is also recommended that we add the Snap-on Precision Measurement Instruments Certification. These recommendations will add rigor and relevancy to the established courses already in place.

[44] Tennessee Department of Education. (2017). *Student Enrollment Data*. Retrieved from Author's calculation of student enrollment data.

[45] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.

2018-19 Program of Study	Level 1	Level 2	Level 3	Level 4
Machining Technology	Principles of Manufacturing (5922)	Principles of Machining I (5929)	Principles of Machining II (5923) -or- **Dual Enrollment** Machining Technology (4060)	Manufacturing Practicum (5926) -or- **Dual Enrollment** Machining Technology (4060)
	Industry Certification: Machining Level I - Measurement, Materials, and Safety Certification (NIMS)	**Industry Certification:** Certified Production Technician (CPT) Safety Module	**Industry Certification:** Certified Production Technician (CPT) Quality Practices and Measurement Module	**Industry Certification:** Certified Production Technician (CPT) Manufacturing Processes and Production Module and Maintenance Awareness Module
	Industry Certification: Snap-on Precision Measurement Instruments Certification			

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O*Net Online, Computer Numerically Controlled Machine Tool Programmers (metal and plastic). Retrieved from: http://www.onetonline.org/link/summary/51-4012.00

O*Net Online, Computer-Controlled Machine Tool Operators (metal and plastic). Retrieved from: http://www.onetonline.org/link/summary/51-4011.00

O*Net Online, Machinists. Retrieved from: http://www.onetonline.org/link/summary/51-4041.00

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Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tn.gov/ecd/news/16577

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Tennessee Department of Labor and Workforce Development. (2014). *Tennessee's Hot Careers to 2020.* Retrieved from https://www.tn.gov/assets/entities/labor/attachments/statewide_2020outlooks.pdf

Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wage Rates.* Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Tennessee Department of Labor and Workforce Development, Jobs4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

TN.gov, Newsroom & Media Center. Retrieved from http://www.tn.gov/news/category/governor-haslam/P720

United States Department of Labor, Bureau of Labor Statistics. (2017, May 2). *Occupational Outlook Handbook, 2016-17 Edition.* Retrieved from http://www.bls.gov/ooh/architecture-and-engineering/electro-mechanical-technicians.htm#tab-2

United States Department of Labor, Bureau of Labor Statistics. (2017, May 15) National Occupational Data, April 2017, Table 1.1.

United States Department of Labor, Bureau of Labor Statistics. (2017, May 15) *Occupational Outlook Handbook, 2014-15 Edition*, Machinists and Tool and Die Makers, http://www.bls.gov/ooh/production/machinists-and-tool-and-die-makers.htm

United States Department of Labor, Employment and Training Administration. (2017). *Career One Stop. Retrieved from* http://www.careeronestop.org/

Mechatronics

2017-18 Program of Study	Level 1	Level 2	Level 3	Level 4
Mechatronics	Principles of Manufacturing (5922)	Digital Electronics (5925) Or Robotics & Automated Systems (6143) Or Project Lead the Way (PLTW) Computer Integrated Manufacturing (6055)	Mechatronics I[1] (6156) -or- **Dual Enrollment** Mechatronics (4063)	Mechatronics II[1] (6157) -or- Manufacturing Practicum (5926) -or- **Dual Enrollment** Mechatronics (4063)
	Industry Certification: Machining Level I - Measurement, Materials, and Safety Certification (NIMS)			**Industry Certification:** Level 1 Siemens Certified Mechatronic Systems Assistant

Description

The *Mechatronics* program of study is designed for students interested in becoming a mechatronics technician, electrical technician, mechanical engineering technician, robotics technician, or mechatronics engineer. Course content focuses on the components of manufacturing systems, collection and analysis of quality data, electronics, mechanics, fluid power systems, computers and control systems, and technical documentation and troubleshooting. Upon completion of this POS, proficient students will be prepared to pursue industry certification at a technology college or more advanced coursework at a two-year or four-year postsecondary institution.

Job Outlook

Back in 2011, Governor Bill Haslam announced six target clusters for which Tennessee had a competitive advantage and would focus its recruitment efforts to bring more businesses to the state.[46] One of those target clusters was Advanced Manufacturing and Energy Technologies, and

[46] TN.gov, Newsroom & Media Center. Retrieved from: http://www.tn.gov/news/category/governor-haslam/P720

after several consecutive years of strong job gains, the demand for skilled workers shows no sign of slowing. Compared to the national rate of 5.2 percent, job creation in Tennessee is soaring in manufacturing fields, accounting for $30.2 billion in manufactured goods exported every year and a 9% overall increase over the last four years.[47]

Tennessee believes in the power of manufacturing. Over the last three years, Tennessee has posted the second largest percentage increase in the Southeast in manufacturing GDP, which reached $45.8 billion in 2015. That's 16 percent of the state's total GDP.[48] With its attractive business climate and strategic location, Tennessee is home to a strong base of manufacturers representing many diverse industries, led by the state's automotive sector, which in recent years has converted into a regional and national powerhouse.[49] In industries such as these, employers like Alcoa, Eastman Chemical, Bridgestone, and Nissan are in need of engineers who can design, maintain, and operate complex production systems. Mechatronics, with its emphasis on applied mathematics and engineering design, offers a wealth of opportunities for career advancement in today's cutting-edge advanced manufacturing industries.[50] Bridgestone has recently partnered with Motlow State Community College to develop a mechatronics program based on the Siemens Mechatronics Systems approach to advanced manufacturing. It's the only program in the U.S. to offer a three-step pathway for advanced manufacturing education.[51]

Mechatronics is the study of complex systems and processes to aid in smarter, more efficient product design and development, particularly within manufacturing environments. Mechatronics systems combine mechanical, electrical, computer, and control systems into a unified process, drawing on principles of industrial engineering and related disciplines to optimize results and minimize defects.[52] Examples of classic mechatronics systems within automotive manufacturing environments include the mobile robots and manipulator arms that operate on assembly lines.[53] In order for them to function properly, however, successful professionals in this field must be able to problem solve and troubleshoot by applying mathematics, design, and systems thinking, while also documenting highly technical processes in a manner that can be replicated by others.[54]

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[47] Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tnecd.com/industries/advanced-manufacturing/. (visited May 16, 2017)
[48] Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tnecd.com/industries/advanced-manufacturing/ (visited May 16, 2017)
[49] Muro, M., Andes, S., Fikri, K., Ross, M., Lee, J., Ruiz, N., & Marchio, N. (2013). Drive! Moving Tennessee's Automotive Sector Up the Value Chain. Brookings Institution. Retrieved from: http://www.brookings.edu/research/reports/2013/10/04-tennessee-automotive. (visited May 16, 2017)
[50] O*Net OnLine (2017). 17-2199.05 - Mechatronics Engineers. Retrieved from: http://www.onetonline.org/link/summary/17-2199.05. (visited May 16, 2017)
[51] Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tnecd.com/advantages/workforce-education/ (visited on May 16, 2017)
[52] North Carolina State University (2015). What is Mechatronics? NC State University-UNC Asheville. Retrieved from: http://www.engr.ncsu.edu/mechatronics/what-mech.php. (visited May 16, 2017)
[53] Sharif, L. (2012). Examples of Mechatronic Systems. Retrieved from: http://www.saylor.org/site/wp-content/uploads/2012/11/ME302-subunit-1.2-Examples-of-Mechatronic-Systems-FINAL.pdf. (visited May 16, 2017)
[54] O*Net OnLine (2017). Retrieved from: http://www.onetonline.org/link/summary/17-2199.05 (visited May 16, 2017)

According to Jobs4TN.gov, the rate of employment is expected to grow in these occupations (See Figure 1 for details). Although these occupations are all related to Mechatronics, they each have different roles and responsibilities. Industrial Engineering Technicians design new equipment or materials, and recommend revision to methods of operation, material handling, equipment layout, or other changes to increase production or improve standards. [55] Industrial Engineering Technologists interpret engineering drawings, sketches, or diagrams and plan the flow of work or materials to maximize efficiency.[56] On the other hand, Mechatronic Engineers design engineering systems for the automation of industrial tasks and create mechanical design documents for parts, assemblies, or finished products[57]

Occupations in this program of study have bright outlooks nationally and statewide. **Figure 1 and Figure 2** outline the related career opportunities in Tennessee.

Figure 1. Tennessee long term employment projections for mechatronic-related occupations in Tennessee for the 2014-2024 projection period.[58][59]

Occupation	2014 Estimated Employment	2024 Projected Employment	Total 2014-2024 Employment Change	Total Percent Change	Median Salary
Mechatronic Engineers (Engineers, All Other)	3,020	3,290	270	8.90%	$82,360
Industrial Engineer Technicians	1,610	1,680	80	4.90%	$61,810
Manufacturing Engineering Technologists	630	660	40	6.0%	$61,810

[55] O*Net Online, Industrial Engineering Technicians, on the Internet at: https://www.onetonline.org/link/summary/17-3026.00 (visited May 16, 2017)
[56] O*Net Online, Industrial Engineering Technologists, on the Internet at: https://www.onetonline.org/link/summary/17-3029.50 (visited May 16, 2017)
[57] O*Net Online, Mechatronic Engineers, on the Internet at http://www.onetonline.org/link/summary/17-2199.005 (visited May 15, 2017).
[58] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj
[59] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wage Rates (OES)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Figure 2. State and national trends for mechatronic-related occupations with positive projections 2014-24[60][61][62]

United States	Employment		Percent Change	Projected Annual Job Openings
	2014	2024		
Mechatronic Engineers (Engineers, All Other)	136,900	142,300	+4%	3,300
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Mechatronic Engineers (Engineers, All Other)	3,020	3,290	+9%	80

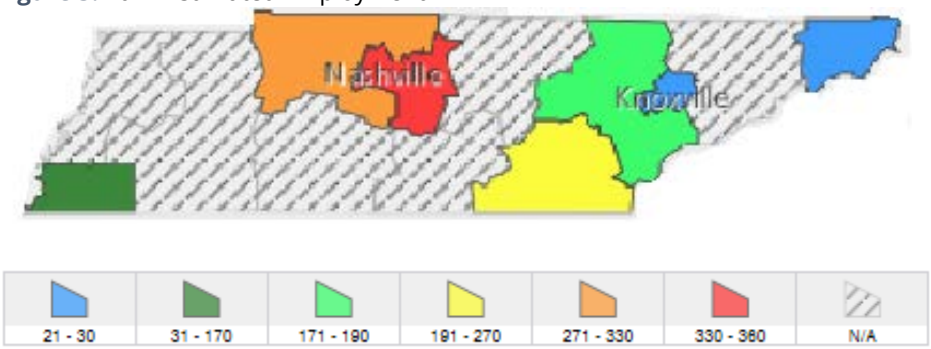
United States	Employment		Percent Change	Projected Annual Job Openings
	2014	2024		
Industrial Engineering Technicians	66,500	63,500	-5%	1,630
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Industrial Engineering Technicians	1,610	1680	+5%	40

United States	Employment		Percent Change	Projected Annual Job Openings
	2014	2024		
Manufacturing Engineering Technologist	70,100	69,900	0%	1,710
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Manufacturing Engineering Technologist	630	660	+6%	20

[60] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* http://www.onetonline.org/link/summary/17-2199.05
[61] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* https://www.onetonline.org/link/summary/17-3026.00
[62] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* https://www.onetonline.org/link/summary/17-3029.06

Job opportunities for mechatronics related occupations are strongest in urban and surrounding areas in Tennessee. **Figure 3** shows that more mechatronic and industrial engineering technician occupations in Tennessee are employed and needed in the Middle Tennessee and Knoxville areas than in surrounding areas.

Figure 3. 2014 Estimated Employment[63]



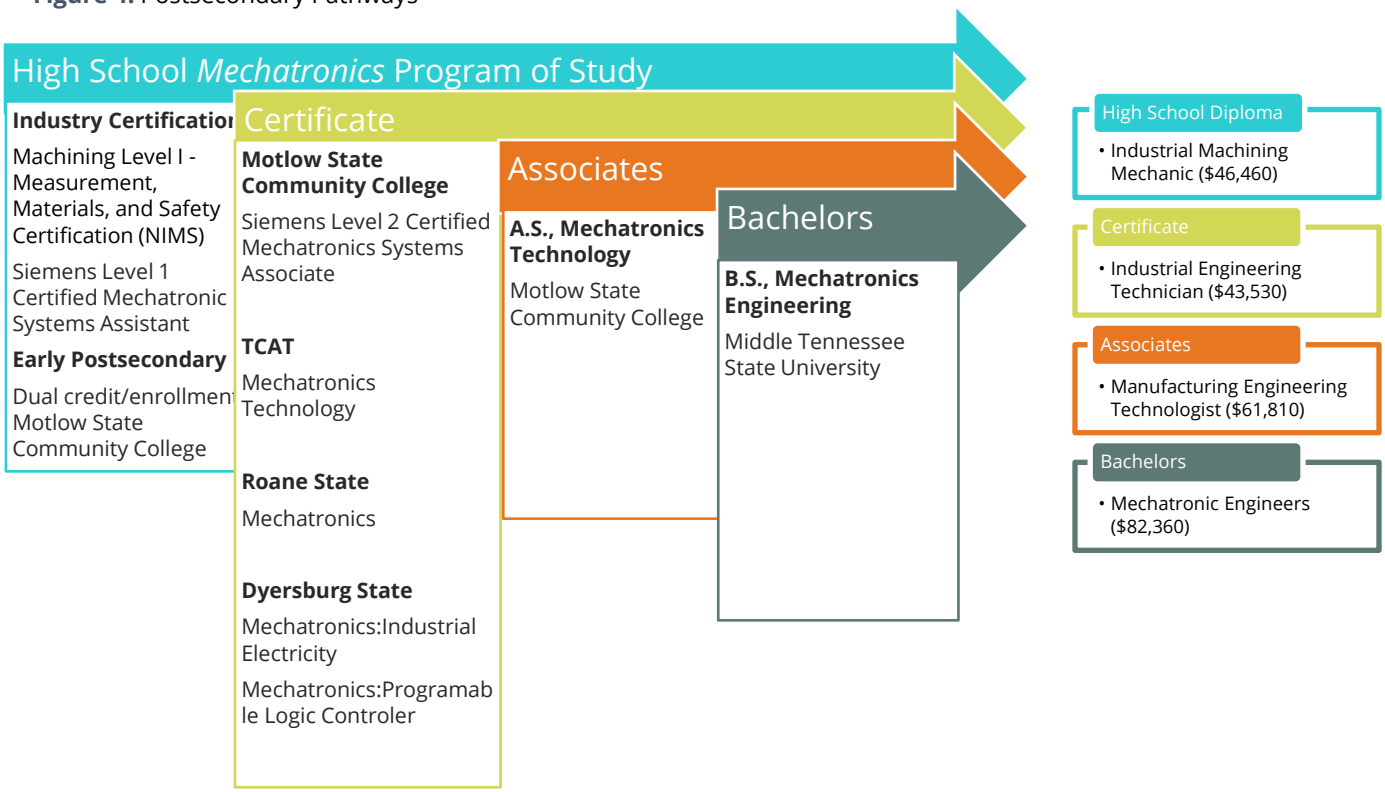
Postsecondary Pathways

What kinds of careers can students expect to pursue upon completion of the Mechatronics POS in Tennessee? In many ways, Mechatronics represents a great example of the department's emphasis on creating pathways linked to local labor market needs, composed of stackable credentials at discrete levels of postsecondary. The figure below illustrates what one such pathway might look like for a student graduating from a Tennessee Mechatronics program in high school.

Pursuing just an additional year or two of study, however, can yield great returns for students. Among Tennessee graduates from public two-year colleges who completed programs in Mechatronics Technology, median wages for their first year out of school was $61,810. This is higher than the state average for all Associate's holders. Beyond that, advanced training at the Bachelor's level will open even more doors for students, moving their employment prospects to the higher-wage engineering and production management occupations.

[63] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Figure 4. Postsecondary Pathways[64]



Mechatronics pathways offer opportunities to funnel into careers at a variety of education levels. Moreover, demand is high for students who can complete with a certificate or related credential from a Tennessee College of Applied Technology (TCAT). The Tennessee Department of Labor and Workforce Development, in its statewide supply and demand analysis for the 16 national career clusters, forecasts that the Production Design, Precision Production, and Operations and Maintenance programs—all of which are aligned to mechatronics-related careers—will produce shortages of qualified labor if the current rate of Tennessee postsecondary completers holds steady. Production Design, in particular, was identified as a high-skill, high-wage, and in-demand pathway that is not producing enough completers to match employer demand.[65]

[64] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wages.* Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

[65] Hedges, K., and Wettemann, M. (2012). Tennessee Statewide Supply and Demand Analysis for the 16 Education Clusters. Tennessee Department of Labor and Workforce Development. (viewed May 16, 2017)

Current Secondary Landscape

In the 2016-2017 school year, 58 schools in Tennessee responded to the demand to grow local talent in emerging manufacturing fields and instituted special programs of study in Mechatronics. District data from SY 17-18 suggest that 65 schools will implement Mechatronics at the beginning of the SY.[66] These figures demonstrate that there is an appetite among schools—and students—to explore mechatronics at the high school level, which bodes well for the growing number of postsecondary institutions to offer machining-related programs.

Figure 5. Open Enrollment Analysis[67]

	Mechatronics
2014-15	12
2015-16	34
2016-17	58
2017-18	65

Student Enrollment[68]

SY	Principles of Manufacturing	Digital Electronics	Mechatronics I	Mechatronics II
2013-14	663	33	0	0
2014-15	793	140	121	43
2015-16	2910	437	443 *Includes DE	72

Mechatronic Concentrators[69]

	Mechatronics
2013-14	0
2014-15	58
2015-16	117

[66] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.

[67] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.

[68] Tennessee Department of Education. (2017). *Student Enrollment Data*. Retrieved from Author's calculation of student enrollment data.

[69] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.

Recommendation

Through advisory council meetings and discussions with industry and postsecondary partners, it is the recommendation to add general standards to the Level 1: Principles of Manufacturing course that aligns workforce requirements addressing on overview of a manufacturing plant, and general manufacturing processes (forging, stamping, injection molds, and casting). It is also recommended that we add the Snap-on Precision Measurement Instruments and the FANUC certifications. These recommendations will add rigor and relevancy to the established courses already in place.

2018-19 Program of Study	Level 1	Level 2	Level 3	Level 4
Mechatronics	Principles of Manufacturing (5922)	Digital Electronics (5925) Or Robotics & Automated Systems (6143) Or Project Lead the Way (PLTW) Computer Integrated Manufacturing (6055)	Mechatronics I[1] (6156) -or- **Dual Enrollment** Mechatronics (4063)	Mechatronics II[1] (6157) -or- Manufacturing Practicum (5926) -or- **Dual Enrollment** Mechatronics (4063)
	Industry Certification: Machining Level I - Measurement, Materials, and Safety Certification (NIMS)			**Industry Certification:** Level 1 Siemens Certified Mechatronic Systems Assistant
	Industry Certification: Snap-on Precision Measurement Instruments Certification	**Industry Certification:** Fanuc Certification		

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O*Net OnLine (2017). 17-2199.05 - Mechatronics Engineers. Retrieved from: http://www.onetonline.org/link/summary/17-2199.05. (visited May 16, 2017)

O*Net Online, Industrial Engineering Technicians, on the Internet at: https://www.onetonline.org/link/summary/17-3026.00

O*Net Online, Manufacturing Engineer Technologist, on the Internet at: https://www.onetonline.org/link/summary/17-3029.06

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Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tnecd.com/industries/advanced-manufacturing/

Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tn.gov/ecd/news/16577

Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tnecd.com/advantages/workforce-education/

Tennessee Department of Education. (2017). *Student Enrollment Data*. Retrieved from Author's calculation of student enrollment data.

Tennessee Department of Labor and Workforce Development. (2014). *Tennessee's Hot Careers to 2020.* Retrieved from https://www.tn.gov/assets/entities/labor/attachments/statewide_2020outlooks.pdf

Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wage Rates.* Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Tennessee Department of Labor and Workforce Development, Jobs4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Tennessee Department of Labor and Workforce Development. Hedges, K., and Wettemann, M. (2012). Tennessee Statewide Supply and Demand Analysis for the 16 Education Clusters.

TN.gov, Newsroom & Media Center. Retrieved from http://www.tn.gov/news/category/governor-haslam/P720

United States Department of Labor, Employment and Training Administration. (2017). *Career One Stop. Retrieved from* http://www.careeronestop.org/

Welding

2017-18 Program of Study	Level 1	Level 2	Level 3	Level 4
Welding	Principles of Manufacturing (5922)	Welding I (6078)	Welding II[2] (6033) -or- **Dual Enrollment** Welding (4062)	Manufacturing Practicum (5926) -or- **Dual Enrollment** Welding (4062)
	Industry Certification: Machining Level I - Measurement, Materials, and Safety Certification (NIMS)	**Industry Certification:** AWS SENSE Entry Level Welder	**Industry Certification:** AWS SENSE Advanced Level Welder or American Welding Society Certified Welder	

Description

The *Welding* program of study is designed to prepare and certify students as entry-level welders. Students will learn safe practices, career exploration, leadership development, and basic arc welding and thermal cuttings skills. Basic arc welding and thermal cutting skills are developed over a series of two courses which will prepare students for an *American Welding Society* certification.

Job Outlook

Back in 2011, Governor Bill Haslam announced six target clusters for which Tennessee had a competitive advantage and would focus its recruitment efforts to bring more businesses to the state.[70] One of those target clusters was Advanced Manufacturing and Energy Technologies, and after several consecutive years of strong job gains, the demand for skilled workers shows no sign of slowing. Compared to the national rate of 5.2 percent, job creation in Tennessee is soaring in manufacturing fields, accounting for $30.2 billion in manufactured goods exported every year and a 9% overall increase over the last four years.[71]

[70] TN.gov, Newsroom & Media Center. Retrieved from: http://www.tn.gov/news/category/governor-haslam/P720
[71] Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tnecd.com/industries/advanced-manufacturing/. (visited May 16, 2017)

Tennessee believes in the power of manufacturing. Over the last three years, Tennessee has posted the second largest percentage increase in the Southeast in manufacturing GDP, which reached $45.8 billion in 2015. That's 16 percent of the state's total GDP.[72] With its attractive business climate and strategic location, Tennessee is home to a strong base of manufacturers representing many diverse industries, led by the state's automotive sector, which in recent years has converted into a regional and national powerhouse.[73] In industries such as these, employers like Alcoa, Eastman Chemical, Bridgestone, and Nissan are in need of engineers who can design, maintain, and operate complex production systems.

The Occupational Outlook Handbook developed by the Bureau of Labor Statistics lists the following occupations and related occupations for welders: Industrial maintenance mechanics, welding engineers, materials engineers, sculptors, welding inspectors, assemblers and fabricators, boilermakers, jewelers and precious stone metal workers, machinists and tool and die makers, metal and plastic machine workers, plumbers, pipefitters, steamfitters, and sheet metal workers.[74] Welding courses are considered necessary by some pipefitter and steamfitter apprenticeship programs.[75]

The nation's aging infrastructure will require the expertise of welders, cutters, solders, and brazers to help rebuild bridges, highways, and buildings. The construction of new power generation facilities and, specifically, pipelines transporting natural gas and oil will also result in new jobs. National employment of welders, cutters, solders, and brazers is projected to grow 7 percent.[76] Employment growth reflects the need for welders in manufacturing because of the importance and versatility of welding as a manufacturing process. The basic skills of welding are similar across industries, so welders can easily shift from one industry to another, depending on where they are needed most. Overall job prospects will vary with the worker's skill level. Job prospects should be good for welders trained in the latest technologies. Welding schools report that graduates have little difficulty finding work, and many employers report difficulty finding properly skilled welders. However, welders who do not have up-to-date training may face strong competition for jobs.

Nationally, demand for welders will create over 12,850 job openings through 2024, the vast majority of which will arise from replacement needs as the current welding workforce approaches

[72] Tennessee Department of Economic & Community Development (2017). Retrieved from: http://www.tnecd.com/industries/advanced-manufacturing/ (visited May 16, 2017)
[73] Muro, M., Andes, S., Fikri, K., Ross, M., Lee, J., Ruiz, N., & Marchio, N. (2013). Drive! Moving Tennessee's Automotive Sector Up the Value Chain. Brookings Institution. Retrieved from: http://www.brookings.edu/research/reports/2013/10/04-tennessee-automotive. (visited May 16, 2017)
[74]United States Department of Labor, Bureau of Labor Statistics (2017). Retrieved from: http://www.bls.gov/ooh/production/welders-cutters-solderers-and-brazers.htm (visited May 16, 2017)
[75] United States Department of Labor, Bureau of Labor Statistics (2017). Retrieved from: http://www.bls.gov/ooh/production/welders-cutters-solderers-and-brazers.htm (visited May 16, 2017)
[76] O*NET Online: Welders, cutters, Solderers, and Brazers 51-4121.00 on the Internet at http://www.onetonline.org/link/summary/51-4121.00 (2017). (visited May 16, 2017)

retirement.[77] Despite this seemingly positive outlook, however, employers frequently report that they cannot find the skilled labor to fill available positions, which has held back the growth of domestic manufacturing even as it has recovered faster than other industries.[78] This much-discussed "skills gap" seems to have disproportionately affected manufacturing: as much as 82 percent of U.S. manufacturers report moderate to serious shortages of skilled labor according to a Deloitte survey, and the U.S. Bureau of Economic Analysis estimates that the shortage could grow to 875,000 machinists, welders, industrial mechanics, and similar welding-related occupations if the supply of qualified labor does not keep pace.[79] Given the current and projected industry needs, it is imperative to train the next generation of skilled welders to fill these positions and help drive the revitalization of U.S. manufacturing. It will be the job of welders and their machinist peers to manufacture the new products and perform the required maintenance in order for this much-needed upgrade to be realized in the coming years.[80]

The TN Department of Labor and Workforce Development projects 570 openings for welders, cutters, solderers, and brazers from 2014 to 2024 with and a total of 9,210 employed in TN in 2024. This includes a state growth rate of 6.60 percent for welders, cutters, solderers, and brazers (51-4121) and 37 percent for welding machine setters and operators (51-4122).[81] In northern middle TN counties in particular, welders, solderers, and brazers occupations are listed as a hot job. Tennessee is one of the top five states with the highest concentration of setters and operators in this field. Welders work in a variety of industries and with their skill sets they can easily transition among different industries.[82]

In Tennessee, the production and refinement of metals, in particular, occupies an important sector of the economy. In 2012, there were 85 primary metal manufacturers and 1,000 fabricated metal product manufacturers operating in the state—both of which industry "clusters" were proportionally greater than the concentration of such manufacturers nationally.[83] Meanwhile, Tennessee employees in primary metal manufacturing were represented at 1.43 times the national proportion. Additionally, Tennessee employees in this cluster enjoy a larger share of total annual wages compared with their peers elsewhere in the country, with a wage location quotient of 1.61.[84] As

[77] O*NET Online: Welders, cutters, Solderers, and Brazers 51-4121.00 on the Internet at http://www.onetonline.org/link/summary/51-4122.00 (2017). (visited May 16, 2017).
[78] ManpowerGroup. (2013) Retrieved from http://www.manpowergroup.com/wps/wcm/connect/587d2b45-c47a-4647-a7c1-e7a74f68fb85/2013_Talent_Shortage_Survey_Results_US_high+res.pdf?MOD=AJPERES (visited May 16, 2017).
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[83] Innovation in American Regions. (2012). Retrieved from: http://www.statsamerica.org/innovation/ (visited May 16, 2017),
[84] Innovation in American Regions. (2012). Retrieved from: http://www.statsamerica.org/innovation/ (visited May 16, 2017).

previously stated, Tennessee demand for welders, cutters, solderers, and brazers is expected to grow 6.6 percent through 2024 (faster than the state average), resulting in approximately 570 annual openings.[85]

Occupations in this program of study have bright outlooks nationally and statewide. **Figure 1 and Figure 2** outline the related career opportunities in Tennessee.

Figure 1. Tennessee long term employment projections for welding-related occupations in Tennessee for the 2014-2024 projection period.[86][87]

Occupation	2014 Estimated Employment	2024 Projected Employment	Total 2014-2024 Employment Change	Total Percent Change	Median Salary
Welders, Cutters, Solderers, and Brazers	8,630	9,210	570	6.60%	$82,360
Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders	1,850	2,530	680	36.50%	$61,810

Figure 2. State and national trends for welding-related occupations with positive projections 2014-24[88][89][90]

United States	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Welders, Cutters, Solderers, and Brazers	397,900	412,300	+4%	12,850
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Welders, Cutters, Solderers, and Brazers	8,630	9,210	+7%	270

[85] O*NET (2017). Retrieved from: http://www.onetonline.org/ (visited May 16, 2017)
[86] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj
[87] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wage Rates (OES)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj
[88] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* http://www.onetonline.org/link/summary/17-2199.05
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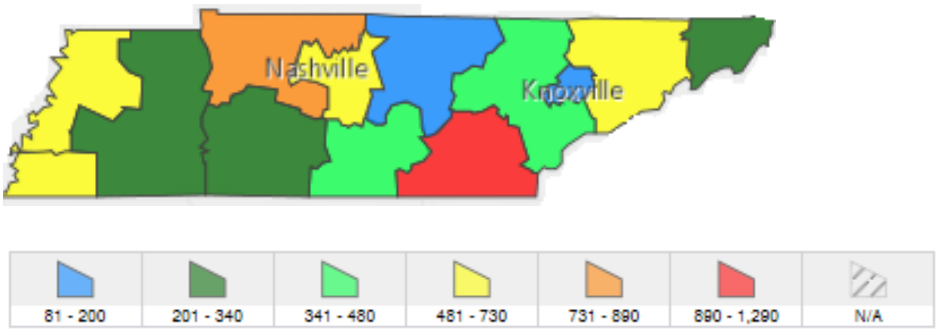
[90] Career One Stop. (2017). *Occupation Profile, State and National Trends. Retrieved from* https://www.onetonline.org/link/summary/17-3029.50

United States	Employment		Percent Change	Projected Annual Job Openings
	2014	2024		
Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders	59,500	48,800	-18%	1,710
Tennessee	**Employment**		**Percent Change**	**Projected Annual Job Openings**
	2014	**2024**		
Welding, Soldering, and Brazing Machine Setters, Operators, and Tenders	1,850	2,530	+37%	110

Job opportunities for welders are strongest in urban and surrounding areas in Tennessee. **Figure 3** shows that more welding occupations in Tennessee are employed and needed in the Chattanooga and Middle Tennessee areas than in surrounding areas.

Figure 3. 2014 Estimated Employment[91]

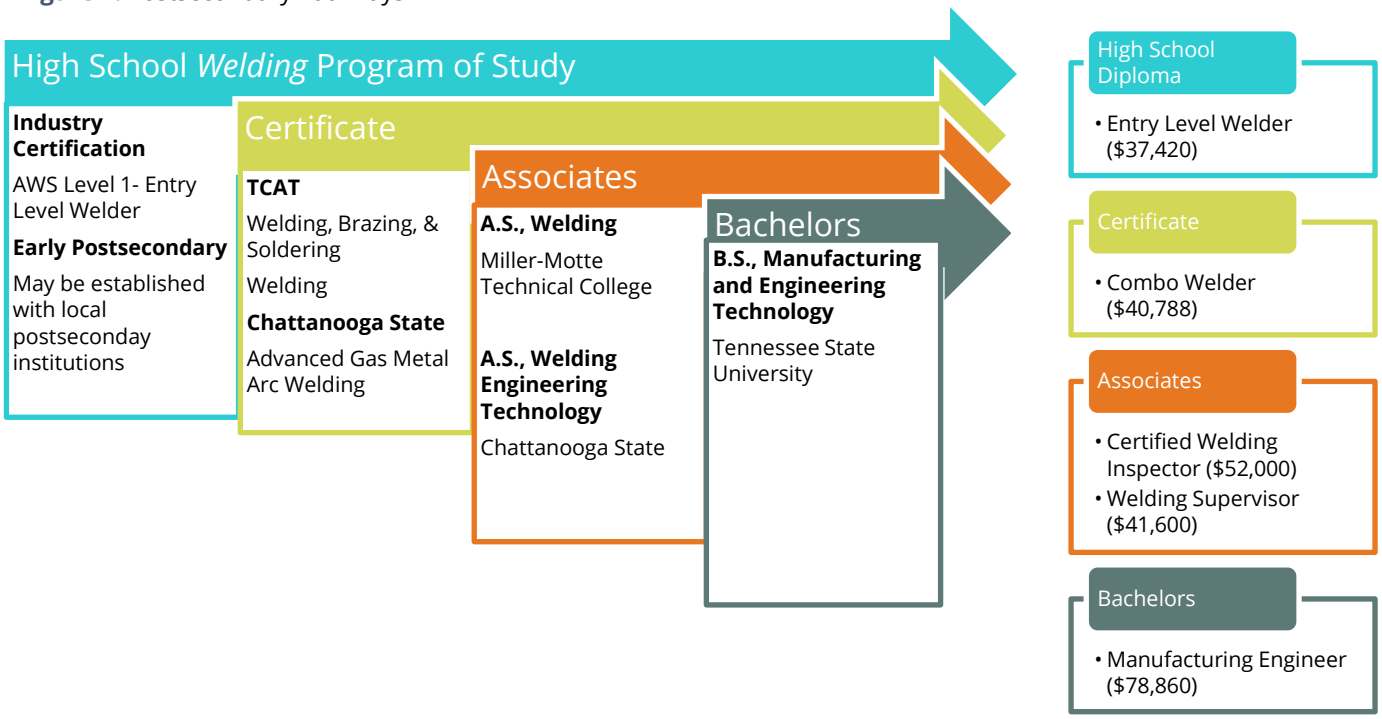


Postsecondary Pathways

What kinds of careers can students expect to pursue upon completion of the Welding POS in Tennessee? In many ways, Welding represents a great example of the department's emphasis on creating pathways linked to local labor market needs, composed of stackable credentials at discrete levels of postsecondary. The figure below illustrates what one such pathway might look like for a student graduating from a Tennessee Welding program in high school.

[91] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Projections (Long-term)*. Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Figure 4. Postsecondary Pathways[92]



Welding pathways offer opportunities to funnel into careers at a variety of education levels. Moreover, demand is high for students who can complete with a certificate or related credential from a Tennessee College of Applied Technology (TCAT). In northern middle TN counties in particular, welders, solderers, and brazers occupations are listed as a hot job. Tennessee is one of the top five states with the highest concentration of setters and operators in this field. Welders work in a variety of industries and with their skill sets they can easily transition among different industries. Pursuing just an additional year or two of study, however, can yield great returns for students. Among Tennessee graduates from public two-year colleges who completed programs in Welding Technology, median wages for their first year out of school was $41,600 and $52,000 respectively (higher than the state average for all Associate's holders). Beyond that, advanced training at the Bachelor's level will open even more doors for students, moving their employment prospects to the higher-wage engineering occupations.

[92] Tennessee Department of Labor and Workforce Development, Job4TN Online. (2017). *Occupational Employment and Wages.* Retrieved from https://www.jobs4tn.gov/vosnet/analyzer/results.aspx?session=occproj

Current Secondary Landscape

In the 2016-2017 school year, 90 schools in Tennessee responded to the demand to grow local talent in emerging manufacturing fields and instituted special programs of study in Welding. District data from SY 17-18 suggest that 110 schools will implement Welding at the beginning of the SY.[93] These figures demonstrate that there is an appetite among schools—and students—to explore welding at the high school level, which bodes well for the growing number of postsecondary institutions to offer welding programs.

Figure 5. Open Enrollment Analysis[94]

	Welding
2014-15	68
2015-16	74
2016-17	90
2017-18	110

Student Enrollment[95]

SY	Principles of Manufacturing	Welding I	Welding II	Manufacturing Practicum
2013-14	663	1499	748	0
2014-15	793	1791	850	175
2015-16	2910	1489	1343 *Includes DE	135

Welding Concentrators[96]

	Welding
2013-14	0
2014-15	0
2015-16	707

[93] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.

[94] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.

[95] Tennessee Department of Education. (2017). *Student Enrollment Data*. Retrieved from Author's calculation of student enrollment data.

[96] Tennessee Department of Education. (2017). Student Enrollment Data. Retrieved from Author's calculation of student enrollment data.

Recommendation

Through advisory council meetings and discussions with industry and postsecondary partners, it is the recommendation to add general standards to the Level 1: Principles of Manufacturing course that aligns workforce requirements addressing on overview of a manufacturing plant, and general manufacturing processes (forging, stamping, injection molds, and casting). It is also recommended that we add the Snap-on Precision Measurement Instruments Certification.

In Welding I, the following are the proposed changes:

- Weld Procedures Specifications Development will replace Welding Design and Layout
- AWS B2.1/B2.1M can be used as a resource guide for instructors

Knowledge Requirements:

1. Elements of a Welding Procedure Specification
    a. Joint Design
    b. Base Metal
    c. Filler Metal
    d. Position
    e. Preheat and Interpass
    f. Heat Treatment
    g. Shielding Gas
    h. Electrical
    i. Variables
2. Procedure Qualification Variables
    a. Understand each variable associated with the above elements
3. Limitations of a Welding Procedure Specification
    a. Understand when a WPS is applicable and when it is not, if not why?
4. How to conduct a welding procedure test
    a. Code Requirements
    b. Materials
    c. Documentation
    d. Destructive Testing
    e. Inspection and evaluation

Skill Requirements:

1. Set up welding equipment for the process being tested
2. Properly select base material and filler metal (gas shielding if required)
3. Gather equipment needed to capture welding variables
4. Properly set up test coupon (per code, or as performed in production)
5. Properly document data as coupon is being welded
6. Perform visual inspection
7. Perform destructive testing
8. If acceptable, properly complete the Welding Procedure Specification document

In Welding II, the following are the proposed changes:

- Add heading Welding Economics
- AWS Quality and Productivity Improvement book can be used as a resource guide for instructors.

Knowledge Requirements

1. Understand the elements that impact welding efficiency.
    a. Arc time
    b. Operating Factor
    c. Deposition Rate (wire feed speed)
    d. Electrode Efficiency
    e. Travel Speed
    f. Weld Size
    g. Poor Fit
    h. Defects/Repairs
2. Cost of welding
    a. Fillet Weld
    b. Groove Welds

Skills Requirements

1. Demonstrate how Wire Feed Speed impacts efficiency
2. Demonstrate how Weld Size impacts efficiency
3. Calculate how long it will take to make a fillet weld
4. Calculate how long it will take to make a groove weld

These recommendations will add rigor and relevancy to the established courses already in place.

2018-19 Program of Study	Level 1	Level 2	Level 3	Level 4
Welding	Principles of Manufacturing (5922)	Welding I (6078)	Welding II[2] (6033) -or- **Dual Enrollment** Welding (4062)	Manufacturing Practicum (5926) -or- **Dual Enrollment** Welding (4062)
	Industry Certification: Machining Level I - Measurement, Materials, and Safety Certification (NIMS)	**Industry Certification:** AWS SENSE Entry Level Welder	**Industry Certification:** AWS SENSE Advanced Level Welder or American Welding Society Certified Welder	
	Industry Certification: Snap-on Precision Measurement Instruments Certification			

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