Executive Summary:
The Lower Saint Anthony Falls project (“Project”) is a 9.176 MW run-of-river hydroelectric project that is estimated to generate enough electricity to power 7,500 average US homes a year. It is the result of a partnership between Brookfield Renewable Power and Nelson Energy. The Project utilizes StraflowMatrix combined turbine/generator units installed in the US Army Corps of Engineers’ (USACE) Lower Saint Anthony Falls auxiliary lock chamber. The combined units are designed to work well in low head environments and could be placed in existing structures such as auxiliary locks. Using existing locks eliminates the need for a totally separate power house with accompanying intake structures as would be needed with traditional bulb turbines. Existing dam sites previously considered uneconomical based on traditional technologies could be economical with efficient turbines that work with low head areas and reduced construction costs. There are 90,000 dams in the United States and only a small fraction has hydropower facilities installed on them. The equipment supplier has identified the following conditions for successful implementation of this technology:
discharge greater than ~60 cubic meters per second; head from 3 meters to 30 meters; draft tube exit submergence of ~1.5 meters; utility grid connection in relatively close proximity; structure available and suitable for the modules. This new technology may open up additional sites for development.

There were three main objectives for the Project:

1) Restore the generating potential of the Mississippi River to the heart of Minneapolis
2) Utilize new StraflowMatrix turbine generator technology
3) Demonstrate how existing dams can be economically developed for renewable hydroelectric generation.

The project has been installed and achieved commercial operation on December 7th, 2011. The Project successfully replaces the former NSP power house formerly located on the east side of the lock and dam. That facility’s foundation failed causing the power house to be decommissioned in 1987. The former NSP site was built to provide power to the city’s public transportation system. The new Project replaces that generation with new technology. The US hydropower industry has been generating power since the early 1880s. Many of the facilities built then are still working today. Because of their demonstrated reliability, existing technologies are often preferred over new technologies. However, the StraflowMatrix turbine generator is specifically designed for low-head rivers such as the Mississippi. (Average gross head at the Lower Saint Anthony Falls Project site is 24 feet.) The RDF Grant provided necessary funding to give the Project confidence to take a risk with this new technology. Successfully installed and operating, it now creates the first US installation of the technology that can be observed, visited and studied by others interested in pursuing hydropower at low-head sites. In addition, existing civil works, such as the Lower Saint Anthony Falls Lock and Dam, provide opportunities that lower overall project costs by eliminating the need for such activities as excavation, full scale power houses, or new dams. Expected to produce approximately 63,300 MWhs annually, the Project is now in operation and has met each of the stated objectives.

**Technical Progress:**

The 9.176 MW Project reached commercial operation on December 7th, 2011. It utilizes 16 StraflowMatrix turbine generator units designed and installed by Andritz Hydro (formerly VA Tech). The facility consists of concrete encased draft tubes that have downstream gates that control water flow, and removable turbine modules on the upstream side. The powerhouse is a gallery or concrete
box between the walls of the auxiliary lock. It houses the electrical and hydraulic controls for the plant equipment. A set of four Obermeyer gates were installed on top of the gallery that can be raised and lowered to provide additional control of river flow. Two turbines are stacked on top of one another creating eight columns of two units each. The turbine spins inside a magnetic frame creating electricity which flows through wires wrapped in sealed cables up to switchgear and then to an Xcel line. The wires/cables, located immediately upstream of the draft tubes, retract when the site’s crane raises and lowers the units into position. This allows the units to be raised out of the flow in the case of flooding or maintenance. A trash boom and warning signs for boaters were installed upstream of the powerhouse. Similar warning signs are installed downstream near the Project’s tailrace. (See Appendix A and B for design schematic.)

During Project preparation, the tragic collapse of the I-35 bridge delayed the Project by approximately two years. Once begun the Project’s construction went as expected with the exception of delays due to equipment availability and performance. Problems with the ceramic coating of the turbines and the sealing of the cable system/generator connections allowed excessive water leakage into the turbine generators. Once identified, the problems with the coating and cables were analyzed and repaired. The leakage was solved by resealing connections and installing cable guards to protect the movement from water turbulence. Additionally, two of the units required new stators. Combined, the cable system repairs and new stators resulted in a delay of final project testing and COD of over six months.

While unfortunately causing delays at the Project, the problems identified with the coating and the cables will result in improved designs for future installations of the technology. The repairs to the cable system identified and implemented in this Project are a permanent solution. To go further, however, in the spring of 2012, the cable systems will be replaced with an updated design that will increase the life of the system. The Project will be able to take advantage of lessons learned as outlined below and in advances in technology since the original design of the turbines.

In order to build the Project a number of permits and licenses were required. The most essential of these was the license to build and operate issued by the Federal Energy Regulatory Commission (FERC license number 12451).
The federal licensing process requires continual involvement of stakeholders and relevant agencies. From initial outreach to project license took five years.

In addition to the FERC license the Project entered into Memorandums of Agreement with the USACE. The Project has both a Power Purchase Agreement and Interconnect Agreement with Xcel Energy. Because the Project is located on federal property, the only state or local permit required was from the Minneapolis Park Board which allowed use of West River Parkway for construction equipment.

Project Benefits:
The Project benefits a wide range of stakeholders. For example, the use of the auxiliary lock chamber leaves the former NSP Hydropower site open for other uses. In addition, the Obermeyer gates installed as a project feature help to handle high flows. The project can utilize up to 6,201 cubic feet per second (cfs) of flow. Together with the USACE’s tainter gates, the Obermeyer gates pass any excess flow, thus helping to regulate the pond between the Upper and Lower Saint Anthony Falls lock and dams. Such regulation is the purview of the USACE and LSAF works at their direction to pass flows above 6,201 cfs. The project is considered run-of-river because it does not create a new pond and is dependent upon naturally available water supply.

The Project will generate approximately 63,300 MWh per year. This will provide enough clean, renewable energy to power 7,500 average US households. LSAF will generate enough emissions free electricity to replace the equivalent of 7,775 tons of coal per year\(^1\) and its associated 142 million pounds of carbon dioxide emissions, 823,000 pounds of sulfur dioxide and 380,000 pounds of nitrogen oxides\(^2\).

Hydropower produces electricity without generating air pollution or toxic by-products. Hydropower is predictable, stable and qualifies under the State’s renewable goals.

The Project, as part of its FERC license, installed an interpretive panel upstream of the site. This panel describes, through text and images, the history of hydropower generation on the Mississippi in Minneapolis. The panel’s content provides context for the Project and will help visitors understand the important role that hydropower has played in the commercial development of the area. (See Appendix C.)

Other Project benefits include:
- 61,000 man hours of project labor
- Over $39,000,000 investment in the region
- Provides real life example of application of the StraflowMatrix turbine technology to developers in the United States

\(^1\) http://www.onlineconversion.com/energy.htm
\(^2\) http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html
- Uses existing auxiliary lock chamber – originally built to handle expected increases in traffic which never materialized. Use of the auxiliary chamber repurposes an otherwise dormant asset.
- Allows for continued safe use of lock for commercial and recreational river traffic as demonstrated in navigation studies and modeling
- New Obermeyer gates help pass excess river flow in high flow events
- Increase public awareness of hydropower – LSAF has conducted many tours for public officials, members of the business community, stakeholders, agencies, and industry professionals. It has provided an opportunity to speak about the technology, hydropower, and development opportunities. In addition, the project team created a website for the general public: http://www.lsafhydro.com/.

Project Lessons Learned:
- StraflowMatrix technology will work for the LSAF project site. The cost of the construction results in a profitable project.
- Given issues with technology, and an expected increased premium for risk, future deployments of technology will depend on updated equipment costs, site specific development costs, and the price of electricity. While the technology could make previously uneconomical sites viable, it can only do so when market prices are also favorable.
- Support from State and Federal programs is essential to project economics when dealing with new technologies. RDF funding, REPI payments, and the federal stimulus grant made the difference with this Project.
- Working with new technologies presents risks including potential design issues with new equipment. The schedule and budget should reflect those risks.
- Working with the USACE can be effective and worthwhile but project schedules should recognize the time required to meet the USACE’s design and construction standards.
- Early and continued outreach to project stakeholders is imperative to a successful project.
- Advances in technology and design will help future projects avoid some of the issues encountered at the Project.

Usefulness of Project Findings:
This Project has provided valuable lessons that will inform future development opportunities, both in the selection of projects and project management. Brookfield will use its experience with this Project as well as market and environmental conditions to evaluate other potential hydropower projects. Not only will Brookfield use this experience to inform its development decisions but other developers, some of whom have followed
this project, will be able to revisit the economic viability of existing sites based on the feasibility of this technology. As stated previously, the technology may reduce civic and construction costs by eliminating the need for a powerhouse separate from the dam itself. At a small site, the reduction in civil costs may be enough to turn a previously unviable project around.

While the Project partners always consider it imperative to work with stakeholders, this Project has reinforced that commitment. Partners such as the USACE, the Minnesota Department of Natural Resources, the Marcie Holmes Neighborhood Association, the National Park Service, the Minneapolis Park and Recreation Board, the University of Minnesota, and state as well as local elected officials were all instrumental to the success of this project.

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Appendix A: Design Schematic for turbine generator layout
The Heritage of Hydro

Two companies controlled the rights to the Mississippi's waterpower with a dam at Saint Anthony Falls. They sold or leased these rights to mill owners and other industrialists, who used waterwheels and turbines to run factory equipment. With few sources of power, waterpower was very valuable.

William De la Barré, a brilliant engineer, wanted to get even more power from the river. Between 1896 and 1897, he oversaw construction of the Lower Dam, which raised the water level in an area of rapids below the falls. The massive dam, called "De la Barré's Folly," cost nearly $1 million—an incredible sum when a horse cost about $50. A plant on the river's east bank used the drop ("head") from the dam to generate electricity for the city's streetcar system.

The Lower Dam Today

The Lower Dam was rebuilt in the 1930s with a 36-wide lock and three gates controlling the spillway. Another lock was built at Saint Anthony Falls. These locks allowed boats to travel above the falls, a long-time goal of some Minneapolis leaders. The bay adjacent to the Lower Lock held a barge that could be converted into a second lock when water traffic increased. This increase never happened. Had a century later, plans were launched to install a hydroelectric marine turbine-generator system in the bay.

The 1897 hydroelectric plant at the dam's east end operated until its foundation failed in 1907, forcing its removal. Today, there is an earthen embankment where the plant stood.

Hydro Revival

Hydroelectricity was an important early source of electricity in Minnesota, with 35 plants operating by 1910. The Mississippi plants, though, were dependent on the river's ebb and flow—range from flooding to frozen.

As steam and other sources of electricity became more economical and reliable, dependence on hydropower dropped. One writer concluded in 1962: "Although Minnesota could develop nearly 90 percent more hydroelectric power than at present, it is unlikely that new developments will be constructed because of various economic factors."

A contemporary observed, though, that "changes in the cost and availability of fuels, in value of lands and water, and in costs and methods of construction may alter this situation in the future." The future has arrived, thanks to increasing fuel costs and innovations in technology.

Appendix C. Interpretive Display Content