Sugar Research Australia

AN ECONOMIC ANALYSIS OF: DEVELOP A BLUEPRINT FOR THE INTRODUCTION OF NEW PROCESSING TECHNOLOGIES FOR AUSTRALIAN FACTORIES

Project 2015/043

Chief Investigator
Ross Broadfoot, Queensland University of Technology

Evaluation completed by AgTrans.

1 Introduction

The following impact assessment has been carried out using the guidelines produced by the Council of Research and Development Corporations (CRRDC, 2018).

1.1 Background and rationale for the project investment

Australian sugar factories processing sugarcane generally are not highly energy efficient compared with some sugarcane factories in other countries. For example, steam consumption levels for most Australian factories are often greater than 40% on cane, far higher than some factories overseas that operate at 28-35%.

Technologies that are not being used in Australian factories include.

- Falling film tube evaporators and Kestner evaporators,
- In-line juice heaters on vapour from the final evaporator,
- Barriquand juice heaters,
- Use of vapour from the 3rd evaporator for pan boiling,
- Direct contact pan feed conditioning systems, and
- Vapour recovery systems such as in condensate cigars.

Some of the technologies being used in energy efficient factories overseas can be introduced into Australian factories to provide both capacity and operational benefits (from project proposal).

Hence a blueprint for Australian factories associated with new processing technologies was seen to be valuable for the Australian industry in their consideration of alternative technologies for reducing steam consumption and hence improving the prospects for generating surplus bagasse for use in alternative revenue production.

2 Project objectives

The overall aim of Project SRA 2015/043 was to develop a blueprint that defines the technologies that are most suited to adoption into Australian factories and that will provide major reductions in process steam consumption in the future.

Specific objectives were:

1) To determine whether the magnitude of sucrose destruction in the first two Robert evaporators in a steam efficient evaporator station warrant that short residence time evaporators be used as an alternative.

2) To determine whether the scaling rates and effectiveness of chemical cleaning in falling film tube evaporators are now sufficiently manageable at the final effect to warrant their adoption, and if so, determine to what extent do these evaporators provide scope for increased juice processing capacity and substantial reductions in steam consumption.
3) To determine the implications of using condensate cigars for collection and flashing of condensates in Australian evaporator stations.
4) To determine by how much a direct contact feed conditioning system will impact on pan cycle times, exhaustions, and the ability to use low pressure vapours on pans.
5) To determine the circumstances under which in-line juice heating will be financially attractive.
6) To determine how the implementation of new technologies will impact on steam consumption for the factory, the cogeneration potential and generation of surplus bagasse.
7) To determine the extent to which the water balance of the factory will be affected through the implementation of the new technologies.

3 Cost of investment for project 2015/043

Estimates of the total investment by year and project funding organisation including Sugar Research Australia (SRA), Queensland University of Technology (QUT), and Isis and Pioneer Mills are provided in Table 1. Investment costs include both cash and in-kind contributions.

TABLE 1: THE COSTS OF THE INVESTMENT IN PROJECT 2015/043 (NOMINAL $)

YEAR ENDED JUNE	SRA	QUT	INDUSTRY (ISIS AND PIONEER MILLS)	TOTAL
2016	149,709	27,828	40,000	217,537
2017	232,975	18,201	5,000	256,176
2018	99,316	4,013	0	103,329
Total	482,000	50,042	45,000	577,042

3.1 Program management and extension costs

The costs of administration and management of the investment from all parties are assumed to be included in the figures appearing in Table1.

4 Activities

A number of major activity phases were planned and actioned in the execution of the project.

The phases were:

1) Determination of the extent of sucrose destruction in Robert evaporators in five Australian factories . These determinations were to determine the costs of retaining conventional Robert Australian evaporator vessels at the front end of the set in the blueprint. Repeat trials were undertaken to increase confidence in the results. Trials were also undertaken in the 2017 season (Ross Broadfoot, pers. comm., 2019).
2) Operations at known-to-be steam efficient overseas sugarcane factories were inspected to assemble information on design and operational performance and the suitability of their use in Australian factories. The overseas factories visited were located in South Africa, Mauritius, Reunion and India.
3) The most appropriate type of evaporator technology to include in the blueprint was determined to suit the front and tail ends of Australian factory evaporator sets. This included the main factors determining the suitability of an evaporator technology such as heat transfer efficiency and operating temperature difference, sucrose destruction, propensity for entrainment of juice, propensity to scale the heating surfaces, footprint, ease of chemical cleaning, robustness in control, and operation in turn-down situations.
4) The operations of four Australian sugar factories were modelled to ascertain the suitability of using the alternative evaporator designs and the preferred steam-efficient technologies to suit the particular objectives

of each of the four factories. In addition, the effect of changes on pan stage productivity when using low pressure vapour, as well as the effects on whole of factory operations from the adoption of the new technologies were ascertained.

5) The preferred final designs were selected from financial considerations and assessments of the operational parameters described above. The target capacity increases for each factory were determined in collaboration with the individual factory.
6) The technologies included in the assessment were the preferred evaporator technology, use of the in-line juice heater, use of molasses conditioners (and other circulation aids) and reuse of flashed vapour (from a condensate cigar). The investigations were undertaken in the context of making realistic use of the currently installed equipment e.g. batch pans, Robert evaporators. Replacement with new technologies were considered only where large benefits resulted.

The blueprint was developed for the application of the new technologies to boost the capacity and operational efficiencies; the blueprint defined the potential use of the technologies for both capacity increases and for reductions in process steam consumption. Recommendations were made on the main features to be incorporated into the designs for the evaporators, in-line juice heaters, molasses conditioners and flash vapour recovery systems. Information on the implementation of the blueprint technologies including the design recommendations were provided to all Australian sugarcane factories.

5 Outputs

A summary of the principal outputs produced from the project activities follows:

- Additional knowledge of sucrose losses in Robert evaporators in Australian factories. The investigations determined that the factories set up for increased steam economy (typically extensive vapour bleeding to heaters and pans, large areas at the front of the evaporator set and use of higher temperature process steam (e.g. 125 ℃ compared with the usual 120 ℃)) experienced large sucrose degradation losses during juice evaporation - being typically between 0.85 and 1%. The reduction in revenue for a factory crushing 500 t/h was estimated at nearly $1m per annum. The magnitude of this loss was not known by the industry before this investigation and based on previous assessments estimated at low values e.g. <0.2% (for the traditional factory configuration). This knowledge has directed the focus of the steam efficient mills to try and reduce these losses operationally and through their future investments in evaporation plant (Ross Broadfoot, pers. comm., 2019).
- Knowledge of the technologies adopted by overseas factories to achieve their low steam consumption levels between 28% and 35% on cane,
- Assessment of the technologies in terms of increased crushing rate, reduced process steam consumption, and reduced sucrose degradation,
- Information on the impact of the technologies on productivity (pan cycle times and exhaustion) for the batch pans used in Australian factories from using vapour from the third evaporation stage, and
- Effect on whole of factory operations of using the steam efficient technologies.
- A blueprint document for Australian sugar factories to guide future investment decisions was produced. The blueprint document enables Australian sugarcane factories to boost the capacity and operational performance using technologies that are suited to future major reductions in process steam consumption.
- The findings of the investigations were reported to the industry in the 2016, 2017 and 2018 Regional Research Seminars which are held each year and in ASSCT papers (two papers in 2017 and two papers in 2018) (Ross Broadfoot, pers. comm., 2019).

6 Outcomes

A summary of the prospective and some actual outcomes of the project follows:

- Some or all of the outputs from the project will be relevant to Factory Managers and Senior Technologists (Production Superintendents, Chief Engineers) at all Australian sugarcane factories when making decisions for the factory for increased crushing rate, improved operational performance and for reduced process steam consumption.

- It is likely that some Factory Managers of Australian sugarcane factories will be influenced by the blueprint information in their future decisions concerning future plans for their factory development.

The investigations emanating from the project have resulted in the following (Ross Broadfoot, pers. comm., 2019):

- A strong focus by the steam efficient factories in trying to limit their sucrose degradation losses as best as possible operationally (higher pH of Evaporator Supply Juice, lower process steam pressure (if possible).
- Interest in Falling Film Evaporators (FFE). One factory installed a FFE for the 2018 season but this decision was not a direct consequence of the project's results. Other factors were involved. However at least four mills have asked QUT for more information on the findings regarding the installation of FFEs into their factories.
- QUT has been requested to design a replacement Robert evaporator with tubes of smaller diameter and greater length as these vessels have shorter juice retention times and hence reduced sucrose losses.
- QUT has undertaken juice evaporation studies for three factories in the last two years to increase capacity, reduce steam consumption and, as requested by the mills, with strong emphasis on limiting the sucrose losses.
- QUT has designed six replacement pans in the past three years, and in most cases the factories have requested that the pans are suitable for operation on lower pressure vapour (based on current knowledge as least).

Also, the blueprint project has spawned two subsequent SRA projects to further advance the findings viz., (1) Investigations to mitigate the effects of juice degradation in factory evaporators on sugar recovery and quality, corrosion and effluent organic loading and (2) Pan design and operational changes to suit Australian pan stages operating on low pressure vapour (Ross Broadfoot, pers. comm., 2019).

7 Impacts

Depending on the extent of future use made of the blueprint by Australian sugarcane factories, the investment could provide significant impacts to the Australian sugarcane industry.

The impacts could include economic (financial) impacts for the factories, by incorporating the blueprint of new processing technologies when making investment decisions for boosting future capacity and operational performance and reducing steam consumption. Other impacts could include the delivery of social impacts via capability enhancement of engineers at QUT (the principal source of engineering expertise with regard to sugarcane factory operations) and spillover impacts on sugarcane communities. Also, some environmental impacts are likely to occur via improved energy efficiencies through the greater use of bagasse as a renewable fuel.

A summary list of the principal types of potential impacts associated with the outcomes of the project is shown in Table 2.

TABLE 2: CATEGORIES OF PRINCIPAL POTENTIAL IMPACTS FROM THE INVESTMENT

ECONOMIC • Avoidance of some factory investment decisions with adverse outcomes. • More efficient and effective future capital investment in sugarcane factories. • Lowered operational costs, including reduced sucrose losses, in some Australian sugarcane factories.
ENVIRONMENTAL • Increased energy efficiency due to more efficient use of bagasse
SOCIAL • Increased experience and capability of QUT engineering personnel, particularly relevant given the pending retirement of Professor Ross Broadfoot. • Spillover impacts to sugarcane communities due to increased sugar factory and grower incomes.

7.1 Public versus private impacts

The key potential impacts will be predominantly private as they will accrue mainly to sugarcane factories, albeit some longer-term indirect sharing of impacts with sugarcane growers. Public impacts will potentially include the environmental impact of energy efficiency associated with the usage of bagasse in energy production and use, as well as the regional community impacts derived from spillovers from the private impacts.

7.2 Distribution of impacts along the supply chain

Potential future impacts associated with this project will most likely accrue to sugarcane factories in the first instance, but these are likely to be of benefit to growers through the sugar factories being more financially sustainable.

7.3 Impacts on other primary industries

There are not likely to be any direct impacts to other agricultural industries from the investment. One potential outcome for other industries is that the generated surplus bagasse may be used for animal feed (Ross Broadfoot, pers. comm., 2019).

7.4 Match with national, state and SRA priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 3. The investment contributes primarily to Rural RD&E Priority 1, and to some extent Priority 4, and Science and Research Priorities 1 and 5.

TABLE 3: AUSTRALIAN GOVERNMENT RESEARCH PRIORITIES

AUSTRALIAN GOVERNMENT	
RURAL RD&E PRIORITIES (EST. 2015)	SCIENCE AND RESEARCH PRIORITIES (EST. 2015)
1) Advanced technology 2) Biosecurity 3) Soil, water and managing natural resources 4) Adoption of R&D	1) Food 2) Soil and Water 3) Transport 4) Cybersecurity 5) Energy and Resources 6) Manufacturing 7) Environmental Change 8) Health

Sources: DAWR (2015) and OCS (2016)

7.5 SRA Key Focus Areas

SRA's key focus areas are presented in Table 4. Project 2015/043 addressed KFA 5, and to some extent KFAs 7 and 8.

TABLE 4: SRA STRATEGIC FOCUS AREAS AND DESIRED OUTCOMES

KEY FOCUS AREA (KFA)	OUTCOMES
1) Optimally adapted varieties, plant breeding and release	Increased sugarcane yield and commercial cane sugar (CCS)
2) Soil health, nutrient management and environmental sustainability	Better soil health, reduced nutrient losses and improved water quality
3) Pest, disease and weed management	Reduced or avoided yield losses and/or added input costs
4) Farming systems and harvesting	Improved farm input-output efficiencies and profitability

5) Milling efficiency and technology	Optimised production, improved capital u4lisa4on and waste minimisation
6) Product diversification and value adding	Diversified revenue streams and product innovation
7) Knowledge and technology transfer and adoption	Accelerated adoption of new technology and practice change
8) Collaboration and capability development	Enhanced industry and research capability and capacity
9) Organisational effectiveness	Increased investor satisfaction and returns on investment

Source: SRA Strategic Plan (2018)

8 Valuation of impacts

8.1 Impacts valued

The number of sugarcane factories operating in Australia currently is 24. For purposes of impact valuation, it is anticipated that a small proportion of these factories (about 15% or 4 factories) will be influenced by the information contained in the blueprint over the period 2022 to 2028. This influence is assumed to be involved with savings in capital investments as well as gains in operational efficiencies, including reductions in sucrose losses.

A summary of the key assumptions made is shown in Table 5.

TABLE 5: SUMMARY OF ASSUMPTIONS

VARIABLE	ASSUMPTION	SOURCE
GENERAL		
Area of sugarcane	386,000 ha	Average over past 15 years (2003-2017); Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, 2017)
Cane yield per ha	86.4 tonnes per ha	Average over past 15 years (2003-2017); ABARES, 2017
Average cane production	33.35 million tonnes per annum	386,000 ha x 86.4 tonnes per ha
Sugar per tonne of cane	13%	Agtrans Research
Number of factories	24	Australian Sugar Milling Council (2018)
Average factory throughput	1.39 million tonnes per annum	33.35/24, but factory size varies about this average
NUMBER OF FACTORIES PROJECTED TO MAKE USE OF THE BLUEPRINT IN THE NEXT EIGHT YEARS		
Number of factories assumed to benefit from capital savings and reduced sucrose losses	4	Agtrans Research
Years of investment	2022, 2024, 2026, 2028	Agtrans Research
SAVED CAPITAL COSTS PER FACTORY		
Average capital expenditure without the blueprint	$27m per factory investing	Adapted from Final Report for SRA Project 2015/043
Average capital expenditure with the blueprint	$25m per factory investing	
Years of impact	2022, 2024, 2026, 2028	Agtrans Research

SAVED SUCROSE LOSSES PER FACTORY		
Assumed losses per factory without the blueprint	0.85%	Final Report for SRA Project 2015/043
Assumed losses per factory with the blueprint assumed to be 20% less	0.68%	Agtrans Research
First year of savings for each of the four factories	2022,2024, 2026,2028	
Years savings are made	Every year following first year of savings	
Value of sucrose ex-factory	$400 per tonne	Agtrans Research, based on Queensland Sugar Limited (http://www.qsl.com.au/sugar-prices/market-snapshot)
ATTRIBUTION TO PROJECT		
Attribution of impact	100%	Agtrans Research
RISK FACTORS		
Probability of outcome (assumed number of factories investing is four)	50%	Agtrans Research
Probability of impacts assumed (given successful outcomes)	75%	

8.2 Impacts identified but not valued

The increase in energy efficiency, the engineering capability enhancement and the spillovers to sugarcane communities were not valued specifically due to the difficulty of making credible assumptions. For example, it would be difficult to estimate any spillovers to regional communities from a marginal increase in profitability to factories via capital and operational savings. The capability enhancement impact was not valued due to the difficulty of valuing increased research capability due to the multiple pathways through which such an incremental gain could be delivered.

9 Results

All past costs and benefits were expressed in 2018/19-dollar terms using the Implicit Price Deflator for GDP. All benefits after 2018/19 were expressed in 2018/19-dollar terms. All costs and benefits were discounted to 2018/19 using a discount rate of 5%. A Re-investment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base analysis used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for a period of 30 years after the last year of investment (2017/18).

The investment criteria are reported for the total investment and the SRA investment in Tables 6 and 7.

TABLE 6: INVESTMENT CRITERIA FOR TOTAL INVESTMENT AND TOTAL BENEFITS (DISCOUNT RATE 5%)

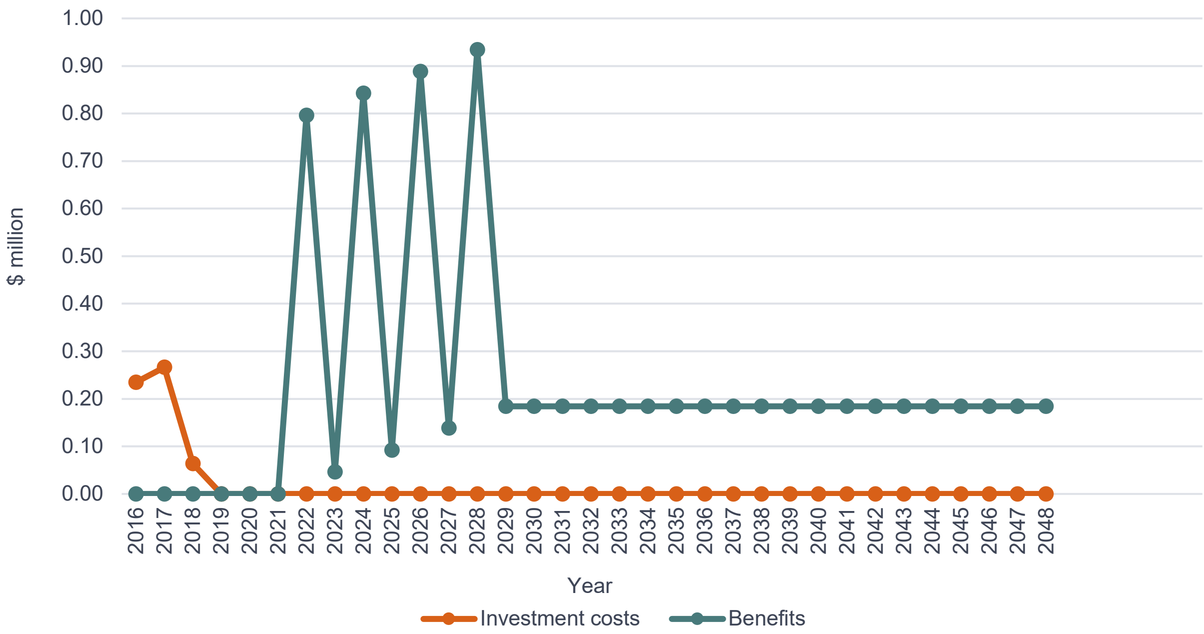
INVESTMENT CRITERIA	YEARS FROM LAST YEAR OF INVESTMENT						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	1.45	3.00	3.47	3.83	4.17	4.26
Present value of costs ($m)	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Net present value ($m)	-0.68	0.78	2.33	2.79	3.16	3.49	3.59
Benefit–cost ratio	0.00	2.15	4.44	5.13	5.68	6.17	6.31

Internal rate of return (%)	negative	18.6	26.4	27.0	27.2	27.2	27.2
Modified internal rate of return (%)	negative	27.2	23.9	18.0	15.0	12.9	11.9

TABLE 7: INVESTMENT CRITERIA FOR SRA INVESTMENT AND SRA BENEFITS (DISCOUNT RATE 5%)

INVESTMENT CRITERIA	YEARS FROM LAST YEAR OF INVESTMENT						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	1.21	2.50	2.89	3.19	3.47	3.55
Present value of costs ($m)	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Net present value ($m)	-0.56	0.65	1.94	2.33	2.63	2.91	2.99
Benefit–cost ratio	0.00	2.16	4.46	5.16	5.70	6.20	6.34
Internal rate of return (%)	negative	19.0	26.8	27.4	27.5	27.6	27.6
Modified internal rate of return (%)	negative	27.3	24.0	18.1	15.1	13.0	11.9

FIGURE 1: ANNUAL CASH FLOW OF UNDISCOUNTED BENEFITS AND COSTS



9.1 Source of benefits

The relative contributions of the two sources of benefits are provided in Table 8. Given the assumptions made, there was not a large difference between the two sources of impacts valued.

TABLE 8: CONTRIBUTION TO PRESENT VALUE OF BENEFITS PVB) FROM EACH SOURCE

SOURCE OF BENEFIT	CONTRIBUTION TO PVB ($M)	CONTRIBUTION TO PVB (%)
Capital savings	2.25	53
Operational savings	2.01	47
Total	4.26	100.0

9.2 Sensitivity analyses

Sensitivity analyses were carried out for several variables and results are reported in Tables 9 to 10. All sensitivity analyses were performed on the total investment only using a 5% discount rate (with the exception of Table 9) with benefits taken over the 30-year period. All other parameters were held at their base values.

Table 9 shows there is a moderately high sensitivity to the discount rate, largely due to the long period of time over which the benefits are delivered.

TABLE 9: SENSITIVITY TO DISCOUNT RATE (TOTAL INVESTMENT, 30 YEARS)

CRITERION	DISCOUNT RATE		
	0%	BASE (5%)	10%
Present value of benefits ($m)	7.42	4.26	2.79
Present value of costs ($m)	0.61	0.68	0.75
Net present value ($m)	6.82	3.59	2.04
Benefit-cost ratio	12.25	6.31	3.71

Table 10 provides a sensitivity analysis for the assumption regarding the risk factors associated with outcomes and impacts. Results show that the investment criteria are highly sensitive to changes in the risk assumptions.

TABLE 10: SENSITIVITY TO RISK ASSUMPTIONS ASSOCIATED WITH ASSUMED OUTCOMES AND IMPACTS. (TOTAL INVESTMENT, 5% DISCOUNT RATE, 30 YEARS)

CRITERION	ASSUMED LEVEL OF RISK FACTORS FOR OUTCOME AND IMPACT ASSUMPTIONS		
	25% AND 50% (PESSIMISTIC)	50% AND 75% (BASE)	75% AND 100% (OPTIMISTIC)
Present value of benefits ($m)	1.42	4.26	8.52
Present value of costs ($m)	0.68	0.68	0.68
Net present value ($m)	0.75	3.59	7.85
Benefit-cost ratio	2.10	6.31	12.62

10 Conclusions

Given the assumptions made on the value of impacts, the investment criteria estimated for total investment in the project of $0.68 million (present value of costs) were positive with an expected present value of benefits of $4.26 million, an expected net present value estimated at $3.59 million and an expected benefit-cost ratio of 6.31 to 1. All investment criteria were estimated using a discount rate of 5% and with benefits estimated over 30 years from the final year of investment. The internal rate of return was estimated at 27.2% and the modified internal rate of return at 11.9%.

As several impacts identified were not valued, the magnitude of the investment criteria estimated and reported are likely to be underestimated.

11 Acknowledgments

Ross Broadfoot, Professor, Science and Engineering Faculty, Queensland University of Technology

Harjeet Khanna, General Manager, Research Funding Unit, Sugar Research Australia

Felice Driver, Program Manager, Sugar Research Australia

Peter Samson, Program Manager, Sugar Research Australia

12 References

ABARES (2017) Australian Commodity Statistics, Accessed May 2019 at http://data.daff.gov.au/data/warehouse/agcstd9abcc002/agcstd9abcc0022017_IugZg/ACS_2017_v1.1.0.pdf

Australian Sugar Milling Council (2018). Statistics. Accessed April 2019 at https://asmc.com.au/industry-overview/statistics/

Council of Rural Research and Development Corporations. (2018). Cross-RDC Impact Assessment Program: Guidelines. Canberra: Council of Research and Development Corporations. Retrieved from http://www.ruralrdc.com.au/wp-content/uploads/2018/08/201804_RDC-IA-Guidelines-V.2.pdf

DAWR 2015, Rural Research and Development Priorities, Department of Agriculture and Water Resources, Canberra, ACT, accessed January 2016, http://www.agriculture.gov.au/ag-farm-food/innovation/priorities

Office of the Chief Scientist (OCS) (2015). Strategic Science and Research Priorities. Canberra: Commonwealth of Australia. Retrieved from http://www.chiefscientist.gov.au/wp-content/uploads/STRATEGIC-SCIENCE-AND-RESEARCH-PRIORITIES_181214web.pdf

SRA (2017) SRA Strategic Plan 2017/18 − 2021/22 Accessed August 2018 at: https://sugarresearch.com.au/wp-content/uploads/2017/09/Strategic-Plan-2017-_FINAL.pdf