Benefits of the Remanufacturing Exclusion:

Background Document in Support of the Definition of Solid Waste Rule

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Benefit Estimates for the Proposed Remanufacturing Exclusion under the Definition of Solid Waste

Benefit Measures and Main Data Sources

In this document, EPA is making preliminary estimates of projected environmental and economic benefits of the proposed Remanufacturing Exclusion. Some estimates will be quantified, and others will be discussed in more qualitative terms. Some societal benefits would occur on a national scale, some will be on a regional scale, and some will be on a local scale.   The quantified estimates are also depicted in an accompanying Excel spreadsheet format ("Table in Support of Technical Document: Benefits of Remanufacturing Exclusion").

- The national (and global) benefits will be reductions in greenhouse gas emissions, which affect global warming.
- The regional and local benefits will be reductions in air emissions in the vicinity of incinerator and cement kiln sites, and also reductions in air emissions and water emissions at some plants making specialty solvents.
- Local benefits could also accrue from not injecting waste solvents underground at chemical processing plants, and from reducing vehicle miles traveled (and associated air emissions) in transport of used solvents. Given the technical containment standards proposed for the Exclusion, and the economic incentive for remanufacturers to sell or use the remanufactured solvent,[1] EPA expects local communities will be adequately protected from risks posed by discarded or released spent solvents.

EPA is using these units to measure environmental and economic benefits:

- Annual metric tons of carbon dioxide equivalent (MTCO2e) for greenhouse gas emissions avoided,
- Annual pounds and tons for hazardous chemical releases to land, air, and water,
- Annual gallons for water saved, and
- Annual dollars for economic savings.

The main data sources that EPA used in developing these estimates are:

- The Toxics Release Inventory (TRI) Database
  - This provided 2008 emissions and transfers for the 16 TRI-reported solvents in the exclusion.
- Chemical Economics Handbook, SRI Consulting, Menlo Park, CA [2]
  - This provided production data on tetrahydrofuran (THF) (from October 2010) and ethanol (April 2009). EPA used the production data to estimate spent-THF numbers and, with further calculations, to estimate spent-ethanol numbers.
- ICIS Chemical Business (periodical) and www.alibaba.com
  - These sources provided chemical pricing numbers.

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[1] See discussion on pages 5-6 (technical containment standards under the exclusion are the same as those under RCRA Subtitle C for hazardous waste; further, it is expected remanufacturers will only realize an economic value from their activities by selling or using the remanufactured solvent, so there is little incentive for abandonment or discard).

[2] Source: IHS Inc. The use of this content was authorized in advance by IHS. Any further use or redistribution of this content is strictly prohibited without written permission by IHS. All rights reserved.

- The GlaxoSmithKline Life Cycle Assessment Waste Treatment Module (as modified by EPA)
  - This model provided formula calculations for
    - rates of distillation recovery;
    - energy use for disposal, re-manufacturing, and manufacturing;
    - distribution of releases to air, land, and water from disposal, re-manufacturing, and manufacturing;
    - emission-reduction benefits from avoided disposal of spent solvents and avoided manufacturing of virgin solvents; and,
    - life-cycle emission reductions from the use of natural gas.
- GlaxoSmithKline
  - Consultation with GSK technical expert provided chemical synthesis pathways for various solvents.
- Commercial carriers and hazardous waste haulers
  - Consultation provided information on shipping costs.
- The Energy Information Administration at the U.S. Department of Energy
  - Consultation provided insight on factors affecting avoided manufacturing and energy values for chemical feed stocks.

Discussion and Calculation of Estimated Benefits

The following provides details on each category of estimated benefits. The discussion under "Metric tons of carbon dioxide equivalents reduced" supplies some context on the chemical industry that is useful for understanding all the benefit categories.

Analytic approach

The analytic approach that EPA used for estimating quantities of benefits is as follows:
- Sum all 2008 waste disposal and waste transfer quantities (but no 2008 recycling quantities) for the 18 spent solvents used for the functions and by the sectors described in the Exclusion;
- Apply a 92% rate of commercial-grade recovery [3] to total spent solvents disposed in 2008, except for spent methanol and ethanol;
- Apply a 75% rate of commercial-grade recovery to spent methanol and ethanol disposed in 2008;
- Estimate the net benefits of avoiding disposal for all solvents recovered to commercial grade;
- Estimate the net benefits of avoiding manufacture of virgin solvents for the recovered specialty solvents; [4]
- Skip estimating the net benefits of avoiding manufacture of virgin solvents for the recovered commodity solvents because commodity solvents are manufactured as co-products [5] and manufacture of virgin solvents may, in fact, not be avoided;

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[3] EPA's modeling is based on distillation technology, and 92% is the rate of recovery for two-time distillation of solvents [The first distillation yields 75%; the second distillation of the 25% distillation bottoms from the first run yields an additional 18%.]. This recovery rate is often achievable with just one distillation, for solvents used just as chemical processing aides, which is the function covered by the Remanufacturing Exclusion. Evaporation-condensation technology can also be used to achieve higher rates of recovery.

[4] Under the Remanufacturing Exclusion, the specialty solvents are acetonitrile, chlorobenzene, chloroform, chlorobenzene, dichloromethane, methyl isobutyl ketone, methyl tert-butyl ether (?), dimethylformamide, and tetrahydrofuran.

[5] One unit operation produces multiple chemical products simultaneously, where each product is stripped off sequentially, so a market shift for one product may or may not drive a change in the whole unit operation.

- Provide a range of possible rates (10%, 25%, 50%, and 75%) at which solvents currently disposed will instead be re-manufactured under the Exclusion; and,
- Provide the correlative range of net benefit rates (10%, 25%, 50%, and 75%) to match the range of re-manufacturing rates.

1. Metric tons of carbon dioxide equivalents reduced

Discussion

The International Energy Agency[6] noted in 2006 that the chemical (including petrochemical) industry accounted for more than 30% of total industry energy use worldwide, with more than half of it tied up in feedstock use. The CO_2 emission intensity of the industry is low[7] because significant amounts of carbon are stored in the products produced.[8] The total share of industrial CO_2 emissions from the sector would be larger if the stored carbon were accounted for. The oil and natural gas feed stocks used to make chemical products account for more than half the energy used in the chemical sector. Feed stock products release their energy and carbon content only at the end of their useful life, when they are incinerated or burned as fuel.

Reduce GHG impacts through re-manufacturing feed stocks. Since the energy in chemical feed stocks is stored, energy efficiency is not a choice for reducing the GHG impacts of the energy in feed stocks. The option is, rather, to get as much use out of the feedstock as practical, so that the rate at which solvents release their energy (and carbon) can be slowed down. This approach shifts the opportunity for reducing GHG impacts from the solvent manufacturer to the solvent processor (the facility processing the solvent in the manufacture of other chemicals). Some solvent processors, especially the large basic organic chemical manufacturers, have already found they can extend the useful life of their solvent feed stocks – they distill or condense their spent solvents in a closed-loop process on site, rendering them clean for use again. The benefit to the solvent processor from using its own facility operations this way is that it can reuse solvent already paid for, reducing feedstock and waste hauling costs. The benefit to society from this arrangement is the slower rate at which solvents release their carbon into the atmosphere.

Analysis supporting this Exclusion shows, in contrast to the multi-use example above, that many chemical processors use solvents purchased for chemical processing just one time. This increases feedstock costs (since feed stocks must constantly be replenished), increases waste hauling costs (since once-used solvents must constantly be disposed of), and increases the rate at which solvents release carbon into the atmosphere. Creation and destruction are the most GHG-intensive stages in solvent life[9], and single use provides just a brief interlude between these two GHG-intensive stages.

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[6] Tracking Industrial Energy Efficiency and CO2 Emissions, In support of the G8 Plan of Action, International Energy Agency, 2007, http://www.iea.org/textbase/nppdf/free/2007/tracking_emissions.pdf, Chapter 4 Chemical and Petrochemical Industry, pages 59-62.

[7] The chemical industry has already made large gains in energy efficiency although, as of 2003, North American steam crackers were still about 30% less energy efficient than Asian steam crackers. Id. at 59 and 70.

[8] In this context, stored means the carbon is unavailable for release into the atmosphere.

[9] Gonzalez, Overcash and Curzons, Waste Treatment Modules – a Partial Life Cycle Inventory, Journal of Chemical Technology and Biotechnology, 76: 707-706, 2001; see also Treatment Modules LCI Calculations, EPA TRI Solvents, Incineration only, prepared by Conchita Gonzalez, GlaxoSmithKline, March, 2008.

Deciding to not reclaim used solvent on-site could result from lack of capacity to distill or condense them, or lack of other cost-effective regulatory options to date (getting a RCRA permit has not been perceived as cost-effective). This exclusion proposes to remove an obstacle to environmentally-protective re-manufacture of solvents, to lengthen their useful life and slow their rate of carbon emissions.

Reduce GHG impacts by making fewer virgin solvents. Is there any opportunity for the solvent manufacturers themselves to reduce the GHG intensity of the solvent feed stocks they produce?   One apparent option would be that, if existing solvents are reused, the decrease in demand for virgin solvents would lead to reduced manufacture of those solvents. As noted in Footnote 1 above, this is likely more true for specialty solvents than commodity solvents which are made as co-products. Specialty solvents like tetrahydrofuran involve more unit operations that in the latter stages are focused just on producing the specific specialty chemical desired. Here it may be more straightforward to conclude that the additional energy and feedstock-based GHG benefits from avoided manufacturing should be included in the estimate of Re-Manufacturing Exclusion benefits.

Calculations
For the 18 solvents listed in the Exclusion, the Agency ran calculations to estimate reduced GHG emissions from one-time avoided disposal of all 18 solvents and one-time avoided manufacturing of the specialty solvents. (If disposal of solvents and manufacture of specialty solvents are avoided more than one time, then benefits would increase.) For 16 chemicals, release and transfer data came from 2008 TRI reports. For the two chemicals not reported under TRI, EPA extrapolated from production data in the Chemical Economics Handbook (April 2009 production data for ethanol[10] and October 2010 production data for tetrahydrofuran).[11]

Apply manufacturing and processing variables. The variables producing estimated *annual GHG emissions* are given as follows in metric tons (MT):
- 52,629 metric tons of natural gas used as fuel in 2008 incineration of spent solvents (198,178 MTCO2e released)
- 112,083 metric tons of spent solvents incinerated in 2008 (217,264 MTCO2e released)
- 107,527 metric tons of solvents burned as fuel in a cement kiln in 2008 (241,029 MTCO2e released)
- 320,449 metric tons of steam used to distill solvents twice[12] in 2008 from 2008 closed-loop recycling of spent solvents (74,904 MTCO2e released)

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[10] For ethanol, EPA set its mass at 1/4 of methanol mass used for the functions covered in the exclusion, based on the ratio of methanol to ethanol used in pharmaceutical manufacturing. (The quantity of ethanol produced for solvent use broadly is high, and EPA scaled back the number to better match the functional use of solvents under the Exclusion.) EPA distributed total ethanol-related emissions according to the distribution of total methanol-related emissions. EPA's estimate of ethanol use as a chemical manufacturing and processing aid may be high, and public input on this estimate is encouraged.

[11]For THF, EPA divided its production mass 30/50/15 between the pharmaceutical, plastics/resin and other sectors, and then counted only ½ the plastics/resins share (EPA estimates only ½ is used as processing aid solvent). EPA distributed THF-related emissions across emission categories in each sector according to the distribution of totaled solvent-related emissions across emission categories in that sector.

[12] EPA calculated the steam used for two-time distillation, instead of one-time distillation, to be conservative. EPA is aware of several instances where 92% recovery is currently being achieved through one-time distillation, but did not extrapolate this capability across all scenarios to keep the EPA estimate conservative.

- 12,407 metric tons of distillation bottoms incinerated in 2008 from 2008 closed-loop recycling of spent solvents (47,138 MTCO2e released)
- 13,229 metric tons of distillation bottoms burned for energy in 2008 from 2008 closed-loop recycling of spent solvents (30,350 MTCO2e released)
- 294,813 metric tons of virgin specialty solvents not manufactured (99,497 MTCO2e not released; [negative] -99,497 MCO2e)
- Projected 239,186 metric tons of steam used to distill solvents (previously sent to underground injection, incineration, or energy recovery) under the remanufacturing exclusion (50,942 MCO2e).
- Projected 9,362 metric tons of distillation bottoms incinerated after the new distillation of solvents (previously sent to underground injection, incineration, or energy recovery) under the remanufacturing exclusion (34,360 MTCO2e).
- Projected 9,053 metric tons of distillation bottoms burned for energy after the new distillation of solvents (previously sent to underground injection, incineration, or energy recovery) under the remanufacturing exclusion (20,130 MTCO2e).
- Projected 211,771 metric tons of virgin specialty solvents not manufactured as a result of the new remanufacture of spent specialty solvents under the remanufacturing exclusion (139,995 MTCO2e not released; [negative] -139,995 MTCO2e).

Sum the manufacturing and processing variables. The totals from above are:
- Total solvent mass involved in calculations: 546,877 metric tons
- Total end-of-life GHG emissions (no offset for avoided manufacturing of specialty solvents) prior to remanufacturing exclusion: **805,925 MTCO2e**.
- Total end-of-life GHG emissions (with offset for avoided manufacturing of specialty solvents) prior to remanufacturing exclusion: **706,428 MTCO2e**.
- Total new end-of-life GHG emissions (reflecting avoided disposal but not avoided manufacturing of specialty solvents) after remanufacturing exclusion, calculated at 100% potential impact: **257,826 MTCO2e**.
- Total new end-of-life GHG emissions (reflecting both avoided disposal and avoided manufacturing of specialty solvents) after remanufacturing exclusion, calculated at 100% potential impact: **18,334 MTCO2e**.

Net benefit of the remanufacturing exclusion on GHG emissions
- The difference between end-of-life GHG emissions before and after the remanufacturing exclusion, not counting avoided manufacturing of specialty solvents: 805,925 MTCO2e – 257,826 MTCO2e = **548,099 MTCO2e reduced per year**.
- The difference between end-of-life GHG emissions before and after the remanufacturing exclusion, counting avoided manufacturing of specialty solvents: 706,428 MTCO2e – 18,334 MTCO2e = **688,094 MTCO2e reduced per year**.

Qualitative estimate of transportation reductions. The Agency estimates that GHG emissions will also be reduced from transportation, due to the likelihood that chemical shipments under the remanufacturing exclusion will altogether be accomplished with less mileage traveled, which would reduce the transport fuel combusted, and thus the GHG emissions. Since it is difficult to predict how much less distance will be traveled, the Agency will simply estimate, with quantifying, that there will be some additional reduction in GHG emissions associated with reduced transport.

2. Pounds/Tons of Hazardous Chemical Releases (to Land, Air, and Water) Reduced

Discussion
Reductions in pounds of hazardous chemical releases are anticipated to be regional and local benefits of the remanufacturing exclusion. Hazardous chemical releases to air should be reduced in the vicinity of incinerator and cement kiln sites, and air emissions and water emissions should be reduced at some plants making specialty solvents.   Local benefits could also accrue from not injecting waste solvents underground at chemical processing plants, and from reducing vehicle miles traveled (and associated air emissions) in transport of used solvents.

EPA expects there will be no significant local risk of environmental damage from discarded or released spent solvents. Since the technical containment standard under the remanufacturing exclusion is equivalent to that under RCRA Subtitle C for permitted hazardous waste facilities, EPA expects a level of protection for local communities equal to that under RCRA Subtitle C. Further, the potential for discard in inter-company remanufacturing transfers is low because economic incentives would be to sell or directly use (avoiding purchase of virgin product) the remanufactured solvent products to realize an economic value. Unlike the RCRA-permitted waste handler which can charge a considerable fee for receiving discarded waste, companies whose primary business is the sale of a commercial product do not operate under the same market forces as commercial recyclers, whose profit depends on maximizing the amount of hazardous secondary material accepted, creating a perverse market incentive to over-accumulate hazardous secondary material, which can result in discard. It is not intended that the exclusion could be used by a commercial recycler even if it undertook reclamation operations involving the chemicals and chemical functions described in the exclusion.   Commercial recyclers are best regulated by RCRA hazardous waste standards since waste handling is their primary business and RCRA standards are the primary governing standards for this line of business.

A company receiving these higher-value hazardous secondary materials for remanufacturing is expected to realize most of its profit from the sale or use of remanufactured solvents. A company sending these solvents for remanufacturing is expected to have little economic incentive to pay the receiving company more than a nominal amount of money, since it would already be transferring something of intrinsic market value (materials that can be easily remanufactured for profit).

Calculations
The total net annual benefit in reduced hazardous releases to air, land, and water provided by the remanufacturing exclusion is itemized below by each benefit or sub-benefit category. Net benefit takes into account emissions from new distillation, incineration of new distillation bottoms, burning the remainder of new distillation bottoms for energy[13], and avoided emissions from avoided manufacturing of specialty solvents. Estimated quantity of avoided carbon monoxide air emissions are 2,676 metric tons (5,899,509 pounds).

- Estimated quantity of avoided volatile organic compounds air emissions are 321 metric tons (707,677 pounds)
- Estimated quantity of avoided NOx air emissions are 497 metric tons (1,095,686 pounds)
- Estimated quantity of avoided SOx air emissions are 2,449 metric tons (5,399,065 pounds)

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[13] EPA applied the ratio found in existing distillation activities (the ratio of distillation bottoms incinerated to distillation bottoms recovered for energy) and applied it to anticipated (new) distillation activities.

- Estimated quantity of avoided Total Organic Carbon water releases are 381 metric tons (839,953 pounds)
- Estimated quantity of avoided Biological Oxygen Demand water releases are 67 metric tons (147,708 pounds)
- Estimated quantity of avoided Chemical Oxygen Demand water releases are 1,483 metric tons (3,269,422 pounds)
- Estimated quantity of avoided Total Dissolved Solids water releases are 17,390 metric tons (38,337,994 pounds)
- Estimated quantity of avoided solid wastes are 3,764 metric tons (8,298,114)

3. Gallons of Water Saved

There are two scenarios under the Re-Manufacturing Exclusion for saving water which can be described in qualitative terms. Both of them involve very site-specific process design, and there are insufficient data to make a quantified estimate of potential water saving benefits.

The first way would be if specialty solvents listed in the Exclusion are re-manufactured and this avoids the manufacture of some virgin specialty solvents. It is likely that some amount of water attributable to the chemical manufacturing process would be saved by avoiding manufacturing.

The second way would be to divert some of the spent methanol or spent ethanol from re-manufacturing and use either of them directly in a heat exchange system that would otherwise operate using water. A heat exchange system sends (pipes) already-hot liquid to a process needing heat, so the contained liquid's heat value is used instead of a fuel's heating value. Adding a heat exchange system is a capital investment with a positive payback in avoided fuel costs.

4. Dollars Saved

Discussion
The opportunity for economic savings is associated with avoiding energy costs (energy costs can be half of chemical production costs), selling remanufactured solvents (or using them to avoid buying new ones), avoiding hazardous waste disposal and shipping costs, and counting the societal benefit (dollars per ton of avoided greenhouse gas emissions).

The Agency projects that both the generator and the re-manufacturer would realize economic savings. The generator would avoid: (1) hazardous waste fuel blending costs; (2) the premium paid for shipping spent solvents under a hazardous waste manifest; and, (3) on average, likely some mileage costs, as a result of some shipments going shorter distances. The remanufacturer would realize an economic benefit from selling remanufactured solvent or using it in place of buying virgin solvent, offset by its costs of remanufacturing.

To the extent the manufacture of virgin specialty solvents is avoided, the manufacturer could likely engage in remanufacturing activities to offset any loss from manufacturing virgin solvent; in the generally expanding global chemical market, however, this may not even be needed.

With regard to shipping costs, the one thing that the Agency has quantified on a price per pound basis is fuel blending costs,[14] which is a component of the expense of shipping hazardous waste to a cement kiln or an incinerator. Solvents must be blended in the appropriate ratios for burning under either scenario. Other aspects of shipping costs the Agency is addressing in a more qualitative way. In comparing the costs of shipping on a RCRA hazardous waste manifest (for hazardous waste)versus a commercial bill of lading (for hazardous chemicals), the Agency initially concludes that shipping on a manifest may cost about 25% more than shipping commercially.[15] To use this percentage factor in a quantitative way, the Agency would need to estimate some quantity of shipments, which it has not done, since too many variables remain unknown. The Agency will observe, however, after evaluating current shipping routes for hazardous waste and the location of plant sites that would be eligible to benefit from the remanufacturing exclusion, that it is very likely that there would be a net reduction in mileage for transporting spent solvent. The Agency considers it likely, then, that there would be cost savings not only from switching to commercial shipping, but also from reducing transport miles, since prices for shipping (be it for hazardous waste or hazardous chemicals)consider mileage as a factor. [16]

The Agency considers there may be other opportunities for cost savings that are unique to methanol and ethanol. One of these opportunities could involve avoiding energy costs from installing a dedicated methanol or ethanol-based heat-exchange system. As noted above under the "water savings" discussion, a heat exchange system sends (pipes) already-hot liquid to a process requiring heat, so the contained liquid's heat value can be used instead of a fuel's heating value. Adding a heat exchange system is a capital investment with a positive payback in avoided fuel costs. Since there are many pricing factors involved, the Agency is simply using the resale value of methanol and ethanol as a conservative placeholder for the value of applying some of the methanol and ethanol to a heat-exchange system instead. It is likely that the resale value of methanol and ethanol is a very conservative estimate of the economic benefit associated with applying some of the methanol and ethanol to a heat-exchange system.

Calculations
The variables consist of **annual cost savings** from:
- The generator avoids fuel blending fees: 219,610 metric tons of used solvent no longer incinerated or recovered for energy (this avoids fuel blending fees of $.02 a pound for incineration and energy recovery, yielding **$9,680,409** in savings)

- The generator avoids the premium paid for shipping spent solvents on a hazardous waste manifest:
  - Avoided premium paid for shipping spent solvents on a hazardous waste manifest: (Consultation with shippers indicates there is a premium paid for shipping spent solvent under a hazardous waste manifest.) To estimate avoided manifest shipping costs, offset by estimated bill of lading costs, the Agency is using a conservative placeholder value of **$5,000,000**.
  - Avoided transportation mileage as a component of shipping fees (the Agency is using a conservative placeholder value of **$5,000,000**)

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[14] Consultation with a hazardous waste handler is the basis for this Agency estimate.
[15] Consultation with several shippers is the basis for this Agency estimate.
[16] Consultation with several shippers is the basis for this statement.

- The remanufacturer realizes a profit from reselling (or using in place of purchase) solvent remanufactured to commercial grade: Resale value of remanufactured solvents to commercial grade: All calculations add the values for 2008 underground injection, 2008 solvent mass combusted, 2008 solvent mass burned for energy, and subtracts final distillation bottoms to get remanufactured quantities. First the resale value for each chemical is given, and then offsets for the cost of steam for distillation and overhead, to reach a net value. EPA used the conversion 1 metric ton = 2204.6 pounds.

    - 13,520 metric tons of acetonitrile ($0.65 per pound; total cost savings $19,374,025)
    - 8,539 metric tons of n-butanol ($0.54 per pound; total cost savings $10,165,543)
    - 1,496 metric tons of chlorobenzene ($0.67 per pound; total cost savings $2,209,715)
    - 5,865 metric tons of chloroform ($0.34 per pound; total cost savings $4,396,193)
    - 0 metric tons of chloromethane
    - 8,758 metric tons of cyclohexane ($0.59 per pound; total cost savings $11,391,653)
    - 5,793 metric tons of dichloromethane ($0.39 per pound; total cost savings $4,980,787)
    - 3,865 metric tons of N,N-Dimethyformamide ($0.48 per pound; total cost savings $4,089,974)
    - 16,018 metric tons of ethanol ($0.45 per pound; total cost savings $15,890,977)
    - 4,592 metric tons of ethylbenzene ($0.52 per pound; total cost savings $5,264,232)
    - 13,084 metric tons of n-hexane ($0.44 per pound; total cost savings $12,691,794)
    - 64,072 metric tons of methanol ($0.13 per pound; total cost savings $18,362,907)
    - 922 metric tons of methyl tert-butyl ether ($0.42 per pound; total cost savings $833,383)
    - 2,578 metric tons of methyl isobutyl ketone ($0.43 per pound; total cost savings $2,443,887)
    - 5,311 metric tons of tetrahydrofuran ($1.55 per pound; total cost savings $18,148,377)
    - 23,964 metric tons of toluene ($0.39 per pound; total cost savings $20,604,103)
    - 769 metric tons of 1,2,4-trimethylbenzene ($0.82 per pound; total cost savings $1,390,177)
    - 12,253 metric tons of xylenes ($0.40 per pound; total cost savings $10,805,186)
    - **TOTAL: $163,042,913**

- Offsets to resale value of recovered solvents to commercial grade
    - EPA is using a five percent overhead factor (for the cost of changing the business model), which would be **$8,152,146**.
    - Cost of steam generation for two-time distillation process. EPA estimated 369,999 million BTU's (rounded up to 370,000 million BTU's) would be used for two-time distillation for recovering solvents, converted BTU's to therms (100,000 BTU's per therm), and then multiplied the therm value (3,700,000) by an estimated cost of $0.70 per therm, to get a value of **$2,590,000**.
    - Total offsets: **$10,742,146**

- **Net value of recovered solvents to commercial grade is $152,300,767.**

- Societal economic value of avoided greenhouse gas emissions (the Agency priced each metric ton of carbon dioxide equivalent avoided at $22 for the year 2012).

- 548,099 MTCO2e (net total GHG emission reductions, omitting reductions from avoided manufacturing of specialty solvents), priced at **$12,058,178**
- 688,094 MTCO2e (net total GHG emission reductions, including reductions from avoided manufacturing of specialty solvents), priced at **$15,138,068**
- Net estimated cost savings: **$164,358,945 - $167,438,835 annually**.

Sample range of re-manufacturing rates (10%, 25%, 50%, and 75% -- rates at which facilities could choose to switch from disposal to re-manufacturing of spent solvents under the Exclusion) and the correlative range of quantified annual net benefit rates:

- 10% implementation rate
  - 54,809 – 68,809 MTCO2e avoided
  - Carbon monoxide air emissions avoided – 267 metric tons (589,951 pounds).
  - VOC air emissions avoided – 32 metric tons (70,767 pounds)
  - NOx air emissions avoided – 50 metric tons (109,568 pounds)
  - SOx air emissions avoided – 245 metric tons (539,906 pounds)
  - Total Organic Carbon water releases avoided – 38 tons (83,995 pounds)
  - Biological Oxygen Demand water releases avoided – 6.7 metric tons (14,771 pounds)
  - Chemical Oxygen Demand water releases avoided – 148 metric tons (326,942 pounds)
  - Total Dissolved Solids water releases avoided – 1,739 metric tons (3,833,799 pounds)
  - $16,435,894 - $16,743,883 dollars saved

- 25% implementation rate
  - 137,025 – 172,024 MTCO2e avoided
  - Carbon monoxide air emissions avoided – 669 metric tons (1,474,877pounds).
  - VOC air emissions avoided – 80 metric tons (176,919 pounds)
  - NOx air emissions avoided – 124 metric tons (273,922 pounds)
  - SOx air emissions avoided – 612 metric tons (1,349,766 pounds)
  - Total Organic Carbon water releases avoided – 95 tons (209,988 pounds)
  - Biological Oxygen Demand water releases avoided – 17 metric tons (36,927 pounds)
  - Chemical Oxygen Demand water releases avoided – 370 metric tons (817,355 pounds)
  - Total Dissolved Solids water releases avoided – 4,348 metric tons (9,584,499 pounds)
  - Solid waste avoided – 941 tons
  - $41,089,736 -- $41,859,709 dollars saved

- 50% implementation rate
  - 274,050 – 344,047 MTCO2e avoided
  - Carbon monoxide air emissions avoided – 1,338 metric tons (2,949,755 pounds).
  - VOC air emissions avoided – 161 metric tons (353,838 pounds)
  - NOx air emissions avoided – 249 metric tons (547,843 pounds)
  - SOx air emissions avoided – 1225 metric tons (2,699,532 pounds)
  - Total Organic Carbon water releases avoided – 191 tons (419,976 pounds)
  - Biological Oxygen Demand water releases avoided – 34 metric tons (73,854 pounds)
  - Chemical Oxygen Demand water releases avoided – 742 metric tons (1,634,711 pounds)
  - Total Dissolved Solids water releases avoided – 8,695 metric tons (19,168,977 pounds)
  - Solid waste avoided – 1882 tons
  - $82,179,473 -- $83,719,418 dollars saved

- 75% implementation rate
    - 411,074 – 516,071 MTCO2e avoided
    - Carbon monoxide air emissions avoided – 2007 metric tons (4,424,632 pounds).
    - VOC air emissions avoided – 241 metric tons (530,757 pounds)
    - NOx air emissions avoided – 373 metric tons (821,765 pounds)
    - SOx air emissions avoided – 1837 metric tons (4,049,299 pounds)
    - Total Organic Carbon water releases avoided – 286 tons (629,964 pounds)
    - Biological Oxygen Demand water releases avoided – 50 metric tons (110,781 pounds)
    - Chemical Oxygen Demand water releases avoided – 1112 metric tons (2,452,066 pounds)
    - Total Dissolved Solids water releases avoided – 13,043 metric tons (28,753,496 pounds)
    - Solid waste avoided – 2823 tons
    - $123,269,209 -- $125,579,126 dollars saved