How Healthy Are Your Advanced Controls?

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Introduction

There is a tendency to assume that the majority of benefits attainable through the application of advanced control technologies have been largely captured within the European refining industry. This is not the case. Although most sites have implemented the technologies, in many cases only a small portion of the available benefits has been realised. In fact the average site is achieving less than half what can be achieved. This paper initially poses questions that the reader should ask of his refinery. The answers to these questions will give a strong indication as to the health of the technology and to that of the refinery's attitude toward it. The paper then goes on to describe the problems commonly found and how these might be resolved.

Questions

Answers to the following questions will give a clear insight into a refinery's commitment to advanced control. If each question can be honestly answered "yes" then the site is likely to be capturing most of the available benefits, or at least will soon be doing so.

1. **Does the refinery manager ask "Why have we *not* got advanced control on this unit?" rather than "Why should we spend money on advanced control?".** The overwhelming majority of European refinery units now have DCS. This means that the additional cost of implementing advanced control will be small compared to the benefits. On major process units the payback could be less than three months. It does not need a rigorous return on investment calculation to decide whether the project would be attractive.

2. **Does investment in financial accounting software get the same detailed scrutiny as investment in advanced control?** It is not uncommon for oil companies to spend in excess of $5m on a project to install a modern integrated financial system. Usually such projects are approved with little consideration of return on investment. They are

considered strategically important. A similar investment in advanced control could readily generate benefits of $15m/yr - considerably more than the benefits arising from accounting systems. Yet in many companies it is difficult to get approval for even a modest investment in advanced control.

3. **Does the refinery give the same priority to advanced control as it does to vital process equipment?** Imagine the plant manager is faced with the imminent failure of equipment essential to plant operation. To minimise lost production he is likely to arrange 24-hour maintenance work and spare no cost in obtaining spare parts. Let us assume that, as a result of giving the work such priority, it is completed 24 hours sooner than would otherwise be the case. If such an event happens once a year he has effectively increased capacity utilisation by about 0.3%. Now imagine there is an advanced control strategy that is capable of increasing feed rate by 2%. Because of instrument problems it is only achieving an 80% service factor. Experience shows that a 95% service factor is feasible. Achieving this would also increase capacity utilisation by about 0.3%. Does the necessary instrument work get treated with the same urgency?

4. **Has the financial director noticed the profit improvement generated by advanced control?** If the improvement is real then he should have done. Benefits are generally accepted to be about 20 cents per barrel of crude, rising to 40 cents if closed-loop optimisation is installed. These numbers are close to, or even exceed, current refining margins. If detailed statistical analysis of process performance is necessary to demonstrate benefit capture then the chances are that the benefits are minor. If they are as large as they should be then the improvement would be obvious without such analysis.

5. **Does the refinery recognise that the advanced control section may be able to change a loss-making site into profit-making one or vice-versa?** If the benefits are comparable to the profit margin then this is exactly the situation. Is the group properly resourced, properly integrated with the rest of the business and properly held accountable? If it were your business, would you give responsibility for the majority of your company's profits solely to a group of inexperienced engineers? Some sites do exactly this.

6. **Is the planning and economics section involved in the development and support of the advanced controls?** Many sites will involve the section during the design stage. The more successful sites have regular meetings to discuss advanced control performance. These are attended by the plant manager, process engineer and planner. On such sites the planners and process engineers are aware that advanced controls are automating part of their job. They need to ensure that, as economics and process performance change, this continues to be done correctly.

7. **Does the refinery management receive and read regular performance reports for the advanced controls?** Many sites produce regular reports but often they do not show the economic impact and (worse) they are often only given cursory attention by management. In some sites one wonders whether the management would prefer not to know, or have made public, that the investment in advanced control has not realised the benefits that were claimed at the approval stage.

Basic Controls

Despite general acknowledgement that basic control strategies must operate correctly before advanced control is commissioned, there are still many examples where they are given insufficient attention. Many sites permit instrument problems to continue unresolved. It is common to find sites where a large proportion of key controllers are operating outside of transmitter ranges or with incorrectly sized control valves. Many mechanical problems, such as transmitter failures and sticking valves, are not treated with the priority they merit.

Many controllers are poorly tuned. Probably the most common example is averaging level control. In many situations level controllers can be used to exploit surge capacity within the process. This can result in much reduced flow disturbances - often resulting in remarkable improvements to process stability. Most control engineers know this, but relatively few properly calculate or properly implement the correct tuning. Figure 1 shows how changing to averaging control permits the level to vary (between alarm limits), thus smoothing the downstream flow.

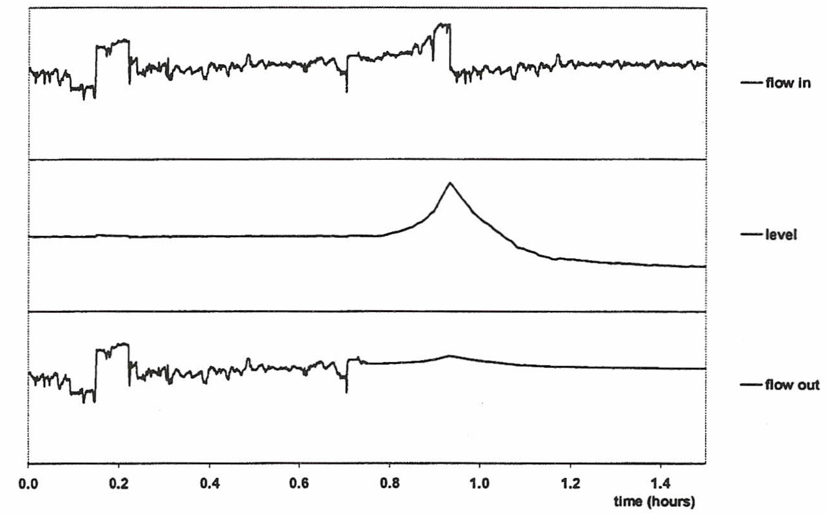


Figure 1 *Impact of changing to averaging level control*

Other examples include incorrect selection of the type of PID algorithm. Most DCS support many versions of this algorithm but few users appreciate the purpose of each and their relative merits. Figure 2, produced by Whitehouse's training software, shows how correct selection can significantly improve the control response to process disturbances - in this case a change in feed rate. On real processes it is common to be able to improve the recovery time for most disturbances by a factor of three - yet few companies take proper advantage of this.

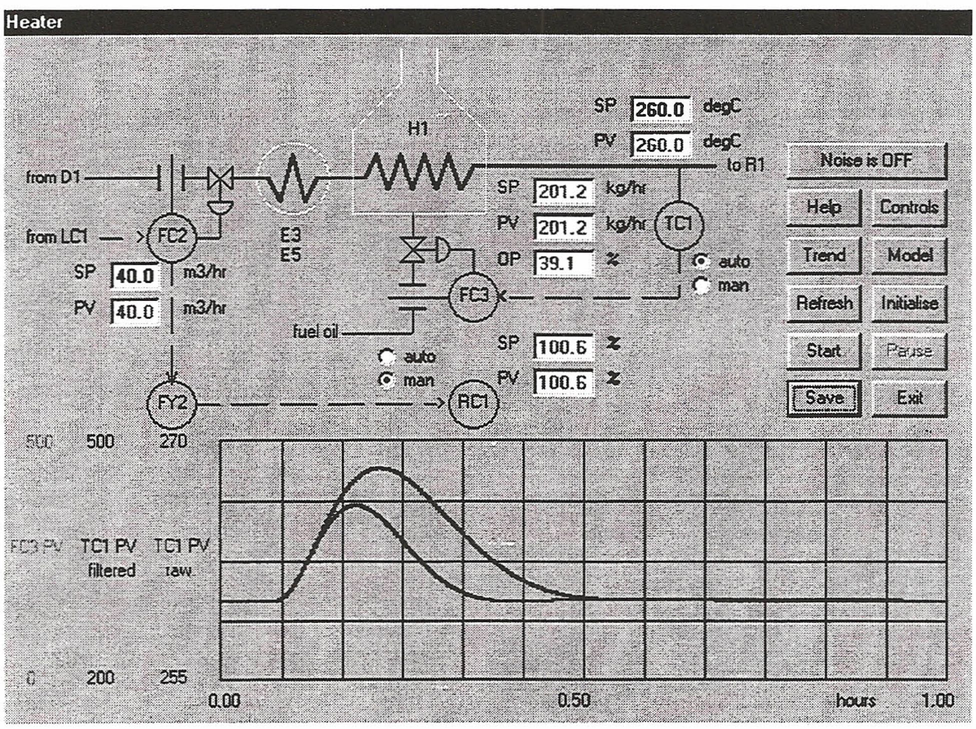


Figure 2 *Reducing recovery time with correct control algorithm selection*

Inferential Properties

Accurate inferential property calculations may permit effective measurement without the need for on-stream analysers. This is particularly attractive to those sites that have difficulty maintaining them. There are also many situations where the property cannot be measured directly. Even if on-stream analysers are installed, the dynamic advantage of inferential properties will improve quality control. On many sites however inferential properties are bringing little advantage and, in many cases, actually having a negative impact. Figure 3 shows both a line plot, typically used for validating the predicted quality against that measured by the laboratory or on-stream analyser, and an X-Y plot. Many would interpret the line plot as a prediction sufficiently reliable to be used as part of a control strategy. The X-Y plot shows there is some relation between predicted and measured, but results in much less confidence. The accuracy is approximately 20% of the measurement range - a large potential error when compared to the variation of about 60% in the property.

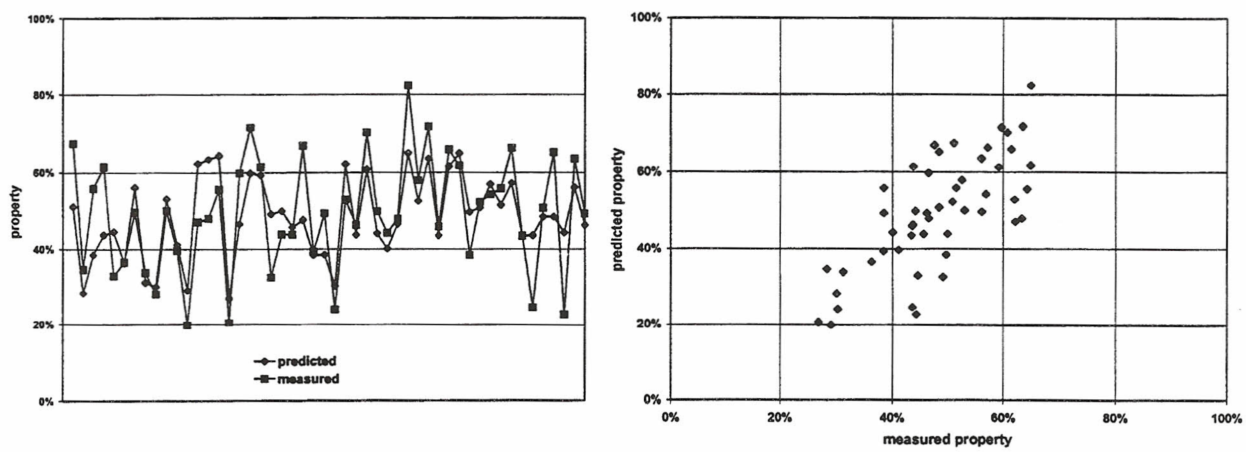


Figure 3 Validating inferential property calculations

Both plots tend to give an indication of the average behaviour of the prediction. The same data has been used to produce Figure 4. This is an indication of how useful the prediction is over time. On average the prediction would permit a reduction of about 30% of the quality giveaway. However for about 10% of the time its contribution is negative, in other words switching off the controller during these periods would improve quality control.

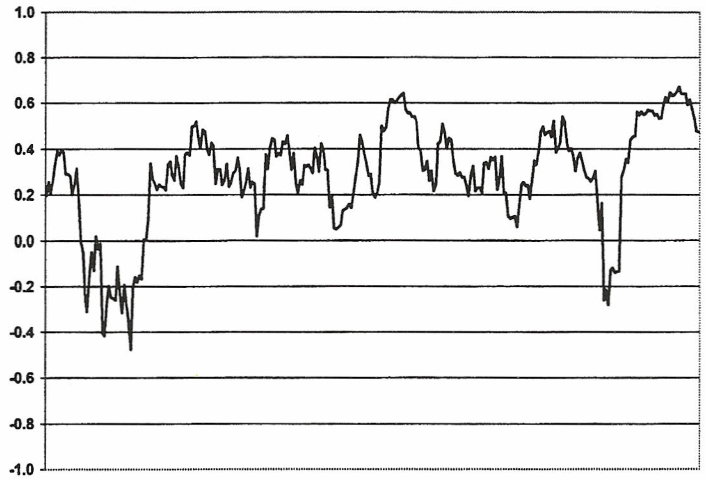


Figure 4 *Measuring the potential improvement*

Such problems usually arise because the inferential calculation has been derived by regressing historically collected process data. Such data may be unreliable, particularly if laboratory data is not accurately time-stamped. Usually there is not enough variation in process conditions to enable the effect to be separated from noise. It may be that the data were collected during plant tests. The model developed may have fitted the data collected at the time but does not work well with the current operation. Neural networks fare little better, particularly as most are simply based on a non-linear regression.

An alternative approach is to install rigorous models. These are difficult to maintain and, because of the number of instruments involved, are often unreliable. The best solution is an intelligent mixture of both approaches, keeping sufficient rigour to maintain accuracy without it becoming impractical. Since process units vary in design and performance, there is no standard design of inferential. Each has to be engineered individually.

Economics

Now be honest. When the multivariable controller was first installed, were real refinery economic factors used or were they adjusted to force the controller to be consistent with the established operating strategy? There are a large number of controllers that are better achieving the *wrong* objective. In other words, commissioning them has reduced refinery profitability. The use of artificial economics often arises because the use of true economics results in the controller implementing a strategy different to that generally accepted to be correct. Remember that the controller is making an objective decision. It is not bound by years of tradition. Provided the process gains are correct and complete then the chances are that the change in strategy is indeed correct. There are many examples of spectacular increases in profitability which have arisen from placing more faith in the controller.

Figure 5 shows a simple example based on a C3/C4 splitter. The controller has two control variables (CVs) - the two product qualities. It has two manipulated variables (MVs) - reflux and reboil.

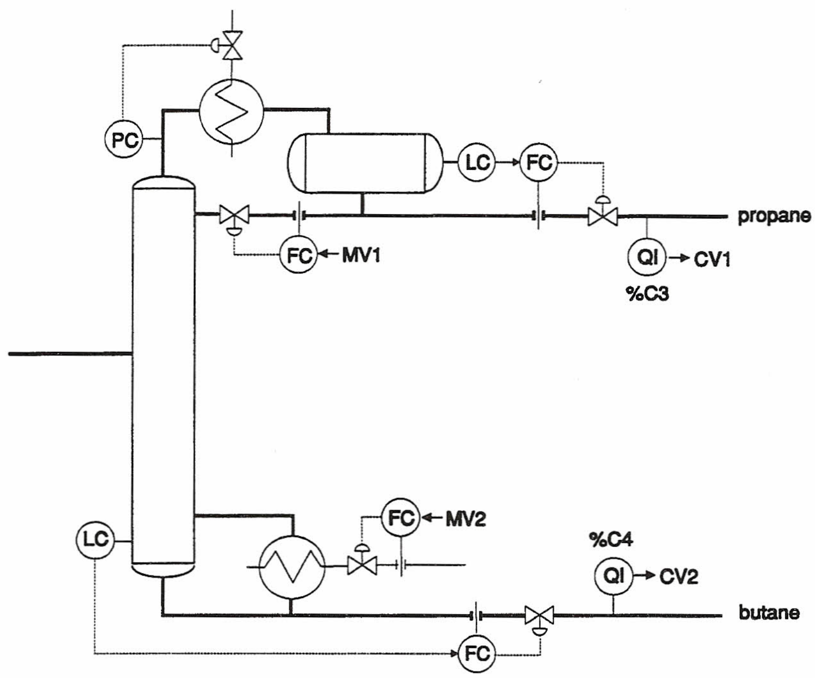


Figure 5 C3/C4 splitter

Figure 6 shows the operating constraints for this column. The established operating strategy is to attempt to exactly meet both product quality specifications. This corresponds to the minimum energy case. In practice there will be other constraints to be acknowledged such as condenser duty, flooding etc. Shown on the drawing is also a maximum reboiler duty limit. Using real economics in the controller may drive the process towards maximum propane recovery or maximum butane recovery. By over-riding these economics we can force the controller to the minimum energy case. Assuming that the process, before advanced control, was operated with some quality giveaway then commissioning such a controller will reduce profitability.

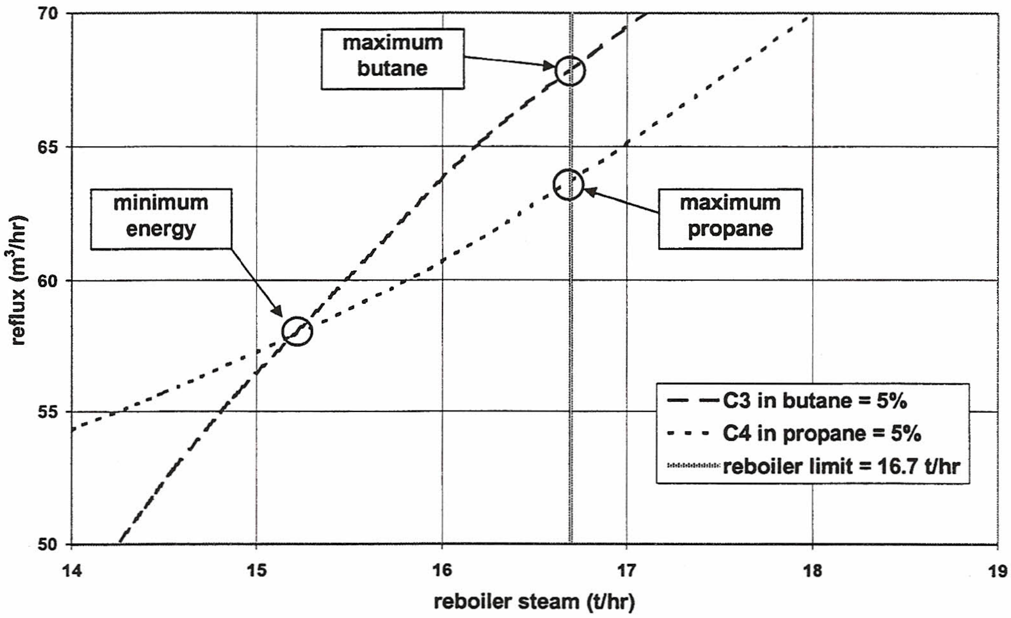


Figure 6 Use of true process economics can influence the operating strategy

This is of course a very simple example. Controllers however are becoming much larger. There are several examples where a single controller covers several processes. It is unlikely that the refinery has explored every operating strategy and cannot therefore be confident that the established operation is optimised. Further, as the scope extends to reach battery limits, it becomes more meaningful to apply real product pricing rather than attempt to value intermediate products. Most refiners recognise the benefit of ultimately putting the refinery LP into closed loop, but few have exploited even the partial solution currently on offer.

Constraints

Most users of multivariable control claim very high service factors, often in excess of 95%. Usually this means the up-time of the controller and takes little account of what the controller is actually achieving. The most common problem is over-constraining the manipulated variables. If all MVs are at a constraint the controller is effectively doing nothing. Figure 7 illustrates the impact this has on the C3/C4 splitter. The operator has imposed limits on both MVs, effectively preventing the controller from reaching the optimum operating point. Presumably when he sees the laboratory results he will change the limits to meet the specifications - much like he did before the advanced control was installed!

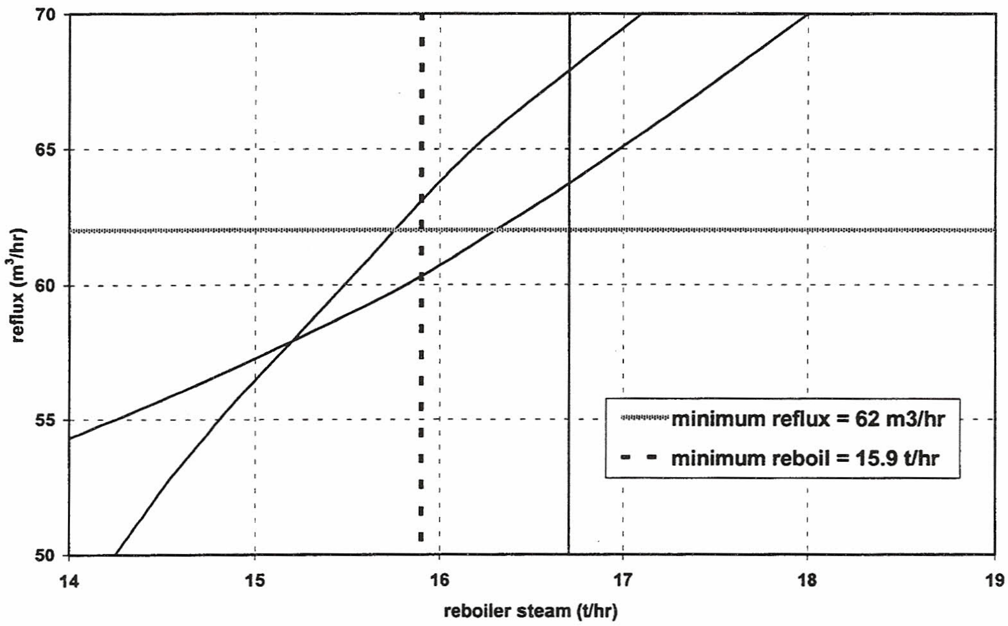
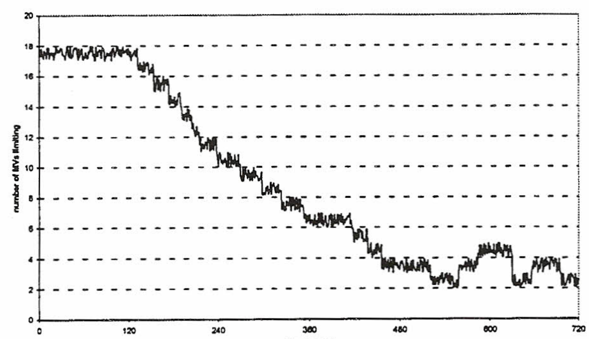


Figure 7 Over-constraining the controller

Such over-constraining usually arises gradually. Operators will tighten constraints when there are operating problems or because they wish to take over more of the control themselves. They usually need to be prompted to relax constraints - usually by the control engineer or, preferably, by the plant manager. Providing effective monitoring tools is important to this activity. Figure 8 shows ways in which this might be achieved - firstly by monitoring the number of MVs that are limiting, secondly by monitoring each MV and its limits.



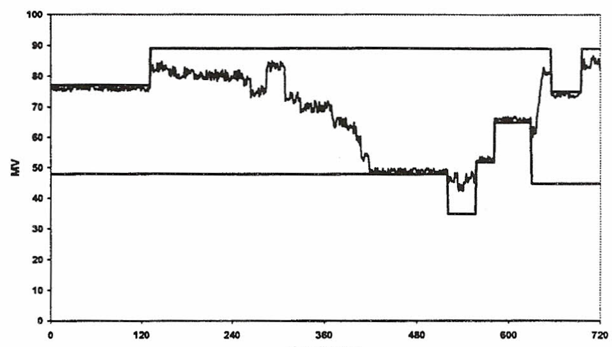


Figure 8 Monitoring MV constraints

Summary

Given the volume of crude processed in European refineries then, on the basis of 20 cents per barrel, the total benefits achievable with advanced control exceeds $1,000m/yr. Figure 9 summarises the benefits actually achieved. Specifically it shows that 50% of the refineries have captured about 40% of the benefits. Extended across Europe, this suggests that about $600m/yr remain. Assuming that about 80% of the major units have some form of advanced control, about $200m/yr of this shortfall can be accounted for because refineries have yet to install the necessary technologies. The remaining $400m/yr requires only that existing advanced controls be upgraded and better utilised.

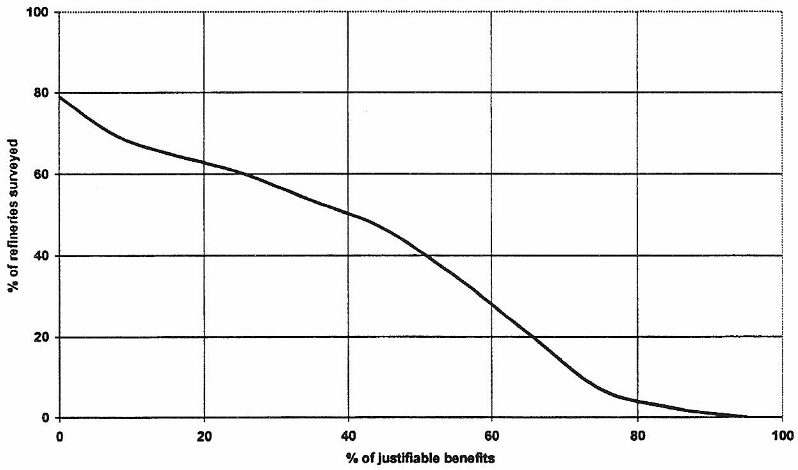


Figure 9 Benefits captured in Europe