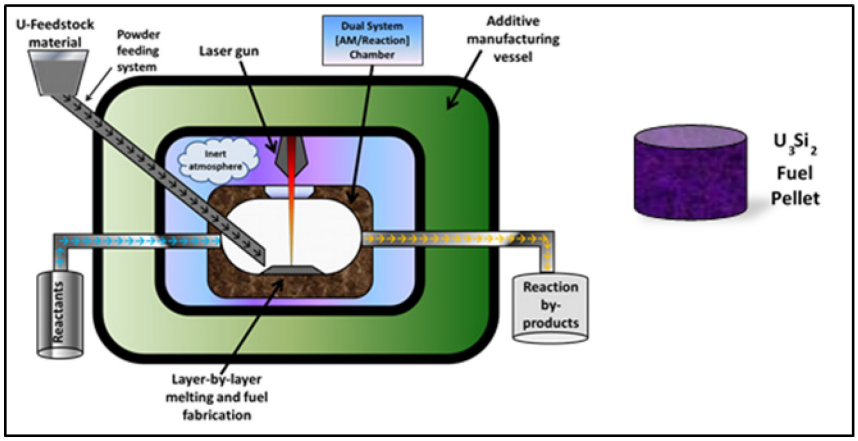
INL/MIS-18-44586

Preliminary AMAFT Commercialization Strategy

George Griffith, Isabella J van Rooyen, and Ed Lahoda

February 2018

The INL is a
U.S. Department of Energy
National Laboratory
operated by
Battelle Energy Alliance



INL/MIS-18-44586

Preliminary AMAFT Commercialization Strategy

George Griffith, Isabella J van Rooyen, and Ed Lahoda

February 2018

Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Preliminary AMAFT Commercialization Strategy

INL/MIS-18-44586

February 2018

Author:

George W. Griffith
AMAFT Entrepreneurial Lead

2/8/18
Date

Technical Reviewer:

Art L. Baker
Technology Transfer

2/8/2018
Date

Approved by:

Isabella J van Rooyen
Distinguished Staff Scientist
AMAFT Project Principle Investigator

2/8/2018
Date

ABSTRACT

The Additive Manufacturing as an Alternative Fabrication Technique (AMAFT) for nuclear fuel technology is being developed by Idaho National Laboratory (INL) and Westinghouse Electric Company (WEC). AMAFT uses unique additive manufacturing processes to produce uranium silicide nuclear fuel in a direct way. As part of the DOE I-Corps program extensive interviews were performed to evaluate the nuclear fuel market and commercial relationships. The commercialization strategy is expected to center on a technology license to WEC. Sublicenses would be created as the technology is deployed. A very small high value market may exist for special purpose nuclear fuel.

ACKNOWLEDGEMENTS

The AMAFT team would like to thank Westinghouse Electric Company, and Ed Lahoda in particular who helped beyond his role as an industry mentor. We would also like to thank the many people interviewed for their open and helpful advice and discussions. This work was sponsored by the U.S. Department of Energy, Office of Nuclear Energy and Office of Technology Transfer, as part of the 2016 Technology Commercialization Fund. Work was completed by Battelle Energy Alliance, LLC, management and operating contractor for the Idaho National Laboratory, under U.S. Department of Energy Idaho Operations Office Contract DE-AC07-05ID14517. We would also like to thank the Idaho National Laboratory (INL).

CONTENTS

ABSTRACT vii

ACKNOWLEDGEMENTS viii

1. Introduction 1

2. AMAFT Project 1

3. Market Description 2

4. AMAFT Technology Risk 3

5. Conclusion 4

FIGURES

Figure 1. DOE Energy I-CORPS Training. 1

Figure 2. AMAFT and Conventional Nuclear Fuel. 2

Figure 3. Example market structure 3

ACRONYMS

AMAFT	Additive Manufacturing as an Alternative Fabrication Technique
ART	Advanced Reactor Technologies
BWXT	BWXT Technologies Inc.
DOE	Department of Energy
INL	Idaho National Laboratory
NREL	National Renewable Energy Laboratory
WEC	Westinghouse Electric Company

Preliminary AMAFT Commercialization Strategy

1. Introduction

The Additive Manufacturing as an Alternative Fabrication Technique (AMAFT) for nuclear fuel technology is being developed by Idaho National Laboratory (INL) and Westinghouse Electric Company (WEC). AMAFT uses unique additive manufacturing processes to produce uranium silicide nuclear fuel in a direct way. To support the technology development and evaluate the commercialization strategy, the AMAFT project was enrolled in the 2017 fifth cohort of the Department of Energy's (DOE) Energy I-Corps Project. The Energy I-Corps program is managed by DOE's National Renewable Energy Laboratory (NREL) and allows DOE researchers and industry mentors to create market pathways and customer discovery. This allows DOE with investment opportunities and innovations to improve long-term U.S. energy industry competitiveness.

The basic steps in the Energy I-Corps process are shown in Figure 1.

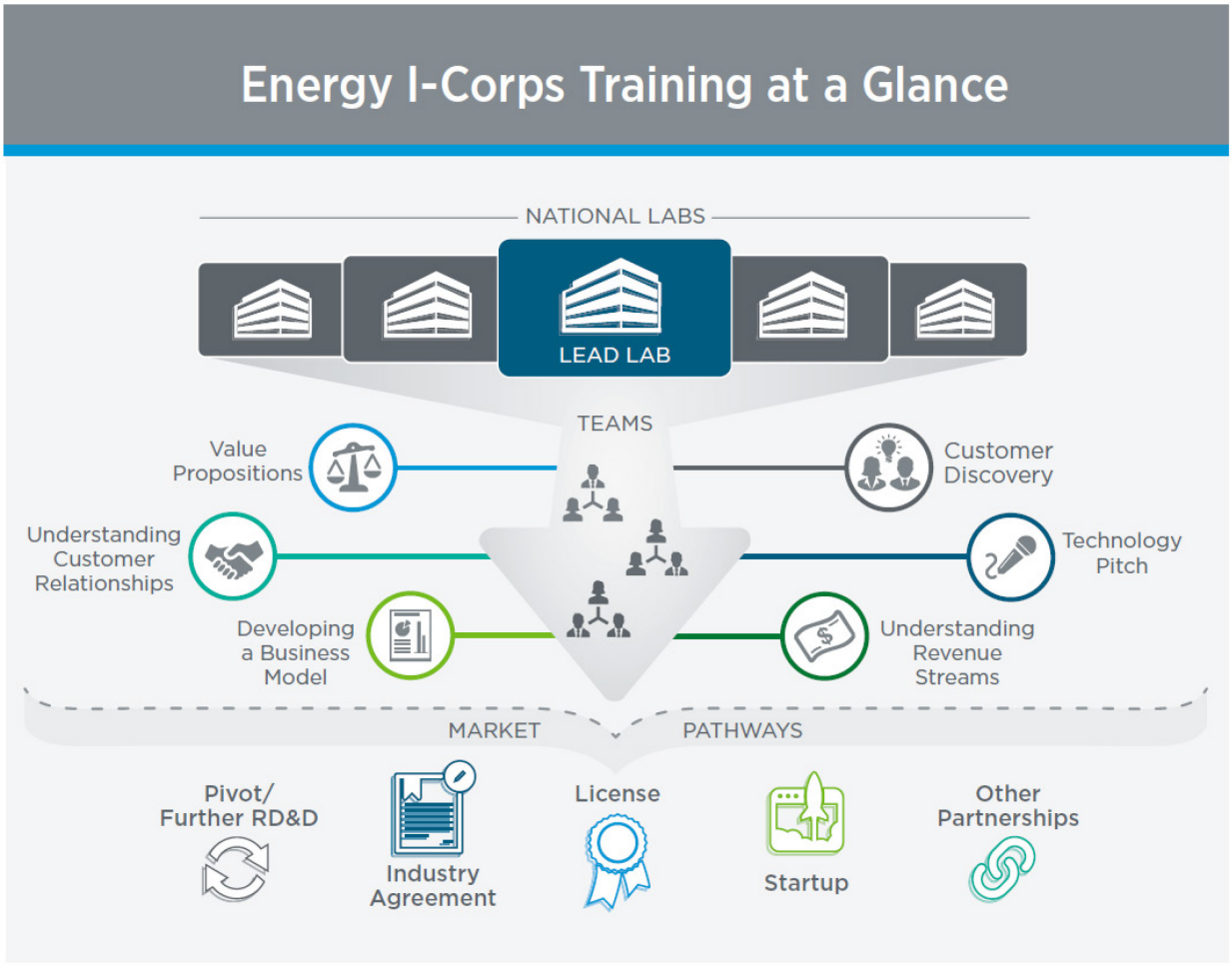


Figure 1. DOE Energy I-CORPS Training.

2. AMAFT Project

The initial stage of the Energy I-Corps program is developing a value proposition for the developed technology. In the case of AMAFT, improved direct nuclear fuel performance of the uranium silicide

metal fuel results. The technology also allows a fuel fabricator to reduce capital costs by simplifying the production process. An unexpected benefit was potential significant savings by reducing the waste streams required for conventional nuclear fuel fabrication. The value proposition initially showed that the AMAFT technology had an economic value.

The AMAFT technology is strongly focused on WEC nuclear fuel technology. The basic conventional and AMAFT nuclear fuel processes are shown in Figure 2. WEC is developing additional advanced nuclear ceramic fuel cladding technology. Combining the cladding and AMAFT technology allows WEC to benefit more than either technology would deliver separately.

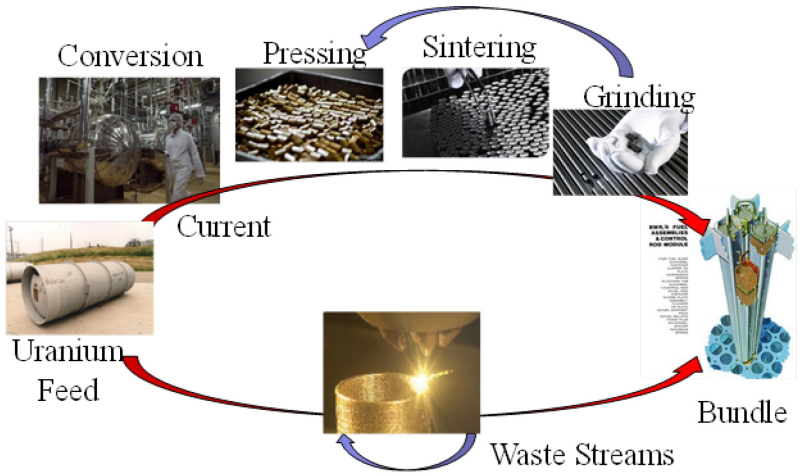


Figure 2. AMAFT and Conventional Nuclear Fuel.

3. Market Description

The Energy I-Corps customer discovery step initially showed that WEC was the only near-term customer that the AMAFT technology could support. This continued until well into the project. The AMAFT Energy I-Corps team performed more than 70 interviews of industry representatives to support the technology observations. Interviews included other advanced nuclear fuel developers and fabricators, additive manufacturing experts, industry suppliers, university and National Laboratory researchers, and people who are actively deploying additive manufacturing technology. The team uniquely found a team developing hazardous material fabrication using additive manufacturing techniques.

A second potential customer was discovered during the interviews. BWXT Technologies Inc. (BWXT) fabricates specialty nuclear fuel for research and special applications. They have a potential application for new uranium silicide fuel. BWXT has a focus on higher value small volume projects. The smaller BWXT market would allow an alternate market channel better fit to new technology deployment. This additional customer also allowed the AMAFT technology to fit more closely with the Energy I-Corps discovery process.

The nuclear fuel market is structured so that once the technology is deployed successfully through WEC, nuclear fuel buyers will demand technology sharing. The market demands that technology be available through multiple channels to avoid single-source risk. The need to avoid a single-source market leads to sublicensing of the technology from WEC to other nuclear fuel vendors. This would add a secondary value to the WEC license agreement.

The nuclear fuel fabrication by BWXT could potentially allow a second specialty nuclear fuel application and license. BWXT could be either a direct licensee or a sublicense to the WEC license. The successful deployment of the AMAFT technology would lead to downstream applications outside the

nuclear industry. These applications would be handled as separate licenses. This product channel would need to be anticipated in the initial technology deployment.

The anticipated market structure for AMAFT is shown in Figure 3. AMAFT would license to BWXT at a higher licensing fee in line with the higher value/lower volume market. The larger market, lower cost, and lower licensing fee market is shown going through WEC. Westinghouse would sell directly to utilities and sublicense the technology to other nuclear fuel vendors, who in turn sell to utilities. The monetary values used here are to help illustrate potential market possibilities, rather than final values. The easily accessible utility market is estimated to be more than $30m/year.

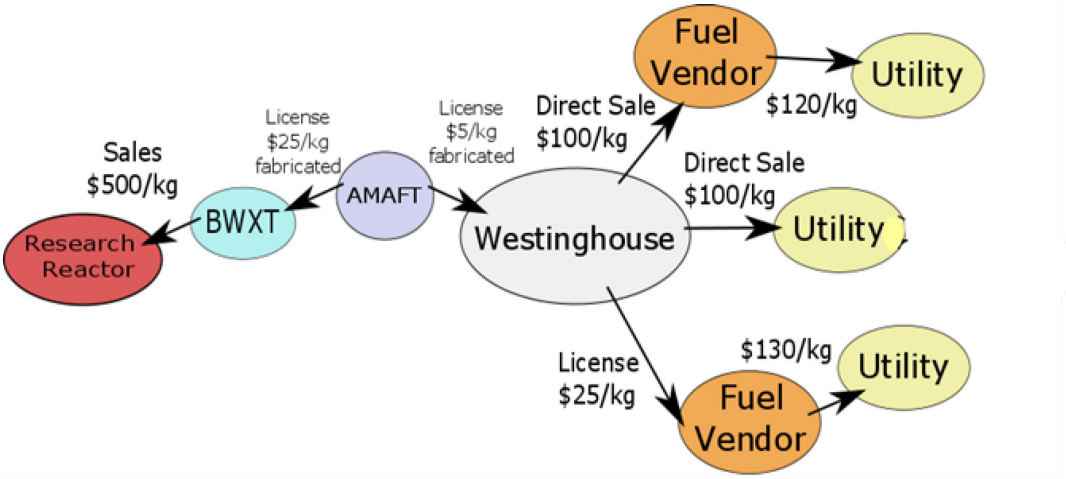


Figure 3. Example market structure.

The AMAFT program developed a more mature technology description and value understanding that could be used to engage the market and understand the value. This improved understanding allowed the AMAFT team to evaluate the potential commercial value and avenues to pursue how that technology can better reach the industry.

The AMAFT team identified licensing of the technology to WEC as the primary commercial deployment of the technology. Independent sales from Idaho National Laboratory (INL) and the creation of a new spin out company were seen as impractical due to high capital requirements and extensive regulation. A direct partnership was also seen as undesirable. Licensing the technology, however, is seen as typical and desirable in the nuclear fuel market.

4. AMAFT Technology Risk

Beyond the failure of base AMAFT technology, the current risks to the AMAFT technology deployment center on changes in the nuclear energy market. General Electric/Global Nuclear Fuels and AREVA are known to be developing their own advanced nuclear fuel that approximately competes with the AMAFT process. Any new nuclear fuel technology competes with the existing fuel fabrication process. If the complexity during the change to the AMAFT process outweighs the near-term benefits, the technology would be at risk. The nuclear market may undergo significant changes during deployment of the AMAFT process. A shrinking of the market would create risk to the deployment. WEC is undergoing business changes that may take their focus away from new nuclear fuel technology deployment.

5. Conclusion

The Energy I-Corps program allowed a much deeper insight into the advanced nuclear fuel market. A viable and well-understood market for the AMAFT nuclear fuel technology was found. The program's focus on interviews and diving into the market greatly improved our understanding regarding how the AMAFT technology can be used by industry. The need to plan for licensing, sublicensing, and future markets was developed. Further, finding a secondary potential customer is seen as a significant discovery that might allow higher value and lower volume initial deployment.